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STRATIGRAPHIC SUCCESSION, POTASSIUM-ARGON DATES, AND VERTEBRATE FAUNAS, VIEJA GROUP, RIM ROCK COUNTRY, TRANS-PECOS TEXAS

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ABSTRACT. Potassium-argon dates from a superpositional succession of igneous and sedimentary rocks of the Vieja, Garren, and Buck Hill Groups are critically evaluated. Five new faunas of vertebrate fossils collected from interbedded tuffs are named, and tentative faunal lists given. Misidentification of fossil vertebrates in an earlier collection are corrected. Abandonment of a previously published K-Ar date of 33.1 m.y. is urged because of lack of stratigraphic and geographic data. An Eocene-Oligocene boundary based on vertebrates seems to fall within the Duchesnean Age.

INTRODUCTION

The Rim Rock Country along the Rio Grande in far west Texas is a remote region of geologic importance. Cutting through a mountain range 110 miles below El Paso, the Rio Grande enters the Rim Rock Country and flows in a southeasterly direction through it for 50 miles between the border range in Chihuahua and the Sierra Vieja in Texas (fig. 1). The river leaves the Rim Rock Country 50 miles above Presidio, Texas, and continues another 100 miles southeast of Presidio to the Big Bend where the Rio Grande turns sharply northeastward.

The Sierra Vieja is composed of Tertiary volcanic rock and interbedded sediments. On its faulted, step-like western flank extrusive igneous rocks cap prominent rims, and tuffaceous sedimentary rocks crop out on hillsides. This volcanic sequence and similar rocks in the Big Bend National Park are yielding an important record of vertebrate life and tectonic history. Structurally this region is part of the Great Basin; geographically it lies in the southward extension of the Rocky Mountain front adjacent to the Gulf Coast where marine Tertiary rocks occur. Thus it offers an unexcelled tie between the geologic records of the Gulf Coast and northeastern Mexico, between the structural history of the Great Basin and of northern Mexico, and between all these and the vertebrate-fossil chronology of the Rocky Mountain region.

Forty-five graduate students have mapped and described the layered volcanic sequence in the Rim Rock Country, which composes the Vieja Group. The results of this work and a detailed analysis of the vertebrate faunas are being compiled and will be more fully presented at a later date. However, because an increasing number of references are being made to K-Ar dates and vertebrate faunas from the Vieja Group, it is thought best to present this preliminary report.[1] One of the chief pur-

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poses is to point out the relative stratigraphic positions of the local faunas and the igneous-rock layers for which there are isotopic dates. One of these dates unfortunately is already widely used in Cenozoic chronologies of North America; it is not tied down geographically or stratigraphically, and it no longer appears to be the correct age for the faunas.

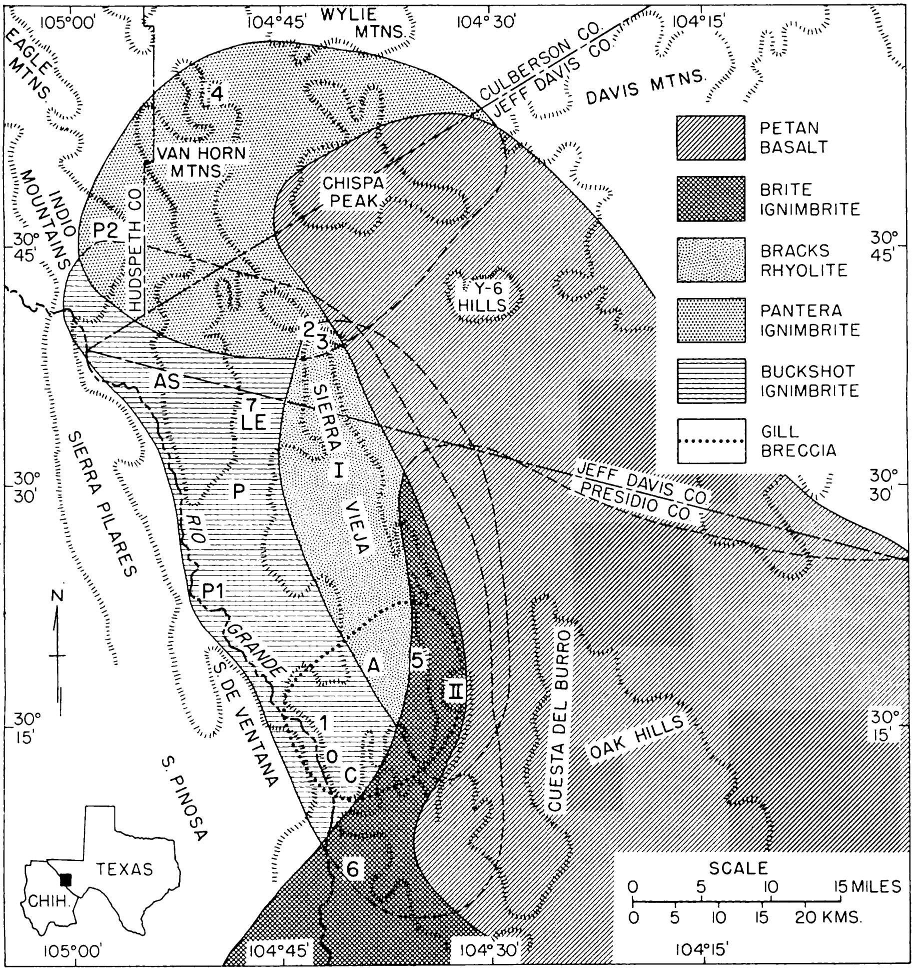

Fig. 1. Map of Trans-Pecos Texas southwest of Davis Mountains, showing initial areal extent of flow rocks. Rim-Rock Country is between Sierra Vieja and Rio Grande. Letter symbols locate sources of vertebrate fossils: C, Canadelaria l.f.; P, P1, P2, Porvenir l.f.; L.E., Little Egypt l.f.; A, Airstrip l.f.; AS, Ash Spring l.f. Numerals locate sources of K-Ar samples (see table 3): 0, volcanic rock in Gill Breccia; 1, 2, (sample 2 and 2a is the same rock specimen) Buckshot; 3, 4, Pantera; 5, Bracks; 6, Brite; 7, sanidine from water-laid tuff of Reeves bonebed; I, KA 1010, Bracks; II, KA 1000, Brite.

GEOLOGIC SETTING

Geologically the Rim Rock Country is part of an unstable zone along the western flank of the late-Paleozoic Diablo Platform, which coincides with the eastern edge of the Mesozoic Chihuahua Trough. In late Cretaceous-early Tertiary (Laramide) diastrophism the thick Cretaceous sedimentary rock of the trough was overthrust against the flank of the platform. After the uplift and erosion of Upper Cretaceous mudstone, shale, and sandstone, late Eocene-early Oligocene eruptions covered most of the area with volcanic rocks of the Vieja Group. Subsequent block faults, following the general trend of the Laramide folds and thrust faults, created the structure that now dominates the topography. Erosion continuing to the present has carved the rims of the Rim Rock Country out of the block-faulted volcanic rocks of the Vieja Group. Meanwhile deposition almost filled the bolsons. Then during the Quaternary Period the Rio Grande broke through to the sea and began removing the fill.

LITHOSTRATIGRAPHY

The Vieja Group of the Rim Rock Country, Trans-Pecos Texas (DeFord, 1958), consists of 2550 feet of interbedded conglomerate, sandstone, water-laid tuff, ash-flow tuff (ignimbrite), and lava rock (tables 1 and 3). Vertebrate fossils from sedimentary layers establish the late Eocene-early Oligocene age of most of the Vieja Group. Some of the potassium-argon dates from sanidine of the ash-flow tuff and lava rock are especially useful in correlation because they are associated with subjacent and superjacent fossiliferous beds.

The Garren Group in the Van Horn Mountains (Twiss, 1959) on the north interfingers southward with the Vieja Group (fig. 2). From the north a tongue of Pantera Ignimbrite extends southward into the Chambers Tuff; from the south the Buckshot Ignimbrite extends northward into the Hogeye Tuff; but individual beds of water-laid tuff cannot be traced more than a few hundred feet.

VERTEBRATE FOSSILS

The sedimentary rocks that contain vertebrate fossils are exposed in the topographically lower and complexly faulted part of the Rim Rock Country. Even with the complete stratigraphic section tantalizingly exposed in the 2100 foot fault scarp a few miles to the east, it was difficult to establish the relative superposition for some of the vertebrate-fossil localities because the same type of sedimentary rock appears at different stratigraphic horizons.

Five local faunas at different stratigraphic levels within the Vieja Group are recognizable. From lowest to highest they are named: Candelaria l.f. (our Candelaria l.f. is the Colmena l.f. of Black and Dawson, 1966), Porvenir l.f., Little Egypt l.f., Airstrip l.f., and Ash Spring l.f. Figure 1 shows geographic positions of the more important localities for each of the local faunas, and figure 2 shows their stratigraphic positions.

TABLE 1

Formations of Vieja Group, youngest at top

Formation	Description
Petan Basalt	Dark gray, vesicular trachyandesite; concordantly overlies Brite Ignimbrite; 0-510 ft thick.
Brite Ignimbrite	Light brownish gray, slightly porphyritic, vitric ignimbrite; up to 25 percent quartz and chatoyant sanidine as phenocrysts; microeutaxitic; 0-255 ft thick, averages about 45 ft.
Capote Mountain Tuff	Fine-grained, vitric, tuffaceous sandstone and siltstone; a few interbeds of conglomerate containing pebbles and cobbles of limestone, sandstone, and igneous rocks. On the north the tuff is dominantly very light gray with a few pale red beds; on the south the lower 2/3 is pale red, the upper 1/3 very light gray; cannot be distinguished from Chambers Tuff where Bracks is absent; 600-2100 ft thick.
Bracks Rhyolite	Dark reddish brown to grayish olive, slightly porphyritic "quartz pantellerite"; rhombic anorthoclase phenocrysts (10 percent) up to 3 mm in matrix of alkalic feldspar, quartz, and mafic minerals; most important stratigraphic marker and rim rock; 0-360 ft thick.
Chambers Tuff	Varicolored, fine-grained, crystal-vitric tuff, containing white, pale red, grayish pink, grayish green, pale purple, and grayish orange pink beds; crystal and vitric fragments equally abundant; 105 ft thick on south, almost 750 ft on north.
Buckshot Ignimbrite	Grayish red, slightly porphyritic, vitric, rhyolitic ignimbrite, containing very dark red spheres 2-10 mm in diameter; many blister cones, 6 ft high and up to 45 ft in diameter, on upper surface; a sharp contact with overlying Chambers; black vitrophyre at base in many places; average thickness 45 ft.
Colmena Tuff	Pale red to white fine-grained, thin-bedded tuffaceous sandstone and pebble-to-boulder limestone-and-sandstone conglomerate; discordantly overlies Gill Breccia in southern 1/3 of area, elsewhere unconformably on Upper Cretaceous; includes Jeff Conglomerate where Gill is absent; predominantly tuffaceous sandstone and limestone on south, mostly conglomerate on north; 0-450 ft thick.
Gill Breccia	Grayish red, porphyritic, trachybasalt breccia, restricted to southern 1/3 of area; 0-360 ft thick.
Jeff Conglomerate	Light gray pebble-to-boulder conglomerate with interbeds of tuffaceous sandstone; unconformably overlies Upper Cretaceous; contains gravel of limestone, sandstone, and chert; 24-300 ft thick.

The Candelaria locality is at the mouth of Capote Creek on the Rio Grande about 2 miles north of Candelaria. Fossiliferous beds in the lower 200 feet of the Colmena Tuff, which crop out on both sides of Capote Creek, consist of tuffaceous sandstone, siltstone, and claystone interbedded with mudstone and conglomerate. The following is a preliminary list of part of the Candelaria local fauna: gastropods, alligator, turtle, insectivores, *Ischyrotomus* n. sp., *Manitsha* sp. indet.[2], Omomyidae gen. et sp. indet., *Harpagolestes, Epihippus,* titanothere, *Helaletes,* rhinocerotid, *Megalamynodon, Protoreodon parvus, Protoreodon pumilus, Leptotragulus* cf. *medius, Leptotragulus* cf. *proavus.*

Porvenir local fauna is in the lower part of the Chambers Tuff at many different localities. Stovall (1948) published the first report on it;

[2] This is the local fauna from which was collected *Manitsha* sp. indet., UTBEG 31281, identified by Wood (1962, p. 224), and attributed to the "Vieja Oligocene at the mouth of Capote Creek".

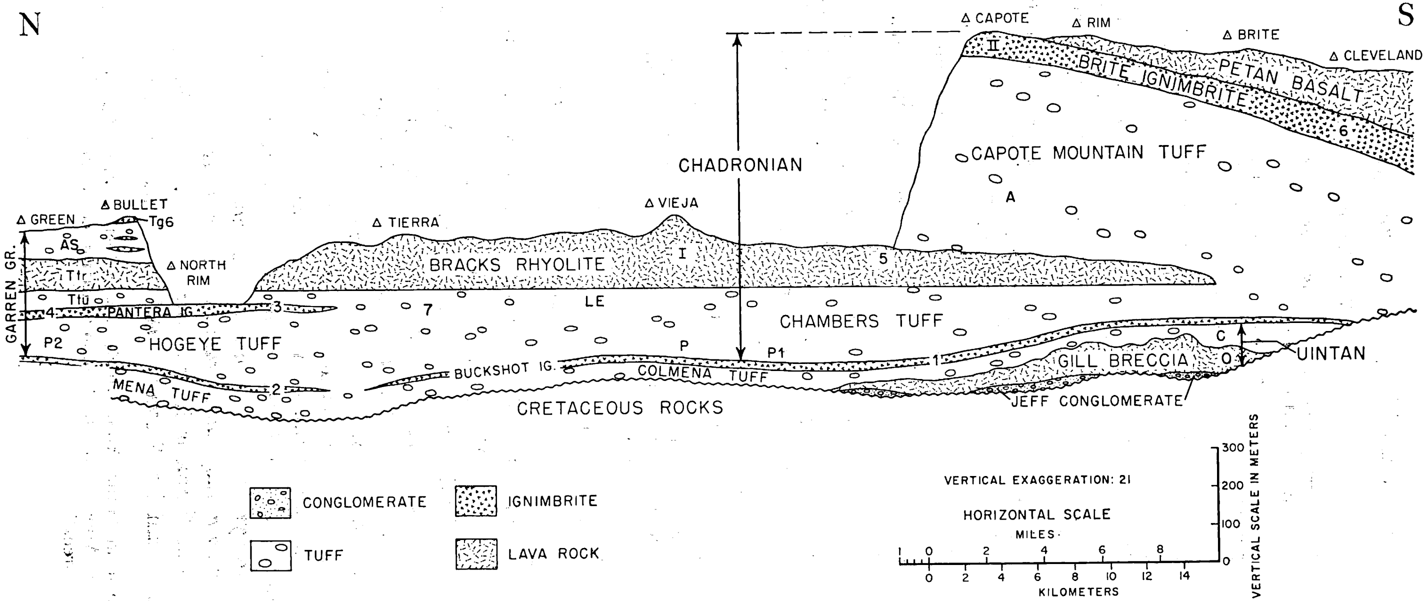

Fig. 2. Idealized cross section of Vieja Group after Schulenberg (ms). Base of Bracks Rhyolite is datum. See tables 1 and 2 for lithologic descriptions. Letter symbols and numerals (see fig. 1 and table 3) show stratigraphic positions of vertebrate fossils and K-Ar samples.

TABLE 2

Components of Garren Group, youngest at top. Symbols Tg6, Ttr, and Ttu refer to cross section (fig. 2)

Formation	Description
Ignimbrite Tg6	Dark yellowish brown, slightly porphyritic, rhyolitic ignimbrite.
Tuff	White to pale greenish yellow, lithic and vitric tuff; maximum thickness 390 ft, two small outcrops of olivine basalt.
Trachyte Ttr	Light brownish gray, aphanitic, non-porous to vesicular, quartz-sanidine trachyte; breccia at base containing a few sanidine phenocrysts and many trachyte tuff fragments: 42-525 ft. thick; occupies nearly same stratigraphic position as Bracks Rhyolite.
Tuff Ttu	Yellowish gray to pinkish gray, friable, vitric-crystal tuff; 150-540 ft thick; grades into upper part of Chambers Tuff.
Pantera Ignimbrite	Light brownish gray to grayish red, porphyritic sanidine-trachyte ignimbrite; eutaxitic to microeutaxitic; black vitrophyre at base; 0-51 ft thick; extends southward into Chambers Tuff about 150 ft below Bracks Rhyolite.
Hogeye Tuff	Pale reddish brown to dusky brown, conglomerate containing pebbles, cobbles, and boulders of limestone and sandstone and layers of white and pink crystal and vitric tuff and, locally, olivine-basalt; 405-720 ft thick; grades into lower 2/3 of Chambers and all the Colmena.

his collection is at the University of Oklahoma, Norman. In 1949 Bryan Patterson and James H. Quinn collected from this part of the stratigraphic section for the Chicago Museum of Natural History. The Bureau of Economic Geology, The University of Texas at Austin, has the rest of the fauna. The major part of these three collections came from areas locally known as Big Cliff, Soldier Flat, and Rifle Range Hollow, all within the lower third of the Chambers Tuff.

A preliminary list of the Porvenir local fauna follows: gastropods, turtles, lizard, insectivores, *Manitsha* and a variety of rodents[3], *Rooneyia viejaensis* (Wilson, 1966; Hofer and Wilson, 1967), *Haplohippus texanus* (McGrew, 1953), *Mesohippus,* titanotheres, *Colodon? hancocki, Hyracodon, Brachyhyops,* small entelodont, *Protoreodon, Agriochoerus* (the most common artiodactyl), *Pseudoprotoceras, Leptomeryx, Heteromeryx, Leptotragulus* cf. *L. proavus, Eotylopus* cf. *E. reedi, Oromeryx.*

The bone-bearing rocks are multicolored tuffaceous beds of conglomerate, sandstone, siltstone, and mudstone. A bed less than 1 foot above the Buckshot Ignimbrite has yielded vertebrate fossils.

The Little Egypt local fauna is named after a locality between the third and fourth crossings of Dieciocho Creek on the San Carlos or Bracks Tunnel road about 8 miles from its intersection with the lower river road (Porvenir mail route). The fauna came from two main localities: Chalk Gap Draw about 1 mile west of the road and Reeves bonebed about 1 mile east of the road. According to our correlation, the fauna is from the upper part of the Chambers Tuff about 60 feet below the Bracks Rhyolite. Some of the fossils are in a pale red sandstone which

[3] At the time Wood (1955) was writing concerning the relative ages of a collection of rodents from the Yoder Formation of Wyoming and a collection of rodents from the Vieja of Texas, he had only the material collected by Patterson and Quinn which is part of the Porvenir local fauna.

we correlate with a similar sandstone directly beneath the Pantera Ignimbrite. Fossils also have been found as low as 60 feet stratigraphically below the sandstone. A preliminary list of the Little Egypt local fauna follows: gastropods, turtles, ?*Ictops,* several rodents including *Manitsha, Hyaenodon, Daphoenus,* felid indet., *Mesohippus,* titanotheres, *Hyracodon,* small entelodont, *Agriochoerus* (rare), *Bathygenys* (very common), *Prodesmatochoerus* n. sp. (common), *Leptomeryx, Leptotragulus, Eotylopus.*

The Airstrip local fauna is a little more than 1½ miles north of the Boyd Chambers ranch house (Dow House) and a little less than the same distance south of an air strip. The fossils are from the Capote Mountain Tuff 570 feet above the Bracks Rhyolite. A preliminary list of identified genera in the Airstrip local fauna follows: turtles, lizard, snake, insectivores, *Leptodus* n. sp., *Ischyrotomus, Cylindrodon,* eomyid, *Hyaenodon, Miacis gracilis, Hesperocyon,* titanothere, rhinocerotoid, *Limnenetes* (very common), large merycoidodontid (rare), *Eotylopus,* large eotylopid, *Poebrotherium.* The fossiliferous rock is pink to reddish brown tuffaceous sandstone.

Stratigraphically the highest vertebrate fauna is at Ash Spring in a poorly consolidated, grayish pink, reworked tuff. Our correlation places it about 105 feet below the upper ignimbrite (Tg6, table 2) of the Garren Group and approximately 510 feet above the Pantera Ignimbrite. Harris (ms) named it the Ash Spring local fauna. It contains turtle, lizard, *Pseudocylindrodon, Titanotheriomys,* eomyid n. sp., felid indet., titanothere, rhinoceratoid, ?*Achaenodon, Hypisodus,* large merycoidodontid, *Eotylopus* cf. E. *reedi,* oromerycid, *Poebrotherium* n. sp.

K-Ar DATES

Because the tuff, silt, and sand grains of the fossilferous rock and the pebbles and cobbles of the associated conglomerate are weathered and water worn, they should yield less satisfactory samples for isotopic dating than the ignimbrite and rhyolite. Moreover the originally incandescent tuff and lava spread rapidly over large areas (fig. 1). The igneous rocks are relatively fresh. Some of them contain as much as 12 percent sanidine as phenocrysts that can be concentrated. We did not find enough biotite or pyrobole to use in dating.

Geochron Laboratories, Inc., Cambridge, Massachusetts, analyzed ten samples (table 3, nos. 0 to 7 and 14) collected by Twiss and Wilson. Evernden, University of California at Berkeley, analyzed and reported (Evernden and others, 1964) on two sent by Wilson (table 3, nos. KA 1000, KA 1010). The sources of these eleven samples are widely spaced, and we know the stratigraphic position of each. The purity of the sanidine concentrates ranges from 30 to 95 percent (table 3). The chief impurity is the partly devitrified glass matrix that adheres to the sanidine grains and has nearly the same specific gravity and magnetic properties as the sanidine. Phenocrysts of the Brite Ignimbrite and the Bracks Rhyolite are large enough (3 mm) to pick by hand.

Some of the K-Ar ages in table 3 do not agree with the order of superposition. The Pantera (samples 3 and 4) and Buckshot (samples 1 and 2) Ignimbrites from the lower part of the column yielded younger isotopic ages than the overlying Bracks Rhyolite. Sample 4 of the Pantera Ignimbrite was collected from the zone of dense welding; many of the feldspar phenocrysts consist of nuclei of oligoclase rimmed with sanidine. In samples 1, 2, 3, and 4 of the Pantera and the Buckshot, the purity of the sanidine concentrate was low with as much as 25 to 70 percent being devitrified glass matrix that may have lost radiogenic argon during a long period of alteration. Furthermore, these units contained smaller and fewer sanidine crystals than the Bracks, and the potassium content of the concentrates was lower. The older dates obtained from the basal Gill Breccia and from alkali feldspar grains picked from Reeves' bonebed near the level of the Pantera supported the hypothesis that the K-Ar ages from samples 1, 2, 3, and 4 of the Pantera and Buckshot are too young.

Geochron Laboratories, Inc., therefore, was requested to reanalyze sample 2. The first determination yielded a date of 34.7 $\pm$ 2.0 m.y., the second 38.6 $\pm$ 1.2 m.y. (table 3, samples 2 and 2a). Both analyses are from the same rock specimen. The date from this new determination (sample 2a) agrees with the order of superposition in the stratigraphic section, and it is a minimum age for the Candelaria l.f. and a maximum for the Porvenir l.f.

One bad date.—Let us recount the pertinent incidents more or less as they happened. Vaughn (1900) named the "Vieja series". Stovall and his students collected bones in 1938 and 1940; Baker (1941, p. 85) reported that Stovall had found ". . . White River Oligocene vertebrate fossils in the lower volcanic rocks near San Carlos". Stovall (1948) called them "Chadron vertebrates", but the "fossil locality" on his map and the location of the source of his collection in his text are both at least 2 miles in error and part of the Stovall collection was misidentified (table 4).

DeFord (1958) named the formations of the Vieja Group. In reporting the age of the Colmena and Chambers as "Duchesnean or Chadronian", he was quoting Wilson's preliminary results. In 1958 or 1959 Curtis as stated in a letter to Twiss dated April 5, 1966, "using Stovall's sketch map", collected a rock specimen from the Vieja Group. The stratigraphic and geographic positions of the parent rock are quite uncertain. Subsequent analysis and calculations gave 33.1 or 33.0 m.y. as the age date.

In discussion of a paper that he read at a New York meeting in March 1960 Curtis (Curtis, Savage, and Evernden, 1961, p. 351) was asked, "What did you date"? He replied, "This was sanidine from what has been named by Stovall the Chadron Tuff". The stratigraphic nomenclature is bad, but Stovall is not to blame; Curtis and his coauthors (1961) had evidently overlooked Vaughn (1900) and DeFord (1958). Curtis continued, "At this locality, I think within a few feet of the

TABLE 3

K-Ar analyses of sanidine concentrates from igneous rocks of Vieja Group (DeFord, 1958), Garren Group (Twiss, 1959), and Buck Hill Group (Goldich and Elms, 1949), Trans-Pecos Texas by Geochron and Evernden and others (1964). Symbols: * = radiogenic; $\lambda_\beta = 4.72 \times 10^{-10}$/yr; $\lambda_e = 0.585 \times 10^{-10}$/yr; $K^{40}/K = 1.22 \times 10^{-4}$g/g

$$\text{Age} = \frac{1}{\lambda_e + \lambda_\beta} \ln \frac{\lambda_e + \lambda_\beta}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1$$

No.	Formation and References	Sanidine in Concentrate	Ar^{40*} (10^{-3}ppm)	$\frac{Ar^{40*}}{Ar^{40}}$	%K	K^{40} ppm	$\frac{Ar^{40*}}{K^{40}} \times 10^3$	Age M.Y.
14	Mitchell Mesa	85%	13.3 14.1	0.594 0.595	5.62 5.57	6.84	2.0	33.9 ± 1.8
KA1000	Brite (Evernden and others, 1964)			0.950	4.61			29.7
6	Brite	95%	10.7 ± 0.5 11.2 ± 0.8 10.0 ± 2.3 9.8 ± 0.6	0.410 0.592 0.115 0.475	4.37 4.36	5.34	1.95 ± 0.07	33.0 ± 1.1
5	Bracks	80%	12.6 12.8	0.401 0.092	4.88 4.78	5.90	2.15 ± 0.08	36.5 ± 1.2
KA1010	Bracks (Evernden and others, 1964)			0.960	5.03			36.8
4	Pantera	30%	3.9 3.8	0.190 0.470	1.66 1.65	2.02	1.91 ± 0.10	32.4 ± 1.7
3	Pantera	65%	5.5 6.7	0.121 0.111	2.52 2.46	3.04	2.01	34.2 ± 3.0

No.	Formation and References	Sanidine in Concentrate	Ar^{40*} (10^{-3}ppm)	$\frac{Ar^{40*}}{Ar^{40}}$	%K	K^{40} ppm	$\frac{Ar^{40*}}{K^{40} \times 10^{3}}$	Age M.Y.
7	Sanidine grains in waterlaid tuff Reeves' bonebed, Chambers Tuff	99%	6.11 6.70	0.713 0.625	2.23 2.23	2.723	2.35	39.8 ± 2.8
2a	Buckshot (rerun on sample 2)	75%	8.34 8.83	0.270 0.245	3.06 3.08	3.74	2.29	38.6 ± 1.2
2	Buckshot	75%	7.5 7.8	0.069 0.275	3.06 3.08	3.74	2.05	34.7 ± 2.0
1	Buckshot	65%	7.6 ± 0.5	0.294	3.00 3.00	3.66	2.09 ± 0.13	35.2 ± 2.3
0	Volcanic rock from Gill Breccia	whole rock	9.23 9.81	0.596 0.610	3.26 3.30	4.01	2.37	40.0 ± 2.0

TABLE 4

Correction of misidentifications in Stovall (1948). The *Colodon?* is close to *C.? hancocki* from the Clarno Formation in Oregon

Published name	Plate	Figure	MOU no.	Corrected name
Protapirus	1	5, 6a, 6b	17.2-S2a	*Colodon? hancocki*
Merycoidodon gracilis	2	5	44-4-S38	*Mesohippus*
Merycoidodon culbertsoni	2	4, 6	44-4-S41 44-2-S23	a primitive species of *Agriochoerus*

tuff, is an extensive lower Oligocene fauna". The "few feet" are uncertain in the opinion of the present writers.

Writing mostly in the first person singular, Curtis and his coauthors published this paper in a 1961 symposium on "absolute geochronology". Their date "Chadronian, Texas 33.1" is considerably the earliest of their critical points in the Cenozoic. The date 33.1 m.y. came from the analysis of Curtis's aforementioned sample. Referring to Stovall (1948), they stated that his "correlation, although based on a large fauna, may or may not be the best basal Oligocene. We expected the base of Oligocene to be somewhat older than this". The corrected identifications of Stovall's fossils in our table 4 and the preliminary list of the Porvenir local fauna indicate a somewhat older assemblage than Stovall's (1948) identifications indicated. Kulp (1961, p. 1107) also published the same age from the same sample as a "critical point": "Chadronian, Texas, Tuff biotite K-Ar, $33.1 \pm 1.0 \times 10^6$ yr". (For "biotite" the reader must substitute "sanidine".)

In February 1964, Evernden and coauthors published the age from the same analysis as sample "KA 483 . . . 33.0×10^6 yrs" from "*Formation*: Vieja Group. *Locality*: Presidio County, Texas, 4 miles east of Rio Grande". This location establishes a line 32 miles long that follows the Rio Grande from Ash Spring to Candelaria (fig. 1). In the same month and year papers read at a symposium in London and published in December gave still wider currency to this date.

We strongly urge abandoning the use of sample KA 483 as a point in the time scale because both the geographic location and the stratigraphic position of the sample are unknown. Further, the 33.1 m.y. age is too low as indicated by subsequent determinations for overlying and underlying rocks (table 3). The expectations of Curtis and coauthors regarding the age of basal Oligocene seem more dependable than this isotopic age.

CORRELATION

Eocene or Oligocene?—We do not propose to correlate the local faunas precisely at this time, because several cooperating vertebrate paleontologists have not finished their studies of particular zoologic groups. Nevertheless, geologists and paleontologists previously unacquainted with the Vieja Group now frequently refer to its rocks, its vertebrate faunas, and its geologic time span. Oldest to youngest the local faunas of the Rim Rock Country are named: Candelaria, Porvenir, Little Egypt, Airstrip, and Ash Spring. The position of the Eocene-Oligocene boundary with respect to these faunas is problematic.

Wood and others (1941) proposed the provincial terms Uintan Age, Duchesnean Age, and Chadronian Age. The new terms were not defined in relation either to epochs or to the European standard. On the committee's correlation chart the Duchesnean-Chadronian boundary coincides with a dashed boundary between the Eocene Epoch and the Oligocene Epoch. The committee agreed that epochs "normally have only regional significance". It had no intention of deciding where the Eocene-Oligocene boundary "really is" but hoped to make it easier to sidestep such controversial questions.

Not long afterward Scott (1945) assigned the Duchesnean to the Oligocene. Simpson (1946) argued it back into the Eocene. The general philosophy seemed to be that the Duchesnean, as a unit, was "either/or", all Eocene or all Oligocene.

Potassium-argon dates in this chronologic neighborhood with or without associated faunas are scarce. For this reason three other vertebrate faunas associated with pertinent K-Ar dates as given by Evernden and others (1964) are of great interest. First, the three dates are all from the same rock sample of Norwood Tuff Formation, Utah: KA 827, 36.0 m.y.; KA 826, 37.5 m.y.; and KA 825, 37.4 m.y. The association is described as follows under KA 825, Evernden and others (1964, p. 183):

> *North American Land-Mammal Age*: Duchesnean. Extract from letter from G. (sic) Lewis Gazin to Max Crittenden, Nov. 6, 1959: "Have gone over the Norwood speciments in the Carnegie Museum and am satisfied that a late Eocene horizon is appropriate for these beds. One of the specimens originally identified for Eardley as *Leptomeryx* was entirely inadequate for a generic assignment. The titanothere was much better but possibly not determinable as to genus. The titanothere specimen is not diagnostic as between late Eocene and early Oligocene, so on the basis of the *Protoreodon* jaw sent me by J. W. Williams, we are better off in the late Eocene.

Large and small protoreodonts are found in the Candelaria l.f., and a large *Protoroeodon* is found in the Porvenir l.f.

Secondly, a somewhat better fauna is associated with KA 818, 37.5 m.y., and KA 824 A, 36.5 m.y., from the Clarno Formation of Oregon. KA 824A, the younger date, is reported as underlying KA 818. The association with the vertebrate fauna is described as follows under KA 818 by Evernden and others (1964, p. 182):

> *North American Land-Mammal Age*: Early Chadronian or late Duchesnean. No fossils found at this locality. Fauna described by McKenna (see below) is from locality approximately 20 miles NE (near Clarno) (Univ. of Oregon "Mammal Quarry" near center sec. 27, T 7 S, R 19 E). Bone locality is at top of a 2200′ section which is incomplete. John Day Formation overlies Clarno with angular unconformity at mammal quarry. Probable that andesite dated is somewhat younger than mammal quarry as K/A locality is in center of syncline at top of Clarno section (R. Hay, personal communication). A preliminary faunal list (M. McKenna, personal communication) from "Mammal Quarry" is crocodile, fish, horse near *Orohippus* or *Haplohippus, Metarhinus,* tapir near *Colodon,* a very large amynodont rhinoceros, small rhinoceros near *Trigonias, ?Merycoidodon, ?Agriochoerus, Hemipsalodon.* No small mammals have been found in spite of

intensive efforts to recover them. The fauna is no older than Uintan and no younger than Chadronian. Fauna similar to that of Hunter Quarry in the Cypress Hills, Saskatchewan, the Titus Canyon Formation in Death Valley, California, and the Vieja Fauna of Texas. All of these sites appear to be either early Chadronian or only very slightly older. Both the small titanothere and the *Orohippus*-like horse may be regarded as relicts.

Hemipsalodon, Agriochoerus, a merycoidodontid, tapir near *Colodon, Haplohippus,* if that is a correct identification of the Clarno specimen, are present in the Porvenir l.f. A large amynodont is present in the Candelaria l.f. A correlation of KA 818, 37.5; KA 824A, 36.5 of the Clarno with 36.5 and 36.8 of the Bracks Rhyolite is very close. The Little Egypt l.f and the Porvenir l.f. both underly the Bracks Rhyolite.

The Colmena Tuff Formation underlies the Buckshot Ignimbrite and overlies the Gill Breccia which contained the volcanic rock dated at 40 m.y. The Colmena Tuff supplies the Candelaria l.f. which contains *Epihippus* and *Harpagolestes* and was correlated by Black and Dawson (1966) as either Uintan or Randlett.

Thirdly, a series of dates from the vertebrate fossiliferous beds of Lone Tree Gulch, Bates' Hole, Natrona County, Wyoming, are given by Evernden and others (1964, p. 190) under KA 1032, The section, "at 690′ along line of section at 6530′ elevation". The relationships of the several ash beds are dated as follows:

Ash J (KA 1032) 31.6	Late Chadronian
Ash G (KA 898) 32.6	Middle Chadronian
Ash F (KA 899) 33.7[4], (KA 900) 35.7[5]	Middle Chadronian
Ash B (KA 895) 35.2[5], (KA 897) 33.3[4]	Early Chadronian

We would therefore suggest that KA 1010, Bracks Rhyolite of Evernden and others (1964, p. 165) would better be placed in their group of dates labeled "Early Chadronian or Duchesnean" rather than as an anomaly within their group of dates labeled "Chadronian".

Most vertebrate paleontologists would assign the Porvenir l.f. to the Oligocene because it includes *Mesohippus, Hyaenodon,* and *Leptomeryx.* Kay (1934) divided the Duchesne River Formation into three members (his "horizons"), which he named in ascending order: Randlett, Halfway, and Lapoint. Small faunas are known from each member. Gazin (1956) correlated the fauna of Wood's Myton Member (1934) of the Uinta Formation with the fauna of the Randlett Member and thus assigned early Duchesnean to the Eocene. Black and Dawson (1966) called the Candelaria (their Colmena) l.f. either Uintan or Randlett. *Epihippus (Duchesnehippus) intermedius,* the only chonologically useful taxon from the Halfway Member, is usually attributed to the late Eocene. One who followed this line of reasoning would place the end of the Eocene Epoch and beginning of the Oligocene Epoch within the Duchesnean Age.

It would seem that the two vertebrate local faunas, Little Egypt and Porvenir both containing *Mesohippus* and found beneath the Bracks

[4] Mineral, sanidine.

[5] Mineral, biotite.

Rhyolite which has been independently dated as 36.5 and 36.8 m.y., are Duchesnean and Oligocene. Furthermore, it would seem that the Candelaria l.f., which contains *Epihippus* and is found above Gill Breccia which is the lowest volcanic formation and has within it a dated volcanic rock of 40 m.y. and beneath the Buckshot Ignimbrite dated as 38.6 m.y., is Duchesnean and Eocene.

It may be that the Duchesnean Age straddles an Eocene-Oligocene boundary, and using the precepts of the Wood committee (1941), a more satisfactory solution might be worked out using only the categories Uintan and Chadronian.

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