Summary Report for the 2001-2002 STATEMAP Project: Geological Mapping to Support Improved Database Development and Understanding of Urban Corridors and Critical Aquifers of Texas

Final Report

by

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INTRODUCTION

This Texas STATEMAP project involves geologic mapping of areas where improved geologic information can assist development, land use, public education, environmental protection, and the economy. Work during the past year focused on new mapping and digital compilation projects within four study areas (fig. 1): (1) digital compilation (1:100,000) of geology of the northern segment of the Edwards aquifer recharge zone, south-central Texas, project 1; (2) geologic mapping (1:24,000) of the Hill Country Trinity aquifer recharge zone, south-central Texas, project 2; (3) geologic mapping (1:24,000) of the San Marcos–Seguin corridor, project 3; and (4) digital compilation of geology of Quihi and Timber Creek quadrangles—part of the West San Antonio corridor and Edwards aquifer, addendum project 4. Geologic maps produced by each of the projects address groundwater resource and urban-development issues that are of paramount importance to the affected regions of Texas. Improved geologic maps benefit the management of two major aquifers that are critical to Texas, the Edwards and Hill Country Trinity aquifers, and a minor aquifer, the Leona aquifer. The improved geologic maps of each of the areas produced by this project will aid professionals and the public in making informed decisions regarding land use, aquifer management, and environmental protection for urban-growth corridors in south-central Texas.

Deliverables produced for this 2001-2002 contract year are (1) project 1: digital 1:100,000-scale open-file map of the northern Edwards aquifer, *Geologic Map of the West Half of the Taylor, Texas 30 × 60 minute Quadrangle*; (2) project 2: 12 open-file geologic quadrangle maps (1:24,000) of the Hill Country Trinity aquifer west of Austin and north of San Antonio; (3) project 3: 2 open-file geologic quadrangle maps (1:24,000) of the San Marcos–Seguin corridor; and (4) addendum project 4: draft digital map/GIS database of Quihi and Timber Creek quadrangles, two quadrangles within the West San Antonio corridor and Edwards aquifer, Quihi and Timber Creek quadrangles.

Methods used for new mapping projects 2 and 3 included standard field techniques, study of aerial photographs, and review of previous work. Unit contacts and faults are portrayed on the maps by solid and dashed lines to reflect the relative certainty of locations of features observed in the field and on aerial photographs. Faults and unit contacts drawn as solid lines are relatively more distinct in the field and on aerial photographs than those indicated by dashed lines. Dotted fault lines show where faults are covered. Most strata in the study areas, almost flat lying, commonly have very low regional dips of less than 1°. Exceptions are where a stratal dip of between 2° and 6° has been recognized on aerial photographs. Unit descriptions and stratigraphic charts are based on observations made during this study and many previous geologic investigations by earlier workers cited throughout this report.

During future studies, it is our intent that quadrangle maps of the project 2 and 3 areas be digitized and combined with existing and future maps to produce published 1:100,000-scale maps and seamless digital data sets. Our intent for addendum project 4 is for other quadrangles to be digitized within the West San Antonio corridor study area and for them to be combined with the Quihi and Timber Creek digital map data to produce a published 1:100,000-scale map and seamless digital data set.

Project 1, digital compilation of geology of the northern segment of the Edwards aquifer recharge zone, south-central Texas, was accomplished by our digitizing 16 Bureau of Economic Geology open-file geologic maps (1:24,000) that had been mapped for previous STATEMAP projects. A regional 1:250,000-scale map that encompasses the project area exists but is not digital (Proctor and others, 1974). Other previous maps of different parts of the study area include works by Adkins and Arick (1930), Marks (1950), Walls (1950), Ward (1950), Gordon (1951), Tydlaska (1951), Hartwig (1952), Atchinson (1954), Arrington (1954), Rogers (1963), Moore (1964), and Collins (1987). Useful stratigraphic studies include the Young (1967) discussion of the Lower Cretaceous and his report (Young and Woodruff, 1985) of the Upper Cretaceous Austin Group, the Rodda and others (1966) study of Lower Cretaceous rocks, the Stricklin and others (1971) investigation of the Lower Cretaceous Trinity deposits, interpretations of the Lower Cretaceous Edwards Group by Rose (1972), Moore's (1964, 1996) evaluations of Fredericksburg strata, Wilbert's (1967) summary of the Georgetown Formation, and Martin's (1967) discussion of the Buda Formation. The McFarlan and Menes (1991) summary of the Lower Cretaceous of the Gulf of Mexico Basin and the Sohl and others (1991) discussion of the Upper Cretaceous of the Gulf of Mexico Basin were also useful, as was the Sellards and others (1932) volume on the stratigraphy of Texas. The work of Garner and Young (1976) of the adjacent Austin area was also used.

Existing regional geologic maps that encompass the project 2 area, Hill Country Trinity aquifer, are the 1:250,000-scale Llano sheet (Barnes 1981) and the 1:250,000-scale geologic map of the Edwards Group by Rose (1972). DeCook (1963) and Hanson and Small (1995) constructed regional maps of Hays County. An unpublished Master's thesis map (Grimshaw, 1970) on an uncorrected planimetric base covers part of the Driftwood quadrangle. The project 2 area lies west of an area that has been mapped and digitized at a 1:62,500 scale (Garner and others, 1976). It is north of an area that was mapped and digitized at a 1:24,000 scale and published at 1:100,000 for previous STATEMAP projects (Collins, 2000). The project 2 area also lies south and east of an area that has been mapped at scales of 1:24,000 and 1:31,600 (Barnes, 1952a, b, c, d, 1954a, b, 1963, 1965, 1966, 1967a, b, 1982a, b, c, d). Previous stratigraphic studies include works by Moore (1964, 1996), Strickland and others (1971), Rose (1972), and Amsbury and Jones (1996). Project 2 mapping will complete detailed geologic map coverage of the Pedernales River 30 × 60 minute quadrangle, scale 1:100,000, and will help us attain the long range goal of compiling a digital database and published map of the Pedernales River 30 × 60 minute quadrangle.

Existing regional geologic and environmental maps that encompass the project 3 study area, San Marcos–Seguin corridor, are the 1:250,000-scale Seguin sheet (Proctor and others, 1974) and the 1:250,000-scale Guadalupe-Lavaca-San Antonio-Nueces River Basins regional study map (Gustavson and Wermund, 1985). Brucks (1927) also produced a page-size regional map that encompasses the study area. Previous maps adjacent to the Martindale and Uhland quadrangle study area include an unpublished 1:24,000-scale map by Grimshaw (1976) of the San Marcos area and a 1:24,000-scale map of the Luling quadrangle completed for an earlier STATEMAP project. The area mapped by Grimshaw (1976) was also mapped by Hanson and Small (1995) at a scale of 1:75,000.

PROJECT 1: DIGITAL COMPILATION (1:100,000) OF GEOLOGY OF NORTHERN SEGMENT OF EDWARDS AQUIFER RECHARGE ZONE, SOUTH-CENTRAL TEXAS

Project 1, a digital compilation project, includes critical parts of the northern segment of the Edwards aquifer and its recharge zone north of Austin and areas of rapid urbanization (figs. 1, 2). The area contains two major highways, Interstate 35 and U.S. 183. Sixteen 7.5-minute geologic

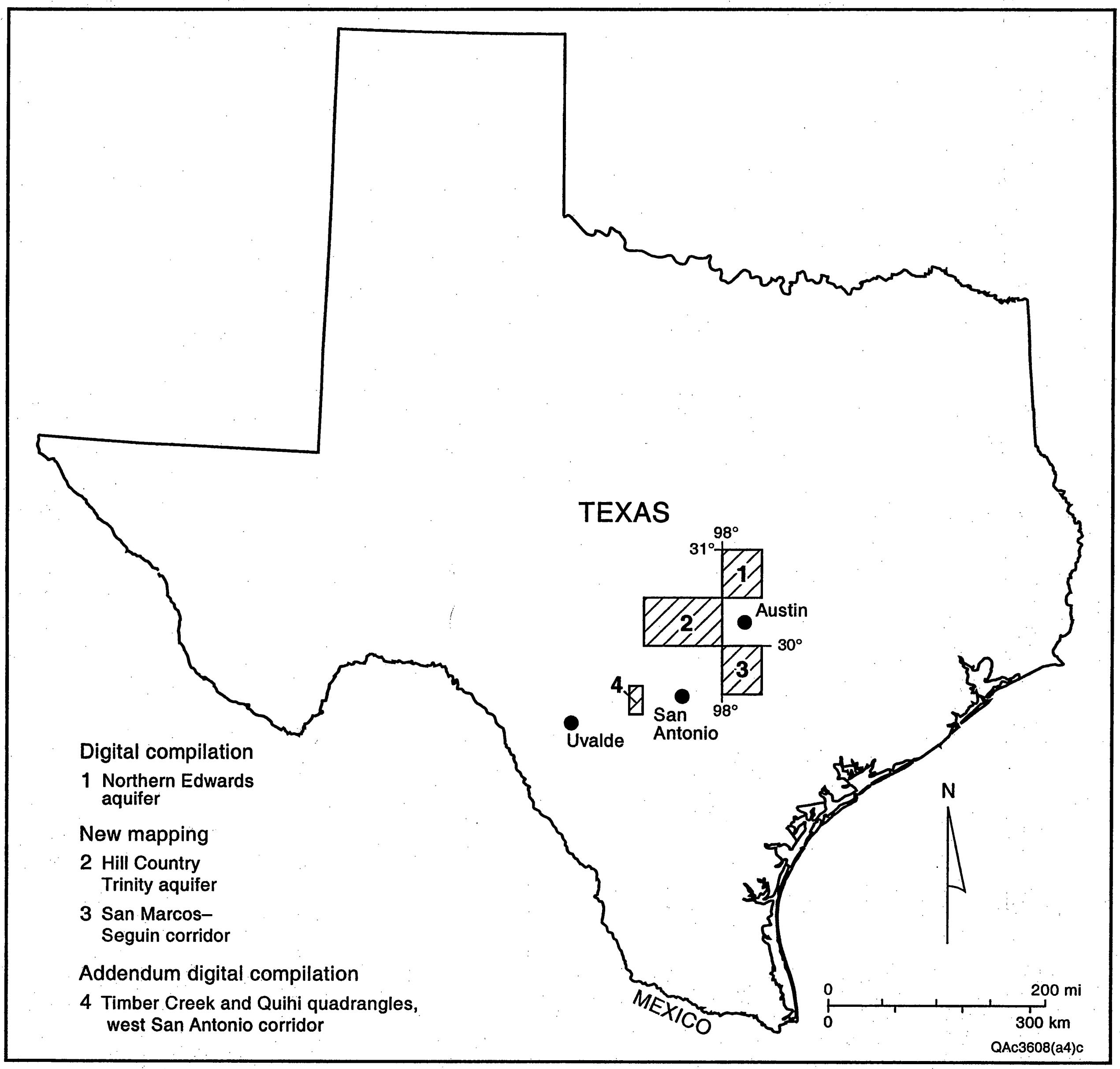

Figure 1. Location of Texas project study areas. The digital compilation project is project 1, northern Edwards aquifer and recharge zone. New map projects include project 2, Hill Country Trinity aquifer and recharge zone, and project 3, San Marcos–Seguin corridor. Addendum digital compilation project 4 includes two quadrangles within the West San Antonio corridor.

quadrangle maps (fig. 3), mapped during previous STATEMAP projects, were digitized and compiled for the project 1 deliverable, *Geologic Map of the West Half of the Taylor, Texas, 30 × 60 Minute Quadrangle: Central Texas Urban Corridor, Encompassing Round Rock,*

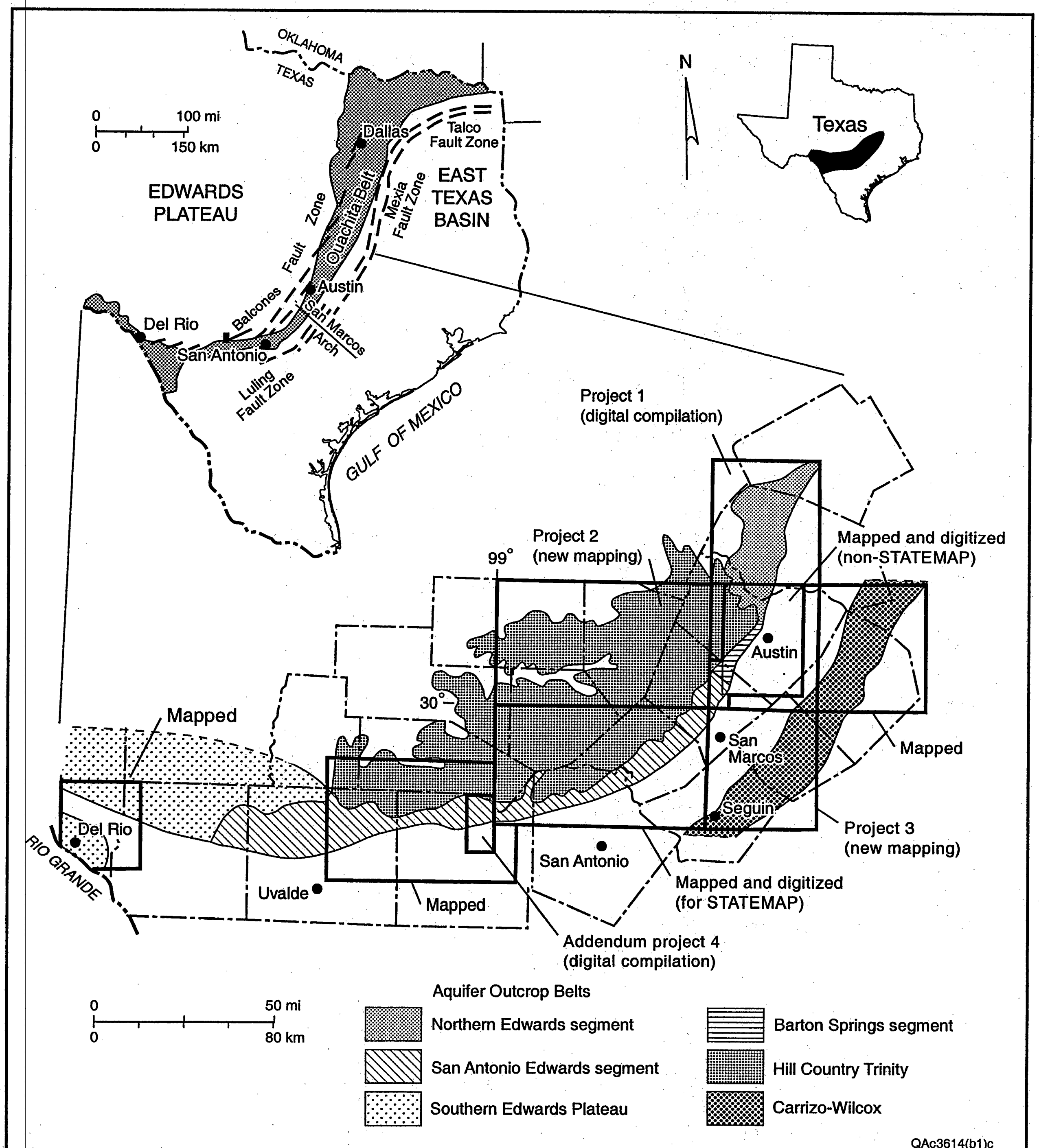

Figure 2. Setting of outcrop belts (recharge zones) for the Edwards, Trinity, and Carrizo aquifers and the location of projects 1, 2, 3, and 4.

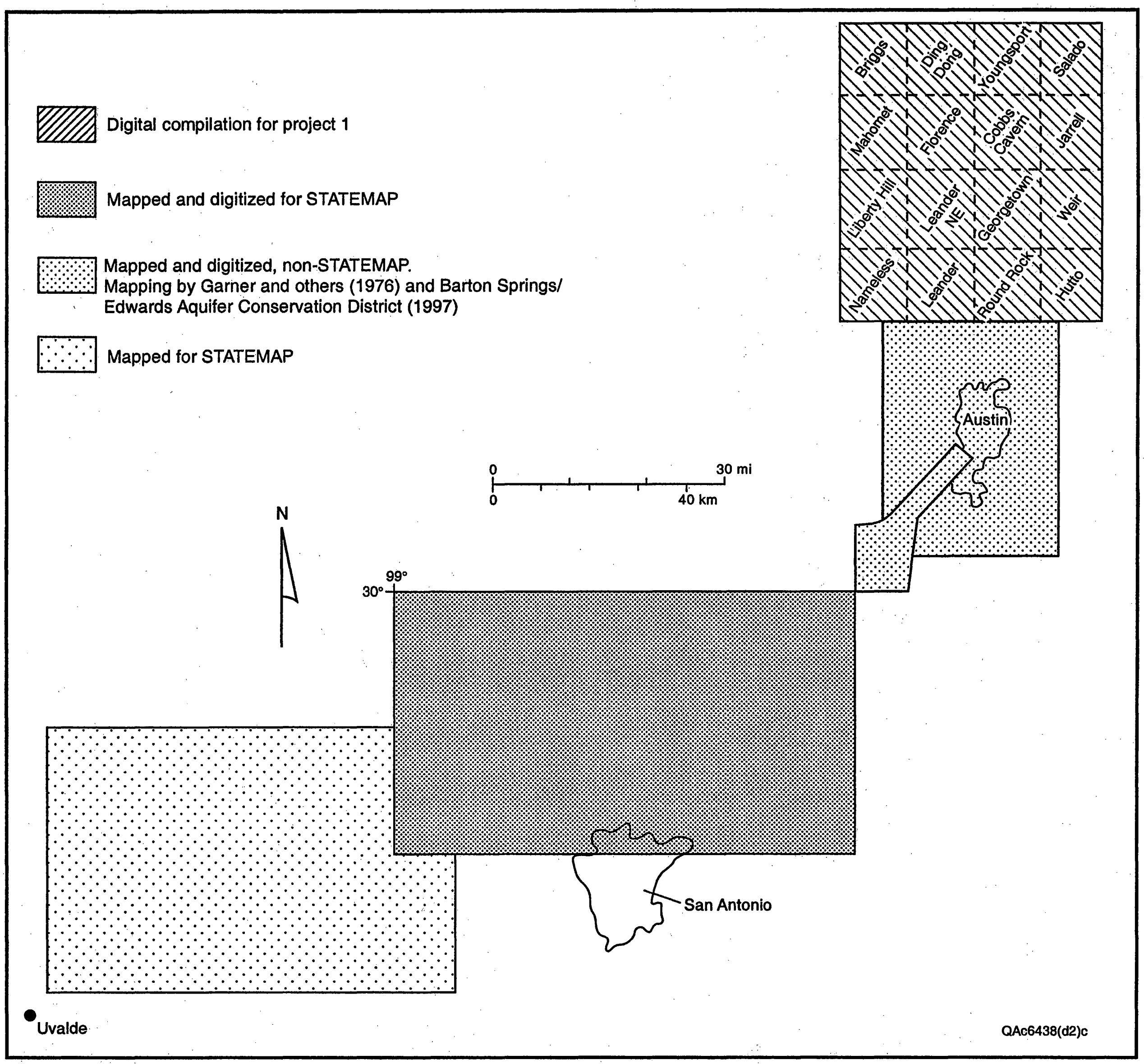

Figure 3. Location and quadrangles (1:24,000 scale) to be digitized and compiled for project 1, digital compilation of the northern Edwards aquifer and recharge zone.

Georgetown, Salado, Briggs, Liberty Hill, and Leander. This map, digital data file, and associated cross sections will be used for (1) identifying aquifer recharge boundaries, (2) recognizing attributes and variations within aquifer strata, (3) making water-management decisions related to groundwater flow and aquifer response for pumpage and recharge, (4) providing information necessary for land-use planning and permitting construction projects, and (5) locating sources of construction materials. The map will also be of immediate use for constructing the geologic framework for new groundwater models of the area.

The project area lies within the Cretaceous outcrop belt that trends generally parallel to the arcuate structural grain of the Miocene-age Balcones Fault Zone, which traverses the area. The fault zone defines the western limit of the coastal plain and marks the southeastern limit of the outcrop belt of the regionally important Edwards limestone aquifer (Rose, 1972; Maclay and Small, 1986; Senger and others, 1990; Collins, 1995; Hovorka and others, 1998). The northern segment of the Edwards aquifer comprises Lower Cretaceous Comanche Peak, Edwards, and Georgetown strata of central Travis, Williamson, and southern Bell Counties, Texas (fig. 4). Across the northern Edwards aquifer area, normal faults of the Balcones Fault Zone displace Cretaceous limestone, dolomite, marl, and shale that represent more than 2,000 ft of shelf and shelf-margin deposition. Composing a commonly prolific part of the aquifer, Edwards limestone, dolomitic limestone, and dolomite are often more porous than the other aquifer strata, Georgetown and Comanche Peak limestone and argillaceous limestone (fig. 4). The composite thickness of the aquifer units within the confined, subsurface part of the aquifer ranges from about 420 ft in central Travis County to about 260 ft in southern Bell County. From central Travis County northward to southern Bell County the highly porous Edwards Group strata thin from as much as about 370 to about 90 ft, whereas the thickness of Georgetown strata increases toward the north from about 50 to about 100 ft. Comanche Peak strata interfinger with Edwards strata and do not exist at the south part of the study area. The unit is between about 30 and 80 ft thick in Williamson and southern Bell Counties. Much of this northward thinning of Edwards Group strata is due to interfingering of upper Edwards strata with Georgetown strata and interfingering of lower Edwards strata with less porous Walnut argillaceous limestone strata that are not considered part of the aquifer in this area (Moore, 1964, 1996; Rose, 1972). Local lithofacies of porous Walnut limestone and dolomitic limestone that are located in northern Travis County and adjacent parts of Williamson County have the potential of being hydrologically connected to aquifer strata.

Normal faults of the Balcones Fault Zone, having throws between about 800 and less than 1 ft, strike northeastward to north-northeastward. Most faults dip eastward, although antithetic

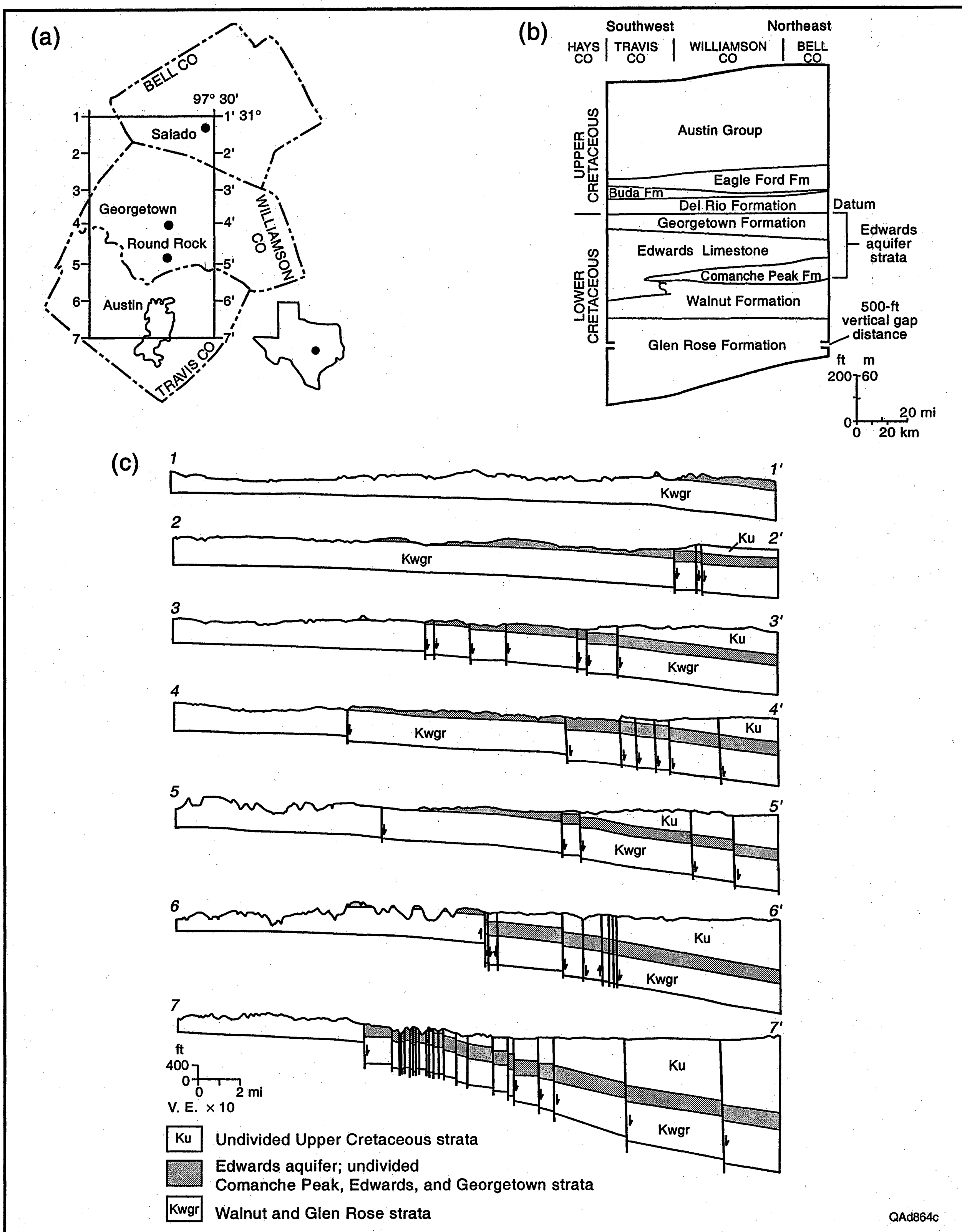

Figure 4. (a) Location of northern Edwards aquifer and cross-section lines. Map study area for project 1 includes the area across cross sections 1 through 5. (b) Lithostratigraphy of study area. Stratigraphy data from various sources, including Moore (1964; 1996), Rose (1972), and Garner and Young (1976). (c) Cross sections illustrating Edwards aquifer strata and faults.

west-dipping faults also occur. Composite structural offset across the fault zone is down to the southeast (fig. 4). Fault intensity and composite structural relief decrease northward from Austin, where the composite structural relief is about 1,600 ft. At the northern boundary of the study area in southern Bell County, the composite structural relief is about 600 ft. Faults control the structural position of the porous limestone units that compose the Edwards aquifer, and they bound much of the aquifer recharge zone/outcrop belt. Faults can serve as conduits for groundwater flow, and at some locations faults may displace porous beds against relatively less porous beds, thus causing abrupt changes in groundwater flow paths. In Travis County the throw on large-displacement faults bounding the recharge zone exceeds the thickness of the aquifer. In central Williamson County the displacements of the larger faults bounding the recharge zone are only between 50 and 150 ft, much less than the composite aquifer thickness but nearing or slightly exceeding the thickness of the porous Edwards unit.

Occurrences of Del Rio clay and Eagle Ford clay, shale, and marl are important to construction because of potential problems related to shrinking and swelling of clays in these units and their associated soils. Limestone is actively being quarried for aggregate, cement, and building stone in the map area.

PROJECT 2: GEOLOGIC MAPPING (1:24,000) OF THE HILL COUNTRY TRINITY AQUIFER RECHARGE ZONE, SOUTH-CENTRAL TEXAS

Work for project 2 occurred within the western urban-growth corridor of Austin, Texas, and within the Hill Country Trinity aquifer and recharge zone (figs. 1, 2). Part of the Edwards aquifer is also within this study area. Open-file geologic maps were completed for the Blanco, Crabapple Creek, Cypress Creek, Driftwood, Dripping Springs, Henly, Pace Bend, Payton, Rafter Hollow, Rough Hollow, Shingle Hills, and Whitworth Ranch quadrangles (fig. 5).

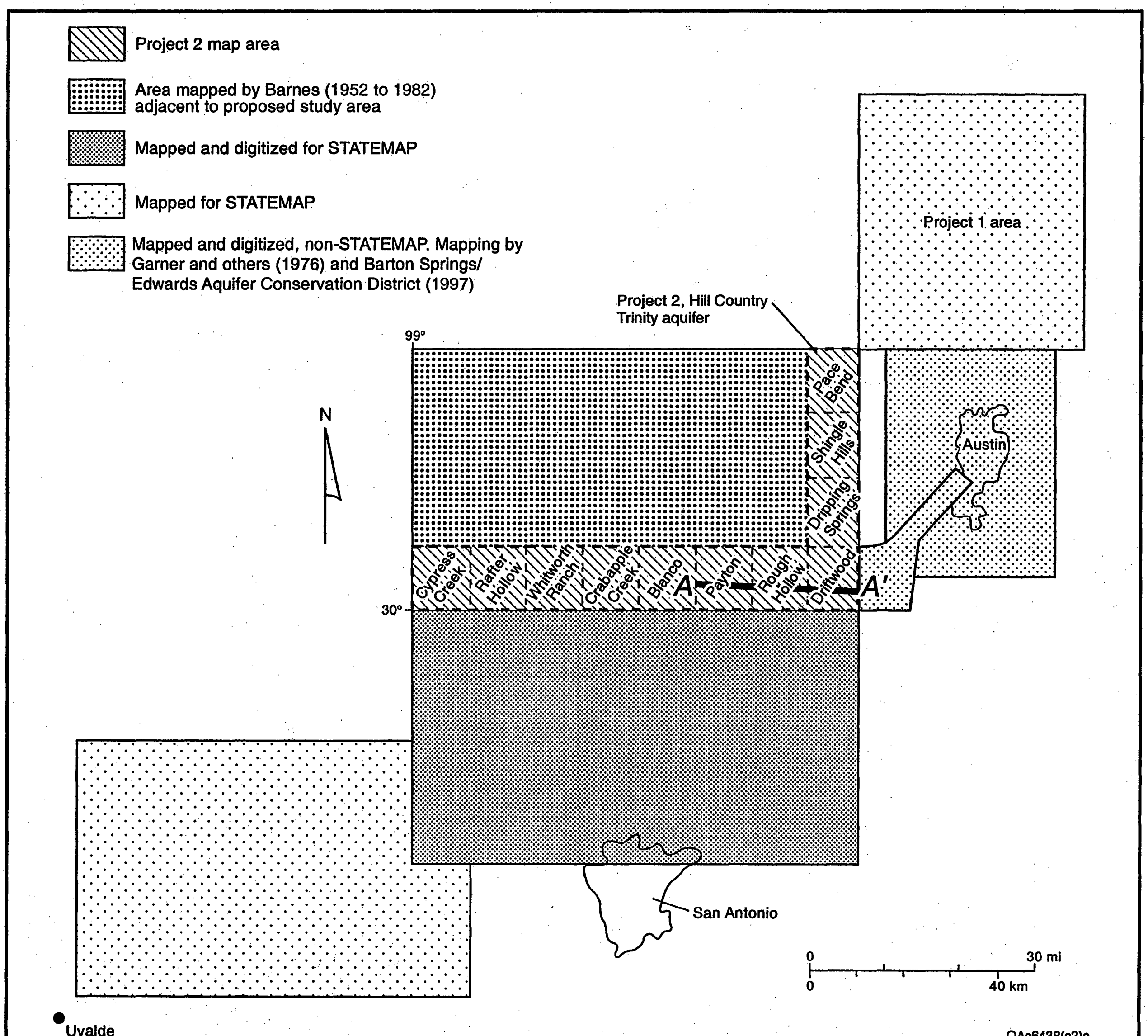

Figure 5. Location and quadrangles (1:24,000) for project 2 area, Hill Country Trinity aquifer and recharge zone, south-central Texas.

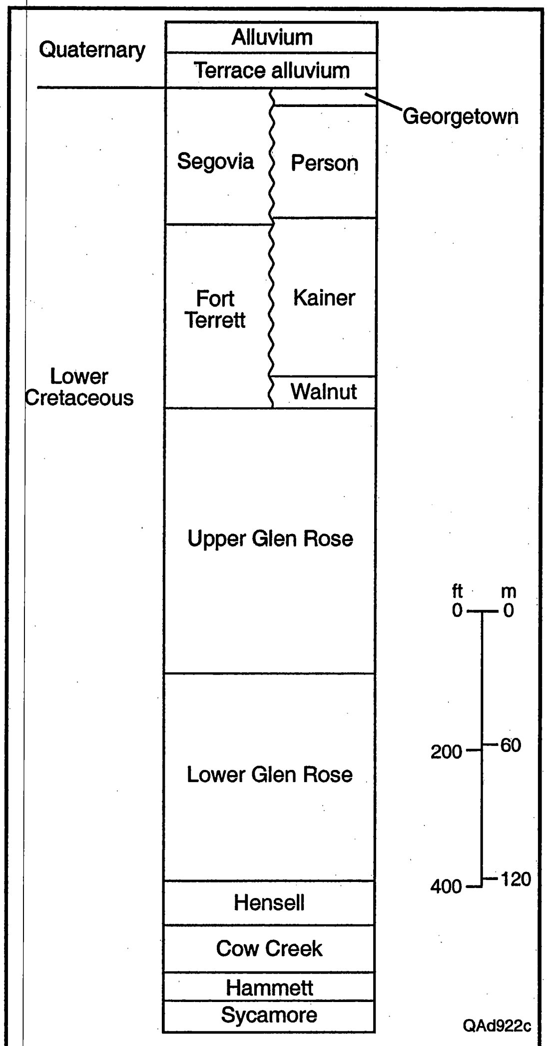

Figure 6. Stratigraphic chart illustrating units for the project 2 area, Hill Country Trinity aquifer and recharge zone, south-central Texas.

Geology of the project 2 study area is dominated by Lower Cretaceous strata that include Cow Creek limestone; Hensell sandstone, mudstone, and conglomerate; and upper and lower Glen Rose, Walnut, Kainer/Fort Terrett, and Person/Segovia limestone, dolomitic limestone, dolomite/dolostone, argillaceous limestone, and lesser marl (fig. 6, app. A). Minor outcrops of older Cretaceous Sycamore sandstone, siltstone, mudstone and conglomerate, and Hammett shale also exist within the Pace Bend quadrangle, although these units are generally covered by vegetation and soil. Lithologic descriptions of these units are in appendix A.

Trinity aquifer strata comprise Sycamore, Hammett, Cow Creek, Hensell, and Glen Rose strata. The Glen Rose, commonly subdivided as two map units, makes up the largest part of the aquifer. In the study area it is as much as 400 ft thick and thins toward the northwest. The Hensell is as thick as 200 ft, and the Cow Creek, Hammett, and Sycamore are less than 60 ft thick. The Balcones Fault Zone crosses the southeast part of the study area where Edwards Group strata (Kainer and Person Formations) make up an important part of the Edwards aquifer recharge zone. Cross section A–A' illustrates faults at the west margin of the Balcones Fault Zone and a representative part of the area from the fault zone to the east edge of the Edwards

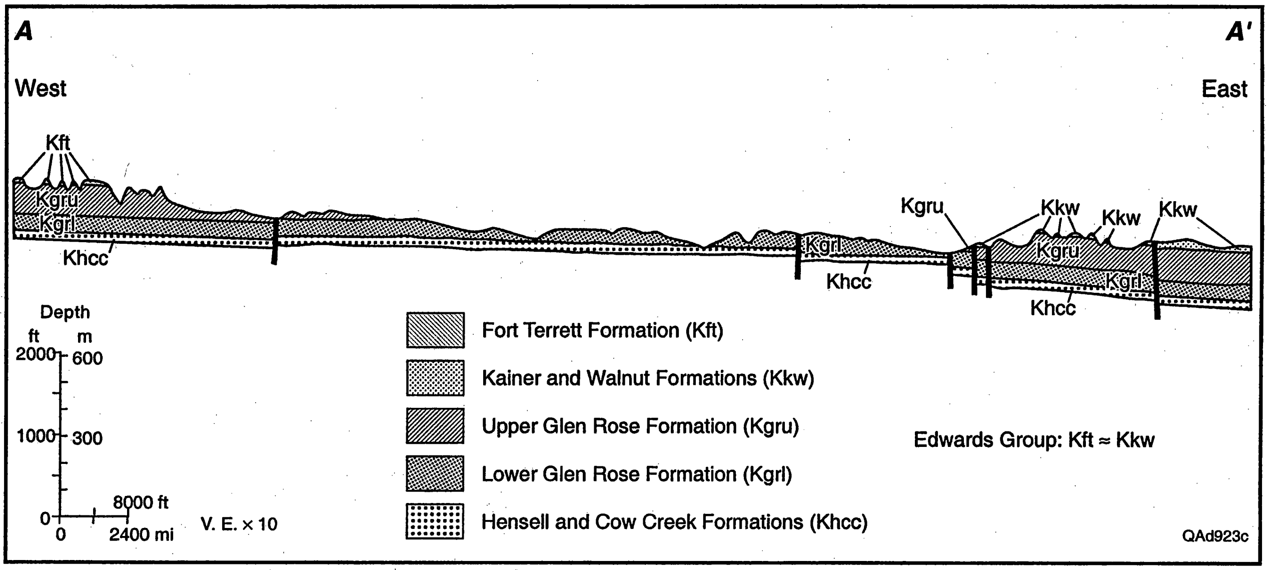

Figure 7. West-east cross section A–A' of project 2 area, Hill Country Trinity aquifer and recharge zone, south-central Texas. Location shown in figure 5.

Plateau (fig. 7). Quaternary terrace deposits and alluvium of the Blanco and Colorado Rivers and their tributaries also exist in the area. Pits dug for limestone aggregate and sand and gravel exist throughout the area and are of environmental concern because they have the potential to be used for illegal dumping and possible impairment of surface water and groundwater quality. The Blanco River State Park is also within this study area.

PROJECT 3: GEOLOGIC MAPPING (1:24,000) OF THE SAN MARCOS—SEGUIN CORRIDOR, TEXAS

Work for the project 3 study area was within the San Marcos–Seguin corridor of Central Texas (figs. 1, 2). This corridor is south of Austin and northeast of San Antonio. It makes up the west half of the Seguin 30 × 60 minute quadrangle. The northwest part of this corridor includes the Edwards aquifer and recharge zone, and the east part of the corridor is within the Carrizo-Wilcox aquifer and recharge zone (Rasmussen, 1947; DeCook, 1963; Follett, 1966; Shafer 1966; Thorkildsen and Price, 1991). The aerially smaller Leona aquifer is also within the area. Geologic maps of the Uhland and Martindale quadrangles, 1:24,000 scale, were completed for this year's work within this corridor (fig. 8).

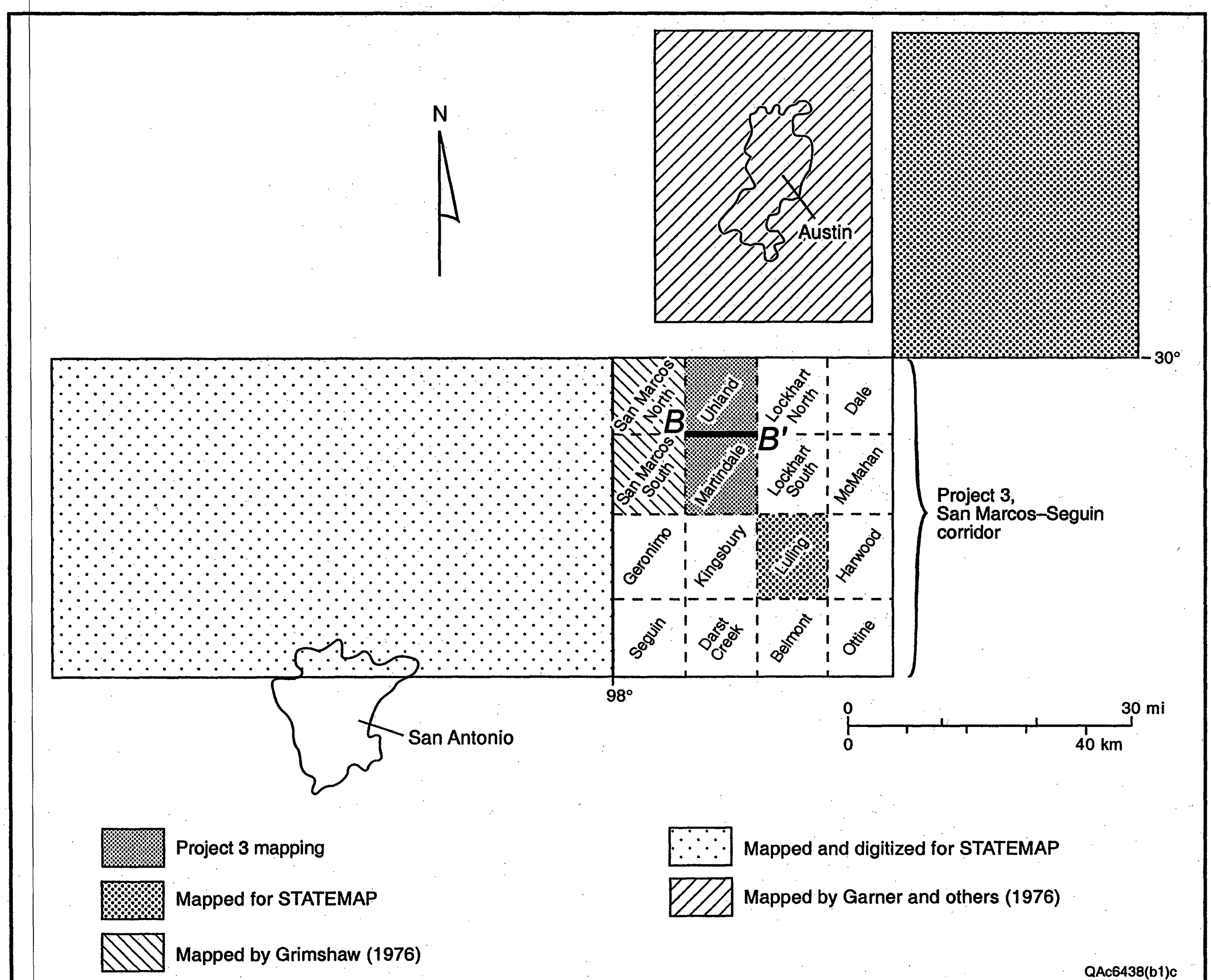

Figure 8. Location and quadrangles for project 3, San Marcos–Seguin corridor.

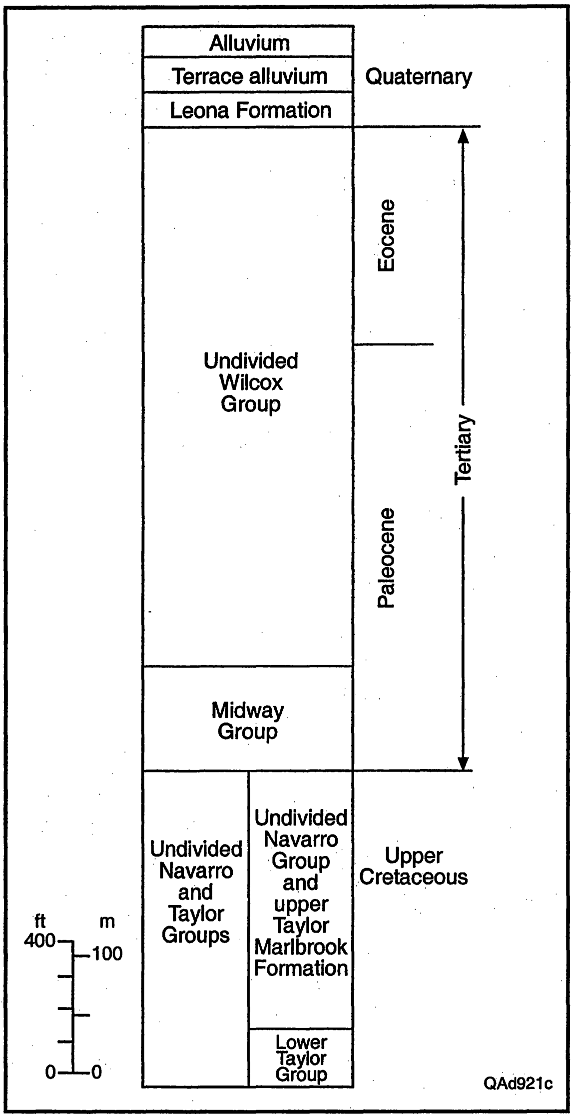

Figure 9. Stratigraphic chart illustrating units for the project 3 area, San Marcos–Seguin corridor.

Geology of the Uhland and Martindale quadrangles is dominated by Quaternary terrace alluvium of the San Marcos River and older sand- and gravel-rich deposits of the Quaternary Leona Formation that are preserved as remnant fluvial deposits within topographically higher areas (fig. 9). Sand and gravel of the Quaternary Leona Formation make up an important shallow aquifer in the study area. Also, mining of Leona and younger terrace deposits has met some of the demand from past development of nearby areas, and the potential for future gravel production still exists.

Other units covering smaller parts of the map area include Upper Cretaceous Taylor and Navarro Group and Tertiary Paleocene deposits of mostly calcareous mudstone and marl, as well as minor argillaceous limestone and siltstone. A minor amount of Tertiary Paleocene to Eocene Wilcox mudstone and sandstone occurs in the southeast part of the map area. Outcrops of these Upper Cretaceous and Tertiary deposits are rare because these units weather rapidly, form thick soils, and are commonly densely vegetated. The contact between these units is mostly inferred from the previous regional work of Proctor and others (1974). West of the Uhland and Martindale quadrangles, normal faults of the Miocene Balcones Fault Zone are abundant, and fault intensity decreases eastward across the San Marcos–Seguin corridor. On the basis of previous work by Proctor and others (1974), a few inferred and covered

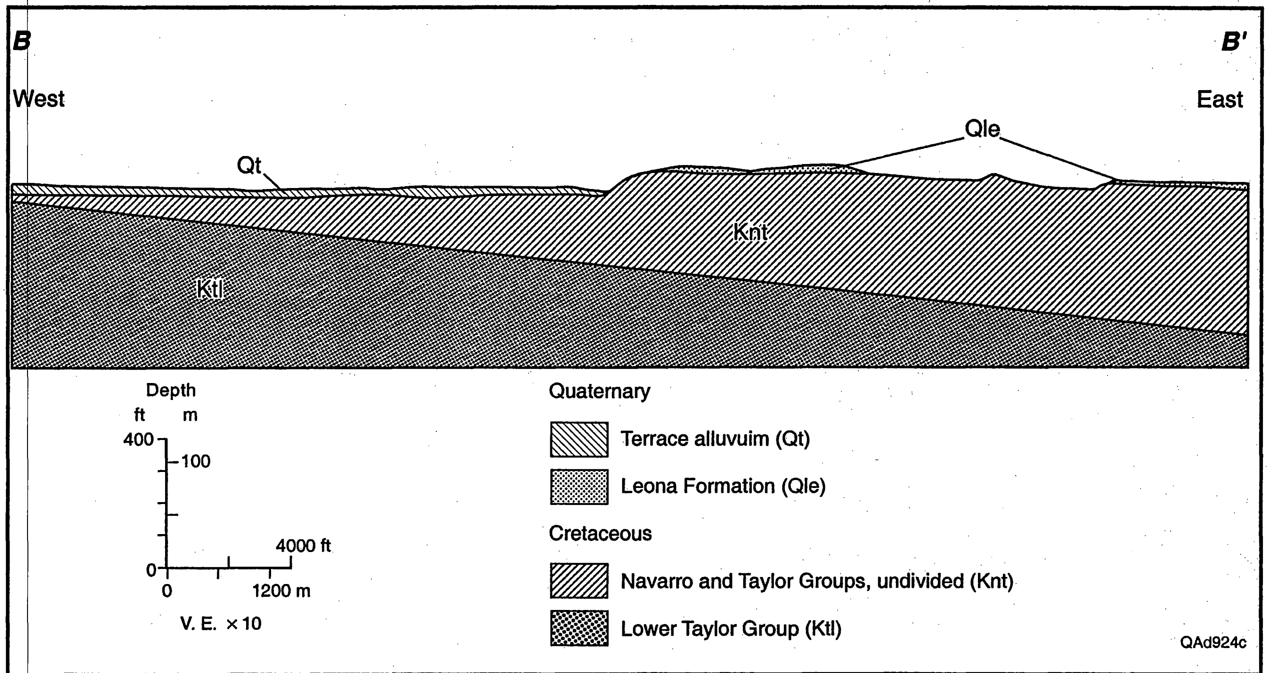

Figure 10. West-east cross section B–B' of project 3 area, San Marcos–Seguin corridor. Location shown in figure 8.

faults have been interpreted to cross the Uhland and Martindale quadrangles. Some of these exhibit displacements that are down-to-the-west, antithetic to the major displacement of the Balcones Fault Zone. Cross section B–B' illustrates the geology across a representative, nonfaulted part of the project 3 study area (fig. 10). Appendix A—Explanation of Geologic Units provides descriptions of the units.

ADDENDUM PROJECT 4: DIGITAL COMPILATION OF QUIHI AND TIMBER CREEK QUADRANGLES—PART OF WEST SAN ANTONIO CORRIDOR, TEXAS

Digitization of open-file geologic maps of the West San Antonio Corridor, mapped for previous STATEMAP projects, was initiated this project year for addendum project 4. Work on this project consisted of digitization in an ARCINFO database of two quadrangles, the Quihi and Timber Creek (figs. 1, 11). Digitization of the other 1:24,000-scale geologic maps within this corridor is planned for future projects. Project deliverables are a draft map of the digitized area comprising the Quihi and Timber Creek quadrangles. A published map of the entire corridor is planned when digitization of the other quadrangles within this corridor is completed during future projects. Descriptions of the geologic units of this study area are in Appendix A—Explanation of Geologic Units.

Geology within the north part of the West San Antonio Corridor consists of faulted Lower and Upper Cretaceous rocks, whereas in the south part of the study area Cretaceous strata are overlain by upper Tertiary and Quaternary gravel- and sand-rich deposits. Most of the normal faults within the West San Antonio study area strike N50°–75°E and are downthrown toward the southeast. The larger faults have throws between 300 and 500 ft. Edwards Group strata exhibit lateral, platform to basin, margin facies and nomenclature changes southwestward across the area. Kainer and Person rocks of the Balcones Fault Zone area in Bexar, Comal, and Hays Counties and Fort Terrett and Segovia rocks of the Edwards Plateau area and its margins represent platform-setting deposits. These platform strata grade into upper and lower Devils River strata representative of a basin-margin setting (Rose, 1972). These Edwards Group rocks, important aquifer strata, are 550 to 650 ft thick. The composite structural relief of these aquifer limestones across the West San Antonio study area is as much as 3,000 ft. The area is important to recharge of the Edwards aquifer because the aquifer strata dip very gently west-southwestward into the subsurface within fault blocks of the Balcones Fault Zone, providing good continuity of aquifer strata from the recharge area to the subsurface.

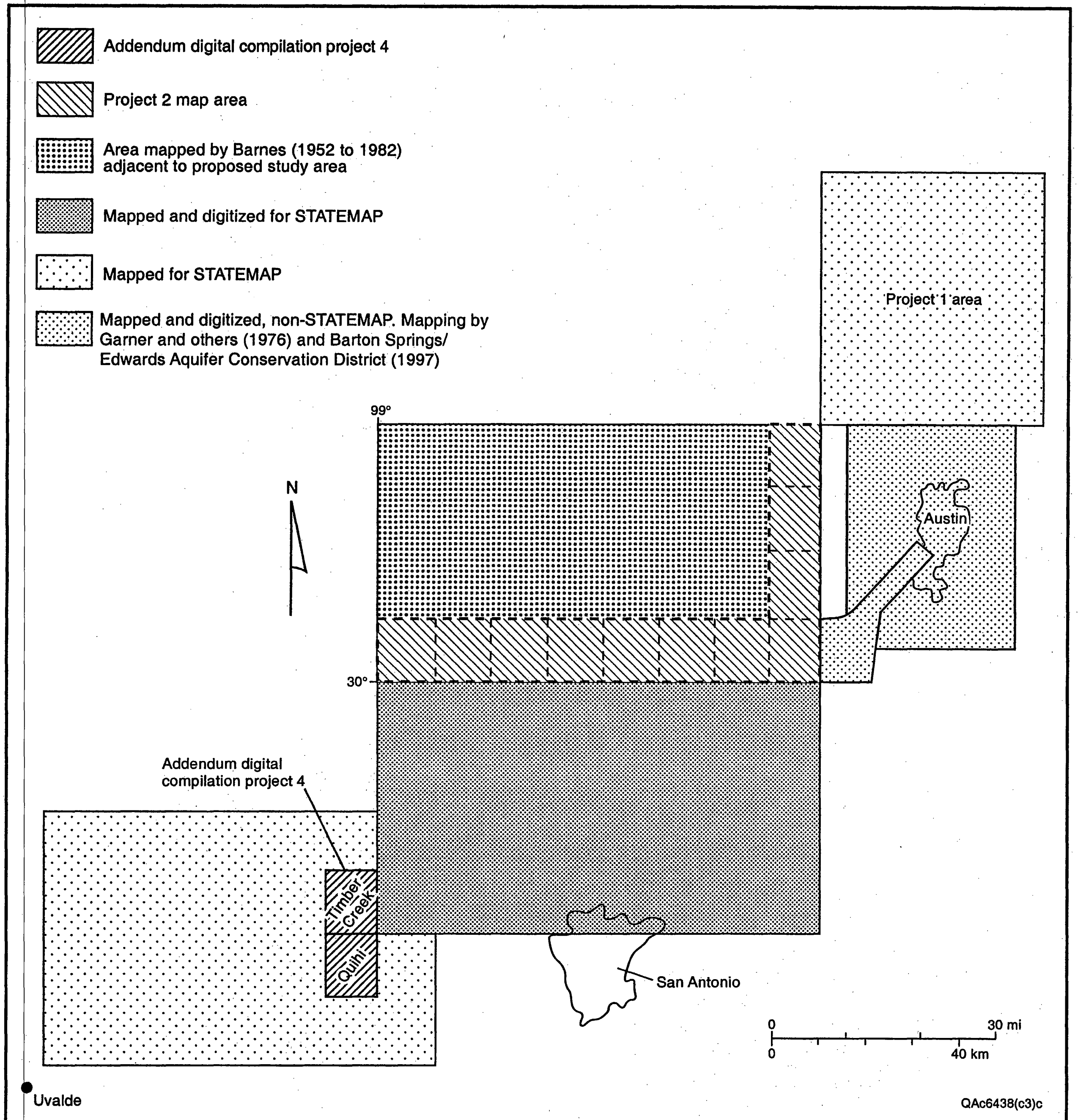

Figure 11. Location of Timber Creek and Quihi Quadrangles of the West San Antonio corridor, addendum digital compilation project 4.

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APPENDIX A—EXPLANATION OF GEOLOGICAL UNITS

HILL COUNTRY TRINITY AQUIFER—
PEDERNALES RIVER 30 × 60 MINUTE QUADRANGLE

Blanco, Crabapple Creek, Cypress Creek, Driftwood, Dripping Springs,

Henly, Pace Bend, Payton, Rafter Hollow, Rough Hollow,

Shingle Hills, and Whitworth Ranch Quadrangles (scale 1:24,000)

QUATERNARY

Qal—Alluvium. Gravel, sand, silt, and mud; mostly modern drainageway deposits; includes some undivided thin, local terrace deposits and local bedrock outcrops.

Qt—Terrace alluvium. Gravel, sand, silt, and mud.

LOWER CRETACEOUS

Edwards Group: Fort Terrett (Kft) and Segovia (Ks) Formations of platform setting of eastern Edwards Plateau and Kainer (Kk) and Person (Kp) Formations of platform setting of Balcones Fault Zone area.

Ks—Segovia Formation. Limestone, dolomitic limestone, dolomite, and lesser argillaceous limestone; approximately equivalent to Person Formation of Balcones Fault Zone area; only minor outcrop areas in west part of study area; west of map area as much as 360 ft thick.

Kft—Fort Terrett Formation. Limestone, dolomitic limestone, dolomite, and lesser argillaceous limestone; approximately equivalent to Kainer and Walnut Formations of the Balcones Fault Zone area; shallow subtidal to tidal-flat cycles common; crystalline limestone/ dolomitic limestone common; fossils include bivalves, gastropods, rudistids, and miliolids; upper part contains some leached evaporitic intervals and breccias; lower 20 to 60 ft is equivalent to the Walnut Formation (Kw) of the Balcones Fault Zone area.

Kp—Person Formation. Limestone, dolomitic limestone, dolomite, and lesser argillaceous limestone; approximately equivalent to Segovia Formation of eastern Edwards Plateau; shallow subtidal to tidal-flat cycles common; crystalline limestone/dolomitic limestone? common; leached and collapsed intervals; local pockets of red clay in karst collapse features; fossils include bivalves, gastropods, rudistids, and miliolids; lower 20 to 30 ft composes regional dense member, a limestone to argillaceous limestone interval sometimes containing thin, flaggy beds; thickness between 130 and 150 ft.

Kft—Kainer Formation. Limestone, dolomitic limestone, dolomite, and lesser argillaceous limestone; approximately equivalent to Fort Terrett Formation of eastern Edwards Plateau; shallow subtidal to tidal-flat cycles common; crystalline limestone/dolomitic limestone common; upper part exhibits abundant beds with grainstone fabric; leached evaporitic intervals and breccias in middle part of unit; fossils include bivalves, gastropods, rudistids, and miliolids; thickness ~250 ft. Some researchers include strata composing Walnut Formation, **Kw**, with lower part of Kainer Formation.

Kw—Walnut Formation. Limestone, argillaceous limestone, marl, and dolomitic limestone; sometimes referred to as lower nodular limestone member of Kainer Formation; equivalent to lower Fort Terrett Formation of eastern Edwards Plateau; fossils common and include oyster *Exogyra texana*; thickness between 30 and 60 ft.

Kgru—Upper Glen Rose Formation. Limestone, dolomitic limestone, argillaceous limestone, and some marl; shallow subtidal to tidal-flat cycles common; alternating resistant and recessive beds form stair-step topography; dolomitic in upper and lower parts; abundant fossils include bivalves, rudistids, oysters, echinoids, and *Foraminifera (Orbitolina texana)*; leached evaporitic intervals often referred to as dissolution zones; thickness as much as 400 ft.

Kgrl—Lower Glen Rose Formation. Limestone, dolomitic limestone, argillaceous limestone, and some marl; top of unit marked by interval with one to three thin, resistant, 1- to 3-ft-thick beds containing *Corbula*; *Corbula* interval above very fossiliferous unit that often includes echinoid *Salina texana*; *Corbula* interval below a leached evaporitic interval of

Upper Glen Rose; abundant fossils include bivalves, rudistids, oysters, echinoids, and *Foraminifera (Orbitolina texana)*; massive and thick beds common; coral reef at base of unit at Narrows of Blanco River; unit thickness between 200 and 270 ft.

Kh—Hensell Formation. Sandstone, siltstone, mudstone, conglomerate, lesser sandy to silty limestone, dolomitic limestone and dolomitic siltstone; forms shoreward facies of Glen Rose Limestone; about 60 ft thick in map area; thickness of as much as 220 ft reported outside of map area (Barnes, 1981).

Kcc—Cow Creek Formation. Limestone and sandy limestone; grainstone fabric dominant; fossil fragments abundant; some siliciclastic grains; moldic porosity; crossbeds common. Barnes (1981) described unit as coquinite in which many of the fossils are dissolved. Thickness as much as 60 ft.

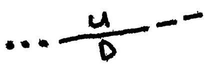
Kh—Hamett Formation. Calcareous mudstone, some silt and sand; pebbles and cobbles at base. Thickness between 15 and 40 ft.

Ksy—Sycamore Formation. Sandstone, conglomerate, siltstone, and mudstone; thickness as much as 40 ft. Study area contains only minor occurrences in northwest part of Pace Bend quadrangle.

Map Symbols

Contacts

Contacts drawn as solid lines are relatively more distinct in the field and on aerial photographs than where they are drawn as dashed lines; question mark (?) indicates where contact is uncertain



Normal fault; U=upthrown block, D=downthrown block

Faults drawn as solid lines are relatively more distinct in the field and on aerial photographs than where they are drawn as dashed lines; dotted lines show where faults are covered by unfaulted deposits; question mark (?) indicates where fault is uncertain.

Strike and dip of beds dipping between 2° and 6°; aerial-photograph interpretation.

SAN MARCOS–SEGUIN CORRIDOR, TEXAS

Martindale and Uhland Quadrangles, Texas

(scale 1:24,000)

QUATERNARY

Qal—Alluvium. Gravel, sand, silt, and mud; mostly modern drainageway deposits; includes some undivided thin, local terrace deposits and local bedrock outcrops.

Qt—Terrace alluvium. Gravel, sand, silt, and mud.

Qle—Leona Formation. Gravel, sand, silt, and mud. Includes some local remnants of gravel at slightly higher elevations that may be equivalent to Quaternary–upper Tertiary Uvalde gravel.

TERTIARY

Eocene–Paleocene

EPAwi—Wilcox Group. Mudstone and sandstone; lower part mostly mudstone with lesser sandstone; upper part sandstone and interbedded sandstone and mudstone; ironstone concretions common; crossbeds; variable amounts of lignite exist regionally, mostly to north-northeast; thickness 1,200 to 1,300 ft outside of study area.

Paleocene

Pami—Midway Group. Clay to claystone, mud to mudstone, lesser siltstone, and sandstone; thick mud- to clay-rich soils. Contains two undivided units: Wills Point (upper) and Kincaid (lower). Group thickness between 325 and 400 ft.

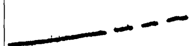
UPPER CRETACEOUS

Knt—Navarro and Taylor Groups, undivided. Marl and calcareous clay of undivided Navarro Group, Kemp and Corsicana Formations, and Taylor Group (mostly or entirely upper Taylor Group Marlbrook Formation). Where chalk, limestone, and argillaceous limestone of

Taylor Group Pecan Gap Formation have graded into marl and calcareous clay, similar to that of the overlying Marlbrook Formation. Total thickness of undivided Navarro and Taylor Groups as much as 1,300 ft.

Ktl—Lower Taylor Group. Includes or is equivalent to Pecan Gap Formation. Marl, argillaceous limestone, limestone, chalk, and some clay-claystone to mud-mudstone. Thickness ~200 ft.

Map Symbols



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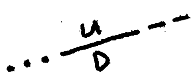
Contacts drawn as solid lines are relatively more distinct in the field and on aerial photographs than where they are drawn as dashed lines; question mark (?) indicates where contact is uncertain.



Normal fault; U=upthrown block, D=downthrown block

Faults drawn as solid lines are relatively more distinct in the field and on aerial photographs than where they are drawn as dashed lines; dotted lines show where faults are covered by unfaulted deposits; question mark (?) indicates where fault is uncertain.

X Pit

WEST SAN ANTONIO REGION

(Quadrangles in bold type were digitized for addendum project 4)

Bandera, Castroville, Comanche Waterhole, D'Hanis, Flatrock Crossing, Hondo, Murphy School, Mustang Valley, **Quihi**, Riomedina, Sabinal, Sabinal NE, Seco Pass, Tarpley, Tarpley Pass, Texas Mountain, **Timber Creek**, and Twin Hollow Quadrangles, Texas (1:24,000 scale)

QUATERNARY

Qal—Alluvium. Unconsolidated gravel, sand, silt, and clay along streams and rivers; inundated regularly. Gravel mostly limestone and chert. Along minor drainages includes undivided low terrace deposits. Includes some local bedrock outcrops that are undivided.

Qt—Terrace deposits. Unconsolidated gravel, sand, silt, and clay along streams and rivers. Mostly above flood level. Deposits of adjacent terraces at different elevations are mapped separately.

Ql—Landslide deposits. Local deposits of Little Creek canyon area within Seco Pass quadrangle.

Qle—Leona Formation. Fine calcareous silt grading down into coarse gravel.

Qt+Qle—Terrace deposits and Leona Formation, undivided.

TERTIARY

QTu—Uvalde gravel (older alluvium). Gravel and sand, some clay; well-rounded pebble- to cobble-sized gravel common, few boulders; mostly chert and limestone, commonly cemented by caliche. Deposits typically cap topographically high areas. Precise age unknown; approximately late Tertiary to Quaternary. Thickness ranges from several feet of gravel lag to more than 10 ft.

Eocene to Paleocene

PAEw+PAm—Wilcox (Paleocene to Eocene) and Midway (Paleocene) Groups, undivided. Outcrops are not common. Wilcox Group is sandstone and mudstone; some shale and lignite. Thickness ranges between 440 and 700 ft. Midway Group is mudstone, silt/siltstone, sand/sandstone, and sandy fossiliferous limestone. Thickness as much as ~75 ft.

TERTIARY TO UPPER CRETACEOUS

PAm+Kes— Midway Group (Paleocene) and Escondido (Upper Cretaceous) Formation, undivided. Midway Group is mudstone, silt/siltstone, sand/sandstone, and sandy fossiliferous limestone. Outcrops are not common. Thickness as much as ~75 ft. Escondido Formation is mudstone, siltstone, sandstone, and silty limestone. Includes thin (as much as ~30 ft), lower marl and mudstone unit, Corsicana marl. Outcrops are not common. Escondido thickness ranges between 550 and 900 ft.

CRETACEOUS

Upper Cretaceous

Ki—Intrusive igneous rocks. Basalt (field term). Generally not well exposed. Locations from Welder and Reeves (1964). Some very small outcrops noted by Holt (1959) in Medina County are not shown.

Kes—Escondido Formation. Mudstone, siltstone, sandstone, and silty limestone. Includes thin (as much as ~30 ft), lower marl and mudstone unit, Corsicana marl. Outcrops are not common. Escondido thickness ranges between 550 and 900 ft.

Kan—Anacacho Formation. Limestone and marl. Grain-rich limestone common. Light-gray to white, thin to thick bedded, glauconitic, and contains fossil fragments. Thickness ranges from 240 to 500 ft.

Kan+QTu—Undivided Cretaceous Anacacho Formation and Quaternary to Tertiary Uvalde gravel.

Kau—Austin Group. Chalk, marl, and limestone. Light-gray to white, thin to thick bedded, massive to slightly nodular. Chalk mostly microgranular calcite with minor foraminifera tests; abundant *Inoceramus* prisms. Chalk forms ledges and alternates with marl and locally bentonitic seams. Sparsely glauconitic, pyrite nodules partly weathered to limonite are common. Thick caliche on most outcrops. Thick black soil with juniper and live oak in low-relief areas. Locally highly fossiliferous with pelecypods, echinoids, ostracodes, and forams. Thickness 135 to 200 ft.

Kef—Eagle Ford Formation. Shale, siltstone, and limestone. Upper part limestone and shale. Shale dark-gray. Limestone light-yellowish-brown, flaggy, in beds as much as 4 ft thick. Lower part siltstone and very fine grained sandstone, light-yellow to gray, laminated, flaggy, some limestone, silty, medium-brown, laminated. Flat to gently rolling topography. Covered by dark-brown soil on slopes; outcrops are rare. Strata at slope break of Eagle Ford/Buda contact commonly fossiliferous with oysters, ostracodes, forams, fish bones and teeth, and *Inoceramus*. Thickness 15 to 30 ft.

Kbu—Buda Limestone. Limestone. Hard and dense to chalky, poorly bedded to nodular, glauconitic, fossiliferous, abundant broken shell fragments locally. Light-gray to pale-orange; weathers dark-gray to brown. Thinner bedded and argillaceous near upper contact. Lower part is soft, chalky limestone. Upper contact is disconformable, sharp, and conspicuous. Forms resistant cap on hills. Weathers to form thin, red-brown soil with rounded cobbles of limestone. Less glauconitic and less iron oxide stained than Georgetown Formation. More fossil gastropods than in Austin Group. Burrows filled with chalky marl. Abundant pelecypods, forams, ostracodes, serpulids, echinoid spines, and bryozoans. Locally, solitary corals and green algae. Thickness 40 to 65 ft.

Kdr—Del Rio Formation. Clay. Gypsiferous, calcareous, pyrite common, poorly indurated, plastic, dark-gray to olive-brown; abundant *Ilymatogyra arietina* (formerly *Exogyra arietina*). Becomes less calcareous and more gypsiferous upward; blocky, medium-gray, weathers light-gray to yellowish-gray. Some thin lenticular beds of highly calcareous siltstone.

Slope forming or under hanging where slumped below overlying Buda. Forms highly expansive soil. Water tanks for livestock commonly excavated on outcrops. Upper and lower contacts gradational. Marine megafossils include abundant *Ilymatogyra arietina* (formerly *Exogyra arietina*) and other pelecypods. Thickness 15 to 50 ft.

Lower Cretaceous

Kgt—Georgetown Formation. Limestone and some marl. Nodular to bedded, gray to tan; abundant fossils include *Waconell wacoensis* (formerly *Kingena wacoensis*) and *Gryphaea washitaensis*. Few interbeds of marl 2 to 3 inches thick. Upper contact is conformable and gradational where exposed, commonly obscured by slumping of the overlying Del Rio Formation. Lower contact is disconformable. Diverse assemblage of fossils includes ammonoids, forams, echinoids, and pelecypods. Unit poorly exposed and mostly inferred on maps; locally may be absent. As much as 30 ft thick.

Kp—Person Formation. The Person Formation is the upper unit of the Edwards Group in the Balcones Fault Zone outcrop belt of the San Marcos Platform. It is approximately equivalent to the upper Devils River Formation (platform-margin facies) and the Segovia Formation of the Edwards Plateau. Limestone and dolomitic limestone. Shallow subtidal to tidal-flat cycles. Honeycombed limestone interbedded with chalky to marly limestone and recrystallized limestone, bedded to massive, leached and collapsed intervals. Locally, pockets of red clay (terra rosa) in karst collapse features. Thin, dark-red soil and residual chert regolith covered by sparse vegetation. Lower 20 to 30 ft composes regional dense member, a dense argillaceous limestone; commonly thin, flaggy beds. Mappable bench (regional dense member) at contact with underlying Kainer Formation. Mud cracks preserved near lower contact. Upper contact is burrowed, disconformable. Fossils include pelecypods, gastropods, rudistids. Thickness ~130 to 150 ft.

Kk—Kainer Formation. The Kainer Formation is the lower unit of the Edwards Group in the Balcones Fault Zone outcrop belt on the San Marcos Platform. It is approximately equivalent to the lower Devils River Formation (platform-margin facies) and the Fort Terrett Formation of the Edwards Plateau. Limestone and dolomitic limestone. Shallow subtidal to tidal-flat cycles. Upper part contains common hard grainstone interbedded with marly mudstone and wackestone; honeycomb porosity common; middle to lower part contains limestone, dolomitic limestone, and some leached evaporitic rocks and breccias in middle part. Some researchers include strata composing Walnut Formation, **Kw**, with lower part of Kainer Formation (**Kk**). Residual chert mantles uplands underlain by Kainer. Horizontal current laminations or low-angle cross-stratification present. Lower part is locally clayey, coarsely crystalline limestone. Fossiliferous; rudistids, caprinids, miliolids, oysters, and gastropods. Thickness ~250 ft.

Ks—Segovia Formation. The Segovia Formation, the upper unit of the Edwards Group in the eastern Edwards Plateau, is approximately equivalent to the Person Formation of the Balcones Fault Zone area of the San Marcos Platform and the upper Devils River Formation of the platform margin. Limestone, dolomitic limestone, and marl. Only minor outcrop areas in northwest part of map area. West of map area as much as 360 ft thick.

Kft—Fort Terrett Formation. The Fort Terrett Formation, the lower unit of the Edwards Group in the eastern Edwards Plateau, is approximately equivalent to the Kainer Formation and Walnut Formation of the Balcones Fault Zone area of the San Marcos Platform and the lower Devils River Formation of the platform margin. Lateral lithologic changes between Kainer and Fort Terrett deposits are gradational related to minor facies changes. Limestone, dolomitic limestone, and marl. Shallow subtidal to tidal-flat cycles. Upper part contains some leached evaporitic rocks and breccias. Lower 20 to 40 ft is subtidal limestone approximately equivalent to the Walnut Formation (Kw) of the Balcones Fault Zone area.

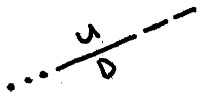
Kdvru—upper Devils River Formation. The upper Devils River Formation is the upper part of the Edwards Group along the San Marcos Platform margin. It is approximately equivalent to the Person Formation of the Balcones Fault Zone outcrop belt of the San Marcos Platform and the Segovia Formation of the Edwards Plateau. Limestone and dolomitic limestone. Shallow subtidal to tidal-flat cycles. Some rudistid mounds. Thickness ~200 to ~250 ft.

Kdvrl—lower Devils River Formation. The lower Devils River Formation is the upper part of the Edwards Group at the San Marcos Platform margin. It is approximately equivalent to the Kainer Formation of the Balcones Fault Zone outcrop belt of the San Marcos Platform and the Fort Terrett Formation of the Edwards Plateau. Limestone and dolomitic limestone. Shallow subtidal to tidal-flat cycles. Upper part contains some leached evaporitic rocks and breccias. Lower 20 to 50 ft is nodular limestone. Thickness ~350 to ~400 ft.

Kw—Walnut Formation. Limestone, marl, and dolomitic limestone; undifferentiated Bull Creek and Bee Cave Members; upper Bee Cave Member consists of fossiliferous marl; *Exogyra texana* common; Bee Cave Member thins and may pinch out toward the southwest; along steep slopes marly Bee Cave Member commonly supports denser vegetation than does the overlying Kainer Formation; lower Bull Creek Member comprises limestone and dolomite interbedded with some marl; gastropods common; *Exogyra texana*; gradational contact with underlying Glen Rose Formation. Cream to light-yellowish-brown. Karst locally; some honeycomb porosity. Some researchers include **Kw** as lower part of Kainer Formation (**Kk**) southwest of Hays County. Formation as much as 30 to 50 ft thick.

Kgru and Kgrl—Glen Rose Formation. *Corbula* interval divides formation into upper and lower parts. **C** on map indicates locality of *Corbula* observed in outcrop. Limestone, dolomitic limestone, and marl. Shallow subtidal to tidal-flat cycles. Alternating resistant and recessive beds forming stair-step topography; limestone, wackestone, packstone, grainstone; hard to soft and marly; 3- to 10-ft-thick; upward -shoaling cycles common; light-gray to yellowish-gray; dolomite, fine grained, porous, yellowish-brown; locally burrowed; local honeycomb porosity; marine megafossils include molluscan steinkerns, rudistids, oysters, and echinoids; local dinosaur tracks. Upper part, **Kgru**, relatively more thinly bedded, more dolomitic, and less fossiliferous; some intervals of disturbed bedding and collapse breccia possibly caused by evaporite solution; thickness ~400 ft. Lower part, **Kgrl**, commonly more massive, contains some rudistid reefs and mounds. *Corbula* interval at top with abundant steinkerns of *Corbula harveyi* (Hill) in one to three thin, resistant, 1- to 3-ft-thick beds composing an interval as much as 15 ft thick; thickness ~200 to ~270 ft. Thickness of entire formation ~650 ft.

Map Symbols



Fault; **U**, upthrown side; **D**, downthrown side; dashed where relatively less distinct than solid; dotted where covered.

Doline. Probable karst-related collapse or subsidence of bedrock.

Strike and dip of beds dipping between 2° and 6°