Preliminary Geologic Map of the Laredo, Crystal City–Eagle Pass, San Antonio, and Del Rio 1º x 2º Quadrangles, Texas, and the Nuevo Laredo, Ciudad Acuña, Piedras Negras, and Nueva Rosita 1º x 2º Quadrangles, Mexico

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Pamphlet to accompany

Open-File Report 2009-1015

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2009

Version 1.0

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Suggested citation:
Page, W.R., Berry, M.E., VanSistine, D.P., and Snyders, S.R., 2009, Preliminary geologic map of the Laredo, Crystal City–Eagle Pass, San Antonio, and Del Rio 1° x 2° quadrangles, Texas, and Nuevo Laredo, Ciudad Acuña, Piedras Negras, and Nueva Rosita 1° x 2° quadrangles, Mexico: U.S Geological Survey Open-File Report 2009-1015, 10 p., 2 plates, scale 1:350,000. [Available at URL http://pubs.usgs.gov/of/2009/1015/]

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Introduction

The purpose of this map is to provide an integrated, bi-national geologic map dataset for display and analyses on an Arc Internet Map Service (IMS) dedicated to environmental health studies in the United States–Mexico border region (Buckler and Stefanov, 2004; Papoulias and others, 2006). The IMS web site was designed by the US-Mexico Border Environmental Health Initiative project and collaborators, and the IMS and project web site address is http://borderhealth.cr.usgs.gov/. The objective of the project is to acquire, evaluate, analyze, and provide earth, biologic, and human health resources data within a GIS framework (IMS) to further our understanding of possible linkages between the physical environment and public health issues. The geologic map dataset is just one of many datasets included in the web site; other datasets include biologic, hydrologic, geographic, and human health themes.

Geologic Setting

Introduction

The map was compiled by integrating the geology of the Laredo (Bureau of Economic Geology, 1976a), Crystal City–Eagle Pass (Bureau of Economic Geology, 1976b), San Antonio (Bureau of Economic Geology, 1974), and Del Rio (Bureau of Economic Geology, 1977) 1:250,000-scale Texas Geologic Atlas Sheets, and the Piedras Negras (Carrasco and others, 2003), Nuevo Laredo (Gutiérrez and others, 2004), Ciudad Acuña (Martinez and others, 2003), and Nueva Rosita (Rodriguez and others, 2000) 1:250,000-scale geologic quadrangles, Mexico (fig. 1). The map area extends along the Rio Grande from San Ygnacio, Texas, and Tamaulipas, to northwest of Del Rio, Texas, and Ciudad Acuña, Coahuila. Other urban centers in the map area include border sister cities Nuevo Laredo, Tamaulipas, and Laredo, Texas, and Piedras Negras, Coahuila, and Eagle Pass, Texas. The map is described in the following sections by three domains: an eastern part in the Gulf Coastal Plain, a western part in the Sabinas folded belt, and a northern part in the Edwards Plateau (fig. 2).

Eastern Part

The eastern part of the map area includes mixed marine and continental Tertiary sedimentary rocks (mostly sandstone and claystone) of the Gulf Coastal Plain (fig. 2). Rocks in the coastal plain include Paleocene to Pliocene rock units that dip gently east (towards the Gulf) and formed as a result of rapid deposition and progradation of sediments across the Cretaceous continental margin and into the Gulf of Mexico. The rapid infilling resulted in the development of syndepositional growth faults, which formed episodically from the Paleocene to the Pliocene. The growth faults are subparallel to the modern coastline and are mostly concealed to form a structurally complex, Gulf Coast Tertiary basin as illustrated in cross sections by Dodge and Posey (1981).

Tertiary rocks in the Gulf Coastal Plain contain oil and gas resources in the Burgos Basin of Tamaulipas, Nuevo Leon, and Coahuila, Mexico, and in southern Texas. Primary oil and gas producing units in the Burgos Basin include Oligocene sandstones of the Frio and Vicksburg Formations, sandstone units in the Eocene Wilcox and Paleocene Midway Groups, and some Jurassic and Cretaceous units. The U.S. Geological Survey recently completed an assessment of undiscovered oil and gas resources in the Burgos Basin (USGS, 2004), Mexico, and estimated a mean total of 12.9 trillion cubic feet of gas and 6.2 billion barrels of oil.

Coal-bearing Tertiary rocks of the Gulf Coastal Plain include the (1) Eocene Jackson Group, (2) Yegua and Cook Mountain Formations, El Pico Clay, and Bigford Formation of the Eocene Claiborne Group, and (3) parts of the Eocene Wilcox Group (Warwick and others, 2002; Bureau of Economic

Geology, 1976a, b). Some Tertiary units in the map area contain uranium deposits; parts of the Eocene Jackson Group, the Oligocene and Miocene Catahoula Formation, and the Pliocene Goliad Formation are classified as uranium-bearing units by the Bureau of Economic Geology (1981). Uranium mines in the South Texas Uranium District are in the northern part of the Crystal City–Eagle Pass sheet (Bureau of Economic Geology, 1976b), and are chiefly in the upper part of the Jackson Group and lower part of the Catahoula Formation.

Tertiary sedimentary strata form major ground-water aquifers in the map area. The southern Carrizo–Wilcox aquifer is exposed in the central part of the map area, and its subcrop extends over much of the eastern part (fig. 3). In parts of the aquifer, water levels have declined about 130 m over the past century due to heavy pumping (Greene and others, 2007). The Texas Water Development Board (2003) completed a water availability model for the southern Carrizo–Wilcox aquifer. The model predicted that water levels will rebound in the western part of the aquifer where pumping was projected to decrease, and that water levels will continue to decline in the eastern part where pumping is projected to increase due to agriculture. The cities of Laredo, Texas, and Nuevo Laredo, Tamaulipas, are located at the southern boundary of the aquifer model study area (Texas Water Development Board, 2003). The western, up-dip part of the Gulf Coast aquifer (fig. 3) extends into the map area and is a composite aquifer consisting of sandstone formations separated by clay units. Major issues associated with this aquifer system include saline water and ground subsidence due to heavy pumping.

Western Part

Rocks in the western part of the map area are Jurassic and Cretaceous marine limestone, sandstone, siltstone, shale, and marl, and minor gypsum and anhydrite. In contrast to the mildly deformed clastic rocks in the Gulf Coastal Plain, these strata are highly deformed by the Sabinas folded belt (fig. 2) and other uplifts associated with the Laramide orogeny in Nuevo Leon and Coahuila (Ewing, 1991). Laramide compressional structures include folded, northwest-trending ridges, and reverse and thrust faults that formed from complex

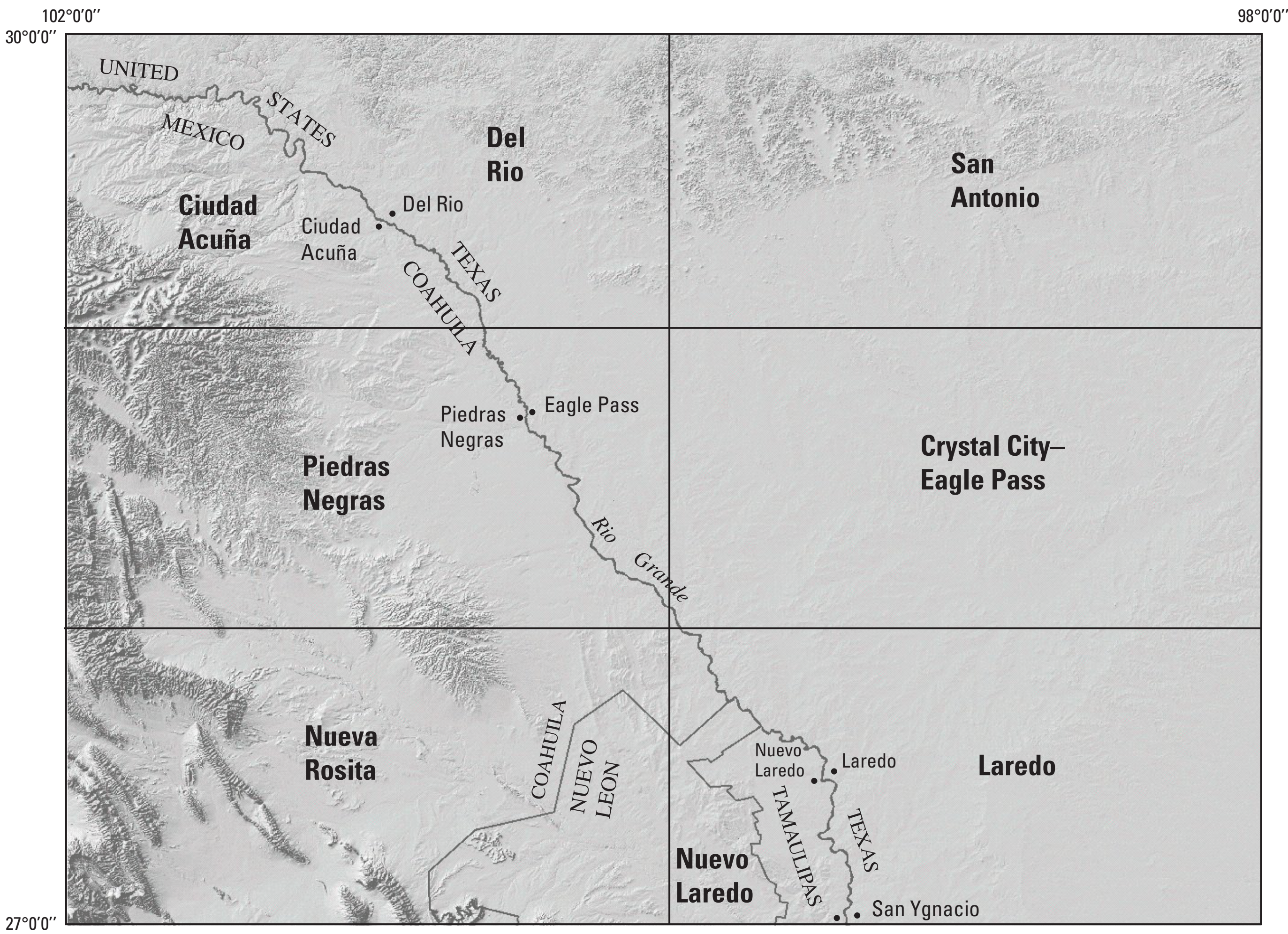

Figure 1. Index to 1:250,000-scale quadrangles in map area.

interactions related to subduction of the Pacific plate beneath North America. In the Ciudad Acuña quadrangle, the Cretaceous strata are intruded by Tertiary igneous rocks, and in the Del Rio and San Antonio quadrangles, Cretaceous strata are intruded by Late Cretaceous mafic igneous rocks related to the Balcones magmatic province (Wittke and Lawrence, 1993). The Cretaceous igneous rocks may be important in the generation of oil and gas resources, and they may also be barriers to ground-water flow (Miggins and others, 2004).

Cretaceous coal-bearing units in the Sabinas folded belt include the Upper Cretaceous Olmos and San Miguel Formations. Numerous coal mines are in these units in the Nueva Rosita quadrangle (Rodriguez and others, 2000). Cretaceous rocks in Mexico also contain some lead-zinc, fluorite, chlorite, barite, magnesium, manganese, and phosphate deposits.

Northern Part

Rocks in the far northern part of the map area (northern half of the San Antonio and Del Rio quadrangles) are mostly Cretaceous rocks in the Edwards Plateau physiographic province (fig. 2). The margin between the uplifted plateau and the subsiding Gulf Coastal Plain is defined by the Tertiary Balcones fault zone (fig. 2), a zone of mostly down-to-the-southeast normal faults with an estimated cumulative offset of 500 m (Ewing, 1991). Cretaceous rocks north of the Balcones fault zone were uplifted along the fault zone during basin and range extension in the Miocene (Ewing, 1991) to form the present-day plateau. The southwest-trending Balcones fault zone terminates southwestward against the northwest-trending Laramide Sabinas folded belt (fig. 2).

The Cretaceous rocks in the Edwards Plateau area form the southeastern extent of the Edwards aquifer in Texas, which is one of the most dynamic aquifers in the United States (Bureau of Economic Geology, 2001) (fig. 3). The Edwards Balcones fault zone and Trinity aquifers are also present in the map area. Rocks that form the aquifers extend southward into Coahuila, Mexico, where little is known about their hydrogeologic characteristics. In the Edwards aquifer of Texas, ground water flows through faults, fractures, and solution cavities in the Lower Cretaceous Edwards Limestone and related rocks. Competing demand for ground water usage between urban and agricultural sectors, and the potential impact of heavy pumping and drought on springs and ecosystems in the Edwards aquifer, are important issues in southern Texas.

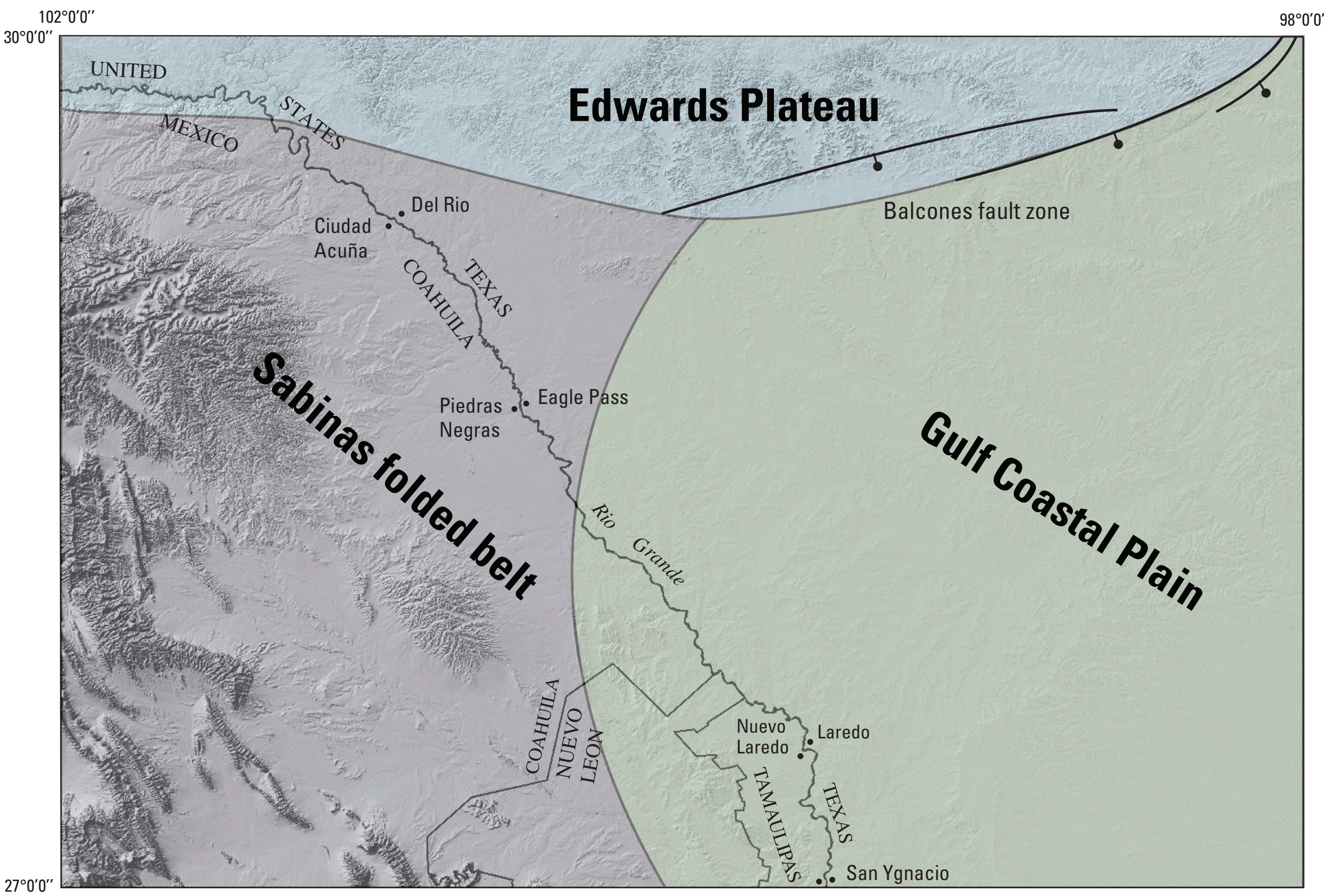

Figure 2. Study area showing three domains described in text: Edwards Plateau, Sabinas folded belt, and Gulf Coastal Plain.

Methods

The map was compiled by integrating geologic-unit polygons, lines, and point data from the Laredo, Crystal City–Eagle Pass, San Antonio, and Del Rio 1:250,000-scale Texas Geologic Atlas Sheets, and the Piedras Negras, Nuevo Laredo, Ciudad Acuña, and Nueva Rosita 1:250,000-scale quadrangles, Mexico (fig. 1). In ArcInfo, the geologic datasets listed above were queried by their original source unit symbol designations and were redefined into the new unit symbols used for the merged bi-national dataset. The datasets were then appended and boundaries removed between like units.

Most of the map unit symbols were redefined from the source map symbols in order to develop a consistent scheme using USGS map standards. The capitalized first letter of the map symbol represents the geologic system as follows: "Q" for Quaternary, "T" for Tertiary, "K" for Cretaceous, and "J" for Jurassic. The capitalized first letter is followed by a lower-case letter, or letters, derived from the formal formation name or informal rock type. In some cases, the new symbols are the same as the source map symbols, but in general, most units were assigned new symbols for overall consistency. The unit names and map unit ages were derived mainly from the source maps. The unit descriptions are lithologic descriptions that are abbreviated versions from the source maps. For greater detail on units, the reader is referred to the original source maps. Supplemental information for map unit thickness and lithology for the Cretaceous rocks is from Humphrey and Díaz (2003), and supplementary information for map unit thickness and other characteristics for the Quaternary units is from Moore and Wermund (1993a, b).

Although geologic map unit polygons generally were consistent across 1:250,000-scale quadrangle boundaries, there were edge-matching inconsistencies, especially in the Quaternary and Tertiary surficial deposits. In places on the boundary between the Piedras Negras and Nueva Rosita quadrangles, Pliocene conglomerate (source unit TplCgo) in the Piedras

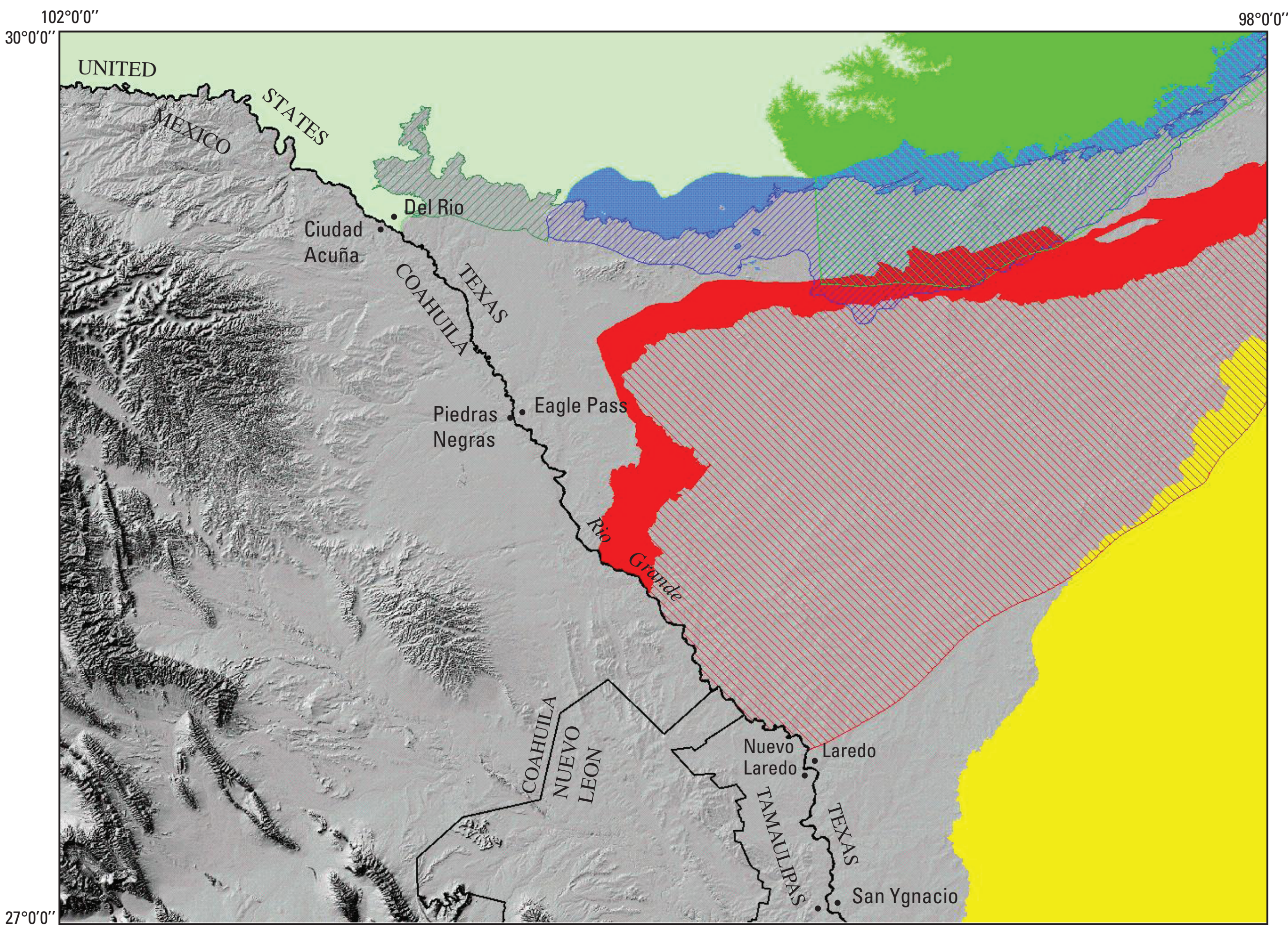

Figure 3. Major aquifers in Texas part of map area. Yellow, Gulf Coast aquifer; red, Carrizo-Wilcox aquifer; light green, Edwards aquifer; blue, Edwards Balcones fault zone aquifer; dark green, Trinity aquifer. Solid colors represent aquifer unit outcrop or unconfined aquifer; hachured areas represent aquifer unit subcrop or confined aquifers in subsurface.

Negras quadrangle was mapped as Holocene conglomerate (source unit QhoCgo) in the Nueva Rosita quadrangle. In other places along the quadrangle boundary, Holocene and Pleistocene conglomerate (source unit QpthoCpg) in the Piedras Negras quadrangle was mapped as Holocene conglomerate (source unit QhoCgo) in the Neuva Rosita quadrangle. We resolved the age difference issue by combining those units into a new unit named Quaternary and Tertiary gravel, undivided (QTg).

There were also edge-matching inconsistencies in the Quaternary surficial deposits between the Texas quadrangles. For example, in the Crystal City–Eagle Pass, Laredo, and Del Rio quadrangles, Pleistocene fluvial terrace deposits (source map unit Qt) were mapped as Holocene in the San Antonio quadrangle. In other places along the Texas quadrangle boundaries, inconsistencies were noted between source map units Qu (Quaternary deposits undivided, Pleistocene), Qle (Pleistocene Leona Formation), and Qt (Pleistocene fluvial terrace deposits). To resolve these differences, we combined source map units Qt, Qle, Qf, Qd, and Qu into new map unit Qal, Holocene and Pleistocene alluvium, undivided. Source map unit symbol Qal, which represents active wash deposits, was changed to new unit symbol Qa, Holocene modern alluvium. Pliocene through Paleocene sedimentary rocks of the Gulf Coastal Plain and Cretaceous map unit polygons generally matched across quadrangle boundaries and only required minor modification.

Some Lower Cretaceous rock units in the northern part of the map area were originally mapped by facies on the San Antonio (Bureau of Economic Geology, 1974), Del Rio, (Bureau of Economic Geology, 1977), and Ciudad Acuña (Martínez and others, 2003) quadrangles. These laterally equivalent rock units include the Edwards Limestone (Ked), Devils River Limestone (Kdvr), and the Salmon Peak Limestone (Ksa), McKnight Formation (Kmk), and West Nueces Formation (Kwn). Because the contacts between these units are facies boundaries mapped at reconnaissance scale, and the facies relationships between these units in United States and Mexico are poorly understood, we assigned all of these units the same color to visually signify them as one combined map unit (see Correlation of Map Units and map A). Internal contacts and original map unit symbols were retained to identify areas where these boundaries might be field checked during further studies. For example, in parts of the San Antonio quadrangle, new detailed geologic mapping of these rocks by Moore (2007) has resulted in revision in places of contacts between the Devils River Limestone, McKnight Formation, and Salmon Peak Limestone.

Western equivalent units to the Edwards and Devils River Limestones, and the Salmon Peak Limestone, McKnight and West Nueces Formations, include the Santa Elena Limestone, Sue Peaks Formation, and Del Carmen Limestone. These units were originally mapped in the far western part of the Del Rio quadrangle along the Rio Grande, but because they were extremely thin, we combined them with the Salmon Peak Limestone so that the mapped geology was consistent across the international boundary.

To better understand and begin to analyze the relationships between naturally occurring geologic materials, related anthropogenic processes (mines, oil and gas wells, and power plants), and human and wildlife health, we included point data layers showing (1) the location of active and inactive mines, mineral prospect/occurrences, coal-burning and gas-fired power plants, and (2) oil and gas wells (map B). For Mexico, these data were recorded directly from the Servicio Geológico Mexicano map sheets. Locations for power plants and coal mines in Texas are from Warwick and others (2002). Locations for oil and gas wells in Texas are derived from a subset of data provided by the Railroad Commission of Texas for the Texas Commission on Environmental Quality's 2002 potential sources of contaminants dataset. Locations for mineral occurrences/prospects and smelters in Texas are from the Bureau of Economic Geology (1987). The locations for uranium mines in Texas were from the Crystal City–Eagle Pass Texas Geologic Atlas sheet (Bureau of Economic Geology, 1976b).

DESCRIPTION OF MAP UNITS

Qa **Modern alluvium (Holocene)**—Active channel, floodplain, and low-lying terrace deposits consisting of gravel, sand, silt, clay, and organic material. About 2–15 m thick

Qcd **Clay to sand dunes (Holocene)**—Clay, silt, and sand; deposits are elongate and on downwind side of intermittently wet basins. Mapped in southeastern map area. About 1.5–9 m thick

Qsd **Active dunes (Holocene)**—Parabolic and barchan sand dunes; high permeability, low water-holding capacity, good drainage. Vegetation cover none to sparse. Mapped in southeastern map area. About 2–9 m thick

Qds **Stabilized sand dunes (Holocene)**—Sand dune deposits stabilized by live-oak, shrub, and grass vegetation; moderate to high permeability, low to moderate water-holding capacity, good to fair drainage, shallow water table. Mapped in southeastern map area. About 2–8 m thick

Qs **Sand sheet (Holocene)**—Wind-blown sand. Deposits have low to moderate water-holding capacity, good to fair drainage. Mostly stabilized by shrub and grass vegetation. Mapped in southeastern map area. About 0.5–5 m thick

Qsi **Silt sheet (Holocene)**—Wind-blown silt and fine sand; deposits form thin discontinuous sheets and are derived from other eolian deposits. Vegetated by shrubs and grasses. Mapped in southeastern map area. About 0.5 to less than 5 m thick

Qla **Lacustrine deposits (Holocene)**—Silt and clay occurring in intermittently wet areas and adjacent to existing lakes and streams. Mapped in south-central map area. Thickness unspecified

Qal **Alluvium, undivided (Holocene and Pleistocene)**—Gravel, sand, silt, and clay in varying proportions; may include channel, floodplain, fan, terrace, and some colluvial deposits. In Texas, most of unit includes Pleistocene fluvial terrace deposits above flood level along entrenched drainages, especially along the Rio Grande, but also in major river drainages south of the Edwards Plateau. In Mexico, unit includes wide variety of Holocene and Pleistocene deposits that generally occur in central parts of basins, but also in drainages entrenched into ranges. About 3–20 m thick

Qtr **Travertine deposits (Pleistocene)**—Limestone originating from paleospring discharge. Mapped mostly in southwestern map area. Thickness unspecified

Qbe **Beaumont Formation (Pleistocene)**—Clay, silt, sand, and gravel deposited in stream channel, point bar, natural levee, and backswamp environments of the Gulf Coastal Plain; includes concretions and massive accumulation of calcium carbonate and iron oxide concretions; mapped along southeastern edge of map area. About 50–60 m thick

Ql **Lissie Formation (Pleistocene)**—Sand, silt, clay, and minor gravel deposited in meander-belt levee, crevasse splay, distributary channel, and floodplain environments of the Gulf Coastal Plain; mapped in southeastern map area. About 60 m thick

QTg **Quaternary and Tertiary gravel, undivided (Holocene to Pliocene)**—Gravel, sand, silt, and some clay; mainly alluvial fan gravel and colluvium on flanks of ranges, but also includes gravel deposits blanketing bedrock units in low hills, and fluvial terraces along drainages within the basins. Mapped primarily in southwestern map area. Thickness unspecified

QTu **Uvalde Gravel (Pleistocene or Pliocene)**—Gravel well cemented with calcium carbonate; gravel clasts consist of chert, quartz, limestone, and igneous rocks; also includes some sand layers. About 1–10 m thick

QTb **Pleistocene and Pliocene basalt**—Basalt mapped in Nueva Rosita quadrangle, southwestern map area; $^{40}Ar/^{39}Ar$ ages for these rocks in the Nueva Rosita quadrangle are about 2 Ma (Iriondo and others, 2004). Thickness unspecified

Tg **Goliad Formation (Pliocene)**—Clay, sandstone, marl, and limestone with calcium-carbonate-cemented gravel cap (1–3 m thick) at top of unit; well-cemented gravel cap locally quarried in Laredo quadrangle. As much as 150 m thick

Tfo **Fleming Formation and Oakville Sandstone, undivided (Miocene)**—Fleming Formation consists of clay and sandstone; unit contains fossil wood. Oakville is sandstone and clay. Fleming and Oakville have combined thickness of about 150–243 m

Tcv **Catahoula (Miocene and Oligocene) and Frio and Vicksburg (Oligocene) Formations, undivided**—Tuff, sandstone, mudstone, claystone, tuffaceous claystone, volcaniclastic sandstone and conglomerate, and minor gypsum. Combined thickness about 337 m

Tj **Jackson Group, undivided (Eocene)**—Bentonitic clay, sandstone, siltstone, shale, and tuff; some clay is carbonaceous and lignitic; sandstone and siltstone are tuffaceous and glauconitic; contains oysters, pelycepods, and burrows. About 250–266 m thick

Ti **Tertiary igneous rocks (Eocene)**—Andesitic porphyry, diorite, monzonite, granite, and syenite. Ar^{40}/Ar^{39} dates for samples collected in Ciudad Acuña quadrangle (northwestern map area) range from 41 to 42 Ma (Iriondo and others, 2004)

Claiborne Group (Eocene)

Ty **Yegua Formation**—Sandstone and clay. Sandstone is indurated to friable, calcareous, glauconitic, massive, laminated, and cross bedded; clay is lignitic, silty, sandy, bentonitic, and laminated. About 120–320 m thick

Tcm **Cook Mountain Formation**—Clay and sandstone; clay is lignitic, silty, and glauconitic; sandstone is at base and top of formation and is calcareous and glauconitic, and contains marine fossils. About 60–105 m thick

Ts **Sparta Sand**—Sand and some siltstone; sand is quartzose, well sorted, and micaceous; includes silty clay partings. About 40 m thick

Tla **Laredo Formation**—Sandstone and clay; sandstone is very fine to fine grained, ferruginous, glauconitic, micaceous, cross bedded, and extensively bioturbated; clay has limestone concretions and some gypsum. Equivalent to the Cook Mountain Formation and Sparta Sand northeast of Frio River. About 190 m thick

Twe **Weches Formation**—Sand and clay; sand is glauconitic and quartzose; clay is silty and glauconitic. About 10 m thick

Tqc **Queen City Sand**—Sandstone and siltstone; sandstone is fine to medium grained, well sorted, noncalcareous, friable to indurated, massive to laminated, and cross bedded; siltstone is friable and contains thin interbeds of silty, sandy clay. About 75–150 m thick

Tep **El Pico Clay**—Clay, silty clay, sandstone, and coal; clay is gypsiferous; sandstone is fine grained, silty, argillaceous, and friable to indurated. Equivalent to the Weches Formation and Queen City Sand northeast of Frio River. About 210–270 m thick

Tr **Reklaw Formation**—Sandstone and clay; sandstone is glauconitic, friable to highly indurated, and cross bedded; clay is silty and lignitic. About 15 m thick

Tb **Bigford Formation**—Clay, sandstone, shale, and lignite; clay is calcareous, selenitic, and sandy; sandstone is cross bedded and interbedded with fissile shale. Equivalent to the Reklaw Formation northeast of Frio River. About 60–245 m thick

Tc **Carrizo Sand**—Sandstone and shale; sandstone is fine to coarse grained, well sorted, weakly cemented to indurated, massive, and cross bedded; shale contains limonite concretions. Forms part of major regional aquifer (Carrizo-Wilcox aquifer). About 60 m thick

Tw **Wilcox Group, undivided (Eocene)**—Mudstone, sandstone, shale, siltstone, and lignite; glauconitic; calcareous and arenaceous concretions. Forms part of major regional aquifer (Carrizo-Wilcox aquifer). About 130–365 m thick

Tm **Midway Group, undivided (Paleocene)**—Clay, sand, and some sandy, fossilferous limestone; glauconitic; argillaceous; phosphatic concretions in lower part. About 30–122 m thick

Kig **Late Cretaceous igneous rocks**—In parts of San Antonio and Del Rio quadrangles in north-central map area includes phonolite, nephelinite, and basalt of the Balcones magmatic province (Wittke and Lawrence, 1993). $^{40}Ar/^{39}Ar$ ages of some of these rocks range from 72 to 80 Ma (Miggins and others, 2004)

Km **Mendez Shale (Upper Cretaceous)**—Fissile, calcareous shale; includes hematite nodules. Partly equivalent to the Escondito, Olmos, and San Miguel Formations and the Upson Clay. Mapped only in Nuevo Laredo quadrangle (south-central map area). May be as thick as 700 m

Kes **Escondito Formation (Upper Cretaceous)**—Clay, sandstone, siltstone, and limestone; sandstone is ripple marked, and cross bedded and forms cuestas; siltstone is fossiliferous. About 60–250 m thick

Kol **Olmos Formation (Upper Cretaceous)**—Clay, sandstone, and coal; includes ferruginous concretions and silicified wood. About 120–150 m thick

Ksm **San Miguel Formation (Upper Cretaceous)**—Sandstone, limestone, clay, and some coal; contains oysters (Exogyra ponderosa). About 120 m thick

Kup **Upson Clay (Upper Cretaceous)**—Calcareous clay; contains oysters (*Exogyra ponderosa*). About 150 m thick

Knm **Navarro Group and Marlbrook Marl, undivided (Upper Cretaceous)**—Marl, clay, sandstone, and siltstone; glauconitic; contains siderite and limonite concretions. Mapped in northeastern map area. As much as 300 m thick

Kac **Anacacho Limestone (Upper Cretaceous)**—Limestone and marl; limestone in part cross bedded and fossiliferous; marl partly sandy and bentonitic. Mapped in northeastern map area. Maximum thickness about 150 m

Kpg **Pecan Gap Chalk (Upper Cretaceous)**—Chalk and chalky marl; contains oysters (*Exogyra ponderosa*). Mapped in northeastern map area. About 30–120 m thick

Kau **Austin Chalk (Upper Cretaceous)**—Lime mudstone and chalk; glauconitic; contains marine fossils. About 175–800 m thick

Kbo **Boquillas Formation (Upper Cretaceous)**—Shale, limestone, silty limestone, and siltstone. Unit mapped in northwestern Del Rio quadrangle west of Devils River; laterally equivalent to the Eagle Ford Group. About 50–60 m thick

Kef **Eagle Ford Group (Upper Cretaceous)**—Shale, siltstone, sandstone, and limestone; flaggy limestone and shale in upper part; lower part is flaggy, laminated siltstone and fine-grained sandstone. About 20–60 m thick

Kbd **Buda Limestone and Del Rio Clay, undivided (Upper Cretaceous)**—Buda Limestone is bioclastic limestone, partly glauconitic, pyritiferous, and argillaceous; massive bedded. About 15–30 m thick. Del Rio Clay is calcareous, gypsiferous, and pyritic clay and calcareous siltstone; thin bedded. About 60 m thick

Kwa **Washita Group, undivided (Upper and Lower Cretaceous)**—Limestone and shale. Mapped in Nueva Rosita quadrangle (southwestern map area). About 135–700 m thick

Kdvr **Devils River Limestone (Lower Cretaceous)**—Limestone, mudstone, and dolostone; limestone is cherty and nodular, and contains pellets, miliolids, and rudistids. Laterally equivalent to the Edwards Limestone, and the combined Salmon Peak Limestone, and McKnight and West Nueces Formations. About 213 m thick

Ksa **Salmon Peak Limestone (Lower Cretaceous)**—Limestone and mudstone; limestone is granular and cross bedded; mudstone has abundant *globergerina* and white chert masses. Laterally equivalent to upper parts of the Devils River and Edwards Limestones. About 95–115 m thick

Kmk **McKnight Formation (Lower Cretaceous)**—Limestone, mudstone, and shale; limestone is granular and pelletic; mudstone is argillaceous and limy, and contains chert layers; formation contains solution-collapse breccia zones. Laterally equivalent to middle parts of the Devils River and Edwards Limestones. About 45 m thick

Kwn **West Nueces Formation (Lower Cretaceous)**—Limestone; contains miliolids, oysters, and mollusks. Laterally equivalent to lower parts of the Devils River and Edwards Limestones. About 42 m thick

Ked **Edwards Limestone, undivided (Lower Cretaceous)**—Limestone with abundant chert; includes rudistids and miliolids; solution collapse zones. Laterally equivalent to the Devils River Limestone, and the combined Salmon Peak Limestone and McKnight and West Nueces Formations. About 150–200 m thick

Kki **Kiamichi Formation (Lower Cretaceous)**—Shale and calcareous shale; mapped in Nueva Rosita quadrangle (southwestern part of map area), and partly equivalent to the Edwards and Salmon Peak Limestones. About 30–70 m thick

Ka **Aurora Formation (Lower Cretaceous)**—Limestone and some chert. Partly equivalent to the Edwards Limestone and Glen Rose Formation in Texas; exposed in southwestern map area. About 700–1,000 m thick

Kgr **Glen Rose Formation (Lower Cretaceous)**—Limestone, dolostone, and marl; limestone is mostly aphanic and marly; dolostone is finely crystalline and porous; contains rudistids, oysters, and echinoids. Forms part of the Trinity aquifer. About 300–1,000 m thick

Klp **La Pena Formation (Lower Cretaceous)**—Shale, limestone, and some chert. Exposed in southwestern map area. About 250–300 m thick

Kcu **Cupido Formation (Lower Cretaceous)**—Limestone and dolostone, some chert. Exposed in southwestern map area. About 125–400 m thick

Klv **La Virgen Formation (Lower Cretaceous)**—Gypsum, anhydrite, and limestone. Laterally equivalent to part of the Cupido Formation; exposed in southwestern map area. About 600–800 m thick

Klm **La Mula Formation (Lower Cretaceous)**—Shale, limestone, and dolostone. Laterally equivalent to part of the Cupido Formation; exposed in southwestern map area. About 200–700 m thick

Kpa **Padilla Limestone (Lower Cretaceous)**—Limestone and dolomitic limestone. Laterally equivalent to upper part of the Taraises Formation and lower part of the Cupido Formation; exposed in southwestern map area. About 170–300 m thick

Kta **Taraises Formation (Lower Cretaceous)**—Argillaceous limestone and shale. Exposed in southwestern map area. Thickness about 230 m

Kbv **Barril Viejo Formation (Lower Cretaceous)**—Shale, sandy shale, limestone, and sandy and marly limestone. Laterally equivalent to middle and upper parts of the Taraises Formation; exposed in southwestern map area. About 500–800 m thick

Ks **San Marcos Formation (Lower Cretaceous)**—Conglomeratic arkosic sandstone to sandy arkosic conglomerate. Laterally equivalent to middle part of the Taraises Formation; exposed in southwestern map area. About 200–500 m thick

Kme **Menchaca Formation (Lower Cretaceous)**—Argillaceous limestone, mudstone, and calcareous shale. Laterally equivalent to lower part of the Taraises Formation; exposed in southwestern map area. About 120–200 m thick

Jlc **La Casita Formation (Upper Jurassic)**—Calcareous shale, sandstone, and mudstone. Exposed in southwestern map area. About 170–500 m thick

Jol **Olvida Formation (Upper Jurassic)**—Salt, anhydrite, limestone, and shale in diapirs exposed in core of anticlinal ranges in Nueva Rosita quadrangle (Rodriguez and others, 2000). Exposed in southwestern map area. Thickness unknown

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