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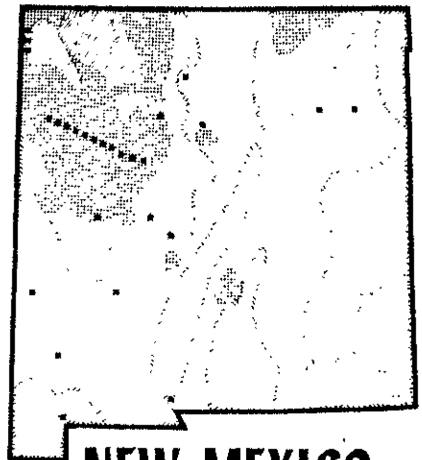
(505) 835-5545



NEW MEXICO
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FINAL REPORT
COAL, URANIUM, OIL & GAS POTENTIAL
OF THE RILEY—PUERTECITO AREA, SOCORRO COUNTY, NEW MEXICO

Charles E. Chapin, Principal Investigator
Glenn R. Osburn, Co-Investigator
Stephen C. Hook, Co-Investigator
Gary L. Massingill, Co-Investigator
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Principal Investigator:
Charles E. Chapin, Ph.D.
New Mexico Bureau of Mines and Mineral Resources

Technical Report

by

Charles E. Chapin, Ph.D.
Glenn R. Osburn
Stephen C. Hook, Ph.D.
Gary L. Massingill
Stephen J. Frost
New Mexico Bureau of Mines and Mineral Resources

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ABSTRACT

The Riley-Puertecito area is located on the southeastern margin of the Colorado Plateau and is underlain by a west-northwest-trending belt of gently dipping Cretaceous and Cenozoic rocks cut by numerous faults and igneous intrusions. Coal beds occur near the base and top of the Mesaverde Formation of Upper Cretaceous age. Coals in the lower Mesaverde were deposited on a coastal or delta plain in a mixed brackish and fresh water environment. Analyses of three samples from beds 13 inches to 5 feet thick yielded values (as received) of 5137 to 9083 BTU/lb, 13.2 to 39.0% ash, and 0.5 to 0.9% sulfur. They range in thickness from one to five feet, but may aggregate as much as 8 feet of coal in areas of stacked coal seams. Coals in the upper Mesaverde were deposited in fresh-water swamps further inland. Analyses of four samples from beds 11 inches to 3.2 feet thick yielded values (as received) of 6083 to 11,555 BTU/lb, 6.4 to 40.3% ash, and 0.3 to 0.5% sulfur. Upper Mesaverde coals occur as isolated, lenticular beds that change thickness rapidly. Inferred resources were not calculated because of lack of subsurface data and structural complexities. Indicated resources of lower Mesaverde coals southwest of Riley are about 1,000,000 tons of bituminous and subbituminous coal which could be mined with a maximum stripping ratio of 10:1. The best use of the coal would probably be a cement plant that could utilize the abundant limestone, travertine, and shale found in this area.

Small, scattered occurrences of uranium are present in terrestrial sandstones of the Baca Formation of Eocene age. A fluvial sandstone facies, 0 to 176 feet thick, crops out over a distance of about five miles along the northeastern edge of the Bear Mountains, southwest of Riley. The sandstone is bleached, contains abundant carbonaceous material, and could contain commercial uranium deposits where downfaulting has protected it from leaching.

The oil and gas potential of Cretaceous rocks in the Riley-Puertecito area is negligible because of shallow depth of burial, low degree of thermal maturation, and probable flushing by ground water. However, structural information developed during this study may be helpful in evaluating deeper formations.

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I. INTRODUCTION

The purpose of this report is to present a concise summary of the coal, uranium, and oil and gas potential of the Riley-Puertecito area along with the geologic maps and stratigraphic framework essential to mineral exploration. Details of the geology are available in the theses and 1:24,000 geologic maps completed as part of the project, all of which are available as open-file reports from the New Mexico Bureau of Mines and Mineral Resources.

The Riley-Puertecito area is located about 20 miles north of Magdalena in northwestern Socorro County, New Mexico. The area lies along the southeastern margin of the Colorado Plateau and consists of Cretaceous and Eocene sedimentary rocks overlain by Cenozoic volcanic and sedimentary rocks, all dipping gently southwestward away from the Colorado Plateau. Attention has been focused on the area in recent years because of the occurrence of coal beds in Cretaceous rocks, uranium prospects in Eocene rocks, and a geologic setting favorable for hydrocarbon exploration.

In May 1976, the New Mexico Bureau of Mines and Mineral Resources began a detailed geologic study of the Riley-Puertecito area in anticipation of probable exploration for energy fuels. The project began as an extension of geologic mapping conducted in the Socorro-Magdalena area since 1970 by the senior author and several graduate students. Detailed mapping and subdivision of the Cretaceous rocks was made possible by paleontological and stratigraphic studies begun in 1976 by S.C. Hook and conducted in collaboration with W.A. Cobban of the U.S. Geological Survey. Since September 1977, the project has been 50% funded by a grant from the New Mexico Energy Resources Board through the Energy Institute at New Mexico Institute of Mining and Technology. The project has been a team effort with overall direction by the senior author and with major assistance by S.C. Hook in the areas of paleontology and Cretaceous stratigraphy. Four thesis and dissertation projects were supported by the grant and provided most of the data on which this report is based. These projects are: 1) Riley-Puertecito area, Ph.D. dissertation, G.L. Massingill, University of Texas at El Paso; 2) Puertecito-La Cruz Peak area, M.S. thesis, R.A. Jackson, New Mexico Tech; 3) Corkscrew Canyon-Abbe Springs area, M.S. thesis, D.L. Mayerson, New Mexico Tech; and 4) Palynology and thermal maturation of organic matter in Cretaceous and Eocene rocks, Ph.D. dissertation, M.S. Chaiffetz, University of Texas at El Paso. Pebble compositions and transport directions in the Miocene Popotosa Formation were determined by G.R. Osburn of the New Mexico Bureau of Mines and Mineral Resources. Chemical compositions and Sr^{87}/Sr^{86} ratios were determined for some of the intrusive rocks by D.L. White, while a post-doctoral fellow with the New Mexico Bureau of Mines and Mineral Resources. K-Ar dating of igneous rocks was performed by Geochron Laboratories and and A.L. Odom of Florida State University.

Three additional thesis and dissertation projects are currently underway to the west of the Riley-Puertecito area. These are: 1) D-Cross Mountain 7-1/2 minute quadrangle, Ph.D. dissertation, B.R. Robinson, University of Texas at El Paso; 2) Gallinas Peak area, M.S. thesis, T.M. Laroche, New Mexico Tech; and 3) a sedimentologic study of the Baca Formation in the Jaralosa Creek area, M.S. thesis, S.M. Cather, University of Texas at Austin. The details of these studies will be published in subsequent reports but they are acknowledged here for the regional perspective they have contributed to the Riley-Puertecito project. In addition, G.L. Massingill is completing a geologic map of the Puertecito 7-1/2 minute quadrangle while a post-doctoral fellow at the New Mexico Bureau of Mines and Mineral Resources.

Several projects of the Coal Research Group of the New Mexico Bureau of Mines and Mineral Resources have also helped in the preparation of this report. These include historical data on coal mining compiled by H.B. Nichelson and S.J. Frost, chemical analyses of coal performed by the U.S. Geological Survey under a grant to F.E. Kottlowski, and an exploratory hole drilled as part of the Datil Mountain Project of D.E. Tabet and S.J. Frost. Several members of the U.S. Geological Survey have also contributed to the project. We especially acknowledge the assistance given by W.A. Cobban to S.C. Hook on the paleontology and stratigraphy of Cretaceous units, the cooperation of

C.H. Maxwell and S.L. Moore on the correlation of stratigraphic units to the north; the assistance of M.N. Machette on Quaternary stratigraphy, and the funds contributed by the Branch of Central Environmental Geology to subsidize mapping for the Socorro 2-degree sheet.

II. GEOLOGIC SETTING

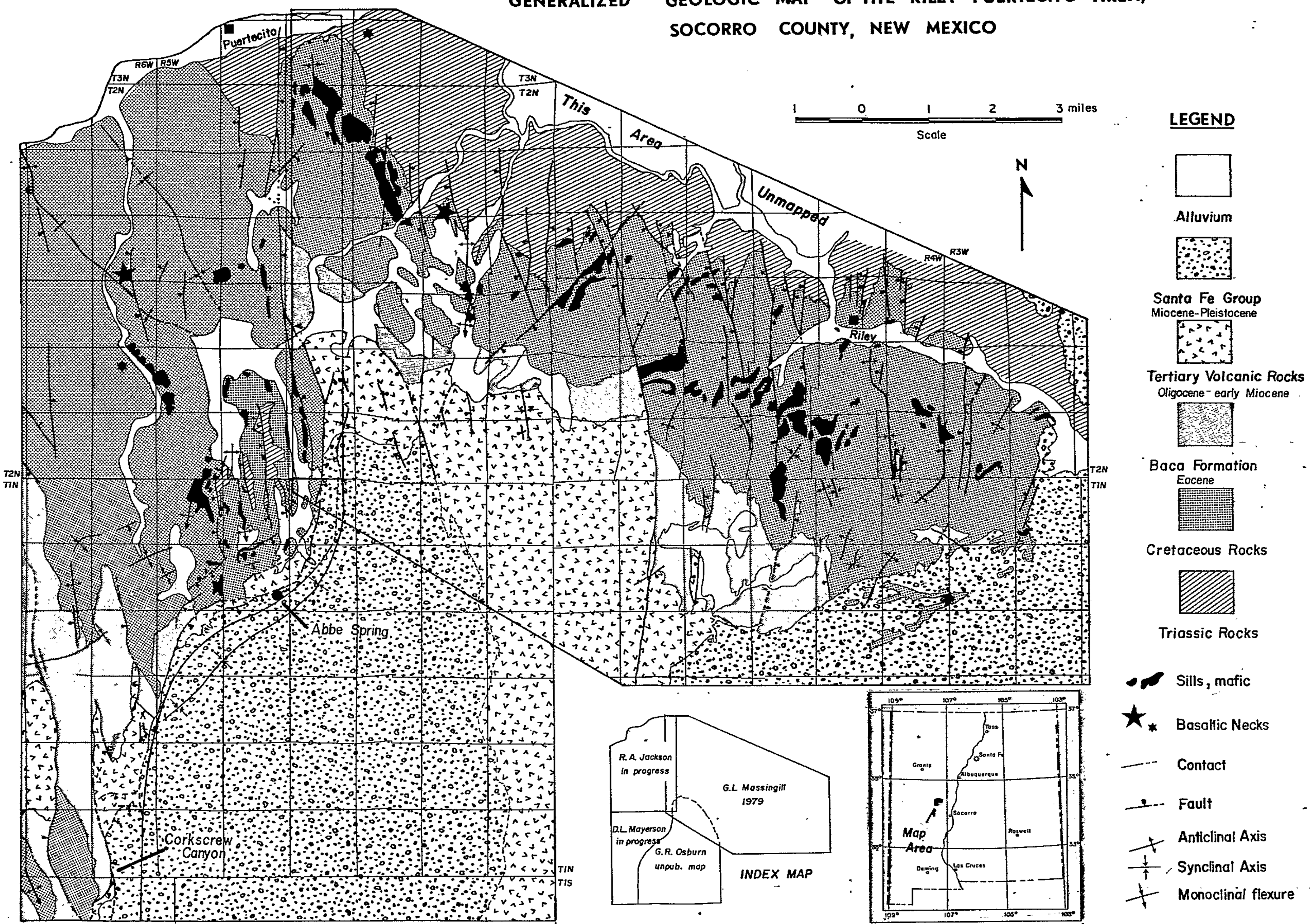
The Riley-Puertecito area is located along the southeastern margin of the Colorado Plateau, the western edge of the Rio Grande rift, and the northeastern margin of the Datil-Mogollon volcanic field (Fig. 2-1). Neogene uplift of the Colorado Plateau tilted Miocene and older strata 10 to 15 degrees to the south and southwest; subsequent erosion by the Rio Salado and its tributaries has exposed a west-northwest-trending outcrop belt of Triassic, Upper Cretaceous, and Cenozoic strata. The Upper Cretaceous Mesaverde Formation contains coal beds and the Eocene Baca Formation contains uraniferous sandstones. Four holes have recently been drilled for oil and gas exploration.

Surface structures in the Riley-Puertecito area are of four types: 1) broad, gentle, north- to northwest-trending anticlines and synclines that developed during Laramide compression; 2) north- to north-northwest-trending normal faults of small displacement that developed during the early stages of opening of the Rio Grande rift and were injected by magmas to form an extensive swarm of mafic dikes (Fig. 2-2); 3) north-trending normal faults of major displacement that bound the Mulligan Gulch graben and the tilted faultblock uplifts of the Gallinas and Bear Mountains; and 4) northeast-trending faults and flexures that formed at various times by reactivation of the

Tijeras lineament, a major northeast-trending basement fault zone of Precambrian ancestry.

Figure 2-1

GENERALIZED GEOLOGIC MAP OF THE RILEY-PUERTECITO AREA, SOCORRO COUNTY, NEW MEXICO



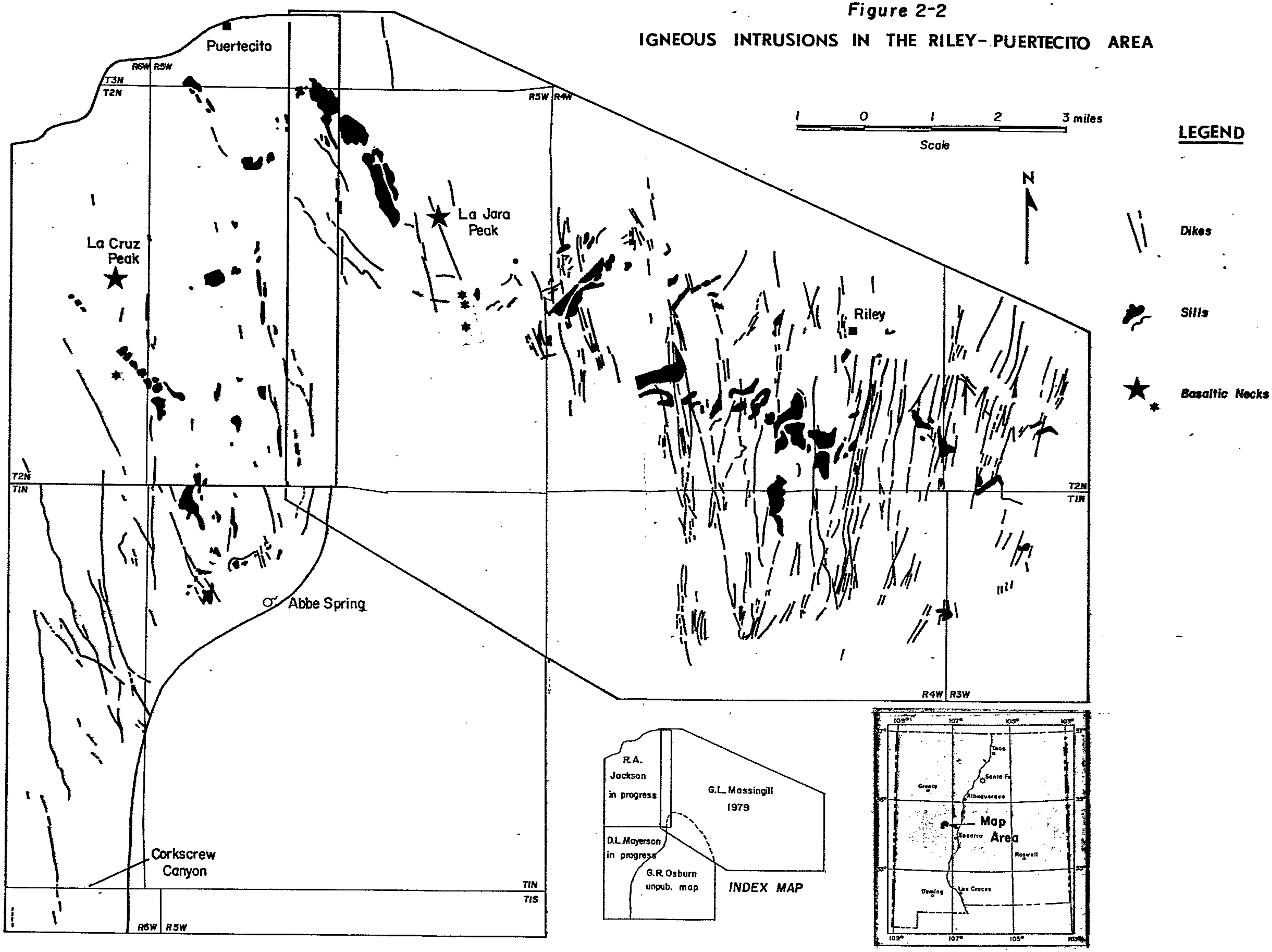


Figure 2-2

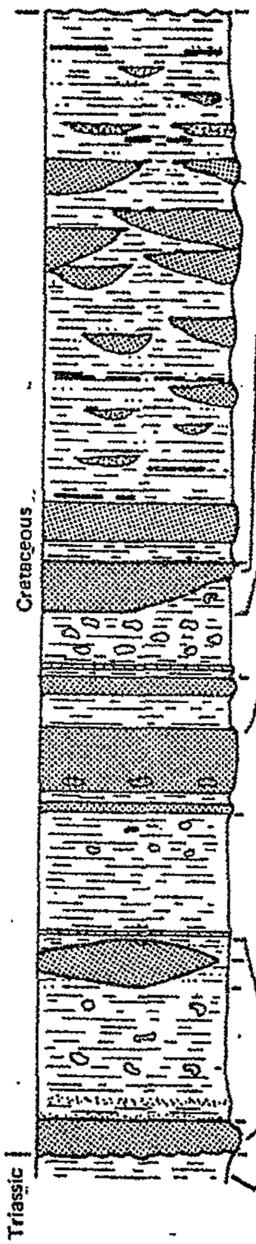
IGNEOUS INTRUSIONS IN THE RILEY-PUERTECITO AREA

III. COAL POTENTIAL

Stratigraphy, Distribution, Thickness

Coal occurs in both the lower and upper portions of the Mesaverde Formation of Upper Cretaceous age (Fig. 3-1). The lower coal-bearing interval begins about 60 feet above the base of the formation and contains numerous thin coal seams in a 200-foot sequence of shales containing thin interbeds of sandstone and siltstone. This lower coal-bearing interval is believed to be stratigraphically equivalent to the Dilco Coal Member of the Crevasse Canyon Formation (Molenaar, 1974); the sandstone underlying the coal-bearing interval is marine and correlative with the Gallup Sandstone (Molenaar, 1974). By agreement with United States Geological Survey personnel and other workers in the area, the term Mesaverde Formation will be abandoned in future reports and Crevasse Canyon Formation adopted.

Coal beds in the upper Mesaverde Formation occur 100 to 300 feet below the top of the unit. They tend to be isolated, lenticular coal seams that change thickness abruptly. Changes in depositional environment account for differences in composition and continuity of coals in the upper and lower Mesaverde Formation. Coals in the basal interval contain baltisphaerid algae typical of brackish water environments, and the enclosing shales are marine to transitional marine and contain at least



Mesaverde Formation: *(950-1050')* SANDSTONES, SHALES, SILTSTONES, and COAL: Generally non-marine sequence, yel.-brn. and grn. channel ss. separated by gry. to blk. shales, siltstones and coal beds. Ironstone concretions common. Lowest ss. is marine and correlative with the Gallup SS. (Molenaar, 1974).

Gallego Sandstone: *(20-100')* SANDSTONE: Brn. to brn.-yel. cliff-forming, highly bioturbated marine ss. Thins to unmapped 20' sandy interval in east part of area. Contains *Lopha sannionis, Inoceramus rotundatus, Inoceramus incertus,* and *Prionocycus quadratus.* (Unit as a formation will be discontinued-see Hook and Cobban, 1979).

Mancos Shale

D-Cross Tongue: *(120-180', to 300' where Gallego SS. missing or not mapped)* SHALE: Med. to drk.-gry., weathering to lt.-gry., fossiliferous, concretionary shale. Thin (7") wide-spread limestone near base. Contains *Scaphites ferronensis, Scaphites whitfieldi,* and *Prionocyclus novimexicanus.*

Tres Hermanos Sandstone Member: *(210-240')* SANDSTONE, SHALE, & SILTSTONE: Interbedded lt.-gry. to yel.-gry. marine ss. and brn.-yel. to drk.-gry. shales. Middle shales are usually non-marine. Contains *Collignoniceras woollgari* at base and *Lopha bellaplicata* at top.

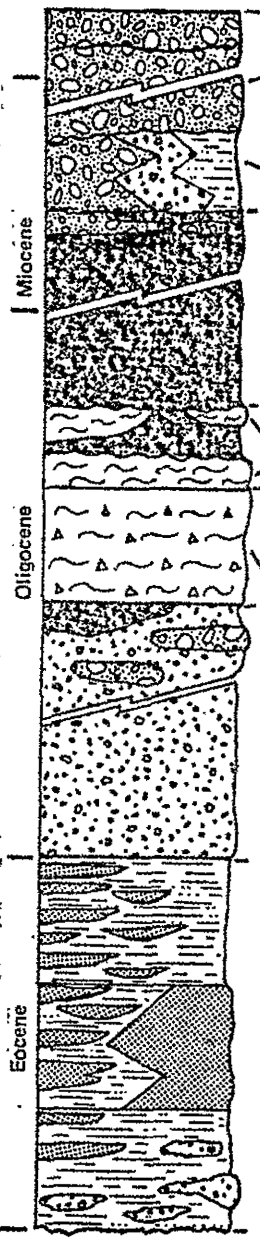
Alamito Well Tongue: *(550')* SHALE: Drk. to med.-gry. silty, fossiliferous concretionary shales. Divided by *Twowells Tongue of Dakota SS.* into lower, *Whitewater Arroyo* (name to be discontinued), contains *Inoceramus arvanus, Ostrea beloiti Turrilites acutus americanus;* and upper, *Rio Salado Tongue* (new name), has thin (6") limestone marker horizon near base. Contains *Sciponoceras gracile, Pycnodonte newberryi, Inoceramus mytiloides, Mammites depressus,* and *Collignoniceras woollgari.*

Dakota Sandstone

Twowells Tongue: *(0-60')* SANDSTONE: Lt.-gry. to yel., cliff-forming, bioturbated sandstone. Contains *Metiococeras defordi.*

Lower Tongue ("main body"): *(0-60')* SANDSTONE and SHALES: Yel. to brn.-yel. cross-bedded, ironstained ss., interbedded at top, in eastern part of area, with thin, dark, carbonaceous shales.

Chinle Formation: *(1150-1250')* SHALES, SILTSTONES, LIMESTONES, and SANDSTONES: Rd., pnk., gry., & grn. shales and siltstones with minor gry., thin-bedded freshwater limestone and yel. arkosic channel ss.



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Plio-Pleistocene Gravels: *(0-500')* CONGLOMERATES & CGL. SANDSTONES: Buff to tan, mod. to poorly indurated, heterolithic fanglomerates. Prob. age equivalent in eastern part to Sierra Ladrones Fm. (Machette, 1978).

Fanglomerate of Dry Lake Canyon: *(0-500')* CONGLOMERATES and SANDSTONES: Dk.-gry. to blk. andesite clasts in buff matrix, mod. to well-indurated conglomerates. Transport to west away from ancestral Magdalena Mtns.

Popotosa Formations: *(0-2000')* CONGLOMERATES, SANDSTONES, & SILTSTONES: Buff to tan, heterolithic, mod.-to well-indurated, crs. cgl. to west; grading into lt.-rd. to brn. muddy siltstones to east (1-3 miles). Transport to south or southeast away from Colorado Plateau. Lower interval interbedded wtih *La Jara Peak Basaltic Andesite* has transport to northeast.

La Jara Peak Basaltic Andesite: *24 to 32 m.y. (0-1200')* BASALTIC ANDESITE LAVAS: Dk.-rd. to blk., dense to vesicular, aphanitic lava flows with abundant red, hematized ferromag. phenocrysts. Upper part interbedded with *Popotosa Fm.,* lower with *A-L Peak Tuff.*

A-L Peak Tuff: *32 m.y. (0-300')* ASH-FLOW TUFFS: Basal gray-massive and flow-banded members undiff. (0-200'), upper pinnacles member (0-150'). Both mod. to densely welded, xl.-poor, 1-feldspar, rhyolite ash-flow tuffs. Sources are in the Magdalena area. Thicknesses partly controlled by paleotopography.

Hells Mesa Tuff: *32-33 m.y. (0-400')* ASH-FLOW TUFFS: Rhyolite, multiple-flow, simple cooling unit, densely welded, xl.-rich, qtz.-rich, 2-feldspar, massive tuffs. Pk. to red-brn. when fresh, weathers to blocky boulders. Source in Magdalena Mtns.

Spears Formation: *33-37 m.y. (0-1500')* SANDSTONES, CONGLOMERATES, MUDFLOW DEPOSITS, LAVAS, and minor ASH-FLOW TUFFS: Volcaniclastic apron of latite to andesite comp.; becomes coarser & contains more volcanic units up and to south. Transport to north.

Baca Formation: *(0-800')* SANDSTONES, SILTSTONES, and MUDSTONES: Rd.-brn. & pale-rd.-pur., med.- to crs.-grnd. ss. and minor cgl. intercalated with rd.-brn. and gry.-rd. mudstones and siltstones. In eastern half of area, center third of unit is 180-ft.-thk. interval of lt.-gn.-gry. to yel.-gry., clayey, poorly indurated sandstones and siltstones with abundant woody debris and cgl. lenses. This facies not recognized to west.

Figure 3-1. Composite stratigraphic column of the Riley-Puertecito area.

five dinoflagellate or planktonic algal morphologic types (M.S. Chaiffetz, 1978, written commun.). These coals apparently formed near mangrove or cyprus swamps on a coastal or delta plain. In contrast, coals in the upper Mesaverde contain abundant angiosperm pollen and lack marine or brackish water palynological indicators (M.S. Chaiffetz, 1978, written commun.). These coals apparently formed in isolated swamps on the upper coastal plain. They are often associated with fluvial sandstones (Massingill, 1979).

Coal beds in the lower Mesaverde range in thickness from a few inches to 5 feet. At some localities, a series of thin coal seams occurring through a stratigraphic interval of 20 to 40 feet will aggregate 5 to 8 feet of coal. For example, a hole drilled about one mile southwest of Riley (SE-1/4, SW-1/4, Sec. 26, T.2N., R.4W.) by the New Mexico Bureau of Mines and Mineral Resources intersected five coal seams ranging in thickness from 1.0 to 2.5 feet, with an aggregate thickness of 8.0 feet in a stratigraphic interval of 28 feet. Such multiple, thin seams may merge laterally into one or more coal beds of commercial thickness. Coal beds in the upper Mesaverde have known thicknesses that range from a few inches to 5 feet. These beds tend to be less continuous laterally than the coals in the lower Mesaverde and change thickness abruptly. They also tend to occur as single beds rather than multiple seams stacked in a stratigraphic sequence.

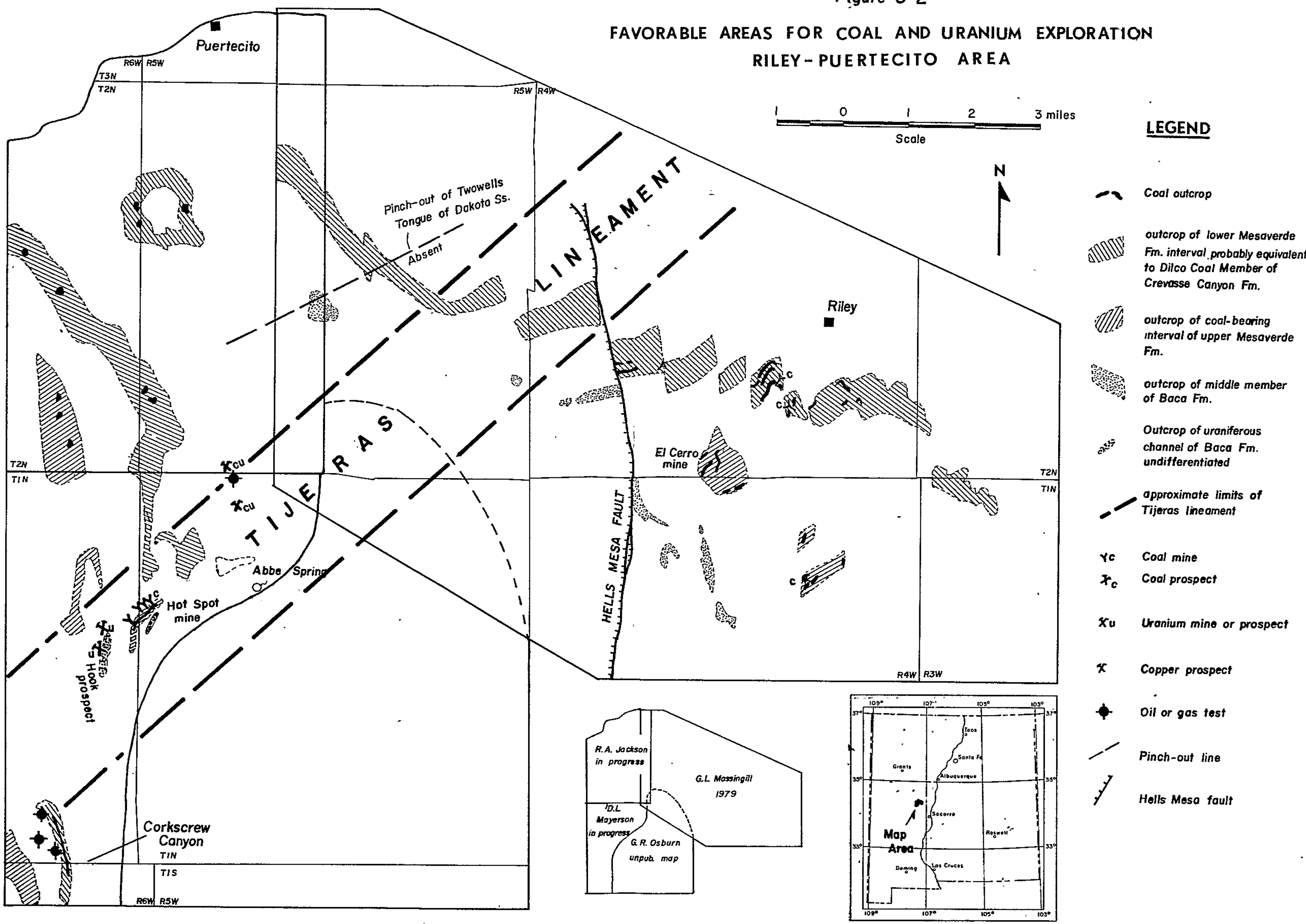
Coals in the lower Mesaverde are most abundant southwest of Riley, south of Puertecito, and in the Corkscrew Canyon area (Fig. 3-2). The northeast-trending Tijeras lineament appears to have influenced the distribution of coal by allowing different rates of subsidence and sedimentation on opposite sides of the lineament. Coal beds are abundant on the southeast side of the lineament in the Riley area, where the marine and brackish water sediments of the lower Mesaverde are relatively thick. This favorable stratigraphic interval thins to the northwest across the lineament, and coal outcrops disappear. However, coal is again present in this interval a few miles to the southwest. At least 8 coal beds in the lower Mesaverde Formation are exposed in the Corkscrew Canyon area (Mayerson, 1979), near the southwest corner of the map area (Fig. 3-2). They range in thickness from 1 to 2 feet. The abundance of these coals may also be due to a favorable rate of subsidence on the southeast side of the lineament.

Mining History

Coal was mined at various times from the lower Mesaverde Formation about one mile southwest of Riley in sections 26 and 27, T.2N., R.4W. No records of these operations have been found. Several small excavations and two adits exist. Most of the production apparently came from an adit in

Figure 3-2

FAVORABLE AREAS FOR COAL AND URANIUM EXPLORATION
RILEY-PUERTECITO AREA



section 26 that was driven on a coal bed 4 feet 8 inches thick. Total production was probably a few hundred tons. Most of the coal produced was probably used in smelters and homes in the Magdalena area and by residents of the Riley area.

Coal has been mined from the upper Mesaverde at the El Cerro mine southwest of Riley and at the Hot Spot mine between Corkscrew Canyon and Abbe Springs (Fig. 3-2). The El Cerro mine is located in Cañon del Tanque Hondo about 3 miles southwest of Riley (SE-1/4, Sec. 33, T.2N., R.4W.). This property is also known as the Sanchez-Romero prospect. The following data have been abstracted from Coal History of New Mexico by Nichelson and Frost (in prep.). Mr. Gregorio Romero and others filed a coal claim in 1917 on the E-1/2, E-1/2, Sec. 33, T.2N., R.4W. and drove an inclined adit about 300 feet long from which they opened three short rooms. Several other short openings were driven along the outcrop to test the coal bed. In 1937, another incline was driven about 100 feet and a 30-foot entry opened to the right. Here, the coal bed was 21 inches to 27 inches thick with a shale roof and floor. As the mine developed, a roll was hit, across which the coal was only 18 inches thick and water was encountered. The Treasurer of the El Cerro Coal Mining Company was Mr. R.H. Stapleton, a prominent resident of Socorro. He died in 1939, after which the company was renamed the Riley Coal Company. Work had ceased at the mine by October 1940 because of the thin coal and long, rough road to market. The lease was cancelled July 17, 1953 retroactive to November 15, 1943. The property produced 788 tons of coal under the Sanchez-Romero lease. The Hot Spot mine (NW-1/4, Sec. 18, T.1N., R.5W.) produced 85 tons of coal from upper Mesaverde strata between 1927 and 1931 (Nichelson and Frost, in prep.). A mining permit was issued to F.L. Dugger on July 15, 1927. Mr. Dugger drove a 90-foot adit on a 46-inch coal bed before hitting a roll across which the coal thinned to 12 inches. The permit expired June 30, 1931. Three other adits are present on the same coal seam but no records are available for these. Mr. Dugger reported that one of these inclines was driven 115 feet without hitting the coal bed. The thickest coal bed observed here is 5 feet thick (D.L. Mayerson, 1979). The coals grade laterally into silty shale and sandstone.

Composition

Analyses of 7 coal samples from the Riley-Puertecito area are listed in Tables 3-1 and 3-2. The coals range from lignite to high-volatile C bituminous and sub-bituminous B classes (ASTM, 1967). The three samples from the lower Mesaverde range from 5137 to 9083 BTU/lb as received. The ash content ranges from 13.2 to 39.0%; sulfur content is low and ranges from 0.5 to 0.9% (as received). The four samples from the upper Mesaverde (Table 3-2) range from 6,083 to 11,555 BTU/lb as received. Ash contents of the

Table 3-1 Analyses of coals from the lower Mesaverde Formation, Riley-Puertecito area, Socorro County, New Mexico. All analyses by United States Geological Survey, Branch of Coal Resources, Denver, Colorado.

USGS Sample ID	D199359			D192387-89			D192390, 91		
Lab No.	K84794						K82071		
Location	SE,27,2N,4W 1 mi SW. of Riley			SE,26,2N,4W 1 mi S. of Riley 3 channel samples			SE,26,2N,4W 1 mi S. of Riley 2 channel samples		
Thickness/sample type	5 ft/channel			1'8", 1'2", 1'1"			1'5", 2'6"		
Collected by	G.L. Massingill			G.L. Massingill			G.L. Massingill		
Height above Gallup SS.				40'-57'			12', 17'		
Air dry loss		-0.2			-6.0			11.2	
	Rec'd	-M	-M&A	Rec'd	-M	-M&A	Rec'd	-M	-M&A
Moisture	8.9	-	-	11.9	-	-	19.0	-	-
Volatile matter	32.2	35.3	41.3	28.4	32.2	57.8	30.9	38.1	46.2
Fixed carbon	45.7	50.2	58.7	20.7	23.5	42.2	35.9	44.4	53.8
Ash	13.2	14.5	-	39.0	44.3	-	14.2	17.5	-
Hydrogen	4.3	3.7	4.3	3.4	2.4	4.3	4.7	3.2	3.9
Carbon	56.0	61.5	71.9	32.5	36.9	66.2	46.1	56.8	68.9
Nitrogen	1.1	1.2	1.4	0.7	0.8	1.5	1.0	1.2	1.5
Sulfur	0.9	1.0	1.2	0.6	0.6	1.1	0.5	0.6	0.7
Oxygen (Ind)	24.4	18.1	21.1	23.8	15.0	26.9	33.6	20.6	25.0
Sulfur-sulfate	0.31	0.34	0.40	0.02	0.02	0.04	0.02	0.02	0.03
-pyrite	0.08	0.09	0.11	0.20	0.22	0.40	0.18	0.22	0.27
-organic	0.54	0.60	0.70	0.34	0.38	0.69	0.27	0.33	0.40
Ash-Initial Deform.		2370F			2755F			2455F	
-softening T.		2410F			2800F			2560F	
-fluid T.		2470F			2800F			2655F	
Heating Value BTU/lb	9083	9975	11667	5137	5831	10467	7179	8858	10740

Table 3-2 Analyses of coals from the upper Mesaverde Formation, Riley-Puertecito area, Socorro County, New Mexico. All analyses by United States Geological Survey, Branch of Coal Resources, Denver, Colorado.

USGS Sample ID	D192392-93			D192394			D192395			D179837		
Lab No.	K82072			K82073			K82074			K67549		
Location	SE,33,2N,4W 2.5 mi SW. of Riley			SE33,2N,4W 2.5 mi SW. of Riley			NW3,1N,4W 3 mi SW. of Riley			NW,18,1N,5W Hot Spot Mine - 9 mi S. of Puertecito		
Thickness/sample type	2 channel samples 1'2", 1'1"			channel sample 11"			channel sample 1'4"			channel sample 3.2 ft		
Collected by	G.L. Massingill			G.L. Massingill			G.L. Massingill			D.E. Tabet		
Distance below top of Mesaverde		~200 ft			~250 ft			~100 ft			?	
Air dry loss		2.2			3.2			6.6			1.6	
	Rec'd	-M	-M&A	Rec'd	-M	-M&A	Rec'd	-M	-M&A	Rec'd	-M	-M&A
Moisture	9.1	-	-	7.6	-	-	13.6	-	-	6.6	-	-
Volatile matter	35.3	38.9	45.3	25.9	28.0	49.7	35.1	40.7	45.9	32.8	35.1	37.6
Fixed carbon	42.7	46.9	54.7	26.2	28.4	50.3	41.5	48.0	54.1	54.2	58.1	62.4
Ash	12.9	14.2	-	40.3	43.6	-	9.8	11.3	-	6.4	6.8	-
Hydrogen	4.7	4.1	4.7	3.7	3.1	5.4	4.8	3.8	4.3	5.0	4.5	4.9
Carbon	56.9	62.6	73.0	36.9	39.9	70.7	54.7	63.3	71.4	67.2	71.9	77.2
Nitrogen	1.1	1.2	1.4	0.8	0.8	1.5	1.1	1.3	1.5	1.3	1.4	1.5
Sulfur	0.4	0.4	0.5	0.4	0.5	0.8	0.3	0.4	0.4	0.5	0.6	0.6
Oxygen (Ind)	24.0	17.4	20.3	17.9	12.1	21.5	29.2	19.8	22.4	19.6	14.7	15.8
Sulfur-sulfate	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.1	0.1	0.1
-pyritic	0.24	0.27	0.31	0.17	0.19	0.33	0.19	0.22	0.24	0	0	0
-organic	0.11	0.12	0.14	0.23	0.25	0.45	0.11	0.13	0.15	0.4	0.4	0.4
Ash-Initial Deform.		2105F			2800F			2210F			2185F	
-softening T.		2205F			2800F			2310F			2290F	
-fluid T.		2305			2800F			2405F			2405F	
Heating value BTU/lb	9315	10253	11951	6083	6580	11672	8876	10276	11591	11555	12374	13279

upper Mesaverde samples ranged from 6.4 to 40.3% (as received) with 3 out of the 4 samples being lower in ash than the samples from the lower Mesaverde. The sulfur contents of samples from upper Mesaverde coals ranged from 0.3 to 0.5% (as received); this is approximately one-half the sulfur content of lower Mesaverde coals. These differences in composition reflect the different environments of deposition for lower and upper Mesaverde coals as discussed earlier in this section. The coals of the lower Mesaverde, deposited under mixed brackish- and fresh-water conditions, tend to be higher in ash and sulfur and lower in BTU values than the fresh-water coals of the upper Mesaverde.

Resource Potential

The tonnage of coal available in the Riley-Puertecito area is difficult to estimate because of the scarcity of subsurface data, the poor surface exposures, the lenticular nature of the coal beds, and the structural complexity of the area. Data are too sparse in the western half of the area to attempt a resource calculation. Inferred resources were not calculated for any areas because of a lack of subsurface data and structural complexities.

Indicated resource computations were made for parts of sections 26 and 27, T.2N., R.4W., located about one mile southwest of Riley, using the system described in U.S. Geological Survey Bulletin 1450-B (1976). In this area, two coal beds, which are three to four feet thick, crop out continuously for about 4000 feet, and at least two other coal beds are present (G.L. Massingill, 1979). The New Mexico Bureau of Mines and Mineral Resources recently drilled a hole in SE-1/4, SW-1/4, Sec. 26, T.2N., R.4W. to aid in resource estimation. This hole intersected five coal seams ranging in thickness from 1.0 to 2.5 feet, with an aggregate thickness of 8.0 feet in a stratigraphic interval of 28 feet. The beds dip southeastward at about 15 degrees. The indicated resource is about 1,000,000 tons of coal that could be mined using a maximum stripping ratio of 10:1.

Resource Utilization

The Riley coal field is about 30 miles by poorly maintained dirt roads from the railroad siding at Bernardo, on the Santa Fe Railroad Albuquerque-El Paso line. The lack of a bridge over the Rio Salado at Riley would pose a problem to trucks, especially during the summer thunderstorm season. The Riley area is about 20 miles by dirt roads from Magdalena and an additional 26 miles by highway from Magdalena to the Santa Fe Railroad siding at Socorro. The old Santa Fe line from Socorro to Magdalena was abandoned several years ago.

The combination of transportation problems, a relatively small resource potential compared to the large coal fields of the San Juan and Raton basins, the relatively low heating values, and the moderately high ash content leads to the conclusion that the Riley coal could best be utilized at the site. Abundant limestone, travertine, and shale deposits in the area and the availability of water along the Rio Salado suggests that a cement plant along the Riley-Bernardo road might be a feasible way to utilize the coal. The labor force could be drawn from Belen, Magdalena, and the Alamo Indian Reservation, all of which have chronic unemployment problems. The very sparsely populated nature of the Riley area would minimize environmental problems.

IV. URANIUM POTENTIAL

Known uranium occurrences in the Riley-Puertecito area are restricted to the Baca Formation of Eocene age (Fig. 3-1). The Baca is a terrestrial sedimentary unit that consists mainly of reddish mudstones, siltstones, and fine-grained sandstones but also contains light-gray to pale-yellow, coarser sandstones. The lighter colored sandstones are often channel-shaped, contain carbonaceous material, and appear to have been bleached by the passage of ground waters. These characteristics are typical of sandstones containing uranium deposits elsewhere in New Mexico and the Intermountain West. In this section, we will not delve deeply into the long and controversial history of the Baca Formation, but will attempt to point out where favorable lithologies exist and give some general guidelines for exploration.

The Baca Formation unconformably overlies the Upper Cretaceous Mesaverde Formation (Fig. 3-1) and contains much material reworked from Cretaceous units. The Riley-Puertecito area is located within the central portion of the Eocene basin in which the Baca accumulated. Consequently, the Baca in this area has a gradational, conformable contact with volcaniclastic sedimentary rocks of the overlying Spears Formation of earliest Oligocene age (37 m.y., Burke and others, 1963). To the south, in the Magdalena and Tres Montosas areas, the Spears rests upon the Abo Formation of Permian age, and the Baca Formation is missing, as is the entire Mesozoic section and most of the Permian section. Somewhere between the Riley-Puertecito area and the Magdalena-Tres Montosas area, the regional southward dip must reverse and units of Permian through Eocene age must be truncated along the north flank of the Laramide Magdalena uplift.

The Baca Formation is exposed along an east-trending outcrop belt that extends from near Springerville, Arizona to the Joyita Hills and Carthage areas, a few miles east of the Rio Grande. This outcrop belt is partly due to southward tilting of Oligocene and older rocks during Neogene uplift of the Colorado Plateau, so that the Baca Formation is exposed between an upwarped, eroded edge to the north and the overlying blanket of younger volcanic and volcaniclastic rocks to the south. Little is known of the original extent and configuration of the Eocene basin in which the Baca accumulated. Regional studies of the Baca Formation by Snyder (1971) and Johnson (1978) have addressed this problem by measuring sections and by gathering data on clast compositions, transport directions, sedimentary structures, and the sequence and geometry of sedimentary units. However, the data are so sparse and detailed mapping so limited that a reconstruction of the Baca basin (or basins) is not yet possible.

Little is known about the age range of the Baca Formation. The top of the Baca in the Riley-Puertecito area is of latest Eocene - earliest Oligocene age because of the gradational contact with the overlying Spears Formation whose age has been well established by radiometric dating (37-33 m.y., Chapin and others, 1978). A fossil mammal tooth from the Baca Formation in the Carthage area suggests a middle Eocene age (Gardner, 1910); a partial section of a jawbone with 4 teeth from the Baca west of the Riley-Puertecito area suggests a late Eocene age (Snyder, 1970). However, the duration of the hiatus between the close of Mesaverde deposition in Late Cretaceous (Coniacian) time and the beginning of Baca deposition is unknown. In the Red Basin area, north of Datil, a sequence of channel sandstones and interbedded carbonaceous shales occurs beneath typical reddish Baca beds and above the Point Lookout(?) Sandstone of Cretaceous age (Anonymous, 1959). Shale beds in this transitional sequence are mostly gray with only a few red lenses; the sandstones are gray to tan and differ from the underlying Point Lookout(?) in being lenticular, relatively friable sands with a coarser grain size and a higher percentage of angular fragments and heavy minerals (Anonymous, 1959). This transitional sequence is about 100 feet thick and apparently fills a north-northwest-trending paleochannel cut into the underlying Point Lookout(?) Sandstone (Anonymous, 1959). The age of these transitional beds is unknown, but they are important because of their favorable characteristics for uranium deposition and the question they raise as to whether there might be similar transitional beds elsewhere along the outcrop belt. Uranium deposits were discovered in the transitional sequence of the Red Basin area in the early 1950's (Griggs, 1954; Bachman, Baltz, and Griggs, 1957; Anonymous, 1959). Unconfirmed reports suggest that Gulf Mineral Resources has extended these discoveries in recent years. No outcrops of beds transitional between Cretaceous and Eocene rocks were found during mapping of the Riley-Puertecito area. However, Tonking (1957, p. 25) states that, "In several outcrops the basal few tens of feet of Baca beds are similar lithologically to Mesaverde strata." In logging drill holes, the Baca-Mesaverde contact may be difficult to pick in some localities.

Along the eastern and northern edges of the Bear Mountains, the Baca Formation can be divided into three members (Fig. 3-1). Potter (1970) called these the lower red unit, middle sandstone unit, and upper red unit. Massingill (1979) also divided the Baca into three members in this area, but used the informal terms conglomeratic, gray sandstone, and red mudstone for the lower, middle, and upper members, respectively. Both schemes emphasize that the middle member is a light-colored sandstone unit that is different from typical Baca lithologies. Outcrops of the middle member are shown on Figure 3-2. West of the Bear Mountains, the middle member is missing and a three-fold subdivision of the Baca is not possible.

Massingill (1979) measured a complete reference section for the Baca at the north end of the Bear Mountains in

W-1/2, Sec. 29, T.2N., R.4W. Here, the lower conglomeratic member is 319 feet thick and consists of reddish-brown mudstone with numerous lenticular, 10- to 30-foot beds of coarse, grayish, arkosic sandstone and conglomerate. The middle gray sandstone member is 176 feet thick and consists of light-greenish-gray to yellowish-gray, friable, clayey, sandstones and siltstones. The upper red mudstone member is 244 feet thick and consists mainly of grayish-red to reddish-brown silty mudstone. The total thickness of the Baca at the reference section is 753 feet (Massingill, 1979).

The middle member of the Baca has several characteristics which are favorable to the occurrence of uranium deposits. The unit crops out over a distance of at least five miles and is thick enough (176 feet) to contain orebodies of commercial size. It may extend to the southeast beneath the piedmont gravels that mask bedrock along the east side of the Bear Mountains and it may extend to the southwest beneath the Bear Mountains. The geometry of the middle member is poorly known. It may be a north-northwest-trending channel-shaped fluvial deposit of a major stream or a wedge-shaped body related to a fluvial fan. Detailed sedimentological studies are presently underway (S.M. Cather, in prep.) to determine the transport directions and the environment of deposition.

Lithologically, the middle member of the Baca is similar to terrestrial sandstones elsewhere that contain uranium mineralization. The sands are bleached and contain abundant carbonized wood fragments that could provide a reducing environment for precipitation of uranium. The sands are clayey but are friable and moderately permeable to the passage of ground water. The existence of a thick section of silicic ash-flow tuffs overlying the Baca Formation (Fig. 3-1) could provide an ample source of uranium. Studies of the uranium content of these tuffs and the mobility of uranium in ground-water and hydrothermal systems affecting the tuffs are currently in progress.

Uranium occurrences were discovered in the lower and middle members of the Baca Formation southwest of Riley in the early 1950's (Collins, 1954; Collins and Smith, 1956; Potter, 1970). Several bulldozer cuts were made in gray sandstones of the middle Baca along the escarpment south of Baca Canyon (N-1/2, Sec. 15, T.1N., R.4W.). Here, anomalous radioactivity and traces of yellow uranium minerals occur in limonitic halos around pieces of carbonized logs (Potter, 1970). Similar carbonized logs surrounded by limonitic halos are conspicuous in the middle member near Fall Spring (SE-1/4, Sec. 5, T.1N., R.4W.) and appear to have been prospected in a minor way. One drill site was observed along a road bulldozed up the side of the escarpment south of Fall Spring. These minor occurrences of uranium in highly oxidized and leached outcrops of the middle member of the Baca are encouraging. The key to exploration of this unit is to find areas where the middle member has been downfaulted and protected from leaching. One such area exists northwest of Fall Spring on the downthrown, west side of the Hells Mesa fault (Fig. 3-2). Displacement on the Hells Mesa fault is about 800 feet at Fall Spring and decreases to the north (Massingill, 1979). The middle member can be inferred to be present in the subsurface at drilling depths from 0 to 1100 feet over an area of about 2 square miles in sections 29, 30, 31 and 32, T.2N., R.4W., and sections 5 and 6, T.1N., R.4W. The selenium indicator plant Astragalus pattersoni grows on outcrops of the middle member where it comes to the surface in sections 29 and 30, T.2N., R.4W. (Massingill, 1979). Here, the Baca dips about 7 degrees to the southeast.

Potter (1970) reports a minor uranium occurrence in the lower member of the Baca in Baca Canyon. The reported location is NW-1/4, Sec. 15, T.1N., R.4W., but this is probably section 10, because the lower Baca is not exposed in section 15. According to Potter, the radioactivity is associated with two small pieces of carbonaceous material at the base of a 5-foot lenticular sandstone bed. The sandstone is pale red to light gray and the underlying red mudstone is bleached gray for a distance of 1.5 feet below the sandstone (Potter, 1970). Such minor occurrences of uranium in the lower Baca probably have little or no commercial potential because of the small volume of the host sandstone lenses.

Uranium occurrences were also discovered in the early 1950's at several localities along Jaralosa Canyon, between Corkscrew Canyon and Abbe Spring. Summaries of uranium investigations in this area have been published by Griggs (1954), Bachman, Baltz, and Griggs (1957), and Anonymous (1959). The prospects are small, open cuts in thin, light-gray, lenticular sandstones containing carbonaceous material. Chemical analyses of samples from these prospects range from 0.036 to 3.27% U_3O_8 and from 0.1 to 9.21% V_2O_5 (Anonymous, 1959). Mineralized zones range from one to two feet in thickness. The richest of these samples (3.27% U_3O_8, 9.21% V_2O_5) came from the Hook prospect (Fig. 3-2) in the S-1/2, Sec. 13, T.1N., R.6W. This prospect has had considerable drilling and surface trenching over the years but has produced little ore. In recent years, it was the site of an ill-fated leaching experiment and is again inactive. These thin, lenticular sandstones have little commercial potential, even though selected samples may yield high assay values. The main value of these scattered, minor occurrences is the indication that the area as a whole has uranium potential. The key is to find favorable host rocks of sizeable thickness and lateral extent. The middle member of the Baca Formation southwest of Riley offers such a target for discovery of uranium deposits of commercial size.

V. OIL AND GAS POTENTIAL

The combination of shallow depth of burial, low degree of thermal maturation, and probable flushing by ground water indicates a very low potential for oil or gas production from Cretaceous rocks in the Riley-Puertecito area. However, the Cretaceous rocks may have potential to the northeast and southwest where they have been downfaulted beneath grabens of the Rio Grande and San Augustin rifts. The low degree of thermal maturation of organic matter in Cretaceous rocks of the Riley-Puertecito area, in spite of the existence of the most spectacular dike and sill swarm in New Mexico and the existence of several major cauldron structures in the Magdalena area (Chapin and others, 1978), indicates that thermal effects from a major volcanic field do not preclude oil and gas production beneath its outflow apron, and may enhance it.

M.S. Chaiffetz (in prep.) collected 125 samples from Cretaceous units, Dakota Sandstone through Mesaverde Formation, and processed them for identification of spores and pollen and for determination of thermal maturation. Vitrinite reflectance values for shales and coals, not near igneous intrusions, average about 0.5%. This is below the peak oil generation stage and well below the peak of dry gas generation. Within 1 to 2 feet of a dike, vitrinite reflectance values approach 1.3 to 1.4%, which is slightly above the peak of dry gas generation. Within 1 to 6 inches of a dike margin, vitrinite reflectance values for organic matter in shales are as high as 2.5% and in coals as high as 4.5%. These values are near, or above, the dry gas preservation limit. In other words, thermal effects from the numerous mafic dikes (Fig. 2-2) in the Riley-Puertecito area are restricted to the immediate vicinity of dike margins. The bulk of the Cretaceous rocks have been very little affected by intrusion of mafic dikes and sills.

There may be some oil and gas potential in Paleozoic rocks beneath the Riley-Puertecito area, but these rocks do not crop out within the area mapped and we have nothing new to report on them. However, the structural framework outlined during this project should be helpful in evaluating the potential of these deeper formations. For example, differential vertical movements across the Tijeras lineament influenced sedimentation rates during the Cretaceous and may have during the Paleozoic as well. The Twowells Sandstone pinches out to the southeast across the lineament, and the Gallego Sandstone thins markedly in the same location. During deposition of basal Mesaverde strata, subsidence on the southeast side of the lineament apparently occurred at a more favorable rate for coal accumulation than on the northwest side. If such differential movements occurred during Paleozoic sedimentation, they may have caused facies changes and thickness variations conducive to entrapment of hydrocarbons.

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SEDIMENTARY ROCKS

HOLOCENE / PLEISTOCENE

- Qal — Alluvium — *Sands and gravels associated with present drainage*
- Qss — Scree slope — *Weathered material derived from the La Cruz Peak intrusive body*
- Qsb — Quaternary slump blocks
- Qpg — Pediment gravels — *Thin gravels and sand covering remnants of high pediment surfaces*

UNCONFORMITY

MIOCENE

- Tp — Popotosa Formation (lower Santa Fe Group) — *White to buff conglomerate, containing mostly clasts of La Jara Peak Andesite, A-L Peak Tuff, and Hells Mesa Tuff, interbedded with La Jara Peak Basaltic Andesite at base*
- La Jara Peak Basaltic Andesite — *Massive to highly vesicular aphanitic basaltic-andesite flows and associated channel sandstones and conglomerates; interbedded with Popotosa Formation in upper part*

OLIGOCENE

- Tal — A—L Peak Tuff — *Purple and gray, crystal-poor, quartz-bearing, ash-flow tuff containing abundant flattened pumice*

UNCONFORMITY

- Thm — Hells Mesa Tuff — *Pink, crystal-rich, quartz-rich ash-flow tuff*

UNCONFORMITY

EOCENE

- Ts — Spears Formation — *Purple to gray volcaniclastic sandstones, conglomerates, mudstones, and siltstones. Base interbedded with Baca Formation*
- Tb — Baca Formation — *Red, yellow, pink, and orange arkosic and conglomeratic sandstones; siltstones and shales; locally contains abundant silicified wood*

UNCONFORMITY

UPPER CRETACEOUS

- Kmvu — Mesaverde Formation undifferentiated — *Yellow, brown, and green sandstones; gray and black shales and siltstones; coal; abundant ironstone concretions*
- Kg — Gallego Sandstone — *Brownish-yellow to brown, highly bioturbated sandstone; contains* Lopha sannionis *near top*

Mancos Shale

- **Kmd** – D-Cross Tongue – *Dark-gray weathering to olive-gray, fossiliferous, concretionary shale, contains* Scaphites whitfieldi *and* Prionocyclus novimexicanus
- **Kmt** – Tres Hermanos Sandstone Member – *Interbedded light-gray weathering to yellowish-gray sandstones and dark-gray weathering to light-gray organic shales, contains* Selwynoceras mexicanum *at base*
- **Kma** – Alamito Well Tongue – *Dark-gray weathering to medium-gray, silty, fossiliferous, concretionary shale, contains* Pycnodonte newberryi, Sciponoceras gracile, *and* Mammites depressus
- **Kmr** – Rio Salado Tongue – *Shale, dark-gray weathering to medium-gray, silty, fossiliferous, concretionary, contains* Pycnodonte newberryi, Sciponoceras gracile *and* Mammites depressus
- **Kmw** – Whitewater Arroyo Tongue – *Shale, dark-gray weathering to olive-gray, several bentonite beds; includes Paguate Sandstone time-equivalent, interbedded light-gray weathering to yellowish-gray, calcareous, fossiliferous sandstones and olive-gray shales; contains* Ostrea beloiti

Dakota Sandstone

- **Kdt** – Twowells Tongue – *Light-gray to yellow, bioturbated sandstone*
- **Kd** – Main Body – *Grayish to browning-yellow, iron-stained, cross-bedded quartzose sandstone and conglomeratic sandstone*

UNCONFORMITY

TRIASSIC

- Trc — Chinle Formation — *Red, pink, gray and green shales and siltstones; thinly bedded, gray, fresh-water limestones; yellow, arkosic channel sandstones*

Formation contact; dashed where uncertain, dotted where covered

Fault; bar and ball on downthrown side; dashed where uncertain, dotted where inferred

Synclinal axis

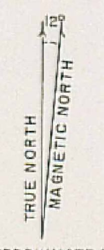
Anticlinal axis

Strike and dip of beds

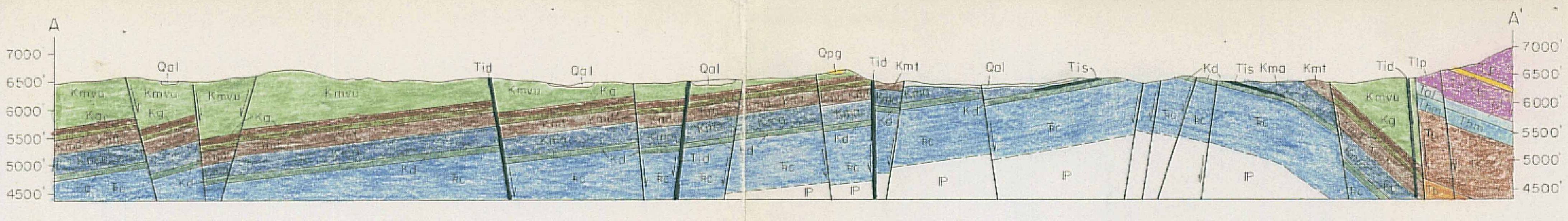
IGNEOUS ROCKS

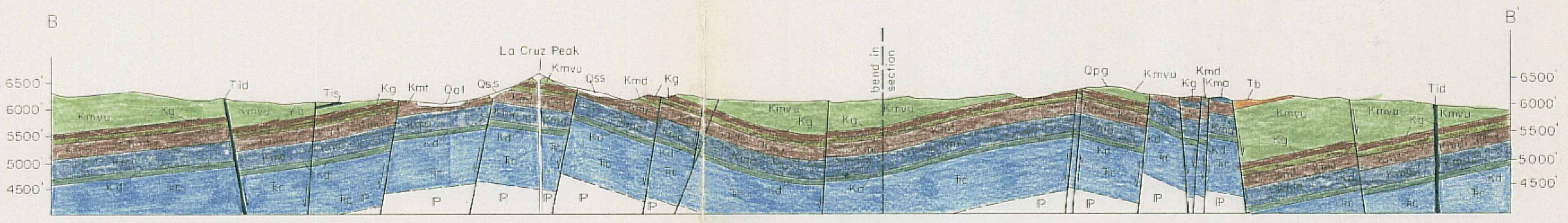
INTRUSIVES

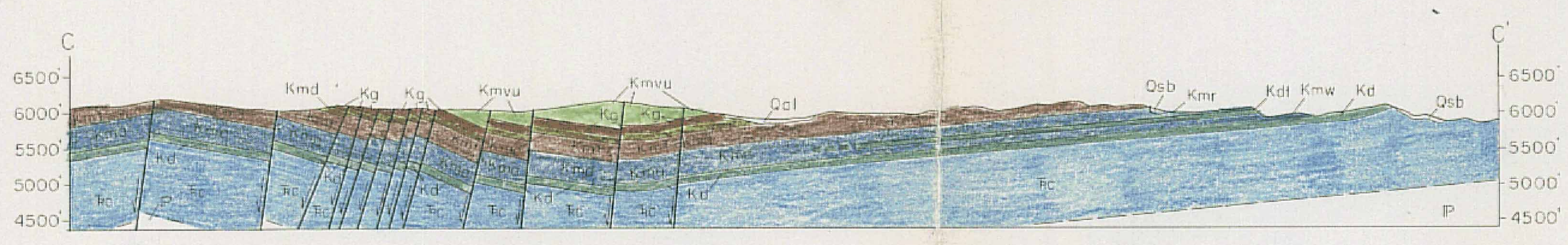
- Tid — Basaltic and basaltic-andesite intrusions, *most altered green in color.* Tid – *dikes,* Tis – *sills*
- Basaltic necks

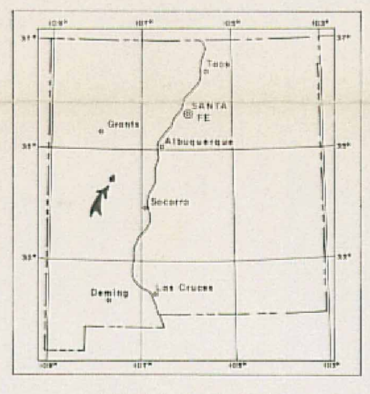


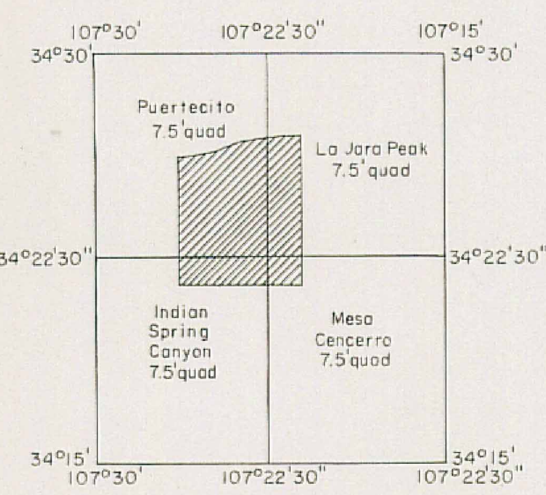
APPROXIMATE MEAN DECLINATION, 1975








INDEX MAP OF NEW MEXICO



Base map key

GEOLOGY OF THE PUERTECITO-LA CRUZ PEAK AREA, SOCORRO COUNTY, NEW MEXICO

by Robert A. Jackson

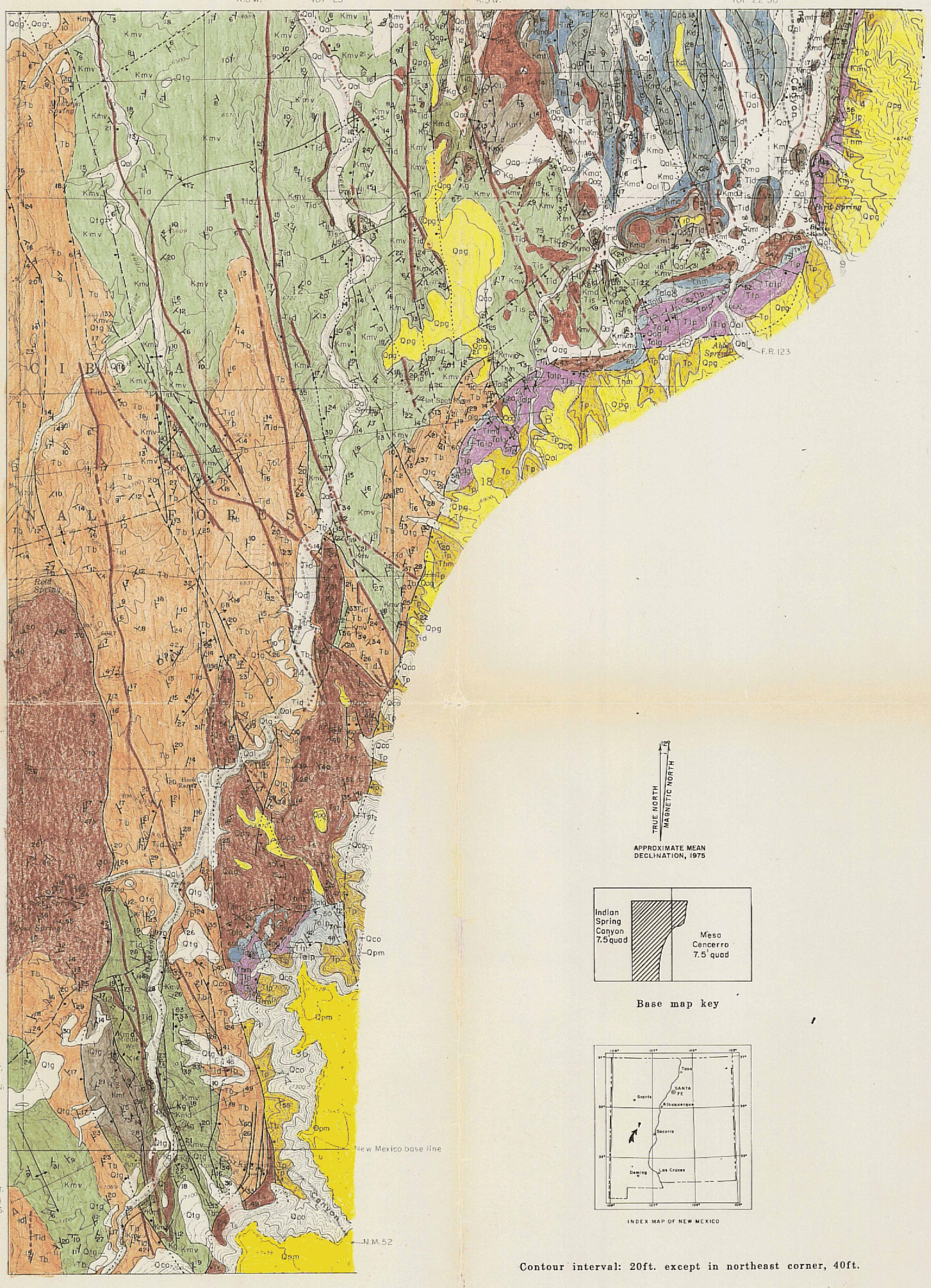
1979

SCALE 1:24,000

1 mi

1 km

Contour interval: 20ft. except in southeast corner, 40ft.



SEDIMENTARY ROCKS

HOLOCENE

- Qal — **Alluvium** — *Sands and gravels associated with present drainage*
- Qsb — **Quaternary slump blocks** — *Mostly of Dakota Sandstone*
- Qag — **Alluvium** — *Sand and gravel covering broad, flat areas and dissected by present drainage; often grades into Qal*
- Qco — **Colluvium**

PLIO-PLEISTOCENE

- Qtg — **Terrace gravels** — *Gravel and sand deposited on terraces of present drainage system*
- Qpg — **Pediment gravels** — *Gravel and sand forming a thin covering over broad flat areas between 6740 and 6920 foot elevations*
- Qpm — **Piedmont gravels** — *Gravels with clasts largely of La Jara Peak Basaltic Andesite, A-L Peak Tuff, and Hells Mesa Tuff at elevations greater than 7000 feet*

UNCONFORMITY

MIOCENE

- Tp — **Popotosa Formation** — *White to buff conglomerate, contains clasts of mostly La Jara Peak Basaltic Andesite, A-L Peak Tuff, and Hells Mesa Tuff; interbedded with La Jara Peak Basaltic Andesite at base*

OLIGOCENE

- Tlp, Talp, Talg, Tlp — **La Jara Peak Basaltic Andesite** — *Massive to highly vesicular aphanitic basaltic-andesite flows and associated channel sandstones and conglomerates; interbedded with Popotosa Formation in upper part and with A-L Peak Tuff in lower part*
- **A-L Peak Tuff** — *PINNACLES MEMBER: Purple and gray crystal-poor quartz-bearing ash-flow tuff containing abundant flattened pumice with sandy texture. GRAY–MASSIVE MEMBER: Gray and orange crystal-poor quartz-bearing ash-flow tuff; pumice is less abundant and exhibits less flattening than in Pinnacles member*

UNCONFORMITY

- Thm — **Hells Mesa Tuff** — *Pink, crystal-rich, quartz-rich ash-flow tuff*

UNCONFORMITY

- Tst_2, Ts, Tst_1 — **Spears Formation** — *Purple to gray volcaniclastic sandstones, conglomerates, mudflow deposits, and siltstones; plagioclase-bearing basaltic-andesite flows present as small discontinuous outcrops in upper part. Tst2: Pink lithic- and biotite-rich ash-flow tuff. Tst 1: Gray crystal-poor ash-flow tuff*

GRADATIONAL, INTERBEDDED CONTACT

EOCENE

- Tb — **Baca Formation** — *Red, pink, yellow, and orange arkosic and conglomeratic sandstones; red siltstones and shale; locally contains abundant silicified wood*

UNCONFORMITY

UPPER CRETACEOUS

- Kmv — **Mesaverde Formation** — *Yellow, brown, and green sandstones; gray and black shales and siltstones; coal; abundant ironstone concretions*
- Kg — **Gallego Sandstone** — *Brownish-yellow to brown, highly bioturbated sandstone; contains* Lopha sannionis *near top*
- Kmd, Kmt, Kma — **Mancos Shale**
  - *Kmd — D-Cross Tongue — Dark-gray weathering to olive-gray, fossiliferous, concretionary shale; contains* Scaphites whitfieldi *and* Prionocyclus novamexicanum.
  - *Kmt — Tres Hermanos Sandstone Member — Interbedded yellowish-brown thin-bedded sandstone and dark-gray organic-rich shale; contains* Selwynoceras mexicanum *at base and* Coilopoceras colleti *at top.*
  - *Kma — Alamito Well Tongue — Dark-gray to medium-gray silty fossiliferous concretionary shale; contains* Pycnodonte newberryi, Sciponoceras gracile, *and* Mammites depressus.
- Kd — **Dakota Sandstone** — *Grayish- to brownish-yellow, iron-stained, cross-bedded quartzose sandstone and conglomeratic sandstone*

UNCONFORMITY

TRIASSIC

- ₮c — **Chinle Formation** — *Red, pink, gray, and green shales and siltstones; yellow arkosic channel sandstones*

IGNEOUS ROCKS

- Tid, Tis — **Intrusives** — *Basaltic and basaltic-andesite intrusions, most altered to green color. Tid – Dikes; Tis – Sills*

Formation contact; dashed where uncertain, dotted where covered

Fault; bar and ball on downthrown side; dashed where uncertain; short dashes where inferred; dotted where covered

Anticlinal axis showing plunge direction — *Synclinal axis showing plunge direction* — *Monoclinal axis*

13 *Strike and dip of beds* — *Horizontal beds* — 14 *Dip of dikes and faults*

Ephemeral streams — *Road; dashed where unimproved* — *Mine adit*

E *Bulldozer excavation* — x 6789 *Point elevation* — *Building* — *Drill hole*

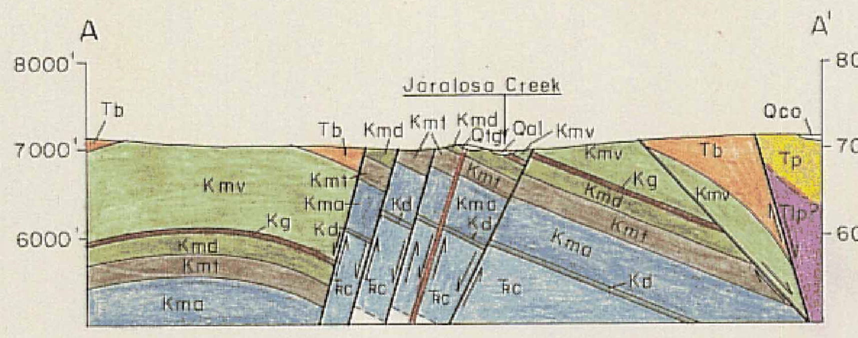
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1975

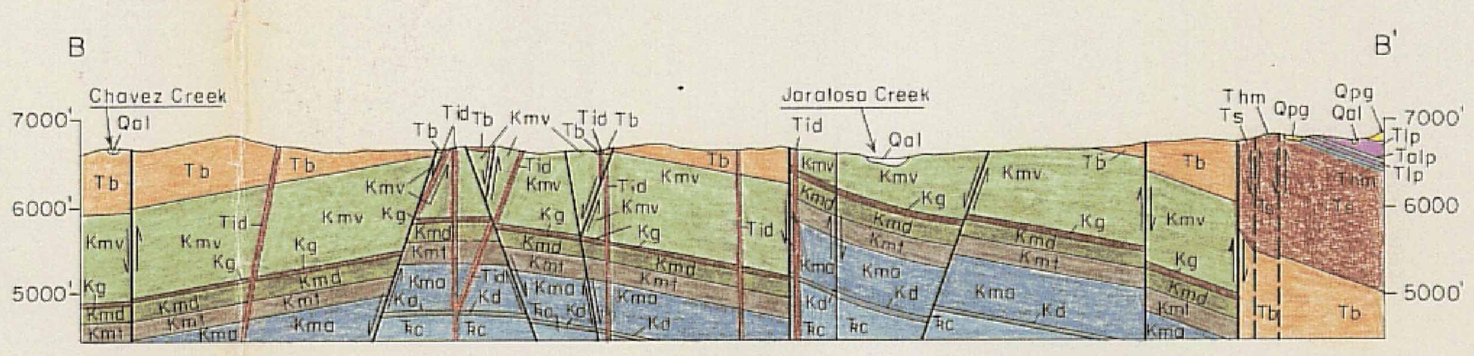
Indian Spring Canyon 7.5' quad
Meso Cencerro 7.5' quad

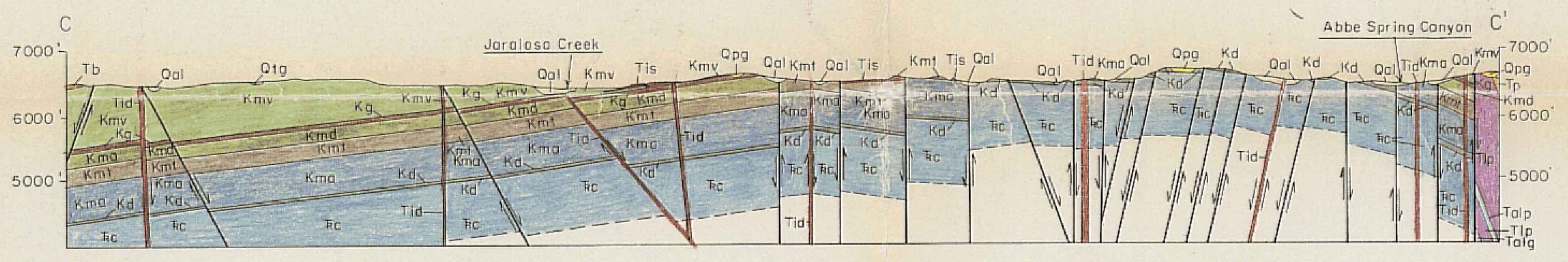
Base map key

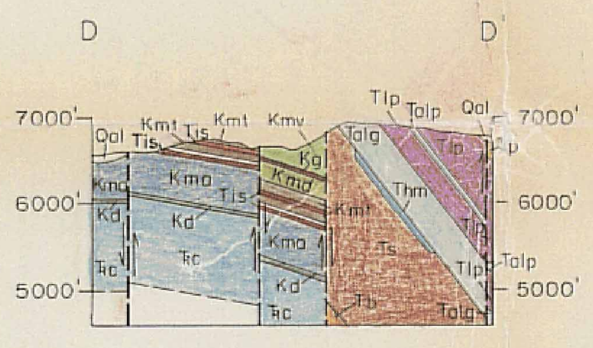
INDEX MAP OF NEW MEXICO

Contour interval: 20ft. except in northeast corner, 40ft.









GEOLOGY OF THE CORKSCREW CANYON-ABBE SPRING AREA, SOCORRO COUNTY, NEW MEXICO

by David L. Mayerson

1978

SCALE 1:24,000

1 0 1 mi

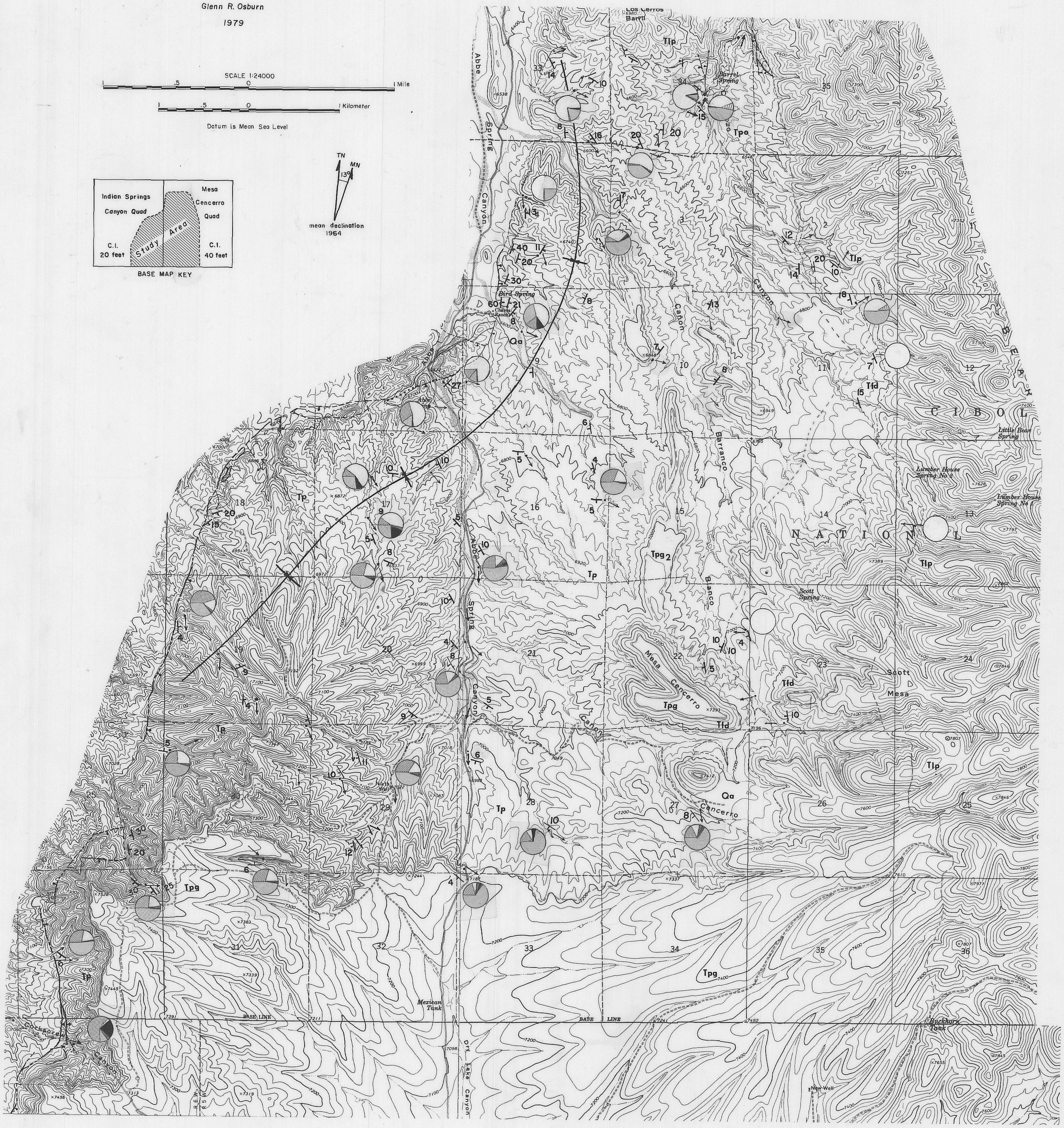
1 0 1 km

PEBBLE COMPOSITIONS AND TRANSPORT DIRECTIONS IN THE POPOTOSA FORMATION
ABBE SPRINGS AREA, SOCORRO COUNTY, NEW MEXICO

by

Glenn R. Osburn

1979



EXPLANATION

QUATERNARY

- **Qa** — **alluvium**
- **Tpg2** — **piedmont gravels,** maximum elevation approximately 7100'
- **Tpg1** — **piedmont gravels,** maximum elevation approximately 7600'

Miocene Pliocene

- **Tfd** — **fanglomerate of Dry Lake Canyon**
- **Tp / Tlp / Tpo** — **Popotosa Formation,** pebble conglomerates, sandstone to siltstones, and boulder alluvium, transport to southeast; Tpo- interbedded in part with Tlp, transport to northeast
- **Tlp** — **La Jara Peak Basaltic Andesite**

Oligocene

- **Tap / Tlp / Taf** — **A-L Peak Tuff,** Tap- pinnacles member, Taf- gray massive and flow-banded members, all are crystal-poor, rhyolite ash-flow tuffs
- **Thm** — **Hells Mesa Tuff,** crystal rich, rhyolite ash-flow tuff
- **Ts** — **Spears Formation,** volcaniclastic sedimentary rocks and mafic lava flows

Eocene

- **Tb** — **Baca Formation,** pre-volcanic sandstones and conglomerates

SYMBOLS

Contact, dashed where inferred

Fault, dashed where inferred, dotted where covered, ball on downthrown side

23 Strike and Dip of Bedding

Transport Direction, from pebble imbrication (two barbs) and axes of small channels (one barb)

Axis of Syncline

KEY TO PEBBLE COMPOSITIONS