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ABSTRACT

This geologic map of the southeast Austin corridor in Central Texas, scale 1:100,000, has been constructed through digital compilation of eight 1:24,000-scale open-file geologic maps. The map is intended to be used by professionals and laypersons as a source of general geologic information that relates to land and resource use and management. Geology of the area consists mostly of Paleocene through Eocene mud- and sand-rich units. Minor Upper Cretaceous marine marl and calcareous mud deposits are in the western study area. Quaternary high-gravel deposits and well-defined terrace deposits of the Colorado River also occur. Bedrock units typically exhibit eastward regional dips of less than 2°. In the west and east parts of the study area, northeast-striking normal faults cut strata. Aquifer units include the Carrizo-Wilcox, Queen City, Sparta, and Yegua . Resources include sand, gravel, clay, lignite, and oil.

Introduction

SUMMARY

The *Geologic Map of the Southeast Part of the Austin, Texas, 30 × 60 Minute Quadrangle: Central Texas Population Corridor Encompassing Bastrop and Smithville*, provides basic geologic information that can be used by laypersons, as well as professionals, who are involved in managing Earth and water resources, planning land use, and designing construction projects within this population/transportation corridor southeast of Austin, Texas. This study area, about 15 mi southeast of downtown Austin, is crossed by two major highways, U.S. 71 and U.S. 290. The area is also within part of the Carrizo-Wilcox aquifer and recharge zone, a significant sandstone aquifer of Texas. Sandstones of the Queen City and Sparta aquifers overlie the Carrizo-Wilcox deposits in the east part of the map area. Earth resources of the area include sand, gravel, clay, lignite, and oil. Bastrop and Buescher State Parks and a relatively large Lower Colorado River Authority (LCRA) park, McKinney Roughs Nature Park, lie in the map area.

Geology illustrated on this map is based on field and aerial-photograph interpretations by the author after review and compilation of previous works. These include regional geologic, environmental-geologic, and land resource maps by Proctor and others (1974), Kier and others (1977), and Henry and Basciano (1979). Master's theses maps by Plummer (1949), Ridley (1954), and Ferguson (1958) illustrate the geology in varying levels of detail for small parts of the study area. Useful soil maps were done by Werchan and others (1974) and Baker (1979). Webber (1968) and Blum (1992) mapped and described Quaternary deposits associated with the Colorado River for investigations that focused on the river's geomorphology, Quaternary stratigraphy, and evolution. Eight 1:24,000-scale open-file geologic maps that cover the study area were mapped by the author between 1999 and 2001 (Collins, 2000a, b, c, d; 2001a, b, c, d). Mapping, reviewing map interpretations, studying subsurface stratigraphic and groundwater data, developing cross sections, and digitizing open-file maps continued during 2007 and 2008 for the construction of this 1:100,000-scale geologic map of the southeast part of the Austin, Texas, 30 × 60 minute quadrangle. The region is vegetated enough to make viewing geologic outcrops difficult. Outcrops best for viewing geologic units are mostly along roadcuts, along the banks of the Colorado River, and in pits. Recognizing differences in vegetation, soil, and landscape development between some units aided in mapping of geologic units. Shallow subsurface data also helped in interpreting the area's geology.

Geology

The map area consists of hilly to flat terrain that is typical of the west-central margin of the Gulf Coastal Plain of Texas. The Colorado River and its well-defined 2- to 4-mi-wide valley is the dominant physiographic feature (Photo 1). In general, higher ground elevations range between 500 and 650 ft, whereas ground elevation near the Colorado River southeast of Smithville is below 300 ft. The area's geology is composed of Upper Cretaceous, Paleocene, and Eocene strata having regional dips generally less than 2° southeastward. Normal faults of the Milano Fault Zone locally cut strata in the central to eastern map area. Quaternary terrace and alluvial deposits of the Colorado River and its tributaries overlie bedrock deposits throughout the area.

Upper Cretaceous marl and calcareous clay of the upper part of the Navarro Group lie in the northwest part of the study area. Marl and clay of the Navarro and underlying Taylor Groups are often undivided on geologic maps of the region because of sparse outcrops. In the study area Navarro deposits are covered mostly by vegetation and clay-rich soil. Contact with overlying Paleocene Midway deposits is inferred.

Paleocene through Eocene units represent marine, deltaic, and fluvial deposition during repetitive cycles of transgression and regression (Fisher, 1964; Galloway and others, 1991; Galloway and others, 2000). Midway Group deposits are dominated by marine slope and possibly shelf mudstone, with minor limestone lenses and glauconitic sand intervals. Midway outcrops are rare because these deposits erode relatively easily and they are covered by vegetation and clay-rich soil. Overlying Midway strata are Wilcox Group mudstones and sandstones of the Hooper, Simsboro, and Calvert Bluff Formations. The Hooper consists of mudstone, along with some sandstone and minor lignite. Ayers and Lewis (1985) reported that, in general, Hooper sediments record prodelta through distributary-channel fill, delta-plain mudstone, and lignite deposition. Some Hooper marine deposits containing thin beds of the oyster *Ostrea duvali* (Plummer, 1949) suggest that at least part of the study area was a marine embayment during some Hooper deposition. Simsboro sandstone with lesser mudstone and mudstone conglomerate and local thin lignite overlie Hooper deposits (Photo 2). Ayers and Lewis (1985) reported that Simsboro sediments were deposited by a bed- to mixed-load fluvial system (McGowen and Garner, 1970) that fed Wilcox deltas farther basinward (Fisher and McGowen, 1967). Calvert Bluff deposits are mudstone, along with some siltstone and sandstone and various amounts of lignite. Kaiser (1978) and Ayers and Lewis (1985) interpreted that Calvert Bluff sediments had been deposited in lower alluvial and upper to lower deltaic-plain settings. They concluded that Simsboro and Calvert Bluff deposition indicates a change from the dominantly alluvial-plain Simsboro to the more deltaic Calvert Bluff. Overlying Wilcox Group deposits are Carrizo Formation sandstone and lesser siltstone and mudstone (Photo 3). Ayers and Lewis (1985) reported that the Carrizo at outcrop is fluvial, although downdip and east of the map study area it is deltaic (Photo 4).

Eocene strata above the Carrizo Formation represent repetitive packages of transgressive to regressive deposits (Fisher, 1964). Fisher (1964) reported that the transgressive deposits generally include open-marine, glauconitic sands and marls overlain by restricted marine clays. He noted that in some areas, open-marine clays that are interbedded with or overlie basal glauconitic strata represent inundative deposits. Regressive deposits generally consist of fluvial to marginal marine, sand-rich deposits overlain by lagoonal and floodplain, mud-rich carbonaceous deposits. Units composing these transgressive-regressive strata packages include the Reklaw-Queen City, Weches-Sparta, and Cook Mountain-Yegua Formations (Stenzel, 1938; Fisher, 1964; Guevara and Garcia, 1972; Ricoy and Brown, 1977; Hobday, 1980). The Reklaw Formation is sand-rich and glauconitic in its lower part, and mostly mudstone and siltstone with lesser thin sandstone in its upper part. Queen City deposits are principally quartz sandstone, along with lesser siltstone and mudstone (Photo 5). The Weches Formation is composed of quartz-rich, glauconitic greensand, mudstone, and claystone. This fossiliferous unit is overlain by Sparta Formation quartz sandstone. The Cook Mountain Formation is mostly mudstone and claystone, along with some glauconitic sandstone. It is fossiliferous and overlain by Yegua Formation sandstone, mudstone, claystone, and lignite.

Quaternary terrace deposits that overlie Cretaceous to Eocene units consist of remnant gravel-rich deposits that are at higher elevations than the broad, well-developed terraces at varied elevations adjacent to the Colorado River. At some places high-gravel deposits are well cemented by hematite and limonite. At other places the high gravel appears to be remnant lag deposits.

Structure

Normal faults in the eastern study area are part of the northeast-striking Milano Fault Zone, a zone of multiple grabens (Ewing, 1990). In the western study area, normal faults may be a northern extension of the Luling Fault Zone, a zone of predominately west dipping normal faults. These fault zones bound the west margin of the Gulf Basin. In the map area, precise fault identification and measurements in outcrop are difficult because of thick vegetation, soil cover, and rapid weathering of outcrops. Broad discontinuities in the stratigraphy along the outcrop belt, local outcrops, and subsurface data, however, enabled previous workers, and this author, to identify and approximate some faults (Ridley, 1954; Sharp, 1966; Follett, 1970; Proctor and others, 1974; Morrison-Knudson Company, 1982; Gaylord and others, 1985; Collins, 2000a, b, c, d; 2001a, b, c, d). Gaylord and others (1985) reviewed the structure of the Camp Swift area within the west part of the study area and reported that a northeast-striking fault west of Camp Swift has a throw of 250 ft, whereas a smaller fault at the southeast part of Camp Swift displays a throw of 15 to 25 ft. Some 1940's oil-prospect data of Elliot (1947a, b) indicate that he thought faults of the Camp Swift area extended southwestward, south of the Colorado River, but these could not be verified to map at the ground surface because of the sparseness of the data. North of the Camp Swift area, Sharp (1966) reported another northeast-striking fault near Elgin that dips westward about 50°. The Milano Fault Zone in the east part of the map area was mapped partly by Ridley (1954), who noted that sandstone adjacent to the fault surface was commonly indurated and cemented by limonite. Proctor and others (1974) also mapped numerous faults composing the Milano Fault Zone, and their work was relied on greatly for the current study.

Aspects of fault timing are uncertain. Youngest deposits known to be offset are Eocene, although Oligocene through Pliocene deposits are absent in the fault-zone area. Because obvious fault scarps in Pleistocene and younger alluvial deposits are absent, detailed studies involving techniques such as trenching of Quaternary alluvial deposits overlying faults have not been done. Weeks (1945) reported that fault movement on faults bounding the west and north margin of the Texas Gulf Coastal Plain occurred during the late Oligocene or early Miocene because transported Cretaceous fossils and limestone and chert pebbles that occur in some lower Tertiary deposits of the Gulf coastal plain imply relative uplift and related fault movement to expose Cretaceous rocks as a source (Weeks, 1945). Historical seismicity has been sparse, with one earthquake being reported in the map area—the 1887 Paige earthquake having an assigned magnitude of 4.1 (Carlson, 1984; Davis and others, 1989)—and two other earthquakes near the map area—the 1873 Manor earthquake and the 1902 Creedmoor earthquake, both having assigned magnitudes of 3.6.

Clues to the origin of these faults lie in their regional geographic position. They are part of a regional zone that marks the edge of the Texas Gulf Coastal Plain. Gulfward extension, flexure, and tilting are likely to have occurred along the perimeter of the Gulf of Mexico Basin. Also, downdip slippage on subsurface Jurassic salt is a likely extensional process that has occurred. The Milano faults of the study area and related Mexia faults may be breakaways that formed above the edge of Jurassic salt, marking updip termination of thin-skinned extension (Jackson, 1982).

Resources and Land Use

Geological considerations are key to managing and planning use of land and natural resources, as well as to designing construction projects within the map region. In his regional study, Woodruff (1979) related surface geology to process units and material-landform units, partly on the basis of physical and landscape characteristics of geologic units. For example, in the Bastrop-Smithville area, he determined that much of the Colorado River valley consists of flood-prone areas and valley bottoms, where slopes are low and processes consist of erosion, slope failure, sediment deposition, and surface-water infiltration. He classified the Simsboro, Carrizo, Queen City, and Sparta sandstone outcrop belts as hilly, sandy, aquifer-recharge areas. Hooper and Calvert Bluff outcrops contain sandstone recharge areas, as well as mud- and clay-rich areas having shrinking and swelling soils. Midway, Reklaw, Weches, and Cook Mountain deposits make up clay and sandy-clay areas, which may have poor drainage, local erosion, shrinking and swelling soils, and slumping of oversteepened slopes.

The map area has had a long history of providing Earth resources, including sand, gravel, clay, lignite, and oil. Groundwater resources are possibly one of the most important natural resources. Three primary sandstone aquifers are: Carrizo-Wilcox, Queen City, and Sparta. Colorado River terrace deposits may also provide lesser amounts of shallow groundwater.

Mining of gravel and sand from Colorado River terrace deposits, high-gravel deposits, and some of the Tertiary units has met some of the past demands of development. Sand and gravel continue to be important future resources. Some well-cemented Eocene sandstones and Quaternary conglomerate have been used for aggregate and building stone, but these rocks probably have limited future resource potential because of relatively minor availability. Clay was used as early as 1841 for brick construction in the Smithville area (Nickell, 1939). The Elgin-Butler Brick Company, which has been operating since 1901 a few miles north of the study area, uses Wilcox clay to make brick and tile (Hunt, 2004).

Inactive pits from local mining of sand and gravel, and possibly clay, are relatively common. These abandoned pits are of environmental concern because they have the potential to be used for illegal dumping, which could impair surface-water and groundwater quality.

Commercial lignite lies mostly in the lower part of the Wilcox Calvert Bluff Formation, although the Hooper and Simsboro Formations contain lesser amounts of lignite (Kaiser, 1974, 1976, 1978; Kaiser and others, 1978, 1980; Morrison-Knudson Company, 1982; Ayers and Lewis, 1985). In general, thickest lignite seams are usually relatively thin (1 to 5 ft thick). Lignite was first mined in Bastrop County in the late 1860's (Williams, 2004). Early lignite mining was underground and apparently reached a peak in the mid-1920's, when between 9 and 11 companies were operating; only 2 companies were still mining in 1939 (Nickell, 1939; Williams, 2004). Lignite mining in the region ceased in the mid-1940's, but regional interest in mining lignite renewed in the 1950's with mining in Milam County, north of the map area (Dietrich and Lonsdale, 1958). In the map area, the Powell Bend lignite strip mine was permitted and opened in the 1980's (Morrison-Knudson Company, 1982). It closed in 1993.

Oil exploration and production also have had a long history in the map area. Exploring for oil in subsurface Cretaceous strata has occurred periodically throughout the map area since the 1940's. It is out of this map's scope to provide information on subsurface geologic framework related to hydrocarbon targets and traps. However, it is worth noting that infrastructure related to hydrocarbon exploration and production is linked to land use. Figure 1 illustrates that oil-field practices, including drilling of wells and construction of pits, pipelines, and roads, have been most abundant in the east and southwest parts of the study area.

The principal aquifer of the area is the Carrizo-Wilcox (Follett, 1970; Thorkildsen and Price, 1991; Fisher and others, 1996). Thickest sandstone intervals of this aquifer are generally within the Simsboro and Carrizo Formations, although the Calvert Bluff may also contain some relatively thick sandstone intervals. The base of fresh water in this aquifer across the map area ranges from altitudes near +150 ft in the west study area to near −1,000 ft in the southeast (fig. 2). Dutton (1999) reported that during the past 45 yr, groundwater pumpage from the aquifer has increased substantially, primarily because of mining needs. Results of regional groundwater modeling studies by Dutton (1999) and Dutton and Nicot (2004) suggest that groundwater will remain available to meet withdrawal scenarios through the year 2050.

Queen City and Sparta aquifers lie above the Carrizo-Wilcox in the east part of the study area. These sandstone aquifers are thinner than the Carrizo-Wilcox but provide shallower fresh water. Yegua sandstone at the east edge of the study area composes part of another aquifer, the Yegua-Jackson, although most waterwells in the area are completed within the other aquifers. Some shallow wells also produce from Colorado River alluvial deposits. These wells are probably used mostly for irrigation and livestock.

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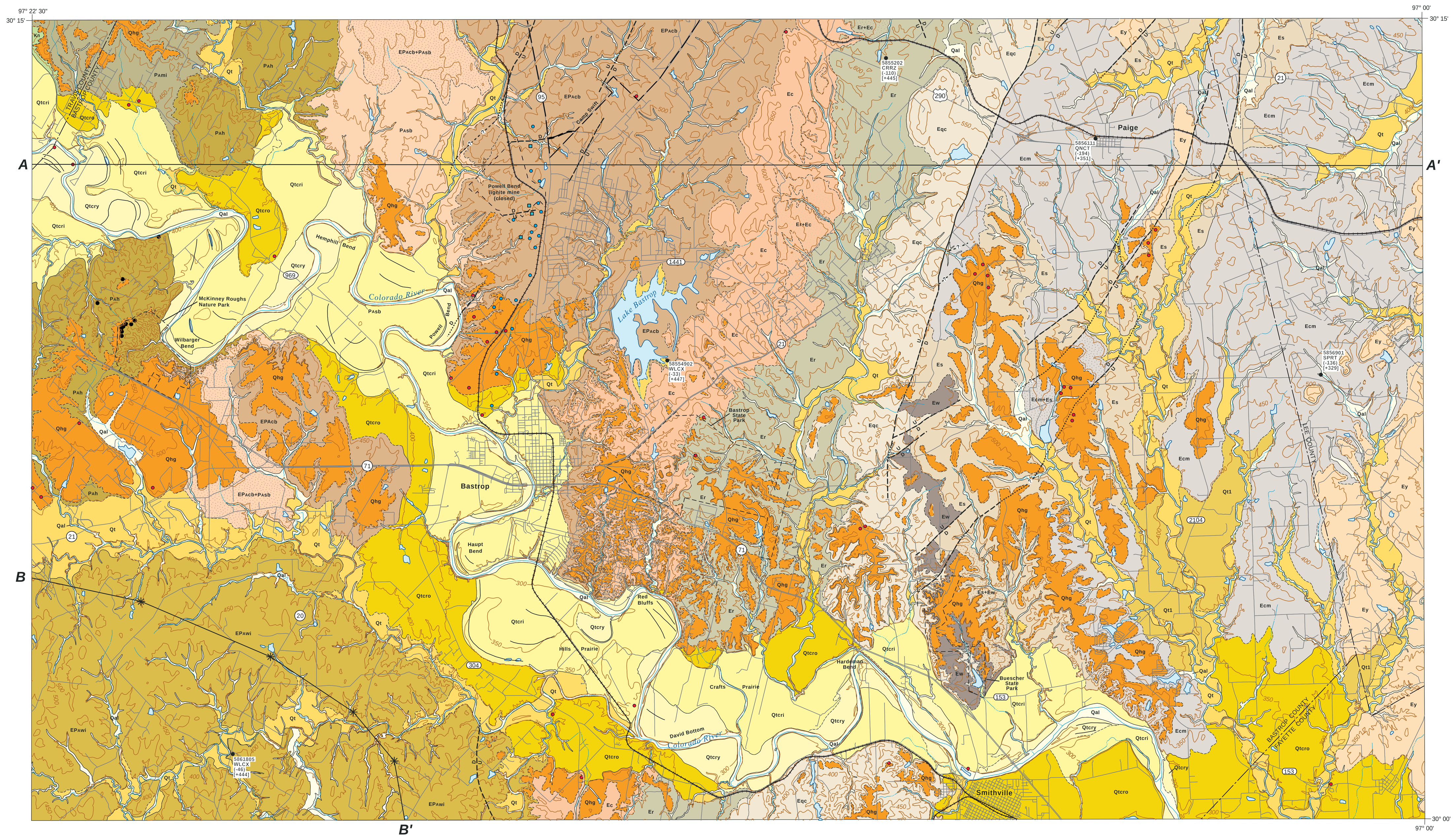


0 5 10 MILES
0 5 10 KILOMETERS
UNIVERSAL TRANSVERSE MERCATOR PROJECTION, ZONE 13N, NAD 83
DATUM IS MEAN SEA LEVEL

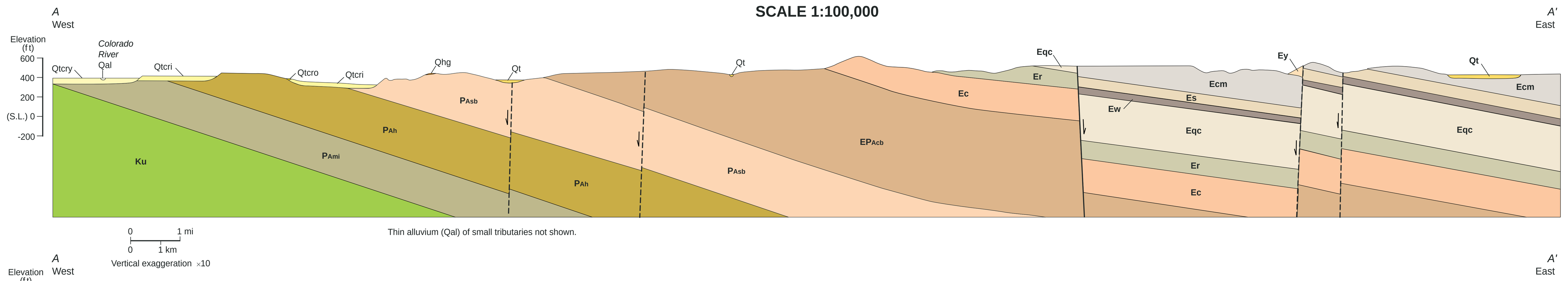
N, MN, 6.5°
1985 magnetic declination (MN)

GEOLOGIC MAP OF THE SOUTHEAST PART OF THE AUSTIN, TEXAS, 30 × 60 MINUTE QUADRANGLE: CENTRAL TEXAS POPULATION CORRIDOR ENCOMPASSING BASTROP AND SMITHVILLE

Edward W. Collins

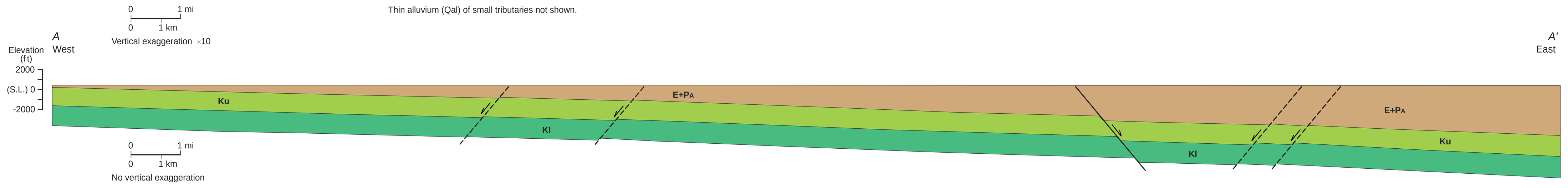
2008

SCALE 1:100,000



0 1 mi
0 1 km
Vertical exaggeration ×10

Thin alluvium (Qal) of small tributaries not shown.

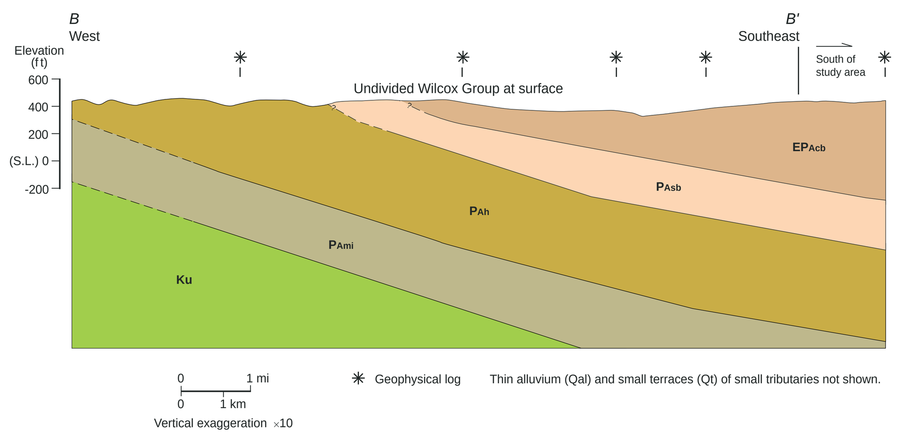


0 1 mi
0 1 km
No vertical exaggeration

E+PA — Eocene and Paleocene units, undivided (Yegua, Sparta, Weches, Queen City, Reklaw, Carrizo, Calvert Bluff, Simsboro, Hooper, and Midway units, undivided).

Ku — Upper Cretaceous Navarro, Taylor, Austin, Eagle Ford, Buda, and Del Rio units, undivided.

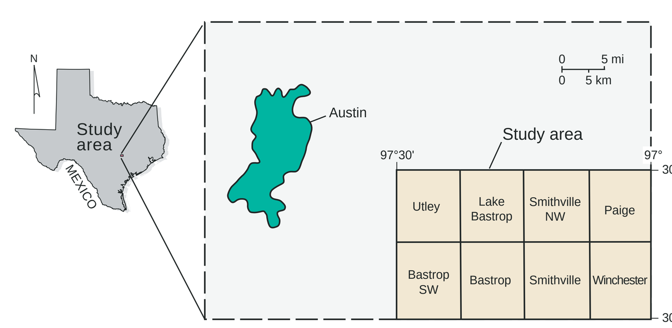
Kl — Lower Cretaceous Georgetown, Edwards, Comanche Peak, Walnut, and Glen Rose units, undivided. (Base of Lower Cretaceous not shown.)

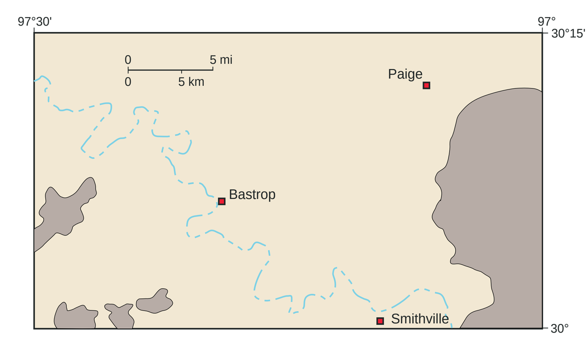


0 1 mi
0 1 km
Vertical exaggeration ×10

✳ Geophysical log

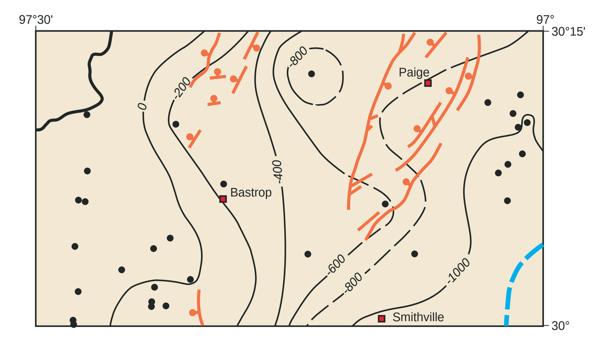
Thin alluvium (Qal) and small terraces (Qt) of small tributaries not shown.





Area where oil-field practices, including drilling of wells and construction of pits, pipelines, and roads, have been relatively abundant.

Figure 1. Areas where oil-field practices have been most common.



Fault

-200 Elevation of base of fresh water in Carrizo-Wilcox aquifer (approximate)

West edge of Wilcox Group strata

East edge of fresh water in Carrizo-Wilcox aquifer (approximate)

0 5 mi
0 5 km

Figure 2. Altitude of fresh water at base of Carrizo-Wilcox aquifer.

Photo 1. Southwest view of Colorado River and a young river terrace (Qtcry) from FM 969 near Wilbarger Bend.

Photo 2. Simsboro (PAsb) sandstone at Powell Bend.

Photo 3. Calvert Bluff (EPAcb) mudstone overlain by thick Carrizo (Ec) sandstone at Red Bluffs.

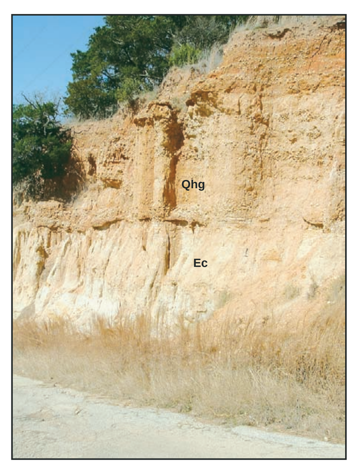


Photo 4. High gravel deposits (Qhg) overlying Carrizo sandstone (Ec) at Red Bluffs along the Colorado River.

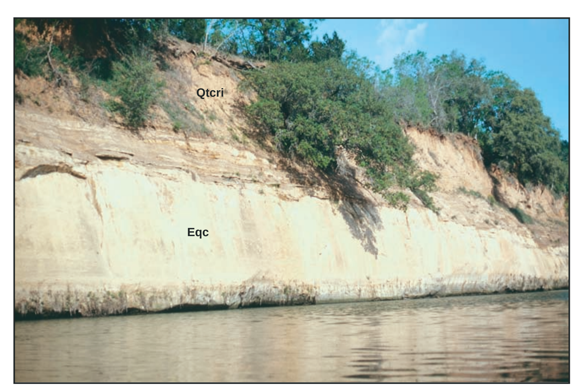
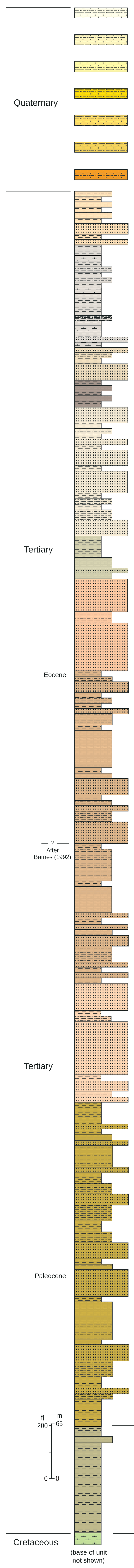


Photo 5. Queen City (Eqc) sandstone and lesser mudstone overlain by Colorado River terrace deposits (Qtcri) at Hardeman Bend.



Qal — Alluvium. Unconsolidated gravel, sand, silt, and mud along streams and rivers; inundated regularly. Colorado River gravel is mostly chert, limestone, quartz, and igneous and metamorphic rock. Includes undivided low terrace deposits along minor drainages. Includes some local bedrock outcrops that are undivided.

Qtcry — Younger terrace deposits of the Colorado River. Unconsolidated and locally cemented gravel, sand, silt, and clay. Generally 5 to 15 ft above river.

Qtcri — Intermediate terrace deposits of the Colorado River. Unconsolidated and locally cemented gravel, sand, silt, and clay. Generally 15 to 45 ft above river.

Qtcro — Older terrace deposits of the Colorado River. Unconsolidated and locally cemented gravel, sand, silt, and clay. Generally 45 to 60 ft above river.

Qt — Terrace deposits of tributaries to Colorado River and minor streams. Unconsolidated gravel, sand, silt, and clay along streams and rivers.

Qt1 — Higher terrace deposits of tributaries to Colorado River and minor streams. Unconsolidated gravel, sand, silt, and clay along streams and rivers.

Qhg — High gravel deposits. Pebble- to cobble-sized gravel, along with sand, silt, and mud. Gravel is chert, quartz, limestone, and igneous and metamorphic rock; lithologies may vary at different locations. At elevations relatively higher than those of well-defined Colorado River terraces. Commonly dissected. Some deposits are gravel lag. Some high gravel deposits in the Bastrop area are well cemented with limonite and hematite. Includes some areas where remnant gravel, sand, silt, and mud have been reworked into the soil but where pebbles and cobbles are common. Mapping of Qhg, particularly the smaller areas, was aided by soil maps by Baker (1979).

Ey — Yegua Formation. Sandstone, mudstone, claystone, some lignite. Hematite- and limonite-cemented mudstone to sandstone, sometimes called *ironstone*, is common aquifer. Total Yegua thickness is 750 to 1,000 ft. Lower 100 ft of Yegua is in the map area.

Ecm — Cook Mountain Formation. Mudstone, claystone, some sandstone. Sandstone is glauconitic. Marine fossils. Four regional members, undivided in this map area, include (from base) Wheelock marl, calcareous mudstone, claystone and glauconitic sandstone, Landrum shale and marl, Spiller sandstone and lignite, and Mount Tabor calcareous shale and siltstone (Stenzel, 1938; Fisher, 1964). Formation name, Cook Mountain, is used on the *Geologic Map of Texas* (Barnes, 1992), although northeast of study area deposits mapped as Cook Mountain by Barnes (1992) were described as Crockett Formation with Stone City member by Yancey and Yancey (1988). Cook Mountain thickness between 300 and 400 ft.

Ecm+Es — Undivided Cook Mountain and Sparta Formations.

Es — Sparta Formation. Sandstone. Sand is quartz; very fine to fine grained; well sorted; micaceous. Minor thin layers and lenses of silt, mud, and clay. Aquifer. Thickness as much as 120 ft.

Es+Ew — Undivided Weches and Sparta Formations.

Ew — Weches Formation. Glauconite greensand, sand, mudstone, and claystone; partly calcareous. Quartz sand common. Hematite- and limonite-cemented claystone to sandstone, sometimes called *ironstone*, is common. Marine fossils. Commonly forms dark-olive and dark-red, mud-rich soil. Thickness between 50 and 100 ft.

Eqc — Queen City Formation. Sandstone. Some mudstone interbeds. Sand is quartz; fine grained. Some glauconite. Aquifer. Total thickness about 500 ft.

Er — Reklaw Formation. Sandstone and mudstone; generally friable. Upper part, sometimes called *Marquez member*, is mudstone and siltstone; carbonaceous; glauconitic. Lower part, sometimes called *Newby member*, is fine- to medium-grained quartz sandstone and mudstone; glauconitic. Hematite- and limonite-cemented mudstone to sandstone, sometimes called *ironstone*, is common. Some ledges of ironstone and eroded pebble-size ironstone. Weathers to brown and yellowish-orange and forms red soil. Total Reklaw thickness between 150 and 200 ft.

Er+Ec — Undivided Reklaw and Carrizo Formations.

Ec — Carrizo Formation. Sandstone, fine to coarse grained, with some siltstone and mudstone; generally friable. Crossbedding common. Mudstone-rich intervals are commonly carbonaceous. Some hematite- and limonite-cemented mudstone and sandstone, sometimes called *ironstone*. Unit commonly forms ridges. Aquifer. Thickness between 300 and 400 ft.

EPAcb — Calvert Bluff Formation. Mudstone, along with some siltstone and sandstone, all friable, and various amounts of lignite. Hematite- to limonite-cemented concretions. Locally glauconitic in upper part of unit. Mudstone is massive to thinly bedded with silt and sand. Sandstone is medium to fine grained, crossbedded, and burrowed. Lignite, with seams generally 1 to 5 ft, most common in lower part of unit. Aquifer. Unit thickness as much as 1,100 ft.

EPAcb+PAsb – Undivided Calvert Bluff and Simsboro Formations.

PAsb — Simsboro Formation. Sandstone and some mudstone and mudstone conglomerate; all generally friable. Sandstone is typically medium to coarse grained, along with some fine-grained sandstone to sandy mudstone. Crossbeds common. Minor lignite. Typically forms gently rolling hills. Aquifer. Thickness generally between 100 and 650 ft. Unit thins and pinches out south of the Colorado River.

EPAwi — Wilcox Group, undivided. Undivided Calvert Bluff, Simsboro, and Hooper Formations in area south of Colorado River with poor to no outcrops and no distinct surface expression of formations. Mudstone, siltstone, and sandstone; friable. Aquifer. Approximate thickness between 2,000 and 2,600 ft.

PAh — Hooper Formation. Mudstone and some sandstone; all generally friable. Minor lignite. Concretions of hematite- and limonite-cemented mudstone and sandstone, sometimes referred to as *ironstone concretions*. Some glauconite in lowermost part. Local oyster (*Ostrea duvali*) beds in lower half of unit in western Bastrop County (Plummer, 1949). Sandstone in upper part of the unit is typically fine to medium grained and crossbedded, whereas sandstone in lower part of the unit is generally very fine grained and crossbedded aquifer. Thickness between 800 and 1,100 ft.

Gravel, sand, and clay
Sandstone
Sandstone and mudstone
Mudstone and claystone
Marl and claystone
L Thin lignite seam (variable locations)

PAmi — Midway Group. Mudstone and lesser sand. Outcrops are rare. Two undivided formations are Wills Point (upper) and Kincaid (lower). Wills Point mudstone is siltier and sand-rich in the upper part where it grades into the Wilcox. Concretions. Wills Point contains glauconitic sand and limestone lenses near its base (Cocovinis, 1949; Gipson, 1949; Plummer, 1949). Kincaid upper part, named Pisgah member, is mudstone, limestone lenses, and minor gypsum within some of the mud (Cocovinis, 1949; Plummer, 1949). Kincaid lower part, named Littig member, is a thin interval of 2 to 15 ft of glauconitic sand and mudstone (Cocovinis, 1949; Plummer, 1949). Midway Group characteristically contains thick mud- to clay-rich soils that are commonly cultivated. Midway Group thickness is between 325 and 400 ft. Pisgah thickness is between 185 and 280 ft. Kincaid thickness is between 140 and 180 ft.

Kn — Navarro Group. Marl and calcareous clay of undivided Navarro Group Kemp and Corsicana Formations. Thickness about 400 ft. Unit typically undivided, with marl and clay of underlying Taylor Group for regional maps.

Map symbols

- Unit contact; contacts drawn as solid lines are relatively more distinct in the field and on aerial photographs than those drawn by dashed lines
- Approximate contact
- Inferred, queried contact
- Fault; U, upthrown side; D, downthrown side
- Approximate fault
- Inferred, queried fault
- Concealed fault
- Contour interval 50 ft
- Road
- Meander scar within large terraces of Colorado River
- Approximate location of lignite outcrop reported by Dietrich and Lonsdale (1958)
- Approximate location of pre-1945 underground lignite mine reported by Dietrich and Lonsdale (1958)
- Approximate location of oyster *Ostrea duvali* intervals in lower third of Wilcox Group Hooper Formation (Plummer, 1949). Locations at Caldwell Knob area of Utley, Texas, Quadrangle were field verified
- Pit. Sand, gravel, or clay. Many are intermittently used or abandoned
- Stream, lake
- Water well. Seven-digit number = State well number. Aquifer: WLCX = Wilcox, CRRZ = Carrizo, QNCT = Queen City, SPRT = Sparta. Most recent mesurement of depth, in feet, to water from surface shown in parentheses (-46). Corresponding elevation of water, in feet relative to mean sea level, shown in brackets [+444]. Complete water-well database maintained and available through Texas Water Development Board

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