New Mexico Geological Society

Downloaded from: https://nmgs.nmt.edu/publications/guidebooks/31



Geochronology of the Trans-Pecos Texas volcanic field

John Andrew Wilson 1980, pp. 205-211. https://doi.org/10.56577/FFC-31.205

in:

Trans Pecos Region (West Texas), Dickerson, P. W.; Hoffer, J. M.; Callender, J. F.; [eds.], New Mexico Geological Society 31st Annual Fall Field Conference Guidebook, 308 p. https://doi.org/10.56577/FFC-31

This is one of many related papers that were included in the 1980 NMGS Fall Field Conference Guidebook.

Annual NMGS Fall Field Conference Guidebooks

Every fall since 1950, the New Mexico Geological Society (NMGS) has held an annual Fall Field Conference that explores some region of New Mexico (or surrounding states). Always well attended, these conferences provide a guidebook to participants. Besides detailed road logs, the guidebooks contain many well written, edited, and peer-reviewed geoscience papers. These books have set the national standard for geologic guidebooks and are an essential geologic reference for anyone working in or around New Mexico.

Free Downloads

NMGS has decided to make peer-reviewed papers from our Fall Field Conference guidebooks available for free download. This is in keeping with our mission of promoting interest, research, and cooperation regarding geology in New Mexico. However, guidebook sales represent a significant proportion of our operating budget. Therefore, only *research papers* are available for download. *Road logs, mini-papers*, and other selected content are available only in print for recent guidebooks.

Copyright Information

Publications of the New Mexico Geological Society, printed and electronic, are protected by the copyright laws of the United States. No material from the NMGS website, or printed and electronic publications, may be reprinted or redistributed without NMGS permission. Contact us for permission to reprint portions of any of our publications.

One printed copy of any materials from the NMGS website or our print and electronic publications may be made for individual use without our permission. Teachers and students may make unlimited copies for educational use. Any other use of these materials requires explicit permission.



GEOCHRONOLOGY OF THE TRANS-PECOS TEXAS VOLCANIC FIELD

JOHN ANDREW WILSON
Department of Geological Sciences
and
Texas Memorial Museum
University of Texas at Austin
Austin, Texas 78712

INTRODUCTION

The occurrence of interbedded fossiliferous volcaniclastic sediments and potassium-argon datable rocks makes the Trans-Pecos volcanic field doubly valuable for geochronology. The superposition of vertebrate fossil faunas and volcanic flow rocks has furnished a correlation of the classical biochronological scale and the radiochronological scale. The span of time when both scales interdigitate stretches from about 45 to 20 million years before present or from middle Eocene to Miocene in the Big Bend area of Texas. Older and younger vertebrate faunas are known in West Texas but they predate or postdate the volcanic activity.

The Trans-Pecos volcanic field lies to the east, southeast, and south of Van Horn, Texas (fig. 1). It is the easternmost and southernmost Tertiary volcanic field in the continental United States. It covers an area of approximately 16,190 sq. km. in Texas, and the volcanic rocks extend southward into Mexico. For the last thirty years the area has been intermittently studied by geologists interested in extracting oil from beneath the volcanics, by those

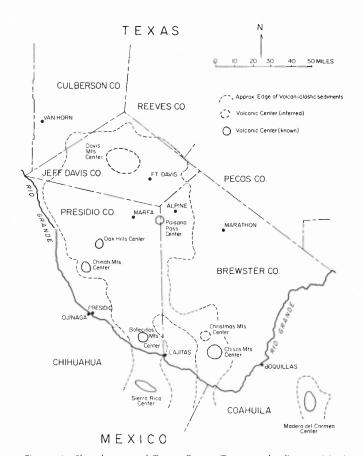


Figure 1. Sketch map of Trans-Pecos Texas and adjacent Mexico showing extent of widespread igneous volcaniclastic rocks, and known and inferred volcanic centers. Modified from Gorski (1970).

searching for minerals, radioactive or other, and lately by those testing for a source of geothermal energy. So far, none of their efforts have turned up commercial quantities of any of these. Over the same span of time, a probably greater number of students of geology have studied parts of the area with more academic goals in mind. Much of the work of the latter group is scattered in theses and dissertations at several universities or in shorter articles on a single quadrangle or on the results of a particular research project. The Geology of Big Bend National Park, Texas, by Maxwell and others (1967) is a comprehensive study but it covers only the Park. The Guidebook to the Geology of the Big Bend Area by Maxwell and Dietrich (1965) described the areal geology south of U.S. 90 but did not include the Vieja area or the northern Davis Mountains. The papers presented at a symposium on the Cenozoic Geology of the Trans-Pecos Volcanic Field in Texas (Walton and Henry, eds., 1979), were devoted to a wide variety of studies: geochemistry, geophysics, radiometric dating, volcaniclastic sediments, and sedimentary diagenesis. These studies are continuing and, one hopes, will eventually be incorporated in a synthesis of the volcanic field as a whole. This contribution is intended as an update for my particular field of study, which deals with the biostratigraphy of the volcaniclastic sediments and their local and regional correlation.

Moderately large collections of vertebrate fossils have been recovered from volcaniclastic sediments in six separate areas (fig. 2) on the periphery of the Trans-Pecos volcanic field. The collec-

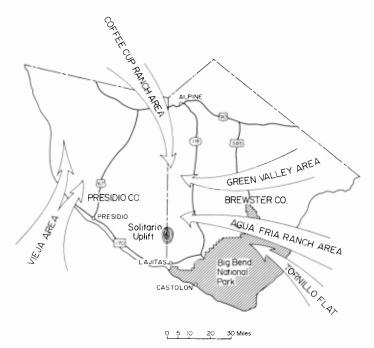


Figure 2. Sketch map of Trans-Pecos Texas showing location of major vertebrate fossil collecting areas.

tions have come from sediments that span the period from middle Pleistocene to early Miocene (Table 1). The rocks from the lower part of the section, middle Paleocene to middle Eocene, are entirely sedimentary and the only volcanic elements included are from a remote source. Local volcanism within the area began slightly earlier in the southern part of the field. The oldest vertebrate fauna associated with locally derived volcaniclastic rocks is early late Eocene, whereas to the north in the Vieja area the earliest fauna is late late Eocene. In the northeastern Davis Mountains and also in the northwestern part of the field in the Van Horn Mountains, the oldest tuffs contain early Oligocene vertebrate fossils. No vertebrate fauna younger than early Oligocene is known at present that is overlain by volcanic flow rock. Those fossils that have been found in the uppermost part of the section that might be late Oligocene are not identifiable, but that part of the section has not been thoroughly searched. An early Miocene fauna has been found in grabens along the Rio Grande near the village of Castolon in Big Bend National Park. A similar fauna, as yet unstudied, was found by Margaret Stevens of Lamar University, up the Rio Grande from Lajitas in rocks mapped by McKnight (1970) as the uppermost part of the Rawls Formation. The early Miocene rocks are intruded by dikes but not overlain by flow rock. The beginning and last phases of local volcanism in the Trans-Pecos volcanic field can be precisely dated with vertebrate faunas and the peak of volcanic activity was in the Oligocene.

CENTERS OF VOLCANIC ACTIVITY

There were several centers of volcanic eruption (fig. 1), three of which have been recently studied. Parker (1979) worked on the Paisano Pass center, Cepeda (1979) on the Chinati Mountains caldera, and Ogley (1979) on the Pine Canyon caldera in the Chisos Mountains. Earlier works that covered areas that include volcanic centers were those of Anderson (1968) for the northern Davis Mountains and McKnight (1968, 1969) for the Bofecillos Mountains. Parker (1979) gave a date of 35 m.y. for the major activity of the Paisano Pass center. His data were based on "four K-Ar alkali feldspar ages of rhyolitic tuff and a trachytic dike from the Paisano volcano . . . (McDowell, unpublished data)" (Parker, 1979, p. 100).

The Chinati Mountain center was studied by Cepeda. The age of units within the Chinati Group cluster around 31 to 32 m.y. (Cepeda, 1979). Because these dates agree so closely with ages of the Mitchell Mesa Ignimbrite (=Brite Ignimbrite) he believed its

source was the Chinati Mountain caldera. The Mitchell Mesa is the most widespread igneous unit so far recognized in the volcanic field, and covers an area of approximately 8,029 sq. km. (Burt, 1970). From the dates presented by Parker (1979) and Cepeda (1979), the Paisano Pass center was active earlier than was the Chinati Mountains center.

The southernmost center within Texas was in the Chisos Mountains in Big Bend National Park. This was one of the first areas to be studied (Udden, 1907). The report by Lonsdale and Maxwell in Maxwell and others (1967) was concerned primarily with the areal distribution of the igneous rocks and their chemical and petrographic analysis. The potassium-argon dates given for various igneous flow rocks within the Park (Maxwell and others, 1967) do not agree entirely with superposition as shown by the local stratigraphic section.

Seven columnar sections are presented in Figure 3. Sections 1 through 3 are from the north-central, the east-central, and the south-central portions of the volcanic field and form a line roughly from north to south, east of the Paisano Pass volcanic center. Sections 4 through 7 lie to the west and south. The Sierra Vieja is north of the Chinati Mountain volcanic center and west of the Paisano Pass center, The Bofecillos Mountains center is a southern volcanic center that can be tied to the northern sections by the Mitchell Mesa Rhyolite. The Bofecillos Mountains section, in turn, can be tied to the Chisos Mountains section in Big Bend National Park. The seventh section in Figure 5 is from Tornillo Flat where the oldest part of the Tertiary is exposed. Sediments here are comparable in age to those in the San Juan Basin, New Mexico.

STRATIGRAPHIC OCCURRENCE OF VERTEBRATE FOSSIL FAUNAS AND POTASSIUM-ARGON DATED SAMPLES

Correlation charts are based on information available at a particular time and, as a result, change over the years as new rock samples are dated or new fossils found. The one I present here is slightly different from my previous one (Wilson, 1977b). One change is based on the identification of a rhinoceros lower jaw from the upper part of the Pruett Formation, near its type section, as early Oligocene (fig. 4, col. 2). In addition, the recent publications of McDowell (1979), Gilliland and Clark (1979), Dailey (1979), Cepeda (1979), and Parker (1979) have furnished potassium-argon dates for additional points on the radiometric time scale. The present status of the combined scales is summarized in Figures 4, 5.

Table 1. Distribution of fossil vertebrate faunas and bibliographic references.

Early Miocene	FVM	Arikareean (Stevens and others, 1969; Stevens, 1977).
Early Oligocene	FV02	Chadronian. Airstrip local fauna (Wilson, 1977 a, b).
	FV01	Early Chadronian. Porvenir, Little Egypt, and Rancho Gaitan local faunas (Wilson, 1977 a, b).
?Oligocene	FVO?	Skyline local fauna. First appearance of Hyaenodon cf. vetus. Present: Simidectes magnus, Mahgarita stevensi, Amynodontopsis bodei, Protoreodon pumilus (Wilson and Szalay, 1976; Gustafson, 1979; Wilson and Schiebout, in press).
Late Eocene	FVE4	Late Uintan. Candelaria local fauna (Wilson, 1977 a, b), and localities "Purple Bench," "Titanothere hill," "Serendipity" in Agua Fria area (Wilson and Schiebout, in press).
	FVE3	Early Uintan. Whistler Squat local fauna (Wood, 1973; Wilson, 1974, 1977 a, b).
Middle Eocene	FVE2	Bridgerian (Wilson, in Maxwell and others, 1967).
Early Eocene	FVE1	Wasatchian (Wilson, in Maxwell and others, 1967).
Middle Paleocene -Late Paleocene	FVP	?Torrejonian to Tiffanian (Wilson, in Maxwell and others, 1967; Schiebout, 1974).

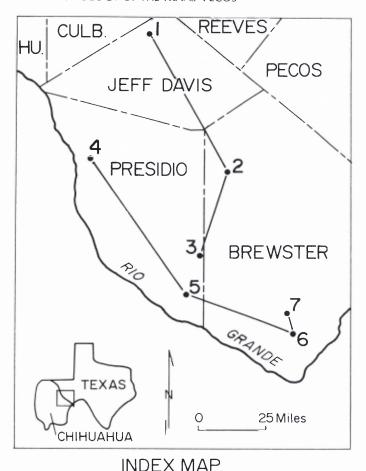


Figure 3. Index map to stratigraphic sections in figures 4 and 5.

Sierra Vieja Area

The first area in Texas in which vertebrate fossils and potassium-argon dated samples were associated was in the Sierra Vieja. The stratigraphic section (fig. 5, col. 4) was described by DeFord (1958) and the potassium-argon dates for samples taken from the volcanic flow rocks were first published in Wilson and others (1968) along with preliminary identification of the faunas. A much fuller analysis of five vertebrate fossil faunas, four of which can be shown in superposition, was listed in Wilson (1977b).

The oldest fauna (Wilson, 1977b) is from the Colmena Tuff and was identified as late Eocene (FVE4, fig. 5, col. 4). The Colmena Tuff is underlain by the Gill Breccia. An igneous boulder from the Gill Breccia was dated at 40.0 m.y. Overlying the Colmena Tuff is the Buckshot Ignimbrite. Four dates have been made on samples from the Buckshot: 38.6, 35.2, 36.2, and 36.4 m.y. Above the Buckshot is the Chambers Tuff from which has come the very extensive early Oligocene or Chadronian fauna (FV01) listed in Wilson (1977a, b). The Chambers Tuff is overlain by the Bracks Rhyolite, dated as 36.5 and 36.8 m.y.

The dates on the Bracks Rhyolite are supported by the dates from the northern Davis Mountains (fig. 4, col. 1) and from the Buck Hill Group (fig. 4, col. 2), all of which overlie elements of FV01, the earliest Oligocene vertebrate fauna. This, in turn, makes 38.6 m.y. the most reasonable of the available dates for the Buckshot Ignimbrite.

The youngest fauna is from the Capote Mountain Tuff (FV02, fig. 5, col. 4). The Capote Mountain Tuff is topped by the Brite Ignim-

brite, which equals the Mitchell Mesa Rhyolite. Extensive effort has been made to accurately date the Mitchell Mesa because it is the most widespread lithologic unit in the volcanic field. According to McDowell a total of 18 dates averages 31.5 m.y.

Agua Fria Area

The Agua Fria area lies between the Paisano Pass volcanic center on the north and the Bofecillos Mountains center on the south. It consists of a thick section of volcaniclastic sediments (fig. 4, col. 1) capped by the Mitchell Mesa Rhyolite. The volcanic flow rocks used by Goldich and Elms (1949) to subdivide the Buck Hill Group (fig. 4, col. 3) do not extend as far south as the Agua Fria area. Nonetheless a succession of vertebrate fossil faunas in superposition have been found in association with tuffs that have been dated.

Large vertebrate faunas have been collected from the Agua Fria area. They comprise insectivores, rodents, primates, carnivores, perissodactyls, and artiodactyls. The rodents have been described by Wood (1973), some of the artiodactyls by Wilson (1974), perissodactyls by Wilson (1977a), carnivores by Gustafson (1977, 1979), amynodonts by Wilson and Schiebout (in press) and the insectivores and primates by West (in progress). The fossiliferous stratigraphic section in the Agua Fria area begins in the middle part of the Eocene. It was originally thought that the vertebrates from the Agua Fria area were all part of a single contemporaneous fauna (Wood, 1973; Wilson, 1974, 1977a) named the Whistler Squat local fauna. Further collecting and an analysis of the micromammal fauna in particular has shown that it may be possible to identify three age levels. The oldest, but least certain, is middle Eocene to Bridgerian, above which is an early late Eocene or Wagonhound level. These are represented as FVE3 in Figure 4. Column 3. A fauna from a still higher level, FVE4, is late Eocene or Myton. Work on the fossil vertebrates already in progress should help to clarify relations in this part of the section.

A quarry at Whistler Squat in the Agua Fria area that contained a large number of remains of the aquatic rhino *Amynodon advenus* is bracketed by potassium-argon dates. A calcareous tuff that lies directly under the quarry gave dates of 45.8 and 48.6 m.y. (McDowell, 1979) and a micaceous tuff less than 100 feet above the quarry was dated as 42.9 m.y. (McDowell, 1979). More dates need to be obtained from the earliest tuffs and flow rocks in the volcanic field but the 45 to 48 m.y. date for the early Uintan fauna at Whistler Squat is reasonable.

The work of J. B. and M.S. Stevens in Green Valley north of the Agua Fria area has shown that the fossiliferous section continues from the Eocene into the Oligocene. Their studies are continuing but the presence of early Oligocene vertebrate faunas FV01 and FV02 (Wilson and others, 1979) will enable the Green Valley section to be more closely correlated with the Sierra Vieja section.

A very small fauna (FVO?, fig. 4, col. 3) containing the primate *Mahgarita stevensi*, a hyaenodont, and the rhinoceratid *Amynodontopsis* has been recovered from a zone of conglomerate between certainly identified late Eocene and early Oligocene units. This fauna relates to the problematic position of the Duchesnean Age and its vertebrate fauna.

Big Bend National Park

The Late Cretaceous and early Tertiary stratigraphic section in Big Bend National Park resembles that of the San Juan Basin (fig. 5, col. 7). Dinosaur-bearing sediments are overlain by mammal-bearing Paleocene and early Eocene sediments. The latter are the earliest Tertiary rocks in West Texas and represent a remnant of a

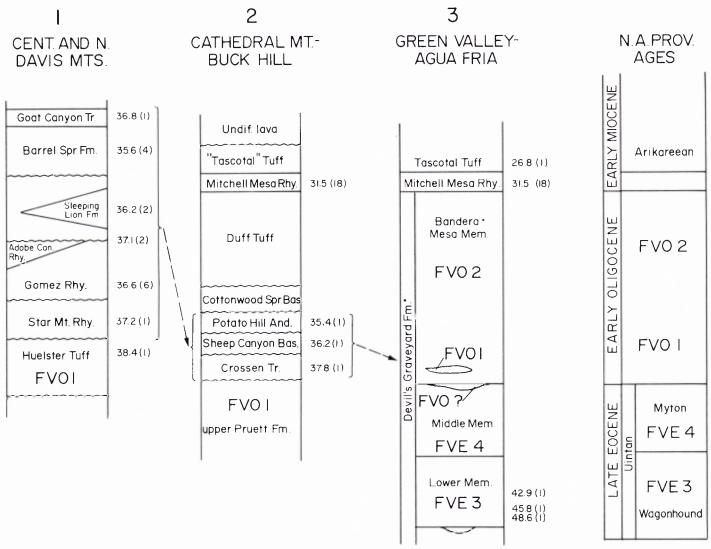


Figure 4. Correlation of diagrammatic stratigraphic sections from the northern and central Davis Mountains, southward to the Cathedral Mountain-Buck Hill area and the Green Valley-Agua Fria area showing the positions of the fossil vertebrate faunas and potassium-argon dates. FVE3 and FVE4 mark the positions of late Eocene fossil vertebrate faunas; FVO1 and FVO2, early Oligocene fossil vertebrate faunas.

larger structural basin that was deformed by the intrusion of the Chisos Mountains volcanic center and still later cut by Basin and Range faulting. The Paleocene and early Eocene sediments were deposited prior to the beginning of local volcanism but they contain reworked volcanic rock fragments and bentonitic clays that had a source somewhere outside the area.

The Paleocene sediments are found on Tornillo Flat in Big Bend National Park (fig. 1). A small vertebrate fauna was described by Wilson (in Maxwell and others, 1967) and greatly augmented by Schiebout (1974). At present, a fauna of 29 species belonging to 29 genera is known from the Black Peaks Formation. Schiebout (1974) dated the Black Peaks Formation as extending from questionably late Torrejonian to Tiffanian. As recognized by Sloan (personal communication, 1979), the age of the Black Peaks Formation extends from the Tiffanian through the Clark Forkian to earliest Eocene. Both Schiebout and Sloan agree that the fauna is late Paleocene.

The Hannold Hill Formation conformably overlies the Black Peaks Formation on Tornillo Flat. It has produced three taxa of undoubtedly early Eocene or Wasatchian age. These are the widely found genera *Coryphodon, Phenacodus,* and *Hyracotherium* or

Eohippus. All three are confined to the early Eocene and were described by Wilson (in Maxwell and others, 1967).

The Big Yellow Conglomerate Member is found at the base of the Canoe Formation, which conformably overlies the Hannold Hill Formation on Tornillo Flat. Another small fauna of vertebrates indicates a middle Eocene or Bridgerian age for the Canoe Formation. The Canoe Formation contains the lowest volcanic flow rock and the lowest tuff, which indicates the initiation of local volcanic activity. Lower jaw fragments of *Helohyus lentus* were found associated with the lowest tuff bed near Tornillo Flat. Unfortunately it has not been possible to obtain a satisfactory date on the oldest flow in the Tornillo Flat area.

In the southwestern part of the Park near Castolon the base of the Tertiary section (fig. 5, col. 6) is represented by the Alamo Creek Basalt. Dates of 40.1, 43.3, 38.7, and 42.7 m.y. are given for it in Maxwell and others (1967). Gustafson (1977) identified a *Uintacyon* skeleton from low in the Chisos Formation above the Alamo Creek as a Uintan species. This clearly indicates a late Eocene age for the lower part of the Chisos Formation.

Maxwell and others (1967) gave potassium-argon dates for higher units in the Chisos and South Rim Formations. They do not

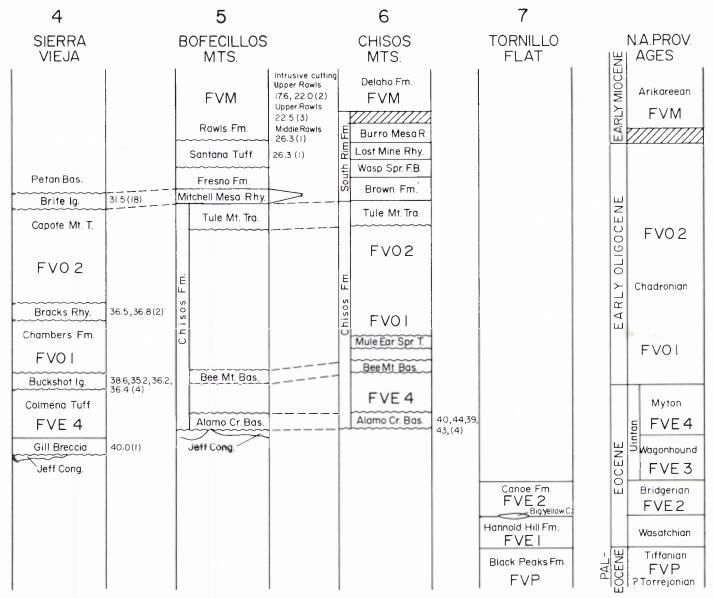


Figure 5. Correlation of diagrammatic stratigraphic sections from the Sierra Vieja to the Bofecillos Mountains and Big Bend National Park, showing the positions of fossil vertebrate faunas and potassium-argon dates. FVP marks the position of the late Paleocene fossil vertebrate fauna, FVE1 an early Eocene fauna, FVE2 a middle Eocene vertebrate fauna. Notations FVE3 and 4, FVO1 and 2 are as in Figure 4.

fit the superpositional succession, however, nor do they tie in with the well established dates from the northern Davis Mountains and the Sierra Vieja. They are therefore omitted from the section in Figure 5, Column 6. Isolated occurrences of fossil vertebrates, as yet undescribed, indicate that the upper part of the Chisos Formation is of early Oligocene or Chadronian age.

Bofecillos Mountains

The Bofecillos Mountains section (fig. 5, col. 5) is important because it forms a link between the Chisos Mountain section and that of the areas farther north. The Alamo Creek Basalt, the Bee Mountain Basalt, and the Tule Mountain Trachyandesite are recognizable in the southeastern part of the Bofecillos. In addition, the southernmost exposures of the Mitchell Mesa lie directly above the Tule Mountain. No vertebrate fossils have been found in the lower part of the section in the Bofecillos Mountains nor have any potassium-argon dates been attempted, to my knowledge.

Neogene Deposits

An early Miocene vertebrate fauna was first discovered in Big Bend National Park near Castolon and described by Stevens and others (1969) and Stevens (1977). The fossiliferous Delaho Formation (fig. 5, col. 6) is found in a series of grabens in the Terlingua Abaja fault zone. It was mapped as Quaternary-Tertiary older gravels by Maxwell and others (1967, pl. 2) prior to the discovery of the Miocene fossils. There are no *in situ* volcanic flow rocks within the Delaho Formation, so volcanic extrusion in the Chisos Mountain area had ceased by early Miocene.

Extrusion continued in the Bofecillos Mountains, however. Potassium-argon dates of 23.6 m.y. for the Santana Tuff and 22.0 to 22.6 m.y. for the Rawls Formation (McDowell, 1979) are well within the range of Miocene as given by Obradovich and others (1973). A date of 17.5 m.y. was obtained for a dike that cuts the upper part of the Rawls Formation. The closing stages of the volcanic activity took place in the Miocene in the Bofecillos Mountains. Dasch and

others (1969) dated two dike swarms in the Vieja area at 22.3 and 19.2 m.y.

The southern end of the Trans-Pecos volcanic field crosses the Rio Grande at the Bofecillos Mountains. Upstream from the Bofecillos Mountains the Rio Grande diagonally crosses a series of bolsons; northwestward toward El Paso these are the Redford Bolson, Presidio Bolson, Green River Bolson, Red Light Bolson, and the Hueco Bolson. They are separated rather distinctly where more north-south-trending structural elements cross the Rio Grande. Vertebrate faunas of late Pliocene and early Pleistocene have been found in the Hueco bolson (Strain, 1966) and in the Red Light Bolson (Akersten, 1966). A fragmentary horse tooth was found by Dickerson (1966) in the Presidio Bolson. Sediments in the chain of bolsons from El Paso to Presidio are topped off with late Pliocene to Pleistocene deposits.

At the Bofecillos Mountains volcanic section the Rio Grande cuts through the Fresno, Santana, and Rawls Formations. These volcanic flow rocks or intrusions that cut them are dated from 26.3 to 17.6 m.y., which makes them early to middle Miocene. From the Bofecillos Mountains through Big Bend National Park the Rio Grande flows on rocks older than middle Miocene. It no longer passes from bolson to bolson, even though it does not reach the edge of the Basin and Range structural province until it passes beyond Big Bend National Park and the Black Cap area (Muehlberger, 1979, fig. 1). I am not sure what significance this has in the development of the Rio Grande. I suggest, however, that the Rio Grande from the Bofecillos Mountains northwestward to El Paso had a different history than did the Rio Grande from the Bofecillos to the Pecos River and on to the Gulf of Mexico, and that the connection of an upper and lower Rio Grande must be post-middle Miocene.

Regional Correlation

The Porvenir local fauna (FV01) from the Chambers Formation is the largest of the West Texas Oligocene vertebrate assemblages. At the present time, three genera of insectivores, five genera each of rodents and carnivores, thirteen genera of perissodactyls and six of artiodactyls—a total of thirty-two genera—are held in common with early Oligocene faunas from the northern states. In addition a succession of potassium-argon dates given by Emry (1973) based on tuffs that are interbedded in a fossiliferous section at Flagstaff Rim, Wyoming, agrees very closely with those from the volcanic flow rocks of the Vieja Group. Both faunas are Chadronian and the radiometric dates span the approximate interval 38 to 31 m.y.

Regional correlation of the older fossil assemblages and dates is more difficult. The problem arises from the fact that the classical fossil collections on which the biochronologic sequence of units was based came from the sedimentary rocks of the intermontane basins and there are few datable rocks directly associated with these published collections. A framework of potassium-argon dates on the volcanic rocks of the Absaroka Mountains has been published by Smedes and Prostka (1972) but only preliminary lists of the associated faunas have been published (McKenna, 1972). Two potentially useful dates were given by Mauger (1977) and can be placed in measured sections of the Washakie Formation of Wyoming as published in Roehler (1973). But only preliminary faunal lists of fossil vertebrates from the pertinent part of the section of the Washakie Basin are listed by Turnbull (1972). None of the potassium-argon dates from the Eocene part of the West Texas section conflict with those from the northern as given by McKenna and others (1973). The dates of 48.6 and 45.8 m.y. from the same tuff that directly underlies the Whistler Squat quarry average within the 47 to 40 m.y. span of the Uintan, as does the average of the dates of the Alamo Creek Basalt. The existence of a biochronologic unit, Duchesnean, must depend on the description of a characterizing fauna rather than on the selection of radiochronologic dates (Berggren and others, 1977).

ACKNOWLEDGMENTS

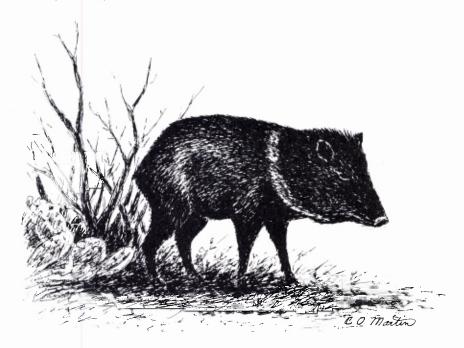
I am grateful for financial support from the Vertebrate Paleontology Laboratory, Texas Memorial Museum, The University of Texas at Austin, and from the Owens–Coates Fund of the Geology Foundation of the Department of Geological Sciences, the University of Texas at Austin. I have benefitted from discussions with J. B. and M. S. Stevens of Lamar University and my colleagues on the faculty at the University of Texas at Austin, S. E. Clabaugh, F. W. McDowell, and W. R. Muehlberger.

REFERENCES

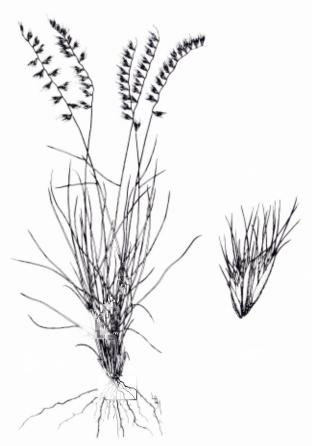
- Anderson, J. E., Jr., 1968, Igneous geology of the central Davis Mountains, Jeff Davis County, Texas: Texas Bureau of Economic Geology, Geologic Quadrangle Map 36, with text.
- Berggren, W. A., McKenna, M.C., Hardenbohl, J. and Obradovich, J. D., 1978 Revised Paleogene polarity time scale: Journal of Geology, v. 86, p. 67-81.
- Burt, E. R., 1970, Petrology of the Mitchell Mesa Rhyolite, Trans-Pecos Texas (M.A. thesis): University of Texas, Austin, 94 p.
- Cepeda, J. C., 1979, The Chinati Mountains caldera, Presidio County, Texas: in Walton, A. W. and Henry, C. D., editors, Cenozoic geology of the Trans–Pecos volcanic field of Texas: Texas Bureau of Economic Geology Guidebook 19, p. 106-125.
- Daily, M., 1979, Age relations in alkaline rocks from the Big Bend region, Texas, in Walton, A. W. and Henry, C. D., editors, Cenozoic geology of the Trans-Pecos volcanic field of Texas: Texas Bureau of Economic Geology Guidebook 19, p. 92-96.
- Dasch, E. J., Armstrong, R. L. and Clabaugh, S. E., 1969, Age of Rim Rock dike swarm, Trans-Pecos Texas: Geological Society of America Bulletin, v. 80, p. 1819-1824.
- DeFord, R. K., 1958, Tertiary formations of Rim Rock country, Presidio County, Trans-Pecos Texas: Texas Journal of Science, v. 10, no. 1, 37 p.
- Dickerson, E. J., 1966, Bolson fill, pediment, and terrace deposits of Hot Springs area, Presidio County, Trans-Pecos Texas (M.A. thesis): University of Texas, Austin, 100 p.
- Emry, R. J., 1973, Stratigraphy and preliminary biostratigraphy of the Flagstaff Rim area, Natrona County, Wyoming: Smithsonian Contributions in Paleobiology, no. 18, 43 p.
- Gilliland, M. W. and Clark, H. C., 1979, Paleomagnetism of early Tertiary volcanics of the Big Bend, Texas, *in* Walton, A. W. and Henry, C. D., *editors*, Cenozoic geology of the Trans-Pecos volcanic field of Texas: Texas Bureau of Economic Geology Guidebook 19, p. 48-54.
- Goldich, S. S. and Elms, M.A., 1949, Stratigraphy and petrography of the Buck Hill quadrangle, Texas: Geological Society of America Bulletin, v. 60, p. 1133-1183.
- Gorski, D. E., 1970, Geology and trace transition element variation of the Mitre Peak area, Trans-Pecos Texas (M.A. thesis): University of Texas, Austin, 200 p.
- Gustafson, E. P., 1977, Carnivorous mammals of the late Eocene and early Oligocene of Trans-Pecos Texas (Ph.D. dissertation): University of Texas, Austin, 209 p.
- ———, 1979, Early Tertiary vertebrate faunas, Big Bend area, Trans-Pecos Texas: *Simidectes* (Mammalia, Insectivora): Pearce-Sellards Series no. 31, Texas Memorial Museum, 9 p.
- McDowell, F. W., 1979, Potassium-argon dating in the Trans-Pecos Texas volcanic field, *in* Walton, A. W. and Henry, C. D., *editors*, Cenozoic geology of the Trans-Pecos volcanic field of Texas: Texas Bureau of Economic Geology Guidebook 19, p. 10-18.
- McKenna, M. C., 1972, Vertebrate paleontology of the Togwotee Pass area, northwestern Wyoming, in West, R. M., coordinator, Guidebook [for] Field Conference on Tertiary biostratigraphy of southern and

- western Wyoming (Aug. 5-10, 1972), privately published by coordinator through Adelphi University, New York, p. 80-101.
- McKenna, M. C., Russell, D. E., West, R. M., Black, C. C., Turnbull, W. D., Dawson, M. R. and Lillegraven, J. A., 1973, K/Ar recalibration of Eocene North American land-mammal "ages" and European ages (abstract): Geological Society of America Abstracts with Programs, 1973, p. 733.
- McKnight, J. F., 1968, Geology of Bofecillos Mountains area, Trans–Pecos Texas (Ph.D. dissertation): University of Texas, Austin, 198 p.
- ———, 1970, Geologic map of Bofecillos Mountains area, Trans-Pecos Texas: Texas Bureau of Economic Geology, Geologic Quadrangle Map 37, with text.
- Mauger, R. L., 1977, K-Ar ages of biotites from tuffs in Eocene rocks of the Green River, Washakie, and Uinta Basins, Utah, Wyoming, and Colorado: University of Wyoming, Contributions to Geology, v. 15, no. 1, p. 17-41
- Maxwell, R. A., Lonsdale, J. T., Hazzard, R. T. and Wilson, J. A., 1967, Geology of Big Bend National Park: University of Texas Publication, 6711, 320 p.
- Maxwell, R. A. and Dietrich, J. W., 1965, Geologic summary of the Big Bend Region: in Geology of Big Bend Area, West Texas: West Texas Geological Society Publication 65-51, p. 11-40; also reprinted as West Texas Geological Society Publication 72-59 with minor additions, 1972.
- Muehlberger, W. R., 1979, The areal extent of Cenozoic faulting in Trans-Pecos Texas, *in* Walton, A. W. and Henry, C. D., *editors*, Cenozoic geology of the Trans-Pecos volcanic field of Texas: Texas Bureau of Economic Geology Guidebook 19, p. 19-21.
- Obradovich, J. D., Izett, G. A. and Naeser, C. W., 1973, Radiometric ages of volcanic ash and pumice beds in the Gering Sandstone (earliest Miocene) of the Arikaree Group, southwestern Nebraska (abstract): Geological Society of America Abstracts with Programs, v. 5, no. 6, p. 499-500.
- Ogley, D. S., 1979, Eruptive history of the Pine Canyon caldera, Big Bend National Park, *in* Walton, A. W. and Henry, C. D., *editors*, Cenozoic geology of the Trans-Pecos volcanic field of Texas: Texas Bureau of Economic Geology Guidebook 19, p. 67-71.
- Parker, D. F., 1979, The Paisano volcano: Stratigraphy, age, and petrogenesis, in Walton, A. W. and Henry, C. D., editors Cenozoic geology of the Trans-Pecos volcanic field of Texas: Texas Bureau of Economic Geology Guidebook 19, p. 97-101.
- Roehler, H. W., 1973, Stratigraphy of the Washakie Formation in the Washakie Basin, Wyoming: U.S. Geological Survey Bulletin 1369, 40 p.
- Schiebout, J. A., 1974, Vertebrate paleontology and paleoecology of the Black Peaks Formation, Big Bend National Park, Texas: Texas Memorial Museum Bulletin 24, 88 p.
- Smedes, H. W. and Protska, J. J., 1972, Stratigraphic framework of the Absaroka Volcanic Supergroup in the Yellowstone National Park region: U.S. Geological Survey Professional Paper 729-C, p. C1-C32.

- Stevens, M. S., 1977, Further study of Castolon local fauna (early Miocene), Big Bend National Park, Texas: Pearce-Sellards Series 28, Texas Memorial Museum, 69 p.
- Stevens, M. S., Stevens, J. B. and Dawson, M. R., 1969, New early Miocene formation and vertebrate local fauna, Big Bend National Park, Brewster County, Texas: Pearce-Sellards Series 15, Texas Memorial Museum, 53 p.
- Strain, W. S., 1966, Blancan mammalian fauna and Pleistocene formations, Hudspeth County, Texas: Texas Memorial Museum Bulletin 10, 55 p.
- Turnbull, W. D., 1972, Washakie Formation of Bridgerian–Uintan Ages, and the related faunas, in West, R. M., coordinator, Guidebook [for] Field Conference of Tertiary biostratigraphy of southern and western Wyoming (Aug. 5-10, 1972), privately published by coordinator through Adelphi University, New York, p. 20-31.
- Udden, J. A., 1907, A sketch of the geology of the Chiso country, Brewster County, Texas: University of Texas Bulletin 93, 101 p.
- Walton, A. W. and Henry, C. D., editors, 1979, Cenozoic geology of the Trans-Pecos volcanic field of Texas: Texas Bureau of Economic Geology Guidebook 19, 193 p.
- Wilson, J. A., 1974, Early Tertiary vertebrate faunas, Vieja Group and Buck Hill Group, Trans-Pecos Texas. Protoceratidae, Camelidae, Hypertragulidae: Texas Memorial Museum Bulletin 23, 34 p.
- ——, 1977a, Early Tertiary vertebrate faunas, Big Bend area, Trans-Pecos Texas. Brontotheriidae: Pearce-Sellards Series 25, Texas Memorial Museum, 15 p.
- ———, 1977b, Stratigraphic occurrence and correlation of early Tertiary vertebrate faunas, Trans-Pecos Texas. Part I: Vieja area: Texas Memorial Museum Bulletin 25, 42 p.
- Wilson, J. A. and Schiebout, J. A., in press, Early Tertiary vertebrate faunas, Trans-Pecos Texas. Amynodontidae: Pearce-Sellards Series 33, Texas Memorial Museum.
- Wilson, J. A., and F. S. Szalay, 1976, New adapid primate of European affinities from Texas: Folia Primat., v. 25, n. 4, p. 294-312.
- Wilson, J. A., J. B. Stevens and M. S. Stevens, 1979, New cross-section from southern Davis Mountains to northeast Solitario, *in* Cenozoic Geology of the Trans-Pecos Volcanic Field of Texas: Texas Bureau of Economic Geology, Guidebook 19, p. 147-149.
- Wilson, J. A., Twiss, P. C., DeFord, R. K. and Clabaugh, S. E., 1968, Stratigraphic succession, potassium-argon dates, and vertebrate faunas, Vieja Group, Rim Rock country, Trans-Pecos Texas: American Journal of Science, v. 266, p. 590-604.
- Wood, A. E., 1973, Eocene rodents, Pruett Formation, southwest Texas; their pertinence to the origin of the South American Caviomorpha: Pearce-Sellards Series 20, Texas Memorial Museum, 41 p.



Collared peccary, Dicotyles tajacu.



Texas grama plant and spikelet cluster, Bouteloua rigidiseta.