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Lee A. Woodward and J. F. Callender, 1977, pp. 209-212

in:
San Juan Basin III (northwestern New Mexico), Fassett, J. F.; James, H. L.; [eds.], New Mexico Geological Society 28th Annual Fall Field Conference Guidebook, 319 p.

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TECTONIC FRAMEWORK OF THE SAN JUAN BASIN

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INTRODUCTION

The San Juan Basin is in the eastern part of the Colorado Plateau, an area that is structurally unique in the western United States insofar as it has been only moderately deformed compared to the more intensely deformed regions that surround it. Monoclines appear to be the most distinctive structural features of the plateau, and much of the deformation has occurred along them (Kelley, 1955a). The geographically widespread uplifts and structural basins, however, are the main features that define the major tectonic divisions of the Colorado Plateau. Most of the uplifts are bounded by monoclines on one side.

The Cordilleran foldbelt (fig. 1), which lies to the west and to the south of the Colorado Plateau (King, 1969), is characterized by flat-lying thrust faults that have yielded toward the foreland to the east and the northeast. Mostly, the zone of frontal breakthrough of the thrusts parallels and nearly coincides with the older zone of transition between the Cordilleran geosyncline and the platform along the western edge of the craton. Locally, the overthrust belt truncates the older geosynclinal margin and involves cratonic basement, as in southern Nevada and southeastern California (Burchfiel and Davis, 1972). The traces of the thrusts appear to bend eastward into Arizona and may connect with a zone of thrusting in southern New Mexico (Corbitt and Woodward, 1963).

The San Juan Basin (fig. 2) is bounded on the southeast by the Puerco fault zone, a group of structures of complex origin but partly related to the development of the Rio Grande rift to the east; the basin is bounded on the east by the Nacimiento uplift, a Rocky Mountain-type uplift that is not part of the Colorado Plateau; to the south, west, north and northeast, the San Juan Basin is bounded by uplifts of the Colorado Plateau.

Structures of the San Juan Basin and adjacent uplifts developed principally during Late Cretaceous and early Tertiary (Laramide) time, whereas epeirogenic uplift of the plateau as a whole probably took place later during Tertiary time. Minor doming related to injection of laccoliths and other intrusions occurred after Laramide time and modified some of the older structures.

REGIONAL TECTONICS

San Juan Basin

The San Juan Basin is nearly circular and is strongly asymmetrical as the axial trace forms an arc near the northern edge of the basin, with a steep northern limb and a gently dipping southern limb. The top of the Precambrian basement in the northeastern part of the basin is in excess of 7,500 ft below sea level.

The central basin, that part south of the Hogback monocline and north of the Chaco slope (fig. 2), is about 100 mi in diameter. Rocks that are exposed in the basin are mostly Late Cretaceous around the outer part and are early Tertiary in the inner part.

The northern boundary of the basin is defined by the Hogback monocline, which dips as much as 60° and has up to 8,000 ft of structural relief. The trace of the monocline is sinuous because of many small southwest, south and southeast-plunging cross folds. The Defiance monocline marks the southwestern boundary of the basin.

The southern margin of the basin grades into the gently dipping Chaco slope, which in turn merges with the Zuni uplift. The Gallup sag extends southward from the San Juan

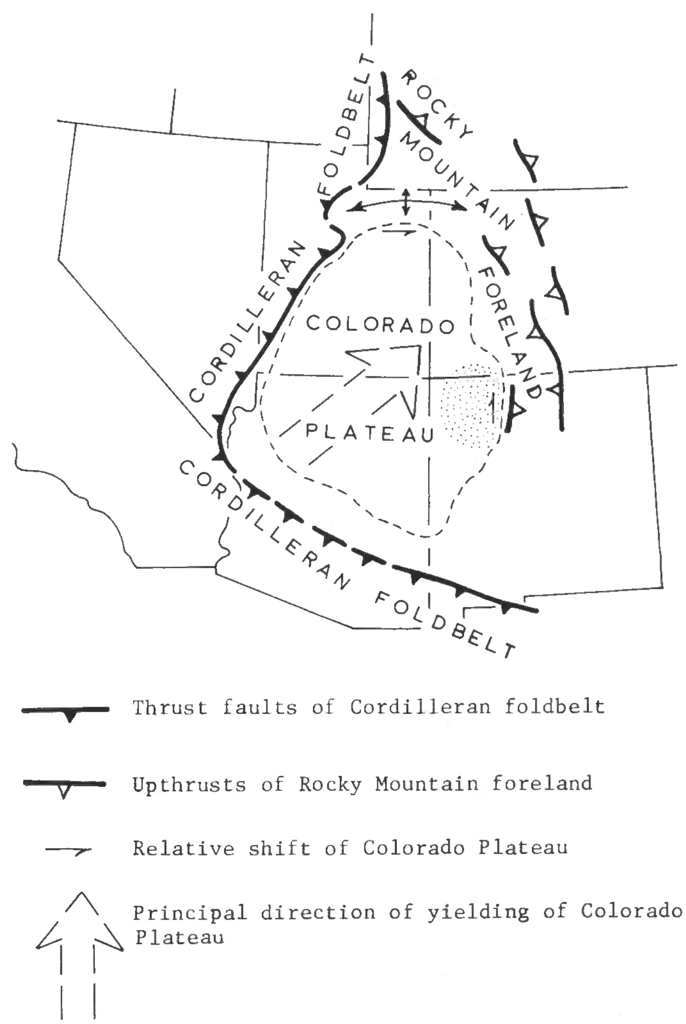

Figure 1. Generalized tectonic map showing Cordilleran foldbelt, Colorado Plateau and Rocky Mountain foreland. San Juan Basin stippled.

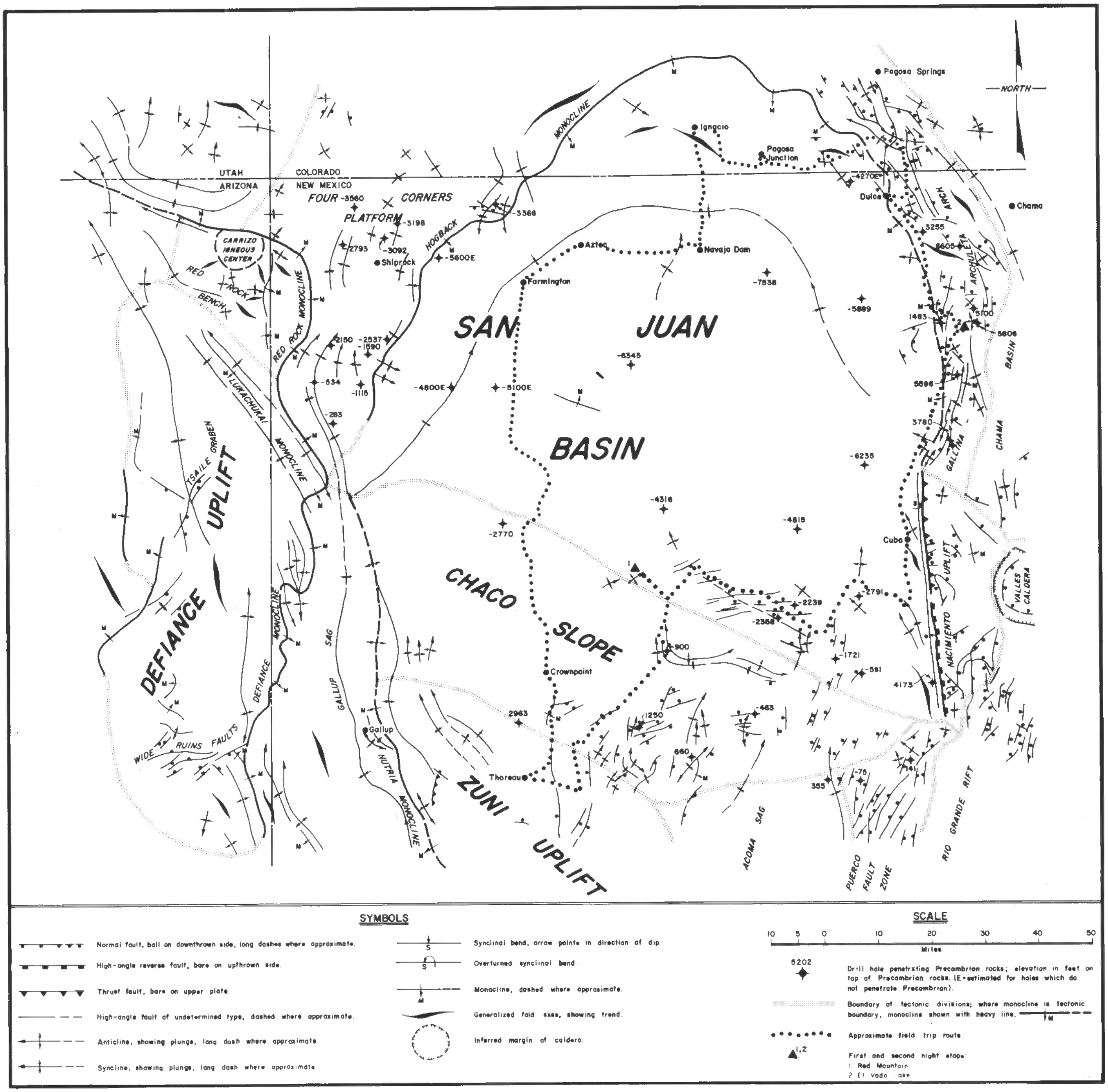

Figure 2. Tectonic map of San Juan Basin and surrounding structurally high areas, showing depth to basement and field trip route. Modified from Kelley and Clinton (1960).

Basin and separates the Zuni and Defiance uplifts. A structurally low extension from the southeastern corner of the basin has been called the Acoma sag (Kelley and Clinton, 1960). This sag plunges gently to the north and is asymmetrical; it has a steep western limb merging with the Zuni uplift and a gently dipping eastern limb that grades into the Puerco fault zone.

The eastern boundary of the San Juan Basin is marked by a monocline along the west side of the Gallina-Archuleta arch and by range-marginal upthrust and reverse faults on the west side of the Nacimiento uplift. A sharp synclinal bend that is locally overturned occurs west of the upthrust and reverse faults. There is at least 10,000 ft of structural relief between the highest part of the Nacimiento uplift and the adjacent part of the San Juan Basin. Structural relief between the basin and the Gallina-Archuleta arch is at least 13,000 ft.

Several northwest-plunging, en echelon, open folds and northeast-trending, high-angle faults of small displacement occur along the eastern margin of the San Juan Basin (fig. 2).

Radial folds plunging toward the center of the basin are found along most of the perimeter of the basin. Slightly arcuate parallel folds occur locally and are generally parallel to the basin margin.

Four Corners Platform

The Four Corners platform is intermediate in structural height between the surrounding uplifts and basins. Overall trend of the platform is northeast, connecting the Defiance and San Juan uplifts. There is about 4,000 ft of structural relief across the Hogback monocline which separates the platform from the San Juan Basin. To the southwest the Red Rock and Defiance monoclines mark the boundary of the platform. Several domes and other anticlines occur within the platform. Axial traces of the folds tend to be arcuate and mostly trend north and northeast.

Defiance Uplift

The Defiance uplift trends north, is about 95 mi long and 35 mi wide, and is asymmetrical, having a steep eastern limb (Gregory, 1917). There is at least 7,000 ft of structural relief between the highest part of the uplift and the adjacent Gallup sag.

The eastern boundary of the uplift is defined by the sinuous Defiance monocline, which dips 20°-90° and has 3,000 to 6,000 ft of structural relief (Kelley, 1967). Sinuosity is caused by a number of southeast-plunging folds that cross the monocline. Northward the uplift merges with the Red Rock bench which, in terms of structural height, is intermediate between the Defiance uplift and the Four Corners platform.

The crest of the uplift is crossed by several northwest-trending, en echelon folds, including the Lukachukai monocline. Faults are not common, but two areas of high-angle faulting reported are the northeast-trending Tsaile graben in the northern half of the uplift and the east-northeasterly-trending Wide Ruins fault zone near the southern end of the uplift (Kelley, 1967).

Zuni Uplift

The Zuni uplift is about 70 mi long and up to 35 mi wide. It trends northwesterly and is markedly asymmetrical, with a steep southwestern flank and a gently dipping northeastern flank (Darton, 1928). There is over 8,000 ft of structural relief between the highest part of the uplift and the Gallup sag near the town of Gallup; maximum structural relief between the uplift and the deepest part of the San Juan Basin far to the north is over 13,000 ft (Kelley, 1955b).

The western margin of the uplift is defined by the Nutria monocline, which dips as much as 80° and has up to 4,600 ft of structural relief (Edmonds, 1961). Locally, minor monoclines occur along the northeast flank, but mostly the uplift merges with the Chaco slope along beds dipping 3-10° (Kelley, 1967). High-angle faults having various strikes occur within the uplift and are common in the Precambrian rocks (Goddard, 1966), and reverse faults having up to 2,000 ft of stratigraphic separation have been noted by Edmonds (1961).

Puerco Fault Zone

Slack and Campbell (1976) described the structure of the Puerco fault zone, and this summary is taken mainly from their work. Three major groups of structures occur here and are, from north to south, northwest-trending en echelon folds, northeast-trending en echelon normal faults, and the Ignacio-Lucero monocline. Major structural relief across the fault zone is down to the east and is a maximum of about 3,000 ft. Slack and Campbell (1976) suggested that this complex geometry resulted from early Cenozoic right shift along the fault zone, middle Cenozoic vertical uplift of the Ignacio-Lucero monocline, and late Cenozoic development of the Rio Grande rift.

Nacimiento Uplift

The Nacimiento uplift trends north and is about 50 mi long and 6 to 10 mi wide. In general, it consists of an uplifted block that is tilted eastward and is bounded on the west by faults. There is at least 10,000 ft of structural relief between the highest part of the uplift and the adjacent San Juan Basin.

East of the range-marginal faults, an anticlinal bend occurs locally along the western margin of the uplift. The Nacimiento fault, an upthrust that is steep at depth but flattens upward and has westward movement of the hanging wall block over the San Juan Basin (Woodward and others, 1972), bounds the northern part of the uplift. Farther south a reverse fault dipping steeply to the east bounds the west side of the uplift.

The northern end of the uplift is a broad, faulted anticline that plunges 10° to 20° northward and merges with the Gallina-Archuleta arch. The uplift terminates at the south with folds that plunge to the south beneath an unconformable cover of Tertiary rocks (Slack, 1973).

Structures within the uplift include north-trending normal faults that bound second-order, tilted fault-blocks at the north end of the uplift and a graben in the southern part of the uplift. There are also high-angle faults trending east-west, northwest, and northeast; these faults separate differentially uplifted segments within the Nacimiento uplift. A few northwest-trending folds are seen near the south end of the uplift (Ruetschilling, 1973). Folds with similar trends may possibly have been present elsewhere in the uplift, but stripping of sedimentary strata from most of the uplift has removed any evidence of them.

Gallina-Archuleta Arch

The Gallina-Archuleta arch separates the relatively deep San Juan Basin from the shallower Chama basin to the east. There is at least 13,000 ft of maximum structural relief between the arch and the adjacent part of the San Juan Basin, whereas the Chama basin is about 1,500 ft structurally lower than the arch.

In general, the Gallina-Archuleta arch is a north-trending, arcuate anticlinorium that is slightly convex eastward. Previously, the southern part of the arch has been called the French Mesa and Gallina uplifts (Kelley and Clinton, 1960); however, together they are only about 24 mi in length and up to 8 mi wide, and they merge with the Archuleta arch to the north. Thus, they are described as a single tectonic feature in this report.

On the west the arch is bounded by a monocline that dips steeply westward at its southern end, but dips more gently as it is traced northward. The southern part of the arch merges with the shallow Chama basin through a broad, gently dipping slope to the east.

The southern part of the arch trends north-northeasterly and contains a longitudinal, high-angle fault near the crest and several longitudinal, doubly-plunging anticlines. In the northern part of the Gallina-Archuleta arch there are numerous longitudinal, high-angle faults. Stratigraphic separation on these faults is mostly less than 100 ft, although a few may have about 1,000 ft of separation (Dane, 1948). There are numerous open folds with trends parallel to the arch; the principal exceptions are west-northwesterly-trending fold axes near Tierra Amarilla (Muehlberger, 1967).

TECTONIC EVOLUTION

Our interpretation of the Laramide and younger tectonic development of the San Juan Basin and adjacent areas is briefly summarized as follows.

Northeast shift of the Colorado Plateau structural block (Kelley, 1955b) occurred as the North American plate drifted westward over an eastward-dipping subduction zone in Laramide time. Northeastward yielding of the plateau appears to have been related to the bend in the Cordilleran foldbelt in southeastern California (fig. 1), where the foldbelt structures cut into crystalline basement rock (Burchfiel and Davis, 1972). East-west compression in the Nevada-Utah segment of the foldbelt and nearly north-south compression in Arizona and New Mexico give a resultant vector trending northeast. Crowding and compression of the Colorado Plateau structural block by forces in the foldbelt to the south and west resulted in shift of the plateau toward the northeast. En echelon, northwest-trending folds and northeast-trending normal faults along the eastern edge of the San Juan Basin and in the Puerco fault zone appear to have been formed by right shift along the eastern margin of the Colorado Plateau.

Monoclines, marking many of the boundaries between uplifts and basins of the plateau, developed shortly after and perhaps in part contemporaneously with the northeast yielding of the plateau. Continued right shift along the Defiance monocline resulted in the southeast-plunging cross folds that give the monocline its sinuosity.

Subsidence of the San Juan Basin was at least in part synchronous with northeast yielding of the plateau, but also may have been caused by volume changes in the lower crust or upper mantle as phase changes took place. Radial folds along the basin margin probably formed in response to greater subsidence in the center of the basin than along the margins. Parallel folds may have been caused by large-scale disharmonic folding as the strata in the basin were compressed during subsidence (Dallmus, 1958); passive draping of strata over basement faults also may have been responsible for a few of the folds.

Lateral transfer of sialic crust from beneath the foldbelt to the plateau may have occurred by metamorphic flowage as the subduction zone was overriden (Gilluly, 1973). When the forces responsible for subduction were dissipated, the thickened sialic crust was free to rise isostatically. This resulted in epeirogenic rise of the entire plateau. This rise may have begun in the early Cenozoic (Lovejoy, 1973) or perhaps later in the Cenozoic (Longwell, 1946).

Major late Cenozoic normal faulting in the Puerco fault zone reactivated faults that were initiated during the Laramide. This extensional faulting is related to development of the Rio Grande rift during and after the Miocene. The Nacimiento uplift continued to rise after the Miocene, possibly as a result of pushing by a proposed mantle bulge beneath the Rio Grande rift (Lipman, 1969). Thus, the Nacimiento uplift on the east side of the San Juan Basin is only partly related to the forces that created the basin; final development of the uplift seems to have been directly related to the evolution of the Rio Grande rift.

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