QUATERNARY GEOLOGIC MAP OF AUSTIN 4° x 6° QUADRANGLE, UNITED STATES

QUATERNARY GEOLOGIC ATLAS OF THE UNITED STATES
MAP I-1420 (NH-14)

State compilations by
David W. Moore and E.G. Wermund, Jr.

Edited and integrated by
David W. Moore, Gerald M. Richmond and Ann Coe Christiansen

1993

NOTE: This map is the product of collaboration of the Texas Bureau of Economic Geology and the U.S. Geological Survey, and is designed for both scientific and practical purposes. It was prepared in two stages. First, the map and map explanations were prepared by the State compiler. Second, information on the map was integrated with that of adjacent maps, locally supplemented, and related to a uniform map symbol classification by the editors. Map unit descriptions were edited, supplemented, and coordinated with those of other maps of this series so that individual unit descriptions are applicable throughout both this map and all other maps of the series. Problems of mapping or interpretation in different areas were resolved by correspondence to the extent possible; most simply reflect differences in available information or differences in philosophies of mapping and serve to encourage further investigation.

Less than forty percent of the surficial deposits of the United States have been mapped and described. Traditionally, mapping of surficial deposits has focused on glacial, alluvial, eolian, lacustrine, marine, and landslide deposits. Slope and upland deposits have been mapped in detail only in restricted areas. However, an enormous amount of engineering construction and many important problems of land use and land management are associated with regions that have extensive slope and upland deposits (colluvium and residuum, for example). These materials have many different physical characteristics. Therefore, an effort has been made to classify, map, and describe these deposits, based in large part on published and unpublished subsoil data, distribution and structure of bedrock parent materials, slope, and unpublished interpretations of individuals. The classification is crude, but represents a first step toward a more refined and useful product.

For scientific purposes, the map differentiates Quaternary surficial deposits on the basis of a combination of criteria, such as lithology, texture, genesis, stratigraphic relationships, and age, as shown on the correlation diagram and indicated in the map unit descriptions. Some geomorphic features, such as relict beach ridges, are distinguished as map units. Erosional features, such as stream terraces, are not distinguished, and differentiation of alluvial deposits of different ages is possible at a scale of 1:1,000,000 only where they are extensive.

For practical purposes, the map is a surficial materials map, on which materials are distinguished on the basis of texture, composition, and local specific characteristics such as swelling clay. It is not a map of pedologic or agronomic soils. Rather it is a generalized map of soils as recognized in engineering geology, or of subsoils or parent materials from which pedologic and agronomic soils are formed. As a materials map it serves as a base from which engineering, land-use-planning, or land-management maps can be derived.

The map contains the following illustrations:

An index map to the International Map of the World 1:100,000 topographic series showing the Quaternary geologic map of the Austin 4°x 6° quadrangle and other published maps of the Miscellaneous Investigations Series (I–1420).

An illustration showing the responsibility for State compilations.

An illustration showing the correlation of map units.

A physiographic map showing features mentioned in Description of Map Units

LIST OF MAP UNITS

HOLOCENE

asa ALLUVIAL SAND, SILT, CLAY, AND GRAVEL
fl NATURAL LEVEE SILT AND CLAY
hmu FRESHWATER-, BRACKISH-, AND SALINE-MARSH SILT AND CLAY
msf LAGOON AND WIND-TIDAL-FLAT SAND AND CLAY
ml LAGOON AND TIDAL-FLAT SILT AND CLAY
msc BACK-ISLAND SLOPE SAND AND SILT
bb BEACH SAND AND SHELL SAND

HOLOCENE AND LATE PLEISTOCENE

afa ALLUVIAL-FAN DEPOSIT
afb ALLUVIAL-FAN GRAVELLY LOAM
es EOLIAN SAND

HOLOCENE TO MIDDLE PLEISTOCENE

oc PLAYA CLAY
cga CALCRETE-CLAST LOAM TO SANDY LOAM COLLUVIUM
cbm LIMESTONE-CLAST LOAMY COLLUVIUM
cbq BASALT-CLAST CLAYEY COLLUVIUM
ccb SLABBY LIMESTONE-CLAST CLAYEY COLLUVIUM
cse RED SELENITIC SANDY COLLUVIUM AND LOCAL GYPSUM SOLUTION RESIDUUM
csf PEBBLY SANDY CLAY LOAM COLLUVIUM
csi QUARTZ SANDSTONE-CLAST SANDY COLLUVIUM
xba SHALE- AND LIMESTONE-CLAST DISINTEGRATION RESIDUUM
xga CEMENTED PEBBLY LOAM DISINTEGRATION RESIDUUM
xsb QUARTZ SAND DISINTEGRATION RESIDUUM
xle FINE SANDY LOAM DISINTEGRATION RESIDUUM
xlc RED SILTY CLAY DISINTEGRATION RESIDUUM
xcb CALCAREOUS CLAY DISINTEGRATION RESIDUUM
zgd CEMENTED PEBBLY LOAM DECOMPOSITION RESIDUUM

LATE PLEISTOCENE

BEAUMONT FORMATION
bma Beach and near-shore marine sand
dsa Delta sand and silt
dla Delta silt and clay
oca LACUSTRINE CLAY AND SILT

LATE PLEISTOCENE TO MIDDLE PLEISTOCENE

aso CEMENTED ALLUVIAL GRAVELLY SAND

MIDDLE PLEISTOCENE

LISSIE FORMATION
alm Alluvium
ash Alluvial sand, silt, and clay
alf Alluvial silt and clay

LATE PLEISTOCENE TO EARLY PLEISTOCENE

asg ALLUVIAL CLAY, SILT, SAND, AND GRAVEL
esa EOLIAN SHEET SAND
cab CEMENTED COLLUVIUM[1] AND SHEETWASH ALLUVIUM

MIDDLE PLEISTOCENE TO EARLY PLEISTOCENE

ago ALLUVIAL GRAVEL AND SAND

EARLY PLEISTOCENE AND PLIOCENE(?)

WILLIS FORMATION
agc Alluvial pebble gravel and sand
alc Alluvial silt and clay
agg ALLUVIAL SANDY GRAVEL

QUATERNARY AND TERTIARY

zsa LIMONITIC SANDY DECOMPOSITION RESIDUUM
zsb QUARTZ SAND DECOMPOSITION RESIDUUM
zse CLAYEY SAND AND SANDY CLAY DECOMPOSITON RESIDUUM
zcb SMECTITIC CLAY DECOMPOSITION RESIDUUM
zcc SILTY CLAY DECOMPOSITION RESIDUUM
zce MASSIVE CLAY DECOMPOSITION RESIDUUM
zcl CEMENTED SANDY CLAY DECOMPOSITION RESIDUUM
rcn CHERTY CALCAREOUS CLAY SOLUTION RESIDUUM
rcv STONY CALCAREOUS CLAY SOLUTION RESIDUUM
usa FELDSPATHIC SANDY FINE GRUS

LIST OF MAP SYMBOLS

CONTACT

FAULT—Bar and ball on downthrown side

DUNE RIDGE CREST

TEPHRA LOCALITY—Lava Creek B (Pearlette O) ash bed

f— ARTIFICIAL FILL

DESCRIPTION OF MAP UNITS

HOLOCENE

asa ALLUVIAL SAND, SILT, CLAY, AND GRAVEL—Gray, brown, grayish-brown, and yellowish-gray, coarse to fine sand and silt, chiefly quartz, and subangular to well-rounded pebble gravel, pebbly sand, and sandy pebble gravel, interbedded and intermixed. Variable grain size and bedding. Near the coast, principally sand and silt, minor clay, sparse gravel; inland, sand-to-gravel ratios 1:1 to 1:1.5. Contains lenses and thin beds of calcareous silt and clay, some organic rich. Includes deposits of point bars, chute bars, active and abandoned channels, natural levees, low terraces, and flood plains. Some point-bar deposits, as exemplified by those of the Brazos River, grade upward from crossbedded basal sandy gravel (2–3 m thick) to festoon crossbedded silt and fine sand and are capped by reddish-brown alluvial clay. In Falls County, Brazos River deposits 15–25 m thick underlie a flat valley floor, 3–7 km wide. Throughout the quadrangle, clasts include subangular to rounded chert, quartzite, and (or) quartz, with minor amounts of limestone, claystone, and petrified wood, except on Edwards Plateau where limestone is dominant. Alluvium along the Colorado River contains granitoid rocks, schist, and gneiss in the Llano uplift area. Gravel in the Rio Grande valley is rounded, composed of sedimentary rocks, and mafic igneous and volcanic rocks derived from Trans-Pecos area (50–250 km west of the quadrangle); flood plain and low terraces covered by 2–4 m of pale-brown sandy and clayey silt. On coastal plain, fine-grained deposits of levees, flood plains, and abandoned channels partially fill valleys cut into Pleistocene deltaic sediments (**dsa**,**dla**). Coastal-plain alluvium consists of clayey silt, clay, and admixed silt; surficial and buried immature soil zones contain fine root tubules, secondary calcium carbonate and ferruginous nodules. Mapped areas include organic-rich swamp deposits on flood plains and dark-gray interlaminated clay and silt in sinuous abandoned channels. Thickness averages about 5–15 m in valleys of large rivers and about 2–6 m elsewhere; locally as much as 25 m

fl NATURAL LEVEE SILT AND CLAY—Brown to grayish-brown, light- to medium-gray silt and silty clay; includes small amounts of fine quartz sand and, locally, abundant plant fragments. Thin bedded to laminated. Secondary structures include parallel, wavy, and climbing ripple cross-laminations and erosional truncations of laminae. Common ferric and calcium carbonate nodules and plant roots. Form broad levees 1–4 m high along present and former courses of Brazos and Colorado Rivers on the coastal plain. Levee deposits thin and slope gently away from channel. Near mouth of Guadalupe River, levee deposits are interbedded with silty sand of abandoned distributary channels of the prograding delta and mapped as unit **hmu**. Thickness 1–4 m

hmu FRESHWATER-, BRACKISH-, AND SALINE-MARSH SILT AND CLAY—Gray, brown, black, bluish- or greenish-gray silt and clay and locally organic-rich sand layers, intermixed and interbedded. In places, sandy clay beds alternate with layers of peat consisting of compressed mats of shoal grass. Includes tidal-flat deposits, and prograding bayhead-delta deposits of the Guadalupe and Lavaca Rivers. Bayhead-delta deposits grade up from shelly, sandy clay at the base into ripple cross-laminated silty sand and mud, locally overlain by fine-grained levee and marsh deposits. Thickness under modern marshes 0.25–3 m; locally thicker

msf LAGOON AND WIND-TIDAL-FLAT SAND AND CLAY—Very pale brown sand and light-gray clay. Includes laminae and very thin beds of fine to very fine quartz and shell sand, interspersed laminae of clay, algal-bound sand, shell fragments, and microcrystalline calcite, intermixed and interlayered, burrowed locally. Chiefly sand with very thin interbeds of clay. Clay accumulates on flats during relatively infrequent north-wind-driven flood tides, producing alternating laminae of clay and blue-green algae. Flats usually subaerially exposed; well-sorted eolian sand accumulates in thin beds. Flats are locally alkaline; finely crystalline dispersed selenite rarely forms rosettes. Deposits intertongue with back-island slope sand and silt (**msc**); in places, cut by tidal channels filled with sand mixed with broken clam and oyster shells and skeletal material of bryozoa and coral. Mapped areas include local eolian sand not shown separately. Thickness 0.5–2 m

ml LAGOON AND TIDAL-FLAT SILT AND CLAY—Light- to dark-gray silt, clay, and very fine sand intermixed and interbedded; includes marine and, locally, eolian deposits on tidal flats and tidal deltas along inland margin of Matagorda Peninsula north of Pass Cavallo. Thickness 0.5–2 m

msc BACK-ISLAND SLOPE SAND AND SILT—Light-gray, very light gray, or brown fine sand and silt grading landward to sandy clay. Sparse interbeds of blue-gray mud, 30–50 cm thick, deposited in local depressions on back-barrier flats. Laminated or massive, mottled, silty. Contains oyster and other pelecypod shells and burrows. Landward edge of Matagorda and San Jose Islands includes wash-over fan sediments deposited by hurricane-driven waves that surge over the islands. Channel sand is interbedded with planar-bedded sand which replaces it landward and in turn merges with lagoonal mud. Medial to distal parts of planar-bedded sand are 10–50 cm thick. Grades upward from a basal layer of clay pebbles and shells through shelly sand into fine sand and is characterized by channel and erosional disconformities. Mapped areas include small dunes, coppice sand mounds, ponds, mudflats, channels, and marshes. Thickness 0.5–3 m

bb BEACH SAND AND SHELL SAND—White to light-gray, very well sorted, angular, fine to very fine quartz sand, shell sand, and shells with subordinate feldspar, rock fragments, and heavy minerals. Shell fragments form lag concentrates in places. Underlies beaches, spits, and barrier bars along coast. Upper shoreface commonly burrowed by the shrimp *Callianassa*; lower shoreface has very low angle crossbedding. On Matagorda Island, fore-island dunes are well developed immediately landward of beach and 3–8 m above it. Heavy minerals (0.1–1 percent of sand) form dark-colored laminae; silt and clay content 4 percent or less. Bedding is subhorizontal planar, low-angle cross-laminated, or massive. Mapped areas include vegetated sand of back-barrier flats and back-island dune fields. Thickness typically 6–12 m; fore-island dunes on Matagorda Island 1–8 m thick

HOLOCENE AND LATE PLEISTOCENE

afa ALLUVIAL-FAN DEPOSIT—Yellowish- to brownish-gray gravel, coarse to medium sand, and minor silt, intermixed and interbedded; structureless to poorly bedded. Clasts chiefly angular to subrounded pebbles and cobbles of limestone, dolomite, and chert. Forms fans at several levels in Nueces and Frio River watersheds. Thickness 2–8 m

afb ALLUVIAL-FAN GRAVELLY LOAM—Pale-brown, yellow, light-yellowish-brown silty clay; calcareous, friable; contains interbeds of pebbly sand to sandy silt. Clasts chiefly scattered, rounded pebbles and cobbles of limestone, dolomite, and chert; local pebbles of basalt and pyroclastic rock. In places layers of concretions and sand are cemented by soft, white to very pale yellow calcium carbonate. Underlies broad, very gently sloping (1 percent slope) alluvial fans in valleys entrenched beneath alluvial gravel (**ago**, **agg**). Thickness 3–12 m

es EOLIAN SAND—Yellowish-red, reddish-brown, reddish-yellow, fine to very fine quartz sand; silty, slightly clayey. Mapped areas include cover sand and stabilized dunes on uplands. Forms active dunes, and underlies blowouts and flats. Relict orientation of pre-existing dunes is apparent on aerial photographs. Thickness 0.5–3 m

HOLOCENE TO MIDDLE PLEISTOCENE

oc PLAYA CLAY—Light-gray to very dark gray, light-grayish-brown to pale-brown, and brownish-gray sandy clay and silt; massive, calcareous; hard when dry, sticky and plastic when wet. Contains decomposed, finely comminuted plant material and organic carbon. Films, threads, and soft masses of calcium carbonate and fine pebbles of limestone are about 5–8 percent of volume. Deposit occurs in circular to oval closed depressions, many of which may contain ephemeral lakes. Playa basins are 100 m to several kilometers across; thousands dot the surface of the Southern High Plains and Rolling Plains in northwest part of quadrangle but most are too small to show on map. On the Rolling Plains, depressions develop on limestone bedrock and colluvium (**cbm**) and are formed by subsidence due to deep solution and collapse of bedrock. On the High Plains, basins are believed to form in the eolian sand and silt (**esa**) by wind erosion and (or) dissolution of near-surface carbonate above the water table and downward transport of silt, clay and colloid-size organic particles carried by infiltrating ground water (piping and eluviation). Some depressions are rimmed by a low circular mound of brown loam about 1 m thick that overlies white indurated secondary calcium carbonate. Nearly flat surface of some deposits characterized by pimple mounds and depressions (gilgai) of Holocene age. Thickness 0.5–5 m

cga CALCRETE-CLAST LOAM TO SANDY LOAM COLLUVIUM[1]—Reddish-brown, yellowish-brown, or brownish-gray, mixture of sand, silt, and clay; locally contains scattered pebbles of limestone, chert, quartz, and fragments of calcrete cemented by calcium carbonate or silica. May develop nodular (pseudopisolitic) texture. Sand, admixed with silt and clay, is fine to medium, chiefly quartz and feldspar; some mica and other heavy minerals. Colluvium is derived from the Ogallala Formation (Miocene) and mantles slopes that dissect that formation in valley of Concho River and tributaries in northwest part of quadrangle. Mapped areas include some bedrock outcrops. Thickness 0.5–3 m

cbm LIMESTONE-CLAST LOAMY COLLUVIUM[1]—Dark-grayish-brown to light-brown, locally reddish-brown, calcareous, moderately alkaline clay and loam containing scattered to abundant, angular blocky to platy fragments of hard limestone, shale chips, and particles of calcium carbonate cement, and, locally, a little chert. Formed by physical and chemical weathering of thinly interbedded marl, limestone, shale, chalk, and minor sandstone. Chiefly coarse limestone clast colluvium on hillslopes, but includes clay on wide, gently undulating divides in about one-third the outcrop area. Colluvium forms on rolling terrain (5–50 percent slopes) within and marginal to Edwards Plateau. Clasts mantle 10–50 percent of the surface. Colluvium may be more than 50 percent pebble- to boulder-size angular fragments with very little matrix, but commonly has a clayey or loamy matrix in the uppermost 0.1–0.3 m; includes bedrock outcrops. In places, colluvium rests directly on a basal zone of hard, laminar, pale-brown to white calcium carbonate overlying fractured limestone bedrock; elsewhere, the calcium carbonate is soft masses and the loam or clay, mixed with fragments, overlies chalky limestone or calcareous claystone. Stripping and reworking of the carbonate zone, limestone beds, and a possible former overlying residual clay may have produced the present colluvium. In the Blackland Prairie south and east of the Edwards Plateau (or Balcones Escarpment), the clay is commonly adjacent to and derived from units **afa** and **afb** or high alluvial terraces. Thickness of colluvium 0.5–2 m. Clay mantles many gently undulating (0–5 percent slopes) divides of the plateau. Clay is grayish brown to brown, extremely hard when dry, sticky and plastic when wet, calcareous, expansive, and contains scattered limestone fragments. A basal zone of secondary calcium carbonate like that beneath the limestone-clast colluvium may occur below the clay. In the west-central part of the plateau, karst features are developed including broad, shallow sinkholes containing gray smectitic clay that expands markedly upon sorption of water. Thickness of clay 0.4–2.5 m

cbq BASALT-CLAST CLAYEY COLLUVIUM[1]—Dark-brown clay mixed with clasts of pyroclastic rock, weathered basalt, and phonolite; contains iron-rich, smectitic clay and soft, calcareous masses. Angular to subrounded cobbles and pebbles of basalt cover about 25–50 percent of surface. Clay has moderate shrink-swell potential; developed on scattered, erosion-resistant plugs and sills of alkalic basalt and pyroclastic rock that form knolls and steep-sloping hills (20–45 percent slopes). Occurs near Uvalde and in an area 10 km south of Austin. Mapped areas commonly include some alluvium and local bedrock outcrops. Thickness 1–3 m

ccb SLABBY LIMESTONE-CLAST CLAYEY COLLUVIUM[1]—Light-brownish-gray, olive, or yellowish-brown silty clay to silty clay loam containing pebble- to small cobble-size, angular to flat fragments of limestone and petrocalcic carbonate, and, locally, sparse fossil shells and iron oxide and (or) calcium carbonate-cemented concretions 1–5 cm in diameter. Colluvium may be alkaline and may contain fine crystals of gypsum. Surface slopes 5–25 percent and is partly covered with angular limestone and carbonate fragments. Developed in strongly dissected, hilly terrain on horizontal, thin interbeds of silty shale, claystone, limestone, and marl or on thick-bedded, fractured limestone. Laminar to weakly cemented secondary calcium carbonate occurs on top of underlying bedrock. Thickness 1–2 m

cse RED SELENITIC SANDY COLLUVIUM[1] AND LOCAL GYPSUM SOLUTION RESIDUUM[2]—Orange-brown to brownish-red, mottled grayish-green, silty, fine quartz sand; locally includes some silty clay. Contains fragments of sandstone, siliceous pebbles derived from local pebble conglomerate, and gravel derived from alluvium (**ago**) capping divides upslope. A lag gravel is present at the surface of the deposit in places. Colluvium is derived from gently rolling uplands where it locally overlies remnants of partly stripped residuum that grades down through a shallow zone of broken rock into red sandstone, mudstone, or local pebble conglomerate. The bedrock contains beds of gypsum, which are represented near the surface by zones of gypsiferous solution residuum and rubble remnant after near-surface dissolution and collapse of the gypsum bedrock. Mapped areas include partly stripped residuum and bedrock outcrops. Thickness 0.5–1 m

csf PEBBLY SANDY CLAY LOAM COLLUVIUM[1]—Reddish-brown, pebbly, silty sandy clay containing fragments of sandstone, dolomite, and limestone. Siliceous pebble lag at surface. Fragments of mica and hornblende schist intermixed in micaceous silty clay forms on Precambrian schist in the Llano area. On some uplands and slopes, overlies pink clay loam or zone of calcium carbonate accumulation. Mapped areas include extensive bare bedrock outcrops, commonly in the form of flatirons and dip slopes. Thickness 0.2–1 m

csi QUARTZ SANDSTONE-CLAST SANDY COLLUVIUM[1]—Pale-gray, yellowish- or reddish-brown, coarse, medium, and fine sand, locally pebbly. Contains sandstone rubble clasts of assorted sizes, some limonite-cemented clasts, and, locally, some limestone and chert rubble derived from rock types upslope. Commonly in abrupt contact with underlying rock. Mapped areas include local bedrock outcrops. Occurs along eastern escarpment of Southern High Plains. Thickness 1–5 m

xba SHALE- AND LIMESTONE-CLAST DISINTEGRATION RESIDUUM[3]—Brown or light-reddish- to yellowish-brown silty clay containing olive-gray to brown shale chips where developed over shale, and forming a thin, brown, calcareous clay matrix containing limestone and chert rubble where developed over fractured limestone. On the northern Nueces Plains, residuum forms on interbedded light-gray to yellow calcareous clay and limestone. Commonly a 2- to 3-cm-thick layer of indurated secondary calcium carbonate discontinuously coats upper surface of bedrock. Underlies gently rolling uplands characterized by stair-step benches in which limestone underlies the bench surfaces and shale the frontal slopes. Mapped areas include bedrock outcrops and local limestone rubble or shale debris colluvium. Thickness less than 0.5 m to 1 m xga CEMENTED PEBBLY LOAM DISINTEGRATION RESIDUUM[3]—Yellowish-red and white pebbly loam, fine to very coarse quartz sand, sandy clay loam, loam, or clay loam matrix. Friable to very compact. Residuum is chiefly sandy gravel composed of well-rounded quartz, quartzite, and chert pebbles. Includes fragments of calcium carbonate and a few fragments of sandstone. Locally cemented by calcium carbonate 0.2–2 m below surface. Carbonate may be platy, massive, laminar, brecciated, chalky, or nodular. Residuum mantles beds of clay, sand, sandstone, marl, calcrete, and limestone of the Pliocene Goliad Formation (not shown). On some gently undulating uplands, the residuum is locally pocked by shallow, nearly circular depressions 50–300 m across, 1–3 km apart, filled with brownish-gray calcareous clay. Thickness 0.3–5 m

xsb QUARTZ SAND DISINTEGRATION RESIDUUM[3]—Pale-gray to reddish-yellow, very fine to fine quartz sand, locally clayey and silty; calcareous, limonite stained in places. Includes angular fragments and chunks of sandstone. Grades down into sandstone bedrock through a fragmented zone locally impregnated and cemented with calcium carbonate. Mapped areas include remnants of calcium carbonate-cemented residuum (**zsb**), colluvium (**csi**), and minor alluvium. Thickness 0.5–2 m

xle FINE SANDY LOAM DISINTEGRATION RESIDUUM[3]—Reddish-yellow to yellowish-red, fine sandy clay loam to fine sandy loam, locally calcareous; common soft concretions and amorphous masses of secondary calcium carbonate (5–20 percent by volume), iron oxide, and seams of finely crystalline gypsum; moderately alkaline. Contains few pebbles of chert and sandstone locally. Grades down into reddish-brown, yellow, or brown, ferruginous, fine-grained, soft to well-cemented sandstone, lignite, varicolored clay, and silty to sandy shale, some containing numerous calcareous concretions. Near the Rio Grande, forms escarpments and narrow, gravel-capped drainage divides; elsewhere in the southwest, developed on broad plains and low hills. Thickness 1–2 m

xlc RED SILTY CLAY DISINTEGRATION RESIDUUM[3]—Orange-brown and red, mottled grayish-green, silty clay; local fine sandy clay. Grades down abruptly into red shale or dolomite on gently sloping uplands. Mapped areas commonly include bedrock outcrops and gravelly loam colluvium on dissected slopes. Gravel is derived from deposits of Pleistocene Seymour Formation (**ago**) capping divides immediately upslope. Thickness 0.5–1 m

xcb CALCAREOUS CLAY DISINTEGRATION RESIDUUM[3]—Light-brown to brown, olive, or light-reddish-brown silty clay to fine sand containing chips of pale-yellowish-brown and olive shale and small fragments of mudstone, siltstone, sandstone, and, in the north-central part only, coarse-grained limestone, on all of which the residuum is developed. May also contain rare small pebbles. Clay is calcareous, alkaline, locally smectitic, and transected by few seams of fine gypsum crystals and sparse, amorphous calcium carbonate. Grades down into bedrock through a thin fragmented zone. Mapped areas may contain sparse colluvium, local alluvial terrace gravels of rounded clasts of quartz and chert, and outcrops of thin-bedded sandstone that form benches, especially along the Rio Grande and in the southwest part of quadrangle; some of these local deposits cemented by laminar calcium carbonate. Thickness commonly less than 1 m; locally only a few centimeters

zgd CEMENTED PEBBLY LOAM DECOMPOSITION RESIDUUM[4]—Reddish-brown, pinkish-white to pinkish-gray (lower part), loamy, fine to very coarse quartz sand, gravelly loam, sandy clay loam, or clay loam matrix. Friable to very compact. Thirty to ninety percent of the residuum consists of well-rounded quartz, quartzite, and chert pebbles, in places as beds 5 cm to 1 m thick. Fragments of calcium carbonate common; locally, a few (as much as 30 percent) fragments of sandstone. Commonly cemented by calcium carbonate 0.2–2 m below surface. Carbonate may be platy, massive, laminar, brecciated, chalky, or nodular; solution channels in the upper part. Residuum veneers the Goliad Formation (Pliocene; not shown). Northeast of the Guadalupe River, the Goliad is overlain by remnants of bedded gravel of the Pliocene and early Pleistocene Willis Formation (**agc**), which overlapped much of the Goliad in early Pleistocene time. Except where pebble beds in the Goliad are exposed, the Willis is a major source of gravel in the residuum. Thus, the residuum is younger than the Willis. Matrix of residuum, however, is mostly derived from beds of clay, sand, sandstone, marl, calcrete, and limestone in the Goliad. On gently undulating uplands, residuum is locally pocked by shallow, nearly circular depressions 50–300 m across, 1–3 km apart, filled with brownish-gray calcareous clay. Thickness 0.3–5 m

LATE PLEISTOCENE

BEAUMONT FORMATION—A body of clastic sediments identified by its land form (a morphostratigraphic unit). Includes three facies (beach ridge, distributary channel, and interdistributary) which form a delta plain that extends along the Gulf Coast. Deposits contain Pleistocene vertebrate fauna that include mammoth, bison, various horses, and turtles. Dips seaward beneath Holocene deposits and rests disconformably on similar middle Pleistocene deposits of the Lissie Formation (**alm**, **ash**, **alf**)

bma Beach and near-shore marine sand (relict beach ridge and associated sand facies)—White, light- to dark-gray, light- to dark-brown, fine to very fine quartz sand; well-sorted subangular grains; contains shells and shell fragments, littoral foraminifera, and minor amounts of silt and clay. Underlies beaches, beach ridges, spits, and fore-island dunes. Part of the Pleistocene Ingleside-Live Oak barrier strandplain system that extends discontinuously and parallel to present coastline from Baffin Bay, Texas, to Lake Charles, Louisiana. Surface characterized by pimple mounds and live oak-covered, subdued linear beach ridges that parallel the modern shore; grassy swales between ridges partly filled with Holocene mud and sand. Locally contains blowouts and intradunal lows producing small ponds or playas as much as 200 m across. Thickness 3–10 m[5]

dsa Delta sand and silt (distributary channel facies)—Yellowish- to brownish-gray, locally reddish orange, very fine to fine quartz sand, silt, and minor fine gravel, intermixed and interbedded. Includes stream channel, point-bar, crevasse-splay, and natural levee ridge deposits, and clayey fill in abandoned channels. Forms poorly defined meander-belt ridges and pimple mounds aligned approximately normal to coast and 1–2 m higher than surrounding interdistributary silt and clay (**dla**). Channel fill is dark-brown to brownish-dark-gray, laminated clay and silt, organic-rich, that underlies sinuous or straight low swales or oxbow lakes (former channels). Includes marine delta-front sand, lagoonal clay, and near-shore marine sand beneath and landward of bays along the coast. Interfingers with interdistributary facies (**dla**) and rests disconformably on Lissie Formation (**alm**, **ash**, **alt**) Thickness 3–10 m on outcrop; thickens southward in the subsurface to more than 100 m[5]

dla Delta silt and clay (interdistributary facies)—Light- to dark-gray and bluish- to greenish-gray clay and silt, intermixed and interbedded; contains beds and lenses of fine sand, decayed organic matter, and numerous buried organic-rich, oxidized soil(?) zones that contain calcareous and ferruginous nodules. Very light gray to very light yellowish gray sediment cemented by calcium carbonate occurs in varied forms: veins, laminar zones, burrows, root casts, nodules, and irregular masses. Cemented zones generally follow bedding. Locally small gypsum crystals abundant. Includes plastic and compressible clay and mud deposited in flood basins, coastal lakes, and former stream channels on a deltaic plain. Underlies and interfingers laterally with delta sand and silt of distributionary channel facies (**dsa**). Mapped areas include a few coastal marsh (**hmu**) and lagoonal (**ml**) deposits near edge of contemporaneous mainland. Thickness 5–10 m along north edge of outcrop; thickens southward in subsurface to more than 100 m[5]

oca LACUSTRINE CLAY AND SILT (Tahoka Formation of Evans, 1949)—Gray, bluish-gray, and black clay and silt; locally sandy and gravelly; indistinctly bedded to massive; weakly coherent, contains very thin beds (2–5 cm) and lenses of dolomite, gypsiferous in places. Grades shoreward into yellowish-gray, friable, fine sand and sandy fine gravel. Clay minerals include bentonite, sepiolite, and illite. Contains molluscan and vertebrate fossils. Deposited in pluvial lakes that occupied deflation basins and subsidence depressions in cover sands. Thickness as much as 8 m but thins to less than 1 m laterally

LATE PLEISTOCENE TO MIDDLE PLEISTOCENE

aso CEMENTED ALLUVIAL GRAVELLY SAND—Very pale brown, light-yellowish-brown, and very light brownish gray, calcium carbonate-cemented quartz sand, silt, clay, and gravel, intermixed and interbedded. Includes alluvial-fan deposits consisting of stratified to massive, poorly sorted clayey sand and sandy to silty clay. Sand and clay contain lenses of pebbles mixed with unsorted platy fragments of calcium carbonate and subangular to subround gravel composed of locally derived limestone, dolomite, and chert. Locally, overlies soft to hard, calcium carbonate-cemented gravelly loam or chalky clay. Deposit stands higher than younger terraced, weakly cemented deposits and interfingers with cemented colluvium on adjacent slopes. In the middle to upper coastal plain, deposits are coeval in part with unit **asg** of Deweyville age, late- or post-

Beaumont but pre-Holocene. In the western part, brown loamy sand sheetwash deposits slope gently toward streams. Mapped areas include some cemented colluvium and small isolated areas of older alluvial deposits. Thickness 2–6 m

MIDDLE PLEISTOCENE

LISSIE FORMATION—Includes alluvium (undifferentiated as to texture and origin), fine-grained channel facies, and fine-grained overbank facies. Together, these deposits form a deltaic plain that parallels the Gulf Coast. Deposits contain Pleistocene vertebrate fauna, dip seaward beneath the Beaumont Formation, and rest disconformably on deposits of the Pliocene and early Pleistocene Willis Formation (**agc**, **alc**). The delta plain is entrenched as much as 7 m by streams

alm Alluvium (undifferentiated as to texture and origin)—Light-gray, brown, tan, yellowish-brown, or reddish-brown sand, silt, clay, and minor gravel; contains iron oxide and iron manganese nodules; locally calcareous and, in places, contains calcite concretions. Includes meander belt, levee, crevasse splay, and distributary sand, and flood-basin mud deposits. Thickness about 60 m[5]

ash Alluvial sand, silt, and clay (fine-grained channel facies)—Light-gray to brown or orange-brown, medium to fine sand and silt; includes minor clay and quartz- and chert-pebble gravel, intermixed and interbedded with coarse sand. Upper part contains calcareous concretions and iron manganese nodules. Local channel-and-fill, graded, crossbedded, and slump structures indicating deposition on point bars, and in channels on headwater plain of delta. Depositional surface characterized by pimple mounds and low dunes of Holocene age. Interfingers with fine-grained overbank facies (**alf**). Thickness 10–25 m; more than 100 m seaward under younger deltaic units[5]

alf Alluvial silt and clay (fine-grained overbank facies)—Light-gray, tan, yellowish-brown, and reddish-brown clay, silt, and fine sand; includes compact clayey sands, sandy clays, and minor pebble or granule gravel; intermixed and interbedded, poorly to well sorted; commonly laminated and locally crossbedded; contains calcium carbonate and iron oxide concretions; organic-rich lenses. Upper part, stained yellow brown, includes small nodules of iron and manganese oxides. Surface locally characterized by abundant shallow depressions and pimple mounds. Comprises flood-basin, backswamp, and lake deposits typically near alluvial channels. Thickness 55–65 m[5]

LATE PLEISTOCENE TO EARLY PLEISTOCENE

asg ALLUVIAL CLAY, SILT, SAND, AND GRAVEL (alluvium of "Deweyville terrace," Beaumont, Lissie, and Willis age, undifferentiated)—Light-brown, reddish-brown, gray, or yellowish-brown, gravelly quartz and lithic sand and silt to sandy gravel. Deposits become increasingly fine grained on the Coastal and Nueces Plains. Sand crossbedded to massive; includes clay lenses mottled pinkish orange or yellowish tan. Gravel is rounded to angular limestone and chert pebbles and cobbles, and some boulders; unsorted to moderately sorted. Underlies vertical sequences of river terraces. Low terraces of major rivers are capped by 2–4 m of clayey sand and silt. Sandy gravel on higher terraces varies somewhat in composition from river to river. Gravel along the Brazos River underlies three main terrace levels (in Falls County, 13–15 m, 27–30 m, and 45–60 m above low water level) and is mostly pebbles of quartz, chert, limestone, and claystone, sparse igneous pebbles, and sandstone or limestone boulders, capped by red, alluvial silty clay 1–3 m thick. In Falls County, fossil vertebrate remains, including elephant, were reported in alluvium (Hatch, 1936). Sandy pebble gravel of Little River (Bell County) underlies three terraces; lower two are less than 20 m above river level; deposits are composed of limestone, minor black chert, red quartzite, sandstone, and reworked Cretaceous fossils, especially *Gryphaea*. Third terrace, 30 m above river, is underlain by 3– to 7–m-thick bed of chert gravel containing sparse fossil vertebrate bones. Deposits along the Colorado River are reddish-brown sand and gravel; clasts of limestone and chert, and minor granite, gneiss, schist, quartz, feldspar, and pegmatite. In Bastrop County, a deposit 27 m above Colorado River contains the Lava Creek B (Pearlette O) volcanic ash (age 0.6 Ma), 2,000 km southeast of its source in Yellowstone National Park, Wyoming (Izett and Wilcox, 1982). Nueces River deposits include clasts of limestone, chert, and various sedimentary rocks; downstream from Cotulla, sandy clay deposits lack gravel. Along the Frio, Leona, and Sabinal Rivers east of Uvalde, gravel is chiefly basalt and pyroclastic clasts, locally cemented by iron oxide. Gravel along the Rio Grande is composed of subrounded clasts of locally derived limestone and chert and rounded clasts of basalt, volcanic porphyry, quartzite, milky quartz, and banded chalcedony derived from the west. Mapped areas include small deposits of colluvium and sediments reworked from older alluvial deposits. Thickness 3–20 m

esa EOLIAN SHEET SAND ("cover sands" of Frye and Leonard, 1957; Blackwater Draw Formation of Reeves, 1976, described by Holliday, 1989)—Grayish-red, reddish-brown, or very light brown, fine to medium quartz sand; silty and clayey; stratified to massive. Includes sparse discontinuous thin beds of gray lake silt and clay, rich in organic carbon. Basal pebbly sand fills channels in places. Sedimentary units typically rest disconformably on one another. Mantles most of the nearly featureless, gently sloping plateau of the Southern High Plains that extends northward 450 km. In northwesternmost part of quadrangle, it rests on calcrete (so-called "caprock caliche") in upper few meters of Ogallala Formation, but elsewhere in quadrangle it overlies rocks of Cretaceous age. Contains several vertically overlapping, buried soil profiles consisting of brown to reddish-brown, pedogenic, clay-rich B horizons, modified by secondary calcium carbonate and sparse calcic C horizons; buried soils lack A horizons. Calcium carbonate in B horizons forms filaments, coatings, nodules, and small concretions, and rare laminar concentrations. Near Lubbock (270 km northwest of San Angelo) a volcanic ash layer in lower part of deposit is compositionally similar to the 1.4-Ma Guaje Pumice Bed in northern New Mexico (Izett and others, 1972). At Tule Canyon (about 340 km north-northwest of San Angelo), the deposit contains the 0.6-Ma Lava Creek B volcanic ash bed. Appears to have accumulated cyclically through most of Quaternary time as a series of sand sheets formed during semiarid to arid periods of eolian deposition between longer subhumid to semiarid intervals characterized by concurrent erosion, playa-lake deposition, and soil formation. Thickness 2–6 m in northwest corner of quadrangle

cab CEMENTED COLLUVIUM[1] AND SHEETWASH ALLUVIUM—White, pink, light- to dark-gray, and light yellowish- to reddish-brown sand, silt, clay, and gravel; extensively cemented by secondary calcium carbonate; stratified to massive, characterized by local concentration of secondary calcium carbonate as indurated laminar horizontal layers or in massive, soft zones and nodules. Forms slope deposits and remnants of nearly level to gently sloping, discontinuous alluvial-fan aprons that include sparse deposits of lacustrine clay and marl. Distribution is spotty in northwest part of quadrangle. Mapped areas include bedrock outcrops and small deposits on uplands. Thickness typically 3–8 m; locally as much as 12 m

MIDDLE PLEISTOCENE AND EARLY PLEISTOCENE

ago ALLUVIAL GRAVEL AND SAND (Seymour Formation and correlative upland gravel; equivalent to parts of Willis and Leona Formations as mapped by Texas Bureau of Economic Geology, 1974b)—Light-gray, medium-gray, or yellowish-brown gravelly sand, silt, and clay. Locally contains zones of secondary calcium carbonate-cemented gravelly loam to clay 1–2 m thick, locally 15 m thick. Rounded to subrounded pebbles and boulders of gray, white, black, green, and red chert and less abundant limestone and dolomite, except in west and north of San Angelo where limestone and dolomite pebbles are prevalent. Includes few pebbles of dark-olive siltstone and hard quartzite, volcanic rock, porphyry, milky quartz, banded chalcedony, and igneous and metamorphic rocks. Caps upland flats and stream divides. Along Rio Grande in Val Verde County, eastward slope of gravel exceeds slope of the river, suggesting that the deposit has been tilted. Thickness 0.5–15 m

EARLY PLEISTOCENE AND PLIOCENE(?)

WILLIS FORMATION—Valley fill and braided-stream deposits of the oldest delta plain that parallels the Gulf Coast. Deposits are deeply and extensively eroded and are higher than those of the Lissie and Beaumont Formations. Includes a channel facies and an overbank facies; these rest unconformably on Tertiary sediments. Some workers consider the Willis Formation to be Pleistocene in age; others believe it to be correlative with the Goliad Formation which contains a vertebrate fauna of Pliocene age

agc Alluvial pebble gravel and sand (channel facies)—Light-gray to orange-brown, orange, or reddish-orange, gravelly, coarse to fine sand containing lenses of moderate- to dark-red sandy silt and white to light-gray clay. Pebbles and cobbles are subangular to subround, mostly quartz and minor chert and petrified wood. Includes deposits of straight torrential channels, braided channels, and meander belts of merged low-gradient alluvial fans, all of moderate relief.

Colluvial gravel and sand (unit **csc** on adjoining White Lake quadrangle) as thick as 2 m veneers some slopes in hilly areas, but not shown as a separate map unit. Thickness commonly 10–30 m; as much as 60 m at southern limit of outcrop[5]

alc Alluvial silt and clay (overbank facies)—Light-brown, pale-yellow, orange, or orange-brown, fine silt and clay, intermixed and interbedded. Includes some slightly consolidated clayey quartz sand and, locally, small iron-stained chert pebbles. Ferruginous nodules common in oxidized upper part; also, sparse petrified wood fragments. Underlies gently rolling to moderately dissected terrain that has local relief of 3–12 m away from major streams. Considered Pleistocene in age on basis of stratigraphic position and lithologic similarity to younger Pleistocene deposits. Thickness 5 m to more than 50 m along southern edge of outcrop[5]

agg ALLUVIAL SANDY GRAVEL (Uvalde Gravel as mapped by Texas Bureau of Economic Geology, 1976a, 1977)—Pale-brown, light-yellowish-brown, and reddish-brown sandy gravel and gravelly sand containing small proportions of silt and clay. Typically cemented by secondary calcium carbonate, ranging from hard calcrete that will not slake in water to soft calcareous zones; depth of cemented zone 0.2–2 m. Abundant, well-rounded pebbles and cobbles composed of chert, quartz, and limestone; minor amounts of igneous rock; some boulders. Caps drainage divides, upland flats, and rounded ridges 30–75 m above streams. Extensive upland deposits on high alluvial terraces along Rio Grande and in northern Nueces Plains. Thickness 1–6 m

QUATERNARY AND TERTIARY

zsa LIMONITIC SANDY DECOMPOSITION RESIDUUM[4]—Light-gray, yellowish-brown, brown, or dark-reddish-brown, clayey to silty, fine to medium quartz sand; limonite cemented or contains irregular masses, nodules, and veins of limonite. Claystone fragments locally abundant. Grades down into sandstone, shale, and siltstone. Mapped areas commonly include some colluvium and local bedrock outcrops. Thickness 1–10 m

zsb QUARTZ SAND DECOMPOSITION RESIDUUM[4]—Pale-gray to reddish-brown and reddish-yellow, coarse to medium or fine quartz sand, locally pebbly, clayey, or silty, and muscovite rich. Contains irregular, hard, limonite-cemented masses, limonite nodules, and veins. Forms resistant escarpments and rolling uplands. On the dissected plateau west of Austin, includes local limestone outcrops. Grades down into friable to locally cemented sandstone, and very locally into pebble conglomerate or claystone. Pebbles are composed of limestone, gneiss, and schist in the Llano area. Mapped areas include broad, low dunes of Holocene age, and, locally, calcium carbonate-cemented sandy clay residuum, too small to map; they also include some colluvium and bedrock outcrops. Thickness 1–3 m

zse CLAYEY SAND AND SANDY CLAY DECOMPOSITION RESIDUUM[4]—Gray, light-brown, orange, or brown, clayey, fine to medium quartz sand to fine sandy silty clay; locally contains subrounded sandstone pebbles. Mapped areas commonly include some colluvium and small bedrock outcrops. Thickness 1–3 m; less than 1 m where developed on tuff

zcb SMECTITIC CLAY DECOMPOSITION RESIDUUM[4]—Yellowish-gray, greenish-gray, light-gray, or gray clay and sand. Locally contains calcareous nodules. Clay is smectitic; expands when wet; shrinks and cracks, forming gilgai, when dry. Residuum grades down into marine clay, marl, calcareous sandstone, or limestone. Mapped areas commonly include colluvium and small bedrock outcrops. Thickness 1–2 m

zcc SILTY CLAY DECOMPOSITION RESIDUUM[4]—Black to dark-gray or dark-brown, light- to reddish-brown where oxidized, silty clay and sandy clay. On upper coastal plain forms a northeast-trending belt, the "blackland prairie" (from Waco to Uvalde) of decomposed chalk and marl. West of Waco, forms low slopes on clayey limestone and thin shale. In northern Bee County, 100 km southeast of San Antonio, residuum is gray, calcareous clay to brown or pinkish-brown, friable, fine sandy clay containing calcium carbonate concretions; at depth of 0.6–1 m residuum rests on a zone of hard calcium carbonate or calcium carbonate-impregnated sandy clay at contact with bedrock. In Bell County, residuum is developed on tuffaceous clay and sandstone underlying rolling, dissected uplands. Clay is smectitic, expands when wet, shrinks and cracks, forming gilgai, when dry. In southwest part of quadrangle, residuum contains gravel relict from alluvial upland gravel (**ago**), and overlies shale and limestone bedrock. Thickness 0.2–2 m

zce MASSIVE CLAY DECOMPOSITION RESIDUUM[4]—Gray to dark-brownish-gray, yellowish- to dark-brown, reddish-brown, or mottled light-red to orange, clay, sandy clay, and fine quartz sand commonly limonite stained. Calcareous; commonly contains limonite nodules and platelets. Contains smectitic clay that typically shrinks or swells depending on moisture content. Lower part locally contains fragments of brown coal. Formed chiefly on dark-gray clay or yellowish-gray and brown, soft, thin sandstone interbedded with shale. Thickness 0.1–3 m

zcl CEMENTED SANDY CLAY DECOMPOSITION RESIDUUM[4]—Yellowish- or reddish-gray sandy clay; cemented by calcium carbonate in upper part; locally, gypsiferous, saline, uncemented clay contains sparse, soft masses of calcium carbonate. Formed on gently sloping to undulating uplands in southwest part of quadrangle. Grades down through zone of decomposed rock into soft, fine-grained, reddish-yellow sandstone or pale-brown shale. Mapped areas commonly include colluvium and local bedrock outcrops. Thickness 1–5 m

rcn CHERTY CALCAREOUS CLAY SOLUTION RESIDUUM[2]—Light-reddish-brown clay to silty or sandy clay and red clay. Where underlain by limestone, contains abundant solution-rounded subangular fragments of limestone and scattered chert. In places, secondary calcium carbonate present in lower 0.5 m. Residuum is in sharp contact with limestone and penetrates it along fractures. Residuum grades down into marl, clay, or soft sandstone. Forms horizontally banded layers of stony and stone-free clay residuum on steplike benches underlain by alternating flat-lying thin beds of hard limestone and softer rocks. Mapped areas include numerous bedrock exposures, chiefly limestone, and deposits of stony clay colluvium on frontal slopes of benches and steep to moderate slopes of valleys that dissect the limestone. Thickness 0.2–2 m

rcv STONY CALCAREOUS CLAY SOLUTION RESIDUUM[2]—Chiefly dark reddish brown or pale- to grayish-brown clay, in places enclosing several square kilometers of loamy residuum. Where underlain by limestone, lower part of residuum is in abrupt contact with zone of clay and remnant solution-rounded limestone fragments comprising 30–80 percent of the material. Fragment zone grades down into fractured limestone bedrock. Where underlain by shale, residuum and shale are in abrupt contact; where underlain by chalk or marl, contact is more gradational. In Bell County, rolling hills and nearly level uplands are veneered with dark-brown silty clay that grades down through soft, white marl and a clay and fragment zone into hard, fragmented limestone. Similar variation in the residuum also is apparent in southwest Edwards Plateau, where residuum covers uplands and hillslopes underlain by interbedded limestone, marl, sandstone, and chalk. Mapped areas include bedrock outcrops and, where slopes are steep to moderate, accumulations of pale-brown, calcareous loamy colluvium, 1–2 m thick, that contains abundant fragments of limestone, shale, and secondary calcium carbonate. Thickness of residuum 1–2 m

usa FELDSPATHIC SANDY FINE GRUS[6]—Pink-tan, angular fragments, 2–4 mm in diameter, in clayey, medium to very coarse sand; matrix composed of quartz, feldspar, and biotite crystals and crystal fragments weathered from granite, gneiss, and schist. Mapped areas commonly include colluvium and local bedrock outcrops. Thickness 1–2 m

[1]COLLUVIUM is a general term applied, for purposes of this map, to unconsolidated rock and soil material transported and deposited by mass-wasting processes.

[2]SOLUTION RESIDUUM, for purposes of this map, is defined as material derived by in-place solution of carbonate rock or carbonate-cemented rock, with no appreciable subsequent lateral transport.

[3]DISINTEGRATION RESIDUUM, for purposes of this map, is defined as material derived by in-place mechanical breakup of rock with no appreciable subsequent lateral transport.

[4]DECOMPOSITION RESIDUUM, for purposes of this map, is defined as material derived primarily by in-place chemical weathering of clastic rock with no appreciable subsequent lateral transport.

[5]THICKNESS is approximate because deposit thickens seaward, the base is usually buried, and underlying deposits often are similar to the unit in question. Drill-hole data, dated materials, and age-diagnostic fossils may be inadequate to aid in locating base of unit. In practice, the base may be assigned in drill holes at the top of a buried paleosol, a major change in dominant grain size, firmness of clay, a change from gray to reddish-tinted clay, a seismic-reflector horizon, or another characteristic that is interpreted to represent a significant unconformity.

[6]GRUS, for purposes of this map, is defined as material derived by in-place chemical and physical weathering of crystalline rock with no appreciable subsequent lateral transport.

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