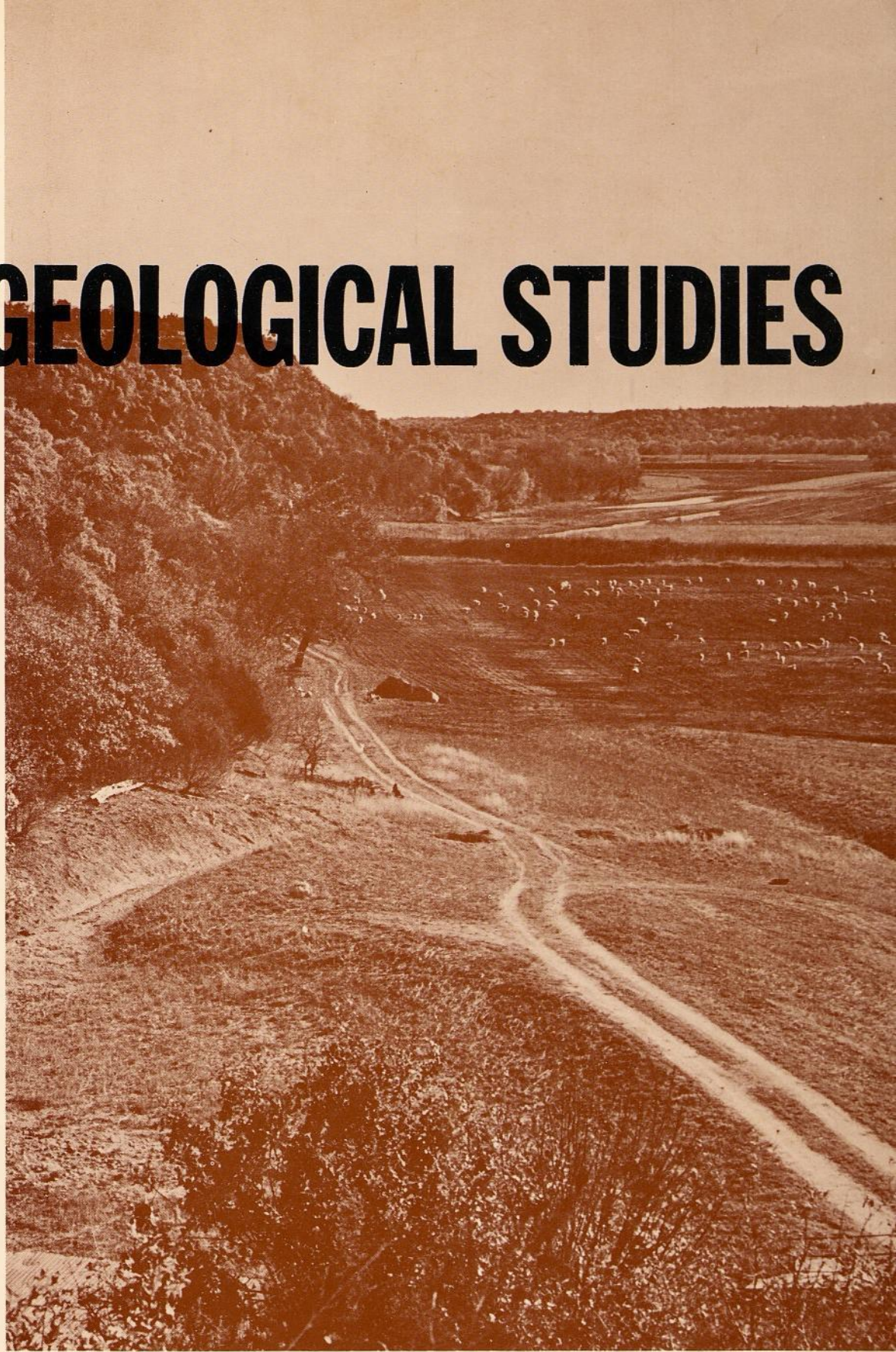
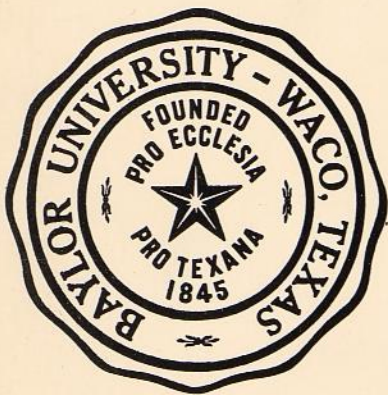


BAYLOR GEOLOGICAL STUDIES



FALL 1969

Bulletin No. 17



*The Geomorphic Evolution
of the Leon River System*

RAYMOND L. LEWAND, JR.

*"Creative thinking is more important
than elaborate equipment--"*

FRANK CARNEY, PH.D.
PROFESSOR OF GEOLOGY
BAYLOR UNIVERSITY
1929-1934

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BAYLOR GEOLOGICAL STUDIES

BULLETIN NO. 17

The Geomorphic Evolution
of the Leon River System

RAYMOND L. LEWAND, JR.

BAYLOR UNIVERSITY
Department of Geology
Waco, Texas
Fall, 1969

Baylor Geological Studies

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The Geomorphic Evolution of the Leon River System

RAYMOND L. LEWAND, JR.

ABSTRACT

The present Leon River valley apparently conducted the discharge of the Brazos River from Early Pleistocene until late Kansan time. Piracy of the headwaters caused diversion of the ancestral course to the present Brazos valley. Inherited features of the former, much larger, river remain within the Leon valley. These features are high abandoned valleys, alien soils, foreign siliceous terrace components, and underfit valley meanders.

The ancestral Leon-Brazos River entered the present Leon basin just north of Eastland, Texas through an abandoned valley. From this point, it extended northwest through the Clear Fork of the Brazos River valley to a point within a deep pass, carved through a drainage barrier ridge in Throckmorton County. From this pass, the projected trunk course continued through the apparently underfit valley of Paint Creek,

south of Rule, Texas. West of this valley, the course of the ancestral system becomes tenuous, but it may have followed the Double Mountain Fork of the Brazos River valley at least as far as the High Plains escarpment.

The Leon-Brazos system is thought to have drained an extensive part of the caprock region since the characteristic large siliceous gravels of its terraces are derived from the basal Ogallala Formation of the High Plains. These gravels represent the unique alien terrace components of the present Leon system and are traceable throughout the postulated drainage routes of the ancestral Leon-Brazos route. A primary source for the alien siliceous terrace lithologies is apparently the quartzitic outcrops of the South Manzano Mountains of Central New Mexico.

INTRODUCTION¹

LOCATION

The Leon River originates in south-central Eastland County at the confluence of the South, Middle, and North forks. From this junction it trends 185 miles southeastward through Eastland, Comanche, Hamilton, Coryell and Bell counties (fig. 1). Communities along the course include Eastland in Eastland County, Hamilton in central Hamilton County, Gatesville in Coryell County, and Temple in Bell County. Major tributaries of the Leon River are the Sabanna River, Rush Creek, and the South Leon River in the upper basin; Warren Creek near midbasin; and Cowhouse Creek in the lower basin. North of Temple, the Leon River and Cowhouse Creek are dammed to form Belton Reservoir. Immediately south of Belton, the Leon

and Lampasas rivers join to form the Little River. Twenty miles south of Cameron, Little River joins the Brazos River.

The Leon River basin is almost surrounded by basins of other Brazos River tributaries. On the north the Leon basin is bounded by basins of several small tributaries; on the east, by the Bosque system basin; on the west, by the Lampasas basin; and on the south, by the main Brazos River valley.

The inner valley of the Leon River is floored by flood-plain land, bounded by rocky valley walls and barren slopes suitable for grazing. The valley has long been used as a major transportation route, first for stage coach lines and later by State Highway 36. The valley includes portions of the Western Cross-Timbers and Lampasas Cut Plain physiographic provinces.

¹A thesis submitted in partial fulfillment of the requirements for the M.S. degree in Geology, Baylor University, 1967.

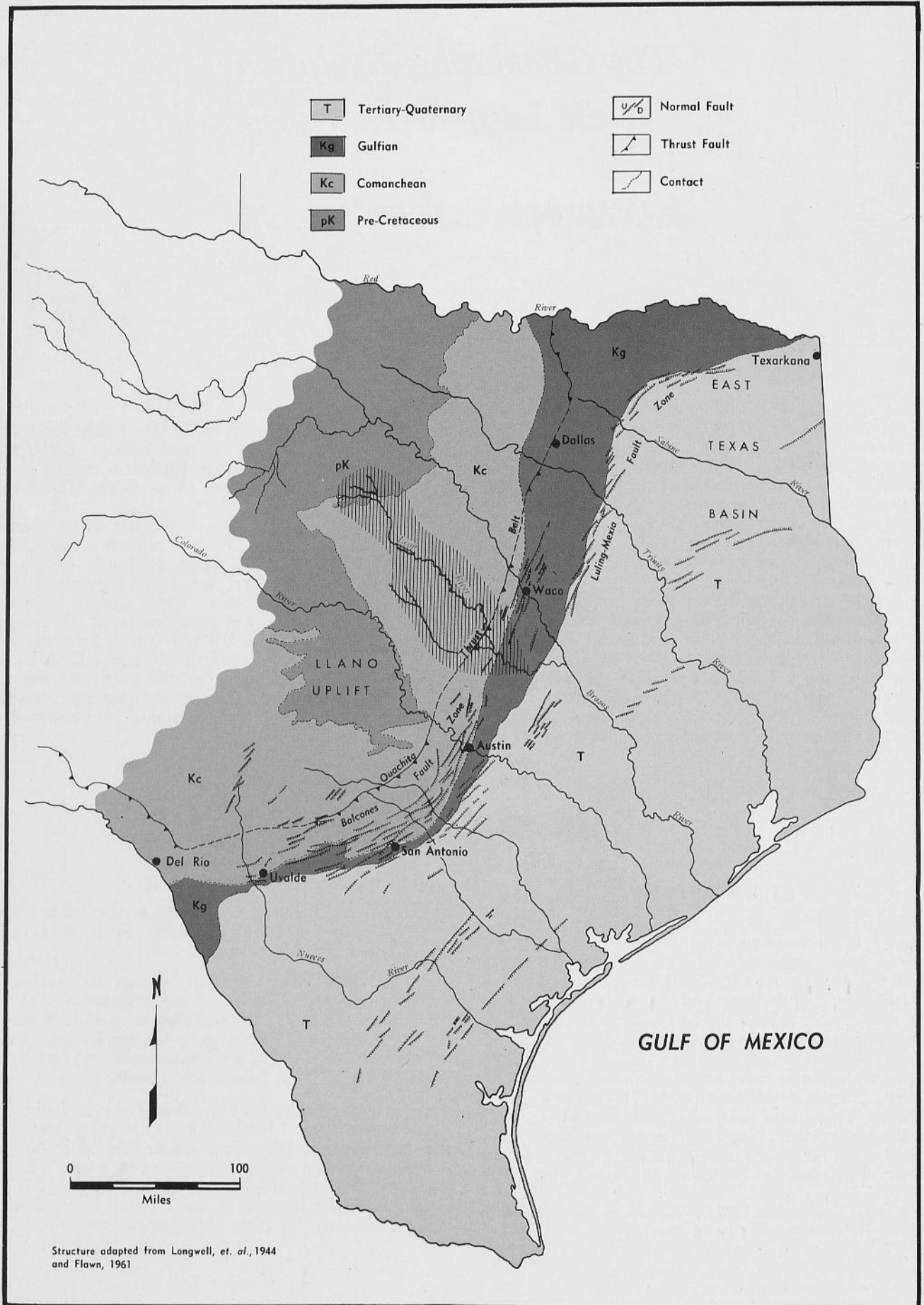


Fig. 1. Index map.

PURPOSE

Valley meanders characterize the Leon River valley throughout three-fourths of the basin length. These meanders are equivalent in radius to those of the present Brazos River, which has a basin roughly eight times that of the present Leon River. Upon this meandering flood plain small meanders of the Leon River, one tenth the radius of the valley meanders, appear grossly underfit.

The purpose of this investigation was to determine the reason for the underfit nature of the Leon River.

METHOD

The method of study included: (1) an inventory of the present river system including discharge, meander geometry, sediment transport, and flood-plain soil character; (2) mapping of the present basin, based on aerial photographs and field checks to determine the contribution of each stratigraphic unit to river flow and sediment load; (3) compilation of interpretive flow-history of the ancestral Leon River, based upon valley meander geometry, maximum sediment size, interpolated discharges and possible sediment sources, based on systematic sampling of the various terrace levels and gravel exposures within the present basin and other areas of the postulated earlier basin (fig. 2); (4) contrast between present and postulated past systems in terms of rainfall and basin area.

Thin sections were made from various *typical* lithologies of the Leon River terraces and of similar lithologies from postulated sediment source areas. The sections were further compared to petrographic sections from widely separated potential source areas described in the literature.

Aerial photographs and topographic maps of the study area were used to identify possible areas of capture, points of major deflection, and abandoned stream courses.

PREVIOUS WORK

Background material relating to this problem may be divided into references about the geomorphic evolution of Central Texas and the Leon River, works on regional geology applicable to a Leon River study, and general studies relating to river mechanics.

R. T. Hill (1901) was perhaps the first to mention the geomorphology of the Leon River area, which he described as "autogenous streams . . . developed upon upland stretches of plain which separate stream valleys of the older class of streams" (p. 64). He defined the trunks of these rivers as "primarily auto-

genous slope streams which were originally established upon higher surfaces, now stripped away; they have maintained their location by inheritance as the general region was degraded by erosion" (*idem*).

Reed (1928) stated that boulders, 50 to 250 miles removed from their outcrop, found within an abandoned Brazos River channel near Bryan, Texas probably were deposited by ice packs during the Pleistocene. He speculated that Central Texas rivers then in existence frequently had ice jams from which material was deposited.

Stricklin (1961), in a study of the Brazos River near Waco, dated the lower terraces of the upper Brazos and defined the areal extent of the ancestral valley. As a result of this study, he suggested that there had been major tributary diversion.

The most recent study of the Leon basin was conducted by Hamlin (1964) who described the geomorphic processes now active within the Leon basin.

Goodson (1965), Proctor (1965), and Ray (1964) reviewed portions of the problem for specific quadrangles along the Leon valley. Other geologists, working in the region, have noted the discrepancy between the present Leon River and its valley, but this information has not been published.

Stratigraphic studies within the Fredericksburg and Trinity groups by Frost (1963), Rodgers (1965), and Boone (1966) have produced some detailed geologic maps and lithologic descriptions of portions of the Leon basin. Regional studies related to this problem include those by Darton (1920) and Patton (1930) who described in detail the Ogallala and Potter gravels of the southern High Plains. These papers represent the first thorough description of the late Tertiary-Quaternary siliceous gravels of the major Central Texas river systems.

Frye and Leonard (1964) studied the stratigraphy of the Ogallala and younger gravels. They dated various deposits and suggested a drainage history for the Pliocene-Pleistocene of the Texas High Plains.

Stark (1956) described the stratigraphy, structure, and petrology of the South Manzano Mountains, a region of quartzitic outcrops and possible source area for much of the High Plains quartzose gravels.

ACKNOWLEDGMENTS

The writer expresses his appreciation to Dr. J. W. Dixon and W. L. Siler, Department of Geology, Baylor University, for their helpful suggestions and invaluable advice; to the Shell Development Company for its radiocarbon age measurements of carbonized wood samples; and to Dr. O. T. Hayward, Department of Geology, Baylor University, for suggesting the problem, evaluating and criticizing the approach, and for advice during manuscript preparation.

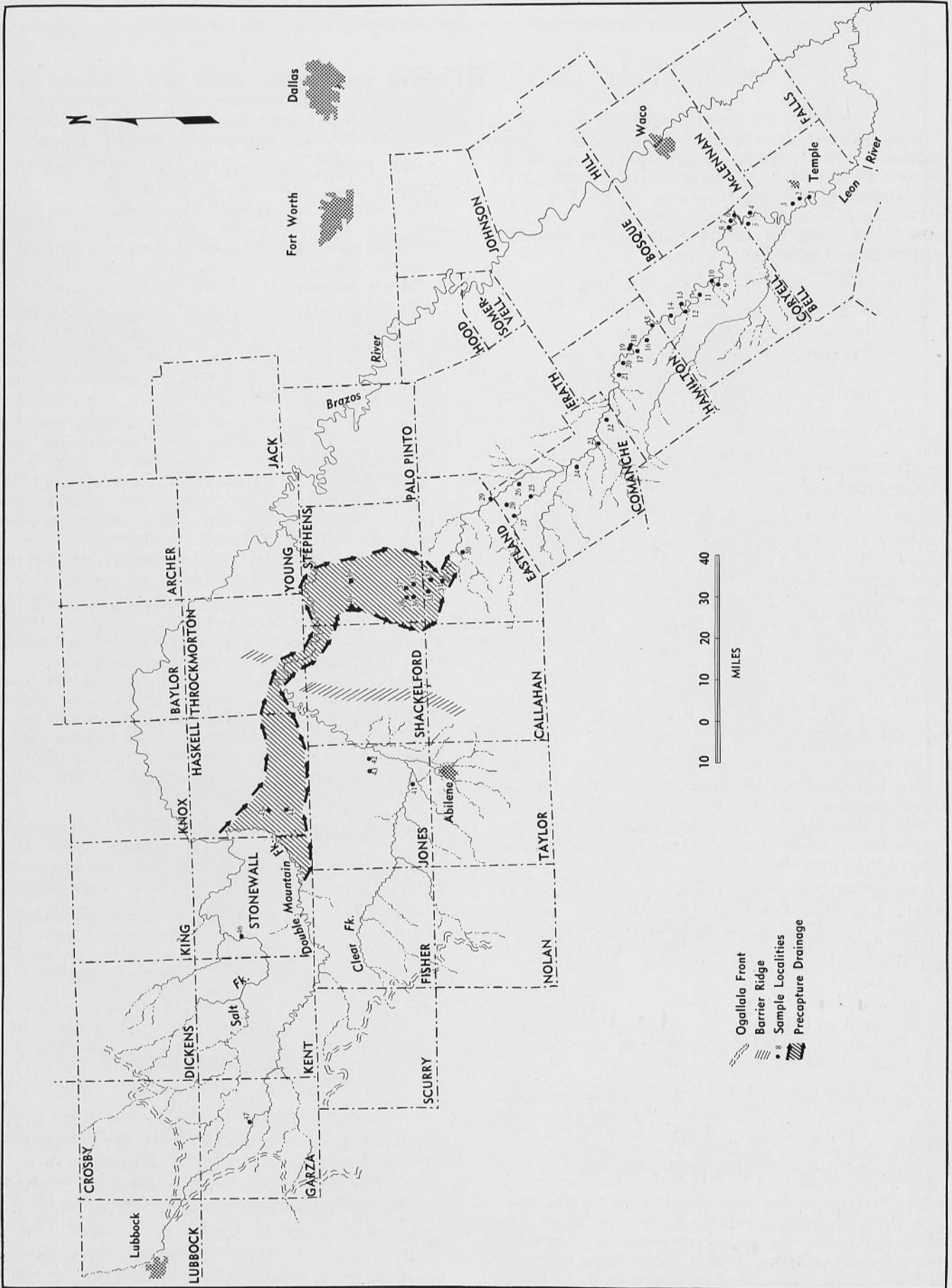


Fig. 2. Leon-Brazos drainage routes.

THE LEON RIVER BASIN

The drainage basin of the Leon River extends southeast from Cisco in Eastland County to Temple in Bell County. Overall basin length is 185 miles. The area of the present Leon basin is approximately 5,040 square miles (Hamlin, 1964, p. 3). Maximum basin width, 35 miles, occurs just north of Hamilton in Hamilton County where the basin is bulbous in shape. Southward, the basin converges slightly toward Gatesville in Coryell County from which point it converges rapidly to its junction with the Lampasas River basin south of Temple.

From Temple to Hamilton, the eastern side of the Leon basin is marked by a distinct high divide, capped by resistant Edwards Limestone (fig. 3). North of Hamilton, the divide between the Leon and Bosque systems becomes less distinct where the Edwards Limestone has been removed by erosion, and the divide is carved in the less resistant rocks of the lower Fredericksburg Group.

The uppermost Leon basin north of Comanche is characterized by ill-defined divides between the Leon and Brazos rivers, which are developed on lower Cretaceous sands and Paleozoic sandstones and shales. To the west the divide between the Leon River and Pecan Bayou (of Colorado River drainage) is low and indistinct (fig. 1). South of the town of Comanche to the southern border of Comanche County, the divide becomes higher and more distinct. South of the southern border of Comanche County to Temple (Bell County), the divide is distinct, formed by the resistant Edwards uplands (fig. 3). On the south, the Leon and Lampasas rivers coalesce to form the Little River system (fig. 1).

Physiographically, the Leon basin can be divided into three sub-basins:

(1) *Upper Basin*—The upper basin has low relief and extends south to the junction of the Sabanna River (figs. 1, 3). This is a region of low rolling topography, comprised of four sub-basins, the South, Middle, and North forks of the Leon River and the Sabanna River. In this region the valley tends to be symmetrical with wide valley floors. The divides are indistinct, and the slopes are gentle and consistently brush covered.

(2) *Middle Basin*—The middle basin extends south to the southern border of Comanche County (figs. 1, 3). This area includes the main Leon valley and the sub-basin of the South Leon River; here the main valley becomes asymmetrical with a steep eastern face. Principal tributaries enter from the west. Valley floors are wide and alluviated, and valley walls and divides tend to be higher, better defined and grass mantled.

(3) *Lower Basin*—The lower basin extends from the southern Comanche County line to the river mouth (figs. 1, 3). This portion consists of the Leon River and the sub-basin of Cowhouse Creek, the largest tributary of the Leon River. In this basin the valleys are markedly asymmetrical with steep eastern walls and gentle western walls. Short drainage enters from the east; long drainage enters from the west. The valley

floors are wide, and valley meanders and terraces are well preserved. The divides are high and distinct, capped by Edwards Limestone.

STRATIGRAPHY

Three physiographic subdivisions of the Leon basin also constitute geologic provinces. The upper basin is developed largely on Paleozoic sands and shales. The middle basin is developed principally on sands and fine gravels of Early Comanchean age. The lower basin is developed in resistant limestone and soft shales of the Trinity, Fredericksburg, and Washita groups.

THE UPPER BASIN

Rocks exposed in the upper basin include Pennsylvanian sands and shales of the Strawn, Canyon, and Cisco groups in the stream valleys, and Cretaceous Trinity sands along the divide.

Strawn Group—Rocks of the Strawn Group (Upper Pennsylvanian age) are the oldest formations exposed in the Leon basin. They occur within an inlier in north-central Comanche County where Rush Creek and the Sabanna River have stripped away the Cretaceous veneer (figs. 1, 3).

Exposed Strawn rocks consist of interlaminated beds of dense red sandstone; dark-green shale; and a few thin, lenticular, dense, crystalline limestones. Strawn rocks support a topography composed of shallow, steep-walled valleys with extensively dissected valley floors.

Soils developed on Strawn formations include varieties of the Renfrow series which include clay, silt, and sandy loams, ranging in color from brown to dark reddish brown. The texture is friable to blocky. The chemistry is neutral to moderately calcareous.

The sediment contributed to the Leon River by Strawn rocks includes grayish clay, red sand, pebbles of soft dark-gray limestone, and cobbles of clay-cemented sandstone.

Canyon Group—Rocks of the Canyon Group are exposed in the upper basin (figs. 1, 3), where the thin Cretaceous cover has been removed by erosion. These Canyon rocks consist of alternating beds of soft light-colored limestone, dark-green brittle shales, and a few dense reddish sandstones. The limestone beds maintain low hills and narrow ridges and serve as minor drainage divides between the stream valleys, dissected in the sandstone and shale.

Soils developed on Canyon rocks are of the Kirkland and Renfrow series, typically reddish, friable, silty to sandy loams, slightly acidic to highly calcareous.

Sediment contributed to the Leon River by rocks of Canyon age includes grayish clay, red sand, pebbles of dark-gray soft limestone, and sandstone cobbles cemented by clay.

Cisco Group—Rocks of the Cisco Group are exposed along the western margin of the basin and along the South and Middle forks of the Leon River (figs.

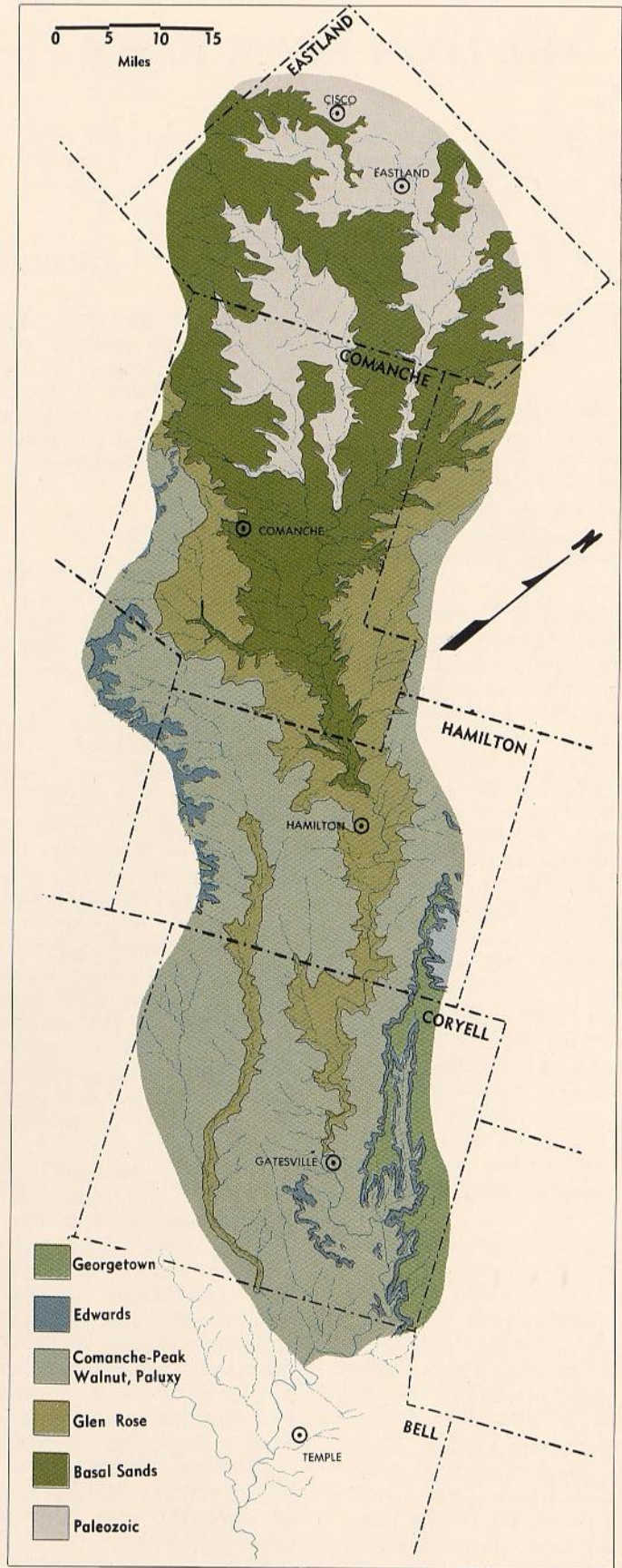


Fig. 3. Geology of the Leon River basin.

1, 3). They consist of gray to green soft shale, dense reddish sandstone, mottled quartzose granule-sized conglomerate, thin beds of dense crystalline limestone, and thin lignite beds.

Low hills and ridges in the outcrop area of Cisco rocks are supported by limestone; valley floors are cut into sandstone and shale. Low banks along stream courses may be supported by conglomerate beds.

Soils developed upon Cisco rocks are of the Kirkland series: silty to clay loam, slightly acidic to neutral, mostly reddish with distinctive clay layers which grade gradually into Permian redbed soils.

Sediment contributed to the Leon River by rocks of the Cisco Group includes silt and sand, small cobbles of dark-gray dense crystalline limestone, and large cobbles of soft reddish sandstone.

THE MIDDLE BASIN

Rocks of the middle basin include the Lower Cretaceous Trinity Sand, exposed along the valley floor, and the Glen Rose Limestone, Paluxy Sand, Walnut Clay, Comanche Peak Limestone and Edwards Limestone in valley walls and basin margins.

"Basal Sands"—The lowermost sands of the Trinity Group are exposed throughout the middle basin in central Comanche County and along the Leon valley floor to a point a few miles north of Hamilton in Hamilton County (figs. 1, 3).

These basal sands include reddish sand, opalized conglomerate, loose pea gravel, thin soft limestone, dark clay, silicified wood, and pebbles and small cobbles of milk quartz and dark chert.

The basal sands support little relief except where the conglomerate maintains low hills and along the inner walls of stream valleys. The floor of the Leon valley and of smaller tributaries is flat and sand mantled.

Soils developed upon the basal sands are of the Windthorst and Stephenville series, typically friable sand and clay loam, generally slightly acidic to slightly calcareous. The soils are reddish brown with distinct light-yellow mottling.

Sediment contributed by the basal sands includes loose pea gravels of chert, flint, jasper, and milky quartz; small cobbles and pebbles of black and green chert; reddish sand; and silicified wood.

Glen Rose Formation—The Glen Rose Formation crops out at the extreme margin of the middle basin and within the valley and the bed of the Leon River in the basin as far south as Gatesville in Coryell County (figs. 1, 3).

The Glen Rose Formation is composed of tan, dense, crystalline, shelly limestone, partly oolitic with grayish, thinly laminated interbedded shale. The formation maintains steep, well-defined valley walls and rounded divides. The gradient of the river on the basal sands is approximately 4 feet per mile. It increases to a maximum of 20 feet per mile in the Glen Rose Limestone. This gradient increase is accompanied by a marked straightening of the channel.

Soils developed upon rocks of the Glen Rose Formation are of the Brackett, Denton, San Saba, and Tarrant series. These are highly calcareous, blocky, brown to black, granular clay soils, often friable and

hard when dry. Just above bedrock, these soils are interbedded with chalky marl and limestone fragments (Texas Highway Department, 1966, p. 42).

Sediment contributed to the Leon River by rocks of the Glen Rose Formation includes cobbles and pebbles of dense, cream-colored, crystalline limestone, fossil shell debris, and gray calcareous clay.

THE LOWER BASIN

Bedrock of the lower basin includes the shale and limestone formations of the Fredericksburg and Washita groups, and younger rocks including the Austin Chalk. Fredericksburg rocks are exposed in valley floors and valley walls, and the uppermost Fredericksburg formation, the Edwards Limestone, supports the divides. Washita rocks occur only on divides in the lower basin.

The Fredericksburg Group is composed of four formations, in ascending order: the Paluxy Sand, the Walnut Clay, the Comanche Peak Limestone, and the Edwards Limestone.

The Washita Group is present along the eastern and western divides of the lower basin. Rocks of this group include the Georgetown Limestone, Del Rio Clay, and Buda Limestone.

Pepper, Lake Waco, South Bosque, and Austin rocks are exposed in the extreme southern part of the lower basin, but their contribution to river sediment is too limited in volume and distribution to be considered here.

Paluxy Sand—The Paluxy Sand crops out along the Leon valley in the lower basin from immediately north of Hamilton to Gatesville. This formation consists of homogeneous, fine-grained, compact, white quartz sand containing lenses and laminae of dark, impure clay. Paluxy Sand maintains benches above the valley floor, north of Gatesville (fig. 4).

Soils of the Paluxy Sand are of the Harbin, Nimrod, and Windthorst varieties. These are slightly acidic, red to orange loams associated with sandy clays (Texas Highway Department, p. 43).

Sediment contributed to the Leon River by the Paluxy Sand includes fine quartz sand and cobbles of sedimentary quartzite.

Walnut Clay—The Walnut Clay is exposed in a wide prairie on either side of the Leon River in the lower basin from northern Hamilton County to near the southern Coryell County line (figs. 1, 4).

This formation is composed of calcareous, gray to brown, fissile clay, containing thin ledges of coquinoïd limestone with tightly cemented *Gryphea marcoui* shells.

The Walnut Clay forms a gently sloping prairie from the flood plain to the valley scarps. Soils of this formation are divided into clay and limestone-derived types. Collectively these are the Denton, Brackett, San Saba, and Tarrant varieties; all are calcareous, blocky, black, granular soils (Texas Highway Department, p. 43).

Sediment contribution of the Walnut Formation to the Leon River includes silt, dark clay, and fossil shells of *Gryphea marcoui* (Pl. I, fig. A).

Comanche Peak Limestone—The Comanche Peak Limestone is exposed within the east and west margins

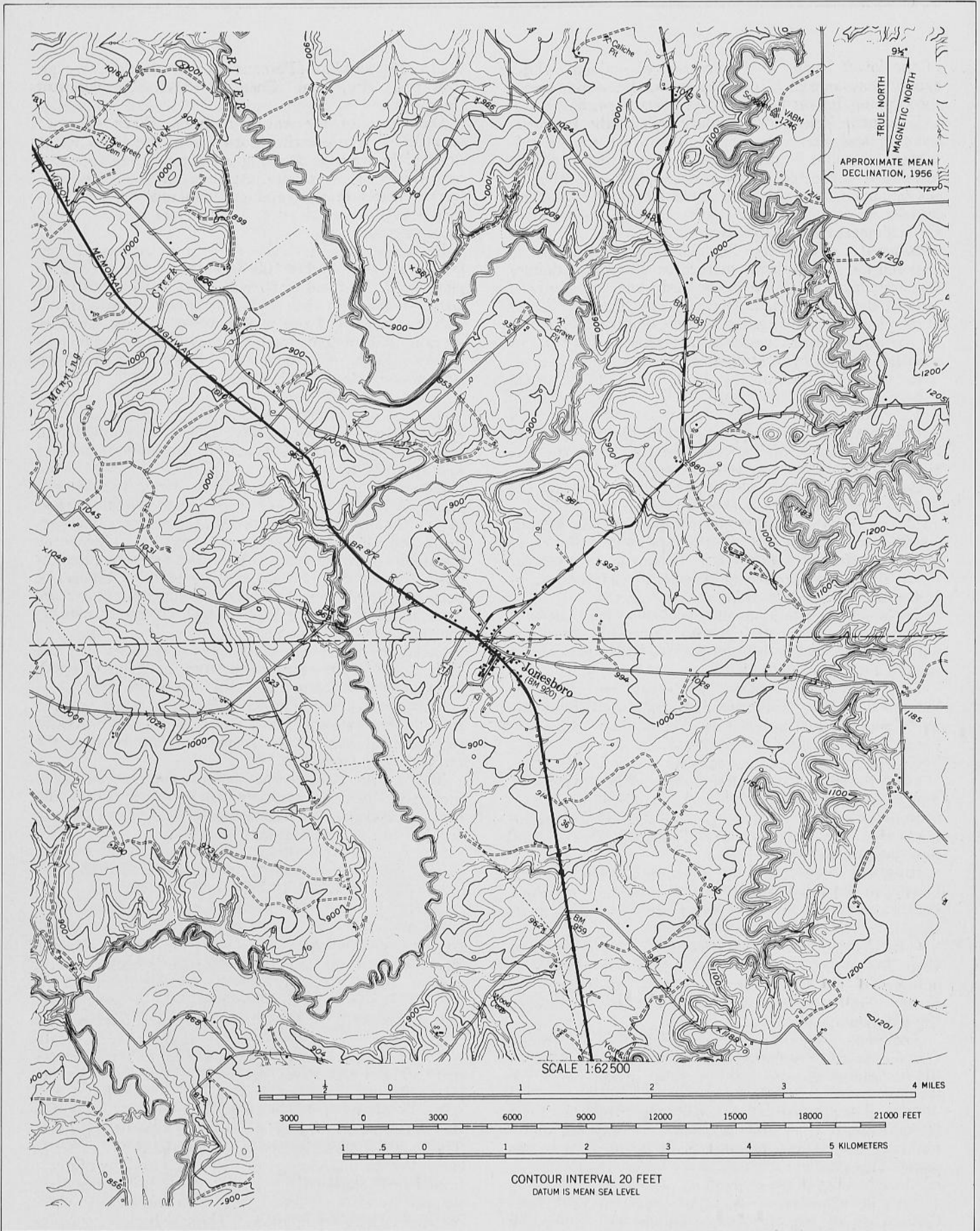


Fig. 4. Leon Valley meanders in the vicinity of Jonesboro, Coryell and Hamilton counties. (Topographic map USGS Jonesboro quadrangle, 1/62,500).

of the lower basin. It is composed of nodular, white, chalky limestone and forms steep barren slopes below the capping Edwards Limestone (figs. 3, 4, 5).

Comanche Peak rocks produce soils of the Brackett, Denton, and San Saba series. These are mostly calcareous, blocky, brown, granular soils that are best developed at the foot of steep slopes (*idem*, p. 44).

Comanche Peak Limestone contributes cobbles and pebbles of cream-colored, soft, chalky limestone to the sediments of the Leon River.

Edwards Limestone—The Edwards Limestone is exposed along two-thirds of the Leon basin. It defines the basin margin in the lower basin and the southern part of the middle basin (fig. 3). The Edwards Limestone is a reef and reef-associated limestone, containing poorly sorted, whole and broken fragments of rudistid clams in a fine-grained limestone matrix. The formation contains black to brown chert which occurs in nodules, lenses, and beds.

Edwards Limestone is the most resistant rock within the basin. It supports the basin margin and caps the drainage divides between the Leon and the adjacent Bosque and Lampasas systems.

Soils derived from Edwards Limestone are of the Brackett, Crawford, and Denton varieties. The Crawford type is the most representative and is a dark reddish, blocky, slightly to strongly acid soil. These soils are often associated with a rubble of irregular chert fragments producing the local name of "flint land" for the Edwards-derived soils (*idem*).

Sediment contribution of the Edwards Limestone to the Leon River includes dense, cream to white limestone cobbles, brown to black chert pebbles, and cobbles of rudistid fragments.

Georgetown Limestone—The Georgetown Limestone is exposed on the divides from Hamilton on the north, to Belton on the south. It is present only where extensive uplands remain.

Georgetown Limestone consists of nodular, white, chalky, fossiliferous limestone, interbedded with thin marly shales.

Soils produced from the Georgetown Limestone include the calcareous Brackett, Crawford, Denton, and San Saba series (*idem*, p. 45).

Sediment contributed to the Leon River by the Georgetown Limestone includes dense, cream to white, fine-grained limestone, and fragments of ammonites, graptolites, and echinoids (Pl. I, fig. A).

Post-Georgetown rocks—Cretaceous rocks younger than Georgetown age are confined to the Leon basin south of Belton. Their contribution to Leon River sediment is limited in volume, and they contribute little to the sedimentary history of the river.

Sediments contributed to the Leon River by all Cretaceous and pre-Cretaceous rocks include dark clay, quartz sand, siliceous pea gravels, various types of limestone, and Edwards chert.

Recent sediments—The flood plain of the Leon River from Eastland to the mouth is composed dominantly of alluvial clays, some sand, and minor amounts of pea gravels.

Soils developed upon the flood plain include Catalpa, Frio, and Kaufman series. These are all dark, calcareous silty loams and clay of alluvial origin. An oak log (Pl. I, fig. B) found in a well at the base of the flood-plain sediment near Temple has been dated at

2320±210 years b.p. (Personal Communication, George Edwards, Analytical Chemist, Shell Development Company).

Sediments of the ancestral Leon River—Terrace remnants marking earlier positions of the Leon River flood plain are present along the Leon valley from the headwaters to the mouth. At least three recognizable terrace levels remain, and on highlands residual terrace gravels give evidence of yet higher and older terraces (fig. 2).

Recognized terrace levels exist at elevations of ±30 feet, ±70 feet, and ±100 feet above present flood-plain level. Residual gravels exist as high as 140 feet above flood-plain level. The terraces form distinct benches, ranging from a few square yards to many acres in areal extent. Residual gravels are usually represented by large cobbles and boulders, scattered on soils or bedrock exposed on uplands.

The terrace and residual gravels are composed dominantly of quartz sand; siliceous pea gravels; pebbles and cobbles of banded chert; moss chalcedony; vein quartz; milk quartz; banded red to black quartzite; nodules of Edwards chert; and purplish, black to white boulders of quartzite. Whole and fragmentary fossils of Fredericksburg origin are common. Silicified wood of two distinctly different types of preservation occurs in all terrace and terrace-derived deposits. Pleistocene mammal bones have been described from terrace deposits (Adkins and Arick, 1930, p. 67). Limestone pebbles, cobbles, and boulders are common in terrace deposits south of Comanche (fig. 1) and constitute the bulk of terrace material south of Hamilton.

Soils developed on Leon River terraces are the Eufaula, Hortman, and Axtell series. These are red, brown to yellow, sandy, acid soils with little clay.

The terraces contribute principally fine gravel and sand to the present Leon River, but they represent the sediment load of the Leon River at the time the terraces were formed.

The contrast in recent and ancient sediments of the Leon River, as represented by the flood-plain and terrace deposits, constitutes one of the principal lines for the present investigation.

GEOLOGIC STRUCTURE

Most of the Leon River drainage basin is developed upon gently, eastward dipping Lower Cretaceous strata with a regional dip of approximately 20 feet per mile. The course of the river is approximately S 30° E. The western flank of the basin is gently sloping and capped by Edwards Limestone. The eastern flank is steeply sloping and capped by a steep northwest-southeast-trending Edwards Limestone escarpment. The Leon River valley is, therefore, asymmetrical.

Rocks of upper Paleozoic age, cropping out within the upper basin, dip to the west off the Bend Arch. The buried Paleozoic topography below the Cretaceous cover has an unknown effect upon the basin configuration. Pre-Cretaceous relief upon this surface has been mapped by Boone (1966), but its relationship to present drainage is yet unknown. The dendritic to subdendritic drainage pattern of the upper basin suggests minimal structural control.

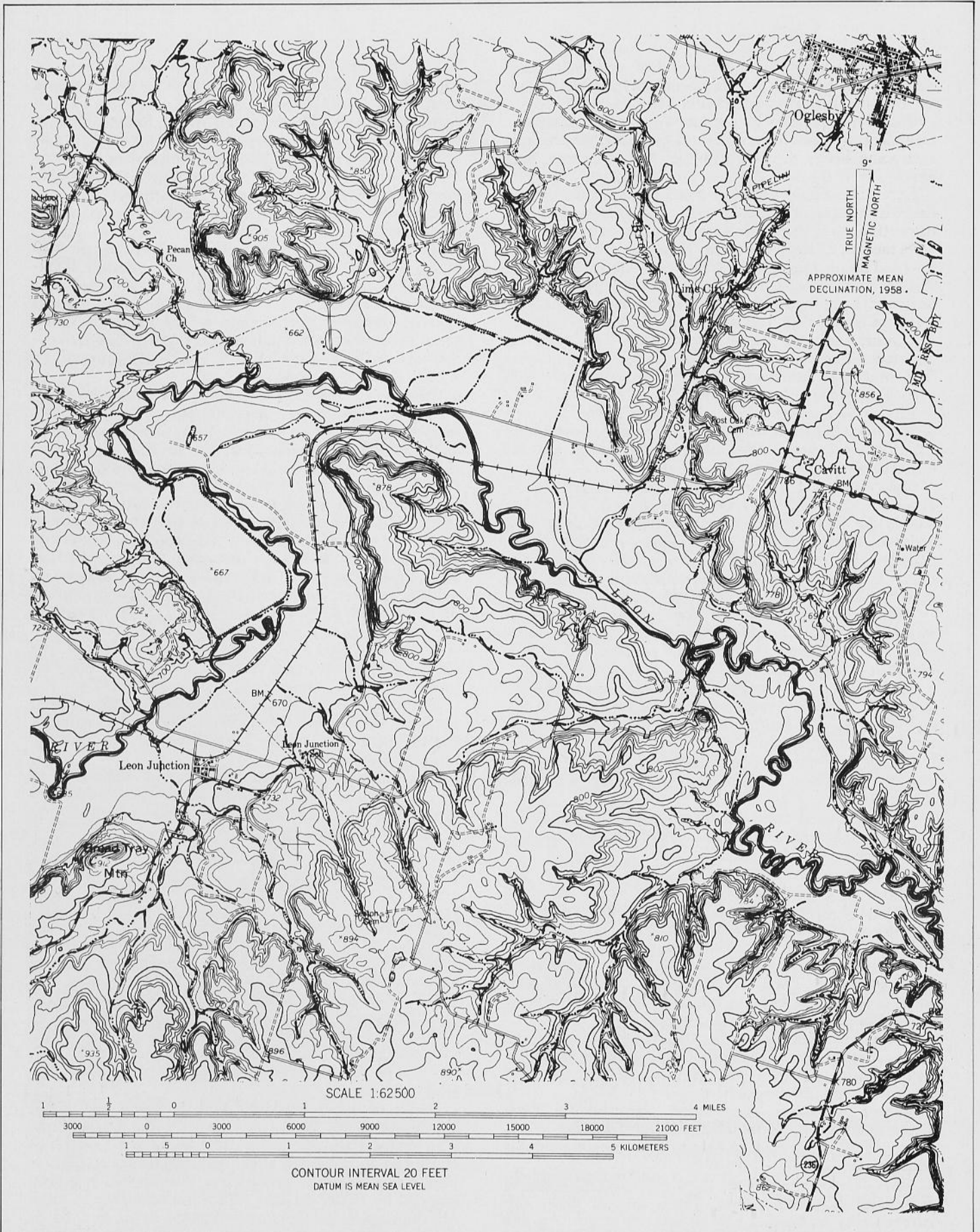


Fig. 5. Leon Valley meanders and abandoned high valley in the vicinity of Leon Junction, Coryell County. Abandoned valley extends west across meander neck from Leon Junction school. (Topographic map USGS Gatesville Quadrangle, 1/62,500).

Faults of the Balcones System are present in the vicinity of Temple and Belton in the lower basin. North of this area in Bell County, conspicuous stream alignments, meander trends, and river deflection suggest some drainage control by joints and faults (fig. 3).

Three abrupt increases in gradient occur along the Leon River (fig. 6). In each case, the increase occurs where the river departs from a pattern suggestive of free meanders and begins to flow by reaches (figs. 3, 6). The average gradient of the river through the middle and lower basins is approximately 4.4 feet per mile. Locally where the gradient increases sharply, it ranges from 15 to 20 feet per mile.

The first increase occurs just north of the Hamilton-Comanche County line, where the river leaves the outcrop of the lower Trinity Sands and encounters the hard limestone ledges of the Glen Rose Formation (figs. 3, 6). The second gradient increase occurs north of the town of Jonesboro where the Glen Rose is incised. The third steeper gradient is in central Coryell County where the Leon River apparently flows over hard ledges in the Walnut Clay. These gradient variations do not appear to reflect change in structure but merely the effect of naturally occurring hard ledges on valley dissection.

PRESENT RIVER STATISTICS

Average discharge of the Leon River within the

upper basin is 45.7 cfs (cubic feet per second), recorded at De Leon. The maximum discharge over a twenty year period at this station was 4,700 cfs in May, 1965; the minimum, 0 cfs in several dry years. At Hasse, in the middle basin, the average discharge is 154 cfs. The maximum was 38,500 cfs in May of 1952, and the minimum was 0 cfs. Gatesville, in the lower basin, reported an average discharge of 288 cfs. The maximum was 51,200 cfs in October, 1959, and the minimum was 0 cfs. At the extreme southern end of the basin, Belton has recorded an average of 653 cfs. The maximum was 56,500 cfs in April, 1945, and the minimum was 0 cfs. The record discharge for Little River, formed by the confluence of the Leon and Lampasas rivers, exceeded 647,000 cfs near Cameron in September, 1921 (U.S.G.S., 1965, pp. 270-285).

Maximum discharges along the Leon system do not occur as the result of a single flood. The random peak discharges occur when flooding sub-basins discharge into the Leon River. Thus the maximum potential flood on the Leon River exceeds the peak floods of present record, probably by a factor of several times.

Approximate bankfull stage at Belton is 4,000 cfs, at Gatesville, 3,000 cfs. Meanders of the present river, in the valley between Gatesville and Belton, were apparently developed by the bankfull flow. These meanders in the lower basin have an average amplitude of approximately 750 feet, an average radius of curvature of 375 feet, and a wave length of 1,200 feet.

INVENTORY OF THE ANCESTRAL LEON RIVER

Within and adjacent to the present basin of the Leon River are the features which appear to be inherited from an earlier and larger Leon River, and which gave direction to this study: (1) Valley meanders, much larger than the present river meanders; (2) high terraces, composed of detritus far larger than the maximum gravel size now being transported by the river; (3) soil suites in the present Leon valley closely related to soils of the Brazos and Trinity river valleys but different from soils characteristic of the Lampasas Cut Plain and derived from parent materials lithologically alien to the Leon basin; (4) high abandoned valleys veneered with alien gravels which were possibly once part of the upper basin.

LARGE VALLEY MEANDERS

The valley meanders of the Leon River are much larger than the river meanders upon the flood plain. These large valley meanders are preserved throughout the course of the river. Within the sand outcrops of the upper and middle basin, they are poorly defined but can be recognized on aerial photographs. Within

the lower basin, the valley meanders are entrenched in upper Trinity and Fredericksburg rocks and are defined clearly (figs. 1, 4).

The diagnostic components of a meander system (fig. 7) include the wave length, amplitude, and the radius of curvature (Leopold *et al.*, 1964, p. 297; Lobeck, 1939, p. 227). Wave length is empirically related to the square root of the effective or dominant discharge. Because channel width is also related to discharge, it has been postulated that there is a fundamental relation between river width and meander length (Leopold *et al.*, 1964, p. 296). The empirical relationships used in this study are those which relate channel width to meander length, channel width to radius of curvature, and meander amplitude to channel width. Meander size is directly proportional to the size of the stream. The amplitude is approximately 18 times the channel width (Lobeck, 1939, p. 227).

Two miles north of Gatesville, Leon valley meanders are well developed. Meander segments in this area have been reconstructed, and stream flow figures interpolated (fig. 8). Five complete or partial meanders were measured from topographic maps (scale 1:24,000)

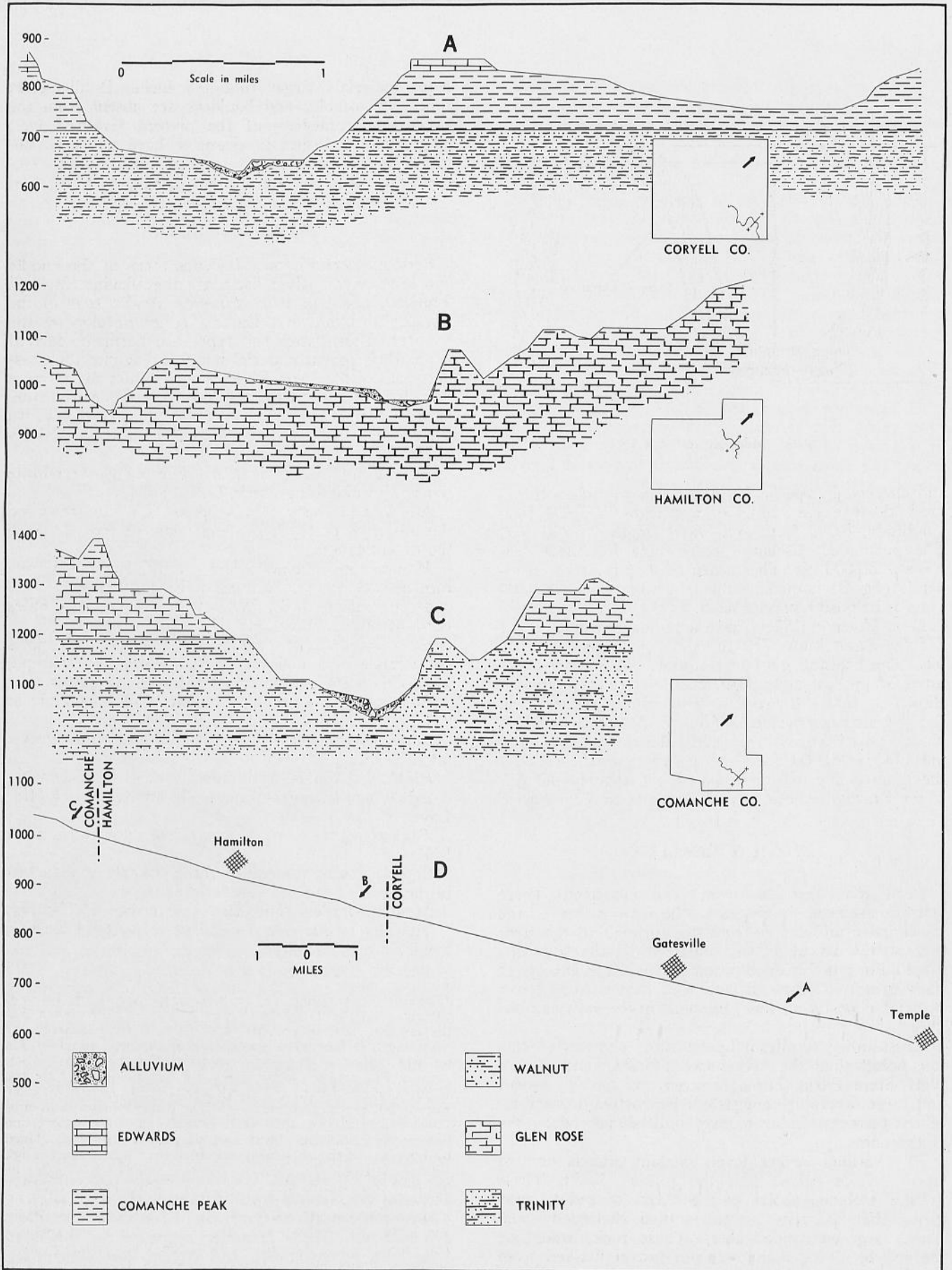


Fig. 6. Cross-valley and longitudinal profiles of the Leon River. Sections A, B, and C are cross-valley profiles at points indicated on small index maps, and on long profile D.

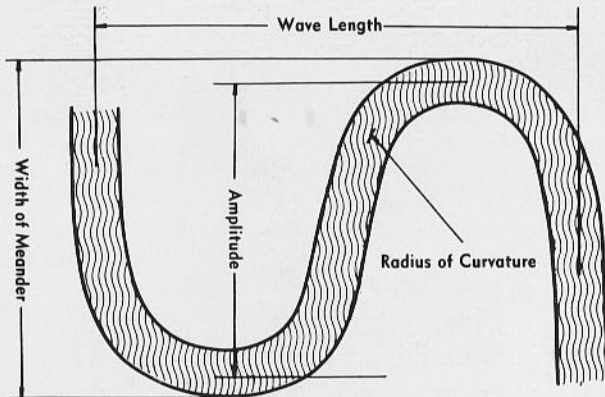


Fig. 7. Meander terminology.

and checked in the field. Of the five meanders measured, the average radius of curvature is 3,800 feet; amplitude, 8,000 feet; and wave length, 10,200 feet. The postulated discharge responsible for these features is 30,000 cfs. The measured amplitude of meander C (fig. 8) is questionable, since several interpretations of its position are possible.

Leon River meanders have a radius of curvature of 375 feet; amplitude, 750 feet; and wave length, 1200 feet. The bankfull discharge responsible for these features is approximately 9,000 cfs. The valley meanders, shown in figure 8 are nearly 10 times greater than the present river meanders (figs. 3, 8). Calculated discharge associated with meanders the size of the valley meanders is 90,000 cfs. Thus, the river which produced the Leon valley meanders was approximately the size of the Brazos River at Bryan, Texas at bankfull stage.*

HIGH TERRACES

Leon River terraces have been described. These terraces are well developed in the main valley of the lower basin and are recognizable throughout the river and northward along an unnamed tributary of the North Fork in Eastland County (fig. 2). Leon River terraces developed by dissection of former Leon River bedload deposits as the river cut larger valley meanders.

Cross-valley profiles (fig. 6) show terraces at various points along the river between Gustine and Mother Neff State Park. Three terraces are clearly evident and three others are suggested. Downstream gradients of the terraces appear to vary only slightly along the river course.

The various terrace levels contain gravels derived from sources other than the present basin. These gravels include cobbles and boulders of red to purplish quartzite, vein quartz, mottled chalcedony, and black to green banded chert. These rocks would be masked by the multicolored pea gravel derived from the basal Trinity sands except for their conspicuous size. The present Leon River does not transport sili-

ceous materials larger than 0.5 inches in diameter; hence, the cobbles and boulders are absent from the banks and point-bars of the present river. Gravels larger than 2 inches in diameter have not been observed in the conglomerate of the lower Trinity section exposed in the upper Leon basin (Pl. I, fig. C).

FOREIGN SOILS

Soils developed upon calcareous rocks of the middle and lower Leon River basin are the alkaline Tarrant, Brackett, and San Saba varieties. Acidic soils of the Axtell, Hortman, and Eufaula series develop on the terraces. These latter soil types are normally derived from silicic parent material not found within the present basin of the Leon River except within the terraces (fig. 10). Terrace materials, in turn, were derived from silicic terrain, no longer part of the Leon basin. In Central Texas only the Colorado, Brazos, and Trinity River valleys today produce similar soils.

The age of the terraces is suggested by vertebrate remains (Adkins and Arick, 1930, p. 67).

Adkins and Arick (1930, pp. 67-68) have recorded the following early Pleistocene mammal remains from the Leon terraces:

Mammot americanum—lower right, last molar, terrace near Sparta; collections of Baylor Museum; second true molar, J. B. Warner gravel pit, 1½ miles north of Shallow Ford, east of Belton.

Elephas boreus ("primigenius")—lower left antepenultimate milk molar, W. S. McGregor gravel pit, 1½ miles north of Shallow Ford, east of Belton.

Elephas imperator—upper left molar, found at Temple; vertebrae, gravel pit near Midway.

Elephas imperator—lower left hindmost molar, gravel pit at Midway.

Elephas columbi—teeth, low terrace at Midway.

Equus semiplicatus—three teeth, low terrace at Midway.

Tapirus—three cervical vertebrae, low terrace at Midway.

Camelop macrocephalus—three camel bones, low terrace at Midway.

Myloodon harlan—humerus, low terrace at Midway.

Testudo francisi—huge land tortoise, type locality, low terrace at Midway.

*Editor's Note: Dury (Theoretical Implications of Underfit Streams, 1965, USGS Prof. Paper 452-C, p. 5) has shown that the relation between meander wave length and discharge for many natural rivers can be expressed by the equation $l = 30q^{0.5}$ which is similar to a derived equation by Inglis (1941, Relationship between meander-belts. . . : Delhi and Calcutta, India, Central Irrig. and Hydrodynamics Research Station, Poona, India, Research pub. 4.). The data for natural streams show considerable scatter when plotted against the regression line, but Schumm has shown that the scatter can be explained by considering the silt-clay percent of the river water. High silt-clay streams plot close to the line while low silt-clay or bed load type streams plot above the line (Schumm, S. A., 1968, River Adjustment to Altered Hydrologic Regimen—Murrumbidgee River and Paleochannels, Australia: USGS Prof. Paper 598, p. 44, 45). Disregarding the silt-clay factor and applying Dury's equation to the data for the Leon River system yields a discharge figure for the ancestral Leon of 115,600 cfs. This approximates the flow of the present Brazos River near Bryan, Texas at bankfull stage.—L.W.E.



Fig. A. Typical fossil shell suite, Leon River terrace. Top row, L to R: internal mold of snail (probably *Tylostoma*), *Ostrea*, *Ostrea*. Bottom row: *Gryphaea*. These fossils were probably derived from the Walnut and Comanche Peak formations of the Cretaceous Fredericksburg Group.

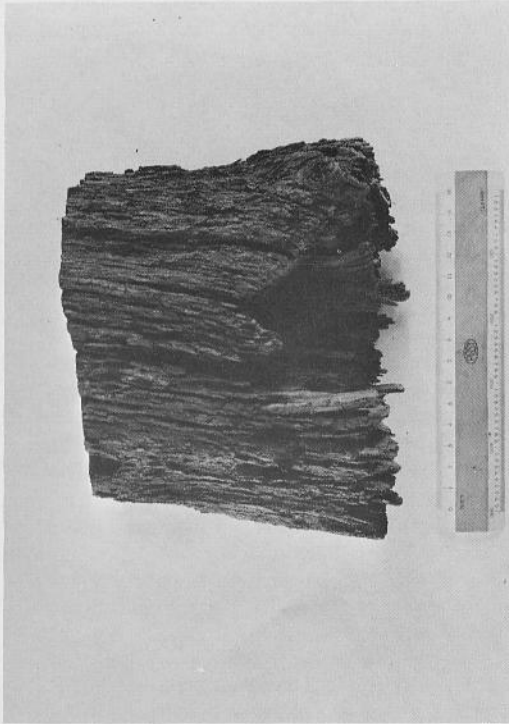


Fig. B. Portion of an oak log found in a well at the bottom of the present flood plain deposits along the eastern margin of the present Leon Valley, near locality 1. The age of this log is 2320 ± 210 years, as determined by radio carbon methods (courtesy Shell Development Co.).

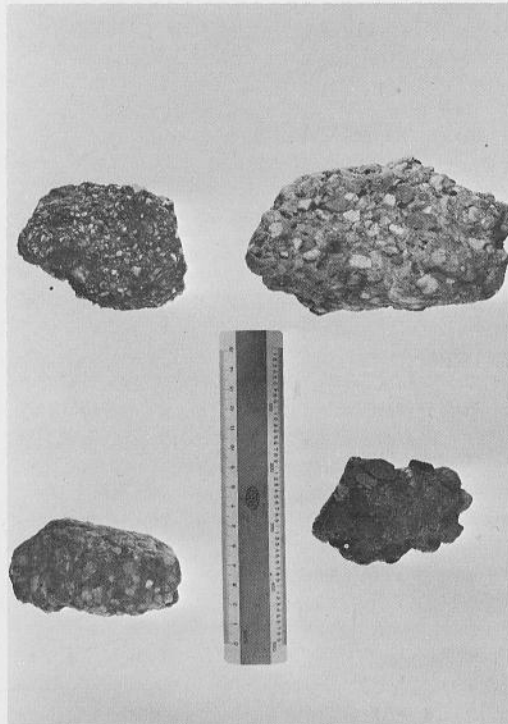


Fig. C. Opalized pea-gravel suite, Leon River terraces. The pebbles are similar to those noted in the disaggregated pea-gravels of Leon terraces. Cement is opalescent silica which bonds the conglomerate into very durable cobbles.

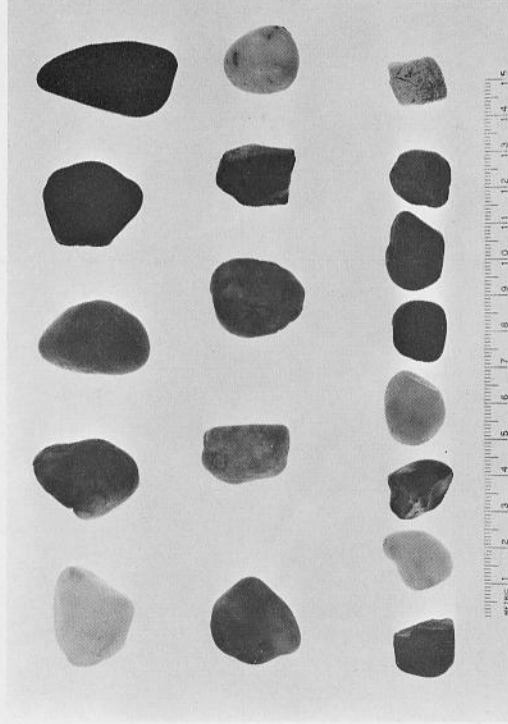


Fig. D. Siliceous pea-gravel suite, Leon River terraces. Pebbles consist of pink and white quartz; brown, gray, black and white chert, with occasional black and white banded chert; white, buff, maroon, black, and banded quartzite; jasper; and black and buff silicified wood.

ABANDONED VALLEYS

Abandoned river valleys occur at three localities within the present Leon basin. These valleys represent isolated trunk features of a large river not now in existence. In three cases the abandoned valleys occur along the present Leon River course. In three other cases, they are found beyond the present basin and may represent extensions of the ancestral valley.

The first of the abandoned valleys occurs just south of Leon Junction in Coryell County (figs. 1, 5, 6). At this locale, an Edwards and Comanche Peak Limestone ridge was bisected and forms a straight valley 1.5 miles long, 0.75 of a mile wide, and 100 feet above the present flood plain. Recent erosion by small tributaries has greatly modified this old valley, destroying any terraces. The floor of this high valley contains badly weathered boulders of quartzite, cobbles of milk quartz, and some scattered pea gravel.

The second abandoned valley occurs just north of Hamilton, Hamilton County (figs 1, 6). Here the old

valley is represented as a nearly complete meander loop. The level of this old meander is 20 feet above the present river, which has abandoned the meander by dissecting the neck. This dissected valley is considerably younger than the high valley at Leon Junction since here it is much lower. However, the dimensions of this old meander closely correspond to the Leon valley meanders.

The third abandoned valley occurs just north of Eastland, Eastland County (fig. 2), where an unnamed intermittent minor tributary of the North Fork occupies a valley three-quarters of a mile wide. The flanks of this valley are bounded by two well developed terrace levels of typical Leon terrace composition. Just upstream in this apparently underfit valley, the divide between Leon and Brazos drainage is within the valley floor. North of this divide, the wide valley character and terrace levels are lost and the now northward-flowing stream is *fit* with the valley. The location of this third abandoned valley represents the northern-most evidence within the present Leon River basin of a large ancestral river.

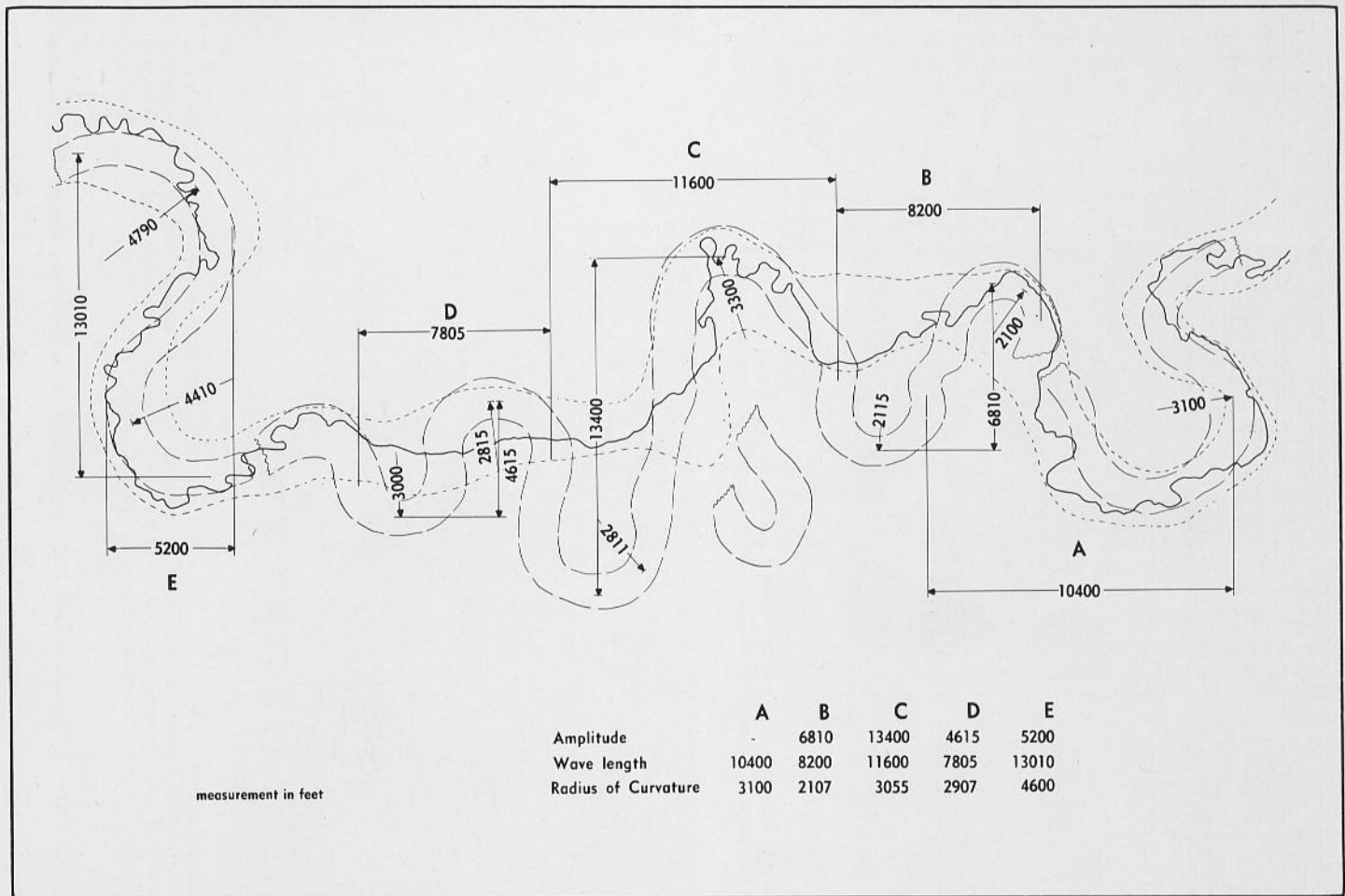


Fig. 8. Meander geometry, Leon River, south of Jonesboro, Coryell County. Detail from USGS. (Topographic maps Jonesboro, Purmela and Gatesville quadrangles, 1/62,500).

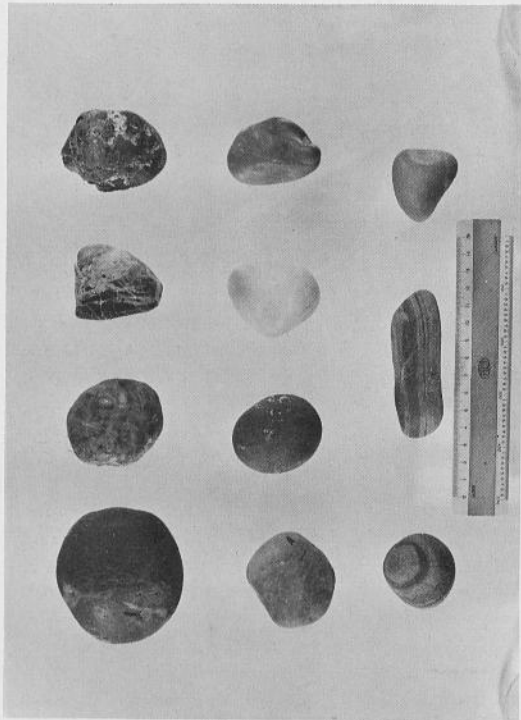


Fig. A. Siliceous cobble suite, Leon River terraces. Cobbles dominantly of maroon, white, buff, fine- to coarse-grained quartzite, banded red and white, gray and white, black and white fine-grained quartzite; white to pink quartz; gray to black chert, often veined or banded; red jasper. Dark fossil wood occurs as occasional cobbles.

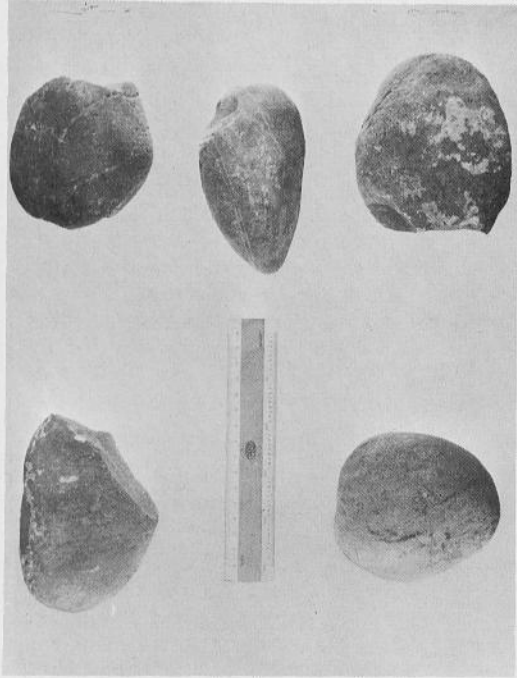


Fig. B. Siliceous "boulder" suite, Leon River terraces. Boulders dominantly maroon, buff, gray or white fine- to coarse-grained quartzite. - Banded fine-grained quartzite less abundant, with occasional boulders of jasper, white quartz, very rare boulders of granite, basalt.

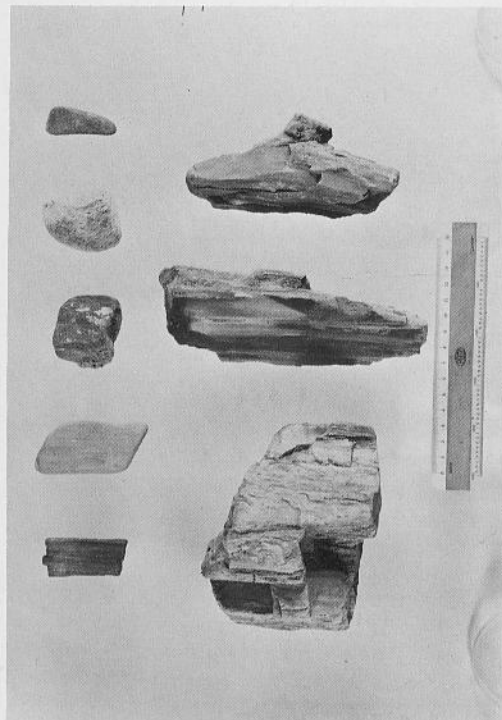


Fig. C. Typical silicified wood, Leon River terraces. Distinct difference between wood type represented in rounded cobbles, and that which occurs in angular blocks. Rounded cobbles of unknown origin. Angular blocks have appearance of fossil wood from lower Trinity Group (Cretaceous) sands of North Central Texas.

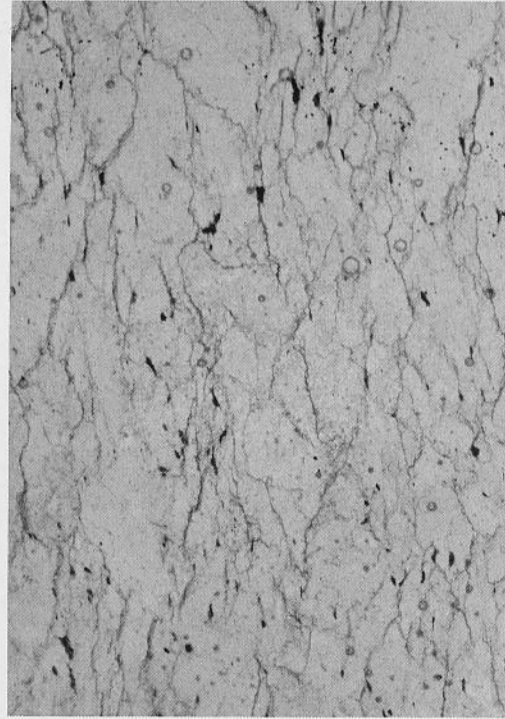


Fig. D. Thin section (X 100 approx) of "stressed quartzite" from the White Ridge quartzite of the Manzano Mountains, New Mexico. Individual grains show flexure, elongation, shearing, and rotation. Identical lithology appears to be represented in cobbles taken from Leon River terraces.

At three other locations north and west of the present Leon drainage basin evidence of pre-existing river valleys occurs, possibly associated with an ancestral Leon River.

The first of these valleys occurs between the last evidence of the ancestral valley north of Eastland and the Clear Fork of the Brazos River (fig. 2). This intermediate area is today drained by Big Sandy and Gonzales creeks (tributaries of the Clear Fork). The valley floors and minor divides between these streams are covered with scattered cobbles and boulders of reddish quartzite and other characteristic Leon terrace components. It appears that this area was once part of an ancestral trunk valley, later destroyed by the migration of the Brazos divide toward the south. The scattered, residual, terrace gravels are the result of the destruction of the old terrace levels.

Northwest in Throckmorton County, another valley exists. This one, however, is not now abandoned but contains the Clear Fork of the Brazos River. This valley is a deep gorge cut within a major drainage barrier ridge of Permian limestone (figs. 1, 2). This gorge forms the lowest point within the ridge and subsequently funnels most of the southern High Plains drainage through the ridge. The ridge, through which the valley is cut, apparently blocked eastward transport of Ogallala and Seymour gravels and probably acted as a barrier to eastward-flowing drainage, except where it was transected by the Clear Fork pass. Therefore, this is of necessity a *fixed point* in the earlier Brazos-Leon drainage.

Just west of the Clear Fork pass evidence of the third abandoned valley outside the Leon River basin occurs. Here in Haskell County (figs. 1, 2), a minor tributary of the Clear Fork, Paint Creek, flows in a large valley. The north margin of this valley is bounded by apparent terrace levels. These terraces contain the same characteristic gravels as do Leon River terraces, terraces of the ancestral valley north of Eastland, scattered gravel along Big Sandy and Gonzales Creeks, and gravels within the Clear Fork pass. The dissected floor of this unnaturally wide valley also contains the reworked siliceous material from its terraces. Recent lateral drainage modification has destroyed much of this old valley, but enough remains to suggest that this valley was previously occupied by a larger stream. This valley joins the Clear Fork valley within the barrier ridge.

Ancient valleys of the present basin and beyond are apparently related to a common system that existed for some time, since the height of the valleys varies from 100 to 20 feet above the present flood plain.

Abandoned valleys of the present Leon River are clearly related to a larger ancestral Leon River. The ancient valleys north of the present Leon basin are apparently also related to this larger ancestral Leon River. This river was already well established when the highest abandoned valley, near Leon Junction (fig. 5), was occupied, and it existed essentially unchanged through formation of valley meanders of the present Leon River.

RECONSTRUCTION OF THE LEON-BRAZOS BASIN

The northernmost positive evidence of the ancestral Leon River is found in the broad valley just north of Eastland (fig. 2). This location is the valley through which the ancestral Leon-Brazos River entered the present basin. The ancestral river apparently extended north from this point along the route followed by Big Sandy and Gonzales creeks to their junction with the Clear Fork of the Brazos River.

The route of the Leon-Brazos River then trended sharply westward through Clear Fork pass in the barrier ridge. This is apparently another *fixed point* along the course of the ancestral Leon-Brazos River. Within Clear Fork pass, the trunk stream of the Leon-Brazos occupying the Paint Creek valley was joined by the Clear Fork of the Brazos. This is the last *fixed point* in the reconstruction of the ancestral system.

However, there is an apparent alignment between this point and the course of the Double Mountain Fork of the Brazos in Stonewall County (figs. 1, 2). In the line of the projected Double Mountain Fork, south of Rule, Haskell County, and within Paint Creek valley, scattered residual cobbles and boulders of Leon terrace lithology occur (Pl. I, fig. D; Pl. II, figs. A, B). These cobbles are missing from the highlands on both the north and south of upper Paint Creek valley.

This evidence suggests that the trunk valley of the Leon-Brazos extended westward essentially along the Double Mountain Fork, at least to the edge of the Ogallala front or caprock (fig. 2). It was this Ogallala front which supplied the larger siliceous cobbles and boulders to the Leon-Brazos River. Silicified wood, characteristically associated with Leon River terraces, is present essentially to the Ogallala front (Locality 47, fig. 2; Pl. II, fig. C). Drainage from the caprock possibly was included in the Leon-Brazos system, but at present there is no evidence for this.

Therefore, the original Leon-Brazos basin included, at least, all the present Leon basin and the combined basins of the Clear Fork and Double Mountain Fork of the Brazos River (fig. 9). The area of this ancestral basin was approximately 31,000 square miles, six times the area of the present Leon basin and large enough to produce the river which formed the Leon valley meanders.

The Leon-Brazos River antedated the formation of the highest abandoned valley at Leon Junction (fig. 5), 100 feet above the present Leon flood plain. The beheading of the Leon-Brazos took place at a time when the floor of the Brazos valley, north of Eastland, was 350 feet above the present Brazos flood-plain level.

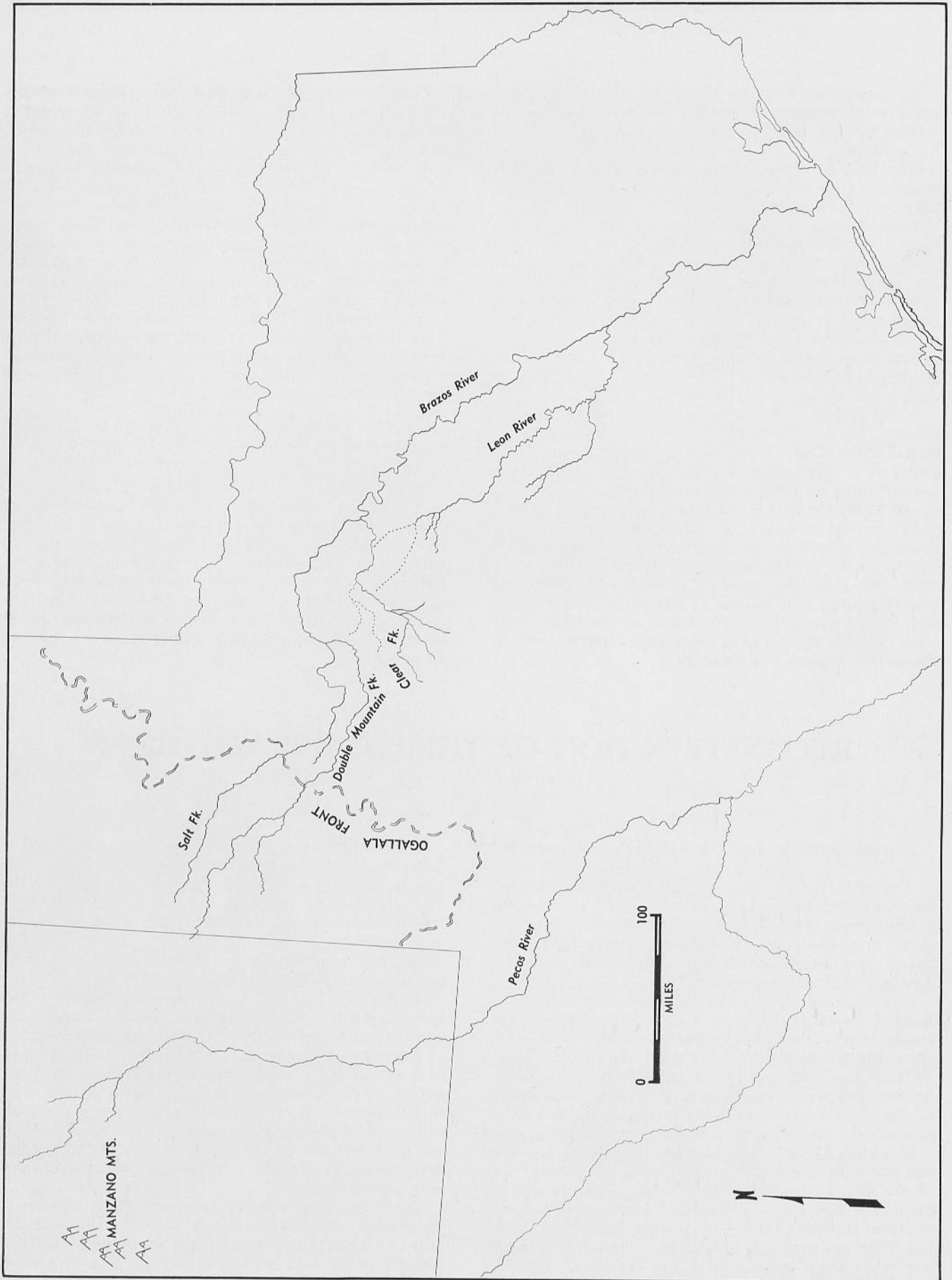


Fig. 9. Present and postulated drainage basin of the Leon River. Postulated drainage connections indicated by dashed lines.

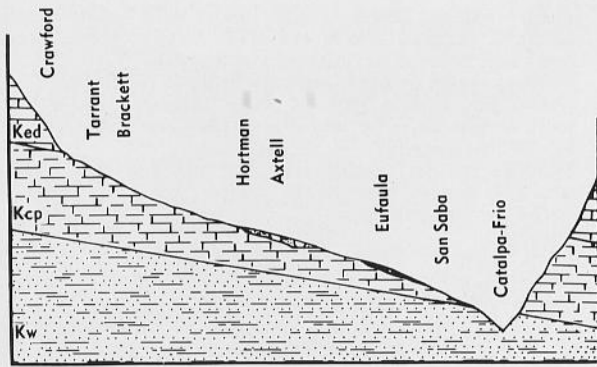


Fig. 10. Generalized geologic and soil cross-valley profile. Soils indicated by name, geologic formations by symbol: Kw, Walnut Clay; Kcp, Comanche Peak Formation; Ke, Edwards Limestone.

During the existence of the Leon-Brazos River, there were five periods of alluviation (high gravels, three terrace levels, and present flood-plain) separated by four periods of downcutting.

The time of piracy of the Leon-Brazos headwaters by the Brazos River is not clearly indicated. However, some speculative evidence exists. West of the barrier ridge, the divides between the Brazos and adjacent streams are probably of late Kansan age (Frye and Leonard, 1964, p. 15; Stricklin, 1961, p. 32). At Seymour, north of the barrier ridge (fig. 1), the divide is 150 feet above the Brazos River level, and is mantled with late Kansan deposits (Stricklin, *idem*).

The Leon divide north of Eastland, 350 feet above the Brazos flood plain, is probably at least as old as Kansan. Thus, the diversion of the Leon-Brazos headwaters into the present Brazos system may have taken place as early as Kansan time.

The earliest history of the Leon-Brazos River is unknown. However, the terrace deposits were clearly derived from the Ogallala gravels. Ogallala deposition (Miocene-Pliocene) extended eastward apparently as far as the barrier ridge, as suggested by the Seymour gravels (fig. 1) now capping the highlands west of the ridge. Ogallala drainage clearly was discharged eastward, and may have initiated the Leon-Brazos route.

The intermediate source for the large quartzitic gravels of the Leon-Brazos terraces and the gravel-capped hills east of the High Plains front is the Ogallala Formation of the High Plains (figs. 1, 2, 9). The lower part of the Ogallala Formation consists of sand and gravel derived from the eastern ranges of the Southern Rockies in central New Mexico, the Manzano, Sangre de Cristo, and Jicarilla mountains (fig. 9).

The contribution of one of these ranges, the Manzano Mountains, is suggested from the following lithologic and petrographic description: "Pre-Cambrian metaclastics of the area [Manzanos] consist of the basal Sais quartzite overlain by the Blue Springs schist and White Ridge quartzite in conformable sequence, fol-

lowed by 5,000 ft. of rhyolite flows and intercalated basic sills. A small outcrop of granite in the northwest part of the area is similar to and is associated with pegmatitic dikes. Vein quartz, ranging from thin stringers to massive quartz reefs of 1,000 feet, are well pronounced" (Stark, 1956, p. i).

The Sais quartzite is generally white with gradations to dark gray and black; greenish facies occur with red to purple beds that are often banded. Associations of quartz, sericite, and biotite are often seen in the handsample. Quartzite grains are rarely more than one millimeter in diameter and often much smaller. The basal beds are tightly fused and banded.

Thin sections show that the quartzite grains are interlocked with quartz inclusions. Some laths of biotite, sericite, and muscovite are present. The White Ridge Quartzite is predominantly gray, pink, red, purple, and white, massively bedded. The bedding planes commonly show reflecting surfaces of muscovite. The grains range from very fine to coarse (greater than one millimeter). Stark (p. 10) states that there "is much evidence of shearing elongation, rotation and granulation of the larger grains" (Pl. II, fig. D). "Thin-sections of the White Ridge quartzite show a high degree of purity, ranging from 95 to 99 percent quartz" (*idem*). The reef-like quartz structures within the area often contain "thin, irregular streaks and stains of manganese oxide and specular hematite" (*idem*, p. 24) even though the general appearance is milky.

The correlation between the siliceous lithologies of the Manzano Mountains, the Leon terraces, and the intermediate Ogallala outcrops is based on the following megascopic and microscopic similarities:

- (1) Clear vein quartz cobbles (Pl. I, fig. A)
- (2) Milky-colored quartz cobbles (much larger than represented in the basal Cretaceous pea gravels) (*idem*)
- (3) White, purple, red, black quartzites of cobble to boulder size (Pl. I, fig. D; Pl. II, fig. A)
- (4) Banded quartzite boulders of all sizes
- (5) Muscovite flakes within quartzites
- (6) Sericite associated with fractures within the quartzite
- (7) Stressed elongated grains within some quartzite samples (Pl. II, fig. D)
- (8) High purity of quartz in some quartzite samples.

The contribution of an unknown source to the Ogallala suite is represented by the mottled chalcedony of the Leon-Brazos terraces.

To the east and south of the Leon basin, isolated, large siliceous gravels described as Uvalde Gravels cap some highlands and divide areas. These show remarkable lithologic similarity to the Ogallala Gravels. These deposits may represent tongues of residual gravels of Ogallala materials which once extended along the valleys of eastward- and southward-flowing rivers originating upon the Ogallala surface during increased pluvial conditions of the early Pleistocene. Extensive southeastward drainage of the eastern marginal ranges of the Southern Rockies of New Mexico coalesced into major routes upon the Ogallala surface. This drainage may have initiated the Leon-Brazos system.

APPENDIX

SAMPLED LOCALITIES

LOCALITY

1. Five miles southeast of Belton on Farm Road 1741. Gravel pit, one-half mile south of Farm Road 1741 on west bank of Leon River (lat 31° 33' 00" N; long 97° 25' 30" W). Siliceous content: abundant pea gravel, small cobbles of quartzite and conglomerate, chert, sandstone. Condition: quartzite badly weathered; predominant colors: red, purple, brown. Calcic content: limestone fragments; sand size through 12-inch boulders. Condition: weathered cream, nodular, porous, gray, dense crystalline limy gravels. Fossils: many worn and well preserved *Gryphea marcoui* plus broken oyster-shell fragments.
2. One-fourth mile north of State Highway 36 at Temple city limits (lat 31° 07' 00" N; long 97° 24' 00" W). Siliceous content: small cobbles of milk quartz and quartzite, quartzitic conglomerate, brown chert. Condition: worn purple quartzite and chert. Calcic content: coarse gravel with a few boulders of limestone and fossil fragments. Condition: worn dense crystalline fragments and nodular white cobbles. Fossils: few worn *Gryphea marcoui*.
3. One-fourth mile south State Highway 36 at Temple city limits (lat 31° 09' 00" N; long 97° 25' 30" W). Siliceous content: large cobbles and boulders of quartzite, flat platy brown chert 6 inches in diameter. Condition: badly weathered purple and red quartzite, upper one foot of terrace cemented by calcite. Calcic content: limestone and chalk, fine gravel to cobble size. Condition: well rounded, dense crystalline, pink to white and nodular. Fossils: few *Gryphea marcoui*.
5. Gravel pit, west of Leon River on highlands one-fourth mile west of Iron Bridge Park (lat 31° 16' 30" N; long 97° 28' 30" W). Siliceous content: very large quartzite 7 inches in diameter, pea size gravel, cobble size vein quartz, mottled chalcedony, chert, and silicified wood. Condition: all lithologies well rounded and coated with calcite wash. Calcic content: nodular white and chalky limestone, gravel to cobble size. Condition: well rounded, often flat. Fossils: many worn *Gryphea marcoui*, few small horned corals.
6. Gravel pit one-fourth mile east of entrance to Mother Neff State Park (lat 31° 19' 00" N; long 97° 28' 00" W). Siliceous content: abundant pea size gravel, cobble size quartzite, silicified wood fragments up to 3 by 6 inches, conglomerate, banded igneous rocks, Edwards chert, and metamorphic rocks. Condition: all material well rounded. Calcic content: limestone and fossils, gravel to cobble size. Condition: well worn to flat and angular. Fossils: many worn *Gryphea marcoui* and gastropod casts.
7. Gravel pit at west edge of Mother Neff State Park (lat 31° 19' 20" N; long 97° 28' 00" W). Siliceous content: pea size gravel, 6-inch boulders of purple quartzite, cobbles of milk quartz, banded igneous and metamorphic rocks, mottled chalcedony, conglomerate, silicified wood, chert. Condition: all material well rounded, many quartzite rocks somewhat flattened. Calcic content: limestone, coarse gravel to large boulders 1-foot in diameter. Condition: rounded to angular. Fossils: worn *Gryphea marcoui*.
8. Low terrace exposed in right roadcut on dirt road approximately 4 miles northwest of Mother Neff State Park (lat 31° 19' 00" N; long 97° 29' 30" W). Siliceous content: much pea size gravel, cobbles of vein quartz and red quartzite, chert, silicified wood. Condition: all material well rounded. Calcic content: not present.
9. Gravel pit, 3 miles south of Gatesville, west side of river (lat 31° 24' 00" N; long 97° 44' 30" W). Siliceous content: much pea size gravel, cobbles of vein quartz, variegated igneous and metamorphic rocks. Condition: well rounded. Calcic content: limestone and fossils with calcite coating on some samples, coarse gravel to large cobbles. Condition: well rounded to flattened and angular. Fossils: many *Gryphea marcoui* in good condition.
10. Gravel pit, 1 mile west of State Highway 36, 2 miles south of Gatesville on east side of the Leon River (lat 31° 24' 30" N; long 97° 44' 30" W). Siliceous content: cobble size quartzite and milk quartz, pea size gravel, chalcedony sample about 2 inches in diameter, conglomerate, silicified wood. Condition: well rounded. Calcic content: limestone and fossils, gravel to large cobbles. Condition: well rounded to flat and angular. Fossils: many excellent *Gryphea marcoui*.
11. Gravel pit approximately 1 mile west of Gatesville School for Boys on east bank of the Leon River (lat 31° 28' 30" N; long 97° 46' 00" W). Siliceous content: large quartzites, much pea size gravel, cobbles of milk quartz, conglomerate, silicified wood. Condition: not badly weathered. Calcic content: very large dense gray limestone, 6 inches in diameter and fossils. Condition: worn. Fossils: few worn *Gryphea marcoui*.
12. Gravel pit 6 miles north of Gatesville at Ater (lat 31° 31' 00" N; long 97° 52' 00" W). Siliceous content: conglomerate, pea size gravel, small cobbles of quartzite and milk quartz. Condition: all material well rounded. Calcic content: limestone and fossils, coarse gravel to cobble size. Condition: well rounded. Fossils: few worn *Gryphea marcoui*.
13. Low terrace in roadcut one-half mile northeast of Ater on the east side of the Leon River (lat 31° 31' 30" N; long 97° 51' 30" W). Siliceous content: abundant pea size gravel, small cobbles of quartzite and quartz, chert, conglomerate, silicified wood, variegated igneous rock. Condition: all material well rounded, some fossil wood is angular. Calcic content: 50 percent limestone (chalk), coarse gravel to cobble size. Condition: well rounded and flat. Fossils: some angular petrified wood.
14. Low terrace, 1 mile northeast of Ater on dirt road (lat 31° 32' 00" N; long 97° 51' 20" W). Siliceous content: abundant pea size gravel, small cobbles of quartzite, granules of vein quartz, chert, variegated igneous rocks, mottled chalcedony, silicified wood, ferrous sandstone. Condition: all material well rounded except for angular fossil wood fragments; quartzite badly weathered and crumbling. Calcic content: few fossils; limestone, coarse gravel to cobble size. Condition: most samples flattened and well rounded. Fossils: worn fragments of *Gryphea marcoui*.
15. Morris gravel pit, 2 miles north of State Highway 36, Jonesboro (lat 31° 39' 00" N; long 97° 53' 00" W). Siliceous content: abundant pea size gravel, boulder size quartzite, cobble size milk quartz, 0.5 to 0.75-inch pieces of silicified wood, mottled chalcedony, chert, variegated igneous rocks. Condition: all materials calcite coated, some fossil wood pieces only slightly worn, some weathering of quartzite. Calcic content: few fossils, abundant limestone, cobble gravel to large flat plates up to 8 inches in diameter. Condition: mostly flattened and rounded. Fossils: very badly worn *Gryphea marcoui* fragments.
16. Gravel pit, 5 miles west of Jonesboro 3 miles north of State Highway 36 at Whiteway (lat 31° 41' 00" N; long 97° 47' 20" W). Siliceous content: mostly pea size gravel, some cobble size quartzite, silicified wood, conglomerate, mottled chalcedony, chert. Condition: badly weathered, small purple quartzite; well cemented conglomerate (opalized). Calcic content: limestone, coarse gravel to cobble size. Condition: badly weathered. Fossils: well preserved *Gryphea marcoui* and badly worn fragments, some angular and worn silicified wood fragments.

17. High terrace at Rock House School about 5 miles north-east of Hamilton (lat 31° 44' 00" N; long 98° 03' 00" W). Siliceous content: mostly pea size gravel, some small cobbles of quartzite and milk quartz, 8-inch piece of silicified wood, conglomerate. Condition: well worn except for angular silicified wood, few quartzite and conglomerate well cemented.
Calcic content: not sampled.
18. Low terrace north side of State Highway 22 about 0.5 mile west of the Leon River (lat 31° 43' 30" N; long 98° 01' 30" W).
Siliceous content: mostly pea size gravel, some large quartzite cobbles, large silicified wood fragments (4-8 inches), mottled chalcedony, milk quartz, conglomerate, sandstone. Condition: slight weathering of quartzite, conglomerate well cemented (opalized), coarse-grained iron-cemented sandstone.
Calcic content: limestone with calcite crystals. Condition: flattened discs of dense limestone and cobble size calcite.
19. Same as locality 18.
20. Abandoned meander, Eidson Lake, one mile east of U. S. Highway 281 about 4 miles north of Hamilton (lat 31° 46' 00" N; long 98° 06' 20" W).
Siliceous content: abundant pea and granule size gravel, some large quartzites, milk quartz. Condition: all materials well rounded; quartzite somewhat weathered.
Calcic content: cobble size crystalline calcite, large clay cobbles, flattened discs of dense limestone. Condition: all material well rounded.
Fossils: none found.
21. Abandoned gravel pit at Springtown about 9 miles northwest of Hamilton, approximately 2 miles northwest of State Highway 36 (lat 31° 48' 00" N; long 98° 12' 00" W).
Siliceous content: mostly pea size gravel, some cobble size quartzite, silicified wood, conglomerate, mottled chalcedony, chert. Condition: badly weathered, small purple quartzite; well cemented conglomerate (opalized).
Calcic content: limestone, coarse gravel to cobble size. Condition: badly weathered.
Fossils: well preserved *Gryphea marcoui* and badly worn fragments, some angular and worn silicified wood fragments.
22. Gravel pit, ¼ mile north of Lamkin, left side State Highway 36 (lat 31° 49' 00" N; long 98° 16' 30" W).
Siliceous content: 98 percent pea size gravel, some large quartzite (6 inches in diameter), cobbles of quartzitic conglomerate, milk quartz, silicified wood, sandstone. Condition: conglomerate well cemented, little weathering of purple quartzite, sandstone iron cemented.
Calcic content: dense limestone cobbles and boulders. Condition: weathered.
Fossils: few worn *Gryphea marcoui*, well rounded silicified wood fragments.
23. Low terrace 5 miles east of Gustine and one mile north of State Highway 36 (lat 31° 52' 30" N; long 98° 20' 10" W).
Siliceous content: milk quartz cobbles, few quartzite boulders, 80 percent pea size gravel, mottled chalcedony, variegated igneous rocks, silicified wood. Condition: all materials well rounded except for silicified wood samples.
Calcic content: flattened small and large discs of limestone, 1 to 8 inches in diameter.
Fossils: bone fragment (turtle breast plate?), one silicified log 2½ feet long, diameter about 6 inches.
24. Terrace gravels in roadcut, 8 miles northeast of Comanche on U.S. Highway 67 (lat 31° 57' 00" N; long 97° 28' 00" W).
Siliceous content: variegated igneous rocks, quartz, sandstone, conglomerate, 90 percent pea size gravel, coarse granules, some small reddish quartzites. Condition: little weathering, quartzite fewer and smaller than in most locales, reddish sandstone very compact.
Calcic content: chalky limestone and dense tan limestone. Condition: badly weathered.
Fossils: none found.
25. Sanbanna River terrace gravels in roadcut, 5 miles south of Gorman on Farm Road 679 (lat 32° 10' 00" N; long 98° 41' 00" W).
Siliceous content: 99 percent pea size gravels, some cobbles of milky quartz and quartzite, silicified wood, variegated igneous rocks, conglomerate. Condition: strong evidence of weathering, variegated igneous rocks laced with quartz stringers, opalized conglomerate.
Calcic content: gravel size chalky limestone. Condition: badly weathered.
Fossils: some well worn and angular silicified wood.
26. Gravel pit, 4 miles east of Gorman on Farm Road 8 (lat 32° 15' 00" N; long 98° 37' 00" W).
Siliceous content: silicified wood, variegated igneous rocks, mottled chalcedony, 80 percent pea size gravel, few quartzite boulders, milk quartz cobbles. Condition: all material well rounded.
Calcic content: flattened small and large discs of limestone, 1 to 8 inches in diameter.
Fossils: none found.
27. Scattered gravels in fields between Leon and Sabanna river drainage (lat 32° 07' 30" N; 98° 46' 00" W).
Siliceous content: mostly pea size gravel, some large quartzite boulders, large silicified wood specimens, sandstone, quartz, mottled chalcedony. Condition: slightly weathered; purple, white, and brown quartzites; elongated to round mottled chert; all materials well rounded except for silicified wood samples.
Calcic content: small pebbles of limestone. Condition: well rounded.
Fossils: angular to worn silicified wood.
28. Scattered gravels, ¼ mile northeast of locality 27 (same coordinates as locality 27).
Siliceous and calcic contents: same lithologies as locality 27.
29. Terrace gravel, 3 miles northeast of Gorman on Leon River west bank (lat 32° 14' 30" N; long 98° 43' 30" W).
Siliceous content: abundant pea size gravel, several large quartzite cobbles, mottled banded milky quartz, conglomerate, sandstone. Condition: slightly weathered, mottled and banded cherts with much tripoli.
Calcic content: dense, reddish limestone; cobble to pebble size. Condition: well rounded and relatively resistant.
Fossils: none found.
30. Terrace gravels, 1 mile south of Eastland on State Highway 6 (lat 32° 22' 00" N; long 98° 50' 00" W).
Siliceous content: abundant pea size gravel, large quartzite cobbles, vein quartz, mottled chalcedony, banded igneous rocks, conglomerate, dense sandstone, abundant variegated chert. Condition: quartzite slightly weathered, sandstone iron cemented.
Calcic content: large cobbles of dense limestone. Condition: well rounded.
Fossils: encrusting bryozoa.
31. Terraces of Morton Valley, 5 miles north of Eastland (lat 32° 27' 30" N; long 98° 49' 00" W).
Siliceous content: mostly pea size gravel, some large quartzite boulders, elongated cobbles of quartz and chalcedony, variegated chert, milky quartz, silicified wood, sandstone. Condition: generally well rounded and often elongated, fossil wood samples slightly to well worn.
Calcic content: generally coarse gravel size pebbles of dark, dense limestone. Condition: apparently resistant and moderately weathered.
Fossils: abundant angular and worn silicified wood.
- 32.-40. Scattered residual terrace gravels along the valleys of Big Sandy and Gonzales creeks approximately 8 miles north of locality 31 (lat 32° 35' 00" N; long 98° 49' 00" W).
Siliceous content: all characteristic Leon terrace gravels. Conditions: all well worn.
Calcic content: not sampled.
41. Terrace gravels in roadcut on U. S. Highway 83 at Clear Fork, 5 miles north of Abilene (lat 32° 38' 00" N; long 99° 47' 00" W).
Siliceous content: quartzite of boulder size, abundant pea size gravel, cobbles of mottled chert, conglomerate, vein quartz, silicified wood. Condition: all material well rounded, slightly weathered quartzite, well cemented coarse conglomerate.
Calcic content: fossils in limestone, pebble to cobble size samples. Condition: crumbling, elongated, flattened, badly weathered.
Fossils: badly weathered *Gryphea marcoui*, some worn silicified wood.
Remarks: one dense black fine-grained basaltic rock.

42. Gravel-capped hills, 10 miles west of Albany (lat 32° 44' 30" N; long 99° 25' 00" W).
Siliceous content: boulder size quartzite, pea size gravel, large pieces of silicified wood, cobbles of variegated and mottled chert, conglomerate. Condition: well rounded, slightly weathered.
Calcic content: none found.
Fossils: some badly worn *Gryphea marcoui* fragments.
43. Gravel-capped hills, 5 miles east of Funston on U. S. Highway 180 on the south bank of Cottonwood Creek (lat 32° 45' 00" N; long 99° 43' 00" W).
Siliceous content: boulder size quartzite, large pieces of silicified wood (6-10 inches), elongated cobbles of mottled and variegated chert, conglomerate, mottled chalcedony. Condition: all material well rounded.
Calcic content: fossils only.
Fossils: badly worn *Gryphea marcoui* fragments.
44. Apparent terrace gravels, 5 miles south of Rule on State Highway 283 (lat 33° 06' 00" N; long 99° 48' 00" W).
Siliceous content: large boulders of red quartzite, cobbles of milk quartz, some boulders of moss chalcedony. Condition: all samples well worn.
Calcic content: not sampled.
45. Apparent terrace gravels, 1 mile north of locality 44.
Siliceous content: large quartzite and vein quartz cobbles, some milk quartz, small moss chalcedony gravels. Condition: all materials well rounded.
Calcic content: not sampled.
46. Terrace gravels, east side of Salt Fork of Brazos, 10 miles west of Aspermont on U. S. Highway 380 (lat 33° 14' 00" N; long 100° 26' 00" W).
Siliceous content: abundant cobbles and boulders of quartzite, moss chalcedony, vein quartz, banded igneous and metamorphic rocks. Condition: all samples well worn.
Calcic content: some soft limestone, gypsum, caliche nodules. Condition: all samples badly weathered.
47. Low terraces on Double Mountain Fork, 7 miles east of Post on U. S. Highway 380 (lat 33° 12' 00" N; 101° 15' 00" W).
Siliceous content: large quartzite boulders, some vein quartz, cobbles and boulders of various igneous and metamorphic rocks, silicified wood. Condition: all samples rounded.
Calcic content: Some caliche nodules, soft gray limestone cobbles, broken shell debris. Condition: all samples well worn.

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