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Superposed deformation in the Santiago and northern Del Carmen Mountains, Trans-Pecos Texas

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SUPERPOSED DEFORMATION IN THE SANTIAGO AND NORTHERN DEL CARMEN MOUNTAINS, TRANS-PECOS TEXAS

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INTRODUCTION

Persimmon Gap, the northeast entrance to Big Bend National Park, lies astride a northwest-trending segment of the Santiago Mountains. Structural features in the Santiagos and northern Del Carmen Mountains display evidence of two periods of deformation. Laramide compressional deformation produced the southwest-facing reverse-faulted monocline of the Santiagos. Reversal of slip during Basin and Range extensional deformation used steep segments of the Laramide fault planes to produce high-angle, normal faults. The regional pattern suggests a strike-slip component of movement along the Texas Lineament: left-lateral during the Laramide episode and right-lateral during Basin and Range time (see also Muehlberger, this guidebook).

Previous Work

Hill (1900, p. 4) pointed out that the long, narrow Sierra de Santiago ". . . is the only uplift in the Great Bend country having resemblance in trend and structure to the true Rocky Mountains . . ." He described the range as consisting of folded Cretaceous limestone and being terminated on the west by faults of the Great Basin type. Baker and Bowman (1917) described the Santiago Range as a single anticline that has been thrusted and locally overturned. Eifler (1943) mapped the Santiago Peak quadrangle and Graves (1954) the Hood Spring quadrangle, both just north of this map area. Pearson and Greenlee (1955) made a reconnaissance geologic map of part of the Santiagos and suggested that the structures may be the results of gravity sliding away from the center of the Marathon uplift. St. John (1965) mapped the Black Gap area east of Big Bend National Park and the southern end of the Santiago Mountains. He described the area as a large, northwest-trending graben flanked by a stable block to the northeast and a series of tilted fault-blocks to the southwest, which are terminated to the north by a large northeast-trending, faulted anticline. Maxwell and others (1967) described the Santiago Mountains in Big Bend National Park as an anticlinal uplift with folds that are overturned to the southwest, with reverse and normal faults. In contrast, the Sierra Del Carmen was described as a west-dipping monocline that is broken by a series of north- and northwest-trending normal faults.

STRATIGRAPHY

Rocks exposed in the Santiago and northern Del Carmen Mountains are primarily Cretaceous, with local cover of Quaternary gravel and alluvium. Paleozoic rocks that crop out in this area consist of shale, chert, sandstone and minor limestone of Ouachita facies. Formations present are the Maravillas Chert, Caballos Formation, Tesnus Formation, and possibly the Dimple Limestone. Neither the thickness of individual formations nor that of the total Paleozoic section has been determined in the area because of imbricate thrust faulting and limited exposure. Figure 1 is a stratigraphic section showing the lithology and approximate thickness of the Cretaceous rocks. The names of the units are those proposed by Maxwell and others (1967) for the Cretaceous section exposed in Big Bend National Park. The massive Santa Elena

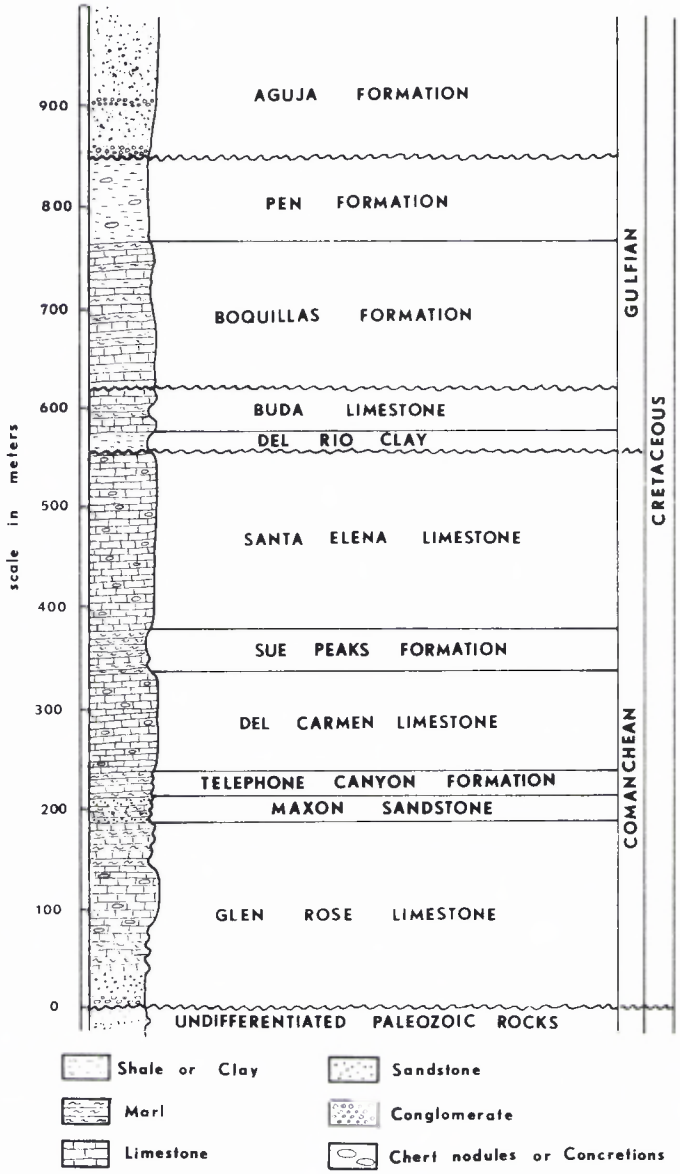


Figure 1. Cretaceous stratigraphic units in study area.

Limestone (Georgetown of central Texas) is the prominent ridge-forming unit in the park area because the overlying formations are easily eroded. In the Santiago Mountains, where beds are steeply dipping, the massive limestones of the Del Carmen and Glen Rose may be the ridge-forming units.

STRUCTURAL GEOLOGY

The Del Norte–Santiago–Sierra del Carmen form a continuous range of mountains. The range consists of long straight segments that trend north or northwest and that are separated by sharp bends (fig. 2). King (1937, p. 11) described the north-trending Del Norte Mountains as an upland, several kilometers broad, formed of Cretaceous limestone which is gently tilted toward the west. To the south, the Santiagos are a narrow ridge formed by a west-facing monocline, which in most of our map area is thrust-faulted. The Sierra del Carmen to the south is a broad, west-tilted uplift broken into blocks by north and northwest-trending normal faults (Maxwell and others, 1967, p. 273). King (1937, p. 40-41) called the Sierra del Carmen trend a northern extension of the eastern branch of the Sierra Madre Oriental of Mexico.

Laramide deformation in this area began with the development of en echelon folds. Steep west-facing monoclines that were thrust-faulted along the axial plane of the lower limb developed with continued deformation. The map pattern suggests a component of left-lateral strike-slip faulting along the northwest-trending segments. Late Cenozoic Basin and Range deformation produced down-to-the-east normal faults. These normal faults are steeply dipping, tend to parallel the trend of earlier folding and thrusting and some have reused the steep segments of the Laramide thrust planes.

Laramide Features

The principal Laramide feature is the reverse-faulted monocline of the Santiago Mountains and Maravillas Ridge, here called the Santiago Thrust. In the gently dipping rocks of Javelina Draw, northwest-trending en echelon folds have been cut by northwest-trending faults. Imbricate thrust faults and strike-slip tear faults are associated with the thrusted monoclines.

The Santiago Thrust Fault

Along the southwest flank of the Santiago Range, older Cretaceous rocks are overturned or vertical; the Boquillas and Buda Formations are the youngest formations (Cenomanian to Santonian) preserved in the hanging-wall block, juxtaposed against younger Cretaceous rocks (Santonian to Maestrichtian), generally the Aguja and Pen Formations.

North of Pine Mountain, the Santiagos trend northward and are unthrusted. Figure 3 is a cross-section through the Santiagos and shows the unthrusted monocline with about 760 m of structural relief, as well as the high-angle normal faults to the northeast.

Southeast of Pine Mountain, toward Persimmon Gap, the Santiago Thrust breaks the monocline at the inflection of its lower limb (fig. 4, cross-section B-B') and there is structural relief of about 910 m on the thrusted monocline. North of the Santiagos at Maravillas Ridge, the Cretaceous rocks have been folded into an east-facing monocline and thrusted at the inflection of its lower limb, but movement along the thrust fault has been in opposite sense to that seen at the Santiago Thrust.

Southeastward the thrust continues through Persimmon Gap and Dog Canyon in Big Bend National Park, with structural relief of about 910 m, to near Dagger Flat where it dies out in an unthrusted monocline (fig. 5) with structural relief of about 760 m. Where displacement ceases on the Santiago Thrust in Dagger Flat, the structural style changes to that of the broad en echelon folds and normal faults characteristic of the northern Sierra del Carmen.

Because of poor exposure measurement of the dip of the fault is difficult. However, on the east side of Javelina Gap, an imbricate thrust was observed in which the orientation of the fault plane was N46°W and dipping 10° northeast. Everett (1964, p. 27) measured dips of 0° to 80° east on the Black Peak Thrust, a concave-downward reverse fault near Del Norte Gap 31.6 km to the northeast.

Maravillas Ridge Thrust

North of the Santiago Mountains and south of the paralleling Maravillas Creek is a narrow ridge of low relief, here called Maravillas Ridge, in which Cretaceous rocks are dipping at high angles. The rocks of Maravillas Ridge have been folded into a N44°W-trending, northeast-dipping monocline. This monocline has been broken at the inflection of its synclinal hinge by a fault which dips to the southwest and has a concave-downward fault plane. Structural relief across the Maravillas Ridge Thrust is about 760 m. The thrust fault, which is upthrown on the south and has pushed Cretaceous rocks northward over younger Cretaceous units, dies out to the west past a tear fault. Translation across the thrust plane appears to have been picked up by the tear fault (fig. 4). Basin and Range extensional tectonism has been superimposed upon this Laramide compressional feature. South of Maravillas Ridge, a high-angle normal fault formed, which dropped Del Carmen Limestone down against Glen Rose Limestone. The planes of the Laramide thrust and the later normal fault are probably coincident at depth, but during the extensional episode the fault broke almost vertically to the surface; thus, its trace lies parallel to, and southwestward of, the thrust fault trace.

En Echelon Folds

North of the Santiago Range the Cretaceous rocks have been folded into northwest-trending anticlines (fig. 2). In Javelina Draw these anticlines parallel the northwest-trending Santiagos. North of Daggar Flat folds also parallel the Santiago structures. In the northern Sierra del Carmen, the Cretaceous rocks have been folded in an en echelon pattern, with an overall trend of about N23°W (St. John, 1965; Maxwell and others, 1967).

Basin and Range Features

Basin and Range features include high-angle normal faults that parallel the northeast flank of the Santiago Range and the normal faults of the Sierra del Carmen, which cut across the en echelon folds. The Chalk Draw Fault (fig. 2), southwest of the Santiagos, is possibly of Basin and Range origin, although it might have an earlier ancestry.

Normal Faults

In Javelina Draw the Cretaceous rocks have been cut by high-angle normal faults which generated a graben parallel to the trend of the structure of the Santiago Range. The largest fault lies north of the Santiago Mountains and parallels the northeast side of the range across its entire length. Displacement along this fault decreases southeastward from Pine Mountain, where maximum separation along the fault is about 850 m, to Persimmon Gap where separation along the fault is at least 60 m. Separation along the normal fault decreases southeastward toward Persimmon Gap whereas separation along the Santiago Thrust Fault increases toward Persimmon Gap; from there the thrust dies out in an unthrusted monocline near Daggar Flat.

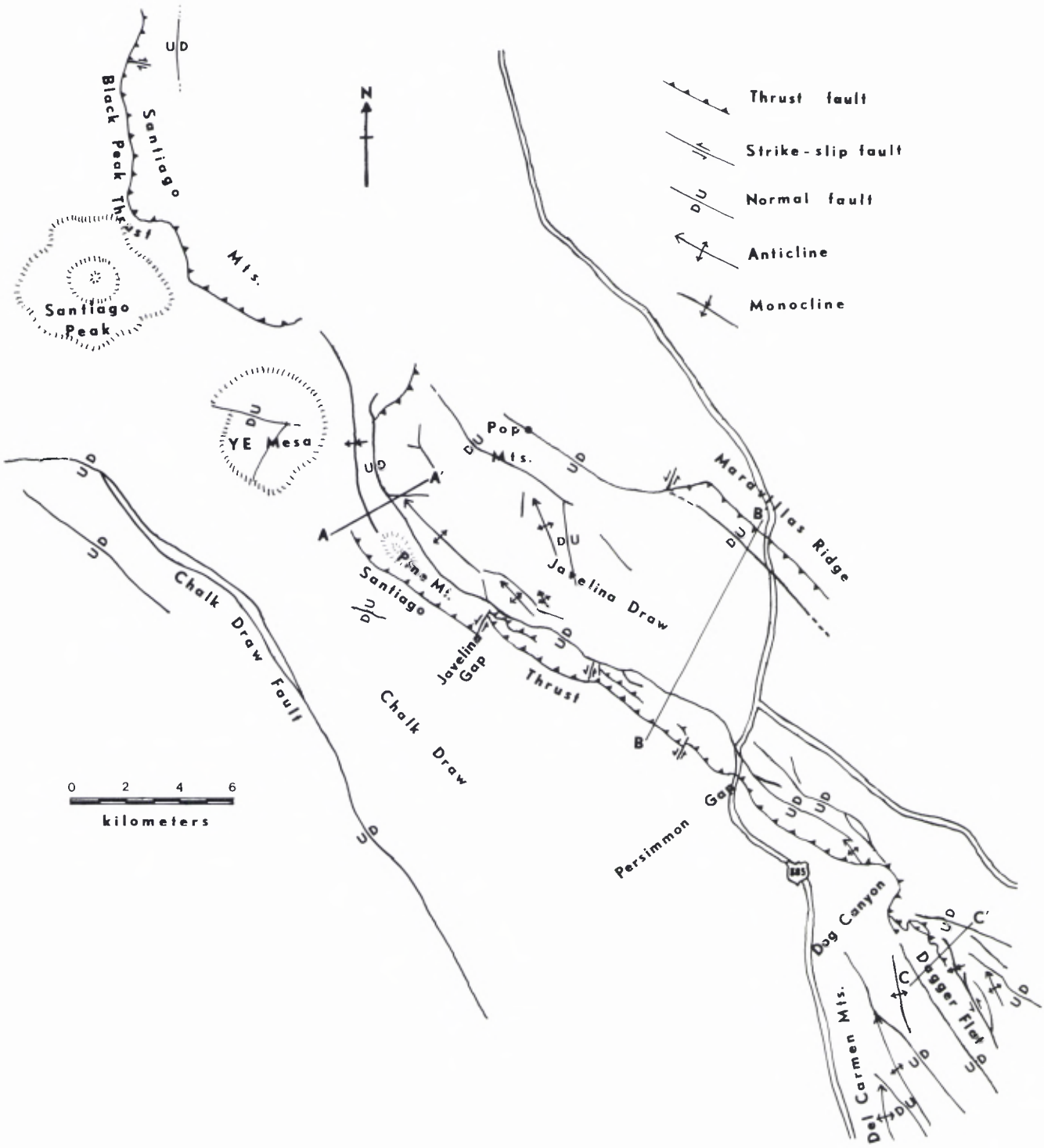


Figure 2. Structural geology of Santiago and northern Del Carmen Mountains. The Del Carmen Mountains are the southward continuation of the Santiago Mountains. Persimmon Gap lies astride the northwest-trending Laramide upthrust in the southern Santiagos. North of the range is a steeply dipping normal fault, along which strata were downdropped to the northeast during Basin and Range extensional deformation. Earlier, during Laramide compressional deformation, that same fault plane served as a thrust plane. Structural data outside study area from Eifler (1943).

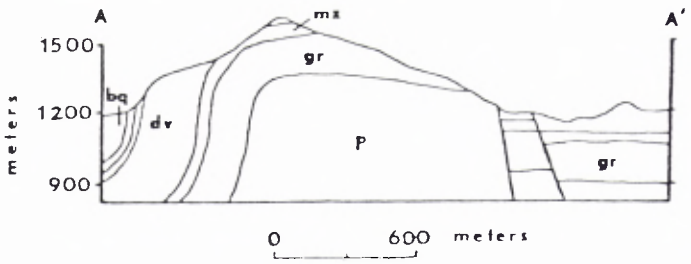


Figure 3. Eifler's (1943) cross-section F-F', showing the unthrusted monocline east of YE Mesa. P-undivided Paleozoic rocks, gr-Glen Rose Limestone, mx-Maxon Sandstone, dv-Devils River Formation equivalent to the Telephone Canyon Formation, Del Carmen Limestone, Sue Peaks Formation, and the Santa Elena Limestone of this study, bq-Boquillas Formation. Figure 2 shows location of section A-A'.

The Chalk Draw Fault

Southwest of the Santiago Mountains the Chalk Draw Fault trends northwest and the Aguja Sandstone (Campanian–Maestrichtian) has been dropped against Santa Elena Limestone (Albian). Displacement on this fault is approximately 545 m. The age of the Chalk Draw Fault, whether it is a Laramide or a Basin and Range structure, can not be adequately determined from the short segment of the fault mapped. The intense fracture cleavage of the Santa Elena Limestone, which forms the escarpment southwest of the Chalk Draw Fault, and rounded limestone cobbles in a conglomerate of the Aguja Formation, which parallels the Chalk Draw Fault, suggests Laramide movement. The present geometry of the feature, however, suggests Basin and Range-type structure.

Origin of Structural Features

Folding and faulting preserved in Cretaceous units in the Santiago Mountains indicate two periods of structural deformation. The block diagrams in Figure 6 demonstrate the geometry and sequence of events which produced the structural features of the Santiago Mountains during Laramide and Basin and Range tectonism.

During Laramide movement a left-lateral shear couple striking N50°W produced en echelon folds which were broken by left-lateral strike-slip faults. With continued movement on the left-lateral shear couple, a southwest-facing monocline was formed

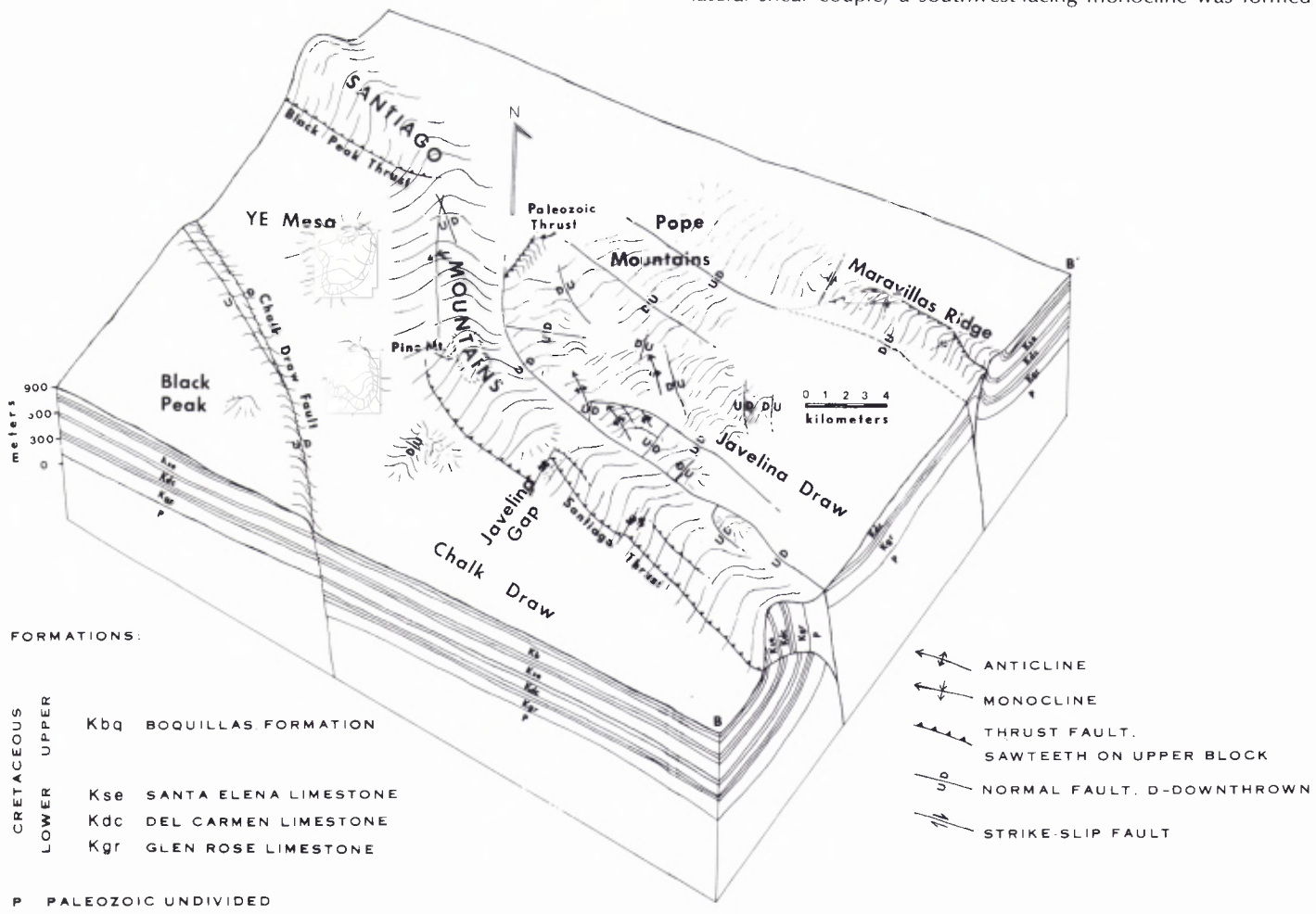


Figure 4. Structural features seen from north of YE Mesa and Pine Mountain to north of Persimmon Gap and surrounding area. Thrust in far northwest corner of Javelina Draw is a Paleozoic feature, other features are a result of Laramide and Basin and Range structural deformation. Block diagram extends northwestward from section B-B' of Figure 2.

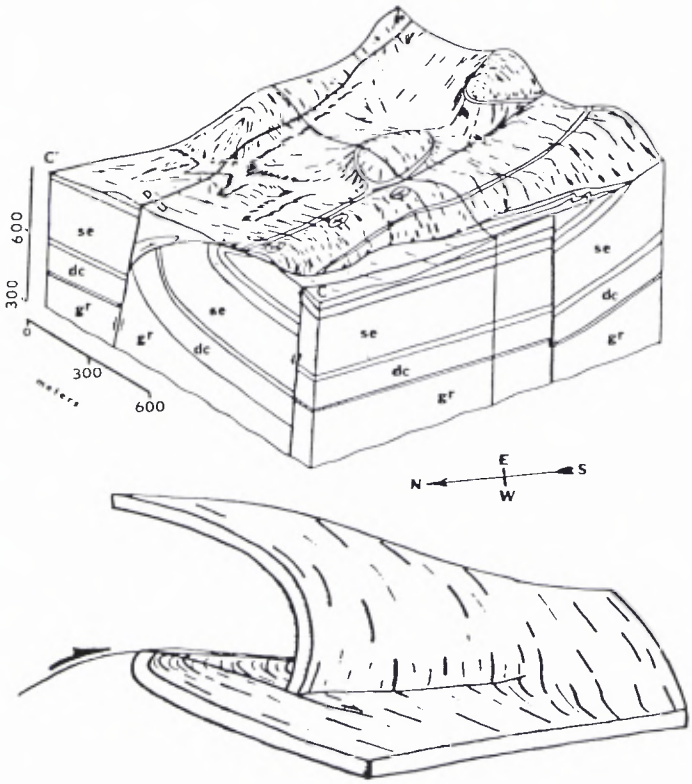


Figure 5. Transition from thrusting to folding. The block diagram at the top illustrates the structures on the east flank of the far northwest corner of Dagger Flat (fig. 2). Below is an idealized version of the geometry that occurs as a thrust dies out into a monoclinal fold. se-Santa Elena Limestone, dc-Del Carmen Limestone, gr-Glen Rose Limestone. Block diagram extends southeastward from section C-C' of Figure 2.

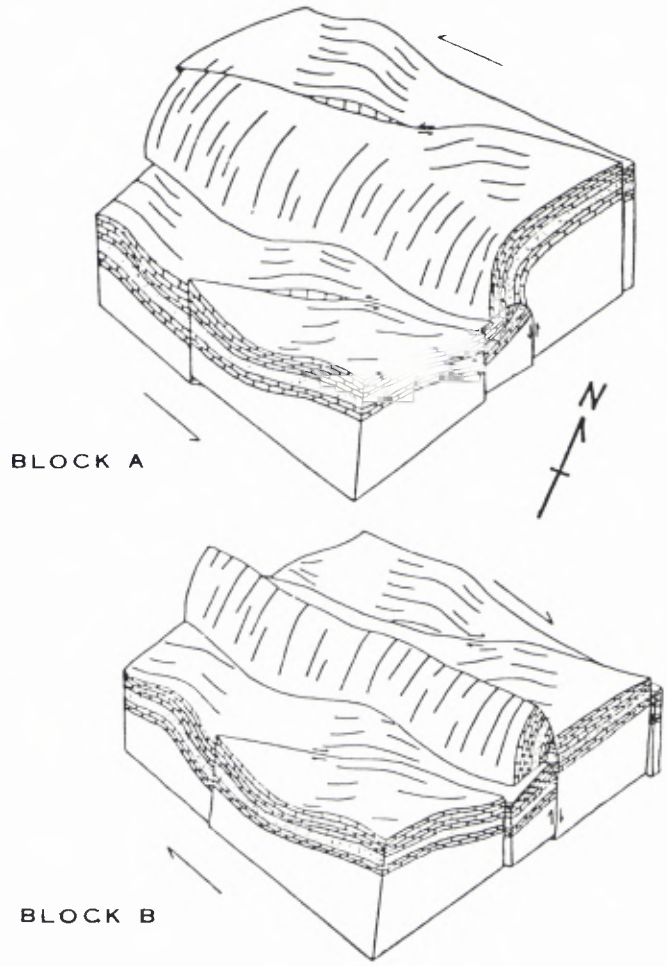


Figure 6. Block A: Laramide deformation produced en echelon folds and faults and a northwest-trending monocline upthrusted at its synclinal flexure. Block B: During Basin and Range deformation, the steep portions of Laramide fault planes were used to downdrop the rocks north of the Santiagos leaving the narrow, northwest-trending range standing in relief.

which was thrust at the axial plane of its lower limb. A second period of deformation, Basin and Range tectonism, produced a reversal of slip. This right-lateral movement dropped the Cretaceous rocks northeast of the Santiagos down to the northeast and left the narrow northwest-trending Santiagos standing structurally high. Subsequent erosion of the soft Upper Cretaceous rocks has produced topography that is a reduced version of the structure.

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Filling a tank wagon at one of the tanks at well No. 3, Illinois Producers Co., 19 miles southeast of Artesia, New Mexico. Man on the right is John D. Clark, Professor of Chemistry at University of New Mexico from 1907–1945. One year he taught mineralogy and geology. He was in effect an economic geologist and published papers on potash, enrichment of copper ores, ore migration and water. He examined coal deposits, oil fields, fluorspar and clay deposits. He also worked on obtaining liquid fuel from coal. Photo by Eldrid Harrington given years ago to V. C. Kelley. September 1, 1924.



"Mr. and Mrs. Walter Glover, Pine Springs, Texas in front of their store and gas station at Pine Springs, 1952."–J. Keith Rigby



W. B. Lang, U.S. Geological Survey, and M. Doyle, drilling superintendent, Sullivan Machinery Company, and driller at diamond core test (potash). New Mexico No. 1, sec. 13, T. 17 S., R. 31 E., about 38 miles east of Artesia. Eddy County, New Mexico. April 5, 1927. Photo by Mansfield.



J. P. Shannon (with stick) and Joseph Mitchell at site of McNutt core test, now capped. Sec. 4, T. 21 S., R. 30 E. Eddy County, New Mexico. April 7, 1927. Discovery of commercial deposits of potash in New Mexico. Photo by Mansfield.