U.S. DEPARTMENT OF THE INTERIOR SCIENTIFIC INVESTIGATIONS MAP 2873 U.S. GEOLOGICAL SURVEY 97°51'00" CORRELATION OF MAP UNITS DEVILS RIVER TREND SAN MARCOS PLATFORM MAVERICK BASIN QI Leona Formation Ki Intrusive igneous rocks, undifferentiated Ki Intrusive igneous rocks, undifferentiated Ku Upper confining units, undivided Ku Upper confining units, undivided Knt Navarro and Taylor Groups, undivided Ka Austin Group Eagle Ford Group Eagle Ford Group Kef Eagle Ford Group Kb Buda Limestone Kb Buda Limestone Kb Buda Limestone Kdr Del Rio Clay Kdr Del Rio Clay Kdr Del Rio Clay Kg Georgetown Formation Kg Georgetown Formation Kg Georgetown Formation Kpcm Cyclic and marine member Salmon Peak Formation Kplc Leached and collapsed member Kmku Upper unit of the McKnight Formation d Regional dense member Devils River Formation mkm Middle unit of the McKnight Formation Kkg Grainstone member Lower unit of the McKnight Formation Kkke Kirschberg evaporite member Kkd Dolomitic member Kkbn Basal nodular member Trinity Group (upper part) (Upper member of the Glen Rose Limestone Kgru Upper member of the Glen Rose Limestone Kgru Upper member of the Glen Rose Limestone LOWER CRETACEOUS STRATA AND EDWARDS GROUP **Dolomitic member**—Mudstone to grainstone and chert-bearing, Lower unit—Thin-bedded, miliolid- and gryphaeid-rich, fragmented Maclay, R.W., and Small, T.A., 1976, Progress report on the geology 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 HYDROSTRATIGRAPHY crystalline limestone. Massive-bedded dolomitic member weathers light mudstone to grainstone. Also contains laminated pellet mudstone and aquifer, San Antonio area, Texas, and preliminary interpretation of borehole Efforts by a National Cooperative Geologic Mapping Program project to compile gray in outcrop and has abundant Toucasia. Cavern development is packstone (Miller, 1983). Thin solution zones and chert beds, but no geophysical and laboratory data on carbonate rocks: U.S. Geological Survey precipitation flows downgradient to the recharge zone of the Edwards aquifer" (Texas directly related to faults, fractures, and bedding planes; thus, significant cavern development. Thickness about 60-80 ft Open-File Report 76–627, 65 p. the geology of the Edwards aquifer recharge area in south-central Texas have helped to Commission on Environmental Quality, 2003). The jurisdictional extent of the The lithostratigraphy of the Edwards aquifer varies from northeast to southwest refine the hydrostratigraphy of one of the most permeable and productive carbonate Edwards aquifer recharge zone as identified and provided online by the TCEQ was due to the three fluctuating depositional environments: the San Marcos platform, the considered nonfabric-selective porosity except where solution along West Nueces Formation (Lower Cretaceous)—Upper unit, considered a Miggins, D.P., Blome, C.D., and Smith, D.V., 2004, Preliminary 40Ar/39Ar bedding planes yields water (Stein and Ozuna, 1995; Small and Clark, geochronology of igneous intrusions from Uvalde County, Texas—Defining a more aquifers in the United States. The complex geology of the recharge area includes slightly modified for illustrative purposes in the current compilation map. Devils River trend, and the Maverick basin. The Edwards Group of the San Marcos confining unit, is gray, thick-bedded, burrowed, shell-fragment 2000). Thickness 110–140 ft wackestone, packstone, and grainstone; thickness 120-260 ft. precise eruption history for the southern Balcones Volcanic Province: U.S. lithologic units assignable to the Lower Cretaceous Edwards Group and related units platform was deposited in shallow to very shallow marine waters and is divided into and the Georgetown Formation, which is underlain by the Lower Cretaceous Glen Rose DESCRIPTION OF MAP UNITS seven hydrostratigraphic units, the eighth hydrostratigraphic unit being the overlying Basal nodular member—Shaly, nodular limestone and burrowed Identified in the field as a miliolid-, gastropod-, and Texigryphaea-Geological Survey Open-File Report 2004–1031, 33 p. Limestone (lower confining unit) and overlain by the Upper Cretaceous Del Rio Clay, Georgetown Formation. The San Marcos platform facies grades abruptly into the mudstone to wackestone; minor lateral cavern development at surface bearing, gray wackestone. Classified as having mostly nonfabric-Miller, B.C., 1983, Physical stratigraphy and facies analysis, Lower Cretaceous Buda Limestone, and Eagle Ford, Austin, Taylor, and Navarro Groups (upper confining QUATERNARY DEPOSITS Devils River trend facies in northern Medina County. The Devils River trend is and nonfabric-selective porosity. Identified in the field as gray nodular selective porosity and low permeability, due to only minor cavern Maverick basin and Devils River trend, Uvalde and Real Counties, Texas: units). The rock units constituting the Edwards aquifer in the northeastern part of the represented by two lithostratigraphic units: the Devils River Formation, historically mudstone, containing black rotund bodies and miliolids, gastropods, formation directly associated with fracture dissolution. Lower unit is Arlington, Texas, University of Texas at Arlington M.A. thesis, 217 p. **Alluvium (Quaternary)**—Unconsolidated gravel, sand, silt, and clay Miller, B.C., 1984, Physical stratigraphy and facies analysis, Lower Cretaceous, recharge area (San Marcos platform facies) include the Kainer, Person, and considered indivisible, and the overlying Georgetown Formation. The lateral transition and Exogyra texana. Considered regionally as a lower confining unit, composed of thin-bedded, *miliolid*- and graphaeid-fragmented Georgetown Formations. The Kainer and Person Formations are subdivided into seven from the Devils River Formation to the deeper water West Nueces, McKnight, and and is locally water bearing through dissolution along bedding planes mudstone to grainstone with thin solution zones and chert beds (Clark, Maverick basin and Devils River trend, Uvalde and Real Counties, Texas, in Smith, normally found around rivers and streams; inundated regularly. Gravel informal hydrostratigraphic members. The central part of the recharge area (Devils mostly contains limestone and minor chert. Undivided terrace deposits Salmon Peak Formations of the Maverick basin facies is highly gradational and variable (Stein and Ozuna, 1995; Clark, 2003). Thickness 20-70 ft 2003); thickness 20-60 ft (Miller, 1984). Clark (2003, p. 5) stated C.L., ed., Stratigraphy and structure of the Maverick basin and Devils River trend, River trend facies) contains reefal facies lithologies of the Lower Cretaceous Devils included within unit along their assumed boundaries (Clark, 2003) that the lower unit is equivalent to the basal nodular member of the Lower Cretaceous, southwest Texas—A field guide and related papers: South Devils River trend facies Leona Formation (Quaternary)—Lenticular beds of sand, gravel, silt, and Kainer Formation, San Marcos platform facies. Lower unit is a lower Texas Geological Society, p. 3–33. River Formation and the overlying Georgetown Formation. The western part of the recharge area contains Edwards Group lithologies of deeper water origin (Maverick clay. Pebbles and cobbles in the Leona are predominantly limestone Georgetown Formation (Lower Cretaceous)—Uppermost unit of the confining unit of the Edwards aquifer, except for areas that are higher Rose, P.R., 1972, Edwards Group, surface and subsurface, central Texas: University Kdvr Devils River Formation (Lower Cretaceous)—Upper 250 ft consists of of Texas at Austin, Bureau of Economic Geology Report of Investigations 74, 198 basin facies) composed of the West Nueces, McKnight, Salmon Peak, and Georgetown with some chert. Coarser gravels are present near base of formation; Edwards aquifer. Reddish-brown and gray to light-tan, marly limestone in porosity and permeability due to solution enhancement of bedding miliolid, shell-fragment wackestones and grainstones containing planes. Formation thickness 140–320 ft silt increases up-section. The Leona is locally a prolific ground-water with biomicritic texture; commonly contains the brachiopod Waconella rudists and chert. Middle of formation consists of recrystallized and Geologic maps of previous workers typically show a vague, dashed boundary source and has rare cavern development and variable (low to high) wacoensis, pectins, the mollusks Kingena wacoensis and Gryphaea Small, T.A., and Clark, A.K., 2000, Geologic framework and hydrogeologic brecciated mudstones that grade downward into alternating beds of characteristics of the Edwards aquifer outcrop, Medina County, Texas: U.S. separating San Marcos platform and Devils River trend exposures because the Devils porosity due to the poorly sorted gravels. Locally, silty and clayey washitaensis (Young, 1967), as well as other pelecypods. Strata Trinity Group (upper part) vuggy spar and chert-bearing wackestone and grainstone. Lower River Formation was historically interpreted as discontinuous and lithologically variable. Geological Survey Water-Resources Investigations Report 00–4195, 10 p., 1 cement significantly reduces the permeability. In general, formation is covered by vegetation and soil in some areas. The Georgetown is 120–250 ft contains sparry limestone and nodular, burrowed mudstone However, current field studies of the San Marcos platform–Devils River trend transition thickest near stream channels or older abandoned meander channels. considered an upper confining unit, has very low porosity and Glen Rose Limestone, upper member (Lower Cretaceous) to wackestone, with gastropods, miliolids, and Exogyra texana. Small, T.A., and Hanson, J.A., 1994, Geologic framework and hydrogeologic area reveal that the facies boundary is distinct and follows topographic expression in Thickness a few feet to 80 ft permeability, and has little or no karstification or cavern development Conformably underlies the West Nueces Formation in the Maverick Upper part of formation has extensive cavern development and some areas. We believe that future work will show that some of the hydrostratigraphic basin and the Kainer Formation in the San Marcos platform, but characteristics of the Edwards aquifer outcrop, Comal County, Texas: U.S. (Stein and Ozuna, 1995). Thickness 2–20 ft; generally thins from abundant caprinids, monopleurids, and requieniids. Highly units belonging to the Kainer Formation, particularly the informal basal nodular and UPPER CRETACEOUS STRATA unconformably underlies the Devils River Formation in the Devils River Geological Survey Water-Resources Investigations Report 94–4117, 10 p., 1 northeast to southwest dissolutioned and brecciated, the middle part has vuggy porosity and dolomitic members, occur in the Devils River trend and deeper water Maverick basin trend (Miller, 1984). Lower confining unit of the Edwards aquifer in sheet, scale 1:75,000. units. Hydrostratigraphic subdivision of the lower part of the Devils River Formation in Small, T.A., Hanson, J.A., and Hauwert, N.M., 1996, Geologic framework and abundant chert, with numerous sinkholes and some cavern Igneous intrusive rocks, undifferentiated (Upper Cretaceous)—Fine- to Edwards Group south-central Texas. development. Solution-enlarged fractures are present in the relatively hydrogeologic characteristics of the Edwards aguifer outcrop (Barton Springs Medina and Uvalde Counties and mapping of Maverick basin lithologies in Kinney coarse-grained ultramafic and hypabyssal rocks that occur as surface Alternating beds of yellowish-tan, medium-bedded limestone and massive, nodular, burrowed mudstone near base of formation. Upper argillaceous limestone with minor evaporite layers. Surface cavern exposures or in subsurface as dikes, plugs, and shallow intrusions. San Marcos platform Segment), northeastern Hays and southwestern Travis Counties, Texas: U.S. County are ongoing. matic field is centered in Uvalde County and extends to the west grades downward into more nonfabric-selective porosity near base. In the San Marcos platform, the Person and Kainer Formations of the Edwards of map area into Kinney County. Igneous rocks are represented by five production at evaporite beds have been noted, but are considered a sheet, scale 1:75,000. Small porosity and permeability are related to solution-enlarged Smith, B.D., Smith, D.V., Hill, P.L., and Labson, V.F., 2003, Helicopter rock types—alkali basalt, melilite-olivine nephelinite, olivine Group were divided into seven informal lithostratigraphic units by Rose (1972). These rare occurrence. Field identification is commonly associated with (1) The Edwards aquifer serves the domestic, industrial, and agricultural needs of nephelinite, nepheline basinite, and phonolite (Miggins and others, units, in addition to the Georgetown Formation, were further modified by Maclay and fractures in lowermost part of formation. stair-step topography that forms through differential erosion of the electromagnetic and magnetic survey of the Seco Creek area, Medina and Uvalde about 2 million people and is the primary source of water for San Antonio, Texas, the Small (1976) into eight informal hydrostratigraphic members that formed the Edwards Formal subdivision of the Devils River Formation has been lacking alternating limestone and marl beds, and (2) the presence of fossilized Counties, Texas: U.S. Geological Survey Open-File Report 03–226, 47 p. to date. Geologic maps of the Texas Bureau of Economic Geology A high-resolution aeromagnetic survey flown in 2001 (Smith and Smith, D.V., Smith, B.D., and Hill, P.L., 2002, Aeromagnetic survey of Medina and Nation's eighth largest city. Northeast of San Antonio, along the Balcones fault zone, ripple marks and sparse casts of Tylostoma sp., Turitella sp., show the Devils River Formation subdivided into upper and lower units, the Edwards aquifer discharges from major artesian springs and provides unique others, 2002) revealed more than 200 shallow igneous intrusive Protocardia texana, and the foraminiferan Orbitolina minuta. Uvalde Counties, Texas: U.S. Geological Survey Open-File Report 02–49. whereas all USGS mapping to date (including this map) shows the Classified hydrologically as having mostly nonfabric-selective porosity Available only at URL http://pubs.usgs.gov/of/2002/ofr-02-0049. habitats for at least eight endangered species. Ground-water development, especially bodies, whereas fewer than 70 have been mapped. An ⁴⁰Ar/³⁹Ar **Person Formation (Lower Cretaceous)**—Variably burrowed mudstone, Devils River Formation as a single undifferentiated unit. According to and generally low permeability (Small and Clark, 2000; Clark, 2003). near San Antonio, has significantly diminished spring flow during recent periods of geochronologic study (Miggins and others, 2004) showed at least two grainstone, and crystalline limestone. Also contains collapsed breccia, Stein, W.G., and Ozuna, G.B., 1995, Geologic framework and hydrogeologic dolomitized biomicrite, burrowed mudstone, and stromatolitic Clark (2003), most workers since Lozo and Smith (1964) have characteristics of the Edwards aquifer recharge zone, Bexar County, Texas: U.S. below-normal rainfall. distinct phases of magmatic activity in Uvalde County. First phase of recognized that the Devils River Formation lacks sufficient marker beds The complex geology of the recharge area includes lithologic units assignable to intrusive activity occurred approximately 82-80 m.y. ago, whereas limestone. Chert is locally abundant and common fossils include Geological Survey Water-Resources Investigations Report 95–4030, 8 p., 1 sheet, to permit detailed or widespread subdivision. the Lower Cretaceous Edwards Group and related units and the Georgetown younger intrusive rocks (phonolites) were emplaced 74–72 m.y. ago pelecypods, gastropods, and rudistids (Collins, 2000). The Person's scale 1:75,000. A helicopter electromagnetic survey flown in the Seco Creek area Texas Commission on Environmental Quality, 2003, www.tceq.state.tx.us, 12100 Formation, which is underlain by the Lower Cretaceous Glen Rose Limestone (lower Upper confining units, undivided (Upper Cretaceous)—Original limestone, dolomitic limestone, and dolomite reflect shallow subtidal to in Medina and Uvalde Counties (Smith and others, 2003) clearly shows <u>U 235 ft</u> Fault—Dashed where inferred. U, upthrown side; D, downthrown side. confining unit) and overlain by the Upper Cretaceous Del Rio Clay, Buda Limestone, tidal-flat cyclic depositional environments (Rose, 1972; Abbott, 1973). Park 35 Circle, Austin, TX 78753. Accessed October 15, 2003. napping of much of the recharge zone concentrated on the Edwards the Devils River as two separate units on the basis of contrasts in Displacement amount in feet Young, Keith, 1967, Comanche Series (Cretaceous), south-central Texas, in and Eagle Ford, Austin, Taylor, and Navarro Groups (upper confining units). The rock Group, the main aquifer-bearing unit of the Edwards aquifer system, Thickness 170–180 ft resistivity. Clark (2003), in mapping Uvalde County, also Cyclic and marine member—Chert-bearing mudstone to packstone and Hendricks, Leo, ed., Comanchean (Lower Cretaceous) stratigraphy and units constituting the Edwards aquifer in the northeastern part of the recharge area and, in some areas, the upper confining units were consolidated. Edwards aquifer recharge zone—Modified from Texas Commission on (San Marcos platform facies) include the Kainer, Person, and Georgetown Formations. demonstrated that the informal basal nodular member of the Kainer miliolid grainstone. Weathers to massive, light-tan outcrops with paleontology of Texas: Society of Economic Paleontologists and Mineralogists, Areas mapped as upper confining unit include any or all of the Formation could be traced from the San Marcos platform into the Permian Basin Section, Publication 67–8, p. 9–29. The Kainer and Person Formations of the Edwards Group were divided into seven following map units: Ka (Austin Group), Kef (Eagle Ford Group), Kb scattered Toucasia present. Member is one of the most productive Cave or sink Maverick basin. Recent fieldwork by a number of authors (Clark, informal lithostratigraphic units by Rose (1972). These units were later categorized (Buda Limestone), and Kdr (Del Rio Clay) hydrologically because of the large number of subsurface caverns Blome, and Faith) now shows that at least the informal basal nodular into seven informal hydrostratigraphic members with the overlying Georgetown Navarro and Taylor Groups, undivided (Upper Cretaceous)—Lithologic associated with incipient karstification. Very permeable with laterally Spring and dolomitic members of the Kainer Formation may be laterally Formation considered the eighth member of the Edwards aguifer (Maclay and Small, similarity makes the Navarro and Taylor difficult to differentiate in extensive, fabric and nonfabric-selective porosity (Small and Hanson, traceable from the San Marcos platform into the Devils River trend and 1976). The central part of the recharge area (Devils River trend facies) contains reefal many areas. Mapped only in the San Marcos platform, where unit 1994; Stein and Ozuna, 1995). Thickness 10–100 ft ACKNOWLEDGMENTS even into the deeper water Maverick basin. This lateral continuity of facies lithologies of the Lower Cretaceous Devils River Formation and the overlying contains gray to brown clay and marly limestone. Very low porosity **Leached and collapsed member**—Crystalline limestone; mudstone to the lowermost units was first observed by Rose (1972) and revisited by Georgetown Formation. The western part of the recharge area contains Edwards and permeability, with no cavern development. The groups are grainstone, with chert, extensive collapsed breccia, and isolated This study was financially supported by the National Cooperative Geologic Miller (1983). Nevertheless, local aquifer researchers have not to date Group lithologies of deeper water origin (Maverick basin facies) composed of the West sometimes considered confining units in the Edwards aquifer region stromatolitic limestone. Identified in the field by bioturbated iron-Mapping Program (NCGMP). We thank Dave Moore (USGS) and John Waugh (San accepted the informal subdivisions throughout the Edwards Group. Nueces, McKnight, Salmon Peak, and Georgetown Formations (Clark, 2003). (Hanson and Small, 1995). Thickness averages 600 ft stained beds separated by massive limestone beds, and presence of the Antonio Water System) for their critical reviews of the map and text. In addition, we Hydrostratigraphic subdivision of the lower part of the Devils River The Edwards aquifer is structurally complex due to the numerous high-angle **Austin Group (Upper Cretaceous)**—Commonly called the Austin Chalk. fossil coral *Montastrea* sp. Considered the most cavernous unit in the appreciate the past efforts of San Antonio Water System, Edwards Aquifer Authority, Formation in Medina and Uvalde Counties and mapping of Maverick Massive, gray to white, chalky to marly, fossiliferous mudstone. normal faults of the Balcones fault zone, which trend, on average, to the northeast, are San Marcos platform facies. Classified as having nonfabric-selective Texas Bureau of Economic Geology, and other water-related governing agencies for basin lithologies in Kinney County are ongoing. downthrown to the southeast, and are linked by scattered cross-faults. This network of Identified in the field as white, chalky limestone, commonly containing porosity and very high permeability rates (Small and Hanson, 1994). their support and guidance of geologic mapping in south-central Texas. Thickness 540-670 ft in Medina and Uvalde Counties, of which overlapping faults has a significant impact on the geohydrology of the Edwards aquifer. the fossil oyster *Gryphaea aucella*. The group is generally referred to Thickness 70–100 ft Clark (2003, p. 4, 10) believed the lower 20–70 ft to be equivalent to Regional dense member—Dense, argillaceous mudstone; unit most The relationship between recharge, ground-water flow paths, fault characteristics, and as a confining unit; however, ground water is locally associated with REFERENCES CITED the basal nodular hydrostratigraphic member of the Kainer Formation, productivity/sustainability of the aquifer must be better understood if regional planners fractures. Scarce cavern development and low porosity and susceptible to erosion within the Edwards Group; also considered a San Marcos Platform facies are to meet future water needs of south-central Texas. permeability. Thickness 130–350 ft vertical barrier to flow throughout the Edwards aquifer. Small and Abbott, P.L., 1973, The Edwards Limestone in the Balcones fault zone, south-central Geologic mapping of the Edwards recharge area by the U.S. Geological Survey has Eagle Ford Group (Upper Cretaceous)—Brown, flaggy, sandy shale and Clark (2000, p. 4) noted the occurrence of wispy iron-oxide stains for Texas: Austin, Texas, The University of Texas Ph.D. dissertation, 122 p. been conducted at 1:24,000 scale and compiled for each county. This map argillaceous limestone identified in the field as thin flagstone with a field identification purposes. Very few caverns have been found, but Maverick basin facies Clark, A.K., 2003, Geologic framework and hydrogeologic characteristics of the compilation was constructed from the original mapping by Clark and Small (1997), petroliferous odor. Strata weather easily and form flat to gently rolling vertical fracture enlargement does occur locally in the nonfabric-Edwards aquifer, Uvalde County, Texas: U.S. Geological Survey Water-Resources Salmon Peak Formation (Lower Cretaceous)—Upper part of the Salmon Clark (2003), Hanson and Small (1995), Small and Hanson (1994), Small and others selective, low-permeability unit (Small and Hanson, 1994). Thickness topography. Primary porosity has been lost, rendering very low Investigations Report 03–4010, 17 p., 1 sheet. Peak is typified by grainstone grading downward to light-gray, (1996), Small and Clark (2000), and Stein and Ozuna (1995). permeability rates in the Eagle Ford Group. Known as lignite by local Clark, A.K., and Small, T.A., 1997, Geologic framework of the Edwards aquifer and fossiliferous mudstone; about 75 ft thick. Minor karst and limited Geologic maps of previous workers typically showed a straight, dashed, northwestdrillers. No cavern development or fossils are evident in this group. Kainer Formation (Lower Cretaceous)—Contains lithologies that range upper confining unit, and hydrogeologic characteristics of the Edwards aquifer, fracture enlargement classifies this unit as having both fabric- and trending boundary line separating San Marcos platform and Devil River trend hickness 30–150 ft throughout the Edwards aquifer region from mudstone to miliolid grainstone to crystalline limestone. Much of south-central Uvalde County, Texas: U.S. Geological Survey Water-Resources nonfabric-selective porosity, except for areas of high dissolution. exposures. This dashed boundary line implied uncertainty, which was due, in part, to formation is fossiliferous; typified by rudistid-rich mudstones and Buda Limestone (Upper Cretaceous)—Variably nodular, buff, light-gray, ovestigations Report 97–4094, 11 p., 1 sheet, scale 1:75,000. Lower part of the Salmon Peak is a thick, chert-bearing, massive lime inaccessibility and poor exposure; but we believe that this vague boundary was also the dense mudstone. Identified in the field as nodular, porcelaneous wackestones that grade into intertidal and supratidal dolomitic Collins, E.W., 2000, Geologic map of the New Braunfels, Texas, 30 x 60 minute result of geologists' conception that the Devils River Formation is discontinuous and mudstone to grainstone; average thickness 310 ft. Lower part has mudstones with evaporites and miliolid grainstones. Other fossil limestone with calcite-filled veins and no common fossils. Limestone quadrangle—Geologic framework of an urban-growth corridor along the Edwards mostly nonfabric-selective porosity associated with minor karst lithologically variable. Our current mapping of the San Marcos platform-Devils River groups include oysters and gastropods (Rose, 1972; Abbott, 1973). beds in the upper part of the Buda are generally hard and dense and aquifer, south-central Texas: University of Texas, Bureau of Economic Geology development and solution along fractures. Total thickness averages trend transition area in this 1:200,000-scale compilation reveals that the Devils River may exhibit conchoidal fracturing and a porcelaneous texture when Chert occurs throughout unit in varying amounts and is locally fiscellaneous Map 39, 28 p., 1 sheet, scale 1:100,000. exposures along the boundary can be differentiated from the San Marcos platform abundant (Collins, 2000). The Kainer's limestone and dolomitic broken. Limestone beds in the lower part of the Buda tend to be Hanson, J.A., and Small, T.A., 1995, Geologic framework and hydrogeologic McKnight Formation (Lower Cretaceous) chalky (Collins, 2000). Regionally considered a confining unit. Unit limestone represent cyclic subtidal to tidal-flat depositional hydrostratigraphic units. characteristics of the Edwards aquifer outcrop, Hays County, Texas: U.S. **Upper unit**—Brown to tan, thin-bedded mudstone, wackestone, has minor surface karst with low porosity and permeability (Small and environments (Rose, 1972; Abbott, 1973). Thickness 250 to more Geological Survey Water-Resources Investigations Report 95–4265, 10 p., 1 EDWARDS AQUIFER RECHARGE AREA Hanson, 1994). Thickness 40–90 ft packstone, and grainstone. Most porous and permeable unit within the sheet, scale 1:75,000. **Del Rio Clay (Upper Cretaceous)**—Primary upper confining unit of the **Grainstone member**—White, chert-bearing, *miliolid* grainstone and McKnight Formation, with collapse breccia, no cavern development, Lozo, F.E., Jr., and Smith, C.I., 1964, Revision of Comanche Cretaceous stratigraphic and very high, mostly fabric-selective porosity where dissolution of The State of Texas officially defined the recharge area and contributing zones of dwards aquifer. Small and Hanson (1994, p. 6) described it as a bluemudstone to wackestone. Crossbedding and ripple marks occur in nomenclature, southern Edwards Plateau, southwest Texas: Gulf Coast evaporite layers occurs. Contact between the upper and middle units the Edwards aguifer in Title 30, Part 1 of the Texas Administrative Code, Chapter 213, green to yellow-brown, variably gypsiferous clay containing iron grainstone; cavern development is rare to nonexistent throughout. Association of Geological Societies Transactions, v. 14, p. 285–306. of the McKnight is gradational, just as the upper unit is conformable Subchapters A and B. The Texas Commission on Environmental Quality (TCEQ) nodules, abundant pectin-type fossil clams, and the fossil oyster Unit is classified as having nonfabric-selective porosity and low with the overlying Salmon Peak Formation. A horizon of bored rip-up regulates and enforces the Edwards aquifer protection plan as stated in Title 30. The Ilymatogyra arietina (formerly Exogyra arietina) (Young, 1967). permeability due to recrystallization (Stein and Ozuna, 1995; Small and clasts described as a conformable "conglomeratic zone" by Lozo and Clark, 2000). Thickness 50-60 ft recharge zone is generally defined as the area where the stratigraphic units of the Minor, thin lenticular beds of highly calcareous siltstone may also Smith (1964) underlies the Salmon Peak Formation and is considered Edwards aquifer are exposed "including the outcrops of other geologic formations in occur. Unweathered Del Rio Clay is composed of kaolinite, illite, and **Kirschberg evaporite member**—Highly altered crystalline limestone, part of the upper McKnight (Clark, 2003). Thickness 100–160 ft proximity to the Edwards aquifer, where caves, sinkholes, faults, fractures, or other lesser amounts of montmorillonite (Collins, 2000). Secondary gypsum chalky mudstone, and chert; fossils uncommon. Identified by boxwork Middle unit—Dark, laminated, fissile mudstone identified by its occurs as fracture fillings in clay-rich exposures near igneous bodies permeable features would create a potential for recharge of surface waters into the voids with neospar and travertine framing. Extensive cavern petroliferous odor and vegetative band on aerial photographs. Very Edwards aquifer. The recharge zone is identified as that area designated as such on (Clark, 2003). The Del Rio has no recognized cavern development and development throughout unit makes the Kirschberg one of the most low permeability, no notable cavern development, and classified as official maps located in the appropriate regional office and groundwater conservation no significant porosity or permeability. Directly overlies the Lower porous (majority fabric selective) and permeable members of the having mostly nonfabric-selective porosity. Considered a confining unit districts" (Texas Commission on Environmental Quality, 2003). North of the Edwards Cretaceous formations in many areas. Thickness about 40–110 ft Edwards aquifer (Stein and Ozuna, 1995). Average thickness 50-60 ft by Clark (2003, p. 5). Thickness about 40 ft STUART CITY REEF 0 50 100 150 200 MILES 0 65 130 195 260 KILOMETERS [Modified from Clark (2003)] **LOCATION MAP**

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

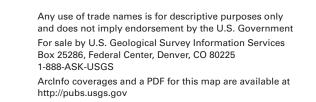
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MEDINA COUNTY

99°24'00"



[Modified from Clark (2003)]



Geology compiled and modified from Clark (2003

Small and Clark (2000), Small and Hanson (1994

Small and others (1996), and Stein and Ozuna (1995). Manuscript approved for publication December 28, 2004

Clark and Small (1997), Hanson and Small (1995)

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D.E., Ozuna, G.B., Cole, J.C., Clark, A.K., Small, T.A., and Morris, R.R., compilers, 2005, Geologic map of the Edwards aquifer recharge zone, south central Texas: U.S. Geological Survey Scientific Investigations Map 2873, 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

UVALDE COUNTY