

GEOLOGIC FRAMEWORK AND HYDROGEOLOGIC CHARACTERISTICS OF THE EDWARDS AQUIFER RECHARGE ZONE, BEXAR COUNTY, TEXAS

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 95-4030



Prepared in cooperation with the
SAN ANTONIO WATER SYSTEM



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By William G. Stein and George B. Ozuna

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**Austin, Texas
1995**

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

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For additional information write to:

District Chief
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PLATE

[Plate is in pocket]

1. Map showing hydrogeologic subdivisions of the Edwards aquifer recharge zone, Bexar County, Texas.

FIGURE

1. Map showing location of the study area 2

TABLE

1. Summary of the lithologic and hydrologic properties of the hydrogeologic subdivisions of the Edwards aquifer outcrop, Bexar County, Texas 4

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
mile (mi)	1.609	kilometer

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Geologic Framework and Hydrogeologic Characteristics of the Edwards Aquifer Recharge Zone, Bexar County, Texas

By William G. Stein *and* George B. Ozuna

Abstract

In Bexar County, residential and commercial development on the Edwards aquifer recharge zone is increasing. The aquifer possibly can be contaminated by spills, leakage of hazardous materials, or runoff from the rapidly developing urban areas that surround, or are built on, the intensely faulted and fractured, karstic limestone outcrops characteristic of the recharge zone. Furthermore, some of the hydrogeologic subdivisions that compose the Edwards aquifer have greater effective porosity than others. The areas where the most porous subdivisions crop out might provide efficient avenues for contaminants to enter the aquifer.

The Edwards aquifer recharge zone has relatively large permeability resulting, in part, from the development or redistribution of secondary porosity. Lithology, stratigraphy, diagenesis, and karstification account for the effective porosity and permeability in the Edwards aquifer outcrop. Karst features that greatly enhance effective porosity in the outcrop area include sinkholes and caves.

Hydrogeologic subdivision VI, the Kirschberg evaporite member, appears to be the most porous and permeable subdivision within the Kainer Formation. Hydrogeologic subdivision III, the leached and collapsed members, undivided, is the most porous and permeable subdivision within the Person Formation. Hydrogeologic subdivision II, the cyclic and marine members, undivided, is moderately permeable, with both fabric- and not-fabric-selective porosity.

The faults in northern Bexar County are part of the Balcones fault zone. Although most of the

faults in this area trend northeast, a smaller set of cross-faults trend northwest. Generally, the faults are en echelon and normal, with the downthrown blocks typically toward the coast.

INTRODUCTION

The Edwards aquifer, which comprises the Kainer and Person Formations of the Edwards Group (Rose, 1972) and the overlying Georgetown Formation in rocks of Lower Cretaceous age, is one of the most productive carbonate aquifers in the nation. The dissolution-modified, faulted limestone aquifer (Buszka and others, 1990) is the sole source of public-water supply for San Antonio (ninth largest city in the United States) and is the major source of water for Bexar County (fig. 1). In addition to providing public-water supply to more than 1 million people in south-central Texas, the Edwards aquifer supplies large quantities of water to agriculture, industry, and major springs. The major springs support recreational activities and businesses, provide flow to downstream users, and provide habitat for several threatened or endangered species.

Most recharge to the Edwards aquifer is from direct infiltration of precipitation and streamflow loss in the recharge zone. Recharge to the Edwards aquifer averaged 683,000 acre-ft/yr during 1934–92 (Bader and others, 1993, table 4.1). After entering the aquifer, the water generally moves from west to east through Bexar County, where it is discharged by wells and springs. Springflow has varied over a wide range during historical time. Annual well withdrawals from the aquifer have gradually increased from 101,900 acre-ft in 1934 to 542,400 acre-ft in 1989 (Bader and others, 1993, table 5.1). During the 10 years from 1983 to 1992, well discharge exceeded springflow by 22 percent (Bader and others, 1993, table 5.1).

In Bexar County, residential and commercial development on the Edwards aquifer recharge zone is

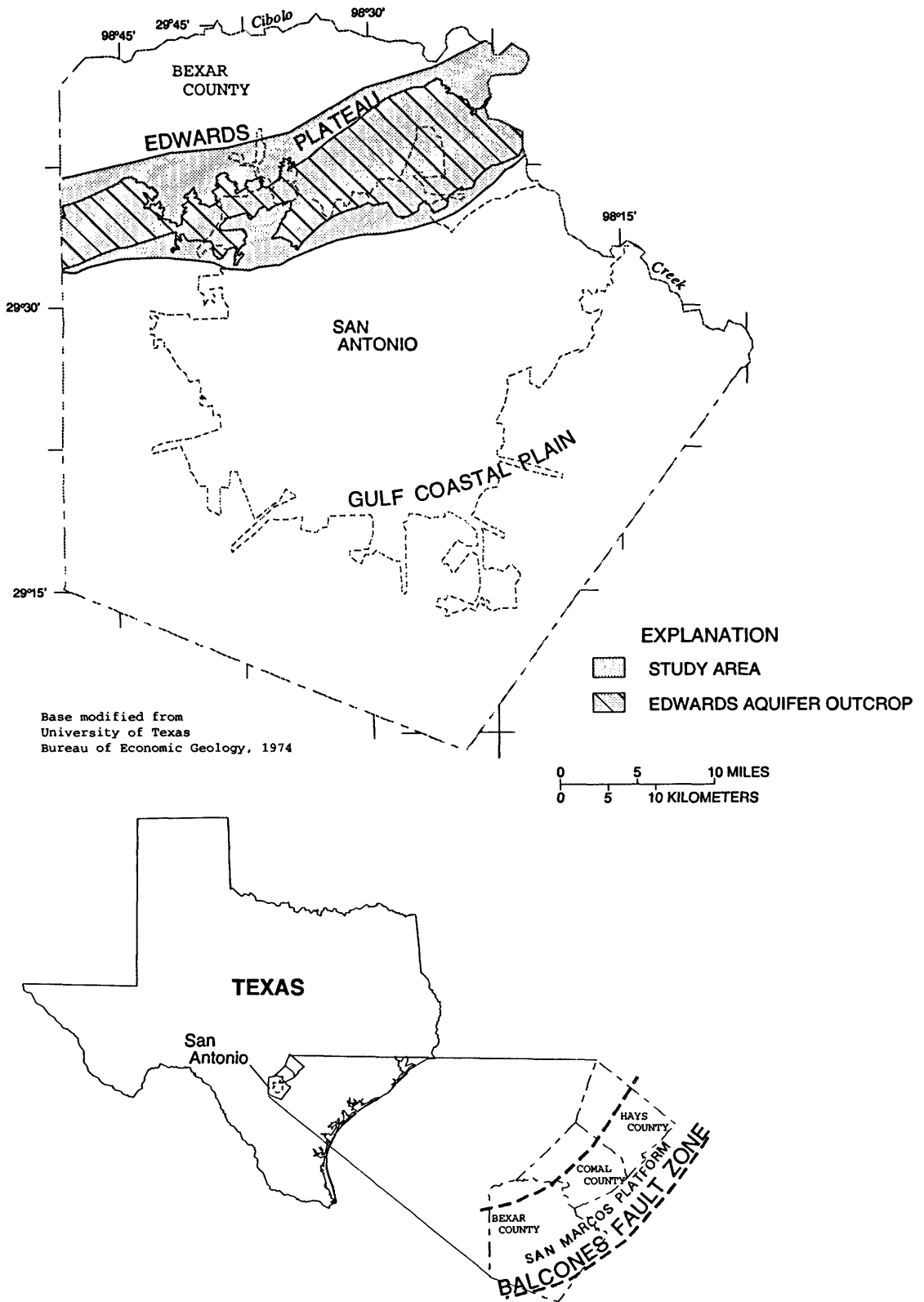


Figure 1. Location of the study area.

increasing. According to Kipp and others (1993), a substantial increase in development activities over the Edwards recharge zone has been observed over the past year, particularly in Bexar County. Kipp and others (1993) further state that a greater threat to contamination of the Edwards aquifer comes with increased development. The aquifer possibly can be contaminated by spills, leakage of hazardous materials, or runoff from the rapidly developing urban areas that surround, or are built on, the intensely faulted and fractured, karstic limestone outcrops characteristic of the recharge zone. Furthermore, some of the hydrogeologic subdivisions that compose the Edwards aquifer have greater effective porosity than others, and in areas where they crop out, might provide efficient avenues for contaminants to enter the aquifer. According to Buszka (1987, p. 2), "carbonate aquifers, such as the Edwards, are readily susceptible to ground-water contamination where the presence of pollutants coincides with the outcrop of the aquifer." In Bexar County, the Edwards aquifer probably is most vulnerable to surface contamination in the rapidly urbanizing areas on the Edwards aquifer outcrop.

The U.S. Geological Survey, in cooperation with the San Antonio Water System, mapped the Edwards aquifer outcrop and described its hydrogeologic characteristics (porosity and permeability) to document conditions pertinent to movement and contamination of ground water.

This report describes the geologic framework and the hydrogeologic characteristics of the Edwards aquifer recharge zone in Bexar County and delineates the surface extent of the hydrogeologic subdivisions described for the confined zone of the Edwards aquifer by Maclay and Small (1976). This information will help to provide a better understanding of the processes controlling the spatial distribution of recharge and the flow of water into the aquifer. The information also will help determine the areas of the recharge zone that are most susceptible to potential contamination from land-use practices.

Methods of Investigation

The Kainer and Person Formations of the Edwards Group were divided into seven informal members by Rose (1972). Rose's (1972) categorization was further modified by Maclay and Small (1976), who added an eighth hydrogeologic subdivision, the overlying Georgetown Formation.

The outcrop of the Edwards aquifer recharge zone was mapped using the hydrogeologic subdivisions (table 1) modified from Maclay and Small (1976). The stratigraphic nomenclature and descriptions of Rose (1972) were used in mapping the geologic units for the San Marcos platform (fig. 1). The hydrogeologic subdivisions of the Edwards aquifer recharge zone in Bexar County are shown on plate 1.

Well logs and geologic map data were compiled and used in mapping the hydrogeologic subdivisions of the Edwards aquifer in the study area. The lower confining unit of the Edwards aquifer, the upper member of the Glen Rose Limestone of Lower Cretaceous age (table 1), was mapped where it is adjacent to the recharge zone. The Del Rio Clay, Buda Limestone, and Eagle Ford Group, constituting the upper confining units, were mapped along the southern boundary of the recharge zone.

Caves and other karst features were located during mapping using information from Veni (1988). Aerial photographs were used to locate the most recent rock exposures so that relatively fresh outcrops could be examined. Original land-surface topography of excavated quarries was interpolated from exposed outcrops and 7-1/2-minute quadrangles. Edwards aquifer outcrop mapping also was interpolated through areas that are covered by alluvial deposits.

Determination of fault displacement generally is difficult in carbonate rocks. Fault traces commonly are obscure and difficult to identify in the field. Fault displacements were postulated and estimated by abrupt lithologic or stratigraphic dissimilarities and at least one of the following: fault scarps, fault breccia, long linear travertine or sparry calcite deposits, or steeply dipping strata thought to represent fault-bend folds. Fault-bend folds are bedding deformation associated with fault-block movement (Suppe, 1985, p. 343). The strike of these features was measured with a compass to determine the orientation of the faults. The lengths of many of the faults were projected by lineaments visible on land surface or in aerial photographs. Faults were inferred by the location of lineaments on photographs in areas where only slight stratigraphic dissimilarities were indicated, or where the faults extended beyond the mapped area.

Acknowledgments

Special thanks are extended to George Veni, a local consulting karst hydrologist, for his assistance in

Table 1. Summary of the lithologic and hydrologic properties of the hydrogeologic subdivisions of the Edwards aquifer outcrop, Bexar County, Texas

[Hydrogeologic subdivisions modified from Maclay and Small (1976); groups, formations, and members modified from Rose (1972); lithology modified from Dunham (1962); and porosity type modified from Choquette and Pray (1970). CU, confining unit; AQ, aquifer]

Hydrogeologic subdivision		Group, formation, or member	Hydro-logic function	Thickness (feet)	Lithology	Field identification	Cavern development	Porosity/permeability type			
Upper Cretaceous	Upper confining units	Eagle Ford Group	CU	30 – 50	Brown, flaggy shale and argillaceous limestone	Thin flagstones; petroliferous	None	Primary porosity lost/ low permeability			
		Buda Limestone	CU	40 – 50	Buff, light gray, dense mudstone	Porcelaneous limestone with calcite-filled veins	Minor surface karst	Low porosity/low permeability			
		Del Rio Clay	CU	40 – 50	Blue-green to yellow-brown clay	Fossiliferous; <i>Hymatogyra arietina</i>	None	None/primary upper confining unit			
Lower Cretaceous	Edwards aquifer	Edwards Group	Person Formation	I	Georgetown Formation	Karst AQ; not karst CU	2 – 20	Reddish-brown, gray to light tan marly limestone	Marker fossil; <i>Waconella wacoensis</i>	None	Low porosity/low permeability
				II	Cyclic and marine members, undivided	AQ	80 – 90	Mudstone to packstone; <i>miliolid</i> grainstone; chert	Thin graded cycles; massive beds to relatively thin beds; crossbeds	Many subsurface; might be associated with earlier karst development	Laterally extensive; both fabric and not fabric/water-yielding
				III	Leached and collapsed members, undivided	AQ	70 – 90	Crystalline limestone; mudstone to grainstone; chert; collapsed breccia	Bioturbated iron-stained beds separated by massive limestone beds; stromatolitic limestone	Extensive lateral development; large rooms	Majority not fabric/one of the most permeable
				IV	Regional dense member	CU	20 – 24	Dense, argillaceous mudstone	Wispy iron-oxide stains	Very few; only vertical fracture enlargement	Not fabric/low permeability; vertical barrier
				V	Grainstone member	AQ	50 – 60	<i>Miliolid</i> grainstone; mudstone to wackestone; chert	White crossbedded grainstone	Few	Not fabric/recrystallization reduces permeability
				VI	Kirschberg evaporite member	AQ	50 – 60	Highly altered crystalline limestone; chalky mudstone; chert	Boxwork voids, with neospar and travertine frame	Probably extensive cave development	Majority fabric/one of the most permeable
				VII	Dolomitic member	AQ	110 – 130	Mudstone to grainstone; crystalline limestone; chert	Massively bedded light gray, <i>Toucasia</i> abundant	Caves related to structure or bedding planes	Mostly not fabric; some bedding plane-fabric/water-yielding
				VIII	Basal nodular member	Karst AQ; not karst CU	50 – 60	Shaly, nodular limestone; mudstone and <i>miliolid</i> grainstone	Massive, nodular and mottled, <i>Exogyra texana</i>	Large lateral caves at surface; a few caves near Cibolo Creek	Fabric; stratigraphically controlled/large conduit flow at surface; no permeability in subsurface
				Lower confining unit	Upper member of the Glen Rose Limestone	CU; evaporite beds AQ	350 – 500	Yellowish tan, thinly bedded limestone and marl	Stair-step topography; alternating limestone and marl	Some surface cave development	Some water production at evaporite beds/relatively impermeable

locating some of the caves while mapping in the field. The authors also express their thanks to all the property owners who granted permission to enter their property.

GEOLOGIC FRAMEWORK

General Features

A regional dip of the rocks of the hydrogeologic subdivisions of 10 to 15 ft/mi to the southeast in Bexar

County was reported by Arnow (1959, p. 19), and the thicknesses of the rocks were reported by Rose (1972). The faults in northern Bexar County are part of the Balcones fault zone (fig. 1). Although most of the faults in the area trend southwest to northeast, a smaller set of cross-faults trend southeast to northwest. Generally, the faults are en echelon and normal, with the downthrown blocks typically toward the coast (southeast). Some of the faults might not result in topographic

relief, partly because the rocks on both sides of the fault have similar weathering characteristics, and possibly because the rate of movement is no faster than the rate of erosion.

Maclay and Small (1984, p. 33) define flow-barrier faults as faults that have vertical displacement greater than 50 percent of the total thickness of the aquifer, sufficient to juxtapose permeable layers against relatively less permeable layers. The thickness of the Edwards aquifer in Bexar County is about 450 ft; 50 percent of this is about 225 ft. Therefore, faults in the study area with a vertical displacement of about 225 ft or greater were designated as flow-barrier faults, as indicated by their displacements on plate 1. A series of flow-barrier faults extends from the southwest part of the study area toward the northeast.

Some of the faults in Bexar County mark the trace of shatter zones, where the faults are not single, sharp breaks as shown by a single line placed on a map (Arnow, 1959, p. 20). Field observations of linear sparry travertine (a clear to translucent secondarily precipitated calcite) deposits within many of the fault shatter zones, and of water discharging from a fault exposed in a road cut northwest of the Loop 1604 and I-10 intersection shortly after local rainfall, support the hypothesis of ground-water flow within some faults.

Stratigraphy

In Bexar County, the Edwards aquifer consists of approximately 450 ft of limestone, with lesser quantities of chert, dolomite, and evaporite (primarily anhydrite/gypsum) (table 1). The major formal lithostratigraphic units of the Edwards aquifer are the Kainer, Person, and Georgetown Formations (Maclay and Small, 1976). The Kainer and Person Formations are subdivided into informal members by Rose (1972). The rocks of these members, or subdivisions, were deposited in shallow to very shallow marine waters (Rose, 1972) and reflect depositional environments resulting from slight changes in water level, water chemistry, temperature, and circulation. All of these factors can cause subtle to not-so-subtle changes in the overall lithology of the various members and some changes within the individual members.

The Georgetown Formation is not known to yield water in Bexar County. Arnow (1959) noted that water-well drillers did not distinguish between the Georgetown Limestone and the underlying Edwards Limestone. Thus, according to Arnow (1959, p. 15),

"The Georgetown is part of the aquifer that comprises the Edwards and associated limestones...."

The thickness of the Kainer Formation (Rose, 1972, p. 18) ranges from about 260 to 310 ft in Bexar County (table 1). The lithology of the Kainer Formation includes marine sediments consisting of fossiliferous (most commonly rudistids) mudstones and wackestones that grade upward into intertidal and supratidal dolomitic mudstones with evaporites, and terminate in a shallow marine *miliolid* grainstone. The lower part of the dolomitic member of the Kainer Formation in western Bexar County is distinctly more burrowed, similar to the facies equivalents of the burrowed member of the Fort Terrett Formation (Rose, 1972, p. 30) northwest of the study area. Major collapsed features noted elsewhere by Rose (1972) in the Kirschberg evaporite member were not evident in Bexar County. This might indicate fewer massive gypsum deposits and more interbedded limestone that would have prevented major collapses after evaporite removal.

The Person Formation (Rose, 1972, p. 19) is about 170 ft thick in Bexar County (table 1). The regional dense member at the base of the Person Formation is a dense, argillaceous mudstone, which is easily recognized in cores and usually recognizable on geophysical logs (Small, 1985). Deposition of the Person Formation above the regional dense member continued with dolomitic biomicrite, which contains layers of collapsed breccias, burrowed mudstones, and stromatolitic limestone. The cyclic and marine members, undivided, consist of small upward-grading cycles of mudstones to grainstones that range from massive to thin beds and occasionally are crossbedded. Much of the cyclic and marine members, undivided, in Bexar County might have been removed by erosion prior to the deposition of the Georgetown Formation (Rose, 1972).

A depositional hiatus occurred before the open marine, biomicritic Georgetown Formation (Rose, 1972) was deposited. Parts of the Person Formation were above sea level during this time and were substantially eroded along the ridge of the San Marcos platform (Rose, 1972). The Georgetown Formation generally is a marly limestone and usually contains the brachiopod *Waconella wacoensis*, formerly *Kingena wacoensis* (Roemer), pectens, and other pelecypods. Most exposures of the Georgetown Formation that were identified in the study area were from 2 to 5 ft thick, and consisted of dark reddish-brown weathered and friable material with some shaly limestone

remnants. However, an outcrop in a quarry near Helotes Creek, east of FM 1560, contains an unweathered tannish-yellow biomicrite sequence of Georgetown Formation that is approximately 20 ft thick. This particular Georgetown Formation outcrop evidently has undergone a different diagenetic history than the other Georgetown Formation outcrops in Bexar County.

The Upper Cretaceous Del Rio Clay, Buda Limestone, and Eagle Ford Group overlie the Georgetown Formation (pl. 1, table 1). The Del Rio Clay is a weathered, poorly compacted, friable, blue-green to yellow-brown clay, with some areas having accumulations of *Ilymatogyra arietina*, formerly *Exogyra arietina* (Roemer). The contact between the Del Rio Clay and the Buda Limestone is transitional to disconformable depending on locality (Rose, 1972, p. 27, 43). The Buda Limestone outcrop is distinctly nodular with small, calcite-filled veins, and generally is buff to light gray, porcelaneous limestone (Sellards and others, 1933, p. 397). The Eagle Ford Group unconformably overlies the Buda Limestone (Arnold, 1959). The Eagle Ford Group consists of thin flagstones of brown, flaggy shale and argillaceous limestone. Some of the freshly fractured flagstones emit a petroliferous odor, indicative of a high organic content.

Field identification of the various members in the Kainer and Person Formations was based on their characteristic lithologies and fossils (table 1). Red clay soil that resembles the "terra rossa" of Pleistocene age, described by Young (1986, p. 63) as a diagenetically altered paleosol, commonly is evident in outcrops of the Edwards Group, but rarely in the Glen Rose Limestone or in the clays or limestones of the upper confining units. According to Young (1986, p. 65), the red clay soil indicates that lithology was important in the development of central Texas terra rossa. Large accumulations of terra rosa relative to the volume of pore space in the limestone decrease the effective porosity and, thereby, decrease the permeability.

HYDROGEOLOGIC CHARACTERISTICS

General Features

The Edwards aquifer has relatively large permeability resulting, in part, from the development or redistribution of secondary porosity (Maclay and Small, 1976). Lithology, stratigraphy, diagenesis, and selective dissolution (karstification) account for the effective

porosity and permeability in the Edwards aquifer outcrop. Karst features that can greatly enhance the effective porosity in the outcrop include sinkholes and caves. The dry-subhumid climate (Thornthwaite, 1952) is not favorable for rapid karst development. The presence of caves in the Edwards Group limestone in Bexar County is random and the morphology is controlled by the local stratigraphy.

Porosity and Permeability

According to Choquette and Pray (1970, p. 212), porosity in sedimentary carbonates is either fabric selective or not fabric selective. Fabric-selective porosity is secondary porosity that preferentially developed along specific sedimentary structures, strata, or mineralogy. Not-fabric-selective porosity is secondary porosity that developed generally without influence of sedimentary structures as well as secondary porosity that developed preferentially along fractures or faults not associated with the original sedimentary or diagenetic processes. Effective, or drainable, porosity consists of pores that are well-connected by sufficiently large openings, generally greater than 0.1 micrometer in diameter. In the Edwards aquifer, effective porosity is more closely associated with large permeability than with total porosity, which includes unconnected or dead-end pores (Maclay and Small, 1976).

Permeability is the capacity of a porous rock to transmit water. According to Ford and Williams (1989, p. 130), permeability depends on the physical properties of the rock, particularly pore size, shape, and distribution. Ford and Williams (1989, p. 150) further state that, "As a consequence of the effects of fissuring and differential solution, permeability may be greater in some directions than in others as well as in certain preferred stratigraphic horizons."

Downdip from the recharge zone, the Edwards aquifer is confined above and below (table 1). The lower and upper confining units, the eight hydrogeologic subdivisions and the names of the corresponding members, and the type of porosity and permeability observed in the field within the subdivisions are discussed in ascending order.

The upper member of the Glen Rose Limestone is relatively impermeable and generally acts as a lower confining unit of the Edwards aquifer. However, in some areas, the upper member of the Glen Rose Limestone yields substantial quantities of water to wells.

Hydrogeologic subdivision VIII (basal nodular member) has negligible porosity and permeability in the subsurface, and can be regarded as part of the lower confining unit (Maclay and Small, 1984). In the outcrop, this subdivision is extensively karstified and has secondary porosity in the form of large lateral caves. The lateral cave development might result from dissolution associated with perching of infiltrating meteoric water on the underlying relatively impermeable upper member of the Glen Rose Limestone (Kasting, 1986). The perching would allow time for dissolution to occur within this subdivision. Many seeps and springs discharge from the lower part of this hydrogeologic subdivision in Bexar County.

Hydrogeologic subdivision VII (dolomitic member) generally is porous and relatively permeable. Some of the evaporite beds within this subdivision are burrowed and dissolved to the extent of being honeycombed and, therefore, permeable. Many of the beds contain isolated molds, casts, and burrows with large secondary (fabric selective) porosity but little permeability because the openings rarely are connected. Therefore, the permeable layers are restricted to solution-enlarged bedding planes.

Hydrogeologic subdivision VI (Kirschberg evaporite member) appears to be the most porous and permeable subdivision of the Kainer Formation. The porosity, chiefly fabric selective, has been described as boxwork (Maclay and Small, 1976) because of the configuration of voids and the secondary neospar and travertine deposits. The boxwork porosity does not prevail throughout hydrogeologic subdivision VI, but is interbedded with massive limestone beds.

Hydrogeologic subdivision V (grainstone member) is widely recrystallized. The recrystallization greatly reduces the effective porosity and permeability of this subdivision; however, there is local interparticle and intraparticle porosity and local fracture porosity and permeability.

Hydrogeologic subdivision IV (regional dense member) is probably an effective vertical confining unit between the underlying Kainer Formation and the overlying members of the Person Formation. However, caves, faults, and fractures, primarily not-fabric-selective porosity, and fracture-associated permeability, might greatly reduce the confining effects of this subdivision in some areas. Many of the caves in this subdivision are vertical shafts with major horizontal cavern development either above or below the subdivision.

Hydrogeologic subdivision III (leached and collapsed members, undivided) is the most porous and permeable subdivision within the Person Formation. The predominant type of porosity in this subdivision is not fabric selective where evaporite minerals have been dissolved. However, breccia porosity resulting from evaporite dissolution can be either fabric selective or not fabric selective (Choquette and Pray, 1970). Cave porosity and permeability associated with faulting and (or) evaporite dissolution also is common.

Hydrogeologic subdivision II (cyclic and marine members, undivided) is moderately permeable, with both fabric- and not-fabric-selective porosity. Field observations indicate that this subdivision has only slightly less porosity and permeability than subdivision III.

Hydrogeologic subdivision I (Georgetown Formation) yields little water to wells. This subdivision has negligible porosity and permeability. Where severely weathered in the outcrop (and, thus, relatively more permeable), this subdivision is considered a part of the unsaturated zone of the Edwards aquifer.

The upper confining units consist of the Del Rio Clay, Buda Limestone, and the Eagle Ford Group (Rose, 1972). Because the Del Rio Clay consists mostly of clay and has negligible effective porosity and permeability, it forms the primary upper confining unit of the Edwards aquifer.

SUMMARY

The Edwards aquifer is one of the most productive carbonate aquifers in the nation. It is the sole source of public-water supply for San Antonio and for most of Bexar County. In addition, the Edwards aquifer provides large quantities of water to agriculture, industry, and major springs. The major springs support recreational activities and businesses, provide water to downstream users, and provide habitat for several threatened or endangered species.

The dissolution-modified, faulted limestone aquifer is recharged in its outcrop area in the Balcones fault zone. In Bexar County, residential and commercial development on the recharge zone of the Edwards aquifer is increasing. The aquifer possibly can be contaminated by spills, leakage of hazardous materials, or runoff from the rapidly developing urban areas that surround, or are built on, the intensely faulted and fractured, karstic limestone outcrop of the recharge zone. Furthermore, some of the hydrogeologic subdivisions

that compose the Edwards aquifer have greater effective porosity than others, and might provide more efficient avenues for contaminants to enter the aquifer in areas where they crop out.

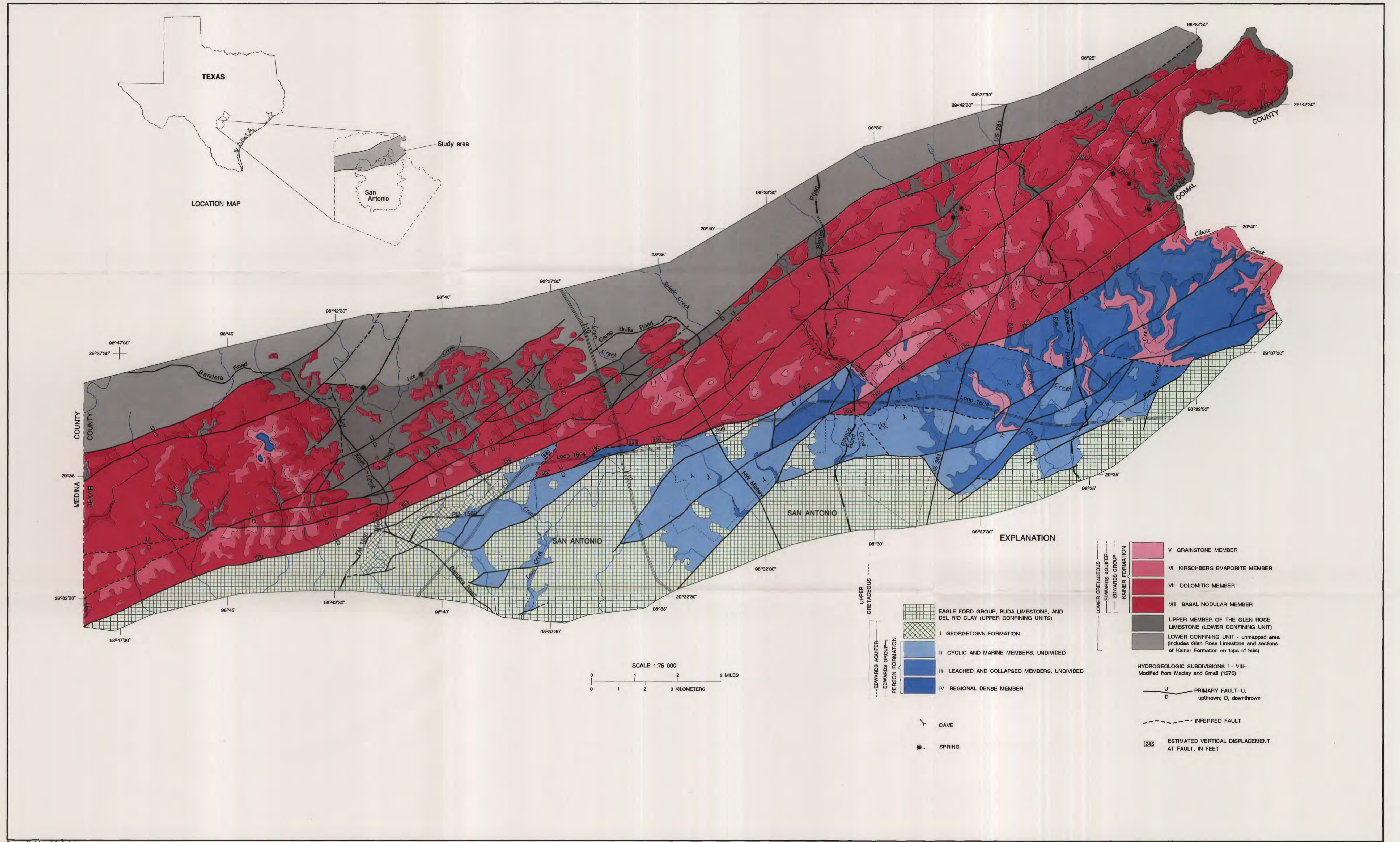
The Edwards aquifer comprises the Kainer and Person Formations of the Edwards Group and the overlying Georgetown Formation. The Kainer and Person Formations consist of seven informal members. These seven members, together with the overlying Georgetown Formation, compose the eight informal hydrogeologic subdivisions of the aquifer.

The Edwards aquifer has relatively large permeability resulting, in part, from the development or redistribution of secondary porosity. Lithology, stratigraphy, diagenesis, and karstification account for the effective porosity and permeability in the Edwards aquifer outcrop. Karst features that greatly enhance effective porosity and permeability include sinkholes and caves.

Hydrogeologic subdivision VI (Kirschberg evaporite member) appears to be the most porous and permeable subdivision in the Kainer Formation. Hydrogeologic subdivision III (leached and collapsed members, undivided) is the most permeable subdivision in the Person Formation. Hydrogeologic subdivision II (cyclic and marine members, undivided) is moderately porous and permeable.

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Base modified from U.S. Geological Survey 1:24,000 quadrangles. Universal Transverse Mercator Projection, zone 14

MAP SHOWING HYDROGEOLOGIC SUBDIVISIONS OF THE EDWARDS AQUIFER RECHARGE ZONE, BEXAR COUNTY, TEXAS

By
William G. Stein and George B. Ozuna
1995