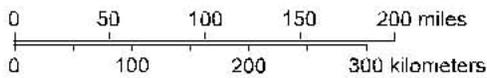
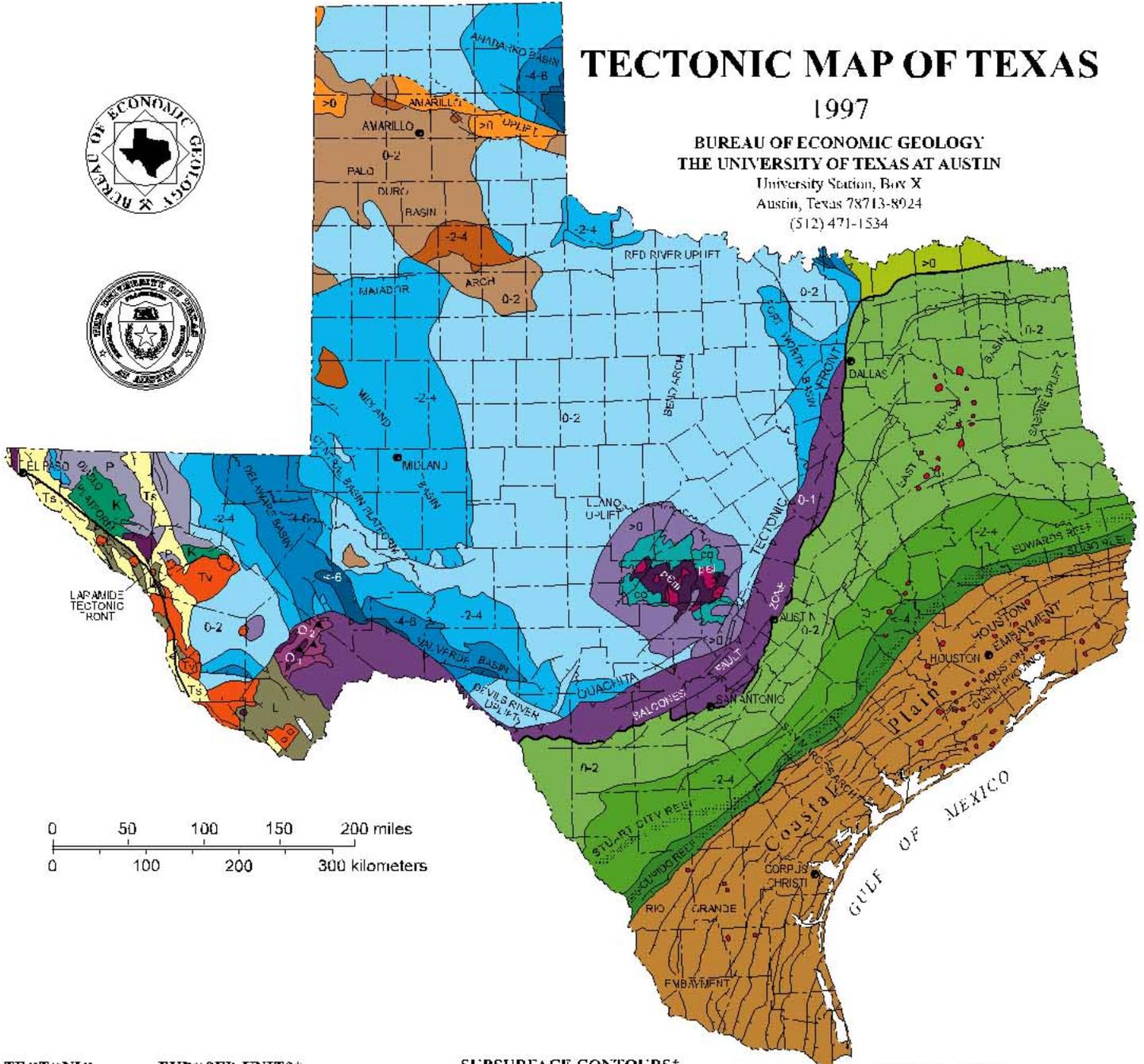


TECTONIC MAP OF TEXAS

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BUREAU OF ECONOMIC GEOLOGY
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TECTONIC EPISODE

EXPOSED UNITS*

Tertiary	Ts	Late Tertiary extensional basin
	Tv	Trans-Pecos igneous
Laramide	L	Deformed Cretaceous strata
Gulf Coast	K	Cretaceous strata
Ouachita	P	Foreland: Upper Paleozoic
	CO	Lower Paleozoic
	O ₂	Marathon: Upper Paleozoic (Hysch)
	O ₁	Lower Paleozoic
Llano	pEi	Precambrian igneous
	pEm	Precambrian metamorphic

SUBSURFACE CONTOURS*

(elevation in kilometers**)

Top of pre-Tertiary				
<-4				
Base of Austin Chalk or Top of Edwards Group Cretaceous				
>0	0 to -2	-2 to -4	<-4	
Top of Ellenburger Paleozoic				
>0	0 to -2	-2 to -4	-4 to -6	<-6
Top of Precambrian				
>0	0 to -2	-2 to -4		
Buried Ouachita facies Paleozoic				
0 to -1				

OTHER FEATURES

- Caldera
- Salt diapirs
- Lower Cretaceous reef trend
- Normal fault, indicating downthrown side
- Thrust fault, teeth on upper plate

TECTONIC FRONTS

- Laramide tectonic front
- Ouachita tectonic front
- Gulf Basin margin

* Note changes in mapped horizon.
** >0, elevation greater than sea level;
<-6, depths greater than 6 km below sea level

Tectonic Map of Texas

Proper appreciation of regional and global deformation comes only from seeing our planet as a fluid overlain by a thin, brittle crust. Although Earth's rocky face seems solid and stationary, it is made of plates that move over millennia because of flow of rocks far below Earth's surface. *Tectonics* is the study of regional and global deformation history and the plate tectonic processes that control such movement. Our understanding of past movements is summarized on *tectonic maps*, such as this *Tectonic Map of Texas*.

The plates that compose Earth's surface move horizontally and vertically relative to each other, at a rate of as much as a few centimeters per year. Motion of Earth's surface can be abrupt, as those who live in earthquake-prone areas can testify, but it is usually gradual and imperceptible. Yet over long periods of time—millions of years—parts of Earth's surface can move tens of thousands of miles relative to other parts. Texans who have handled rock samples recovered from the state's deep petroleum and geothermal wells know that such rocks can be nearly too hot to touch. At greater depth, temperatures are higher still. Because rock strength decreases exponentially with increasing temperature, Earth's interior is weak and able to flow plastically. It is this deep-seated flow that causes mountain ranges to be thrust up and plateaus torn apart to form ocean basins.

Tectonic maps document movement history by highlighting structural relationships among segments of Earth's crust that may extend across hundreds of miles. Such maps show crustal architectural patterns that indicate the sequence of tectonic events. To better understand the uses of these maps, compare this *Tectonic Map of Texas* with the Bureau of Economic Geology's page-size *Geology of Texas* map.

Geologic maps show where rock strata (layers) occur at Earth's surface or under a thin veneer of soil and vegetation. These maps have elaborate color patterns because their purpose is to depict many distinctive rock formations.

In contrast to the complicated color pattern of the geologic map, the *Tectonic Map of Texas* has a simple color pattern that depicts basic map elements, called tectonostratigraphic units. These units are sequences of sedimentary rock strata or groups of metamorphic and igneous rocks that share a common history of deformation. Combining individual geologic formations removes distracting detail that obscures the shared deformation histories of large blocks of crust. On the *Tectonic Map of Texas*, for example, the various Paleozoic formations between Midland, Dallas, and Amarillo have been combined. Not shown is the thin veneer of younger Cretaceous, Tertiary, and Quaternary deposits that lie at the surface over much of the area.

Structural information taken from records of deep wells is illustrated on the tectonic map by color coding that shows depth to a particular formation chosen as a reference horizon. Different rock formations have been used in various parts of Texas as reference horizons; these once were nearly horizontal layers at Earth's surface. As a result of deformation, parts of these formations have been raised or lowered, and color coding on the map shows how deeply buried these horizons are now. For example, in West Texas darker shades of blue mark the deep West Texas and Anadarko Basins. The reference horizon used there is the Paleozoic Ellenburger Formation, a petroleum reservoir rock widely penetrated by oil and gas drilling.

Tectonic maps show major structural features, including tectonic fronts that mark edges of major basins and former mountain ranges (orogenic belts). Crosscutting relations show the relative ages of features. For example, the blue patterns of Paleozoic basins and uplifts in West Texas are crosscut by the light green of the younger Gulf Coast Basin east of San Antonio, Austin, and Dallas.

Several tectonic cycles have affected Texas. These are informally listed on this map as "tectonic episodes," but they are actually local subdivisions of global plate movements that did not begin or end everywhere at the same time, and which—to a certain extent—are arbitrary milestones in a continuous history of movement. Each cycle produced tectonostratigraphic units that record initially the generation of rifts and divergent continental margins, followed by destruction of an ocean basin and mountain building (orogeny). The *Tectonic Map of Texas* distinguishes three principal tectonic cycles:

(1) Precambrian cycles are recorded in the ancient rocks of the Llano region and near Van Horn and El Paso. Of these the best known is the Llano cycle of between 1,200 and 1,080 million years ago (mya). At the close of this cycle, parts of present-day Texas were attached to rocks that now are located in Antarctica and southwest Australia.

(2) The Paleozoic Ouachitan cycle began with continental rifting about 550 mya, followed by inundation of much of Texas by shallow seas. This cycle closed with the collision of South and North America, which caused the Ouachita mountain-building event, ending about 245 mya. At this time much of Texas was in the shadow of vast mountain ranges that crossed the southern and east-central part of Texas.

On the tectonic map, two major features record this Ouachitan history. The most prominent is the foreland area of West Texas, shown in shades of blue. Here the legacy of ocean opening and the rise and fall of sea level created the stratigraphic and

structural features that would later trap vast quantities of oil and gas. The term foreland signifies that the paleogeography and structure of this area were shaped by a nearby mountain belt. The ancient and almost entirely eroded mountain belt is the other Ouachitan feature shown on the map. The Ouachitan mountain belt lay south and east of the Ouachita tectonic front. Its mostly buried roots extend from the Marathon area of West Texas, where deeply eroded relics of the mountain belt are exposed, through a great northward-curving arc to near Dallas, thence into Oklahoma. This zone of profound crustal contraction continues in the Appalachian Mountains of eastern North America and beyond.

(3) The current tectonic cycle in Texas is the Gulf Coast, which began in Texas with continental rifting in the Late Triassic about 220 mya and eventually led to creation of oceanic crust in the Gulf of Mexico. Well after this ocean began to open in South and East Texas, between 85 and 50 mya (Late Cretaceous to Paleocene), a mountain-building event called the Laramide Orogeny occurred in West Texas. This event is part of widespread deformation in the western United States, Canada, and Mexico that created the Rocky Mountains.

The *Tectonic Map* indicates where the Gulf Coast and Laramide events had their strongest impact on Texas geology. Rocks shown in green and brown (Gulf Coast Cretaceous and Tertiary strata), mainly east of Dallas, Austin, and San Antonio, were deposited during the creation of the Gulf of Mexico and Atlantic Ocean. Byproducts of basin formation depicted on the map include normal faults and intrusions of mobile salt (salt diapirs). Between Del Rio and Dallas, the edge of the Gulf Coast Basin follows the older Ouachitan tectonic front, testifying to the tendency for deformation to be localized through time along preexisting fault zones. Green and tan patterns and fault traces extending southeast of El Paso mark the edge of the Laramide orogenic belt and the frontal edge of the Rocky Mountains.

Formation of both the Gulf of Mexico and the Rocky Mountains is part of continuing global deformation. The Atlantic Ocean is widening as Europe and North America separate, while the Pacific Ocean basin is closing as the North American plate and Asia converge. The earliest phases of this modern pattern of movement can be read in the Gulf Coast and Laramide tectonic history of Texas.

Tectonic maps help illustrate Earth's restless history by highlighting the major episodes of plate tectonic motion, including mountain building and ocean formation. With this map as a guide, map users can retrace the experience of Texas in Earth's history of regional and global movement.

—Text by Stephen E. Laubach

Bureau of Economic Geology

The **Bureau of Economic Geology**, established in 1909 as the successor to the Texas Geological Survey and the Texas Mineral Survey, is a research entity of The University of Texas at Austin. It also functions as the State Geological Survey, a quasi-State agency, and the Bureau Director serves as the State Geologist. Advisory, technical, and informational services relating to the resources and geology of Texas are provided by the Bureau to governmental agencies, private industry, and the general public. The Bureau conducts basic and applied research projects in energy and mineral resources, coastal and environmental studies, land resources, geologic mapping, and other research programs in areas such as hydrogeology, basin analysis, and geochemistry. Reports and maps published by the Bureau are available for a nominal price. A list of publications is available on request.