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PALEOZOIC HISTORY OF THE ALBUQUERQUE TROUGH: IMPLICATIONS OF BASEMENT CONTROL ON RIO GRANDE RIFT

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INTRODUCTION

The Miocene and younger history of the Albuquerque trough and the Rio Grande rift has been discussed endlessly in numerous volumes and conferences. The events leading up to the Miocene adventure are less well known. Kelley (1977) placed considerable emphasis on Laramide compressional structures having preceded rifting, and Read and Wood (1947) inferred north-trending peculiarities in the Pennsylvanian System in the vicinity of Albuquerque. Because of the nature of exposures of Paleozoic strata in and near the Albuquerque basin, only the Pennsylvanian System may be used as diagnostic evidence of paleotectonic ancestry of the rift zone. It is the purpose of this discussion to suggest that the rift may have had a very long tectonic history, dating back at least to Pennsylvanian and probably to Precambrian structural regimes. Perhaps the mystery of the location and significance of the rift will be resolved by the understanding of basement tectonics, rather than by surface structure.

BASEMENT TECTONICS

The Precambrian structural fabric of the Colorado Plateau has been summarized recently by Baars and Stevenson (1981). In brief, several basement rift zones transect the present Plateau and form the western and southern boundaries of the province. The dominant northwesterly oriented basement rifts display right-lateral displacement, but the northeasterly trends are left-lateral. The large-scale conjugate fracture sets resulted from a north-south oriented stress field. Related smaller structures resulting from the same Precambrian episode were north-south-trending tensional featues, namely normal faults and horst-graben structures over which the much later Laramide compression from the west formed drape monoclines. Expected east-west-trending compressional folds are found in the Uinta Mountain arch and several related folds of the northern Plateau. The rejuvenations of these basement features obviously controlled sedimentation throughout at least Paleozoic time.

In Pennsylvanian time, the Ancestral Rockies orogeny was an episode of great east-to-west extension of the crust, and the Paradox basin sagged into existence along the Olympic-Wichita lineament, adjacent to the positive Uncompahgre uplift. The north-trending basement extensional faults remained active, forming tectonic linear positive features that either shed sediments or created major facies changes in late Paleozoic sediments.

New Mexico Basement Structures

Northwestern New Mexico is dominated by the San Juan Basin; however, the basin is bounded by several basement structures (fig. 1). On the south, the dominant feature is the Zuni Mountains uplift, a northwest-trending anticline in which the basement is onlapped by Pennsylvanian strata and buried by the Permian Abo Formation. The broad structure may date back to the Precambrian and the axis is in compliance with the dominant northwesterly trend of that time. Rocks of Pennsylvanian age nearly surround the structure in the subsurface but never covered the basement high. The structural homocline north of the Zuni uplift, the Chaco slope, is bounded on the northeast by deep-seated fault blocks that traverse the southern San Juan Basin from Tocito dome

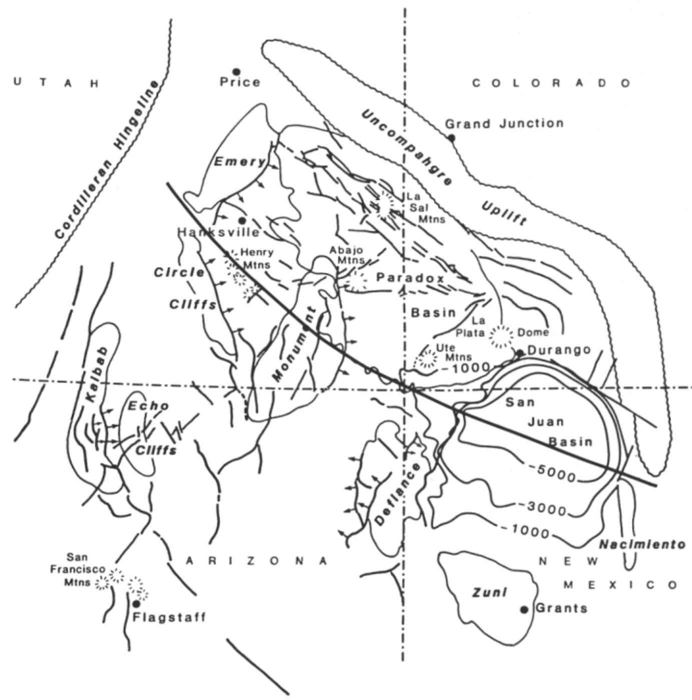

Figure 1. Index map showing locations of major structural features of the Colorado Plateau. Structure contours in the San Juan Basin are on top of the Paradox Formation (Middle Pennsylvanian). The heavy northwesterly trending line is the hypothetical basement lineament described in the text.

through Hospah to the southern Nacimiento uplift (Stevenson and Baars, 1977).

The western side of the basin is bounded by the Defiance uplift, a complex structural massif that trends north-south but is composed of northeast-and-northwest-trending basement fault blocks. Like the Zuni uplift, the Defiance is onlapped by Mississippian and Pennsylvanian strata and is buried by Permian red beds. A northeasterly trending basement fault underlying the Hogback monocline bounds the San Juan Basin on the northwest. The deep Hogback fault is a high-angle reverse fault in Paleozoic rocks, with Mesozoic beds draped by Laramide compression to form the southeast-facing monocline.

An interesting but little understood trend of geologic features forms the northeastern margin of the San Juan Basin. The surface monocline lies in a northwest trend between about Durango and Pagosa Springs, Colorado, and is essentially on trend with an eastward displacement of the southern Uncompahgre (perhaps better called the ancestral San Luis uplift) and the Archuleta anticlinorium. A few miles to the south, a northwesterly trend of features is apparent (see fig. 1). If this trend is started at the southern end of the San Luis (Uncompahgre) uplift near Santa Fe and projected northwest, (1) it passes just north of the Jemez caldera, the northern end of the Nacimiento—San Pedro uplift, and the strong northwesterly trend of the San Juan Basin gas fields; (2) it marks the southwestern margin of the Paradox salt deposits; (3) it crosses the Monument upwarp through the anomalous Fish Creek structure and White Canyon, through the Mille Crag Bend fracture zone, and along the northwest-oriented intrusions of the Henry Mountains; and (4) it separates the Circle Cliffs and San Rafael uplifts. This hypothetical lineament is either a long string of coincidental features or a basement fracture zone that parallels the more obvious Olympic-Wichita lineament.

Completing the borders of the rhombic-shaped San Juan Basin is the north-trending Nacimiento—San Pedro uplift north of the Albuquerque basin. Again, the Mississippian and Pennsylvanian formations thin dramatically onto the linear uplift, culminating with Abo-Cutler redbeds lying directly on the Precambrian basement on San Pedro Mountain east of Cuba (fig. 2).

PALEOZOIC STRATIGRAPHY

It should be obvious from these relationships that the Albuquerque basin lies at the southeastern corner of a "hornet's nest" of basement structures that date back to at least Pennsylvanian and perhaps Precambrian times. The Albuquerque basin lies just east of the Zuni uplift, south of the Nacimiento—San Pedro uplift, and between Precambrian and Paleozoic exposures in the Ladron Mountains on the west and the Sandia-Manzano mountains on the east. A detailed study was conducted many years ago of the Pennsylvanian outcrops of this area and includes a recent review of several deep wells drilled in and near the basin, mostly by Shell Oil Company. The results of these studies are summarized in Figure 2 and Tables 1 and 2.

Mississippian Rocks

Mississippian strata are sparse in central New Mexico but where present, scattered exposures rest directly on the Precambrian basement. The Caloso and Kelly limestones are present in the southern Ladron Mountains but pinch out northward, partly by onlap and partly by pre-Pennsylvanian erosion. Very thin remnants of Mississippian limestones and sandstones may be present in the Joyita Hills, Abo Canyon, Tijeras Canyon, and the Placitas area, but the occurrences are not all verified by faunal data. The somewhat younger Arroyo Peñasco Formation occurs in what appear to be paleotectonically-controlled topographic lows in the southern Nacimiento Mountains (Stevenson and Baars, 1977). The Leadville—Arroyo Pehasco carbonates vary from 0 to 61 m (0 to 200 ft) in thickness in the San Juan Basin, with the southern limits trending along the Chaco slope. It has long been the contention that this broad area with little or no Mississippian rocks (through the Albuquerque area) was a southwestern extension of the "Transcontinental arch." It is here contended that the apparent "Transcontinental arch," in New Mexico at least, is a coincidence of exposures of the several disconnected basement positive features described above. The Caloso-Kelly and Leadville—Arroyo Peñasco strata may well have been interconnected along paleotectonic low areas in Mississippian time.

Table 1. List of measured sections used in the preparation of this summary.

Measured Section	Unit Thickness (ft)			
Section, Location	Mississippian Strata	Sandia Fm	Gray Mesa Member	Atrasado Member
Joyita Hills sec. 23, T1N, R1E	12?	144	134	125
S. Ladron Mountains sec. 31, T2N, R2W	79	437	696.5	428 +
N. Ladron Mountains secs. 5 & 23, T3N, R3W secs. 23& 24, T4N, R4W	0	405	760	573
Abo Canyon secs. 26, 35, 36, T3N, R4E	10?	350 ±	861	565
Tijeras Canyon secs. 21, 22, T10N, R5E	10?	98	514	790
Zuni Canyon sec. 18, T10N, R11W	0	0	0	37
Placitas secs. 34, 35, T13N, R5E	94	133	864	302 +
Los Piños Arroyo sec. 5, T16N, R1E	0-137	68	38 + faulted	
Peñasco sec. 20, T16N, R1E	0	18	15	0
Guadalupe Box Canyon sec. 6, T17N, R2E sec. 31, T18N, R2E	22	192	702 [Madera undif.]	
Rio Vaca secs. 1, 2, T19N, R1E	0	567 [Penn. undif.]		
S. San Pedro Mountain sec. 34, T21N, R1E	0	0	0	0-50

Table 2. List of recently drilled deep tests that aid in the resolution of the subsurface structure of the Albuquerque basin.

Well, Location	Year	TD (ft)	Deepest Formation Penetrated	Thickness of Pennsylvanian Strata (ft)
Shell, 2 Santa Fe sec. 29, T6N, R1W	1974	14,305	Morrison?	NA
Shell, 1 Isleta Central sec. 7, T7N, R2E	1975	16,350	Precambrian?	570
Shell, 1 Laguna-Wilson sec. 8, T9N, R1W	1972	11,116	Precambrian	2,945
Shell, 1-24 West Mesa sec. 24, T11N, R1E	1981	19,375	Tight Hole	?
Shell, 3 Santa Fe sec. 28, T13N, R1E	1976	10,270	Chinle	NA
Shell, 1 Santa Fe sec. 18, T13N, R3E	1972	11,045	Precambrian	580

Pennsylvanian Rocks

The exposures of Pennsylvanian strata along margins of the Albuquerque basin appear to be normal interbedded limestones and marine clastics. Studies of the rather abundant fusulinid Foraminifera reveal that marine rocks are present for each of the epochs of the period. The combined Sandia and Madera formations total over 457 m (1,500 ft) in the southern Ladron Mountains and over 518 m (1,700 ft) in thickness north of the Ladrons. Recent drilling has disclosed thicknesses of nearly 914 m (3,000 ft) north of the Ladrons in the Acoma sag (fig. 2). On the eastern side of the Albuquerque basin the Pennsylvanian section is very similar. Over 579 m (1,900 ft) of Sandia and Madera strata are present in Abo Canyon, around 427 m (1,400 ft) were measured in Tijeras Canyon, and something over 396 m (1,300 ft) are present near Placitas (fig. 2).

At the southern end of the Albuquerque basin and about midway between the Ladron and Abo Canyon sections are exposures of Precambrian through Permian rocks in the Joyita Hills (fig. 2). These exposures have been discussed by numerous authors but are generally ignored by those researchers who attribute the rift primarily to Tertiary-age tectonic events. A measured section of the Pennsylvanian in the Joyita Hills totals only 122 m (400 ft) but contains faunas of Atokan, Lower Desmoinesian, and Lower Missourian ages. Although thin, the Atokan—Lower Desmoinesian section appears to be continuous with a disconformity near the top of the section. The overlying Lower Missourian beds are overlain disconformably by the Lower Permian Abo Formation. Clearly, this is an anomalous section which occurs roughly in the middle of the Rio Grande rift.

At the northern end of the Albuquerque basin and the Nacimiento-San Pedro uplift, the Pennsylvanian formations vary from zero on San Pedro Mountain to nearly 274 m (900 ft) in thickness in Guadalupe

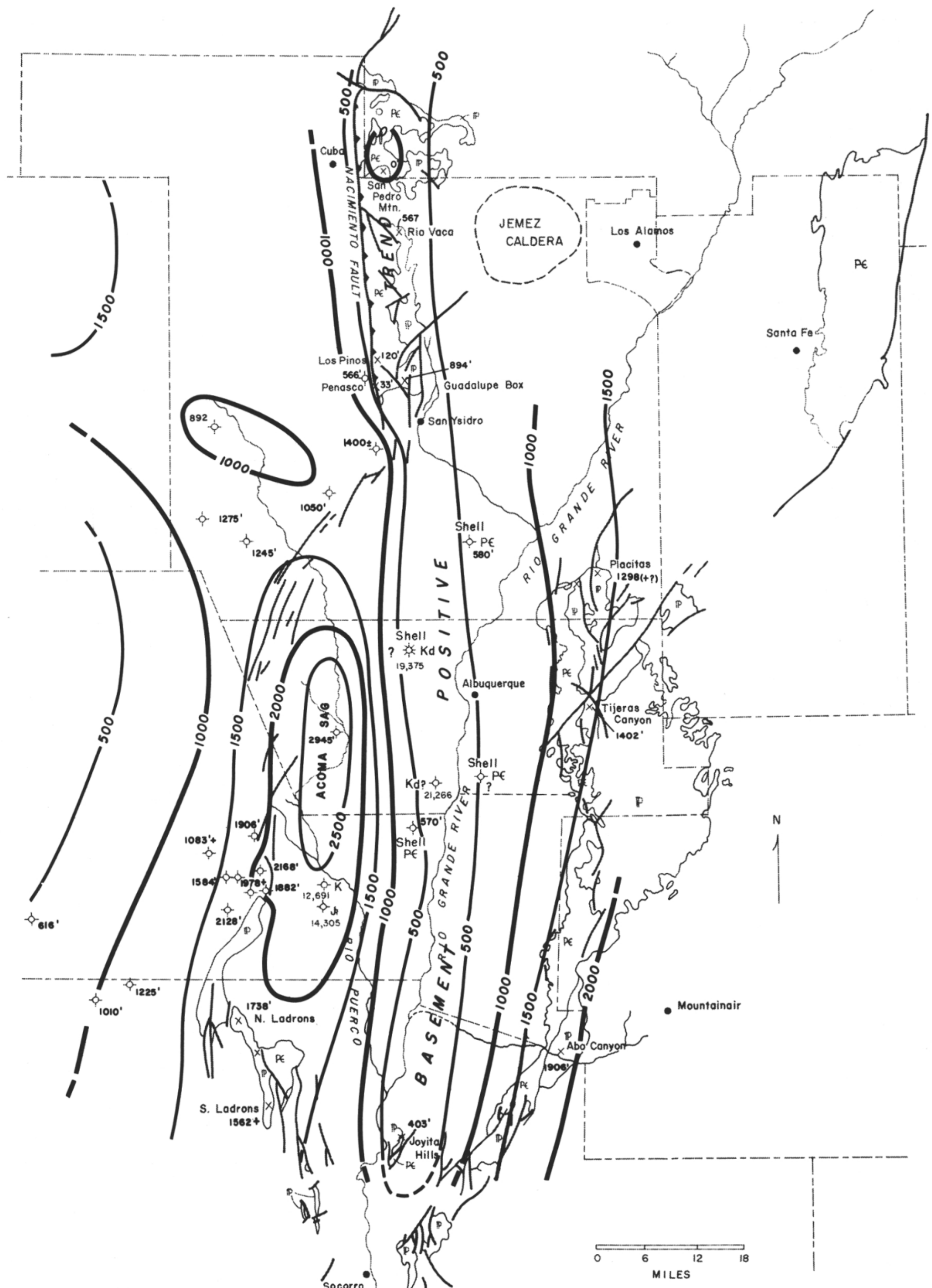

Figure 2. Isopachous map of the Pennsylvanian System of the Albuquerque basin and vicinity. The trend of positive structural features between the Joyita Hills and the Nacimiento–San Pedro areas is marked by the anomalous 500-foot contour under the Albuquerque basin.

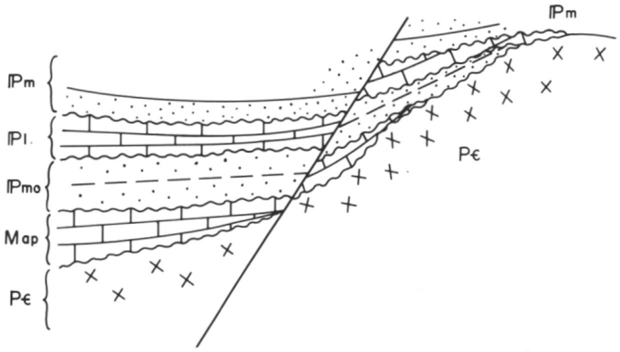

Figure 3. Sketch of stratigraphic relationships along the Nacimiento fault at the Los Piños section (fig. 2). Note the truncation and overlap of each formation from west to east (left to right) on the flank of the paleo-positive feature now marked by the Nacimiento fault. P€ = Precambrian basement, Map = Arroyo Peñasco Formation, IPmo = Molas (Log Springs) Formation, IPl = Lower Pennsylvanian (Morrowan or "Schizophoria" beds), IPm = Madera Formation.

Box Canyon near San Ysidro (fig. 2). The overall trend from south to north along the uplift is that the Pennsylvanian System onlaps San Pedro Mountain. Locally, however, the total section varies from only 10 m (33 ft) thick at the Pefiasco section to 273 m (894 ft) a couple of miles east at Guadalupe Box across a complex fault zone. Clearly, there are some peculiarities of significant antiquity in this area.

Futher complications in local stratigraphy were noted at the Los Pifios section, measured just east of the old Warm Springs resort along the southern Nacimiento fault (fig. 2). On the immediate eastern, or up-thrown, side of the fault, the Mississippian Arroyo Penasco Formation overlies Precambrian basement but is truncated in a few feet by the Lower Pennsylvanian Log Springs (Molar) Formation. The Log Springs is in turn truncated by the Morrowan-age beds which are, in turn, truncated by Madera rocks containing Lower Desmoinesian fusulinids (fig. 3). Although it is well established that the Nacimiento fault is Laramide in age, the same fault zone was recurrent in post-Mississippian, post—Log Springs, post-Morrow, and post-Madera times. The three stratigraphic units were removed by erosion, successively, within a couple of hundred feet laterally, across the fault zone. The Nacimiento fault clearly has a Paleozoic history.

Read and Wood (1947) speculated that the anomalous sections in the Joyita Hills and southern Nacimiento areas may represent a north-trending Pennsylvanian positive anomaly underlying the Albuquerque basin. Wells drilled recently by Shell Oil Company make it clear that their interpretation was correct. Two of these wells penetrated the Pennsylvanian strata and the basement near the center of the Albuquerque basin, and from the well data, only 174 to 177 m (570 to 580 ft) of Pennsylvanian strata were found to rest directly on the basement. These two wells, showing anomalously thin Pennsylvanian strata and lying along a line connecting the Joyita Hills and the Nacimiento area, require that the isopachous lines must trend in a north-south, elongated manner under the Albuquerque basin. Figure 4 is a generalized interpretation of the subsurface geology underlying the basin at about Permian time. The cross section was drawn without the aid of seismic data and is based on relationships seen both in outcrop and subsurface records.

PALEOTECTONIC IMPLICATIONS

At least the Albuquerque basin portion of the Rio Grande rift is in compliance with a well-established basement tectonic fabric of the Colorado Plateau province. Pennsylvanian stratigraphic relationships dictate that a parallel north-south positive feature directly underlies the basin. In other words, the Nacimiento—San Pedro uplift extends, in the subsurface, as far south as the Joyita Hills and perhaps beyond to the south. The entire length of the basement uplift has a history of tectonic activity dating back to at least the beginning of Pennsylvanian time and probably is related directly to a Precambrian fracture pattern that dates at around 1.7 billion years ago. It is here suggested that in the vicinity of the Albuquerque basin, the late rifting of the Rio Grande system recurred over basement rifting long in place, thus localizing the later opening. Additionally, there is still plenty of space for the compressional Laramide monocline proposed by Kelley (1977). If the proposed basement fault block acted, as did others, on the Colorado Plateau, an east-facing monocline would be expected to have been formed in Laramide time (e.g., Comb Ridge monocline, East Kaibab monocline, San Rafael monocline, etc.). When extension of the crust occurred starting around

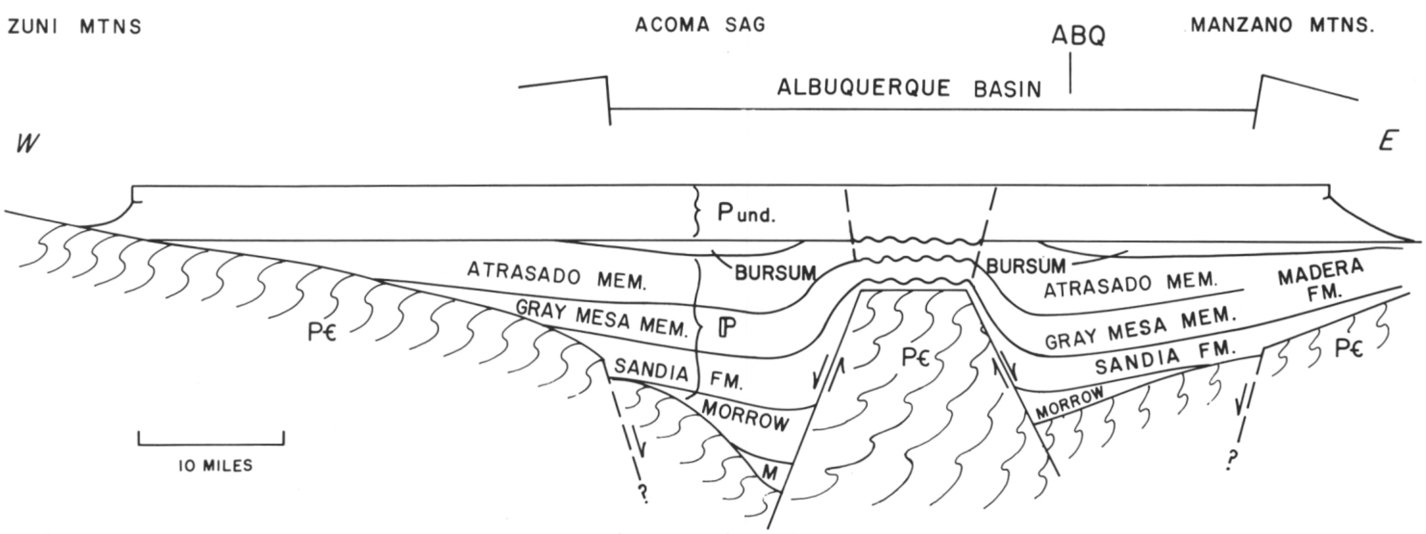

Figure 4. Generalized cross section from west to east across the central Albuquerque basin, representing interpreted relationships at about Permian time. The interpretation is based on relationships observed in outcrops in the Joyita Hills and in the southern Nacimiento Mountains (without the benefit of seismic data) and in deep wells drilled recently by Shell Oil Company. The basement high under the basin is undoubtedly far more complex than shown here but must be generally as illustrated. The approximate location of surface bounding faults of the Albuquerque basin is shown at the top for orientation. Symbols: M = Mississippian; Pund = Permian undifferentiated (Abo and younger beds).

17 m.y. ago, the monocline of Kelley collapsed across the pre-existing structure, utilizing already weakened basement fractures.

And why in the world would the Albuquerque rift take a sharp turn to the northeast in the Espanola basin to join the north-trending San Luis basin? It is here suggested that the Nacimiento—San Pedro—Joyita uplift is a southern extension of the San Luis (Uncompahgre) uplift that has been displaced in a right-lateral sense along a major basement fracture lineament previously described as a hypothetical lineament (fig. 1) that extends northwestward across the entire Colorado Plateau. Thus, the north-south basement fractures along which the Rio Grande rift formed were offset in a northwesterly direction, creating a kink in the rift in the Espanola basin area. This also provided a "soft spot" for the Jemez volcanic complex to utilize.

A number of structural geologists have called upon a rotation of the Colorado Plateau to form the compressional Uinta Mountains and open up the Rio Grande rift in Laramide time. The only problem with that suggestion is that the timing is all wrong. In the first place, the Uinta Mountain arch was in place in Late Precambrian time and only enhanced by the Laramide events. The second problem is that the Albuquerque section of the Rio Grande rift was a compressional monoclinal feature in Laramide time (Kelley, 1977) and did not begin its collapse until about middle Miocene time. If the Colorado Plateau ever did rotate clockwise as suggested, it had to be a Precambrian event dating around 1.7 b.y. Perhaps we have all just misplaced a decimal point, changing 1.7 b.y. to 17 m.y.

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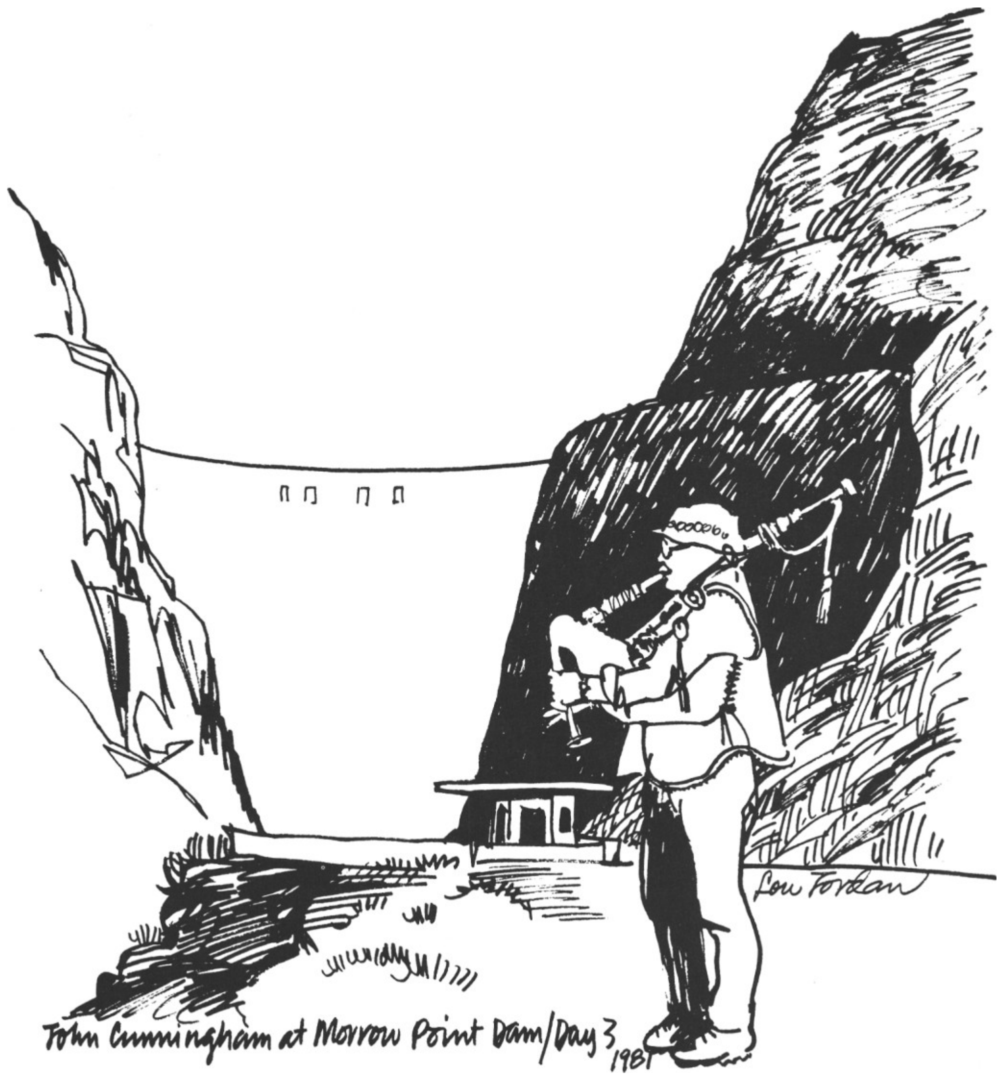
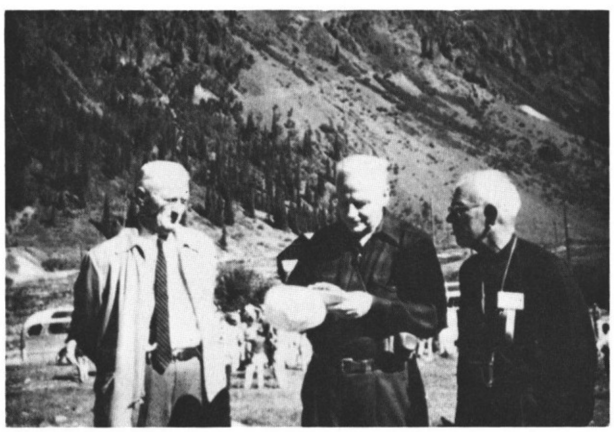


Some guys with limited intellectual capacity have to carry voluminous files along to help run a field trip. Sherm Wengerd at the D&RG Train Station, Silverton. September 7.

Deep in the Precambrian of the Animas post-glacial gorge between Silverton and Durango. A stop by the D&RG tracks. Terrible rocks, good only to furnish sediments to make sedimentary rocks that could contain oil. Saturday, September 7.



Three grand "old" men—far younger than their age—stalwarts in the early and middle history of the New Mexico Geological Society. From the left—Tom Cabeen, manager of Arizona–New Mexico Land Company; Martin Van Couvering, independent from California and 1960 Honorary Life Member of the Society; and John "Navajo Jack" Frost, Conservation Manager for the USGS in Artesia, New Mexico until his death a few years after this photo was taken. Jack was Vice-Prexy of the Society during this field trip. All have passed on, and all were vital to natural resource exploration in New Mexico and the West in general. Stop #3. East of Silverton, Saturday, September 7.