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STRUCTURE AND STRATIGRAPHY IN THE VICINITY OF THE SHELL OIL CO. SANTA FE PACIFIC NO. 1 TEST WELL, SOUTHERN SANDOVAL COUNTY, NEW MEXICO[1]

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INTRODUCTION

The petroleum resources of rocks older than the Tertiary Santa Fe Group in the Rio Grande trough of central New Mexico are virtually untested. Prior to the completion of the Shell Oil Co. Santa Fe No. 1 test well, geologists could only speculate about the stratigraphic section beneath the Santa Fe Group in the northern part of the Albuquerque-Belen basin. Useful subsurface control and valuable information pertaining to the Lower Cenozoic, Mesozoic, and Paleozoic rocks in the basin has been obtained from this "wildcat" oil-test well.

The Santa Fe Pacific No. 1, located about 7 miles (11 km) northwest of Bernalillo in sec. 18, T.13 N., R.3 E., was spudded in the Santa Fe Group on June, 1972, and subsequently abandoned on August 28, 1972 at a depth of 11,045 ft (3,367 m) after penetrating 90 ft (27.4 m) of the Precambrian basement complex (Fig. 1; Plates 1 and 2, in pocket inside back cover of guidebook).

The depth and altitude with respect to sea level of some of the stratigraphic horizons encountered during the drilling of this important test well are shown in Table 1. The depths to several of the stratigraphic units were released by Shell Oil Co. to the public and were confirmed by correlation with electrical logs of the well. Additional stratigraphic horizons were determined by correlation of the electrical logs from the Shell Oil Co. Santa Fe Pacific No. 1 with similar logs run in other wells in the basin and nearby areas (see Table 2).

The stratigraphic nomenclature used in this report is that used by the New Mexico Geological Society and does not necessarily conform to that used by the U.S. Geological Survey.

Acknowledgement

The assistance provided by Shell Oil Company is gratefully appreciated.

STRUCTURE AND STRATIGRAPHY

Generalized structural setting

The Shell Oil Co. Santa Fe Pacific No. 1 well was drilled in the northern part of the Albuquerque-Belen basin, the largest basin in the Rio Grande trough (Fig. 1 and Pls. 1 and 2). The Rio Grande trough is a series of complexly faulted grabens, arranged en echelon, extending from the northern end of the San Luis basin in Colorado, southward along the course of the Rio Grande in New Mexico, to near El Paso, Texas (Kelley, 1952, and 1954; and Joesting, Case, and Cordell, 1961). The age of the faulting is generally considered to be Late Tertiary.

[1]Publication approved by Director, U.S. Geological Survey.

The Albuquerque-Belen basin trends in a north-northeasterly direction; it is approximately 90 miles (145 km) long and 30 miles (48 km) wide. The uplifted Sandia and Manzano Mountains form the eastern boundary of the basin in the Albuquerque area. The western margin of the Albuquerque-Belen basin is formed by the Ladron and Lucero uplifts, the Puerco platform, and the southern extension of the Nacimiento Mountains. Structural displacement along the front of the Sandia Mountains may be as much as 22,000 ft (6,700 m), whereas the western margin of the basin is probably displaced about 16,000 ft (4,880 m) oesting, Case, and Cordell, 1961).

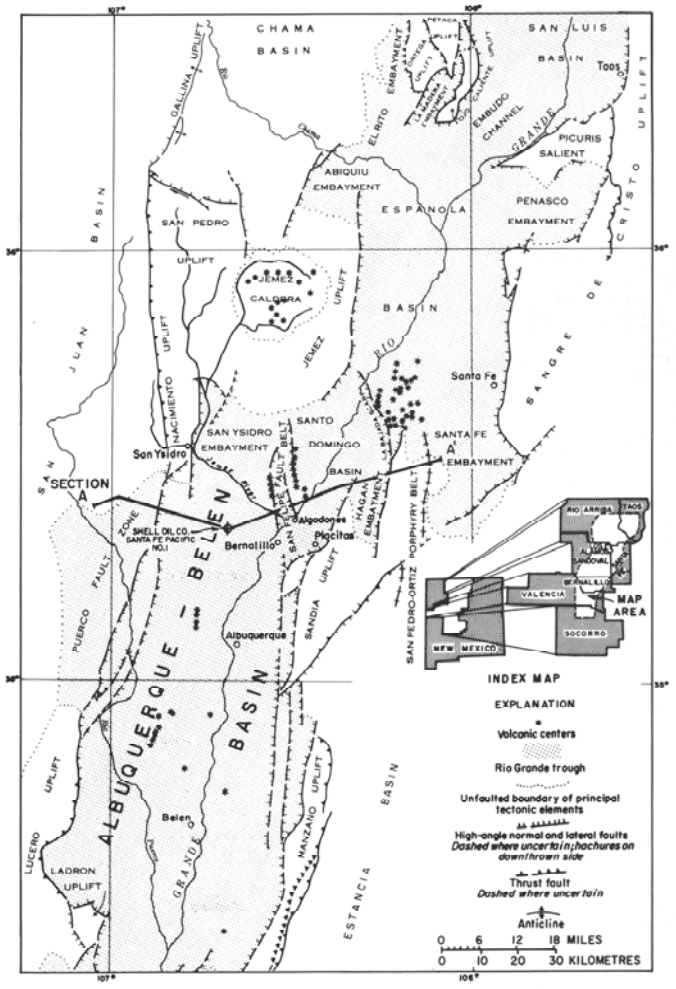

Figure 1. Tectonic diagram of a part of the upper Rio Grande area. [Adapted from Kelly (1954), and from Dane and Bachman (1965).]

Table 1. Depth to and altitude of stratigraphic horizons encountered in the Shell Oil Co. Santa Fe Pacific No. 1 [Altitude of land surface at well is 5,733 ft (1,747.4 m).]

Erathem	System	Series	Stratigraphic unit	Depth from kelly bushing reference datum, 5,753 ft (1,753.5 m) above sea level[1]		Altitude above(+) or below(-) sea level	
				Feet	Metres	Feet	Metres
Cenozoic	Tertiary	Pliocene-Miocene	Santa Fe Group	0	0	+5,733	+1,747
			Zia Sand Formation of Galusha (1966)	2,800	853	+2,953	+ 900
		Eocene	Galisteo-San Jose Formations undivided	2,970	905	+2,783	+ 848
Mesozoic	Cretaceous	Upper	Menefee Formation	3,644	1,111	+2,109	+ 643
			Point Lookout Sandstone	4,378	1,334	+1,375	+ 419
			Mancos Shale	4,520	1,378	+1,233	+ 376
			Crevasse Canyon Formation	4,920	1,500	+ 833	+ 254
			Niobrara Formation	5,695	1,736	+ 58	+ 18
			Sanostee marker[2]	6,095	1,858	- 342	- 104
			Greenhorn Limestone	6,426	1,959	- 673	- 205
			Dakota Sandstone	6,542	1,994	- 789	- 240
			"A" Sandstone Zone[2]	6,542	1,994	- 789	- 240
			"B" Sandstone Zone[2]	6,600	2,012	- 847	- 258
			"C" Sandstone Zone[2]	6,710	2,045	- 957	- 292
		Lower	"D" Sandstone Zone[2]	6,793	2,071	-1,040	- 317
	Jurassic	Upper	Morrison Formation	6,907	2,105	-1,154	- 352
			Todilto Limestone	7,452	2,271	-1,699	- 518
		Lower	Entrada Sandstone	7,528	2,295	-1,775	- 541
	Triassic	Upper	Chinle Formation	7,727	2,355	-2,004	- 611
			Agua Zarca Sandstone Member	8,738	2,663	-2,985	- 910
Paleozoic	Permian	Leonardian	San Andres Limestone	8,875	2,705	-3,122	- 952
			Glorieta Sandstone	8,900	2,713	-3,147	- 959
			Yeso Formation	8,990	2,740	-3,237	- 987
			Meseta Blanca Sandstone Member	9,375	2,858	-3,622	-1,104
		Wolfcampian	Abo Formation	9,500	2,896	-3,747	-1,142
	Pennsylvanian		Madera Limestone	10,376	3,163	-4,623	-1,409
			Sandia Formation	Not Present		-	-
Precambrian	-	-	Precambrian	10,955	3,339	-5,202	-1,586

1/ Reference datum is 20 ft (6.1 m) above land surface. Depths recorded on electrical logs are referenced to this datum.

2/ Marker beds and zones used locally in northwestern New Mexico.

Late Tertiary and Cretaceous Strati graphic Relationships

Late Tertiary sediments are present on the surface over most of the northern part of the Albuquerque-Belen basin. They have been studied by Stearns (1943, 1953a, and 1953b), Spiegel (1961), Galusha (1966); and others. Spiegel (1961) mapped the surface geology of the lower Jemez River region and subdivided the Santa Fe Group into three unnamed formations and several members. The formational units of Spiegel can be traced throughout much of the report area and are shown on Plate 2.

The Miocene Zia Sand Formation, named and described by Galusha (1966), is prominently exposed in sec. 3, T.15 N., R.1 E. The Galisteo-San Jose Formations, and locally the Cretaceous Menefee Formation and Mancos Shale, are overlain by the Zia Sand Formation with angular unconformity in this area. The Zia Sand Formation is present in the Shell Oil Co. Santa Fe Pacific No. 1 well from a depth of 2,800 ft (850 m) to the top of the Galisteo-San Jose Formations at 2,970 ft (905 m).

In southern Sandoval County, the Lower Tertiary San Jose and Galisteo Formations were apparently deposited in individual basins lying to the northwest and east, respectively, of the tectonically active southern extension of the Nacimiento uplift. However, the two units are not easily distinguishable in the vicinity of the medial Nacimiento uplift. Therefore, the San Jose and Galisteo Formations arc, at least in part, age equivalents and are referred to in this report as the Galisteo-San Jose Formations and are not differentiated.

The Galisteo-San Jose Formations of Eocene age underlie the Miocene Zia Sand Formation within the report area. These units have been observed to overlie Cretaceous rocks with angular unconformity in sec. 33, T.15 N., R.1 E., and secs., 2, 3, and 4, T.14 N., R.1 E. Slack (1973) recently mapped these Tertiary sediments as the San Jose Formation and correlated them with the Cuba Mesa and Regina members of the San Jose

Table 2. Thicknesses of stratigraphic units in the vicinity of the Shell Oil Co. Santa Fe Pacific No. 1.

Erathem	System	Series	Stratigraphic unit	Avila Oil Company Odlum Federal No. 1, Sec.15, T.15 N., R.1 W. Sandoval Co., N. Mex		Shell Oil Company Santa Fe Pacific No. 1, Sec.18, T.13 N., R.3 E. Sandoval Co., N. Mex.		Composite section from Sandia Mountains Kelly and Read (1962)	
				Feet	Metres	Feet	Metres	Feet	Metres
Cenozoic	Tertiary	Pliocene-Miocene	Santa Fe Group and Zia Sand Formation of Galusha (1966)			2,970	905	"Up to several thousand feet" (Kelly and Read, 1962, p. 15)	
		Eocene	Galisteo-San Jose Formations undivided			674	205	2,400	732
Mesozoic	Cretaceous	Upper	Menefee Formation Point Lookout Sandstone Mancos Shale Crevasse Canyon Formation Niobrara Formation Sanostee marker[1] Greenhorn Limestone Dakota Sandstone "A" Sandstone Zone[1] "B" Sandstone Zone[1] "C" Sandstone Zone[1]			3,263	995	3,800-4,750	1,158 -1,448
		Lower	"D" Sandstone Zone[1] (undivided)						
	Jurassic	Upper	Morrison Formation	> 738[2]	> 68[2]	545	166	500-1,000	152 - 305
			Todilto Limestone	122	37	76	23	5- 250	1.5- 76
		Lower	Entrada Sandstone	200	61	199	61	100- 150	30 - 46
	Triassic	Upper	Chinle Formation	1,080	329	1,011	308	1,000-1,500	305 - 457
			Agua Zarca Sandstone Member	80	24	137	42	600- 800	183 - 244
Paleozoic	Permian	Leonardian	San Andres Limestone	90	27	25	8	100- 200	30 - 61
			Glorieta Sandstone	640	195	90	27	50- 150	15 - 46
			Yeso Formation	710	216	385	117	400- 500	122 - 152
			Meseta Blanca Sandstone Member	70	21	125	38	Not recognized	
		Wolfcampian	Abo Formation	815	248	876	267	800-1,000	244 - 305
	Pennsylvanian		Madera Limestone	705	215	579	176	1,000-1,300	305 - 396
			Sandia Formation			-	-	50- 270	15 - 82
Precambrian	-	-	Precambrian	-		-	-	-	-
			Combined Paleozoic, Triassic, and Jurassic strata	>5,250	>1,600	4,048	1,234	5,680	1,731

1/ Marker beds and zones used locally in northwestern New Mexico.
2/ Commenced drilling in eroded Jurassic Morrison Formation.

Formation, as named and described by Baltz (1967) from outcrops near Cuba, N. Mex.

The Shell Oil Co. Santa Fe Pacific No. 1 well was fortuitously located at the midpoint between outcrops of Cretaceous strata on opposite sides of the Albuquerque-Belen basin. Using the section penetrated in this well, the Cretaceous rocks can be correlated with exposures on either side of the basin and with similar strata in the southern Nacimiento Mountains to the northwest and the northern Sandia Mountains to the southeast.

Cretaceous strata observed in outcrops in Tps. 14 and 15 N., R.1 E., on the west side of the Albuquerque-Belen basin are essentially equivalent to the Cretaceous exposed on the east side of the trough in Tps.12 and 13 N., Rs.4 and 5 E., and Tps.10 and 11 N., Rs.5 and 6 E. A similar correlative Cretaceous section appears to have been penetrated in the Shell Oil Co. Santa Fe Pacific No. 1 well. No evidence of structural deformation or unusual subsidence in the area of the Albuquerque-Belen basin can be inferred to have taken place during the Cretaceous. In this well, the Cretaceous is overlain by the Galisteo-San Jose Formations, probably along an angular unconformity, as observed in outcrops.

The presence of Cretaceous rocks at least as young as the Menefee Formation at this location indicates that there was no pronounced uplift of the area prior to subsidence into the Albuquerque-Belen basin and suggests that Cretaceous rocks may be preserved at depth over large areas of the Rio Grande trough. A discussion of the detailed lithology of the various Cretaceous units is beyond the scope of this short paper; however, the lithologies as inferred from the electrical logs appear to be essentially identical to those observed in the outcrops on either side of the basin. A northwest-trending coastline during Cretaceous time similar to the trend of the coastline in the San Juan Basin is suggested by these relationships.

Pre-Cretaceous Stratigraphic Relationships

The apparent thinning of the pre-Cretaceous section, the Paleozoic units in particular, in the section penetrated in the Shell Oil Co. Santa Fe Pacific No. 1 is of interest. A comparison of the section penetrated in the Shell Oil Co. Santa Fe Pacific No. 1 to the section drilled in the Avila Oil Co. Odium Federal No. 1 well in sec. 15, T.15 N., R.1 W. located approximately 18 miles (29 km) to the west (Pls. 1 and 2; Table 2), and to the composite section for the northern Sandia Mountains given by Kelley and Read (1961) suggests that Shell may have drilled the Santa Fe Pacific No. 1 well on or near a persistent Paleozoic structural high. However, the possibility of thinning by normal faulting in the Shell well cannot be disregarded, particularly in the Paleozoic section where correlations are difficult. The Pennsylvanian Sandia and Mississippian Arroyo Penasco Formations, if present in the well, were exceptionally thin and were not recognizable. These units

probably either were never deposited in this area or, if deposited, were removed by erosion prior to deposition of the Madera Limestone.

Unconformities Observed in the Northern Part of the Albuquerque-Belen Basin

Approximately 12 miles (19 km) to the northwest of the Shell Oil Co. Santa Fe Pacific No. 1 well in the northern one-half of T.14 N., R.1 E. Cretaceous strata are unconformably overlain by the Galisteo-San Jose Formations (Fig. 2).

Approximately 12 miles (19 km) to the southeast of the Shell Oil Co. Santa Fe Pacific No. 1 well, the Galisteo Formation also unconformably overlies the Cretaceous. These exposures can be seen just west of Placitas in the southeast corner of T.13 N., R.4 E., and the western one-half of T.12 N., R.5 E.

Sands near the base of the Santa Fe Group, the Zia Sand Formation, the Galisteo-San Jose Formations, and Cretaceous rocks outcrop north and west of the Shell Oil Co. Santa Fe Pacific No. 1 well. At these localities, the angular unconformity between the Cretaceous and the overlying Lower Tertiary strata is particularly well exposed. The attitude of the beds and the unconformities exposed in this area are important factors to consider in understanding the tectonic events that have taken place west of the Albuquerque-Belen basin where the axis of the Nacimiento uplift plunges to the south under the Late Tertiary sediments.

In secs. 3, 4, 10, and 11, T.14 N., R.1 E., the Galisteo-San Jose Formations overlie Upper Cretaceous shales with a pronounced angular unconformity (up to 45 degrees). The Galisteo-San Jose Formations, in turn, have been faulted and folded. In secs. 3 and 4, T.14 N., R.1 E., the Zia Sand Formation overlies the Galisteo-San Jose Formations along an angular unconformity of up to 12 degrees. At one exposure, in sec. 4, the Galisteo-San Jose Formations were removed by erosion prior to deposition of the Zia Sand. Because of this, the Zia Sand now rests directly on Cretaceous strata. The Zia Sand Formation overlying the Galisteo-San Jose Formations now dips as much as 12 degrees to the south. According to Slack (1973) the "Middle Red Member" of the Santa Fe Group unconformably overlies the Zia Sand Formation in the northern one-half of T.14 N., R.1 E., and the Santa Fe Group also dips as much as 10 degrees to the south.

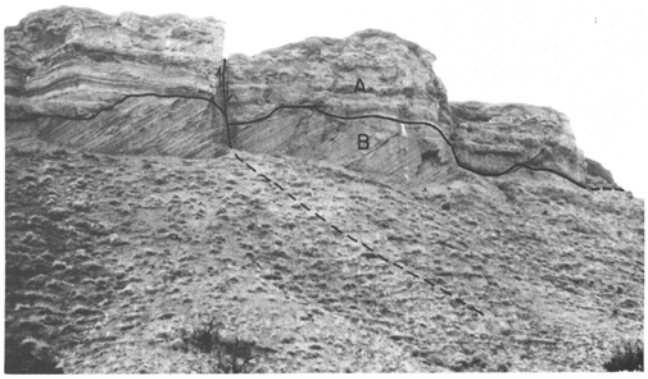

Figure 2. View to northwest of (A) basal part of Galisteo-San Jose Formations undifferentiated, unconformably overlying (B) steeply dipping Cretaceous shale; in sec. 3, T.14 N. R.1 E., Sandoval County, New Mexico. Small-scale normal faulting has displaced beds downward to the north.

This sequence of unconformities graphically demonstrates post-Cretaceous-pre-Galisteo-San Jose Laramide folding followed by erosion of the exposed uplifts and structures prior to deposition of the Tertiary rocks. A conglomeratic sandstone unit composed predominantly of Cretaceous debris, but also containing numerous clasts of Permian and Pennsylvanian rocks and even Precambrian detritus is present near the base of the Galisteo-San Jose Formations. This sandstone was probably deposited in or on the margin of one of the structurally high and tectonically active features that probably separated the Early Tertiary basins. Most of these clasts indicate that the Nacimiento uplift was already well exposed to the north and in places may have been stripped as deep as the Precambrian by Galisteo-San Jose time, although the quartzite clasts suggest a Brazos or Sangre de Cristo source further to the northeast (Baltz, 1967). The upper units of the Galisteo-San Jose Formations in this area generally are composed of much finer-grained elastics. These predominantly red, pale green, and cream colored siltstones, mudstones, and shales with some sandstones suggest a rather quiet environment of deposition.

Post-Galisteo-San Jose folding in secs. 1 and 3, T.14 N., R.1 E. resulted in southern and eastern tilting of these beds. Uplift, folding, and subsequent erosion, particularly in the eastern one-half of sec. 4, T.14 N., R.1 E., occurred along the western edge of the projected southern-plunging axis of the Nacimiento uplift. In this area, locally, pre-Zia Sand Formation erosion completely removed the Galisteo-San Jose sediments and cut into the underlying Cretaceous sediments.

The Zia Sand Formation was subsequently deposited on this unconformable surface and then folded, faulted, tilted—generally in a southerly direction—as the uplift of the Nacimiento positive area continued. The "Middle Red Member" of the Santa Fe Group then was deposited unconformably on the Zia Sand Formation. Subsequently, the entire stratigraphic section was faulted and folded as the Albuquerque-Belen basin subsided to the east. Meanwhile, the Nacimiento uplift probably continued to move intermittently. The present topography was sculptured during the Pleistocene and Holocene Epochs.

Delineation of Deeper Structures

A careful reconstruction of the pre-Galisteo-San Jose and pre-Cretaceous structures in this area suggest the presence of a series of north-northwest trending folds that are probably related to a structural trend with similar axial orientation found as far north as Cuba in the Cretaceous outcrops on the west side of the Nacimiento fault (Baltz, 1967). The unconformable relationships overlying these structures date this folding as Larmide (pre-Galisteo-San Jose) in age. The fact that the Galisteo-San Jose is itself overlain by the Zia Sand Formation along an angular unconformity suggest further Tertiary movement of the Nacimiento uplift—possibly a sporadic continuation of the last of the Laramide tectonic activity in this area. This area of interesting stratigraphic and structural change lies directly on the southward projection of the Nacimiento uplift.

A generalized geologic section extending approximately 60 miles (95 km) from the Rio Puerco on the west across Mesa Prieta through the Humble Oil and Refining Co. Santa Fe Pacific No. B-1, sec. 20. T.14 N., R.2 W., the Shell Oil Co. Santa Fe Pacific No. 1, sec. 18, T.13 N., R.3 E., and the Tejon

Oil Co. No. 1, sec. 7, T.14 N., R.6 E., wells and terminating in the Cerillos Hills is shown in Plates 1 and 2 (in pocket). The Shell Oil Co. Santa Fe Pacific No. 1 well was drilled near the crest of a large gravity high located west of Bernalillo. The test well confirmed beliefs that this prominent high was probably underlain by denser Paleozoic and Precambrian rocks covered with a relatively thin valley fill (Joesting, Case, and Cordell, 1961). This feature has been interpreted as a large horst block at depth (Pls. 1 and 2, in pocket).

Key exposures leading to a definition of the Late Tertiary structural pattern of the Albuquerque-Belen basin can be seen two miles (3 km) northwest of the Shell Oil Co. Santa Fe Pacific No. 1 test well in sec. 11, T.13 N., R.2 E. The Santa Fe Group, well exposed in badlands topography in this area, dips gently 10 to 15 degrees to the south and cast. The prevailing eastward dip of the Santa Fe beds can be observed in scattered outcrops from this locality to a point east of Bernalillo. West of sec. 11, T.13 N., R.2 E., however, a dramatic reversal of dip occurs and the sediments dip generally southwesterly for several miles at 15 to 20 degrees.

The axial trend of a large southerly plunging anticline herein referred to as the Ziana anticline can be followed on the surface from sec. 11, T.13 N., R.2 E. northward approximately 12 miles (19 km) to the vicinity of T.15 N., R.3 E. The Ziana anticline can be traced only with difficulty for a distance of approximately 10 miles (16 km) south of sec. 11, T.13 N., R.2 E. because the surface in this area is generally covered by Quaternary sands and gravels (Pl. 2 and Fig. 3). The strike of many normal faults of undetermined displacement generally parallels the axis of this large anticline. On the east side of the anticline, the fault planes of the larger faults generally dip easterly at 70 to 90 degrees, whereas, in locations west of the axis of the Ziana anticline, the fault planes of several apparently major normal faults dip westerly at 70 to 90 degrees. Smaller-scale normal faults are common and can be frequently found near and parallel to the crest of the anticline (Fig. 3).

The large faults appear to have formed in response to differential movement of deep-seated fault blocks underlying the Santa Fe Group, and therefore, they probably represent the surface expression of large normal faults that displace the basement rocks. Small-scale, eastward-dipping, normal faulting just west of the crest of the Ziana anticline undoubtedly indicates tensional relief over the crestal area of the structure (Figs. 3 and 4).

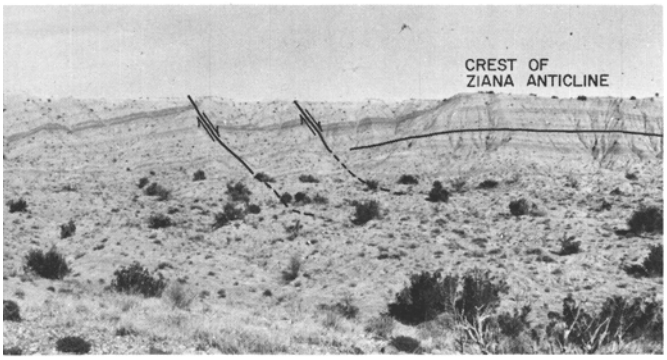

Figure 3. Santa Fe Group in a view to north along the crest and west flank of the Ziana anticline in sec. 1, T.13 N., R.2 E., Sandoval County, New Mexico. Small-scale, normal faults displace strata on the west flank of the structure. Fault planes dip to the east.

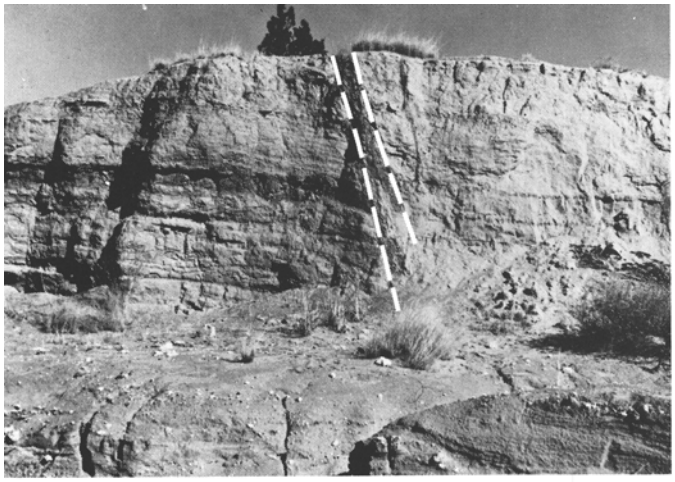

Figure 4. View to north of small-scale normal faulting in the Santa Fe Group in sec. 35, T.14 N., R.2 E., Sandoval County, New Mexico. Drag of bedding adjacent to fault plane can be seen. Gouge zone is approximately 10 inches (25 cm) wide.

West of sec. 1, T.13 N., R.2 E., a number of small, faulted anticlines and synclines with northerly trending axes can be seen in the exposed Santa Fe Group. However, west of the crest of the Ziana anticline the dip of the Santa Fe Group is generally southwesterly. Other than possible local closure resulting from small-scale normal faulting, no closure on the northern end of the Ziana anticline can be mapped on the surface. The Ziana anticline appears to open to the north in the northern one-half of T.15 N., R.3 E. From this point northward, the prevailing dip of the Santa Fe Group is to the east. The Ziana anticline, as mapped in exposures of the Santa Fe Group, has probably also resulted from differential movement of major fault blocks in the Rio Grande trough. The Santa Fe beds were probably folded and faulted over a deep-seated horst that subsided into the Albuquerque trough at a slower rate than the adjacent fault blocks. The large gravity high in the area may also be the result of that form of tectonism.

West of the Shell Oil Co. Santa Fe Pacific No. 1, a major fault that is possibly an extension of the Jemez fault zone (Pl. 1) can be traced southward from San Ysidro and State road 44 in outcrops of the Santa Fe Group. On the west side of the fault zone in the northeastern part of T.14 N., R.1 E., both Cretaceous beds and the Galisteo-San Jose Formations are in fault contact with the folded Santa Fe Group.

CONCLUSIONS

The stratigraphic and structural relationships observed in the northwestern part of the Albuquerque-Belen basin and on the southward-plunging Nacimento uplift clearly document the Late Cretaceous to Holocene geologic history of this relatively unexplored part of New Mexico. Multiple periods of tectonic unrest and subsequent erosion and deposition are recorded in the spectacular angular unconformities of the area. The potential for development of additional oil, gas, uranium, coal, geothermal, and ground-water resources make the geologic understanding of this area not only of academic interest but also of great economic importance for the future of New Mexico.

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