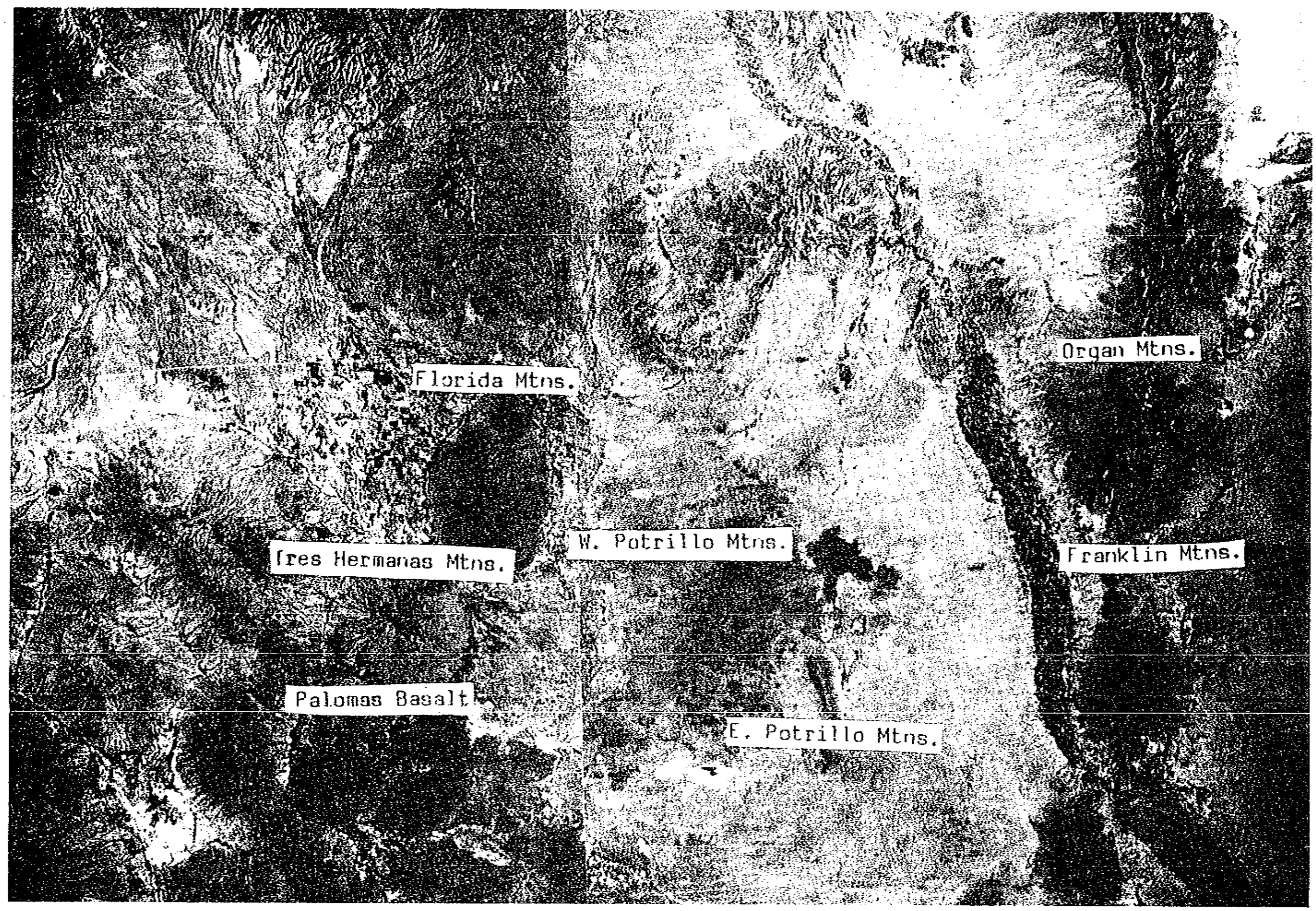
E L   P A S O

G E O L O G I C A L   S O C I E T Y   F I E L D T R I P

O N

T H E   B O R D E R   R E G I O N



Editors

Jerry M. Hoffer

Robin L. Hoffer

Department of Geological Sciences
The University of Texas at El Paso
El Paso, Texas 79968

April 10-11, 1981

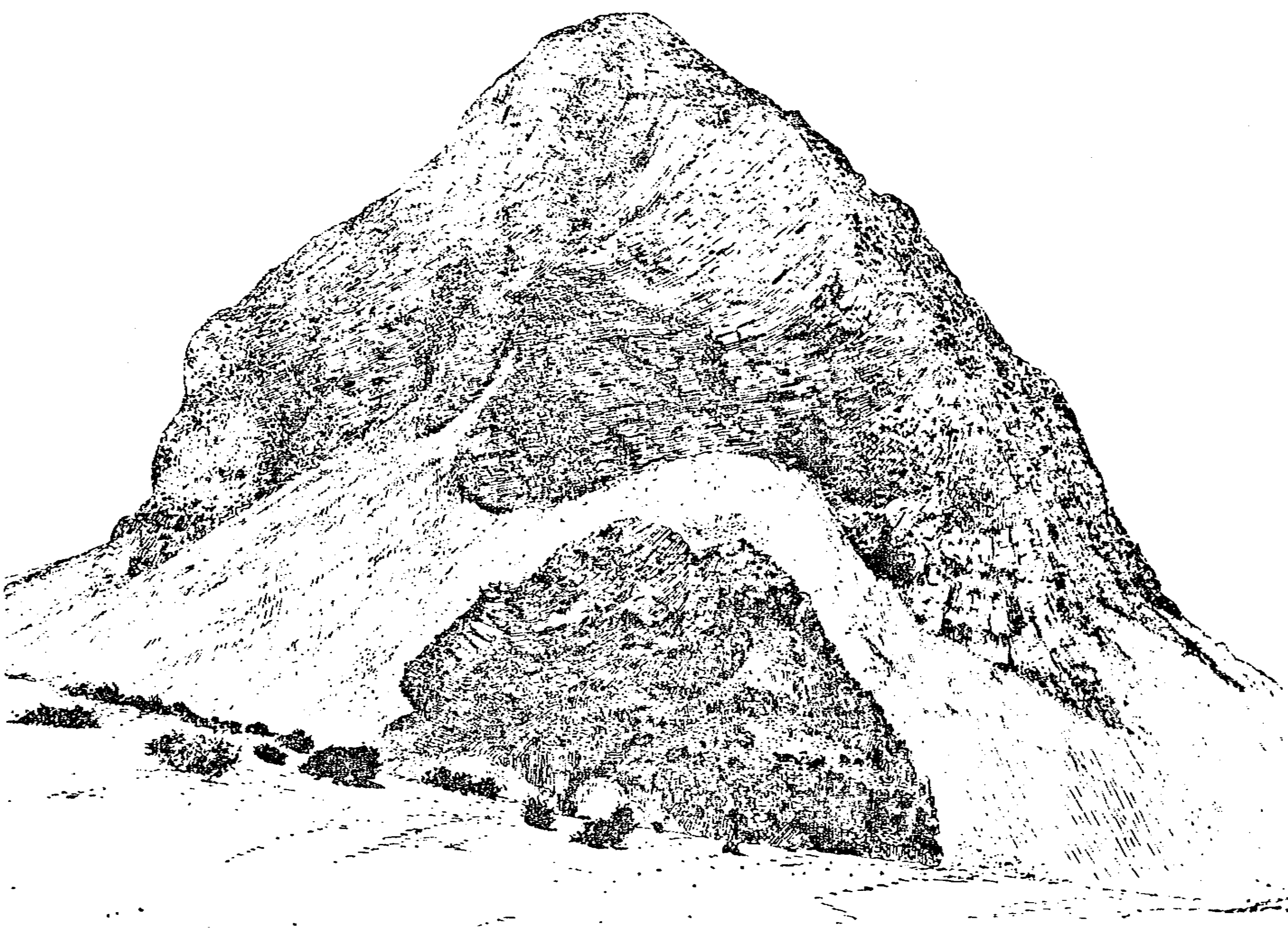
CONTENTS

ROAD LOGS

ARTICLES

Geography and Geomorphology

Stratigraphy and Paleontology



Officers for 1981

El Paso Geological Society

President	William N. McAnulty, Jr.
Vice President.	Donald M. Davidson, Jr.
Secretary-Treasurer	Kenneth F. Clark
Councilor	John G. Lay
Councilor	Dale E. Lockett

Past Presidents

1967 - Earl M.P. Lovejoy
1968 - Robert O. Habbit
1969 - William N. McAnulty
1970 - Charles J. Crowley
1971 - John M. Hills
1972 - Dale E. Lockett
1973 - C. Tom Hollenshead
1974 - Jerry M. Hoffer
1975 - William C. Cornell
1976 - John H. Earl
1977 - Marion E. Spitler
1978 - Philip C. Goodell
1979 - G. Randy Keller
1980 - Michael Shearn

COMMENTS FROM THE EDITORS

Welcome to the El Paso Geological Society Spring Fieldtrip to the border region of Southern New Mexico and Northern Chihuahua. 1981 marks the 14th year of the Society. During that period of time a number of interesting one-day fieldtrips have been undertaken into southern New Mexico and west Texas.

This year a two-day trip is planned to examine the volcanic rocks and Permian-Cretaceous strata on both sides of the border. Barring a southern New Mexico "dust" storm, we hope you will enjoy the interesting and diverse geology of this region.

The trip will center around Columbus, New Mexico and a small town located on the border in south-central New Mexico (see Kottlowski; this guidebook). This town represents the only area of the United States that has been invaded by a foreign power. In 1916 Pancho Villa crossed the border and attacked Columbus killing a number of people and burning the town. The U.S. government retaliated by sending General Pershing and 15,000 troops after Villa. Pershing chased Villa all over northern Mexico, but never caught him. Today the quiet little town has approximately 300 residents, a museum, small motel, post office, bank, grocery store, one restaurant (which isn't always open), and most importantly, a bar. Life here is quiet and peaceful; we hope you enjoy the trip and your stay in Columbus.

Jerry and Robin Hoffer
April 1, 1981

DEDICATION

William N. McAnulty

1913-1980

It is appropriate that this guidebook be dedicated to the memory of William Noel McAnulty. He was the primary force in organizing the El Paso Geological Society, served as its president, and was an honorary life member.

He was born November 26, 1913 in Howe, Oklahoma and was educated in the Oklahoma public schools. He received the B.S. and M.S. degrees from the University of Oklahoma and the Ph.D. degree from The University of Texas at Austin.

While pursuing graduate studies at the University of Oklahoma, he was an instructor in geology. After graduation he became Associate Professor and first chairman of the Geology Department at Sul Ross State University. He left Sul Ross to become Chief Geologist for Dow Chemical Company in Freeport, Texas. During his employment there he supervised the development of the fluorite mine and mill in the Big Bend region of Texas and Mexico.

In 1964 he joined the faculty of The University of Texas at El Paso as Chairman of the Geology Department. Owing to his intellectual drive, foresight, and guidance, both the Masters and Doctoral degree programs were established. Dr. McAnulty was a dedicated teacher and an excellent field geologist.

He was a registered Professional Geologist, a Fellow of the Geological Society of America, a member of the Society of Economic Geologists, American Association of Petroleum Geologists, American Institute of Mining, Metallurgical, and Petroleum Geologists, and other professional societies. He wrote numerous technical papers and gained wide recognition of an authority on flourite and other economic mineral deposits. He particularly enjoyed a professional challenge and his many accomplishments bear witness to it.

At the time of his death, December 14, 1980, he was Professor Emeritus of the Department of Geological Sciences at The University of Texas at El Paso. The geological profession suffered a great loss by his passing and his sound advice and friendship will be greatly missed.

Endowments in his honor have been established at Sul Ross State University and The University of Texas at El Paso.

William S. Strain
April, 1981

COMMITTEES 1981 FIELDTRIP

Guidebook

Jerry M. and Robin L. Hoffer, Editors . . . . U. T. El Paso

Fieldtrip Leaders

Jerry M. and Robin L. Hoffer. . . . . U. T. El Paso
John W. Hawley. . . . . New Mexico Bureau of Mines and Mineral Resources
David V. LeMone . . . . U. T. El Paso
Thomas J. Frantes . . . . U. T. El Paso

Registration

Kenneth F. Clark. . . . . U. T. El Paso

Caravan

G. Randy Keller . . . . U. T. El Paso
L. A. Nelson Geology Club . . . . U. T. El Paso

Roadlogging

Jerry M. Hoffer, Thomas J. Frantes and Robin L. Hoffer. . . . . U. T. El Paso

Technical Assistance

Schlumberger Well Services. . . . . Beverages, en route
Robin L. Hoffer and Kelly A. Embrey . . . . Drafting and Illustrations
Sandy S. Ladewig. . . . . Typing

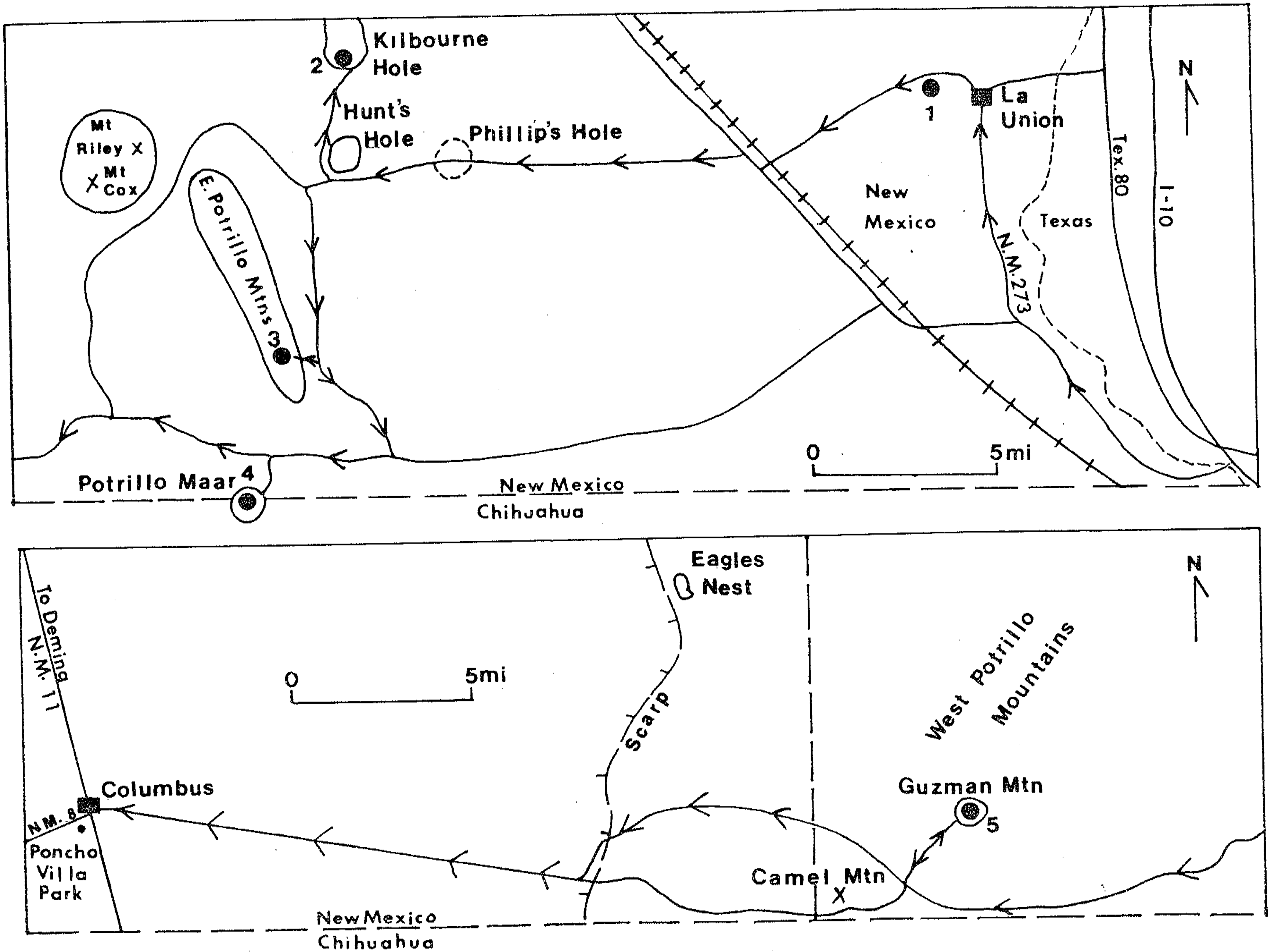
SCHEDULE OF FIELD TRIP

Friday, April 10, 1981 -- First Day Fieldtrip and Registration

8:00-9:30 am: Registration, Department of Geological Sciences, U. T. El Paso
9:30-5:00 pm: Field trip to Columbus, New Mexico
7:00 pm: Supper at Tilley and Petes in Palomas, Mexico (after dust-cutting refreshments).

Saturday, April 11, 1981 -- Second Day Fieldtrip

9:00 am - 4:30 pm: Fieldtrip from Columbus to Palomas Volcanics (visas not needed to enter Mexico as we will not go through the immigration check point) to Tres Hermanas Mountains and return to El Paso via border road.



First Day Route

First Day -- April 10, 1981

Road Log from El Paso to Columbus New Mexico, via La Union, Kilbourne Hole, East Potrillo Mountains, and West Potrillo Mountains

by

Jerry M. Hoffer and Thomas J. Frantes
Department of Geological Sciences
U. T. El Paso

Driving Distance and Time: 108.4 miles, 7 1/2 hours, including stops

Starting Time: 9:30 am

Assembly Point: Geology Building, U. T. El Paso

Summary

Today's trip will view the Quaternary sediments of the Rio Grande Valley, the Quaternary maar volcanoes of Kilbourne Hole and Potrillo Maar, the Permian and Cretaceous sedimentary units in the East Potrillo Mountains, and the internal structure of a recent cinder cone in the West Potrillo Mountains.

Cumulative Mileage	Mileage Between Points	
0.0	0.0	Geology Building, U. T. El Paso Campus
0.1	0.1	Intersection of University Avenue and Hawthorne; turn right.
0.3	0.2	Intersection of University Avenue and Sun Bowl Drive; turn left.
0.5	0.2	Intersection of Schuster Avenue and Sun Bowl Drive; turn right to I-10.
0.7	0.2	Enter I-10.
1.6	0.9	Campus Andesite at 3:00; contact zone with Cretaceous units (Hoffer, 1971).
2.0	0.4	ASARCO overpass.
2.5	0.5	Executive Park overpass.
5.3	2.8	Sunland Park overpass.
7.2	1.9	Exit at Mesa Road.
7.4	0.2	Stoplight at Mesa Road; turn left on Mesa Road.
8.1	0.7	Intersection of Mesa and Doniphan Drive; continue straight ahead on Country Club Road (Farm Road 260)
9.6	1.5	Cross Rio Grande.
10.1	0.5	Turn right on Farm Road 260.
13.1	3.0	Intersection with Borderland and Farm Road 2 W; continue straight ahead on 260.
15.4	2.3	Intersection with New Mex. 28; turn left, then bear right.
16.4	1.0	New Mex. 28 curves left; stay on New Mex. 28.

18.2	1.8	Enter La Union.
18.3	0.1	Turn left on West Main Street.
19.4	1.1	Turn right on Alvarez Street (A-44)
19.7	0.3	Pavement ends.
19.9	0.2	Bear left on A-20.
21.6	1.7	STOP 1: Rio Grande overview (see Hawley, this guidebook) (half hour stop).
26.6	5.0	Cross Southern Pacific railroad tracks; turn right.
27.0	0.4	Cross cattleguard and turn left on A-14.
31.3	4.3	Windmill on left.
34.6	3.3	Mount Riley-Cox Tertiary intrusive at 12:00; East Potrillo Mountains at 10:00 to 12:00; cinder cones of West Potrillo Mountains, 12:30-1:30. Note low rim deposits of Kilbourne Hole at 2:00. Mount Riley (north) and Mount Cox (south) are two distinct peaks representing a single pluton. The stock is a steep-sided domical intrusion of dense microporphyritic rhyodacite of probable Tertiary age. Millican (1971) reports that the pluton has intruded Cretaceous (?) strata (arkosic sandstone, unfossiliferous gray limestone, and chert conglomerates) and Tertiary volcanic and sedimentary units.
35.4	0.8	Entering a large depression called Phillips Hole. This depression, about 1 mi wide and several miles long, is thought to represent a maar volcano or a deflation basin.
36.4	1.0	West rim of Phillips Hole.
37.5	1.1	Cross olivine basalt flows of the Afton Basalt (see Hoffer, 1975).
38.9	1.4	Turn right on A-13.
39.1	0.2	Bear left on dirt road.
39.2	0.1	View of Hunts Hole (see Stuart, this guidebook).
41.1	1.9	Small spatter cone at 12:00
41.8	0.7	Cross lava flows of the Afton Basalt.
42.9	1.1	STOP 2: Kilbourne Hole (half hour stop) -- Kilbourne Hole is a maar volcano 2 mi long and a mile and a quarter wide. The floor of the depression is 250 to 300 ft below the surface of the surrounding desert and is bordered on the north, south, and east sides by a 20 to 170 foot rim (Reiche, 1940). Maar volcanoes receive their name from small crater lakes of the Eifel district in Germany. Fisher and Waters (1970) state that such craters are generally less than a mile in diameter and are bordered by a low rim of ejecta. The rims are composed of chilled volcanic debris and shattered bits of the underlying bedrock. Lava flows are absent or sparse. Nearly all maar craters appear to have been formed where strong phreatic stream eruptions have occurred, resulting from magma coming in contact with shallow lakes, marshes, or flood plains, or prolific aquifers. In addition, four other maar craters exist in the Potrillo Basalt field. They include Hunts Hole and Potrillo Maar to the south (DeHon, 1965; Reeves and DeHon, 1965), and Malpais and Mount Riley Maar southwest of Kilbourne in the West Potrillo Mountains (Hoffer, 1973). From the bottom of the crater to the top the following major units are exposed: sand, silts, and clays of the Santa Fe Formation, dense porphyritic olivine

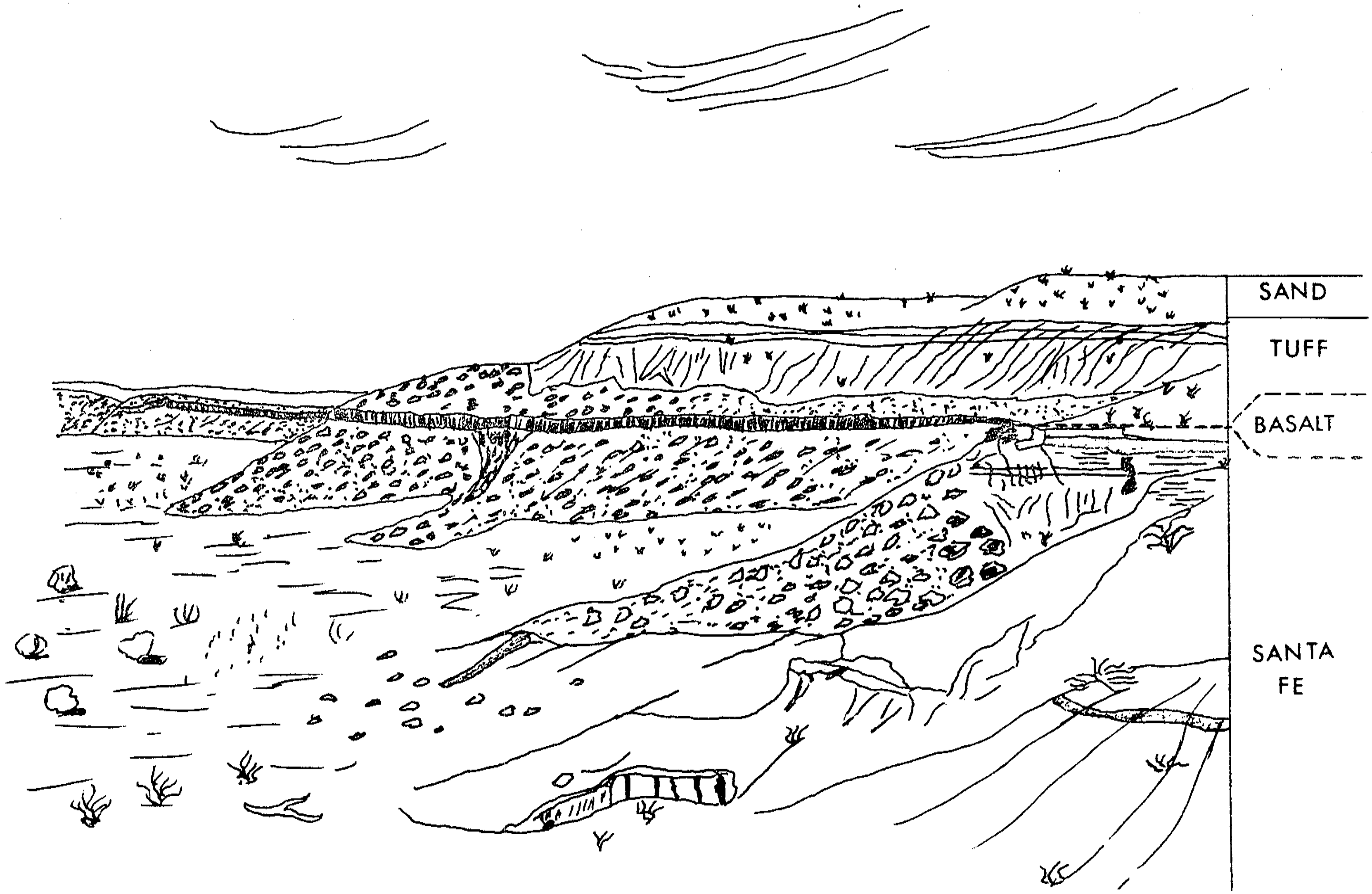


Fig. 1-1 Kilbourne Hole

basalt, bedded tuffs and ejecta, and loose blowsand on the rim and outer flanks (see Fig. 1-1).

DeHon (1965) has outlined four stages in the development of Hunts Hole which will also apply to Kilbourne: 1) separation of volatiles; 2) initial perforation; 3) gas venting; and 4) crater enlargement. The initial stage, separation of volatiles from the magma, has been attributed to either a reduction of confining pressure or changes in composition due to crystallization and reduction of pressure (DeHon, 1965). However, Fisher and Waters (1970) state that maar volcanoes occur in environments where an available source of groundwater is abundant or could have been present in the past. King et al. (1969) report a present mound in the groundwater table under the maar craters giving support to the idea that groundwater seepage into a deep fracture zone beneath the Holes, and its contact with the magma, could have produced the necessary volatiles to trigger the initial explosion. From their study of over 30 maars, Fisher and Waters (1970) conclude on the basis of morphological and geological evidence, together with the presence of abundant sideromelane within the ejecta layers, that steam explosions are an important factor in the development of maars. Sideromelane has been identified within the ejecta layers in Kilbourne Hole.

During the initial perforation stage large blocks of granular basalt from the overlying flow were thrown outward from the vent area along with bombs, scoria, and other rock fragments derived from the vent at depth. Contemporaneous with the emplacement of the larger fragments, which concentrated near the vent area, horizontally moving base surge density currents spread outward from the vent. These turbulent density clouds of steam and solid ejecta along with air fall debris constructed a rampart of stratified tuffs displaying antidune bedforms and cross laminae. The activity probably occurred as staccto-like eruptions of progressively lesser intensity as the over-all grain size decreased upward into the section. Periodically, a large block was ejected from the vent and accumulated with the finer-grained tuffs; bedding sags under large basalt blocks high in the tuff section testify to this activity. Not all of the ejected material accumulated on the rim as sand- and lapilli-size fragments can be seen mixed with recent blow-sand in a 5 and 2 1/2 mi diameter circle outward from the vents of both Kilbourne and Hunts Hole, respectively. DeHon (1965) attributes contemporaneous "rains", caused by condensation of expelled volatiles or by precipitation initiated by volcanism as producing accretionary lapillae, reworking much of the rim material, and initiated slippage along bedding planes and mud flows.

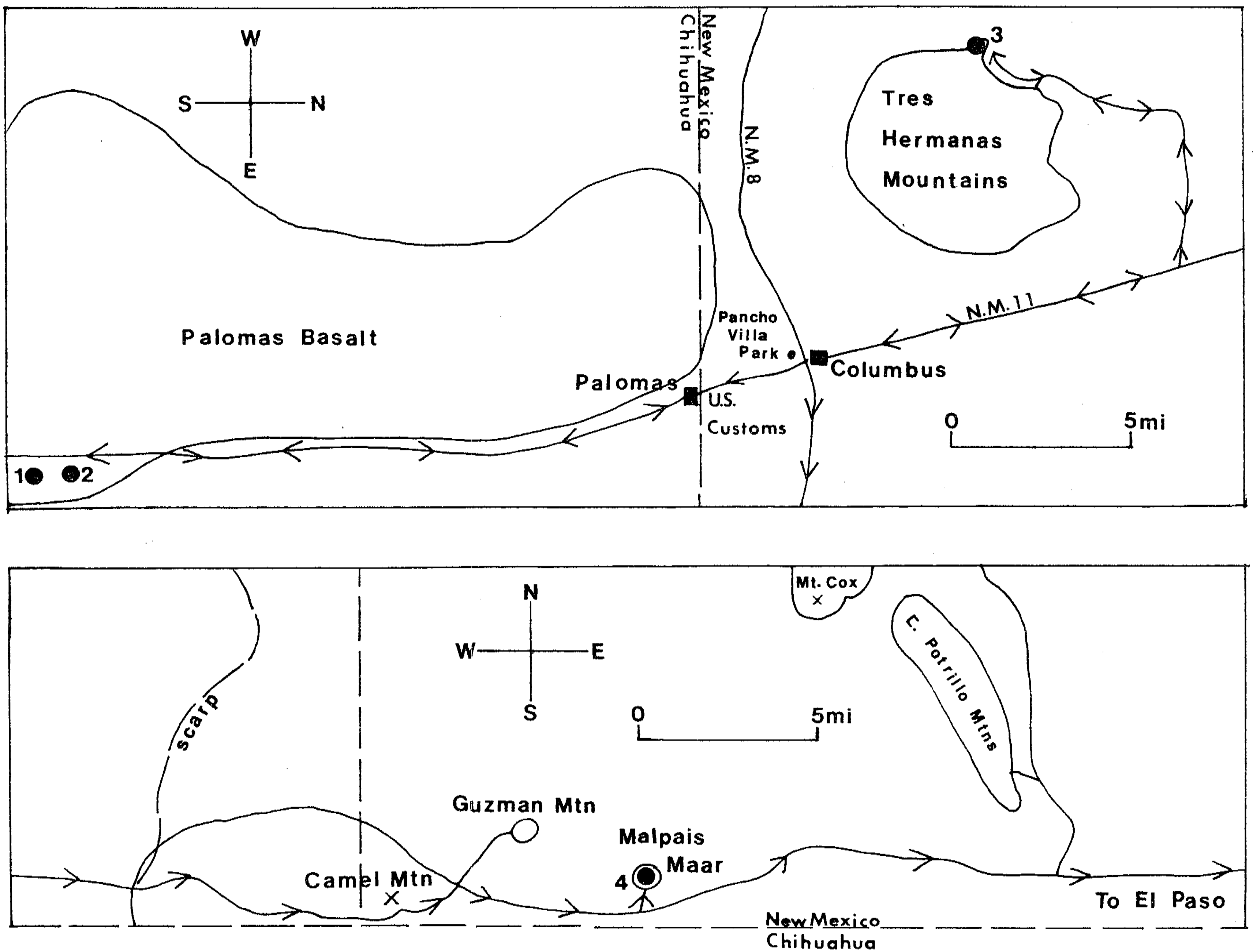
Return to main road, passing by Hunts Hole.

47.0	4.1	Turn right on A-13 toward East Potrillo Mountains.
48.5	1.5	Turn left at ranch gate.
51.4	2.9	Cattleguard; at 2:00 bulldozer pad of Pure oil test on east slope of East Potrillo Mountains.
52.9	1.5	Turn right into East Potrillo.
54.0	1.1	STOP 3: East Potrillo Mountains (see Hoffer and Hoffer, this guidebook) (one hour stop, lunch).
55.1	1.1	Turn right at main road and head south.
56.9	1.8	Fork in road; bear right.
58.8	1.9	Road forks; bear right.
58.9	0.1	Intersect border road; turn right toward west.
59.5	0.6	Cross recent fault scarp.

60.3	0.8	Cross cattleguard; drive up on old railroad bed and continue south on dirt road toward Old Mexico.
61.5	1.2	STOP 4: Potrillo Maar (see Reeves and DeHon, 1965) (15 minute stop).
62.7	1.2	Old railroad bed; turn left and head west.
63.8	1.1	Road cut in caliche; fault scarp at 3:00.
68.5	4.7	Intersection of A-5 and border road; continue straight ahead. A-5 leads past the old Cox Ranch and north to Mount Riley-Cox. Just northeast of the Cox ranch was the site of one of General Pershing's main camps in 1916. The area is strewn with numerous old bottles, cans, uniform buttons, boot fragments, etc. The former ranch foreman at the Cox Ranch, Bill Sullivan, reported finding an 1899 dime at the site in 1974. It is thought that Pershing camped in this area because there was a good supply of water.
69.0	0.5	Cross fault scarp on east edge of West Potrillo Mountains.
74.6	5.6	Leave railroad bed; bear left; pass through fence; bear right and return to railroad bed.
75.4	0.8	Malpais maar at 3:00 (we will stop here tomorrow).
77.2	1.8	CAUTION -- bridge out; bear right into arroyo and return to railroad bed.
79.2	2.0	Turn left on A-2 to cinder cone.
81.4	2.2	STOP 5: Guzman Lookout (see Hoffer and Sheffield, this guidebook).
		Turn around and return to railroad bed.
83.6	2.2	Intersection of A-2 and railroad bed; turn right.
84.3	0.7	Bridge.
87.5	3.2	Eagles Nest at 2:00 (see R. Hoffer, this guidebook); composed of lower Cretaceous clastics and carbonates; 2:30, rounded hill of granite, andesite, and Cretaceous; 12:00, Tres Hermanas Mountains, high peaks of quartz monzonite surrounded by Cretaceous and Tertiary volcanics.
89.4	1.9	9:00, hill composed of Lower Cretaceous and Permian Hueco Limestone (Hoffer, 1976).
91.8	2.4	9:00, sand-covered hill of Silurian Fusselman dolomite (Hoffer, 1976).
94.0	2.2	Turn left off railroad bed; pass through fence and bear right. We have just passed over the Camel Mountain escarpment and into pluvial Lake Palomas (see Reeves, 1969). The escarpment extends south to southeast from the southeast corner of Luna County, New Mexico into northern Mexico. It is thought to be tectonic in origin, but the lower part of the scarp has been modified by wave action. During the mid to late Pleistocene, the area was inundated by the waters of Lake Palomas covering an area of approximately 3000 mi^2 (Reeves, 1969). Evidence of Lake Palomas is from the occurrence of abandoned beaches, spits, wave-cut escarpments, multiple shorelines and lacustrine deposits (Reeves, 1969).
94.4	0.4	Gate; last vehicle through please close the gate.
94.6	0.2	Cattleguard.
100.0	5.4	Cattleguard.
103.2	3.2	2:00, Florida Mountains composed of Precambrian, Paleozoic, Cretaceous, and Tertiary rocks (see Corbitt, 1971); 12:00, Tres Hermanas Mountains; 11:00, Sierra Baca Grande of Pennsylvanian, Permian, and Cretaceous strata.
105.7	2.5	Cattleguard.
108.0	2.3	Enter Columbus, New Mexico; bear right at fork.

108.1	0.1	Turn left onto railroad bed.
108.3	0.2	Turn left onto New Mex. 11; then right on New Mex. 9.
108.4	0.1	Turn left into Pancho Villa State Park (see Kottlowski; this guidebook).

END OF FIRST DAY.



Second Day Route

Second Day -- April 11, 1981

Road Log from El Paso to Columbus to Palomas Volcanic Field to Tres Hermanas Mountains to West Potrillo Mountains to El Paso, Texas

by

Jerry M. Hoffer, Robin L. Hoffer, and Thomas J. Frantes
Department of Geological Sciences
U. T. El Paso

Driving Distance and Time: 160 miles, 7 hours, including stops

Starting Time: 9:00 am

Assembly Point: Pancho Villa State Park, Columbus, New Mexico

Summary

The second day field trip will start by viewing some features of the Palomas Volcanics in Mexico. The trip will then visit the Tres Hermanas Mountains to observe the Cretaceous section and then return to El Paso via the West Potrillo Mountains with a stop at Malpais Maar.

Cumulative Mileage

Mileage	Between Points	
0.0	0.0	Intersection of New Mexico Highways 9 and 11; Pancho Villa State Park; turn right at intersection.
3.2	3.2	Cross U.S.-Mexico border; proceed south on Mex. 25.
11.3	8.1	Roadcut in Palomas Volcanics, olivine basalt.
14.2	2.9	Tertiary volcanic outcrops, 9:00 to 11:00
17.7	3.5	Palomas flows exposed in roadcut; trachybasalt.
19.1	1.4	Palomas flows exposed in roadcut.
19.9	0.8	STOP 1: pull off road to the right and stop (15 minute stop). Walk 50 yards to the northwest for view and discussion of Palomas Volcanic field (see Fig. 2-1).
		The Palomas Volcanic field is composed of cinder-spatter cones and thin lava flows of Tertiary-Quaternary age. The flows are primarily alkali olivine basalt, but also include older trachybasalt and trachyandesite. The field covers approximately 300 mi^2. Here on the eastern edge of the field we can see evidence of basalt extrusion into a hydrous environment, i.e. swamp, lake, or wet sediments. At this stop we will view the platy jointing displayed by the basalt. Such jointing is thought to represent shear planes which developed as the viscosity of the lava increased during flowage (Frantes and Hoffer, 1981).
		Return to cars; turn around and head north.
20.8	0.9	STOP 2 (half-hour stop): Park cars on right and walk south on Mex. 25 to view the hydroclastic sediments and basaltic pillows (?). Return to vehicles and continue north toward border on Mex. 25.

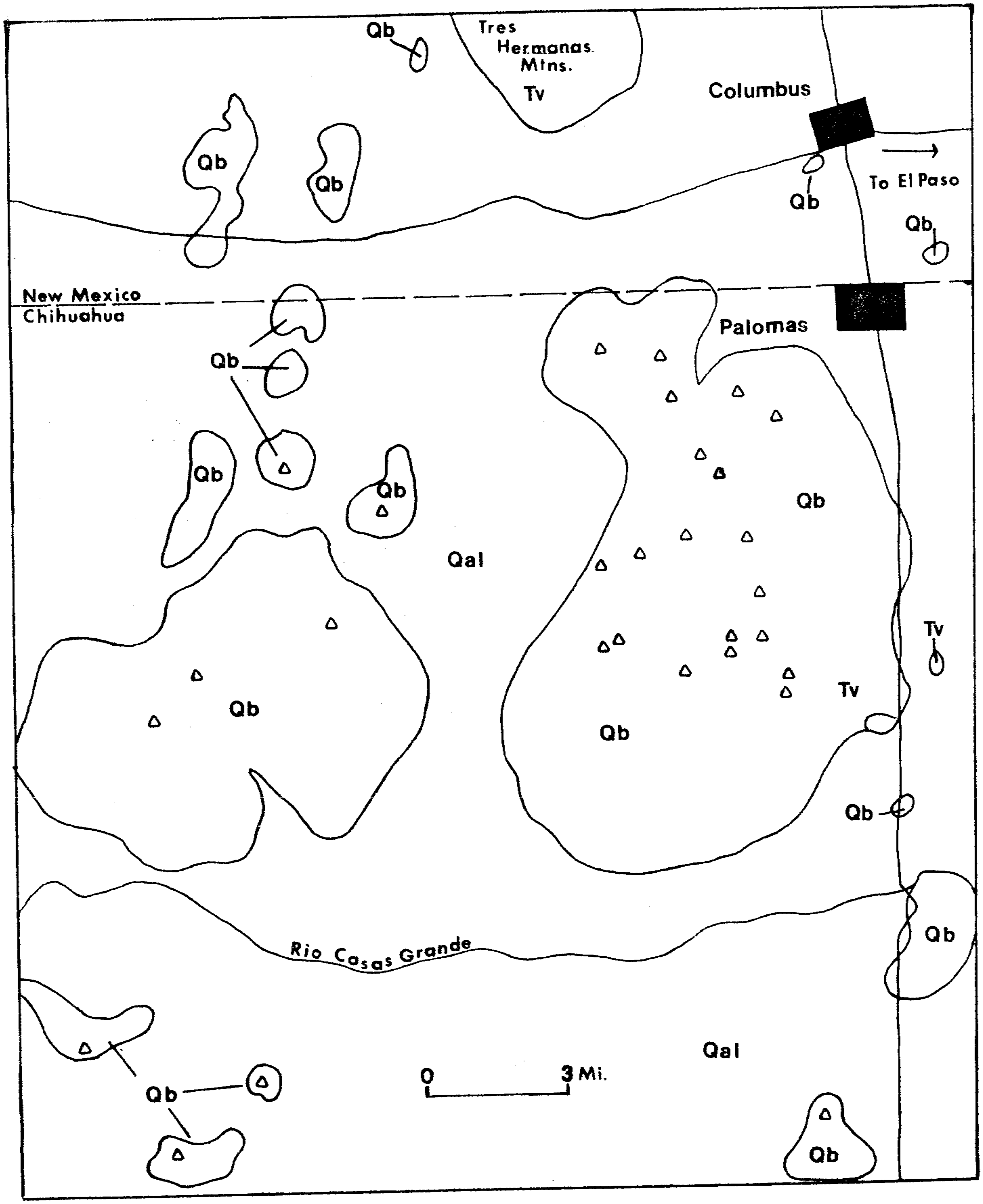


Fig. 2-1 Palomas basalt field. Qb-Quaternary basalt, Tv-Tertiary volcanics, Qal-Quaternary alluvium. Small triangles represent volcanic cones.

34.6	14.7	Palomas City limits.
35.7	1.1	Cross Mexico-U.S. border.
35.8	0.1	Stop at American Customs. They will ask you your citizenship and what you are bringing from Mexico; don't hassle Customs!!!!
38.9	3.1	Intersection of New Mexico 9 and 11; continue straight ahead.
39.1	0.2	Junction State 11 and Broadway Street; continue straight ahead.
45.0	5.9	9:00, Tres Hermanas Mountains which represent a central stock of Tertiary granite-quartz monzonite which has intruded Paleozoic and possibly Cretaceous sedimentary units and Tertiary volcanic rocks (Balk, 1962). The sedimentary strata consists of Silurian, Mississippian, Permian, and Lower Cretaceous units. Approximately 2000 ft of Paleozoic rocks crop out north of the stock where they have been marbleized, silicified, and mineralized. Lower Cretaceous strata crop out on the west side of the area where approximately 1530 ft are exposed (Kottlowski and Foster, 1962). Igneous rocks consists of intrusive andesite and granite-quartz monzonite and dikes of monzonite, latite, rhyolite, and basalt. Extrusive igneous rocks consist of Tertiary breccias, tuffs, flows and agglomerates of andesite to latite composition. Two types of mineral deposits occur in the Tres Hermanas Mountains: 1) manto-like replacement bodies in Paleozoic limestones, and 2) vein deposits in vertical fractures and/or faults in Paleozoic limestone and Tertiary volcanic units (Griswold, 1961). Chief metallic minerals of the deposits are zinc and lead with lesser amounts of silver, copper, and gold. At the Mahoney mines, in the northwest corner of the area, Griswold (1961) reports the occurrence of sphalerite, galena, chalcopyrite, willemite (?), and scheelite in the primary zone; gangue minerals include calcite, pyrite, wollastonite, garnet, epidote, magnetite, and quartz. Secondary ore minerals are willemite, calamine, smithsonite, hydrozincite, cerussite, anglesite, azurite, malachite, and cerargyrite. Mines operating in this area until 1920 produced about $500,000 worth of zinc, lead, silver, gold, and copper. Griswold (1961) reports that the mineralization took place after emplacement of the granite-quartz monzonite stock and nearly contemporaneous with the latite volcanic sequence. At 11:00 are the northernmost outcrops of the Palomas Volcanics; Florida Mountains at 1:00.
48.3	3.3	CAUTION; narrow bridge.
49.8	1.5	Intersection of State 11 and 495; turn left on 495.
52.0	2.2	Pavement ends; turn left on dirt road.
52.3	0.3	Road curves; bear right.
53.3	1.0	Road curves to right.
54.3	1.0	Intersection; turn left on dirt road.
57.3	3.0	Road forks; take center road into corral.
57.33	0.03	Pass through left gate.
57.35	0.02	Bear right; road to the left leads to the old Mahoney mines.
57.5	0.15	Bear right and pass through gate.
57.8	0.3	Cross arroyo.
57.9	0.1	Road forks; bear left.

59.1	1.2	Road forks; bear right.
60.0	0.9	Intersection; turn right.
60.1	0.1	Cross arroyo.
60.2	0.1	Road forks; bear right.
60.5	0.3	STOP 3 (1 1/2 hour stop): Examine Lower Cretaceous strata. Over 1500 ft of Lower Cretaceous strata are exposed at this location; the section, described by Kottlowski and Foster (1962), consists of basal clastics (arkosic sandstones and chert conglomerate), massive limestone, limestone conglomerate, and upper limestone. Approximately 1 1/2 hours will be spent here examining the section (see Figs. 2-2 and 2-3). The Lower Cretaceous of southern New Mexico is currently under study by Robin L. Hoffer.
71.2	10.7	Return to cars and return to intersection of State 11 and 495; turn right on State 11 towards Columbus.
72.7	1.5	CAUTION; narrow bridge.
81.9	9.2	Intersection on Broadway Street and State 11 in Columbus; gas station on left.
82.1	0.2	Turn left at the old Columbus railroad station and head east on old railroad bed.
82.2	0.1	Turn right on dirt road.
82.3	0.1	Bear left and head east.
84.6	2.3	Cattleguard.
90.4	5.8	Cattleguard.
95.8	5.4	Cattleguard.
96.0	0.2	Gate (last vehicle please close gate).
96.3	0.3	Bear right onto County road A-1.
98.9	2.6	Tertiary andesite intrusive rock at 2:00 on U.S.-Mexico border.
100.5	1.6	Tertiary rhyolite volcanic hill at 3:00.
101.0	0.5	Camel Mountain at 12:00, composed of Tertiary tuffs and breccia of rhyolite to latite composition. The mountain is cut by several shear or brecciated zones, striking N15°E to N45°W; within these zones the fragments are recemented by quartz and manganese oxides (Hoffer, 1976).
103.1	2.1	Hill of Tertiary volcanics similar to Camel Mountain.
103.8	0.7	Intersection; turn left on A-1.
104.2	0.4	Road forks; bear right.
106.2	2.0	Road forks; bear left.
108.1	1.9	CAUTION; bridge out; drive into arroyo.
108.2	0.1	Return to railroad bed.
110.0	1.8	Turn left onto dirt road leading to Malpais maar.
110.5	0.5	Road divides; bear right.
111.4	0.9	Stop 4 (15 minute stop). Base-surge and air-fall deposits form Malpais maar, walk down small arroyo about 100 yards (Page, 1973).
		Return to vehicles and retrace route to old railroad bed.
112.8	1.4	Intersection of old railroad bed and Malpais maar road; turn left.

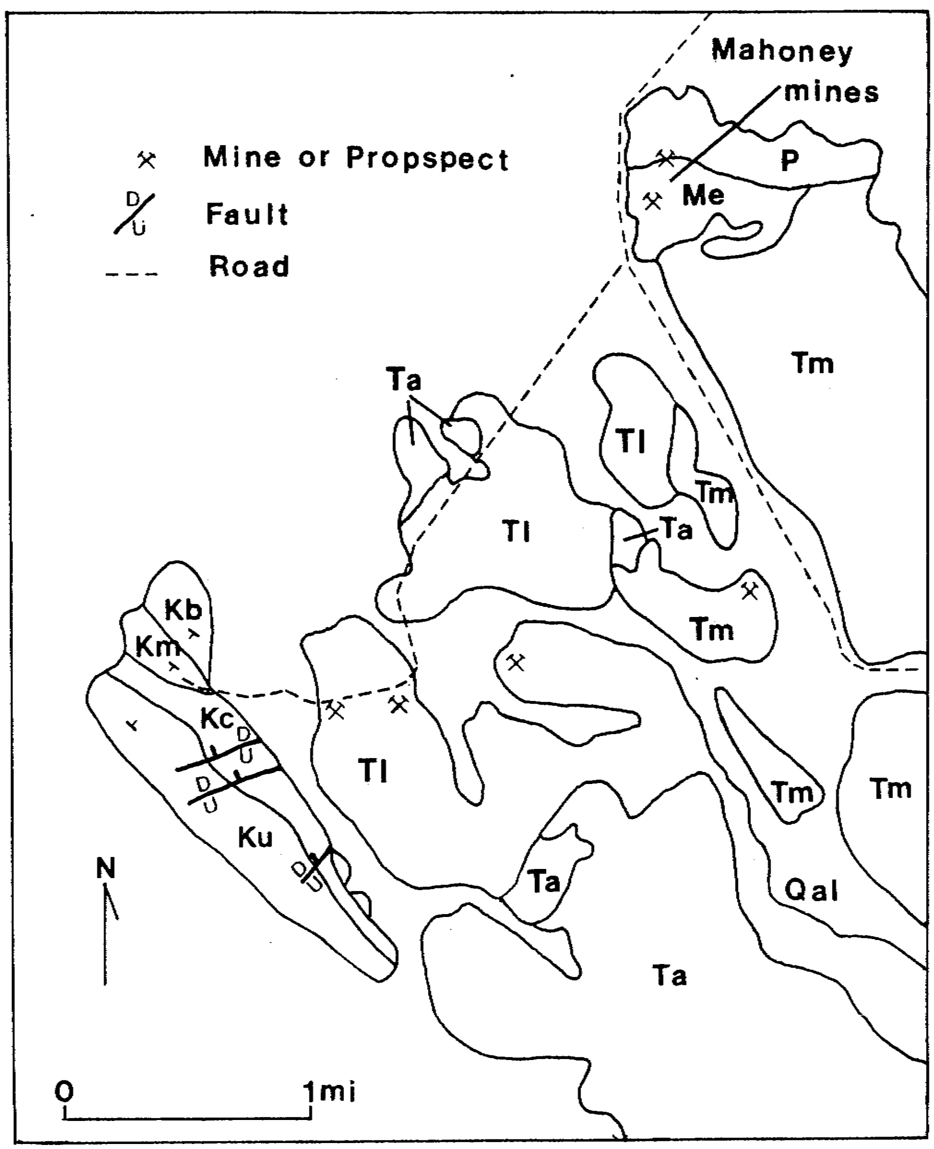


Fig. 2-2 Geology of NW Tres Hermanas Mountains. Qal-Quaternary alluvium, Tr-Tertiary rhyolite, Tm-Tertiary quartz monzonite, Ta-Tertiary andesite, Tl-Tertiary latite, Ku-Cretaceous upper limestone, Kc-Cretaceous limestone conglomerate, Km-Cretaceous massive limestone, Kb-Cretaceous sandstone and conglomerate, P-Pennsylvanian limestone, Me-Mississippian, Escabrosa limestone.

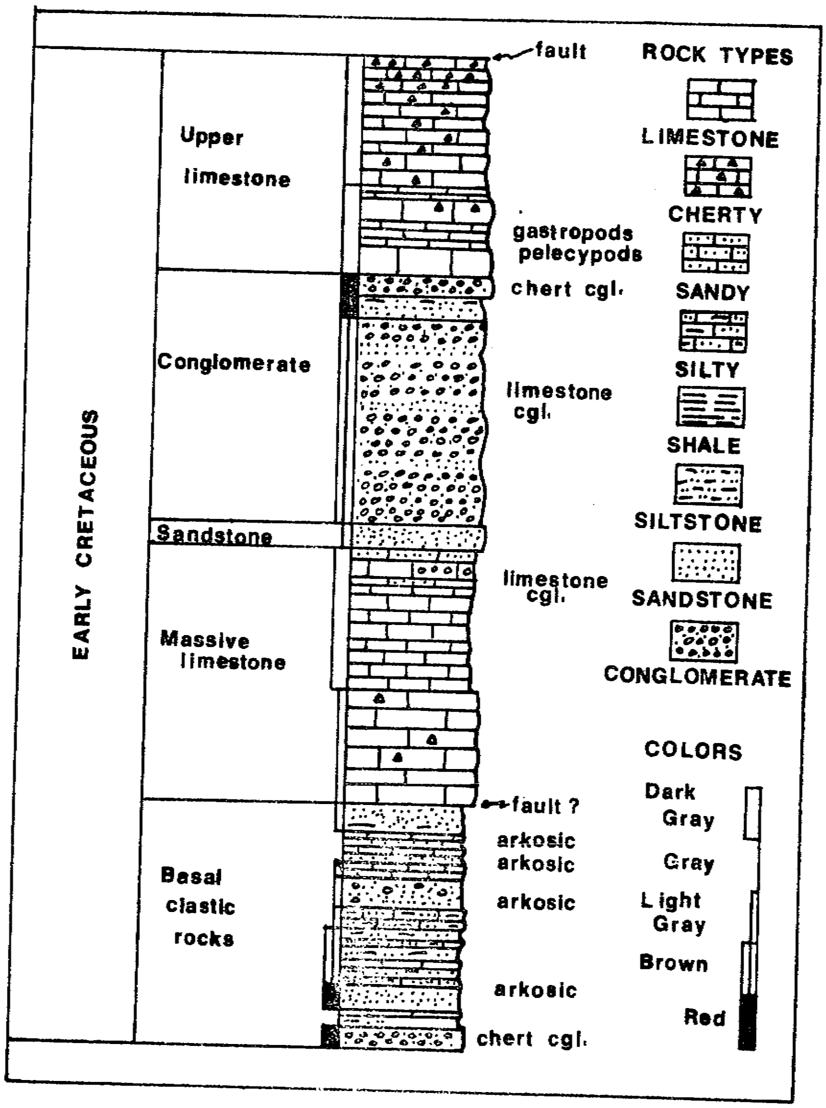


Fig. 2-3 Stratigraphic section of the lower Cretaceous, Tres Hermanas Mountains (after Kottlowski and Foster, 1962).

113.5	0.7	Leave railroad bed; bear right and then left through gate.
113.6	0.1	Return to old railroad bed and continue east.
119.7	6.1	Road to left leads to old Cox Ranch and north to Mount Riley-Cox; continue straight ahead.
125.5	5.8	Bear left; leave old railroad bed; cross cattleguard onto dirt road.
127.0	1.5	Road forks; bear right and continue straight ahead.
129.0	2.0	Intersection; continue straight ahead.
143.2	14.2	Cross cattleguard.
143.9	0.7	Intersection; turn right on A-5.
144.9	1.0	Bear left; cross railroad tracks onto A-17.
147.6	2.7	Intersection; turn right on blacktop.
149.3	1.7	Intersection; turn left onto Country Club Road.
149.9	0.6	Stop sign; then continue straight ahead.
150.4	0.5	Cross Rio Grande.
152.0	1.6	Intersection and stoplight; continue straight ahead onto North Mesa.
152.6	0.6	Turn right at stoplight onto Interstate access road.
152.8	0.2	Enter I-10, eastbound.
154.7	1.9	Sunland Park overpass.
157.4	2.7	Executive Park overpass.
159.3	1.9	Leave Interstate at U.T. El Paso exit.
159.5	0.2	Stop sign; turn left under the Interstate.
159.6	0.1	Stop light; turn left onto Sun Bowl Drive.
159.7	0.1	Turn right into U.T. El Paso campus.
159.9	0.2	Intersection of Hawthorne Avenue and University Avenue; turn left on Hawthorne.
160.0	0.1	Geology Building.

END OF FIELD TRIP

REFERENCES CITED IN ROAD LOGS

Balk, R., 1962, Geologic map of the Tres Hermanas Mountains: New Mex. Bur. Mines & Min. Res., Geol. Map 16.

Corbitt, L.L., Structure and stratigraphy of the Florida Mountains, New Mexico: Univ. New Mex., Ph.D. Dissertation 115 p.

DeHon, R.H., 1965, A maar origin of Hunt's Hole, Dona Ana County, New Mexico: Texas Tech Univ., M.S. Thesis, 70 p.

Fisher, R.V., and Waters, A.C., 1970, Base surge bed forms in maar volcanoes: Am. Jour. Sci., v. 268, p. 157-180.

Frantes, T.J. and Hoffer, J.M., 1981, Geology of the Palomas Volcanic field, northern Chihuahua, Mexico and southern New Mexico, United States (abst.): Geol. Soc. Amer. Cordill. Sec. Mtg. Prog. (in press).

Griswold, G.B., 1961, Mineral deposits of Luna County, New Mexico: New Mex. Bur. Mines & Min. Res., Bull. 72, 157 p.

Hoffer, J.M., 1973, Quaternary basalts of the West Potrillo Mountains, south-central New Mexico: El Paso Geol. Soc. Guidebook 7, p. 16-22.

———, J.M., 1975, The Aden-Afton Basalt, Potrillo Volcanics, south-central New Mexico: Texas Jour. Sci., v. 26, p. 379-390.

———, 1976, Geology of the Potrillo Basalt field, south-central New Mexico: New Mex. Bur. Mines & Min. Res., Cir. 149, 30 p.

King, W.E., Hawley, J.W., Taylor, A.M., and Wilson, R.P., 1969, Hydrogeology of the Rio Grande valley and adjacent intermontane areas of southern New Mexico: Water Res. Inst. Rept. 6, New Mex. State Univ., 141 p.

Kottlowski, F.E. and Foster, R.W., 1962, Pre-Tertiary strata of Tres Hermanas Mountains, Luna County, New Mexico: Amer. Assoc. Petrol. Geol., Bull., v. 46, p. 2090-2098.

Millican, R.S., 1971, Geology and petrography of the Tertiary Riley-Cox pluton, Dona Ana County, New Mexico: Univ. Texas, El Paso, M.S. Thesis, 88 p.

Page, R.O., 1973, Stratigraphy of the Quaternary Malpais maar volcano, Dona Ana County, New Mexico: Univ. Texas, El Paso, M.S. Thesis, 46 p.

Reeves, C.C., Jr., 1969, Pluvial lake Palomas, northwestern Chihuahua, Mexico: New Mex. Geol. Soc. Guidebook, p. 143-1954.

———, and DeHon, R.A., 1965, Geology of Potrillo maar, New Mexico and northern Chihuahua, Mexico: Am. Jour. Sci., v. 263, p. 401-409.

Reiche, Parry, 1940, The origin of Kilbourne Hole, New Mexico: Amer. Jour. Sci., v. 238, p. 212-225.

PANCHO VILLA STATE PARK*

by

Frank E. Kottlowski, Director
New Mexico Bureau of Mines and Mineral Resources
Socorro, New Mexico 87801

INTRODUCTION

Pancho Villa State Park, on the southwest edge of Columbus, was created by the 24th New Mexico Legislature on March 6, 1959, "in interest of preservation of the memory of the unique, historical occasion of the last hostile action by foreign troops within the continental United States." The park was dedicated on November 18, 1961, by Governor Edwin Mechem of New Mexico and Governor Teofilo Borunda of Chihuahua; it occupies the grounds of old Camp Furlong, southwest of Columbus. Creation of the park was a gesture of good will between the United States of America and Los Estados Unidos Mexicanos.

As a further step of good feeling between New Mexico and Chihuahua and between Mexico and the United States, Avenida de Amistad (Avenue of Friendship) was dedicated in June 1966 by Chihuahua's Governor Praxedes Giner Duran, and a gift of 400 sycamore trees was presented to New Mexico's Governor, Jack M. Campbell.

Some of the original Camp Furlong buildings, relics of Pershing's expedition into Mexico, an outstanding desert botanical garden, and panoramic views of southern New Mexico and northern Mexico are features of the park. Facilities include picnic and camping shelters, barbeque grills, restrooms with showers, and a fully equipped playground. Stone-lined driveways and foot trails lead through the desert garden, up Villa Hill, and to the remnants of the military camp. The headquarters building, partly in ruins, is an adobe house with a rusty sheet-metal roof. Nearby is the first great rack installed to service U.S. Army motorized transport engaged in actual field operations. Across and east of the Columbus-Palomas highway is the site of the first operational military air base established by the U.S. Army. From the site, biplanes flew into Mexico to aid the Pershing expedition. In Columbus is the privately owned Pancho Villa museum.

Along the west side of the park, centered on Villa Hill, is the desert-vegetation garden. This plant paradise contains spiney wands of ocotillo; pointed, sawtoothed leaves of yucca and agave; thorny branched mesquite, purple cholla, snowball cactus, and stag horn cholla; polkadot, bunnyear, and prickly pear cacti; barrel cacti; jubilee tree; and creosote (greasewood bush).

HISTORY

During the late months of 1914, Francisco "Pancho" Villa was part-time president of Mexico, alternating in office with Emiliano Zapata. Disliking Mexico City, Villa left and headed home to Chihuahua. His enemies, Venustiano Carranza and Alvaro Obregon, united against Villa, and during 1915 their armies defeated the villistas in a series of battles. The United States officially recognized Carranzas the main power in Mexico, supplied arms to carrancistas, and transported Mexican troops through Arizona to fight in Sonora against Villa.

Before 1915 Villa had been friendly with the United States; he went on hunting trips with Generals Pershing and Hugh Scott, rented a house in El Paso, purchased military supplies from New York, and basked in the aura of a favorable American press. Florence and Robert Lister in Chihuahua, Storehouse of Storms, noted General Scott's comment that the United States government's recognition of Carranza solidified the power of a man who rewarded the United States with kicks on every occasion. It also made an outlaw of Pancho Villa, who had helped the United States by returning millions of dollars worth of property to Americans in Mexico.

After his defeats in Sonora, Pancho Villa vowed retaliation against the United States for its support of the carrancistas. In March 1916 he moved northward toward Palomas with 400 men. At 4:30 am in the moonless, black hours of March 9, 1916, a shot shattered the silence at Campe Furlong, killing sentinel Fred Griffin at Troop K's headquarters. "Viva Villa!" rang out in all parts of the camp and in adjacent Columbus, as Pancho Villa's

---

*reprinted from New Mexico Geology, vol. 2, 1980.

villistas began their historic raid. Buildings were set afire as the battle swirled through Camp Furlong and Columbus. American machine guns helped keep the invaders at bay; as the eastbound morning train approached in the early dawn, the Mexicans retreated. Smoke drifting up from the smoldering ruins hung over the battleground. American casualties included 24 dead and seven wounded (soldiers and civilians). Villa's dead have been estimated at between 50 and 200.

General "Black Jack" Pershing's punitive expedition into Mexico sent 15,000 men to capture Villa. Motorized transport was used for the first time in a military compaign; also for the first time, the Army Air Corps went into action in foreign skies. Pancho Villa escaped. Within a year Pershing's expedition reentered New Mexico, and the Columbus raid became history. That memories have been softened by desert breezes and bitterness replaced by friendship between Chihuahua and New Mexico is proclaimed by the establishment of Pancho Villa State Park. To most Mexicans, Pancho Villa was a hero of the Mexican Revolution. The blame for the Columbus raid can be shared by both nations.

GEOLOGY

In the northwest corner of the park is Villa Hill, labeled "the hill with a view" by park signs. Rising about 25 ft above the surrounding sloping plain, it is topped by a flagpole with American and Mexican flags. From the crest, the Mexican-American border is clearly visible, and broad vistas stretch to the horizon in all directions.

Villa Hill is an outcrop of reddish-brown basalt similar to that on Loma Vista, the 75-ft hill lying 2 mi southeast. On the hilltop the basalt is highly vesicular with irregular cavities scattered throughout. These indicate that basalt flowed as a hot, semiliquid mass on the land surface, with the vesicles left as a result of gas-filled cavities when the rock cooled. East of Villa Hill, rocks exposed along the paths are a typical cross section of volcanic flows, showing flow basalt that is locally brecciated and contains small angular fragments of the gravels onto which it was extruded.

To the north-northeast is Columbus, and in the distance are the rugged Florida Mountains. On the eastern skyline, across the irrigated sandy Columbus Valley, the low volcanic hills of the West Potrillo Mountains stretch southward into northern Chihuahua. Other volcanic hills and ranges lie to the south amid sandy plains south of Palomas in northern Mexico. Underground water from ancient rains, stored in sand and gravel underlying the plains around Columbus, is now pumped to irrigate the green fields that circle the town.

During past centures the Mimbres River (which rises in the Mogollon and Black Range areas north of Santa Rita) has, during flood stage, swept past Deming, rushed around the north and east sides of the Florida Mountains, and passed east of Columbus into Mexico to fill playas below Palomas.

To the southwest are the rugged peaks of Sierra de Palomas in northern Chihuahua, and on the western horizon is the sharp peak of Big Hatchet Mountain in southwest New Mexico. Sierra de Palomas' extension across the Mexican-American border (15 mi to the west) is the Carrizalillo Hills; the Cedar Mountains form the low skyline ridges to the west-northwest. Five miles to the northwest, bold, jagged triple peaks of the three sisters (Tres Hermanas Mountains) block distant views in that direction.

Pancho Villa State Park is on the low edges of the large alluvial fan that extends southeast from the Tres Hermanas Mountains. Pebbles, cobbles, and boulders in the park were derived from rock outcrops in those mountains; they include fragments of quartz, feldspar, monzonite, rhyolite, latite, basalt, limestone, chert, and andesite. Mines in the northwest Tres Hermanas Mountains operated until the 1920's and produced about one-half million dollars worth of zinc, lead, silver, gold, and copper. Present-day outcrops of interest to rock hounds contain Mexican onyx, calcite, spurrite, and dumortierite.

GEOMORPHIC PARAMETERS OF LOS MEDANOS DE SAMALAYUCA, CHIHUAHUA, MEXICO

by

Richard A. Marston and Robert H. Schmidt, Jr.
Department of Geological Sciences
University of Texas at El Paso
El Paso, Texas 79968

INTRODUCTION

The Samalayuca dune field, located approximately 50 km south of El Paso-Ciudad Juarez, covers about 145 km^2 (Fig. 1). Los Medanos de Samalayuca have posed persistent environmental opportunities and constraints on human activities (Brand, 1933, 1937). Physical parameters of los Medanos de Samalayuca have not been well documented, despite persistent effects of the dune field on local water supplies and on migration and trade along the Chihuahua Trail.

The main part of los Medanos de Samalayuca has a maximum extent of approximately 32 km in length and 13 km in width. The sand hills are located between and parallel to the Sierra del Presidio on the northeast, and the Sierra de Samalayuca on the west. These linear mountain ranges rise abruptly 300 to 400 m from the basin floor to maximum elevations of 1843 m and 1771 m, respectively, and assume the north- northwest trend characteristic of the Basin and Range Physiographic Province in the Chiuhuahuan Desert. Most of the unconsolidated sand surface is located between elevations of 1275 m on the west and 1450 m on the east. The dune area occupies the easterly edge of a transition zone between the Tertiary volcanic ranges to the west, and the Cretaceous limestone mountains on the east. The main part of the dune field is underlain by limestone as evidenced by numerous karst features on the margins of the sand area.

CLIMATIC SETTING

The climate of the study area is typical of the north-central portion of the Chihuahuan Desert (Schmidt, 1979). The mean annual precipitation at Estacion Samalayuca is 212 mm, most of which falls as rain in the three summer months (Alvarez, 1973). The mean average annual temperature is 17.9°C with monthly extremes of 28.6°C in July and 7.0°C in January. Frequency analysis of surface wind directions for various velocities at Estacion Samalayuca indicates the greatest occurrence of 10, 15 and 20 knot winds are from the west nearly 45 percent of the time and winds in excess of 25 knots are predominantely from the southwest. A spectra analysis of winds was also made for Villa Ahumada (80 km south of the study area), where the anemometer and vane are not influenced by nearby mountains. Here the prevailing winds, and all of the strongest winds, are from the southwest.

Inspection of the wind data for four additional stations in the region (Cd. Juárez, Guzman, Banderas, and Ascension) confirm the analysis of wind data from Villa Ahumada. The prevailing westerly flow of air at Estacion Samalayuca is probably the result of the climatic station being located in the wind shadow of the Sierra de Samalayuca. All of the high dunes are south of the instrument shelter at Samalayuca, and two-thirds of these dunes are south of Sierra de Samalayuca. Therefore, the prevailing and strongest winds are probably from the southwest.

GEOMORPHIC ELEMENTS

The origin and development of the dune field has been a subject of controversy and disagreement. The dune sand, composed primarily of quartz, was probably first deposited by the ancestral Rio Grande during the Pleistocene in a large pluvial lake which occupied much of the north-central Chihuahuan Desert. The present-day Bolson de los Muertos is the largest remaining vestige of this lake. As the Rio Grande changed its course and

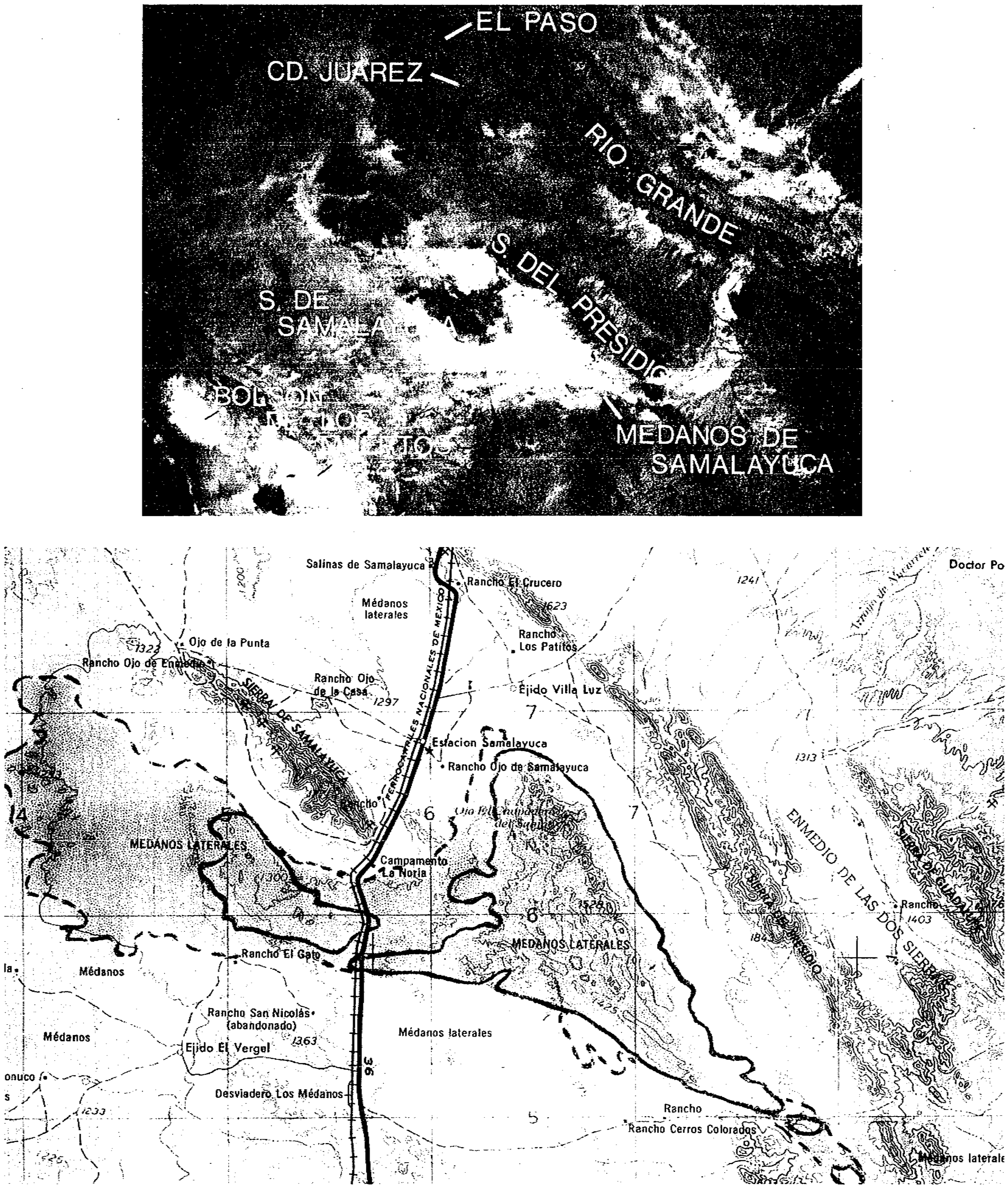


Fig. 1 Location of Los Medanos de Samalayuca. Top: ERTS image 25 Feb. 73, and AMS/DETENAL map, 1963/1976. The solid dark line indicates the area presently covered with sand dunes. The dashed line delineates the medanos surface indicated on the map (original scale 1:250,000).

pluvial conditions vanished, sand moved eastward from the ephemeral lake beds and shore line dunes to its present location. At the southern end of the Sierra del Presidio, sand has migrated through a low pass into a large valley to the east. This extension of the dune field ends abruptly at the Arroyo de Bandejas. A 1:250,000 scale map based on 1954-57 aerial photographs (AMS, 1969; DETENAL, 1976) and a 1:50,000 scale map (DETENAL, 1977) show the sandy surface medanos extending over a much larger area than is evident on satellite imagery or as observed by field reconnaissance. A zoom-transferscope was used to compare the mapped dune area with a 1972 LANDSAT color composite image and two black and white LANDSAT images taken in February and June of 1973. The northeast and southern boundary of the main dune field appear consistent over time. However, the area immediately west of the main dune field now occupies a much smaller area than indicated on the earlier maps. Surfaces covered with a thin veneer of sand were also delineated on the imagery. Again on the western portion of the dune field, there was little agreement on the boundaries between the maps and satellite images. This discrepancy may be attributed to one or more of several factors. First, the main dune area may be increasing in thickness as sand accumulates from eastward transport. Second, sand may be subject to transport beyond the Sierra del Presidio to a greater extent than indicated by the small extension to Arroyo de Bandejas. Finally, differences may result from errors in map compilation or interpretation of the aerial photographs and satellite imagery.

The general shapes and patterns of the Medanos de Samalayuca are not easily recognized as conventional dune forms. Webb (1969) describes the dune field as "nondescript piles of sand with irregular and inconsistent shapes". Examination of false-color infrared aerial photographs reveals an akle dune pattern, with sinuous dune ridges oriented transverse (NNW) to the prevailing winds. The akle dune pattern is typical where large dune sheets are subject to uni-directional winds. The field of akle dunes leads up to a high ridge near the downwind edge of the Medanos de Samalayuca. The long linear dune ridge is serrated by deep depressions. Although local relief is appreciable throughout the dune field, the elevation difference along the ridge between several dune crests and adjacent troughs exceeds 100 m. The dune sand becomes compacted with depth to an extent that moisture storage is provided near the surface. As a result, isolated shrubs and grasses are found at all topographic positions on the dunes except the slipface.

The traditional explanation for the formation and configuration of the high dunes has been irregular bedrock topography beneath the dune sand (Webb, 1969). This speculation is reinforced by the presence of a small limestone hill which protrudes through the dunes in the northwest section. In addition, the trend of the high dune ridge follows that of the Sierra del Presidio and an intervening set of low limestone hills. To test this hypothesis, magnetic and gravity surveys were conducted in the area of the high dune ridge. Transects were made using a portable Geometric proton magnetometer which relies differences in the magnetic composition of dune sand and limestone to detect a subsurface contact. Transects using a LaCoste-Romberg Model G gravity meter rely on differences in the density of dune sand and limestone to detect a subsurface contact. The two geophysical surveys failed to identify any significant irregularities in bedrock topography beneath the dune sand.

An alternate explanation for the formation and configuration of the high dunes is by eolian processes (Schmidt, 1978). The prevailing southwesterly winds approach the mountain front of the Sierra del Presidio and create a standing rotary wave. The winds flow over the ground surface in a direction opposite to the prevailing winds, sweeping away any unconsolidated sand from the pediment between the mountain front and dune field. The rotary action also explains the formation of the high dune ridge as sand accumulates from opposite directions. The high dune ridge, therefore, is appropriately termed an echo dune. This eolian process has been noted in a number of desert settings and is responsible for some of the highest dunes in the world. Echo dunes have even been found 3 km upwind from a major escarpment (Clos-Arceduc, 1966; Mabbutt, 1977; Warren, 1979).

A comparison of photographs taken in the study area during the past 10 years, including two aerial photographic surveys, show that there is considerable shifting of the high dune ridge and slipface on the dunes. What does appear to be consistent is the rather distinct line between the dune field and the adjacent desert, and the distance (approximately 2 km) to the steep mountain face of the Sierra del Presidio.

A second eolian process may account for the impressive local relief between dune crests and adjacent troughs. Intense heating of the air immediately above the dune sand creates a convective-cellular motion. The horizontal prevailaing winds distort the cells into a helical vortex (Embleton et al., 1979). This action is reinforced by the sinuous pattern of the akle dunes and high dune ridge. Where two vortices converge near the ground, a dune crest is formed; where to vortices diverge near the ground, a dune trough is formed. The helical flow of air is analogous to the fluid motion of oceans and streams (McLeish, 1968; Allen, 1969). The excessive height of the echo dune ridge above other portions of the dune field only serves to accentuate the helical flow of air.

SUMMARY

Frequent reference to los Medanos de Samalayuca has been made by travelers on the Chihuahua Trail for nearly 400 years, and more recently, scientific speculation has emerged pertaining to the origin and development of the dune field. Analysis of climatic data, interpretation of maps and satellite imagery, and geophysical surveys conducted in the field have established the significance of eolian processes, rather than subsurface controls, on the morphology of the Samalayuca dune field. Ongoing research by the authors will provide an historical perspective to resource uses of the dunes by pre-Columbian inhabitants and establish the sand area as an effective groundwater recharge zone for local water supplies.

REFERENCES CITED

Allen, J.R.L., 1969, Erosional current marks on weakly cohesive mud beds: Jour. Sed. Petrol., v. 39, p. 607-623.

Alvarez Gomez, Angel, 1973(?), Boletin Meteorologico: Compendio de 1957 a 1971, Estado de Chihuahua, Union Ganadera Regional de Chihuahua, Boletin No. 10, p. 153-157.

Brand, Donald D., 1933, The historical geography of northwestern Chihuahua: Ph.D. Dissertation, Univ. of Calif., Berkeley, p. 21-23.

———, 1937, The natural landscape of northwestern Chihuahua: Univ. of New Mexico Bull., Geol. Series, v. 5, n. 2, p. 26-27.

Clos-Arceduc, A., 1966, Le role determinant des ondes aeriennes stationnaires dans la structure des ergs sahariens et les formes d'erosion aroisinantes: Acad. des Sci., Paris, C.R., Ser. D., n. 262, p. 2673-2676.

Embleton, C., J. Thornes, and A. Warren, 1979, The nature of fluid motion, in Process in Geomorphology: John Wiley and Sons, N.Y., p. 65-68.

Mabbutt, J.A., 1977, Desert Landforms: M.I.T. Press, Cambridge, p. 246-248.

McLeish, W., 1968, On the mechanics of wind-slick generation: Deep Sea Res., v. 15, p. 461-489.

Schmidt, Jr., Robert H., 1978, The Samalayuca sand dune area and its relation to the physical environment: Abstracts, 74th Annual Mtg., Assoc. Amer. Geographers, p. 112.

———, 1979, A climatic delineation of the "Real" Chihuahuan Desert: Jour. Arid Environ., 2(3), p. 243-250.

Warren, A., 1979, Aeolian processes, in Process in Geomorphology: John Wiley and Sons, N.Y., p. 388-342.

Webb, Donald S., 1969, Facets of the geology of the Sierra del Presidio area, north-central Chihuahua: Guidebook of the Border Region (Cordoba, Wengerd and Shomaker, eds.), New Mex. Geol. Soc., 20th Field Conf., p. 182-185.

PLEISTOCENE AND PLIOCENE HISTORY OF THE INTERNATIONAL BOUNDARY AREA, SOUTHERN NEW MEXICO

by

John W. Hawley
New Mexico Bureau of Mines
and Mineral Resources
Socorro, New Mexico 87801

INTRODUCTION

The International Boundary area discussed in this paper (Fig. 1, adapted from Clemons, 1981; Seager, 1980) extends westward from the Organ-Franklin-Juarez mountain chain to the Florida and Tres Hermanas Mountains, and southward from Interstate Highway 10 (U.S. 70), between Las Cruces and Deming, to the Bolson de los Muertos region of northwestern Chihuahua. It includes parts of the two large intermontane basins, the Mesilla Bolson on the east and the lower Membres Basin on the west. These two basins are separated by the Aden Hills and West Potrillo volcanic highlands. They lack integrated surface drainage, except where crossed by the Rio Grande (Mesilla) Valley and channels of the lower Mimbres system.

Emphasis of this paper is on the evolution of bolson areas flanking the Mesilla Valley of the Rio Grande. The following discussion of the past 5 m.y. of the area's history expands upon concepts of Quaternary and late Tertiary geology that were developed by many individuals, including Kottlowski (1958), Ruhe (1962, 1964), Hawley and Gile (1966), Strain (1966, 1971), Metcalf (1967, 1969), Hawley and Kottlowski (1969), Hawley _et al._ (1969), Gile _et al._ (1970), Lovejoy (1971, 1975), Hoffer (1973), and Seager and Clemons (1975). These concepts have recently been reviewed by Hawley (1975), Hoffer (1976), Lovejoy and Hawley (1978), Seager and Morgan (1979), and Strain (1980).

Since 1975 there has been a major effort in mapping (1:24,000 to 1:62,500 scale) and dating of upper Cenozoic sedimentary and volcanic units that make up the basin-fill sequence. A compilation of geologic mapping (1:125,000) by Seager, Clemons and Hawley, is almost completed and will be published the next two years. New information on radiometric ages of sediments and volcanics is outlined in Table 1. Reference should also be made to Hawley (1978, Chart 2) and Luedke and Smith (1978) for correlation of stratigraphic units and compilations of radiometric dates in the region. Gile _et al._ (1981) discuss the late Cenozoic geomorphic evolution of the Rio Grande Valley area in detail.

TECTONIC AND GEOMORPHIC SETTING

The Plio-Pleistocene history of the eastern Basin and Range province has been greatly influenced by epeirogenic uplift, tectonic deformation, and basaltic volcanic activity that started in late Miocene time (between 8 and 13 m.y. ago, Seager and Morgan, 1979). The location and gross form of intermontane basins and major stream valleys, as well as the ranges, are controlled by deep-seated processes. Uplift and differential movement of crustal segments have affected the entire region; with the effects of Basin and Range faulting and volcanism being particularly pronounced in the broad zone of structural depressions at the southern end of the Rio Grande rift. Displacements of Pliocene and lower Pleistocene beds along faults and in flexures locally exceed 200 m. Significant fault displacements (usually < 10 m) of upper Quaternary units have been documented along the east fronts of the Robledo, Organ and Franklin Mountains; with movement along a segment of the Organ frontal fault occurring in Holocene time (last 10,000 years). Prominent fault scarps (up to 3 m) produced by the Sonoran Earthquake of 1887 extend almost to the International Boundary at the New Mexico-Arizona border (DuBois and Smith, 1981). Most of the "recent" basaltic volcanism in the area appears to be older than 0.5 m.y. The extensive lava flows and numerous volcanoes of the Las Palomas and Potrillo fields were formed in late Miocene through middle Pleistocene time (Table 1).

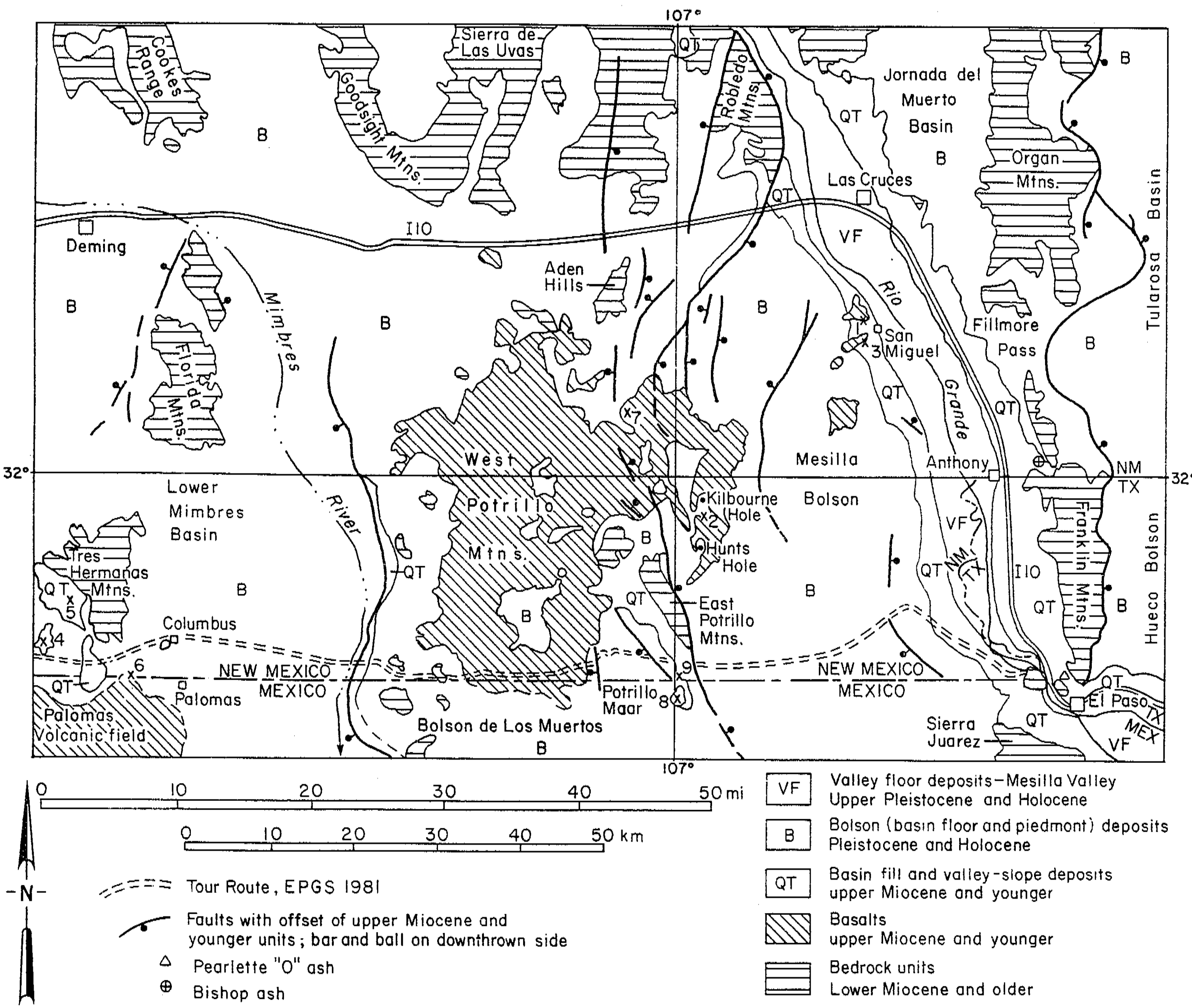


Figure 1. Index map of major Plio-Pleistocene features, with locations of dated basalts (Table 1)

Table 1

Summary of Recent K-Ar Dates for Plio-Pleistocene Basalts in the International Boundary Area, Southern New Mexico

Sample No. (Fig. 1)	Laboratory	Lab No.	Age (m.y.) (whole rock)	Comments
1	USGS-Denver[1]	D2719R	0.55 ± 0.03	Basalt at Santo Tomas; Mobil FRL #1315
2	"	D2720R	0.53 ± 0.03	Basalt of Kilbourne Hole; South Rim, Mobil FRL #1318
3	"	D2725R	0.49 ± 0.02	Basalt of San Miguel; Mobil FRL #1314
4	Univ. of Arizona[2]	UAKA79-120	3.91 ± 0.18	Basalt west of Mimbres; Siding, north end of Palomas field
5	"	UAKA79-121	5.17 ± 0.11	Basalt plug - remnant SW of Tres Hermanas; intrudes fanglomerate of Gila Group
6	"	UAKA79-122	2.96 ± 0.07	Basalt flow SW of Columbus; on alluvial surface at NE edge of Palomas field
7	"	UAKA79-130	0.533 ± 0.043	Basalt of Aden Volcano lava lake
8	"	UAKA79-131	0.183 ± 0.03	Basalt of cone flow in Potrillo Maar
9	"	UAKA79-132	1.23 ± 0.06	Basalt of Potrillo Maar north rim

[1] Cooperative research R. Marvin and J. Hawley - unpublished.
[2] Cooperative research with W.R. Seager, NMSU - unpublished.

On a regional scale during late Cenozoic time (past 15 m.y.), tectonism and volcanism have also been major factors influencing climate and thus the geomorphic processes involving mass wasting and water, wind and glacial action. On a local scale, during late Pliocene and Quaternary time, episodic changes in climate associated with interglacial-glacial cycles (with periods of thousands to hundreds of thousands of years) have been the primary factors controlling erosion-sedimentation processes in individual basins and river-valley segments. Most Quaternary deposits in this warm, arid to semiarid region record a succession of landscape instability intervals (with active erosion-sedimentation), interspersed with long periods of surface stability and soil formation. They reflect cyclic shifts in the climatic-hydrologic regimes and resultant changes in vegetation and land surface form. It is inferred that parts of glacial-pluvial intervals correspond with more moist surface conditions and better vegetative cover, as well as with increased river discharge, entrenchment of major valleys, and formation of permanent lakes. Large areas of piedmont and valley-side slopes, and tableland surfaces were stable during full glacial-pluvial intervals because of increased effectiveness of vegetative cover associated with increase in winter-spring precipitation and decrease in summer-fall rainstorm activity (Wells, 1979; Van Devender and Spaulding, 1979). Aridity and probably rainstorm intensity increased during the transition from glaciation to interglaciation, such as the late Wisconsinan to middle Holocene interval. Resultant decrease in vegetative cover and increase in erosion-sedimentation led to surface instability on piedmont slopes and valley borders. Concurrent decrease in river discharge (Rio Grande and Mimbres) and increased storm runoff and sediment production from tributary arroyo systems caused aggradation of valley floors and encroachment of arroyo-mouth alluvial fans onto flood plains. Deflation and eolian deposition also affected large areas during early parts of interglaciations, particularly to the leaward of river valleys or basins formerly occupied by pluvial lakes. Paleosols that developed on stable surfaces throughout the region are prominent in both relict and buried positions in Pliocene and Pleistocene stratigraphic sections.

PLIOCENE TO MIDDLE PLEISTOCENE EVENTS AND DEPOSITS

The base of the Pliocene Series is about 5 m.y. old. Estimates of the age of the Pliocene/Pleistocene boundary range from about 1.7 to 2.2 m.y. (Geologic Names Committee, 1980). In March of 1981, the International Quaternary Association (INQUA) Subcommission on the Pliocene/Pleistocene Boundary will hold a field conference in Arizona and southern California in order to review criteria and evidence (marine as well as nonmarine sections and fauna) for placement of the boundary.

The Pliocene Epoch in southern New Mexico marks 1) the culmination of the major interval of tectonic deformation that started in late Miocene time, 2) continuation of basaltic volcanism, and 3) onset of fluvial deposition by the ancestral upper Rio Grande. Recent K-Ar dating of basalts interbedded with deposits of the Upper Santa Fe Group (Bachman and Mehnert, 1978; Seager, unpublished) demonstrate that a major fluvial system (with its axis near deeper parts of the Rio Grande rift) extended as far south as Elephant Butte by 3 m.y. ago. Dated basalt deposits of this river near Socorro are between 4 and 5 m.y. old.

The oldest dated fluvial deposits in the Mesilla and Hueco Bolson area are in the lower Camp Rice Formation (Strain, 1966, 1980). In the Camp Rice type area near McNary, Texas, W.S. Strain has described two volcanic ash deposits, and associated vertebrate faunas of late Blancan provincial age, in the lower part of the formation. The ash is partly-reworked air-fall deposit from a major eruption of the Yellowstone caldera complex about 2 m.y. ago (Izett, pers. comm.). This ash, designed Pearlette type B, blanketed much of the Great Plains and Rocky Mountain region. In the midcontinent area the ash overlies the earliest continental glacial deposits. These deposits are between 2 and 2.5 m.y. old, and they have traditionally been considered to be part of the lower Pleistocene-Nebraskan drift sequence. However, other "type Nebraskan" deposits in the midcontinent region are as young as 0.6-0.7 m.y. (Fullerton, pers. comm., 1979). Thus, there are clearly problems in correlation with glacial sections in the Midwest; and many international workers place older glacial sequences (> 1.8 m.y.) in the upper Pliocene (Bloom, 1978). Almost all specialists in Quaternary geology feel that the midwestern glacial terminology for the early and middle Pleistocene (Nebraskan-Aftonian-Kansan-Yarmouth) should be restricted to local areas or dropped (Boellstorff, 1978).

The main point of this discussion is that environmental effects of a major continental glaciation are first recognized in the stratigraphic record a short time prior to 2 m.y. ago. The older ancestral-river deposits of the Camp Rice Formation at its type area (Strain, 1966), and similar deposits in the Rincon Valley (Hawley et al., 1969; Seager et al., 1975), most likely reflect regional climatic effects of this glaciation. However, very similar deposits upstream from Elephant Butte are older than 2.6 m.y. (Bachman and Mehnert, 1978). Thus, there are probably physiographic factors unique to the southern Rocky Mountain-Rio Grande rift region that acted as fundamental controls on fluvial processes in the ancestral Rio Grande system. Early continental (and related alpine) glaciations, prior to 1.4 m.y. and between 1.2 and 0.6 m.y. ago, certainly would have affected this system; but the ancestral Rio Grande was contributing significantly to bolson aggradation (Camp Rice and Fort Hancock Formations of Strain) between about 0.5 to 2.4 m.y. ago, regardless of presence or absence of glaciers in the southern Rocky Mountain headwaters region. Prior to final integration of the upper and lower Rio Grande segments between 0.5 and 0.6 m.y., the major effects of glaciation would have been the episodic formation of large lakes that are collectively designated Lake Cabeza de Vaca (Strain, 19661, 1971).

Hawley et al. (1969) and Hawley (1975, Fig. 1) show the general pattern of the distributary net that formed the distal part of the ancestral Rio Grande system in late Pliocene to middle Pleistocene time. The relict surface of these deposits has been designated the La Mesa geomorphic surface by Ruhe (1964). Paleosols associated with this surface, with prominent horizons of carbonate accumulation, mark the top of the Camp Rice Formation in bolson-floor areas. In the southern Jornada del Muerto and northern Mesilla basins the ancestral river deposited mainly sand and gravel in the proximal part of a large fluvial fan. In the southern Mesilla Bolson, Hueco Bolson de los Muertos distal distributaries of this fan deposited an extensive blanket of interbedded sand, silt and clay that locally exceeds 200 m in thickness. At the lower end of the fluvial system there is a very complex zone of intertonguing fluvial, deltaic and lacustrine deposits; and the upper part of the Camp Rice fluvial sequence progrades over deltaic or lacustrine units in much of the area. The lower fluvial deposits of the Camp Rice Formation are transitional with deltaic to lacustrine deposits that form central bolson facies of the Fort Hancock Formation. Both formations have peripheral piedmont alluvial facies that usually must be lumped into an undifferentiated, upper Santa Fe, unit.

The very important stratigraphic and mapping problem of separating the Camp Rice from the Fort Hancock in areas of complex intertonguing of fluvial-lacustrine facies has not been resolved. In New Mexico, Plio-Pleistocene sections primarily made up of fluvial sand are arbitrarily mapped as Camp Rice by Seager, Clemons and Hawley

(Las Cruces and El Paso 2° sheets, in progress). Sandy and finer-grained basin-floor facies of similar age in the El Paso region are designated Fort Hancock Formation by Lovejoy (1976) and Willingham (1979).

Major correlation problems have occurred because the locus of active fluvial deposition shifted so widely during the 2 m.y. interval that included the main time of Camp Rice deposition as well as the later part of Fort Hancock deposition. Ancestral Rio Grande distributaries and their distal deltaic and lacustrine counterparts shifted both evulsively and gradually in response to climatic and tectonic controls. During major glacial-pluvial intervals (before 2 m.y. and between 1.2 and 0.6 m.y. ago) river discharge greatly increased, and Lake Cabeza de Vaca expanded in basin-floor areas without external drainage (e.g. Bolson de los Muertos, Hueco Bolson, and lower Mesilla and Mimbres basins). Playa, eolian and fluvial depositional environments prevailed during interglacials just as they do today. A distributary of the ancestral river emptied into Hueco Bolson through Fillmore Pass in late Pliocene and early Pleistocene time and constructed a large fan-delta complex that extended northeastward into the Tularosa Basin and southeastward into Hueco Bolson (Seager, 1981). At the same time, large lakes or playas existed in lower parts of adjacent closed basins, and other fluvial distributaries may have spread out in the Mesilla Bolson. Subsequent uplift and westward tilting of the Organ-Franklin range apparently blocked the Fillmore Pass distributary system and confined active loci of fluvial deposition to the Mesilla Bolson.

Pearlette "O" (0.6 m.y.) and Bishop (0.7 m.y.) ashes interbedded with axial stream and overlapping piedmont facies of the upper Camp Rice Formation in Selden and El Paso Canyons, as well as adjacent to Rincon and Mesilla Valleys, prove that the ancestral Rio Grande was near its present position, although not cutting a valley, by middle Pleistocene time. These ashes are, respectively, from Yellowstown and Long Valley (CA) caldera sources. High-level fluvial terrace gravels in Presidio Bolson near Candelaria, which also contain lenses of Pearlette "O" ash, were deposited by an integrated river that extended from the Mesilla and Hueco Bolsons at least as far as the confluence of the Rio Conchos and Rio Grande at Presidio, Texas (Hawley, 1975). River-valley incision, which began before emplacement of the Pearlette "O" ash in Presidio Bolson, appears to have proceeded rapidly upstream, because significant entrenchment of the Mesilla Valley had occurred prior to emplacement of basalt flows near San Miguel with K/Ar ages of about 0.5 m.y. (Table 1, nos. 1 and 3).

MIDDLE TO LATE QUATERNARY EVENTS AND DEPOSITS IN BOLSON AREAS

Much of middle to late Quaternary time (past 0.5 m.y.) in internally-drained basin areas adjacent to the Mesilla Valley was characterized by long intervals of general landscape stability. These soil-forming intervals were interrupted by several episodes of surface instability with widespread (water and wind) erosion and sedimentation, particularly on piedmont slopes and contiguous basin floors. The main geomorphic difference between bolson and river-valley areas is that basin-floor depressions were sites of lakes or aggrading alluvial plains during full glacial-pluvial times, while the inner Rio Grande valley was being widened and deepened during parts of glacial intervals. Bolson fills, which overlie Camp Rice and older Santa Fe Group and bedrock units, are relatively thin, with aggregate thicknesses rarely exceeding 10 m. The thickest alluvial and lacustrine deposits are associated with the lower Mimbres drainage system that extends from the Deming area into Chihuahua southeast of Palomas.

There is good evidence that large perennial lakes formed in the Bolson de los Muertos-lower Mimbres Basin area. Reeves (1969) has described relict shoreline features and deposits of pluvial Lake Palomas that flooded large areas of northwest Chihuahua and probably expanded into the lower Mimbres Basin east of Columbus during late Pleistocene glacial-pluvial intervals. Numerous saline playa depressions now dot the relict floor of Lake Palomas.

Most of the major lava flows of the Potrillo volcanic fields appear to have been emplaced by 500,000 years ago (Table 1). However, phreatomagmatic eruptions and maare development continued in the southwestern Mesilla Bolson and West Potrillo Mountains. Kilbourne Hole was formed after emplacement of a basalt flow about 0.5 m.y. ago (Table 1, no. 2). A basalt flow associated with a cinder cone in the floor of Potrillo Maar has a K/Ar age of about 183,000 years (Table 1, no. 8). this is the youngest dated volcanic feature in the area.

REFERENCES CITED

Bachman, G.O., and Mehnert, H.H., 1978, New K-Ar dates and late Pliocene to Holocene geomorphic history of the central Rio Grande region, New Mexico: Geol. Soc. Amer., Bull., v. 89, n. 2, p. 283-292.

Bloom, A.L., 1978, Geomorphology, Englewood Cliffs, NJ: Prentice-Hall, Inc., 510 p.

Boellstorff, J., 1978, North American Pleistocene stages reconsidered in light of probable Plio-Pleistocene continental glaciation: Sci., v. 202, p. 305-307.

Clemons, R.E., 1981, Geologic roadmap of New Mexico: New Mex. Geol. Soc. (in press).

DuBois, S.M. and Smith, A.W., 1981, The 1887 earthquake in San Bernadino Valley, Sonora: Historical accounts and intensity patterns in Arizona: Ariz. Bur. Geol. & Min. Tech., Spec. Paper, n. 3 (in press).

Geologic Names Committee, 1980, Major geochronologic and chronostratigraphic units: Isochron/West, No. 29, inside cover.

Gile, L.H., Hawley, J.W., and Grossman, R.B., 1981, Soils and geomorphology in a Basin and Range area of southern New Mexico Guidebook to the Desert Project: New Mex. Bur. Mines & Min. Res., Mem. 139 (in press).

Hawley, J.W., 1975, Quaternary history of Dona Ana County region, south-central New Mexico, in Las Cruces Country: New Mex. Geol. Soc. Guidebook, 26th Field Conf., p. 139-150.

———, 1978, Guidebook to the Rio Grande rift in New Mexico and Colorado: New Mex. Bur. Mines & Min. Res., Circ. 163, 241 p.

———, and Gile, L.H., 1966, Landscape evolution and soil genesis in the Rio Grande region, southern New Mexico: Friends of the Pleistocene: Rocky Mountain Sec., Guidebook, 11th Field Conf., 74 p.

——— and Kottlowski, F.E., 1969, Quaternary geology of the south-central New Mexico border region, in Border Stratigraphy Symposium: New Mex. Bur. Mines & Min. Res., Circ. 104, p. 89-115.

———, Kottlowski, F.E., Strain, W.S., Seager, W.R., King, W.E., and LeMone, D.V., 1969, The Santa Fe Group in the south-central New Mexico border region, in Border Stratigraphy Symposium: New Mex. Bur. Mines & Min. Res., Circ. 104, p. 52-76.

Hoffer, J.M., 1973, The geology of south-central Dona Ana County, New Mexico: El Paso Geol. Soc. Guidebook, 7th Field Conf., 67 p.

———, 1976, Geology of Potrillo basalt field, south-central New Mexico: New Mexico Bur. Mines & Min. Res., Circ. 149 30 p.

Kottlowski, F.E., 1958, Geologic history of the Rio Grande near El Paso: West Texas Geol. Soc. Guidebook, 1958 Field Trip, p. 46-54.

Lovejoy, E.M.P., 1971, Tectonic implications of high-level surfaces bordering Franklin Mountains, Texas; Geol. Soc. Amer., Bull., v. 28, p. 433-445.

———, 1975, An interpretation of the structural geology of the Franklin Mountains, Texas, in Las Cruces Country: New Mex. Geol. Soc. Guidebook, 26th Field Conf., p. 261-268.

———, 1976, A little problem concerning Fort Hancock-Camp Rice "mixed round gravels" correlation in the El Paso-Las Cruces region as viewed by a skeptic, in Symposium on the Stratigraphy and Structure of the Franklin Mountains: El Paso Geol. Soc., p. 99-103.

———, and Hawley, J.W., 1978, Southern rift guide 1, El Paso to New Mexico-Texas State Line, in Guidebook to Rio Grande Rift in New Mexico and Colorado: New Mex. Bur. Mines & Min. Res., Circ. 163, p. 57-71.

Luedke, R.G. and Smith, R.L., 1978, Map showing distribution composition and age of Late Cenozoic volcanic centers in Arizona and New Mexico: U.S. Geol. Sur., Miscellaneous Investigations Map I-1091-A, scale 1:1,000,000.

Reeves, C.C., Jr., 1969, Pluvial Lake Palomas, northwestern Chihuahua, Mexico, in The Border Region: New Mex. Geol. Soc. Guidebook, 20th Field Conf., p. 143-154.

Ruhe, R.V., 1962, Age of the Rio Grande Valley in southern New Mexico: Jour. Geol., v. 70, p. 15-167.

———, 1964, Landscape morphology and alluvial deposits in southern New Mexico: Annals of Assoc. Amer. Geographers, v. 54, p. 147-159.

Seager, W.R., 1981, Geology of Organ Mountains and southern San Andres Mountains, New Mexico: New Mex. Bur. Mines 7 Min. Res., Mem. 36 (in press).

———, 1980, Quaternary fault system in the Tularosa and Hueco Basins, southern New Mexico and west Texas, in Trans-Pecos Region: New Mex. Geol. Soc. Guidebook, 31st Field Conf., p. 131-135.

———, and Morgan, P., 1979, Rio Grande rift in southern New Mexico, west Texas, and northern Chihuahua, in Rio Grande Rift, Tectonics and Magmatism: Amer. Geophys. Union, Spec. Pub., p. 87-106.

———, and Clemons, R.E., 1975, Middle to late Tertiary geology of the Cedar Hills-Selden Hills area, New Mexico: New Mex. Bur. Mines & Min. Res., Circ. 133, 24 p.

———, Clemons, R.E. and Hawley, J.W., 1975, Geology of Sierra Alta Quadrangle, New Mexico: New Mex. Bur. Mines & Min. Res., Bull. 102, 55 p.

Stain, W.S., 1966, Blancan mammalian fauna and Pleistocene formations, Hudspeth County, Texas: Univ. Texas, Austin, Texas Mem. Mus., Bull. 10, 55 p.

———, 1971, Late Cenozoic bolson integration in the Chihuahua tectonic belt, in The Geologic Framework of the Chihuahua Tectonic Belt: West Texas Geol. Soc., Pub. no. 71-59, p. 167-173.

———, 1980, Pleistocene rocks in El Paso and Hudspeth Counties, adjacent to Interstate Highway 10, in Trans-Pecos Region: New Mex. Geol. Soc. Guidebook, 31st Field Conf., p. 179-181.

Van Devender, T.R., and Spaulding, W.G., 1979, Development of vegetation and climate in the southwestern United States: Sci., v. 204, p. 701-710.

Wells, P.V., 1979, An equable glaciopluvial in the West: Pleniglacial evidence of increased precipitation on a gradient from the Great Basin to the Sonoran and Chihuahuan Deserts: Quaternary Res., v. 12, no. 3, p. 311-325.

Willingham, D.L., 1979, Stratigraphy of the Pliocene-Pleistocene upper Santa Fe Group in the El Paso region, west Texas and south-central New Mexico (abs.): Geol. Soc. Amer., Abstracts with Programs, v. 11, p. 305.

THE UPPER SANTA FE GROUP IN THE EL PASO AREA

by

Daniel L. Willingham
El Paso Exploration Company
Wellington Office Park
Amarillo, Texas 79102

INTRODUCTION

The uppermost Santa Fe Group in the El Paso, Texas region (Fig. 1) is composed of two Pleistocene formations — the Fort Hancock Formation of Blancan age and the Camp Rice Formation of Irvingtonian age (Strain, 1966). These formations are well exposed at the southern end of the Mesilla bolson, where the Rio Grande is incised into the Pleistocene deposits and flows around the southern end of the Franklin Mountains at El Paso.

Stratigraphic and sedimentologic studies of these formations (Willingham, 1980) show that the Fort Hancock Formation consists of two distinct lithofacies — a lower fine-grained facies of predominantly fluvial floodplain origin and an upper coarser-grained facies of predominantly fluvial channel origin (Fig. 2). Two minor facies — a local piedmont facies in the El Paso area and a probable lacustrine facies at the southern end of the Hueco bolson — crop out in association with the major facies.

The Camp Rice Formation consists of two distinct fluvial facies — a lower coarse sandstone and pebble conglomerate facies and an upper sandstone facies. The lower facies is a fluvial channel deposit containing "exotic" mixed pebble gravels, while the upper facies is a floodplain deposit. This facies relationship is well exposed in the type area southeast of El Paso, and can be traced in outcrop, as can the Fort Hancock facies, northwestward into the Mesilla bolson.

The importance of studies of these formations relates to the late Cenozoic history of the Rio Grande and the late Cenozoic tectonics of the Franklin Mountains and the Hueco and Mesilla bolsons.

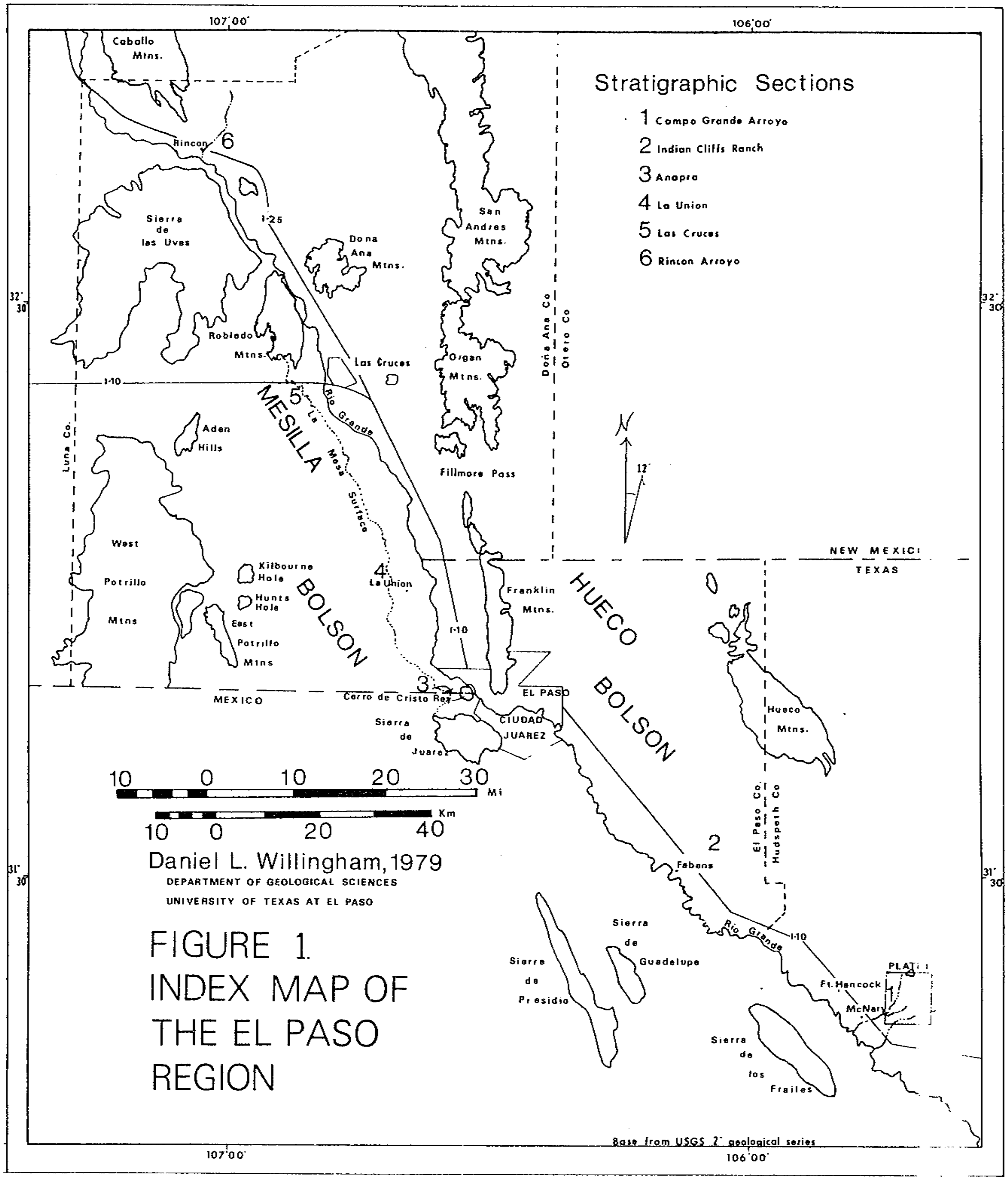
HISTORICAL BACKGROUND

Strain (1958, 1966, 1969) named and described the Fort Hancock and Camp Rice Formations as the type sections about 96 km (60 mi) southeast of El Paso, Texas, and dated the deposits by means of Blancan and Irvingtonian vertebrate fossils. He interpreted the Fort Hancock Formation as lacustrine in origin and the Camp Rice Formation as fluvial. Strain (1966, 1970) divided the Camp Rice Formation into two members — a lower member containing Blancan vertebrate fossils and an upper member containing Irvingtonian vertebrate fossils. I reinterpreted the formation boundaries (Willingham, 1980) which resulted in placing Strain's Blancan fossils solely within the upper part of the Fort Hancock Formation and the Irvingtonian fossils solely within the Camp Rice Formation. A bed of type B Pearlette ash (2.0 m.y. old) occurs about 1 m (3 ft) above the base of the redefined Camp Rice Formation at the type area (Strain, 1966).

Additional studies relating to the late Cenozoic deposits in the El Paso region include: Sayre and Livingston (1945), Kottlowski (1953, 1958), Albritton and Smith (1965), Ruhe (1962, 1964), Hawley (1965, 1969, 1975, 1978), Hawley and Kottlowski (1969), Hawley et al. (1969), Cliett (1969), Seager and Hawley (1973), and Lovejoy (1975, 1976a, 1976b).

THE MESILLA BOLSON

The Mesilla bolson is bounded on the west by the Potrillo Mountains and on the east by the Franklin Mountains. The Rio Grande enters the Mesilla bolson at Las Cruces and leaves the bolson at El Paso.



Daniel L. Willingham, 1979
DEPARTMENT OF GEOLOGICAL SCIENCES
UNIVERSITY OF TEXAS AT EL PASO

FIGURE 1. INDEX MAP OF THE EL PASO REGION

The Fort Hancock Formation is exposed beneath piedmont alluvial fans and associated Pleistocene terrace deposits. Four major terraces are evident on the west side of the Franklin Mountains — La Mesa surface (Kansan, Kern Place (Illinoisan ?), Gold Hills (Wisconsinan ?), and a lower unnamed terrace about 10-20 ft above the present river level. Excellent exposures of the Fort Hancock Formation occur in road cuts along North Mesa Street and along Interstate Highway 10. These exposures show cut-and-fill structures, trough cross-bedding, and current ripples typical of a fluvial environment.

Camp Rice deposits crop out at two topographic levels west of the Franklin Mountains. The lower level is west of the Rio Grande beneath the La Mesa surface. The higher level is east of the Rio Grande beneath a piedmont alluvial fan along the mountain front along Mesa Hills Drive. Fort Hancock and Camp Rice deposits crop out as far west as Kilbourne Hole and the East Potrillo Mountains (Fig. 1). They can also be traced beneath the La Mesa surface from Anapra to Las Cruces (Fig. 2).

LITHOLOGY

The Fort Hancock Formation is composed of very fine- to medium-grained arkosic sandstones and claystones. The deposits are brown and buff colored and moderately well-cemented to friable. They are composed of fining-upward genetic sedimentary units which contain trough cross-bedding and current ripples.

The Camp Rice Formation consists of quartzose sandstones with little or no feldspar. The deposits contain "exotic" mixed pebble gravels of granite, quartzite, and ignimbrites. The Camp Rice sandstones are gray and light brown, massive, and contain minor zones of trough cross-bedding and imbricate gravels. The pebble-gravel conglomerate almost always occurs within and near the base of the Camp Rice Formation.

REGIONAL ASPECTS AND IMPLICATIONS

The Fort Hancock Formation exhibits four distinct facies in the El Paso region — lacustrine (including evaporites) at the southern end of the Hueco bolson, lacustrine-floodplain in the central portion of the Hueco bolson, and fluvial channel in the central portion of the Hueco bolson and northwestward into the Mesilla bolson. Multiple channeling and apparent thickening of the uppermost fluvial facies occurs northward of the type area and it is possible that the upper facies correlates with the El Paso aquifer beneath the surface of the Hueco bolson along the east side of the Franklin Mountains (Fig. 3). The fluvial channel facies overlies the floodplain facies which overlies the lacustrine facies suggesting a progradation of the facies from north to south in the late Cenozoic (Fig. 4).

The Camp Rice Formation unconformably overlies the Fort Hancock Formation and also exhibits multiple channeling in the Mesilla bolson, from Anapra to Rincon, New Mexico.

The presence of quartz, orthoclase feldspar and mica in the Fort Hancock Formation, and granite, quartzite, and ignimbrite clasts in the Camp Rice Formation suggests that the sediments were derived from source areas north of the El Paso region, probably from central New Mexico and Colorado.

Multiple channeling and thickening of the Fort Hancock Formation in the Hueco bolson (and possibly in the subsurface of the Mesilla bolson) is probably related to basinal subsidence and aggradation. Multiple channeling and thickening of the Camp Rice Formation in the Mesilla bolson is probably related to intra-rift subsidence and subsequent aggradation in the Pleistocene.

REFERENCES CITED

Albritton, C.C., Jr., and Smith, J.F., Jr., 1965, Geology of the Sierra Blanca area, Hudspeth County, Texas: U.S. Geol. Surv., Prof. Paper 479, 131 p.

Cliett, T., 1969, Groundwater occurrence in the El Paso area and its related geology, in The Border Region: New Mex. Geol. Soc. Guidebook, 20th Field Conf., p. 209-214.

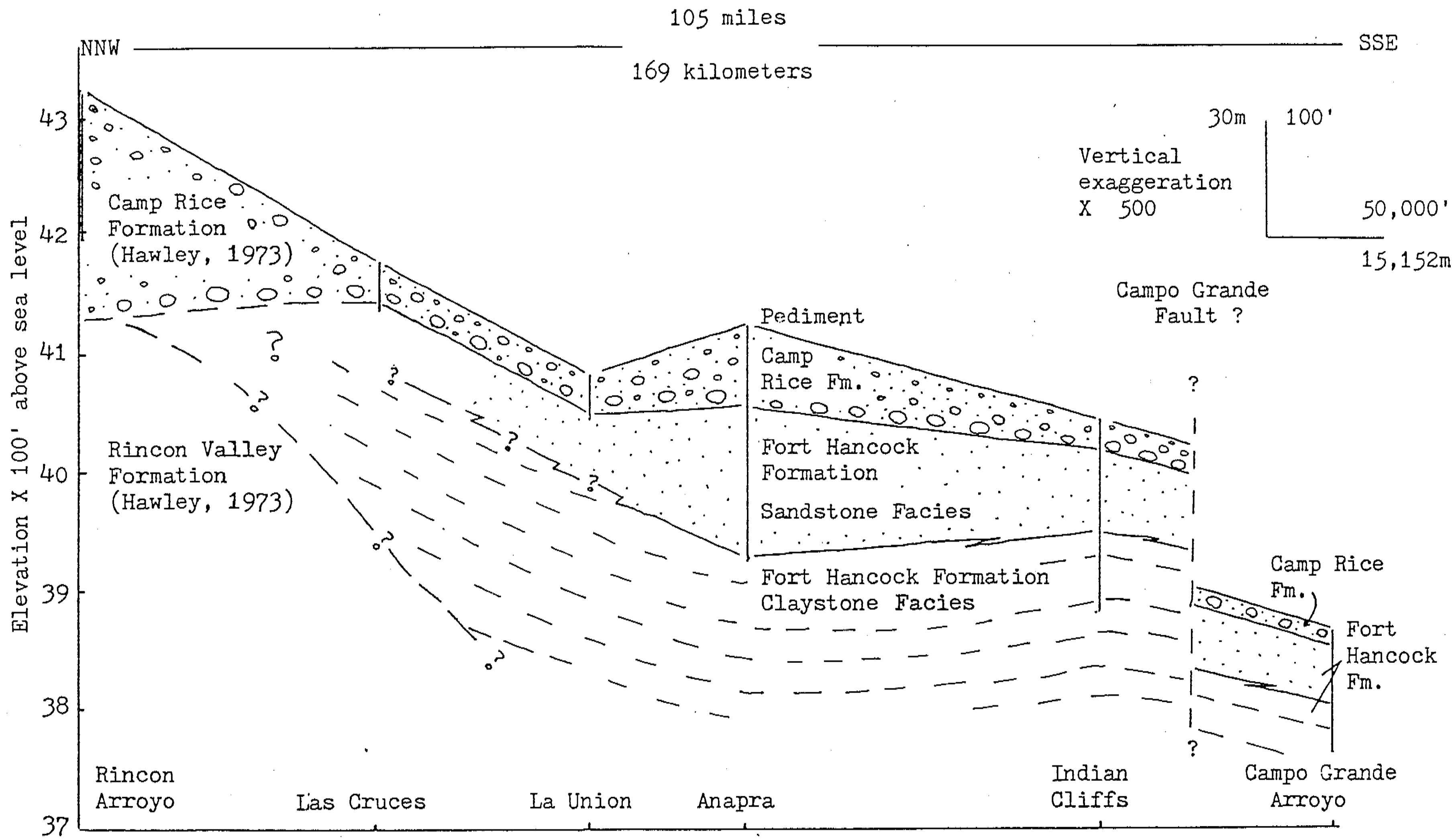


Figure 2 Schematic Longitudinal Section from Campo Grande Arroyo to Rincon Arroyo along the Rio Grande valley in the El Paso region.

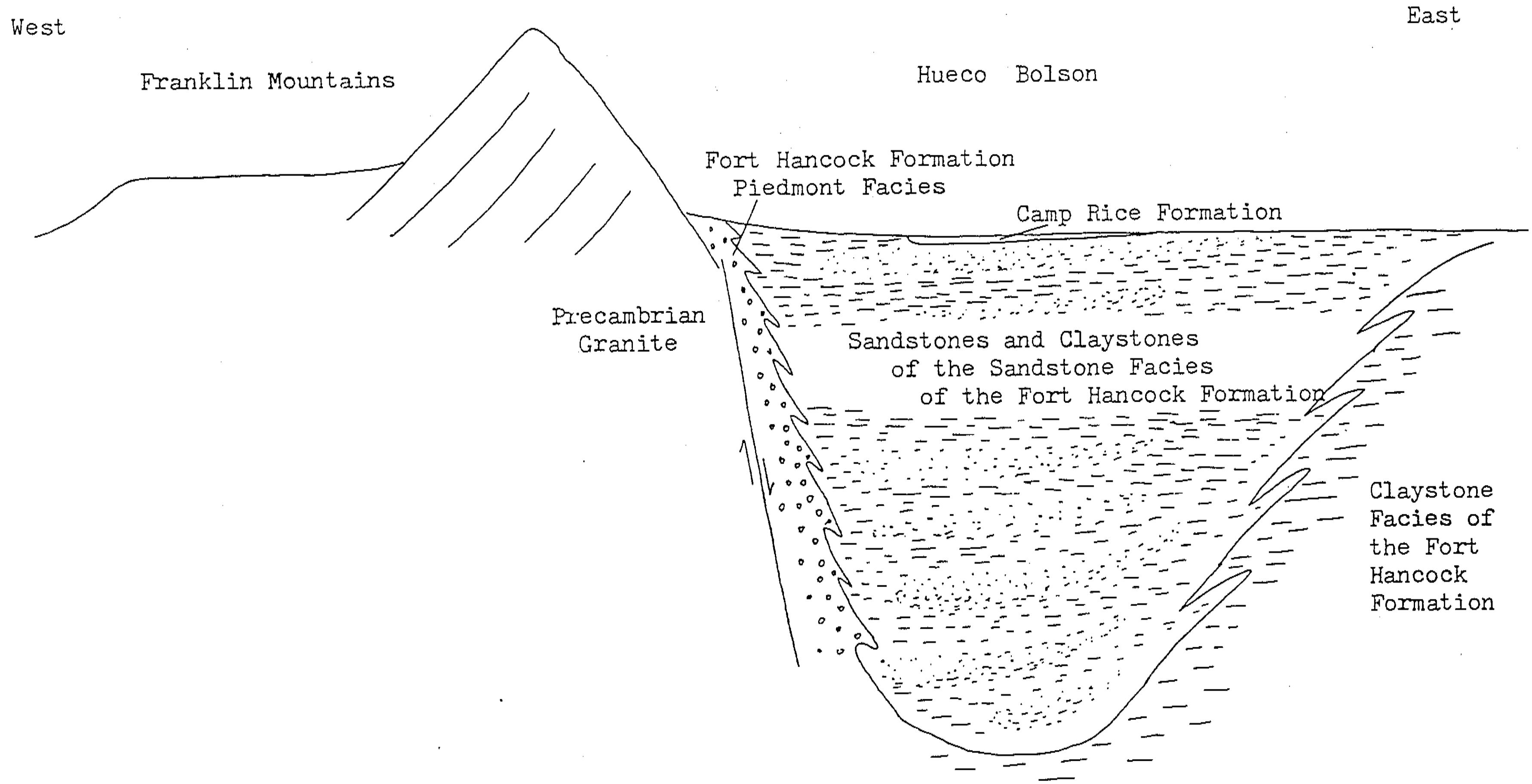


Figure 3 Schematic Cross-section of the subsurface of the Hueco Bolson along the eastern side of the Franklin Mountains. (Modified from Cliett, 1969).

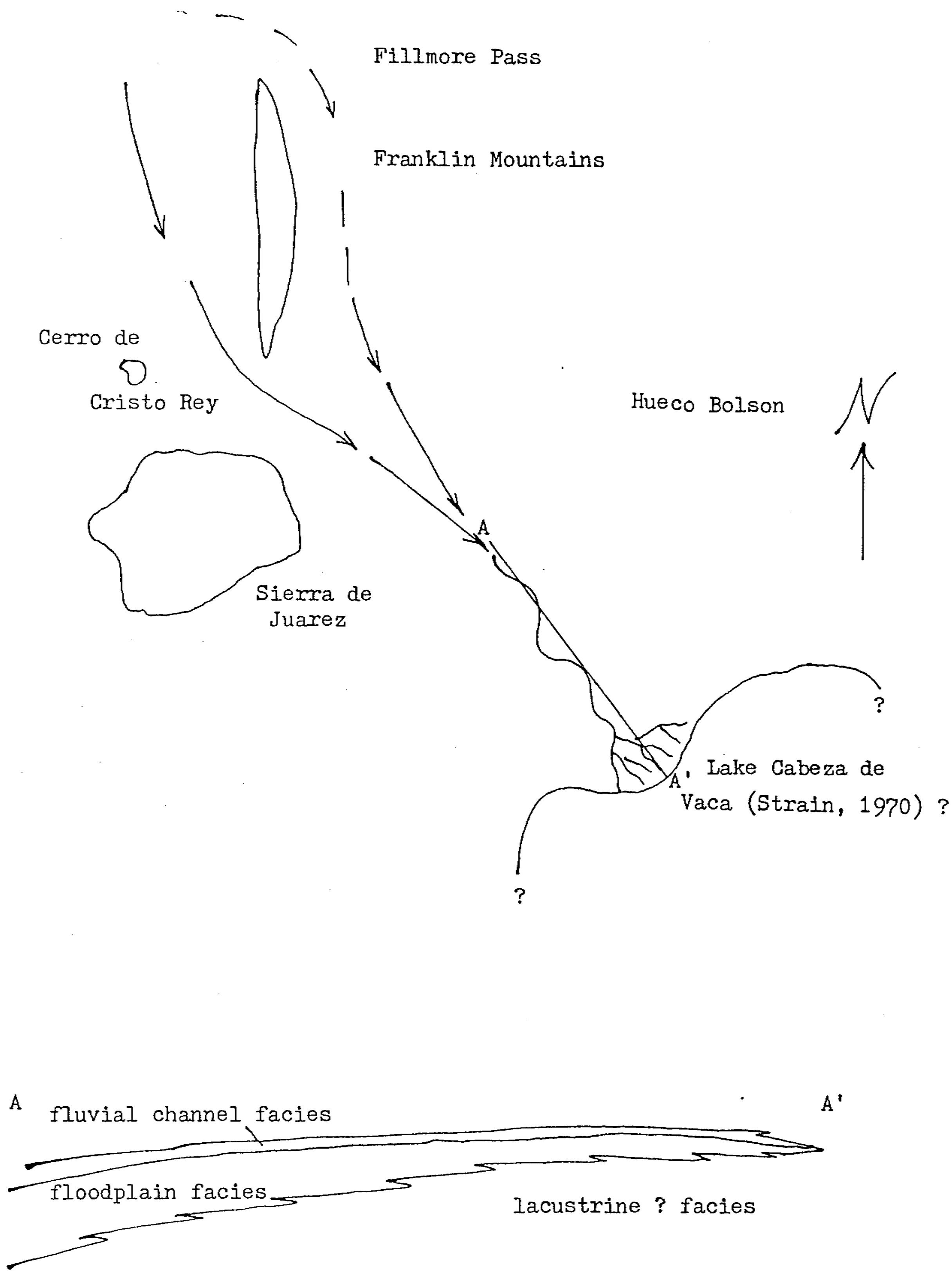


Figure 4 Proposed river system during deposition of the Fort Hancock Formation.

Hawley, J.W., 1965, Geomorphic surfaces along the Rio Grande Valley from El Paso, Texas to Caballo Reservoir, New Mexico, in Southwestern New Mexico II: New Mex. Geol. Soc. Guidebook, 16th Field Conf., p. 118-198.

———, 1969, Notes on the geomorphology and late Cenozoic geology of northwestern Chihuahua, in The Border Region: New Mex. Geol. Soc. Guidebook, 20th Field Conf.,, p. 131-142.

———, 1975, Quaternary history of Dona Ana County region, south-central New Mexico: New Mex. Geol. Soc. Guidebook, 26th Field Conf., p. 139-150.

———, 1978, Guidebook to Rio Grande rift in New Mexico and Colorado (Chart 1): New Mex. Bur. Mines & Min. Res., Circ. 163, p. 238-240.

———, and Kottlowski, F.E., 1969, Quaternary geology of the south-central New Mexico border region, in Border Stratigraphy Symposium: New Mex. Bur. Mines & Min. Res., Circ. 104, p. 89-115.

———, Kottlowski, F.E., Strain, W.S., Seager, W.R., King, W.E., and LeMone, D.V., 1969, The Santa Fe Group in the south-central New Mexico border region, in Border Stratigraphy Symposium: New Mex. Bur.Mines & Min. Res., Circ. 104, p. 52-76.

Kottlowski, F.E., 1953, Tertiary-Quaternary sediments of the Rio Grande Valley in southern New Mexico, in Southwestern New Mexico: New Mex. Geol. Soc. Guidebook, 4th Field Conf., p. 144-148.

———, 1958, Geologic history of the Rio Grande near El Paso, in West Texas Geol. Soc. Guidebook, Field Trip, Franklin and Hueco Mountains, Texas, p. 46-54.

Lovejoy, E.M.P., 1973, Evolution of western boundary faults, Franklin Mountains, Texas: Amer. Assoc. Petrol. Geol. Bull., v. 57, p. 1766-1775.

———, 1975, An interpretation of the structural geology of the Franklin Mountains, Texas, in Las Cruces Country: New Mex. Geol. Soc. Guidebook, 26th Field Conf., p. 261-268.

———, 1976a, A little problem concerning the Fort Hancock-Camp Rice "mixed, rounded gravels" correlation in the El Paso-Las Cruces region, as viewed by a skeptic, in Symposium on the Stratigraphy and Structure of the Franklin Mountains: El Paso Geol. Soc. Quinn Memorial Vol., p. 99-103.

———, 1976b, Neotectonics of the southeast end of the Rio Grande rift along the Mesilla Valley fault zone, and the course of the Rio Grande, El Paso, Texas, in Symposium on the Stratigraphy and Structure of the Franklin Mountains: El Paso Geol. Soc. Quinn Memorial Vol., p. 123-138.

Ruhe, R.V., 1962, Age of the Rio Grande Valley in southern New Mexico: Jour. Geol., v. 70, p. 151-167.

———, 1964, Landscape morphology and alluvial deposits in southern New Mexico: Assoc. Amer. Geog. Annuals, v. 54, p. 147-159.

Sayre, A.N., and Livingston, P., 1945, Ground-water resources of the El Paso area, Texas: U.S. Geol. Surv., Water Supply Paper 919, 190 p.

Seager, W.R., and Hawley, J.W., 1973, Geology of the Rincon quadrangle, New Mexico: New Mex. Bur. Mines & Min. Res., Bull. 101, 42 p.

Strain, W.S., 1958, Blancan mammalian fauna from Rio Grande Valley, Hudspeth County, Texas: Geol. Soc. Am., Bull., v. 70, p. 375-378.

———. 1966, Blancan mammalian fauna and Pleistocene formations, Hudspeth County, Texas: Texas Mem. Museum Bull. 10, Austin, Texas, 55 p.

———, 1969, Late Cenozoic strata of the El Paso-Juarez area: New Mex. Geol. Soc. Guidebook, 20th Field Conf., p. 155-157.

———, 1970, Late Cenozoic bolson integration in the Chihuahua tectonic belt (summary), in The Geologic Framework of the Chihuahua Tectonic Belt: West Texas Geol. Soc., p. 167-173.

Willingham, D.L., 1980, Stratigraphy and sedimentology of the upper Santa Fe Group in the El Paso region, west Texas and south-central New Mexico: M.S. Thesis, Univ. Texas, El Paso, 93 p.

THE PERMIAN HUECO LIMESTONE OF TRES HERMANAS MOUNTAINS, LUNA COUNTY, NEW MEXICO

by

Ronald D. Simpson and David V. LeMone
Department of Geological Sciences
University of Texas at El Paso
El Paso, Texas 79968

INTRODUCTION

The saga of the partially metamorphosed, structurally complex Permian in the Tres Hermanas Mountains is a typical one to illustrate the tangle of confusion we create within the geological literature. The Permian was first cited as a portion of the composite, problematic Gym Limestone as defined by Darton (1916). It was a problem then, and it continues to be an enigma into the eighties. This sequence is important or, if you prefer, critical to paleogeographical and structural interpretation of the area. Is it in place? If so, what does the sequence reveal concerning the paleoenvironment? Is it possible to speculate on what the true thickness of this sequence was? Is all of the structural and metamorphic activity reflected in the sediments related to the quartz monzonite intrusion in the northern part of the range, or is this stock merely an incidental, complexing factor? These are questions that may be of primary importance to the evaluation of this area as a potential petroleum province and/or a future commercial mining district.

Darton first briefly visited Luna County in 1903 (Darton, 1916) which may have been the first time he viewed the northern Tres Hermanas and the Permian. It would seem more likely that he first examined the area in the Autumn of 1910 during his first field season in the county. He subsequently visited the area in 1911, 1912, and 1913 which is the date shown on his geologic map which was published in 1915; it accompanies his geology and groundwater paper of 1916.

It might be wise for us as modern geologists, who travel this area in our air-conditioned 4 by 4 blazers with well-stocked ice chests, to reflect on the working conditions of Darton's time. Travel was by rail to sidings or small towns and then by foot, horseback or horsedrawn vehicle. Recall that it had been only two decades since the last of the Indian raids. Homesteaders from the east were flooding into the area; they were lured by the prospect of unlimited groundwater for domestic use and irrigation. Most of these homesteaders were settling in the Deming area. The government decided to map the "underground water" and geology to aid these new territorial citizens and, perhaps, discover some new mineral deposits in Luna County. The old major trails and roads were still in existence from 1952 to 1955 when Robert Balk was mapping the area and still later in the late fifties when Kottlowski and Foster were measuring the stratigraphic sections for inclusion in Griswold's (1961) mineral deposits of Luna County. These studies resulted in the posthumous publication of the geologic map of the Tres Hermanas Mountains by Balk in 1961 some six years after his tragic death in an airplane accident at Albuquerque in February, 1955.

Darton (1916) suspected the presence of Permian in the Tres Hermanas based on the character of some of the gastropods which had a strong affinity with the Hueco fauna. He reasoned, however, based on G. H. Girty's identification of the fauna of his Gym Limestone (Florida Mountains, Tres Hermanas Mountains and a few scattered outliers) that he was dealing with an equivalent of the Manzano Group of Pennsylvanian age. It turned out that in the Tres Hermanas he mapped units of the Silurian, Mississippian, Pennsylvanian, Permian and Cretaceous all as Gym Limestone. The fossils of Pennsylvanian persuasion that he recovered were from probable Missourian aged strata.

The major nomenclature problem was put to rest with the later studies of Kelley and Bogart (1952) and Bogart (1953). These works clearly follow the literature tangle. In 1917 Darton (1917a) published his Deming Folio following the same view as his 1916 paper. His southern New Mexico Paleozoic section paper (1917b) arrived at the conclusion that Manzano Group was at least in part contemporaneous to both the Hueco and Gym Limestones. In his 1922 and famous red beds 1928 papers, he equated the Gym Limestone to his Chupadera Formation which was correlated to the Yeso and San Andres Formations of the upper part of the Manzano Group. This established the age as Permian until the abandonment of the lithostratigraphic term by Kelley and Bogart in 1952. King (1942) eliminated Darton's Chupadera Formation in his studies on the Permian of west Texas and southeastern New Mexico. The only other statement was a virulent or, more accurately, vitrolic attack by Keyes (Pan American Geologist) on Darton. Keyes was attempting to move the Gym Limestone to a Pennsylvanian designation by equating it to the Magdalena based on the faunal list. Bogart (1953) clearly established the Gym Limestone as a composite formation and established the Permian Gym Limestone as being equivalent to the Hueco Limestone of Permian age. Bogart was aided in his faunal identifications by Ellis Yochelson (Smithsonian) (Yochelson, 1960) and R. V. Hollingsworth (Midland Paleontological Laboratory).

A composite of the modern Permian invertebrate possibilities from Darton (1916), Bogart (1953), Yochelson (1960), and Kottlowski and Foster (1962) is as follows:

Foraminifera
- *Staffella* sp.
- *Schwagerina* sp.

Bryozoa
- Ramose and fenestrate forms

Brachiopoda
- *Meekella mexicana* (Girty)
- Productoid possibly *Costellarina* sp. (*Marginifera* of Bogart
- *Composita mexicana* (Hall
- *Linoproductus* sp.
- *Pontisia* sp.
- *Neospirifer* sp.

Gastropoda
- *Bellerophon (Bellerophon)* sp.
- *Bellerophon (Pharkidonotus)* sp.
- *Knightites (Knightites)* sp.
- *Knightites (Retispira) eximia* Yochelson
- *Straparollus (Euomphalus)* sp.
- *Straparollus (Amphiscapha)* sp.
- *Omphalotrochus obtusispira* (Shumard)
- *Baylea* sp.
- *Amaurotoma* sp.
- *Paleostylus (Pseudozygopleura?)* sp.
- *Orthonema* sp.
- *Meekospira* sp.

Scaphopoda
- *Plagioglypta* sp.
- *Prodentalium* sp.

Bivalvia
- *Nuculopsis* sp.
- *Aviculopinna peracuta* (Shumard)
- *Grammatodon (Cosmetodon)* sp.
- *Astartella* sp.

Echinoidea
- *Archaeocidaris* sp.

The modern concept of the regional Permian paleogeography emerged with Kottlowski's 1958 paper which was followed by a series of studies which are in chronological order (Kottlowski and Foster, 1962; Kottlowski, 1963; Kottlowski, 1970, Greenwood, 1970; Jordan, 1971, 1975; Navarro and Tovar, 1975; Simpson, 1975; Greenwood and Kottlowski, 1975; Greenwood, Kottlowski and Thompson, 1977; Thompson *et al.*, 1978; and Thompson, 1980).

The Permian Hueco Limestone at Tres Hermanas would seem to paleogeographically lie southwest of the northwest-southeast trending Florida-Moyotes axis which in Lower Permian time could have been an archipelago of variant sized islands shedding limited local quantities of clastics. The Tres Hermanas Mountains themselves would be essentially on the shelf between the Florida-Moyotes positive axis and the paralleling deeper Pedregosa basin axis some 60 mi to the southeast.

The solution of a portion of the problem is entwined with the rigorous interpretation of the flora and fauna of this range from the perspective of both microscopic and megascopic analysis. The authors hope to have some answers, at least some more problems, by next year.

REFERENCES CITED

Balk, R., 1961, Geologic map of Tres Hermanas Mountains: New Mex. Bur. Mines & Min. Res., GM 16.

Bogart, L.E., 1953, The Hueco (Gym) Limestone, Luna County, New Mexico: M.S. Thesis, Univ. New Mexico, 91 p.

Darton, N.H., 1916, Geology and underground water of Luna County, New Mexico: U.S. Geol. Sur., Bull. 618, 88 p.

———, 1917a, Description of the Deming Quadrangle, New Mexico: U.S. Geol. Sur., Geol. Atlas, Deming Folio, 15 p.

———, 1917b, A comparison of Paleozoic Sections in southern New Mexico: U.S. Geol. Sur., Prof. Paper 108, p. 31-55.

———, 1922, Geologic structures of parts of New Mexico: U.S. Geol. Sur., Bull. 726, p. 173-275.

———, 1928, Red Beds and associated formations in New Mexico with an outline of the geology of the state: U.S. Geol. Sur., Bull. 794, 356 p.

Greenwood, E., 1970, Oil and gas possibilities in the Chihuahua area, in The Geologic Framework of the Chihuahua Tectonic Belt: West Texas Geol. Soc. and Univ. Texas, Austin, p. 62-68.

——— and F.E. Kottlowski, 1975, Geology of the Pedregosa Basin in southwestern New Mexico and adjoining areas, in Exploration from the Mountains to the Basin: El Paso Geol. Soc., p. 29-36.

———, F.E. Kottlowski, and S. Thompson III, 1977, Petroleum potential and stratigraphy of Pedregosa Basin: Comparison with Permian and Orogrande basins: Am. Assoc. Petrol. Geol., Bull., v. 61, p. 1448-1469.

Griswold, G.B., 1961, Mineral deposits of Luna County, New Mexico: New Mex. Bur. Mines & Min. Res., Bull. 72, 157 p.

Jordan, C.F., 1971, Lower Permian stratigraphy of southern New Mexico and west Texas: Ph.D. Dissertation, Rice Univ., 140 p.

———, 1975, Lower Permian (Wolfcampian) sedimentation in the Orogrande Basin, New Mexico, in Las Cruces Country: New Mex. Geol. Soc. Guidebook, 26th Field Conf., p. 109-117.

Kelley, V.C., and L.E. Bogart, 1952, Gym Limestone, New Mexico: Amer. Assoc. Petrol. Geol., Bull., v. 36, p. 1644-1648.

Keyes, C.R., 1940, "Gym Limestone of New Mexico is What?": Pan Amer. Geol., v. 73, p. 535-763.

King, P.B., 1942, Permian of West Texas and Southern New Mexico; Part II of West Texas-New Mexico Symposium: Amer. Assoc. Petrol. Geol., Bull., v. 26, p. 535-763.

Kottlowski, Frank E., 1958, Pennsylvanian and Permian Rocks near the Late Paleozoic Florida Islands, in Roswell Geol. Soc., 11th Field Conf., p. 79-87.

———, 1963, Paleozoic and Mesozoic strata of southwestern and southcentral New Mexico: New Mex. Bur. Mines & Min. Res., Bull. 79, 100 p.

———, 1970, Paleozoic geologic history of southwest New Mexico and northwest Chihuahua, in The Geologic Framework of the Chihuahua Tectonic Belt: West Texas Geol. Soc. & Univ. Texas, Austin, p. 16-18.

———, and R.W. Foster, 1962, Pre-Tertiary strata of Tres Hermanas Mountains, Luna County, New Mexico: Amer. Assoc. Petrol. Geol., Bull., v. 45, p. 2090-2098.

Navarro, G.A., and J. Tovar R., 1975, Stratigraphy and tectonics of the state of Chihuahua-Mexico, in Exploration from the Mountains to the Basin: El Paso Geol. Soc., p. 23-27.

Simpson, R.D., 1975, Systematic Paleontology and paleoenvironmental analysis of the Upper Hueco Formation, Robledo and Dona Ana Mountains, Dona Ana County, New Mexico: M.S. Thesis, Univ. Texas, El Paso, 252 p.

Thompson, S., III, 1980, Pedregosa basin's main exploration target is Pennsylvanian dolostone: Oil & Gas Jour., 4 p.

———, J. Tovar R., and J.N. Conley, 1978, Oil and gas exploration wells in the Pedregosa Basin, in Land of Cochise: New Mex. Geol. Soc. Guidebook, 21st Field Conf., p. 331-342.

Yochelson, E.L., 1960, Permian Gastropoda of the southwestern United States — Bellerophontacea and Patellacea: Amer. Mus. Nat. Hist., v. 119, art. 4, p. 209-293.

COLOR PATTERN ON THE CRETACEOUS BIVALVE TEXIGRYPHAEA WASHITAENSIS (HILL)

by

Ronald D. Simpson
Department of Geological Sciences
University of Texas at El Paso
El Paso, Texas 79968

INTRODUCTION

Texigryphaea washitaensis (Hill) has a pattern of dark-black radial bands on the external surface of the left valve. The preserved color pattern is similar to those reported present on other Cretaceous and Eocene gryphaid oysters (Stephenson, 1929; Stenzel, 1971; and Stokes and Stifel, 1964).

Specimens of the bivalve Texigryphaea washitaenisis (Hill) with preserved color patterns are described herein for the first time. These specimens from the Albian (Washitian) Muleros Formation, in Texas exhibit a series of longitudinal dark-black radial banks on the external surface of the left valve. The specimens under consideration were collected from an outlier on the western side of the Franklin Mountains (Lat. 30°50'51"N., Long. 106°30'22"W); El Paso, El Paso County, Texas.

MATERIALS

Sixteen specimens of the bivalve Texigryphaea washitaensis (Hill) with traces of color pattern preserved on them are deposited in the University of Texas at El Paso Cretaceous Paleontological Collection of the Southwest Biostratigraphic Institute.

COLOR PATTERN

The color pattern is best preserved on the external surface of the left valve. Not all speciments recovered exhibit color patterns. Prolonged exposure to the elements and weathering has destroyed all traces of color pattern on some specimens (Fig. 1).

Traces of coloration in previously reported fossil oysters are in the form of radial brownish or brownish-black bands on the exterior of the shell (Stenzel, 1971; Stokes and Stifel, 1964). It is believed that the brownish or brownish-black color develops from oxidation of purplish colors which are the result of deposition of waste products in the shell (Stenzel, 1971). Those present on Texigryphaea washitaensis (Hill) are blackish in color. The color pattern begins as narrow bands near the umbo and expand in width with the growth of the shell extending to the edge. Stenzel (1971) reports the presence of brownish radial bands on Ilymatogyra arietina (Roemer), from the Grayson Shale (Cenomanian) of Texas and Mexico; Exogyra (Exogyra) tigrina Stephenson and Exogyra (Exogryra) laeviuscula Roemer, both from the Dessau Chalk (Santonian) of Texas; Odontogryphaea thirsae (Gabb) from the Nanafalia Formation (Sparnacian) of Alabama to Mexico; and Rhynchostreon suborbiculatum (Lamarck) from the Cenomanian and Turonian of Europe, North Africa, and the Near East.

The color pattern present on Texigryphaea washitaensis (Hill) appear similar to those present on Odontogryphaea thirsae (Gabb) as figured by Stenzel (1971) and Pycnodonte newberryi (Stanton) and Pycnodonte convexa (Say) as figured by Stokes and Stifel (1964).

CONCLUSIONS

The species of Texigryphaea described with color patterns are very similar to those of other Cretaceous and Eocene oysters. The pattern present strongly resembles that of Odontogryphaea thirsae (Gabb), Pycnodonte newberryi (Stanton), and Pycnodonte convexa (Say).

REFERENCES CITED

Stenzel, H.B., 1971, Pigmentation; In Treatise on Invertebrate Paleontology: GSA Pt. N. Mollusca 6, Bivalvia: N 977-8.

Stephenson, L.W., 1929, Two new mollusks of the genera Ostrea and Exogyra from the Austin Chalk, Texas: U.S. Nat. Museum, Proc. 76:1-6.

Stokes, W.L. and P.B. Stifel, 1964, Color markings of fossil Gryphaea from the Cretaceous of Utah and New Jersey: J. Paleontol. 38:889-90.

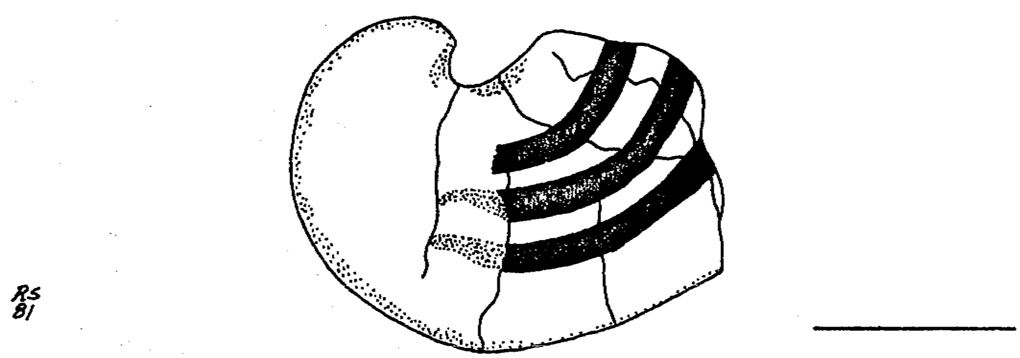


Figure 1. Texigryphaea washitaensis (Hill). Side view of single left valve showing color bands. Width of line 1 cm.

CRETACEOUS FAUNA OF THE FRANKLIN MOUNTAINS, EL PASO COUNTY, TEXAS

by

David V. LeMone and Ronald D. Simpson
Department of Geological Sciences
University of Texas at El Paso
El Paso, Texas 79968

INTRODUCTION

The Cretaceous rocks of the Franklin Mountains consist of a series of scattered and discontinuous outcrops as opposed to the nearly complete sequences observed at Sierra de Cristo Rey (New Mexico and Mexico) and the Sierra de Juarez (Mexico). A current faunal list of these exposures is presented.

The combined middle Cretaceous sequence in the Franklin Mountains, Cristo Rey, and Juarez Mountains consists of (in ascending order): Cuchillo, Benigno, Lagrima, Finlay, Del Norte, Smeltertown, Muleros, Mesilla Valley, Anapra, Del Rio, Buda, and Boquillas Formations.

The entire sequence is apparently Albian-Cenomanian in age. Swift (1972) suggested the possibility of the presence of the Aptian Las Vigas Formation. This suggestion, if true, has yet to be verified. The Aptian-Cenomanian boundary is placed at the base of the environmentally transitional Anapra Sandstone (Strain, 1976). It might just as well have been drawn within the formation or near the top of it. The Comanchean-Gulfian boundary would be placed between the Buda and Boquillas Formations.

The Cretaceous outcrops of the Franklin Mountains are exposed either by intrusive activity or in association with the Western Boundary Fault (Fig. 1).

INTRUSIVE-RELATED CRETACEOUS EXPOSURES

The intrusions on the western flank of the Franklin Mountains all appear to be petrographically similar to the Muleros Andesite (Cristo Rey, New Mexico and Mexico). The Campus Andesite has been dated as Middle Eocene (47.1 ± 2.3 m.y. B.P.) by means of K-Ar radiometric dating (Hoffer, 1970). The mechanism of the intrusion of the Muleros Andesite and its consequent tectonics have been worked out in detail by Lovejoy (1976a). All of the post-Paleozoic intrusions on the western flank of the Franklin Mountains appear to be genetically related to the Muleros Andesite (Garcia, 1970). Exposures of the intrusive system seem to be confined to the area west of the Western Boundary Fault (Fig. 1).

Four major areas of intrusion are noted; they are: Campus Andesite, Coronado Andesite, Thunderbird Andesite, and the Three Sisters Andesite (Fig. 1). Scattered peripheral Cretaceous outcrops are recorded in association with all of these intrusions.

The Campus Andesite is the largest of the intrusions and includes four outcrops on its margin (Hoffer, 1969). Hoffer assigned all but one of these locales to the Boquillas Formation on a lithological basis. The remaining area of exposures which is along the southeastern margin of the intrusion contains, in part, a sequence of carbonates which have been silicified and slightly metamorphosed. Apparently these outcrops do not contain the megascopically identifiable fauna necessary to establish either the lithostratigraphic unit represented or its chronostratigraphic position.

The Thunderbird Andesite has four scattered outcrops of Cretaceous. The southernmost exposure contains the Muleros Formation. Kufal (1977) has suggested the possibility of the presence of the Boquillas Formation which typically crops out as an easily eroded shale weathering brown to yellow brown. The Muleros Formation here is determined largely on the basis of the echinoid fauna.

Intrusions and Faults Associated with
Cretaceous Outcrops, Franklin Mts.

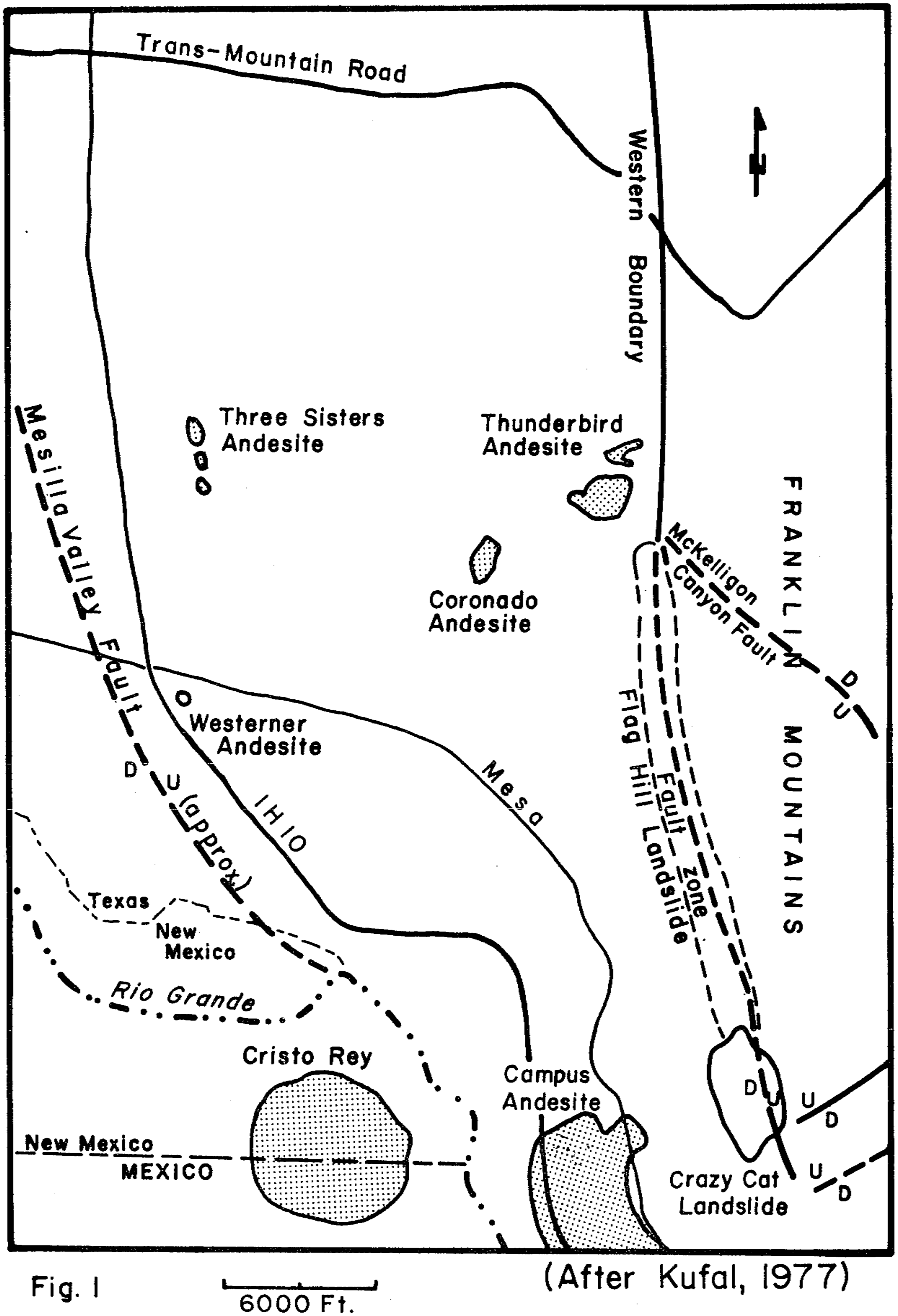


Fig. 1

(After Kufal, 1977)

Kufal (1977) reports the occurrence of four small exposures of Cretaceous sandstone, marly limestone and shale in association with the Coronado Andesite. Sandy shale is the dominant lithologic component of these exposures. Fauna of the Smeltertown Formation is recognized. Two other scattered exposures .4 to .5 mi due north of the northern margin of the Coronado Andesite have yielded some fauna assignable to the Muleros Formation.

The Three Sisters Andesite consists of three parallel, northwest-trending intrusions with associated outcrops of the Cretaceous (Garcia, 1970). Garcia (1970), also, has reported numerous Cretaceous xenoliths associated with the intrusions. These rocks have been assigned to the Muleros and Mesilla Valley Formations. The Mesilla Valley Formation cannot be currently established at the Three Sisters on a paleontological basis.

A strip of the Cretaceous Finlay Formation is exposed along the area between IH-10 (Interstate Highway-10) and the Rio Grande (Fig. 1). These exposures are best displayed in the vicinity of the El Toro Cement Plant. These outcrops actually belong more properly to the New Mexico-Mexico Muleros Andesite intrusion activity rather than related intrusions in Texas and will not be considered in this discussion.

The Cretaceous fauna currently studied from exposures related to Cenozoic intrusion include (in ascending lithostratigraphic sequence):

Cuchillo Formation, Benigno, Lagrima, Finlay and Del Norte Formations

Not recognized from faunal aspect.

Smeltertown Formation

Coronado Andesite; Western Franklin Mountains, El Paso County, Texas

Foraminifera

Cribratina texana (Conrad)

Porifera

Cliona sp.

Coelenterata

Trochosmilia sp.

Platycyathus sp.

Gastropoda

Amberleya sp.

Aporrhais sp.

Pleurotomaria (Leptomaria) austinensis Shumard

Turritella planilateris Conrad

Cephalopoda

Mortoniceras wintoni (Adkins)

Bivalvia

Anatina sp.

Cyprimeria? sp.

Lima (Lima) wacoensis Roemer

Lopha quadriplicata Shumard

Lopha subovata Shumard

Ludbrookia arivechensis (Heilprin)

Neithea (Neithea) texana (Roemer)

Nucula sp.

Pinna guadalupae Bose

Pleuriocardia (Pleuriocardia) orthoprymnos Scott

Plicatula sp.

Protocardia multistriata (Shumard)

Pteria bosei Perkins

Pterotrigonia (Scabrotrigonia) emoryi (Conrad)

Rastellum (Arctostrea) carinata (Lamarck)

Tapes sp.

Texigryphaea tucumcarii (Marcou)

Annelida

Serpula sp.

Echinoidea

Dumblea symmetrica Cragin

Stereocidaris hudspethensis Cooke

Muleros Formation

A. Three Sisters Andesite; Western Franklin Mountains, El Paso County, Texas

Foraminifera

Cribratina texana (Conrad)

Porifera

Cliona sp.

Coelenterata

Dungulia texana (Conrad)

Gastropoda

- Ampullina collina (Conrad)
- Helicocryptus sp.
- Natica? parvum Perkins
- Turritella sp.
- Tylostoma sp.

Cephalopoda

- Cymatoceras sp.
- Mortoniceras sp.

Bivalvia

- Camptonectes? (Camptonectes?) sp.
- Corbula sp.
- Lima (Lima) wacoensis Roemer
- Lopha quadriplicata Shumard
- Modiolus (Modiolus) sp.
- Neithea (Neithea) texana (Roemer)
- Neithea (Neithella) wrighti (Shumard)
- Plicatula subgurgitis Bose
- Protocardia texana (Conrad)
- Pteria bosei Perkins
- Pterotrigonia (Scabrotrigonia) emoryi (Conrad)
- Texigryphaea washitaensis (Hill)

Annelida

- Hamulus sp.
- Serpula sp.

Echinoidea

- Dumblea symmetrica Cragin
- Enallaster (Washitaster) bravoensis Bose
- Globator parryi (Hall)
- Hemiaster (Macraster) elegans Shumard
- Holectypus (Caenholectypus) transpecosensis Cragin
- Phymosoma mexicanum Bose

B. Coronado Andesite (0.4 to 0.5 mi north); 31°52'09" N, 106°32'31" W; Western Franklin Mountains, El Paso County, Texas

Porifera

- Cliona sp.

Gastropoda

- Turritella sp.

Bivalvia

- Lima (Lima) wacoensis Roemer
- Neithea (Neithea) texana (Roemer)
- Neithea (Neithella) wrighti (Shumard)
- Texigryphaea washitaensis (Hill)

Annelida

- Serpula sp.

Echinoidea

- Enallaster (Washitaster) bravoensis Bose
- Tetragramma streeruwitzi (Cragin)

C. Thunderbird Andesite; 30°51'51"N, 106°30'23"W; Western Franklin Mountains, El Paso County, Texas

Porifera

- Cliona sp.

Coelenterata

- Dungulia texana (Conrad)

Gastropoda

- Aporrhais subfusiformis (Shumard)
- Cerithium sp.
- Nerinea sp.
- Turritella leonensis Conrad
- Tylostoma elevatum (Shumard)

Bivalvia

- Lima (Lima) wacoensis Roemer
- Lima (Plagiostoma) elpasensis Stanton
- Modiolus (Modiolus) sp.
- Neithea (Neithea) texana (Roemer)
- Plicatula subgurgitis Bose
- Protocardia sp.
- Texigryphaea washitaensis (Hill)

Annelida

- Hamulus sp.
- Serpula sp.

Echinoidea

- Enallaster (Washitaster) bravoensis Bose
- Holectypus (Caenholectypus) transpecosensis Cragin

Mesilla Valley, Anapra, Del Rio, Buda and Boquillas Formations
Not recognized from faunal aspect.

FAULT-RELATED CRETACEOUS EXPOSURES

A number of Cretaceous outcrops are exposed along the western side (downthrown block) of the north-south trending Western Boundary fault zone. These exposures include from north to south: Richardson's 1909 Locality, Flag Hill Landslide and Crazy Cat Landslide.

Lovejoy in a series of four papers (1976b, c, d, and e) has discussed the tectonics and emplacement of the slide units. Richardson's 1909 Locality is probably located along the western side of the fault zone approximately 0.7 to 1.0 mi north-northeast of the northern boundary of the main mass of the Thunderbird Andesite. The Cretaceous locality illustrated by Lovejoy (1976b) is on the downthrown side of the Western Boundary Fault Zone just at the south end of the Flag Hill Landslide. Lovejoy identifies this lithostratigraphic unit as being Cuchillo Formation. He also reports other scattered Cretaceous exposures (pers comm., 1981).

The Crazy Cat Landslide is the southernmost unit and has the best exposures of fault-related Cretaceous outcrops (Fig. 2). The Crazy Cat Landslide Cretaceous has one major problematic area at the northernmost Cretaceous outcrop in West Crazy Cat Canyon. This feature is identified simply with a K on Figure 2. The dipping sequence indicates Lower Permian (Wolfcamp) Cerro Alto Formation of the Hueco Group overlain by a conglomerate containing carbonate clasts with fusulinids. The conglomerate is overlain by an apparently unfossiliferous sandy unit which, in turn, is overlain by a muddy, calcareous unit containing charophytes. The age of this unit is speculative, although charophytes have been recorded from the pre-Finlay rocks in the Sierra de Juarez.

The fault-related Cretaceous exposures observed include fauna from the following formations:

Cuchillo and Benigno Formations
Not recognized from faunal aspect.

Lagrima Formation
A. East Crazy Cat Canyon; Southern Franklin Mountains, El Paso County, Texas

Porifera
Cliona sp.

Coelenterata
Gen. et. sp. indet.

Bryozoa
Membranipora sp.

Gastropoda
Avellana sp.
Cerithium? sp.
Lunatia praegrandis (Roemer)
Mesalia seriatimgranulata (Roemer)
Nerita? marcouana (Cragin)
Peruviella dolium (Roemer)
Trochus? sp.
Turritella? sp.
Tylostoma sp.

Cephalopoda
Metengonoceras hilli (Bohm)

Bivalvia
"Cardium" sp.
Ceratostreon texana (Roemer)
Cyprimeria? sp.
Homomya sp.
Inoceramus? sp.
Ludbrookia arivechensis (Heilprin)
Mutiella roblesi Bose
Neithea (Neithea) irregularis (Bose)
Pholadomya sp.
Protocardia texana (Conrad)
Pterotrigonia (Scabrotrigonia) guadalupae (Bose)
Tapes sp.
Texigryphaea navia (Hall)

Crazy Cat Area, El Paso, Tx.
Cretaceous Base Map
(After Lovejoy, 1976)

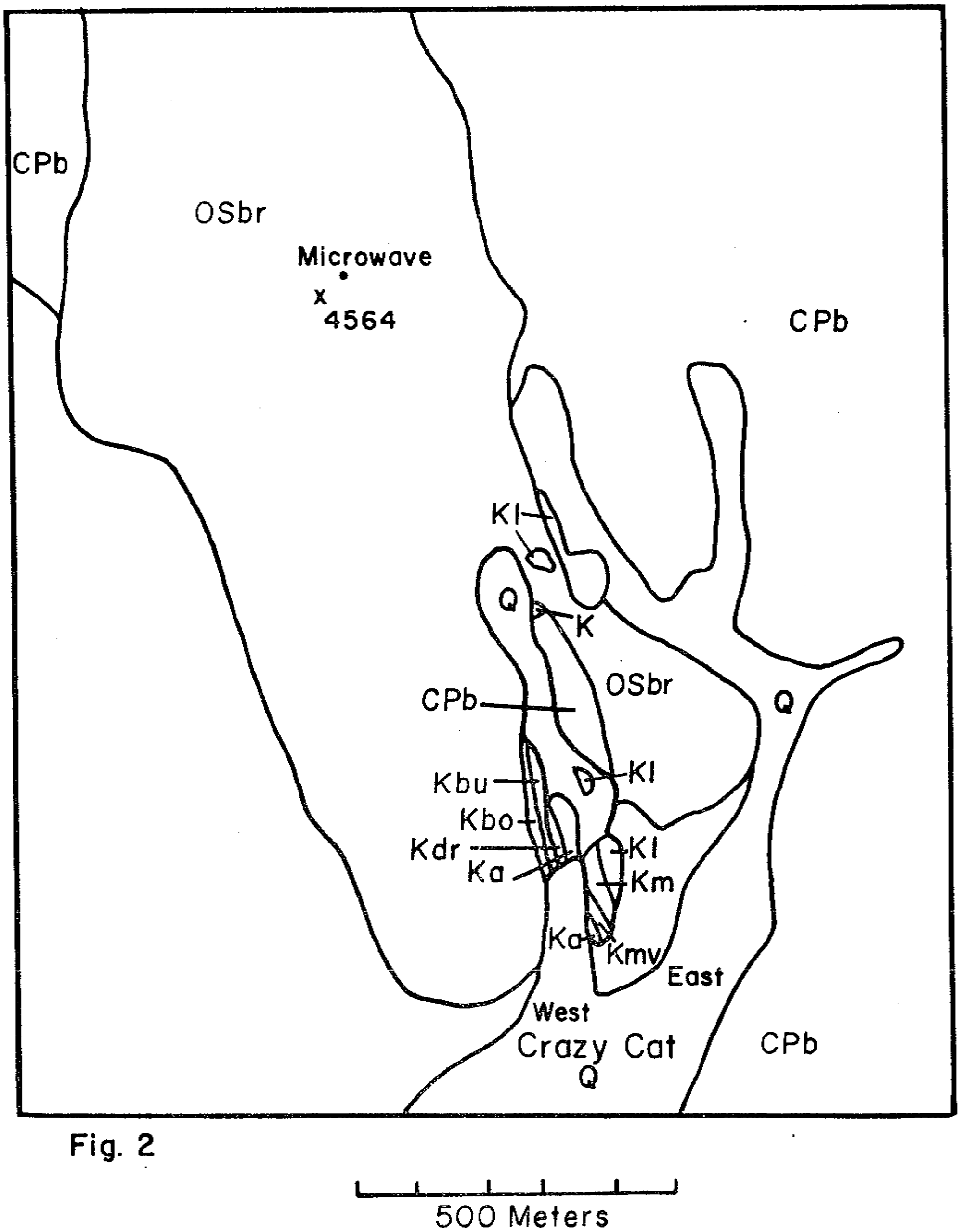


Fig. 2

Q Quaternary Alluvium
Kbo Boquillas Formation
Kbu Buda Formation
Kdr Del Rio Formation
Ka Anapra Formation
Kmv Mesilla Valley Formation
Km Muleros Formation
Kl Lagrima Formation
OSbr Ordovician, Silurian Breccia
CPb Colluvium and Paleozoic Bedrock

N

Annelida

Serpula sp.

Echinoidea

Enallaster (Enallaster) mexicanus Cotteau

B. West Crazy Cat Canyon; Southern Franklin Mountains, El Paso County, Texas

Porifera

Cliona sp.

Gastopoda

Ampullina collina (Conrad)
Lunatia praegrandis (Roemer)
Peruviella dolium (Roemer)
Pleurotomaria sp.
Turritella sp.
Tylostoma sp.

Bivalvia

Ceratostreon texana (Roemer)
Ludbrookia arivechensis (Heilprin)
Neithea (Neithea) irregularis (Bose)
Protocardia sp.
Pterotrigonia (Scabrotrigonia) sp.
Texigryphaea navia (Hall)

Annelida

Serpula sp.

Echinoidea

Holectypus (Caenholectypus) planatus Roemer

Finlay, Del Norte, and Smeltertown Formations

Not recognized from faunal aspect.

Muleros Formation

Richardson's 1909 Locality; Western Franklin Mountains, El Paso County, Texas

Porifera

Cliona sp.

Gastropoda

Aporrhais subfusiformis (Shumard)
Cerithium pecosense Stanton
Nerinea sp.
Neritina? sp.
Turritella leonensis Conrad
Tylostoma elevatum (Shumard)

Bivaliva

Cyprimeria sp.
Lima (Lima) wacoensis Roemer
Modiolus (Modiolus) sp.
Neithea (Neithea) texana (Roemer)
Neithea (Neithella) wrighti (Shumard)
Poladomya shattucki Bose
Protocardia sp.
Tapes sp.
Meretrix? fortworthensis Perkins
Texigryphaea washitaensis (Hill)

Annelida

Serpula sp.

Echinoidea

Anorthopygus texanus Cooke
Dumblea symmetrica Cragin
Enallaster (Washitaster) bravoensis Bose
Globator parryi (Hall)
Holectypus (Caenholectypus) transpecosensis Cragin
Loriolia clarki Cooke
Phymosoma mexicanum Bose
Tetragramma streeruwitzi (Cragin)

Mesilla Valley Formation

Not recognized from faunal aspect.

Anapra Formation

West Crazy Cat Canyon; Southern Franklin Mountains, El Paso County, Texas

Bivalvia

Exogyra (Exogyra) whitneyi Bose

Grayson (Del Rio) Formation

West Crazy Cat Canyon; Southern Franklin Mountains, El Paso County, Texas

Foraminifera
Cribratina texana (Conrad)

Coelenterata
Unidentifiable Genus et species

Bivalvia
Exogrya (Exogyra) whitneyi Bose

Neithea (Neithea) sp.

Porifera
Cliona sp.

Bryozoa
Encrusting on *E. (E.) whitneyi* Bose

Buda Formation

West Crazy Cat Canyon; Southern Franklin Mountains, El Paso, County, Texas

Coelenterata
Lophosmilia texana (Vaughan)

Gastropoda
Aptyxiella? sp.

Turritella sp.

Bivalvia
Pinna guadalupae Bose

Texigryphaea sp.

Annelida
Serpula sp.

Brachiopoda
Waconella wacoensis (Roemer)

Echinoidea
Enallaster (Washitaster) bravoensis Bose

Boquillas Formation

West Crazy Cat Canyon; Southern Franklin Mountains, El Paso County, Texas

Cephalopoda
Acanthoceras alvarodense Moreman
Tarrantoceras rotatile Stephenson
Turrilites cf. *T. acutus americanus* Cobban & Scott

Bivalvia
Inoceramus arvanus Stephenson

CONCLUSIONS

The Cretaceous fauna of the Franklin Mountains should be a useful reference to the area; however, it is, obviously, less critical than the final analysis of the complete exposures cropping out at Cristo Rey and Sierra Juarez. A full biostratigraphic analysis of this suite and the American Cristo Rey sections are in progress. The relationships between the Permian Cerro Alto Formation and the overlying post-Paleozoic charophyte unit in West Crazy Cat Canyon must be evaluated. The coral megafauna of the area is in the process of being revised currently by Turnsek and LeMone. Cyclostome bryozoa have been described from the Smeltertown Stratotype and other exposures at Cristo Rey and the Franklin Mountains (Nye and LeMone, 1978). Scott (1977, 1978) has completed studies on the carditid and cardiid Bivalvia. He is currently studying other portions of that taxon. Cornell (Nodeland and Cornell, 1978) is in the process of examining the foraminifera of the El Paso Region Cretaceous. Hook and Cobban have been working with ammonoids of the Cenomanian within the El Paso area and the Texas-New Mexico Region. Microfacies studies are currently in progress at Cristo Rey, Sierra Juarez and the Franklin Mountains.

R. Hoffer is currently studying the Cretaceous sequences in the area between the East Potrillo Mountains and the Tres Hermanes to as far north as Interstate 10. West of the field trip area James Weise will be completing a major study on the Big Hatchet Mountains this year. A number of Cretaceous Mexican studies are also in progress and completed.

REFERENCES CITED

Garcia, R.A., 1970, Geology and petrography of andesitic intrusions in or near El Paso, Texas: M.S. Thesis, Univ. Texas, El Paso, 139 p.

Hoffer, J.M., 1969, Geology and petrology of the Campus Andesite Pluton, El Paso County, Texas, in The Border Region: New Mex. Geol. Soc. Guidebook, 20th Field Conf., p. 102-107.

________, 1970, Petrology and mineralogy of the Campus Andesite Pluton, El Paso County, Texas: Geol. Soc. Am. Bull., v. 31, p. 2129-2136.

Kufal, Dennis, 1977, Geology and geomorphology of the western slopes of the Franklin Mountains: Department of Planning, Research and Development, City of El Paso, 56 p.

Lovejoy, E.M.P., 1972, Structure and intrusive tectonics of Cerro de Cristo Rey, Chihuahua, Mexico and New Mexico, United States, in The Stratigraphy and Structure of the Sierra de Juarez, Chihuahua, Mexico: El Paso Geol. Soc. Guidebook, 6th Field Conf., p. 25.

________, 1976a, Geology of Cerro Cristo de Rey Uplift, Chihuahua and New Mexico: New Mex. Bur. Mines & Min. Res., Mem. 31, 82 p.

________, 1976b, The Western Boundary Fault Zone and Crazy Cat Landslide, Franklin Mountains, Texas, in Structure and Stratigraphy of the Franklin Mountains: El Paso Geol. Soc., Quinn Memorial Vol., p. 107-122.

________, 1976c, Neotectonics of the southeast end of the Rio Grande Rift, and the course of the Rio Grande, El Paso Texas, in Structure and Stratigraphy of the Franklin Mountains: El Paso Geol. Soc., Quinn Memorial Vol., p. 107-122.

________, 1976d, Crazy Cat Landslide, its age and geomorphology and its tectonic significance, Southern Franklin Mountains, in Structure and Stratigraphy of the Franklin Mountains: El Paso Geol. Soc., Quinn Memorial Vol., p. 139-148.

________, 1976e, A preliminary note on the Flag Hill and associated landslides, Southern Franklin Mountains, Texas, in Structure and Stratigraphy of the Franklin Mountains: El Paso Geol. Soc. Guidebook, Quinn Memorial Vol., p. 149-154.

Nodeland, Steve and William C. Cornell, 1976, Microfossils of the Smeltertown Formation Stratotype (Cretaceous, Albian), Cristo Rey, New Mexico, in Structure and Stratigraphy of the Franklin Mountains: El Paso Geol. Soc., Quinn Memorial Vol., p. 87-89.

Nye, Jr., O.B., and D.V. LeMone, 1978, Multilaminar growth in Reptomulticava texana, a new species of cyclostome Bryozoa: Jour. Paleont., v. 52, n. 4, p. 830-845.

Richardson, G.B., 1909, Geological Atlas of the United States, El Paso Folio: Folio No. 166, 11 p.

Scott, R.W., 1977, Paleobiology of Lower Cretaceous carditid bivalves, North America: Jour. Paleont., v. 51, n. 6, p. 1150-1160.

________, 1978, Paleobiology of Comanchean (Cretaceous) cardiids (Cardiinae), North America: Jour. Paleont., v. 52, n. 4, p. 881-903.

Strain, William S., 1976, New formation names in the Cretaceous at Cerro de Cristo Rey, Dona Ana County, New Mexico, in Geology of Cerro Cristo de Rey Uplift, Chihuahua and New Mexico: New Mex. Bur. Mines & Min. Res., Mem. 31, Appendix II, p. 77-82.

Swift, Douglas, 1972, The stratigraphy and structure of Cretaceous rocks in north-central Sierra de Juarez, Chihuahua: M.S. Thesis, Univ. Texas, El Paso, 324 p.

A NOTE ON LOWER CRETACEOUS OUTCROPS, SOUTHEASTERN LUNA COUNTY, NEW MEXICO

by

Robin L. Hoffer and Jerry M. Hoffer
Department of Geological Sciences
University of Texas at El Paso
El Paso, Texas 79968

INTRODUCTION

Six Cretaceous outcrops have been mapped in extreme southeastern Luna County, New Mexico just west of the Quaternary basalts of the West Potrillo Mountains (Hoffer, 1976) (see Fig. 1). In addition, several small outcrops of Cretaceous have been reported around Mt. Riley, 15 mi to the east in Dona Ana County (Millican, 1971). All the exposures consist primarily of massive limestone, chert limestone conglomerates, and arkosic sandstone.

OCCURRENCES

Five Lower Cretaceous outcrops occur in the vicinity of T.27S, R.5W at the Eagles Nest and three small hills to the north and east (Fig. 1). Approximately 500 ft of strata crop out at the Eagles Nest; the section is composed of an upper massive limestone, limestone chert conglomerate, arkosic sandstone, basal units of thin-bedded siltstone and limestone, and a basal fossiliferous reef. A preliminary stratigraphy section at the Eagles Nest is shown in Figure 2.

East of the Eagles Nest, less than 1 mi, Lower Cretaceous strata occur in contact with both granite (Precambrian?) and andesite (Tertiary?). The exact nature of the above contacts has not yet been determined.

South of the old railroad bed (T.28S, R.5W) strata of probable Lower Cretaceous age occur in contact with Permian rocks (Hueco Group). The exact relationship between the two units is unclear as numerous faults and silicified zones have been noted.

CORRELATIONS

The only Lower Cretaceous outcrop in this region that has been studied in any detail is the section at the Eagles Nest. This section is almost identical lithologically to the Lower Cretaceous in the Tres Hermanas Mountains, 24 mi to the west (Kottlowski and Foster, 1962). Studies are in progress to determine the nature and relationships of these Lower Cretaceous occurrences to outcrops in the East Potrillo and Tres Hermanas Mountains.

REFERENCES CITED

Hoffer, J.M., 1976, Geology of the Potrillo Basalt field, south-central New Mexico: New Mex. Bur. Mines & Min. Res., Cir. 149, 30 p.

Kottlowski, F.E. and Foster, R.W., 1962, Pre-Tertiary strata of Tres Hermanas Mountains, Luna County, New Mexico: Amer. Assoc. Petrol. Geol. Bull., v. 46, p. 2090-2098.

Millican, R.S., 1971, Geology and petrography of the Tertiary Riley-Cox pluton, Dona Ana County, New Mexico: M.S. Thesis, Univ. Texas, El Paso, 88 p.

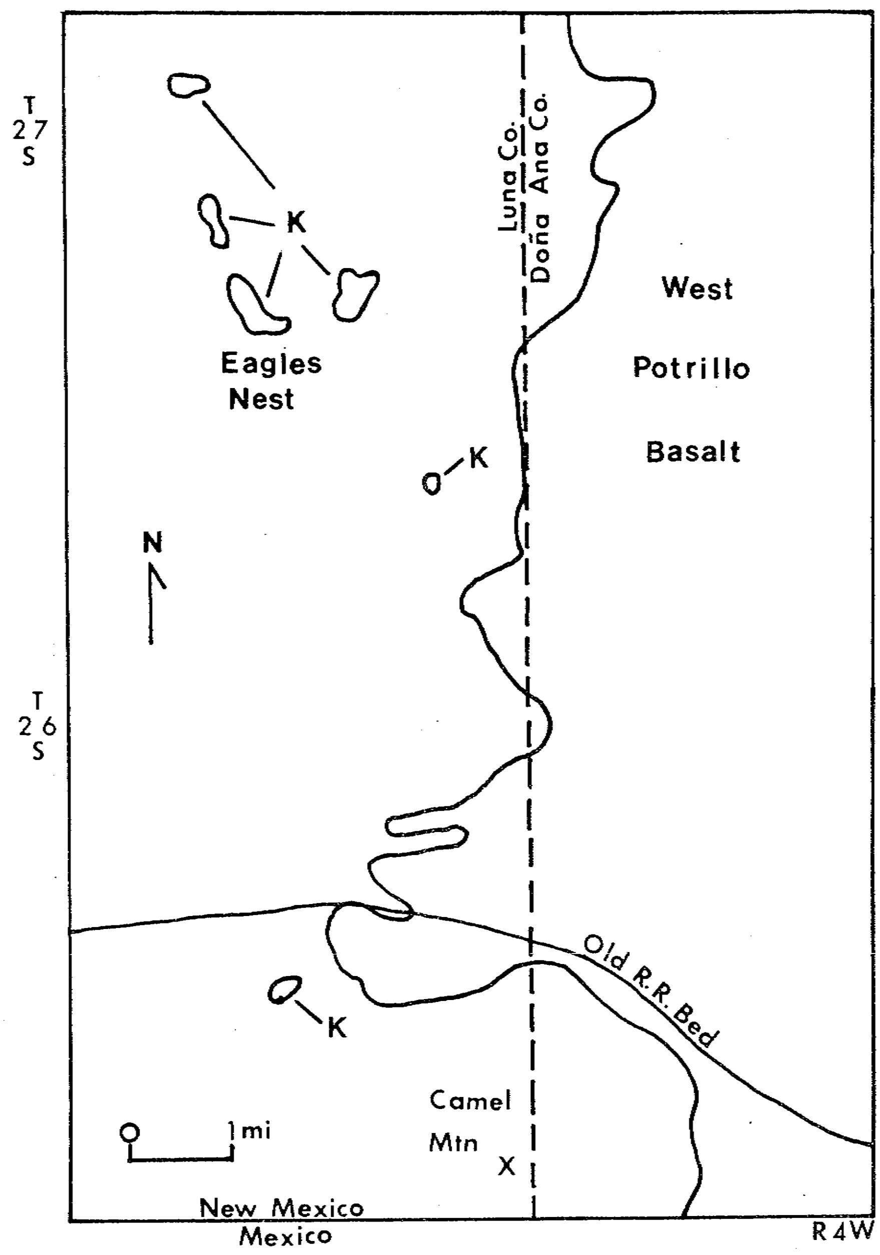


Fig. 1 Cretaceous outcrops in southeastern Luna Co., New Mexico (after Hoffer, 1976).

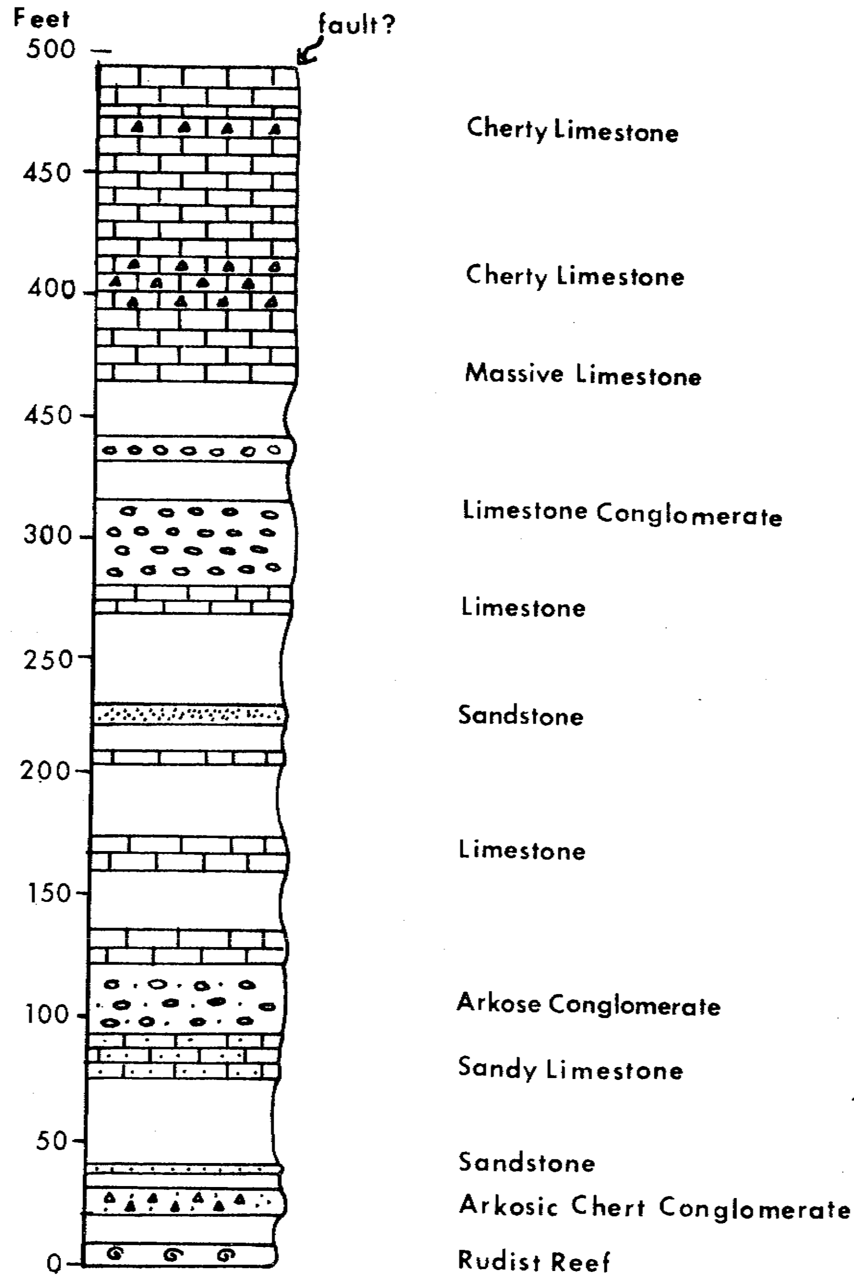


Fig. 2 Preliminary Startigraphic Section of the Eagle's Nest.

GEOLOGY OF THE EAST POTRILLO MOUNTAINS, SOUTHERN DONA ANA COUNTY, NEW MEXICO

by

Jerry M. Hoffer and Robin L. Hoffer
Department of Geological Sciences
University of Texas at El Paso
El Paso, Texas 79968

INTRODUCTION

The East Potrillo Mountains are located in southern New Mexico approximately 30 mi west of El Paso, Texas. The range trends northwesterly and is 7 mi in length and approximately 1 mi in width. The East Potrillos contain over 1000 ft of Permian and Lower Cretaceous strata that have been thrusted and folded during the Laramide orogeny. A number of Tertiary dikes intrude the sedimentary units.

Bowers (1960) completed the first detailed study on the range which included a stratigraphic and structural study of the sedimentary units. In 1976, Hoffer reported on the mineralization and the petrography of the Tertiary dikes as a part of his study of the Potrillo Basalt. R. L. Hoffer is currently studying the Lower Cretaceous units as a part of a project on the Lower Cretaceous of southern New Mexico.

STRATIGRAPHY

Sedimentary Strata

Permian

The oldest rocks that crop out in the range are those of the Permian Hueco Formation. The Hueco crops out along the east side and northwest end of the mountains (Fig. 1). A 218-ft section of the Hueco Formation was measured just north of the old marble quarry (Sec. 1, T.28S., R.2W.). The section consists of medium- to dark-gray to black, fine- to medium-grained limestone, dolomite, and silicified marble, with interbedded lenses of limestone conglomerate (Hoffer, 1976). Based upon similar lithology, stratigraphiic position, and the presence of bellerophontid gastropods the unit is assigned to the Hueco Formation.

Cretaceous

The Cretaceous rocks in the East Potrillos have been divided into 3 major units by Bowers (1960) on the basis of different lithologies, each unit separated by an unconformity or disconformity (Fig. 1). Because of the uncertainty in correlation with known formations in nearby areas, the Cretaceous units outlined by Bowers (1960) were named after local geographic features. The units are informally called (oldest to youngest) Noria, Little Horse, and Restless formations and will be referred to in this paper as Cretaceous units 1, 2 and 3, respectively.

Units 2 and 3 contain Lower Cretaceous fossils of Comanchean age belonging to the Fredericksburg Group or older; fossils from these Cretaceous units resemble both Fredericksburg and Trinity forms (Bowers, 1960; Darton, 1928). Craig (1972) indicates that unit 2 (Little Horse), based on lithologic and fossil evidence, correlates with the upper Cuchillo and Benigno Formations of Sierra de Juarez, Mexico.

The oldest Cretaceous unit in the East Potrillos, unit 1, lies unconformably on the Hueco and ranges from 270 to 600 ft thick. It consists of basal conglomerate of limestone and cherty pebbles and cobbles in a calcareous matrix. This is overlain by a sequence of silty to sandy limestone and dense claystone. A soft, thin-bedded shale marks the top of this unit. The shale is white to light green; locally it is silicified, bleached, and stained red with iron oxides from hydrothermal solutions.

Lying unconformably on unit 1 is unit 2. It ranges from 219 ft in the south to over 300 ft at the north end of the range. At the base of this unit is a massive, gray fine-grained limestone which can be traced the entire length of the range. The upper part of this unit is fossiliferous, containing pelecypods, corals, and large

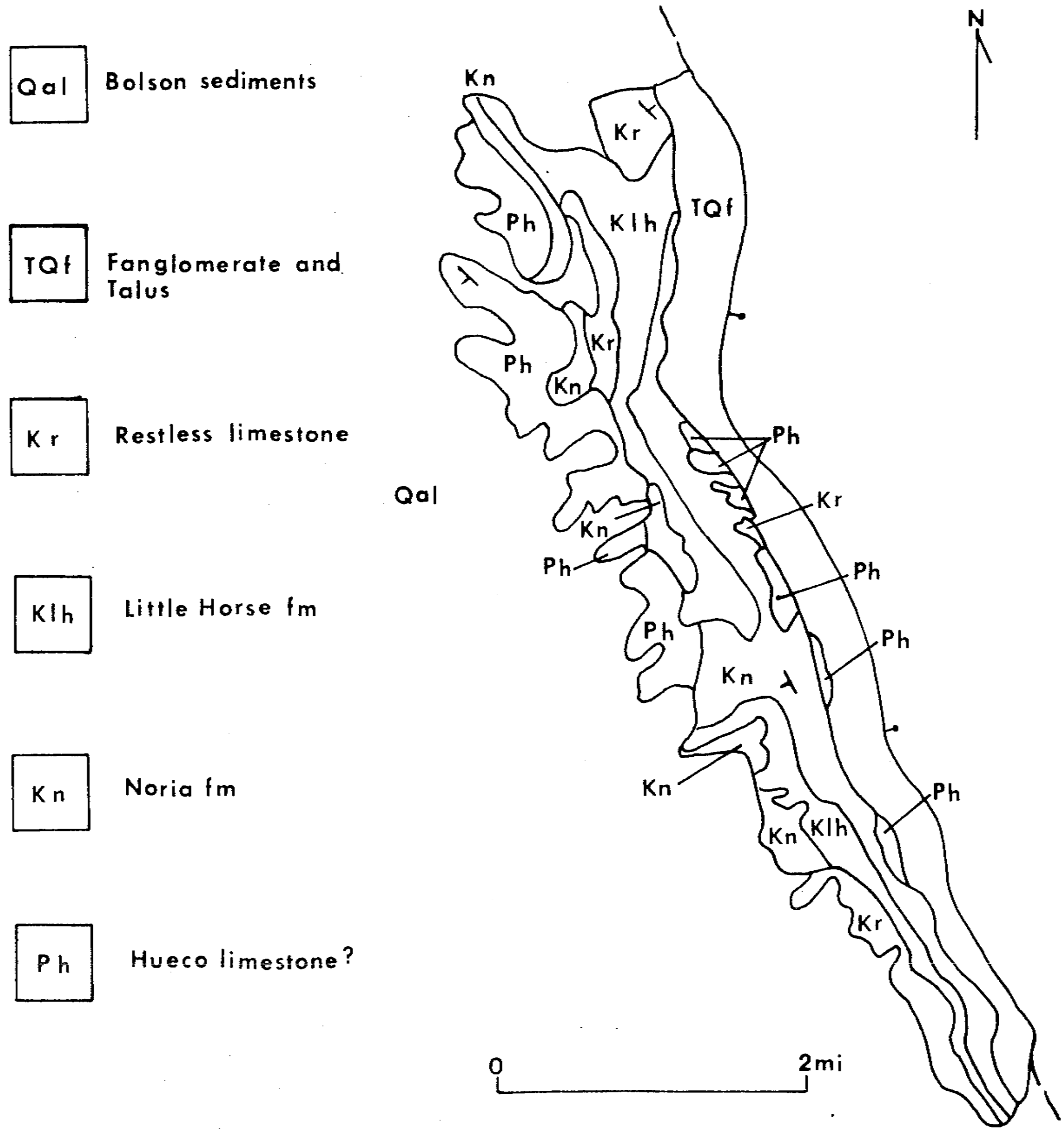


Fig. 1 Geologic map of the East Potrillo Mountains (after Bowers, 1960).

gastropods. Above this sequence are fine- to coarse-grained sandy limestone and light-gray bioclastic limestone; the formation is fossiliferous near the top, containing fragments and shells of gastropods and pelecypods.

Unit 3 is locally disconformable on unit 2. It ranges from 150 to 470 ft thick and consists of massive, fine-grained, fossiliferous limestone at the base and grades upward into a silty and sandy limestone.

Igneous Rocks

Andesite to latite dikes intrude all sedimentary rocks of the East Potrillo Mountains. The dikes, generally northeast-trending, average less than 10 ft thick and extend from 200 to over 3000 ft. They are generally aphanitic, displaying sharp contacts with the surrounding sedimentary strata. Bowers (1960) reported that the dikes are younger than the overturned folds and thrust faults in the range, but have been cut by high-angle faulting.

The dikes can be divided into 3 types: 1) light-colored porphyritic andesite, 2) dark-colored andesite, and 3) microporphyritc quartz latite (Hoffer, 1976).

The light-colored andesite dikes are the most abundant and occur predominantly in the northern part of the range within secs. 11 and 14, T.28S., R.2W. The dikes consist primarily of andesine with minor amounts of K-feldspar and quartz. Mafics that were formerly biotite and/or hornblende are completely altered to chlorite and iron oxides. The feldspars show moderate alteration to sericite, clay, and calcite. The subhedral to anhedral groundmass crystals, with subparallel orientation, average 0.3 mm. There are occasional pheonocrysts of plagioclase.

The dark-colored andesite dikes, resembling basalt, occur within the middle part of the range in secs. 14 and 25, T.28S., R.2W. These dikes are distinctly porphyritic with small subhedral to anhedral calcic andesine and minor K-feldspar pheonocrysts set in a very fine-grained groundmass; the phenocrysts average 0.05 mm. Parallel alignment of the lath-shaped phenocrysts is well developed. The finer grained groundmass is composed of anhedral plagioclase, iron oxides, biotite (?), and magnetite. Alteration is moderate to light.

A light-colored dike of latitic composition is exposed at the south end of the range (sec. 21, T.28S, R.2W). The dike averages approximately 50 ft in width and can be traced within the Cretaceous rocks for over 3000 ft in a north-northeast direction. The dike rock is microporphyritic with occasional small phenocrysts of plagioclase and K-feldspar set in a fine-grained anhedral groundmass, averaging 0.05 mm of feldspar and quartz. The rock shows only minor alteration and is classified as a quartz latite.

Most of the dikes in the range are locally cut by thin veinlets of calcite and/or quartz. The more highly altered dikes are less resistant to erosion than the recrystallized and silicified bordering limestone and therefore form narrow drainage channels on steeper slopes.

STRUCTURE

The East Potrillo Mountains can be divided into 2 structural regions (Fig. 1). The northern part of the range is an asymmetrical branched anticline with a steeper dipping western limb. The axis of the anticline trends north-northwest and plunges to the north. East of the crest near the center of the range, Cretaceous units 2 and 3 have been compressed into a series of tight anticlines and synclines overturned to the east. Further north (secs. 2 and 3, T.28S., R.2W.) folding has produced a synclinal structure within units 1 and 2; the western limb of the structure is overturned and has been thrust eastward along a low-angle fault.

A major eastern boundary fault, expressed as a low fault scarp, parallels the crest line east of the range. Bowers (1960) indicated that it is a high-angle normal fault. The fault cuts the coarse bajada deposits on the east flank of the Potrillos, abruptly terminating these rocks against the sand and silt of the bolson. This fault can be traced from the southern end of the range northward over 19 mi where it is covered by Aden Basalt. The scarp ranges in height from 5 to 35 ft and can be seen to displace caliche horizons and a flow from the

Potrillo Basalt in the bolson north of the range. These displacements indicate that there has been renewed or continued movement along the post-Cretaceous boundary fault during middle to late Quaternary.

The northern end of the range is intensely faulted. Within the northern end of the range two predominant fault sets exist; one trending northwest and the other approximately northeast. The northwest-striking faults consist of both low- and high-angle reverse faults and high-angle normal faults.

Northwest-striking thrust faults occur predominantly at the northern end of the range in secs. 2, 3, 10, and 11, T.28S., R.2W. These faults have produced eastward thrusting along both high- and low-angle faults. A small klippe (Sec. 11, T.28S., R.2W.) of Cretaceous unit 2 rests on Cretaceous unit 3 along one of the high-angle thrusts. This fault can be traced over 2 mi northward from NE 1/3 sec. 10, T.28S., R.2W. where it is covered by Holocene alluvium north of the range.

In the northwest part of the range, Bowers (1960) inferred northwest-striking, high-angle faults based on the presence of shear zones and bands of metamorphosed limestone which are silicified, iron stained, and locally contain fault breccia. On many of these faults the direction of movement cannot be differentiated because of the homogeneity of the limestone and the lack of a marker bed; many may be reverse faults.

The central part of the range (sec. 14, T.28S., R.2W.) is cut by two sets of high-angle oblique faults; one set strikes east and the other northeast. The northeast-striking faults are nearly parallel to the andesite dikes. Stratigraphic throw of unit 1, from 100 to 400 ft, and the slight displacement of higher beds along the same faults suggests renewed movement along faults that were active before deposition of unit 2 (Bowers, 1960). A low-angle thrust is associated with the closed folds in the Lower Cretaceous units 2 and 3.

The southern end of the range is relatively undisturbed. It represents a simple homocline dipping from 15 to 30° to the west, bounded by a high-angle fault on the east (Hoffer, 1976).

ECONOMIC POTENTIAL OF THE AREA

Mineralization

Scattered mineralized zones occur throughout the north end of the East Potrillo Mountains as discontinuous pods, lenses, and veins filling fissures or replacing wall rock along fractures and fault zones. In addition, numerous prospect pits can be found along unconformities and clay horizons. Especially prominent is the iron-stained, bleached, and silicified clay beds at the top of the Cretaceous unit 1. Stringers of malachite and azurite have been seen in these horizons, but the most abundant minerals consist of limonite (replacing pyrite), quartz, and calcite (Hoffer, 1976).

Dunham (1935) mentioned a pocket of rich gold ore that was said to have been mined from a quartzite bed on the east side of the East Potrillo Mountains by John Graham around the year 1900.

At the north end of the range, associated with the northeast-trending, high-angle faults, are replacement horizons of abundant barite with small disseminated crystals of pyrite, galena, sphalerite, and malachite. The limestone is highly silicified in the immediate area. The degree of silicification and accompanying barite mineralization increases toward the northwest. Although abundant barite is available, its close association with silica would make it undesirable.

The highly silicified northeast-trending faults and shear zones seem to have been channels for the introduction of low temperature hydrothermal solutions. The northeast-trending andesite dikes are not mineralized but show the effect of minor hydrothermal alteration which include sericitization. Other hydrothermal solutions, depositing primarily silica, moved along northwest-trending, older faults and unconformities. Replacement and cavity fillings have both been formed along the fault zones.

Oil and Gas

The area of the East Potrillo Mountains falls within the Rocky Mountain overthrust belt which currently is actively being explored for hydrocarbons in North America. The marine deposits of Cretaceous strata give this region a setting of high potential for oil and gas discovery (Wengard, 1969). However, hydrocarbon exploration has been slow and made difficult because the area has experienced late to post-Cretaceous tectonics, Tertiary extrusive and intrusive igneous rocks, and widespread cover of Cenozoic and Holocene sediments (Wengerd, 1969).

Kottlowski et al. (1969) suggest that the highest potential for hydrocarbons in this area lie in the Cretaceous limestones with possible traps to include bioherms and anticlinal structures.

The only wildcat in the immediate are was drilled in 1962. The Pure No. 1 Federal "H" test (Sec. 24, T.28S., R.2W.) is located in the East Potrillo Mountains and was drilled to a depth of 7346 ft. Drilling penetrated lower Cretaceous units to a depth of 4200 ft, gouge-like material to 6960 ft and below 6960 ft diorite (Kottlowski et al., 1969).

REFERENCES CITED

Bowers, W.E., 1960, Geology of the East Potrillo Hills, Dona Ana County, New Mexico: Univ. New Mexico, M.S. Thesis, 67 p.

Craig, R., 1972, Stratigraphy of the Cuchillo Formation of Sierra de Juarez: El Paso Geol. Soc., Guidebook 6, p. 66-67.

Darton, N.H., 1928, "Red Beds" and associated formations in New Mexico, with an outline of the geology of the State: U.S. Geol. Sur., Bull. 794, 356 p.

Dunham, D.C., 1935, The geology of the Organ Mountains, with an account of Dona Ana County, New Mexico: New Mex. Bur. Mines & Min. Res., Bull. 11, 272 p.

Hoffer, J.M., 1976, Geology of Potrillo Basalt Field, South-central New Mexico: New Mex. Bur. Mines & Min. Res., Circ. 149, 30 p.

Kottlowski, F.E., Foster, R.W., and Wengerd, S.A., 1969, Key oil tests and stratigraphy sections in southwestern New Mexico: New Mex. Geol. Soc. Guidebook, 20th Field Conf., p. 186-196.

Wengerd, S.A., 1969, Geologic history and the exploration for oil in the border region: New Mex. Geol. Soc. Guidebook, 20th Field Conf., p. 197-204.

RECONNAISSANCE GEOLOGY OF THE SIERRA ALTA-BOCA GRANDE AREA, CHIHUAHUA, MEXICO

by

B. Russell Robinson and Kenneth F. Clark
Department of Geological Sciences
University of Texas at El Paso
El Paso, Texas 79968

INTRODUCTION AND LOCATION

Reconnaissance geologic mapping of 1100 km^2 in the Los Moscos and western part of the Guadalupe Victoria quadrangles (Fig. 1) in Chihuahua, Mexico, has shown that a thick sequence of Paleozoic and Mesozoic age strata cropping out in the Sierra Alta, Sierra Boca Grande, and Sierra Rica are correlative with rock units present in the Big Hatchet Mountains of southwestern New Mexico. Furthermore, crystal-lithic and lithic-crystal tuffs and breccias in the northern Sierra Alta suggest the presence of a Tertiary volcanic center in that area.

The Sierra Alta-Boca Grande is a north-oriented, arcuate-shaped, uplifted mountain chain that averages 8 km wide and extends for more than 40 km. The range has been tilted to the southwest as the result of movement along suspected boundary faults that are concealed beneath basin-fill alluvium in a typical basin and range fashion. A Quaternary fault scarp with several meters of relief parallels the mountain front for more than 20 km and may define the location of the eastern boundary fault.

Topographically the Sierra Alta and Sierra Boca Grande are separated by a drainage divide occupied by the Rio Casas Grandes. Structurally and stratigraphically the two sierras are continuous. In general, strata in the ranges have dips of 15-30° to the south-southwest; northwest-oriented Laramide related structures produce local deviations in bedding attitudes.

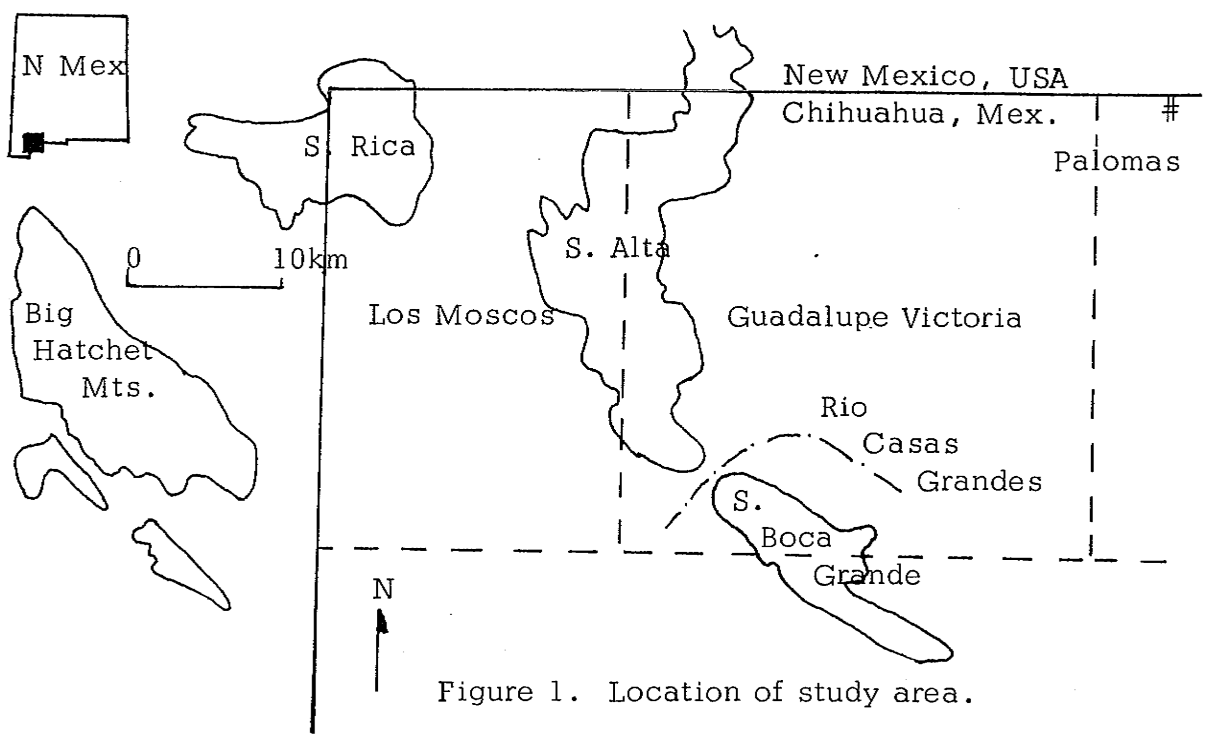


Figure 1. Location of study area.

STRATIGRAPHY

The base of the sedimentary section is composed of a sequence of medium to thick beds of light grey, cherty, biomicrites, biosparites, and oosparites containing rugose corals, Syringopora, fusulinids, and crinoid stems. These rocks are equivalent to the Escabrosa Limestone and Paradise Formation of the Big Hatchet Mountains. At the extreme southern end of the Sierra Alta a 75-100 m thick, massive, medium grey, cliff-forming limestone unit, the Concha Limestone (Zeller, 1965; Tovar, 1969), is unconformably overlain by red siltstones, shales and arkoses of the Cretaceous age Hell-to-Finish Formation. Detailed stratigraphic work should, as suggested by Tovar (1969) and Lopez-Ramos (1969), prove that the sequence of Paleozoic carbonates and clastics present in the Sierra Alta is similar to that described by Zeller (1965) in the Big Hatchet Mountains of New Mexico.

A continuous Cretaceous section is exposed from the southern end of the Sierra Alta to the crest of the Sierra Boca Grande. The cliff-forming cap rock of the Sierra Boca Grande is composed of a sequence of Orbitolina-bearing biosparites, biomicrites, and recrystallized biolithites (?) that is correlative with Zeller's (1965) Reef and Suprareef members of the U-Bar Formation. The contact between the Hell-to-Finish and U-Bar Formations occurs approximately along the course of the Rio Casas Grandes.

At the north end of the Sierra Alta, the Paleozoic sequence is in fault contact with a thick pile of Tertiary age volcanic rocks. The volcanic strata are dominantly quartz-bearing crystal-lithic and lithic-crystal tuffs and breccias. Dips of the volcanic units are to the northeast at 15-25°. The volcanic terrain appears to extend for a considerable distance into southern New Mexico which suggests that an erupted center existed in that area. Small exposures of Tertiary volcanic rocks and associated intrusions also occur a few kilometers northeast of the Sierra Boca Grande, and in the Sierra Rica. Flat-lying flows of dense, black, porphyritic basalt that crop out in the lowlands along the Rio Casas Grandes represent isolated remnants of the Quaternary age Palomas basalt field.

The Sierra Rica occupies the northwestern corner of the study area. Structural complications and metamorphism of the host rocks by Tertiary intrusives (including granite) makes correlations of the sedimentary section exposed in that area difficult. We have, however, recognized equivalents of the Escabrosa Limestone, Hell-to-Finish, and U-Bar Formations in the sierra.

REFERENCES CITED

Lopez-Ramos, Ernesto, 1969, Marine Paleozoic rocks of Mexico: Amer. Assoc. Petrol. Geol. Bull., v. 53, n. 12, p. 2399-2417.

Tovar, Jorge, 1969, Stratigraphic study of the Sierra Santa Rita: New Mex. Geol. Soc. Guidebook, 20th Field Conf., p. 165-170.

Zeller, Robert A., 1965, Stratigraphy of the Big Hatchet Mountains Area, New Mexico: New Mex. Bur. Mines & Min. Res., Mem. 16, 122 p.

HUNT'S HOLE MAAR VOLCANO, DONA ANA COUNTY, SOUTH-CENTRAL NEW MEXICO

by

Charles J. Stuart
Department of Geological Sciences
University of Texas at El Paso
El Paso,Texas 79968

INTRODUCTION

Hunt's Hole is the smallest of three circular maar volcano craters excavated in the westernmost part of the flat surface of the Mesilla bolson (La Mesa surface), approximately 64 km west of El Paso, Texas (DeHon, 1965a; Fig. 1). The other craters on this surface are Kilbourne Hole (Brenner, 1979), the largest of the three, located 3.4 km north of Hunt's Hole, and Potrillo maar 16.5 km to the south. The three craters are aligned north and south along the inferred down-to-the-west Fitzgerald fault. The fault is not exposed in the craters or on the La Mesa surface, but is expressed by a line of depressions on the desert floor. Hunt's Hole is 2.4 km long, 2.0 km wide, and 76 m deep, and is excavated in mudstone and sandstone of the Pleistocene Santa Fe Group, which is partly overlain by a basalt flow forming the south end of the Aden-Afton basalt field (Hoffer, 1975). The oldest flow (AF_1) of the Aden-Afton basalt field is exposed in the eastern half of Hunt's Hole. Radiometric analyses of this flow provide ages of 141,000 $\pm$ 75,000 years and 103,000 $\pm$ 84,000 years (Denison, 1975). The age of phreatic eruption, however, is indeterminable, but probably is less than 50,000 years based on the degree of dissection and lack of weathering of the base-surge tuffs.

Hunt's Hole formed as a result of steam-magma (phreatomagmatic) eruptions, which are characteristic of maar volcanos. The term "maar" refers to small volcanic cones and craters, commonly with central lakes, in Germany where they were first described. During eruption, maar volcanoes form a vertical eruption column, which partially collapses into a outward-moving cloud that transports tuff away from the vent. The outward-moving cloud is called a base surge. If the eruption is continuous, base surges form continuously. The tuffs deposited by base surges typically construct a ring or cone around the central vent and are cross bedded.

Cross-bed foreset beds at Hunt's Hole dip away from the vent and generally form a radial pattern (Fig. 2). The cross beds form dunes with an average height of about 40 cm, and wavelengths of 190 cm. The upcurrent side of the dunes dips an average of 7° toward the vent, and the downcurrent side about 23° away from the vent, making the dunes asymmetrical. Similar structures in base-surge tuffs elsewhere are generally smaller, near-symmetrical and the dips on either side are less than 15°. These structures have been interpreted as antidunes characteristic of upper regime flow. However, the form and vertical and lateral continuity of Hunt's Hole dunes suggests that they are more like lower-regime "mega-ripple-drift" structures (Fig. 3). That is, they form climbing dune sequences. If this interpretation is correct, this is the first described occurrence of lower-regime bedforms in base surge tuffs.

The purpose of this short paper is to describe the setting of these base surge dunes, summarize the general features of the stratigraphy and other sedimentary structures at Hunt's Hole and interpret the geologic history of the tuffs and the crater itself.

PREVIOUS STUDIES

Hunt's Hole was first studied by Lee (1907) who interpreted it as a phreatic explosion pit. Other studies include those of Darton (1916, 1933), Dunham (1935), Reiche (1940), and Shoemaker (1957). The base surge origin of the tuff ring, however, was not recognized until later by DeHon (1965a and b) and Reeves and DeHon (1965). These studies, however, concentrated on general features and the origin of the crater. More recent studies (Stuart, 1979; Stuart and Brenner, 1979) have concentrated on the bedforms and origin of cross bedded dune structures.

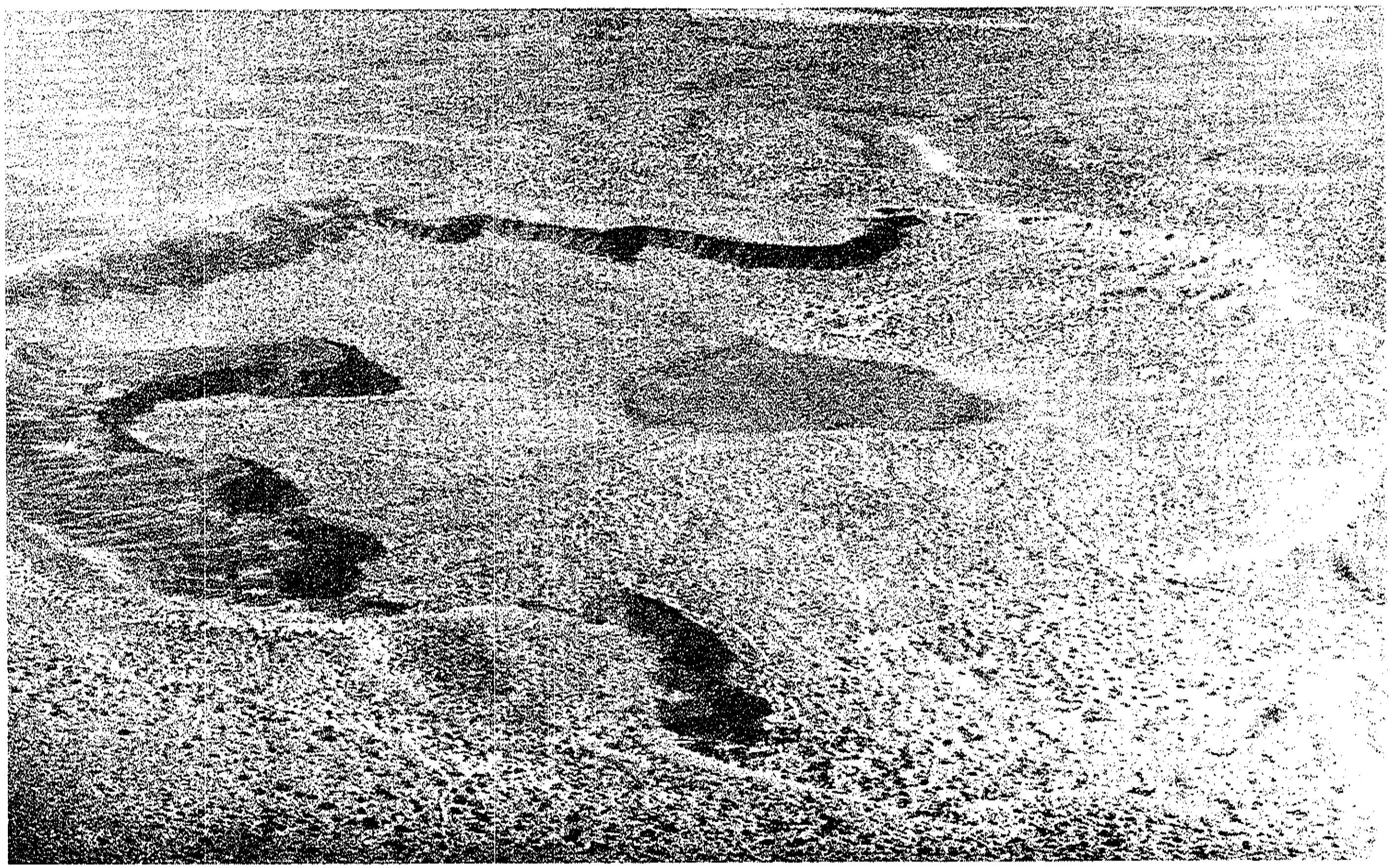


Figure 1 Aerial view of Hunt's Hole looking toward the southeast. The dark, cliffed outcrops in the left-hand part of the photograph are pre-tuff basalt flows of the Aden-Afton basalt field. Tuff and eolian sand dunes are light colored.

HUNT'S HOLE TUFF RING

Distribution

Base-surge tuff forms a ring deposit surrounding Hunt's Hole (Fig. 2). The tuff was deposited on a nearly horizontal erosion surface cut across the Aden-Afton Af_1 basalt flow and a sandy, locally caliche-capped, soil zone developed on Santa Fe Group sandstone and claystone. The basalt flow trends northerly, terminating to the east and west (Fig. 2). It forms the distal end of a southward-extending lava flow. The pre-base surge surface was not absolutely flat but consisted of two broad swales separated by low ridges in the vicinity of the crater. The swales are northeast-southwest trending and appear to deepen a few meters toward the northeast rim. These irregularities may have had a minor influence on the lower-most tuff beds, but no specific effects, other than variations in thickness, were observed.

Present thickness of the tuff rim is 3.0 to 18.0 m although it was probably thicker and more extensive originally. The rim edge has been eroded back as evidenced by outcrops of the underlying basalt and Santa Fe Group sedimentary rocks crater-ward of the present rim edge (Fig. 2). The thickness of the tuff reflects proximity to the eruptive vent and location relative to the prevailing westerly winds. Thus the tuff is thickest to the east and in more proximal localities such as along the north-central and west-central parts of the rim. The more distal southern and northwestern parts of the rim are characterized by thin accumulations. The eruptive center appears to have been located at the present playa in the center of the crater. This is inferred from cross bed dip directions and bomb-impact trajectories (Fig. 2).

Stratigraphy

The tuff was measured at eight localities around the crater, supplemented by less comprehensive measurements at intermediate points. Five bedding units were identified and correlated around part or all of the rim. Figure 4 illustrates this stratigraphic sequence in representative thick and thin sequences.

Unit 1 - Air Fall Tuff

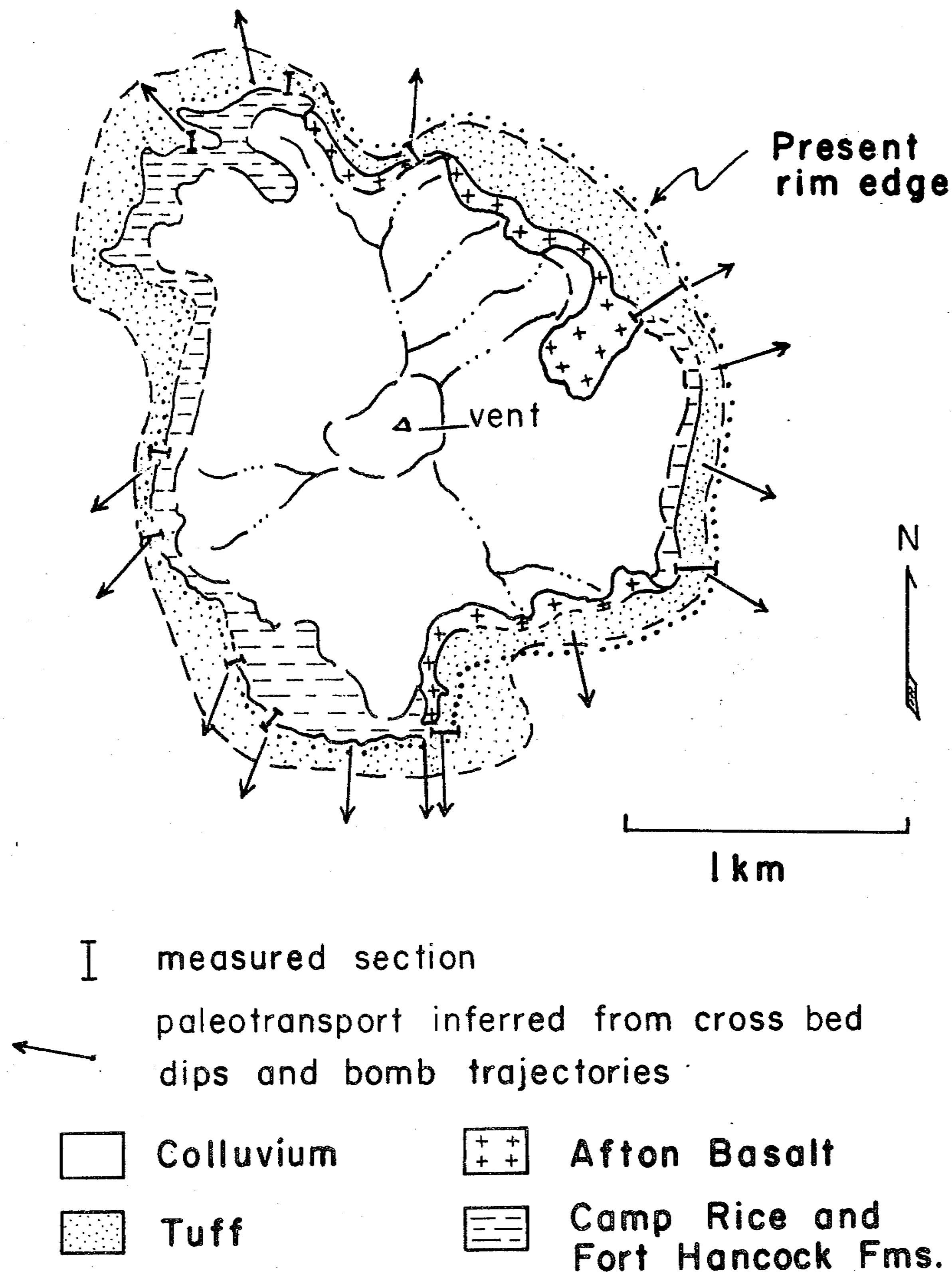
Unit 1 sharply overlies basalt, and sandy caliche soil zones of the underlying Af_1 basalt and Santa Fe Group, respectively. It varies in thickness from 5.0 to 20.0 cm and occurs as a distinct unit in all but the eastern portion of Hunt's Hole (Figs. 4 and 5). It consists of two thin beds, a basal massive, laminated or normally-graded fine-sand size tuff 2.0 to 15.0 cm thick, overlain sharply by a massive to graded accretionary- lapilli bed 2.5 to 8.0 cm thick. These beds are unconformably overlain by coarser deposits of unit 2 along the eastern side of Hunt's Hole. Unit 1 beds are interpreted as airfall deposits because of their lateral continuity and grading.

Unit 2 - Airfall to Base Surge Tuff-Breccia

Unit 2 beds occur along the eastern and northern parts of Hunt's Hole sharply overlying and perhaps in erosional contact with unit 1. Unit 2 varies in thickness from 30 cm to 10.9 m, and consists of massive, laminated and low-angle cross bedded coarse tuff and pebbly tuff-breccia with scattered boulders (bombs). Locally, unit 2 beds are contorted along the northern rim. The massive units may be airfall beds, the laminated and cross bedded layers probably are base surge deposits.

Unit 3 - Dune Cross Bedded Tuff

Unit 3 is the most distinctive tuff layer at Hunt's Hole because of pervasive medium-scale cross bedding. The unit sharply to transitionally (eastern rim) overlies unit 1 or 2, and grades upward into unit 4. Unit 3 occurs in all parts of the rim varying in thickness from 2.1 to 6.5 m. The tuff is generally fine-sand size at the base grading upward into interbedded fine-sand size tuff and granular pumice-lapilli tuff. A few layers of and accretionary lapilli are interbedded with these tuffs along the western rim. The basal portion of unit 3 is slightly more consolidated than the overlying beds, thus forms a relatively resistant ledge. All tuffs of this unit, however, are very friable. The cross bedding indicates that these beds are base-surge deposits.



After DeHon, 1965b

Figure 2 Geologic map of Hunt's Hole. Modified from DeHon (1965b).

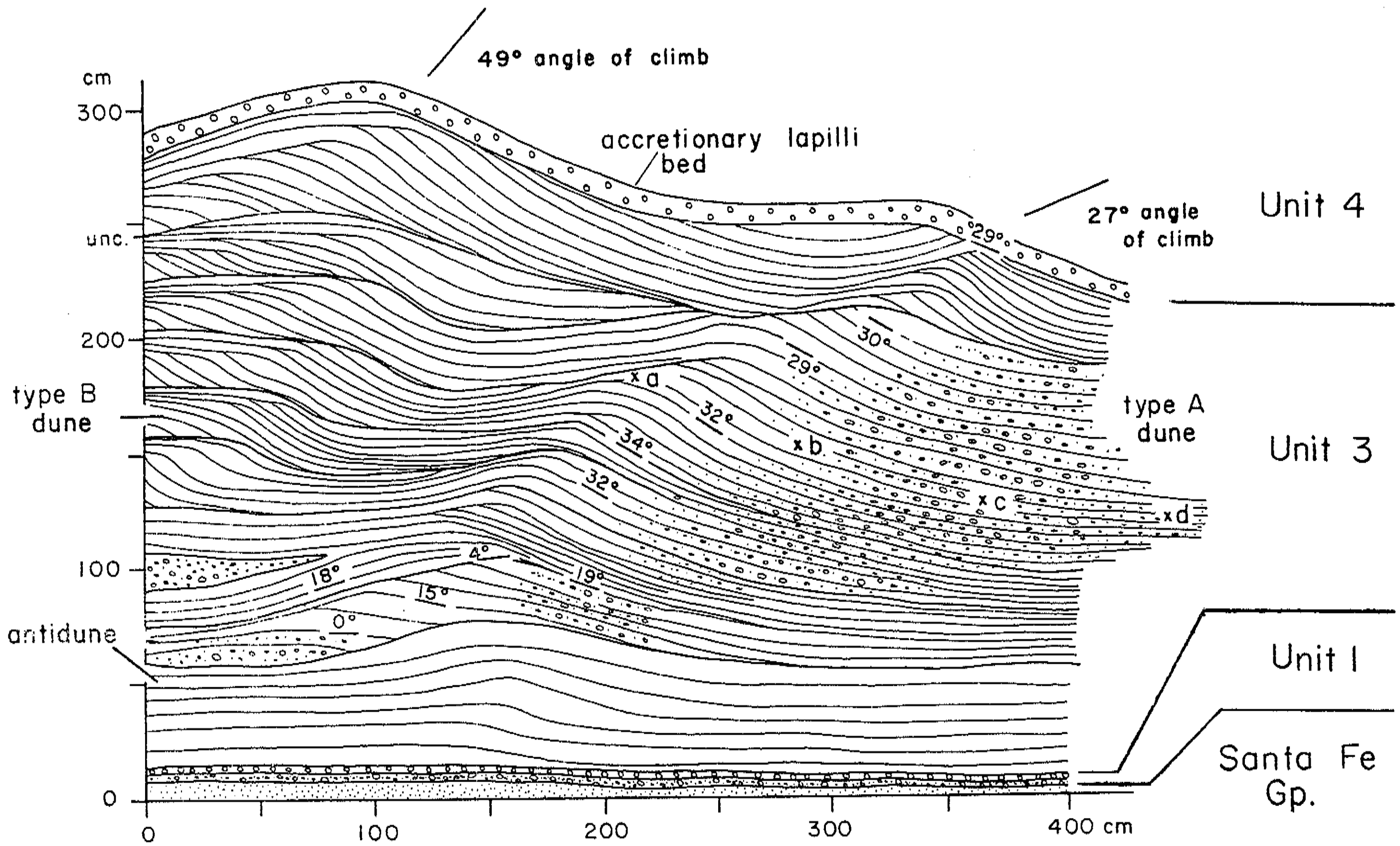


Figure 3 Field sketch of a dune sequence typical of the tuff ring surrounding Hunt's Hole. The dunes form ripple-drift (climbing) sequences consisting of lower-regime (type A and B) and upper-regime (antidunes) types.

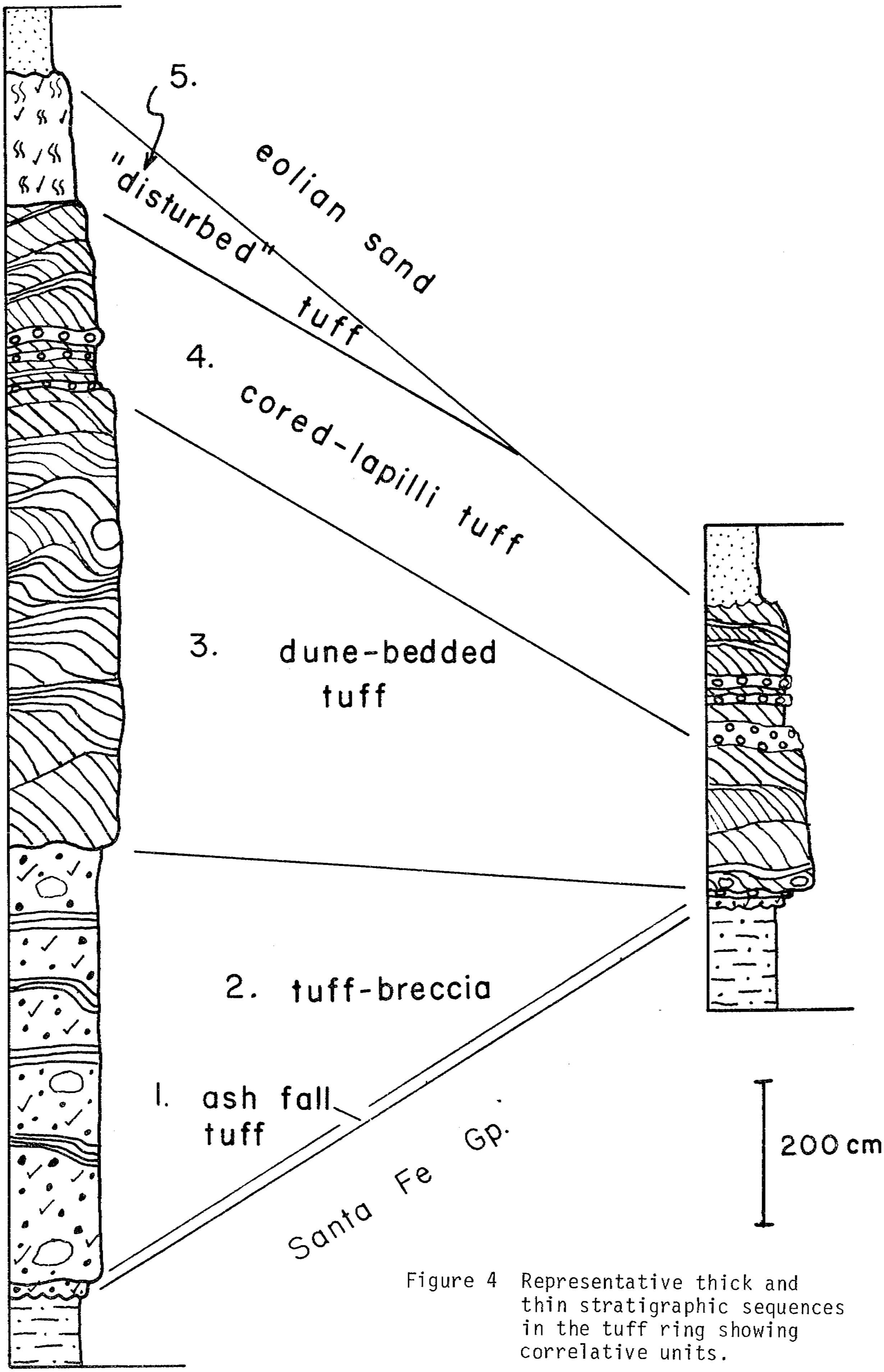
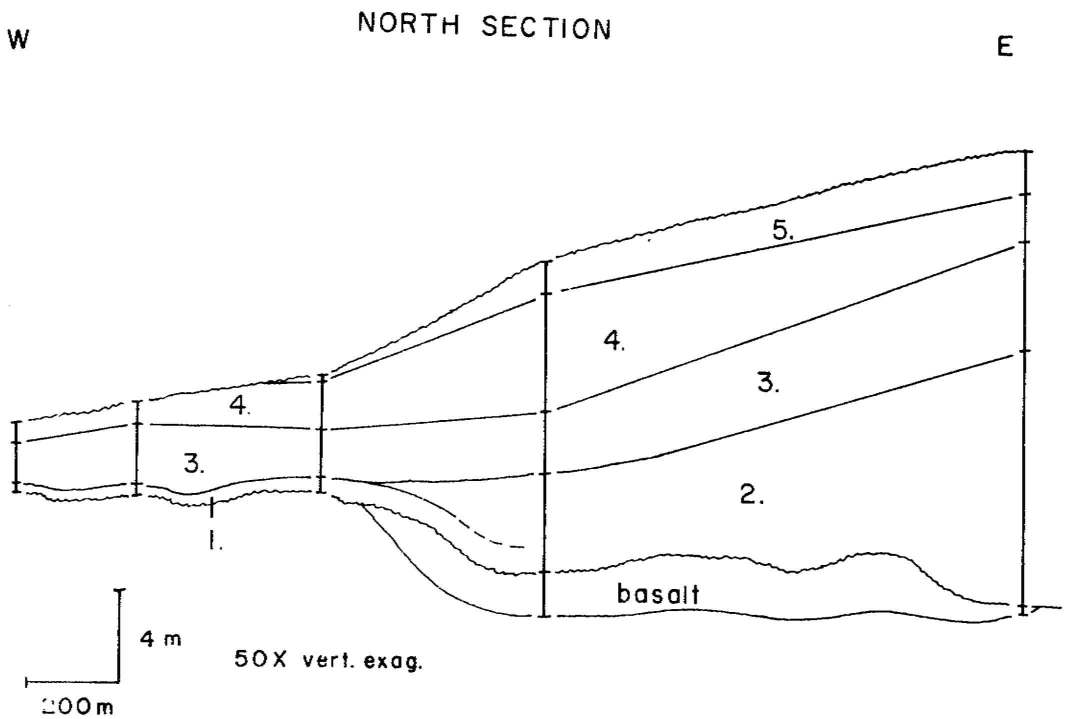


Figure 4 Representative thick and thin stratigraphic sequences in the tuff ring showing correlative units.



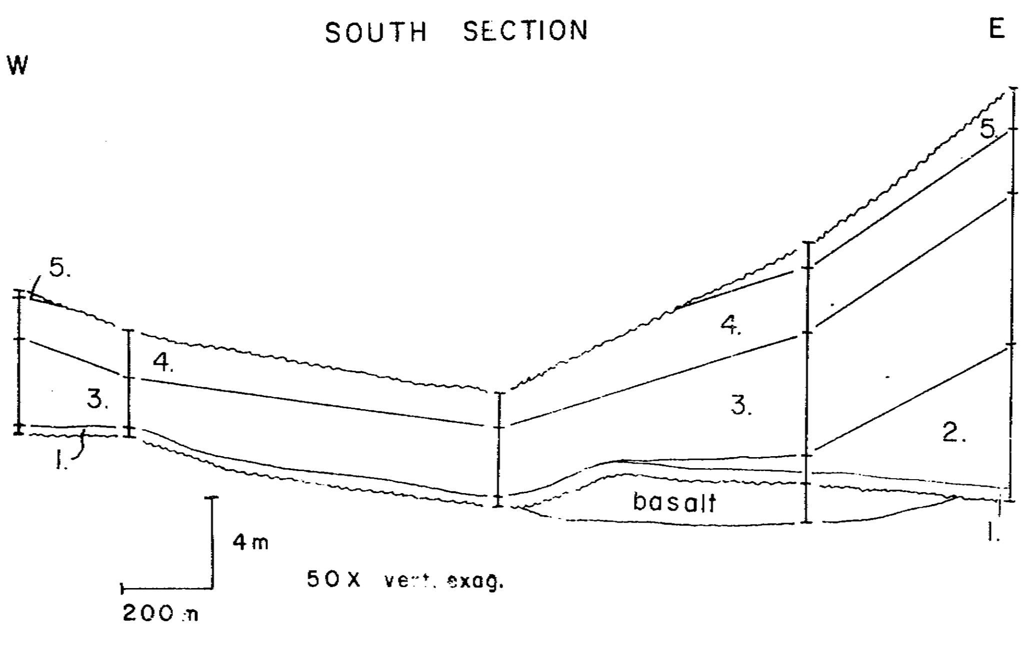


Figure 5 Stratigraphic sections along the northern and southern parts of the Hunt's Hole rim. Numbers refer to units described in Figure 4.

Unit 4 - Accretionary-Lapilli Tuff

Unit 4 transitionally overlies unit 3 and is sharply overlain by unit 5. Unit 4 is incompletely exposed but varies in thickness from 2.0 to 2.7 m where it is overlain by unit 5. Unit 4 consists of interbedded cross bedded, fine- to medium-sand size tuff with scattered pumice-lapilli layers, and massive, laminated or normally graded accretionary-lapilli tuff layers. Individual accretionary lapilli average about 1 cm in diameter. They differ from those described by Moore and Peck (1962) in consisting of a massive ash-ball core surrounded by only a single lamination of accreted fine ash. Accretionary lapilli described by Moore and Peck (1962) consist of multiple accreted layers. Accretionary-lapilli tuff forms wavy beds of fairly uniform thickness, from 2.0 to 15.0 cm thick. The wavy bed form probably developed by uniform accumulation of accretionary-lapilli layers over mounded tuff surfaces (dunes). Layers within these beds are continuous over the dune crests and troughs, although some are thinned by scouring at the top. These characteristics indicate that the tuff formed as an air-fall deposit evenly coating the mounded tuff surface, although laminated beds may have formed by deposition from or reworking by base-surge currents.

Unit 5 - Disturbed Tuff

Unit 5 is poorly exposed along the crater rim sharply overlying unit 4, and is covered locally by post-eruption eolian sand. Unit 5 attains thicknesses up to 2.0 m and forms a single massive, fine-sand size tuff bed with no internal bedding surfaces. The bed is characterized by crenulate structures (DeHon, 1965b) which appear to be curved, rosette-like laminations of tuff that fill intersecting tube-like structures.

The origin of these structures is uncertain but probably they are biogenic. There is no evidence of subaqueous deposition, therefore, they may be bioturbation features of large insects, possibly beetles, or small animals. Since these features occur at the top of the tuff sequence, bioturbation occurred after or in the final stages of volcanic activity. The tuff probably was water-saturated and soft making it a suitable burrowing habitat.

CRATER FORMATION

The origin of the Hunt's Hole crater is poorly known although some reasonable possibilities can be suggested. Alternative hypotheses were considered in the masters thesis of DeHon (1965b) as summarized below:

1) Meteor impact
2) Collapse
   a. subsidence due to solution of underlying rocks
   b. subsidence due to the removal of volcanic materials
3) Volcanic explosion
   a. cratering by phreatic explosion
   b. cratering by juvenile volatiles

The number of maar craters in this part of the Mesilla bolson precludes the first possibility. The rocks underlying the crater are sandstones and shales not subject to solution. Thus solution subsidence is unlikely. Removal of erupted volcanic materials is possible, but the volume of tuff at Hunt's Hole is dwarfed by the volume of the crater. This process, therefore, is unlikely as a major source of crater subsidence. Mechanisms of volcanic explosion are the most likely of the group. Blasting during eruption could have pulverized rock, forming the crater. However, there are few bombs in the tuff and little evidence of such an event.

DeHon (1965a and b) concluded that some form of coring or rasping by jets of sediment-laden steam gradually formed the crater at the same time the tuff was deposited. Thus the crater most likely developed passively (unlike the dramatic explosions at Mt. St. Helens) during most or all phases of eruption.

After the volcano became extinct, normal weathering and erosional processes modified the crater, partially filling it and causing the rim to retreat. In addition, slumps along the rim edge caused rim retreat and crater filling.

CONCLUSIONS

The different units making up the Hunt's Hole maar tuff ring record a series of eruptive events during which tuff accumulated, and the crater itself formed. Unit 1 consists of thin, continuous airfall units. Apparently the eruption was very small initially, forming a dilute eruption cloud and depositing a tuff layer over only a few km^2. This activity ceased but was followed by a moderately violent eruption probably of relatively dry material. This formed the tuff-breccia deposits of unit 2. As more water entered the vent, the ejecta became wetter and finer-grained, and base surges developed forming unit 3. These eruptions appear to have been continuous because there are no major unconformities within unit 3, although minor scour surfaces developed. Since a continuous supply of relatively uniform tuff was available during formation of unit 3, the dune forms migrated downcurrent and upward forming ripple-drift sequences. Surge velocities probably were moderate to low compared to other maar volcano eruptions.

Periodic lessening of the eruption intensity reduced base-surge activity allowing the eruption cloud to deflate. Accretionary lapilli that formed in the cloud were then deposited, forming parts of unit 4. This fluctuation in eruption intensity resulted in the interbedding of accretionary lapilli and base surge dune deposits.

Unit 5 was deposited during waning stages of the eruption after which the maar abruptly became extinct. Burrowing insects or animals possibly reworked this tuff forming the crenulate-lamination-filled tubular structures common in unit 5. The maar has since been eroded at the margins and filled in the center, and the rim has retreated outward to its present position.

The occurrence of lower-regime ripple-drift structures indicates that large-scale lower-regime bedforms can be preserved in base surge tuff. Previously, it was thought that upper-regime structures only are preserved. Preservation of lower-regime structures apparently depends on the fortuitous combination of tuff coarseness, surge fluid characteristics (viscosity and density), and surge velocity, in addition to periodic coating of lower-regime dunes by cohesive fine tuff. Based on the absence of descriptions of these structures in the literature, the conditions necessary for their formation must occur only rarely.

REFERENCES CITED

Brenner, M.G., 1979, Sedimentary features in base surge tuffs, Kilbourne Hole, Potrillo Mountains, Dona Ana County, New Mexico: Geol. Soc. Am. Progs. with Abs., v. 11, n. 6, p. 267.

Darton, N.H., 1916, Explosion craters: Sci. Monthly, v. 2, p. 417-430.

———, 1933, Guidebook of the western United States, Southern Pacific route: U.S. Geol. Sur., Bull. 845, 384 p.

DeHon, R.A., 1965a, Maare of La Mesa, in Southwestern New Mexico II: New Mex. Geol. Soc. Guidebook, 16th Field Conf., p. 204-209.

———, 1965b, The geology of Hunt's Hole: M.S. Thesis, Texas Tech Univ., 70 p.

Dunham, K.C., 1935, Geology of the Organ Mountains: New Mex. Bur. Mines & Min. Res., Bull. 11, 272 p.

Hoffer, J.M., 1975, The Aden-Afton basalt, Potrillo volcanics, south-central New Mexico: Texas Jour. of Sci., v. 26, p. 379-390.

———, 1976, The Potrillo basalt field, south-central New Mexico: New Mex. Geol. Soc., Spec. Publ. 5, p. 89-92.

Lee, W.T., 1907, Afton craters of southern New Mexico: Geol. Soc. Am. Bull., v. 18, p. 211-220.

Moore, J.G., and D.L. Peck, 1962, Accretionary lapilli in volcanic rocks of the western continental United States: Jour. Geol., v. 70, p. 182-193.

Reeves, C.C., Jr. and R.A. DeHon, 1965, Geology of Potrillo maar, New Mexico and northern Chihuahua, Mexico: Am. Jour. Sci., v. 263, p. 401-409.

Reiche, P., 1940, The origin of Kilbourne Hole, New Mexico: Am. Jour. Sci., v. 238, p. 212-225.

Shoemaker, E.M., 1957, Primary structure of maar rims and their bearing on the origin of Kilbourne Hole and Zuni Salt Lake, New Mexico (abs.): Geol. Soc. Am., Abs. with Progs., v. 68, pt. 2, p. 1846.

Stuart, C.J., 1979, Hunt's Hole maar volcano, Aden-Afton basalt field, Dona Ana County, south-central New Mexico (abs.): Geol. Soc. Am., Progs. with Abstracts, v. 68, pt. 2, p. 1846.

———, and M.G. Brenner, 1979, "Low-regime" base surge dunes — An example from Kilbourne and Hunt's Holes, south-central New Mexico (abs.): Geol. Soc. Am., Progrs. with Abstracts, v. 11, n. 7, p. 525.

THE COMPOSITION OF FELDSPAR MEGACRYSTS; POTRILLO BASALT, WEST POTRILLO MOUNTAINS SOUTHERN NEW MEXICO

by

Jerry M. Hoffer and Terri S. Ortiz
Department of Geological Sciences
University of Texas at El Paso
El Paso, Texas 79968

INTRODUCTION AND GEOLOGIC SETTING

The occurrence of exotic nodules and crystals in alkali olivine basalt is common, and most of the inclusions are of peridotite composition. Less common are feldspar megacrysts; they have been reported from Antarctica, Africa, Australia, Canary Islands, Mongolia, and southwestern United States (Mountain, 1925; Vlodavetz and Shavrova, 1953; Boudette and Ford, 1966; Borley et al., 1971; Hoffer and Hoffer, 1973; Laughlin et al., 1974; Foder, 1978; Lynch, 1978; and Warren et al., 1979).

The West Potrillo Mountains occupy an area of approximately 320 mi^3 in south-central New Mexico. The range is composed of thin Quaternary alkali basalt flows and associated cinder, cinder-spatter cones, and maar volcanos (Hoffer, 1976). The lava flows are pyroxene-rich with small phenocrysts of olivine; the flows show little to no evidence of differentiation. In addition to the occurrence of abundant feldspar megacrysts, inclusions of clinopyroxenite, kaersutite-clinopyroxenite, kaersutite, wherlite, and olivine-clinopyroxenite are common (Ortiz, 1979).

OCCURRENCE AND PETROGRAPHY

Feldspar megacrysts, of both alkali and plagioclase feldspar, are the most abundant type of inclusion occurring in the basalts of the West Potrillo Mountains. Single crystals are found as loose crystals on the flanks of cinder cones, in the cores of volcanic bombs, or as inclusions in lava flows.

The crystals are typically anhedral to euhedral, gray to colorless, and range in size from 3 mm up to 6 cm. Many of the crystals display megascopic fractures and, in thin section, show strain shadows and occasionally microfractures and bent twin lamellae.

Inclusions of iron oxides and apatite are present in some of the crystals. No chemical zoning was noted in thin section or on the scanning electron microscope (Ortiz, 1979). Little to no reaction has taken place between the feldsapr megacrysts and host basalt other than rounding and slight corrosion of crystal edges.

COMPOSITION AND MINERALOGY

Introduction

A total of 32 feldspar megacrysts were chemically analyzed by x-ray fluorescence. Samples were ground to 500 mesh, pelletized, X-rayed with an ORTEC Tefa model 6110 energy dispersive fluorescence analyzer. Eight feldspar standards, NBS-70a and b, Ab-1, Or-1, and four analyzed by the NASA Johnson Space Center laboratories, were used to analyze the megacrysts.

Chemical Composition and Classification

Each feldspar megacryst was analyzed for nine major oxides; the results are shown in Table I. Total oxide percentages range from 98.98% to 101.02%.

TABLE I

CHEMICAL ANALYSES OF FELDSPAR MEGACRYSTS, WEST POTRILLO BASALT

	Anorthoclase	Andesine	Andesine	Oligoclase	Potash Oligoclase	Oligoclase	Anorthoclase
Sample	13K	621K	621H	75F	67J	68L	57K
SiO_2	65.59	62.47	60.74	61.40	58.07	62.33	64.61
TiO_2	0.02	0.02	0.03	0.04	0.04	0.04	0.03
Al_2O_3	20.68	24.92	24.84	23.74	27.15	23.35	21.29
Fe_2O_3	0.25	0.37	0.33	0.34	0.39	0.28	0.26
MnO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MgO	0.14	0.12	0.15	0.10	0.12	0.12	0.07
CaO	0.86	5.44	5.36	.27	8.30	3.91	1.69
Na_2O	8.62	8.00	7.97	8.59	5.89	8.38	8.56
K_2O	4.84	1.08	1.20	1.23	1.06	1.49	3.13
Total	101.00	100.42	100.62	99.71	101.02	99.90	99.64
Or%	26.0	6.0	6.7	6.9	6.2	8.5	17.9
Ab%	70.1	68.3	68.0	73.0	52.6	72.7	74.0
An%	3.9	25.7	25.3	20.1	41.1	18.8	8.1
Total	100.0	100.0	100.0	100.0	99.9	100.0	100.0

	Andesine	Anorthoclase	Andesine	Anorthoclase	Potash Oligoclase	Potash Oligoclase	Anorthoclase
Sample	13L	54M	551A	56K	61K	621 I	621J
SiO_2	60.34	64.44	59.57	64.87	63.54	63.05	64.28
TiO_2	0.04	0.03	0.04	0.03	0.04	0.02	0.01
Al_2O_3	24.83	21.29	25.65	21.31	.49	22.47	21.54
Fe_2O_3	0.39	0.26	0.34	0.22	0.25	0.29	0.23
MnO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MgO	0.11	0.10	0.12	0.11	0.11	0.10	0.09
CaO	5.56	1.60	6.61	1.53	2.86	2.78	1.91
Na_2O	6.63	7.85	6.10	7.75	8.39	8.82	8.68
K_2O	1.08	3.66	1.22	3.32	1.88	2.14	3.18
Total	98.98	99.23	99.62	99.14	99,56	99.67	99.92
Or%	6.8	21.6	7.6	20.3	11.1	12.0	17.7
Ab%	63.6	70.4	57.8	71.8	74.8	75.0	73.3
An%	29.5	8.0	34.6	7.9	14.1	13.0	9.0
Total	99.9	100.0	100.0	100 0	100.0	100.0	100.0

TABLE I

(continued)

Sample	Oligoclase 67C	Oligoclase 68F	Anorthoclase 751E	Potash Oligoclase 751P	Anorthoclase 76B	Anorthoclase 13C	Potash Oligoclase 57A	Lime Anorthoclase 75E
SiO_2	60.29	61.33	63.88	63.28	64.68	64.44	61.48	63.47
SiO_2	0.04	0.03	0.02	0.03	0.02	0.03	0.03	0.01
Al_2O_3	24.95	24.32	21.88	22.81	21.48	21.14	24.44	22.01
Fe_2O_3	0.39	0.36	0.36	0.28	0.27	0.16	0.18	0.11
MnO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MgO	0.14	0.11	0.12	0.11	0.17	0.11	0.15	0.04
CaO	5.37	4.57	1.86	3.12	1.65	2.02	5.30	2.23
Na_2O	7.83	7.42	8.60	8.35	9.36	8.65	7.30	8.33
K_2O	1.29	1.21	3.40	1.73	2.99	3.87	1.40	3.24
Total	100.30	99.35	100.12	99.71	100.52	100.42	100.28	99.44
Or%	7.3	7.4	18.9	10.2	16.1	20.7	8.3	18.3
Ab%	67.2	69.0	72.4	74.4	76.4	70.2	65.4	71.2
An%	25.5	23.5	8.7	15.4	7.5	9.1	26.3	10.5
Total	100.0	99.9	100.0	100.0	100.0	100.0	100.0	100.0

Sample	Potash Oligoclase 621L	Anorthoclase 63S	Oligoclase 63I	Oligoclase 64M	Anorthoclase 64N	Anorthoclase 64Q	Anorthoclase 660
SiO_2	63.19	63.18	60.26	60.68	64.80	63.00	64.25
TiO_2	0.73	0.01	0.03	0.03	0.03	0.02	0.02
Al_2O_3	22.56	.64	24.18	24.61	21.21	21.45	21.43
Fe_2O_3	0.32	0.34	0.42	.38	0.19	0.66	0.27
MnO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MgO	0.12	0.19	0.12	0.09	0.11	0.10	0.13
CaO	2.73	1.80	5.19	5.18	1.65	1.38	1.77
Na_2O	8.08	8.87	9.06	8.54	8.42	9.37	9.27
K_2O	2.17	3.13	1.17	1.11	3.43	3.16	3.48
Total	99.90	99.06	100.43	100.62	99.84	99.14	100.62
Or%	13.0	17.3	6.1	6.0	19.5	17.0	18.3
Ab%	73.3	74.4	71.3	70.4	72.6	76.7	73.9
An%	13.7	8.3	22.6	23.6	7.9	6.3	7.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE I

(continued)

	Potash Oligoclase	Lime Anorthoclase	Lime Anorthoclase
Sample	66X	63K	75M
SiO_2	61.90	64.11	64.68
TiO_2	0.03	0.01	0.03
Al_2O_3	22.98	22.11	21.66
Fe_2O_3	0.16	0.16	0.15
MnO	0.00	0.00	0.00
MgO	0.11	0.15	0.12
CaO	3.62	2.33	2.08
Na_2O	9.18	7.56	7.48
K_2O	2.54	3.19	3.48
Total	100.52	99.62	99.68
Or%	13.0	19.2	21.0
Ab%	71.4	69.1	68.5
An%	15.6	11.7	10.5
Total	100.0	100.0	100.0

Based upon the chemical analysis the percentage of the end members, Or, Ab, and An were calculated and plotted on a standard Or-Ab-An triangle along with those reported in the literature. Each feldspar was identified following the classification of Muir (1962) (Fig. 1).

The majority of the feldspars fall in the field anorthoclase, potash oligoclase, and oligoclase although lime anorthoclase, andesine, and potash andesine are also represented.

DISCUSSION AND ORIGIN

Feldspar megacrysts, from the West Potrillos and occurrences reported in the literature, are found in association with relatively recent alkali basalt, pyroclastic events, and associated mafic and ultramafic inclusions.

The megacrysts are larger in size than the associated crystal aggregate rocks and apparently are not broken relicts from polymineralic bodies (Ortiz, 1979). Their trend from andesine to anorthoclase could indicate a source from a differentiated magma that became progressively enriched in alkali elements during crystallization of two feldspars, one alkali-rich and the other calcic-rich, from a magma at depth.

The presence of associated high temperature, mantle-derived, olivine-pyroxene-spinel inclusions, the high structured state of the feldspars, and their vitreous luster, conchoidal fracture, and lack of chemical zoning all suggest that the feldspar megacrysts formed at high temperature and at great depth (Hoffer and Hoffer, 1973; Ortiz, 1979).

Nash (1973) used experimental data from the literature to determine the relationship between An content of plagioclase and the pressure which it crystallized. Based upon his equation Pressure (kilobars) = -.038 (% An)

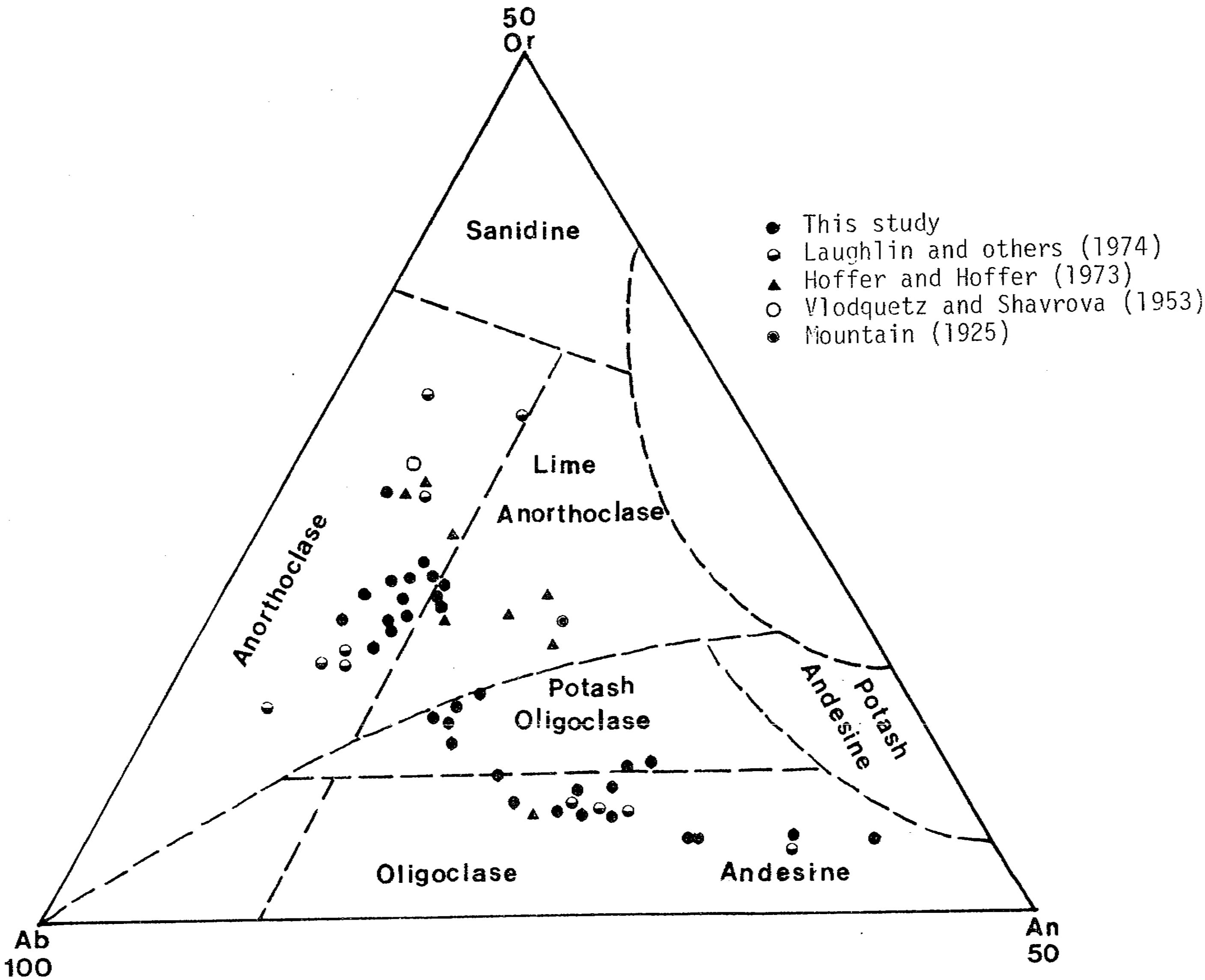


Fig. 1 Composition of feldspar megacrysts.

+ 34.7, the West Potrillo feldspar megacrysts crystallized at pressure ranging from 18 to 28 kilobars, averaging about 25 kilobars. This average pressure value corresponds to a depth of approximately 75 km.

ACKNOLWEDGMENTS

This investigation was supported by the National Aeronautics and Space Administration Grant NSG 9062 to the senior author.

REFERENCES CITED

Borley, G.D., Suddaby, P., and Scott, P., 1971, Some xenoliths from alkalic rocks of Teneriffe, Canary Islands: Contr. Min. & Petrol., v. 31, p. 102-114.

Boudette, E.L., and Ford, A.B., 1966, Physical properties of anorthoclase from Antarctica: Am. Min., v. 41, p. 1374-1387.

Foder, R.V., 1978, Ultramafic and mafic inclusions and megacrysts in Pliocene basalt, Black Range, New Mexico: Geol. Soc. Am. Bull., v. 89, p. 451-459.

Hoffer, J.M., 1976, Geology of Potrillo Basalt field, south-central New Mexico: New Mex. Bur. Mines & Min. Res., Circ. 149, 30 p.

______, and Hoffer, R.L., 1973, Composition and structural state of feldspar inclusions from alkali olivine basalt, Potrillo Basalt, southern New Mexico: Geol. Soc. Am. Bull., v. 84, p. 2139-2142.

Laughlin, A.W., Manzer, G.K., Jr., and Carden, J.R., 1974, Feldspar megacrysts in alkali basalt: Geol. Soc. Am. Bull., v. 85, p. 413-416.

Lynch, D.J., 1978, The San Bernadino volcanic field of southeastern Arizona: New Mex. Geol. Soc. Guidebook, 29th Field Conf., p. 261-268.

Mountain, E.D., 1925, Potash-Oligoclase from Mt. Erebus, Antarctic, and anorthoclase from Mt. Kenya, East Africa: Min. Mag., v. 20, p. 331-345.

Muir, I.D., 1962, The parageneis and optical properties of some ternary feldspars: Norsk Geol. Tidsskr., v. 42, p. 477-492.

Ortiz, T.S., 1979, Megacrysts and mafic and ultramafic inclusions of the southern West Potrillo Basalt Field, Dona Ana County, New Mexico: M.S. Thesis, Univ. Texas, El Paso, 95 p.

Nash, W.P., 1973, Plagioclase resorption phenomena and geobarometry in basaltic lavas (abst.): Am. Geophys. Union, Trans., v. 54, p. 507.

Vlodavetz, V.I., and Shavrova, N.N., 9153, On anorthoclase from a lava in Darigan volcanic region, southeast Mongolia: Akad. Naukk SSSR, Mineralog. Abs. 13, p. 480.

Warren, R.G., Kudo, A.M., and Keil, K., 1979, Geochemistry of litic and single crystal inclusions in basalt and a characterization of the upper mantle-lower crust in the Engle Basin, Rio Grande rift, New Mexico in Rio Grande Rift; in Tectonics and Magmatism: Am. Geophys. Union Spec. Pub., p. 393-415.

GEOLOGY OF THE WEST POTRILLO MOUNTAINS, SOUTHCENTRAL NEW MEXICO

by

Jerry. M. Hoffer and Tatum M. Sheffield
Department of Geological Sciences
The University of Texas at El Paso
El Paso, Texas 79968

INTRODUCTION

The West Potrillo Mountains consist of a broad topographic high covered by Quaternary olivine alkali basalt. The plateau rises 400-800 ft above the La Mesa surface (4200 ft) and is dotted by numerous volcanoes that reach elevations of nearly 5500 ft.

The volcanoes are predominantly cinder cones, but two maar volcanoes have been identified. Lava flows, erupted from central vents, cover approximately 300 square miles.

VOLCANIC FEATURES

Cinder Cones

Cinder cones are the most abundant volcanoes in the range; over 150 cones have been mapped (Hoffer, 1976). They range from 200 to 500 ft in height and 1000 to 3000 ft in diameter. Typically, the cones are composed of basal agglutinated cinder, bedded cinder, and bombs, with a partial to complete spatter rim at the top. Most are horseshoe-shaped in plain view, with one or more vents.

The cones do not appear to be of the same age. Based upon shape and degree of dissection, two types have been differentiated — young and old. The younger cones are generally large and steep-sided with slopes of from 20 to 25°. Most are relatively undissected by erosion with their slopes possessing shallow closely spaced arroyos. The cinder cones usually contain a single vent with a breached rim through which a lava flows has been extruded.

The older cinder cones are much more subdued with slopes of from 10 to 20°; deep arroyos cut the slopes. In addition, these cones occur in complexes with multiple vents. Within these complexes, three to six individual cones with abundant spatter are arranged in an irregular or linear pattern. Those displaying a linear outline trend north and extend for up to one and one-half miles. It is with these older cones that xenoliths of plagioclase and anorthoclase occur most abundantly as loose crystals or in the interior of bombs and cinders.

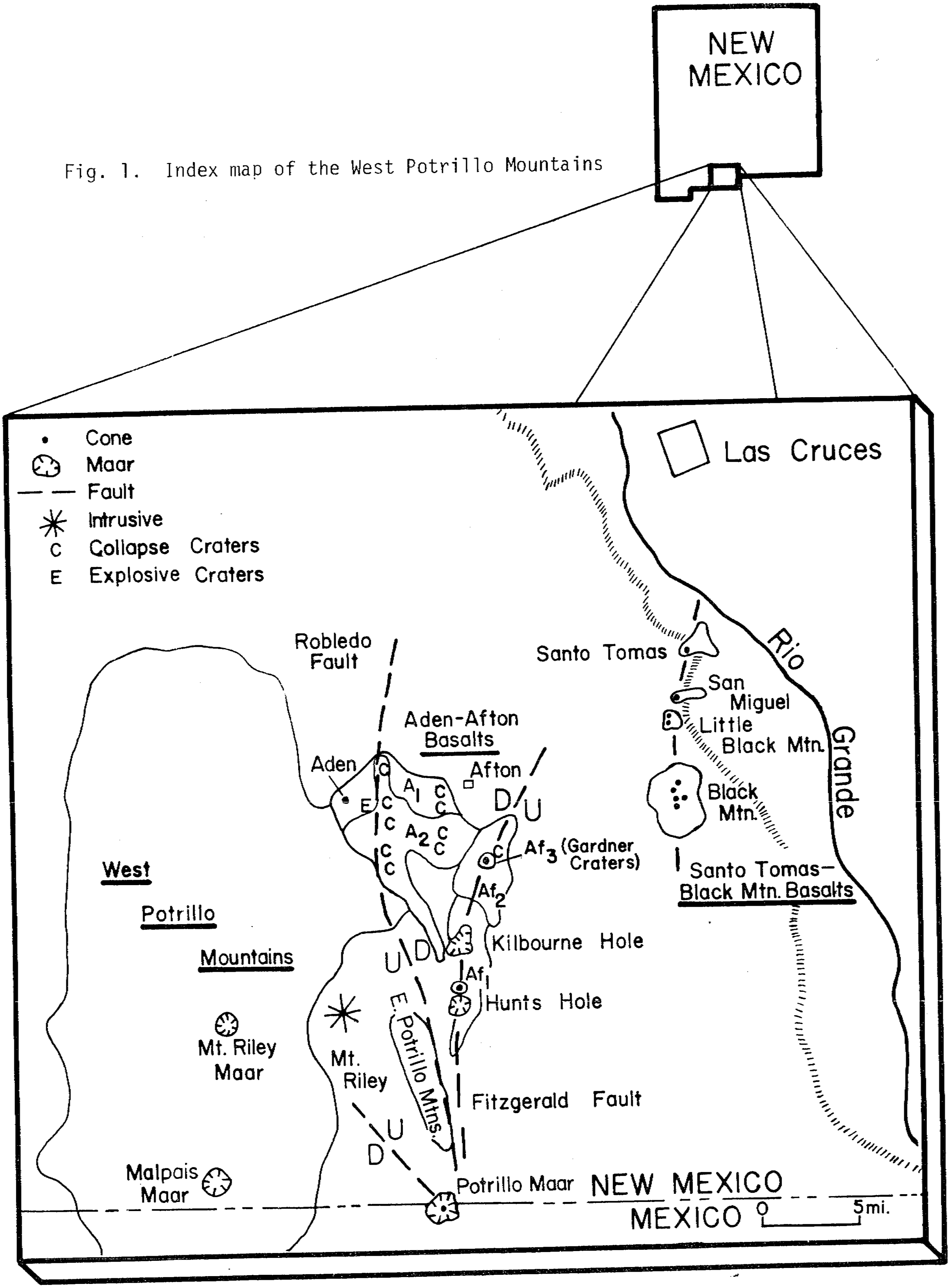
Maar Volcanoes

Two maar cones occur in the West Potrillo Mountain. These explosive craters are called Mount Riley maar and Malpais maar; they are located 5 mi west of Mount Riley and 3 mi east of Malpais, respectively (Fig. 1).

The Mount Riley maar is nearly circular in outline with an interior diameter of approximately 2500 ft (Bersch, 1977). The rim deposits are composed of poorly sorted, subangular to subrounded basalt, scoria, mineral, and lithic fragments. Mineral fragments include large crystals of feldspar, pyroxene, and olivine-enstatite aggregates up to three inches in size. Similar olivine-enstatite masses occur as bomb cores and inclusions at Kilbourne Hole and Potrillo Maar, respectively. The east and northeast floor of the crater are covered by a thin basalt flow that appears to have emerged from a vent within the crater.

The age of the maar is unknown, but it appears to be one of the older features in this section of the volcanic field. Lava flows from cones to the north and west have buried parts of the bedded rim deposits and the crater is highly dissected.

Fig. 1. Index map of the West Potrillo Mountains



At Malpais maar the rim tuffs outline a broad area 8000 ft long and 6000 ft wide (Page, 1973). The rim volcanics are composed of silt- to sand-size particles displaying gentle undulating bed forms and dipping cross-bedded layers. These base-surge deposits contain fine-grained, thin, parallel layers and blocks of air fall origin. The air fall blocks have produced bedding sag structures in the underlying tuffs.

Within the maar occurs a large cinder-spatter cone complex with two to three associated vents. Several basaltic dikes crop out on the east side of the maar.

Lava Flows

The basaltic lava flows of West Potrillo Mountains are individually thin. The cover of Recent alluvium and lack of sufficient erosion makes it impossible to determine the total thickness of the lava pile. If the entire West Potrillo upland is composed of lava flows, then the total basalt thickness would approximate 400 to 1000 ft. Individual flows, as measured in several arroyos, average about 10 ft in thickness.

A well located 5 mi southwest of Mount Riley (T.28S, R.3W, Sec. 13) at the southeast end of the volcanic pile penetrates approximately 285 ft of basalt and interbedded sands, and gravels (King et al., 1969). Individual flows average about 17 ft in thickness.

The basalt flows are microporphyritic with small phenocrysts of olivine and minor pyroxene and plagioclase. The groundmass is mostly pyroxene and glass. A preliminary petrographic analysis of the lavas indicates two different basalts. These include an olivine-rich basalt and an olivine-poor basalt.

The basalts were classified based upon their alkali and silica contents. The majority of the samples are olivine basalt but range in composition from basanite to basaltic andesite.

Based upon field relationships and petrography Hoffer (1976) divided the basalts of the West Potrillo Mountains into two members; Member 1 — an older plagioclase-rich basalt (low MgO), and Member 2 — a younger olivine-rich basalt (high MgO). Table 1 shows the average chemical composition of these two members.

TABLE 1

Chemistry of the West Potrillo Basalt
(*total iron reported FeO)

Member 1 (30 samples)		Member 2 (45 samples)	
SiO_2	45.14	SiO_2	44.97
TiO_2	2.53	TiO_2	2.36
Al_2O_3	14.47	Al_2O_3	14.28
FeO*	12.46	FeO*	11.96
MnO	0.17	MnO	0.17
MgO	8.67	MgO	10.43
CaO	10.69	CaO	9.97
Na_2O	2.87	Na_2O	2.79
K_2O	1.43	K_2O	1.42
P_2O_5	0.67	P_2O_5	0.65

XENOLITHS

Exotic crystals of feldspar, pyroxene, amphibole, and olivine-pyroxene-spinel masses occur abundantly in the volcanic field; they are found as isolated crystals or within volcanic bombs associated with the older cinder and maar cones or as inclusions in basalt flows. Similar xenoliths are found at Kilbourne and Hunt's Holes. To date, only the olivine-pyroxene-spinel nodules represent a portion of the upper mantle derived by partial fusion — partial recrystallization — and brought to the surface during volcanic eruption (Carter, 1970).

The most abundant crystals are feldspar; they occur most commonly as loose crystals or as inclusions in bombs associated with the older cones. The crystals are anhedral to euhedral, white to colorless, and range from several millimeters to nearly 5 cm in diameter. They range in composition from anorthoclase to plagioclase (see Hoffer and Ortiz, this guidebook).

STRUCTURE

The Aden-Afton basalts to the east of the Potrillo's lie in a graben bounded on the west by the Robledo fault and on the east by the Fitzgerald fault. Alignment of depressions and craters within the field suggests that faulting was active during eruption of these lavas. The West Potrillo Mountains appear to represent a horst; the range is bounded on the east by the Fitzerald fault and on the west by an unnamed high-angle fault (Hoffer, 1976).

The structure of pre-Quaternary rocks in the area is complex. To the west and north of the mountains are fault block hills exposing sedimentary units ranging from lower Paleozoic to Cretaceous age and Tertiary flows, tuffs, and breccias. Most of these hills are surrounded and/or nearly buried by a cover of Recent blowsand or valley-fill deposits. The diversity of lithology and age of the rocks suggests a complexly faulted sequence beneath the cover of Quaternary basalt.

At the north end of the area are a series of fault block hills exposing Tertiary volcanic units which underly the Quaternary basalts. The blocks all dip to the southwest and the faults strike to the northwest. These faults align with structural trends in the Aden-Afton basalt field to the east. The Potrillo faults cut rocks of probably Tertiary age, but the volcanic units in these fault blocks show onlap by Quaternary volcanic materials. Therefore the age of the faulting is probably mid- to late-Tertiary.

Approximately 7 mi south of Mount Riley a north-striking fault cuts caliche and sediments of Quaternary to Recent age. The fault is upthrown on the east side and disappears to the north under the Quaternary basalts. A north-striking fault borders the western portion of the area. The fault, upthrown on the east, displays a prominent scarp near Indian Basin but northward the scarp decreases in elevation and at the north end of the area is unnoticeable.

In summary, the West Potrillo Mountain area displays two structural trends. First, the area appears to be a horst bounded on the east and west sides by two major north-striking faults. Movement along the north-striking faults has continued into the Recent as evidenced by displacement of Recent caliche layers. Second, a series of northwest-striking faults occur at the north end of the area; these faults are post-Tertiary.

REFERENCES CITED

Bersch, M., 1977, Petrography and geology of the southern West Potrillo Basalt Field, Dona Ana County, New Mexico: U.T. El Paso (M.S. Thesis), 89 p.

Carter, J.E., 1970, Mineralogy and chemistry of the earth's upper mantle based on partial fusion-partial crystallization model: Geol. Soc. Am., Bull. 81, p. 2021-2034.

Hoffer, J.M., 1976, Geology of the Potrillo Basalt Field, southcentral New Mexico: New Mex. Bur. Mines & Min. Res., Cir. 149, 30 p.

Page, R.O., 1973, Stratigraphiy of the Quaternary Malpais maar volcano, Dona Ana County, New Mexico: U.T. El Paso (M.S. Thesis), 46 p.

LARAMIDE STRUCTURES IN THE SNAKE HILLS, SOUTHWESTERN NEW MEXICO

by

L. L. Corbitt
Gulf Oil Corporation
Midland, Texas

F. L. Nials
Eastern New Mexico University
Portales, New Mexico

R. J. Varnell
Mineral Ventures, Inc.
Denver, Colorado

INTRODUCTION

The Snake Hills are in the Basin and Range Province in south-central Luna County, New Mexico about 10 mi southwest of Deming. The Snake Hills trend west-northwest across the southern part of T.24S., and the northern part of T.25S., R.10W. (Fig. 1). The ridge is about 3 1/12 mi long and exposes Ordovician El Paso and Montoya carbonates with higher knobs rising 100 to 250 ft above the surrounding alluvium plain.

The eastern portion of the Snake Hills consists of El Paso limestone dipping 5-30° to the southwest with the exception of the eastern-most knob which dips 30° to the north. The western fourth is characterized by complexly deformed Montoya Group. Complex tectonic slicing along saucer-shaped thrust faults diping 0- 30° to the south is present in the Upham and Aleman Formations with both repetition and elimination of strata. Also the contact between the El Paso and Montoya is a low-angle thrust fault. Yielding on the thrusts is northward toward the foreland.

Similar structures are present 15 mi to the southeast in the Florida Mountains (Corbitt, 1971) and 10 mi to the west in the Victoria Mountains where a thrust fault has brought Ordovician El Paso strata northward over Lower Cretaceous clastic rocks (Kottlowski in Griswold, 1961).

The thrust faults of the Snake Hills, Florida Mountains, and Victoria Mountains mark the northern erosional limit of the Laramide Cordilleran foldbelt of southwestern New Mexico (Corbitt and Woodward, 1970, 1973). The foldbelt trends west-northwest through the southwestern corner of New Mexico and is characterized mainly by low-angle thrust faults and subordinate closely compressed overturned folds. Yielding on the thrusts is north-northeastward toward the foreland with displacements as much as several miles.

STRATIGRAPHY

The Ordovician El Paso and Montoya Groups are the only strata exposed in the Snake Hills. The exact thickness of the formations cannot be determined because of the complex structure, however, the section appears to be very similar to the one exposed 15 mi to the southeast in the Florida Mountains (Corbitt, 1971).

Approximately 700 ft of the Lower Ordovician El Paso Group are exposed through Quaternary alluvium and overlain by the Upper Ordovician Montoya Group. The El Paso Group is a white-gray to blue-gray limestone with interbedded stromatolithic and sponge reefs, fossiliferous calcirudites with many lime-pellet and pebble beds, nodules and crinkled laminae of buff silt. The outcrop is characterized by a light blue-gray tint on weathering, pale reddish-brown elongate blotches on the bedding planes, and thin slabby bedding. The unit is recognized as a light-colored slope below the black-weathering cliff forming Upham Dolomite of the Montoya Groups. The El Paso Group has been highly silicified in the western part of the area (Fig. 1).

The El Paso Group is overlain by 75-100 ft of dark brown to black, coarse crystalline, crinoidal Upham Dolomite with a sandy unit at its base. The contact between the El Paso and Montoya Groups appears to be a low-angle thrust fault.

The Upham Dolomite is overlain by about 100 ft of the easily recognized Aleman Formation which is a prominent ridge former because of its high bedded chert content.

TECTONIC MAP OF SOUTHWESTERN NEW MEXICO

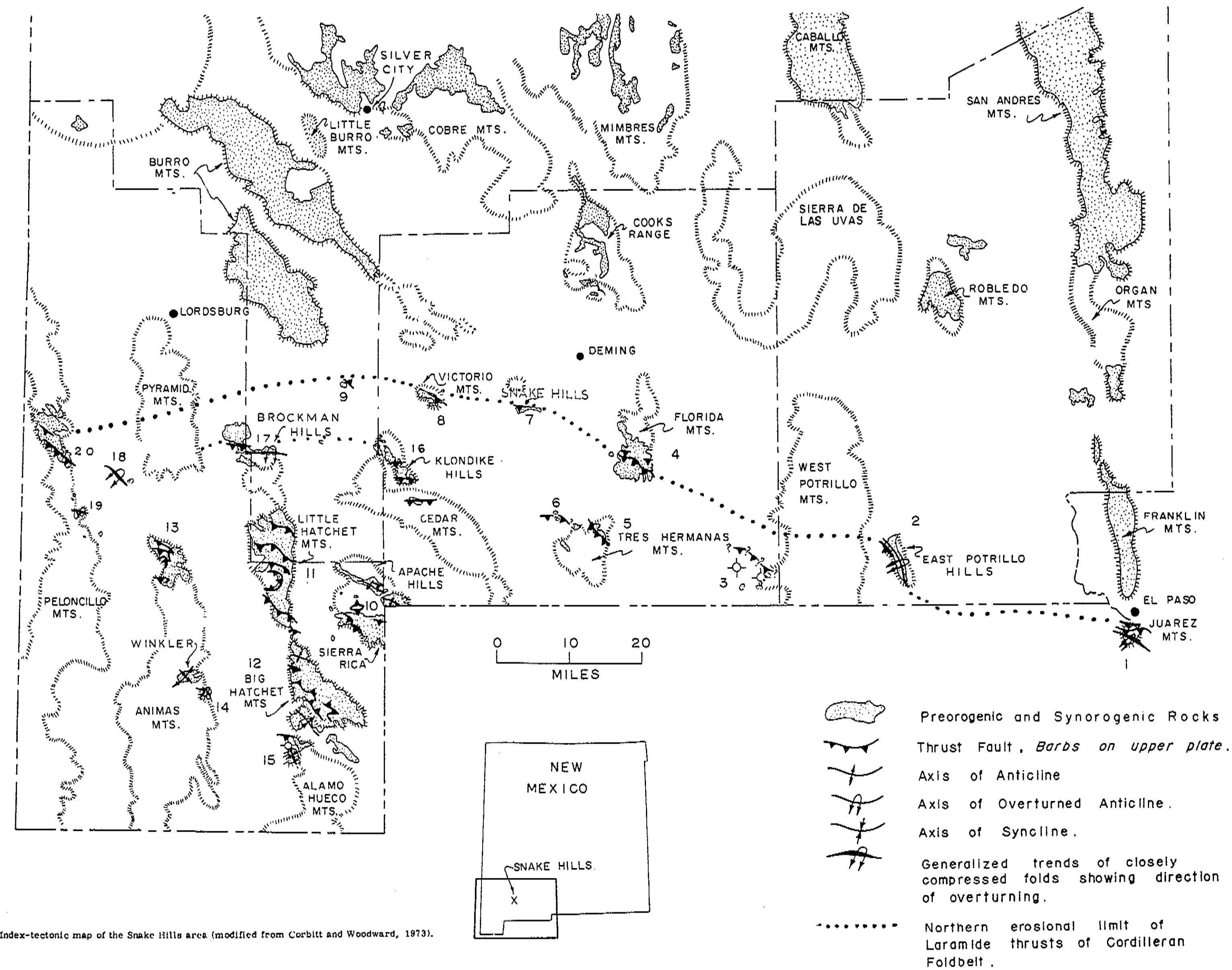


FIG. 1 -- Index-tectonic map of the Snake Hills area (modified from Corbitt and Woodward, 1973).

STRUCTURE

The Snake Hills are a west-northwest trending ridge of Ordovician carbonates. The eastern three-fourths consist of El Paso limstone dipping 5-30° to the southwest with the exception of the easternmost knob which dips 30° to the north.

In the western portion of the ridge complex tectonic slicing and tectonic mixing along thrust faults dipping 0-30° to the south are present. In the southeast part of Section 32 T.24S., R.10W., four saucer-shaped thrust slices repeat portions of the Montoya Group. There is also tectonic elimination of strata along the faults where the middle part of the Montoya group overlies the El paso Group and where the Upham Dolomite has been thrust over the Aleman Formation. Also the El Paso-Upham contact is a flat thrust fault where most of the displacement appears to have been localized in the sandy basal portion of the Upham Dolomite which has been considerably thickened. Complex tectonic mixing of several large blocks of the cherty Aleman Formation are the lower part of the Upham Dolomite near the El Paso-Upham contact apparently indicates that the Upham Dolomite has completely overridden the Aleman Formation in this area.

Yielding along the thrusts was northward toward the foreland. The amount of displacement on the thrust cannot be determined accurately but appears to be at least a few thousand feet. These structures appear to be Laramide in age and mark the northern erosional limit of the Cordilleran foldbelt in southern New Mexico (Corbitt and Woodward, 1970, 1973).

Laramide thrust faults and folds exposed in the Cordilleran foldbelt of southwestern New Mexico show a consistent direction of yielding to the north-northeast toward the foreland with displacements up to several miles. Laramide structures in the nearby Brockman Hills and Klondike Hills (Fig. 1) have been described by Corbitt et al. (1977, 1978).

The Snake Hills structures are a well-exposed, key part of the Laramide Cordilleran foldbelt in southwestern New Mexico and illustrate the structural style of the foldbelt.

REFERENCES CITED

Corbitt, L.L., and Woodward, L.A., 1970, Thrust faults of the Florida Mountains, New Mexico and their regional tectonic significance: New Mex. Geol. Soc. Guidebook, 21st Field Conf., p. 69-75.

Corbitt, L.L., 1971, Structure and stratigraphy of the Florida Mountains, New Mexico: Ph.D. Dissertation, Univ. New Mexico, 115 p.

———, and Woodward, L.A., 1973, Tectonic framework of Cordilleran foldbelt of southwestern New Mexico: Amer. Assoc. Petrol. Geol., Bull., v. 57, p. 22-7-2216.

———, Nials, F.L., and Varnell, R.J., 1977, Structure of Brockman Hills, southwestern New Mexico: Amer. Assoc. Petrol. Geol., Bull., v. 61, p. 601-607.

———, Nials, F..L., and Varnell, R.J., 1978, Laramide thrust faulting Klondike Hills, southwestern New Mexico: New Mex. Geol. Soc. Guidebook, 29th Field Conf., p. 297-300.

Dane, C.H., Bachman, G.O., 1965, Geologic map of New Mexico: U.S. Geol. Survey.

Darton, N.H., 1916, Geology and underground water of Luna County, New Mexico: U.S. Geol. Sur. Bull. 681, 188 p.

———, 1917, Deming folio, New Mexico: U.S. Geol. Sur. Geol. Atlas, Folio 207.

Griswold, G.B., 1961, Mineral deposits of Luna County, New Mexico: New Mex. Bur. Mines & Min. Res. Bull. 72, 157 p.

A REGIONAL GRAVITY STUDY OF SOUTHWESTERN NEW MEXICO AND ADJACENT AREAS

by

J. O. Lance and G. R. Keller
Department of Geological Sciences
University of Texas at El Paso
El Paso, Texas 79968

INTRODUCTION

The region of southwestern New Mexico and southeastern Arizona (Fig. 1) poses many challenges to efforts to understand its tectonic history. Although the area lies principally in the southeastern Basin and Range Province, its tectonic history includes both Paleozoic and Mesozoic basin development, Laramide compressional deformation, and several episodes of plutonism and volcanism. Interpretation of the tectonic evolution of the region may be further complicated by the presence of the southern Rio Grande Rift (Seager and Morgan, 1979). Recent economic interest in the area is focused on the potential production of both petroleum (Thompson et al., 1978; Greenwood et al., 1977) and geothermal energy (Swanberg, 1979). The purpose of this paper is to present a brief discussion of the regional Bouguer gravity anomalies in the area and their relation with known geologic features.

GEOLOGIC AND TECTONIC OVERVIEW

Exposures of Precambrian rocks in far southwestern New Mexico are somewhat limited and consist mainly of granite with locally abundant metamorphic rocks (Woodward, 1970). There are no significant Precambrian outcrops in southeastern Arizona east of Douglas (Silver, 1978; Fig. 1), and the paucity of radiometric ages makes a regional interpretation of Precambrian events very tentative (Woodward, 1970). Also, no radiometric dates are available for Precambrian rocks encountered in deep exploration wells in southwestern New Mexico (Thompson et al., 1978).

During the Paleozoic, the area was dominated by the formation of the Pedragosa basin (Kottlowski, 1960). Greenwood et al. (1977) discuss the history of this basin (Fig. 2) in considerable detail. They present an isopach map for each major stratigraphic unit and compare source and reservoir quality with correlative units in the Permian Basin of southeastern New Mexico and West Texas. Thompson (1978) points out that the Upper Pennsylvanian-Lower Permian, Alamo-Hueco basin, as defined by Zeller (1965), lies within the Pedragosa Basin and is analagous to the deep-marine Delaware basin lying within the Permian Basin. The Paleozoic strata in the study area are usually of shallow-marine origin and thin generally towards the north (Greenwood et al., 1977).

While there are no Triassic rocks in the Pedragosa basin area (Greenwood et al., 1977), the middle Mesozoic was a time of major deposition in the Chihuahua trough (Deford, 1969). The northwestward marine transgression which followed during the Lower Cretaceous (Deford and Haengii, 1971) resulted in a northward thinning Lower Cretaceous section. Triassic and Jurassic plutonism and volcanism in southeastern Arizona are described by Hayes and Drewes (1968). However, Greenwood (1977) reports that igneous activity of this age has not been recognized in southwestern New Mexico.

Late Cretaceous-early Tertiary (Laramide) deformation in the Florida Mountains of New Mexico is described by Corbitt and Woodward (1970). Drewes (1978) presents evidence that the Cordilleran orogenic belt of North America is continuous from southern Nevada to beyond El Paso and his analysis implies that extensive Laramide compressional features are buried in the subsurface of the study area. Laramide intrusive rocks in the Pedragosa Basin region indicate that disturbed subsurface fluid systems may have altered hydrocarbon accumulation (Greenwood et al., 1977).

Cenozoic volcanism and block faulting are widespread in the study area. The dominant physiographic features are high-standing fault blocks composed of both sedimentary and volcanic rocks. Seager (1975) discusses the Cenozoic evolution of the Las Cruces area, and Deal et al. (1978) describe the Cenozoic volcanic geology of Hidalgo County, New Mexico. Cook et al. (1979) present a model for the Cenozoic evolution of the Rio Grande rift.

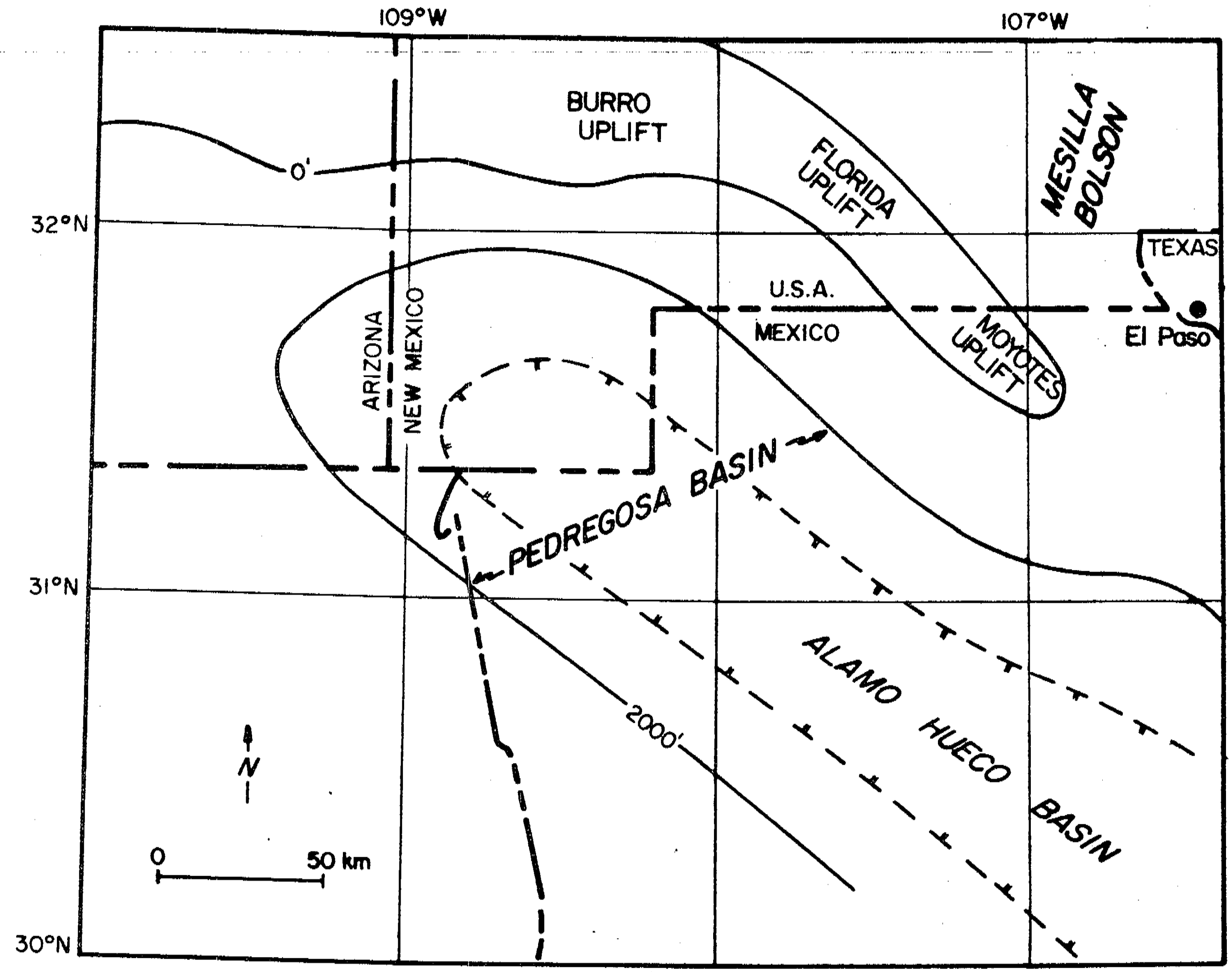


Fig.1 Pedregosa Basin, Southwest New Mexico and Northern Chihuahua

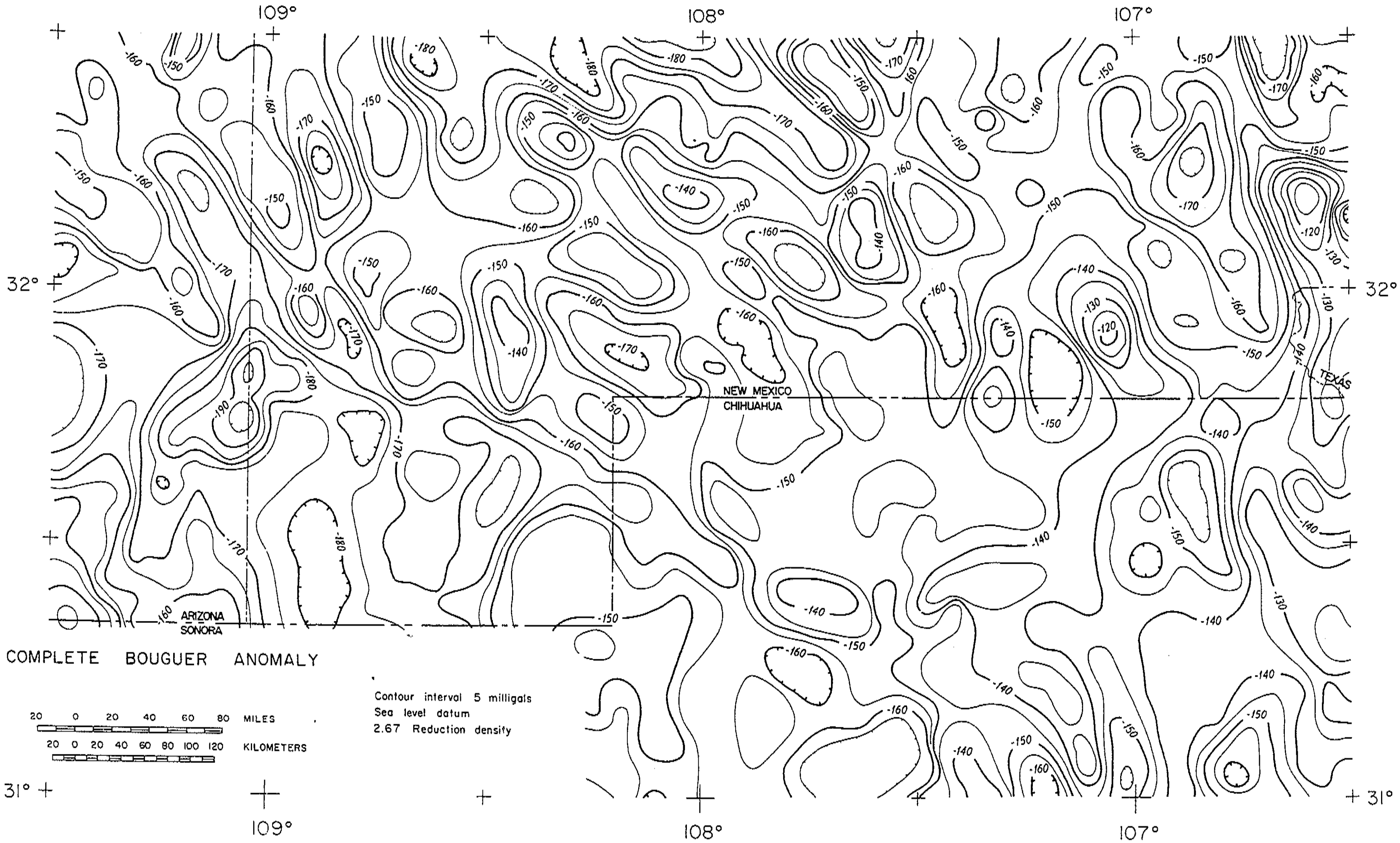


Fig. 2 Gravity map, Southwest New Mexico and Northern Chihuahua

Although there is no general agreement concerning the southern limit of the Rio Grande rift, many workers feel that the high heat flow, recent faulting (<0.4 m.y.), late Pliocene and younger volcanoes, and deep basins found in south-central New Mexico delineate the southern extension of the rift (Seager and Morgan, 1979, Fig. 1). In any event, the tectonic history of southwestern New Mexico and southeastern Arizona is intriguingly complex and further study should incorporate as many geophysical and geological methods as possible.

ANALYSIS OF REGIONAL GRAVITY DATA

The gravity map of Figure 3 represents complete Bouguer anomaly values computed for a sea level datum and reduction density of 2.67 gm/cc. These data were compiled from several sources (Ramberg et al., 1978; U.S. Geological Survey; New Mexico State University; and the University of Texas at El Paso) and have been adjusted to the IGSN71 base station network (Morelli, 1976). Terrain corrections were computed using the computer technique of Plouff (1977) and should provide a significant improvement over previous maps. The contours were drawn from grid values (2 km grid spacing) that were generated by the minimum curvature technique (Briggs, 1974) as programmed by Swain (1975).

The data are somewhat sparse in northern Chihuahua and the contours in that area show less detail than other portions of the map. However, in spite of this, a dominant northwest trend of anomalies is evident. Comparison of the western portion of the map with the physiographic features (Fig. 1) shows that topographic basins are marked by gravity lows and mountain ranges generally coincide with gravity highs. The San Simon Valley and Animas Valley are especially well defined by their gravity signature. These north-trending valleys intersect the strong northwest trend of gravity highs associated with the Burro-Florida uplift (Fig. 2). There is also a north-south grain to the anomaly patterns in the eastern portion of the map. It is possible that these trends reflect the Rio Grande rift and have been superimposed upon older Basin and Range trends (northwest). Further processing of the data (such as strike filtering) should provide more insight into this question.

Several other interesting features can be noticed on the eastern portion of Figure 3. The Potrillo volcanic field generally coincides with a gravity high. Directly west of the Potrillos, the surface geology would not predict the series of north-trending lows and high seen on the gravity map. These anomalies suggest a complicated block-faulted subsurface structure in this area.

The northeast corner of Figure 3 coincides with the Mesilla Bolson (Fig. 2). It trends north-northwest and coincides with several strong gravity lows. The faulting and subsurface structure of this area has received various interpretations (Uphoff, 1978) and the pattern of gravity lows suggests that the structure is more complicated than that of a single down-faulted block. The strong gravity high on the eastern edge of the map is probably related to an intrusive body. A more detailed study of the Mesilla Bolson is underway.

CONCLUSIONS

The regional Bouguer gravity anomaly map of southwestern New Mexico and southeastern Arizona correlates well with the major tectonic features of the area (Burro-Florida Uplift, Basin and Range structures, etc.). However, it also suggests the presence of other structural trends that are not yet well defined geologically. Future work will involve digital processing of these data to highlight the more subtle features and integration with surface and subsurface geology to produce computer-derived models.

ACKNOWLEDGEMENTS

The authors have greatly benefitted from discussions with Sam Thompson III. This work was partially supported by Union Texas Petroleum.

REFERENCES CITED

Cook, F.A., D.B. McCullar, E.R. Decker, and S.B. Smithson, 1979, Crustal structure and evolution of the southern Rio Grande rift; in Rio Grande Rift: Tectonics and Magmatism: Am. Geophys. Union, p. 195-208.

Corbitt, L.L., and L.A. Woodward, 1970, Thrust faults of Florida Mountains, New Mexico and their regional tectonic significance: New Mex. Geol. Soc. Guidebook, 21st Field Conf., p. 69-74.

Deal, E.G., W.E. Elston, E.E. Erb, S.L. Peterson, D.E. Reiter, P.E. Damon, and M. Shafiqullah, 1978, Cenozoic volcanic geology of the Basin and Range Province in Hidalgo County, southwestern New Mexico: New Mex. Geol. Soc. Guidebook, 29th Field Conf., p. 219-119.

DeFord, R.K., 1969, Some keys to the geology of northern Chihuahua: New Mex. Geol. Soc. Guidebook, 20th Field Conf., p. 61-65.

———, and W.G. Haeggni, 1971, Stratigraphic nomenclature of Cretaceous rocks in northeastern Chihuahua: West Tex. Geol. Soc. Pub. 71-59, p. 173-196.

Drewes, H., 1978, Cordilleran orogenic belt between Nevada and Chihuahua: Geol. Soc. Am. Bull., v. 89, p. 641-657.

Greenwood, E., F.E. Kottlowski, and S. Thompson, III, 1977, Petroleum potential and stratigraphy of Pedragosa basin: Comparison with Permian and Orogrande basins: Am. Assoc. Petrol. Geol. Bull., v. 61, p. 1448-1469.

Hayes, P.T., and H. Drewes, 1968, Mesozoic sedimentary and volcanic rocks of southeastern Arizona; in Southern Arizona: Ariz. Geol. Soc. Guidebook 3, p. 49-58.

Kottlowski, F.E., 1960, Summary of Pennsylvanian sections in southwestern New Mexico and southeastern Arizona: New Mex. Bur. Mines and Min. Res. Bull. 66, 187 p.

Morelli, C., 1976, Modern standards for gravity surveys: Geophysics, v. 41, p. 1051.

Plouff, D., 1977, Preliminary documentation for a Fortran program to compute gravity terrain corrections based on topography digitized on a geographic grid: U.S. Geol. Surv. Open-file Rpt. 77-535, 45 p.

Ramberg, I.B., F.A. Cook, and S.B. Smithson, 1978, Structure of the Rio Grande rift in southern New Mexico and west Texas based on gravity intepretation: Geol. Soc. Am. Bull., v. 89, p. 107-123.

Seager, W.R., 1975, Cenozoic tectonic evolution of the Las Cruces area, New Mexico: New Mex. Geol. Soc. Guidebook, 26th Field Conf., p. 241-250.

———, and X. Morgan, 1979, Rio Grande rift in southern New Mexico, West Texas, and northern Chihuahua; in Rio Grande Rift: Tectonics and Magmatism: Am. Geophys. Union, p. 87-106.

Silver, L.T.,(1978, Precambrian formation and Precambrian history in Cochise County, southeastern Arizona: New Mex. Geol. Soc. Guidebook, 29th Field Conf., p. 157-163.

Swain, C.J., 1976, A Fortran IV program for interpolating irregularly spaced data using the difference equations for minimum curvature: Computers and Geosciences, v. 1, p. 231-240.

Swanberg, C.A., 1979, Chemistry of thermal and nonthermal groundwaters in the Rio Grande rift and adjacent tectonics provinces; in Rio Grande Rift: Tectonics and Magmatism: Am. Geophys. Union, p. 279-288.

Thompson, S., III, J.C. Tovar R., and J.N. Conley, 1978, Oil and gas exploration wells in the Pedragosa basin: New Mexico Geol. Soc. Guidebook, 29th Field Conf., p. 331-342.

Uphoff, T.L., 1978, Subsurface stratigraphy and structure of the Mesilla and Hueco bolsons, El Paso region, Texas and New Mexico: Masters Thesis, Univ. Texas, El Paso, 66 p.

Woodward, L.A., 1970, Precambrian rocks of southwestern New Mexico: New Mex. Geol. Soc. Guidebook, 21st Field Conf., p. 27-31.

Zeller, R.A., Jr., 1965, Stratigraphy of the Big Hatchet Mountains area, New Mexico: New Mex. Bur. Mines & Min. Res. Mem. 16, 128 p.

GEOPHYSICAL/GEOTHERMAL STUDIES IN THE SOUTHEASTERN MIMBRES BASIN NEAR THE CITY OF THE COLUMBUS, SOUTHERN RIO GRANDE RIFT, NEW MEXICO

by

Chandler A. Swanberg, Robert Sanders and Peter R. Marvin
Departments of Geology and Physics
New Mexico State University
Las Cruces, New Mexico 88003

Charles T. Young,
Geology and Geological Engineering Department
Michigan Technological Institute
Houghton, Michigan

Paul Daggett
Department of Geological Sciences
University of Texas at El Paso
El Paso, Texas 79968

Paul Morgan
Lunar and Planetary Institute
3303 NASA Road One
Houston, Texas

INTRODUCTION

The study area consists of approximately 2000 km^2 (750 mi^2) centered on the southeastern Mimbres Basin, New Mexico. The area extends east along the international boundary with Mexico from the city of Columbus, to the West Potrillo Mountains (Fig. 1). The geology of the area is summarized by Woodward et al. (1978) who show the basin to contain a thick sequence of synorogenic sedimentary deposits of Miocene to Holocene age. The basin is bounded on the east by a major Quaternary fault which also bounds the northern part of the Los Muertos Basin of Chihuahua, Mexico. Woodward et al. (1978) show the west margin of the basin to be an inferred fault which extends south from the east flank of the Florida Mountains into the study area. Gravity profiling confirms the existence of this fault in the Columbus area. The city of Columbus itself lies on the alluvium covering the upthrown block a few kilometers west of the southeastern Mimbres Basin.

There are several geological data sets which imply that the southeastern Mimbres basin may be favorable for geothermal exploration: 1) the basin itself is part of the Rio Grande Rift, a north-south trending feature which is characterized by Quaternary tectonics and volcanics, deep sedimentary basins, high heat flow (Swanberg, 1978), numerous hot springs, and enhanced geothermal potential (Seager and Morgan, 1979); 2) several of the groundwaters in the area have chemical characteristics which imply that they might have originated within the active geothermal system (Swanberg, 1978); and 3) finally, although hot springs are not observed in the southeastern Mimbres Basin, Swanberg et al. (1981) have reported hot spring activity on the Mexican side of the border near the southern end of the Los Muertos Basin. The above geological data coupled with an increasing demand for geothermal energy associated with the development of the Columbus International Industrial Park, prompted the present study.

GRAVITY AND MAGNETIC SURVEYS

The initial geophysical data collected in the Columbus area were profiles of gravity and magnetic data. The gravity data were collected with a LaCoste Romberg gravimeter and reduced to simple Bouguer anomalies by traditional techniques. The magnetic data were recorded with a proton precession magnetometer which reads directly the total magnetic field. These profiles were run along the roads shown in Figure 1. The purpose of these profiles was to determine the location of the major faults in the area in order to more precisely design the more detailed electrical and heat flow surveys. An interpretation of the gravity and magnetic data is shown in Figure 1. The gravity data confirms the presence of the fault which forms the west margin of the southeastern Mimbres Basin. The precise location of this fault, which is buried beneath the alluvium, had not been previously determined. The location of the east boundary fault is evident from surface geology as well as from the gravity data. The magnetic data reveal a very uniform magnetic field over the basin itself (i.e., variations generally less than 100 γ) but a very erratic field outside the basin with variations up to 800 γ) occurring over a few kilometers or less. This pattern is most easily explained by assuming that high susceptibility rocks (presumably basalt) are much nearer the surface outside the basin. Implicit in this interpretation is that shallow volcanics may be present underneath the alluvium in the immediate vicinity of Columbus, a feature which has been verified by the drilling of the 296-m heat flow test well.

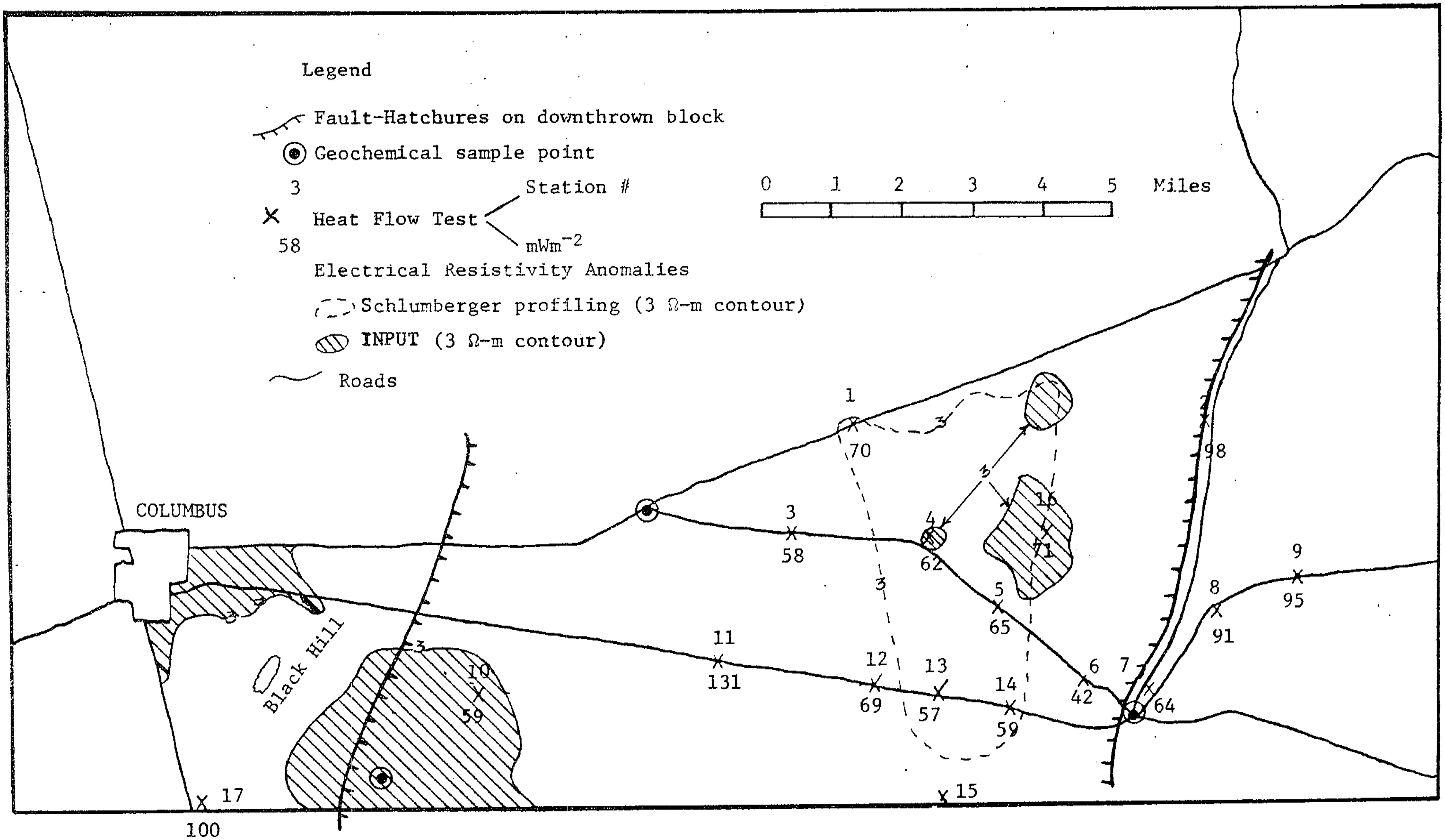


Fig. 1. Location map showing sites of gravity, magnetic and heat flow data

SURFACE RESISTIVITY SURVEY

The surface electrical resistivity study has consisted of 45 km (28 mi) of profiling using a Schlumberger configuration with an electrode spacing of both AB/2 = 100 and 800 m. The profiling was conducted along the same roads as the gravity and magnetic surveys. This electric survey has delineated a zone of low apparent resistivity (< 3 Ωm) located near the east margin of the southeastern Mimbres Basin (Fig. 1). There are several possible explanations for this resistivity anomaly including increased temperature and/or salinity of the groundwater, increased porosity, additional quantitities of clay, or some combination of these and other factors. However, a lack of an obvious temperature gradient anomaly associated with the resistivity low (following sections) seems to preclude the possibility of a geothermal origin.

INDUCED PULSE TRANSIENT (INPUT) AIRBORNE ELECTRICAL SURVEY

The INPUT survey is a less conventional type survey than the preceding surveys and therefore requires a more detailed explanation of its application and limitations. The basic system consists of a large loop of wire strung in a triangle along the aircraft wings and from the wing tips to the tail, and an induction coil towed behind the aircraft on a 500-foot cable. Discontinuous current pulses in the loop create a magnetic field which induces eddy currents in the ground. The magnetic field from the eddy currents is detected by the induction coil during the "off-time" of the discontinuous current pulse. Since the eddy currents are stronger for more conductive earth material, this method provides a method for airborne mapping of the ground conductivity.

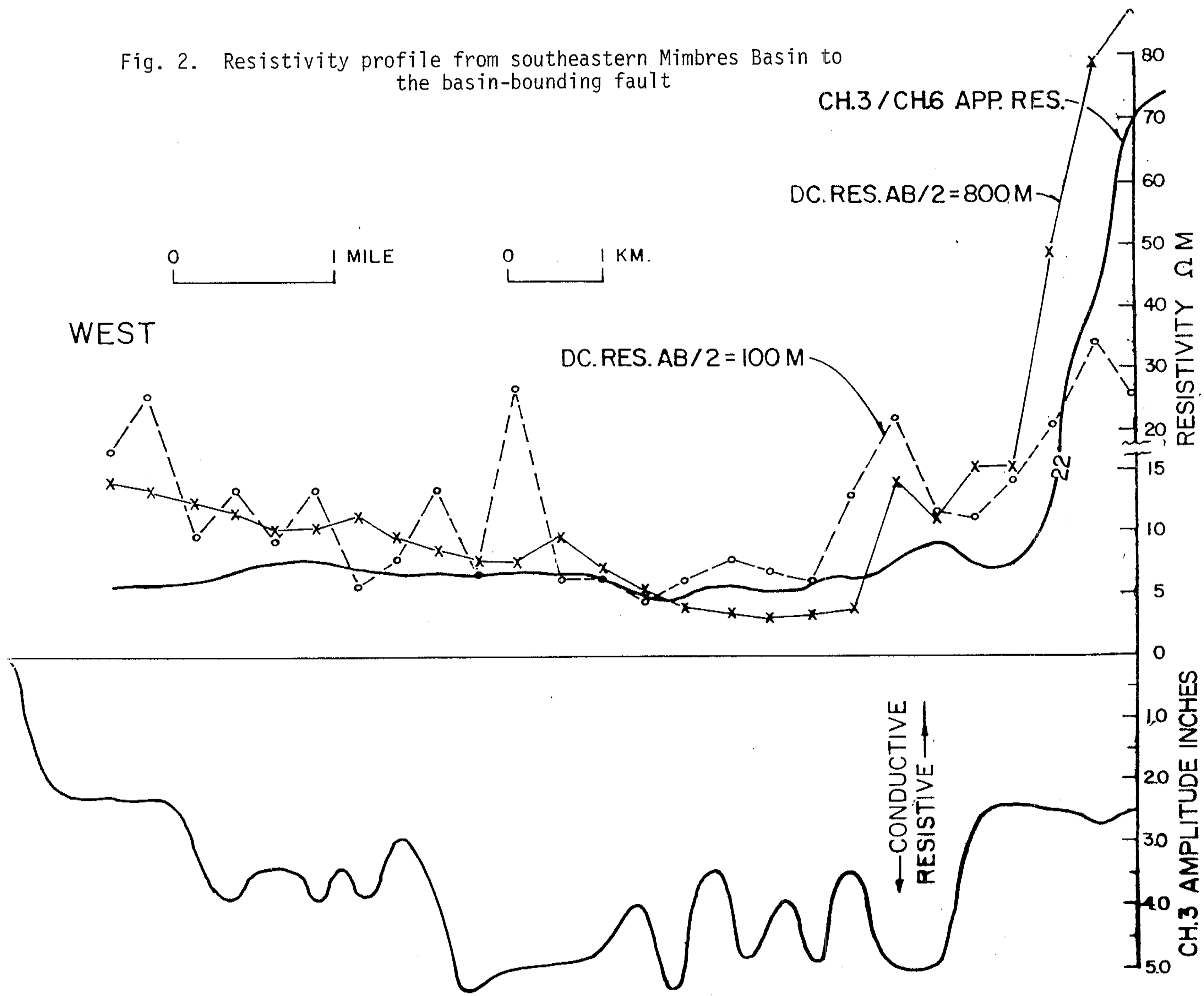
The electromagnetic data is recorded in analogue fashion in six separate channels, each of which represent a different time lag since the cessation of the current pulse. The higher numbered channels (longer delay time) represent deeper penetration. For a normal flight line altitude of 120 m, effective depth penetrations of about 120 m are obtained. For the present survey, this penetration depth is approximately 2 to 3 times the depth to the water table.

A significant limitation of the INPUT technique is that the received signals are strongly dependent upon the altitude. Depending upon ground conductivity, the signals decrease according to the fourth to sixth power of altitude. Thus a slight variation in altitude can cause a significant error in the received signals and therefore, a significant error in the ground conductivity. To reduce this problem, channel ratios (Ch3/Ch6) have been used in the quantitative interpretations. Figure 2 shows the apparent resistivity along a profile extending east from the center of the southeastern Mimbres Basin to a point just east of the basin-bounding fault. Shown are resistivities as calculated by the Schlumberger profiling (AB/2 = 100 m and 800 m) and by the INPUT (Ch3/Ch6) technique. The excellent agreement between these independently calculated resistivities shows that reliable ground resistivities can be obtained by the INPUT technique. Also shown in Figure 2 is the channel 3 signal as measured in inches on the analog chart recording. The channel 3 data imply that highly resistive rocks are present in the western part of the profile. This erroneous interpretation exemplifies the problem discussed above and emphasizes the need to interpret channel ratios rather than the signal amplitudes themselves.

The area covered by the INPUT survey is shown in Figure 1. Detailed coverage has been obtained over the area under investigation for geothermal evaluation with flight lines spaced one-half mile apart. In addition, two lines were extended 40 km to the east of the detailed area in order to tie into the surface resistivity data of Jackson and Bisdorf (1975). Two lines were also extended 17 km to the west of the detailed area in order to complete the regional picture.

Figure 1 shows the areas of low resistivity as determined by the input (Ch3/Ch6) technique described above. The resistivity low near the east margin of the southeastern Mimbres Basin which had been depicted on the basis of surface resistivity is also obvious from the INPUT data. In addition, a second resistivity low (or two lows separated by a topographic feature known as Black Hill) is also apparent from the INPUT data. The significance of this anomaly cannot be determined due to the possibility of interference from power lines and other cultural activity near the city of Columbus.

Fig. 2. Resistivity profile from southeastern Mimbres Basin to the basin-bounding fault



SHALLOW HEAT FLOW SURVEY

Seventeen shallow (35 m) heat flow test holes have been drilled in the study area. The locations of the holes and their respective heat flow values are given in Figure 2. The temperature gradients were obtained by making discrete temperature measurements (± 0.01°C) at 5 m intervals and applying the method of least squares to the most stable portion of the hole. Conductivity measurements were made with a standard divided bar apparatus using a cylindrical cell containing the rock fragments (Sass et al., 1971). A porosity value of 40% has been assumed for these shallow alluvial sedimens.

The heat flow tests were positioned in such a way as to obtain data both inside and adjacent to the southeastern Mimbres Basin. Also, the holes were positioned so as to determine heat flow within and adjacent to the electrical resistivity anomalies described above. The average geothermal gradient is high (52.5 ± 17.1°C/km). However, the conductivity of these air-filled alluvial sediments is low, averaging only 1.4 ± 0.11 W/m°C. Therefore, the average heat flow over the study area is 75 mW m^{-2} (1.8 HFU). One obvious feature of the heat flow distribution is that the heat flow is higher on the upthrown sides of the two faults, an occurrence which we attribute to thermal refraction. Heat flow values in the basin typically fall in the range 55-70 mW m^{-2} (1.3-1.7 HFU). These values are lower than normally found in the Rio Grande Rift and these low values may reflect thermal refraction, convective disturbances at depth, or the general difficulty in getting reliable heat flow values from such shallow holes. None of the heat flow holes located inside the resistivity anomalies show elevated heat flow. Therefore, we conclude that the resistivity anomalies are related to geological factors (i.e., increased groundwater salinity) rather than geothermal activity. The two highest heat flow values are 100 and 131 mW m^{-2} for holes 17 and 11, respectively. Since hole 17 is located at the Columbus International Industrial Park and therefore closest to potential users of geothermal energy, this site was selected for the 296 m temperature test.

DEEP GRADIENT TEST

During late September and early October, 1980, a 296 m temperature test well was drilled at location 17 (Fig. 1) and encountered a maximum bottom hole temperature of 33.4°C. The hole generally penetrated alluvial strata of sand, clay, and gravel although at least two basalt flows were encountered at depths of 81 and 244 m. Both basalts were underlain by highly permeable zones resulted in lost circulation during drilling. The temperature data from this well is given in Table 1. The quasi-equilibrium temperature gradient over the depth interval 135-296 m is 49.08 ± 0.22°C/km, a value which is high, even for the Rio Grande Rift. If this gradient is maintained for another 300 m, then temperatures in the range of 45-50°C should be encountered. Such temperatures would be sufficient for low temperature geothermal applications such as space heating provided that suitable aquifers are present.

ACKNOWLEDGEMENTS

V. Harder made the thermal conductivity measurements and J. Gilkey prepared the figures. Geoterrex Ltd. flew the airborne electrical survey. INPUT is a registered trademark of Geoterrex Ltd.

REFERENCES CITED

Jackson, D.B., and R.J. Bisdorf, 1975, Direct-current soundings on the La Mesa surface near Kilbourne and Hunt's Holes, New Mexico: New Mex. Geol. Soc. Guidebook, 26th Field Conf., p. 273-275.

Sass, J.H., Lachenbruch, A.H., and Munroe, R.J., 1971, Thermal conductivity of rocks from measurements on fragments and its application to heat flow determinations: Jour. Geophys. Res., v. 76, p. 2391-3401.

Seager, W.R., and P. Morgan, 1979, Rio Grande Rift in southern New Mexico, west Texas, and northern Chihuahua, In Rio Grande Rift: Tectonics and Magmatism: Am. Geophys. Union, p. 87-106.

Swanberg, C.A., 1978, Chemistry, origin and potential of geothermal resources in southwestern New Mexico and southeastern Arizona: New Mex. Geol. Soc. Guidebook, 29th Field Conf., p. 349-351.

———, L.S. Salazar, and G.M. Garcia, 1981, Preliminary report on the hot springs of the State of Chihuahua, Mexico: Geol. Soc. Am., Cordilleran Sec., Abst. with Programs, in press.

Woodward, L.A., J.F. Callender, W.R. Seager, C.E. Chapin, J.C. Gries, W.L. Shaffter, and R.E. Zilinski, 1978, Sheet 2 -- Tectonic map of Rio Grande Rift region in New Mexico, Chihuahua, and Texas; in Guidebook to Rio Grande Rift in New Mexico and Colorado: New Mex. Bur. Mines & Min. Res., Circ. 163, Scale 1:1,000,000.

TABLE I

Test Hole #18, Columbus, NM
10/20/80

Depth m	Temp.	Depth m	Temp.
5	22.40	155	26.44
10	21.13	160	26.72
15	21.27	165	26.99
20	21.32	170	27.25
25	21.78	175	27.53
30	22.02	180	27.78
35	22.35	185	28.06
40	22.76	190	28.32
45	23.21	195	28.57
50	23.63	200	28.84
55	23.80	205	29.07
60	23.99	210	29.28
65	24.07	215	29.53
70	24.15	220	29.74
75	24.23	225	29.96
80	24.73	230	30.20
85	24.43	235	30.47
90	24.27	240	30.69
95	25.26	245	30.99
100	24.52	250	31.24
105	24.66	255	31.47
110	24.74	260	31.67
115	24.75	265	31.88
120	24.88	270	32.10
125	25.05	275	32.32
130	25.26	280	32.58
135	25.49	285	32.85
140	25.70	290	33.09
145	25.93	295	33.39
150	26.18	296	33.40