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THE TEXAS ACADEMY OF SCIENCE

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# Index to Volume X

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# Tertiary Formations of Rim Rock Country, Presidio County, Trans-Pecos Texas

*by* **RONALD K. DeFORD**
*The University of Texas*

ABSTRACT

The rim rock of the Vieja Rim, the quartz pantellerite of Lord, is named the Bracks Rhyolite. Beneath the Bracks, the "Vieja series" of Vaughn (1900), which is newly subdivided into five formations named, in descending order, the Chambers Tuff, Buckshot Ignimbrite, Colmena Tuff, Gill Breccia, and Jeff Conglomerate, rests unconformably on Upper Cretaceous formations. The Vieja Group is expanded to include also the Bracks and three overlying formations, named, in ascending order, the Capote Mountain Tuff, the Brite Ignimbrite, the Petan Basalt. An ancient post-volcanic gravel above the Petan antedates the bolson fill. The minimum hiatus at the base of the Vieja may include part of the Upper Cretaceous, all the Paleocene, and most of the Eocene epochs. The age of major faulting that created the bolsons is pre-Pleistocene, and probably most of the bolson fill was deposited before the end of the Tertiary Period.

INTRODUCTION

In 1922 Charles Laurence Baker (1927, p. 5, fn. 1) completed a manuscript on the geology of the most inaccessible part of Texas, which he had mapped at the rate of 35 square miles per day. His mapping was an exploratory feat of the first order, and his account of the geology is fundamental. All geologic maps (Stose, 1932; Sellards, Adkins, and Plummer, 1933b; Baker, 1935; Sellards, 1936, 1939; Darton, Stephenson, and Gardner, 1937; Longwell, 1944; Sellards and Hendricks, 1946; Stose, 1946) of the Rim Rock country subsequently published are versions of Baker's (1927: Pl. 1), although Stovall's map (Stovall, 1948: 80) of part of it has additional information.

The Texas-Chihuahua border region, which is still a challenge to map makers, was long a veritable terra incognita. The first Europeans (Davenport and Wells, 1919: 248–259 and map) to visit the Rim Rock country were the fabulous Cabeza de Vaca and his companions, Castillo and Dorantes, who traversed it in 1535, traveling on foot up the east bank of the Rio Grande. In 1581, forty-six years later, Rodriquez (Bolton, 1915: 135–145), two other friars, nine soldiers, and sixteen Indian servants traveled the same route, and the Rodriquez party was followed in 1582 by another party led by Espejo (Bolton: 163–175), a wealthy citizen of the City of Mexico. Then almost exactly a hundred years elapsed before the next party, led by Captain Mendoza (Bolton: 316–326) and preceded 15 days by two friars, went down the west side of the river from El Paso to La Junta (Ojinaga) in the last half of December 1683, recording the precipitous topography

> well overgrown with lechuguilla so that it was not possible to travel by night.[1]

Three hundred years after Cabeza de Vaca's 17 *jornadas*, the first authentic map of any kind, geological or otherwise, was yet to be made. Two early summaries (Hitchcock and Blake, 1874: 8; Hitchcock, 1887) of geological maps of the United States record that Maclure's of 1809 and 1817, the first to be published, and James Hall's of 1843 showed only the geology of the eastern states and that the coloring on Sir Charles Lyell's of 1845 did not extend much west of the 95th meridian. The list contiues: Marcou, 1853; Edward Hitchcock, 1853; Keith Johnson, 1856; and a second by Marcou in July 1855, republished in March 1856 and in 1858. After the return of the Pacific Railway exploring expeditions in 1854–1855, a map of the region west of the 100th meridian was compiled by C. H. Hitchcock or W. P. Blake and exhibited at the meeting of the American Association in Albany, New York, 1856, but it was never published (Hitchcock and Blake, 1874: 8). Shortly afterward, the map of the country west of the Mississippi compiled by James Hall (1875b) of Albany was published.

The geology of the Rim Rock country as published for the first time on Hall's map was based on Emory's boundary survey. Fifteen years later Hitchcock and Blake prepared a geological map of the United States dated 1872 and another dated 1874. On these two most of Trans-Pecos Texas is shown as a wide outcrop of Cretaceous rock. Surprisingly, the 1872 version of Trans-Pecos geology is better than the 1874, and Hall's mapping in the Trans-Pecos region is better than either.

I have not seen Hitchcock's large wall map, scale 20 miles to the inch

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[1] " . . . es forzoso parar por ofrecerse el dia siquiente tierra fragosa y poblada de mesquite, y Uña de Gato aunque andable, y luego ofrecerse una Cuesta muy encumbrada y de la parte del Oriente ocinada y muy poblada de Lechuguilla, casi hasta llegar al Rio del Norte, y no poderse andar de noche."

(Hitchcock, 1887: 482) which was published in 1881. McGee's map (1885: 36–38) of 1884, scale 112.3 miles to the inch, served as the base for Hitchcock's handsomely colored map of 1886, on which the geology of Trans-Pecos Texas was revised once more; but Hall's version of the southwestern part was still the best to date. Hitchcock (1887: 488) justly concluded that

> In the earlier surveys no name stands more prominent than that of James Hall.

Hall's map provides interesting examples of geologic extrapolation. It was based on the work of early explorers, who, by submitting specimens to geologists, had correctly identified Carboniferous rocks, now called Permian, in the Guadalupe-Delaware Mountains on the north and in the Chinati Mountains on the south. Reasonably enough, albeit incorrectly, Hall joined the two outcrops through the Davis Mountains east of the Rim Rock country. He also showed an apocryphal Carboniferous core in the 120-mile range in Chihuahua immediately west of the Rim Rock country. A dozen years later Kimball (1869: 387) remarked that

> The number of Cretaceous fossils collected by myself west of Presidio del Norte, quite disproves the position of Dr. Parry, viz., that the "natural boundaries of this basin (near Presidio del Norte) consist of irregular mountain ranges composed principally of carboniferous limestone similar to that seen above" (near El Paso). But Dr. Parry (1857: 50) in this matter seems to follow Prof. Hall (1857a: 110) who referred the limestone of this section to the carboniferous exclusively on the ground of the lithological analogy with the Carboniferous limestone in numerous western localities of a simple specimen from the rapids of the Rio Grande, in which no fossils could be recognized.

When Streeruwitz (1891b: 685; Geiser, 1957) crossed Vieja Pass in 1886, he made no map but observed with foresight

> that the basaltic and other volcanic rocks predominate in that portion of Trans-Pecos Texas, and that in all probability they are second in value to the Chinatti prospects and the Quitman and the Carrizo Mountains, as far as ore bearing is concerned.

The topography was surveyed in 1892 (Chispa Sheet) and in 1895 (San Carlos Sheet; Vaughn, 1900: Pl. 6). In 1904, B. F. Hill and Udden published a geologic map of the region. Their rough reconnaissance was transferred to the first geologic map of North America (Willis and Stose, 1911) and the first detailed geologic map of Texas (Udden, Baker, and Böse, 1916b). Earlier versions of the geology of

Texas are shown in maps by McGee (1885: 40–41), the Merchants' Association of New York (1901: Chart 8), Simonds (1905: Fig. 2), and Dumble (Merrill, 1920: 492–493). The geology of the adjoining part of Chihuahua is not well known; it is shown on Hall's map, the maps of North America, the tectonic map of the United States, and the recent maps of Mexico (Flores, 1942; King, 1942: Pl. 1; King, 1947: Láminas 1 and 2; Eardley, 1951: Fig. 249, 422; Guzman et al., 1952; Carta Geológica, 1956; Diaz and de Cserna, 1956: Fig. 2). I have not seen "Senor Antonio Castillo's excellent Geological Map of Mexico, Mexico, 1889," which was utilized by R. T. Hill (1893: Fig. 2), or Fleury's map, which was criticized by Kimball (1869: 382 and 383).

In July 1895 (Parker, 1895b: 193; Vaughn, 1900: 75; Bilbrey, 1957), when all Texas west of the hundredth meridian was wild, the Rim Rock country already had a railroad. The Rio Grande Northern, a spur line that extended from Chispa siding on the Galveston, Harrisburg, and San Antonio Railroad (Southern Pacific) over Chispa summit in the pass between the Van Horn Mountains and the Sierra Vieja, was laying track toward the coal deposits at San Carlos, where shafts were being sunk. The railroad reached San Carlos in November, but the shafts did not penetrate commercial coal. Mining by means of adits was begun in January, 1896, but the production was so small that the Galveston, Harrisburg, and San Antonio refused to furnish transportation because it would not be economical. The coal company hired an engine and may have hauled a little coal between January and June 1896, although there is no record of sale. Prior to 1896 the *Mineral Resources* volumes (Ashburner, 1886: 68; Parker, 1895a, 1895b: 193) gave highly optimistic reports of anticipated production, finally in summary (Parker, 1896: 522) of the year 1895, stating that

> The San Carlos mines in Presidio County did not get out any coal, commercially, before the close of the year, the first run over the tipple being made on January 3, 1896.

The authors of subsequent volumes not only failed to report production but simply ignored the subject. (*Cf.*, however, Ries, 1905: 105; Hornaday, 1911; Phillips and Worrell, 1913: 29–31; Phillips, 1915: 201–202; Dumble, 1916: 193; Darton, 1933: 120.) In 1900 the Rio Grande Northern was abandoned. To this day the chief sources of ranch lumber under the rim are the old ties and bridge timbers, and several miles of the old roadbed still serves as the main ranch road, which goes through the railroad tunnel (Vaughn, 1900: Pl. 10) at San Carlos.

The preceding paragraph might be taken as a paraphrase of the futile history, so far, of each mining prospect in the Rim Rock country—

nitrate, silver, manganese, uranium—although none other has entailed quite so elaborate a development as the San Carlos coal district. Exploration for petroleum has also been unsuccessful and unavoidably expensive in this remote country, but at least the wildcatters have drilled their dry holes without erecting tank farms or laying pipe lines to handle the oil they hoped to produce. The outlook for eventual discovery is still favorable.

In 1911, W. B. Phillips (1910, 1911a, 1911b, 1911c; Gale, 1912: 28) inspected a nitrate prospect in the Rim Rock country near Candelaria, where

> nitrate of soda exists as thin crusts on and thin seams in a hard dense trachyte, or lava.

Writing in the third person, Phillips summed up his investigation of nitrate in northern Mexico and western Texas (1911b) in words of disillusionment:

> He has ridden many miles to see white encrustations on the walls of canyons, along arroyos, etc., in the hope that they would prove to be what some enthusiastic prospector had reported they were. Except for the pleasure of the ride and the views of impressive scenery he might have been better employed.

H. M. Robinson (Mansfield and Boardman, 1932: 69–75, Fig. 8) examined the nitrate deposits at a mining camp on Capote Creek 8 miles NE by E of Candelaria in August 1918 and reconnoitred the geology (Robinson, 1918) within 5 or 6 miles of the camp. Mansfield and Vanderwilt examined other nitrate deposits (Mansfield and Boardman, 1932: 77, Figs. 9 and 10, Pls. 9B and 10; Wooton, 1927) in the Candelaria vicinity in June, 1928.

Darton's (1933: Sheet 15) guidebook has a sketch of the geology of the eastern slope of the Sierra Vieja. There is no published record of Sellards' (1933) trip through the Rim Rock country after the Valentine earthquake of 16 August 1931 or of the surveys made by a number of oil company parties in the three decades between 1927 and 1957. Among the early petroleum explorers were V. C. Maley and M. B. Arick; among the later, H. M. Neilson and associates.

In 1932 (Stovall, 1948: 84) Baker discovered bone fragments in the Rim Rock country. Stovall (1948: 85), Savage, McAnulty, and Langston collected fossil mammals in 1938 and 1940; Brown (1941: 103) and Bird collected a few bones and teeth in November 1940. Bryan Patterson (Goldich and Elms, 1949: 1144–1145) and Quinn collected vertebrate fossils in 1946, and Goldich and Patterson made a brief reconnaissance in November 1946; Carlisle, Mankin, and Quinn collected bones in 1954; and J. A. Wilson and Clabaugh, in 1956 and

1957. A field examination has indicated that the X marked "Fossil Locality" on Stovall's map and the corresponding description in the first paragraph of his text must both be wrong; it is probable that his fossils came from Big Cliff two miles farther west, where Patterson and Wilson subsequently collected.

In 1954, 1956, and 1957 graduate students from The University of Texas (DeFord, 1957) mapped the geology of the Rim Rock country in greater detail than has yet been published. The mapping in the summer of 1954 extended from Lat. 30° 06′ to 30° 22′ N. J. E. Peterson mapped part of the eastern slope of the Sierra Vieja east of the high rim. Four parties mapped between the Rio Grande and the high rim, as follows: 06′–10′ N, C. J. Mankin and B. J. McGrew; 10′–14′ N, J. C. Carlisle and C. R. Sewell; 14′–18′ N, B. Buongiorno and J. T. Smith; 18′–22′ N, R. C. Duchin and S. S. Moran.

The mapping in the summers of 1956 and 1957 extended from south of Lat. 30° 22′ to 30° 42′ N. Five parties mapped between the Rio Grande and Vieja Rim, as follows: from south of 22′ to 26′ N, D. G. Bilbrey and J. T. Schulenberg; 26′–30′ N, J. D. Ferguson and W. D. Miller; 30′–34′ N, C. R. Colton and R. G. McKinney; 34′–38′ N, L. W. Bridges and E. J. Dasch; 38′–42′ N, P. Braithwaite and D. R. Frantzen. Robert Allen and J. C. Nichols mapped the Sierra de los Fresnos across the Rio Grande in Chihuahua from 15′ to 23′ N, and D. B. Clutterbuck and A. D. Ferrell, the north end of the Sierra Pilares from 34′ N to the Rio Grande. The mapping in 1957, north of 34′ N, is not shown in the figures in this paper.

As a result of the mapping, the Tertiary sequence may be divided into formations. The purpose of this paper is to present a local classification of the Cenozoic volcanic rocks to serve as a basis for further investigation and publication. It may prove useful to those who undertake to organize the biostratigraphic classification or unravel the tectonic history or find oil.

## GEOGRAPHY AND STRUCTURE

The Rim Rock country occupies a deep valley between parallel mountain ranges. The talweg, the south-southeasterly course of the Rio Grande, called Rio Bravo del Norte by the Mexicans, descends about 7 feet per mile through this drouth-stricken country, which has long been dry. In 1535 Cabeza de Vava (Davenport and Wells, 1919: 253) asked the Indians along the river

> why they did not raise maize, and they replied that they were afraid of losing the crops, since for two successive years it had not rained, and the seasons were so dry that the moles had eaten the corn, so

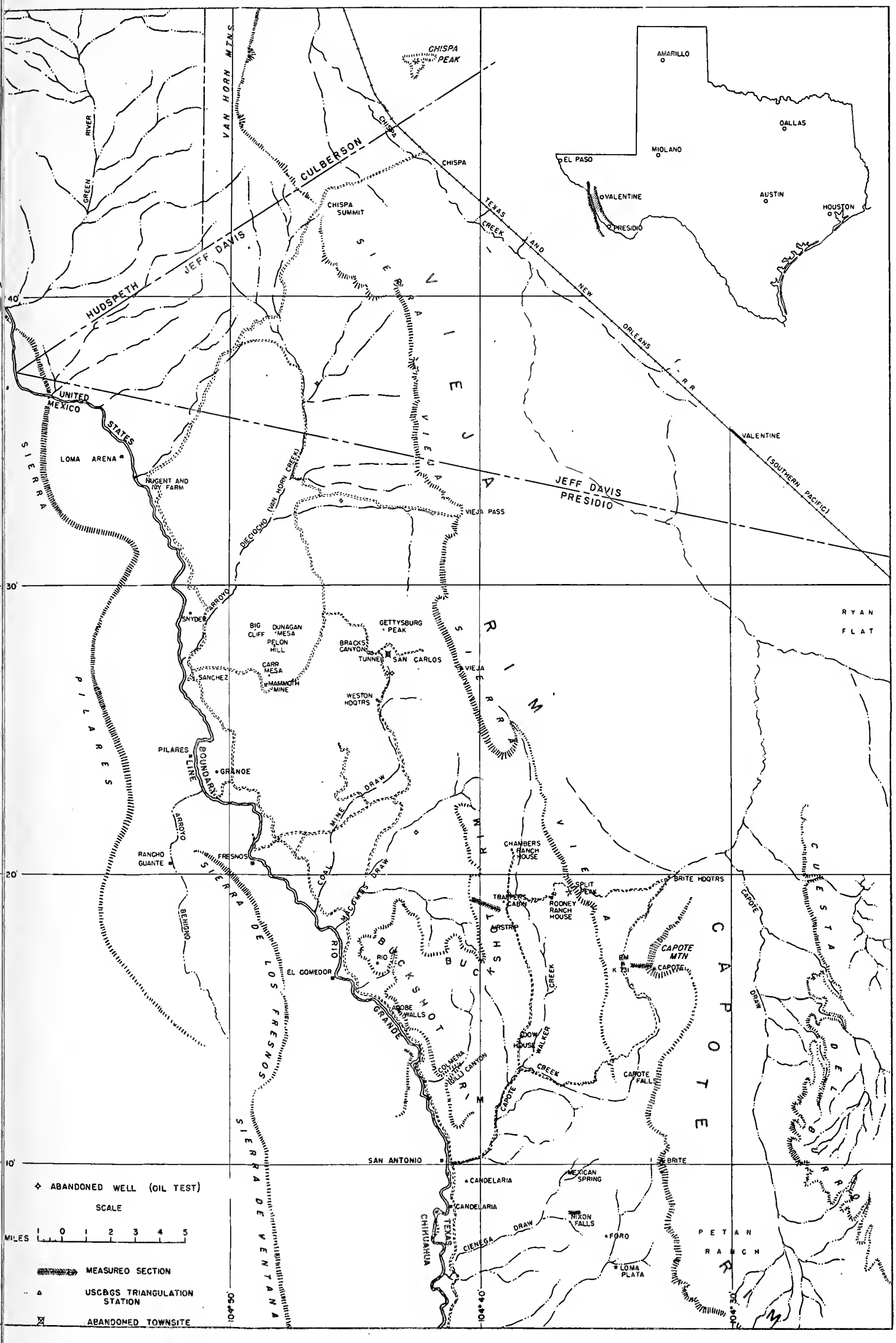


**Fig. 1. Map of Rim Rock Country, Trans-Pecos Texas.**

> that they did not dare to plant until it rained very hard. And they also begged us to ask Heaven for rain.[2]

All the explorers found the same xerophytes that still grow on the rims above the river.

Emory (1857, Part 1: 50)

> was informed, on good authority, that in the summer of 1851 a man drove a gang of mules along the bed of the river from Presidio del Norte to El Paso. The bed was dry for nearly the whole distance, occasional pools of water standing in places. . . .

Nearly 50 years later Dumble (1898: 491) described the river bed below El Paso as

> a sandy plain which is often entirely dry or with water standing in pools. At other times great floods pour down its channel and spread out in the valley. . . .

The drouth then recurrent has since become chronic: from McNary, about 50 miles southeast of El Paso, through the Rim Rock country to Ojinaga (Presidio del Norte), 140 miles southeast of McNary, the Great River now flows only when flooded by summer cloudbursts. Any upstream water spared by the drouth is claimed for irrigation.

The eastern border of the Rim Rock country, the Sierra Vieja, is about half of a 100-mile mountain range along the Texas border. From the north end of the range seven miles south of Van Horn, Texas, the Van Horn Mountains extend southward 17 miles to Chispa Summit. Thence the Sierra Vieja continues 35 miles southward to Capote Peak (Gannett, 1899: 684, 1906: 947; 1928 Texas Almanac: 45), and thence on southward another 15 miles to the head of Pinto Canyon. The high Chinati Mountains, about 20 miles long, extend from Pinto Canyon to Shafter, Texas. Beyond Shafter the range continues another 10 miles to its southern end in Cienega Mountain.

[2] "Preguntámosles cómo no sembraban maíz; respondiéronnos que lo hacían por no perder lo que sembrasen, porque dos años arreo les habían faltado las aguas, y había sido el tiempo tan seco que a todos les habían perdido los maíces los topos, y que no osarían tornar a sembrar sin que primero hobiese llovido mucho; y rogábannos que dijésemos al cielo que lloviese y se lo rogásemos, y nosotros se lo prometimos de hacerlo ansí . . . dijérronos que el camino era por quel río arriba hacia el Norte, y que en diez y siete jornadas no hallaríamos otra cosa niguna que comer, sino una fruta que llaman chacan, y que la machucan entre unas piedras si aun después de hecha esta diligencia no se puede comer, de áspera y seca . . . y ansí, sequimos nuestro camino, y atravesamos toda la tierra hasta salir a la mar del Sur; y no bastó a estorbarnos esto el temor que nos ponían de la mucha hambre que habáiamos de pasar, como a la verdad la pasamos, por todas las diez y siete jornadas que nos habían dicho . . . y ansí pasamos todas las diez y siete jornadas, y al cabo de ellas atravesamos el río. . . ."

The Sierra Vieja (San Carlos Sheet, 1896; Hill, 1899; Gannett, 1902: 139; Phillips, 1904: 5; Simonds, 1905: Fig. 133; Bailey, 1905: Pls. 1, 3, 12, and 14; Deussen, 1910: 62, and 1911: 141; Ransome, 1915: 335; Dumble, 1916: 174; Mansfield and Boardman, 1932: Pl. 10; Texas almanacs, maps of Texas, 1936 and 1943; Darton, 1937; Sellards and Hendricks, 1946; Blair and Miller, 1947: 67, 68, 88; Handbook of Texas, 1952, Vol. 2: 609, 780; Texas almanacs, maps of Texas and Presidio County maps, 1941, 1945, 1947, 1949, 1951, 1953, 1955; Hammond and Encyclopedia Britannica atlases) has also been called the Vieja Mountains (Livermore, 1883; Havard, 1886: 482, 492; Vaughn, 1900: 73; Clarke, 1900: 60; Gannett, 1902: 153; Simonds, 1905: 28; Hammond atlas), the Vieja Range (Shipman, 1926: 19), the Tierra Vieja Mountains (Gannett, 1902: 42, 148; Udden, Baker, and Böse, 1916, 1st ed.: 12, 15, 78, 101; Baker and Bowman, 1917: 119, 124, 141; Baker, 1921: 25; Smith and Walker, 1923, Political Map; Texas almanacs, maps of Texas, 1925, 1926, 1927, 1928; Shipman, 1926: 116; Baker, 1927: 37, 49; Texas almanacs, 1927: 57, 1928: 338; Baker, 1928: 343, 348, 354, 355, 371; Adkins, 1931: 35 and Fig. 7; Carter, 1931: 159; Carter and Cory, 1932: 30; Sellards, 1933: 115; Plummer, 1933: 801, 803; Darton, 1933: 99, 101, 102, and Sheet 15; Baker, 1935: 156, 187, 188, Fig. 15 and Pl. 4; Sellards, 1936; Baker, 1941: 82, 88, 89, 90; Goldich and Elms, 1949: 1144–1145, Fig. 2; Eifler, 1951: 342; Handbook of Texas, 1952, Vol. 2: 780; McAnulty, 1955: 558; Rand McNally and Glydendals atlases) the Tierra Vieja Range (Texas almanac, 1929: 347), the Sierra Tierra Vieja (King, 1935: 241, 243, 254, and Fig. 5; Hinckley, 1947: 162, 164, 165, 171, 172, 177), the Sierra de Tierra Vieja (Baker, 1928: 373, Pls. 20, 21, 22; Baker, 1941: Pls. 10 and 11), the Rim Rock Mountains (Dumble, 1895: 385; Dumble, 1898: 485; Baker, 1935: Fig. 15 and Pl. 4), and, redundantly, the Sierra Vieja Mountains (Hill and Udden, 1904; Chispa Sheet as reprinted in 1938; Jameson and Flury, 1949: 54; York, 1949: 59 and Fig. 2; Phillips and Thornton, 1949: 102; Texas almanac, 1939: 447; Cram's and Stieler's atlases), the Sierra Vieja Range (Blair and Miller, 1949: 67; Jameson and Flury; York; Phillips and Thornton; Texas almanac, 1926: 178; Handbook of Texas, Vol. 2: 609, 841), the Sierra Viejas (Dumble, 1916: 176; Blair and Miller; Jameson and Flury; Phillips and Thornton), and the Sierra Tierra Viejas (York), and, mistakenly, the Sierra de Pilares (Humboldt, 1812b; Solm-Braunfels, 1846a and 1936), and the Chanatte Mountains (Roessler, 1874).

The forms *Viega* (Gannett, 1899, p. 706; 1906, p. 972) and *Viego* (Gillett, 1921: 278–280) are due to inaccurate transcription. The form *Viejo* (Streeruwitz, 1891b: 685; 1892: 386, and 1893: 175; Osann, 1893: 134; Dumble, 1895: 385, and 1898: 485; Shipman, 1926: 95, 156) probably came from Paso Viejo (Gillett, 1925, 200–202, account of 1881; Shipman, 1926: 95 and 199), now called Vieja Pass; indeed, the name of the mountains themselves may have been derived from the name of this old pass. The Sierra Vieja is bounded by two passes and subdivided by two more. From north to south these are Chispa Summit, Vieja Pass, the divide between Capote Creek and Capote Draw near Capote Peak, and the head of Pinto Canyon. Two early maps (Chispa Sheet, 1892; Vaughn, 1900: Pl. 6; cf. Presidio County maps in Texas almanacs, 1941, 1945, 1947. 1949, 1951, 1953, 1955) imply that the name *Tierra Vieja* denoted only that part of the range between Chispa Summit and Vieja Pass. Chispa Summit is mislabeled "Vieja Pass" on Presidio County maps in Texas almanacs, 1945, 1947, 1949, 1951.

The eastern face of the Van Horn Mountains is a scarp related to normal faulting downthrown to the east. The northern and southern parts of the scarp join in a sharp angle. The northern part extends about 9 miles S 10° W to the angle; from it the southern part continues about 5 miles S 45° E to Chispa Summit, beyond which the northern part of the Sierra Vieja shows the same trend for another 3 miles.

Reversing the features of the Van Horns, the western face of the Sierra Vieja, the great rim, is related to normal faulting downthrown to the west. A system of large persistent faults with less persistent smaller faults parallels the rim for 50 miles. The whole Rim Rock country is an intermontane depression due to block faulting. The mean trend of the crest of the sierra is close to SSE, and the local variations from this trend are neither marked nor persistent.

On the eastern slope of the Sierra Vieja the strata dip (Sellards: 1939; Sellards and Hendricks, 1946) eastward under Ryan Flat (Hill, 1900: 9, col. 1), a broad valley of interior drainages, Capote Draw and Chispa Creek, that are not connected with the sea. The altitude of the flat ranges between 4,000 and 4,500 feet above sea level. From it the surface of the ground rises (Vaughn, 1900: Pl. 7) approximately 2,000 feet in 4–8 miles to the crest of the range, terminating in a westward-facing precipice several hundred feet high. Between Chispa Summit and Capote Mountain this precipice (Vaughn: Pl. 8; Baker, 1928: Pls. 21 and 22; Baker, 1941: Pl. 11; Hinckley, 1947: Fig. 1; Keith, 1950: xix) is the Vieja Rim. On the north where its crest is about 12 miles from and 3,000 feet above the Rio Grande, there is a 2,000-foot difference in elevation within a mile and a half of the rim in places; at San Carlos, where the river is 11 miles away, the difference is 2,700 feet (Vaughn: 75, Pl. 6) in 3 miles; the topography of the rest of the country from rim to river is up and down. Farther south the rim is but 10 miles from the river and 3,500 feet above it; this has been described (Shipman, 1926: 117) as

> the highest, wildest looking bluff in the lonesome stretches of the Big Bend. The border bandit could stand on this bluff and look down two thousand feet, then out over miles of broken, uninhabited country to the Rio Grande. In the opposite direction, twenty miles distant he

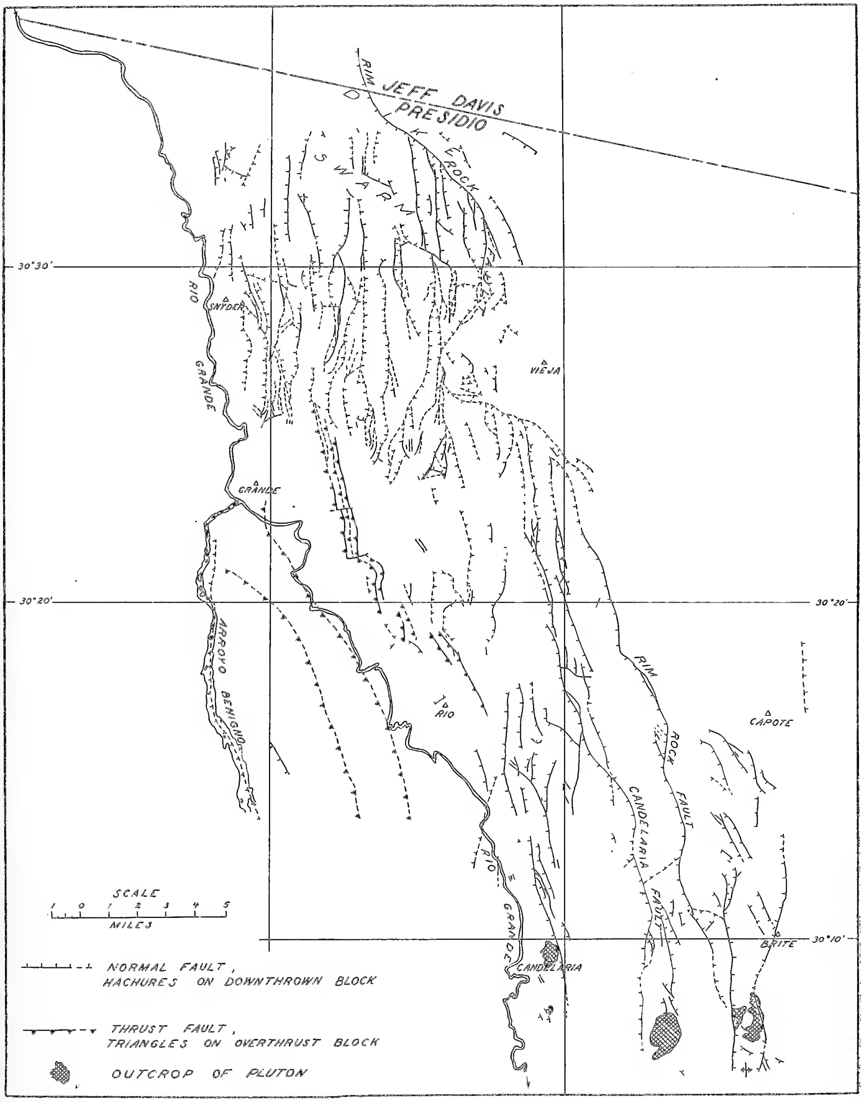


**Fig. 2. Fault pattern in Rim Rock country.**

> might see the link with the outside world—the Southern Pacific passenger train. . . .

At first look the Vieja Rim appears to extend all the way to Pinto Canyon, but closer inspection shows that the still higher Capote Rim, which caps Capote Mountain, is the chief rim of the southern third of the Sierra Vieja. On Robinson's 1918 map the Capote Rim is mislabelled "pantellerite." It was correctly shown above the Vieja Rim by Baker (1928: Pl. 10), by Carter (1931: Fig. 82, mislabelled "Chinati Mts."), and by Baker (1941: Pl. 20; see also Keith, 1950: xix, xxix, and end papers).

The great valley under the Vieja Rim has many local rims that cap tilted blocks bounded by faults. One of the most prominent is the Buckshot Rim (Hinckley, 1947: Fig. 3), which rises many hundred feet directly above the Rio Grande in the southern part of the Rim Rock country (Fig. 1).

The western border of the Rim Rock country formed by the Sierra Pilares and Sierra de Ventana comprises about half of a 120-mile mountain range, most of which is in Chihuahua, Mexico. At the north end of the range, in Texas, is the imposing mass of the Eagle Mountains (Sierra Cola de Aguila of Humboldt, 1812b; Solms-Braunfels, 1846a, 1936; Streeruwitz, 1891a: xci), about 12 miles west of the north end of the Van Horns. The Indio Mountains extend from the Eagle Mountains 15 miles S by E to the Rio Grande, which transects the range in a deep canyon. The dry wash, tributary to the Rio Grande, between the parallel Van Horns and Indios is called Green River. On the Chispa Sheet and most subsequent maps it is named Glenn Creek, but that name is no longer in local use. Streeruwitz's usage (1891a: xci and xcii) seems to indicate that Green River Canyon and Glenn Creek once were names of different places, whereas Baker (1927: 40; see also 1935: 139 and 201) 30 years later wrote about the "head of Green River (Glenn Creek)" as a single locality.

From the Rio Grande the Sierra Pilares extends 30 miles S by E and the Sierra de Ventana continues another 30 miles, whence it swings due S 10 miles to a junction, near Cuchillo Parado, with the Sierra Grande, which continues 25 miles S by E to the southern end of the range at La Mula. The mountains are composed dominantly of Lower Cretaceous limestone, which, in contrast with the rim rocks, is sharply folded and thrust-faulted. The front of the Ventanas rises steeply from the Rim Rock country within three or four miles of the Rio Grande. The steep front of the Pilares is in similar position expect that on the north it joins the river, and on the south the Sierra de los Fresnos stands as a partly distinct frontal element within a mile of the river. The *ventana* from which the Sierra de Ventana probably got its name is actually in the crest of the Fresnos; it was mentioned in Mendoza's narrative[3] of the expedition of December 1683.

### LITHOSTRATIGRAPHY

The chief rim rock, the Bracks Rhyolite that caps the Vieja Rim, is the key to the Tertiary stratigraphy of the Rim Rock country. This is the quartz pantellerite of Lord (Vaughn, 1896; Vaughn, 1900: 77, 81, 82, 83, Pls. 8 and 10; Lord, 1900: 88–95). The "Vieja series" as originally defined by Vaughn (1900: 77; p. 81, Resumé of San Carlos section) included all the Tertiary formations below the base of the Bracks, but excluded the Bracks, although Adkins (1933: 513) stated inaccurately that Vaughn's Vieja included the pantellerite. Adkins instinct was right. Vaughn was not aware of the presence of volcanic rocks younger than the pantellerite. Mapping in the northern part of the Rim Rock country where the Bracks key bed is missing has emphasized the practical need for a group of all the volcanic formations. It is therefore proposed to expand the Vieja Group to include also the Bracks, the Capote Mountain, the Brite, and the Petan formations.

The Vieja rests unconformably on Upper Cretaceous rocks; in many places the contract is concordant, but in others the Cretaceous rocks were folded or thrust-faulted prior to Vieja deposition. The minimum unconformity at the base of the Vieja Group under the Vieja Rim near San Carlos probably entails the absence of some of the Upper Cretaceous, all the Paleocene, and most of the Eocene. In some other outcrops in the Rim Rock country most of Upper Cretaceous is also missing.

In descending order the formations of the Vieja Group are:

> Petan Basalt, Brite Ignimbrite, Capote Mountain Tuff, Bracks Rhyolite, Chambers Tuff, Buckshot Ignimbrite, Colmena Tuff, Gill Breccia, Jeff Conglomerate.

All except *Jeff* and *Vieja* are new names proposed in this paper; their descriptions are extracted chiefly from two unpublished theses by Sewell and McGrew. To understand the derivation of the new names let us refer to Figure 1, beginning at Candelaria (8.5–41).[4] The mouth of Capote Creek is two miles upstream from Candelaria. Colmena Canyon, the next considerable tributary to the Rio Grande on

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[3] "En veinte y quatro dias del dho. mes y año salimos de este pasage que por nombre se le puso N. S. de Belen por un Portillo que hace en los alto de una sierra que está de dicho pasage como media legua poco mas ó menos y el dicho Portillo hace como á modo de ventanas." Bolton (1916: 323).

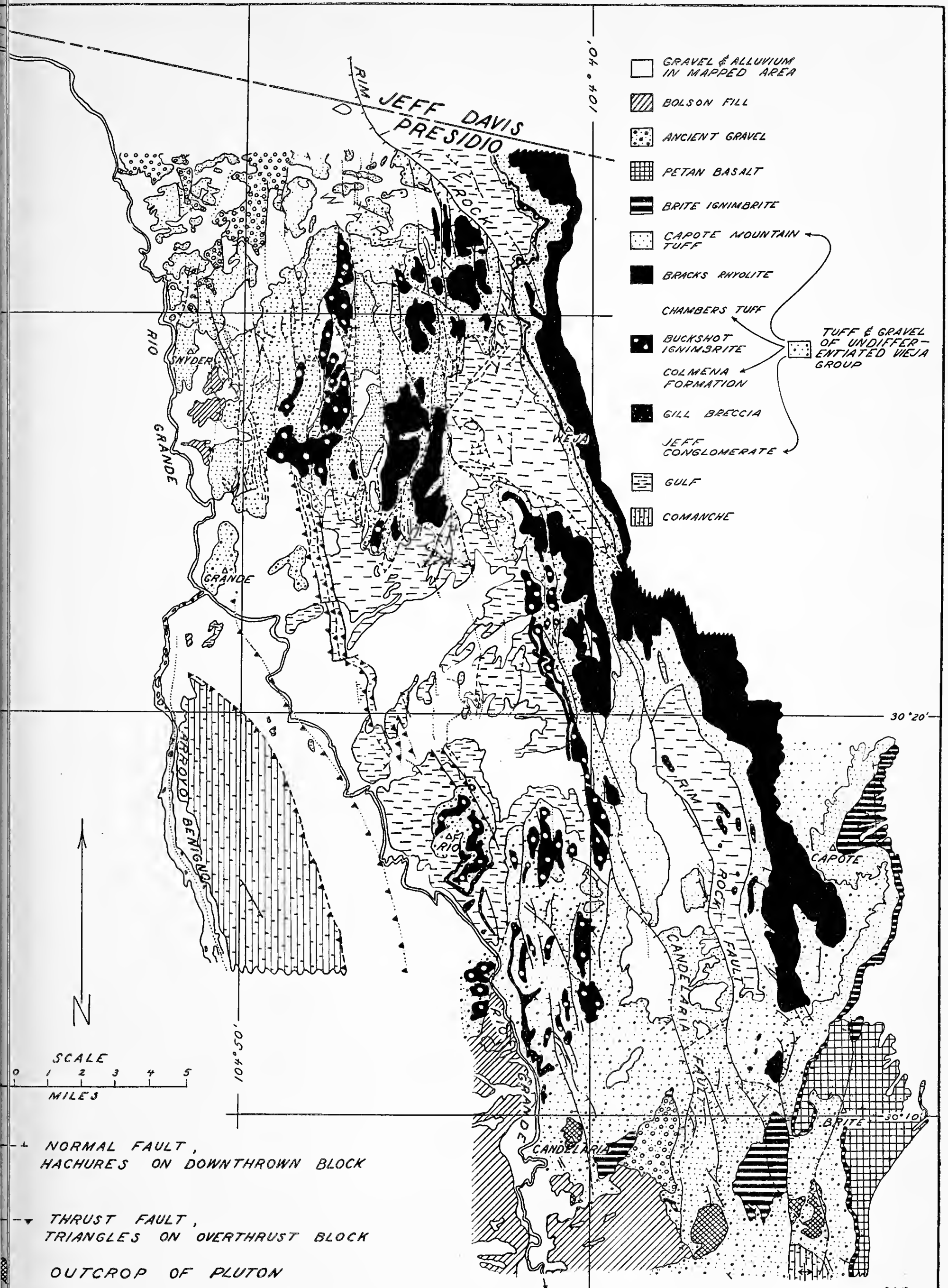
[4] 30°8.5'N, 104°41'W; the geographic coordinates used hereinafter are all in minutes north of Lat. 30°N and west of Long. 104°W.

the Anglo-American side, three miles farther upstream (13–42), called Gill Canyon on the San Carlos Sheet, is a gap in the Buckshot Rim. The Chambers (20.8–38.8) and the Rooney (19–37.2) ranches are N of Candelaria between the river and the Vieja Rim, the Chambers headquarters 15 miles N by E from Candelaria and the Rooney 2½ miles SE of the Chambers. The Rooney ranch is directly beneath Split Peak (Keith, 1950: xxxvii), where a trail over the high rim marks the site of an abandoned road; this is 8 miles N of another trail over the rim that marks the site of the abandoned grade of the old county road from Valentine to Candelaria via the Brite headquarters N of Capote Mountain. The Petan ranch is on the Capote Rim near Pinto Canyon. The name *Jeff* does not belong to the Rim Rock country.

*Jeff Conglomerate.*—Eifler (1951: 343–344) named the Jeff Conglomerate, the type locality of which is in the Barrilla Mountains about 70 miles from the Rim Rock country, NE of Pinto Canyon (2–28) and E of Chispa Summit (43–47). By mapping outcrops, the Jeff has been traced as a practically continuous body from its type locality to the northern end of the Davis Mountains about 30 miles NE of Chispa Summit. There are no outcrops of Jeff in these intervening 30 miles.

The basal conglomerate (Baker in King, 1935: 243; Goldich and Elms, 1949: 1145) of the Vieja Group is notably similar to the Jeff Conglomerate (Eifler: Pl. 2; McGrew, 1955: 34–36, Figs. 9–11: Sewell, 1955: 17–19, Pl. 9; Peterson, 1955: 20–22). In much of the southern part of the Rim Rock country the Gill Breccia intervenes between the basal conglomerate and the Colmena Tuff. Northward the breccia pinches out and the conglomerate thickens, presumably as the lower part of the Colmena Tuff grades into conglomerate, so that on the north a major part of the interval between the Buckshot Ignimbrite and the base of the Vieja Group is occupied by conglomerate. It is arguable that a new name should be given to the basal conglomerate of the Rim Rock country or that the conglomerate and the tuff should be described as interfingering facies of the Colmena Formation, but it is proposed, nevertheless, to use the name *Jeff Conglomerate*, at least until the detailed mapping on the north is more nearly complete.

*Gill Breccia.*—In much of the southern part of the Rim Rock country where the outcrops of Jeff Conglomerate are difficult to detect, the obvious basal unit of the Vieja Group is a flow breccia, named herein the Gill Breccia, which attains a maximum thickness of 300 feet in the type section in Colmena Canyon. The Gill may be composed of a series of flow breccias. Sewell (1955: 22–31, Pls. 11–16) recognized three rock types, to-wit: (1) medium gray fragments in a grayish red




3 Areal geology of Rim Rock country.

matrix; (2) mottled fragments (pink, green, yellow, gray, and brown) in a dark greenish gray to orange pink matrix; and (3) brecciated to massive light olive green to dark greenish gray fine-grained rock. The majority of the fragments are composed of trachybasalt porphyry. although the composition of the rock may be said to range from trachyandesite to basalt. McGrew (1955: 36–43, Figs. 12–16) described and illustrated the petrography in detail.

The Gill Breccia contains blocks (Sewell, 1955: 14, 23–26, Pl. 8; Moran, 1955: 55–60, Figs. 12 and 13; Duchin, 1955: 26) of massive Lower Cretaceous limestone, some of them as large as a three-story building. The locations of nine of these blocks were described by Sewell (1955: 23–24) as follows: (block 1) the most accessible limestone block is on the east bank of the Rio Grande, where it causes a steep hill (10.5–41.4) on the river road about 2½ miles N of Candelaria and a quarter of a mile N of the Capote Creek crossing; (blocks 2 and 3) there are two blocks in Colmena Canyon (13–41.5) about 0.8 mile from the mouth, and (blocks 4 and 5) two more in Colmena Canyon (13.5–41.1) about a mile and a half from the mouth and about 0.1 mile up the eastern fork of the mainstream; (blocks 6 and 7) there are two blocks about a mile (16–34) up a draw from its mouth at Adobe

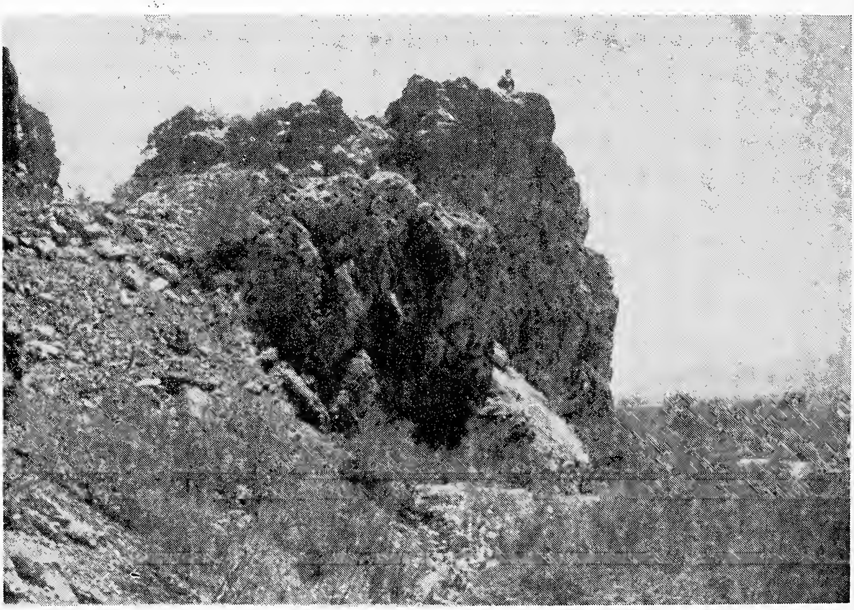


**Fig. 4. South-southwestward view of block of Lower Cretaceous limestone (block 1) in Gill Breccia 2½ miles N of Candelaria. The Rio Grande skirts the base of the block. In the distance beyond the Rio Grande valley is the Sierra de Ventana. Man on top gives scale. River road passes through notch at upper left. Photograph by C. R. Sewell (1955).**

Walls on the river road about six miles upstream from block 1; (block 8) there is a block under the Vieja Rim about a mile N (13.7–35.4) of the old Candelaria-Brite ranch county road; (block 9) and another along the Rim Rock fault about a mile NW (14–36.3) of block 8. After reviewing the several possibilities that the blocks are klippen, landslide blocks, peaks of buried mountains or eroded crests of anticlines, or the result of sedimentary intrusion, Sewell, Moran, Clabaugh, and DeFord favored the hypothesis that the blocks were brought up by the magma that formed the Gill Breccia. Lonsdale did not concur.

In most of the few good exposures on the south, the base of the Gill Breccia is concordant with the underlying Jeff Conglomerate or Upper Cretaceous formation. Its upper surface appears to form buried hills under the Colmena Tuff.

*Measured Section 1.*—The type locality (8.3–37.2) of the Colmena and Buckshot formations, which overlie the Gill, is Measured Section 1 (MS 1), four miles due E of Candelaria (8.5–41). It is hard to get to. The trail to Mexican Spring (9.7–36.6) joins Cienega Draw about three miles east of Candelaria and continues thence up the draw the rest of the way, passing the mouth of the tributary from Nixon Falls about half a mile upstream. MS-1 (8.3–37.2) is in a northeastern side canyon about a mile up this tributary from its mouth and about a mile down it from Nixon Falls (8–36.4), which are a mile and a half WNW of Ford ranch (7.5–35). It may prove desirable after further work to propose a more accessible reference locality, although no part of the Rim Rock country is readily accessible.

From bottom to top, MS-1 extends from SW to NE. The beds dip about 8° E. The section was measured and sampled in August, 1954, by C. J. Mankin and B. J. McGrew (McGrew, 1955, MS 4: 100–102; Sewell, 1955, MS 4: 96–98; Peterson, 1955, MS-4: 65–68). Their description follows:

| *Unit* | *Description* | *Thickness in feet* |
|---|---|---|
| BUCKSHOT IGNIMBRITE: | | |
| 18 | *Rhyolite porphyry* | 50 |
| COLMENA TUFF: | | |
| 17 | *Tuff conglomerate:* dusky yellow, weathers dark brown; massive; extremely hard; boulders round to subround | 32 |
| 16 | *Tuff conglomerate:* white on fresh exposure, weathers light brown; weathered surface is rough and hackly; contains well-rounded pebbles, cobbles, and boulders of igneous and tuffaceous material; jointing strikes N66°E, dips 75°SE | 21 |

| Unit | Description | Thickness in feet |
|---|---|---|
| 15 | *White tuff:* hard; slightly nodular on surface; random jointing probably due in part to weathering | 18 |
| 14 | *Tuff and conglomerate:* pale red purple tuff grading upward into red conglomerate with boulders up to 2 feet in diameter; conglomerate grades upward into pale purple tuff | 106 |
| 13 | *Tuff:* light brown; containing numerous holes due to weathering; locally changes to tuff conglomerate and grades upward into conglomerate | 81 |
| 12 | *Tuff conglomerate:* yellow; massive; boulders and pebbles subangular to subround, diameter 1 inch to 1 foot, average 3 inches; resistant to weathering | 48 |
| 11 | *Tuff:* pale purple; nodular; no evident bedding; locally numerous holes due to weathering; faintly cross-bedded in a few places | 49 |
| 10 | *Tuff:* white; thin-bedded; grading upward into light brown tuff, then upward into pale green tuff; upper 4 feet resistant and thick-bedded; green tuff contains pebbles of purple, white, and dark green tuff | 11 |
| 9 | *Tuff:* dark red; hard; beds 1 foot or more thick; nodular | 11 |
| 8 | *Tuff:* variegated, predominantly pale green with stringers of pale purple | 5 |
| 7 | *Tuff:* pale red purple with white splotches; hard; nodular; some beds are honeycombed | 22 |
| 6 | *Tuff:* very light gray (N8), containing small, greenish yellow, rounded inclusions and random splotches of pale purple; massive | 11 |
| 5 | *Tuff:* variegated, grayish red purple on fresh exposure, weathering to pale purple; nodular; very loose; contains several 6-inch bands of greenish yellow tuff | 11 |
| 4 | *Tuff breccia:* matrix pale red purple on fresh exposure, weathering to light brownish gray; angular fragments pale green, red, brown, and black; massive | 22 |
| | Measured thickness of Colmena Tuff | 448 |

UNCONFORMITY.
JEFF CONGLOMERATE:

| | | |
|---|---|---|
| 3 | *Conglomerate:* cemented by calcareous reworked material; boulders and pebbles subround to round, chiefly well-polished sedimentary-quartzite pebbles and dark-gray limestone pebbles, diameter ranging from 1 inch to more than 1 foot, with a few boulders of 3 feet, average 4 inches; local sandstone lenses 1–2 feet long, sand is the same as in Unit 2 | 20 |

| Unit | Description | Thickness in feet |
| --- | --- | --- |
| 2 | *Sandstone:* dusky yellowish gray on fresh surface weathering to dark yellowish gray; medium-grained; calcareous; faint cross-bedding in places; grades upward into conglomerate | 2 |
| | Measured thickness of Jeff Conglomerate | 22 |
| | Total thickness measured | 520 |

BASE OF VIEJA GROUP.
UPPER CRETACEOUS MARL:

| | | |
| --- | --- | --- |
| 1 | *Marl:* dark yellowish orange on weathered surface, medium yellowish orange on fresh exposure; massive; locally contains gypsum and irregular concretions; in places bears shells of *Gryphaea aucella;* shows polygonal jointing on exposed surface | ? |

*Colmena Tuff*.—The rough topography created by the emplacement of the Gill Breccia was smoothed by the deposition of the Colmena Tuff. Consequently the Colmena is missing in some places, even though its thickness exceeds 450 feet in others.

The Colmena is composed of beds of rhyolitic tuff and beds of conglomerate with pebbles, cobbles, and boulders of Gill Breccia and some pebbles and cobbles of Lower Cretaceous limestone; near the mouth of Capote Creek it contains beds of tuffaceous non-marine limestone 4 to 10 feet thick; near Loma Plata (6.3–34.5), beds of silty claystone and a layer of a glassy flow-rock. It can be described as a light-brown tuff-conglomerate interbedded with variegated tuff. The principal colors are brown, pink, and red. The lower part of the formation is calcareous. Four random thin sections described by McGrew (1955: 44 and 114) show a fine-grained rhyolitic tuff containing 7–10% quartz with some chert; the remainder is composed of sanidine, orthoclase, plagioclase, and igneous-rock fragments; magnetite or ilmenite is common; biotite, sphene, apatite, and augite are present. The grains are subangular, poorly to well sorted. The usual cement is opal and chalcedony; locally the rock contains as much as 30% calcite. Bone fragments are common in the lower part of the formation.

The available information about the vertebrate fossils collected from the Colmena Tuff in the southern part of the Rim Rock country has been summarized by Mankin (1955: 86–91). The age of the fossils is Duchesnean or Chadronian; that is, latest Eocene or early Oligocene. In most places, but unfortunately not in all, the Colmena is overlain by the Buckshot Ignimbrite; the caprock of the Buckshot Rim is a typical outcrop of the Buckshot.

*Buckshot Ignimbrite.*—Although the rhyolite prophyry that caps the Buckshot Rim looks like lava rock, its matrix in thin section shows glass shards and other pyroclastic material, and it is proposed to call it the Buckshot Ignimbrite (McGrew, 1955: 25–30, 44–53, Figs. 18–21). It is resistant to erosion and forms a caprock 40 to 75 feet thick in many places. The rock exhibits well-developed vertical jointing and breaks with an even to slightly conchoidal fracture. The color of the fresh rock is grayish red to moderate yellowish brown; the weathered surface, pale to dark reddish brown. A dusky green layer of brittle glassy rock is present locally at the base of the Buckshot. The ignimbrite ranges from non-porous at base to vesicular at the top, the length of the amygdules averaging about 1 cm., most of them containing a ferriferous carbonate or chalcedony or both. In many places the rock is characterized by abundant round dark-reddish-brown spots of buckshot size, many of which have small centers, grayish red like the matrix, and thick, very dark red to blackish red rims. Most of the phenocrysts, which compose about 20% of the rock are sanidine; some are orthoclase, and some, quartz.

The upper surface of the Buckshot Ignimbrite (Sewell, 1955: 34–38, Pls. 17–20; Peterson, 1955: 27–29) is dotted by circular blister cones (Sewell, Pl. 17) from 1 foot to 5 feet high and 2 to 50 feet in diameter and marked by folds (Sewell, Pl. 18) about 100 feet long, 6 feet high, and 5 feet across. Next above the Buckshot is a thick tuff, which rests directly on the Colmena Tuff where the Buckshot is absent.

*Chambers Tuff.*—The name *Chambers Tuff* is proposed for a formation that comprises the strata between the top of the Buckshot Ignimbrite and the base of the Bracks Rhyolite. Where the Buckshot is absent the Chambers and Colmena may be differentiated by identifying the horizon of the Buckshot; if its identity proves somewhere to be too problematic for practical use, the lithostratigraphic name *Vieja* will still be applicable to the combined sequence. Similarly where the Bracks Rhyolite is absent as in the southern end of the Rim Rock country and in its northern third west of the Vieja Rim, the undifferentiated Vieja may serve as a map unit. Probably the horizon of the Bracks, that is, the Chambers-Capote Mountain contact, can be practically established in some places, but not everywhere.

The moderately to well bedded Chambers Tuff presents a drab array of colors, mostly pale yellowish brown, and grayish green in the upper 250 feet, and dull somber, pale red to dark reddish brown in the lower 150 feet (Sewell, 1955: 39–40, 100–101, 105–106, Pl. 17). In the southern part of the Rim Rock country it contains a persistent layer of coarse sandstone with lenses of cobble conglomerate about 130 feet above the base.

In two thin sections from the Chambers, McGrew (1955: 53–55, 104–105, 108–109, 113) described a fine- to medium-grained rhyolitic tuff containing 5 to 10% quartz with some chert, sanidine, orthoclase, plagioclase, and fragments of rhyolitic glass and volcanic rock. Magnetite or ilmenite, biotite, and a pyroxene are also present. The grains are subangular. Most of the cement is calcite; some of it is silica.

The vertebrate fossils collected in the northern part of the Rim Rock country by Stovall, Patterson, Wilson, and their associates all came from the Chambers Tuff. Although superposition demonstrates that the Chambers is younger than the Colmena, the first look at the fossils from each seems to indicate the same geologic age. Careful paleontological work may yet show a difference or may fail to show it; the resemblance is close.

*Measured Section 2.*—The type locality (20–40) of the Chambers Tuff is at Measured Section 2 (MS-2), about 12 miles N of Candelaria (8.5–41). The river road extends about 2 miles N of Candelaria to the mouth of Capote Creek. Thence the road to Chambers, formerly Dan (Robinson, 1918), Ranch (20.8–38.8) extends northeastward up Capote Creek about 5½ miles to the mouth of Walker Creek, up which it extends about 1½ miles N to the Dow house and continues N up Walker Creek 5 miles to an airplane landing strip and thence N another mile to a house on the W side of the road, known as the trapper's cabin. The end of the road is at Chambers Ranch another 2 miles N. The top (18.75–39.1) of MS-2 is 0.3 mile W of the road, half a mile NNW of the airstrip, and 0.4 mile S of the trapper's cabin. The base (19.2–40.4) of MS-2 is about 1.4 miles almost due W of the cabin and 2.5 miles SW of the Chambers headquarters. From bottom to top, MS-2 extends about 1½ miles ESE. The section was measured and sampled by R. C. Duchin and S. S. Moran in the summer of 1954. Their description follows:

| *Unit* | *Description* | *Thickness in feet* |
|---|---|---|
| CAPOTE MOUNTAIN TUFF: | | |
| 54 | *Tuff:* very thin-bedded; above is about 100 feet of tuff that was not measured; section ends on Triangle Hill between the Bracks Rhyolite and the Brite Ignimbrite | 9 |
| 53 | *Tuff:* alternating red and pink beds that weather to rounded ledges; fine-grained | 76 |
| 52 | *Tuff:* pinkish gray; hard; fine-grained; thick-bedded; bottom part is very pitted by weathering | 13 |

| *Unit* | *Description* | *Thickness in feet* |
|---|---|---|
| 51 | *Sandy tuff:* pale reddish brown with mottled patches locally; fine- to coarse-grained; weathers to rounded ledges | 77 |
| 50 | *Tuff:* pale reddish brown; coarse-grained; beds 1–3 feet thick, weather to rounded ledges; surfaces pitted | 51 |
| 49 | *Calcareous tuff:* white at base, grading upward to alternating soft and hard, pale purple layers; weathers into the hill | 5.8 |
| 48 | *Purple tuff* | 12 |
| 47 | *Tuff:* very light gray (N8) at base, beds above are grayish pink (5R8/2) and pale red (5R6/2); beds 1–8 feet thick, weather to rounded ledges | 70 |
| 46 | *Tuffaceous-sandstone key-bed:* brown, weathering to pale red and dark reddish brown, hard, tuffaceous quartz-sandstone, just below which is 3-foot bed of pink, highly calcareous tuff; beds 1–4 feet thick weather to rounded, prominent ledges | 16 |
| 45 | *Tuffaceous quartz-sandstone:* pale red; hard; medium- to coarse-grained; beds 1 foot to several feet thick; weathers to well-rounded ledges | 45 |
| 44 | *Tuffaceous quartz-sandstone and sand:* brown; subrounded fine-to-medium quartz grains; weathers to form ledges | 47 |
| 43 | *Sand and sandstone:* interbedded, fine- to coarse-grained sandstone and calcareous sand; sand is light yellow green, soft, friable, with subrounded quartz grains; sandstone is brown to pale red purple, hard; together they form a slope with protruding ledges; harder layers are near the top | 68 |
| 42 | *Quartz-sandstone:* light brown to reddish brown; hard; coarse-grained; thick-bedded at base and thin-bedded at top; quartz grains subrounded; weathers to form large rounded masses and ledges | 29 |
| 41 | *Quartz-sandstone:* light gray; fine-grained; calcareous; alternating soft and hard layers; thin-bedded | 3.8 |
| 40 | *Sandstone and tuffaceous sandstone:* medium- to very coarse-grained; some beds well consolidated, light yellow gray, form ledges; interbeds of soft, loose, grayish red sandstone | 45 |
| 39 | *Argillaceous limestone:* soft; thin beds; weathers back into the hill | 12 |
| 38 | *Sandstone and tuff:* pale reddish brown; coarse-grained; a few soft tuff beds and one thin calcareous layer are present | 16 |
| 37 | *Sandy tuff:* red brown; indurated; top 3–5 feet is pale pink, soft | 24 |
| 36 | *Quartz-sandstone:* grayish brown, weathering to dark red brown; coarse-grained; forms rounded ledges | 11 |
| 35 | *Quartz-sandstone key-bed:* moderate brown, weathered surface reddish brown; irregularly bedded to cross bedded; medium-to-coarse subangular quartz grains; weathers to form prominent ledge above the light-colored beds | 27 |

| *Unit* | *Description* | *Thickness in feet* |
|---|---|---|
| 34 | *Sandstone:* light pink to grayish pink, (light color distinguishes this bed); very fine-grained; indurated to hard; calcareous at base, tuffaceous at top; thin-bedded, weathers to thin ledges and rounded blocks | 6.4 |
| 33 | *Tuffaceous sandstone:* pale red purple, weathered surface grayish red; coarse-grained with a few pebbles; subrounded quartz grains; weathers to prominent ledges several feet thick | 30 |
| 32 | *Tuff:* pale purple; soft; weathers back into hill | 11 |
| 31 | *Tuff:* pale purple; very fine-grained; hard; thick-bedded; pitted surfaces; weathers to prominent, rounded ledges | 8.8 |
| 30 | *Sandstone and tuff:* purple; soft; medium-grained; thin-bedded; hard, pale purple sandstone forms a prominent ledge in middle of Unit 30 | 7.6 |
| 29 | *Sandstone and tuff:* dusky red; coarse, subrounded quartz grains; beds 1–3 feet thick | 34 |
| 28 | *Sandstone:* pale grayish purple to light gray, weathers to give a pink and white streaked appearance, upper part is brown and contains pebbles locally; coarse, subrounded quartz grains; forms a rounded ledge | 27 |
| 27 | *Tuff:* dull red with white spots; hard; fine-grained; slightly sandy; weathers to form block-shaped ledges | 1.8 |
| 26 | *Sandy tuff:* mottled and purple and white; indurated; fine-grained; contains large amount of biotite; weathers to gentle slope | 4.3 |
| 25 | *Tuff:* brownish gray, weathering to rusty gray brown with white patches; very fine-grained; hard; contains key bed 1–4 feet thick that stands out as a massive ledge | 22 |
| 24 | *Tuff:* mottled, light grayish purple; indurated; very fine-grained; thin-bedded | 6 |
| | Measured thickness of Capote Mountain Tuff | 817 |

BRACKS RHYOLITE:

23 *Rhyolite:* thickness not measured.

TOP OF VIEJA GROUP.
CHAMBERS TUFF:

| | | |
|---|---|---|
| 22 | *Quartz-sandstone:* light gray, weathers to light green; indurated; grains coarse to very coarse, subangular; beds 1–4 feet thick | 25 |
| 21 | *Tuff:* light grayish purple; hard; thin-bedded; weathers to broken, block-shaped ledges | 17 |

| Unit | Description | Thickness in feet |
|---|---|---|
| 20 | *Tuff:* light gray with white specks; slightly sandy; hard; massive; weathers to steep, rounded ledges which form prominent breaks in the slope | 18 |
| 19 | *Tuffaceous quartz-sandstone:* light gray; grains coarse to very coarse, subangular to round; beds 1–2 feet thick | 22 |
| 18 | *Tuffaceous sandstone:* very dull reddish brown; hard; grains subrounded, medium to coarse; thin-bedded; weathers to a ledge with some thin tuff breaks | 15 |
| 17 | *Tuffaceous quartz-sandstone:* light gray; medium-grained; indurated; thin-bedded; weathers to ledges with some soft breaks | 15 |
| 16 | *Tuff:* light gray with green splotches; slightly sandy; alternating soft and hard layers | 9.8 |
| 15 | *Quartz-sandstone:* reddish brown; indurated; coarse-grained; beds 1–2 feet thick form subrounded ledges | 23 |
| 14 | *Quartz-sandstone:* light gray to dull reddish brown; medium- to coarse-grained; most layers are indurated, some are friable; slightly calcareous; beds 1–2 feet thick weather to rounded ledges | 30 |
| 13 | *Tuff key-bed:* grayish red (10R4/2); very hard; very fine-grained; weathers to sharp, angular blocks that form a ledge | 1.8 |
| 12 | *Tuff:* pale red purple; fine-grained; beds 1 foot to several feet thick; weathers to rounded blocks | 139 |
| 11 | *Tuff:* pale red purple with white specks; beds 1 foot to several feet thick weather to rounded blocks | 32 |
| 10 | *Tuff:* grayish purple; fine-grained; indurated; poorly bedded | 37 |
| 9 | *Tuff:* pale green; fine-grained; indurated; some dark minerals present, but sparse; irregular, nodular bedding with more consistent bedding toward the top | 7.2 |
| 8 | *Tuff:* grayish purple (5P4/2) to dark gray (N4); fine-grained; soft at bottom grading to hard at top; weathers to resistant, block-shaped masses | 6.0 |
| 7 | *Tuff:* light greenish gray to greenish white; fine-grained; thin-bedded; weathers to rounded blocks | 13 |
| 6 | *Tuff:* dark reddish brown with small dark specks; hard; thin-bedded; contains some small pebbles; weathers to small blocks | 57 |
| 5 | *Tuff:* grayish purple; homogeneous, very fine-grained; beds 1–2 feet thick; some beds form ledges | 64 |
| 4 | *Tuff:* pale red purple; fine-grained; massive | 11 |
| 3 | *Sandy tuff:* grayish purple with dark specks; massive; weathers back into hill | 6.1 |
| 2 | *Tuff:* pale red (5R6/2) speckled by muscovite; fine-grained; beds form ledges | 4.7 |

| Unit | Description | Thickness in feet |
|---|---|---|
| 1 | *Tuff:* pale red purple; soft; friable; thin-bedded, forms gentle slope | 4.8 |
| | Measured thickness of Chambers Tuff | 558 |
| | Total thickness of MS–2 (excluding Bracks) | 1,375 |
| | TOP OF BUCKSHOT IGNIMBRITE. | |

*Bracks Rhyolite.*—The preceding section (MS–2) shows more than 800 feet of tuff overlying the Chambers and separated from it by the Bracks Rhyolite, which Lord called pantellerite. This important stratigraphic marker is the chief rim rock of the Rim Rock country. Its place in the stratigraphy was first recognized during the development of the coal deposits at San Carlos. The end of the abandoned railroad grade still marks the site of the coal mining town, but not a building remains. San Carlos was located in a topographic basin (Vaughn, 1900: 75) that is almost completely surrounded by rims of Bracks Rhyolite, and Coal Mine Draw (Fig. 1), Vaughn's San Carlos Arroyo, drains the basin southward. The newly proposed stratigraphic name *Bracks* is taken from the narrow gorge (38–44) called Bracks Canyon (San Carlos Sheet; Vaughn: 82, Pls. 6 and 10), which cuts through the outcrop of Bracks Rhyolite just west of San Carlos. In view of the original description, the proper place for a type locality appears to be in the vicinity of San Carlos, probably the high Vieja Rim (Vaughn: Pl. 8) east of the basin, which is the thickest outcrop of Bracks, although the rim is not readily accessible, and the high cliff face would be difficult to sample foot by foot. The maximum thickness of 300 feet or more decreases northward, southward, and westward, as the Bracks completely peters out on the northwest, north, and south; but its fate due west of San Carlos is not recorded in the outcrops, and eastward it dips underground.

The characteristic color of the Bracks is greenish, ranging from light olive gray to greenish black. In places it is dark reddish brown. The original description by Lord (1900: 90–95), which includes a chemical analysis (also in Clarke, 1900: 60–61), has recently been supplemented by McGrew (1955: 55–60, 113, Figs. 24–26). Sewell (1955: 40–46, Pls. 7 and 10), in restudying its origin, concluded that it was probably emplaced by lava flows. In the few places where the Bracks-Capote Mountain contact (Sewell: 43) is exposed, it appears to be fairly regular with a suggestion of breccia on the surface of the Bracks. The Bracks-Chambers contact also appears to be regular. The following section (MS–3) begins not far above the top of the Bracks.

*Measured Section 3.*—The type locality (17–34) of the Capote Mountain Tuff is Measured Section 3 (MS–3) on the high west face of Capote Mountain. The base of MS–3 is appoximately 4 miles from the Brite Ranch headquarters along the abandoned county-road to Candelaria; it is 0.28 mile E of U.S. Coast and Geodetic Survey's bench mark *K731*, 1943, and 30 feet NE of a wooden hitching post at the base of the mountain. The top of MS–3 is 0.1 mile NW of triangulation station *Capote* (16.75–33.0), which is on the summit of Capote Peak, the highest point of Capote Mountain. (The 1928 Texas Almanac: 45, has a striking picture of "Summit of Capote Peak, Presidio County.") Thus, MS–3 extends eastward up the face of the mountain, ascending 1,000 feet in a horizontal distance of about 3,000 feet. Near the top, the beds dip about 9° E. The section was measured and sampled in the summer of 1954 by J. E. Peterson (1955: 97–105; Sewell, 1955: 110–111; McGrew, 1955: 110–111).

| *Unit* | *Description* | *Thickness in feet* |
|---|---|---|
| BRITE IGNIMBRITE: | | |
| 7 | *Rhyolite porphyry:* with aphanitic grayish orange pink (5YR7/2) to light brownish gray (5YR6/1) groundmass; phenocrysts are small angular clear quartz and opalescent tabular sanidine crystals; forms a cliff ........ Estimated | 100 |
| CAPOTE MOUNTAIN TUFF: | | |
| 6 | *Tuff:* moderate orange pink; indurated | 24 |
| 5 | *Tuff:* very light gray (N8) to white (N9), contains black and orange specks; fine- to coarse-grained; indurated; bottom 15 feet is massive, but most beds are 2 inches or less thick; cross-bedded; forms a slope under the Capote Rim | 288 |
| 4 | *Tuff:* white to pinkish gray, overall appearance is whitish gray with many black specks that give a salt-and-pepper effect; fine- to coarse-grained; indurated; weathered surface is rough and irregular | 51 |
| 3 | *Tuff:* variegated, predominant colors are white, pinkish gray, moderate orange pink, and moderate reddish orange; indurated bottom 20 feet forms cap of ledge with white tuff beneath; upper 75 feet is not so well indurated and forms stair-step ledges; fine- to coarse-grained; weathered surface is rough, uneven, and nodular | 123 |
| 2 | *Tuff:* white to grayish pink, overall appearance is dull pinkish white, salt-and-pepper; indurated; beds are 6 inches to 2 feet thick; most beds are fine- to medium-grained and nodular on the surface, a few beds are very fine-grained and weather into smooth vertical faces; strike N4°W, dip 9°NE; bottom contact is obscured by pebbles, cobbles, and boulders littering the slope | 42 |

| *Unit* | *Description* | *Thickness in feet* |
|---|---|---|
| 1 | *Tuff:* pale red to grayish red, overall appearance is pale red alternating with grayish red; fine- to coarse-grained; indurated; beds 2 inches to 6 feet thick; the beds 2 feet thick to 6 feet thick form most of the ledges, beds less than 2 feet thick form most of the slopes; material from 230 to 280 feet above base of MS–3 exhibits castellated weathering, with alternating light and dark red beds, the lighter beds 1 foot to 3 feet thick, the darker beds 2 to 6 inches thick appearing as plates between the thicker, lighter beds; weathered surface is rough and uneven, and the slopes are littered with pebbles, cobbles, and boulders | 1,350 |
| | Measured thickness of Capote Mountain Tuff | 1,878 |
| | Total thickness of MS–3 | 1,978 |

At this place the basal part of the Capote Mountain Tuff is covered by alluvial and colluvial material, but the top of the Bracks Rhyolite is not far below the base of MS–3.

*Capote Mountain Tuff.*—At places in the southern part of the Rim Rock country, according to Sewell (1955: 48, Pl. 21), the Capote Mountain Tuff has a characteristically three-fold outcrop that exhibits an upper white-to-pinkish-gray member nearly 1,300 feet thick, a middle red siltstone layer 10–40 feet thick, and a lower variegated tuff member, predominantly dusky brown to grayish red purple, more than 200 feet thick. According to Peterson (1955: 34, Fig. 6) the lower 1,350 feet of the type section shows alternating pale red and grayish red beds above which are white beds and gray beds. Be that as it may, a thick sequence of white tuff characterizes the Capote Mountain, but more work needs to be done assuredly to differentiate the Capote Mountain from the underlying Chambers on the north and south where the Bracks is absent.

The Capote Mountain (Peterson, 1955: 33–36, 90–94, 97–105, Figs. 4 and 6; Sewell, 1955: 47–50, 99–104, 110–111, 115–116, Pls. 6, 7, 21, 22; McGrew, 1955: 60–62, 103–107, 110–111, 113, Figs. 21, 27, 40) has the general composition (McGrew: 61) of a fine- to coarse-grained non-calcareous rhyolitic tuff consisting of 70–80% volcanic glass (*n* c. 1.50) with 2–5% quartz and 1% biotite and heavy minerals; the remainder is alkalic feldspar with a little plagioclase. The rock is loosely cemented with silica. In places it contains beds of pebble-to-boulder conglomerate. The middle, resistant layer of red siltstone is well-sorted and cemented with calcite and some opal; it has an even to subrounded fracture and is minutely cross-laminated; it is an arkose composed of subangular grains of which 70% are alkalic feldspar and

10% quartz and chert; the rest are volcanic rock, magnetite altering to hematite, pyroxene, and rare plagioclase. Only a few turtle bones have yet been collected from the Capote Mountain. The top of the Capote Mountain Tuff is at the base of the overlying rhyolite, which is called the Brite Ignimbrite.

*Brite Ignimbrite.*—Capote Mountain, which towers above the headquarters of the historic Brite Ranch (Keith, 1950; Shipman, 1926: 115–119; Darton, 1933: 100), is composed of typical Capote Mountain Tuff, capped by typical Brite Ignimbrite about 100 feet thick (Peterson: Fig. 6; Baker, 1928: Pl. 10; Baker, 1941: Pl. 20; 1928 Texas Almanac: 45; Keith, 1950: xix, xxix, and end papers). In other words, the top of Capote Mountain is the type locality of the Brite. The rock (McGrew: 62–71, 103, 110, 112–113, Figs. 21, 28–32, 36; Sewell: 50–52, 99, 102, 110, 114, 115, Pl. 23; Peterson: 36, 69, 73, 97, Fig. 6) resembles a sanidine rhyolite porphyry, but the matrix (McGrew: 62) shows glass shards and other pyroclasitic material in thin section. The sanidine crystals are opalescent. The fresh rock is light-colored ranging from grayish orange pink to light brownish gray. The Brite is overlain by the Petan Basalt.

*Petan Basalt.*—The first part of the new name *Petan Basalt* is taken from the Petan Ranch, which occupies the Capote Rim and Capote Draw from the south fence of the Brite Ranch to the head of Pinto Canyon. The second part is a field term for a dark-colored fine-grained igneous rock not necessarily used in a strictly petrographic sense. The Petan is exposed in the general vicinity of the U.S. Coast and Geodetic Survey's triangulation station *Brite* (19.1–32.4), where it attains a maximum thickness (Peterson, 1955: 37) of approximately 300 feet. The rock appears to have poor resistance to erosion, for only remnants rest on the Brite Ignimbrite in the form of small hills up to 300 feet high. Both the Brite and the Petan crop out in the Cuesta del Burro, a westward-facing bluff along the east side of Capote Draw about 5 miles east of the Capote Rim. Amsbury plans to describe the Petan in more detail in a forthcoming paper.

The Petan is composed of trachyandesite porphyry (McGrew, 1955: 71–74, 112, Figs. 33, 34; Sewell, 1955: 56, 114–115, Pls. 21, 26). The color of the fresh rock is dark greenish gray to brownish gray. It contains numerous vesicles partly filled with calcite. The texture is merocrystalline, porphyritic with an aphanitic matrix. Andesine ($An_{35}$) and orthoclase phenocrysts compose 25–50% of the rock. Accessory minerals are magnetite or ilmenite, augite, olivine almost completely altered to iddingsite, and apatite. The groundmass consists of laths of plagioclase and orthoclase, the interstices filled with orthoclase and cryptocrystalline material. The formation next above the Petan is an ancient gravel, which, for the time being, will be informally called the post-volcanic gravel.

*Post-volcanic gravel.*—The post-volcanic gravel lies discordantly on the Petan Basalt, and, in places, on the Brite Ignimbrite. It antedates the mighty faulting that created the rim-rock topography, for it too is faulted down into the southern part of the Rim Rock country. Its deposition was subsequent to most of, and perhaps all, the volcanic outbursts, for no igneous rock has yet been found in or on it. Its subround-to-round pebbles and cobbles are composed chiefly of extrusive igneous rock and Lower Cretaceous limestone. The gravel is cemented with caliche.

*Bolson fill.*—During the Tertiary Period, subsequent to the widespread volcanism, extensive faulting created deep intermontane basins, which were thereafter partly filled with bolson deposits. The fill tends to be conglomeratic near the mountains and to grade outward into calcareous sandstone and silt. Recent work by W. S. Strain (oral communication, Aug. 1956) near McNary, Texas, indicates that the age of the top of similar bolson fill in the Rio Grand Valley 70 miles upstream from the Rim Rock country is latest Pliocene or earliest Pleistocene.

## CONCLUSION AND ACKNOWLEDGMENT

Inasmuch as this preliminary paper aims chiefly to lay a nomenclatural foundation for stratigraphic geology of the Tertiary volcanic deposits of the Rim Rock country, the intrusive igneous rocks in the form of dikes and thick sills are not described. The lithostratigraphic data are taken largely from the work of students, particularly Messrs. Buongiorno, Carlisle, Duchin, Mankin, McGrew, Moran, Peterson, Sewell, and Smith and the petrographic data from Messrs, McGrew and Sewell, whose theses were supervised by Dr. Clabaugh. Drs. J. A. Wilson, S. E. Clabaugh, and J. T. Lonsdale kindly contributed additional information and editorial criticism.

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# *Polistes e. exclamans* Viereck: The Anatomy of the Stinging Apparatus

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INTRODUCTION

Severe reactions from the venom of *Polistes exclamans exclamans* Viereck are not uncommon among people who have been stung by this wasp. Several persons have died as the result of such reactions; many others have been made acutely ill (McCall, 1949). Because of the abundance of *P. e. exclamans* in the southwestern part of the United States, and particularly in the central Texas area, investigations have been initiated to discover, if possible, the basis for the severe reactions. Such investigations necessarily involve the extraction of the venom from the wasp. In order that the extraction procedure may be carried out to obtain the venom more readily and in a more natural form, a thorough study of the structure of the stinging apparatus of the wasp is essential. The results of such a study are presented in this paper.

A survey of the literature shows that the honeybee (*Apis mellifica* L.) has been the subject of many anatomical investigations. The wasp, on the other hand, has been studied very little in this respect. Both the wasp and the bee are members of the same sub-order (Aculeata), since in each the ovipositor is modified to form the sting. A comparative study of the anatomy of these structures in the wasp and the bee, therefore, should prove to be valuable.

Newell (1918) gives a brief account of the female genitalia of *Vespa maculata* L. and shows how the stinging apparatus of the Aculeata is used as an ovipositor. The most recent work on the anatomy of the wasp is that of Bender (1943) on *Habrobracon juglandis* (Ashmead). Although this Hymenopteron differs in detail from the honeybee and the *P. e. exclamans*, the general structural characteristics are much the same. Bender does not make a thorough study of the stinging apparatus of the parasitic wasp, but focuses his attention on the female reproductive system proper with only brief treatment of its modified parts.

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## MATERIALS AND METHODS

The insect material used in this study was collected in the environs of Waco, Texas, during the months of May, June, and July, 1955. Dissections were made on the abdomen of the wasp under a binocular dissecting microscope. The instruments used for this delicate work were iris scissors with spring steel handle, Swiss watchmaker's forceps No. 4, and small glass rods drawn to extremely fine points. The fluid in which dissections of the abdominal viscera were made was insect Ringer's solution modified by Ephrassi and Beadle, to which a drop or two of Tergitol penetrant was added to lower the interfacial tension (Bender, 1943). In order to see the abdominal viscera more clearly many of the dissections were stained immediately with Harris' hematoxylin and destained with acid alcohol.

After the abdomen of the wasp was studied for gross structure by dissection, some of the dissected material, as well as some fresh material, was embedded in paraffin and serially sectioned. The well known major difficulty in obtaining good sections of insect material is the presence of chitin in the exoskeleton. To soften the exoskeleton the fixed specimens were treated with Jurray's chitin softener as suggested by Gray (1952). The fluid of Carnoy and Lebrun gave extremely rapid penetration of hard outer coverings.

Because of the difficulty involved in cutting the exoskeleton, the best results were obtained by sectioning the abdominal viscera which had been dissected free of the chitinous outer coverings. The stain most often used for sectioned material was Harris' hematoxylin with an eosin counterstain. In an attempt to better differentiate the various types of tissues, Mallory's triple stain as suggested by Kennedy (1932) was used for some specimens. Drawings were made with the aid of the camera lucida.

## EXTERNAL STRUCTURE OF THE ABDOMEN

The abdomen of adult Hymenoptera usually consists of ten segments; in the embryo, however, the abdomen may have as many as twelve segments. Nelson (1915) states that there is evidence of twelve segments in the honeybee embryo but that the two terminal segments disappear during development. In *P. e. exclamans*, as is true of Hymenoptera generally, the first segment of the ten-segmented abdomen actually becomes a part of the the thorax during the pupal stage of development. This first segment forms the propodeum of the adult thorax, leaving the abdomen with only nine segments. Hence, in counting the segments of the adult abdomen one must consider the first segment to be the true second segment (Figs. 1, 2). Only six segments of the abdomen are visible, segments VIII, IX, and X being concealed by the last visible segment (VII).

The abdomen of the worker and queen of the *P. e. exclamans* is broad at the anterior end and gradually tapers to a point at the posterior end. The first abdominal segment (II) bears a small stalk or petiole which attaches the abdomen to the propodeal segment (I) of the thorax, thus allowing foi freedom of motion for both parts (Fig. 2). Each segment consists of two distinct plates, a tergum and a sternum. The tergal plates cover the dorsal surface of the abdomen and extend far down on the lateral surface overlapping the ventrally placed sternal plates. The tergum and sternum of the last visible segment (VII) are separated by a cleft on each lateral margin to allow for expansion or opening when the sting is protruded. Each tergal and sternal plate overlaps the one posterior to it by a wide margin, and the edges are connected by a thin intersegmental membrane. This overlapping divides each plate into an anterior region which forms part of the inner wall of the abdominal cavity and a posterior region which forms a flap or projection over the immediately posterior plate. The anterior edge of each tergal and sternal plate serves as an attachment for muscles which connect the segmental plates with each other. In addition to these muscular connections, each sternum bears an armlike projection on each side which extends anteriorly and serves as an attachment for muscles connected to the immediately anterior tergum and sternum.

Each of the first eight tergal plates contains two spiracles, the first pair belonging to the propodeum. The spiracles of the visible abdominal segments, II through VII, are small openings located on the sides of each segment. The last pair of spiracles is found on the tergal plate of segment VIII which is concealed within the tergum and sternum of segment VII and covers the terminal portion of the alimentary canal (Fig. 3).

The last three abdominal segments (VIII, IX, X) differ in the male and female wasp, since they are modified in the male to form the organs of copulation and in the female to form the stinging apparatus. In males the tergum and sternum of segment VIII are clearly visible as an additional segment. In the females (queen and worker), however, segment VIII, together with IX and X, is completely concealed within the last visible segment (VII). They will be described in detail in connection with the sting.

The differences in the appearance of the abdomen of the queen and worker of the *P. e. exclamans* are merely differences of size and coloration. The coloration is similar in both forms except that the first sternum of the queen shows a lighter brownish-yellow marking than

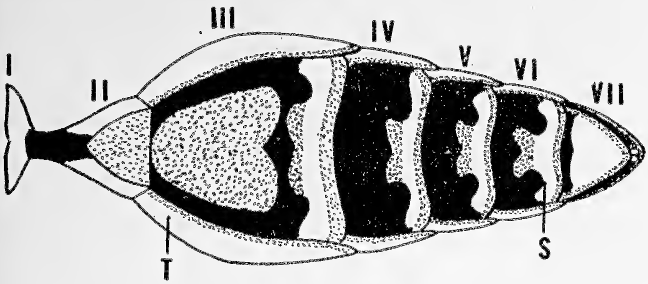


FIG 1

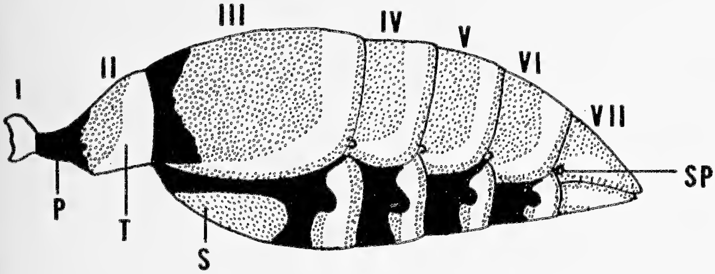


FIG 2

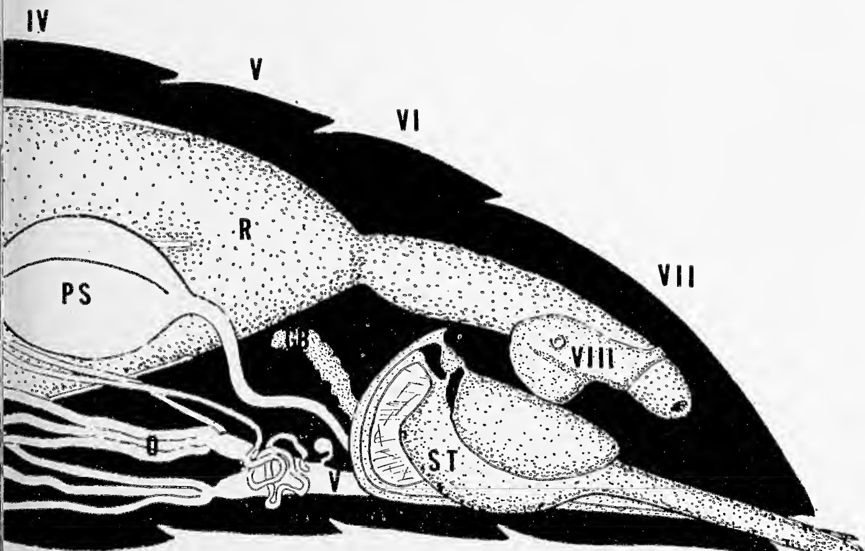


FIG 3

j. 1. Ventral view of external features of abdomen.
j. 2. Left lateral view of external features of abdomen.
j. 3. Left lateral view of viscera within posterior portion of abdomen.

that of the worker. This sternal marking is very prominent in the male, being a bright yellow spot almost covering the entire exposed surface of the first sternum. The abdominal plates have the same shape in both female forms, but the abdomen of the queen is usually larger than that of the worker. It is difficult at times to distinguish readily the queens from the workers. Abdomens of males and females are notably different, however, since there is one more obvious segment in males.

## GROSS ANATOMY OF THE STINGING APPARATUS

### *The Sting*

For convenience and for comparative purposes, the nomenclature used by Snodgrass in his anatomical study of the bee (1925) will be used in the description of the stinging apparatus of the *P. e. exclamans.*

The stinging apparatus of the wasp is located in the sting chamber within the last visible segment (VII) of the abdomen (Fig. 3). As previously suggested, the sting chamber also houses the modified sclerites of abdominal segments eight, nine and ten. Such an arrangement, according to Snodgrass (1925), is seen in the bee also. Snodgrass further states that the chamber is actually formed by an infolding of the last three segments into the seventh segment. The modified sclerites of the three terminal segments form definitely shaped plates surrounding the bulb of the sting (Fig. 4). Each plate bears on its inner surface strong muscles arranged in such a way that their contraction causes the venom to be exuded from the sting.

The entire sting measures approximately 4.0 mm. in length and is composed of three major divisions; namely, the shaft, the bulb, and the accessory plates. The shaft of the sting is composed of three distinct pieces which are placed together in such a way that they form a hollow central cavity—the poison canal (Fig. 11). The dorsal component of the sting shaft forms a portion of the bulb of the sting proximally and is referred to as sheath B (Fig. 4). Sheath B begins anteriorly as a prominent covering of the bulb and continues posteriorly to within 0.1 mm. of the distal tip of the shaft, tapering gradually to a thin covering. Its total length is approximately 3.5 mm. This sheath is a single, unpaired, dome-shaped structure forming a roof over the bulb of the sting. It is at the anterior border of this sheath that the duct of the poison sac and gland B each enters the bulb. The outer surface of the bulb is covered with muscle fibers which compress the bulb to aid in propelling the venom through the poison canal.

The two ventral components of the shaft of the sting are paired, slender, hollow rods called the lancets (Fig. 4). The lancets are flexible,

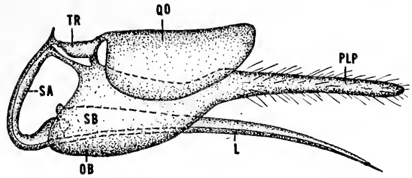


FIG 4

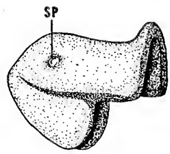


FIG 5

**Fig. 4. Left lateral view of chitinous components of sting. 13x**

**Fig. 5. Left lateral view of eighth tergum. 13x**

allowing for the projection of the sting from the sting chamber. These rods slide freely on tracks formed by the ventral border of sheath B (Fig. 11) and decrease in diameter to a fine point at the distal tip of the shaft. The lancets do not completely meet at the mid-ventral line on the distal two thirds of the shaft, thus leaving a small opening in the poison canal (Fig. 11). Consequently, the poison may leave the canal at any place along this ventral opening when the sting is inserted into the victim. The two lancets gradually diverge anteriorly and lose connection with sheath B at its anterior border. At this border the lancets curve dorsally and outward as basal arms of the shaft to form the most anterior margin of the entire sting (Fig. 4). The ducts carrying venom from the poison sac and the body of gland B pass between these two arms to enter the bulb.

The basal arm of each lancet is covered by a sheath which continues over its posterior surface from the proximal border of sheath B. This sheath (sheath A) curves dorsally with the basal arm but does not meet and fuse with its fellow of the opposite side as does sheath B. Each of the sheaths A articulates at its end farthest from the bulb with the oblong plate of the same side, one of the accessory plates previously mentioned. The paired oblong plates normally overlap the sides of the bulb and bear striated muscles on their inner surfaces. The plate itself measures approximately 1.7 mm. in length by 1.0 mm. at its widest point. Each plate, however, bears a long, slender posterior extension, the palpus of the sting (Fig. 4). The palpi are laterally concave and are thin, finger-like projections which lie at the sides of the shaft when the sting is retracted into the sting chamber. Each palpus is covered with delicate hairs directed at an angle posteriorly. In the bee, according to Snodgrass (1925), these hairs appear to be sensitive organs which indicate to the bee that her abdomen is in contact with the object to be stung.

Each oblong plate articulates by a small projection on its dorsal anterior margin with the ventral posterior angle of a small paired triangular plate (Fig. 4). A triangular plate thus lies dorsal to the base of each of the oblong plates. The shape of the triangular plate forms an isosceles triangle with dorsal and ventral borders of approximately 0.4 mm. and a posteriorly directed base of approximately 0.2 mm. The apex of each triangular plate is directed anteriorly and articulates with the base of each lancet. By its dorsal posterior angle each triangular plate articulates with one of a pair of large quadrate plates (Fig. 4).

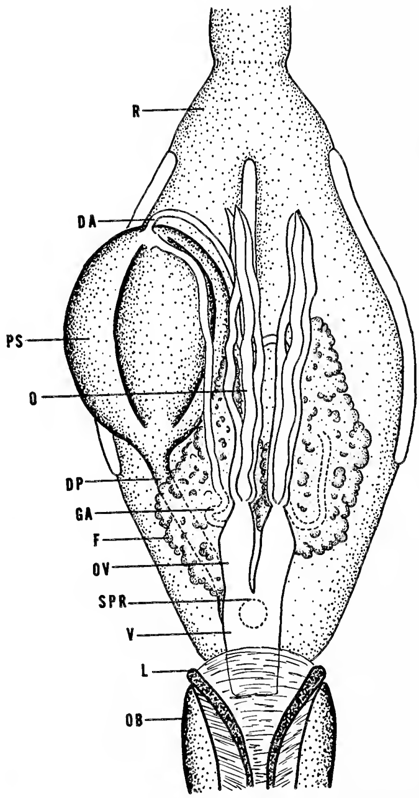


FIG 6

**Fig. 6. Ventral view of viscera of posterior portion of abdomen after dissection. (Reconstruction from sections) 24x**

Each quadrate plate, in turn, overlaps the dorsal portion of the oblong plate of the same side. The quadrate plates, like the oblong plates, bear muscles on their medial surfaces and measure approximately 1.6 mm. in length by 0.7 mm. at their widest point.

As previously stated, and according to Snodgrass (1933), the accessory plates described represent modified parts of abdominal sclerites eight, nine, and ten. Within the dorsal portion of the sting chamber, surrounding part of the terminal portion of the alimentary canal, is a chitinized plate bearing a spiracle on each side (Fig. 5). Snodgrass (1933) indicates that this plate is the modified eighth tergum bearing the last true abdominal spiracle. Zander (1910, 1911) in his studies has shown that the triangular plate is a remnant of the eighth sternum. He states, further, that because the triangular plate carries the lancet, it too belongs to the eighth segment. Zander has shown also that the quadrate plate is a part of the ninth tergum, since, in many other Hymenoptera, it is connected by a bridge with its fellow of the opposite side. Snodgrass (1933) finds evidence for calling the oblong plate a representative of the ninth sternum, since it carries both the palpus and sheath A. The tenth segment is undoubtedly the extremely thin chitinized membrane which surrounds the anus but appears to be free of attachments to the other plates.

*The Venom-producing Structures*

Figures 6 and 7 show diagrammatically the organs associated with the sting after dissection and removal of these organs from the abdominal cavity. The drawings represent reconstructions of the whole organs from sectioned material, and, therefore, do not necessarily give a true representation of the structural relationships of these organs within the abdominal cavity. Figures 12, 13, and 14 are representative sections of those used in preparing the reconstructions. Figure 3 may be referred to for correct positions of the abdominal organs.

From gross dissection and from microscopic examination it appears that there are two systems of glands which may secrete substances constituting the venom of the *P. e. exclamans*. For lack of more evidence as to the nature of the glandular secretion these glands will be referred to, hereafter, as glands A and gland B.

Glands A, of which there are two, are homologous in position and number to the acid glands of the bee as described by Snodgrass (1925). They are simple, unbranched( tubular glands and, *in situ*, are loosely coiled on either side of the vagina and oviducts, immediately ventral to the distal third of the rectum (Figs. 6, 7). The average diameter of the tubule composing each gland is approximately 0.05 mm. The glands are closely surrounded by masses of yellowish fatty tissue which, in many cases, fills a greater part of the posterior portion of the abdominal cavity (Fig. 6). If the fat cells are removed piecemeal from the surface of the gland, the coils of the gland will be seen to have an opaque whitish appearance. Glands A appear to have no attachments to any of the surrounding structures; if, however, the sting is grasped and pulled to remove the viscera from the abdominal cavity, the glands, in most cases, will remain within the abdomen. This is probably because of the fact that the fat bodies which so closely surround the coils of the gland are connected to the body wall by membranes.

Each of the glands A is continuous at its proximal end with a minute uncoiled duct which extends anteriorly for a distance of approximately 1.5 to 2.0 mm. before it makes connection with the anterior end of a large spherical structure, the poison sac (Fig. 7). Each duct enters the poison sac by a separate opening, whereas in the bee, according to Snodgrass (1925), the two ducts join a short distance before entering the poison reservoir. Each duct has an average diameter of approximately 0.04 mm. and is milky white in its external appearance.

The poison sac lies adjacent to the left ventro-lateral surface of the rectum, somewhat anterior to its center (Fig. 7). The sac is scarcely visible to the naked eye, measuring approximately 0.88 mm. at its greatest diameter and 1.16 mm. in length. Without the aid of lenses the poison sac appears as a minute white ball, but when viewed under the dissecting microscope it appears almost transparent. Its over-all shape is roughly that of an ellipse, narrower at the posterior end where the neck originates. The sac receives the two ducts of glands A at its anterior end and issues a single duct from its posterior end. The poison sac is externally lobulated with the long axis, which lobulation is caused by the presence of four large muscle bundles in the wall of the sac. The presence of these bundles explains the apparent hardness or resistance to maceration of the sac during dissection.

The duct of the poison sac appears as a whitish, transparent tube which is continuous with the sac at its neck (Fig. 7). This duct extends postero-medially for a distance of approximately 2.0 mm, and has an average diameter of approximately 0.09 mm. It passes ventral to the rectum and dorsal to the oviducts and vagina to enter the bulb of the sting on the left ventro-lateral side of gland B. Figure 8 shows the entrance of this duct and gland B into the bulb of the sting after dissection and removal of the surrounding tissues. The duct may be traced into the bulb of the sting and may be seen to become continuous with the poison canal of the sting shaft.

Gland B of the *P. e. exclamans* is homologous in position and structure to the alkaline gland of the bee as described by Snodgrass (1925) and is sometimes referred to as Dufour's gland in the bee and in the other Vespine wasps (Trojan, 1929, 1930). This gland is an opaque, whitish, tubular structure and is slightly convoluted in external appearance. It is unpaired and, *in situ*, lies in the mid-ventral line adjacent to the ventral surface of the rectum immediately dorsal to the vagina and oviducts (Fig. 7). The gland is approximately 1.3 mm. in length and has a diameter of 0.13 to 0.16 mm. It extends posteriorly to the bulb of the sting. It enters the bulb on the right dorso-lateral margin of the duct of the poison sac. The gland empties into the bulb of the sting, but no union between gland B and the poison canal has been observed.

The reproductive organs of the wasp are in close relation to the entire stinging apparatus (Fig. 6). The ovaries, oviducts, vagina, and spermatheca lie ventral to the other organs within the abdominal cavity and occupy much more space in the queen than in the worker. The

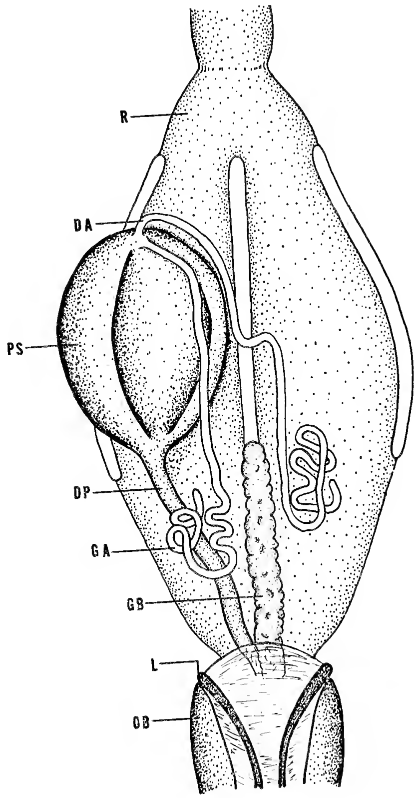


FIG 7

**Fig. 7. Ventral view of viscera of posterior portion of abdomen after dissection and removal of fatty tissue and reproductive organs (Reconstruction from sections). 24x**

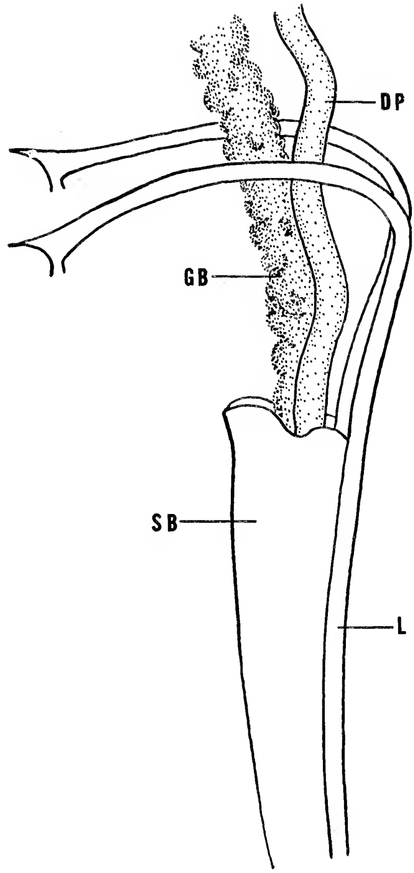


FIG 8

Fig. 8. Left lateral view of bulb of sting showing entrance of gland B and duct of poison sac. 22x

vaginal opening lies immediately dorsal to the base of the sting and is attached to it by thin membranes. The eggs are extruded from the vagina into the sting chamber immediately before being deposited. It is thought that the stinging apparatus acts as an ovipositor at the time of egg-laying in the stinging Hymenoptera (Snodgrass, 1925).

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Fig. 9. Cross-section through anterior third of bulb of sting. 90x

Fig. 10. Cross-section through middle third of bulb of sting. 90x

Fig. 11. Cross-section through posterior third of shaft of sting. 90x

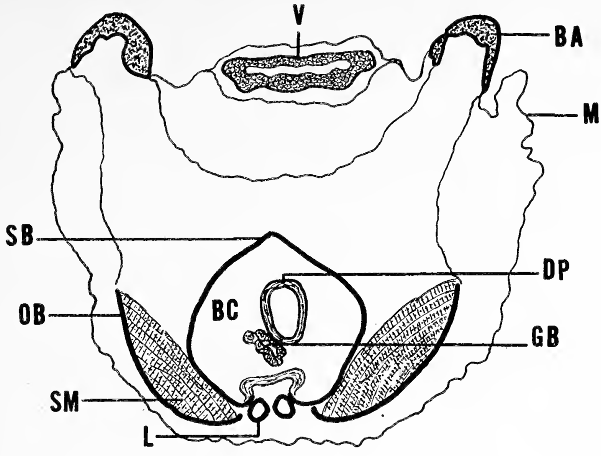


FIG 9

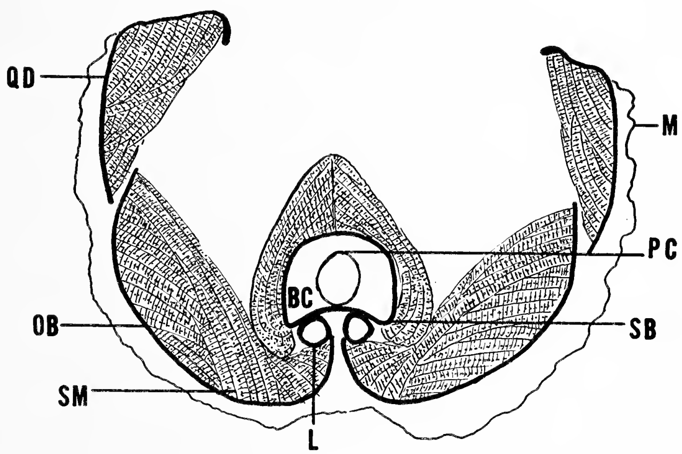


FIG 10

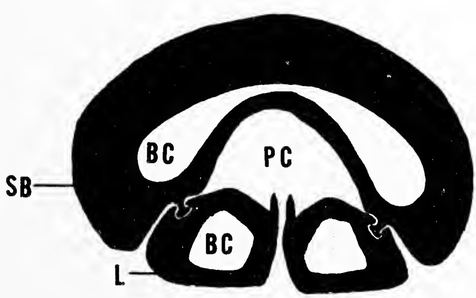


FIG 11

## MICROSCOPIC ANATOMY OF THE STINGING APPARATUS

### *The Sting*

The sting itself, as previously stated, is composed of a basic framework of modified portions of the exoskeleton, covered with thin membranes, and surrounded in certain areas by muscles. The description of its microscopic structure is based on selected sections through various regions of the sting.

A section taken transversely through the anterior region of the bulb of the sting shows the duct of the poison sac centrally located within the bulb and gland B immediately to the right of the duct (Fig. 9). Sheath B is seen as a thin layer of chitinized material forming the bulb of the sting. Sections of the oblong plates are seen as the lateral boundaries of the sting, and the basal arms of the lancets form the dorso-lateral margins. The two basal arms are connected by a membrane which lies between the bulb and the vagina. Cross-sections of the lancets are seen at the ventral border of the bulb, but the poison canal is not open to the exterior at this level. The body cavity extends into the bulb of the sting and into each of the lancets. The inner surface of the oblong plates show the presence of heavy muscle bundles, but muscles are not visible over the surface of the bulb. The entire sting is surrounded in this region by a thin membrane.

A transverse section through the middle third of the sting shows the bulb to have the same general shape as that described above, except that the roof is less pointed (Fig. 10). Sheath B is covered on its outer surface by a layer of striated muscle, and the over-all size of the bulb is somewhat decreased. The poison canal is centrally located as a continuation of the duct of the poison sac in the extension of the body cavity within the bulb; gland B terminates immediately anterior to this region. The oblong plates are visible on the lateral margins of the sting; the basal arms have been replaced by the quadrate plates on the dorso-lateral margins. Striated muscle bundles cover the inner surfaces of the oblong plates and the inner surfaces of the quadrate plates. The membrane which lines the sting chamber connects to the dorso-lateral surface of each quadrate plate and ends there, not covering the dorsal surface of the entire sting.

A section through the distal third of the shaft of the sting illustrates the absence of any accessory plates or muscles around its margins (Fig. 11). The bulb is smaller and its walls are composed of a thicker layer of chitinized material than the walls of the bulb described in the previous sections. The roof of the bulb is rounded and another chitinous component is seen in sheath B; *i.e.*, the poison canal is ventrally located and its roof is a chitinized portion of sheath B. The poison canal is not membranous throughout but is actually a space formed between sheath B dorsally and the lancets ventrally. The space is lined with a delicate membrane and is open to the exterior through its mid-ventral portion. The extension of the body cavity is visible in both sheath B and the lancets. The tracks on which the lancets glide during the stinging process are clearly visible in cross-section and are located on the ventro-medial margins of sheath B. The palpi of the sting are located on each side of the shaft.

The remaining length of the distal end of the shaft is essentially the same in shape and form as in the last section described. The size of the sheath diminishes more rapidly than that of the lancets until the former ends approximately 0.1 mm. from the distal tip of the shaft. The lancets continue as the only remaining component of the shaft.

*The Venom-producing Structures*

As stated in the preceding section, glands A of the *P. e. exclamans* are simple, unbranched, tubular glands which have approximately the same diameter throughout. Microscopic examination of the tubules shows that they consist of a single thick layer of large cuboidal or pyramidal glandular cells surrounding a central lumen which is apparently loosely lined with much smaller cells (Fig. 15). There is present on the periphery of the cuboidal cells a distinct basement membrane. The cytoplasm of these glandular cells appears homogeneous and finely granular with a few small vacuoles visible in some cells. The cytoplasm stains a dark purple color with hematoxylin and eosin while the nuclei appear in a lighter shade of bluish-purple. There are two distinctly different sizes of nuclei visible in a cross-section through the tubules of glands A. The nuclei of the cuboidal cells are large round-to-oval structures located, in almost all cases, in the peripheral portion of the cell. The nuclear membrane is distinct, and a single dark blue nucleolus is easily seen in most of the large nuclei. The light blue karyoplasm contains numerous dark granules of considerable size. Smaller nuclei are seen scattered along the inner boundary of the cuboidal cells, appearing to line the lumen of the tubule in certain areas. Bender (1943) reports a similar situation in the poison glands of the parasitic wasp, *Habrobracon juglandis*, but gives no explanation for the presence of the smaller nuclei. Their staining characteristics in the wasp are much the same as those of the larger nuclei except that the small ones appear to be more vesicular and show no distinct nucleoli. In some scattered areas of the gland there appear to be small amounts of clear homogeneous cytoplasm surrounding these nuclei, but no distinct cell boundaries are visible. Thus, it is possible that the cuboidal epithelium of the tubule of glands A is partially lined by a loose, incomplete endothelial-like tissue.

The transition from the tuble of glands A to its duct is clearly visible when examined microscopically because of the difference in their staining characteristics. The ducts of glands A, like the tubules, are composed of a single layer of cuboidal epithelial cells surrounded by a distinct basement membrane, but the cell boundaries are barely visible (Fig. 16). The cuboidal cells of the duct contain a finely granular, homogeneous cytoplasm which stains pinkish-lavender with hematoxylin and eosin. The nuclei are large round or oval structures which stain pale blue and contain a single dark nucleolus. The nuclear membrane is distinct and the karyoplasm contains a few large dark granules. Smaller nuclei with the same staining characteristics as the larger ones are seen at the edge of the lumen, but no vacuoles are visible in any of the cells of the duct.

The poison sac into which the ducts of glands A empty is a muscular reservoir, its wall varying in thickness with the amount of distention caused by venom in its lumen (Figs. 12, 17). The outer layer of the sac consists of four large bundles of striated muscle symmetrically placed around the lumen. The muscle fibers stain pinkish-lavender and show purple cross striations. A sarcolemma is present but very indistinct. The round to oval nuclei, which stain pale blue with dark granules, are located in the center of the fibers, one nucleus between each two striations (Fig. 18).

Inside the heavy layer of muscle in the wall of the poison sac there is a single layer of thin cells with elongated nuclei. These cells are apparently a connective tissue which is continuous from the poison sac throughout the length of its duct. Immediately inside this tissue lies a band of laminated chitin which gives some degree of rigidity to the lining of the lumen. These non-cellular homogeneous lamina stain light pink with hematoxylin and eosin. The lumen of the poison sac is lined with a relatively thick layer of epithelium which stains dark reddish-purple with very dark purple nuclei. The cell boundaries of the epithelial cells are indistinct, but the nuclei show evidence that the entire epithelium is several layers of cells thick.

The thick epithelium does not continue as such from the poison sac to the duct but becomes reduced to a single layer; on the other hand, the laminated chitin and the one cell thick layer of connective tissue

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**Fig. 12. Cross-section through anterior third of poison sac and surrounding structures. 90x**

**Fig. 13. Cross-section through neck of poison sac and surrounding structures. 90x**

**Fig. 14. Cross-section through vagina and surrounding structures at level of spermatheca. 90x**

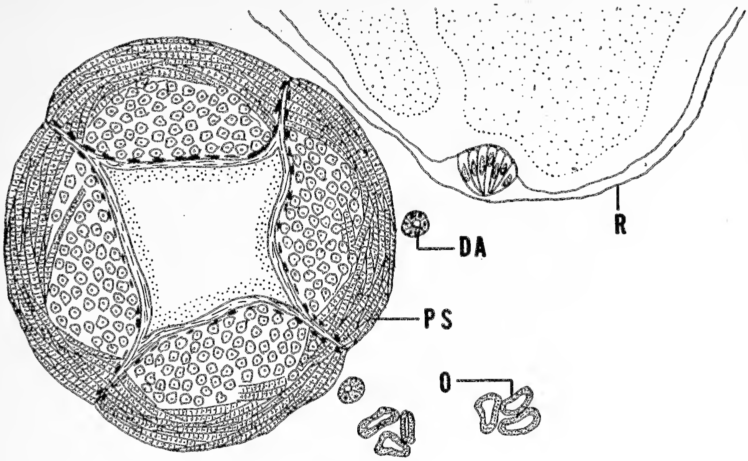


FIG 12

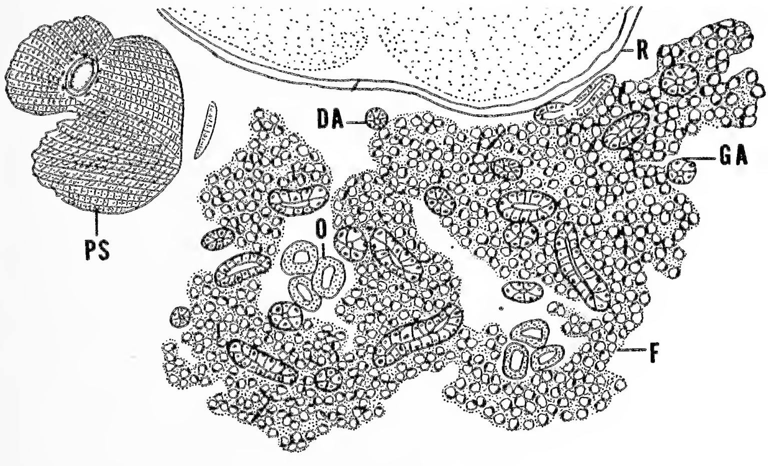


FIG 13

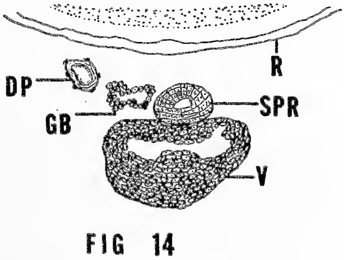


FIG 14

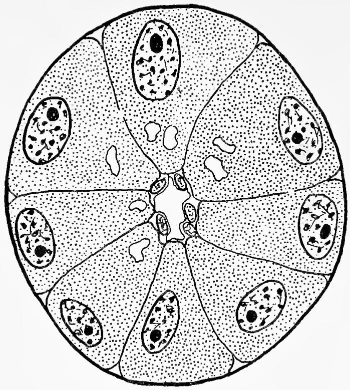

FIG 15

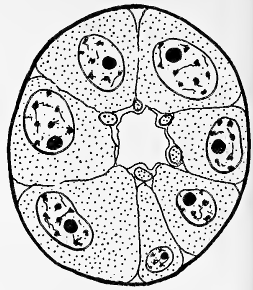

FIG 16

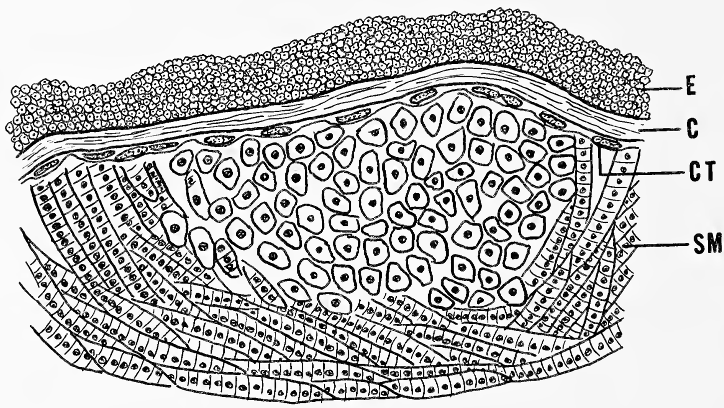


FIG 17

Fig. 15. Cross-section through tubule of gland A. 890x
Fig. 16. Cross-section through duct of gland A. 890x
Fig. 17. Cross-section through portion of wall of poison sac. 140x

are continuous from the sac to the duct forming the peripheral layer of the duct (Fig. 19). The duct of the poison sac, therefore, is composed of three layers; namely, the external connective tissue layer, the laminated chitin, and the epithelial lining.

Gland B is composed of a greatly convoluted layer of polygonal epithelial cells surrounding a central irregular lumen (Fig. 20). The cytoplasm of the epithelial cells appears finely granular and stains light pinkish-lavender with hematoxylin and eosin. The cytoplasm is rather scant and the large round nuclei almost fill the cells. The nuclei stain pale blue and show as many as two nucleoli in some cells while there are no nucleoli visible in others. All the nuclei contain numerous large dark granules in the karyoplasm. The cell boundaries are more distinct than those in gland A, but a basement membrane is not distinctly visible.

The epithelial cells of gland B are surrounded by a thin layer of cells resembling a mesothelial covering. The cytoplasm of these cells is faint and the cell boundaries are indistinct. The nuclei are granular, thin, and flat or elongate; nucleoli appear to be absent in most cases.

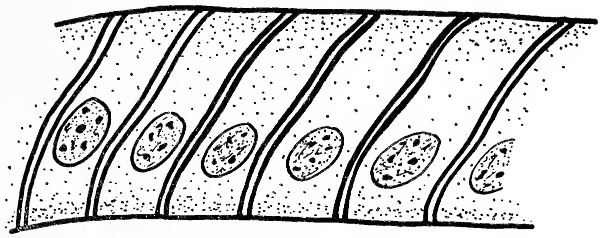

FIG 18

Fig. 18. Enlarged view of striated muscle fiber from wall of poison sac. 960x

## COMPARISON OF THE STINGING APPARATUS OF THE WASP WITH THAT OF THE BEE

A comparison of the stinging apparatus of the wasp with that of the bee shows that these devices possess striking similarities and differences. Since both insects belong to the same sub-order (Aculeata), one would expect the general body plan to be the same. The comparison of the two, however, may be carried further. In the discussion which follows, references to the bee are based on investigations by Snodgrass (1925, 1933).

Glands A of the wasp correspond in position, number, and general structure to the acid glands of the bee. The end of each gland in the bee, however, is enlarged into a small sac-like swelling, whereas in the wasp each gland is of the same diameter throughout. The ducts of glands A, or of the acid glands in the bee, consist of two simple tubules. In the bee the two ducts join a short distance before entering the poison sac; the ducts in the wasp, on the other hand, remain separate and empty into the poison sac by individual openings.

The poison sacs of both insects are similarly located, but their structure shows a most striking difference; namely, the poison sac of the wasp is covered by heavy bundles of muscle fibers which contract to aid in expelling the venom, whereas the venom reservoir of the bee is completely devoid of any muscular elements. The general shape of the two poison sacs differs in that the sac in the bee gradually tapers into the duct while that in the wasp shows definite junctions between sac, neck, and duct. The neck of the poison sac of the bee is supported by interrupted chitinous rings, not seen in the wasp. The walls of the poison sacs contain laminated chitin in each of the insects.

Gland B in the wasp is homologous in position and structure to the alkaline, or Dufour's gland of the bee. As previously mentioned, however, the exact connections of this gland can only be ascertained by further investigation.

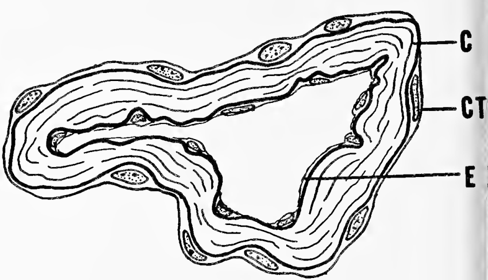


FIG 19

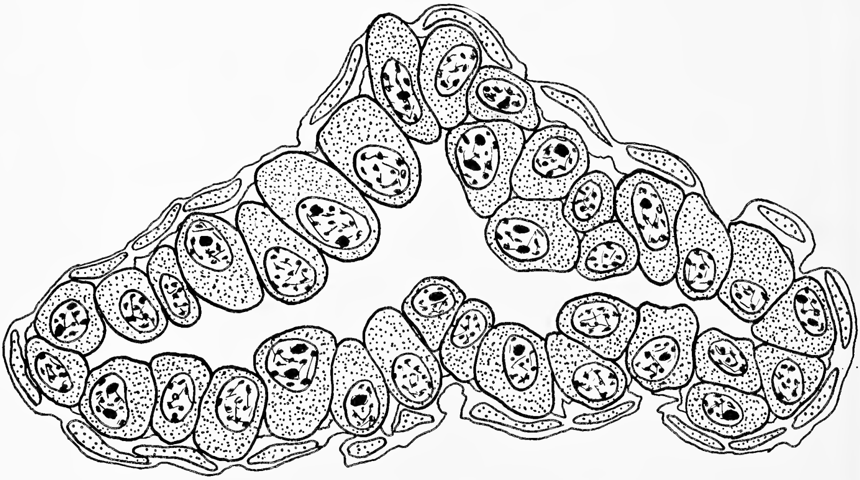

FIG 20

Fig. 19. Cross-section through duct of poison sac. 532X
Fig. 20. Cross-section through gland B. 655X

The sting of the bee and that of the wasp are almost identical in structure except for minor differences in size and shape of the various chitinous components. The same number of components are present in the sting of each animal, and their connections and arrangements are essentially the same. The major difference between the two insects with regard to the sting itself is that the lancets in the bee bear several barbs near their distal ends, whereas the sting of the wasp is smooth throughout its entire length. The presence of these barbs on the sting shaft of the bee explains the fact that when a bee stings, the sting and some or all of the viscera are pulled from the abdominal cavity and left in the victim. This loss of body parts does not occur when wasps sting; hence, they are able to sting many times without damage to their body.

## SUMMARY

The gross structure of the stinging apparatus of the *P. e. exclamans* may be divided into two major parts; namely, the sting and the venom producing structures. The sting consists of a framework of chitinous plates, sheaths, and bars held together by membranes and moved by bundles of striated muscle. The sting shaft is composed of a sheath covering two slender lancets which glide freely on the ventral surface of the former during the stinging process. The poison canal passes through the center of the shaft as a hollow channel between the sheath and the lancets and opens to the exterior along the mid-ventral line of the posterior two thirds of the shaft. Three pairs of accessory plates are disposed around the bulb of the sting. These bear muscles on their inner surfaces which are concerned with the protrusion and retraction of the sting and with forcing the sting into the tissues of a victim. It is possible that these muscles also aid in expelling the venom from the bulb and shaft.

The venom producing structures consist of two glands, their ducts, and a reservoir. One type of gland (gland A) is a paired, simple tubular gland homologous in position to the acid gland of the bee. It is composed of large secretory cuboidal cells surrounding a central lumen. The ducts of this gland empty into a muscular poison sac whose duct becomes continuous with the poison canal as the former passes through the bulb of the sting.

Another type of gland, a single convoluted tube of secretory epithelium (gland B), is homologous in position and structure to the alkaline or Dufour's gland in the bee. This gland may or may not contribute secretions to the venom of the wasp.

The stinging apparatus of the wasp and the bee are similar in many respects, although there are two major differences. The poison sac of

the bee has no muscle fibers in its wall; the poison sac of the wasp, on the other hand, is composed of four thick bundles of striated muscle fibers which are apparently the major force in expelling the venom during the stinging process. The other major difference is the presence of barbs on the sting in the bee which results in the loss of the sting and some of the viscera from the abdominal cavity when the insect stings. The absence of barbs on the sting of the wasp prevents loss of body parts.


## ACKNOWLEDGMENT

The authors wish to express appreciation to the following persons for helping to bring this study to completion: Dr. Floyd F. Davidson for suggestions on microtechnique, Mr. Logan A. Smith for contributions and suggestions on many phases of the problem, Mrs. Patricia Johnson and Miss Joyce Ehman for assistance in collecting insect material and Mrs. Willa Parks for preparation of the manuscript.


## EXPLANATION OF ABBREVIATIONS USED IN FIGURES

| | | | |
|---|---|---|---|
| BA | basal arm | PC | poison canal |
| BC | body cavity | PLP | palpus of sting |
| C | laminated chitin | PS | poison sac |
| CT | connective tissue | QD | quadrate plate |
| DA | duct of gland A | R | rectum |
| DP | duct of poison sac | S | sternum |
| E | epithelium | SA | sheath A |
| F | fatty tissue | SB | sheath B |
| GA | gland A | SM | striated muscle |
| GB | gland B | SP | spiracle |
| L | lancet | SPR | spermatheca |
| M | membrane | ST | sting |
| O | ovary | T | tergum |
| OB | oblong plate | TR | triangular plate |
| OV | oviduct | V | vagina |
| P | petiole | | |

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# Tissue Abnormalities in Newborn Rats from Biotin-Deficient Mothers

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The role of biotin in reproduction has been the subject of relatively few investigations. Kennedy and Palmer (1945) reported reproductive failure in the albino rat on diets of raw egg white containing the biotin antagonist, avidin. These workers showed that intra-uterine resorption and production of weak and unhealthy offspring resulted from this diet. No histological studies were made of the offspring. Reproductive failure in the male albino rat was described by Shaw and Phillips (1942) and by Katsh, *et al.* (1955) who both reported testicular degeneration. Couch, *et al.* (1948) demonstrated that muscular and skeletal abnormalities were present in the newly hatched biotin-deficient chick and these abnormalities were accompanied by increased embryonic mortality. Jones, *et al.* (1955) showed that young rats born to vitamin $B_{12}$-deficient mothers had immaturity of hearts and kidneys along with vascular blocks and passive congestion of the livers. Other workers have demonstrated that maternal deficiencies of folic acid, riboflavin, vitamin A, and vitamin E (reviewed by Bourne and Kidder 1954) produce various abnormalities in the newborn albino rat.

The purpose of this investigation was to study the influence of a maternal biotin deficiency on the heart, kidney and liver tissue of the newborn offspring of the albino rat. The deficiency was produced by feeding raw egg white containing avidin to the mother rat prior to and during the gestation period.

### METHOD

Forty female rats of the Wistar strain and 30 of the Texas A. and M. College strain were maintained on a stock ration (Purina dog chows) until they attained a weight of 140 to 160 grams. Twenty of these animals were placed on a semi-synthetic diet (see Table I) which had been previously used and was known to be adequate for normal reproduction. The experimental ration was the same as the control except that raw egg white containing the biotin antagonist was substi-

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tuted for 50 per cent of the protein and biotin was omitted from the diet. All the animals were fed *ad libitum;* however, the food consumption was found to be approximately the same in both the control and experimental groups.

Daily vaginal smears showed the status of the estrus cycle, and the presence of sperm in the smear was considered to initiate the gestation period. All females were killed upon littering or on the 22nd day of

TABLE I

Dietary Constituents

| | Grams/100 grams feed | |
|---|---|---|
| | Control Ration | Experimental Ration |
| Vitamin-free Casein | 30.00 | 15.00 |
| Raw Egg White* | .... | 15.00 |
| Cerelose (Dextrose) | 61.00 | 61.00 |
| Salts Mixture† | 5.00 | 5.00 |
| Wood Pulp | 3.00 | 3.00 |
| Nopco (fish oil)‡ | 1.00 | 1.00 |
| Vitamins | | |
| Vitamin A (in Nopco) | 3,000 I.U. | 3,000 I.U. |
| Vitamin D (in Nopco) | 400 I.U. | 400 I.U. |
| Menadione ($K_3$) | 0.75 mgm. | 0.75 mgm. |
| Alpha Tocopherol Acetate | 2.50 mgm. | 2.50 mgm. |
| Thiamine Hydrochloride | 1.00 mgm. | 1.00 mgm. |
| Calcium Pantothenate | 4.00 mgm. | 4.00 mgm. |
| Niacin | 5.00 mgm. | 5.00 mgm. |
| Inositol | 10.00 mgm. | 10.00 mgm. |
| Choline Chloride | 100.00 mgm. | 100.00 mgm. |
| Para-Amino-Benzoic Acid | 50.00 mgm. | 50.00 mgm. |
| Folic Acid | 0.10 mgm. | 0.10 mgm. |
| Riboflavin | 1.00 mgm. | 1.00 mgm. |
| Pyridoxine | 1.00 mgm. | 1.00 mgm. |
| Vitamin $B_{12}$ | 2.50 mcg. | 2.50 mcg. |
| Biotin | 10.00 mcg. | .... |
| Methyl Lineolate | ad libitum twice weekly by dropper | |

* Armour and Company, Fort Worth, Texas.
† Richardson and Hogan (1946).
‡ Nopco Chemical Company, Richmond, California.

the gestation period. The young were killed with ether within 3 or 4 hours after birth and were preserved in Bouins', neutral formalin, or formolacetic-alcohol fixatives. The hearts, livers, and kidneys were excised and weighed prior to fixation. Microscope slides of sections 7 microns thick were prepared by paraffin technique. Masson's trichrome stain was used routinely. Frozen sections of 13 microns thickness were prepared for fat studies. The following histological and histochemical techniques were employed in addition to the routine staining: Sudan IV for lipids, periodic acid-Schiff reaction for polysaccharides (presumably glycogen), Kurnicks' methyl green-pronin for nucleic acids, and the Feulgen-Schiff reaction for deoxyribonucleic acid. Specific enzymes were used for ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) degradation for control. Ninety animals from deficient mothers and 40 from animals on the control diet were examined histologically.

## RESULTS

*Structure and histology of organs of biotin-deficient young.*

The weights of the organs on a body-weight: organ-weight ratio showed no significant variation between the control and experimental rats when subjected to statistical analysis. The average weight of the young born to deficient mothers was 4.65 (4.2–5.4) grams while that of the controls was 5.38 (4.7–6.2) grams.

*Heart:* Neither the aortic arches nor the chambers of the heart showed any abnormalities when examined grossly with a dissecting microscope. In approximately 55 per cent of the viable young born to mothers on the biotin-deficient diet, however, the heart presented abnormalities of histological structure. The most striking feature was the erosion of the myocardium of the right ventricle, and of both auricles, which resulted in extremely thin walls (Figs. 2, 4, 6, 8). In many cases the auricular walls were reduced to only one or two cell layers in thickness (Fig. 4) and the right ventricular wall was often only 4 or 5 layers thick (Fig. 6). Large sinusoidal spaces permeated the tissues of the right ventricle; however, this condition was rarely seen in the left ventricle. Macrophages, histocytes and other types of inflammatory cellular elements showed no significant increase.

The myocardial cells showed disorganization of the myofibrilli and inclusions of irregularly shaped vacuoles, both of which are suggestive of hydropic degeneration. The muscle cells showed a decrease of basophilic material with almost a total disappearance of cross-striations except in some of the cells in the peripheral regions of the myocardium.

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**Fig. 1. Auricle of newborn rat from control-fed mother. 80x**

**Fig. 2. Auricle of newborn rat from experimental mother. Note very thin wall. 80x**

**Fig. 3. Longitudinal section of auricle from control newborn rat. Note thickness of auricular wall and uniformity of cellular structure. 344x**

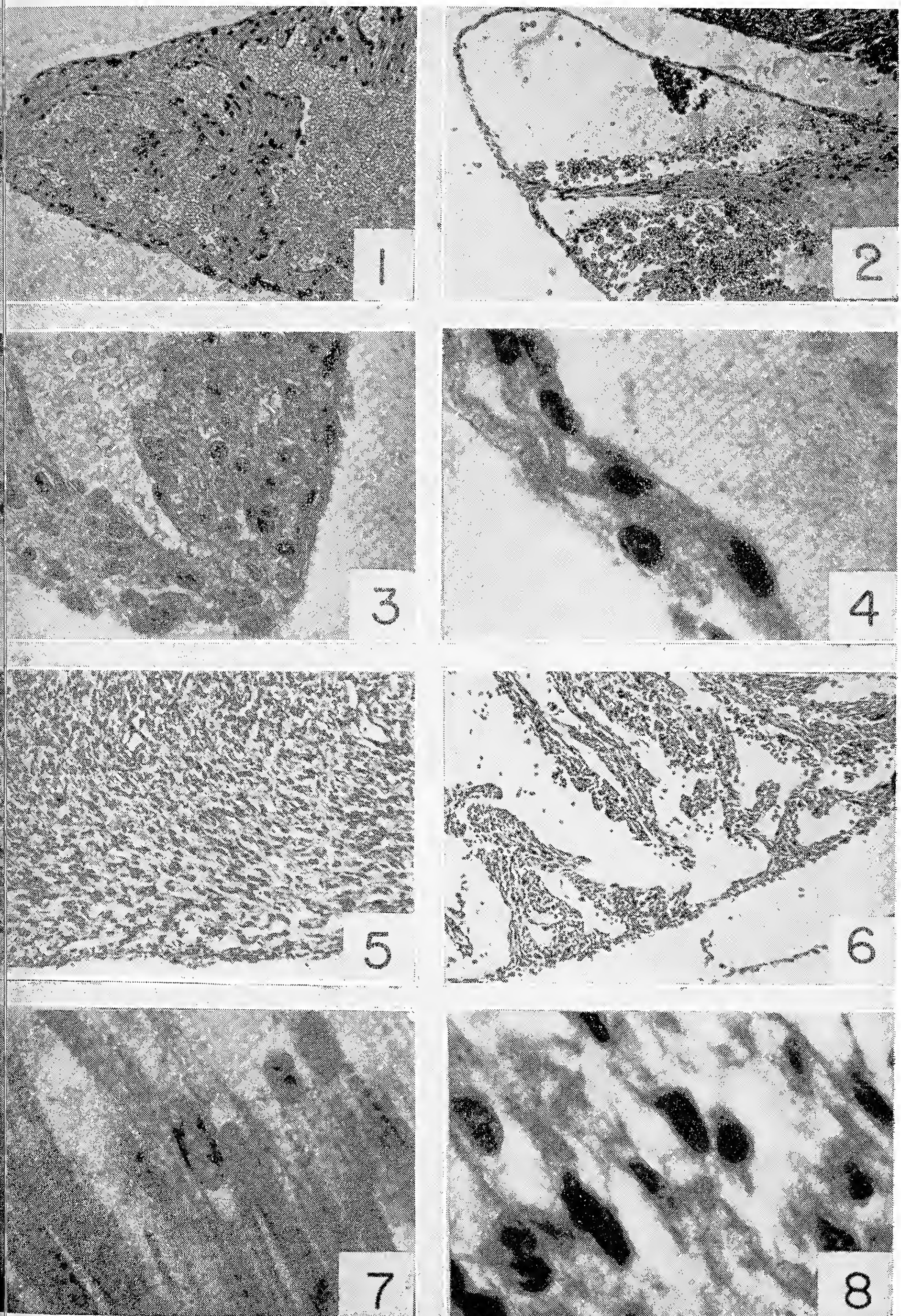
**Fig. 4. Longitudinal section of auricle from biotin-deficient newborn rat. Notice the denseness of the nuclei. 480x**

**Fig. 5. Longitudinal section of ventricular myocardium of a control newborn rat. 80x**

**Fig. 6. Longitudinal section of ventricular myocardium of experimental newborn rat. Thin walls, eroded areas, and disorganization. 80x**

**Fig. 7. Longitudinal section of control ventricle. 768x**

**Fig. 8. Longitudinal section of experimental ventricle. Cytoplasmic vacuolations, dense nuclei, and disorganization are evident. 768x**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The nuclei were enlarged and irregular in shape. They were less chromatic than those of the controls and had a perinuclear ring of chromatin material. The thin-walled condition of the auricles was apparently not due to blood engorgement but was the result of developmental failure or of secondary degeneration. The cellular elements of the auricular myocardium were more normal in appearance than were those of the ventricles.

The periodic acid-Schiff reaction showed a slight reduction in polysaccharides (presumably glycogen) in the hearts of the deficient animals. There was a reduction of the ribonucleic acid reaction (RNA) in the cytoplasm of the deficient muscle cells. Deoxyribonucleic acid (DNA) tests made by the Feulgen technique showed no apparent difference in deficient and control cardiac tissues. Lipids remained unchanged.

*Kidney:* The kidneys of the newborn biotin-deficient albino rat showed immaturity of development, glomerular degeneration, and hypertrophy and distention of the convoluted tubules. The cortex was thin with the external regions showing delayed development; the glomeruli were less differentiated and more disorganized than in the controls. Bowman's capsules were dilated and often the lumen was filled with detritus. The convoluted tubules were greatly distended and hypertrophy of capillary ducts and collecting tubules was observed (Figs. 10, 12). The lumina of the tubules contained some detritus. The hilus of the kidney was often very large and distended. Infiltration of medullary mesenchyme and precollagenous fibrocytes was extensive in the external regions of the medulla. In these animals 56 per cent of the deficient animals showed the extreme condition described above while the remainder showed a lesser degree of abnormality in structure. The kidneys of the control animals appeared normal (Figs. 9, 11).

Histochemical tests showed an overall reduction in the PAS reaction

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**Fig. 9. Control specimen of kidney with occasional enlargement of proximal tubules. 80x**

**Fig. 10. Biotin-deficient kidney with degenerate and enlarged proximal tubules. 80x**

**Fig. 11. Control kidney in area of Bowman's capsule. 344x**

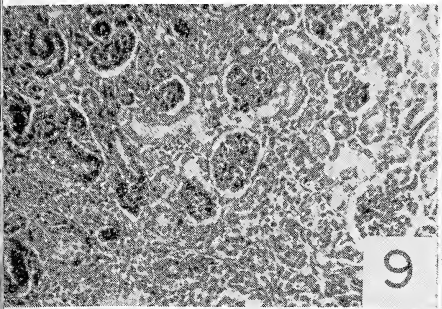
**Fig. 12. Kidney of biotin-deficient rat showing dilation and detritus deposits within lumen of Bowman's capsule. 344x**

**Fig. 13. Liver from control newborn rat. 80x**

**Fig. 14. Liver from experimental rat showing erythrocytic engorgement and liver cord disruption. 80x**

**Fig. 15. Liver from control rat. Note mitotic figure. 768x**

**Fig. 16. Liver from experimental rat. Diminution of cytoplasmic elements, "free" nuclei and fragments of erythrocytes. 768x**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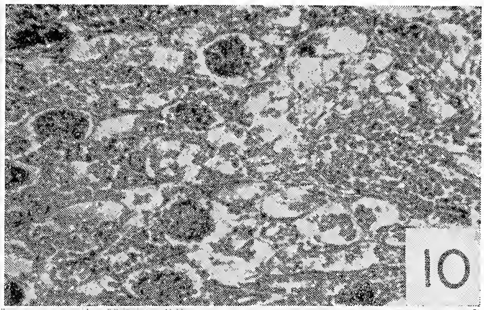
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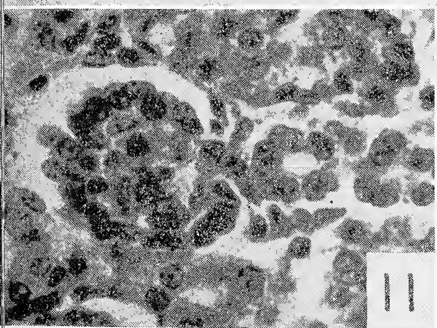
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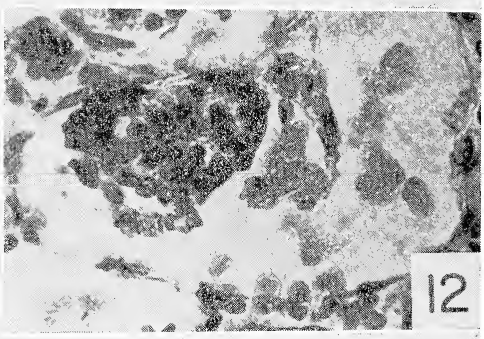
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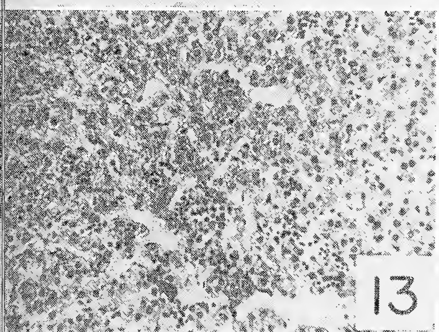
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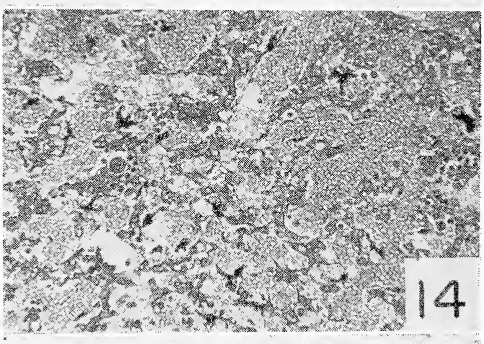
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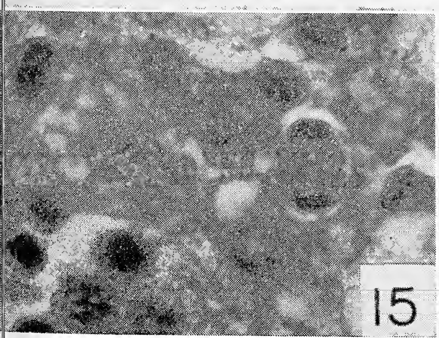
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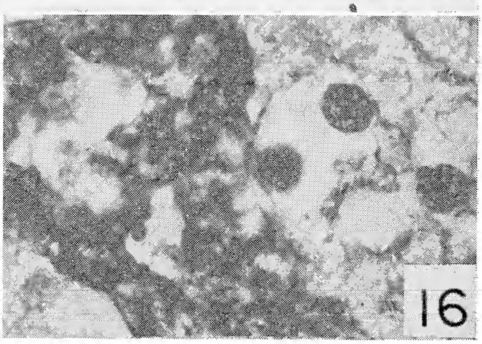
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in the biotin-deficient renal tissues. A greater decrease was noted in the convoluted tubules of the biotin-deficient kidneys, in contrast to the control tissues, which showed the greatest concentration of PAS positive materials in the convoluted tubules. The cytoplasmic RNA content was reduced in all areas, particularly in the periphery of the cortex. Fatty infiltration was not observed in the biotin-deficient kidneys and no apparent change was visible in nucleic DNA content.

*Liver:* The livers of the albino rats born to mothers on the biotin-deficient diet showed sinusoidal dilation, degeneration of the hepatic cells, and lymphocytic infiltration (Fig. 14). The sinusoidal spaces were dilated and distended with non-nucleated red blood cells. Ghosts of red cells often were concentrated in the periphery of the sinusoids. The general structure of the liver was disrupted and the cellular pattern disarranged. The more degenerate hepatic cells were swollen and often devoid of glycogen. Large irregularly-shaped vacuolar spaces present in the cytoplasm suggested hydropic degeneration (Fig. 16). Lymphocytes were often present throughout the liver tissue. Of the deficient animals only 26 per cent showed the extreme picture depicted above. The remaining 74 per cent showed a variable amount of liver damage. In the controls some 30 per cent showed lymphocytic invasion or atrophy of the hepatic cells which was seldom as severe as that observed in the less pronounced of the deficient animals. Since this condition had been noted in the control newborn on other adequate diets it was considered as "normal" for these rats.

The results of the histochemical tests were essentially the same as those observed in the tissues of the hearts and kidneys in that biotin-deficiency had no apparent influence on lipoidal or DNA content of the hepatic tissue, whereas amounts of glycogen (PAS) and RNA were reduced.

## DISCUSSION

Adult female white rats placed on biotin-deficient rations for relatively short periods of time do not exhibit external deficiency symptoms. However, deficiencies are manifested in reproductive processes and in growth abnormalities of their young. The work of many authors dealing with vitamin A deficiency (Wilson and Warkany, 1948, 1949) and with blocking agents like urethane, galactoflavin (Baird, Nelson, Monie, Wright and Evans, 1955), methylene blue, irradiation (Rugh, 1949), etc., show that whatever specificity these agents seem to have lies in the particular moment of susceptibility of tissues at the time of impact of the reagent or of the deprivation of some essential nutrient.

The study of biotin deficiency showed that some of the manifestations seen after birth could be explained as the indirect result of blocks in liver or kidneys. Similarly, cardiac anomalies were held responsible for urogenital hypoplasias in the work of Baird, *et al.* (1955) using glactoflavin.

The role of biotin in biochemical reactions has been reviewed by Sebrell and Harris (1954) and was summarized as follows: "Biotin appears to participate in various enzymatic reactions such as in the decarboxylation of oxaloacetate and of succinate, in the deamination of aspartic acid and serine and threonine, in the dehydrogenation of succinic acid, and indirectly in the synthesis of citrulline and of oleic acid." Some of these reactions have been reported to be reduced in duck heart (Olsen, Miller, Topper and Stare, 1948), in turkey liver (Ochoa *et al.* 1947), and in rat liver (Grisolia and Cohen 1948). From these malfunctions it could follow that if biotin is not supplied to the mother in sufficient quantity, the developing embryo would likewise show upset metabolic activities. These metabolic changes could in turn be manifested by structural abnormalities. The ultimate result of this interference would be the death of the embryo or the formation of abnormalities that would persist throughout fetal life.

The abnormal changes in the heart, liver, and kidney that were found in our experiments with white rats were entirely prevented either by injection of a biotin solution into the females or by supplementing the deficient maternal diet with biotin at the time of mating.

## SUMMARY

*Conclusions:* Female rats deprived of biotin from before the time of mating until the end of gestation, produced offspring that were smaller than normal newborn rats and that had a high percentage of abnormalities of the hearts, livers, and kidneys. The defects involved vascular blocks, especially in the liver, with consequent passive congestion suggesting hydropic degeneration. The heart showed severe degeneration in the myocardium of the right ventricle and a thin-walled condition was present in both auricles. Bowman's capsules were enlarged and often filled with detritus and the proximal convoluted tubules more distended and filled with degenerate cellular material. Histological tests showed an overall reduction in cytoplasmic RNA and in PAS-positive substances (presumably glycogen) while the DNA content of the nuclei and the deposition of lipoidal material remained unchanged.

## ACKNOWLEDGMENTS

This work was made possible through grants-in-aid from the National Institutes of Health of the United States Public Health Service and from the Surgeon General's office of the U. S. Army.

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# Notes on the Life History of the Bonnetnose Shark, *Sphyrna tiburo*[1]

*by* **H. D. HOESE** *and* **R. B. MOORE**[2]
*Marine Laboratory, Rockport, Texas*

From August 20 to September 3, 1957, collections by the Marine Laboratory in lower Aransas Bay took six pregnant females of the common bonnetnose shark, *Sphyrna tiburo* (Linnaeus). All six were mature females with well developed foetal young nearing full term. The specimens were 120.5, 112.9, 112.8, 110.5, 109.0, and 108.9 cm. in total length. The number of young varied from eleven to fourteen (see table I). Radcliffe (1916:266) took a female 124.0 cm. in length which contained nine young, six in the left uterus and three in the right. Bigelow and Schroeder (1948:424) list the number of young from six to nine, but if our specimens are typical, the average number is higher, with the maximum possibly fourteen. Gunter (1945:21) took four pregnant females from lower Aransas Bay, 104.0 to 112.5 cm. in length, containing 4, 5, 8, and 8 young. The maximum number of young we find recorded is that of Radcliffe (loc. cit.) and Longley and Hildebrand (1941:3) who report a 92.5 cm. female with nine young all 137 mm. long.

Table I

Sex Ratio of Foetal Young in Six Female *Sphyrna tiburo*

| *Size of Mother* (Total length in cm.) | *Number of Young* Right Uterus | | Left Uterus | | |
|---|---|---|---|---|---|
| | Males | Females | Males | Females | Total |
| 120.5 | 6 | 1 | 4 | 3 | 14 |
| 112.9 | 4 | 2 | 3 | 2 | 11 |
| 112.8 | 3 | 4 | 1 | 5 | 13 |
| 110.5 | 4 | 3 | 2 | 4 | 13 |
| 109.0 | 3 | 3 | 4 | 2 | 12 |
| 108.9 | 2 | 4 | 1 | 4 | 11 |
| Total | 22 | 17 | 15 | 20 | 74 |

[1] Contribution No. 40 from the Marine Laboratory, Texas Game and Fish Commission, Rockport, Texas.

[2] Present Address: Department of Biology, Texas Christian University, Fort Worth, Texas.

A total of 74 foetal young was taken from the six female sharks, 37 males and 37 females. As can be seen from table I, the sex ratio was never equal in any one individual. There seems to be a possible correlation between the number of fully developed foetal young and the size of the mother, although Radcliffe's (loc. cit.) large specimen contained only nine young. Gunter's (loc. cit.) four pregnant females averaged slightly smaller than ours, and his wording suggests that the larger specimens contained the most young.

Two partly developed foetuses were found; one in the 112.8 cm. specimen, 94 mm. long, and one in the 112.9 cm. specimen, 123 mm. long. The largest undeveloped foetus still retained its yolk-sac placental connection with the uterus, but the blood flow had ceased. Apparently the number of ova that reach foetal maturity depends on the size and vigor of the mother.

Longley and Hildebrand (Ibid.) have described the uteri of *S. tiburo*. In our specimens each foetal young had a separate placental attachment with the uterine wall. Each yolk-sac placenta attached to the posterior end of the uterus to a placental disk which was connected to anastomosing uterine vessels. These young were all facing anteriorly.

Size of the female foetal young ranged from 295 to 348 mm., excepting a 273 mm. foetus which was normal in every respect but size. The male foetal young ranged from 306 to 339 mm. The males in each parent averaged larger than the females, the average of the 37 males being 326.7 mm., compared to 319.6 mm. for the females.

Gunter (Ibid.) found that birth evidently takes place in late summer and early fall. He took two small specimens, 30.8 and 31.5 cm. long, in September and October. The foetal young he found were evidently nearing full term as they approached the size of the small free-swimming specimens he subsequently took. Our foetal young were larger. Five free-swimming specimens that were taken on August 28 and 29, 342, 354, 357, 359, and 369 mm. long, were recently born as the stomachs were still empty and the intestine still contained meconium.

One spent female (117.0 cm.) was collected on September 5 and a ripe male (108.7) cm. was collected on September 3 from the same locality. All mature specimens collected after these dates were spent.

Stomach analysis of the adult females yielded mainly blue crabs, *Callinectes sapidus* Rathbun. All had eaten one or two mature female crabs. One had eaten three pigfish, *Orthopristis chrysopterus* (Linnaeus), from 69 to 77 mm. standard length; one pinfish, *Lagodon rhomboides* (Linnaeus), 81 mm. s. l.; and one croaker, *Micropogon undulatus* (Linnaeus), 110 mm. s. l. Trawl collections in the area yielded large numbers of these fishes. Other items in the diet of *S.*

*tiburo* as listed by Bigelow and Schroeder (Ibid.) include mantis shrimps, isopods, barnacles, pelecypods, and cephalopods. One of our specimens had a mat of algae in its stomach. Two immature specimens (790, 678 mm.) taken on September 3 contained a mat of *Thallasia testudinum* Koenig and Sims and *Diplantheria wrightii* (Ascherson) Ascherson, two "grasses" common in the area. This habit had been noted by Radcliffe (Ibid.), Bigelow and Schroeder (Ibid.) advancing the idea that the algae and "grasses" are taken incidentally with the crabs.

Springer (1938) has shown that the main diet of *S. tiburo* is crabs and Gunter (1945) subsequently found *Callinectes sapidus* to be the one utilized in Texas waters. Two specimens taken by the senior author in Aransas Bay in August, 1956, had eaten *Callinectes danaë* Smith. At this time *C. sapidus* was absent from Aransas Bay and *C. danaë* had invaded with the high salinities of 45 parts per thousand.

*S. tiburo* is a shallow water species, being very common on Texas beaches in summer and fall. Gunter (1945) took specimens only in spring, summer, and fall. In an eighteen-month survey conducted by the Marine Laboratory in Aransas Bay *S. tiburo* has been collected from May to October when water temperatures were above 26.5 degrees Centigrade. Hildebrand (1954:282) belives that there is an off-shore migration in winter. The *Oregon* (Springer and Bullis, 1956) took no bonnetnose sharks in waters deeper than nine fathoms. Possibly they move southward along shore in the winter, but we do not have the data to confirm this. Bigelow and Schroeder (1948:425) state that *S. tiburo* is found in South Carolina from June to October, and is a year around resident in southern Florida.

Hildebrand (Ibid.) quotes Gunter in saying that *S. tiburo* is probably the most abundant shark in Texas waters. Our data confirm this for the shallow Gulf and Aransas Bay. Apparently it invades only primary bays, possibly being limited by salinity. We have taken only *Carcharhinus leucas* (Müller and Henle) from Mesquite Bay, a tertiary bay when Cedar Bayou is closed from the Gulf. *S. tiburo* has been collected from Mesquite Bay when Cedar Bayou is open to the Gulf.

We are glad to acknowledge the aid of Miss Patricia Pew who supplied some of the data and Dr. Sewell H. Hopkins for critizing the manuscript.

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## Science in Texas

Addition of a proposed science incentive contest to the University Interscholastic League's schedule of competitions is being considered by the League's rules-making body, the legislative council, through a sub-committee.

The added contest was requested by Wayne Taylor, Alan Humphreys and John Wagner of The University of Texas Division of Extension science teaching improvement program, who appeared before the legislative council at its annual meeting.

On behalf of the Texas Academy of Science, the three-man committee outlined a plan for an objective science test at the district, regional and state levels. The contest would be designed to stimulate independent scientific reading by outstanding students and help develop abilities to read, understand and apply problem solving techniques.

Meanwhile, the League has published a completely new "Beginners' Slide Rule Manual" to keep pace with increased participation in the slide rule contest, up 116.6 per cent since 1953. The new manual was prepared by Otto G. Brown, state slide rule director for the League, and H. Grady Rylander, former state director, to aid slide rule coaches in preparing contestants for competition.

Regional student activities conferences in preparation for Interscholastic League contests in number sense and slide rule, ready writing, journalism, speech and drama have been held at the University of Houston, Southern Methodist University, Abilene Christian College, Kilgore (Junior) College and Southwest Texas State Teachers College, Odessa (Junior) College, East Texas State Teachers College, Texas A & I College, Sam Houston State College, and Stephen F. Austin State College (speech and drama workshops only).

★ ★ ★ ★

Henry C. Cortes died Friday, December 6, 1957. He was a vice-president and director of Magnolia Petroleum Company and had executive charge of Field Research Laboratory and coordination of Magnolia's offshore operations.

Cortes joined Vacuum Oil Company in June, 1924, and came to Magnolia in 1932, when Vacuum merged with Standard Oil of New York to form Socony-Vacuum Oil Company.

In 1937, Cortes was named director of geophysics and, nine years later, in 1946, he was made assistant manager of the Exploration Division. He was elected to the board of directors and named executive in charge of the Field Research Laboratory in March, 1954. In August, 1956, he was made a vice-president of Magnolia Petroleum Company.

Cortes has received national and international recognition for his work on offshore oil exploration and fundamental and applied research. In June, 1955, Cortes presented a paper on "Geophysical Prospecting Over Continental Shelves" at the Fourth World Petroleum Congress in Rome, Italy. He was recently honored by the University of the South at Sewanee, Tennessee, where he was awarded the Honorary Degree of Doctor of Science.

He has been a leading pioneer in oil exploration in the Gulf Coast land areas of Louisiana and Texas, and he had a large part in the finding of several oil fields there.

Cortes was a past president of the Society of Exploration Geophysicists, Dallas Geological Society, and Dallas Petroleum Club. He was a Fellow of the Texas Academy of Science. Cortes was also a member of the American Association of Petroleum Geologists, American Geophysical Union, American Association for the Advancement of Science, Seismological Society of America, and Dallas Geophysical Society.

★ ★ ★ ★

Dr. Walter Prescott Webb, noted University of Texas historian, became president of the American Historical Association when the organization met December 28–30 in New York City.

Dr. Webb served as AHA vice-president the past year. He was president of the Mississippi Valley Historical Association in 1955.

Dr. Webb is known internationally for his "frontier" theory of modern world history, which he explained in Paris in 1950 before the International Congress of Historians.

★ ★ ★ ★

Dr. Fred M. Bullard, University of Texas volcanologist who has been keeping constant check on volcanic action in Central America for 11 years, plans to expand his research project to include Ecuador's volcanoes. Dr. Bullard is conducting a long-term survey of Latin America's volcanoes for the Pan American Institute of Geography and History. He makes regular observation trips to chart each volcano's activity.

Dr. Bullard and volcanologists working with him hope their research will someday enable scientists to predict the time of destructive volcanic eruptions. Studies of the volcanoes will provide information on some of "the fundamental geological problems involving the nature of the earth's interior and the origin of mountains," Dr. Bullard said.

Central America is part of the "fire girdle" of the Pacific Ocean, he explained. That area contains the world's most highly-explosive volcanoes. Geologists classify volcanoes in two categories, the highly-explosive and the "quiet type" Mauna Loa in Hawaii is a "quiet type," for it pours out lava without violent explosions. But the highly-explosive volcanoes found in Central and South America eject great clouds of ash and cinders accompanied by tremendous explosions. Nicaragua contains the greatest number of explosive volcanoes, 37, in an area about as large as three counties in Texas, Dr. Bullard said.

The "fire girdle" follows the west coastal area of Central America moving southward toward Peru and northward along the U. S. Pacific coast to Alaska. The line of volcanic activity continues down from Alaska to Japan, following again the ocean-shoreline, before curving over to Java and Sumatra.

It is a common saying in Italy that land ruined by volcanic eruption will not be agriculturally productive for 100 years. However, Dr. Bullard says the time required for Nature's rehabilitation of the land depends on weathering—due to rain and the elements which decompose the volcanic ash into soil.

★ ★ ★ ★

A two-year study to observe how mental patients who are furloughed or discharged from Texas state hospitals work out their readjustment to community life as they return home and what measures the community takes to assist them in the process was started at The University of Texas, January 1. Dr. Robert L. Sutherland, sociologist, director of the University's Hogg Foundation for Mental Health, is principal investigator. Co-directors are Dr. Wayne H. Holtzman, psychologist, Hogg Foundation associate director, and Dr. R. C. Rowell, psychiatrist, Terrell State Hospital superintendent. The National Institute of Mental Health has allocated $48,300 to support the study for two years.

"Bridging the Experience from Hospital to Community" is the first community-centered rehabilitation study undertaken in Texas. The research team hopes to "determine the nature and dimensions of the problems and problem-solving patterns" associated with the return of furloughed and discharged patients from two state mental hospitals to four Texas communities with populations under 50,000. Research will deal with hospital and community procedures associated with the furloughing and discharging of mental hospital patients; rehabilitation problems which confront the patient as he attempts to re-establish relationships at home, on the job and in community groups; problem-solving patterns of the patient and his family as they attempt to meet such problems, and the community's reaction to rehabilitation problems of citizens who have returned from mental hospitals.

★ ★ ★ ★

The 1958 Southwestern Institute of Radio Engineers Conference and Electronic Show will be held at the St. Anthony Hotel and the Municipal Auditorium in San Antonio. It is anticipated that 2,000 engineers and scientists will attend the three-day event. Ten technical sessions will be conducted plus a student paper contest. The current interest in the International Geophysical Year will be the conference theme. Proceedings of the conference will be published for the first time in the 10-year history of the SWIRECO. An elaborate program is planned for the ladies. Highlights include a party at the "Pearl Corral," and an evening of entertainment at San Antonio's famous "La Villita." There will be 125 exhibit booths for leading Electronic Equipment and Component Manufacturers to show their latest products. The dates are April 10, 11, and 12, 1958.

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The Department of Oceanography and Meteorology at the A. and M. College of Texas has announced the availability of fellowships and research assistantships to qualified graduates in physics, chemistry, geology, meteorology, biology, and engineering for 1958–59. Included are three fellowships with stipends ranging from $1,800 to $3,000 and research assistantships ranging from $1,800 to $2,775 for 12 months.

Fields of emphasis include interaction between ocean and atmosphere, marine meteorology, radar meteorology, ocean waves and wave forces, weather analysis, water level problems, micrometeorology, agricultural meteorology, marine geochemistry, carbon dioxide relationships in the sea and atmosphere, radioactive and industrial waste disposal, comparative biochemistry of marine organisms, organic composition of marine sediments, demineralization of sea water, estuarine pollution, coastal and estuarine geology, trace minerals, and bacteria-phytoplankton relationships in the sea.

Application forms may be obtained from the Head of the Department of Oceanography and Meteorology, the A. and M. College of Texas, College Station, Texas.

★ ★ ★ ★

Heavy fall rains played havoc with the schedule of a University of Texas archeologist and his assistants digging for Caddo Indian artifacts at the Ferrell's Bridge damsite near Jefferson in northeast Texas.

The research team directed by Dr. E. Mott Davis, University of Texas research archeologist, was working against a Jan. 1 deadline to collect artifacts before the dam reservoir area was permanently flooded.

Dr. Davis explained that the huge reservoir at the Ferrell's Bridge damsite was to have been filled early in 1958, thus making further archeological research there impossible. But rains filled the reservoir with disregard to man-made schedules. Not only were the archeologists' plans disrupted—the dam construction schedule was also delayed, so the setback in construction offers one advantage to the archeologists—it will give them more time to cover the area in the spring, if spring rains don't interfere.

It rained from Oct. 15 until just before Thanksgiving, Dr. Davis related. "Once we had eight inches in two days. The reservoir where we were supposed to be working was filled within eight feet of being flooded."

The area Dr. Davis is exploring is about 15 to 20 miles long and two miles wide.

At present the group is investigating burial sites and searching for location of a possible permanent settlement. Dr. Davis explained that burial sites are usually about 100 feet from the houses. He and his assistants are first working the burial sites, hoping this work will lead them to the permanent settlements. They have covered the ground surrounding the burial sites, searching in a 200-yard radius pattern from the burial area.

After completing the digging and collecting of artifacts, they will be taken back to the laboratory where the archeologists will piece together thousands of pottery fragments and other revealing evidence in their effort to recreate a reliable picture of the Caddo civilization which thrived in northeast Texas about 1400 A.D. Funds for the investigations are furnished by both state and federal governments under a 1946 congressional act providing the National Park Service with money to salvage archeological ruins before they are forever lost beneath giant dams and concrete highways.

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T. J. Greaney and G. W. Wilson have been promoted to assistant division heads in Technical Service Division at Humble Oil & Refining Company's Baytown, Texas, refinery. Greaney is responsible for the activities of the economic analysis, the catalytic cracking, the catalytic light ends, and the aviation sections of the Division. In addition the specialists on electronic computers come under his supervision. Wilson is responsible for the activities of the lubricating oil, distillate finishing, and distillation and utilities sections; the Technical Service Practice School is also under his supervision.

Both Greaney and Wilson are graduates of Rice Institute with B.S. degrees in chemical engineering.

Dr. John T. Lonsdale (director), Bureau of Economic Geology at The University of Texas has announced receipt of a $1,650 grant from the Colorado River Industrial Development Association, which will aid Bureau geologist in synthesizing "in one report all available information on the location, quality and quantity of mineral materials" in San Saba, Llano, Burnet, Blanco, Travis, Bastrop, Fayette, Colorado, Wharton and Matagorda counties. John W. Dietrich, Bureau research scientist, will be in charge of the survey.

Dr. Lonsdale said that a report of survey findings will serve "as a reference handbook on the area's mineral resources and will also point the way for specific detailed investigations which may be needed." Although the survey will be primarily a compilation of existing information, some new field work and testing will be done. The area to be investigated contains deposits of dolomite, graphite, lignite, high-quality limestone and other building stone, volcanic ash, salt, sulphur, iron ore, vermiculite and other minerals.

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Dr. Clark Hubbs, University of Texas zoologist, will continue his search for new knowledge about interbreeding among fish species on an $11,800 renewal grant awarded him by National Science Foundation. The new grant, beginning February, 1958, will support Dr. Hubbs' investigations through 1961. He has had a two-year NSF grant which ends in January. His basic research project seeks answers to these questions: What keeps one fish species from mating with another? How can a fish recognize one of its own species?

Dr. Hubbs' findings to date suggest that the mechanism which enables one species to avoid mating with another species may have a visual basis. By observing fish placed in "courtship" tanks in an aquarium room at the University, Dr. Hubbs has identified three factors which affect the sexual behavior of fish species: Visual recognition of distinctive "approaches," varying behavior patterns among species, and proximity. Interbreeding occurs where species are "rare." If a male is looking for a mate and can't find one of his own species, he is forced to pick a female not of his species. "This unnatural circumstance we find more in fresh water," Dr. Hubbs said.

The number of salt water fish hybrids is low, occurring among about 10 to 15 individuals compared to fresh water hybrids totaling 400 to 500 hybrid combinations, many with several thousand individuals. Ever-changing conditions in fresh water lead to more "mistakes" in mate-choosing; the fish is able to see more clearly in salt water where his visibility is not hampered by muddy water.

"Hybrids naturally produced do exist, but the number varies with different fishes," he added. "There is never a crossing between widely divergent species." In artificial breeding the strongest hybrids produced are crosses between closely-related species, between two kinds of minnows, for example.

Dr. Hubbs first collects fish from streams around the country and then puts them in aquariums. He collects about 90 per cent of his specimens from Texas rivers, especially the Colorado, San Saba, South Concho, Guadalupe and San Gabriel.

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University of Texas geographers led by Dr. Donald D. Brand, geography department chairman, have explored a little-known shoreline in Michoacan, a Southwest Mexico state on the Pacific Ocean, bringing back data never before recorded. Results of their explorations are being published in two technical reports, the first, "Coastal Study of Southwest Mexico," printed recently, and the second, due off the press in a few months.

Primary aim of geographers investigating Michoacan was to learn facts about the coastline, rivers and natural barriers in order to map the area accurately. Until now only the crudest charts and incorrect maps were available. Dr. Brand, with two assistants, Pablo Guzman-Rivas of Austin and Boulder, Colo., and Alfonso Gonzalez-Perez of Brooklyn, N. Y., covered the entire coast of Michoacan on foot, then by launch and air.

Because of its inaccessibility the Michoacan coast has remained an isolated area. Obstacle to approaches by sea is the rocky coastline itself. "Not only are there no ports on the Michoacan coast," Dr. Brand says, "but the number of landing places is not fixed, since skill, courage, and foolhardiness determine the feasibility of making a canoe landing." Along the middle Michoacan cost high cliffs rise almost directly from the sea and waterfalls spill directly into the ocean. Dr. Brand found Michoacan springs steaming with water at the boiling point, a geographic feature quite uncharacteristic of the area.

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Dr. Clarence P. Oliver, University of Texas director of zoology research, says hereditary basis exists for cancer to occur at specific organs in some families. Brothers, sisters and parents of persons with stomach and breast cancer have a higher rate of cancer of the same type than does the general population.

By collecting family histories of cancer patients, Dr. Oliver is trying to determine what part heredity plays in causing cancer. Studies of family pedigrees indicate that susceptibility to cancer is inherited in certain families and in branches of families; however, environment may be responsible for variations in age of onset.

Geneticists face two major difficulties in collecting histories of cancer families. First, some persons refuse to give information about cancer in their family because they fear their family might suffer economically as a consequence. Second, tracing the hereditary cancer line from mother to daughter is difficult because only 71 per cent of the cancer victims have had any offspring. Pointing out that low fertility rate plays a part in breast cancer development, Dr. Oliver said unmarried women face a much greater possibility of having cancer than do married women.

Further, childless married women face a greater hazard of cancer than married women with children. Statistics compiled from Australia, England, and the U. S. indicate that mothers who breast-feed their children have the lowest rate of breast cancer development.

Average age of onset of breast cancer is 53.2 years. Approximately 68 per cent of breast cancer occurs in women between 41 and 65. Only five per cent of breast cancer is found in young women under 29, Dr. Oliver said. Youngest victim of breast cancer which Dr. Oliver has recorded was 20.

A high frequency of cancer in a family group may be the result of "gene action" but that is not necessarily the explanation, he said. "An environmental agent common to the relatives could theoretically cause multiple cases in a family." Dr. Oliver said genticists now believe a "wild gene" or possibly hormone disbalance causes cancer. Dr. Dudley Jackson, Sr., San Antonio surgeon, is cooperating with Dr. Oliver in his genetic studies of cancer families.

Another group of University of Texas scientists are searching for a possible anti-cancer vaccine. Dr. Alfred Taylor, biochemist, and his assistants are testing more than 1,000 extracts from plants all over the world in their attempt to ferret out a plant juice that will destroy or retard cancerous tissue growth. The plant extracts are supplied by the U. S. Department of Agriculture.

In testing the anti-cancerous capacity of plant extracts, Dr. Taylor is injecting the extracts into mouse tumors grown in incubating eggs. The blood stream of the embryonic chick supports the cancerous tissue. This method of growing live cancerous tissue was originated at the University's Biochemical Institute, one of six great centers of cancer research in America.

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The hypothesis that talent can be developed as well as discovered will be studied by a group of University of Texas Educational Psychologists. A project to investigate this idea has been approved by the U. S. Department of Health, Education and Welfare, with a grant of

$115,836 for a 43-month study. Talent may be guided, nudged, or even pushed into existence—within certain biological limits. Few people even approach the limits of their potential talent because their natural curiosity gets "fenced off" somehow, the group of behavioral scientists believe. Improving the utilization of human talent is the goal of the long-range study, which may continue four or more years beyond the initial project. Junior high school students in two or more communities will participate in the original investigations. The psychologists want to follow all groups through their senior high school careers, possible choice of higher education and transition to adult life. The study will focus on seventh-graders the first year, eighth-graders the second year and ninth-graders the third year. "Experimental" and "control" populations will have several hundred boys and girls each. The school-community settings will be comparable. The "experimental" groups will be in a school where teachers and counselors agree to take part in an in-service education program leading to "deliberate, purposeful utilization of planned variations in teaching and guidance processes inside and outside classrooms." The "control" groups will continue under present educational methods. The team of researchers working on the project includes Dr. Carson McGuire, director and principal investigator; Drs. Ralph L. Duke, Benjamin Fruchter, Beeman N. Phillips, John Pierce-Jones and Jackson B. Reid, professorial collaborators.

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Dr. Norman Hackerman, University of Texas chemistry department chairman, was elected Electrochemical Society president by the national organization's 3,000 members, in January. Dr. Hackerman will take office in May. He has previously been vice-president and technical editor of the society's journal. Prof. Hackerman is best known for his studies of corrosion on steel and in natural gas and sulphur production processes. He developed a new process for plating chromium on automobiles, certain home furnishings and other articles, and also helped develop a process for de-inking newsprint. Last year he received the National Association of Corrosion Engineer's Whitney Award "in recognition of public contributions to the science of corrosion."

## Affairs of The Texas Academy of Science

The sixty-first annual meeting of The Texas Academy of Science was held at Southern Methodist University, Dallas, December 12–14, 1957. The interesting program, in abbreviated form, is given below.

GENERAL SESSIONS

*Friday, December 13*

11:00 A.M. Presidential address: E. L. Miller (Stephen F. Austin State College), "The Making of a Scientist"

7:00 P.M. Willis M. Tate (Southern Methodist University) gave the banquet address.

SECTION I—Physical Sciences, Texas Section, American Association of Physics Teachers, and Texas Section, Mathematics Association of America.

*Friday Morning, December 13*

E. A. EADS and J. C. POTTER, *Presiding*

W. R. Woolrich (The University of Texas), "Solutions to Some New Destructive Hot Climate Condensation Problems in Building Wall Insulation".

Paul D. Minton (Southern Methodist University), "The S.M.U. Laboratory's Univac Scientific 1103 Computer".

James C. Bradford (Abilene Christian College), "Mapping Topology to Dual in Linear Space".

Joe S. Ham (Texas A. and M. College), "Thermal Diffusion of Polymer Solution 3".

B. C. Thompson and P. M. Windham (North Texas State College), "Research Using Low Energy Charged Particles".

Fred W. Inman (Howard Payne College), "Parity Non-Conservation in Hyperon Decays".

Jack C. Fuller (Baylor University), "Angular Distribution of the D (d,n) He Reaction Below 1 MEV."

Robert G. Packard (Baylor University), "Measuring the Acceleration of a Ballistic Pendulum With a U-Effect Accelerometer".

*Friday Afternoon, December 13*

DIVISION A

C. R. SHERER and C. M. LLOYD, *Presiding*

H. P. Gregor (Brooklyn Polytechnic Institute), "Physical-Chemical Properties of Ion-Selective Membranes".

James C. Bradford (Abilene Christian College), "Comments on the Use of the Dirac Delta Function with Transform Methods".

W. T. Guy, Jr. (The University of Texas), "Approximations for the Inverse Laplace Transforms".

E. Volterra and E. C. Zachmanglou (The University of Texas), "Longitudinal Waves in Elastic Plate".

R. K. Russell (Texas A. & M. College), "The Rotational Analysis of the 3400–3900 A° Absorption System of Sulphur Dioxide".

James W. Riggs (Texas A. and M. College), "2000 A° System of Sulphur Dioxide".

Donald A. Cowan (Texas Christian University), and J. H. Brown (Texas Electric Service Company), "Some Effects of Turbulence on Electrolytic Conduction".

DIVISION B

D. A. COWAN and F. INMAN, *Presiding*

Moody L. Coffman (Abilene Christian College),"Where Superposition Fails".

B. J. Hackfield, B. L. Lamb, and J. C. Young (North Texas State College), "Low Budget Research Program with Cockcroft-Walton Accelerator".

B. P. Foster (North Texas State College) and W. W. Givens (Magnolia Field Research), "Investigation of Gamma Rays from Neutron Bombardment of Arsenic".

Brother Romard Barthel (St. Edwards University), "Physical Theory and Objective Reality".

Ben P. Miller (Texas A. and M. College), "The Effect of Anharmonicity on Intensity Calculations of Ultra-Violet Absorption Bands".

R. L. Wilson (Texas Christian University and Convair), "The Reducibility of Polynomials".

*Saturday Morning, December 14*

DIVISION A

R. A. Eads and Moody L. Coffman, *Presiding*

Don A. Edmonson (Southern Methodist University), "An Experimental Summer Program for High School Students".

H. J. Ettlinger (The University of Texas), "What is Modern Mathematics".

Jane S. Crocker (Garland High School), "Some Techniques of Teaching Secondary Chemistry".

C. R. Sheren (Texas Christian University), "What Should We Do With Our Gifted Freshmen?"

Cicero Bernard (Texas A. and M. College), "Nuclear Experiments for Elementary Physics".

J. G. Potter (Texas A. and M. College), "New Physics Program for Engineering Students with Increased Modern Physics".

DIVISION B

James C. Bradford and R. L. Hoyle, *Presiding*

M. S. B. Munson and R. C. Anderson (The University of Texas), "Effects of Additives on Flames and Explosion of Acetylene".

Sally Cauthen (Abilene Christian College), "Preparation and Properties of Biotinyl Phosphate".

T. S. Burkhalter (Texas Instruments), "An Analytical Study of the Hydrolysis of Aqueous Solutions of Pilocarpine Hydrochloride".

Newton Gaines (Texas Christian University), "Some Texas Additions to the Six Simple Machines, and The Boomerange, A Neglected Gyroscope".

J. A. Scanlin (The University of Texas), "A Cheap Method of Fabricating Small Thermocouples".

L. A. Youngman (Pan American College), "A Simple Demonstration for A.C. Circuit Phenomena".

Section II—Biological Sciences

*Friday Morning, December 13*

Bryce C. Brown, *Presiding*

Clark Hubbs (The University of Texas), "The Correlation of Fish Distribution with Water Chemistry".

Pauline James (Pan American College), "Notes on the Nesting Behavior of the Least Grebe, Podiceps dominicus".

Clarence Cottam and Caleb Glazener (Rob and Bessie Welder Wildlife Foundation), "Late Waterfowl Nesting in South Texas".

O. S. Lin (Huston-Tillotson College), "Biology of Some Sphecid Wasps".

T. P. Dooley and George Mercer (Prairie View A. and M. College), "A Preliminary Report on the Development of Curculio victoriensis".

Ralph W. Axtell (The University of Texas), "The Transcontinental Biotic Filtering Area".

S. W. Geiser (Southern Methodist University), "William Lloyd, British-American Natural History Collector in Texas".

*Friday Afternoon, December 13*

DIVISION A

Dixie Young, *Presiding*

Ernest Joe Harber and W. E. Norris, Jr. (San Antonio College), "Cellular Respiration in Onion Roots".

James E. Butler and W. E. Norris, Jr. (Southwest Texas State Teachers College), "Determination of the Presence and Distribution of Certain B Vitamins in the Onion Root Tip".

J. C. Streett, Jr. (Texas Wesleyan College), "A Quantitative Interpretation of Liver Restoration in Rana pipiens".

Allen Chittenden and Mary E. Sauer (The University of Texas Medical Branch), "Desoxyribonucleic Acid Content of Cell Nuclei in the Neural Tube of the Chick: Evidence for Interkinetic Migration of Nuclei".

Robert L. Tips (The University of Texas Medical Branch), "Arthus Reactions in Inbred Mice: Sensitization of the CFW Strain with Egg Albumin".

Paul S. Hill and Robert L. Tips (The University of Texas Medical Branch), "Arthus Reactions in Inbred Mice: Comparison of Reaction Sites in Mice Passively Sensitized to Egg Albumin".

C. Wallace McNutt, Paul S. Hill, and Robert L. Tips, (The University of Texas Medical Branch), "Mouse Strain Variation to Arthus Hypersensitivity".

Milton Altschuler and Robert L. Tips (The University of Texas Medical Branch), "A Study of Antigens of Histoplasma Capsulatum".

P. O'B. Montgomery (The University of Texas Southwestern Medical Branch), "Ultra-Violet Flying Spot Television Microscopic Technics for Living Cell Study".

Frederick H. Kasten (The A. and M. College of Texas), "Use of Aldehyde-Specific Reagents in Multiple Staining Procedures".

DIVISION B

GEO. E. POTTER, *Presiding*

R. W. Strandtmann (Texas Technological College), "Report on a Hand-Raised Golden Eagle".

Howard McCarley (Stephen F. Austin State College), "The Effect of Stream Flooding on a Marked Population of Wild Mice".

Larry Renshaw (North Texas State College), "The Effect of Cartozone of $C^4$ in Guinea Pigs".

S. T. Lyles (Texas Christian University), and E. W. Gardner, Jr. (The University of Texas), "The Relationships of Growth Media Composition and Methods of Treating Antigens of Rough and Rho Strains of Vibrio cholerae to Their Agglutinability in Antisera Prepared Against Smooth Strains".

C. E. Dowell, Jr., and S. T. Lyles (Texas Christian University), "Antibiotic Resistance of Staphylococci Isolated from Patients and Presumably Healthy Students".

John Philip Baumgardt (East Texas State Teachers College), A Study of Fusarium Wilt Resistance in Tomatoes".

Eb. C. Girvin (Southwestern University), "Plasma Iron Turnover Rate as a Measure of Hemopoetic Activity".

J. K. G. Sivley (North Texas State College), "Laboratory Culture Techniques of the Aquatic Actinomycetes".

*Saturday Morning, December 14*

DIVISION A

BRYCE C. BROWN, *Presiding*

Howard T. Odum and Charles Hoskin (Institute of Marine Science, The University of Texas), "Photosynthesis and Respiration of the Texas Bays".

William A. Kratz and Betty W. Patterson (Trinity University), "Studies on the Obligate Photoautotropic Nature of Some Blue-Green Algae".

Ruth Doney and Jack Myers (The University of Texas), "The Algae Versus Mouse Experiment".

Florence I. Scoular (North Texas State College), "The Nutrients Provided by Fluid Milk of Self-Selected Diets".

John T. Falkenburty (Fort Worth, Texas), "The Effects of Distilled Water, Biologically Sterile Conditions, and Mechanical Stimulation of the Cortical Membrane on the Egg of Rana pipiens".

Andrew Couch (Southern Methodist University), "A Survey of Haemoproteus in Mourning Doves".

DIVISION B

J. K. G. SIVLEY, *Presiding*

William Stalcup (Southern Methodist University), "Preliminary Report on a Study in the Comparative Serology of Song Birds".

George E. Potter (Texas A. and M. College), "The Circulatory System of the Guinea Pig".

John G. Sinclair (The University of Texas Medical Branch), "Functional and Genetic Backgrounds of Developmental Anomolies".

A. R. Schrank (The University of Texas), "Growth and Geotropic Curvature as Affected by Several Cations".

Glenn V. Russell (The University of Texas Medical Branch), "A Method for the Permanent Implantation of Electrodes in the Brain of Experimental Animals".

Donald Cundan, James F. Eades, and Sidney R. Julian (The University of Texas Medical Branch), "Some Ultramicroscopic Features of the Mosquito".

SECTION III—Social Sciences

*Friday Morning, December 13*

THOMAS E. COMFORT, *Presiding*

Frank E. McFarland (Texas A. and M. College), "Use of Psychological Tests in Counseling".

W. L. Cash, Jr. (Prairie View A. and M. College), "The Relationship of the Minnesota Multiphasic Personality Inventory and Aptitude Test to Achievement in Nursing Education".

Max Leach (Abilene Christian College), "An Experiment in Learning from Two Simultaneous Audible Sources".

Norris C. Campbell (Abilene Christian College), "A Study of Counseling Competencies for Ministers".

*Friday Afternoon, December 13*

MAX LEACH, *Presiding*

Edwin W. Gaston, Jr. (Stephen F. Austin State College), "Travel Accounts of the Southern Plains: 1800–1850".

A. A. Dunson (Prairie View A. and M. College), "Languages: Means of World Peace and Understanding".

Rev. John M. Sheehan, C.S.B. (St. Thomas High School, Corpus Christi, Texas), "Value of Latin in a Scientific Age".

Lloyd C. Taylor (Texas A. and M. College), "A Romantic Looks at the Race Question".

Joseph U. Yarborough (Southern Methodist University), "The Psychology of Prejudice".

J. E. Marshall (USAF, Gulfport, Mississippi), "An Experiment in Teaching English Language and Literacy Skills for Non-English Speaking Illiterates".

Domenic A. Vavala (USAF, Lackland Air Force Base, Texas), "The Meaning and Use of Academic Degrees and Titles".

*Saturday Morning, December 14*

Gordon V. Anderson, *Presiding*

J. S. Spratt (Southern Methodist University), "Another Look at an Old Problem—Economics".

Richard B. Johnson (Southern Methodist University), "The Dynamic Concept in Economics".

Wendell Gordon (The University of Texas), "Freely Fluctuating Foreign Exchange Rates vs. an International Currency".

Lawrence G. Hines (Dartmouth College), "The Economic Aspects of the Problem of Water Conservation".

E. E. Stokes (Texas A. and M. College), "Bernard Shaw and Economics".

E. E. Liebhafsky (Texas A. and M. College), "Some Economic Implications of Basic Research".

Section IV—Earth Sciences

*Friday Afternoon, December 13*

Keith Young, *Presiding*

Walter Huang (Sul Ross State College), "Occurrences of Boron Minerals in the Wichita Mountains, Oklahoma".

Robert R. Wheeler (The Pyramid Oil and Gas Corporation), "Orogenic Significance of Midcontinent Deformation".

Symposium on Undergraduate Geology Curricula:

Paul H. Fan (University of Houston), "The Development and Current Curriculum of the Geology Department, University of Houston".

S. P. Ellison, Jr. (The University of Texas), "The Undergraduate Geology Curriculum at the University of Texas".

H. E. Eveland (Lamar College of Technology), "Building a Geology Curriculum in an Undergraduate College".

R. K. DeFord (The University of Texas), "The Development of an Undergraduate Curriculum in Preparation for Graduate Study".

*Saturday, December 14*

Bob F. Perkins (Shell Development Corporation, in charge). Field Trip in the vicinity of Dallas, through the Fredericksburg Rocks of the Trinity River Valley.

Section V—Conservation

*Friday Afternoon, December 13*

Paul H. Walser, *Presiding*

W. E. Williams (Sul Ross State College), "The Work of the Advisory Committee on Conservation Education".

Trigg Twitchell (USDI Geological Survey), "Water Conservation and Flood Flows of Texas Streams, April 1 to June 30, 1957".

Carter B. Gibbs and George K. Stephenson (Southern Forest Experiment Station), "Profits and Problems in the East Texas Woodland Conservation".

W. N. Williamson (Extension Service, College Station, Texas), "Rural Development Program in Texas".

Omer E. Sperry (Texas A. and M. College), "Weeds".

*Saturday Morning, December 14*

Paul H. Walser, *Presiding*

Olan W. Dillon (Soil Conservation Service), "Wildlife and Water Conservation in Texas".

John Webb (International Paper Company), "Conservation Use of Forest Resources by Wood-Using Industries".

Howard T. Odum (Institute of Marine Science), "A Conservation Plan for Marine Resources of Texas".

Lewis L. Yarlett (Soil Conservation Service), "Changes in Native Vegetation of the Grand Prairie of Texas".

Thacher Gary (Southwest Texas State Teachers College), "The Nature Study Workshop in Teacher Education".

# PUBLICATIONS OF THE TEXAS ACADEMY OF SCIENCE, 1892–1957

Compiled and edited by

T. N. Campbell

with the collaboration of

W. Frank Blair, Stephen E. Clabaugh, William T. Guy, Jr., Charles Heimsch, Clark Hubbs, Leon O. Morgan, and W. R. Woolrich

## TABLE OF CONTENTS

## LIST OF SEPARATE PUBLICATIONS, WITH PRICES

Each item listed below represents a separate publication. Orders may be sent to the Editor, The Texas Academy of Science, Box 7984, University Station, Austin 12, Texas.

*Proceedings and Transactions of The Texas Academy of Science*

Transactions of the Texas Academy of Science, Volume I, Number 1, Austin, 1892. Out of print.

Transactions of the Texas Academy of Science, Volume I, Number 2, Austin, 1893. Out of print.

Transactions of the Texas Academy of Science, Volume I, Number 3, Austin, 1895. Out of print.

Transactions of the Texas Academy of Science, Volume I, Number 4, Austin, 1895. Out of print.

Transactions of the Texas Academy of Science for 1896, with the Proceedings since its organization, January 9, 1892, to January 1, 1897, Volume I, Number 5, Austin, 1897. Out of print.

Transactions of the Texas Academy of Science for 1897, Volume II, Number 1, Austin, 1897. Out of print.

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ABBREVIATIONS

CCM—The Texas Academy of Science Conservation Council Monographs.
P—Proceedings of The Texas Academy of Science.
PT—Proceedings and Transactions of The Texas Academy of Science.
T—Transactions of The Texas Academy of Science.
TJS—The Texas Journal of Science.

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## Cover Picture

Standing on the Capote Rim and looking north at the Rim Rock country, one sees the Vieja Rim capped by the Bracks Rhyolite extending from the deep canyon of Capote Creek in the foreground to the distant high point above San Carlos. The type section of the Capote Mountain tuff is exposed in Capote Mountain in middle distance at the extreme right. Capote Mountain, capped by the Brite Ignimbrite, is part of the Capote Rim.

From near the Brite headquarters just north of Capote Mountain, Capote Creek drains toward the observer through the abandoned Cienega Ranch in the right foreground and falls into the canyon. The Candelaria-Valentine county road and mail route, now abandoned, ascends the Vieja Rim north of the canyon and continues up Capote Creek to the Brite Ranch.

A party of Mexican irregulars traveled this route to raid the Brite headquarters on Christmas Day 1917. The ranch house was successfully defended, but when the mail stage arrived the bandidos shot the passengers and hung the driver. They confiscated supplies and fled back over the rim into Mexico.

Photograph by C. R. Sewell.

See "Tertiary formations of rim rock country, Presidio County, Trans-Pecos, Texas" by R. K. DeFord for further details.

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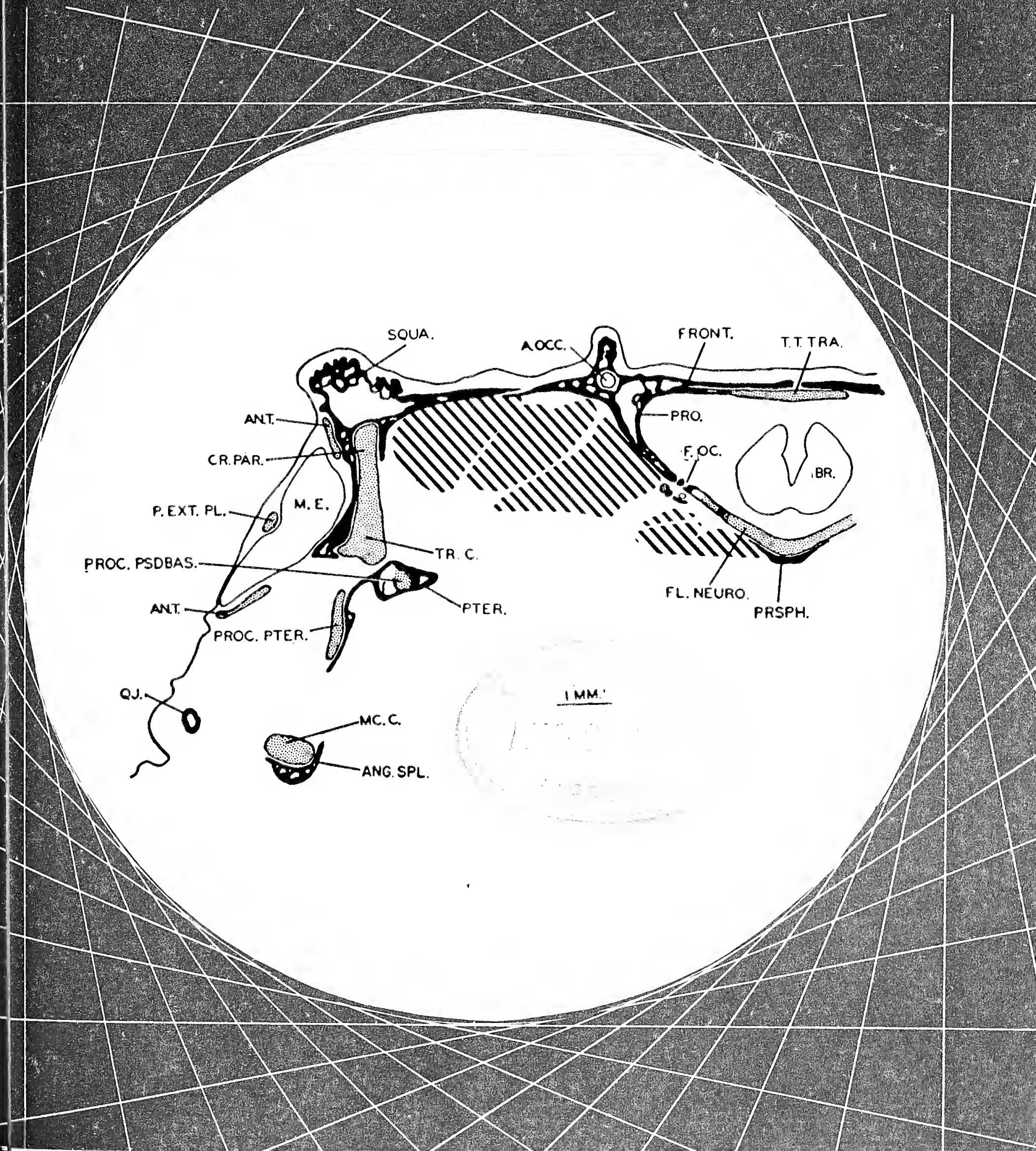

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## CONTENTS

# Professional Directory

# Arthus Reactions in Inbred Mice. Comparison of Reaction Sites in Mice Passively Sensitized to Egg Albumin[1]

*by* **ROBERT L. TIPS** *and* **PAUL S. HILL, JR.**
*University of Texas Medical Branch*

The local reaction to the introduction of antigen into tissues of sensitized animals is known as the Arthus phenomenon (Arthus and Breton 1903). An inflammatory response results from the union of the injected antigen with its specific antibody which is present in the serum of sensitized animals (Opie, 1924abc; Culbertson, 1935). The severity of the reaction depends upon the quantity of antibody available to the antigen (Opie, 1924abc; Benacerraf and Kabat, 1950), and varies from a mild edema and induration to local necrosis and sloughing of the tissues (Stetson, 1951; Gell and Hinde, 1954; Benedict and Tips, 1954).

The skin and subcutaneous tissues are the usual sites to demonstrate the Arthus phenomenon. In mice, the skin reaction may be elicited by injecting egg albumin intradermally into animals which have been sensitized actively by inoculating the antigen into the peritoneum and allowing a suitable induction period. It may be produced also by reverse passive transfer in which serum (containing antibodies) is injected into the skin of mice passively sensitized by giving the antigen intravenously (Benedict and Tips, 1954). The lip and foot pads also have been utilized as reaction sites in sensitized mice (Stone and Freund, 1956; Lipton, Stone, and Freund, 1956; Freund and Stone, 1956).

Certain strains of mice are more easily sensitized than others (unpublished data). The CFW strain is relatively resistant and the BALB/C strain is readily sensitized to Arthus reactivity.

It is the purpose of this work to compare the skin, lips, and foot pads as reaction sites in both CFW and BALB/C strains by determination of the amount of antibody (rabbit anti-ovalbumin serum) required to give reactions at these sites in passively sensitized mice.

[1] This investigation was supported in part by a research grant (USPHS No. E 1342) from the National Institutes of Health, Public Health Service.

## MATERIALS AND METHODS

The CFW strain (obtained from Thomas E. Euers Farm, Austin, Texas) consisted in equal numbers of males and females weighing 15 to 20 grams. The BALB/C strain were a similar group obtained from Roscoe B. Jackson Memorial Laboratories (Bar Harbor, Maine).

Each mouse was sensitized by intravenous injection of egg albumin (0.130 mgm. of nitrogen) dissolved in 0.5 ml. saline and given approximately 30 minutes prior to testing. These passively sensitized mice were tested with different quantities of antibody [in mgm. antibody nitrogen (AbN)] by injection of rabbit antiovalbumin serum into the reaction site and with normal rabbit serum to serve as "control" site. The mice were grouped according to the reaction site to be tested and to the amount of antibody to be injected, so that each mouse was injected with only one concentration of antibody in only one reaction site plus the injection of normal rabbit serum in the corresponding control site on the opposite side of the body. Intradermal reactions were graded in severity from one plus to 4 plus depending on the extent of edema, induration, hemorrhage, and necrosis as previously described (Benedict and Tips, 1954). Intralabial and foot pad reactions were graded as positive or negative depending on the presence or absence of marked local edema and cyanosis occurring in 15 minutes to 2 hours after testing and on comparison to the control injection site.

The anti-serum was obtained from rabbits actively sensitized with egg albumin in Freund's adjuvant. The AbN content of the serum was determined by micro-kjeldahl analysis of precipitated antibody employing the technique given in Kabat and Mayer (1947).

## RESULTS

Intradermal reactions occurred uniformly when 0.03 mgm. antibody nitrogen were injected into the skin of the passively sensitized mice of both strains (Table I). Larger quantities of antibody increased the severity of the reaction, smaller quantities gave minimal or no reactivity. The intradermal reactions were maximum about 24 hours after testing.

Quantities of antibodies as small as 0.005 mgm. nitrogen gave marked reactions in the lip and minimal reactions in foot pads when injected into these sites in passively sensitized mice of both strains. 0.001 mgm. AbN gave minimal intralabial reactions. The intralabial and foot pad reactions were maximum in 15 minutes to two hours after testing. No reactivity was detectable in these sites at 24, 48, or 72 hours.

TABLE I

Intradermal, Intralabial, and Foot Pad Reactions to Rabbit Anti-Ovalbumin Serum in Passively Sensitized Mice of the CFW and BALB/C Strains

| Antibody in mgm. Nitrogen* | Strain of Mice | Reactions in Numbers of Mice† | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Intradermal | | | Intralabial | | Foot Pad | |
| | | 0 | 1–2+ | 3–4+ | 0 | + | 0 | + |
| 0.07 | CFW | 0 | 0 | 10 | not tested | | not tested | |
| | BALB/C | 0 | 0 | 7 | 0 | 7 | 0 | 7 |
| 0.05 | CFW | 0 | 0 | 10 | not tested | | not tested | |
| | BALB/C | 0 | 0 | 7 | 0 | 7 | 0 | 7 |
| 0.03 | CFW | 0 | 25 | 0 | 0 | 10 | 0 | 6 |
| | BALB/C | 0 | 14 | 0 | 0 | 14 | 0 | 14 |
| 0.02 | CFW | 4 | 4 | 0 | 0 | 5 | 0 | 5 |
| | BALB/C | 7 | 0 | 0 | 0 | 7 | 0 | 7 |
| 0.01 | CFW | 8 | 0 | 0 | 0 | 5 | not tested | |
| | BALB/C | 7 | 0 | 0 | not tested | | not tested | |
| 0.005 | CFW | not tested | | | 0 | 6 | 1 | 4§ |
| | BALB/C | not tested | | | 0 | 7 | 0 | 7§ |
| 0.001 | CFW | not tested | | | 0 | 6‡ | not tested | |
| | BALB/C | not tested | | | 0 | 7‡ | not tested | |
| Control Sites‡ | CFW | 61 | 0 | 0 | 32 | 0 | 16 | 0 |
| | BALB/C | 42 | 0 | 0 | 49 | 0 | 42 | 0 |

* Given intradermally, intralabially, or in foot pad in a volume of 0.05 ml. serum thirty minutes after passive sensitization.
† All mice were passively sensitized by intravenous injection of ovalbumin (0.130 mgm. nitrogen) in 0.5 ml. saline.
‡ Injection of 0.05 ml. normal rabbit serum into control site corresponding and opposite to test site in each mouse tested.
§ Minimal reactions.

Injection of normal rabbit serum into the skin, lip or foot pad, given at the time of testing into a corresponding site on the opposite side of the body, produced no visible reactions in any of the mice. This served as a control injection in each mouse tested.

Despite the differences in minimal quantity of antibody required for reactivity in different test sites, there was no difference in these quantities for each site between the two strains of mice.

## DISCUSSION

Inbred strains of mice vary in their immunological capacities. Differences in antibody production (Fink and Quinn, 1953), anaphylactic and histamine sensitivity (Fink and Rothlauf, 1954; Munoz and Schuchardt, 1953), and the immunizability to tetanus toxoid (Ipsen, 1954) occur between certain strains. The variation in susceptibility to active induction of the Arthus phenomenon in the BALB/C and CFW strains has been observed (unpublished data).

The skin, lips, and foot pads of the two strains responded similarly in reverse passive transfer of the egg albumin-anti-egg albumin system; thus, the sensitivity of the reaction sites to the antigen-antibody mechanism is similar in both strains. Strain variation in active sensitization would not be explained on differences of reaction site susceptabilities.

The intradermal reactions require a minimum of 0.03 mg. anti-egg albumin nitrogen for uniform response in both strains of mice. This is a larger quantity of antibody than the amount reported for rabbits (0.02 by Fischel and Kabat, 1947), guinea pigs (0.01 mg. by Benacerraf and Kabat, 1950), and rats (0.005 by Ovary and Bier, 1952).

The foot pad and lips require a minimum of 0.005 and 0.001 mg. antibody nitrogen respectively for reactivity. Nothing is known for minimal quantities in other species of animals.

The differences in minimal quantities of antibody required for each site are considerable (0.001, 0.005, and 0.03 mg. N). This may be related to differences in vascularity (Rich and Follis, 1940), type of tissue, and/or histamine content (Bendett, Bader, and Lam, 1955).

The intralabial and foot pad reactions develop quickly, are transient, and are manifest only as edema and cyanosis. These are dissimilar to the local hemorrhagic reactions in the lips and foot pads of mice and rats actively sensitized to other antigens and tested after a short induction period (Freund and Stone, 1956; Stone and Freund, 1956; and Lipton, Stone and Freund, 1956). These reported reactions are similar to the skin reactions in severity, onset, and duration of reaction. Hemorrhagic reactions were not noted in the lip and foot pads in reverse passive transfer.

In actively sensitized animals other reaction sites have been studied (Rich and Follis, 1940). Local reactions in rabbits have been reported in the lungs (Cannon, Walsh, and Marshall, 1941), the pericardium, heart, aorta (Seegal, Seegal, and Jost, 1932) and the brain (Davidoff, Seegal and Seegal, 1932). However, comparison of these reaction sites by reverse passive transfer remains to be studied in mice.

SUMMARY


1. The sensitivity of the reaction site (skin, lip or foot pads) to reverse passive transfer of egg albumin anti-egg albumin (rabbit) system were similar in CFW and BALB/C inbred strains of mice.
2. The minimal amounts of antibody required for reactivity were 0.03 mgm. N in the skin, 0.005 mgm. N in the foot pads, and 0.001 mgm. N in the lips in both strains of mice.
3. The intradermal reactions in both strains were manifest as local edema, induration, hemorrhage and necrosis which reached maximum intensity at 24 hours after injection of antibody.

4. The lip and foot pad reactions in the two strains consisted in transient severe local edema and cyanosis which persisted about 2 hours after injection of antibody.

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# Comparisons of Morphology and Life History of Two Species of Pocket Gophers

*by* **THOMAS E. KENNERLY, JR.**

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## INTRODUCTION

Blair has recently (1956) pointed out that, eventual understanding of any species as a dynamic system is dependent upon synthesis of all areas of scientific inquiry into natural populations. The pocket gopher in deference to its fossorial habits is less known in terms of this concept than most mammals. The pocket gophers of the United States have been subjected to rather extensive taxonomic examinations but the resultant dispensations are not wholly satisfactory and there are significant gaps in our knowledge of life history, behaviorism, ecology, and genetics. The purpose of this report is to augment little known features of life history and to furnish morphological comparisons of two closely related species of pocket gophers, *Geomys personatus fallax* and *G. bursarius attwateri.* The species *personatus* occurs locally throughout much of the lower Rio Grande Valley and reaches the northeastern periphery of its range in the eastern part of the Tamaulipan biotic province (Blair, 1950). The species *bursarius* has a considerably wider distribution, occupying much of the Mississippi Valley, but reaching the southwestern extent of its range in southern Texas in the eastern part of the Tamaulipan biotic province. In southern Texas the ranges of these two species are adjacent in several places without overlap along a line closely approximating the boundary between the Tamaulipan and Texan biotic provinces (Blair, *op. cit.*). Contact between the ranges of the related species which have similar ecological requirements occurs generally between Falls City, Karnes County, on the north and Skidmore, Bee County, on the south. This curious distribution is highly significant in terms of factors responsible for the maintenance of allopatry. An analysis of this phenomenon will be attempted in a subsequent report.

I am indebted to the following people whose cooperation helped make this study possible: Rocky Reagan, Beeville, Texas; Roy Freeman, Kenedy, Texas; A. G. Flury, Mathis, Texas. My wife, Betty, my brother, Dan Kennerly, Jack Cheesman, W. N. Bradshaw and A. O. Wasserman rendered valuable assistance in field work. Grateful acknowledgment is extended W. Frank Blair, Department of Zoology, University of Texas, for supervision and encouragement in pursuance of this study and helpful criticism in the preparation of this report.

## METHODS

Ninety-one specimens of *bursarius* and 113 specimens of *personatus* were collected during field operations which proceeded irregularly between December 12, 1952 and April 6, 1955. Twenty skeletal and external dimensions were measured with vernier callipers in the conventional manner. The following measurements and the points between which they were taken are indicated in a previous report (Kennerly, 1954): body length, hind foot length, length of tail, width of maxillary zygoma, maxillary tooth row, mandibular width, femur length, and humerus length. Other measurements and the points between which they were taken are as follows:

*Jugal Length*—Maximum dorso-lateral exposure of jugal.

*Dorsal Width of Rostrum*—Maximum dorsal width across rostrum.

*Ventral Width of Rostrum*—Width of rostrum ventrad to infraorbital foramina.

*Mastoid Breadth of Skull*—Width of skull across mastoid processes.

*Width of Squamosal Zygoma*—Maximum width across squamosal zygoma.

*Palato-Frontal Depth*—Distance between bony palate and frontals measured to one side of sagittal crest.

*Condylo-Premaxillary Length*—Length of skull from left condyle to most anterior part of left premaxilla.

*Width of Upper Incisors*—Width across upper incisors measured ventrad to posterior alveoli.

*Interorbital Width*—Width of most constricted part of interorbital space across top of skull.

*Condylo-Zygomatic Length*—Distance from left condyle to angle of zygomatic process of left maxilla.

*Mandibular Diastema*—Distance between posterior margin of alveolus of left lower incisor to anterior margin of alveolus of first cheek tooth.

*Mandibular Length*—Length of left mandible from condyle to posterior border of alveolus of the incisor.

It is the intention of this study to compare dimensional variability of two species, therefore, specimens were grouped according to species rather than locality. All specimens were collected within the general zone of contact indicated previously. Live-traps used in capturing pocket gophers for marking were adapted from Howard (1952) with modifications; traps were constructed somewhat larger to accommodate the large *personatus* pocket gopher. Dead-trapping was accomplished by means of pincher-type steel traps. Measurements of burrow diameter were taken vertically in millimeters. Skeletal and burrow measurements were treated statistically according to species and sex. Sexual dimorphism is marked in the pocket gopher therefore the sexes were separated in statistical analyses. Immature pelage and imperfect cranial sutures were useful characters in deletion of juvenile specimens. Standard deviations and standard errors of the means were computed and the results are presented graphically (Figs. 1–3) after the method of Hubbs and Hubbs (1953). A series of ratios were employed to determine certain comparative dimensional relationships both intra- and interspecifically. The relative average degree of sexual dimorphism (Table I) of each species of pocket gopher was determined by means of comparisons of skeletal and external dimensions. In each of these comparisons the size of males in excess of female measurements is expressed as a percentage value.

TABLE I

Comparison of Sexual Dimorphism
Figures represent percent of male size in excess of female size.

| | Species | |
|---|---|---|
| | *G. personatus* | *G. bursarius* |
| Body length | 12.02 | 8.04 |
| Hind foot length | 7.88 | 7.04 |
| Length of tail | 8.56 | 6.04 |
| Jugal length | 13.79 | 9.58 |
| Dorsal rostrum | 12.48 | 10.81 |
| Ventral rostrum | 11.84 | 7.20 |
| Mastoid breadth | 13.74 | 10.19 |
| Squamosal zygoma | 14.42 | 11.41 |
| Maxillary zygoma | 17.05 | 14.06 |
| Palato-frontal depth | 11.49 | 8.18 |
| Condylo-premaxil. length | 13.04 | 9.82 |
| Upper incisors width | 13.29 | 11.02 |
| Maxillary tooth row | 7.90 | 5.63 |
| Interorbital width | .... | .... |
| Condylo-zygoma length | 10.65 | 8.45 |
| Mandibular diastema | 19.69 | 14.28 |
| Mandibular width | 17.24 | 14.42 |
| Mandibular length | 13.55 | 8.81 |
| Femur length | 9.39 | 9.21 |
| Humerus length | 12.64 | 10.01 |
| Total Average | 12.67 | 9.69 |

*Collecting Stations*

The total number of specimens taken in each county and the collecting stations are listed below. Towns followed by an asterisk (*) indicate collection of specimens within the city limits.

*G. personatus fallax—Bee County* 49: Beeville*, 2, 3 and 6 miles south, 6 miles west, 2 and 3 miles north, 1, 2 and 5 miles northwest; Mineral*, 1 mile south, 4 miles northeast; Skidmore, 1 mile southwest, 1 mile southeast; Papalote, 1 mile south; Orangedale*, 2 miles north; Normanna, 1 mile east, 3 miles southeast, 1 mile south; Pettus, 1 and 2 miles south; Cadiz, 2 miles east; Tulseta, 1 mile west. *Atascosa County* 2: Campbellton, 1 mile south. *Goliad County* 5: Pettus, 6 and 8 miles east; Berclaire, 10 miles northwest. *Karnes County* 24: Kenedy, 1, 3, 4 and 5 miles northeast, 4 and 5 miles east; Nixon, 5 miles south; Gillett, 2 and 3 miles north, 4 miles south; Helena, 8 miles north; Hobson*, Charco, 7 miles west; Choate, 2 miles southeast; Falls City, 1 mile southeast; Runge, 5 miles northwest. *Live Oak County* 29: Beeville, 13 miles west; George West, 8 miles northwest, 5 miles east. *San Patricio County* 4: Mathis, 2 miles west, 5 miles southeast; Odem, 3 miles southwest; Edroy, 5 miles southeast.

*G. bursarius attwateri—Bee County* 18: Beeville, 13 miles south, 6 and 7 miles northeast, 10 and 12 miles southeast; Skidmore, 4 miles south; Balconia, 1 mile south. *Atascosa County* 4: McCoy*; Campbellton, 6 miles northwest. *Goliad County* 19: Berclaire, 2 and 5 miles northwest, 5 miles northeast, 2 miles southeast; Charco, 5 miles south, 1 mile southwest; Goliad, 9 and 10 miles west, 10 miles southwest. *Gonzales County* 6: Luling, 6, 9 and 11 miles south; Leesville, 1 and 2 miles south. *Guadalupe County* 3: Seguin, 3, 5 and 11 miles south. *Karnes County* 26: Cestohowa*; Helena*, 3 miles north, 2 miles south, 3 miles southeast; Runge, 2 and 9 miles southeast; Falls City, 1 mile southeast. *Refugio County* 4: Woodsboro, 7 and 9 miles southwest, 3 miles northeast, 4 miles northwest. *San Patricio County* 3: Aransas Pass, 2 and 4 miles southwest; Sinton, 1 mile northwest. *Wilson County* 11: Floresville, 3 and 6 miles southwest, 4 miles northeast, 1 mile north; Falls City, 2 miles northwest; Stockdale, 3 and 8 miles north, 6 miles south; Poth, 3 miles northwest, 4 miles southeast.

*Burrow Diameter*

The diameter of the burrow of adult specimens was found to vary according to species and sex (Fig. 1, upper left). Although measurements of burrow diameter were too few to class according to soil texture, burrow diameter tended to be smaller in areas of indurate soils than in regions of friable soils. The burrow diameters of *personatus* males, *personatus* females, *bursarius* males and *bursarius* females were progressively smaller. Burrow diameters of *personatus* males were significantly larger than those of either sex of *bursarius* and burrow diameters of *bursarius* females were significantly smaller than those of either sex of *personatus*. With a larger series of measurements the burrow diameters would probably differ significantly according to species and sex. In addition, there seemed to be a correlation between depth of burrow (as measured from the roof of the burrow to the ground surface), species and sex of pocket gopher and friability of the soil. These data were too few to show significance or to be presented graphically but available data did seem to indicate that larger pocket gophers (males of either species or males and females of the species *personatus*) tend toward deeper burrows. Also deeper burrows seem generally to occur in sandy soils and shallower burrows in indurate soils.

### *Skeletal and External Dimensions*

*Sexual Dimorphism*—(Table I) Sexual dimorphism is marked in both species and is apparent in all dimensional characters except interorbital width. The interorbital width dimension apparently undergoes little ontogenetic increase as evidenced by examination of immature specimens of both species and sexes. In all dimensional characters except two, ventral width of rostrum and interorbital width, significant differences appeared between the same sexes of the two species, i.e., *personatus* males were larger than *bursarius* males and *personatus* females were larger than *bursarius* females. In the ventral width of rostrum dimension *personatus* males were significantly larger than *bursarius* males but the females of both species failed to show significant difference. In the interorbital width dimension no significant differences were indicated between any of the four categories. In all characters except interorbital width males and females of the same species were significantly different. In 19 characters *personatus* males averaged 12.67% larger than *personatus* females with extremes of 19.69%, mandibular diastema, and 7.88%, hind foot length. For these 19 dimensions *bursarius* males averaged 9.69% larger than *bursarius* females with extremes of 14.42%, mandibular width, and 5.63%, maxillary alveolar length. Sexual dimorphism is particularly marked in the mandibular dimensions and zygomatic arch dimensions (width of maxillary zygoma and squamosal breadth). These data indicate that sexual dimorphism is more pronounced in *personatus* than in *bursarius*.

*Relative Proportions*—Four ratios obtained by the use of average measurements were employed to determine relative proportions in the two species of pocket gophers.

1. *Jugal/Ventral Width of Rostrum*—This ratio represents the key diagnostic between these two species (Davis, 1940; Merriam, 1895). In *personatus* the jugal is longer than the ventral width of rostrum; in *bursarius* the jugal is shorter. Results obtained from this ratio were: *personatus* males 1.16, *personatus* females 1.13; *bursarius* males 0.78, *bursarius* females 0.76. This diagnostic ratio was found to be reliable except when applied to very young specimens of *personatus*, in which the jugal is shorter than the ventral width of rostrum.
2. *Skull Length/Rostrum Length*—Skull length is here identical with condylo-premaxillary length. Rostrum length is condylo-premaxillary length minus condylo-zygoma length. Results indicate little if any specific differences in length of rostrum but seemingly indicate a relatively shorter rostral length in females of both species: *personatus* males 3.28, *personatus* females 3.50; *bursarius* males 3.27, *bursarius* females 3.39.
3. *Body Length/Tail Length*—This ratio indicates a slight specific difference and probably implies a relatively longer tail in females of both species. Results of this ratio were: *personatus* males 2.21, *personatus* females 2.13; *bursarius* males 2.34, *bursarius* females 2.29.
4. *Width of Maxillary Zygoma/Mastoid Breadth*—This ratio was employed to determine relative flaring of the zygoma in terms of skull width. Results indicate that *bursarius* displays a more widely flaring zygoma than does *personatus: personatus* males 1.07, *personatus* females 1.03; *bursarius* males 1.11, *bursarius* females 1.07.

*Lambdoidal Crest*—A seemingly significant qualitative diagnostic is the curvature of the labdoidal crest. In *bursarius* it assumes only a slight convexity posteriorly and in the median region of the skull roof the lambdoidal crest is only slightly posterior to a line connecting left and right mastoid processes. The supraoccipital in *bursarius* tends to be convex dorso-posteriorly and extends relatively farther anteriorly over the roof of the skull thus establishing a more anterior position for the medial portion of the lambdoidal crest than in adult *personatus*. In *personatus* the curvature of the lambdoidal crest reflects ontogenetic change. In immature specimens of *personatus* the lambdoidal curvature is similar to that of both immature and adult *bursarius*. This condition suggests specialization in the case of *personatus*. In adult specimens of *personatus* the flattened, more vertical alignment of the supraoccipital results in a more posterior position of the lambdoidal crest in the region of the interparietal and hence a stronger posterior convexity than in *bursarius*.

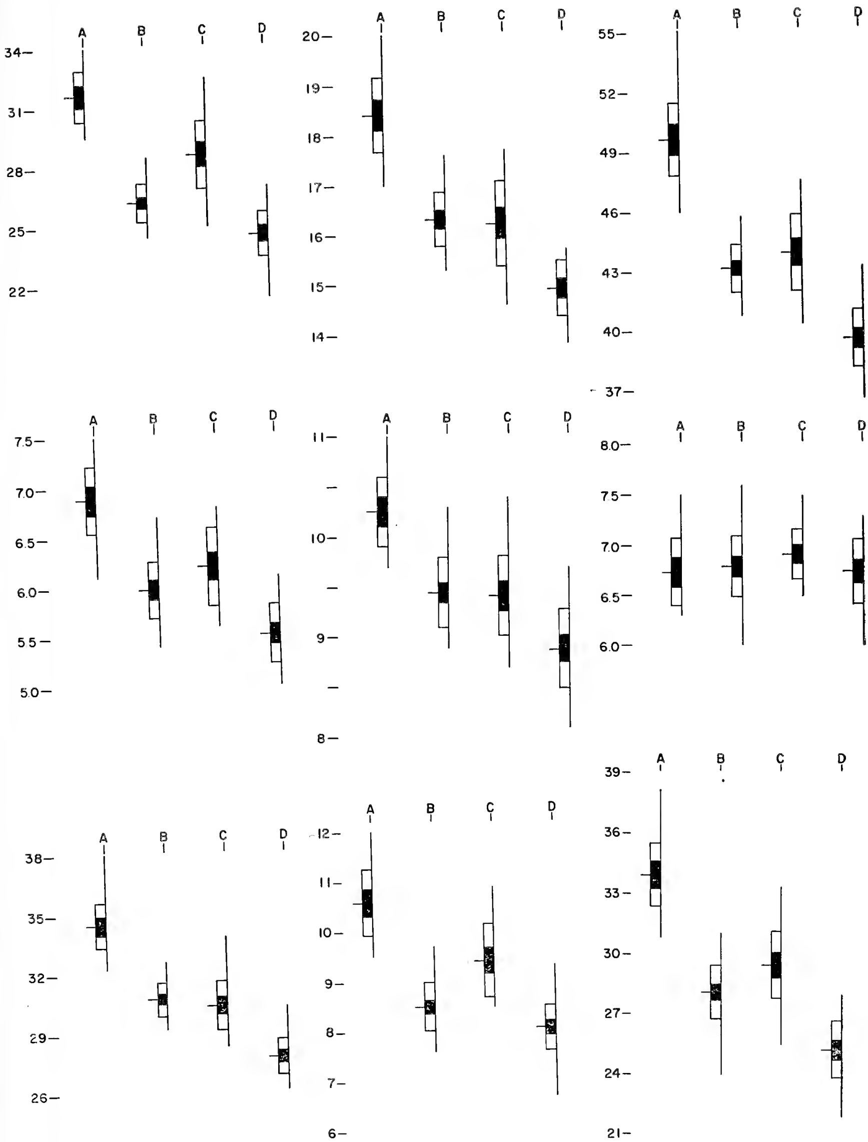


Fig. 1. A. *Geomys personatus* Males, B. *Geomys personatus* Females, C. *Geomys bursarius* Males, D. *Geomys bursarius* Females.

*Top Row:* Left, Burrow Diameter; Middle, Body Length; Right, Hind Foot Length.

*Middle Row:* Left, Length of Tail; Middle, Jugal Length; Right, Dorsal Width of Rostum.

*Bottom Row:* Left, Ventral Width of Rostrum; Middle, Mastoid Breadth of Skull; Right, Width of Squamosal Zygoma.

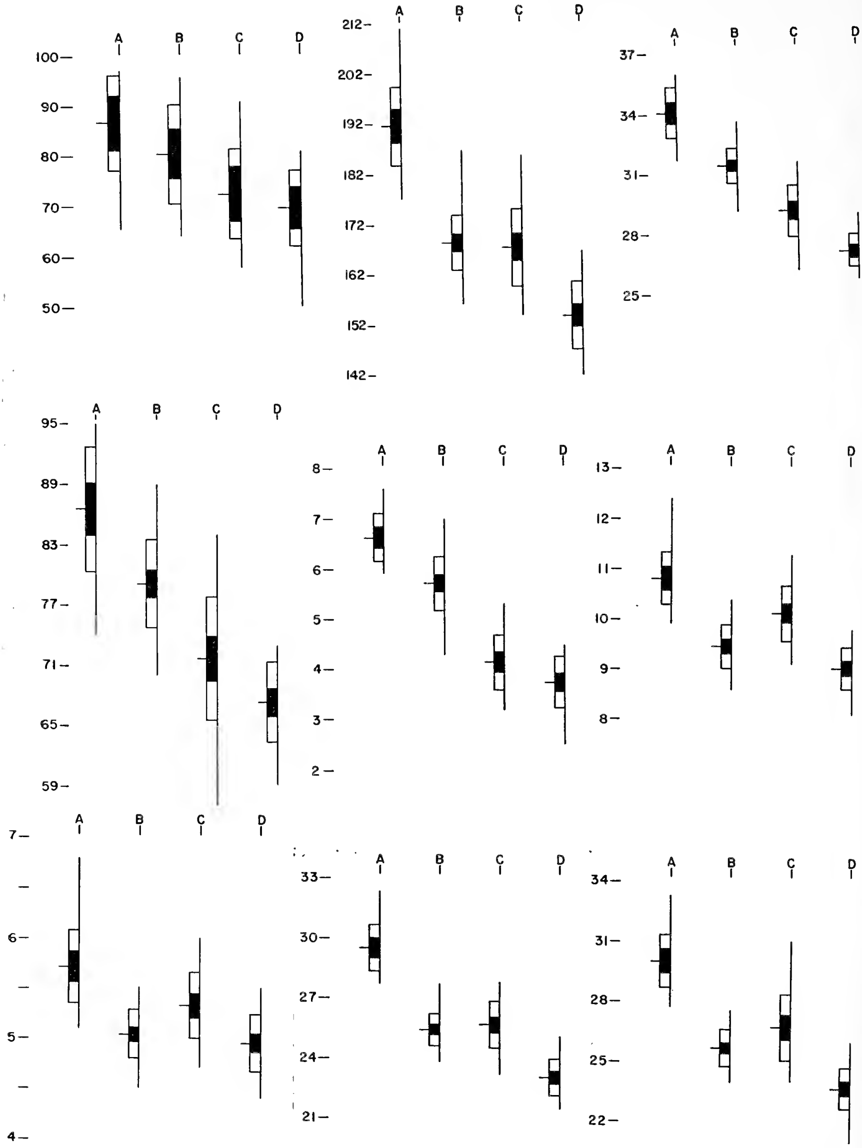


Fig. 2. A. *Geomys personatus* Males, B. *Geomys personatus* Females, C. *Geomys bursarius* Males, D. *Geomys bursarius* Females.

*Top Row:* Left, Width of Maxillary Zygoma; Middle, Palato-frontal Depth; Right, Condylo-premaxillary Length.

*Middle Row:* Left, Width of Upper Incisors; Middle, Maxillary Tooth Row; Right, Inter-orbital Constriction.

*Bottom Row:* Left, Condylo-zygomatic Length; Middle, Mandibular Diastema; Right, Mandibular Width.

*Skeletal and External Dimensions*—Twenty skeletal and external dimensions were compared according to species and sex and are presented graphically (Figs. 1–3). There were three dimensional characters in which both sexes of *personatus* were larger than either sex of *bursarius:* hind foot length, tail length and jugal length. These characters when averaged in series are helpful specific diagnostics. In the following 10 dimensions *personatus* males were significantly larger than *bursarius* males and females but insignificant differences appeared between *personatus* females and *bursarius* males: femur length, humerus length, palato-frontal depth, condylo-premaxillary length, condylo-zygoma length, mastoid breadth, maxillary alveolar length, width of upper incisors (borderline significance), interorbital width and body length. In seven dimensional characters sexual dimorphism between the sexes of both species was great and *bursarius* males were significantly larger than *personatus* females. These seven characters are: mandibular diastema, mandibular width, mandibular length, ventral width of rostrum, dorsal width of rostrum, squamosal breadth and maxillary zygoma breadth.

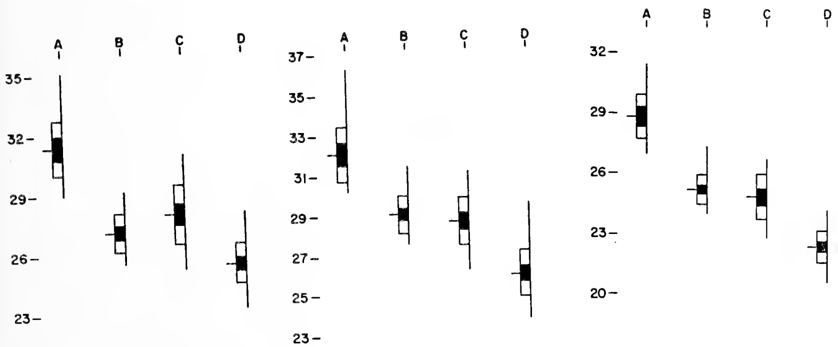


**Fig. 3 A. Geomys *personatus* Males, B. Geomys *personatus* Females, C. Geomys *bursarius* Males, D. Geomys *bursarius* Females. Left, Mandibular Length; Middle, Femur Length; Right, Humerus Length.**

## *Natural History*

*Live-Trapping*—Between December 12, 1952 and September 12, 1953 nine specimens of *personatus* were live-trapped and marked on the Reagan ranch eight miles northwest of George West, Texas. Specimens were marked by clipping toes of the hind feet. The clipping of toes of the forefeet seems undesirable as a marking technique in view of the fact that the digging claws probably represent a significant selective factor. The area in which the live-trapping was accomplished is a relatively isolated "island" of light-colored, deep sand.

Dense stands of woody vegetation (chiefly mesquite) and fairly indurate, dark soils circumscribe the island of sand, roughly 200 yards on a side, and probably impede the movement of pocket gophers away from and into the sand area. It is believed that over half, and probably a much larger proportion of the pocket gopher population in the sand area was marked. Seven females and two males were field-marked and returned to their burrows. Efforts were made to recapture marked individuals during susequent months but only two were recaptured. Adult female No. 5 was marked on February 26, 1953 and was recaptured March 17, 1953 at the original site. This specimen was in winter pelage at the time of both captures and no initiation of summer molt was noted. Adult female No. 3 was marked on February 20, 1953 and was recaptured four times, about a week apart, the last live-capture being March 26, 1953. At the time of marking this specimen was initiating summer molt and displayed two "centers of origin" of summer pelage arbitrarily termed "mantle" and "mid-dorsal." On February 20, 1953, the mantle of summer pelage extended posteriorly from the head to a point just behind the ears in the shape of an arc and the mid-dorsal area of summer pelage appeared as a small oblong patch about an inch posterior to the mantle. During subsequent captures the mantle changed in shape, pushing a dorsal projection of summer pelage posteriorly from the original symmetrical arc and halving the distance to the mid-dorsal. The mid-dorsal patch of summer pelage changed less obviously but on the last date of capture had attained a laterally bilobed appearance in addition to becoming slightly larger in area. The observations on molt dynamics are in general agreement with the findings of Morejohn and Howard (1956) with regard to pattern of molt in *Thomomys bottae*. Female No. 3 was eventually dead-trapped on December 10, 1953. At this date, some 10 months after marking, this specimen was still inhabiting the original burrow where it was marked and was in entire winter pelage. Adult male No. 1 was marked on February 6, 1953 and was dead-trapped eight and one-half months later on October 28, 1953 in the same burrow. This specimen was in entire winter pelage at the time of both trappings. Adult female No. 6 was marked on March 26, 1953 and was dead-trapped nine months later on December 26, 1953 in the same burrow. At the time of marking this specimen displayed a mantle of summer pelage which extended halfway to the tail; at the time of dead-trapping this specimen was in entire winter pelage. Until the spring of 1955 periodic attempts were made to trap near fresh mounds in the same area, and, although six specimens were dead-trapped there, none was a marked specimen. Two of the animals dead-trapped were young and were conceivably born subsequent to the marking operation. The remaining four specimens were adult and were either missed at the time of live-trapping or invaded the sand area later. The accrued data from the marking operation are scanty, yet some information can be added to the little known life history of this species. It is possible that longevity in this species may be about two years since of all adult specimens marked in 1953 none was recovered after 10 months although trapping was continued until 24 months (excepting one specimen marked in September, 1953). It seems improbable that all marked individuals dispersed out of the area. Following dispersal from the maternal burrow at sexual maturity, adult pocket gophers may reside permanently in the same burrow, because three specimens of *personatus* were found to be inhabiting the original burrows after periods of eight and one-half, nine and ten months.

*Multiple Catches*—The pocket gopher is ordinarily a solitary animal, a habit appropriate to the high energy requirements of fossorial animals. During the breeding season however, adult male and female specimens are often found living together in the same burrow. It has not been determined which sex is the visitor in such pairings. A comparison of average burrow diameter in which a pair of animals was taken and the average burrow diameter of male and female animals would help establish which sex is the visitor. A cursory examination of the literature reveals no record of more than two adult pocket gophers occurring in a single burrow, and further, no record of the coexistence in a burrow of two adult pocket gophers of the same sex. Russell (1954) recorded a multiple catch of three pocket gophers of the genus *Cratogeomys* from a single burrow: adult female, adult male and juvenile female. Two cases of double catches were recorded for *personatus* and three double catches were recorded for *bursarius*. The first double catch of *personatus* occurred on January 8, 1954, about five miles south of Beeville and included an adult male and an adult female. The female was gravid with three late embryos. On January 20, 1954, two miles south of Pettus, another double catch of *personatus* was recorded, again including adult male and adult female. This female was also gravid with two embryos. Two double catches of *bursarius* occurred on January 31, 1954 on the Cobb ranch seven miles northeast of Beeville. One of these catches included an adult female and a juvenile male. This adult female was gravid with three embryos and was undoubtedly the parent of the very young male (body length 114mm.). The other catch of this date included an adult male and an adult female which was early gravid and had lactating mammae. The final double catch for *bursarius* was recorded March 25, 1955 three miles north of Helena, Karnes County, and consisted of an adult male and an adult female which was questionably gravid. On this same date an adult female *bursarius* was live-trapped two and one-half miles north of Helena. This specimen was questionably gravid and was returned to the laboratory where it survived for 40 days. No embryos were evident as a result of dissection. During these 40 days the second nail on the left forefoot which had been worn down or broken close to the fleshy digit grew 10 mm. This growth rate appears comparable to that reported in *Thomomys bottae* by Howard (1953). On April 6, 1955, an adult male *bursarius* was dead-trapped from the same burrow in which the adult female had been live-trapped. These two animals may have occupied this burrow simultaneously. There is some evidence for superfetation in both species of pocket gophers, i.e., the occurrence of a second fertilization before parturition and the consequent overlapping of two gestations. In *bursarius* the evidence for superfetation includes: the occurrence of a gravid female with a very young male (presumably of her last litter), and the occurrence of a gravid female which was lactating with an adult male. In *personatus* the evidence is similar: there were two occurrences of gravid females in late pregnancy in the company of adult males. Hediger (1948) has established this phenomenon for the European hare and Soderwall and Britenbaker (1955) reported this phenomenon for the hamster but superfetation has apparently not been recorded in the Geomyidae.

*Breeding Season*—Wood (1949) in his study of *Geomys bursarius brazensis* in central Texas, states that there are seven consecutive months of breeding activity from February until August. A peak in production was found to occur in June and July and a lesser peak in April. He suggested that two broods are produced in rapid succession (superfetation?) and he estimated the average number of young per litter at 2.60 with extremes of one and five young, based on embryo counts and placental scar counts. The breeding activity of *G. bursarius attwateri* as evidenced in the present study does not seem to comply with Wood's findings in the race *brazensis*. Females with embryos were collected during the months of November (this subspecies was not trapped in December), January, February, March and June. No gravid females were recorded during April and May and this period seems to represent a temporary cessation of reproductive activity before the summer breeding period. The different breeding cycle indicated for the race *attwateri* is perhaps attributable to a warmer climate. The average number of embryos of 10 gravid females of *bursarius* was 2.50 with extremes of two and four. *G. personatus* females with embryos were collected during the months of December, January, February and March. A *personatus* female which was taken on May 23, 1954 was apparently gravid. Thus there is a possibility that *personatus* too may exhibit a double peak of reproductive activity. Further investigation may reveal some intraspecific variation in reproductive cycle for *personatus* in deference to climate conditions within its range. The average number of embryos of 11 gravid specimens of *personatus* was 3.18 with extremes of two and four.

*Sex-Ratio*—Of a total number of 561 specimens of the race *G. b. brazensis* Wood (1949) states that the sex-ratio was 40.4% males and 59.6% females. Of 91 specimens of *G. b. attwateri* the sex-ratio was 42.8% males and 57.2% females. Of 113 specimens of *G. personatus* the sex-ratio was 38.1% males and 61.9% females. The predominance of females is insignificant in *G. b. attwateri* but is significant in *personatus* as indicated by the Chi-square test, 1.857 and 6.451, respectively. During the course of this study 204 specimens of both species were trapped alive or dead. The total sex-ratio was 40.2% males and 59.8% females. There is reason to regard the apparently consistent preponderance of female pocket gophers with reservation. The larger, stronger males probably work free from conventional dead-traps more often than do the smaller females. Although seven females were caught in live-traps as compared with only two males, the total number of captures is obviously too small to be significant and there is the further possibility of males exercising more caution in approaching a trap than females do. It is therefore suspected that although females may actually predominate in population, the percentage of dominance may be less than is indicated by present techniques.

*Range Extensions*

Range extensions for both *personatus* and *bursarius* were recorded. An adult female *personatus* was collected April 6, 1955 approximately one-half mile southeast of Falls City, Karnes County, on the alluvial terrace of the south bank of the San Antonio River. This represents the northern-most record for *personatus* (except *G. p. fuscus* at Del Rio, Texas) and extends the known range of this species some 35 miles northward from a collecting site reported by Blair (1952): 12 miles north of Beeville, Bee County. In December 1955 *bursarius* was collected four miles south of Skidmore, Bee County. This represents a range extension of about 25 miles beyond the nearest previous records which are those of Davis (1940), eight miles southwest of Rockport, Aransas County and of Blair (1952), 11 miles east of Beeville.

## SUMMARY

Ninety-one specimens of *Geomys bursarius attwateri* and 113 specimens of *G. personatus fallax* were trapped in south Texas. Field

work proceeded irregularly between December 12, 1952 and April 6, 1955. Burrow diameter was found to vary according to sex and species. Seventeen skeletal and three external dimensional characters were measured and expressed graphically. Sexual dimorphism in both species was pronounced in all characters except one. In *G. personatus* males averaged 12.67% larger than females. In *G. bursarius* males averaged 9.67% larger than females. Information on breeding activity, multiple catches and sex-ratio was recorded. Range extensions of about 35 miles for *G. personatus* and about 25 miles for *G. bursarius* were reported.

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# Ecology, Behavior and Population Dynamics of *Peromyscus nuttalli* in Eastern Texas

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## INTRODUCTION

The golden mouse (*Peromyscus nuttalli*) is a woodland form that is restricted in its geographic distribution to the southeastern part of the United States. It occurs as far north as the Mississippi Valley in Iowa and Illinois and the Allegheny Plateau in northern Kentucky. Eastward its range extends to the Atlantic Coast and the western limits of its range are in the timbered regions of eastern Oklahoma and Texas. In Texas it extends at least as far as 20 miles west of Palestine, Anderson County (McCarley, 1953).

There are a considerable number of papers dealing with the geographic and to some extent, ecologic, distribution of the golden mouse. There are, however, apparently only two papers of any length dealing with the ecology and dynamics of *nuttalli* populations. These are, one which is concerned with population fluctuations by Pearson (1953), and one on the life history and ecology of *nuttalli* by Goodpaster and Hoffmeister (1954).

The present paper is an outgrowth of a rodent population dynamics study supported by U. S. Atomic Energy Commission grant No. AT–(40–1)–1980). This paper is a report of part of the work performed under this contract and covers a period from March 24, 1955 to June 30, 1957.

Some information on the ecology and dynamics of *P. nuttalli* populations has been made available by George K. Stephenson, Officer-in-Charge, U. S. Forest Service Research Center, Nacogdoches, Texas, and Phil D. Goodrum, Research Biologist, U. S. Fish and Wildlife Service. Appreciation is expressed to these men and their agencies for these data. Appreciation is also expressed to W. Frank Blair for suggestions on procedure and for reading the manuscript. W. V. Robertson, Roger Williams, Robert Timbrook, Norman Beal and W. A. Stoddard served at various times as research assistants on the part of the project supported by the Atomic Energy Commission.

## DESCRIPTION OF REGION

The region in which this study was conducted is located in the central part of the so-called East Texas Timbered Region and the majority of the field work was conducted in Nacogdoches County. The timbered region of eastern Texas is considered by Dice (1943) and Blair (1950) to be a part of the Austroriparian Biotic Province. This region in Texas is classified by Thornthwaite (1948) as a $B_1$ (humid) climate with a moisture surplus of 40 per cent.

The East Texas Timbered Region is generally considered to be composed of three distinct vegetational regions (Tharp, 1926). These are: pine-oak forest region in the central and northern part, the pine forest region in the southeastern part and the oak-hickory forest region which forms the western limit of the timbered region of eastern Texas. *Peromyscus nuttalli* occurs in the pine-oak and the pine forest regions but has not definitely been shown to occur in the oak-hickory forest.

The majority of the information contained in this paper came from studies conducted in the pine-oak region. This region in Texas is characterized by the occurrence, in the better drained areas, of loblolly pine (*Pinus taeda*), shortleaf pine (*P. echinata*), postoak (*Quercus stellata*), blackjack oak (*Q. marilandica*) and hickory (*Carya* spp.) as the dominant woody species.

In the pine-oak region two distinct natural vegetational types are important to the ecology of the golden mouse. These are the upland forest and the floodplain forest. The dominant vegetation of the upland forest is similar to that described immediately above for the dominant vegetation of the pine-oak forest and is more fully described by Tharp (1926). The floodplain forest in the central part of eastern Texas is generally characterized by the absence of the plant species mentioned above and by the presence of stands of water oak (*Quercus nigra*), willow oak (*Q. phellos*), sweet gum (*Liquidambar styraciflua*), blue beech (*Carpinus caroliniana*), black gum (*Nyssa sylvatica*) and birch (*Betula nigra*) as the dominant species.

The upland forest is the most xeric natural vegetational type in eastern Texas and the floodplain forest is the most mesic natural habitat. It is only rarely that there is a sharp division between these two vegetational types of environments; but, instead, there is usually an ecotone or intergrade zone of vegetation which is not strictly referable to either environment. Because *P. nuttalli* is restricted to forested areas, no other types of environments are here considered.

## METHODS

The main means of studying *P. nuttalli* has been through the use of three study plots or study quadrats surveyed in the form of a grid pattern. All of these plots were located in the Stephen F. Austin Experimental Forest, 9½ airline miles southwest of Nacogdoches, Texas.

Studies began on all three plots in March, 1955. Two of the plots were located on the floodplain of the Angelina River and have been arbitrarily designated as Plots A and B. The third plot was located in the upland forest habitat and was designated as Plot C.

Plots A and B contained 101 and 100 live traps respectively. These traps were set in rows 75 feet apart with the traps also 75 feet apart as shown in Figure 1 for Plot A. Each plot also contained 101 and 100 nest boxes respectively. These nest boxes were similar to those described by Howard (1949) and were placed alternately on the ground and in trees. Some information concerning the life history and social behavior of *nuttalli* was gathered from these boxes, but the mice did not utilize the boxes to the extent desired.

If we consider that each trap is in the center of a square 75 feet on each side, then the 101 traps of Plot A sampled an area of 13.04 acres. By the same reasoning the 100 traps of Plot B sampled an area of 12.91 acres. The dominant vegetation on each of these plots was similar in most respects to that of the other and to the vegetation previously described for the floodplain forest habitat. Slight differences in vegetational composition between Plot A and Plot B will be discussed later where pertinent.

Plot C was laid out in a somewhat different manner than Plots A and B. As was mentioned earlier Plot C was in the upland forest and was under the supervision of the U. S. Forest Service and the U. S. Fish and Wildlife Service. Traps on this plot were in rows 66 feet apart and the traps were 66 feet apart in the rows, with a total of 80 traps. No nest boxes were used here. This plot sampled an area of 8.0 acres.

The procedure generally followed on Plots A and B was an intensive sustained system of live trapping. The trapping procedure on these plots was exactly the same; that is, when traps were set on one plot they were always set on the other plot. Traps were set on each plot an average of about 900 trap nights per month except August when traps were not set. On Plot C the trapping procedure was slightly different with an average of 240 trap nights per month including ten-night trapping periods once each season (spring, summer, fall, winter).

As each mouse was captured for the first time on each of the plots it was assigned a number by a system of ear punching and toe clipping except on Plot C where ear tags were used. After marking the mouse and recording pertinent information about the individual it was released at the site of capture and in most cases subsequently recaptured.

Some data from field notes and trapping records taken elsewhere in eastern Texas are also incorporated in the discussions to follow.

*Habitat Preference*

*Peromyscus nuttalli* has been reported by several workers to occur in a variety of wooded habitats throughout its range in the southeastern part of the United States. A. H. Howell (1921) found this species usually living in canebrakes and swampy woodlands and only rarely in dry woods in Alabama. Ivey (1949), Pournelle (1950) and Pearson (1953) reported much the same lowland distribution for the golden mouse in northern Florida but made no mention of its occurrence in upland wooded areas. In North Carolina, Odum (1949) found golden mice living in the Highland Plateau Region in heavily forested areas at altitudes ranging from 3400 feet to 4200 feet. In Virginia, Handley (1948) found this species occurring with equal frequency in pine-oak and other woods, as well as quite frequently in edges of canebrakes and moist thickets in the Dismal Swamp Region. Goodpaster and Hoffmeister (1954) stated that the brushy valleys along the streams were the favorite haunts of the golden mouse in the Allegheny Plateau Region in central and eastern Kentucky. There are no published records discussing the habitat preference of *nuttalli* in Texas. One general mammalian publication (Taylor and Davis, 1947) simply stated that *nuttalli* is found in lowlands. Bailey (1905) did not list this species as occurring in Texas.

In eastern Texas, the golden mouse occurs in both lowlands and uplands but always in a forested or wooded habitat. In the lowlands (floodplain forest habitat) of eastern Texas it was nearly always found in conjunction with *Peromyscus gossypinus* and usually in fewer numbers. This density relationship was also similar to the findings of Pearson (1953) in a lowland area in Florida. Trapping records showed that in such lowland environments in eastern Texas live-trapping generally resulted in the capture of about one *nuttalli* to three *gossypinus*.

In more xeric habitats, particularly those areas of vegetational transition at the margins of the floodplains and upland forest the ratio of *nuttalli* to *gossypinus* was about one to two with the actual catch of each species usually being higher than on the floodplain proper.

Possible reasons for this increase in the apparent population density will be discussed shortly. In the upland forest the golden mouse was frequently the only mouse species present, but it was not necessarily more abundant here than in the floodplain forest. In some upland forested areas which were adjacent to nearby lowlands, it was occasionally taken with *gossypinus*, but the latter species generally avoids the uplands (McCarley, 1954a). In upland areas that are distantly removed from lowland areas, the golden mouse was seldom encountered which may indicate that the floodplains served as the focal point of *nuttalli* distribution in this region. In eastern Texas, however, there did not seem to be any overall pattern of ecological distribution of golden mice that can always be directly related to upland or lowland forest environments.

A factor that seemed to be of more importance in controlling the ecologic distribution of *nuttalli* than mesic or xeric conditions was the density per unit area of woody vegetation, particularly the low understory or underbrush. There was an indirect relation, however, in that extremely xeric conditions in eastern Texas do not generally produce heavy undergrowth.

This correlation of ecologic distribution of *nuttalli* with density of underbrush was indicated by the fact that Plots A and B, which were in similar floodplain forest habitats, supported different sized populations of golden mice. It was mentioned earlier that there were slight differences in the vegetational composition of the two plots. Plot B was cut over by lumbering operations some 30 to 40 years ago so that the dominant vegetation that is now present is all second growth hardwoods. These trees have become large enough, however, to have formed an almost complete overhead canopy which has restricted the amount of sunlight that reaches the forest floor. This has created a more or less open vegetational community with comparatively little underbrush. In the 28 months of this study only 38 *P. nuttalli* were captured on Plot B. On the other hand Plot A was cut over in more recent years. The dominant vegetation is now approximately the same as on Plot B, but the size of the dominant trees (mainly oaks) was much smaller. (List quadrat sampling showed that the average-sized tree on Plot A was 10½ inches in diameter measured breast high while on Plot B the average-sized tree was 16 inches in diameter measured breast high). The smaller trees on Plot A have not yet formed a complete canopy so that there is more sunlight reaching the forest floor here than on Plot B. This has produced, in some parts of Plot A, a rather dense growth of various species of oak seedlings, rattan (*Berchemia scandens*), poison ivy (*Toxicodendron radicans*) and grapevine (*Vitis* sp.). In the same 28 month period on Plot A, 99 *P.*

*nuttalli* individuals were captured. This would seem to indicate that environmental conditions on Plot A were more favorable to *nuttalli* than those on Plot B.

In another attempt to analyze more concisely the effect of underbrush on the distribution of the golden mouse, each trap square (5,625 square feet) was classified as to whether the underbrush on that particular square was dense, sparse, or intermediate. The distribution of the areas of dense underbrush on this plot is shown in Figure 1.

Figure 1 and Table 1 show that 11 of the 101 traps on Plot A were located in areas that could be considered to be densely covered with underbrush. These 11 traps (approximately 11 per cent of the total trap number) had 26 per cent of the captures with an average of 13.6 captures per trap. This percentage of captures is considerably higher than would be expected on the basis of chance alone. The 57 traps located in areas with a moderate amount of underbrush had about the expected percentage of captures while the traps located in areas with a sparse growth of underbrush had considerably fewer captures than would ordinarily be expected. Of those traps located in densely thicketed areas, two were in fairly well-drained areas which approached the upland habitat type in vegetational composition and nine were located in poorly-drained areas which had a vegetational complex more typical of the floodplain forest habitat. There was apparently no preference shown by the golden mice on this plot for either the lowland or upland type. Plots B and C supported too small a population of *nuttalli* to analyze effectively but it appeared that the same correlation of underbrush and mouse distribution as encountered on Plot A was also true of Plots B and C.

Table I

Distribution of Traps and Captures of *P. nuttalli* on Plot A According to the Distribution of the Traps in Three General Conditions of Underbrush.

| Condition of Underbrush | No. of Traps | Per Cent of Total Traps | No. of Captures | Per Cent of Total Captures | Average Catch Per Trap |
|---|---|---|---|---|---|
| Dense | 11 | 11 | 150 | 26 | 13.6 |
| Intermediate | 57 | 56 | 336 | 58 | 5.8 |
| Sparse | 33 | 33 | 93 | 16 | 2.8 |
| Total | 101 | 100 | 579 | 100 | ... |

An examination of trapping records and field notes taken in eastern Texas since 1950 in other widely separated localities showed that this same general habitat type preference existed elsewhere in the pine and pine-oak regions of eastern Texas.

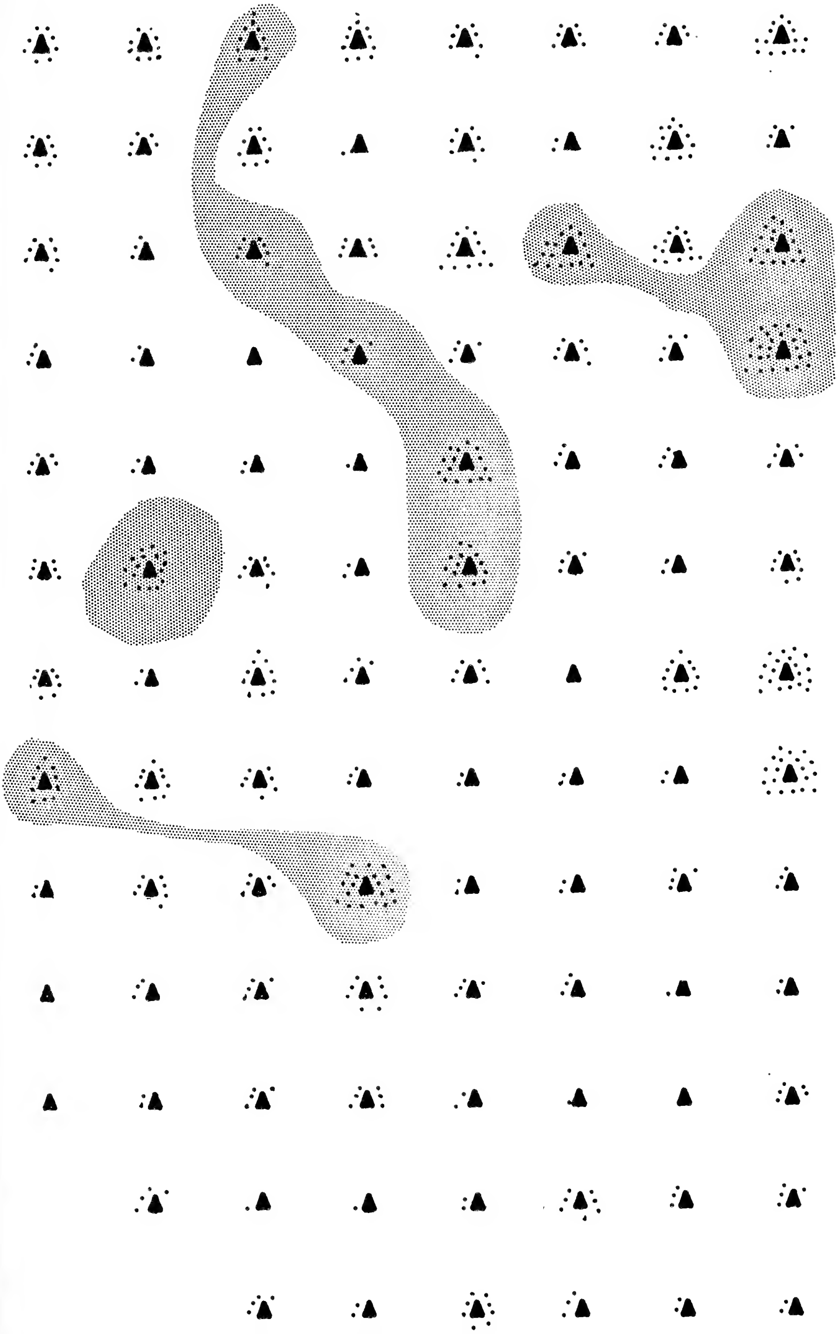

Fig. 1. The arrangements of the traps (triangles) on Plot A, the distribution of captures of *nuttalli* (dots) and the distribution of areas of dense underbrush (stippled).

Consequently it is believed that the main factor in eastern Texas that controls the ecologic distribution of the golden mouse is the density of the underbrush. In eastern Texas densely thicketed underbrush is most often encountered where the upland forest habitat meets the floodplain forest habitat. This could account for the apparent scarcity of *nuttalli* in certain forested floodplain habitats which have a complete overhead canopy of tall trees which shut out the sunlight from the forest floor and consequently reduce the amount of undergrowth.

*Nesting and Social Behavior*

A review of the scanty literature dealing with the habits and ecology of *Peromyscus nuttalli* indicated, almost without exception, that this species is primarily arboreal in its choice of a nesting site. The only published records indicating that *nuttalli* is not completely arobreal are the statements by Pournelle (1950) and Goodpaster and Hoffmeister (1954) that during the summer months, golden mice in Florida and Kentucky apparently spend much of their time on the ground and possibly build nests under logs and other debris. Apparently the usual nesting preference of *nuttalli* over most of its geographic range is an arboreal nest constructed in a globular shape out of leaves, bark, grass and other available materials and anchored varying heights off the ground.

In eastern Texas none of these arboreal nests has been discovered, even in areas where *nuttalli* was known to be quite numerous. In only one instance was a globular nest (which may have been built by *P. gossypinus*) found. This nest was built in the midst of a shredded stump some two feet off the ground and contained no occupants. Diligent searching during both summer and winter have failed to produce any nest of the golden mouse in eastern Texas other than crude nests constructed under logs.

One indication of the nesting habits of this species in eastern Texas was obtained by the use of the nest boxes which were mentioned earlier. These boxes were distributed over Plots A and B in the same manner as the traps (i.e., 75 feet apart). These boxes were first placed on the plots in August of 1955. The placement of the boxes was arranged so that all the boxes at odd numbered trap stations were on the ground, usually by a tree, log or under some brush. All of the boxes located at even numbered stations were placed in trees and secured there with wire. The height of the boxes in the trees varied from three feet to about six feet.

Golden mice were not found in any of these boxes until November 28, 1955, when one pregnant female was found in a ground box and an adult male was found in a tree box on Plot A. On December 1, 1955, one adult pregnant female was found in a tree box on Plot B. Thereafter, until March 20, 1956, on Plot A and February 7, 1956 on Plot B, varying numbers of *nuttalli* were found in both the tree boxes and ground boxes. Periodic inspection of the boxes through the spring and summer of 1956 revealed that no golden mice were living in the boxes at these times. In the fall of 1956, the first occupancy of the boxes by golden mice was on November 1, on Plot B, and November 6, on Plot A (both plots were checked on November 1). Mice utilized the boxes on both plots through the rest of November, December, and January, but in February it was obvious that the utilization of the boxes by golden mice was decreasing even though the population density of *nuttalli* was increasing. By the middle of February golden mice on both plots had ceased using the boxes.

There seemed to be a slight correlation between the occurrence in the boxes of *nuttalli* and occurrence of inclement weather during the months of the year when the mice were using the boxes. Generally, it was found that there would be more mice living in the boxes during wet, cold weather than at other times. It was not known whether the mice were forced to vacate nesting sites on the ground because of the wet conditions or whether unknown factors were responsible. The time of the year when the mice did begin to utilize the boxes was also a time when the populations were beginning to increase through increased reproductive activities. It is possible that some of the mice found in the boxes during these periods of unfavorable weather were simply mice that had no definite nest site but instead stayed in poorly adapted situations when the weather was mild and were forced by the rain and cold to take refuge in drier and warmer places.

There did not appear to be any preference of the mice for either the ground boxes or tree boxes. This was surprising in view of the reported and observed arboreal habits of this mouse elsewhere. On Plot A for the late fall and winter of 1955–56 and 1956–57, mice were found 23 times in tree boxes and 37 times in ground boxes and on Plot B for the same periods mice were found 15 times in tree boxes and ten times in ground boxes. These figures indicated that the golden mice had no particular preference for the arboreal boxes over the terrestrial boxes. There was some suggestion, however, that in densely thicketed areas (as on parts of Plot A) the mice were more terrestrial than they were in areas with a scanty growth of underbrush (as on most of Plot B).

Cotton had been placed in each box, and it was found that the golden mice did construct a globular nest out of this cotton and quite frequently added various plant fibers and leaves. These nests, which were built in both the ground and tree boxes, were restricted to about six inches in diameter by the size of the box.

There seems to be no indication that in eastern Texas golden mice build globular arboreal nests or that they are as arboreal in other aspects of their life habits as they are reported to be elsewhere in their geographic range.

Since golden mice are commonly found in areas where stream-valley flooding is always a possibility it is fortunate that an opportunity to study the effect of flooding on *nuttalli* populations was presented. In the spring of 1957 heavy rains produced flooding of both the flash and more prolonged variety on the two study plots on the floodplains. Trapping immediately before flooding on both plots enabled the investigators to know almost precisely just what individuals were making up the population. On Plot A flooding was of a nature that could best be described as flash-flooding with a later prolonged overflow of about a week. This type and duration of flooding apparently had no detrimental effect on the golden mice. It did not reduce their numbers nor did it cause any movement of the mice out of the plots and caused no change in the home ranges of the resident mice. On Plot B flooding was more prolonged, lasting about three weeks. This type of flooding was detrimental to the population in that it tended to reduce the numbers of mice that were present prior to flooding. A more detailed report on the effect of flooding on these populations is now in press. (McCarley, 1958)

*Behavior Characteristics*

When a golden mouse was released from a trap or taken from a nest box, it was usually observed until it reached cover of some sort. The majority of *nuttalli* that were released went into brush piles or holes at the bases of trees and tree roots. The remainder of the individuals usually went up a tree. No individual consistently sought refuge in either an arboreal or terrestrial situation. Of those mice that climbed trees on being released there did not appear to be any particular direction to their travel, but instead they simply climbed the first available bit of woody vegetation. Frequently they would disappear in a tangle of vines, but definitely not into any nest of a globular form as has been mentioned earlier. Sometimes they would simply climb out on a limb, sit there, nervously wash their front paws and face, and then settle down with all apparent intentions of staying in that particular, rather exposed place for some time. Only rarely did a particular mouse climb the same tree as it had earlier. On the other hand those mice which tended to take refuge on the ground could usually be predicted to go to a certain hole in the ground or the same brush pile time after time. It is believed that in those cases the mice probably had a nest there and that it was not necessarily a refuge only.

The behavior of the mice after they were released was probably influenced by the fact that after repeated captures most of the golden mice became rather gentle and in most cases could be handled easily without irritating them enough to bite. When these gentled mice were released, they appeared to be in no hurry to get under cover but investigated the area around the trap and frequently crawled over the feet of the investigators. In more than one instance various golden mice tried to climb up the trousers of the investigators.

For the first few captures, most of the mice emitted a series of high pitched squeaks during the time of handling. After the mice had been handled several times, this squeaking reaction ceased. At the same time *nuttalli* was being trapped. *P. gossypinus* was also being caught on the same plots. It was noticed that *gossypinus* rarely emitted the squeaking noise and never became accustomed enough to handling to quit trying to bite or escape. Another comparison that can be made between these two species is that *gossypinus*, when released, never lingered in the vicinity but immediately scampered to a refuge of some sort such as a brush pile, hollow tree, or hole in the ground.

Golden mice are apparently fairly social mice. This has been indicated earlier by Goodpaster and Hoffmeister (1954), Howell, Joseph C. (1954) and Dunaway (1955). All of these workers reported instances of more than one mouse using the same arboreal nest and in some cases as many as four individuals living together (Goodpaster and Hoffmeister, 1954).

In the present study it has been observed that there is a considerable overlap of home ranges of golden mice as revealed by repeated trap and nest box captures. Frequently more than one mouse was found in the same nest box. Often this was a part of a family group, usually a female and one to three immature individuals. In one case that was fairly typical, a pregnant female, was first found in a ground box on the 17th of December, 1955. She was subsequently found in the same or adjacent boxes several times and usually in company with a particular male. On January 14, 1956, the male was found in the original box with three juvenile mice. Presumably, these three juveniles were the offspring of these adults. The female was subsequently recaptured on January 14, and 21, 1956, once in company with one of these juveniles. Until the juveniles dispersed, this family group more or less lived together or at least in the same immediate area with no apparent conflict. There was no indication that the mating relationship between the above mentioned adult male and female was of a permanent nature.

No indication of any particular social affinities was observed in *P. gossypinus* either in the use of the nest boxes or in overlapping home ranges to the extent encountered in *nuttalli*. There was some evidence to indicate that the juvenile golden mice remained with or close to the parent(s) until they were about 30 days old. After this they generally dispersed and usually resumed social relations with another mouse in another part of the plot.

*Longevity*

In any discussion of longevity a distinction should be made between what Lankester (1870) called potential longevity and the mean duration of life. There are unpublished instances in which golden mice have lived for approximately two years in the laboratory and were apparently in good health when they were killed for other purposes. Figures are available for other species of the genus *Peromyscus* which indicate that in captivity they may live as long as eight years with an average life span in captivity of five to six years (Dice, 1933). This would be approaching the potential longevity.

There is fairly general agreement among students of wild populations that the mean duration of life of most animals is considerably less than their potential life span. This is particularly true of most rodent species because they form the basic food of many predators.

In an attempt to find out the average longevity or mean duration of life of *nuttalli* in the wild, several factors needed to be considered. The most important was determining whether or not the disappearance of an individual indicated mortality or dispersal. It can never be said with certainty just what was the fate of the majority of the mice that disappeared. It is known, however, that when a mouse establishes itself in a certain area (so that it is caught within a particular group of traps over a period of time), it will generally stay in that area as long as it is alive (Errington, 1939; Blair, 1953). Prior to establishment of a home range a mouse is usually considered a transient or migrant.

In this study a mouse must have established residence on the plots before it was eligible for consideration in the calculation of life spans. The criteria used to distinguish transient from resident individuals were that if a mouse was caught two or more times in one area it was considered a resident but if it was caught only two times, the times of capture must have been at least 20 days apart. All other mice were considered transients. It is believed that in most cases these criteria eliminated the individuals that were simply moving through the plots.

Another factor that needed to be considered was the age of a mouse when it was first captured. Condition of the pelage and size of the mouse were the two criteria used to determine age. In addition to small size the pelage of juvenile golden mice generally has a somewhat dingy yellow appearance. Mice with these characteristics were considered juveniles and at least 25 days old. Sudadults differ from juveniles only slightly in pelage conditions and size and in many cases it was impossible to be sure whether a mouse was a juvenile or a subadult. If a mouse was considered to be a subadult it was asumed that its maximum age was at least 35 days. Adults were distinguished by the brighter pelage and larger size and in some cases by whether the animal was sexually mature or not. Those mice which were called adults were considered to be at least 60 days old.

To show how the life span of a mouse was calculated in this study, let us assume that when a mouse was first caught it showed adult pelage conditions indicating that it was at least 60 days old. Assume further that it was caught an additional number of times over a 93 day period, after which it was not caught again. Thus we can assume that when the mouse was last caught it was at least 153 days, or approximately 5.01 months old (153/30.5 days). This then would be the minimum life span of that particular mouse or similar to what Lankester (1870) called the mean duration of life.

Only mice from Plots A and B were considered in this study since Plot C had comparatively few golden mice living on it and the times between trapping periods were considerable longer in most cases than on Plots A and B.

Since it was impossible, using the techniques in this study, to capture the very young individuals, the data below are biased to some extent. In other words if a mouse did not live long enough to get caught its very short life span was not considered.

The mice were first considered from the standpoint of age and sex on each of the two plots. Generally the life spans of adult males on both plots were slightly longer than those of the adult females on both plots but the difference between the two groups was not of statistical significance (using the "t" test of comparison). Snyder (1956) also found that there was no overall difference in mortality rates for male and female *P. leucopus* in Michigan. There was a slight difference between adults and immatures (there were not enough subadults to consider separately so this group and the juveniles were lumped together as immatures) but again the differences were not statistically significant. There were no significant differences between mice of the same age or sex group from Plot A to Plot B. On Plot A, 38 adults had an average minimum life span of 6.8 months and 39 immature mice had an average minimum life span of 6.0 months. On Plot B, 17 adults had an average minimum life span of 6.5 months and ten immature mice had an average minimum life span of 3.1 months. This latter figure is not reliable because of the small number of individuals in this combined age group.

It would thus appear that the average golden mouse in the floodplain forest habitat of eastern Texas has an average life span of approximately 6.5 months. This figure is slightly higher than life spans published for other small mammals (Blair, 1948, Snyder, 1956). The present study considered only those mice that lived long enough to be captured and does not take into consideration the extremely short life span of those individuals which were possibly caught by predators before they were old enough to be captured two or more times. If it had been possible to consider these individuals, the average minimum life span of *nuttalli* in eastern Texas would undoubtedly have been shorter than the 6.5 month figure given above.

The longest time that any golden mouse lived was an adult male which lived on Plot A for 19.0 months and was still alive when the study was discontinued. Apparently the longest natural life span of *nuttalli* that has been published to date is the record by Pearson (1953) of one male golden mouse that was known to have lived at least two and one-half years.

Of the 137 golden mice captured on Plots A and B during this study, 104 remained on the plots long enough to be considered residents by the criteria mentioned earlier. Table 2 shows the percentage of mice that were recaught over varying lengths of time. The only pattern to the time a mouse remained on the plots was that a higher percentage of immatures (juveniles and subadults) than adults were transient in nature (Table 2). Slightly over one-half (53%) of the immatures

TABLE II

The Percentage Distribution of the Time Adults and Immature *P. nuttalli* Remained on Plots A and B.

| | 1–15 days | 15 days-1 mo. | 1–2 mos. | 2–3 mos. | 3–4 mos. | 4–5 mos. | 5–6 mos. | 6–9 mos. | 9–12 mos. | Over 12 mos. |
|---|---|---|---|---|---|---|---|---|---|---|
| Adults | 25.0 | 8.3 | 19.4 | 6.9 | 9.7 | 6.9 | 8.3 | 6.9 | 1.3 | 6.9 |
| Immatures | 35.9 | 17.1 | 10.9 | 17.1 | 4.6 | 0.0 | 4.6 | 7.8 | 0.0 | 6.2 |

remained on the plots only one month or less while only 33.3% of the adults remained on the plots for such a short time.

There were not enough individual golden mice present at any one season to calculate mortality rates for the different age groups or for different seasons but other workers (Howard, 1949; Pearson, 1953; Snyder, 1956) have reported that there was a higher mortality rate at certain seasons of the year among the younger age classes of other species of *Peromyscus.*

*Population Fluctuations, Structure and Reproductive Patterns*

It is a well-known fact that population size of animals fluctuates from season to season and in some cases from year to year and that these fluctuations are dependent on several factors, all of which probably influence in some manner the reproductive pattern. The pattern of reproduction is apparently the main factor influencing the seasonal rise and fall of animal populations.

Many workers have demonstrated that in small mammal populations a seasonal rise and decline is normal. In the northern part of the United States this pattern is generally that of a low population during the late fall, winter and early spring because of lack of reproduction during these times (Burt, 1940; Howard, 1949; Snyder, 1956 and others). In the southern part of the United States this reproductive pattern with its effect on population size is more or less reversed with the low ebb in populations coming during the warm months of the year (Pournelle, 1952; McCarley 1954b). Pournelle (1952) has shown that at least part of this decrease in reproduction in *P. gossypinus* can be attributed to a decrease in fertility of the male mice when the temperature reaches 89 degrees Fahrenheit and above. Apparently the lack of reproduction during the winter months in the northern part of the United States can be attributed at least indirectly to the extremely low temperatures which frequently prevail.

The number of *P. nuttalli* captured each month on each of the study plots is shown in Figure 2. The population estimates for each month in this particular case were based upon the number of individuals known to be living on the plots during each month as revealed by trap and nest box captures. (The number of mice indicated for the month of August was an extension based on mice captured prior to August and later found to be still living on the plots.) The estimate of population size also includes, for each month, those individuals which did not happen to be caught on that particular month but had been previously caught and were subsequently caught again after the month in question. These estimates were based on an average of about 900 trap nights per month for Plots A and B. As was mentioned earlier the trapping on Plot C was not so intensive but a partial comparison of the population on this plot can be made with Plots A and B as regards fluctuations since there is no indication here of population density.

It can be seen from Figure 2 that the population trends on Plots A and B closely paralleled each other, although Plot B consistently sup-

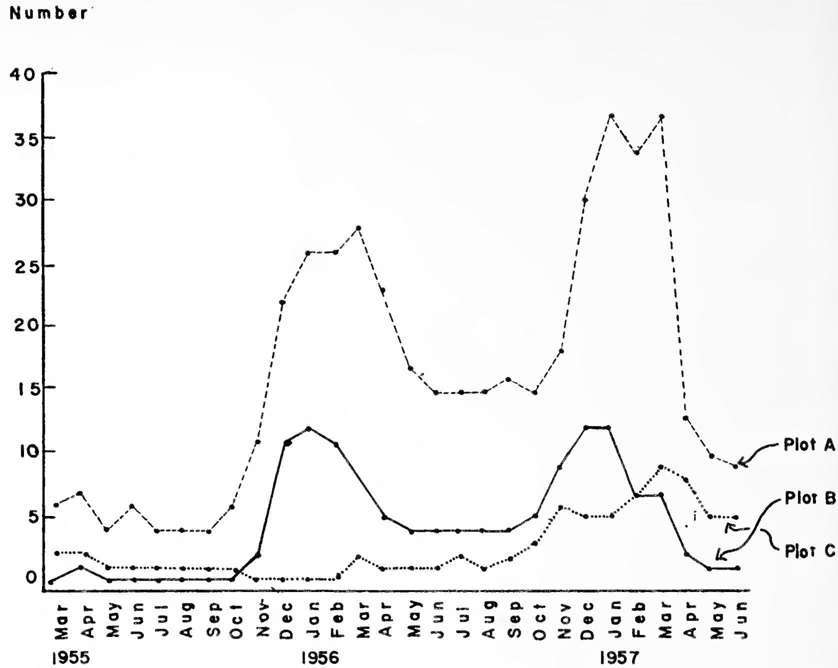


**Fig. 2. Population fluctuations of *P. nuttalli* on three study plots for a 27 month period according to the number of individual mice caught on each plot each month.**

ported a smaller number of mice than did Plot A. (Reasons for this have been discussed earlier.) On both these plots the peaks of population size were attained during the late winter and early spring. This is approximately the same situation as was reported by McCarley (1954b) for *P. gossypinus* in this same region from late 1950 until June of 1952. The low ebb of population size of *nuttalli* was reached during the summer months when the population, in spite of its small size, remained fairly constant on both Plot A and Plot B.

On Plot C the pattern does not repeat that of Plots A and B, except generally for the winter and spring of 1957. The reasons for this are unknown but there are several possible explanations. The population size of *nuttalli* in this particular upland habitat was generally lower than the population in the lowland habitats and there was little or no opportunity for fluctuations because of the low numbers of mice (as in the lowlands in the summer). Another possibility is that there was very little actual reproduction in this particular upland habitat on the part of *nuttalli* and the resident and transient animals encountered there were simply those individuals that had been forced to disperse out of more favorable environments by an increase in population pressure. A third reason may be that because of the low number of trap nights per month (an average of 240) and the comparatively small size of the sample plot, the trapping procedure on Plot C did not give a true idea of population size.

The pattern on the floodplains (Plots A and B) is in many respects similar to the situation reported by Pearson (1953) for *nuttalli* in Florida during 1949–1950 on a nine-acre study plot. Here he found that the peak of population size came in the period from January to May with a general decrease through the rest of the trapping period.

Table 3 shows the per cent of immatures and adults in the population on Plot A for each of the months of the study. (Because of the small number of individuals present on Plots B and C, percentage figures in these cases would be misleading.) It can be seen that for both years of the study there were more immatures in the population during the late fall, winter, and spring than at other times. It would be valid to take the abundance of immature mice as an indicator of reproductive activity. The conclusion that could be drawn is that the golden mouse, like other southern United States rodent species, does not reproduce to any extent during the summer months. In eastern Texas breeding apparently begins in September (probably as the nights become cooler) and is reflected by the appearance of immature mice in October. Goodpaster and Hoffmeister (1954), however, reported instances of the golden mouse breeding during the summer months in northern Kentucky.

Table 3 also shows that there were no great variations from the expected 1:1 ratio of adult males to females. In the months when the

TABLE III

The Percentage Composition of the *P. nuttalli* Population on Plot A for Each Month of the Study, According to Age and Sex.

| Per Cent | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1955 | | | | | | | | | | | | |
| Adults | | | 17 | 43 | 100 | 50 | 50 | 100 | 100 | 84 | 82 | 82 |
| Immatures | | | 83 | 57 | 0 | 50 | 50 | 0 | 0 | 16 | 18 | 18 |
| Adult Males | | | 60 | 16 | 0 | 43 | 0 | 0 | 0 | 75 | 50 | 50 |
| Adult Females | | | 40 | 84 | 100 | 57 | 0 | 0 | 100 | 25 | 50 | 50 |
| 1956 | | | | | | | | | | | | |
| Adults | 69 | 77 | 75 | 79 | 94 | 100 | 100 | 100 | 100 | 89 | 70 | 68 |
| Immatures | 31 | 23 | 25 | 21 | 6 | 0 | 0 | 0 | 0 | 11 | 30 | 32 |
| Adult Males | 33 | 31 | 38 | 50 | 0 | 25 | 66 | 0 | 60 | 60 | 78 | 58 |
| Adult Females | 66 | 69 | 62 | 50 | 100 | 75 | 33 | 0 | 40 | 40 | 22 | 42 |
| 1957 | | | | | | | | | | | | |
| Adults | 68 | 91 | 98 | 100 | 90 | 89 | | | | | | |
| Immatures | 32 | 9 | 2 | 0 | 10 | 11 | | | | | | |
| Adult Males | 53 | 46 | 44 | 11 | 33 | 40 | | | | | | |
| Adult Females | 47 | 54 | 56 | 89 | 66 | 60 | | | | | | |

sex ratio departed drastically from 1:1, there were few mice present on the plot (Figure 2).

The average size of a litter of golden mice was not ascertained in this study since no mouse ever gave birth to a litter in either a trap or a nest box. Tentative conclusions that can be drawn from the appearance of juvenile mice in an area where a suckling female was known to be present and dissection of dead pregnant females indicated that the number of young in a litter was about two or three. This was also the finding of Goodpaster and Hoffmeister (1954).

Evidence was also obtained in this study which indicated that a female golden mouse which was an adult at the beginning of the breeding season in the fall may have as many as three litters during that current breeding season. There were also instances which indicated that those mice which were born in October and November reached reproductive maturity within one to two months and reproduced at least once during that breeding season.

*Home Ranges and Territoriality*

There are several ways in which home range size can be estimated (Hayne, 1949). Most of the methods currently in use recognize that it is almost impossible to get an absolute measure of home-range-size by use of traps alone. Instead any home range figure derived from trap data is, at best, an estimate of the area an animal covers but it is useful for comparative purposes. This estimate of home range is sometimes called the "trap range" (Blair, 1951).

Estimates of home ranges of golden mice were made from trap data, and in some cases nest box data, by the method used by Blair (1940) and described by Stickel (1954) as the inclusive boundary strip method. This method assumes that the home range of an animal may extend beyond the traps in which it is caught so that one-half the distance to the next trap is added to the calculations.

The grid pattern of the traps and the spacing of the traps have already been discussed. It should be mentioned that in most cases the traps were not placed precisely beside the stake but anywhere within a four to five foot radius in a position which would be most likely to catch a mouse. At various times the trapping procedure was varied so that not all traps were set at the same time. This variation included such procedures as setting alternate traps and in the latter part of the study, setting only alternate rows of traps after several nights of total trapping. This was done to eliminate the constant recapture of one particular individual in the same trap when the trap happened to be near the nest or home-site of the mouse. Another procedure used to discourage the mice from relying on the traps for a source of food was to close a trap for a night after it had caught the same mouse on two consecutive nights.

In the considerations to follow, certain mice were excluded from the calculations. These were individuals caught less than three times and immature individuals which may have been captured three or more times but which were obviously wandering around without any definite home range. Also excluded from the calculations were the occasional and usually obvious travels made by a mouse outside the normal established home range. The length of periods of observation varied because of the variation in time a mouse remained on the study plots. Because of these long periods of observation it was necessary in a few cases to exclude from home range estimates those individuals that changed their home range. This was a rare occurrence and was always obvious in the raw data so that no problem was posed by this factor.

Haugen (1942), Blair (1942), and others have shown that it is necessary to capture a mouse about ten or more times before it is possible to have an accurate estimate of the home range size. Table 4 shows the average home ranges in acres of males and females from Plots A and B, according to the number of times an individual was captured. It can be seen, that in general, the size of the home range increased with the number of captures. An average of the home ranges of five male mice caught ten or more times shows that these males (from Plot A) had a mean home range of 1.46 ± .17 acres. An average of the home ranges of ten females from Plot A captured ten or more times was 1.40 ± .22 acres. There is no significant difference

TABLE IV

Size of Home Range of Males and Females on Plots A and B According to the Number of Times Captured. (Number of Individuals in Each Case Shown in Parentheses.)

| Times Captured | Plot A Males | Plot B Males | Plot A Females | Plot B Females |
|---|---|---|---|---|
| 3 | (24) .60 | (10) .62 | (39) .35 | (8) .52 |
| 4 | (22) .72 | ( 7) .61 | (31) .50 | (5) .75 |
| 5 | (17) .93 | ( 5) .76 | (26) .60 | (5) .81 |
| 6 | (15) .93 | ( 4) .91 | (20) .74 | (3) .79 |
| 7 | (12) 1.12 | ( 4) 1.17 | (14) .90 | (3) .82 |
| 8 | (10) 1.25 | ( 4) 1.21 | (13) .96 | (3) 1.05 |
| 9 | ( 8) 1.23 | ( 4) 1.21 | (12) .99 | (2) 1.60 |
| 10 | ( 6) 1.23 | ( 3) 1.40 | (10) 1.14 | (2) 1.60 |
| 11 | ( 6) 1.25 | ( 3) 1.40 | ( 8) 1.06 | |
| 12 | ( 6) 1.41 | ( 3) 1.40 | ( 8) 1.06 | |
| 13 | ( 4) 1.42 | ( 3) 1.40 | ( 7) 1.15 | |
| 14 | ( 2) 1.03 | ( 3) 1.40 | ( 7) 1.19 | |
| 15 | ( 1) 1.35 | ( 3) 1.40 | ( 5) 1.33 | |
| 20 | ( 1) 2.01 | ........ | ( 2) 2.09 | |

between the sizes of these home ranges. There were too few individuals captured ten or more times on Plot B to accurately compare with Plot A except for the comparison given in Table 4.

Plot C, which had the traps spaced 66 feet apart, had only 11 individuals living on the plot long enough to be considered residents. These 11 individuals (four males, seven females) were caught an average of 8.3 times each and had an average home range of 1.21 ± .17 acres. This should not be interpreted to mean that in this upland habitat, golden mice had a smaller home range than in the lowlands because (1) the average number of captures per home range calculation was less than above, (2) the traps on Plot C were closer together than on the other two plots and (3) no allowance was made on Plot C for any variation of trapping procedure to encourage the mice to move around.

The largest home range calculated was 2.77 acres for a female on Plot A which was captured 29 times over a six-month period. Both the maximum and the average size of home ranges of golden mice in this study were considerably larger than the only previously published estimate of .26 acre based on three female *nuttalli* captured an average of 15 times each in Tennessee (Howell, J. C., 1954).

Not enough golden mice were captured at any two seasons of the year to give any accurate comparison of home range sizes according to the season of the year. There is some indication, but certainly not conclusive, that golden mice ranged over a larger area in the colder months of the year than they did in the warmer months of the year.

There was no evidence of territoriality among the golden mice as revealed by location of home ranges. Home ranges were plotted of mice from Plot A which were captured during January and February of 1957, when the population was at its peak. Of the 37 golden mice captured on this plot during these months, only 18 mature mice were captured three or more times so that their movements could be plotted. It was found that there was, in all cases, a considerable overlap of home ranges of these mice. The home ranges of males and females overlapped 16 times, the ranges of males overlapped nine times and the ranges of females overlapped seven times. Since this was the time of the year when practically all the mature mice were in breeding condition, it was believed that any evidence of territoriality as expressed by discreteness of home ranges would have showed itself at this time. In some of the cases of overlap mentioned above it was found that two or more mice of the same sex would frequently have almost identically located home ranges.

It was mentioned earlier that nest box observations indicated that these mice were rather gregarious in behavior and this seems to be borne out by an examination of the distribution of the home ranges of the mice. It was also observed that *nuttalli* seldom showed any signs of fighting as can sometimes be seen in other mouse species by torn and bitten ears and other combat wounds. It should be mentioned, however, that in one instance, two *nuttalli* were caught at the same time in the same trap and one of the mice, an adult female, killed and ate the other mouse (sex unknown).

*Population Density*

Population density of animals is usually expressed as the average number of individuals per acre. In a study such as the present one, certain problems are posed in attempting to calculate population density. For example the population density may fluctuate widely from one season to another (Table 5), and may in fact fluctuate from

TABLE V

Number of Resident and Transient Golden Mice on Plots A and B for 11-Day Periods With Calculated Density Per Acre of Resident Mice for Each Plot for Each Season.

| | Plot A | | | Plot B | | |
|---|---|---|---|---|---|---|
| | Total No. of Residents | Total No. of Transients | Pop. Den. of Residents | Total No. of Residents | Total No. of Transients | Pop. Den. of Residents Per Acre |
| 1955 | | | | | | |
| Summer ...... | 6 | 1 | 0.3/A | 0 | 0 | 0.0/A |
| Fall .......... | 6 | 0 | 0.3/A | 0 | 0 | 0.0/A |
| Winter ........ | 13.5 | 2 | 1.0/A | 5 | 1 | 0.4/A |
| 1956 | | | | | | |
| Spring ....... | 21 | 1 | 1.6/A | 4.5 | 1 | 0.3/A |
| Summer ...... | 12 | 0 | 0.9/A | 3.5 | 0 | 0.3/A |
| Fall .......... | 10.5 | 1 | 0.8/A | 3.5 | 0 | 0.3/A |
| Winter ....... | 20.5 | 0 | 1.6/A | 6.5 | 0 | 0.5/A |
| 1957 | | | | | | |
| Spring ....... | 29 | 3 | 2.2/A | 5.5 | 0 | 0.4/A |
| Summer ...... | 8 | 0 | 0.6/A | 0.0 | 0 | 0.0/A |

one day to another. In other words a population of animals is constantly changing with dispersal into and out of an area, normal predation, birth and other factors. Consequently when population density is considered it must be a measurement of a population at a particular time. It is well known that in most small mammal studies it takes more than one night of trapping even with saturation trapping to catch all or nearly all of the animals with ranges in the trapping area (Gentry and Odum, 1957). A distinction must also be made between resident and transient individuals as has been done earlier in this paper.

In the consideration of population density of the golden mouse certain well-defined trapping periods which were conducted four times a year were used as the basis of measurement. Part of the trapping procedure in the study of *nuttalli* was to trap intensively for 11 nights on or around the summer and winter solstices and the spring and fall equinoxes. At these times all traps on Plots A and B were set continuously for five nights. After five nights, alternate traps or rows of traps were set for three nights then those traps or rows which had been open were shut and the remainder opened for three nights. There was ample evidence to indicate that this period of trapping was enough to catch the great majority of the mice living on the study areas. Our records indicated that this procedure caught approximately 97 per cent of the population.

Table 5 shows the estimated number of individuals per acre living on Plots A and B for each of the four seasons of the year since the study was inaugurated. (The spring of 1955 is not included because trapping at this time was interrupted by extremely cold weather.) A resident is again defined as an individual caught 2 or more times, but if only two times, the times of capture must have been at least 20 days apart. In addition at least one of the captures must have been in a trap or box that was not on the perimeter of the plot. All individuals which were captured only in perimeter traps were considered to have only a part of their home range on the study plot and were arbitrarily considered as only one-half a resident.

It is fairly common in population work to either add one-half the width of an average home range to each side of the study area which is continuous with similar environments, or add to the outside of the area enclosed by traps, one-half the distance to the next trap. This latter alternative was used in this study and was so indicated when the size of the plots was discussed earlier.

Table 5 shows the calculated population density per acre of resident *nuttalli* for each season of the year. There was a wide fluctuation in number of mice per acre from one season to the next ranging from a high of 2.2 mice per acre on Plot A in the spring of 1957 to the low of 0.0 mice per acre at several times on Plot B. These fluctuations follow the trends displayed by Figure 2 with the greatest density generally coming in the colder months of the year. It is interesting to note that on both plots there were comparatively few transient mice. It is also interesting to note that there was a wide discrepancy between population density of Plot A and Plot B. This supports the earlier claim that *nuttalli* are rather selective in their choice of habitat and prefer an area with dense underbrush over an area with a sparse amount of underbrush.

SUMMARY

*Peromyscus nuttalli* in eastern Texas was investigated by using live traps on two 13.0 acre study plots in the lowlands and one 8.0 acre plot in the uplands, marking the mice, releasing them at the site of capture, and studying them by subsequent recapturing. This study extended over a 27 month period. In eastern Texas golden mice are restricted to a forested habitat and the main factor that controls their ecologic distribution is a dense growth of underbrush regardless of whether it is in the upland or lowland. Golden mice in eastern Texas are at least partly arboreal but apparently do not construct arboreal nests as has been reported elsewhere. The average length of life in the wild for both males and females is about 6.5 months. The period of greatest population density (2.2/acre) is in the late spring as a result of a breeding pattern which begins in September and continues through the cooler months of the year. The average size of the home range of *nuttalli* is approximately 1.42 acres with no significant difference between males and females. There was a considerable overlapping of home ranges of individuals of both sexes with no evidence of territoriality. These mice are inclined to be gregarious in their social behavior.

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# Contributions to the Cranial Morphology of *Bufo valliceps* Wiegmann

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It seems necessary to understand the basic morphology of the bufonid head before full consideration can be given to the natural affinities within the genus *Bufo*. With this in mind I previously described certain aspects of the head of *B. w. woodhousei* Girard (Baldauf, 1955, 1957) which, in my opinion, is a member of a distinct group of bufonids. Another group is represented by *B. valliceps*, the cranial anatomy of which is described here and compared with that of *B. w. woodhousei*. All references to *woodhousei* refer to the publications already mentioned.

Methods employed for this study are essentially the same as those previously described by me (1955) and are not repeated here. Serial sections were made of the heads of two males with a snout-vent length of 62.0 and 66.0 mm. and one 67.0 mm. female. Sectioned material was compared with and augmented by dried skeletons, cleared specimens, dissections, wax-plate models, and graphic reconstructions.

I again have the pleasure to gratefully acknowledge support of this study by a AAAS grant through the Texas Academy of Science.

Unless otherwise stated, all descriptions are based on the examination of serial sections, starting with the olfactory capsule and proceeding toward the rear of the head.

### *Olfactory Region*

The septum nasi is not completely ossified; instead, ossifications are represented by a thin perichondral lamina on each side of the septum in the region of the olfactoria eminentia.

The tectum nasi is present in front of the cartilago obliqua, but posterior sections show the nasal bones as the only roof of the nasal capsule. Posterior extensions of the planum antorbitale proceed upward and medially to re-establish a tectum after the connection of the planum with the solum and tectum is severed. Thus, the tectum nasi is absent between the levels of the oblique cartilage and the anterior cartilaginous limits of the sphenethmoid.

An intermaxillary cartilage is present.

The inferior prenasal cartilage fuses to the ventral surface of the solum nasi after the lamina inferior detaches from the crista intermedia. Although the alary cartilage displays the same general relationship to adjacent structures as described for *woodhousei*, it nevertheless extends farther to the rear and serves as a lateral support for the external narial opening. The latter opening is more posterior in *valliceps* than in *woodhousei*.

The premaxilla does not extend up to the nasal cartilage in section until the inferior and superior laminae, the cavum medium, and the cavum inferius appear in sections. Therefore, the anterior portions of the crista intermedia and associated structures in *valliceps* are without lateral protection and support.

The cavum inferius appears in section before the cavum medium. First evidence of the cavum inferius is at the level of the fenestra nasobasalis (Fig. 1). The solum nasi and the crista intermedia are therefore not differentiated laterally. Appearance of the cavum medium is accompanied by the separation of the distal portion of the crista into its laminal components. Thus, when the cavum medium first appears the solum is not yet completely separated from the crista. The relationship of the crista and solum described here and shown in Figure 2 for *valliceps* duplicates, in my opinion, the condition illustrated for *B. angusticeps* by Schoonees (1930, Fig. 7). The latter author clearly states, however, that the cavum medium appears first in that species. Dr. du Toit has been kind enough to recheck the slides of *B. angusticeps* and has informed me that the cavum medium is farther to the front than the cavum inferius. I cannot reconcile this anterior position of the cavum medium in *angusticeps* with Schoonees' Figure 7.

The infundibulum is flexed laterad as it descends toward the cavum medium. The latter cavity is divided by the septomaxilla.

The anterior process of the crista subnasalis first appears at the anterior level of the cavum medium (Fig. 2). The level of fusion of the anterior process with the crista subnasalis proper does not differ from the condition described for *woodhousei*. The extremely short, posterior process of the crista subnasalis rests on the pars palatina of the maxilla and ends far forward of the eminentia (Fig. 3).

Figure 3 shows that the crista intermedia ends as a free piece after loosing its connection with the septum nasi. The posterior free piece of the crista does not connect with the solum nasi (Fig. 4).

The cartilaginous support for the eminentia olfactoria is at first low and broad, at which point the septum begins to show perichondral ossifications. The same supports become thicker toward the rear and eventually bifurcate (Fig. 5). The ossification of the septum spreads out posteriorly at the level shown in the last figure. Perichondral ossifications form a uniform covering of the septum, the medial portions of the tectum nasi, the solum nasi, and the medial surface of the eminential support. The same figure shows that bony invasion of the cartilages proceeds laterally; thus, the invasions are not present at the same level in all sections. The nasal cartilages (including the supports for the eminentia) are not completely replaced by bone, except for one portion of the septum that becomes so narrow that its very existence depends upon the two perichondral layers.

The efferent ducts of the intermaxillary glands open into the oral cavity by means of a shallow channel located on each side of the palate directly beneath the prevomer bone (Fig. 6). Each channel appears posterior to the choana of the same side and therefore has no relation with the opening of the latter. Prechoanal sacs and grooves are absent.

The size of the planum terminale is reduced rather quickly in sections and ends without continuing back as a processus lingularis.

The nasal region posterior to this level is without lateral supports of bone or cartilage until the large nasal alae are met (Fig. 7).

The pars nasalis of the maxilla is absent; therefore the anterior portion of the planum antorbitale is supported laterally only by the pars palatina of the maxilla. The V-shaped notch formed by the pars facialis and the pars nasalis in *woodhousei* is absent (Fig. 8).

### *Dermal Bones of the Olfactory Region*

The nasal bone is notable for its thickness, particularly in the region of the ala and canthal crest. The thickness allows for extensive bone marrow cavities (Fig. 5). The medial edges of the nasal bones become progressively separated toward the rear and this is accompanied by an increased thickness of the sphenethmoid.

### *Sphenethmoid Region*

The cartilages of the sphenethmoid region are not completely replaced by bone anteriorly. The increased thickness of the spheneth-

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**Fig. 1. Transverse section through the anterior level of the olfactory capsule.**

**Fig. 2. Transverse section through the region of fusion of the crista intermedia and solum nasi.**

**Fig. 3. Transverse section through the olfactory capsule at the posterior level of the crista intermedia.**

**Fig. 4. A reconstruction of the nasal cartilages at the posterior level of the crista intermedia.**

**Fig. 5. Transverse section through the nasal capsule anterior to the prevomer.**

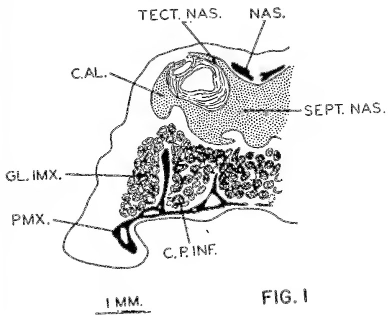


FIG. 1

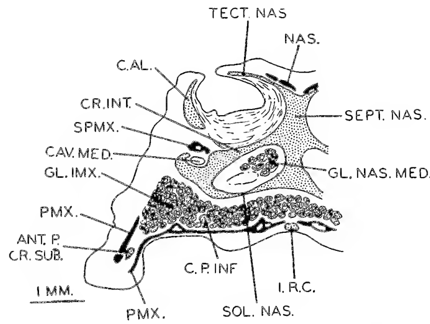


FIG. 2

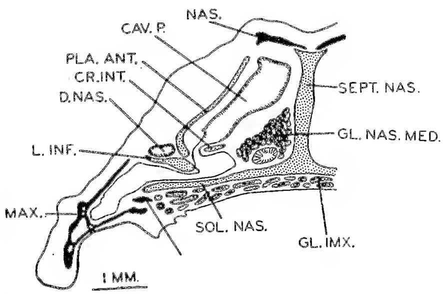


FIG. 3

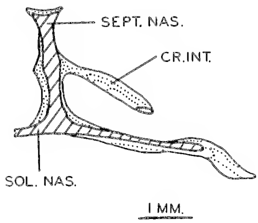


FIG. 4

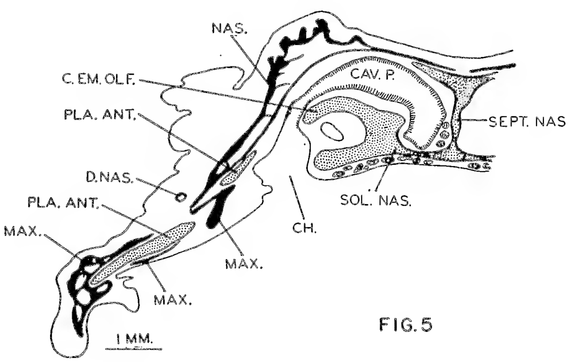


FIG. 5

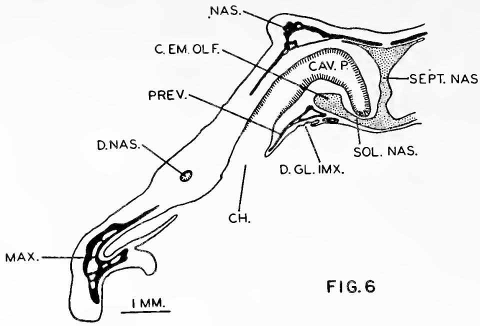


FIG. 6

**Fig. 6. Transverse section through the nasal capsule at the level of the efferent duct of the glandula intermaxillaris.**

moid in sections showing the separated nasal bones has been mentioned previously. At the level of complete ossification, the sphenethmoid is low and broad and encloses vast marrow cavities (Fig. 9).

A small unidentified cartilage appears on each side of the sphenethmoid posterior to the orbitonasal foramen. Each cartilage is replaced posteriorly by bone which is then incorporated with the sphenethmoid.

*Orbital, Otic, and Occipital Regions*

When the foramen trochleare appears (Fig. 10), the taenia tecti marginalis is well-developed and curves medially at the top to form the limits of the fenestra frontale. The frontoparietal bone extends obliquely upward and laterally to form the large interorbital crest. The same bone encloses large marrow cavities, but does not send a definite wall of bone down over the lateral portion of the taenia. Thus, the lamina perpendicularis is absent. The parasphenoid at this level is a mere sliver of bone, almost horizontal in position.

That region of the neurocranium represented by the taenia marginalis becomes perichondrally and endochondrally ossified progressively to the rear until, at the level of the optic foramen, most of that cartilage is replaced by bone. The boundary of bone at the top of the optic foramen (represented by the prootic in *woodhousei*) is synosteotically united to the frontoparietal (Figs. 11, 13). The taenia tecti

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**Fig. 7. Transverse section of the olfactory capsule at the posterior level of the choana.**

**Fig. 8. Transverse section through the olfactory capsule immediately posterior to the choana.**

**Fig. 9. Transverse section through the sphenethmoid.**

**Fig. 10. Transverse section through the neurocranium at the level of the trochlear foramen.**

**Fig. 11. Transverse section through the region of the optic foramen.**

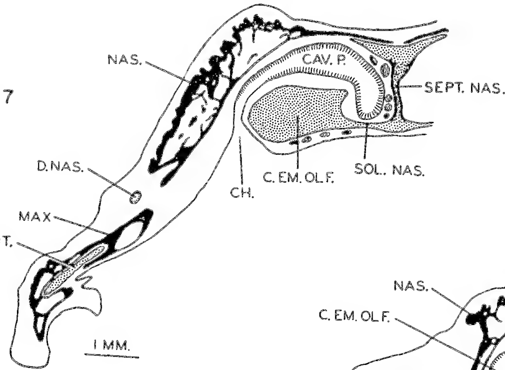


FIG. 7

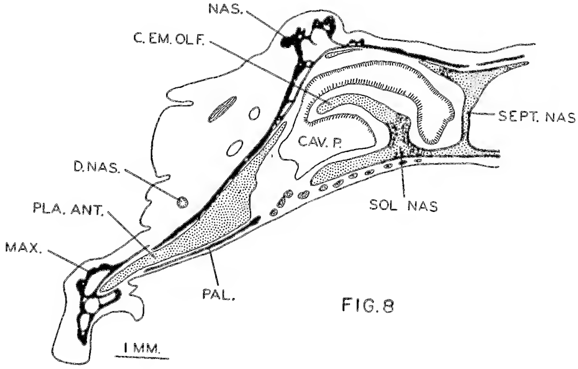


FIG. 8

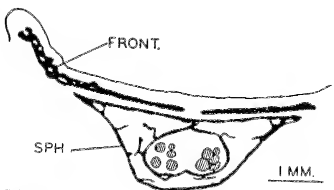


FIG. 9

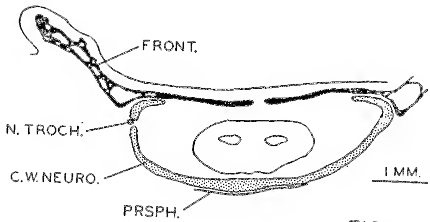


FIG. 10

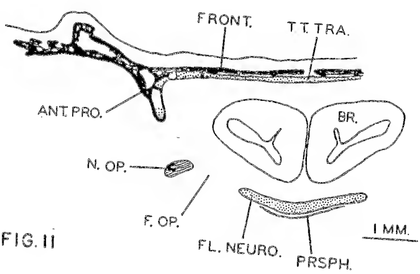


FIG. 11

transversalis is complete at the level of the optic foramen; it does not have a median anterior process.

The oculomotor foramen is bounded by bone on all sides, but at this level the relationship of the elements enclosing the cavum cranii is quite different from that given for *woodhousei* The taenia tecti medialis is not completely isolated. A dorsal cartilage represents the taenia tecti transversalis, the lateral ossified limits of which is in synosteosis with the prootic and frontoparietal bones as explained

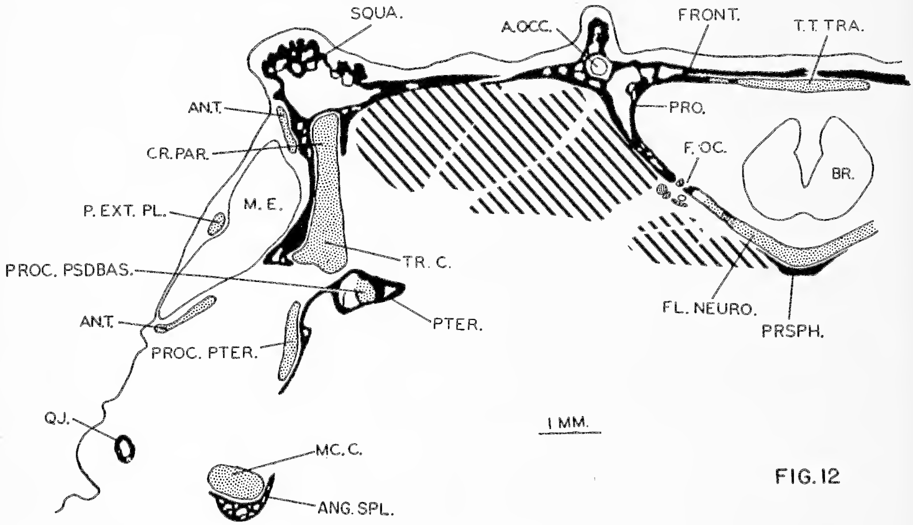


**Fig. 12. Transverse section through the region of the foramen oculomotorium.**

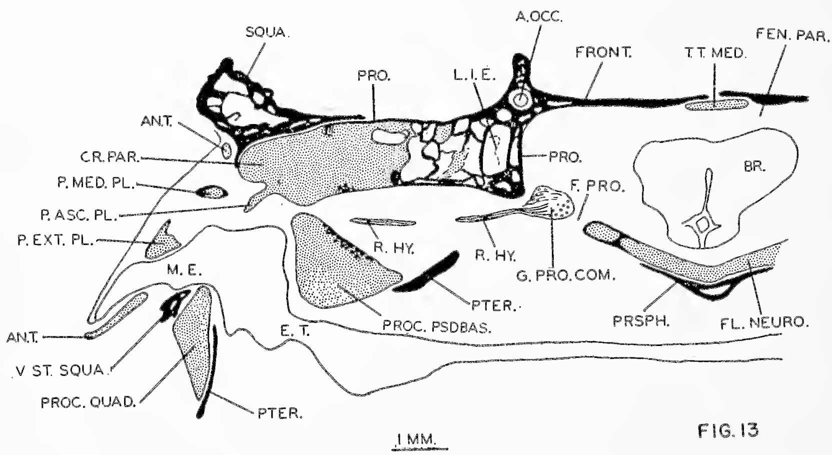


**Fig. 13. Transverse section through the region of fusion of the pars ascendens plectri with the crista parotica.**

above. The latter fusion forms a complex of bone and cartilage composed of the prootic, frontoparietal, and the taenia tecti transversalis, which forms a dorsal arcade over the cavum cranii (Fig. 12). The arcade is entire in front of the oculomotor foramen where the upper bony walls are fused to the ossified portions of the cartilaginous floor. The same completeness obtains to the rear of the oculomotor foramen, except for the absence of the taenia tecti transversalis. At this level the taenia tecti medialis represents the only dorsal cartilage.

The processus pseudobasalis is in synchondrosis with the otic capsule.

The trunk of the glossopharyngeal proceeds anteriorly to a level above the operculum, where it turns laterally to connect with ganglion "X" (Baldauf, 1955, p, 297). Before turning toward the ganglion the trunk gives off the small ramus communicans. The relationships of the glossopharyngeal nerve, its branches, and ganglion "X" are like those of *woodhousei*, except that the ganglion is an elongate structure extending from the dorso-lateral edge of the operculum to a position laterad of the same structure. The ramus hyomandibularis does not appear above the operculum.

The pars ascendens plectri leaves the pars externa plectri and proceeds mediad and dorsad to effect synchondrosis with the crista parotica (Fig. 13). Thus, the pars ascendens plectri is placed at about a 45-degree angle. Figure 13 also show the synosteotic union of the prootic and frontoparietal bones. The crista parotica is not excavated ventrally for muscle attachments (Fig. 14).

Fusion of the cornu principalis of the hyale to the ventro-lateral edge of the otic capsule occurs in front of the pars interna plectri. Replacement of the cartilaginous otic capsule by bone is not very extensive at this or any other level farther to the rear.

Three acustic foramina are present. The foramen acusticum anterior is extremely large and is in front of the operculum and foramen endolymphaticum. The latter is large and is present in sections from the level of the foramen acusticum medium to the foramen acusticum posterior (Fig. 15). The latter foramen is very large, however, and extends back for a considerable distance. These figures also show that the cartilago prootico-occipitalis is well-represented in the sectioned material; the otic capsule is in general not extensively replaced by bone.

The M. depressor mandibulae has its origin on the crista parotica posteriorly (Fig. 15), but the anterior portion of the head of that muscle is wedged between the crista and the overhanging squamosal bone. A close association of the M. depressor mandibulae and the squamosal is possible in *valliceps*, therefore, because the squamosal is present at this level. That bone is not present at the level of the muscle origin in *woodhousei*. The origin of the M. depressor mandibulae in *valliceps* therefore conforms to the condition described by Sedra (1950, p. 440) for *B. regularis* of Africa. The possible variations of the origin of this muscle in the bufonids must be carefully analyzed to avoid such

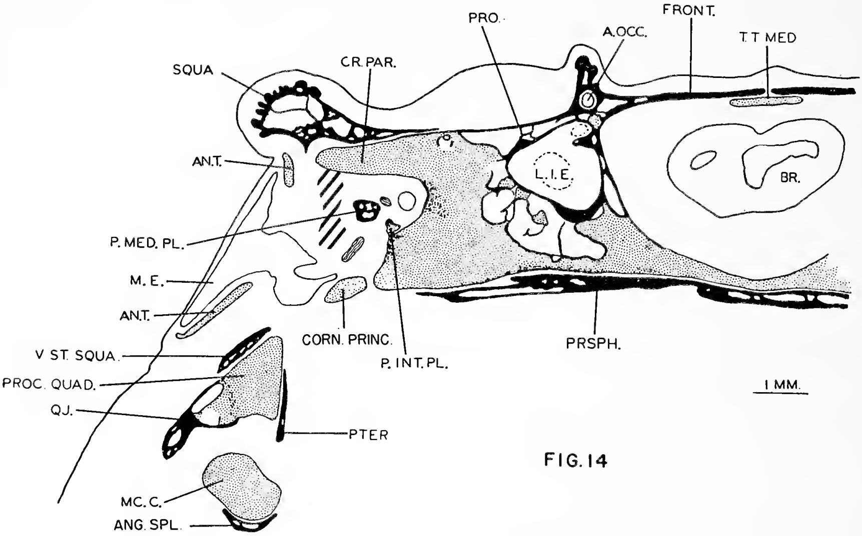


FIG. 14

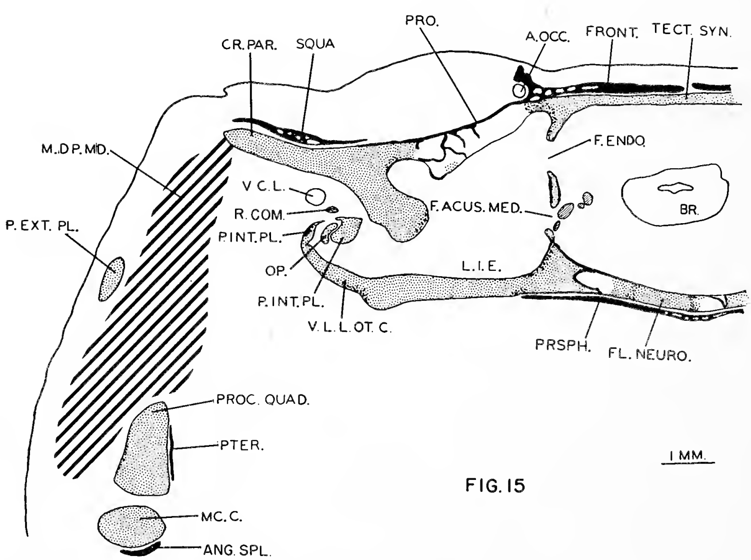


FIG. 15

**Fig. 14. Transverse section through the anterior level of the otic capsule.**

**Fig. 15. Transverse section through the region of origin of the depressor mandibulae muscle.**

conflicting ideas as those of Sedra (1950), who states that in *B. regularis* the origin of the muscle is on the crista parotica as well as from the definitive squamosal, and Griffiths (1954), who states that the Bufonidae studied by him (including *B. regularis!*) have a definite compound squamosal which is accompanied by a specialization of the origin of the muscle—the origin being only on the posterior border of the squamosal.

Figure 15 shows that the otoparietal region of the frontoparietal cannot be distinguished from the prootic, due to synosteosis of the two. The synotic tectum appears at the same level and, since it remains cartilaginous for a long distance, is separated from the frontoparietal bone by connective tissue. The tectum marks a level of the otic capsule that is not extensively ossified. The otic capsule regains its cartilaginous condition toward the rear and is gradually freed from the frontoparietal until, finally, the rear edge of the bone is entirely isolated from the otic capsule. The synotic tectum is perichondrally and enchondrally ossified.

The exoccipital bone is synosteotically united to ossified portions of the otic capsule and exhibits no cartilage remnants. The occipital condyles are completely ossified.

### *Dermal Bones of the Orbital, Otic, and Occipital Regions*

In *valliceps* the frontoparietal bone exhibits the same relationships to adjacent structures as described for *woodhousei*, except for the following points. As explained above, the frontoparietal is in synosteosis with the ossified portion of the taenia tecti marginalis and the prootic bone. Thus, a complex unit is formed by the frontoparietal uniting to the above mentioned taenia, the latter serving as a connecting link between the frontoparietal plus taenia tecti transversalis and the prootic, which in turn serves as a link between the frontoparietal and exoccipital bones. The absence of a lamina perpendicularis has been mentioned previously. The frontoparietal is very wide and exhibits extensive bone marrow cavities at all levels.

The occipital groove is roofed by bone, except posteriorly, to produce a long passage, the occipital canal, located directly beneath the parietal crest. If, as in *woodhousei*, the occipital groove separates the otoparietal plate of the frontoparietal from the medial part of that bone, then it is the otoparietal plate which fuses to the prootic in the region of the occipital canal in *valliceps*.

In general the dermal bones of *valliceps* are massive and have large extensive marrow cavities. The portion of the parasphenoid lying directly beneath the sphenethmoid is paper-thin, a condition that persists until it reaches the prootic bone.

*Septomaxillary Bone*

The septomaxilla of *valliceps* shows the same general relationships and shape as described for *woodhousei*. The dorsal process does not project anteriorly and, therefore, does not appear as a free piece in the plica obliqua. Thus, the bone appears first as a single piece between the crista intermedia and the alary cartilage (Fig. 2) and then as two pieces, one a cap over the distal tip of the crista intermedia and the other a thick lateral limb between the lamina inferior and the cartilago oblique (Fig. 16). Farther to the rear the wide base of the dorsal

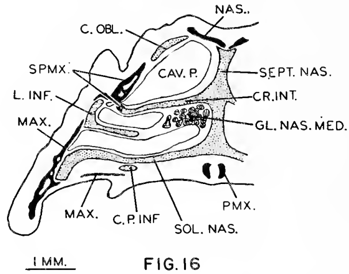

FIG. 16

Fig. 16. Transverse section through the olfactory capsule in the region of the septomaxilla.

process is oriented as an irregular horizontal plate which serves first as a floor for the glandula nasalis lateralis and later also as a support for the ventral edge of the planum terminale. The same horizontal plate becomes thicker toward the rear and, after the medial limb of the bone disappears from sections, fills the space between the planum and the lamina inferior. The wall thus formed separates the medially flexed infundibulum from the ductus nasolacrimalis. The thick piece separates into two small posterior projections before the bone disappears from sections.

The septomaxilla of *valliceps* is especially thick and contains extensive marrow cavities. That part of the bone which serves to cap the lamina superior is not separated from the latter by connective tissue (Fig. 16).

*Articular Region*

The jaw articulation occurs at the posterior level of the operculum. Meckel's cartilage ends in the region of the perilymphatic foramen.

*Lower Jaw*

The components of the lower jaw differ but slightly from those described for *woodhousei*. The anterior tip of the angulosplenial is not surrounded by dorsal and ventral extensions of Meckel's cartilage. The angulosplenial is thick and contains large marrow cavities.

### SUMMARY OF *Bufo valliceps*

1. The septum nasi is weakly ossified perichondrally at the niveau of the eminentia olfactoria. Somewhat greater invasion of the cartilage by bone takes place farther to the rear.
2. A tectum nasi is absent between the first appearance of the cartilago obliqua and the sphenethmoid.
3. The posterior limits of the crista intermedia end freely without attaching to the solum nasi.
4. The cavum inferius extends farther to the front than the cavum medium.
5. The intermaxillary glands open into the buccal cavity via a shallow channel located on each side of the palate directly beneath the prevomer bone. Prechoanal sacs and grooves are absent.
6. A pars nasalis of the maxilla is absent, therefore making it impossible for the same structure with the aid of the pars facialis to form a V-shaped notch to hold the planum antorbitale. The planum rests only on the pars palatina of the maxilla.
7. All of the dermal bones are thick and enclose extensive marrow cavities.
8. The sphenethmoid is low and broad and encloses large marrow cavities.
9. Small pieces of cartilage of undetermined origin lie on each side of the sphenethmoid.
10. The lamina perpendicularis of the frontoparietal is undeveloped.
11. The frontoparietal is synosteotically united to the prootic bone and to the ossified taenia tecti marginalis.
12. An anterior process of the taenia tecti transversalis is absent.
13. Ganglion "X" of the glossopharyngeal nerve is elongate and extends from the dorso-lateral edge to the side of the operculum.
14. The pars ascendens plectri is synchondrotically united to the crista parotica.
15. The ventral surface of the crista parotica is not excavated for muscle attachments.
16. The cartilaginous otic capsule is not extensively replaced by bone.
17. The M. depressor mandibulae has its origin on the crista parotica and the squamosal bone.

18. The synosteosis of the prootic and frontoparietal bone makes obscure the otoparietal region of the latter.
19. The anterior half of the median process of the parasphenoid is extremely thin.
20. The dorsal process of the septomaxilla is not curved forward and therefore never appears as an isolated bone in the plica obliqua.
21. A posterior limb of the septomaxilla forms a wall between the planum terminale and the lamina inferior and thus separates the medially-flexed infundibulum from the ductus nasolacrimalis.
22. A portion of the septomaxilla is not separated from the lamina superior by connective tissue.
23. The articular region of the jaws occurs at the level of the operculum.
24. Meckel's cartilage ends in the region of the perilymphatic foramen.
25. The angulosplenial does not fit into a cartilaginous pocket anteriorly.

EXPLANATION OF ABBREVIATIONS WITH NUMBER OF FIGURE IN WHICH EACH FIRST APPEARS

| | |
|---|---|
| A. OCC. | arteria occipitalis (12) |
| AN. T. | annulus tympanicus (12) |
| ANG. SPL. | angulosplenial (12) |
| ANT. P. CR. SUB. | anterior process of crista subnasalis (2) |
| ANT. PRO. | anterior part of prootic (11) |
| BR. | brain (11) |
| C. AL. | cartilago alaris (1) |
| C. EM. OLF. | cartilaginous support of eminentia olfactoria (5) |
| C. OBL. | cartilago obliqua (16) |
| C. P. INF. | cartilago prenasalis inferior (1) |
| C. W. NEURO. | cartilaginous wall of neurocranium (10) |
| CAV. MED. | cavum medium (2) |
| CAV. P. | cavum principale (3) |
| CH. | choana (5) |
| CORN. PRINC. | cornu principalis (of hyale) (14) |
| CR. INT. | crista intermedia (2) |
| CR. PAR. | crista parotica (12) |
| D. GL. IMX. | duct of intermaxillary glands (6) |
| D. NAS. | ductus nasolacrimalis (3) |
| E. T. | Eustachian tube (13) |
| F. ACUS. MED. | foramen acusticum medium (15) |
| F. ENDO. | foramen endolymphaticum (15) |
| F. OC. | foramen oculomotorium (12) |
| F. OP. | foramen opticum (11) |
| F. PRO. | foramen prooticum (13) |
| FEN. PAR. | fenestra parietalis (13) |
| FL. NEURO. | floor of neurocranium (11) |

| | |
|---|---|
| FRONT. | frontoparietal (9) |
| G. PRO. COM. | ganglion prooticum commune (13) |
| GL. IMX. | glandula intermaxillaris (1) |
| GL. NAS. MED. | glandula nasalis medialis (2) |
| I. R. C. | isolated rods of cartilage (2) |
| L. I. E. | labyrinth of inner ear (13) |
| L. INF. | lamina inferior (3) |
| M. DP. MD. | musculus depressor mandibulae (15) |
| M. E. | middle ear (12) |
| MAX. | maxilla (3) |
| MC. C. | Meckel's cartilage (12) |
| N. OP. | nervus opticus (11) |
| N. TROCH. | nervus trochleare (10) |
| NAS. | nasal (1) |
| OP. | operculum (15) |
| P. ASC. PL. | pars ascendens plectri (13) |
| P. EXT. PL. | pars externa plectri (12) |
| P. INT. PL. | pars interna plectri (14) |
| P. MED. PL. | pars media plectri (13) |
| PAL. | palatine (8) |
| PLA. ANT. | planum antorbitale (3) |
| PMX. | premaxilla (1) |
| PREV. | prevomer (3) |
| PRO. | prootic (12) |
| PROC. PSDBAS. | processus pseudobasalis (12) |
| PROC. PTER. | processus pterygoideus (12) |
| PROC. QUAD. | processus quadratus (13) |
| PRSPH. | parasphenoid (10) |
| PTER. | pterygoid (12) |
| QJ. | quadratojugal (12) |
| R. COM. | ramus communicans of IX (15) |
| R. HY. | ramus hyomandibularis of VII (13) |
| SEPT. NAS. | septum nasi (1) |
| SOL. NAS. | solum nasi (2) |
| SPH. | sphenethmoid (9) |
| SPMX. | septomaxilla (2) |
| SQUA. | squamosal (12) |
| T. T. MED. | taenia tecti medialis (13) |
| T. T. TRA. | taenia tecti transversalis (11) |
| TECT. NAS. | tectum nasi (1) |
| TECT. SYN. | tectum synoticum (15) |
| V. C. L. | vena capitis lateralis (15) |
| V. L. L. OT. C. | ventro-lateral ledge of otic capsule (15) |
| V. ST. SQUA. | ventral stylus of squamosal (13) |

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# A Comparative Histological Study of Fossil and Recent Bone Tissues. Part III

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## INTRODUCTION

The present study concludes a three part series. Parts I and II, previously published in the Texas Journal of Science[2], included the introduction, literature survey, methods, bibliography, a classification of bone tissue types, and descriptions of fish, amphibian, reptilian, and bird bone tissues. The bone tissue descriptions of mammals, a general discussion of the skeletal tissues of all major vertebrate groups, and the summary are presented in Part III.

Unless otherwise indicated, the photomicrographs in Plates XXVIII–XXXX are of transverse bone sections, and total magnification of each figure is approximately 100 diameters. Fossil forms are indicated by an asterisk (*).

## CLASS MAMMALIA

*Order Monotremata.* The long bones of the spiny anteater, *Echidna*, are made of primary vascular tissue. The canals are primarily longitudinal, but a number of radial vessels are present within the endosteal lamellae. The inter-vascular matrix is composed of circumferential lamellae containing many cell spaces. Outer periosteal lamellae are poorly developed, but an endosteal lamellar layer is evident. The endosteal lamellae extend into the marrow cavity as concellous trabeculae wherever spongy tissues occur. A single circle of osteocytes surrounds each canal. Sharpey's fibers are abundant. The rib (Plate XXVIII, Fig. 1.) appears much like limb bones except that the compacta is quite narrow in rib tissue.

The rib and femur of *Ornithorhyncus* (Plate XXVIII, Fig. 3) have a well-developed layer of endosteal lamellae, but the periosteal lamellae are irregular in extent and distribution. From the non-cancellous,

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central marrow cavity in the shaft of these bones, a series of radial canals pass through the endosteal layers and join with the longitudinal, primary osteones of the middle and outer compacta. Haversian development is not present, but endosteal resorption of the middle compacta by the inner lamellae is evident. Many of the longitudinal primary osteones present an unusual appearance. The lumina of these canals are rather small, and, surrounding each canal, a broad corona-like ring is present. The unusually long canaliculi from the single circle of osteocytes at the periphery of this ring can be seen extending into the canal. This acellular, perivascular tissue appears non-lamellar, and it has apparently been formed by deposition on the inner wall of the canal. Areas of unorganized, non-lamellar, osteoid tissue can be seen between regions of well-developed, lamellar bone.

*Order Multituberculata.* The mandible of a single specimen of the paleocene multituberculate *Ptilodus* (Plate XXVIII, Fig. 2) shows a wide compacta composed of periosteal and endosteal lamellar layers enclosing a middle region of indistinct, unorganized lamellae. The lacunae of the inner and outer layers are arranged in the usual manner, but cell spaces in the middle layer have little, if any, consistent orientation. Haversian tissue is not found, but numerous primary canals are present and are arranged into a radial pattern from the inner and outer surfaces. Other areas of the bone possess only a few longitudinal primary osteones.

*Order Marsupialia.* The long bones of the opossum, *Didelphis* (Plate XXVIII, Figs. 4–7) do not differ greatly in tissue structure from the bones of monotremes. The tissue, however, contains a greater concentration of vascular canals and possesses limited Haver-

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**PLATE XXVIII**

**Fig. 1. *Echidna*. Rib. Scattered primary canals extend through the thin compacta.**

**Fig. 2. *Ptilodus*.* Mandible. Paleocene. Radial and longitudinal primary vascular canals are present in the indistinctly lamellated compacta.**

**Fig. 3. *Ornithorhynchus*. Rib. Several primary, radial canals extend into the compacta from the endosteal margin.**

**Fig. 4. *Didelphis*. Nasal bone. Primary, longitudinal canals penetrate most of the compacta. The outer compacta is composed of non-vascular lamellae.**

**Fig. 5. *Didelphis*. Humerus. Longitudinal and radial canals are present in the outer compacta.**

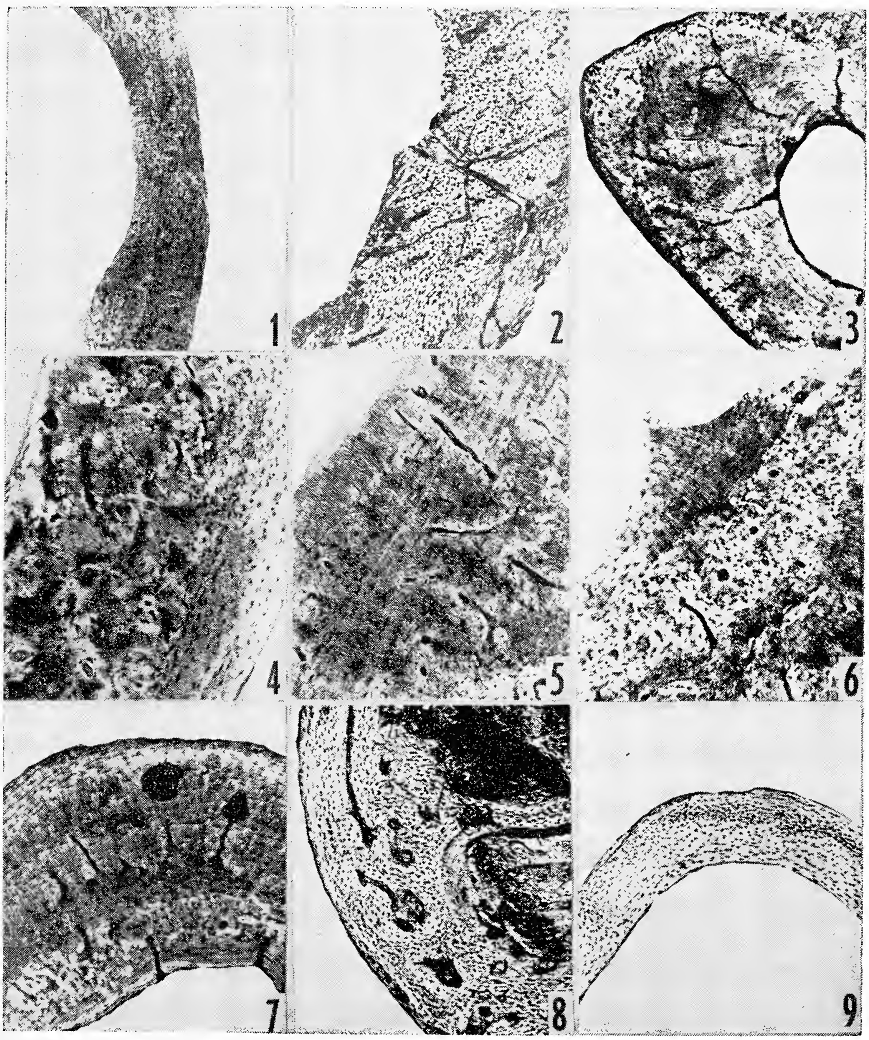
**Fig. 6. *Didelphis*. Humerus. Restricted areas containing poorly differentiated secondary tissue are found within the inner compacta.**

**Fig. 7. *Didelphis*. Rib. The compacta contains longitudinal and radial primary canals.**

**Fig. 8. *Sorex brevicaudis*. Mandible. Large marrow sinuses in the compacta have become filled in with concentric lamellae. Secondary reconstruction is not evident.**

**Fig. 9. *Talpa europea*. Tibia. The compacta is entirely non-vascular.**

sian development. The endosteal lamellar layer is thick and well-formed. A specific periosteal lamellar border is not present, but in areas where outer vascularization does not occur, distinct non-vascular lamellae are evident. In other regions, vascular canals extend to the outer margin of the bone, and a periosteal layer is necessarily omitted. Where outer circumferential lamellation is present, a number of radial Volkmann's canals extend through this layer and join the canal system located in the inner compact regions. The canals of the compacta are mostly primary in structure and extend in a predominantly longitudinal direction. They are deposited in well-defined layers and are arranged in radial rows. The osteocytes located near



osteones are arranged in a circle surrounding each canal. Secondary reconstruction of existing tissues is seen in relation with a number of vascular canals. Resorption of bone surrounding a canal is followed by the deposition of secondary, concentric lamellae. The resulting structure contains only one or two rows of osteocytes, and in comparison with the secondary osteones of many other vertebrates, the Haversian system appears poorly developed. Such secondary osteones may be found in any skeletal element but are not usually as common as the primary osteones. The endosteal lamellar layer extends out into the inner marrow cavity as cancellous trabeculae. The spongy sinuses located on the inner margin of the compacta are active in the resorption of endosteal tissues during bone growth. The secondary deposition of a few concentric lamellae within these eroded channels forms poorly-developed and infrequent endosteal Haversian systems. Long, penetrating fibers of Sharpey are seen in some areas of the various bone tissues.

The zygomatic bone is composed of an outer, non-vascular, lamellated layer covering extensive cancellous tissue. The nasal bone of the skull conforms to the pattern found in long bones. The compacta of the rib is essentially simple lamellar, but a few primary, radial, and longitudinal canals are present. The tissue structure of the mandible is almost identical with the mandible of the extinct multituberculate *Ptilodus* and the Paleocene primate *Plesiolestes*. The compacta is penetrated by many primary, radial canals, but Haversian tissues do not occur. The endosteal and periosteal lamellae, where present, are well-developed. Lamellation in other regions of the compacta is obscure, and cellular arrangement in such areas is unorganized.

*Order Insectivora*. The humerus and radius of the common mole, *Talpa* (Plate XXIX, Fig. 1), follows a simple, primary vascular tissue pattern. The canals are oblique, radial, circumferential, or longitudinal in course, but an enclosed vascular reticulum is not formed. Endosteal and periosteal lamellation, in the materials examined, were not present. On the outer surface, however, an accumulation of disorganized osteoid tissue is present. Whether this substance would become organized into a mature lamellar tissue as the bone grows in diameter, or would be retained in the growing compacta as osteoid tissue, has not been determined. The arrangement of lamellation in this bone follows a unique pattern. Lamellae usually conform in direction to the nearest vascular canals. If such canals extend in a circular or longitudinal course around the bone, then the lamellae assume the typical circumferential position. If, on the other hand, the canals are oblique, then the lamellae are likewise oblique to the principal bone axis. If the canals penetrate the compacta in a radial direction, their lamellae are actually perpendicular to the surface of the bone. The inner lamellar tissue of the compacta extends into the central marrow cavity as long trabeculae.

The tibia of *Talpa* (Plate XXVIII, Fig. 9) is of an entirely different and reduced structure. The compacta is quite thin, and cancellous bone is absent in the diaphyses. The tissue of the compacta is almost entirely non-vascular and simple lamellar, but a few narrow, short, primary canals enter the endosteal surface in a radial direction. This tissue pattern closely resembles the bone of many lizards, small birds, and modern amphibians.

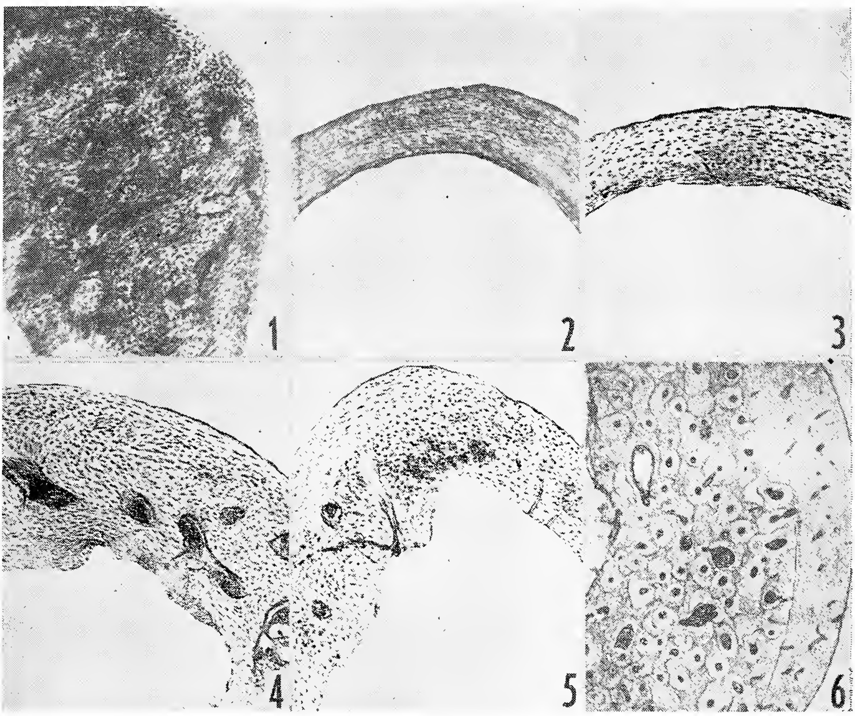



PLATE XXIX

Fig. 1. *Talpa europea. Humerus.* The compacta contains an irregular network of primary canals.

Fig. 2. Bat. Radius. Non-vascular bone tissue.

Fig. 3. Bat. Humerus. Non-vascular bone tissue.

Fig. 4. *Pteropus.* Mandible. Cancellous sinuses are present in the compacta.

Fig. 5. *Antibeus jamaicensis.* Mandible. Several primary canals penetrate the endosteal surface.

Fig. 6. *Pithecus nemestrinus* (from Amprino). Tibia. Extensive secondary reconstruction is found in all canals except those near the periosteal border.

The mandible of the tiny shrew, *Sorex* (Plate XXVII, Fig. 8), is cancellous. A thin, non-vascular, periosteal layer of lamellae encloses a number of marrow spaces which, near the periosteal margin, are relatively small. The sinuses located within the inner cancellous regions are somewhat larger. The outer marrow spaces are comparatively small because their enclosing surfaces have received supplementary lamellar deposition. The resulting lumen is no larger than a typical vascular canal. The structure, as a whole, closely resembles a true secondary osteone, but, in the absence of resorption, more correctly represents a protohaversian system.

*Order Chiroptera.* Long bones of the bat (Plate XXIX, Figs. 2, 3) are entirely simple lamellar in tissue structure. The thin compacta is composed of circumferential lamellae that encircle a large, non-cancellous marrow cavity. The numerous osteocytes conform in orientation to the concentric lamellation. Vascular canals of any description are completely lacking.

The tissue structure in the mandibles of the megachiropteran, *Pteropus* (Plate XXIX, Fig. 4), and the microchiropteran, *Antibeus* (Plate XXIX, Fig. 5), are quite similar to the mandibular tissue found in the shrew. The outer and inner compact regions of the bones are made of non-vascular, circumferential lamellae. The inner bone areas are occupied by a series of small marrow sinuses. These spaces, unlike those found in the shrew, are not filled in with lamellae to form protohaversian systems. Perhaps with further development, supplementary deposition would have eventually taken place.

*Order Primates.* The mandible of an early, extinct primate, the Paleocene *Plesiolestes* (Plate XXX, Fig. 1) differs from the Haversian pattern typical among modern primates. This jaw is composed of primary vascular tissue similar to multituberculate or marsupial bone. The compacta is simply composed of a single, wide, lamellar layer containing oblique or longitudinal primary canals.

The rare long bones of ancient primates have not been available for examination, but it is hoped that, in future studies, sufficient material from this and other primitive mammalian groups can be accumulated.

In the bones of modern primates, the fundamental pattern of tissue, prior to reconstruction, is a longitudinal, primary vascular structure. Primate bone tissue (Plate XXIX, Fig. 6) is distinctively lamellated, and the lamellae are deposited in a circumferential plane about the central marrow cavity. Some areas of this compata do not contain any vascularization. Other regions possess a comparatively few, scattered canals. Much of the compacta, however, is densely vascularized. The relative concentration of original, primary vascular canals will determine the eventual architecture and pattern of that particular bone region.

Primary bone is deposited as a series of lamellae which embody a number of small primary vascular canals. The canal system is included within this new tissue as an integral tissue component, but the dominant structural influence of vascular activity has not yet begun. The osteocytes of newly formed bone conform at first with the plane of lamellation and only later become oriented with respect to vascular pattern. In many bone areas, this primary pattern is found in outer or periosteal bone regions that recently received deposition. Such primary bone does not necessarily experience immediate reconstruction, for it may be retained for a considerable time in periosteal tissues. In the usual interpretation of Haversian formation, the matrix surrounding each primary osteone is completely resorbed with the resulting formation of an eroded tunnel of considerable diameter. This cylindrical space is then filled in with concentric lamellae, and a secondary osteone is formed. Such a Haversian system may receive continual alteration through subsequent enlargement, removal, or replacement. In very dense Haversian tissues, secondary osteones of second, third, and even fourth generations are superimposed upon each other in older tissue regions.

If the original primary canals were numerous and closely placed, the resulting Haversian tissue will likewise be dense. If, on the other hand, the preliminary canals were widely separated, then Haversian tissues of a scattered, irregular pattern will develop. All primate bones are not necessarily composed exclusively of dense Haversian tissue, for, even in the well-described bones of the human, large areas occur in which one finds massive lamellation containing only a few, scattered, secondary osteones. Extensive primary vascular areas are also observed.

In dense Haversian tissues, distinct periosteal and endosteal layers enclose the middle, secondary region. The remnants of past periosteal levels are often retained as interstitial lamellar tissue.

*Order Carnivora.* The mandible of the Paleocene creodont, *Dissacus* (Plate XXXIV, Fig. 2), is a small bone, but it is quite dense and complex in tissue structure. A wide lamellar periosteum is penetrated by a few radial Volkmann's canals which proceed directly into the vascular tissues of the middle compacta. A sharp line of resorption delineates the outer primary from the inner secondary tissue zones. Beneath the periosteal layer, a large number of secondary osteones have been developed. Unlike the dense Haversian tissues of the primates, however, this bone contains only osteones of the first generation. Such a secondary tissue, while Haversian in pattern, is obviously different in appearance from the dense Haversian tissues possessing several generations of osteones. An endosteal lamellar layer is well-developed, and the resorptive activity of cancellous tissues upon the inner compacta is evident. The zone occurring between the endosteal lamellae and the organized Haversian region is composed of a highly disorganized secondary tissue. The osteones are not arranged into uniform, longitudinal systems, but rather follow an irregular, inconsistent, tortuous course. Such disorganization of the inner compacta is seen in many mammalian groups.

The long bone of the Eocene creodont *Oxyaena* (Plate XXX, Figs. 2, 3, 4) does not differ in basic tissue pattern from most recent carnivores. The periosteal circumferential layer is usually very thick and may constitute as much as a third of the compacta. This outer layer contains only a few radial or longitudinal canals. These primary vascular canals are deposited in well-arranged layers, and even following subsequent secondary activity, this vascular stratification is evident. In the Haversian tissue of the middle compacta, the secondary osteones are entirely separated from each other by interstitial tissue so that densely packed Haversian systems are not formed. Only systems of the first generation are present. In areas where original primary vascularization was relatively deficient, only scattered secondary osteones are found. The inner compacta has been resorbed by the invasion of cancellous tissues.

The long bone epiphyses of *Oxyaena* contain a few secondary osteones, but an unorganized, vascular reticulum within a lamellar

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**PLATE XXX**

Fig. 1. *Plesiolestes.** Mandible. Paleocene. The primary vascular canals have not received secondary reconstruction.

Fig. 2. *Oxyaena ultima.** Long bone (epiphysis). Eocene. The tissue contains a primary reticulum of vascular canals.

Fig. 3. *Oxyaena ultima.** Long bone (diaphysis). Eocene. A number of canals appear to have received secondary reconstruction.

Fig. 4. *Oxyaena ultima.** Long bone (diaphysis). Eocene. Haversian tissues of the first generation are present in the compacta.

Fig. 5. *Didymictis.** Mandible. Paleocene. The compacta appears to have received disorganized secondary reconstruction.

Fig. 6. *Didymictis.** Mandible. Paleocene. Limited secondary tissue surrounds most of the canals.

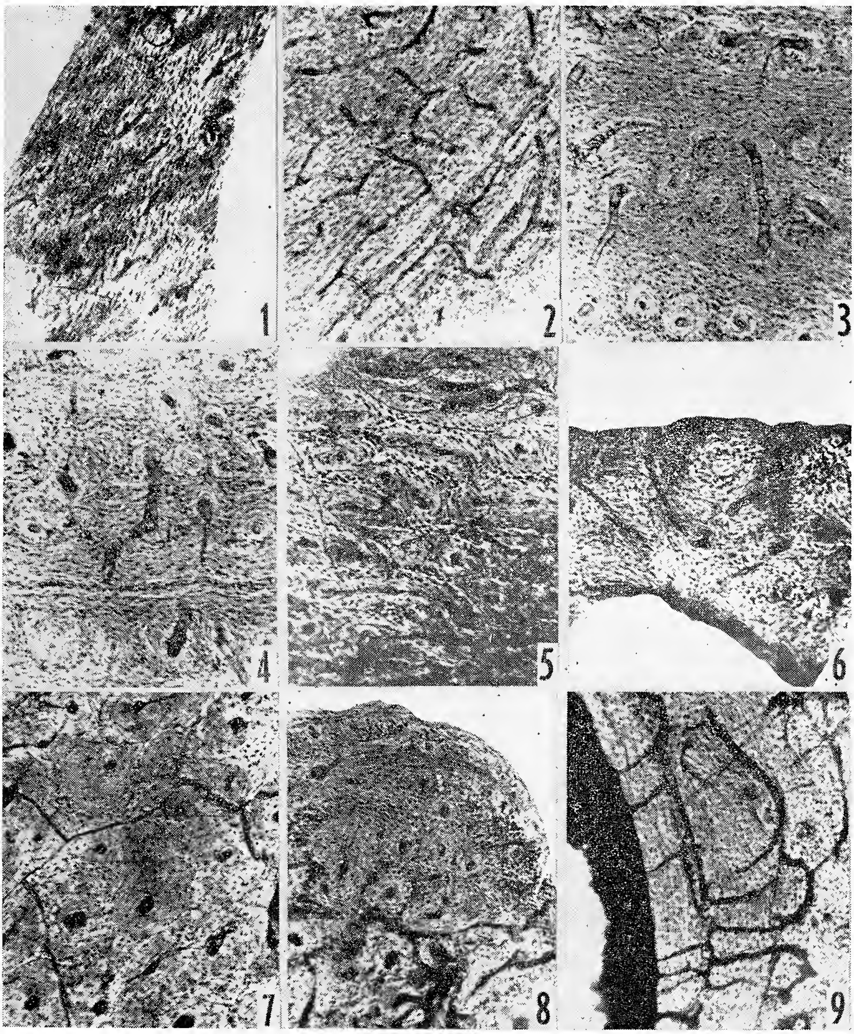
Fig. 7. *Dinictis.** Rib. Oligocene. Dense Haversian tissue.

Fig. 8. *Mustelavus.** Rib. Oligocene. The compacta contains Haversian systems of the first generation.

Fig. 9. *Mustelavus.** Rib. Oligocene. Primary recticular bone tissue.

matrix is predominant. The primary canals may form an irregular reticular meshwork, or they may be singularly radial, oblique, longitudinal, or circumferential.

The diaphysis of a long bone belonging to an unidentified Miocene carnivore (Plate XXXIII, Fig. 1) is composed of irregular Haversian tissue. The predominant structural component of the compacta is its lamellation. Because circumferential lamellae constitute the entire compact region, no distinct endosteal and periosteal lamellae occur. The deposition of successive, outer lamellar layers includes a longitudinal series of primary vascular canals. These canals soon develop



into secondary osteones, but because the canals are somewhat separated, an irregular Haversian tissue has resulted.

In the mandible of the Paleocene creodont *Didymictis* (Plate XXX, Figs. 5, 6), the inner and outer circumferential lamellae enclose a middle dense Haversian region. The secondary osteones are exclusively of the first generation, and each is surrounded by an area of primary interstitial tissue.

The rib tissue of the Oligocene creodont *Dinictis* (Plate XXX, Fig. 7) is dense Haversian in structure, and osteones of the second and third generations are common. Narrow inner and outer lamellar layers are present, but little interstitial substance remains in the middle compacta. Inner cancellous tissue is well-developed.

The rib of the Oligocene creodont *Mustelavus* (Plate XXX, Figs. 8, 9) is composed of heterogeneous tissues that are both primary and secondary in structure. Haversian areas are present, but most of the bone is primary, containing longitudinal, primary canals. Other portions of the rib contain either radial or longitudinal vessels. Endosteal lamellae, in the shaft of the rib, do not form cancellous trabeculae.

The rib of the bear, *Ursus* (Plate XXXII, Fig. 2), is almost entirely dense Haversian in structure. Relatively thin, enclosing lamellae cover well developed and closely-packed secondary osteones of several generations. The vascular canals of the bear's mandible. (Plate XXXIII, Fig. 3) form a complex, irregular reticulum. Considerable Haversian replacement has taken place, but the basic reticular pattern is still evident.

In the mandible and maxilla of the cat, *Felis* (Plate XXXII, Fig. 1), densely-concentrated Haversian tissue of several generations is present. In areas of such secondary tissue, the outer circumferential lamellar layer is narrow. The endosteal layer, regardless of surrounding structure, is usually thick and well-developed. Volkmann's canals are frequently seen. Areas occur that are deficient in vascularization, and here only irregular Haversian tissues, separated by large interstitial lamellar areas, are found. The ribs and long bones (Plate XXXII, Fig. 2) follow the same pattern of inner and outer circumferential lamellation enclosing a middle compact region composed of dense Haversian tissue. In the epiphyses of long bones, Haversian tissues have not entirely replaced the primary, reticular bone in the middle of the compacta.

The compacta of the lion, *Felis* (Plate XXXI, Fig. 9), is similar to that of the domestic cat but is considerably larger and more massive. The outer lamellar layer is relatively thin, and it contains small primary canals that eventually become Haversian in structure. The middle secondary region is very broad, and the secondary osteones are dense and well-developed.

The outer lamellae in the long bone compacta of the skunk, *Mephitis* (Plate XXXI, Figs. 7, 8), contain primary vascular canals. The middle region of the compacta, like that of the cat and most other carnivores, is Haversian in structure and composed of numerous secondary osteones. Haversian tissues are present in the epiphyses, but an irregular reticular or radial pattern of primary bone dominates. The mandible is reticular. Many of the canals of this primary, irregular mandibular reticulum have become secondary.

The mandibles of the raccoon, *Procyon* (Plate XXXIII, Fig. 9), mink, *Mustela* (Plate XXXI, Fig. 5), badger, *Taxidea* (Plate XXXII, Fig. 9), dog, *Canis* (Plate XXXIII, Fig. 6), wolf, *Canis* (Plate XXXIII, Fig. 7), cat, *Felis* (Plate XXXII, Fig. 1), and fox, *Urocyon* (Plate XXXIV, Fig. 1), all possess a basic reticular and radial pattern of vascularization. In the majority of tissue regions, Haversian development has replaced this basic pattern, but clear indications of a former vascular reticulum remain. Some areas retain their primary tissue status.

In the compacta of long bone diaphyses of the dog (Plate XXXIII, Fig. 5) and bear, the deposition of primary tissues on the outer bone surface frequently follows a typical plexiform structure similar to that of most artiodactyls. The regular, organized plexus or network of vessels is primary in structure, but scattered secondary osteones develop within the system. The inner areas of the compacta are usually completely replaced by Haversian tissues. The rib of *Canis* (Plate XXXIII, Fig. 8), on the other hand, is composed of dense Haversian bone derived from original primary canals that followed a longitudinal course. The reticular pattern of the dog's mandible was described in a preceding paragraph.

The femur of the mongoose, *Herpestes* (Plate XXXII, Figs. 7, 8) is composed of a homogeneous, longitudinal, primary vascular bone tissue. Haversian replacement of these canals has not taken place. In one region of the compacta, a small reticulum of vascular canals is present.

The occipital bone of the mink (Plate XXXI, Fig. 1) has a thin compacta penetrated by a few primary radial canals. The lamellae of the inner surface form the extensive cancellous tissues present in the bone. The rib of the mink (Plate XXXI, Fig. 2) contains a few small, irregular, secondary osteones, several primary, longitudinal canals, and a series of endosteal radial vessels. Periosteal and endosteal lamellar layers are thin but easily seen. The femur, humerus, and tibia (Plate XXXI, Figs. 3, 4, 6) of the adult mink have a reticular pattern.

In this vascular reticulum, an irregular network is formed, but the radial components of the system are longer and of larger diameter. The resulting structure resembles the radial pattern seen in many rodents. With successive periosteal deposition, this reticular pattern may be retained, or the newly deposited tissues may possess only longitudinal vessels. These longitudinal, primary canals usually receive Haversian reconstruction. The mandible, as described previously, is composed of a basic reticular bone possessing much secondary tissue.

*Order Amblypoda.* The wide rib compacta of the Eocene *Coryphodon* (Plate XXXV, Fig. 8) is composed predominantly of circumferential lamellae, but a number of isolated, longitudinal canals are scattered throughout most of the compact areas. In the periosteal regions, these canals are primary, but in the middle and inner compacta, they have undergone reconstruction into small secondary osteones. A poorly-developed reticulum of primary canals occupies several areas of the compacta.

*Order Proboscidea.* The greater portion of the long bone compacta of *Elephas* (Foote, 1916) is made of dense Haversian tissue. Inner and outer lamellar layers are present. A pattern of primary plexiform tissue is found in several outer regions of the compact bone.

*Order Sirenia.* The rib of an unidentified Pleistocene manatee has an unusual tissue structure. The entire bone is composed of compact tissue. A central region of cancellous tissue, or a central marrow cavity, is completely lacking. The inner portions of the bone, altogether compact in arrangement, were formed by the development of protohaversian tissue through concentric lamellar deposition on the trabecular surfaces of the original spongy tissue. The outer portions of the bone,

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**PLATE XXXI**

Fig. 1. *Mustela*. *Occipital*. The canals of the compacta have remained primary.

Fig. 2. *Mustela*. Rib. Primary vascular bone tissue.

Fig. 3. *Mustela*. Femur. Primary vascular bone tissue.

Fig. 4. *Mustela*. Humerus. A reticulum of primary canals extends through the compacta.

Fig. 5 *Mustela*. *Mandible*. Several of these canals appear to have received secondary reconstruction.

Fig. 6. *Mustela*. Tibia. 50X. The vascular network, composed of radial and longitudinal vessels, is entirely primary

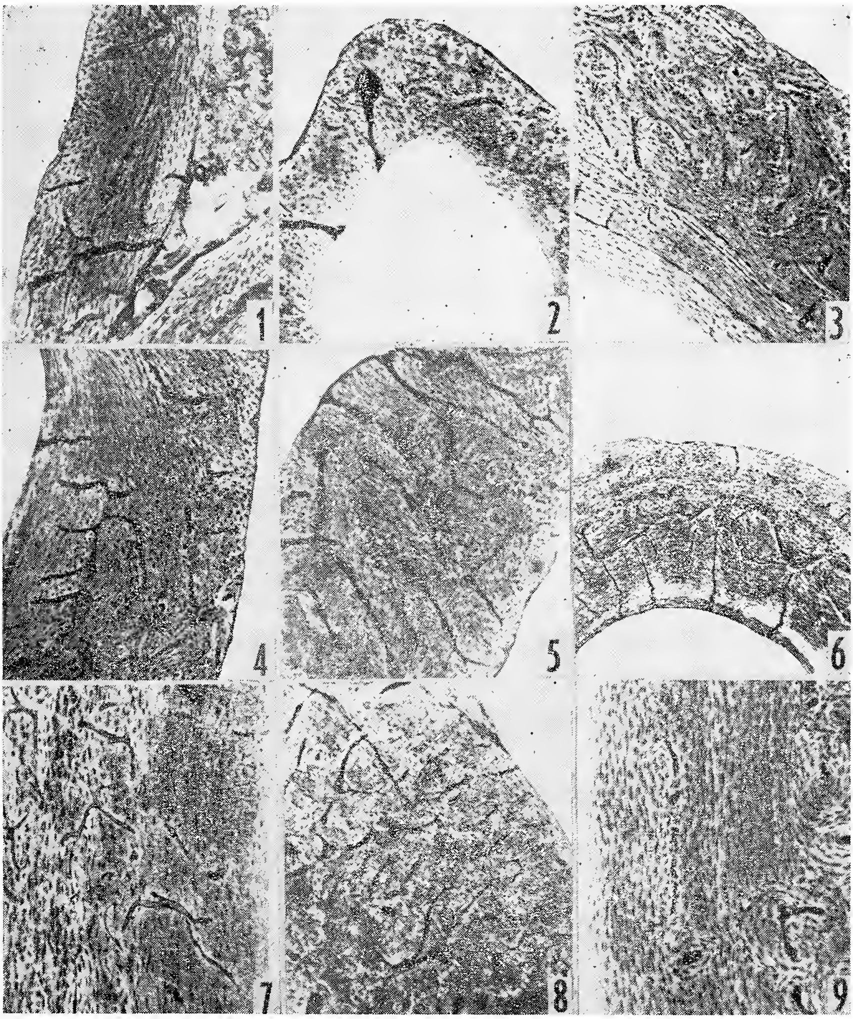
Fig. 7. *Mephitis*. Femur. l.s. Primary vascular bone tissue.

Fig. 8. *Mephitis*. Mandible. Primary vascular bone tissue. A very few scattered secondary osteones may be distinguished.

Fig. 9. *Felis leo*. Femur. Most primary canals of the compacta have become replaced by secondary osteones.

corresponding to the normal location of the compacta, is made of circumferential lamellae enclosing numerous layers of longitudinal canals. The outermost canals had not as yet received Haversian reconstruction, but the majority of osteones deeper within the bone are secondary. These Haversian systems are all of the first generation, and thus appear poorly-differentiated. It is possible that a more mature bone would possess more highly-developed secondary tissue. In a Pliocene manatee (Plate XXXIV, Fig. 3), such dense Haversian bone is well-formed.

*Order Perissodactyla.* The mandibular bone of the Oligocene *Mesohippus* (Plate XXXIV, Fig. 4) follows an intricate, complex, reticular



pattern of vascularization. The canals form an elaborate but irregular network, and most have experienced secondary reconstruction. The diaphyseal structure in the humerus of the Miocene *Parahippus* (Plate XXXIV, Figs. 5–8) is made of a plexiform tissue. The vascular canals form an extensive network, but the pattern is uniform and well-organized. Haversian reconstruction is present in a few of the canals, but primary vessels are predominant. The vessels of the epiphysis, likewise, form a network, but uniform organization is lacking, and the tissue assumes a reticular pattern. Haversian development, especially in endosteal regions, is more extensive than in the diaphysis. The rib of *Parahippus* is dense Haversian in structure, and narrow endosteal lamellar layers enclose the central secondary regions. Primary canals are laid down in well defined layers and soon become converted into secondary osteones. The successive vascular layers are separated by thin layers of circumferential lamellae each representing a former periosteal growth level. Such lamellation is obscured or destroyed in the older tissue regions by Haversian reconstruction. The rib of *Plesippus* (Plate XXXIV, Fig. 9) follows a similar dense Haversian pattern. The mandible of *Merychippus*, like *Mesohippus*, is composed of a basic, unorganized, reticular tissue. Many of the canals received secondary reconstruction.

An unusually fine tissue specimen of the Miocene titanothere *Moropus* (Plate XXXV, Fig. 5) illustrates the growth and development of this bone. In the compacta, a stratified series of well defined layers is present. The outermost layer contains a single row of primary

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**PLATE XXXII**

Fig. 1. *Felis domestica*. Mandible. Several secondary osteones have replaced the original primary canals.

Fig. 2. *Felis domestica*. Rib. The middle compacta contains Haversian tissue. The inner and outer layers of the compacta are composed of non-vascular lamellae.

Fig. 3. *Bassariscus*. Femur. Secondary osteones of the first generation are present in the compacta.

Fig. 4. *Bassariscus*. Mandible. A basic reticular tissue has been largely reconstructed into secondary bone.

Fig. 5. *Bassariscus*. Mandible. Secondary reticular bone tissue.

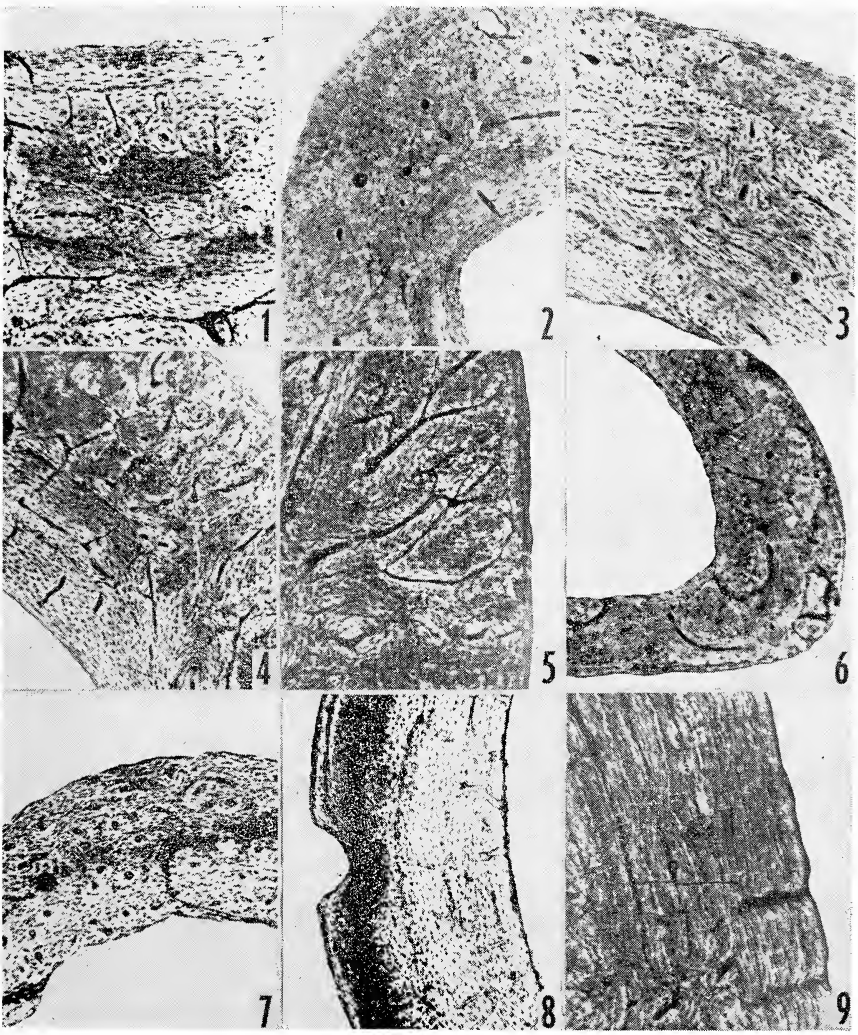
Fig. 6. *Bassariscus*. Rib. Haversian tissue forms the middle compacta.

Fig. 7. *Herpestes*. Femur. Longitudinal primary canals constitute the vascular network of the compacta.

Fig. 8. *Herpestes*. Femur. Primary vascular bone tissue.

Fig. 9. *Taxidea*. Mandible. A number of circumferential canals extend through the middle compacta.

vascular canals that encircle the periphery of the bone parallel to its surface. This vascular row is bordered on each side by a thin plate of lamellae. Beneath this, the next two or three vascular layers follow a similar structure. Then, three or four rows from the bone surface, indications of secondary reconstruction become apparent. These layers of vessels undergoing resorption were once the primary canals next to the outer bone surface, but following successive periosteal deposition, now represent an older growth period. The secondary osteones formed near the surface are small and indistinct, and their borders are ill-defined. Progressing toward the middle of the compacta, the secondary osteones found here, which were originally the primary osteones of a



former periosteal margin, have been re-worked, enlarged, and somewhat consolidated. The original stratified pattern, however, is still evident, and remnants of the circumferential lamellar borders are common. In the endosteal compact regions, Haversian development of this older tissue has proceeded to its climax. The individual osteones have become large, well defined, and tightly-compacted. Haversian systems are superimposed upon one another in several generations, and all vestiges of circumferential lamellation have been destroyed. The invading resorptive activity of the nearby concellous tissue has either removed or greatly enlarged the inner osteones. Deposition of new lamellae on the inner surface, following such tissue resorption and cancellous reconstruction of existing canals, provides a limiting endosteal border.

The rib of the Eocene tapir *Heptodon* (Plate XXXV, Fig. 6) is composed of a thin compacta containing two or three rows of secondary osteones. The periosteal lamellar surface contains scattered, primary canals. In the Eocene *Hyrachyus* (Plate XXXV, Fig. 7), the well-preserved rib tissues conform to the preceding description of *Moropus*. The rib of *Teleoceras* also follows a similar structural plan.

The long bones of the modern horse, *Equus* (Plate XXXV, Figs. 1, 3, 4) vary somewhat in tissue structure according to location. In both the diaphysis and epiphysis, the basic primary vascular pattern is reticular. In epiphyses, the reticular network is irregular and unorganized, and considerable Haversian development has occurred. In diaphyses, the basic primary pattern, while reticular, is more uniform and organized in arrangement and often approaches a plexiform configuration. Stratification of vascular layers in younger tissue areas is

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PLATE XXXIII

Fig. 1. *Carnivore.** Humerus of an unidentifed Miocene specimen. Scattered secondary osteones are present in the thick, lamallated compacta.

Fig. 2. *Ursus.** Rib. Pleistocene. Dense Haversian tissue.

Fig. 3. *Ursus*. Mandible. Dense Haversian tissue.

Fig. 4. *Canis*. Malar. Dense Haversian tissue.

Fig. 5. *Canis*. Humerus. A plexiform pattern of primary canals is present in the compacta.

Fig. 6. *Canis*. Mandible. Secondary reticular bone tissue.

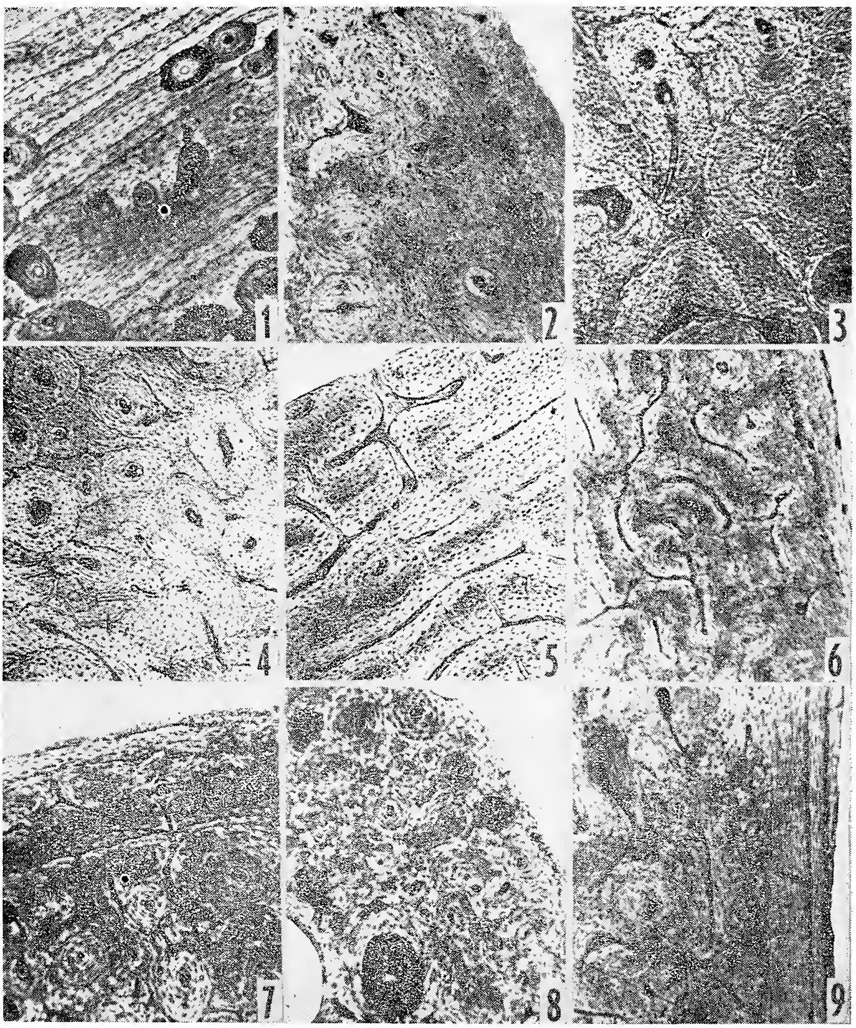
Fig. 7. *Canis*. Mandible. A dense area of Haversian tissue is enclosed by primary periosteal lamellae.

Fig. 8. *Canis*. Rib. Dense Haversian tissue.

Fig. 9. *Procyon*. Mandible. The non-vascular periosteal lamellae surround dense Haversian tissue. The basic reticular pattern is evident.

usually evident. The intensity of Haversian development differs considerably in various areas. In some, the primary reticular pattern is dominant, and only scattered secondary osteones are found. In other areas, often in the same bone, dense Haversian displacement has entirely supplanted the basic primary tissues. In skull bones, as well as in the rib (Plate XXXV, Fig. 2), a very thin layer of periosteal lamellae encloses dense Haversian tissues.

*Order Artiodactyla.* The maxilla, mandible, and rib of the Oligocene *Oreodon* (Plate XXXVI, Fig. 6), *Leptomeryx,* and *Merycoidodon* are composed of a basic primary reticular tissue. Most of the vessels have been exposed to Haversian development, but much of the reticular



pattern is retained even by the secondary tissues. In the mandible of an unidentified Miocene artiodactyl, the basic reticulum is composed largely of secondary vessels.

The long bone tissue of most modern artiodactyls follow a common structural pattern. In the hog (Plate XXXVI, Figs. 1, 2), peccary (Plate XXXVI, Figs. 3, 4), cow (Plate XXXVII, Figs. 5–8), ox, and goat (Plate XXXVI, Figs. 7–9), a well-organized plexiform tissue structure is characteristic. In the formation of this bone, lamination of vascular canals occurs, but the vessels of one layer are connected with adjacent layers by numerous, short, radial canals. A three dimensional network or lattice is thus formed. This plexiform tissue differs from reticular bone in that the vessels are arranged in a uniform, orderly manner. The appearance of the tissue is the same both in transverse and longitudinal sections. Actually, both plexiform and reticular tissues are but variations of the same basic pattern. A number of vertebrates possess reticular bone tissues, and such a descriptive title simply indicates the presence of vascular canals which are unorganized in pattern, and which may extend and branch in almost any direction. The relative irregularity of this vascular reticulum varies considerably among different groups, but the network attains regular uniformity chiefly in the long bones of artiodactyls. Hence, the qualifying title of plexiform serves to distinguish such a tissue from others of lesser organization. The presence of plexiform tissue, however, does not necessarily preclude the presence of reticular patterns in other regions of the same bone.

The outer portions of the compacta are usually composed exclusively

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**PLATE XXXIV**

**Fig. 1.** ***Urocyon.*** **Mandible. Dense Haversian tissue.**

**Fig. 2.** ***Dissacus.**** **Mandible. Paleocene. The outer compacta is composed of a thick layer of lamellae containing a few radial, primary canals. Secondary replacement occurs in endosteal compact areas.**

**Fig. 3. Manatee.* Femur. Pliocene. Dense Haversian tissue.**

**Fig. 4** ***Mesohippus.**** **Mandible. Oligocene. The reticular canals show indications of secondary reconstruction.**

**Fig. 5.** ***Parahippus blackburgi.**** **Humerus (diaphysis). Miocene. Primary plexiform tissue.**

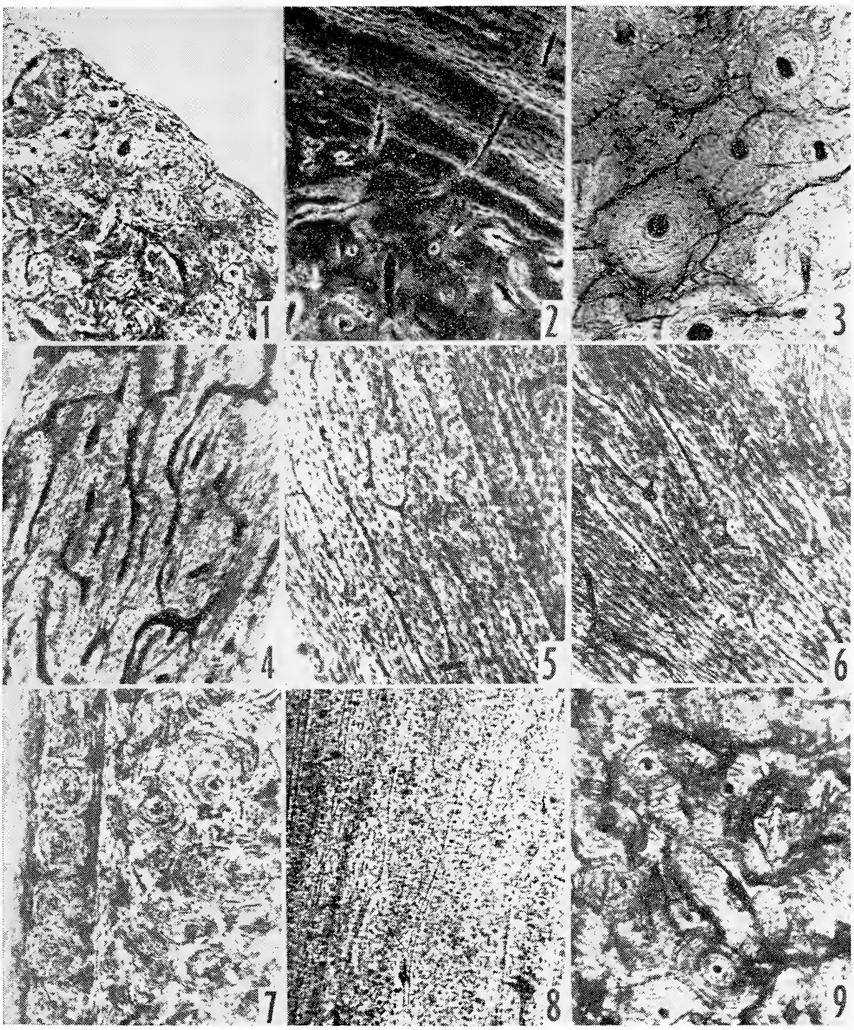
**Fig. 6.** ***Parahippus blackburgi.**** **Humerus (epiphysis). Miocene. Reticular bone tissue.**

**Fig. 7.** ***Parahippus blackburgi.**** **Rib. Miocene. Dense Haversian tissue. The new layer of periosteal bone has already received secondary reconstruction.**

**Fig. 8.** ***Parahippus blackburgi.**** **Phalanx. Miocene. Primary reticular tissue.**

**Fig. 9.** ***Plesippus shoshonensis.**** **Rib. Pliocene. Dense Haversian tissue.**

of such plexiform tissue, and all vessels are primary in structure. In older tissue regions, scattered secondary osteones are developed, but they are usually relatively few in number. The endosteal compact regions, however, are often completely reconstructed into dense Haversian bone. While such a distribution of primary and secondary tissues may be considered typical, complete Haversian displacement can occur in younger tissue areas, and a bone may therefore be composed almost entirely of secondary tissue. In the epiphysis of long bones, vascular arrangement is not usually as uniform in pattern as in diaphyses. Here vascularization is reticular, and extensive Haversian development is present.



The rib tissues of the cow (Plate XXXVII, Fig. 9), the goat, and the peccary (Plate XXXVI, Fig. 5) are composed of dense Haversian bone, but in the domestic hog, of the specimens sectioned (Plate XXXV, Fig. 9), the bone has remained entirely plexiform. A basic plexiform structure in the sheep's rib has been partially replaced by secondary development. The skull bones, including the mandible, are made of irregular reticular tissue, and all stages of development are encountered, including a simple reticulum composed of primary canals, or a reticulum modified by partial or complete Haversian reconstruction.

The bony antler of the deer, *Odocoileus* (Plate XXXVIII, Fig. 1), is composed of a very broad compacta encircling the inner spongy tissue. The vessels follow a complex reticular or plexiform pattern, and some appear to have become secondary.

*Order Cetacea.* The skull bones of the porpoise (Plate XXXIX. Fig. 2) are basically reticular in structure, but secondary development is extensive and remaining primary tissues are uncommon. In the centrum, some primary reticular areas remain near the periosteal border, but the endosteal compacta is largely secondary. The various vertebral processes (Plate XXXIX, Fig. 3) are composed of dense Haversian bone, and little, if any, primary areas remain in mature bone. The humerus of an unidentified whale, found on a Texas beach, is dense Haversian in structure (Plate XXXIX, Fig. 1). The secondary osteones often attain four or five superimposed generations. The primary vessels are transformed into secondary canals immediately following their inclusion in the periosteal compacta so that the entire compacta, in the specimen studied, is secondary.

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PLATE XXXV

Fig. 1. *Equus.* Humerus. Layers of longitudinal secondary canals alternate with rows of secondary, circumferential canals.

Fig. 2. *Equus.* Rib. Dense Haversian tissue.

Fig. 3. *Equus.* Metatarsal. Dense Haversian tissue.

Fig. 4. *Equus.* Humerus. Dense Haversian tissue. Vestiges of former periosteal lamellae are included as interstitial lamellae.

Fig. 5. *Moropus.** Mandible. Miocene. Dense Haversian tissue.

Fig. 6. *Heptodon brownorum.** Rib. Eocene. Dense Haversian tissue.

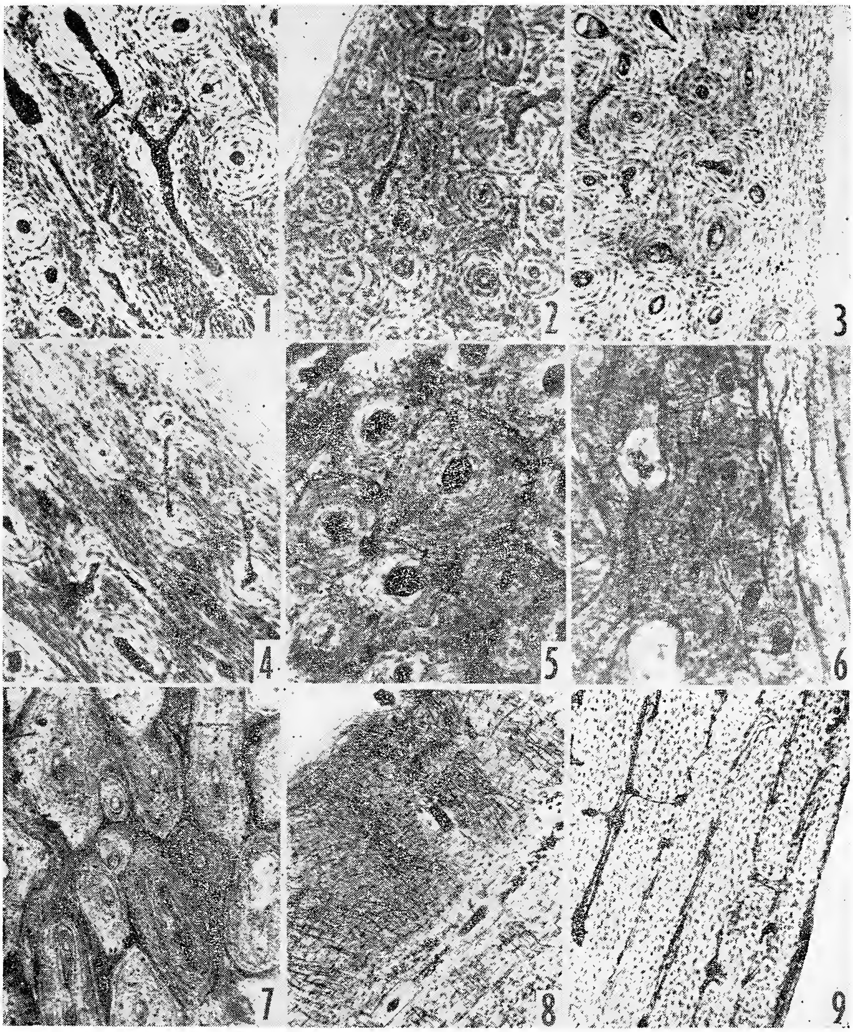
Fig. 7. *Hyrachyus.** Rib. Eocene. Dense Haversian tissue.

Fig. 8. *Coryphodon.** Rib. Eocene. Sharpey's fibers enter the thick compacta. The canals of the middle compacta are secondary.

Fig. 9. *Sus.* Rib. Primary plexiform tissue.

The otic capsule of the whale is by far the hardest and heaviest of all bone tissues yet examined. The compacta, however, does not differ from the typical reticular pattern. A few Haversian systems are found, but a primary vascular reticulum is dominant (Plate XXXVIII, Fig. 9).

*Order Edentata.* Armadillo bone tissues (Plate XXXVIII, Figs. 4–8) are distinctive in structure. Most of the compacta is composed of primary reticular bone, but in some areas only longitudinal vessels occur. In the regions containing longitudinal vascularization, lamellar arrangement follows the usual circumferential pattern. The lamellae associated with reticular tissues, however, characteristically follow the



direction and orientation of component vessels. In the reticular tissues of groups other than the edentates, lamellation is usually circumferential. The vessels in armadillo bone wind irregularly through the compacata, and because their related lamellae so conform, they also twist about in a tortuous manner. Secondary osteones occur, but they appear poorly-differentiated and are relatively infrequent.

The rib of the armadillo possesses a rather thin compacta. One or two layers of irregular vessels, some of which are secondary, are present. In the large Pleistocene sloth *Megalocnus*, on the other hand, the rib compacta is broad and well-differentiated. It is composed of distinct, dense Haversian tissue of several superimposed generations. Stratification of vascular layers is evident in younger regions, and a few circumferential, interstitial lamellae are present (Plate XXXVIII, Fig. 3).

The bony dermal plates of the modern armadillo (Plate XXXVII, Fig. 8) are thin but well-ossified. They are composed of radial or circumferential primary canals embedded within a narrow, fibrous compacta. The central region of each plate contains small marrow sinuses which have developed into secondary canals. The dermal plates of the large, extinct *Glyptodon* follow a similar pattern, except that tissue proportions follow a much larger scale.

*Order Rodentia.* The tissues found in the long bones of rodents are similar to those in corresponding bones of a number of small carnivores. Both groups possess a basic reticular pattern, but in most rodents, a variation of this reticulum is found. The inner third of the rodent compacta is composed of circumferential lamellae containing canals

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**PLATE XXXVI**

**Fig. 1. *Sus*. Mandible. The reticular pattern of canals has experienced limited secondary reconstruction.**

**Fig. 2. *Sus*. Mandible. The vascular reticulum is composed of large vessels comparable with marrow sinuses.**

**Fig. 3. *Pecari*. Malar. The reticular tissue appears similar to embryonic bone tissue.**

**Fig. 4. *Pecari*. Mandible. Secondary tissue has replaced much of the original, primary recticulum.**

**Fig. 5. *Pecari*. Rib. The canals of the middle compacta are largely secondary.**

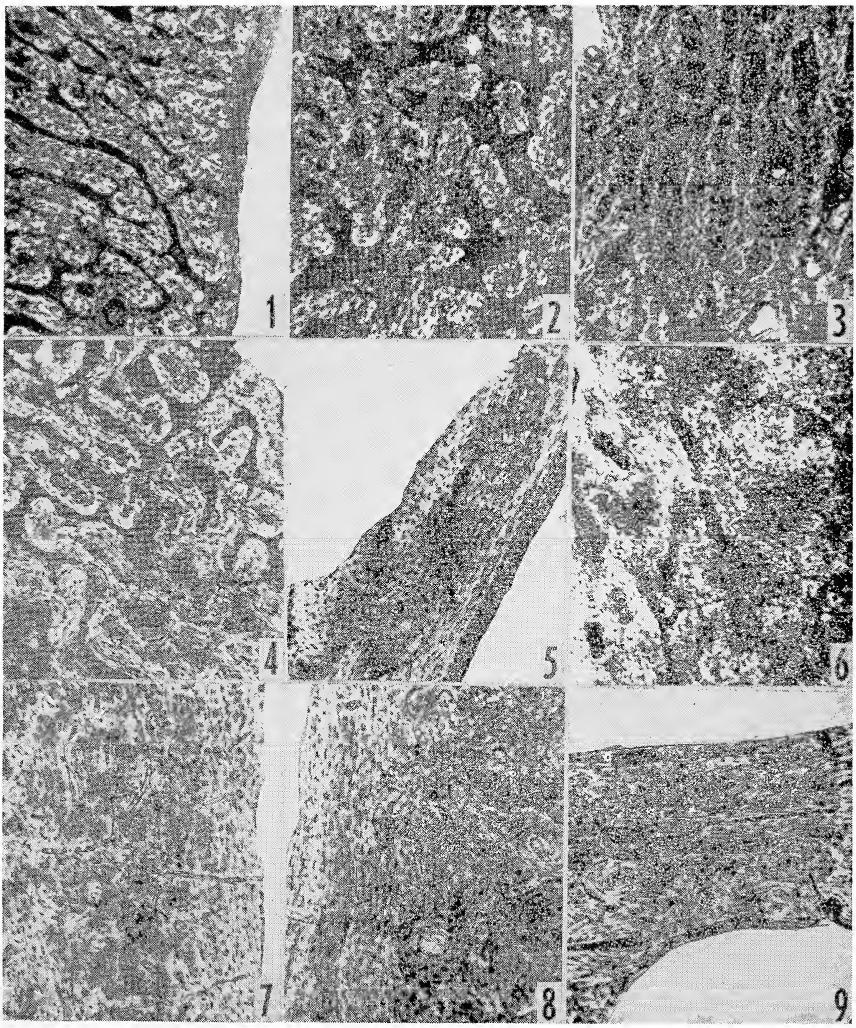
**Fig. 6. Oreodon.* Maxilla. Oligocene. Primary reticular tissue.**

**Fig. 7. Oreamnos. Mandible. Primary reticular tissue.**

**Fig. 8. Oreamnos. Mandible. Secondary osteones have replaced most of the primary canals.**

**Fig. 9. Oreamnos. Scapula. Dense Haversian tissue is enclosed by thin periosteal and endosteal layers.**

of an exclusive radial pattern. These radial vessels extend into the approximate middle of the compacta and there arborize into a brief reticulum. The outer compacta is made of circumferential lamellae containing a few vessels, but it is essentially non-vascular in structure. In the middle reticular compacta, secondary activity is evident, but Haversian tissues are not always formed. Rather, in the rat, *Rattus* (Plate XXXX, Fig. 2), tissue resorption with subsequent disorganization seems to take place, but reconstruction into organized Haversian bone does not follow. The resulting tissue of the middle compacta is loosely-assembled and poorly-differentiated. It remains to be determined whether this middle area of tissue disorganization is actually



secondary, following some undescribed mechanism of bone reconstruction, or if the tissue is still primary, having been originally deposited in this disorganized pattern. In the ground hog, *Marmota*, and hamster, *Cricetus*, a radial pattern of endosteal canals also occurs, but the middle compacta has become irregularly Haversian. Small carnivores possess a similar arrangement of endosteal radial vessels with limited Haversian replacement in the middle compacta (compare Plate XXXX, Fig. 2 with Plate XXXI, Fig. 6). The larger carnivores usually develop extensive, dense, Haversian tissues.

The mandibular tissues of the squirrel, *Sciurus* (Plate XXXX, Fig. 1), and the guinea pig, *Cavia* (Plate XXXIX, Figs. 4, 5), possess primary radial canals, similar to the multituberculates, that penetrate the lamellar compacta both from endosteal and periosteal borders. Limited areas are found that contain longitudinal canals, most of which are in the form of indistinct, poorly-differentiated, secondary osteones. The lower jaws of both the gopher, *Citellus* (Plate XXXIX, Fig. 8), and the beaver, *Castor* (Plate XXXIX, Fig. 6), differ considerably from such a pattern in that they are composed of wide periosteal layers of circumferential lamellae containing a number of primary longitudinal canals. Very few secondary osteones appear in the outer and middle compacta, but endosteal Haversian replacement is well-developed.

*Order Lagomorpha.* The rabbit, *Lepus* (Plate XXXX, Figs. 3–6), formerly classified as a rodent, does not possess rodent-like bone tissue. The vascular pattern, in contrast, is longitudinal, and the structural arrangement and formation of the primary osteone is not comparable. In the development of new primary bone, the deposition of periosteal lamellar layers alternates with vascular strata. Each primary canal is surrounded by one, two, or three rings of osteocytes forming a Haversian-like structure. These primary vessels may extend across the

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**PLATE XXXVII**

**Fig. 1. *Ovis*. Humerus. Several secondary osteones are superimposed upon the primary pattern of plexiform tissue.**

**Fig. 2. *Ovis*. Mandible. Dense Haversian tissue.**

**Fig. 3. *Bison*.* Rib. Pleistocene. Dense Haversian replacement of primary plexiform tissue.**

**Fig. 4. *Ox*. Hyoid. Dense Haversian tissue.**

**Fig. 5. *Bos*. Tibia. l.s. Primary plexiform tissue.**

**Fig. 6. *Bos*. Tibia. Primary plexiform tissue.**

**Fig. 7. *Bos*. Tibia. Primary plexiform tissue containing scattered Haversian systems.**

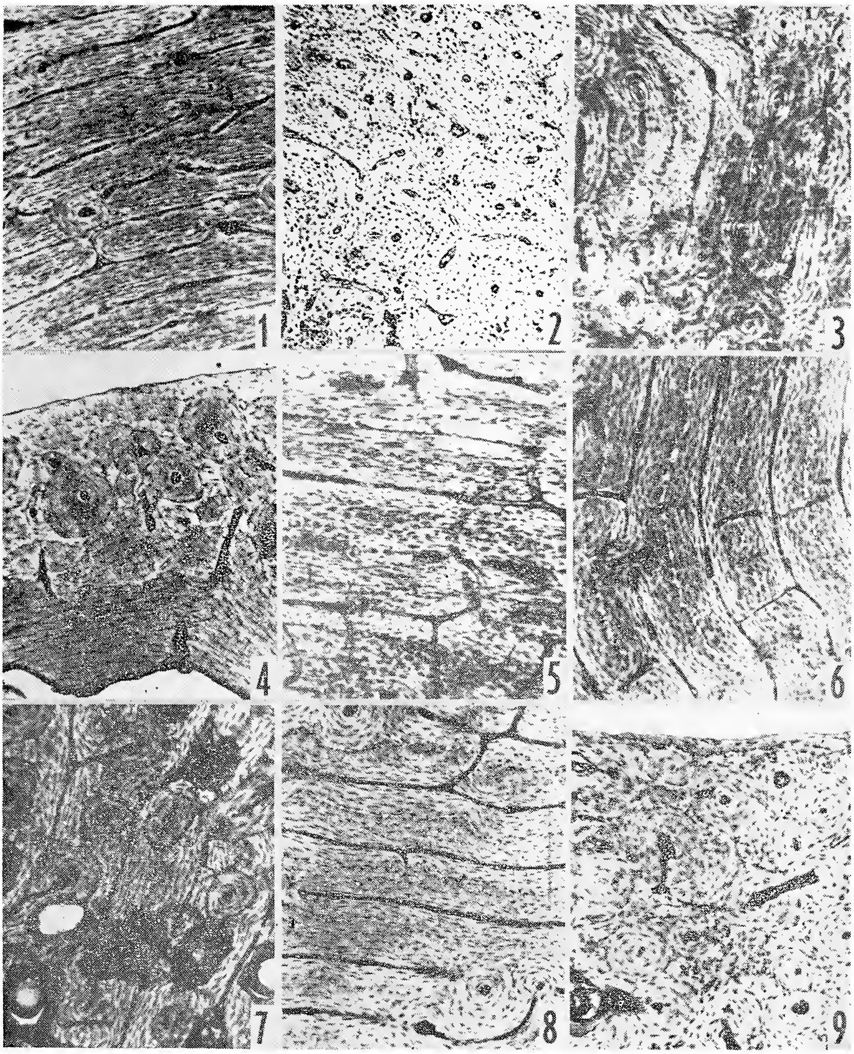
**Fig. 8. *Bos*. Humerus. Primary plexiform tissue containing scattered Haversian systems.**

**Fig. 9. *Bos*. Rib. Dense Haversian tissue.**

greater portion of the compacta without secondary intervention, or areas of dense Haversian reconstruction may occur. The ribs and skull bones are largely Haversian in structure, and well-developed secondary osteones appear in several generations. The thin compacta found in the centrum and vertebral processes is composed of a primary, reticular tissue containing scattered secondary canals.

## DISCUSSION

Most vertebrates do not possess the classic pattern of bone tissue structure described in modern textbooks of histology. The descriptions



of bone tissues in current texts are concerned primarily with human bone and a few other forms selected because of their tissue similarity with human bone. Despite the fact that a number of the sharply contrasting differences in bone tissue structure among various groups have been known for over a hundred years, modern textbook authors do not recognize and catalogue these differences. A great many experimental studies, conclusions, and generalizations concerning bone tissues are based upon observations of laboratory animals which do not possess typical human-like bone tissue. Differences in the histology of mature bone and possibly correlated differences in the histogenesis, physiology, and biochemistry of bone tissues between different vertebrate groups should be considered in detail by experimental investigators.

*Bone tissue.* While much structural variation of bone tissue is found, these differences usually involve variation in the *arrangement* of fundamental components and not major differences in the structure of the components themselves. Most bone tissues, of all vertebrate groups, are composed of a fundamental complement of structures or elements. Bone differences are variations in the combination and organization of these components.

Most bones possess an outer layer of tissue, the compacta. This compacta may contain a number of vascular canals, or it may be entirely non-vascular. The basic component of the compacta is the circumferential lamella. Lamellation, either circumferential or Haversian, is found in most bone tissues and is to be considered a structural constant. With the exception of certain fishes, bone cells are found in the osseous skeletons of all vertebrates, and canalicular processes accompany

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**PLATE XXXVIII**

Fig. 1. *Odocoileus.* Antler. Longitudinal, primary vascular bone tissue.

Fig. 2. *Artiodactyl.** Phalanx of an unidentified Miocene specimen. Primary reticular tissue.

Fig. 3. *Megalocnus.** Rib. Pleistocene. Dense Haversian tissue.

Fig. 4. *Dasypus.* Fibula. Longitudinal, primary bone tissue. An acellular area occurs around each canal.

Fig. 5. *Dasypus.* Ischium. Primary vascular tissue.

Fig. 6. *Dasypus.* Rib. Primary vascular tissue.

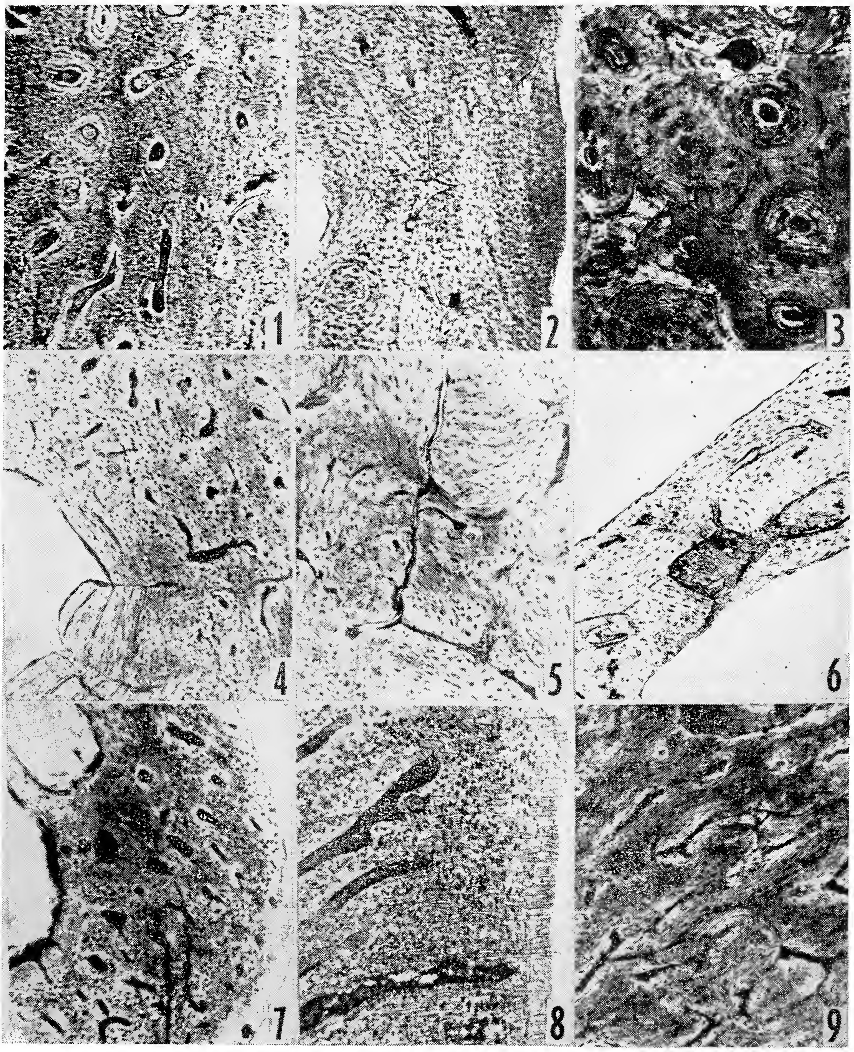
Fig. 7. *Dasypus.* Pubic bone. Longitudinal primary vascular tissue.

Fig. 8. *Dasypus.* Dermal plate. Large, radial, primary vascular canals pass through the compacta. Sharpey's fibers penetrate the periosteal lamellae.

Fig. 9. Whale. Petrous bone. A number of the canals of the vascular reticulum have received secondary replacement.

such cells wherever present. Cancellous trabeculae are usually found in flat bones and in the epiphyses of long bones but are not always found in diaphyses. The general histological appearance of cancellous bone differs very little among vertebrate groups, fossil or recent.

The bones of several major vertebrate groups are composed partially or entirely of simple, undifferentiated, non-vascular lamellae containing layers of osteocytes. Most vertebrate bone tissues, however, are vascular, and the inclusion of canals within the hard, lamellar matrix follows several characteristic patterns. Primary canals may be longitudinal, radial, or circumferential in orientation, or they may be or-



ganized into a complex, vascular reticulum. Secondary reconstruction of primary bone tissue is found in a number of groups, including many early tetrapods as well as most modern mammals. If the relative number of primary vascular canals in a given area of tissue is extensive, then secondary conversion of this bone will produce dense Haversian tissue. If, on the other hand, only a few primary canals are originally present, then a scattered or irregular Haversian bone results. Endosteal Haversian tissue results from the secondary reconstruction of marrow sinuses near the endosteal margin of the compacta.

*Animal size and age.* Generalizations concerning relationships between body size of an individual and bone tissue pattern are not apparent. Many large forms have only a simple, non-vascular bone. Small forms, likewise, may have complex or simple bone, depending upon the specific characteristics of their particular group. All members of any particular group may not necessarily have similar bone tissues, and the histological differences present do not seem to be based primarily upon variations of actual body size, for the tissue types involved may be found in both large and small forms.

Most of the tissues described in this study are from mature, fully grown individuals. The bones of several immature forms have been examined, however, and observations suggest that the bone tissues of very young individuals may differ from those of adults in the same species. The immature bone of the bullfrog, *Rana catesbeinana,* is nonvascular, but subsequent peripheral deposition results in simple vascular bone tissue. The reticular or plexiform tissue pattern of many mammals is often partially or entirely replaced by Haversian tissue. Mature bones of many fishes lack bone cells, but the histogenesis of such tissue has not been adequately studied. Variation in bone tissue

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**PLATE XXXIX**

**Fig. 1. Whale. Humerus of an unidentified specimen. Dense Haversian tissue.**

**Fig. 2. *Phocaena*. Basioccipital. Dense Haversian tissue.**

**Fig. 3. *Phocaena*. Lateral vertebral process. Dense Haversian tissue.**

**Fig. 4. *Cavia*. Mandible. The compacta contains numerous primary radial canals.**

**Fig. 5. *Cavia*. Mandible. Longitudinal primary vascular tissue.**

**Fig. 6. *Castor*. Mandible. Longitudinal primary vascular tissue.**

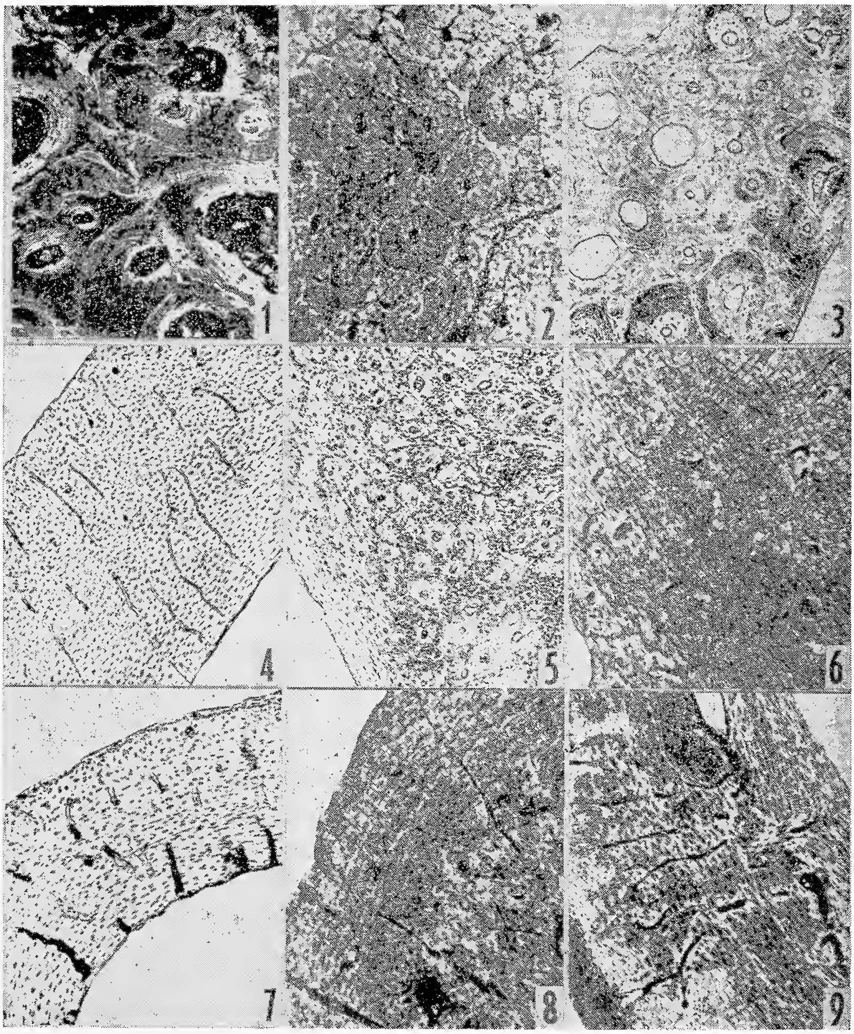
**Fig. 7. *Citellus*. Tarsal. Radial primary vascular tissue.**

**Fig. 8. *Citellus*. Mandible. Primary canals are present in the outer compacta, but poorly organized secondary tissues comprise the inner compacta.**

**Fig. 9. *Citellus*. Femur. Primary vascular tissue.**

structure of various age levels for most vertebrates remains as yet undescribed.

*Body location.* In some fishes, amphibians, reptiles, birds, and mammals, bone tissue patterns of the compacta do not seem to be influenced by specific body location or by the particular skeletal element involved. The histological structure of any skeletal element, thus, may be generally the same as any other element. In other vertebrates of these same groups, however, all bones within an individual do not necessarily follow a single structural pattern. The compacta of long bones, for example, may be composed entirely of simple vascular tissue, but the ribs of the same individual may have experienced



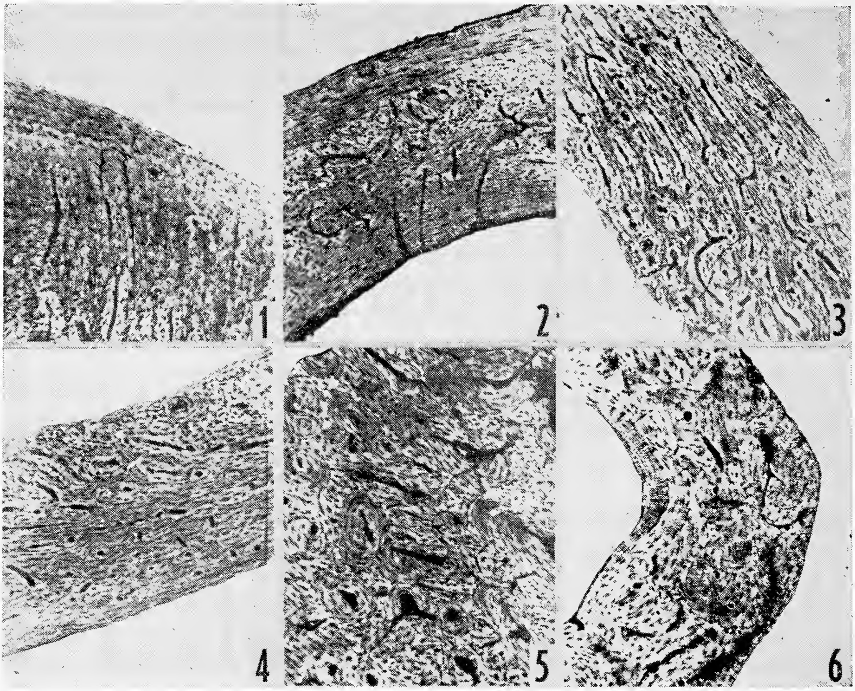



PLATE XXXX

Fig. 1. *Sciurus*. Mandible. Radial, primary vascular tissue.

Fig. 2. *Rattus*. Femur. Primary, radial canals enter the endosteal lamellae and extend into the vascular reticulum of the middle compacta.

Fig. 3. *Lepus*. Humerus. Longitudinal and circumferential primary vascular tissue.

Fig. 4. *Lepus*. Humerus. Longitudinal primary vascular tissue.

Fig. 5. *Lepus*. Malar. Dense Haversian tissue.

Fig. 6. *Lepus*. Rib. Dense Haversian tissue.

Haversian replacement. One side of a bone may be richly vascular, but the other side of the same bone can be entirely non-vascular.

*Dermal and cartilage-replacement bone tissues.* This classification of bone tissue is based upon developmental mechanism and relative body location. Both categories, within any specific group, include bones which are composed of the same structural components that characterize the bone of that particular vertebrate group. Both dermal and cartilage-replacement bone, thus, contain lamellae, osteocytes, and vascular canals. Should one or more of these components be lacking in the bone of a group, both of these bone types experience an identical loss. Dermal bone, however, is characteristically superficial in body distribution, and all dentinal tissues, including dentine, enamel, cosmine, ganoine, other fish scales and spines, and all vertebrate teeth, are associated only with this dermal bone.

*Secondary bone tissues.* Resorption and reconstruction of primary bone into secondary bone tissue is customarily interpreted as a mechanism which makes possible the removal and redeposition of inorganic salts. The classic Haversian system is regarded as the structural unit of secondary bone.

Although the Haversian system appears to be a common and frequent product of secondary activity, there is good indication that resorptive processes may result in secondary bone that is not composed of typical Haversian tissue. A series of primary lamellae, for example, may terminate abruptly, yielding to another series of lamellae which extend in an entirely different plane. Although Haversian formation has not occurred, it would appear that resorption and redeposition had taken place. Areas of extreme disorientation are frequently seen in the middle of compactae. Perhaps this represents a kind of secondary resorption or reconstruction. Investigation into this possibility is suggested.

Structures in the outer compacta of many vertebrates, such as the very young rabbit and human, appear to represent Haversian systems. These systems, however, are poorly defined and differentiated. Although such structures are sometimes identified as true secondary osteones, they may actually represent primary systems. Well-prepared, decalcified sections demonstrate the presence of rather large sinuses which appear to have been directly incorporated into the outermost layer of the compacta. In the slightly older bone just beneath this most recently deposited outer layer, these sinuses seem to have been filled in with concentric lamellae. The resulting structures are still primary, for resorption and redeposition apparently have not taken place. In deeper, much older areas of rabbit and human bone, however, positive indications of secondary activity are apparent, and these tissues are dense Haversian in structure. The incorporation of relatively large sinuses within outermost periosteal lamellae has not been generally observed in the mature bone of most vertebrates. Periosteal canals are usually rather small, and if Haversian systems are to develop from these vessels, as they seem to do in a number of vertebrates, the canals must first be eroded into channels of larger diameter. Secondary deposition, then, follows this resorption. It should be noted, however, that this observation is based upon study of adult forms. Perhaps the inclusion of large sinuses with outer lamellae is a feature of bone growth restricted to very young, rapidly growing bone. Here is a specific area inviting further investigation.

The distribution of Haversian tissues among the various vertebrate groups appears inconsistent and has not been satisfactorily explained. All vertebrates do not possess Haversian systems. Secondary tissues have been observed in many fish, but true Haversian systems are seldom encountered in their bones, fossil or recent. The earliest and most primitive known amphibians, however, possessed well-developed endosteal or irregular Haversian tissues. Dense Haversian bone, however, is lacking.

Parathyroid tissue has not been reported, with certainty, in any living fish group, but it is considered to be present in amphibians. It could be logically assumed that with the development of parathyroid glands, calcium mobilization from bone, under the influence of parathormone, results in bone tissue resorption and secondary deposition. This would serve to explain the usual absence of Haversian tissue in fossil and recent fish and the sudden appearance of Haversian systems in ancient tetrapods. While there may be significance to such an interpretation, two factors should be considered. First, although fish do not usually have Haversian systems, many fish do possess definite indications of secondary activity. What agency, if fish truely lack parathyroid tissue, is responsible for this bone tissue reconstruction? Second, amphibians, reptiles, birds, and mammals are reported to be in possession of well-developed parathyroids. Many of these vertebrates have Haversian tissues, but a great many others, representing numerous groups from all of these tetrapod classes, do not possess Haversian or other recognizable secondary tissues of any known description. If parathyroid influence is actively concerned with bone resorption and reconstruction, why do these forms apparently lack secondary tissues? It is possible that fishes do possess parathyroid tissue or some equivalent, but it may be so diffuse in distribution that it cannot be postively identified as a discrete organ. Perhaps the parathyroids of tetrapods vary in the intensity of their influence upon bone tissue. Perhaps there are physiological relationships between parathyroid secretions and bone tissues of a kind which have not been recognized or identified. Further and considerable work is indicated.

In personal conversation with R. S. Benton, who has recently completed a study series on the demineralization of bone[3], Mr. Benton pointed out that bone resorption, presumably for the purpose of calcium remobilization, results in the gross destruction of considerably more bone tissue than would seem necessary for only the release of calcium.

Is it necessarily true that animals with a high rate of body metab-

[3] Studies on Demineralization of Bone. Vol. 26, Amer. Journ. of Clin. Path., Four Parts.

olism have Haversian replacement? Most small birds and rodents lack Haversian tissue.

Forms which may have Haversian tissues do not always possess this tissue in all of their skeletal elements, or even in all parts of a single element. One bone may be predominantly Haversian in structure, and another bone, or part of the same bone, may retain the primary vascular pattern characteristic for that animal. It is interesting to note that if a form does possess Haversian tissue in any part of its skeleton, the rib is, with very few exceptions, Haversian. This has been observed in vertebrates of all classes.

Secondary activity is usually much more intense within inner bone areas than near the outer or periosteal border. A great many vertebrate groups possess only endosteal Haversian tissue. This is secondary bone located within cancellous bone next to the endosteal margin. In many forms, the vascular canals of the compacta near the endosteal border become converted into secondary osteones while those located peripherally are primary. In some forms, however, secondary reconstruction extends nearly to the periosteal border, with only a narrow periosteal layer remaining primary. In all cases, outer layers of the compacta are younger than middle and endosteal regions and have not been afforded as much exposure to the processes of reconstruction. Whether this factor adequately accounts for the preponderance of secondary tissues within middle and, especially, inner compact areas, has not been determined. A supplemental factor which may well be involved is suggested by the normal process of diametrical bone growth. This mechanism involves internal resorption complemented by peripheral deposition. The concentration of increased secondary activity near inner bone surfaces may be an expression of this process. This possibility, and the predisposing factors involved, should be investigated.

Cancellous bone tissue may form in two entirely different ways. First, the vascular canals of the compacta, either primary or secondary, are enlarged into channels of greatly increased diameter. As the endosteal areas of the bone are approached, the canals of the compacta are thus seen to become progressively larger until they attain dimensions of cancellous proportions. Second, the endosteal border of a bone may be completely eroded away during bone resorption. This is followed by the deposition of new endosteal, circumferential lamellae from which cancellous trabeculae extend into the marrow cavity.

The functional significance of the Haversian system is usually regarded as associated with calcium mobilization. An alternate possibility should be considered. In order to accomplish the growth of a bone in diameter, erosion of internal surfaces must accompany the deposition of external, primary bone. Perhaps the destructive process of internal bone tissue removal is not selectively confined only to the endosteal margin, but may extend into the inner, middle, or even outer layers of the compacta. The lamellar surfaces adjacent to vascular canals of the compacta, presumably, would be exposed to the same resorptive influence that is acting upon the inner margin of the compacta. Following this resorptive or destructive phase of diametrical bone growth, lamellar deposition would proceed around the periosteal border as well as within the recently eroded channels of the compacta and the endosteal margin. Thus, the resorptive and constructive processes of bone growth act upon all exposed bone surfaces, including the primary vascular canals of the compacta. Secondary Haversian tissue is the result. This supposition should receive experimental investigation.

The real meaning of Haversian tissue, in view of its peculiar distribution among different vertebrate groups, has not been adequately explained.

*The history of bone tissue and evolutionary interpretation.* Organic evolution is usually associated with organs and organ systems. Only in the skeleton can the history of a *tissue* be followed through time. Bone tissue offers the unique opportunity of a vertical approach to the study of tissue evolution.

In the history of bone tissue, a single "evolutionary line" cannot be recognized. It is not possible to trace a precise series of progressive, increasingly complex developmental stages from extinct fish to modern mammal. It cannot be maintained that Haversian tissue is the evolutionary culmination of all bone development, or that the ontogeny of mammalian bone tissue recapitulates the phylogeny of the bone of lower vertebrate groups.

A generalized evolutionary study which is restricted to ontogenetic development and the comparative histology of recent forms is inadequate and can be misleading. It would be possible to design a very attractive, but entirely erroneous, sequence of presumed, progressive advances in the design of the Haversian system. Assuming, without basis, that dense Haversian tissue, as typified by human bone, represents the climax of bone evolution, representatives of the lower vertebrate classes can be selected, all recent forms, which demonstrate a series of increasingly complex combinations of Haversian components. The frog, lizard, turtle, alligator, and human are thus selected to represent levels in a single evolutionary line of tissue development. This naiveté has been attempted (Crawford, 1940).

Application of the Biogenic Law to a study of human bone histogenesis might suggest that the relatively simple structure of young, developing bone represents a phylogenetically primitive condition, and that all adult "primitive," or perhaps non-mammalian, vertebrates could thus be regarded as having possession of this supposed ancestral bone tissue structure. Contradictory evidence, of course, is overwhelming, although the idea has been repeatedly stated in texts. The projection of preconceived concepts and prejudices of evolutionary mechanics into the interpretation of observations is a consideration that must consciously, and continually, be recognized and evaluated. It is a constant temptation to look for, and thereby find, a logical, uni-linear assemblage of structural changes that conform with and confirm some pre-existing idea on how things should be happening.

It is possible that bone tissue evolution has followed an infinite number or series of linear "progressive advances" involving particular tissue specializations which are unique or characteristic for individual groups. It is certainly not justifiable, however, to arrange a system of tissue changes, usually involving a number of forms already considered intermediate on the basis of gross anatomical relationships, and conclude that one tissue pattern is therefore directly ancestral to another. There is no evidence to support such an approach, although it has been conveniently employed in descriptions of the history of bone tissue changes, both for changes observed among major classes and changes in sub-groups within any class.

This approach is dangerous because it can become adopted as a routine tool of explanation while concealing any other, and possibly more accurate, understanding of phylogenetic mechanism. For example, if it is decided to trace the evolutionary history of some form, specimens of fossil relatives from several different geologic strata are selected and studied. Special attention is customarily, and understandably, devoted to forms which have been described as morphologically intermediate. Then it is assumed that the tissue structure of Form A is ancestral to Form B, which is ancestral, or at least representative of an ancestral condition present at the time, to Form C, and so on. All of this does not necessarily hold true, although it is certainly one of several possibilities. First, it would have to be assumed that the evolutionary mechanism involved incorporates a single series of relatively small, subtile, linear changes which finally emerge as the tissue type found in the most modern of the specimens studied. While it is usually possible to find what seems to be a series of histological tissue changes that can be presumed as phylogenetically intermediate and thus progressive for the particular forms studied, it must be realized that this entire system of thinking is based upon an original assumption, and that this assumption may not always apply to bone tissue evolution. Because Form A is geologically earlier than Form B, because they are related through common membership in a certain group, and because a series of presumably ancestral structural levels can be interpreted, this does not prove that the tissue found in Form B is directly derived from Form A.

Other suppositions can be drawn from these same circumstances. If the bone tissues of a series of Forms A, B, C, and D, each representing a successive geologic period, are studied, it is found that the vascular canals of Form A are very large and those of Form D are very small. The canals of Forms B and C are intermediate in size. This evidence, then, could demonstrate a very logical sequence of changes involving the gradual phylogenetic reduction of vascular canal size, a conclusion which would be based upon a well-known but controversial concept of evolutionary mechanics. Other conclusions, however, should be considered. Perhaps the intermediate tissues of Forms B and C, mentioned above, are not ancestral at all. The tissue differences may be independent and entirely incidental, not even representing the condition which was generally present in the actual ancestors of the time. Or perhaps the tissue situation found in intermediate Forms B and C represent a reflection of the same agencies that acted upon Form D, but the results were not identical and the evolutionary changes proceeded in somewhat different directions. If this were true, B and C were not actually intermediate but rather different products of an original condition which produced similar but varying results. This idea is supported by the possibility that a variety of similar influences acting upon the bone tissues of related animals might produce similar structural changes. The fact that the forms are related, but still somewhat different, would suggest that their response to the influences of change would likewise be somewhat different, with the resulting development of certain structural variations. Because the forms are related, bone tissue responses might also be related, thus producing fundamentally comparable tissue patterns. If circumstances such as this should exist, it would be misleading to attempt to derive Form B from A and D from B and C. It should be mentioned that evolutionary history does not necessarily follow a gradual, singles series of changes. It is possible that structural change in a tissue can be relatively abrupt and divergent. A measure of caution should be exercised when attempting to construct precise evolutionary sequences and relationships involving tissues.

Dermal, perichondral, endochondral, compact, and cancellous bone tissues, cartilage, and dentine were all present in the earliest and most primitive vertebrates yet discovered. Apparently none of these skeletal tissues were phylogenetically derived from any of the others, for they were already highly developed and well-differentiated in structure in their first known appearance. In various vertebrate groups, one or the other of these tissues may become locally or entirely predominant or absent, but all may be considered to be of the same relative primitiveness[4] in the sense that all experienced an approximately simultaneous origin, so far as is now known.

Whether the bone tissues of all vertebrate groups are directly homologous as a result of evolutionary descent from a single, common beginning, or whether bone tissues experienced polyphyletic development following a multiple origin in two or more groups, all bone tissues are nevertheless related in the sense that they are derived from embryonic mesenchyme. All seem to represent a calcified connective tissue usually containing undifferentiated, stellate cells. It is possible that supporting tissues of entirely different vertebrate groups, prior to genetic establishment of an osseous skeleton, might have received separate mesodermal ossification through similar predisposing agencies.

When bone became established as an adult skeletal tissue for then existing vertebrates, it was presumably subjected to divergent alteration among succeeding vertebrate groups. The earliest bone yet described had all of the basic components that define bone tissue, including lacunae, canaliculi, lamellae, and vascular canals. Subsequent bone history did not witness the addition of any supplemental structural parts, and in only a few groups have one or more of such components been lost or failed to develop. Primitive bone tissue, then, is not simple in structure but, conversely, is complex in that all structural units are present and well-developed. The history of bone tissue is one of rearrangement and recombination.

*Fishes.* The bone of the most primitive known fossil vertebrates is complex in structure and well-organized, but secondary tissues are generally absent or poorly-developed. True Haversian tissue, composed of secondary osteones, is seldom found in any fossil or living fish. Spongy areas may appear Haversian, but this resemblance, where present, is due to a small diameter of individual cancellous marrow spaces. As in all spongy bone, concentric lamellae and rows of lacunae partially enclose a central marrow cavity. These lamellae, however, are not discontinuous; secondary resorption and deposition have not occurred, and an outer cementing line is not present. The tissue is, therefore, primary. Marrow spaces or large primary vascular

[4] The idea that cartilage is more primitive than bone because it is found in "primitive" sharks and because it appears first in the embryo is seldom supported by modern zoologists (Romer, 1945, 1952).

canals may become filled with primary, concentric lamellae. These are termed protohaversian systems.

Living and extinct fishes may be grouped into three categories. The first group, including most early fishes, the "lower" teleosts, and the various lung fishes, possess a basic, generalized pattern of bone composed of osteocytes, lamellae, and primary vascular canals. The second group, lacking bone cells, includes the "higher" teleosts and the extinct heterostracans. The third group contains the Subholostei and is characterized by the unique possession of lepidosteoid tubules.

Although secondary tissues are seldom encountered in the bone of fishes, bone tissue resorption is present, for enlargement and invasion of cancellous sinuses into the compacta is frequently seen in most forms. Some mechanism of resorption is certainly necesary as a requisite for bone growth. In one very large teleost fish, *Pogonias,* vascular canals of the compacta are enlarged into marrow spaces as the bone grows in diameter. Following such resorption, deposition of lamellae within the sinuses results in secondary structures grossly comparable with the endosteal Haversian systems of tetrapod bone. It is interesting to observe that such primary and secondary bone tissues can develop in the total absence of adult osteocytes.

The bone tissues of many modern fishes bear little resemblance to the early, generalized bone of extinct fish groups. Several distinctly different patterns of fish bone, fossil and recent, can be recognized. Correspondingly, distinctly different morphological groups of fishes are included within the category of Pisces. If duration of time is a significant factor, fishes have been afforded more opportunity for phylogenetic development, for either organs or tissues, than have most higher vertebrates. It is evident that the bone tissues of certain living fish groups appear quite specialized if compared with the early, generalized pattern.

The bone structure of the fossil and recent crossopterygians and dipnoans that have been studied is of a generalized, cellular, primary pattern that does not demonstrate any singular tissue relationship with the highly developed, elaborate skeletal tissues of the known early amphibians. This observation does not discredit a theory of probable crossopterygian ancestry of tetrapods based upon comparative anatomical evidence.

*Amphibians.* The bone of early, extinct amphibians and reptiles, like that of the early fishes, is complex in structure and well-organized. In tetrapod bone, the capacity for internal secondary tissue reconstruction has been greatly amplified. This did not incorporate additional basic parts but involved the reorganization of exisiting components into new tissue patterns. In structure, the individual Haversian systems of early tetrapods seem to be identical with secondary osteones of modern mammalian bone tissues, but only in a few extinct reptilian forms did entire bones become replaced by dense Haversian tissue. Widely distributed, dense Haversian bone has not been observed in either early or modern amphibians. Secondary tissue, where present, is restricted to scattered, irregular, or endosteal Haversian systems.

Bone structure of early amphibians, generally, is unlike the bone tissue of living amphibians. Bone tissues in most of the extinct forms studied were massive and elaborate, whereas, the bone of modern amphibians is simple and delicate. A few frogs and toads possess undifferentiated, primary vascular bone tissue, but most living amphibians have only a simple, non-vascular bone composed of concentric, cellular lamellae.

Three general bone varieties exist: (1) simple lamellar bone completely lacking vascular canals; (2) lamellar bone which contains primary vascular canals; and (3) lamellar bone containing primary canals that have received partial or complete Haversian reconstruction.

Most labyrinthodonts had a relatively complex bone containing irregular or endosteal Haversian tissues. Some extinct reptilian forms, likewise, possessed very similar, complex bone containing scattered secondary tissues. One known Paleozoic labyrinthodont, *Parioxys*, and several Paleozoic reptiles, had a simple, primary vascular bone closely resembling the bone of some modern amphibian representatives. The bone of most anurans and urodeles is composed of non-vascular, undifferentiated lamellae which surround a large, central marrow cavity. In certain frogs and toads, however, peripheral layers of primary vascular tissue are deposited around this basic, non-vascular bone.

*Reptiles.* Like other vertebrate classes, the reptiles do not possess a single, typical pattern of bone structure. Most of the extinct reptilian groups had dense, heavily-laminated bone with well-developed endosteal or irregular Haversian tissue. Only the saurischian and ornithischian dinosaurs and certain therapsids possessed dense Haversian tissue. Living and fossil turtles and crocodiles have complex, predominantly primary bone tissues which conform, in basic structural plan, to the pattern found in most other archosaurs. Modern lizards and snakes do not develop bone tissue vascularization, for only concentric, cellular lamellae constitute the entire compacta.

It is interesting to note that the bone structure of most extinct reptilian groups, including the pelycosaurs and cotylosaurs, was generally similar to the bone tissue of labyrinthodonts. Ancient amphibian and reptilian bone tissues are distinctly more similar than those found in their modern descendants.

The living *Sphenodon* differs from extinct rhynchocephalians in bone tissue structure. The compacta of *Sphenodon*, like lizards, is non-vascular, whereas, the compacta of the extinct rhynchocephalian is composed of primary and secondary vascular tissue.

Of three therapsids studied, one revealed dense Haversian tissue and two had a plexiform structure. Dinosaurs and many mammals demonstrate similar bone tissue patterns.

*Birds.* The compacta of a bird bone is narrow, and the central marrow cavity is large. In larger birds, the compacta is composed of three layers: the outer and inner lamellar layers, and a central vascular layer. This vascular tissue is reticular, and it may or may not receive Haversian replacement. Haversian tissues, where present, may be either dense or irregular. Different bones in the same individual may possess different tissue patterns, and even the same bone may have two or more regions that differ in tissue structure. Penetrating Sharpey's fibers are seldom observed even in the epiphyseal compacta. Well-developed cancellous tissue is not usually encountered in the diaphyses of long bones, but small marrow sinuses are occasionally found in the endosteal compacta. Cancellous bone is extensive in most epiphyses and flat bones.

Lamellation is indistinct in the bone tissues of birds, and is difficult to distinguish even under polarized light. The lack of well-defined lamellae is possibly due to the absence of alternate cross fibrillation in adjacent lamellar layers. Haversian systems, when present, are indistinct and poorly defined. Haversian lamellae are indistinguishable. In transverse section, Haversian systems appear as homogenous structures containing two, three, or four circles of lacunae.

The osteocytes which are embedded within inner and outer circumferential lamellae are parallel to the bone surface, but osteocytes near primary vascular canals are usually oriented in such a position that the maximum surface area is exposed to the vessel. Bone cells of other areas are often disorganized and can occur in almost any plane of orientation.

The compacta of smaller birds has only a single layer, and the primary vascular reticulum is poorly developed or entirely absent. Haversian replacement is not usually encountered in smaller birds.

The non-vascular bone of many small birds closely resembles the non-vascular bone tissue of snakes and lizards, but the primary and secondary vascular bone of larger birds is unlike corresponding structural patterns found in fossil or recent reptiles. While the reticular tissue found in *Pteranodon* is very similar to the reticular bone of many birds, the usual pattern of archosaur bone tissue is quite different from known recent and Cenozoic birds. Mesozoic bird material has not been available for this study, but a detailed study of the origin of bird bone tissue should be done.

The distinct differences between the bone tissues of birds and other vertebrate groups suggests corresponding differences in the skeletal physiology, biochemistry, and histogenesis of avian skeletal tissues.

*Mammals.* The impression that the bone of all lower vertebrates is simple and primitive in structure, and that the developing bone of mammals recapitulates such phylogeny, is not justified. Neither can the bone tissues of mammals be regarded as a culmination of skeletal tissue evolution. Although many mammals exhibit well-developed, dense Haversian bone, Haversian tissues are also found in a number of amphibians, reptiles, and birds. While several lower vertebrate groups possess simple, even non-vascular bone, a number of mammals also display simple, non-Haversian and non-vascular bone tissues.

Early mammal-like reptiles, the pelycosaurs, did not have typical mammalian bone tissue. Rather, their bone tissue structure follows the laminated, endosteal Haversian pattern common to labyrinthodonts and other early reptilian groups. Therapsids possess either a dense Haversian or plexiform bone tissue. The bone of living, morphologically primitive groups of mammals, including the monotremes, marsupials, and insectivores, are not composed of dense Haversian tissues. Their bone tissues, rather, are of a generalized, primary vascular design. Monotremes and marsupials have elaborate, primary vascular tissues, but Haversian replacement is usually absent or undifferentiated. The longitudinal, primary vascular pattern of many primates, on the other hand, commonly becomes replaced by extensive, dense Haversian tissues.

The insectivores and the bats possess either poorly developed primary vascular or completely non-vascular bone tissues. This tissue design, although common among other vertebrate classes, is unique among mammals.

The complex, reticular pattern of perissodactyls may receive secondary replacement, or, in other bone regions, such primary tissues may be retained permanently. Artiodactyls possess a reticular, or more often, a typical plexiform bone tissue. In many skeletal elements, these patterns may remain as adult tissue, but in other bones they may become partially or entirely secondary in structure.

A well-developed, radial pattern of primary vascular bone tissue is found in the long bone of rodents, and a reticular tissue is found in other elements of the skeleton. In some forms, Haversian tissues may partially replace the primary bone, but such secondary development is usually meager. The bone of the lagomorphs studied does not resemble typical rodent bone tissue. Its basic pattern is longitudinal, and Haversian reconstruction is extensive.

Carnivore bone tissues demonstrate structural similarities with all the basic tissue patterns of most other mammalian groups, exclusive of the completely non-vascular bone of some elements of the bats and insectivores. Depending upon the skeletal element examined and the particular species, carnivore bone may appear primary longitudinal, radial, reticular, or plexiform in vascular arrangement, any of which may receive extensive Haversian replacement.

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## SUMMARY

1. Extensive variation exists in bone tissue structure of different vertebrate groups.

2. Most vertebrates do not have *dense* Haversian bone tissue. The bone tissues in a number of vertebrate groups have only scattered Haversian systems. Many groups entirely lack secondary Haversian tissues.
3. Vascular canals and bone cells are absent in several major vertebrate groups.
4. Only in the skeleton can the *vertical history* or evolution of a *tissue* to be followed.
5. Bone tissues of the earliest, most primitive, extinct fishes possessed all of the fundamental components that define bone tissue.
6. Bone, cartilage, dentine, and enamel are equally primitive in the sense that all had about simultaneous origin. None is believed to be ancestral to any other.
7. Different skeletal elements within an individual may differ in bone tissue structure. Variation in bone structure may exist in different parts of the same skeletal element.
8. Structural differences in bone tissue usually involve variation in the arrangement of components and not extensive variation in the structure of the components themselves.
9. The functional nature of the secondary osteone, or Haversian system, is not well understood. The presence or absence of Haversian tissue in the various vertebrate groups cannot be explained with the current concepts of Haversian system "purpose" and functioning.
10. Distinct differences in bone tissue structure suggest the possibility of contrasting differences in bone histogenesis, physiology, and biochemistry.
11. Conclusions derived from bone studies using experimental laboratory animals must be interpreted with caution if applied to human bone in view of the great range of variation in normal bone tissues.
12. One or more representatives of *geologically early* fish, amphibians, reptiles, and mammals possessed a generalized, unspecialized pattern of bone tissue. Other members of these same classes possessed a specialized bone tissue design. The first known appearance of both generalized and specialized bone types were geologically contemporaneous.
13. The structure of generalized and specialized bone tissues found in modern forms is closely similar to corresponding generalized

and specialized bone in ancient, extinct members of the same taxonomic classes.

14. Non-vascular bone has been produced by some members of each vertebrate class. It is noted that vertebrates possessing this bone type are all essentially modern forms, and that they are among the relatively small representatives of their classes.

# Occurrences of Boron Minerals in the Wichita Mountains, Oklahoma

*by* **W. T. HUANG**

*Sul Ross State College*

The intensive search for uranium in the Wichita Mountains of southwestern Oklahoma during recent years is yielding discoveries not only of a uranium mineral (Huang, 1956) but also two uncommon boron minerals. The presence of the boron minerals was brought to the writer's attention early in September 1953 by Jerry Sparkman, Jr., when he examined several core samples taken at a depth of 25 feet in Comanche County, Oklahoma. After some preliminary tests of the materials collected by Sparkman, the area was visited by the writer in April 1954. Laboratory work has confirmed the presence of sassolite, $B_2O_3.3H_2O$, and boracite, $5MgO.7B_2O_3.MgCl$, at two localities in Permian and recent sediments in the Wichita Mountains. In August 1955 the writer had sent a collection of boracite crystals to the Geological Survey of Oklahoma at Norman for cataloguing. The sassolite was then still under investigation. The two boron minerals to be described are reported for the first time in the Wichita Mountains, Oklahoma.

## OCCURRENCE

The sassolite and boracite occur in soft, gray to yellowish brown efflorescent masses in the Permian and recent reddish weathered sandy shale and siltstone within 4 to 11 inches of the surface in a valley, in NE ¼ section 18, T. 3 N., R. 13 W. Comanche County, about 3 miles southwest of Mount Sheridan. Excellent boracite crystals were found in the siltstone about 5 feet below the surface. The boracite crystals ranging from 0.05 to 4.2 mm. in diameter, are coated with silty materials and are embedded in a reddish brown matrix of sassolite and clay. In this matrix pearly sassolite plates as much as 1.2 mm. in diameter are present.

In NE ¼ section 12, T. 4 N., R. 13 W., about 5 miles northeast of Mount Sheridan, the sassolite occurs in pearly yellowish brown plates which average about 0.1 to 1.2 mm. in diameter and are admixed with white to gray aggregates of small boracite grains and clay. A few grains of titanclinohumite are present. The titanclinohumite may have been derived from the nearby "intermediate rock" of gabbro-granophyre complex in which the mineral originated (Huang, 1957).

In these two occurrences of boron minerals minute grains of gypsum, anhydrite, barite, micas and quartz are sporadically distributed in the efflorescence.

### SASSOLITE

The optical properties of Oklahoma sassolite are listed as follows:

Refractive indices

$N_x = 1.340 \pm 0.004$

$N_y = 1.456 \pm 0.003$

$N_z = 1.459 \pm 0.002$

Optical sign is negative

2V calc. 15° to 15.5°

Orientation X angle base approximately 90°

Other Plates lack regular outlines (Fig. 1) and show strong wavy extinction

Sassolite contaminated with white-colored clay, was analyzed for water soluble $B_2O_3$ and water-insoluble material. The recalculated analysis is compared with the California sassolite (Allen and Kramer, 1957) and the theoretical combining proportions for boric acid in Table 1.

TABLE I

Chemical Analyses of Sassolite

| | Sassolite, Oklahoma (per cent) | Sassolite, California (per cent) | Boric Acid (theoretical) (per cent) |
|---|---|---|---|
| $B_2O_3$ | 56.88 | 57.19 | 56.39 |
| $H_2O$ | 43.12 (by difference) | 42.81 | 43.61 |
| Total | 100.00 | 100.00 | 100.00 |

X-ray powder pattern was prepared for sassolite with nickel-filtered copper radiation over the range $2\theta = 5° - 90°$, being scanned with a Geiger counter spectrometer at 1° per minute. The pattern for sassolite from Oklahoma are compared with those published for California sassolite in Table 2. Although several of the weaker peaks for Oklahoma sassolite are missing from the x-ray pattern, in other respect the diffraction data are in essential agreement with those for boric acid. The pattern for California sassolite likewise is not as well developed as the pattern for synthetic boric acid. This phenomenon is

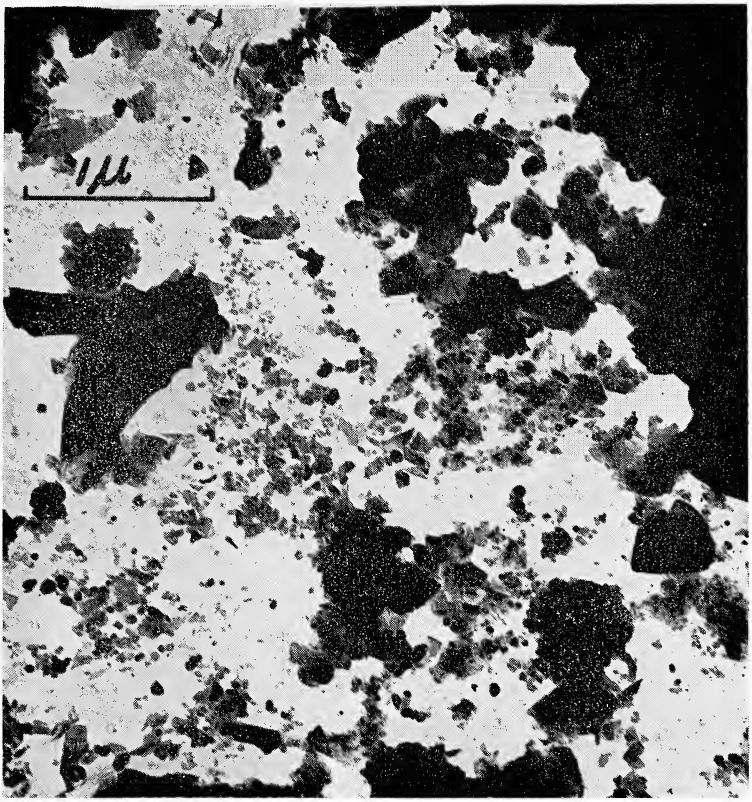


**Fig. 1. Electron micrograph of sassolite, NE ¼ sec. 18, T. 3 N., R. 13 W., about 3 miles SW of Mt. Sheridan, Wichita Mountains, Oklahoma. The micrograph shows anhedral to subhedral overlapping plates of sassolite. The transparent platy material may be an admixed montmorillonite clay.**

probably related to differences in the size of crystals between the natural and synthetic individual. Also, preferred orientation of plates is probably more accentuated in x-ray samples prepared from the synthetic material. The pattern for analytical reagent boric acid, which is more completely developed than the pattern for sassolite from Oklahoma, confirms the identity of this mineral.

BORACITE

The boracite crystals have the form of cubes truncated by octahedron, a crystal habit similar to those found in Choctaw salt dome in Louisiana (Hurlbut and Taylor, 1938: 899–900). The boracite is white to grayish-white in color; some are colorless with a corroded appearance and dull vitreous luster. The fracture is uneven. The hard-

TABLE II

X-ray Pattern: Interplaner Spacings and Relative Intensities
Ni-filtered Cu Radiation

| Sassolite, Oklahoma | | Sassolite, California (Allen and Kramer, 1957) | | Boric Acid, C. P. | |
|---|---|---|---|---|---|
| d (Å) | I | d (Å) | I | d (Å) | I |
| 6.04 | 1 | 6.02 | 1 | 6.04 | 3 |
| 5.90 | < 1 | 5.89 | < 1 | 5.91 | < 1 |
| 4.58 | < 1 | 4.59 | < 1 | 4.60 | < 1 |
| 4.20 | < 1 | 4.20 | < 1 | 4.22 | < 1 |
| 4.03 | < 1 | 4.04 | < 1 | 4.06 | < 1 |
| 3.50 | < 1 | 3.52 | < 1 | 3.50 | < 1 |
| 3.18 | 10 | 3.18 | 10 | 3.18 | 10 |
| ... | | ... | | 3.02 | < 1 |
| ... | | 2.95 | < 1 | 2.94 | < 1 |
| 2.90 | < 1 | 2.92 | < 1 | 2.92 | < 1 |
| ... | | ... | | 2.84 | < 1 |
| .... | | 2.71 | < 1 | 2.70 | < 1 |
| ... | | 2.64 | < 1 | 2.64 | 1 |
| 2.54 | < 1 | 2.56 | < 1 | 2.55 | < 1 |
| ... | | ... | | 2.53 | < 1 |
| ... | | ... | | 2.48 | < 1 |
| ... | | ... | | 2.28 | < 1 |
| ... | | 2.23 | < 1 | 2.22 | < 1 |
| ... | | ... | | 2.10 | < 1 |
| ... | | ... | | 2.04 | 1 |
| 1.948 | < 1 | 1.949 | < 1 | 1.948 | < 1 |
| ... | | ... | | 1.904 | < 1 |
| ... | | ... | | 1.886 | < 1 |
| ... | | ... | | 1.690 | < 1 |
| ... | | ... | | 1.670 | < 1 |
| ... | | ... | | 1.640 | < 1 |
| 1.588 | < 1 | 1.590 | 1 | 1.590 | 2 |

ness is about equal to that of quartz, and the crystals scratch the blade of a pocket-knife with ease. The specific gravity is 2.92.

Optically the mineral is biaxial. Indices of refraction were found to be: $N_x = 1.656$, $N_y = 1.662$, and $N_z = 1.667$. Optical sign is positive. Eight measurements of optical axial angles enclosing the acute bisectrix by universal stage gave an average value 2V 82°, the values ranging from 79° to 85°.

Although the specific gravity for Oklahoma boracite is the most reported one (Palache, Berman, and Frondel, 1944, p. 379; also ref. no. 9, p. 381), the refractive index values are close to those recorded for Aislaby boracite by Guppy (1944, p. 52).

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Mr. Jerry Sparkman, Jr., student of the University of Oklahoma, for field assistance and for the boron minerals found in the core samples that he contributed to this investigation. Field observations and laboratory work were carried out during the academic year of 1953–1954 when the writer was teaching at the University of Oklahoma. The work was continued and completed at the University of Illinois while attending the first Summer Institute in Geology for College Teachers, 1957 which was supported by a grant from the National Science Foundation. Appreciation is expressed to Dr. D. M. Henderson and Dr. A. F. Hagner, Co-directors of the Institute, for their keen interest and assistance in the work. The writer has also benefited through discussions with Dr. R. M. Garrels, Associate Director of the Institute. Dr. A. E. Vatter kindly took the electron micrograph.

Special thanks are due to Dr. R. D. Allen, Jet Propulsion Laboratory, California Institute of Technology, for the California sassolite sample and for discussion of X-ray crystallography of that mineral.

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# The Relation Between Liver Weight and Degree of Restoration After Partial Hepatectomy in Rana pipiens

*by* **J. C. STREETT, JR.**

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INTRODUCTION

In the course of investigations of the restorative powers of the liver of the leopard frog after a portion had been removed, an attempt was made to secure a growth curve. The experiment was based upon a mistaken impression, derived from a few morphological data, of the time required for full restoration to occur. When the results had been graphically arranged, the progress of restoration showed unexpected decrements during two distinct periods of time after partial hepatectomy. (Table 1). At the time there was no explanation for such fluctuations. What had begun as a simple inspection of phenomena turned out to entail such complications as make it desirable to present here the quantitative findings while reserving the morphological aspect for later treatment.

Several studies appear in the literature concerning the rate and extent of liver restoration under experimental conditions. Fishback (1929) found restoration complete in dogs in from six to eight weeks after removing about 70% of the liver. In the rat, Higgins and Anderson (1931) found restoration complete by 28 days, and Brues, Drury, and Brues (1936) found the remnant doubling in volume within two days and in cell number within three days following 70% removal.

In the domestic fowl the remnant restores in four months an amount of tissue greater than the amount removed provided the portal circulation is increased by surgical means. (Higgins, Mann, and Priestley, 1932).

The most thorough study to appear concerning restorative processes of the amphibian liver is that of Heberlein (1930) who found extensive "compensatory hypertrophy" in *Siredon pisciforme* in 70 days. Jordan and Beams (1930) observed some restoration in the liver of *Triturus viridescens* during the third month after partial hepatectomy. The effects of temperature, bile duct ligation, and circulation upon liver restoration in *Bufo arenarum* have been reported by Flores (1951).

It will be seen that the data for a true growth curve for the restoring liver of *Rana pipiens* have not been fully gathered. The purpose of securing such a curve is partly to furnish a comparison with other species, but primarily to detect a critical time of gain as a basis for investigating the histological and chemical factors of restoration. This paper presents an account of an unexpected relationship between the weight of the liver at the time of partial hepatectomy and the degree of restoration observed.

## MATERIALS AND METHODS

A. *Technical.* The specimens were sexually mature female *Rana pipiens* obtained commercially from Stillwater, Minnesota, and ranging in body length from 71 to 102 mm., and averaging 82 mm. Upon arrival in the laboratory they were placed in separate aquaria in 0.15% NaCl in tap water after the recommendation of Rose (1946) and so maintained for the duration of the experiment.

Under ether anesthesia and a putative aseptic routine, the left lobe of the liver was exposed through a left paramedian incision and the isthmus was securely ligated with cotton thread. The isthmus was then severed immediately distal to the ligature and the left lobe removed. The muscle and skin were then closed by 4–0 or 5–0 plain catgut, and the frog was returned to its aquarium. The left lobe was bled on absorbent paper and weighed to the nearest 0.01 gram and preserved in Bouin's or 10% formalin. At the time of sacrifice the remnant was removed and handled as in the case of the biopsy, except that the gall bladder and the tag of pancreas were trimmed away prior to weighing.

The frogs were sacrificed at 1, 30, 50, 70, 90, 110, 130, 150, 170, and 200 days after operation. Counting frogs other than the 1 and 30 day groups, 44.7% died before time of sacrifice and are not further considered here. The losses were made good by additional operations until 20 frogs survived to be sacrificed in each time group. For the purpose of clearness the foregoing specimens are termed experimental frogs.

The animals were fed upon such insects as became abundant from season to season, including June beetles, moths, grasshoppers, and crickets. In cold weather they were given mealworms or force fed with pieces of beef heart.

B. *Statistical.* The operative procedure above described left the right and middle lobes as the remnant and involved the removal of the entire left lobe as the biopsy. In order to determine the average proportion of the weight of the remnant to that of the entire liver, a series of 44 normal frogs was sacrificed and in the case of each the weights of the entire liver and of the remnant were determined. These are termed statistical frogs. The left lobe was removed by ligating and cutting before removal of the rest of the organ, and the livers were handled in all other respects as with the experimental frogs except that they were not preserved. The remnant was found to average 70.98% of the weight of the entire liver as found by the expression

$$(1)\quad \frac{Rs \times 100}{Rs + Bs}$$

where

Rs=weight of remnant (right and middle lobes) of statistical frogs; and

Bs=weight of biopsy (left lobe) of statistical frogs.

It had been the plan to use the above data with the experimental frogs as a basis for estimating, at the time of operation, the weight of the entire liver from the weight of the biopsy. However, when the standard deviation was found to be ± 5.51, the use of an approach having a smaller variability appeared desirable.

By modifying expression (1):

$$\frac{(Rs + Bs) \times 100}{Rs + 2Bs} = 77.64$$

with a standard deviation of ± 3.31.

Now, should the remnant in the experimental frog just make up through restoration for the amount of tissue lost, its weight would be equal to that of the entire original liver before surgery. Therefore, when restoration is complete,

$$Re = Rs + Bs, \text{ and}$$
$$Re + Be = Rs + 2Bs$$

where

Re=weight of remnant of the experimental frog at the time of sacrifice, and

Be=weight of biopsy of experimental frog at the time of operation.

By arranging equivalent terms,

$$(2)\quad \frac{(Rs + Bs) \times 100}{Rs + 2Bs} = \frac{Re \times 100}{Re + Be} = 77.64,$$ the figure used as the index of 100% restoration. The determination resulting from expression (2) is accordingly termed the gain, so that 77.64 gain = 100% restoration.

It could be predicted that where experimental frogs were sacrificed before the restoration process could begin, the gain would approximate 70.98, the average finding of expression (1). In fact, the average gain for the 20 frogs which were sacrificed one day after surgery was found to be 70.84.

The gain values were averaged for each age group of experimental frogs in the construction of Table 1, and by biopsy weight groups in the construction of Table 2. The other statistical determinations were made according to standard methods. The coefficient of correlation was calculated as between biopsy weight and gain, biopsy weight and total liver weight, and between total liver weight and body length.

## RESULTS

Between one and thirty days after operation the remnant increased in weight to a point in substantial excess of complete restoration, but this gain was followed through 50, 70, and 90 days by a steady decline in weight to a level which indicated superficially that most of the ground initially won had been lost. Between 90 and 110 days there was another increase, again to a degree in excess of 100% restoration, and this level was maintained through 170 days. Between 170 and 200 days there was a second decline to a point somewhat below 100% restoration. These observations are presented in Table 1.

TABLE 1

Average gain in remnant of liver in 200 frogs at intervals after partial hepatectomy

| Days after operation | 1 | 30 | 50 | 70 | 90 | 110 | 130 | 150 | 170 | 200 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gain | 70.8 | 79.9 | 74.9 | 73.1 | 72.7 | 80.9 | 80.7 | 80.6 | 80.5 | 76.3 |

The data so presented appeared meaningless in relation to growth, and indeed they raised a serious question as to the permanence of any gain so far as indicated by weight. There is yet no explanation on histological grounds for the decrements observed after 30 and 170 days. However, upon recanvassing the original measurements, it was found that the biopsies representing the 50, 70, 90, and 200 day frogs happened to include an unusually large number which were above the average in weight. The individual biopsy weight and gain for each of the 180 frogs in the 30 through 200 day groups were accordingly plotted on a scatter diagram, which then revealed a trend of inverse relationship between biopsy weight and gain. Mathematically the same data yielded a significant negative correlation, r = —.5944. The results are summarized in Table 2.

Concerning the question of whether a heavy biopsy necessarily means a heavy liver, the answer would seem obvious in view of the technique of measurement described. However, the data from the 44

TABLE 2

Average gain corresponding with biopsy weights averaged by classes as indicated, for the 180 frogs sacrificed 30 or more days after operation

| Biopsy weight, grams Class range | Class value | Frequency | Average gain |
|---|---|---|---|
| 0.16–0.25 | 0.206 | 20 | 83.8 |
| 0.26–0.35 | 0.304 | 24 | 81.8 |
| 0.36–0.45 | 0.405 | 52 | 79.7 |
| 0.46–0.55 | 0.510 | 27 | 78.0 |
| 0.56–0.65 | 0.606 | 21 | 76.9 |
| 0.66–0.75 | 0.704 | 12 | 72.9 |
| 0.76–0.85 | 0.795 | 14 | 71.3 |
| 0.86–0.95 | .... | 3 | |
| 0.96–1.05 | .... | 2 | |
| 1.06–1.15 | .... | 2 | |
| 1.16–1.25 | .... | 2 | 65.5 |
| 1.26–1.35 | .... | 0 | |
| 1.36–1.45 | .... | 0 | |
| 1.46–1.55 | .... | 1 | |

statistical frogs and the 20 one day experimental frogs were combined and a high correlation was found as between biopsy weight and total liver weight: r = +0. 8973.

Table 3 shows the gain expectancy related to biopsies of different weight ranges. The proportion of individuals showing 100% or more restoration declines with increasing biopsy weights. No interpretation can yet be offered for those cases which apparently terminated with less tissue than the operation presumably left them. For the 155 frogs whose gain was 71.0 or more, the r value between biopsy weight and gain was —0.5289.

In view of the commonly held opinion that regenerative powers of an animal decline with age, the question arises whether the age factor

TABLE 3

Percentage of cases showing 100% or more restoration according to biopsy weights. 180 animals, 30 through 200 days after operation.

| Biopsy weight, grams Class range | Frequency | % showing 100% or more restoration |
|---|---|---|
| 0.1–0.39 | 68 | 79.5 |
| 0.4–0.69 | 81 | 56.8 |
| 0.7–0.99 | 25 | 8.3 |
| 1.0–1.47 | 6 | 0.0 |

influences the results outlined above. There was no information available concerning the age of the specimens. The 100 animals showing the greatest gain, namely the 30, 110, 130, 150, and 170 day groups, included 53 which ranged in body length from average to the extreme high figure (102 mm.). Of these, 44, or 83.0% showed 100% or more restoration. While the data thus do not necessarily support an age factor, it could not be satisfactorily eliminated by any other test which was applied.

A serious criticism of the results might arise from the possible fluctuation of the weight of the frog liver at different seasons, so that a frog operated upon when the liver is light and autopsied when it is heavy would present a spurious impression of a gain which might in fact be due to natural seasonal changes rather than to experimental conditions. The ratio of biopsy weight/body length did show a tendency for the liver to reach maximum weight in September and to decline to a minimum through May and June. The fact that the experiments were carried out through all seasons would seem to minimize this source of error. However, there were 39 experimental frogs which were sacrificed at a season when their livers would be hypothetically either equal to, or, in the majority of cases, lighter than their original weight. The average gain for this group was 79.3 and the inverse correlation between biopsy weight and gain was high: $r = —0.7918$. Moreover, most of those frogs showing a decrement, namely the 50, 70, 90, and 200 day groups, were operated "light" and autopsied "heavy," so that the results contradict what would be expected from fluctuations of a seasonal character alone. For these reasons the influence, if any, of seasonal changes in the weight of the liver is held to be negligible.

Should the restoration process be superimposed upon the natural growth of the animal, the gain apparently would be higher than that reflecting restoration alone. There was no evidence of body growth in any of the specimens. Among the 30 and 50 day groups were 32 frogs showing a gain of 71.0 or better. Their value for biopsy weight and gain was −0.7049, and it may be doubted that 50 days' time would be sufficient to allow growth to impair the interpretation of the results.

## DISCUSSION

The results demonstrate that, after removal of the left lobe, the average frog restored in excess of 100% of the tissue removed by 30 days after operation, insofar as gain in weight indicates the progress of restoration. This finding appears to be in contrast to the results of Heberlein (1930) for *Siredon pisciforme* and of Jordan and Beams (1930) for *Triturus viridescens*, although quantitative data were not reported.

There is also demonstrated an inverse relationship between the original weight of the liver and the degree of restoration. The presence of many variants requires this relationship to be described as a trend whose direction in individual cases is modified by vectors of largely unknown character and magnitude. Since partial hepatectomy places an increased functional demand upon the remnant, the results should be considered in relation to the liver reserve, which may be read as the power of the part to assume the function of the whole. It may be considered that where the reserve is small, the removal of tissue so taxes the remnant as to stimulate it into hypertrophy, whereas in case there is a large reserve the added burden of function may be assumed by the remnant without much increase in weight. An obvious test of this hypothesis is to increase the functional demand by removing two lobes and observing the effect upon the heavier livers. Such an investigation is now in progress. While it would seem obvious that the greater reserve is associated with the heavier organ, this circumstance assumed additional interest upon failure to show a significant correlation between total liver weight and body length among the combined statistical and 1 day experimental frogs.

The results also account for the data of Table 1. In those frogs where a patent degree of restoration occurred the process was completed by 30 days, and if biopsies weighing 10% or more above average are eliminated from consideration it can be shown that the gain is permanent and that the decrements are essentially spurious.

## SUMMARY

1. From a series of 44 leopard frogs the liver was removed and weighed, and the proportion by weight of the right and middle lobes to the weight of the entire liver was determined. A formula is described for reducing the degree of variability of the data.

2. The left lobe of the liver was surgically removed from a series of 200 experimental frogs, which were sacrificed at intervals through 200 days after partial hepatectomy. The results of the procedure mentioned in (1) above were used to assess the degree and time of restoration on the part of the remnant.

3. There was no restoration in frogs sacrificed 1 day after operation, but restoration was in excess of 100% by 30 days.

4. An inverse relationship is demonstrated between the original weight of the liver and the degree of restoration. This result is discussed in relation to the liver reserve.

ACKNOWLEDGEMENT

It is with great pleasure that the author expresses his indebtedness to the trustees of the Brown-Lupton Fund of Fort Worth for their generosity in supporting the investigations; to Dr. E. M. Bowman of Texas Wesleyan College for his counsel on statistical interpretation; to Mr. James L. Morris for the use of his shop facilities; and to Mrs. Frances H. Streett for the final preparation of the manuscript.

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## Science in Texas

Dr. Robert C. De Hart has recently joined the staff of Southwest Research Institute as manager of the structural mechanics section of the Department of Engineering Mechanics. He will be responsible for the development of a research program directed toward the solution of industrial, armed forces and other government agency problems concerning structural response to static and dynamic loads and thermal radiation. For the past three years he has served as an aeronautical research engineer with the Armed Forces Special Weapons Projects, Washington, D.C., where he conducted research concerning the effect of nuclear weapon blast forces and thermal radiation on aircraft, structures and equipment.

While on the staff of the Illinois Institute of Technology and Armour Research Foundation, Dr. De Hart conducted a research program aimed at reducing the cost of multi-story housing structures. He has also designed pressure vessels, piping systems and industrial structures for oil processing plants for the Standard Oil Company of Indiana.

Dr. De Hart has a B.S. in civil engineering from the University of Wyoming and M.S. and Ph.D. degrees in the same field from the Illinois Institute of Technology. He has taught civil engineering at Montana State College and at George Washington University.

★ ★ ★ ★

Professor Phil M. Ferguson, University of Texas civil engineer, on February 26 was honored by award of the American Concrete Institute's Wason medal for his study of the problems of diagonal cracks in concrete construction. Professor Ferguson was also named "Outstanding Engineer of the Year" by the Travis chapter, Texas Society of Professional Engineers.

★ ★ ★ ★

Patrick E. Haggerty, executive vice president of Texas Instruments, Inc., Dallas, has recently been elected a Fellow of the Institute of Radio Engineers. The award was based on Mr. Haggerty's "dynamic and inspiring management of the electronics activities of his company and his large personal part in leading the technical efforts of Texas Instruments." The citation reads: "For leadership in the advancement of the semiconductor industry."

Dr. Frederick A. Matsen, professor of theoretical chemistry and physics at The University of Texas, was awarded a $40,000 grant by the American Chemical Society in recognition of his achievements in basic chemical research. The award, given to advance basic research "of potential value in the petroleum field," will provide funds for two years' research, from September 1, 1958, to August 31, 1960. The funds may be used by Dr. Matsen in any way he sees fit, to advance the research for which the award is made. It will further his fundamental research on the theory of organic molecules, through which Dr. Matsen attempts to predict "from the first principles what the properties of molecules will be." His approach is mathematical rather than experimental.

★ ★ ★ ★

Dr. Fred C. Jonah, of Chance Vought Aircraft, Inc., in Dallas, taught a special course on latest advances in missiles and piloted aircraft systems at The University of Texas this spring. In the course, "Advanced Problems in Aircraft Systems Design," Dr. Jonah lectured on various aspects of aerodynamics: structural analysis, control, guidance and propulsion.

★ ★ ★ ★

A special series of lectures in Botany at The University of Texas during the spring term featured two international and six American scientists. Dr. Torbjorn Caspersson, of Karolinska Institute, in Stockholm, Sweden, presented lectures on cell growth and differentiation during February. During March, Dr. Hans Gaffron, University of Chicago biochemist, David Rockwell Goddard, University of Pennsylvania biology division director, and Dr. Arnold Hicks, senior cytologists with Brookhaven National Laboratory, Upton, N.Y., lectured in the series. Scientists visiting in April were Dr. Alfred Ezra Mirsky, of the Rockefeller Institute for Medical Research, New York City, Dr. Carl Pontius Swanson, Johns Hopkins University biologist, and Dr. Arthur William Galston, Yale University plant physiologist. The series was concluded in May with lectures by Dr. Robert Brown, of Oxford University, England. General topic for the series was "The cell and the modern interrelationship of its structure and function."

★ ★ ★ ★

Dr. O. P. Breland, University of Texas zoologist, is investigating the possible significance of Haemagogus mosquitoes near Brownsville. His research is being sponsored by the Department of the Army, Office of the Surgeon General. Presence of the Haemagogus mosquito near Brownsville, added to the fact that the yellow fever virus is moving northward toward the United States with jungle animals as carriers, increases chances of reintroduction of the disease, Dr. Breland said.

He has conducted an intensive search along the Texas-Mexico border to determine how well the Haemagogus mosquito has established its breeding areas. Common breeding places for the "jungle mosquito" are water-filled tree holes. In making collections from 100 breeding holes from Brownsville to El Paso, Dr. Breland found Haemagogus six different times, all in the Brownsville vicinity.

Yellow fever has been eliminated from the United States for many years, but several years ago yellow fever broke out in South and Central America. The virus kept alive in monkeys and other jungle animals, is gradually moving north with those animals as carriers. Last year the virus was carried into Guatemala, Dr. Breland said. "The virus is moving northward about 60 miles a year, but we don't know if it'll keep moving at this rate or not."

★ ★ ★ ★

A new periodical, The Texas Quarterly, began publication this spring. It is of interest to scientists as well as scholars in other fields. Among articles in the first issue are "Natural and Supernatural," by C. Judson Herrick, "The Improper Study of Mankind," by Roger J. Williams, "Structure of the Nucleus," by C. W. Horton, "Aristotle and the American Indians," by Lewis Hanke, as well as others in the sciences, social sciences and humanities.

★ ★ ★ ★

The Spring semester, 1958, saw the introduction of a new course, Aviation Physiology, in the evening division at Incarnate Word College, San Antonio, Texas, This course offering is the only one of its kind offered on the college level in the entire Southwest area. Reportedly, there are only three other colleges in the United States which offer a similar course, in addition to two military schools. Among others, the course at Incarnate Word College will include: physics of the atmosphere, effects of altitude on the respiratory and circulatory systems, hypoxia, altitude dysbarism, acceleration and "G" Forces, hypoglycemia, hyperventilation, physiologic problems of space flight and space travel, cabin pressurization and sudden depressurization. The course is taught by Dr. Domenic A. Vavala, who joined the Incarnate Word College faculty in February, as Special Instructor in Aviation Physiology.

★ ★ ★ ★

Two reports of a survey of administrative practices and board policies in Texas public schools are available from Texas Committee of Ten, P.O. Box 7721, Austin 12. Titles are "Pupil Personnel Practices in Texas Public Schools" and "Staff Personnel Practices in Texas Public Schools." The reports are based on data collected and compiled by the Texas Committee of Ten, a research and study group appointed jointly by the Texas Association of School Administrators and the Texas Association of School Boards.

★ ★ ★ ★

A University of Texas Biochemical Institute scientist, Dr. Roy B. Mefferd, Jr., has been awarded a U. S. Air Force contract for $24,903 to help set up biochemical tests for preselecting pilots who can withstand prolonged stress better than others. With 300 selected cadets from Lackland Air Force Base, Dr. Mefferd and his associates will conduct intensive tests to establish a "normal reaction pattern" of human beings to altitude and temperature stresses. A new approach will be taken by investigating the "whole man." Each cadet will be studied in detail, not only on the basis of the usual psychological tests, but also from physiological, biochemical and even dental approaches. Dr. Louis J. Moran has devised the psychological tests to be used, and will collaborate in the interscience investigation.

★ ★ ★ ★

An 18-month study of junior college community service programs will be supported by a $50,000 research grant from the U. S. Department of Health, Education and Welfare. Dr. James W. Reynolds, University of Texas professor of junior college education, will direct the study. He will attempt to discover "definitive criteria for an accurate description of junior-college community-service programs through an analysis of programs with community-service characteristics and geographical communities served by those junior colleges." The research will be conducted in four regions of the U. S., with several junior colleges in each region serving as experimental centers.

★ ★ ★ ★

A $25,860 one-year grant has been made by the U. S. Department of Health, Education and Welfare to Dr. Clarence P. Oliver and Dr. Robert P. Wagner, specialists in genetics at The University of Texas. They will investigate "inherited metabolic blocks" which prevent some people from utilizing foods in a normal manner. Inheritance data on different family groups from all over Texas will be compiled for comparison studies in connection with the research.

★ ★ ★ ★

Dr. W. Frank Blair, University of Texas zoologist, has been awarded $15,300 from the National Science Foundation for a three-year continuation of his studies of interbreeding in amphibian populations.

★ ★ ★ ★

Dr. Norman Hackerman, chemist and Corrosion Research Laboratory director at The University of Texas, received $33,290 from the

Office of Naval Research metallurgy branch, for a three-year research project on surface adsorption and corrosion reactions of metals.

★ ★ ★ ★

Geneticists Wilson S. Stone and Marshall R. Wheeler of The University of Texas will expand their fruit fly research into the Caribbean region and four South American countries on a three-year grant of $25,000 from the National Science Foundation. Dr. Wheeler is now in South America collecting new specimens and living strains of Drosophila flies. The investigators are making extensive fruit fly collections in order to conduct species relationship studies of the genus Drosophila of North, South and Central America. In the current collecting trip, Dr. Wheeler, accompanied by Dr. Theodosius Dobzhansky, Columbia University geneticist, is covering Colombia, Ecuador and Panama. They plan to collect specimens also in Honduras, Costa Rica and Trinidad. Dr. Marvin Wasserman, Genetics Foundation research scientist, has gone to Brazil and Bolivia to collect specimens.

★ ★ ★ ★

The basic ecology of a 5-acre Puerto Rican rainforest was investigated on a $10,000 Rockefeller Foundation grant to two University of Texas scientists, Dr. Howard Odum, director of the Institute of Marine Science at Port Aransas, and Dr. Robert Keith Selander, zoologist. "After obtaining basic ecological data, we can determine the metabolism of the rainforest—how fast energy flows through that type of natural community," Dr. Selander explained. The scientists spent a month in the area on a pilot investigation to determine "whether the research problem is so big that it will not be feasible to attempt it." In determining the basic ecology of a tropical rainforest, the scientists want to find out how much living material is in the area, the percent of total mass taken up by insects, amphibians, plant growth, etc. In calculating the rainforest's "biomass," i.e., weight of biota—plants and animals, they took an animal census. They will hire natives to help them trap and weigh all the mammals in an effort to determine the area's mammal population. In their inch-by-inch and pound-by-pound rainforest investigation, they will also determine the amount of chlorophyl in the plants by using a colorimeter, chlorophyl measuring device.

★ ★ ★ ★

About 300 Texas psychology students will be the subjects in a new study on "the influence of serial associations formed during paired associate learning." The National Science Foundation has granted $5,000 to Dr. Robert K. Young, University psychologist, for a two-year project on how learning takes place. The subjects will look at words flashed on a screen, first in sequence, then in pairs. Relationships between the two standard types of learning will be studied.

★ ★ ★ ★

Dr. Frederick H. Kasten, Assistant Professor of Biology, A&M College, recently received notice of a substantial grant from the United States Public Health Service. The award of $25,409 was granted by the National Advisory Council (Cancer) and approved by the Surgeon General. Notice was received from Dr. R. G. Meader, Chief of the Research Grants of the National Cancer Institute. The work is to be administered through the A. and M. Research Foundation over a three-year period. Dr. Kasten will make a Cytochemical Study of Nucleic Acids and Proteins in Certain Mouse Tumors. Because of their importance in cell division and metabolism, these chemicals have been of particular research interest in recent years.

★ ★ ★ ★

The Civil Aeronautics Administration has awarded a contract for $4,691,000 to Texas Instruments, Inc., Dallas, for airport surveillance radar systems to be installed at 14 different sites. These systems will embody many new improvements over systems currently in use at several airports of the country. They are being installed at Albany, N. Y., Fort Wayne, Ind., Akron, O., Burlington, Vt., Sacramento, Calif., Charleston, S. C., Bedford, Mass., Boise, Idaho, Charlotte, N. C., Little Rock, Ark., Youngstown, O., Rochester, N. Y., Syracuse, N. Y., and Orlando, Fla.

★ ★ ★ ★

Texas Instruments, Inc., of Dallas, and the International Business Machines Corporation announced the first of the year that an agreement had been signed under which both companies will work together in the area of transistors for data processing machines. The agreement is expected to expedite progress in this area of interest to both companies through the exchange of technical information.

★ ★ ★ ★

The Texas Petroleum Research Committee has approved a study to be made by Dr. George W. Crawford, assistant director of the committee, of gamma radiation effects on crude oil. It will investigate the possibility that radioactive waste may open up new avenues for secondary oil recovery methods. "Injection of radioactive waste materials in some carefully chosen reservoirs should result in a new secondary recovery method, as well as offer a safe way to store radioactive waste—provided all the tremendous problems involved can be solved," Dr. Crawford said. "Gamma radiation bombardment of the crude oil breaks the bonds holding the heavy molecules together, thus causing the formation of lighter molecules from the heavy molecules. The resulting condition decreases the oil viscosity and permits recovery by a secondary process."

★ ★ ★ ★

The Texas Department of Health has made a grant for an eight-month study of the amount of "natural occurring" radioactivity in Texas streams and river sediments. Dr. Ernest F. Gloyna, University Sanitary Engineering Project director will conduct the study. David F. Smallhurst, chief engineer, Division of Water Resources, and Dr. Henry Holle, Commissioner of Health, are coordinators of the project. The goal will be to determine the "base level" of radioactivity presently in Texas streams. The base level is the amount of naturally occurring radiation in the streams plus the artificially produced radiation distributed since the 1945 atomic bomb explosions. The project will be an "analytical operation," and it is hoped that research will provide a standardized procedure for measuring small amounts of radiation occurring in surface waters.

★ ★ ★ ★

A new $10,000 loan fund has been established for University of Texas engineering students by the William A. and Elizabeth B. Moncrief Foundation of Fort Worth, Engineering Dean W. R. Woolrich announced. The fund will provide loans to financially-needy and worthy University engineering students who are U. S. citizens. A student will be allowed to borrow up to $300 per semester. The fund will be administered through a trust agreement between the Foundation and the American National Bank of Austin. Applications for loans will be considered by a committee composed of Dr. George H. Fancher, petroleum engineering department chairman and Dean Woolrich. W. A. Moncrief is a prominent member of the oil industry and a long-time friend of the University," Dr. Fancher commented. His son, W. A. "Tex" Moncrief, Jr., also of Fort Worth, who is president of the Foundation, received a University of Texas degree in petroleum engineering in 1942.

★ ★ ★ ★

The University of Texas will receive two post-graduate fellowship grants from the Du Pont Company during the next academic year, one in chemistry and other in chemical engineering. Each fellowship provides $1,500 for the student, with an additional allowance of $600 for a married student. Tuition and educational fees also are paid and contribution of $1,200 is made to the University with each fellowship. Purpose of the fellowships is to encourage advanced training in chemistry, engineering and other sciences. Recipients are selected by the University.

To support studies of the mourning dove in Texas, the Rob and Bessie Welder Wildlife Foundation of Sinton has established a new research scholarship at The University of Texas. Aim of the scholarship will be to further knowledge of the density and production of nesting populations and other aspects of the mourning dove's relation to its environment. Field studies are to be carried out on the Welder Wildlife Refuge near Sinton from February through August, 1958, during which period the student may reside on the refuge. Course work will be taken at the University's main campus in Austin. Cooperating agencies are the Texas Game and Fish Commission and the U. S. Fish and Wildlife Service. The $2,400 scholarship is for a 12-month period starting September 1, 1957, with provision for renewal if satisfactory progress is made. An additional sum of $500 is provided to cover travel expenses. The appointee must qualify for graduate standing in the University and must have a superior academic record in zoology. He may be a candidate for either a Master of Arts or Doctor of Philosophy degree. Scholarship applicants should contact Dr. Robert K. Selander, Zoology Department, University of Texas, Austin 12, Texas.

★ ★ ★ ★

The Brazoport community comprising five towns have launched a plan for an Oceanarium on the Gulf Coast near Freeport. At the initiative of the chamber of commerce and acting through the county Commissioners they plan a bond issue of several million dollars for this project. It will combine public entertainment with an educational program and continuous research on marine life. The operation will be headed by a directorate containing both business men from the Brazoport area and a technical group of scientific advisors.

A volunteer scientific group has been meeting and pushing this project on a high level of operation. Ray MacAllister from A. and M. College originally headed the group but because of pressure of duties he has resigned. Five elected representatives of the scientific group asked the Texas Academy of Science to give them their official approval to act on this projct. These five are temporarily included in the directorate until the entire organization has been stabilized. The Academy which has been interested in an Oceanarium for many years has approved the representatives. This carries no financial obligation. Richard M. Adams of A. and M. College is the present Chairman of the Scientific group.

# ERRATA

in

"Tertiary formations of Rim Rock country, Presidio County, Trans-Pecos Texas"

By Ronald K. DeFord

The Texas Journal of Science, v. 10, no. 1 (March, 1958).

Page 6, line 36: change *Cabeza de Vava* to *Cabeza de Vaca.*

Page 13, line 19: change *contract* to *contact.*

Page 13, footnote 4: change *well* to *all.*

Page 23, 7th line from bottom: delete TOP OF VIEJA GRCUP.

Page 36, Solms-Braunfels: change *1946b* to *1846b.*

# THE TEXAS JOURNAL OF SCIENCE

Volume X, No. 2 June, 1958

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## Cover Picture

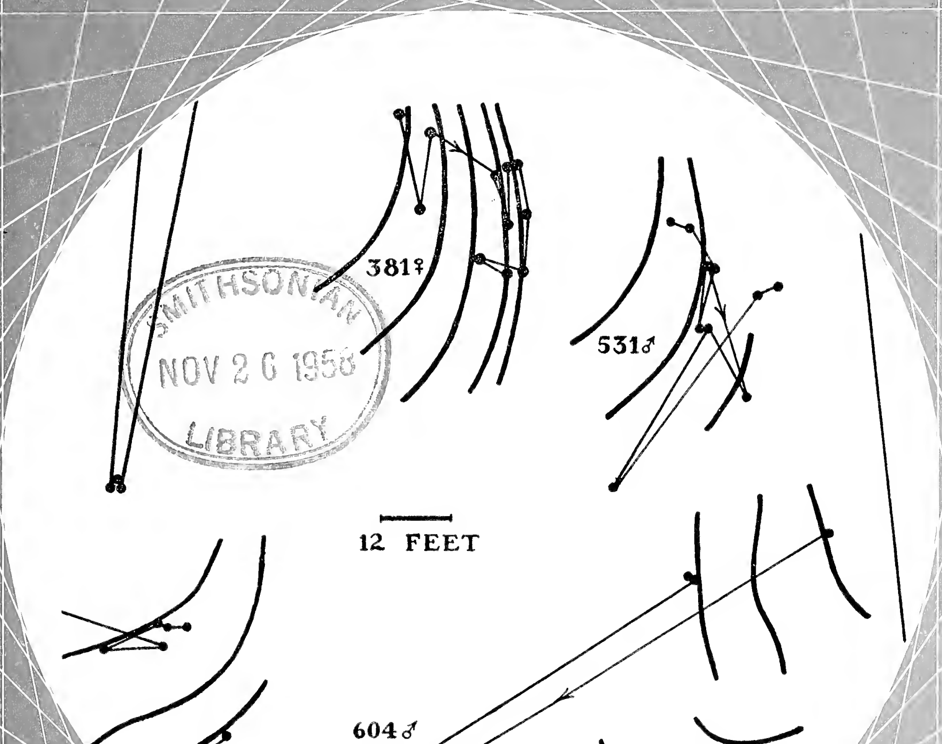
Diagram of a transverse section through the skull of the Mexican toad. For further information on the skull of this amphibian, see "Contributions to the Cranial Morphology of *Bufo valiceps* Wiegmann' by Richard J. Baldauf. The picture is taken from figure 12 of his paper.

VOL. X, NO. 3 SEPTEMBER, 1958



# THE TEXAS JOURNAL OF SCIENCE

PUBLISHED QUARTERLY BY THE TEXAS ACADEMY OF SCIENCE



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TEXAS JOURNAL OF SCIENCE. The JOURNAL is a quarterly publication of The Texas Academy of Science and is sent to all members. Institutions may obtain the JOURNAL for $5.00 per year. Single copies may be purchased from the Editor for $1.25.

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Volume X, No. 3 September, 1958

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# Radar Observations of Blackbird Flights[1]

*by* **MYRON G. H. LIGDA**

*A. & M. College of Texas*[2]

## INTRODUCTION

At the Sixth Weather Radar Conference in Cambridge, Mass., Floyd C. Elder of the University of Michigan gave a thought-provoking paper (2) describing radar echoes which expanded in circular rings from a number of fixed points ranging from 4.7 to 21 miles distant from his radar station at the Willow Run Airport. The reader is referred to Elder's article for details of the observations which were made with a 23-cm wavelength radar, an AN/FPS-3.

Perhaps because of the striking similarity these echoes bear to ripples resulting when a stone is dropped into a quiet pool of water (see Fig. 2), Elder hypothesized that such echoes might conceivably have resulted from strong downward refraction of the radar beam by atmospheric gravity waves expanding from a localized disturbance of low-level temperature inversions. It may be remarked that this explanation is rather hard to accept for several reasons; Elder himself does not seem to be entirely satisfied with it.

The Elder pictures were obtained under conditions of radar adjustment which are never duplicated in films studied by the Radar Meteorology Section at Texas A. & M. College (very short range setting and use of moving target indication), so little hope was held of seeing similar echoes in radarscope film records obtained from the network of stations providing us with data, though it spans the United States. However, in routine inspection of some film obtained from the Air Defense Command Radar at Texarkana, Texas, during the summer of 1957, expanding ring echoes of a somewhat similar nature were found.

[1] Contribution from the Department of Oceanography and Meteorology, the Agricultural and Mechanical College of Texas, Oceanography and Meteorology Series No. *114*, based on investigations conducted for the Texas A & M Research Foundation through the sponsorship of the Geophysics Research Directorate of the Air Force Cambridge Research Center, Air Research and Development Command, under Contract No. AF 19(604)–1564.

[2] Now at Stanford Research Institute, Menlo Park, California.

DESCRIPTION OF THE PHENOMENON

While grossly similar to the Michigan rings, those detected at Texarkana had some basic differences. These may be briefly summarized:

1. Speed of radial growth was only about 15 mph for all rings detected, while the Michigan rings expanded at from twice to six times this rate.
2. One, and only one, ring was detected each day, in contrast to the Michigan observation where four or five and more a day were frequently observed.
3. Only one ring was observed to grow from an origin; (as many as three concentric rings were seen at one time spreading from the same point at Michigan).
4. All Texarkana rings were observed to start about the same time each and every day and end from 1–1½ hours later. Rings were observed to form and grow over periods of several hours at Michigan.
5. Texarkana rings grew broader and more diffuse as they expanded in contrast to the Michigan rings which showed no behavior of this type. (See Figs. 1 and 2.)
6. All Texarkana rings disappeared at more distant ranges first and nearest ranges last; Michigan rings faded at all points at about the same time.
7. The Texarkana rings were somewhat larger in size than the Michigan rings.
8. The Texarkana rings always started from the same single region about 36 miles southeast of the station. Six different "ring sources" were observed within a twenty mile radius of the radar at Willow Run Airport.

Interesting statistics concerning the Texarkana rings are given on p. 257.

From the weather records it will be noted that rings occur under a wide variety of conditions; their daily occurrence, however, suggests some other cause. During the period rings were observed, time of local sunrise was approximately 5:27 CST.

The appearance of a typical ring at several stages during its growth is shown in Figure 1. Figure 2 shows a fairly typical Michigan ring. A number of the differences between the two mentioned in the above summary may be confirmed by close inspection of these two series.

Inspection of a large-scale aeronautical chart of the Texarkana area shows nothing remarkable about the spot where the echoes originate except, perhaps, its complete lack of any map-worthy indication of human activity in the area such as a railroad, airways beacon, road, etc. The Red River, which runs close by, appears to be the major geographical feature.

The description of the radar observation would not be complete without mention of one other significant characteristic. In most in-

| DATE[1] | TIME (CST) Appeared[2] | TIME (CST) Disappeared[3] | MAXIMUM RADIUS (miles)[4] | WEATHER AT TEXARKANA AIRPORT[5] (0500 CST) Clouds | Visibility (miles) | Temp./Dewpt. | | Wind (kt.) |
|---|---|---|---|---|---|---|---|---|
| July | | | | | | | | |
| 20 | 0505 | 0635 | 15 | Clear | 8 | 72 | 71 | Calm |
| 23 | 0520 | 0634 | 15 | Overcast | 3 (fog) | 74 | 73 | SW 3 |
| 24 | 0440 | 0700 | 25 | Broken | 12 | 76 | 72 | W 4 |
| 25 | 0510 | 0710 | 20 | Overcast | 10 | 74 | 71 | ENE 5 |
| 26 | 0515 | 0635 | 15 | Scattered | 7 | 72 | 68 | NE 3 |
| 27 | 0510 | 0625 | 12 | Clear | 12 | 71 | 68 | Calm |
| 28 | 0510 | 0640 | 17 | Clear | 12 | 74 | 68 | Calm |
| 29 | 0515 | 0630 | 18 | Clear | 12 | 78 | 72 | Calm |
| 30 | 0507 | 0620 | 16 | Thin overcast | 12 | 75 | 66 | ESE 10 |
| Aug. | | | | | | | | |
| 2 | 0508 | 0635 | 25 | Clear | 12 | 77 | 75 | SE 5 |
| 4 | 0445 | 0615 | 20 | Clear | 10 | 77 | 72 | SSW 8 |
| 5 | 0515 | 0615 | 15 | High overcast | 10 | 76 | 74 | NE 8 |
| 6 | 0505 | 0620 | 17 | Clear | 15 | 63 | 60 | NE 5 |
| 7 | 0524 | 0625 | 25 | Clear | 15 | 63 | 60 | NE 5 |
| 8 | 0521 | 0605 | 15 | High scattered | 15 | 73 | 70 | Calm |
| 9 | 0518 | 0648 | 35 | Clear | 10 | 70 | 67 | Calm |

[1] 20 July was the date of the first film available; on missing dates in the table, no film was exposed. In other words, the ring was observed *every* day during the interval 20 July to 9 August (after which no film was exposed during the proper time until 23 August, on which date there was no ring) except for those days for which no film was obtained.

[2] Times listed in this column may be off by as much as about 15 minutes since photographs were only made at fifteen minute intervals and presumably an echo might have appeared just after an exposure and no record obtained until the next was taken, fifteen minutes later.

[3] Times of disappearance are very uncertain—by as much as half an hour or more because of the very gradual way the echo faded each day (see Fig. 1).

[4] Radius of maximum size is very approximate since in final stages of existence the echo was very broad and diffuse. In one or two cases (4, 6 August especially), the echo ring was quite elliptical in shape and the size given is that of the major semi-diameter.

[5] The information given in the table pertains to the radar station location and can only be taken as approximately representative of conditions at the point of origin of the ring, some 35 miles to the southeast.

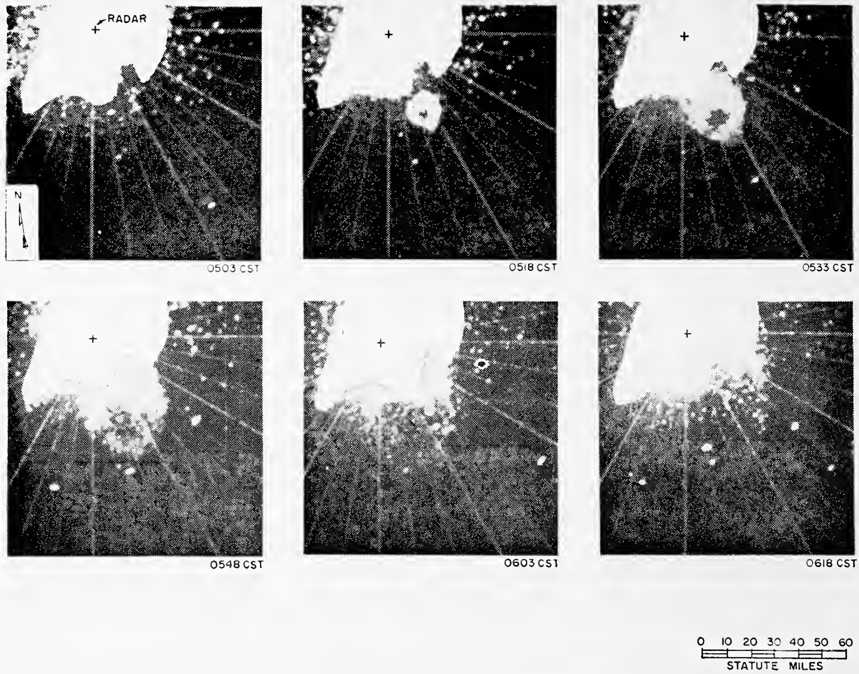


**Fig. 1. Ring echo detected by the radar at Texarkana, Arkansas, airport, August 9, 1957. Note increasing thickness of ring as it grows.**

stances of ring echo observation for which film covering the period some six or more hours previously is available, a rather weak, irregularly-shaped echo may be detected which appears to approach, converge upon, and ultimately disappear at the exact spot where the ring echo is observed to originate some 10 hours later. An example of such a "contracting" echo is shown in Figure 3. The rate of contraction, while irregular, is about equal to the rate of expansion of the rings.

## EXPLANATION OF CAUSE

The time of appearance, rate of growth, and other features of the Texarkana ring echoes may be quite satisfactorily explained if they were produced by any one of the several species of blackbirds which fly, feed, and roost in large flocks. Anyone who has lived in this region of the United States for several years has probably observed these flocks from time to time.

According to authorities, the habits of the redwinged blackbird, Agelaius phoeniceus, fit particularly well with characteristics of the radar echo and they are, in addition, indigenous to eastern Texas, Arkansas, and Louisiana. The following description of their habits by Cypert (1) is germane:

THE REDWING FLIGHT AT REELFOOT LAKE

*by* **EUGENE CYPERT**

*Paris, Tennessee*

"The late afternoon flight of Redwing Blackbirds (Agelaius phoeniceus) at Reelfoot Lake, Tenn., during the fall and winter has received very little

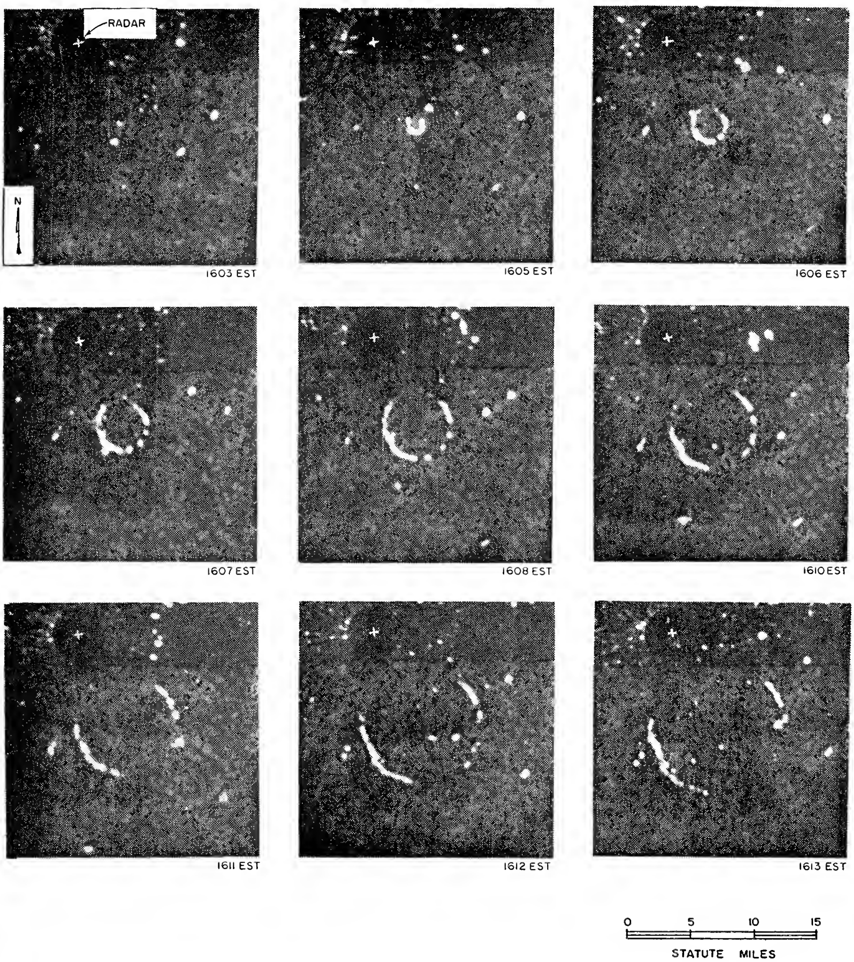


**Fig. 2. Ring echo detected by the radar at Willow Run Airport, Detroit, Michigan, January 17, 1956. Note that ring does not get thicker with increasing size.**

publicity, but it is certainly one of the nation's most impressive wildlife spectacles. Literally millions of these birds swarm in to roost in the thickets of giant cutgrass (Zizaniopsis miliacea), willow (Salix nigra), and button-bush (Cephalanthus occidentalis), which cover a large part of Reelfoot's shallow water areas, and swarm out again next morning. During a period of an hour or more, from before sunset until dusk, one may see these birds stream by, not in little flocks, but in a continuous seemingly endless cloud, from which a few all along can be seen dropping into the thickets.

The roosting habits of the Redwing appear to be closely associated with the cutgrass. In 1927, cutgrass was nearly wiped out at Reelfoot Lake by weather and water conditions, and residents of that vicinity say that very

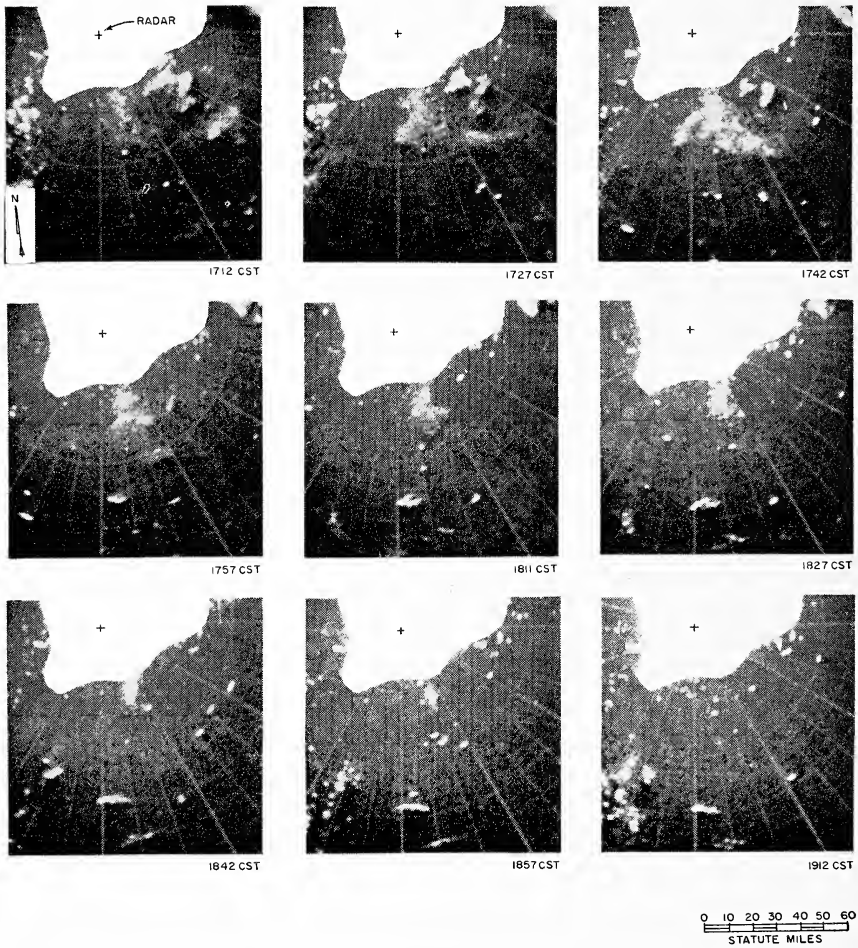


**Fig. 3. Contracting echo detected by radar at Taxarkana airport, July 24, 1957. Other irregularly-shaped echoes which change but little are caused by small rain showers.**

few blackbirds roosted there after that. But as the cutgrass once more began to encroach upon the shallow water areas, the blackbird numbers increased. Now (1948) there are nearly 2000 acres of shallow water areas there covered by this plant.

In traveling through the country surrounding Reelfoot Lake during the day, not many Redwings are to be seen. Only a few comparatively small flocks will be seen, here and there, feeding in the stubble fields. One wonders where the great concentration that gathers at the lake to roost comes from. The answer is that these birds fly farther to roost than we would ordinarily believe. Mr. Johnson A. Neff, of the United States Fish and Wildlife Service, states that he has trailed Redwings to their roost for as much as 23 miles, and he believes it not unlikely that they travel as much as 40 or 50 miles to the limits of their feeding range. Assuming that these birds feed over an area with a radius of 40 miles, this would mean that they would have more than 5000 square miles of feeding territory. A lot of blackbirds can feed on the stubble fields on 5000 square miles.

Then the question arises: Why should the blackbirds be tied down to Reelfoot Lake or any other single place at all? Why don't they go where the search for food takes them and just roost in the grasses, weeds, and bushes where the night finds them? The answer is doubtless tied up with the physical characteristics and feeding habits of the species. To begin with, the Redwing has long been a dweller among reeds and brushy growth and is probably not equipped to withstand the exposure associated with roosting in treetops. Since it is gregarious in its feeding habits, it would be very vulnerable to its natural enemies if it roosted in the grasses and shrubbery of the upland. The large flocks of birds roosting in the upland vegetation would be an obvious attraction and easy prey to every night-prowling predator. To avoid such predators, the Redwing nearly always roosts over water. Here its enemies are stymied. Most of the predators will not go very far into the water, and those that do would be at a disadvantage in catching the blackbirds. Reelfoot Lake, being the only place in the vicinity that has extensive patches of large marsh grasses growing in water, as is required by these birds for proper protection while roosting, serves as the single roosting place for all of that part of the country.

Blackbirds, including the Redwing, are so numerous in parts of the country that their depredations on grain fields are at times serious. Because of this, they have recently been removed from the list of birds protected by federal law. However, they are still protected by state laws in many states."

As closely as can be determined, the Texarkana rings originate in the immediate vicinity of the Black Bayou Wildlife Reservation between Hosston and Vivian, La. (Fig. 4). Excellent identification of the area is provided by a semi-permanent radar echo which appears on some of the films very close to the center of the expanding rings and is undoubtedly produced by a three hundred foot (estimated) micro-

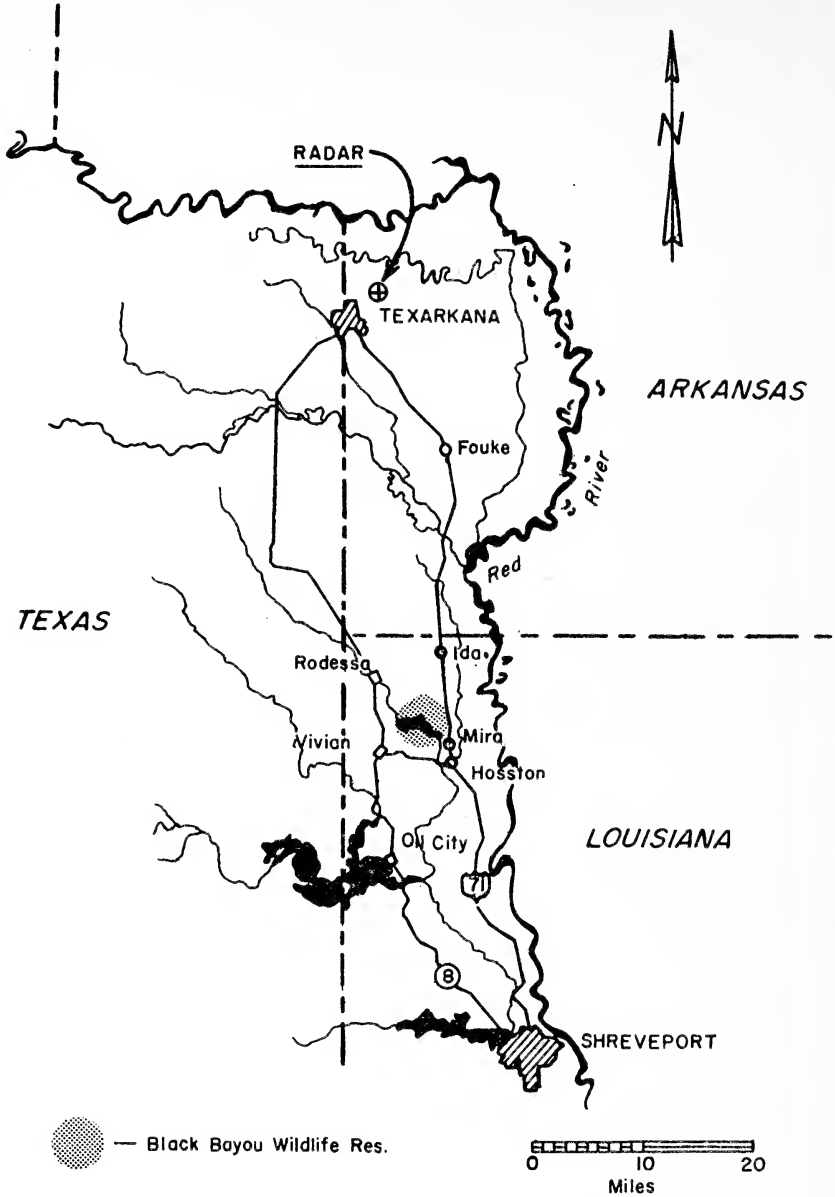


Fig. 4. Map of general area where the "Texarkana rings" were observed showing relative location of features of interest.

wave relay tower visible on a slight rise a mile or two west of the highway between Mira and Hosston. This tower is by far the highest structure for many miles around. The countryside in the area is characterized by marshes and swamplands, and is rather heavily wooded in spots. There are a number of oil well towers in concentrated areas, but there is little else besides the small towns in the region. A few local residents who were questioned did not recall any particularly special concentrations of blackbirds during the summer of 1957, but remarked that the birds are fairly plentiful the whole year around. It seems probable that only rather careful observations would serve to reveal a marked increase in the population, since even at maximum concentration the whole flight would be spread over literally thousands of acres and birds much more than a mile or two from the casual viewer would probably escape attention.

Deductive reasoning and the above-described behavior of these birds serves to explain *every* observable feature of the Texarkana echoes. The rings are first detected about half an hour before local sunrise, at which time they have the appearance of point targets. The birds, all leaving their roosts about the same time and flying away from the roosting area at about the same speed (roughly 15 mph), would give a ring-shaped echo. In the absence of winds of more than a few miles an hour (see table of observations), which is usual around sunrise in summer here, the ring appears to expand about its point of origin; its gradual broadening is readily explained by the slight difference in flying speed which the different flocks will have. Since there is no reason to expect the slowest flocks to fly preferentially in one direction and the fastest flocks in another, expansion of the ring may be expected to be quite uniform, as observations confirm. Also, within each individual flock, the speed of the flock must be geared to the slower fliers, for the flocks move as units with very few stragglers, indicating that the fastest fliers do not exert themselves and outstrip their companions.

The disappearance of the more distant part of the ring before the nearer, which is apparent in Figure 1, may be due to two contributing factors. First, the power of the radar echo for such a swarm of individual targets is inversely proportional to the square of the distance from the radar; hence, more distant flocks will give weaker echoes and, as the ring expands, echoes from the nearer portion will get stronger while those from the more distant will get weaker. Secondly, assuming that the various flocks all around the ring settle to feed at about the same time, the more distant flocks disappear below the radar horizon before the ones which are closer to the station. During the day there is no particular evidence of the birds, since only individual flocks will occasionally be in the air and then very close to the ground where radar detection is difficult or impossible. An additional factor aids radar detection of low-level targets at various times. Under favorable weather conditions of temperature and moisture-lapse rate, which frequently exist around sunrise in the area, the radar beam may be refracted downward slightly so that objects which are usually below the radar horizon may be detected. The phenomenon is quite similar to a mirage, when objects below the horizon can be seen in the sky slightly above it. Radar specialists call the phenomenon "anomalous propagation". Anomalous propagation most frequently occurs when the air is quite stable and the moisture decreases rapidly with increasing height. These particular atmospheric conditions are very often established during the late evening and early morning hours in swampy country during the summer time, for radiational cooling at night creates the still, stable air. Moisture, evaporating from the shallow, sun warmed pools cannot rise but remains concentrated near the ground level. After sunrise, surface heating destroys the stability, the moisture is carried aloft, and conditions return to "normal". The occasional observation of the tower in the area where the echoes are seen substantiates these remarks, for, if tower and radar were located on perfectly flat ground, the *top* of the tower would be about 20 feet below the beam under standard refractive conditions at this range.

At evening it cannot be expected that a contracting, symmetrical ring will be formed, for flocks in different parts of the circle cannot be in communication with each other and will start homeward at somewhat different times. From the appearance of the radar echoes (Fig. 3), it looks as if the birds, like a formation of aircraft, "circle" the roosting area and "peel off" in an orderly fashion to land.

Radar echoes from birds have several times previously been reported (3, 4, 5), and indeed at the radar conference they were offered in explanation for the Michigan rings, but in that case the explanaation is rather more difficult to accept than in this because of the highly variable and high speed of growth of the rings (34-100 mph), the lack of broadening or dispersal of the ring with increasing expansion, the occasional observation of concentric rings, and the fact that an aircraft observer in the area when a ring was observed to form made no report of birds. Concerning the latter objection, it must be noted that the observation of flying birds from aircraft is not simple; many species have rather dark-colored upper parts which blend with ground surface colors and provide protection from predators such as hawks, so this cannot be taken as a very strong argument against an avian origin of the Michigan rings. Also, Elder's paper indicates that the pilot was apparently looking more for smokestacks or other sources or indications of atmospheric contaminants and discontinuities than for birds.

According to calculations by Richardson, et al., one seagull per square mile at a range of ten miles could give a very strong signal on the type of radar used for these observations. Richardson also notes that observations made with a radar at Cape Cod, Massachusetts, showed seagulls to give ring-like echoes. Instead of single gulls (they do not very often gather in flocks to feed), we are dealing here with dense flocks of smaller birds. At a distance of thirty miles, the AN/FPS–3 radar will receive simultaneous echoes from targets contained in a volume of about one cubic mile. Since at some distance from the radar the flying birds may be considered to cover a horizontal area more than they fill a volume, it is more logical to say that all birds within an area of about ½ square mile give echoes which are simultaneously detected by the radar (at thirty miles). Clearly, thousands of birds could contribute to the power of the echo at a given instant, so while the individual birds are appreciably smaller than seagulls, their numbers overcome this deficiency and there can be but little doubt that they present quite readily-detectable radar targets.

## CONCLUSION

While visual confirming observations are lacking, reasonable arguments can be made that the ring-like radar echoes observed at Texarkana in the summer of 1957 were caused by blackbirds, probably the red-winged blackbirds. Some doubts exist that birds were the cause of the Michigan rings, but the possibility should not be excluded on the basis of available evidence. While making no particular contribution to our knowledge of the habits of the blackbird, the observation is an interesting one. It would also be of interest to obtain radar observations of bats, ducks, geese, swallows, buzzards, pigeons, and other species which tend to flock in large numbers or fly at appreciable altitudes.

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# A Simple Method of Butt-Welding Small Thermocouples

*by* **J.A. SCANLAN**

*The University of Texas*

## INTRODUCTION

Because of the need of minimizing any disturbance associated with laminar flow through a small passage having a rectangular cross-section only 1 by 0.1 inch, an investigation was undertaken to determine the optimum method of measuring the temperature of the flowing water. As a result of theoretical considerations and experiments with dye injected into the water to show streamlines, it was concluded that the best arrangement in this instance consisted of a rake of fine thermocouple wires extending straight across the flow stream in the shorter dimension.

Another need was to measure the temperature of the heating surface used in the primary investigation. In order to eliminate any flow disturbances at this most critical location, it was decided to measure the temperature on the back side of the heating surface. This required the surface to be very thin to avoid any appreciable temperature gradient; the thin surface, on the other hand, made it difficult to attach anything to it without destroying its smoothness. The final arrangement consisted of the use of 0.002 inch thick Nichrome V as the resistance-heated surface. The heating current flowed crosswise to the water flow, while fine thermocouple wires were laid parallel to the direction of water flow as a precautionary measure in case they should slightly deform the surface. The thermocouple junctions were soft-soldered to the Nichrome just at the junction points and were insulated from it otherwise. Grooves were machined in the supporting block of vulcanized fiber to provide clearance for the thermocouple wires; these grooves were only slightly larger than the wires in order to minimize the unsupported extent of Nichrome. This arrangement suggested the elimination of the conventional twisted or overlapped thermo-couple junctions.

## CIRCUITRY AND POSITIONING JIG

The requirements described above suggested the use of butt-welded thermocouples. Because of the small size (0.010 inch diameter) of the copper and constantan wires and because of the desire to preserve the integrity of the enamel insulation right up to, but not including, the junction, flame welding seemed impractical.

It was decided to try flash welding, using the discharge of a capacitor as the energy source. In order to make a few preliminary attempts just to see if the idea had any merit, the extremely crude jig shown in Figure 1 was assembled from two pin vises, an old hinge, and other material on hand. Surprisingly, this particular jig proved to be so practical in operation that it was used henceforth without alteration. The eccentrically located, flexible, operating handle serves two very important functions. By always taking up the slack in the same manner it obviates need for expensively machined parts. Also, it eases making the initial contact without bending the wires and permits good control of welding pressure, even by an operator with none too steady hands.

The capacitor, C, Figure 2, was charged, for convenience, from the field supply of an electrodynamic speaker with a Variac on the input side. Variable series resistance, $R_2$, was inserted in the discharge circuit for welding current control. The discharge circuit was closed by


**Fig. 1. Positioning Jig**

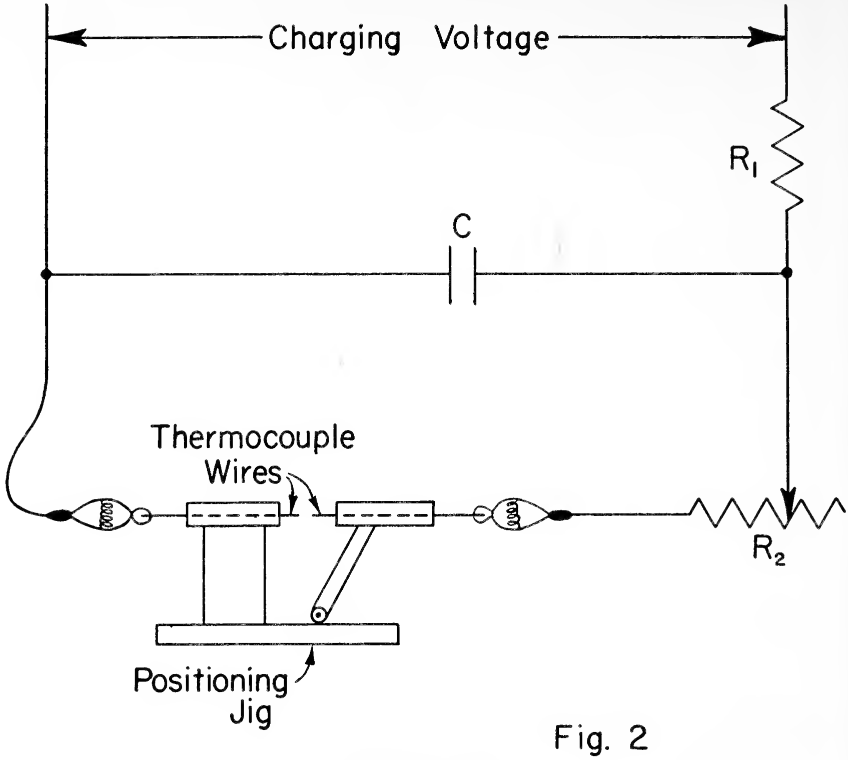


Fig. 2. Circuitry

bringing together the two wires to be joined, they being held in previously established alignment by the jig.

EFFECTS OF CIRCUIT VARIATIONS

Sixty-nine combinations of circuit values were tried. Under some conditions several attempts had to be made before successful welding was achieved. For some of the tests the charging current (through its limiting resistor, $R_1$) was left on during the welding operation and for a few seconds afterward as a means of decreasing the cooling rate of the weld. This, however, seemed to have no effect. The various welds (more than 400) were examined by means of a binocular microscope. An assortment of 19 welds varying from very good in appearance to extremely poor (some so fragile they broke during subsequent careful handling) were checked for thermoelectric effect in a stirred water bath at 34 F, 87 F, 115 F, and 173 F by means of a Leeds and Northrup Portable Precision Potentiometer, No. 8662. No measurable difference ($\pm 0.001$ mv) in generated voltage could be detected among the entire group, so it was concluded that any welded thermocouple of this type which would stay physically intact was as good as any other in this respect.

Tensile tests were conducted on all the thermocouples as the most convenient indication of mechanical integrity.

The "weldability," *i.e.*, the ratio of the number of achieved welds (good or poor) to the number of welding attempts, for various combinations of circuit parameters is shown in Figure 3 as a function of discharge circuit resistance. In spite of considerable scatter of the points, there appear to be fairly definite maxima.

In Figure 4 the tensile breaking force is shown as a function of discharge circuit resistance. Figure 5 shows both weldability and strength as a function of charging voltage (welding energy) with rather less scatter.

These tests, of course, cover only a small portion of the possible combinations of thermocouple materials and wire diameters. It is felt, however, that the results indicate typical trends. These trends should be of considerable assistance to other experimenters who may find it necessary to fabricate similar thermocouples of other materials or sizes.

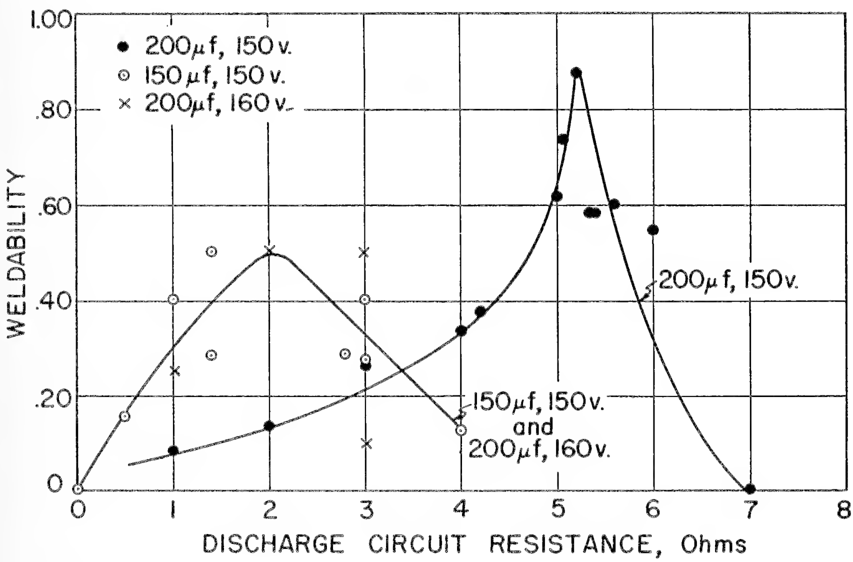


Fig. 3

Fig. 3. Effect of limiting discharge current on welding success

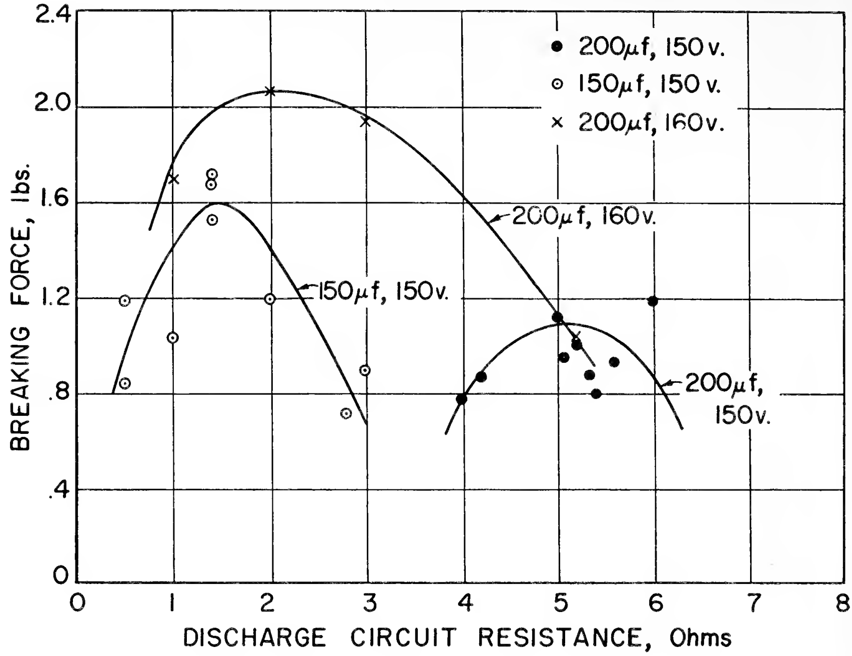


Fig. 4

**Fig. 4. Effect of limiting discharge current on junction strength**

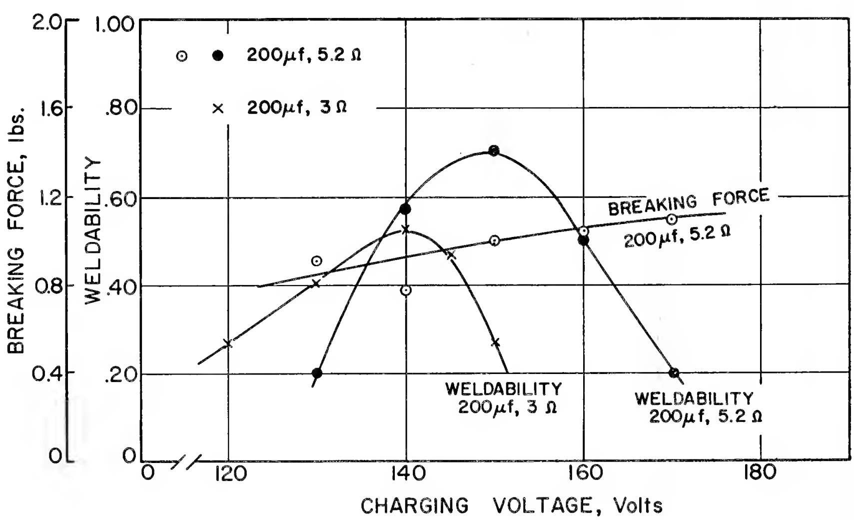


Fig. 5

**Fig. 5. Effects of various charging voltages**

# The Thermal Decomposition of Inorganic Compounds I Cobalt (III) Complexes

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## INTRODUCTION

Since the first crude thermobalance built by Honda (1915) in 1915, interest in the thermal decomposition of organic and inorganic compounds has increased rapidly. With the advent of the Chevenard (1944) automatic recording thermobalance, Duval (1953) has studied the thermal decomposition of some 1000 analytical precipitates. Although the emphasis has been on the determination of temperature stability limits for analytically useful compounds, this technique has great potential for the inorganic chemist. It can be used for the detection of new compounds that are formed during the thermal decomposition of known compounds. The thermobalance can also record the thermal stability limits as well as the composition of these new compounds.

With this purpose in mind, it is the object of this series of papers to study the thermal decomposition of a number of inorganic compounds. In this first paper, the thermal decomposition patterns of some complex compounds of cobalt (III) are presented.

Little is known concerning the thermal decomposition of cobalt (III) complexes. Duval (1953) has previously studied several complexes which have proven useful in analytical chemistry, but outside of this, there has not been a systematic study of the thermal decomposition processes. Since there are a vast number of cobalt (III) complexes, only 15 representative type complexes were chosen for this first investigation.

## APPARATUS

An automatic recording thermobalance as described by Wendlandt (1958) was employed. A linear heating rate of 5.4° C. per minute was used, with a maximum temperature limit of about 900° C. The sample sizes ranged from 80 to 100 mg. and were run in duplicate with a resulting agreement to within 1%. A slow stream of air was passed through the furnace during the pyrolysis.

## PREPARATION OF COMPLEXES

The cobalt salts used were of C.p. quality while the other chemicals employed were of similar quality.

The complexes were prepared according to the directions of standard textbooks by Walton (1948), Palmer (1954), King (1936), and Booth (1939). Usually the complexes were washed with water, ethyl alcohol, and ether, and then air dried at room temperature for 24 hours before pyrolysis on the thermobalance.

## RESULTS AND DISCUSSION

The thermal decomposition curves for the cobalt complexes are given in Figures 1–3. Each compound will be discussed individually.

*Aquopentaamminecobalt (III) chloride,* $[Co(NH_3)_5H_2O]Cl_3$. The thermal decomposition curve is given in Figure 1, curve F. The complex began to lose weight at 150° C. It is not known for sure if the first weight loss is due to evolution of ammonia or water but one would predict that it is the latter. After a fairly rapid weight loss, a break in the curve was observed at 360° C. which had the stoichiometry for the compound, $CoCl_2$. Additional heating caused decomposition of this compound to give the oxide level, $Co_3O_4$, at 620° C.

It is rather interesting to note that the intermediate compound is actually anhydrous $CoCl_2$. Such a decomposition pattern is to be found with other cobalt complexes also reported in this investigation.

The following reactions probably take place during the thermal decomposition:

$$2[Co(NH_3)_5H_2O]Cl_3 + 3O_2(air) \xrightarrow{\Delta} 2CoCl_2 + 6NH_3 + 6H_2O + 2NH_4Cl + N_2$$

$$CoCl_2 + H_2O(air) \xrightarrow{\Delta} CoO + 2HCl$$

$$6\ CoO + O_2 \xrightarrow{\Delta} 2Co_3O_4$$

The thermal decomposition reactions for the other complexes are probable quite similar to the above so will not be repeated.

*Hexaamminecobalt(III)chloride,* $[Co(NH_3)_6]Cl_3$. The thermal decomposition curve is given in Figure 1, curve E. At 160° C. the compound began to lose weight rather rapidly, giving a break in the curve at 360° C. which again corresponded very closely to $CoCl_2$. This compound gradually decomposed to give the $Co_3O_4$ level at 655° C.

*Nitropentaamminecobalt(III)chloride,* $[Co(NH_3)_5NO_2]Cl_2$. The thermal decomposition curve is given in Figure 1, curve D. The com-

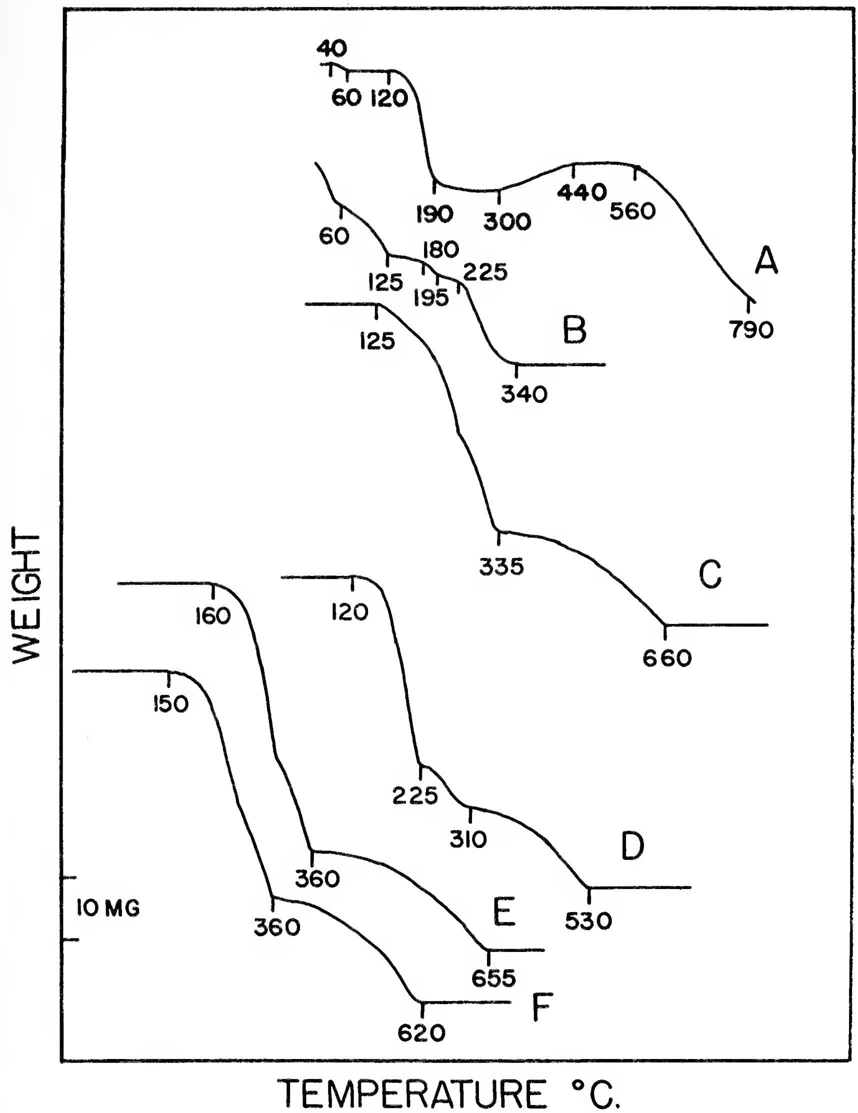


Fig. 1. Thermal Decomposition Curves for the Cobalt Complexes.

A. $Na_3[Co(NO_2)_6]$
B. $K_3[Co(Co_2O_4)_3]\cdot 3\ H_2O$
C. $[Co(NH_3)_4H_2OCl]Cl_2$
D. $[Co(NH_3)_5NO_2]Cl_2$
E. $[Co(NH_3)_6]Cl_3$
F. $[Co(NH_3)_5H_2O]Cl_3$

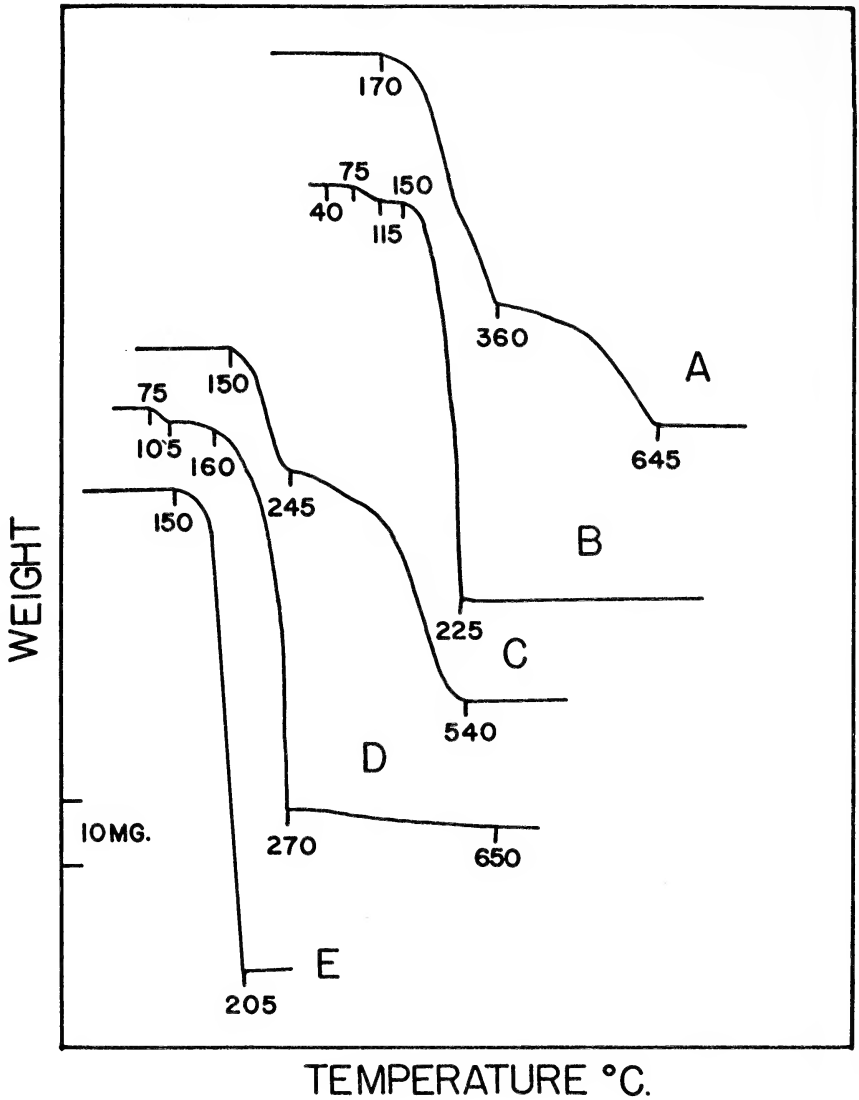


Fig. 2. Thermal Decomposition Curves for the Cobalt Complexes.

A. $[Co(NH_3)_5Cl]Cl_2$

B. $[Co(NH_3)_4CO_3]NO_3 \cdot 0.5H_2O$

C. $[Co(NH_3)_5H_2O]Br_3$

D. $[Co(NH_3)_5F](NO_3)_2 \cdot$ (?) $1H_2O$

E. $[Co(NH_3)_5Br](NO_3)_2$

pound began to lose weight at 120° C. Two intermediate breaks were observed in the curve, one at 225° C. and the other at 310° C. The composition of the curve at the 310° C. break corresponded closely to that for $CoCl_2$. The break in the curve at 225° C. did not correspond to a stoichiometrical compound. Further decomposition resulted in the formation of the $Co_3O_4$ level at 530° C.

*Chloroaquotetraamminecobalt(III)chloride, $[Co(NH_3)_4H_2OCl]Cl_2$.* The thermal decomposition curve is given in Figure 1, curve C. The first weight loss was observed at 125° C., giving a break in the curve at 335° C. which corresponded to the stoichiometry for the compound, $CoCl_2$. Further decomposition resulted in the formation of the $Co_3O_4$ level at 660° C.

*Potassium trioxalatocobaltate(III)3-hydrate, $K_3[Co(C_2O_4)_3]\cdot 3H_2O$.* The thermal decomposition curve is given in Figure 1, curve B. The complex must have retained some loosely held water because it began to lose weight at a little above room temperature. After the loss of this residual water, a break in the curve was observed at 60° C. which corresponded closely to the composition for the 3-hydrate, $K_3[Co(C_2O_4)_3]\cdot 3H_2O$. The 3-hydrate decomposed to give the anhydrous complex level, $K_3[Co(C_2O_4)_3]$, at 125° C. From 125° to 180° C. an exactly horizontal weight level was not obtained but sloped gradually, indicating a slight continuous weight loss. At 180° C., further rapid weight loss was observed giving a break in the curve at 195° C. The composition of the compound at this break did not correspond to any known stoichiometry. Further decomposition took place above 225° C. to give a horizontal weight level at 340° C. The composition of this weight level is not known but it is probably a mixture of $Co_3O_4$, $K_2CO_3$, and C.

*Sodium hexanitrocobaltate(III), $Na_3[Co(NO_2)_6]$.* The thermal decomposition curve is given in Figure 1, curve A. The complex began to lose loosely held water at 40° C. giving a horizontal weight level from 60° to 120° C. which corresponded to the anhydrous complex, $Na_3[Co(NO_2)_6]$. Beyond 120° C. the complex decomposed rapidly, resulting in a break in the curve at 190° C. The composition of the curve in this region is not known. At 300° C. however, an oxidation reaction apparently began to take place because the curve indicated a weight gain. The weight gain curve leveled off between 440° and 560° C. and then began to lose weight at 560° C. Again, the composition of the curve in the 440° to 560° C. region is not known. The curve was stopped at 790° C.

*Bromopentaamminecobalt(III)nitrate, $[Co(NH_3)_5Br](NO_3)_2$.* The thermal decomposition curve is given in Figure 2, curve E. The first

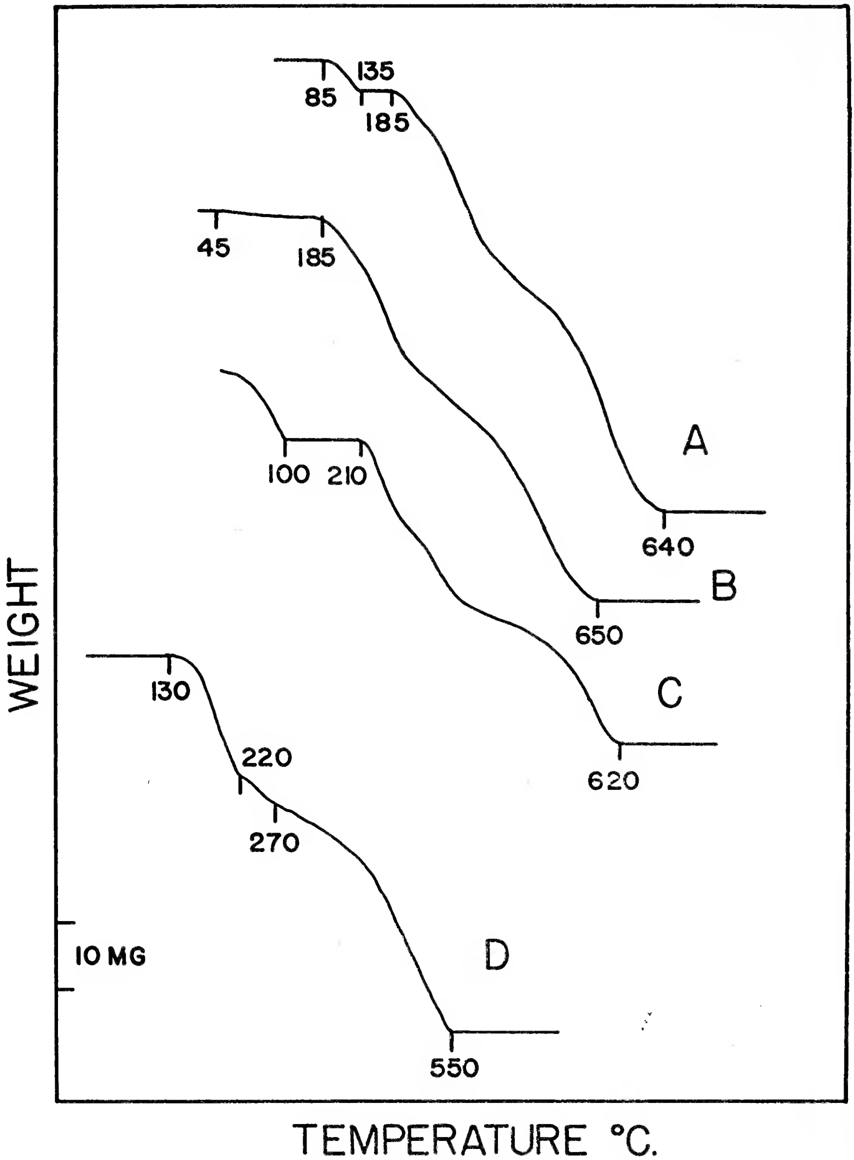


**Fig. 3. Thermal Decomposition Curves for the Cobalt Complexes.**

A. *cis*-[Co(en)$_2$Cl$_2$] Cl ·(?)l $H_2O$

B. *trans*- [Co(en)$_2$Cl$_2$] Cl

C. [Co(en)$_3$] Cl$_3$ ·3$H_2O$

D. [Co(NH$_3$)$_5$Br] Br$_2$

weight loss was observed at 150° C. The rate of weight loss was slow at first but became explosive at a little above 150° C. As a result of this explosion, some of the thermobalance pan contents were expelled, giving a lower residual $Co_3O_4$ content than was expected. This type of behavior was found with all of the complexes containing ammonia in the coordination sphere and nitrate ions in the ionization sphere.

*Fluoropentaamminecobalt(III)nitrate, $[Co(NH_3)_5F](NO_3)_2$. (?)-$1H_2O$.* The thermal decomposition curve is given in Figure 2, curve D. The first weight loss was observed at 75° C., resulting in the formation of a short horizontal weight level from 105° to 130° C. This first weight loss corresponded to the loss of 1 mole of water per mole of complex, suggesting perhaps that the complex was a 1-hydrate. However, this could be fortuitous as the water may be loosely retained water and not water of hydration. Beyond 130° C. the complex decomposed rapidly, in fact, an explosion occurred just above 160° C. Again the weight of residual $Co_3O_4$ was less than expected, due to the explosive disruption of the complex. The decomposition curve leveled off at 650° C.

*Aquopentaamminecobalt(III)bromide, $[Co(NH_3)_5H_2O]Br_3$.* The thermal decomposition curve is given in Figure 2, curve C. The complex began to lose weight at 150° C., resulting in a break in the curve at 245° C. which corresponded approximately to the stoichiometry for the compound, $CoBr_2$. Beyond this temperature, further decomposition took place to give the $Co_3O_4$ level at 540° C.

*Carbonatotetraamminecobalt(III)nitrate 0.5-hydrate, $[Co(NH_3)_4CO_3]NO_3 \cdot 0.5\ H_2O$.* The thermal decomposition curve is given in Figure 2, curve B. Water of hydration began to come off very slowly at 40° C., giving the anhydrous complex, $[Co(NH_3)_4CO_3]NO_3$, at 115° C. Beyond 150° C. the complex decomposed rapidly to give the $Co_3O_4$ level at 225° C.

*Chloropentaamminecobalt(III)chloride, $[Co(NH_3)_5Cl]Cl_2$.* The thermal decomposition curve is given in Fig. 2, curve A. The complex began to lose weight rapidly at 170° C. to give a break in the curve at 360° C. which corresponded closely to the composition for the compound, $CoCl_2$. Further decomposition took place above 360° C. to give the $Co_3O_4$ level at 645° C.

*Bromopentaamminecobalt(III)bromide, $[Co(NH_3)_5Br]Br_2$.* The thermal decomposition curve is given in Figure 3, curve D. The complex began to lose weight at 130° C., giving a break in the curve at 220° C. Further decomposition then resulted in the formation of the $Co_3O_4$ level at 550° C.

*Tris(ethylenediamine)cobalt(III)chloride 3-hydrate, $[Co(en)_3]$-*

*$Cl_3 \cdot H_2O$*. The thermal decomposition curve is given in Figure 3, curve C. The complex began to lose water of hydration at a little above room temperature giving the anhydrous complex, $[Co(en)_3]Cl_3$ (en=ethylenediamine), level from 100 to 210° C. Beyond 210° C. the complex decomposed rapidly, resulting in the $Co_3O_4$ level at 620° C.

TRANS-*Dichlorobis(ethylenediamine)cobalt(III)chloride,*$[Co(en)_2Cl_2]Cl$. The thermal decomposition curve is given in Figure 3, curve B. The complex began to lose weight very gradually at 45° C. At 185° C., the rate of weight loss became much more rapid, resulting in the $Co_3O_4$ level at 650° C.

CIS-*Dichlorobis(ethylenediamine)cobalt(III)chloride.(?)1-hydrate,* $[Co(en)_2Cl_2]Cl \cdot (?)1H\ O$. The thermal decomposition curve is given in Figure 3, curve A. The complex began to lose weight at 85° C; the weight loss corresponding to the stoichiometry of 1 mole of water per mole of complex. It is not known if this is hydrate water or loosely retained water. From 135° to 185° C. the horizontal weight level corresponded to the composition for the anhydrous complex, $[Co(en)_2Cl_2]Cl$. Beyond 185°C. the complex decomposed rapidly to give the $Co_3O_4$ level at 640° C.

*General considerations.* Although only a limited number of the cobalt complexes were studied on the thermobalance, certain correlations regarding the introduction of various ligands or ions into the coordination sphere as well as certain ions into the ionization sphere of the complexes with thermal stability can be made.

A. The substitution of water for ammonia in the coordination sphere tends to decrease the thermal stability of the complex. The thermal stability was found to increase in the order: $[Co(NH_3)_4ClH_2O]Cl_2 < [Co(NH_3)_5H_2O]Cl_3 = [Co(NH_3)_5H_2O]Br_3 < [Co(NH_3)_6]Cl_3$.

B. Introduction of halogen into the coordination sphere, in general, decreased the thermal stability of the complex. The thermal stability increased in the order: $[Co(NH_3)_5F](NO_3)_2 = [Co(NH_3)_5Br]Br_2 < [Co(NH_3)_5Br](NO_3)_2 < [Co(NH_3)_5Cl]Cl_2 <$ *cis-*and *trans-*$[Co(en)_2Cl_2]Cl$.

C. The presence of nitrate ions in the ionization sphere, as was expected, resulted in rapid decomposition of the complex and a lower oxide level minimum temperature. The nitrate ion acts as a powerful oxidizing agent on the coordinated ammonia at elevated temperatures.

D. There was no difference in the decomposition temperatures for the *cis-* and *trans-* isomers. For $[Co(en)_2Cl_2]Cl$, both isomers began to decompose at 185° C. with the oxide levels being obtained at 640° and 650° C., respectively.

E. The complexes containing bidentate chelate groups appeared to be more thermally stable than those containing only unidentate groups. The relationships found were: $[Co(en)_3]Cl_3$ and $K_3[Co(C_2O_4)_3]$ > $[Co(NH_3)_6]Cl_3$ or $Na_3[Co(NO_2)_6]$; and *cis*- and *trans*- $[Co(en)_2Cl_2]Cl$ > $[Co(NH_3)_5Cl]Cl_2$ or $[Co(NH_3)_5Br]Br_2$.

## SUMMARY

The thermal decomposition of fifteen cobalt (III) complexes was studied on the thermobalance. Although only a limited number of complexes were studied, correlation between the introduction of certain ligands or ions in the coordination sphere and certain ions in the ionization sphere with thermal stability could be made.

## ACKNOWLEDGMENT

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# Some Co-ordination Compounds of Palladium

*by* **RAY F. WILSON** *and* **LAWRENCE BAYE**

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In the earlier papers (Wilson and Wilson, 1955; 1956; and Wilson, Wilson, and Baye, 1957) data on the interaction of palladium (II) with 1,2,3-benzotriazole were reported. During further studies several additional compounds have been prepared.

## EXPERIMENTAL

*Materials and Preparation of Solutions.* — A palladium (II) nitrate solution was prepared from palladium metal powder obtained from A. D. Mackay, Inc. This solution was standardized using modifications of the Gilchrist-Wichers procedure (Hillebrand, *et al*, 1953). Standard 1,2,3-benzotriazole solution was prepared as described by Wilson and Wilson (1955). All other materials used were C. P. reagent grade chemicals. Ferricyanic acid was prepared by treating reagent grade potassium ferricyanide with sulfuric acid and extracting with ethyl alcohol. Reagent pair solutions of 1,2,3-benzotriazole with hydriodic acid, with hydrobromic acid, and with ferricyanic acid were prepared in which the ratio of the 1,2,3-benzotriazole to acid was approximately 1:1. All precipitates were filtered using fine porosity sintered-glass crucibles.

## PROCEDURE

Three samples of the standard palladium (II) nitrate solution, each containing 0.1392 mole of palladium, were treated with an excess amount of the reagent pair benzotriazole-ferricyanic acid solution; a gelatinous precipitate was obtained. After digesting this precipitate in a water bath for 15 minutes, the precipitate became crystalline. The precipitates were filtered, washed first with a dilute solution of potassium ferricyanide and secondly with hot water, and dried in a vacuum dessicator over magnesium perchlorate. The following weights were obtained from the three greenish blue, colored precipitates: 67.8, 67.8, 67.9 mg. Anal. Calcd. for the precipitates: Pd, 21.94; Fe, 7.66; C, 39.52; N, 28.81; H, 2.08. Found: Pd, 21.92; Fe, 7.68; C, 39.24; N, 29.04; H, 1.78. Formula of the compound appears to be $Pd_3[Fe(CN)_6]_2$-$(C_6H_4NHN_2)_6$.

Three aliquots of the standard palladium (II) nitrate solution were treated with excess hydrobromic acid—sodium bromide solution and the resulting solutions were heated for 10 minutes. The solutions were treated with excess stock 1,2,3-benzotriazole-hydrobromic acid solution and digested on a water bath for 30 minutes. The precipitates were filtered, washed several times with a dilute acetic acid-hydrobromic acid solution and finally with hot distilled water, and dried at 110°. The following weights were obtained for the three precipitates: 46.8, 46.8, 46.9 mg. Anal. Calcd. for the beige, colored precipitates: Pd, 21.14; C, 28.55; N, 16.65; H, 2.00; Br. 31.67. Found: Pd, 21.14; C, 28.38; N, 16.79; H. 2.18; Br, 31.59. Formula of the compound corresponds to $Pd(C_6H_4NHN_2)_2Br_2$.

Aliquots of the standard palladium (II) nitrate solution were treated with excess stock 1,2,3-benzotriazole-hydriodic acid solution. The precipitates were digested for one hour after the appearance of the final color, dull yellow. During the first 10 minutes of digesting, the precipitate changes through a series of colors in the order, black, brown, red, orange and finally to dull yellow. The precipitates were washed with 1% acetic acid solution, dried and weighed as usual. The weights of the dull yellow, colored precipitates were: 89.5, 89.7, 89.4 mg. Anal. Calcd. for Pd, 17.82; C, 24.07; N, 14.04; H, 1.69; I, 42.39. Found: Pd, 17.83; C, 24.32; N, 13.79; H, 1.48; I, 42.35. The data indicate that the formula is $Pd(C_6H_4NHN_2)_2I_2$.

## DISCUSSION

The results obtained in this study show that three new palladium co-ordination compounds can be prepared in high yield and purity. On the basis of the elemental analyses the observed formulas are $Pd(C_6H_4NHN_2)_2Br_2$, $Pd(C_6H_4NHN_2)_2I_2$ and $Pd_3[Fe(CN)_6]_2$-$(C_6H_4NHN_2)_6$, and their formula weights are 504.78, 598.76 and 1458.76, respectively.

*Acknowledgment.* The authors wish to express their sincere thanks to the National Science Foundation and the Robert A. Welch Foundation for grants which supported this study.

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# Prehnitization of Gabbro

*by* **W. T. HUANG**

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## INTRODUCTION

The igneous rocks of Precambrian age in the Wichita Mountains of southwestern Oklahoma comprise a stratiform complex in which intrusions of granophyre cross-cut and overlie anorthosite and gabbro (Huang, 1953; and Hamilton, 1956: 1319–1326). The gabbro north and northwest of Mount Sheridan has undergone saussuritization, uralitization, and locally intense prehnitization, leading to the development of prehnite-zoisite rock.

Although Dott (1948) reported the occurrence of prehnite and discussed the possibility of commercial use of the mineral, the origin of prehnite and related features were neglected.

This paper presents a detailed account of the petrochemical and mineralogical characters of prehnitization, mode of occurrence, and related alteration that took place in the gabbro. It is hoped that the present investigation may contribute to the pertrology and mineral deposits of the Wichita Mountains igneous complex.

## GABBRO

The gabbro is composed principally of calcic plagioclase, $An_{58}$ to $An_{70}$, clinopyroxene (diallage) and olivine. A chemical analysis of the least altered gabbro from section 24, T.4N., R.14W., is given in Table 1, and a mode of the analysed rock, determined by Rosiwal analyses of three thin sections is included in the table. The rock shows considerable structural and textural variation. Most of its outcrop is, however, a medium hypautomorphic granular gabbro in which ferromagensian minerals and plagioclase crystals are altered and locally the plagioclase tablets occur in parallel orientation, forming a banded gabbro (Huang, 1954a).

The banded gabbro is locally contorted, and the bands may be slightly displaced along fractures healed by recrystallization and now marked by quartzo-feldspathic bands, stringers, and veins continuous and identical in nature with the quartz and feldspars of the granophyre. Pegmatite patches, a fraction of an inch to several feet in thick-

TABLE 1

Chemical analyses

| | Gabbro | Prehnite-zoisite Rock |
|---|---|---|
| $SiO_2$ | 47.25 | 44.64 |
| $TiO_2$ | 1.12 | 0.08 |
| $ZrO_2$ | 0.08 | tr |
| $CrO_2$ | 0.02 | tr |
| $Al_2O_3$ | 18.27 | 19.10 |
| $Fe_2O_3$ | 2.22 | 0.96 |
| FeO | 5.80 | 2.50 |
| MnO | 0.05 | tr |
| MgO | 7.06 | 5.38 |
| CaO | 11.23 | 25.20 |
| $Na_2O$ | 2.55 | 0.10 |
| $K_2O$ | 1.21 | 0.01 |
| $H_2O+$ | 2.28 | 2.26 |
| $H_2O-$ | 0.96 | 0.08 |
| $P_2O_5$ | 0.57 | |
| $CO_2$ | tr | |
| S | tr | |
| Cl | tr | |
| Total | 100.67 | 100.30 |

Gabbro

| Norm | | | Mode | |
|---|---|---|---|---|
| Or | | 7.23 | Plagioclase | 52 |
| Ab | | 16.24 | Diallage | 28 |
| An | | 34.75 | Olivine | 12 |
| Ne | | 2.84 | Prehnite | 8 |
| Di | Wo | 4.06 | Uralite | |
| | En | 2.61 | Amphibole | |
| | Fs | 1.19 | Chlorite | |
| Ol | Fo | 3.36 | Biotite | |
| | Fa | 15.30 | Epidote | |
| Il | | 1.82 | Magnetite | |
| Ap | | 4.03 | Zircon | |
| Mt | | 3.02 | Apatite | |
| $H_2O$ | | 3.24 | Sphene | |
| | | | Carbonates | |
| | | 99.69 | | |
| | | | Sp. Gr. | 3.02 |
| | | | Porosity | 0.42%±0.01 |

Prehnite-zoisite Rock

| Norm | | | Mode | |
|---|---|---|---|---|
| An | | 51.42 | Prehnite | 82 |
| Ne | | 0.53 | Zoisite | 12 |
| Di | Wo | 18.91 | Leucoxene | 6 |
| | En | 13.54 | Magnetite | |
| | Fs | 3.69 | Zircon | |
| Cs | | 7.57 | Quartz | |
| Il | | 0.15 | | |
| Mt | | 1.39 | | |
| $H_2O$ | | 2.34 | | |
| | | 99.54 | | |
| | | | Sp. Gr. | 3.16 |
| | | | Porosity | 0.82%±0.01 |

Analyses by W. T. Huang.

ness, cut and enclose blocks of gabbro near the contact of the granophyre on the northern slope of Mount Sheridan, about 3 miles southwest of Meers. Contacts between the pegmatite and gabbro are interlocking, and the enclosed blocks are disorientated. The pegmatite veinlets and stringers, which are made up of riebeckite, quartz, and alkalic feldspar, form a criss-cross network in gabbro.

Scattered throughout the gabbro outcrops there are masses of gabbro elongated generally parallel to the local banding, of coarser texture than the average, and composed of minerals of similar composition to those of the surrounding gabbro. The coarse gabbro tends to be more feldspathic, with diallage as the dominant colored silicate, and iron ores present in much greater amounts than in the normal gabbro.

The masses of coarser gabbro may owe their textural features to relative enrichment in volatile constituents in the magma compared with that of the normal gabbro. The presence of considerable amount of such secondary minerals as chlorite, actinolite, calcite and iron ores seems to confirm this belief. The occurrence of xenoliths in the gabbro may also have stimulated the development of coarse texture. The xenoliths themselves may have provided volatile fluxes to the surrounding magma.

Two small gabbro outcrops exhibit peculiar pseudodiabasic texture. Separate crystals of calcic feldspar and pyroxene are associated with such magmatically incongruous minerals as quartz and alkalic feldspar. Both textural and mineralogical characters of the rock strongly point to the striking resemblance of the "intermediate rock," which occur as a narrow zone between gabbro and granophyre in the Wichita Mountains, Oklahoma (Huang, 1955).

## PREHNITIZED GABBRO AND PREHNITE-ZOISITE ROCK

### *Mode of Occurrence*

It was apparent in the field and later confirmed in the laboratory studies that the gabbro had undergone prehnitization and related alterations which could not be attributed to atmospheric weathering alone. The distribution of alteration products is patchy and irregular as if affected by granophyric fluids and vapors which migrated through the rock and altered the minerals in their paths.

The altered gabbro outcrops are lighter shades of greenish gray. Advanced saussuritization of plagioclase and uralitization of pyroxene produce patches of a soft green color; altered olivine crystals are grayish black and mottled with rusty color. The highly prehnitized gabbro is a conspicuous green rock composed of prehnite or prehnite and zoisite, though the zoisite is commonly difficult to see in hand specimen.

Although chalky apple green to deep green prehnite patches, a fraction of a square inch to a square inch (Fig. 3 upper left), are ubiquitous in the prehnitized gabbro, thick veins and large bodies of prehnite are limited to a few strongly fractured areas. The location of these large prehnite bodies is indicated in figure 1. Detailed description of the mode of occurrence of the prehnite rock is given below.

Two large prehnite outcrops were found: one near the center and the other in the northeastern corner of section 36, T. 4 N., R. 14 W. The prehnite near the center of the section is well exposed in a river bank,

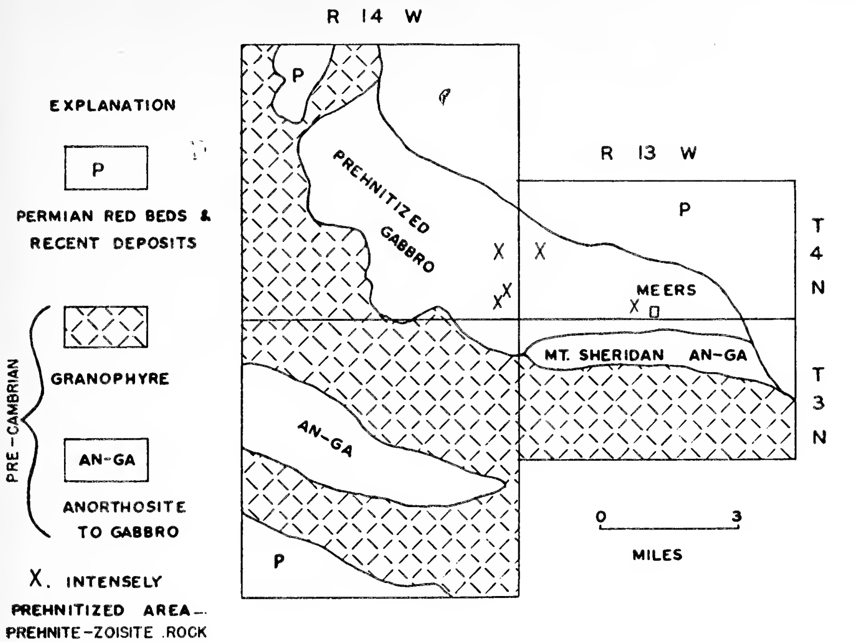


FIG. I GEOLOGIC MAP SHOWING THE LOCATION OF PREHNITIZED GABBRO AND ASSOCIATED IGNEOUS ROCKS, WICHITA MOUNTAINS, OKLAHOMA

about 3 miles northwest of Meers (Fig. 2). The prehnite body striking almost E-W, dipping about 75° S, and having an average width of about 27 feet, is associated, on the south side of the body, with brecciated gabbro mixed with prehnite cement. Here the contact between the prehnite and gabbro is commonly gradational, but to the north the contact between the two rocks is very sharp. Two irregular and broken narrow zones of prehnite rock lie several feet north of the main prehnite body. These are believed to be an offshoot of the main prehnite body and a small parallel vein that has been completely prehnitized and have been fragmented by shearing movement in the gabbro. The prehnite is a conspicuous green rock composed of a mixture of granular prehnite and a fine chalky type of greenish prehnite, admixed with riebeckite and alkalic feldspar crystals apparently derived from the nearby pegmatite. The prehnite of granular variety occurs in considerable amounts.

The prehnite outcrop in the northeastern corner of section 36 is considerably larger than the one in the center, although it is covered with rock debris in several places. Here the gabbro has been altered to numerous aggregates and masses consisting principally of prehnite,

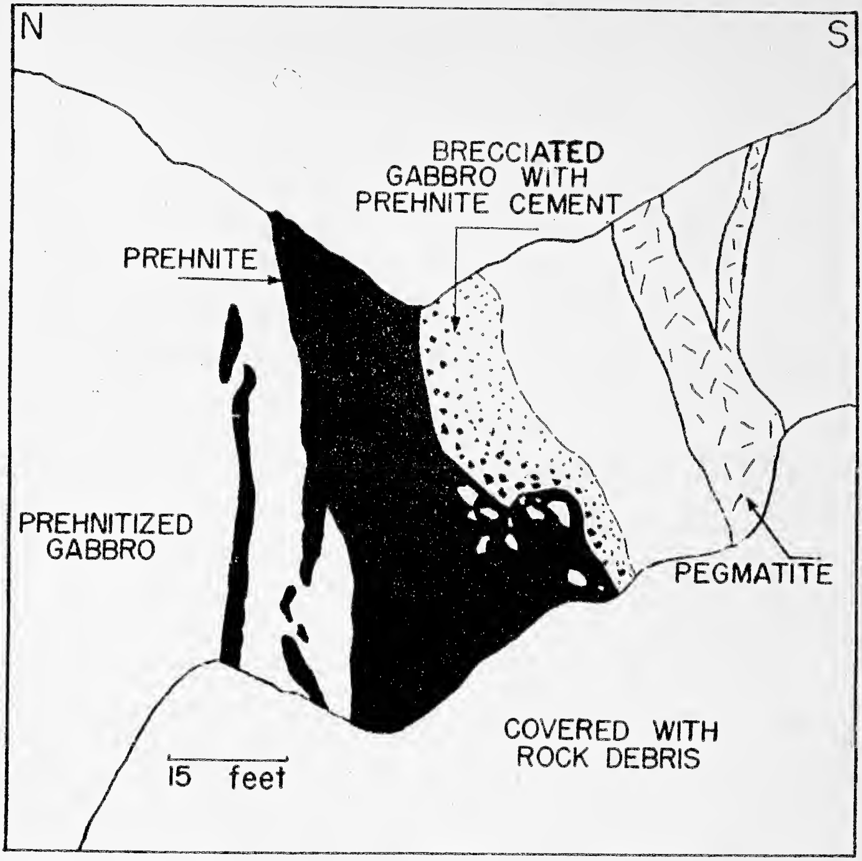


FIG. 2. Section showing geology of the prehnitization of gabbro in a stream bank, 3 miles NW of Meers.

zoisite, and a little quartz. The prehnite-zoisite rocks are from deep green to faintly greenish in color, depending upon the degree of alteration and presence of chlorite and actinolite, and varies in grain size from extremely fine to fairly coarse. In the vicinity of the large prehnite mass, ranging from 5 feet to 18 feet in diameter, the gabbro is penetrated by multitudes of thinner, gray, fine-grained prehnite veinlets and crack fillings; where they widen, small pockets of calcite, quartz, uralitized pyroxene appear. The gabbro between the finer prehnite veinlets is brecciated, and for several inches up to a foot in the vicinity of the gray cracks the gabbro may be discolored to a matted, dull greenish gray. Numerous prehnite veins, more than half an inch in width, are commonly surrounded by brecciated gabbro, and the fragments of the breccia have been characteristically altered.

Plagioclase tablets have been corroded and surrounded by patches of lamellar sodic plagioclase with variable amounts of chlorite, epidote, actinolite and quartz. Pyroxene crystals are invariably uralitized, and patches of magnetite grains have been deposited.

In section 25, T. 4 N., R 14 W., and in the east bank of a road cut just west of the U.S. Post Office at Meers, in section 33, T. 4 N., R. 13 W., more than a dozen of prehnite veinlets, ranging in width from a fraction of an inch to about 11 inches, cut and enclose the gabbro and a little anorthosite. At one place, about half a mile west of Meers, two veins of prehnite which appear to be offset about 3 feet by a small fault, are cut along the line of displacement by a third prehnite vein.

About 3 miles northwest of Meers, in section 30, T. 4 N., R. 13 W., the gabbro is transected by ramifying albitite veinlets. The veinlets are flecked by opaque iron ores and replaced by apple green prehnite. They grade imperceptibly into fine-grained prehnite. Commonly a uniform, apple to deep green matrix of large prehnite veinlets encloses small "islands" of less altered albite grains. In many places, however, the albitite veinlets are thoroughly altered to granular prehnite. The prehnitization of albitite veinlets in the area studied is reminiscent of the albitite dike in Gold bridge of southwestern British Columbia described by Watson (1953).

*Petrography of Prehnite and Associated Alterations*

The plagioclase is partly replaced by aggregates of prehnite. The aggregates form irregular patches and are associated with amphibole, chlorite and carbonates. Much of the remaining plagioclase is intensely saussuritized, but some of the plagioclase crystals are rimmed by clear albite. It is believed that the process of saussuritization involves the breakdown of plagioclase with separation of sodium and calcium into different products. Sodium forms clear albite rims and calcium appears chiefly in zoisite and epidote.

Alteration of pyroxene indicates a tendency toward separation of calcium from magnesium in the minerals formed. Calcium contributed to the formation of prehnite and pale brown calciferous amphibole. Magnesium formed biotite and chlorite (penninite). Chlorite may be pseudomorphous after biotite and amphiboles, and like prehnite, may be found in irregular patches of erratic distribution (Fig. 3, upper right). Magnetite is thrown out in the process and forms small grains along the cleavages. The original structures and inclusions are preserved, and the amphibole pseudomorph looks exactly like pyroxene in ordinary light. Some pyroxene crystals appear to change directly to pale green uralitic amphibole. Olivine grains were replaced by late iron ores, a common feature of the alteration of olivine in gabbro and troctolite of the Wichita Mountains (Huang, 1954b).

Much of the highly altered gabbro consists principally of irregular or slightly radiating aggregates of prehnite grains. Minute crystals of zircon, apatite, sphene, leucoxene, and quartz are sporadically distributed in the less altered gabbro; but sphene and apatite tend to disappear as alteration increases.

A chemical analysis of typical prehnite-zoisite rock from section 36, T. 4 N., R. 14 W., and a mode based on Rosiwal analyses of six thin sections are given in Table 1.

Commonly prehnite occurs alone as radiating sheaves, 1.2 to 2.5 mm. in length (Fig. 3, lower left). The optical properties of prehnite are $N_x = 1.614$, $N_y = 1.618$ and $N_z = 1.642$; optical sign is positive; $2V = 65°$ (universal stage measurement of 10 grains). A fairly common characteristic of the prehnite is wavy extinction. Pleochroism is from pale yellow to colorless. The specific gravity is $2.84 \pm 0.001$.

Zoisite is intimately penetrated by an intricate network of minute prehnite veinlets (Fig. 3, lower right). The anhedral zoisite grains characterized by anomalous gray-bluish interference color, are readily distinguished from prehnite because of higher relief and lower birefringence. According to Rogers and Kerr (1942:321), the anomalous deep blue interference color is characteristic of the non-ferrian variety of zoisite. Other optical properties are: $N_x = 1.700$, $N_y = 1.703$, and $N_z = 1.708$; $(+)2V = 10$, optical plane $\perp$ (010) cleavage.

The petrography of prehnite and related alterations and the mineralogy of the principal minerals involved have just been treated in detail. Additional mineralogical features strongly suggestive of results of hydrothermal alteration are worthy of attention:

(1) Thin sections of the least-altered gabbro showed that even the fresh-looking rock is slightly altered. Most biotite crystals are partially altered to chlorite. In "intermediate rock" the alkalic feldspar is changed to clay mineral.

(2) In some case, two generations of biotite are indicated. The small laths of secondary biotite are considered alteration mica, formed at the expense of earlier chlorite. The chlorite fringe around unaltered residual biotite was in turn changed to an alteration biotite. Sales and Meyer (1948:19) note the similar recrystallization of biotite in wall-rock alteration at Butte, Montana.

(3) A striking texture found in chlorite pseudomorphs in "intermediate rock" consists of a grid of delicate rutile needles within the altered chlorite and partially altered biotite flakes. The needeles are orientated parallel to three directions at angles of about 60°. The formation of rutile in the al-

teration of biotite has been attributed by Sales and Meyer (1948: 16) to displacement of titanium from biotite by base exchange. In the present area, the titanium dioxide may have been derived from the breakdown of accessory sphene, which is present in the least-altered phase of gabbro and "intermediate rock" but gradually disappears as alteration increases. A similar view was held by Leroy (1954: 750) in his description of formation of rutile in the alteration of biotite in granodiorite.

(4) Zircon crystals persist throughout the various kinds of alterations. Although minute apatite crystals resist destruction in the early stages of hydrothermal alteration, as alteration progresses, the crysals become more and more corroded, and in areas of most intense prehnitization the apatite disappears.

## CAUSE OF PREHNITIZATION

The saussuritization of plagioclase and uralitization of pyroxene in gabbroic rocks are well known. Harker (1939: 174) attributes these alterations to deuteric action, and states that the usual lime-aluminosilicates in saussurite are zoisite and epidote, but that prehnite is also present. In discussing metasomatism, however, he attributes the extreme prehnitization of various lime-aluminosilicates to the action of heated water of magmatic origin. "In the near neighborhood of a plutonic contact, this destructive action has been carried far, even in the extreme case to the reduction of the whole rock to an aggregate essentially of prehnite and quartz. Any lime-feldspar present is first converted." (1939: 133).

In view of the intense hydrothermal activity in the Wichita Mountains, as evidenced by the mineralogical changes already described, it is believed that the uralitization of pyroxene and saussuritization of plagioclase of the gabbro is due to the permeation of liquids and vapors of the invading granophyric melt through the gabbroic rocks. It seems probable that somewhat similar hydrothermal solutions from the same source could alter the gabbro to the prehnite-zoisite rock. During the alteration a change in conditions resulted in the replacement of zoisite by prehnite, leading to the development of prehnite rock.

In his studies of zoisite-prehnite alteration of gabbro in the vicinity of Barie Verte, Newfoundland, Watson (1942: 641–644) concluded that the alteration of gabbro is attributed to hydrothermal solutions probably related to the nearby granitic rocks. He also referred to the saussuritization and prehnitization of gabbroic anorthosite in eastern Adirondacks described by A. F. Buddington, and Willsboro quadrangle, New York jointly investigated by Buddington and L. Whitcomb. In both instances the prehnite and related alterations is attributed to solutions derived from nearby granitic magmas.

Tectonic control of the prehnitization of gabbro in the area studied may have been important. As previously stated, intense prehnite alteration is restricted to strongly fractured areas of the gabbro outcrops. These areas may have been more permeable and soaked with liquids and vapors of the invading granophyric melt. Furthermore, the fractured areas might have been faulted, as indicated by the offset of many prehnite veinlets; but the faults are hardly recognizable in the field because they have been concealed by prehnite alteration and brecciation.

A comparison of the composition of the least-altered gabbro with that of prehnite-zoisite rock given in Table 1, shows that the principal change involved in the formation of prehnite was large addition of lime. The slight increase of alumina is believed as a result of alumina metasomatism, a feature so characteristic of certain rocks in the Wichita Mountains igneous complex (Huang, 1957). Decreases in the silica, iron, magnesium and alkalic content are also evident.

Many of the albitite veinlets that are injected into the gabbro have been prehnitized. Watson (1953: 203–205) believed that the lime necessary for the change has been yielded by the serpentinization of clinopyroxene-bearing peridotite. In view of the absence of peridotite in the area, it is believed that the possible sources of fluid brought lime into the albitite veinlets may have formed during the uralitization of pyroxene in the gabbro. Field and microscopic observations support the view just set forth.

## CONCLUSION

Field and microscopic observations show that the gabbro north and northwest of Mount Sheridan has been altered to masses of prehnite and related minerals. A comparison of the chemical analysis of the least-altered gabbro with that of prehnite-zoisite rock, indicates a large increase in lime and a decrease in silica, iron, magnesium and alkalic content. The alterations are attributed to hydrothermal solutions probably related to the intrusions of the nearby granophyre in the Wichita Mountains of southwestern Oklahoma.

## ACKNOWLEDGMENTS

Field observation and laboratory work were carried out during the academic years from 1950 to 1954 when the writer was teaching at the University of Oklahoma. The writer has also examined over 300

thin sections of gabbroic rocks in the collection of the School of Geology at the University. Part of this work was done at the University of Illinois while attending the first Summer Institute in Geology, 1957 which is supported by a grant from the National Science Foundation. The writer is indebted to Drs. Donald M. Henderson, Arthur F. Hagner, and Robert M. Garrels, staff members of the Institute, for following the work with interest and providing facilities. Professor H. J. Hey

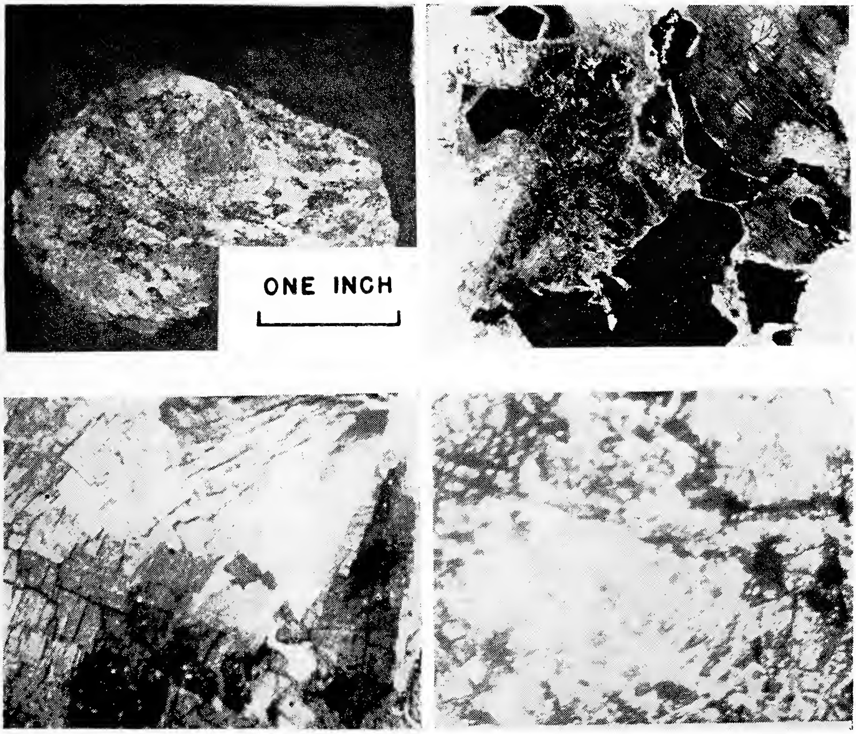


Fig. 3.

Upper left. Hand specimen of typical prehnitized gabbro, somewhat fractured. The gray areas consist of prehnite, the light areas saussuritized plagioclase, and the dark areas uralitized pyroxene with iron ores. Sec. 33, T. 4 N., R. 13 W.

Upper right. Altered gabbro showing saussuritized plagioclase, uralitized pyroxene, and replacement of olivine by late iron ores. Prehnite and chlorite are found in irregular patches of erratic distribution (light area). Sec. 36, T. 4 N., R. 14 W.

X 24, nicols not crossed.

Lower left. Radiating sheaves of prehnite. NE Sec. 36, T. 4 N., R. 14 W.

X 48, nicols crossed.

Lower right. Zoisite replaced by an intricate network of minute prehnite veinlets. Note the uralitization of diallogic pyroxenes. Sec. 25, T. 4 N., R. 14 W.

X 120, nicols not crossed.

of the Department of Chemistry of this College, is heartily thanked for his many advices in chemical analyses. Finally, the writer wishes to express his appreciation to Dr. Warren B. Hamilton of the U. S. Geological Survey, for stimulating discussions relative to the petrogenesis of the Wichita Mountains igneous complex.

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# Pothole Grooves in the Bed of the James River, Mason County, Texas[1]

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## INTRODUCTION

While assisting graduate students in geologic mapping in the valley of the James River in southern Mason County, Texas, during the summer of 1956, the writer noticed parallel markings in the dry river bed, which, as seen from the top of the high rocky banks, closely resemble wagon or automobile tracks in dried mud, and suggest the ruts of pioneer trails like those still visible on the Great Plains (Fig. 1). Closer inspection, however, showed them to be continuous grooves, worn in the hard limestone of the river bed, and connecting slightly deeper potholes into long chains.

These "wagon track" pothole grooves are best developed for a distance of about three fourths of a mile in the bedrock floor of the river at a point about eight miles by river (or five miles in a straight line) above its mouth, on property of the Thad Ziegler ranch. The locality, 14.3 miles from Mason by road, may be reached by the so-called James River Road, which branches off from Farm Road 1723 about three miles south of the city of Mason and runs southwestward across the Llano River and up the valley of the James.

The writer is happy to acknowledge the assistance of Mr. George D. Dannemiller (1957, pp. 21–22), who mapped the geology of the area and supplied one of the photographs.

## DESCRIPTION

The James River flows upon nearly horizontal limestone strata at this locality. Thus individual strata form the stream bed for its entire width and for several hundred yards of its length, until they are broken off by the combined effects of gentle undulations in the rock layers and of the gradient of the stream. The pothole grooves are worn into a hard, white, rather massive limestone transitional between the Cap Mountain and Lion Mountain members of the Riley formation of Cambrian

[1] Presented at the meeting of Section IV, Texas Academy of Science, Brownwood, Texas, December 14, 1956.

age. These beds should probably be assigned to the upper part of the Cap Mountain, but they display a greater thickness of white limestone, nearly free from sand, than is typical of that member. The rock contains considerable disseminated glauconite, but otherwise resembles a medium-grained marble in texture, crystallinity, and toughness.

The "wagon track" grooves follow the curving course of the river, and for the most part are approximately parallel, although at places some of them converge at small angles and unite. Where best developed they are spaced remarkably regularly at about five feet apart (whence the resemblance to artificially made ruts, Fig. 2), but at other places

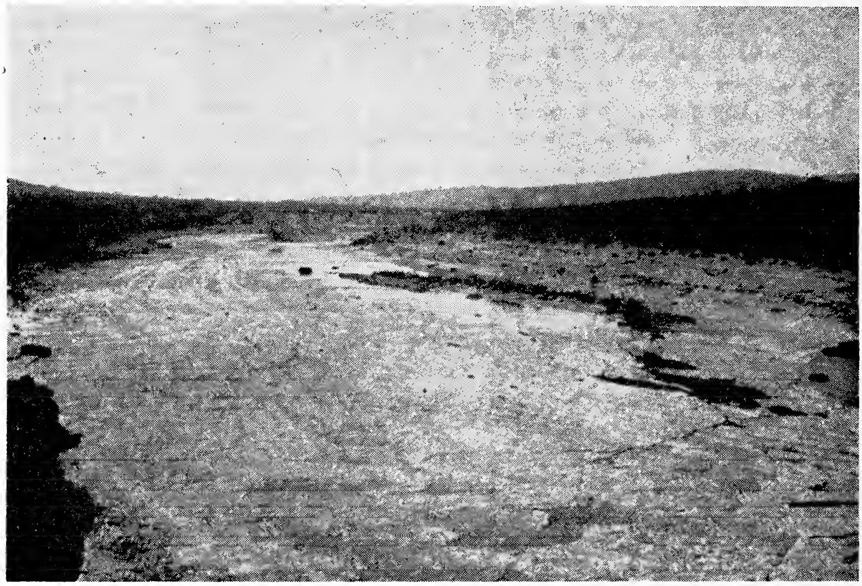

**Fig. 1. General view of the "wagon track" grooves in the bed of the James River, Mason County, Texas.**

they are closer together and more numerous. Each groove includes and connects a series of elongated potholes, which are from nine inches to one foot deep and from three to four feet apart along the grooves. Grooves and potholes are of the same width, about nine inches at the top, and between potholes the grooves reach a maximum depth of about four inches. Most of the grooves and potholes narrow downward, but some have nearly vertical sides. Only a very few potholes are at all undercut, and the long axes of these depart slightly from the general alignment.

The grooves and potholes show no tendency to follow the occasional joints which occur in the limestone, except where these joints are nearly tangent to the course of the river. Elsewhere joints and grooves cross without interruption of either. At a few places large slabs of the limestone have been torn out by the current along these joints, leaving gravel-filled depressions in the river bed, and at such places the "wagon tracks" are abruptly cut off.

**Fig. 2. Regularly spaced grooves where best developed.**

## PREVIOUS INVESTIGATIONS OF EROSIONAL DEPRESSIONS IN STREAM BEDS

It is generally accepted that potholes in stream beds are formed by the abrasive action of sand and gravel carried by the current. The typical pothole is hemispherical to cylindrical, and is attributed to the whirling of the suspended sediment by eddies having nearly vertical axes of rotation (Lobeck, 1939, p. 195; Holmes, 1945, p. 150; Cotton, 1948, p. 43; Longwell *et al.*, 1948, p. 77; Gilluly *et al.*, 1951, p. 255; Emmons *et al.*, 1955, pp. 497–498). A few investigators have recognized erosional depressions not strictly of this form in bedrock stream beds, and have included some of them under the general name "pothole" (Alexander, 1932). On the other hand, a few writers have included depressions whose origin is not at all connected with stream action under this same general name (Elston, 1917; Zotov, 1941; Ives, 1948).

Elston (1918), in his description of the "ideal normal pothole," suggested that closely-spaced potholes in the beds of turbulent streams could enlarge their bottoms and undercut their sidewalls until they broke through into each other. Natural bridges can be formed temporarily in this manner (as may be seen at the "Narrows of the Blanco River" in westernmost Hays County, Texas). Von Engeln (1942, pp. 170–172) and also Cotton (1948, p. 43) believed this process to be of major importance in the lowering of a stream bed. However, the groove thus formed of connecting potholes should have markedly arcuate and undercut sides and should be of varying width, none of which features is prominent in the James River "wagon tracks."

Lugeon (1915) described "erosional striae" at the Falls of the Yadkin River in North Carolina which are somewhat similar to the "wagon tracks," although on a much smaller scale. The grooves or furrows he discusses are only about one to four millimeters wide and two millimeters deep, and the ridges between them are rarely over ten centimeters long. According to Lugeon's photographs the grooves are very closely spaced, and here and there they are slightly divergent. At places they radiate from the centers of obstacles. Lugeon describes similar striae found on vanes and needle valves of hydraulic turbines at electric generating stations in Switzerland. His photograph of one such valve needle shows that the grooves contain and connect elongated depressions and closely resemble the James River "wagon tracks" in miniature.

Lugeon attributes this "fluvial engraving" to jets of sand-laden water impinging at high velocity upon the rock surface. He thinks that under normal flow the river wears away its bed by means of eddies, which may pass over the rock irregularly or may become fixed in one location and form ordinary potholes. At high velocities the sand-laden water moves in straight lines, and consequently engraves the striae. Lugeon emphasizes that ordinary potholes are absent wherever striae are found.

Blackwelder (1933) stated briefly that "rippling or vibrating currents laden with sand tend to carve parallel grooves in rock surfaces over which they flow. The grooves are round-bottomed and in plan are lenticular. They are separated by sharper ridges. Both are elongated in the direction of flow. . . ."

Maxson and Campbell (1935), in their work in the Grand Canyon of the Colorado River, termed this type of erosion "stream fluting." They describe small-scale depressions similar to those observed by Lugeon, but attribute them to the numerous small vortices formed where the swift, sand-laden current impinges upon its bed or upon obstructing boulders. They classify the resulting depressions into "sweep flutes" ("elongated parallel grooves . . . particularly well developed by currents of high velocity"); "undulation flutes" ("broad shallow depressions having little or no elongation"); "pocket flutes", which are similar but relatively deeper and often undercut on their up-current sides; "pothole flutes" and "sprila flutes," which are attributed to vortices with nearly vertical axes of rotation; and "fret flutes," which are minor furrows, similar to Lugeon's striae, superimposed on any of the preceding types. None of the flutes illustrated in their article approaches the size of the James River "wagon tracks."

Alexander (1932, pp. 330–331), combining field observations with laboratory experiments, divided potholes into three types: eddy holes, gouge holes, and plunge-pool holes. He defines gouge holes as "elongated holes with a more or less flaring U-shaped vertical section parallel to stream flow and caused by the oblique direct impact of water. The length of the diameter at the top, measured in the direction of stream flow, is often several times the transverse diameter, or width. . . . As the direction of the eroding jet approaches the horizontal, the U shape flares more, becoming a long groove. . . . The typical gouge hole is characteristic of steep rapids." In a diagram he illustrates their formation by the sediment carried by water revolving partly or completely around a horizontal axis.

## ORIGIN OF THE JAMES RIVER GROOVES

It would appear that the "wagon track" grooves in the bed of the James River have developed from gouge holes of the type described by Alexander. All stages of their formation may be seen within a short distance upstream and downstream from the place where they are most prominent.

The gouge holes are most numerous just downstream from low barriers caused by the eroded upper end of a downstream-dipping stratum or by the edge of an excavation left by the plucking out of slabs of limestone along a prominent joint. Their formation seems to begin with the flaking or spalling of thin pieces from the limestone surface. The broad, shallow depressions thus created become smoothed and elongated in the direction of the current, and elliptical basins are produced (Fig. 3). This process may be similar to the development of Maxson and Campbell's undulation and pocket flutes, but is on a much larger scale.

The low flow of the stream fills the gouge-hole basins and overflows from one to another, gradually wearing a connecting channel between them, probably as much by solution as by abrasion (Fig. 4). (Sufficient sand is carried by the James River for abrasive action, but very

Fig. 3. Shallow gouge holes becoming elliptical.

little of it is moved at times of low flow). If the slope of the limestone stratum is nearly uniform, all such channels will be approximately parallel, and thus the "wagon tracks" are initiated. Close to the original barrier these grooves are shallow and are only a foot or two apart, but farther downstream they tend to unite into fewer and deeper ones, as low-flow rills on a gentle slope might be expected to do. The original gouge holes are not all in perfect alignment; consequently the incomplete grooves tend to have a slightly zigzag course, but they become straighter as they become deeper and wider. For long periods the low flow is insufficient to cover the entire stream bed; consequently many gouge holes are left unconnected with their fellows during much of the time and can be deepened only during floods. As more and more of the current concentrates in the connected holes and grooves, the unconnected holes fail to keep pace with them and gradually disappear in the general erosion of the stream bed (Fig. 5). Thus where the grooves are most perfectly developed isolated gouge holes are not numerous. It is significant that the well-developed "wagon tracks" are confined to that part of the stream bed followed by the maximum current, with which they are in perfect alignment, and are not found at places such as the inside of curves where the stream volume and velocity must be less.

Inasmuch as the James River is floored by limestone bedrock throughout the greater part of its course, the question arises why the "wagon track" grooves should be confined to this particular stretch. The answer seems to lie in the presence here of a limestone whose attitude departs just enough from the horizontal to provide occasional barriers to the stream, and whose resistance is sufficient to prevent the plucking away of slabs except at long time intervals.

It is interesting that Lugeon likewise attributes the preservation of the "fluvial engraving" at the Falls of the Yadkin River to the presence there of an unusually durable and homogeneous rock. Maxson and Campbell believe the fluting process to be relatively fast, yet they consider the flutes to be evidence of the long-continued fixed position of the boulders on which they occur.

The "wagon track" grooves of the James River evidently require a

Fig. 4. Gouge holes intersecting to form groove.

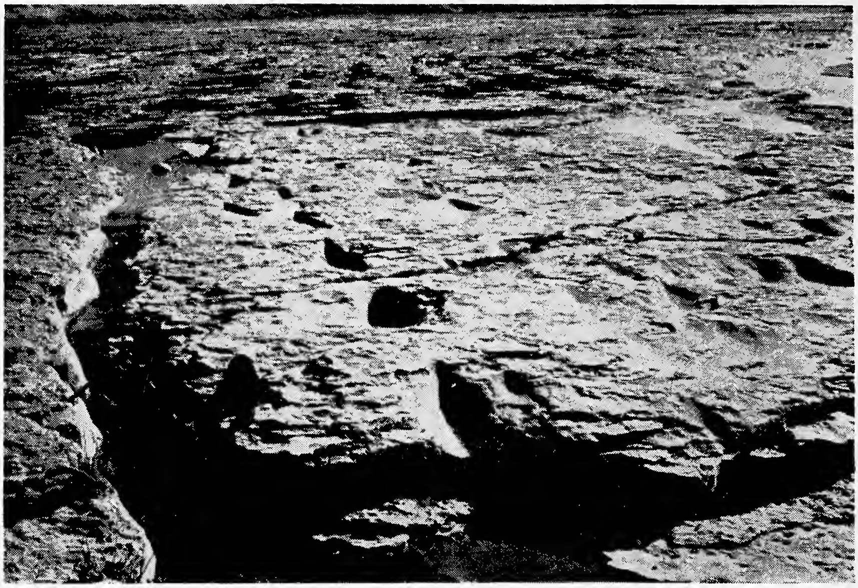

**Fig. 5. Completed groove and abandoned gouge holes.**

long time to develop, and a single limestone stratum in the stream bed must endure long enough to preserve them. At the locality described the presence of a more than usually massive limestone with few joints has provided these favorable circumstances.

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# Profits and Problems in East Texas Woodland Conservation

*by* **CARTER B. GIBBS** *and* **GEORGE K. STEPHENSON**[1]

East Texans have long recognized their woodlands as a basic source of income. More than 2 million acres under industrial forest management attest to the conviction of industrialists that forestry practices are profitable.

Yet the bulk of east Texas forests are woefully mismanaged, and most east Texas landowners do little if anything towards better woodland conservation. Over the past 12 years the East Texas Forest Research Center has tried to learn the reason for this neglect and what can be done about it.

There is little question that a high level of woodland management is in the public interest. Such desirable objectives as wildlife production, public recreation, watershed protection, and soil conservation require that the woodlands of this area be maintained as a vegetative cover. The needs of the area for raw material and the well documented present and future need of the nation for timber products from this region put a premium on higher levels of forest productivity. After a very thorough survey of forest resources and prospective timber needs, the Forest Service estimates the nation will require at least 25 percent more wood by 1975, and twice our present production by the year 2000. Only with the help of southern forests can these anticipated needs be met.

With minor exceptions east Texas forest lands have the capacity to grow 250 to 300 board feet per acre each year of pine or valuable hardwoods. Yet presently the average growth is less than 150 board feet, including low grade hardwoods; over 5 million acres grow at less than 100 feet, and almost 2 million acres average only 35 board feet per acre per year.

The Forest Survey of east Texas, completed in 1955, provided some further data that help to clarify the situation. The 19 timbered counties of northeastern Texas, including Anderson, Cherokee, Nacogdoches and Shelby, were reported separately from the 18 southeastern counties. Some rather remarkable differences came to light.

[1] East Texas Research Center of the Southern Forest Experiment Station, Forest Service, U. S. Department of Agriculture.

Southeast Texas is 68 percent forested, predominately with pine types, while the northeast is only 53 percent forested, and half of that is in hardwood. Net annual growth in the southeast is 181 board feet, in contrast to the northeast's 100 board feet per acre. This reflects differences, not in soil but in growing stock, for in the southeast the average acre now supports 2,954 board feet while the comparable figure for the northeast is 1,269 board feet. In both areas forest land has shown a net increase over the past 20 years. The increase has been primarily in hardwood types in the northeast, and mostly pine in the southeast. Since much of the increase in hardwood types results from depletion of pine in mixed pine-hardwood stands, the change suggests progressive deterioration of the forests of northeast Texas.

While many factors contribute to these differences, the contrasts in ownership pattern are particularly noteworthy. The woodlands of northeast Texas are held in small parcels by a multitude of farmers and other individual owners. Only one organization is known to own more than 100,000 acres; relatively few ownerships exceed 5,000 acres, and the average is probably less than 100 acres.

In the southeast counties forest ownership is dominated by large holdings, mostly industrial. Well over 2 million of the 7 million forest acres are managed for timber production by 10 wood-using enterprises. Most of the 655,000 acres of national forests are also in this area. In addition, some degree of forestry is being practiced on a large number of intermediate sized ownerships.

There is more than a fortuitous relationship between the prevalence of large ownerships and the productive condition of the forests. Studies have revealed that in Texas, as elsewhere throughout the South, the large industrial owners retain far higher levels of growing stock, grow better trees, and leave their recently cut lands in better condition than do owners of smaller tracts. Among the smaller ownerships, those under 5,000 acres are generally in poorer condition than those from 5,000 to 50,000. Farm woodlands are well below average.

The industrial manager, of course, looks on his forest from a different economic viewpoint than the smaller owner. His primary concern is with a complex manufacturing and marketing enterprise. His forests are his source of raw material, and their purpose is to produce timber that can turn a profit in his mill. The emphasis is on quantity and quality of output, rather than the rate of return on the forest investment. To such owners long-term forest production makes economic sense. They have their problems, but by and large they are well on the road to solving them.

The owner of smaller woodlands, on the other hand, must make his decisions in the light of his personal economic situation, and alternative investment opportunities. The income from his forest will be related to the investment he puts into it, whether that means his own labor for improvement work, cash outlay for tree planting, or simply the foregoing of present income by leaving a growing stock on the land. Though foresters and economists have repeatedly demonstrated such investments to be economic, owners of small tracts have so far invested very little in forestry. Above all, they have failed to regulate timber harvests so as to retain enough trees to grow new crops of wood.

Fifteen years of remeasurements at the San Jacinto Experimental Forest in Walker County illustrate how growth can vary with growing stock. Stands where only pulpwood trees were left in 1938 have averaged less than 100 board feet of growth per acre per year. Stands averaging 2,700 board feet have grown at the rate of 178 board feet, and stands ranging from 5 to 8 thousand board feet have averaged from 300 to 400 board feet per acre per year. Obviously, high growth per acre requires large growing stocks.

On the Austin Experimental Forest near Nacogdoches, one study illustrates how a well-informed farm owner might handle his woodland. It is assumed that he needs some income from his woodland each year, and that his eventual objective is maximum total income from the woodland rather than maximum returns from his investment in timber.

When the study was established in 1947, this 67-acre tract was rather typical in that the site was good but more than half the volume was in hardwoods, mostly defective and undesirable. The original pine stocking of 3,300 board feet per acre, though better than that of the average farm woodland, was about ⅓ optimum. Over the past 10 years annual cuts have provided income, while reservation of growth and some investment in cash and labor have improved the capacity for future production. Control of hardwoods and lack of natural regeneration have been the major forest improvement problems.

Early in the program all defective hardwoods that were merchantable were cut for sawlogs and crossties. Because of low quality, some 65 thousand feet brought only $390. Yearly cuts of imperfect and mature pines have brought the total income from stumpage up to $2,777 in ten years.

Since 1947, costs totaling $638 have been charged to the woodland. Of this $100 is the estimated taxes, and $141 is the cost of marking and scaling the annual harvests. The remaining $397 has been invested in removal of unmerchantable cull hardwoods which were interfering with pines, and in underplanting pines where no reproduction had volunteered. This investment is the equivalent of about 3½ work days annually. Similar investments are needed on most Texas woodlands.

Over the ten years, during which the pine sawtimber has increased by 10 percent and the smaller pines by a greater proportion, there was a net total income of $2,139 from stumpage cut from this 67-acre tract. On an annual per-acre basis, gross income has been $4.15, cost $0.95, and net return $3.20. Nor is this the limit. As foresters like to point out, an owner who will do his own logging, and sell logs instead of stumpage, can often double these values.

Why then, if forestry can pay so well, do so few small owners practice it? Of all the tens of thousands of woodland owners in Texas, why are there only 1,000 recognized tree farmers?

We feel that the classic excuses, ignorance of basic principles of forestry or lack of market information, are no longer of primary importance. Most owners pay lip service to the benefits of forestry, and exhibit at least a rudimentary understanding of it, though few of them put such knowledge into practice. High stumpage values are now widely recognized and foresters are generally available to help the uninformed. Much more important, apparently, is the poor competitive position of the seller of a small amount of stumpage, and the fact that most small owners have urgent and recurring needs for cash.

The disadvantages of small stumpage sales have been demonstrated repeatedly in the operation of our farm forest study. Out of proceeds from the timber they cut, buyers must recover fixed costs such as moving equipment to the job. If the volume is small, the stumpage price must be reduced. While our special research requirements add to loggings costs and reduce stumpage values, a private owner selling 5 to 10 thousand feet at a time would also have to sell below going prices.

By harvesting periodically instead of annually, an owner can sometimes accumulate enough volume to avoid selling at an excessive discount. To do so, however, he sacrifices an annual income. In practice, the fact that it may bring more per thousand board feet as well as more total dollars is a powerful economic argument for clearcutting growing stock instead of harvesting growth.

Even more powerful is the fact that owners of small woodlands are generally people of small resources, beset like most of us with needs that are not adequately met by current income. The economist may choose a $200 annual income beginning now, with prospects of more later, over a $5,000 cash offer. The average owner, who perhaps owes hospital bills or needs a new car, generally takes the cash, even though he knows his choice will reduce his future earnings.

A study by Arnold Mignery of the East Texas Research Center revealed one consistent characteristic of the better forest managers of Nacogdoches County—they were all well off financially when they started to practice forestry. Among people of average means, woodland conservation was consistently poor. Mignery concluded that while such people did not intentionally abuse their woodlands, they almost invariably liquidated their forest capital when financially hardpressed, or when there appeared to be an opportunity to cash in on peak prices.

On superficial view, the history of some of these tracts appears to refute the foresters' contention that such liquidation is bad economics. Cuts in the late thirties and early forties left many small trees as worthless. Now trees of those sizes sell for pulpwood, or even small sawlogs. The owner, selling for the second time in fifteen years, thinks he has grown a phenomenal income, without reserving the growing stock that foresters recommend. The truth, of course, is that he has now liquidated the little growing stock that economics forced on him the first time. In most cases his second cut has eliminated seed-bearing trees, so that worthless brush will take over long before more pine can grow.

Much hope was once held for the thesis that farm woodlands were especially suited to good forest management. The status of woodlands as a part of the farm acreage, the stability of family farm ownerships, the need for fuel and timber in the farm enterprise, the availability of off-season labor, and the proximity of farm power and equipment were among the recognized advantages of farm forestry. Many of them are still valid, though bottled gas has largely supplanted fuelwood, industry offers jobs for most surplus labor, and the handling of timber has become a business of specialized skills and equipment. Yet even among the few farmers who are conservation-minded, few augment their income by personally engaging in woodland work.

That there would be an aversion to woods work is perhaps incomprehensible to the theoretical conservationist or to the desk-bound forester to whom a few hours out-of-doors is an invigorating exercise. I suspect, however, that a generation raised to firewood cutting and newground clearing may view woods work as the ultimate in distasteful toil. The axe, like the rock hammer, is the symbol of onerous unrewarding labor. When the farmer invests in butane equipment he is buying not just convenience, but emancipation from the woodpile. How, too, shall we appraise the gratification of being able, once in a lifetime, to sell a commodity without the trouble and sweat of harvesting and delivering it? We can only speculate on the importance of such psychological factors, but the fact remains that extensive effort has largely failed to interest farmers in the substantial opportunities to profit by working in their own woods.

What then, of the prospects for woodland conservation?

Because it is needed for the national welfare, good public policy demands that it be fostered. On large holdings economic factors appear favorable and progress may be expected to continue as in the past. For the small ownerships, economic considerations have generally worked out unfavorably to good forestry. The present economic situation, however, does afford good possibilities for improvement in small-tract forestry through judicious public action.

While continuing educational efforts may increase the popularity of farmer operation of woodlands, progress is likely to be slow. Changes in east Texas agriculture and industry are increasing the importance of the "non-operating" small woodland, whether it belongs to a non-resident or to an operating owner whose time is too fully occupied for woods work. For such owerships periodic rather than annual cutting may be most economic, and the requisite forestry skills are likely to be supplied by the public or consulting forester, rather than the owner. Among owners of better stocked properties, there seems to be an encouraging interest along these lines.

Because the time element and the low prospective returns are unattractive, restoration of many of the most depleted areas is unlikely without public financial assistance. Where overall public benefits justify, forms of public aid which reduce the investment and improve the earning rate should be very effective in getting forestry work accomplished. Early experience in the forestry phases of the Soil Bank Program, for example, suggests that it will be a powerful incentive to woodland conservation.

The initial cost of such direct financial aids may seem high. But if they succeed where the previous educational approaches have been only moderately successful, it is quite possible that they may get forestry on the ground at a lower public cost per acre than ever before.

# Reproduction in the Biotin-Deficient White Rat

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The influence of biotin on reproductive processes was first shown by the work of Cravens *et al.* (1942) who reported that biotin was essential for successful reproduction in the domestic fowl. Subsequent investigations by Cravens *et al.* (1944) and Couch *et al.* (1948) demonstrated that hens fed rations low in biotin produced chicks with manifestations of congenital perosis, ataxia, and skeletal abnormalities. Increased embryonic mortality and chondrodystrophy were also reported.

Relatively few papers have been published on the influence of biotin deficiency on reproduction in the albino rat. Chief among the investigations is that of Kennedy and Palmer (1945) who demonstrated that biotin was essential to reproduction and lactation in the rat. They found that 30% uncoagulated egg albumen in the diet did not upset the estrus cycle and that pregnancy continued until the 11th to 13th day. The number of resorptions induced by this diet was high when compared with the controls. No statement was made about the length of time the egg white diet was fed before mating. It was also noted that folic acid was not included in the experimental diet.

Lewis and Everson (1952), using *Lactobacillus arabinosus*, microbiologically assayed normal maternal and fetal rat tissues for biotin and pantothenic acid. They found that maximum transfer of biotin and pantothenic acid from mother to fetus took place on the twenty-first day of gestation. They also demonstrated that there was no increase in the requirement for either vitamin during the first 14 days of gestation. From the data obtained they concluded that the maximum need for biotin was just previous to parturition.

The aim of this investigation was to study the influence of biotin on reproduction in the albino rat by rendering the maternal animals deficient in biotin using raw egg white as a part of their diets.

## METHODS

Normal weanlings were obtained from a stock of Wistar Institute strain albino rats and from A. and M. College strain rats maintained

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by the biological section of the Texas A. and M. Research Foundation. These weanlings were kept on laboratory rations (Purina Lab Chows) until they attained an average weight of 140 to 160 grams. The female rats were then placed on a semi-synthetic control diet or on the biotin-deficient experimental ration which consisted of "vitamin-free" casein, dried uncoagulated egg white (which contains the biotin-binding substance, avdidin), cerelose (glucose), salts mixture, necessary vitamins (less biotin) and essential fatty acids (Table 1).

This study, which extended over a period of two years, is based upon breeding data and offspring from three series of rats. Series A rats (A. and M. strain) were divided into 4 groups; Group A-I (24 experimental and 6 control) were maintained on a diet for 5 weeks

TABLE 1

Dietary Constituents

| | Grams/100 gms. feed | |
|---|---|---|
| | Control Ration | Biotin-Deficient Ration |
| Vitamin-free Casein | 30.00 | 15.00 |
| *Raw Egg White | | 15.00 |
| Cerelose | 61.00 | 61.00 |
| Wood Pulp | 3.00 | 3.00 |
| †Salts Mixture | 5.00 | 5.00 |
| ‡Oil (Nopco fish oil) | 1.00 | 1.00 |
| Methyl Lineolate | ad libitum twice weekly by dropper | |
| Vitamins | | |
| Vitamin A | 3,000 I.U. | 3,000 I.U. |
| Vitmain D | 400 I.U. | 400 I.U. |
| Menadione ($K_3$) | 0.75 mgm. | 0.75 mgm. |
| Alpha Tocopherol Acetate | 2.50 mgm. | 2.50 mgm. |
| Thiamine Hydrochloride | 1.00 mgm. | 1.00 mgm. |
| Calcium Pantothenate | 4.00 mgm. | 4.00 mgm. |
| Niacin | 5.00 mgm. | 5.00 mgm. |
| Inositol | 10.00 mgm. | 10.00 mgm. |
| Choline Chloride | 100.00 mgm. | 100.00 mgm. |
| Para-Amino Benzoic Acid | 50.00 mgm. | 50.00 mgm. |
| Folic Acid | 0.10 mgm. | 0.10 mgm. |
| Vitamine $B_{12}$ | 2.50 *mcg.* | 2.50 *mcg.* |
| Riboflavin | 1.00 mgm. | 1.00 mgm. |
| Pyridoxine | 1.00 mgm. | 1.00 mgm. |
| Biotin | 0.10 mgm. | |

* Armour and Company, Fort Worth, Texas.
† Richardson and Hogan (1946).
‡ Nopco Chemical Company, Richmond, California.

before mating; Group A-II (25 experimental and 5 control) for 7 weeks before mating; Group A-III (11 experimental and 2 control) for 12 weeks; and Group A-IV rats (12 controls), which were maintained on the control ration for 12 weeks, were mated with non-deficient males of the same stock. Offspring from Groups I and II were examined histologically. The results of this study are reported elsewhere (Cooper and Brown, 1958).

Series B (Wistar strain) experimental rats were maintained on the deficient diet for 20 weeks. They were then divided into four groups and subjected to the following treatments: Group B-I (4 controls) received no treatment; Group B-II (5 experimental) rats were injected intraperitoneally with 50 micrograms of biotin in aqueous solution at mating and twice weekly until parturition; Group B-III (6 experimental) rats were returned to the control ration at mating; and Group B-IV (4 experimental) remained on the biotin-deficient diet throughout the 23 week experiment.

Series C (Wistar strain) rats were all placed on the experimental ration at the same time. Relatively few control-fed animals were considered necessary since the diet that these animals were fed has been demonstrated many times in this laboratory to be adequate for normal reproduction in albino rats. Eight groups of one control and 5 experimental rats each were mated during successive weeks beginning after on week on the experimental diet. This program was designed to obtain breeding and reproduction data for maternal rats that were maintained for progressively longer periods of time on the biotin-deficient diet. The longer the rat is fed the diet, the more depleted the body store of biotin becomes.

The estrus cycle and time of fertilization was followed by vaginal smear techniques. The date on which sperm appeared in the vaginal smear, if followed approximately 11 days later by the presence of erythrocytes which indicates implantation, was considered to be the first day of the gestation period.

The mother rats were killed upon parturition or at the end of the normal gestation time of 21-22 days. The young were weighed and preserved for other studies. The uterus was excised, the number of implantation sites counted, and then it was preserved in 10 per cent neutral formalin for future study.

## OBSERVATIONS

In Series A, in which rats of the A. and M. College strain were used, the 24 Group A-I females on the experimental ration had 22 conceptions and produced 16 litters. Each litter averaged 8.3 newborn with an average weight of 4.8 grams for each individual. A total of 30 resorptions occurred in the 22 mothers that did conceive. In the controls all animals conceived and produced an average of 8.6 individuals per litter having an average weight of 5.2 grams for each individual. There were no resorption sites in the uteri of the control rats.

Group A-II females were mated after 7 weeks on the experimental ration and allowed to produce one litter each which was killed at birth. These females were maintained on the experimental diet for another three weeks after which they were mated a second time. From the results given in Table 2 it may be seen that of the 25 experimental animals only 9 produced litters from the first matings. The average litter was reduced to 7.1 individuals and the average weight

TABLE 2

Mating, conception, absorption, and littering of control and biotin-deficient rats fed for 5, 7, and 12 weeks before mating.

| | Number Mated | Number Conceived | Number Littered | Avg. Number Per Litter | Avg. Weight Offspring | Total Resorb | Total Dead |
|---|---|---|---|---|---|---|---|
| Group I | | | | | | | |
| Deficient | 24 | 22 | 16 | 8.3 | 4.8 (4.5–5.4) | 30 | 2 |
| Control | 6 | 5 | 5 | 8.6 | 5.2 (4.7–6.2) | 0 | 0 |
| Group II | | | | | | | |
| Deficient | 25 | .. | 9 | 7.1 | 4.5 (4.2–4.9) | .. | 12 |
| Control | 5 | 5 | 5 | 10.4 | 5.4 (5.1–6.2) | 0 | 0 |
| (2nd mating) | | | | | | | |
| Deficient | 25 | 15 | 0 | 9.7 (implants) | .. | 146 | 0 |
| Control | 5 | 4 | 4 | 13.0 | 5.3 (5.1–5.4) | 0 | 0 |
| Group III | | | | | | | |
| Deficient | 11* | 11 | .. | 10.0 (implants) | .. | 110† | 0 |
| Control | 2 | 2 | 2 | 12.0 | 5.7 (5.4–6.0) | 0 | 0 |
| Group IV | | | | | | | |
| Control | 12* | 12 | .. | 13.0 (implants) | .. | 5 | 0 |

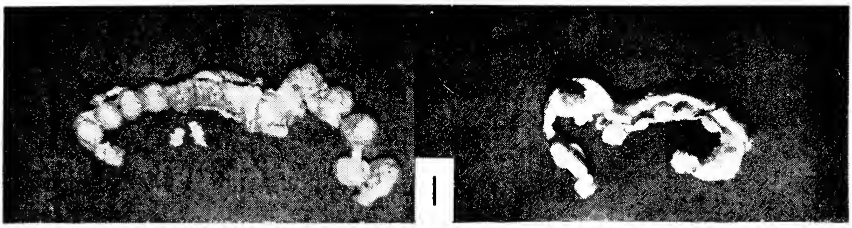
* Sacrificed for embryo comparison studies.
† Regarded as resorptions due to appearance in uterus.

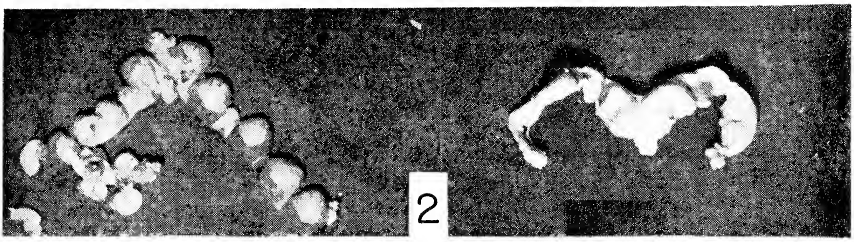
of each offspring was 4.5 grams. Since the animals were saved for another mating placental counts were not made. The control rats in this group gave birth to litters averaging 10.4 in number and 5.4 grams in individual weight. The second matings, made after the animals were on the deficient diet for a total of 13 weeks, produced only one litter which was dissected out dead when the animals were killed on the twenty-third day after conception. In this animal at 8 implantation sites there were 5 embryos that were resorbed; two were hydrocephalic, small, and had malformations of mouth and snout; the remaining one was normal but smaller than the litter mate monsters. Autopsy of this series of females, which were on the deficient diet for a total of 13 weeks, showed that in the 15 females that conceived at second matings a total of 146 resorptions occurred. Nine of the 10 females that apparently did not conceive had periovarian capsules on one or both ovaries, which condition is a normal indication of pregnancy. No implantation sites were found in the uteri of these females.

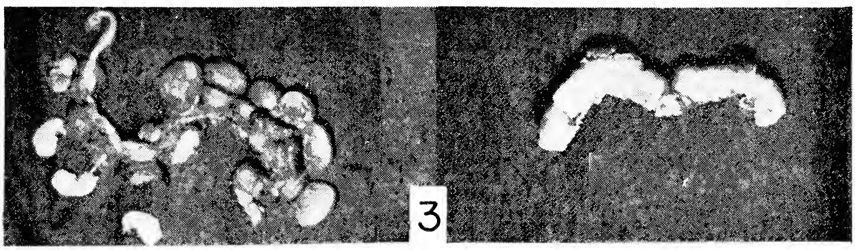
Two female rats of Group A-III, which had been on the raw egg white diet for 12 weeks previous to mating, were sacrificed each day, beginning with the thirteenth day after successful breeding, in order to obtain deficient uteri and embryos for comparison with the uteri and embryos of the same period from the control animals. The small sizes of the uteri containing the embryos indicated that resorption had already begun as early as the thirteenth day of gestation (Figures 1, 2, 3, 4). Examination of free hand sections through the embryo sites with a dissecting microscope revealed little more than a mass of disoriented tissues. Further investigations of embryonic mortality in the biotin-deficient rats are now in progress.

The female rats which had been maintained continuously on the control diet (Group A-IV) were killed at daily intervals beginning on the thirteenth day of gestation in order to obtain embryos of known age for comparison with embryos and uteri from the deficient Group A-III rats above. The gross differences in size and distention of the uteri may be noted from Figures 1, 2, 3, and 4. Since the swellings in the uteri of the biotin-deficient females were all essentially the same size on the thirteenth, fourteenth, fifteenth, and sixteenth days of gestation, it appears that embryonic death occurs before the thirteenth day of gestation.

*Series B.* The 15 females in these experiments were maintained on the experimental diet for 20 weeks in order to insure depletion of biotin. They were then mated, divided into 3 groups, and treated as previously described. Table 3 shows the results of these experiments. Of the 5 dams which were injected with 50 micrograms of biotin (Group



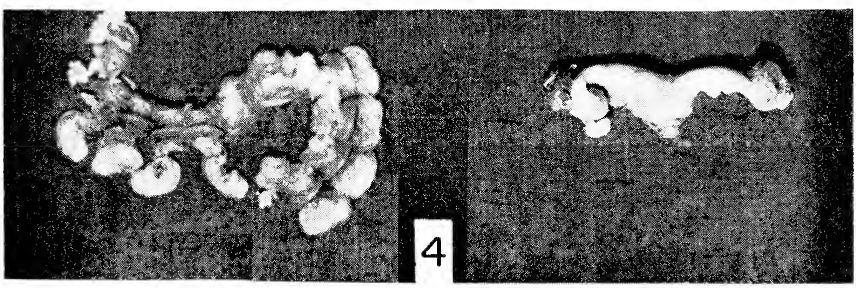




Fig. 1. Uteri of control (left) and biotin-deficient white rats at thirteen days gestation. 0.75 actual size.

Fig. 2. Uteri of control (left) and biotin-deficient white rats at fourteen days gestation. 0.75 actual size.

Fig. 3. Uteri of control (left) and biotin-deficient white rats at fifteen days gestation. 0.75 actual size.

Fig. 4. Uteri of control (left) and biotin-deficient white rats at sixteen days gestation. 0.75 actual size.

TABLE 3

Mating, conception, resorption, and littering of control rats, biotin-injected deficient rats, deficient rats returned to control rations, and biotin-deficient rats.

| Group | Treatment | Number Mated | Number Conceived | Number Littered | Avg. Number Littered | Avg. Weight Offspring | Total Resorb | Total Born Dead |
|---|---|---|---|---|---|---|---|---|
| I | Control | 4 | 4 | 4 | 10.5 | 5.7 (5.7–5.8) | 2 | 0 |
| II | Injected 50 *mcg.* biotin | 5 | 4 | 4 | 9.0 | 5.8 (5.1–6.2) | 2 | 0 |
| III | Returned to Control | 6 | 5 | 5 | 6.2 | 5.2 (4.4–6.0) | 11 | 0 |
| IV | Deficient | 4 | 4 | 1 | 2 (dead) | 1.25 | 33 | 2 |

B-II) 4 conceived and littered. The average number of newborn rats per litter was 9.0 with each newborn weighing an average of 5.8 grams. Two resorptions occurred in this group. It is interesting to note that the average weight of these offspring was slightly higher than that of the controls. It is possible that this weight increase could have been caused by the increased biotin administered to the mothers. Further experimentation would be required to establish this, however.

The mother rats which were returned to the control diet (Group B-III) had an average of 6.2 offspring per litter with an average individual weight of 5.2 grams. Eleven resorptions occurred in the 5 dams that conceived.

The females that remained on the experimental diet throughout the 23 week experiment (Group B-IV) did not litter and were sacrificed. All embryos were in various stages of resorption. The two largest embryos in one female still retained their body shape and were included in the data as still births.

*Series C.* This experiment was designed to learn the length of time that the diet had to be fed in order to produce a decrease in litter size and an increase in the number of resorptions. The results of this experiment are show in Table 4. From these data it is apparent that rats maintained for progressively longer periods on the raw egg white diet show a decrease in the average weight of the newborn, a decrease in the average litter size, and an increase in the number of resorptions. In this strain of rats (Wistar), it appears that the biotin necessary to maintain pregnancy and produce viable offspring is depleted by the end of the second week preceding mating. This would be the end of the fifth week on diet if one adds the three weeks of gestation. The average weight of the newborn rat decreases after the first week preceding gestation (four weeks before parturition). It appears that as the biotin supply within the body of the mother rat becomes depleted the offspring become smaller in body weight and show less activity at birth. These smaller offspring also appear paler in color than the offspring of the controls.

## DISCUSSION AND CONCLUSIONS

The data presented show that a partial biotin deficiency in the albino rat produced by raw egg white diet results in reduced litters and

TABLE 4

Breeding data according to length of time the biotin-deficient diet was fed to mother rats.

| Weeks Fed Before Mating | Number Mated | Number Conceived | Number Littered | Average Number Per Litter | Average Weight Each Offspring | Total Number Implants | Total Resorbed | Total Born Dead |
|---|---|---|---|---|---|---|---|---|
| Control | 8 | 8 | 8 | 9.8 | 5.4 | 82 | 4 | 0 |
| 1 Deficient | 5 | 5 | 5 | 8.0 | 5.5 (5.3–5.8) | 49 | 9 | 0 |
| 2 Deficient | 5 | 5 | 5 | 10.2 | 4.5 (3.5–5.0) | 59 | 8 | 0 |
| 3 Deficient | 5 | 4 | 3 | 9.0 | 4.4 (3.9–5.6) | 45 | 18 | 9 |
| 4 Deficient | 5 | 5 | 1 | 11.0 | 4.4 (3.0–4.8) | 59 | 48 | 0 |
| 5 Deficient | 5 | 4 | 2 | 2.5 | 3.6 (3.4–3.8) | 46 | 41 | 5 |
| 6 Deficient | 5 | 3 | 1 | 3.0 | 3.1 (2.9–3.2) | 41 | 38 | 3 |
| 7 Deficient | 5 | 4 | 1 | 8.0 | 4.6 (4.5–4.7) | 39 | 31 | 1 |
| 8 Deficient | 5 | 4 | 1* | 2.0 | 3.4 | 43 | 41 | 2 |

* Did not litter; sacrificed after 23 days gestation. See text.

small offspring. A more complete biotin-deficiency results in resorption of almost all embryos.

Since all groups of experimental animals received the same ration, but for varying periods of time before mating, the number of weeks on the diet was arbitrarily used as an indication of the severity of the deficiency, rather than the variable external symptoms. Thus, it was found that female rats maintained on a biotin-deficient diet for longer than two weeks before mating showed a marked reduction in the number of litters produced, a reduction in the average weight of the offspring, and an increase in the number of intrauterine resorptions. After 10 or more weeks on the deficient diet no litters were produced and all embryos were in final stages of resorption when the uteri were dissected.

Since the average number of implantation sites found in the experimental animals was approximately the same as that found in the control rats, it would appear that the effect of the biotin deficiency is not on the ovary, on ovulation, or on the estrus cycle. Normal estrus cycles were shown by vaginal smear to be present in all groups of experimental and control animals except those previously described in Series A.

The day of implantation (10–13 days) was determined by the occurrence of erythrocytes in the vaginal smear. After the twelfth day of gestation, marked differences in uterine and embryo sizes in the deficient animals were noted when compared with the uteri and embryos of the control animals.

From this work it may be concluded that the most critical demand by the embryo for biotin exists on or before the twelfth day. Lewis and Everson (1952) stated that the maximum need for biotin in the rat is present on the twentieth or twenty-first day. This may be the time of maximum transfer of biotin from mother to fetus, but it is not necessarily the time of maximum need for biotin in embryonic development since the resorption of the embryos of biotin-deficient rats occurred much earlier in the gestation period in this experiment. Further work must be done to determine the exact time of embryonic death.

A deficiency produced by twenty weeks feeding of the experimental diet caused resorption of all embryos. When these animals were given biotin by injection or in their diet their reproductive ability was restored.

A comparison of average weights of newborn control rats showed that as litter size increased the average weight of the individual decreased, as is the usual case. However, in the biotin-deficient animals the number of individuals in the litter had little effect on the average weight of the individual.

## SUMMARY

1. Female white rats maintained on the experimental biotin-deficient diet for two weeks or more before mating produced offspring which were lighter in average body weight than offspring from control-fed animals.

2. Females remaining on the experimental diet for more than 10 weeks before mating produced no litters. All uteri from experimental mothers that did conceive contained embryos that were in various stages of resorption.

3. Progressive time-feeding studies showed a correlation between the length of time the mother remained on the diet and the occurrence of resorptions; the longer the time on the experimental diet, the larger the number of resorptions.

4. Intraperitoneal injections of 50 micrograms of biotin to experimentally non-productive females during the gestation period resulted in recovery of reproductive ability and the production of normal offspring.

5. Twenty-weeks-deficient mother rats returned to the control ration at the time of mating produced litters in which the offspring appeared intermediate in size and weight between control and partially deficient ones.

6. It appears that the effect of the biotin deficiency is not on the ovary, on ovulation, or on the estrus cycle. Apparently, then, the effect of biotin is either on the embryo itself or on the placenta. Further experimental work is necessary to determine the exact manner in which biotin exerts its influence on reproduction in the white rat.

## ACKNOWLEDGMENTS

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# The Vocal Sac of the Colorado River Toad (*Bufo alvarius* Girard)

*by* **ROBERT F. INGER**
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## INTRODUCTION

The function of the voice of frogs and toads as a species isolating mechanism has been assumed, explicitly or implicity, by many authors (e.g., Blair, 1955; Blair and Pettus, 1954; Jameson, 1955; Inger and Greenberg, 1956). Consequently, the suggestion by Blair and Pettus that the voice and vocal sac of *Bufo alvarius* are degenerating is of interest to students of speciation.

Direct aural perception by Blair and Pettus and measurements made by them on sonograms produced from tape recordings constitute their evidence for degeneration of the voice in this big toad. Dissection of the vocal sacs of twelve males seemed to provide evidence of morphological degeneration, for Blair and Pettus found one toad without a vocal sac and the sacs in " . . . remaining males varied in degree of development." Some doubt was thrown on this interesting correlation of degeneration in behavior and structure by the statement that two females had vocal sacs " . . . in practically the same state of development as in the average male."

Observation of vocal sacs in female frogs or toads is so unusual that confirmation is required. But confirmation of all of Blair and Pettus' anatomical data is needed because their description of the vocal sac of the males does not agree with other published descriptions (Liu, 1935; Inger and Greenberg, 1956) of this structure nor with my dissections of *alvarius* (see below).

Thirty adult *alvarius*, nine females (snout-vent 125-175 mm.) and twenty-one males (103–155 mm.) from Arizona (Maricopa, Pima, Pinal, and Santa Cruz Counties) and Sonora, Mexico, were dissected for this study. Individuals having nuptial pads and vocal sacs were identified as males; the sex of all other toads was determined by examination of the gonads. Measurements were made with dial calipers graduated in 0.1 mm. and a steel rule graduated in 0.5 mm. I am grateful to Mr. C. M. Bogert, American Museum of Natural History

(AMNH), and to Dr. W. F. Blair, Texas University (TNHC), for the use of these specimens.

MALES

The vocal sac of AMNH 19539 is typical of maximum development in these males. An oblique slit-like opening is present in the floor of the mouth on each side of the tongue. The sac, a smooth epithelial structure, is continuous between these openings, and its antero-posterior dimension (without stretching) is greatest laterally (Fig. 1). Dorsally the sac is covered by *Mm. geniohyoideus* and *sternohyoideus* and ventrally by the *M. subhyoideus*. As in other toads, e.g., *Bufo regularis* (Inger and Greenberg, 1956), the subhyoid muscle is attached to the sac and, in its posterior half, the muscle fibers are separated and stretched longitudinally. Posteriorly the sac and its investing muscle overlie part of the pectoral muscle mass.

This individual (snout-vent 141 mm.) is clearly mature, judging not only by its size but also by the well-developed, pigmented nuptial pads on the first three fingers. Nine additional males (106-137 mm.) have vocal sacs essentially identical to those of AMNH 19539, except

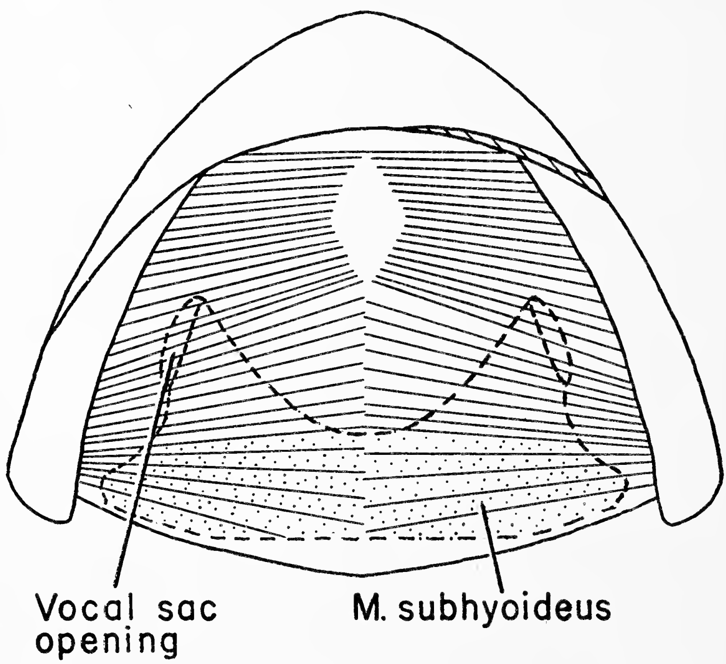


Fig. 1. Ventral view of head of *Bufo alvarius* with skin partly removed. Position of vocal sac shown by dashed line. (Semidiagrammatic, X2)

that only a single opening is present in eight. All nine have nuptial pads on the three inner fingers.

Another male (AMNH 51219, Sonora), that because of its size (155 mm.) must be judged mature, has paired vocal sacs separated medially by 11.5 mm. The distance between the two openings is 31.5 mm. A weak nuptial pad is present on the first finger. Two other males (TNHC 16416–17, Maricopa County) also have two vocal sac openings and paired sacs separated medially. These males have black nuptial pads on the first three fingers and are considered mature even though they are smaller (103–115 mm.) than the preceding one. Another male (TNHC 16419; 113 mm.) has a single vocal sac reaching only to the mid-line from an opening on the right side of the mouth. Black nuptial pads are present on the first three fingers.

The vocal sac openings were measured in six males and vary in length from 3.5 to 6.5 mm., representing 0.027–0.051 of the snout-vent lengths.

Four smaller males have no vocal sacs. One (119 mm.; AMNH 19826, Pima Co., Arizona) lacks nuptial pads. Three (111-119 mm.; AMHN 19535, 53071 from Pima Co.; AMNH 19547 from Pinal Co.) have nuptial pads on the two inner fingers. Their size and the presence of nuptial pads are reliable indicators of maturity.

### FEMALES

The presence or absence of vocal sacs in female *alvarius* has little bearing on the interesting question of degeneration of the call and vocal sac of this toad. Nevertheless, this matter must be discussed because errors of fact are often perpetuated through secondary references.

Posteriorly the *M. subhyoideus* in both sexes is reflected dorsally. The reflected portion is closely applied to the septum between the submaxillary and pectoral lymph spaces and overlies the *M. coracoradialis* and part of the *M. deltoideus* (Fig. 2.) If a sagittal section is made through the subhyoid muscle of a female (Fig. 2a) and the cut edge examined, a space bounded by the doubled subhyoid and the mass of the geniohyoid and sternohyoid muscles will be seen and may be mistaken for a pouch or sac. But if the submaxillary septum is separated from the pectoral muscle mass and the margin of the subhyoid stretched caudad, the "sac" disappears. Superficial examination of a similar cut made in a male having a fully developed vocal sac (Fig. 2b) may suggest a condition identical to that of the female. However, if the lymphatic septum of the male is torn and the margin of the subhyoid stretched caudally, the sac remains distinctly recognizable.

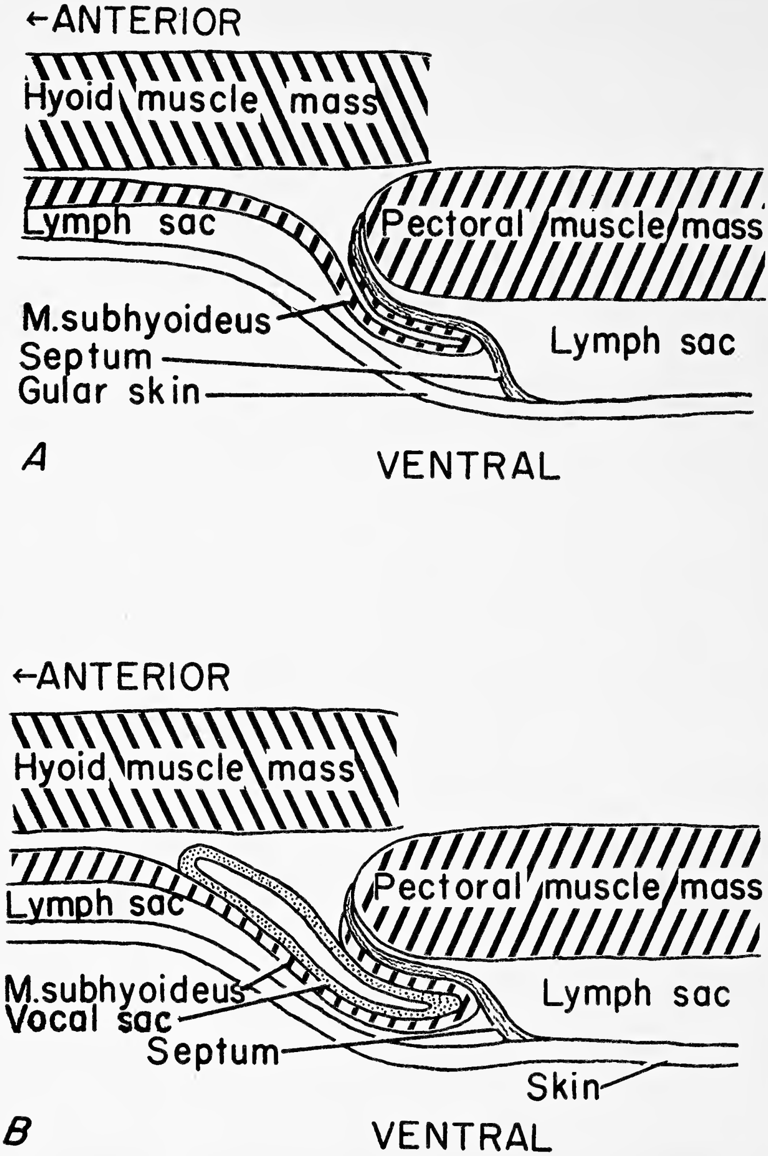


**Fig. 2. Diagrammatic sagittal section through throat of *Bufo alvarius*. A. Female. B. Male.**

Having examined the material (TNHC 16424, 20012) used by Blair and Pettus as well as other female *alvarius*, I am convinced that the "vocal pouches" they attribute to two females were nothing but the space between the reflected layers of the subhyoid muscle.

Though Blair and Pettus do not refer to vocal sac openings, neither of the females they examined nor any others I have seen have slits in the floor of the mouth. A toad without vocal sac openings cannot have a vocal sac because of the developmental pattern of these structures. Vocal sacs are evaginations from the lining of the mouth (Noble, 1931; Liu, 1935); the sac develops from its opening and not as a blind pouch that later ruptures the oral epithelium (Inger and Greenberg, 1956).

Females of *alvarius,* like those of other species, lack vocal sacs.

## DISCUSSION

Several features of the vocal sac of *Bufo alvarius* support the suggestion of Blair and Pettus that the structure is degenerating. (1) Three adult males have paired vocal sacs. This conditions is an ontogenetically early stage of the single subgular vocal sac usual in bufonids (Inger and Greenberg, 1956). Thus these males are cases of arrested development. One adult male with a small vocal sac reaching only to the mid-line falls in the same category.

(2) The vocal sac openings in all males are relatively small compared to other bufonids. The length of the opening as a proportion of snout-vent is 0.027–0.051. In ten *Bufo woodhousei fowleri* (New York, Virginia, Illinois, and Missouri) the openings vary from 3.8 to 5.8 mm., or 0.069–0.106 of snout-vent (46.0–64.5 mm.). Vocal sac openings of ten *Bufo marinus* (Mexico and Panama) vary from 4.6 to 11.4 mm. and represent 0.043–0.087 of snout-vent (104–132 mm.) Comparison of the relative lengths by means of the Mann-Whitney U Test (Siegel, 1956) shows *alvarius* vocal sac openings to be significantly smaller than those of the other forms at the 0.001 level.

(3) Four adult males lack vocal sacs. Most species of *Bufo* have well developed vocal sacs (Liu, 1935) and it may be assumed that the stock from which the genus arose also had vocal sacs. On this basis, absence of these structures in species of *Bufo* represents secondary loss. Therefore, the situation in *alvarius* is to be interpreted as degeneration rather than development.

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# Size and Movements of a Local Population of Cricket Frogs *(Acris crepitans)*

*by* **WILLIAM F. PYBURN**
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## INTRODUCTION

A population of cricket frogs (*Acris crepitans*) was studied, beginning in the fall of 1952, with two objectives in mind: (1) to determine the population size, and (2) to obtain information concerning the movements of frogs. Certain other pertinent information concerning seasonal activity and breeding behavior was obtained.

The cricket frog is a small, terrestrial member of the family Hylidae. Adult males are about one inch in snout-vent length, while adult females are a little larger. In suitable situations it occurs over most of the eastern United States from New England to Virginia, west to the Mississippi, south to Louisiana (Schmidt, 1953, under *Acris gryllus crepitans*), and in Texas and Mexico as far south as central Coahuila (Smith and Taylor, 1948). Cricket frogs occur commonly about the margins of permanent and semipermanent bodies of water, often being the most conspicuous amphibian in these situations. The species lends itself well to population study since it is usually present in large numbers where conditions are favorable. Some individuals may remain active during the winter months, making it possible to study a population throughout the year.

The author is indebted to Dr. W. Frank Blair for constructive criticism and valuable suggestions in the course of this work.

## STUDY AREA

Field work was done five miles east of Austin, Travis County, Texas. The study site consisted of a pond and the surrounding area, including two ravines. The pond was 112 feet long and 79 feet wide on December 3, 1953. A natural ravine (Fig. 1, A), entering the pond at its northeast end, ran north some 300 feet where it was abruptly interrupted by a limestone outcrop which rose five feet above the ravine floor. Above the outcrop this ravine was very shallow, so that, throughout the study period, it contained no surface water except during or directly after a rain.

The pond was bounded on the south and west by an earthen dam. A second ravine (Fig. 1, B), running east and west, joined the first just below the dam.

In the winter of 1952 and spring of 1953 rains produced pools and eventually small streams in the beds of both ravines. A semipermanent

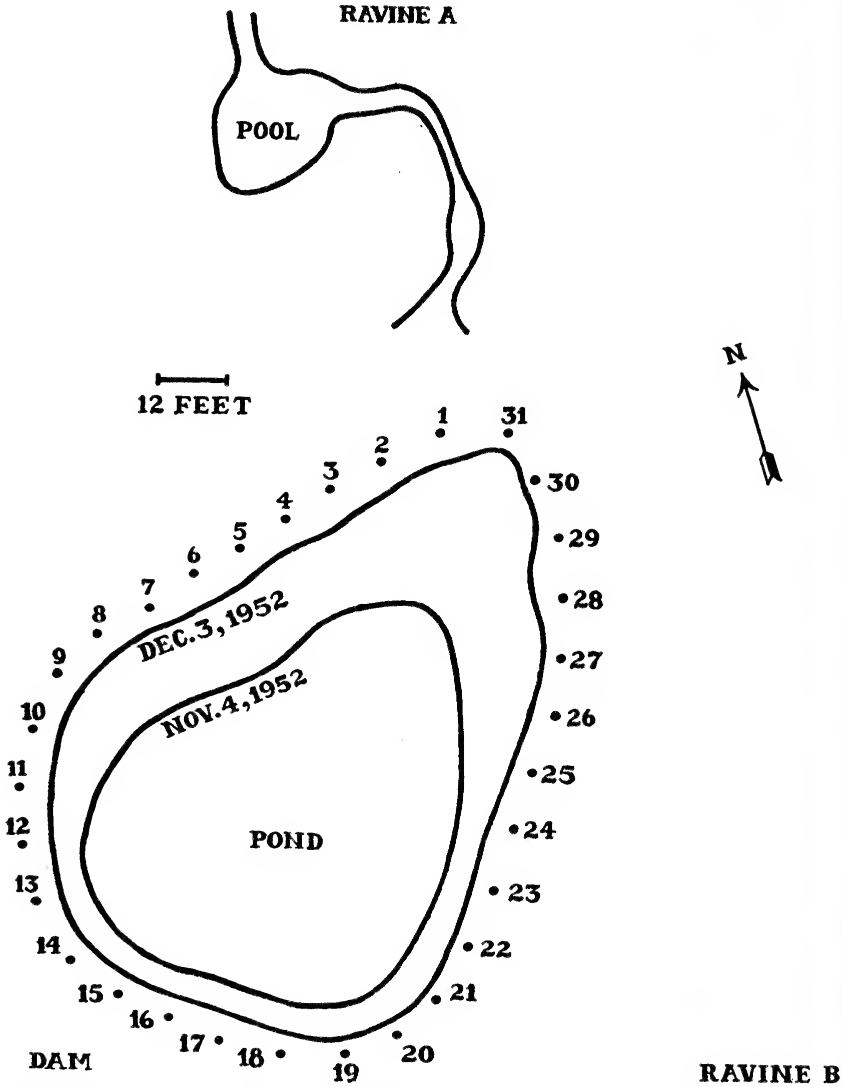


Fig. 1. Map of the study area showing position of the pond margin on November 4 and December 3, 1952. Numbers refer to stakes.

spring in ravine B maintained a small pool during the spring of 1953 at its source about 150 feet east of the pond. The pools in ravine A dried up and were refilled at various times, but both ravines were dry by the first part of June, 1953, and remained so through August, 1953.

A gravel pit, which had resulted from an excavation into the south side of a hill, was situated about 183 yards north of the pond. Greater porosity of the soil and lower than normal precipitation resulted in this pit having no permanent surface water. At no time was there a stream connection between gravel pit and pond-ravine area.

With the exception of the southern edge, the margin of the pond was lined by black willow (*Salix nigra*). Hackberry (*Celtis laevigata*) and cork elm (*Ulmus crassifolia*), as well as black willow, were to be found in both ravines. More prominent grasses within the study area included *Elymus canadensis, Sporobolus asper, Aristida glauca, Cynodon dactylon, Sorghum halepense* and *Paspalum langei*. *C. dactylon* was particularly abundant at the pond, but was replaced to the south and east in ravine B by *S. asper* and *A. glauca*. Other conspicuous plants in the area included *Xanthium speciosum, Ambrosia psilostachya, Helianthus annuus, Iva ciliata, Vernonia interior, Rumex altissimus* and *Physostegia canadensis*.

## METHODS

Numbered stakes were placed at intervals of 10 feet around the circumference of the pond so that points of capture could be located (Fig. 1). These original stakes were supplemented at various times in the following months by stakes placed at the edge of the water.

The sampling method was to proceed around the pond from a given point attempting to take frogs at random. Each frog was marked, measured, located according to the nearest stake, and released at the point of capture. For the most part, captures were made by hand; however, a net made of heavy grade cheesecloth was used with some success at the beginning of the study in an effort to mark as much of the population as possible. Frogs that were captured in places other than the immediate vicinity of the pond were located in relation to numbered trees.

Each frog was assigned a number by clipping various combinations of toes. The first 800 frogs marked in this manner are those with which the study is principally concerned. Most of the individuals marked toward the end of the study period (numbers above 800) were not recaptured. For this reason they are not included in the section concerning the movements of individual frogs.

The snout-vent length was measured by placing the frog, ventral side downward, on a metal ruler. Light pressure was applied with the thumb to prevent the frog from bowing its back. Measurements were read to the nearest half millimeter.

One hundred and sixteen field trips were made in the period September 19, 1952, to July 3, 1953. Eighty-two of these were day trips and 34 were at night. A total of 2,313 records were obtained on 800 frogs.

### POPULATION SIZE

Between the dates of September 19 and October 21, 1952, 510 frogs were captured and marked for the purpose of estimating the population size. Three complete turns were made around the pond in the period of September 19 to October 2. Since time would not allow a complete turn to be made in one day, the place of the last capture was noted and work was resumed at this point at the next time in the field. Three hundred and thirty-five frogs were marked in this manner. A second census was taken between the dates October 7 and October 21, inclusive, using the same procedure as before. Two hundred and forty-five frogs were taken in the second census period, 70 of which had been marked in the first census.

From these data the population size at the time of study has been estimated by the ratio method as follows:

$$\text{Population Size (P)} = \frac{\text{Number of frogs taken in first census period X number of frogs taken in second census period}}{\text{Number of frogs common to both samples}}$$

$$= \frac{335 \times 245}{70}$$

$$= 1{,}172.5$$

Lincoln (1930) used this equation in estimating waterfowl abundance and since then it has frequently been referred to as the "Lincoln Index." Fitch (1949), Seibert (1950), and Carpenter (1952) have used the method in estimating sizes of snake populations. Pearse (1923) and Cagle (1942) have estimated numbers of turtles in the same manner. For a more complete list reference is made to the papers of Hayne (1949) and Stickel (1950). The latter two authors, among others, have discussed the assumptions upon which a population estimate by this method is based. In view of the circumstances under which sampling of the *Acris* population was carried out, it is desirable to repeat some of these assumptions for comparative purposes.

It is assumed that there is no replacement of marked by unmarked animals during the census. In order to make this assumption, the sampling period should be relatively short; yet it should be long enough to include a large part of the resident population. Replacement of marked animals may occur as a result of death or emigration of marked frogs and their subsequent replacement by unmarked animals from areas outside the study area, or replacement by newly metamorphosed frogs.

With the exception of a trace on October 6, 1952, no precipitation was recorded for the period September 19 to November 3. The pond was completely isolated from any other source of water during this time. The nearest habitat from which any influx of individuals could have occurred is approximately one-half mile distant. Since these frogs are largely restricted to some immediate source of moisture, it is unlikely that any addition to the population occurred between the sampling dates. The same may be said for any possible movement of individuals out of the study area.

Livezey (1950), in commenting on the breeding season of *Acris*, says that, in Texas, choruses have been recorded from February until October, with the peak of the breeding season evidently extending from the latter part of April through July. In the population under observation, the 1952 breeding season had terminated before sampling was begun, but since the tadpole stage may be from 50 to 90 days or longer (Wright and Wright, 1942), some addition of young frogs from this source could have occurred during the census. The fact that only 15 frogs were found to be 15 mm. or less when first marked indicates that this number was small. The maximum length at the end of metamorphosis was less than 16 mm. in over 700 young frogs marked the following year.

It is evident that tadpoles from eggs laid even as late as the middle of July and which metamorphosed in a minimum number of days would have been part of the "adult" population during the first sampling. Field observations in 1953 indicated that breeding activity had begun to decline early in June.

It is assumed that the probability of capturing any one animal in the population is equal to that of any other, and further, that one part the population is of neither more nor less extensively sampled than another. The possibility should be considered that the marking method (toe clipping) might affect the randomness of the sampling. The extent to which permanent injury is caused by toe clipping is unknown. It can only be said that no apparent adverse effect was produced by the marking method, although any subtle effect caused by toe clipping may be very difficult to detect. The method of marking and sampling, as outlined earlier, appeared to be as nearly random as could be devised.

Hayne (1949) has proposed a modification of the ratio method based "upon the increase in the proportion marked which is observed in succeeding catches, as more animals become marked. . . ." Each sampling after the first is used to estimate the proportion of marked individuals at that stage in the marketing process. The average amount by which the marking of one individual changes the proportion of marked animals is then used to estimate the population size. The formula is

$$P = \frac{WX^2}{WXY}$$

in which W is the total number of animals caught in each sample, X is the number of marked animals which have been released into the population, P, and Y is the proportion of marked animals now in the population. Carpenter (1952) and Seibert (1950) have used Hayne's method, as well as the "Lincoln Index".

In applying the Hayne method, each of the six turns around the pond has been used as a separate sample. The data (Table I) yield an estimate of 1,052.9, which is somewhat lower than, although fairly close to, that obtained by the "Lincoln Index" (1,172.5).

In Figure 2 the data have been plotted to show the increase in proportion marked as more frogs were marked during the sampling. The fact that these closely approximate a straight line is further evidence that there was little replacement of marked animals in the sampling period.

TABLE I

Record of captures of cricket frogs (*Acris crepitans*), from which a population estimate of 1,052.9 was obtained.

| Date of Capture | No. of Captures (W) New | No. of Captures (W) Previously Caught | Proportion of Catch Previously Caught (Y) | Total No. Previously Caught (X) |
|---|---|---|---|---|
| Sept. 19–Sept. 21 | 109 | 0 | .00 | 0 |
| Sept. 22–Sept. 25 | 118 | 15 | .11 | 109 |
| Sept. 28–Oct. 2 | 108 | 30 | .22 | 227 |
| Oct. 7–Oct. 9 | 49 | 23 | .32 | 335 |
| Oct. 11–Oct. 14 | 87 | 47 | .35 | 384 |
| Oct. 16–Oct. 21 | 39 | 33 | .46 | 471 |

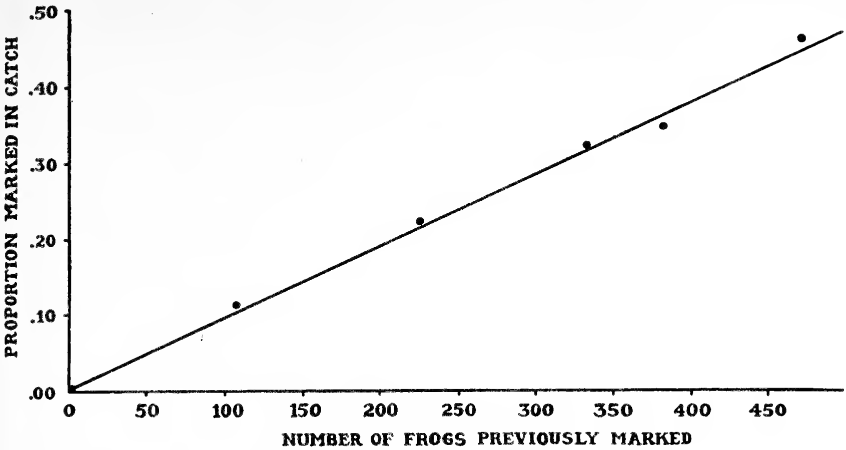


Fig. 2. Increase in proportion of marked frogs as more frogs were marked during sampling.

## MOVEMENTS WITHIN THE STUDY AREA

Of 800 frogs which were marked from the beginning of the study to April 21, 1953, 491 (61.4 per cent) were recaptured at least once; 135 (16.9 per cent) were captured five or more times, and 32 (four per cent) were caught 10 or more times. The records of these frogs are shown in more detail in Table II.

The points of capture of all frogs with two ore more captures have been plotted on a map of the entire area and from this the distance between extreme captures for each frog was measured. In Figure 3 these distances are shown in relation to the total number of captures for each frog. Lack of correlation between extreme points of capture and number of captures is evident. The maximum distance moved by frogs in any one class (number of captures) was highly variable. For instance, some frogs in the five-capture class apparently moved less than 50 feet, while others moved more than 300 feet. A few individuals in most classes approached or exceeded distances of 250 feet. Thus, the extreme distance between their captures approached the maximum diameter of the area. It might seem that the time lapse between captures would affect the distance which a frog was found to travel, but this was often not true. To mention a single example, No. 140 (Fig. 4) moved 113 feet between January 13 and January 28, 1953, yet this same frog was caught 10 consecutive times, within a maximum distance of 25 feet, from February 12 to April 4, 1953. Although some individuals moved 100 feet or more with a time lapse of two or three months between captures, others were found to have moved equally as far in a few days. Even so, these movements cannot be explained mere-

TABLE II

Summarization of numbers of captures of each of 800 cricket frogs from September 19, 1952, through July 3, 1953.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. of Captures | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| No. of Frogs | 309 | 163 | 129 | 64 | 47 | 28 | 8 | 8 | 12 | 7 |
| | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| | 5 | 6 | 4 | 4 | 2 | 2 | 1 | 0 | 0 | 1 |

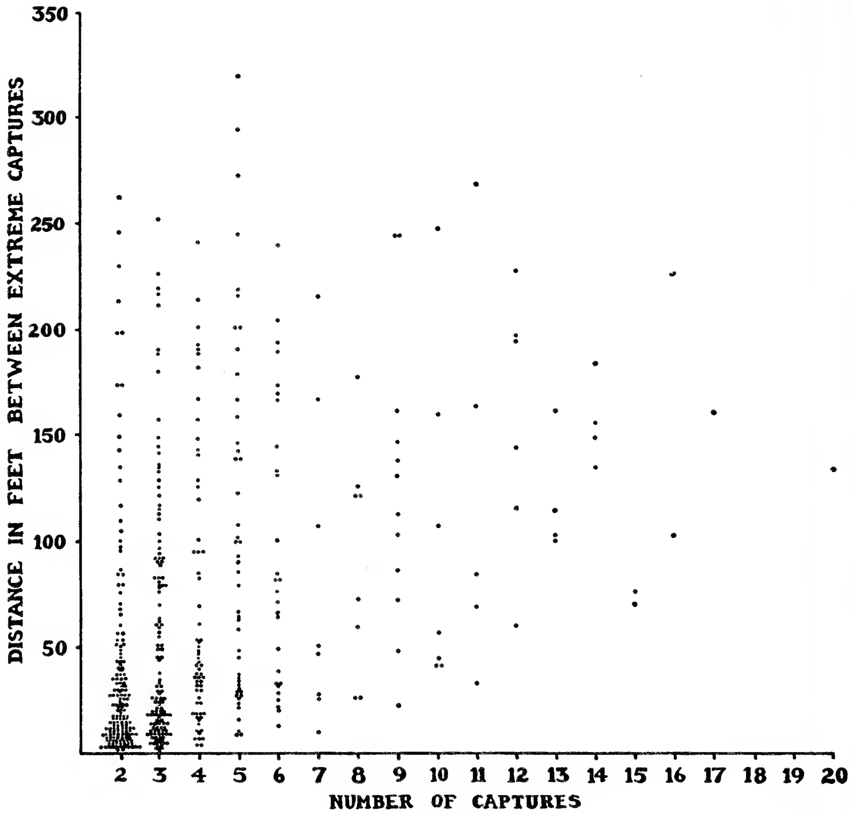


Fig. 3. Distance between extreme captures plotted against the total number of captures for each frog.

ly as random wandering from one place to another. Position records show that many individuals had an affinity for one or more particular localities within the study area. This, of course, is most apparent in individuals with a larger number of captures. All frogs which were caught seven times or more (60) exhibited an affinity for a certain position at the pond, or for a certain pool in one of the ravines. In some instances, all of the captures were very close together, but usually the

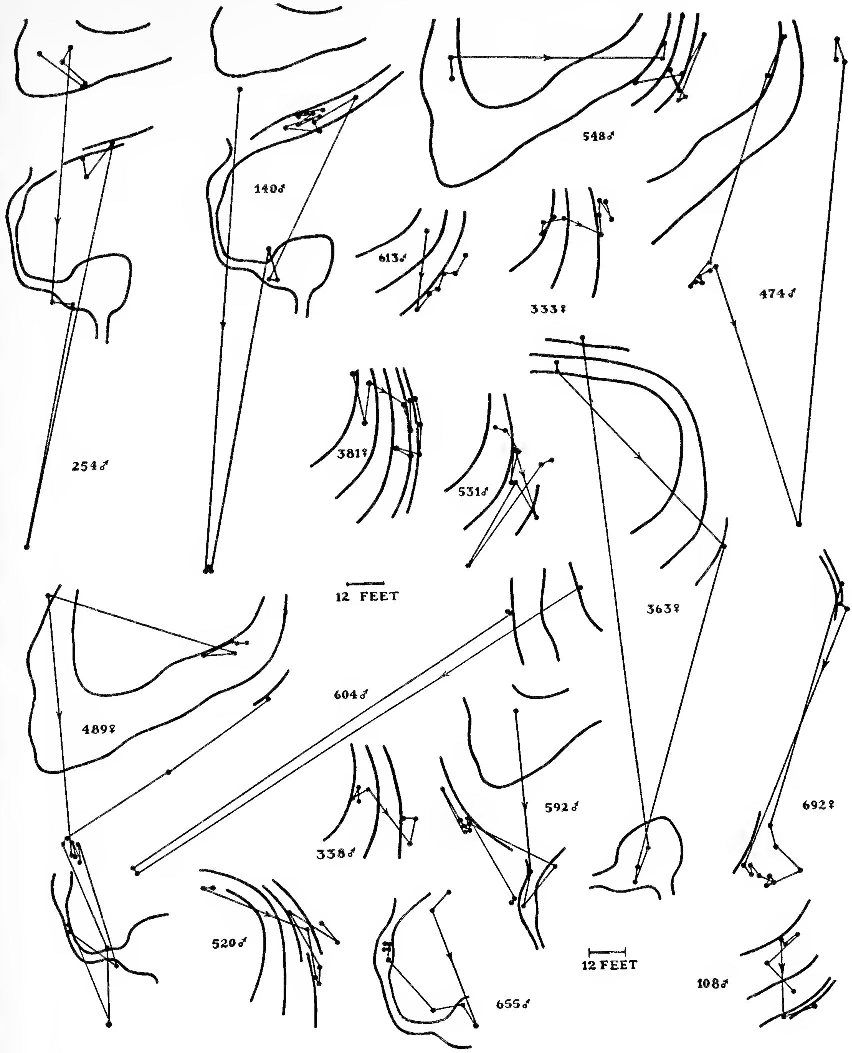


**Fig. 4. Positions of capture of selected individual cricket frogs. Dots connected by straight lines indicate points of capture. Irregular lines show positions of water's edge at various times.**

frogs were found to remain in one locality for a time and then move to another. Of the frogs which were captured six times or less, the tendency to remain in any one place was much less apparent than in those captured more often. The movements of representative individuals are illustrated in Figure 4.

During the first 45 days of observation, the major part of the population was restricted to the immediate vicinity of the pond. Intermittent rains, beginning in November, 1952, allowed frogs to move considerable distances away from the pond's edge. Some individuals simply changed positions at the pond; others moved to semipermanent puddles in one of the two ravines. As long as water remained in the ravines, frogs were able to move freely between pond and ravine with very little danger of desiccation. Five animals which had been marked at the pond were later recaptured in the gravel pit, approximately 183 yards away. Frogs that are able to move to the gravel pit apparently must do so during or fairly soon after a rain, since they must cross a considerable area which is otherwise almost completely dry. The same may be said of frogs attempting to move in the other direction. Movement between the pond and gravel pit is therefore considerably restricted.

The tendency for individuals to return to a location after being displaced from it is believed to indicate an affinity for that location. McAtee (1921) noted that a bullfrog returned in one night to its "accustomed haunt" after being removed to the other side of a lake. This frog later returned a distance of one-fourth mile overland. Breder, Breder and Redmond (1927) found that 22 (43 per cent) of 51 *Rana clamitans*, which were removed some 150 feet or more, returned "to approximately their 'home' region". Two of three frogs, not included in the above figures, were said to have returned to the location of original capture, even though this necessitated movement through an equally suitable habitat. These same authors observed the voluntary movements of 32 *Rana clamitans* in New York over a period of four months. Their data (op. cit., pp. 216 to 220) show that a number of frogs moved from one station to another yet remained, at least for a time, within a rather limited area. Raney (1940) found little evidence of well developed homing behavior in bullfrogs, but Ingram and Raney (1943) recorded three instances of homing in bullfrogs that returned distances of 675 feet, 570 feet and 400 feet to the area of original capture. Bogert (1947) moved three groups of toads (*Bufo terrestris terrestris*) in three directions 700 yards from the home site. Each group consisted of 61 individuals selected at random. He estimated that approximately 30 toads from each group returned to the home site within a 14-day period. His observations on the normal movements of these toads showed that they "tend to remain within a limited area".

In the present study, all frogs were released at the point of capture. With few exceptions (Fig. 4, No. 692), only those frogs that moved from one side of the pond to another, from the pond into one of the ravines, or from a ravine to the pond were considered to have changed location. In other words, frogs that moved from one location to another of their own accord, without moving out of the area, are concerned with here. Of the 491 frogs with two or more captures, 212 definitely moved away from the site of original capture, excluding the five frogs that moved to the gravel pit. Some of the remaining 274 apparently did not move. In other cases it was not clear whether the frogs had moved or not.

Since 34 of the 212 were captured only twice, the nature of their later movements is unknown. One hundred and seventy-eight were captured three or more times. Fifty-eight (33 per cent) returned to, or in a direction toward, the vicinity of the original capture. The data are show in Table III in which the average distance moved is indicated for each class (number of captures). The figures given in the last row of this table were arrived at by dividing the total distances moved by the total number of frogs. Seven frogs were considered to have moved away from and returned to the vicinity of the second capture, rather than the first. These frogs made at least three moves. In all other records the distance that animals failed to return was measured from the

TABLE III

Record showing the distances moved by classes of frogs that moved away from the site of original capture. See text for further explanation.

| Classes (No. of Captures per Frog) | No. of Frogs Moved | Distance Moved Away (Avg. for each Class) | No. of Frogs Moved Back | Mean Distance Moved Away (Feet) | Mean Distance Moved Back (Feet) | Mean Distance Lacked Returning (Feet) |
|---|---|---|---|---|---|---|
| 2 | 34 | 120.6 | . | .... | .... | ... |
| 3 | 55 | 109.0 | 8 | 115.3 | 75.5 | 41.5 |
| 4 | 27 | 128.4 | 7 | 143.4 | 127.0 | 38.9 |
| 5 | 28 | 145.9 | 10 | 153.9 | 126.6 | 38.0 |
| 6 | 19 | 126.7 | 7 | 162.1 | 160.4 | 25.1 |
| 7 | 4 | 127.0 | 3 | 152.3 | 139.0 | 21.7 |
| 8 | 7 | 91.3 | 2 | 114.5 | 91.0 | 24.5 |
| 9 | 10 | 137.4 | 4 | 128.2 | 106.8 | 29.8 |
| 10 | 5 | 116.0 | 3 | 138.3 | 143.3 | 30.7 |
| 11 | 4 | 148.5 | 1 | 166.0 | 138.0 | 21.0 |
| 12 | 6 | 153.7 | 4 | 157.8 | 148.8 | 31.0 |
| 13 | 3 | 124.3 | 2 | 130.0 | 130.0 | 9.0 |
| 14 | 4 | 157.8 | 2 | 168.0 | 153.0 | 14.0 |
| 15 | 2 | 74.0 | 1 | 71.0 | 51.0 | 21.0 |
| 16 | 2 | 133.5 | 2 | 133.5 | 138.5 | 15.0 |
| 17 | 1 | 159.0 | 1 | 159.0 | 154.0 | 20.0 |
| 20 | 1 | 130.0 | 1 | 130.0 | 121.0 | 20.0 |
| Totals | 212—34= 178 | 124.4 (Avg.) | 58 (33%) | 141.9 (Avg.) | 124.8 (Avg.) | 30.5 (Avg.) |

place of original capture. In some instances frogs evidently failed to effect a more complete return due to changes in the position of the pond's edge (Fig. 4: Numbers 254, 140, 474, 604, 489). In general the frogs were found to prefer particular locations at the pond or in one of the ravines. Although many individuals moved from one location to another, they often returned to the vicinity of some location which they had occupied previously.

Except during or directly after rains, frogs preferred to sit on the bank near the edge of the pond and were seldom seen more than a few feet out in the water. During the long dry period from September 19 to November 4, 1952, evaporation from the surface of the pond resulted in the gradual retreat of its margin. The frogs were forced to move toward the center of the pond in order to maintain their positions near the edge of the water. This restriction to the water's edge was temporarily alleviated by precipitation. With the advent of rains, the margin of the pond advanced as much as 30 feet or more at its shallow northern end completely submerging locations that many of the frogs had maintained during the dry period. Some frogs apparently did not change locations (as far as can be determined from records of recapture), but were gradually forced from their original positions by advancement of the pond margin (Fig. 4: Numbers 381, 333, 520, 338, 531, 108). Others moved to newly formed pools in the ravines or from one location to another at the pond (Fig. 4: Numbers 254, 140, 548, 474, 363, 692, 604, 489).

Since there is little danger of desiccation involved in position changes at the pond even in dry periods, increase in frequency of such movements in periods of rains suggests that precipitation may be a causative factor rather than one which simply allows such movements to occur. On this view precipitation, or some physical event which accompanies it, would be considered a stimulus, the response to which is movement. I have seen cricket frogs travel 200 feet or more away from any permanent water during a rain. In so far as dispersal is concerned, such a mechanism would almost certainly be adaptive in that it would facilitate rapid occupation of new breeding sites as they become available.

## SEASONAL ACTIVITY AND BREEDING BEHAVIOR

Frogs were very abundant in September and October, 1952, and on an average day in the field approximately 35 could be caught and recorded in a two-hour period. When pursued, the frogs were observed to hop along the bank for a short distance and then either jump into the grass away from the pond or into the water. Upon entering the water they almost invariably reversed their direction and swam back to the shore. This trait has also been observed by Marr (1944). At this time the water level was very low and the edge of the pond was almost totally devoid of vegetation. In the following months the edge of the pond advanced and retreated several times but in general remained above the September-October level. As a result, vegetation which had been some distance away from the edge was then partly or completely submerged. The frogs hopped into the water with little hesitation and either went directly to the bottom, where they concealed themselves under dead leaves and other debris, or hid among the dense culms of emergent grass. Stebbins (1951) has recorded similar behavior in cricket frogs which he observed near Quemado, Texas. I believe these differences in behavior to be correlated with differences in the micro-environment. The absence of suitable hiding places on the bottom or in the water at the pond's edge appeared to be the reason that frogs returned to shore after being forced into the water. Later, incorporation of the surrounding vegetation by the edge of the pond furnished such easily accessible hiding places that they were seldom reluctant to jump into the water and go directly to the bottom.

Toward the end of November the number of active frogs declined rapidly so that activity reached its lowest point in December of 1952. In 15 visits during the latter month only 36 frogs (not including recaptures) were recorded. This scarcity persisted through most of January, 1953, from which time activity increased steadily to the peak of the breeding season. Presumably due to predation and movement of frogs out of the study area, the population failed to reach its former abundance. The number of frogs captured each month from October, 1952, through June, 1953, is shown in Figure 5.

The breeding season begins in early February. The first cricket frog of the 1953 season was heard calling about 6:00 p.m. on February 5 near the ravine mouth at the northeast end of the pond. The water temperature taken near the surface at this location was 21°C. Air temperature recorded at the municipal airport, about one mile away, was 72° F (22.2° C). The number of calling males increased gradually through February, but no frogs were heard on days when temperatures were low. On February 25 at 8:00 p.m. air temperature at the pond was 4.5° C. Water temperature was 11.5° C at the northeastern end of the pond and 10.5°C at a large puddle in ravine A. No frogs were heard and none could be found at this time. The following day calling was resumed at the northeastern end of the pond where the water temperature at 4:00 p.m. was 25°C and the air temperature 24°C. Thirteen frogs were captured, measured and recorded in approximately two hours. By the middle of March, full choruses could be heard on almost any night and frequently during the day. Males were most often found calling in low vegetation at the very edge of the water, although many individuals were observed calling on the bank from five to 10 feet, or more, from the edge, while others called from floating adgae out in the water. On one occasion (May 9, 1953 about 3:00 p.m.) an individual was observed calling in ravine B below the dam and approximately 50 feet from the nearest water. The frog was found on moist ground near a decayed log.

There is no evidence of defensive territorialism. On a number of occasions frogs were seen calling within a few inches of one another.

Although amplectant pairs were not found until March 18, females containing eggs were taken as early as March 1. Clasping pairs were usually found in the water near the edge of the pond, but occasionally frogs were observed in amplexus well away from the water.

The breeding peak continued through April and May with some signs of decline toward the end of the latter month. Calling continued through June but with a general decrease in intensity, even though the average minimum and maximum temperatures for May and June showed a decided increase (Fig. 5). The total precipitation for these months was only 1.88 inches and 1.59 inches respectively, as compared to 4.69 inches for April.

Newly metamorphosed frogs began appearing early in May. The first was taken on the night of May 2. During the next few weeks the number of young frogs increased rapidly so that by the end of May, and particularly in June, I was confronted with an almost overwhelming number of unmarked frogs. Since other phases of this work were to be pursued in the following months, it was necessary to mark as many young frogs as possible. As a result, members of the greatly diluted adult population were not captured nearly as often as before.

The number of frogs captured each month from September, 1952, through June, 1953 is shown in Table IV and Figure 5. Numbers of

TABLE IV

Record showing the number of frogs captured each month from September, 1952, through June, 1953. See text for further explanation.

| | 1952 Sept. | Oct. | Nov. | Dec. | 1953 Jan. | Feb. | March | April | May | June |
|---|---|---|---|---|---|---|---|---|---|---|
| Males | 37 | 68 | 66 | 22 | 35 | 74 | 128 | 140 | 74 | 39 |
| Females | 24 | 28 | 27 | 6 | 23 | 32 | 71 | 54 | 14 | 11 |
| Unsexed | 243 | 237 | 172 | 8 | 17 | 27 | 10 | 0 | 152 | 755 |
| Totals | 304 | 333 | 265 | 36 | 75 | 133 | 209 | 194 | 240 | 805 |

males and females indicated for the months previous to February, 1953, are based upon those frogs which were recaptured during the spawning period after they had become sexually mature. The number of frogs indicated for September, 1952 is not representative, since field

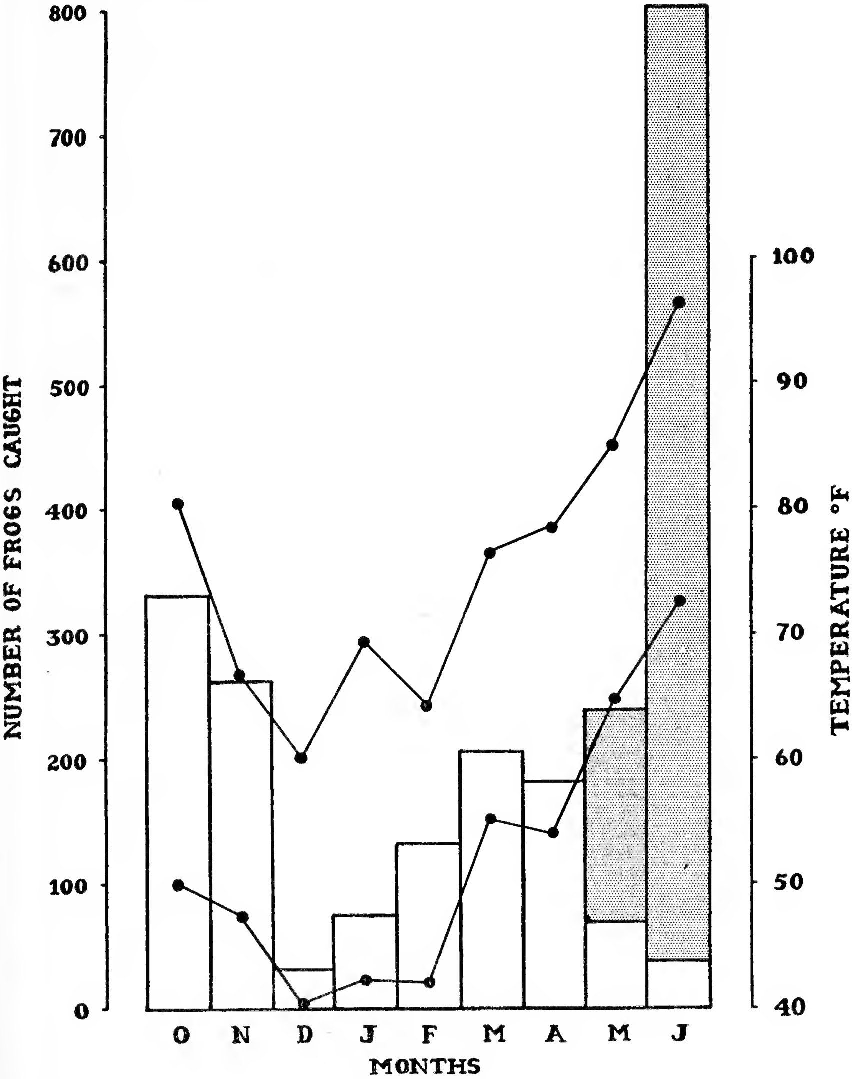


Fig. 5. Relation between total number of frogs captured per month and average minimum and maximum monthly air temperature as recorded at the Austin Municipal Airport, about one mile from the study area. White retangles represent frogs that metamorphosed before 1953. Stippled rectangles represent frogs that metamorphosed in 1953. October, 1952, through June, 1953, are the months represented. Time spent in the field was approximately the same each month.

work was not begun until the 19th. This month is omitted in Figure 5. The small number of adults caught in May and June, 1953, is indicative of a small adult population since 85% of these had been marked in some previous month.

### SEX RATIO

The first 800 frogs, with which the major part of this report has been concerned, were all marked before newly metamorphosed frogs began to appear in May. Two hundred and eighty-three of the original 800 were captured at least once during the breeding season. One hundred and eighty-nine of these were males and 94 were females, a ratio of two to one.

An unequal sex ratio in anurans may be due to unequal numbers of males and females at hatching, or to differential survival later on. Little information is available on sex ratios in tadpoles and young frogs due primarily to difficulties in determining the sex of immature individuals, but several authors have reported differences in numbers of adult males and females in population samples. Raney (1940) obtained ratios of two males to one female in samples of both *Rana clamitans* and *R. catesbeiana*, and A. P. Blair (1943) found that *Bufo americanus* males greatly outnumbered females (six to one) in breeding ponds.

Some time after the work reported here had been completed, Dr. Kirk Strawn and I obtained information from other population samples which indicated that the sex ratio in an adult population of cricket frogs was, in fact, very nearly equal. These collections were obtained from a breeding colony at Ft. McKavitt, Menard County, Texas in April, 1954. A sample taken the night of April 24 consisted of 12 females and 51 males. The next morning, beginning about 8:00 a.m., a second collection was made at the same place. This series consisted of 62 females, 27 males and one immature frog. In all there were 74 females and 78 males. Inequality in the number of males and females in the separate samples was very probably the result of differences in behavior. In the first sampling, not only were calling males more conspicuous to the collector and therefore more likely to be captured, but females that were not in laying condition that night had evidently moved into the dense vegetation away from the water so that they were more easily overlooked. Return of females to the water the next morning, in addition to the fact that a large proportion of the males had been removed the night before, probably accounted for the greater number of females in the second sample.

SUMMARY

The study of a population of the cricket frog *(Acris crepitans)* was conducted in the fall of 1952 and spring and early summer of 1953, five miles east of Austin, Travis County, Texas. The site consisted of a permanent pond, two ravines and the immediately surrounding area. Frogs were marked, recorded and located according to numbered stakes which had been placed at intervals of 10 feet around the circumference of the pond. Estimates based on samples taken in the period September 19 through October 21, 1952, revealed that the population consisted of approximately 1,100 individuals in the latter part of September.

The distances which individual frogs moved varied considerably. Little if any correlation was found between the number of times that frogs were captured and the maximum distances which they were known to have moved.

Although the frogs moved about over the study area, their movements were not simple random wanderings. Frogs that were captured a sufficient number of times were found to prefer certain locations, either at the edge of the pond, or in a ravine, or both. Many individuals that moved from the site of original capture to another location were not known to have made a second move. Others moved a second time without returning to the original location, as far as is known. Of the frogs that did move a second time, 33 per cent were found to have returned to, or in a direction toward, the site of a previous capture. All of the frogs that showed no locality preference were captured less than seven times.

During dry periods frogs were restricted to the edge of the pond and were seldom seen more than a few feet out in the water. Periods of precipitation not only allowed extensive movements to occur, but apparently furnished the stimulus which brought these about.

Activity during the study period, as indicated by the number of frogs captured in each month, was found to be greatest in September and October, 1952, and least in December of that year. A steady increase in the number of active frogs began the latter part of January, 1953, and, except in cool intervals, continued to the peak of the breeding season.

Breeding activity began in early February, increased considerably in March, and reached its peak in April and May of 1953. Newly metamorphosed frogs began appearing early in May, and increased rapidly in number in this and the following month.

The sex ratio was found to be approximately two males to one female in population samples, but evidence obtained later on (April

1954) indicated that this difference was due to sampling error as a result of differences in behavior in adult males and females in the breeding period.

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# Notes and Records of Marine Fishes from the Texas Coast

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During the course of the junior author's compiling of a check-list of marine fishes of the Texas coast it became apparent that new information was at hand. It was felt that because of the limited nature of a check-list that this information would be best served by a separate report.

Of the fourteen species discussed below, nine are first records for the Texas coast, three are additional records of species previously reported from few specimens, one is a correction of a species previously reported, and one is an extension of the range of a larva.

All measurements are standard length unless indicated otherwise. Gratitude is expressed to Miss Mary Frances Bell for typing the manuscript, and Dr. H. H. Hildebrand for use of material.

### *Hoplunnis tenuis* GINSBURG

Mr. R. Collette obtained a specimen, 424 mm. total length, from the waters off Port Aransas (date unknown), together with two specimens of *H. macrurus* Ginsburg. The specimen has the characteristic eight palatal fangs as described by Ginsburg (1951). Since we have no comparative material the identification is only tentative. Hildebrand (1954) found *H. macrurus* abundant on the brown shrimp grounds, but reported no *H. tenuis*. Springer and Bullis (1956) reported the only Texas specimens from 27° 22′ N, 96° 08′ W. The specimen is deposited in the collections of the Marine Laboratory at Rockport.

### *Ablennes hians* (VALENCIENNES)

Baughman (1955) reported a single specimen taken near Port Aransas. A second specimen, taken by Mr. M. Robinson from Heald Bank during April, 1957, has been deposited in the collections of the Department of Wildlife Management of Texas A. & M. College.

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### *Syngnathus pelagicus* LINNAEUS

No specimens have been taken close to shore, but the junior author has collected one in floating *Sargassum* at 28° 43′ N, 94° 30′ W. Springer and Bullis (1956) record two specimens taken by the *Oregon* off the Texas coast at 26° 60′ N, 96° 10′ W, and 27° 00′ N, 93° 55′ W. Baughman (1950a) quotes Herald in saying it is to be expected here, but no others are mentioned in the literature.

The specimen is no longer extant.

### *Thunnus thynnus* LINNAEUS

On August 24, 1957, five thirteen-inch bluefin tuna were caught in the Gulf about 24 miles northeast of Port Aransas by Mr. T. E. Belcher. The identifications were made by Dr. H. H. Hildebrand.

One specimen was mounted and retained by its capturer, who resides in Port Aransas. This specimen was examined by the junior author.

### *Istiophorus americanus* (CUVIER)

On July 19, 1957, a larval sailfish 37.0 mm., somewhat dried, was discovered on the deck of the ship "Wrangler" by Mr. J. Sharp. The ship had just returned to Port Aransas after having fished an area about forty miles offshore between Hospital Bank and the buoy light (approximately 27° 40′ N, 96° 20′ W) along the forty fathom contour. The exact point at which the specimen became shipbound is not known, but the specimen must have come aboard sometime during the trip as it was not crisp dried. It became soft upon preservation in alcohol.

Gehringer (1956) reported eight localities in the Gulf from which larval sailfish had been taken. The most western of these is 27° 55′ N, 93° 38′ W. He omitted Arnold's (1955) record of a mutilated specimen taken from 24° 30′ N, 96° 35′ W. The locality of origin of the present specimen, which is intermediate between these others, is not an unexpected one, but due to present interest in the life history of the sailfish and lack of pertinent information concerning it, it is reported here.

The measurements given below were made in the manner described by Gehringer (op. cit.).

| | | | |
|---|---|---|---|
| Standard length | 37.0 mm. | Snout extension | 8.7 mm. |
| Total length | 41.0 | Eye diameter | 3.0 |
| Head length | 21.0 | Pterotic spine length | 0.9 |
| Head depth | 3.9 | Main preopercle spine length | 2.2 |
| Head width | 3.5 | Pectoral fin length | 3.4 |
| Snout length | 14.4 | Pelvic fin length | 8.0 |
| Lower jaw length | 9.0 | | |

The specimen agrees well with Gehringer's description of a 38.8 mm. specimen, though some of the actual measurements are larger in the shorter individual. The specimen is deposited in the reference collection of the Institute of Marine Science.

Appreciation is due to Mrs. Charles F. Urschel of Port Aransas for calling this sepcimen to our attention.

### *Tetrapterus belone* (?) RAFINESQUE

On August 6, 1957, at 11 a.m., Dr. Robert Ladd of Chicago, Illinois, hooked a large istiophorid nine miles south-southeast of Port Aransas. Lack of comparative material forces us to leave open the species determination; however, the only species known from the Atlantic is *T. belone.* The specimen, measuring 1845 mm., was a female with immature gonads; however, the eggs were sufficiently large to be recognizable individually. The fish after having been under refrigeration for twenty-four hours, was found to weigh thirty-three pounds. The stomach contained the remains of a small squid and an isospondylus fish.

The following measurements were made using a metal tape graduated in millimeters.

| | |
|---|---|
| Tip of bill to fork of caudal fin | 1845 mm. |
| Tip of bill to most posterior margin of opercle | 604 |
| Tip of bill to most anterior bony margin of orbit | 386 |
| Tip of bill to tip of mandible | 190 |
| Dorsal origin of pectoral fin to tip of fin | Rt. 315 Lt. 310 |
| Origin of left pelvic fin to tip of fin | 359 |
| Distance from point between caudal keels to tip of ventral lobe of caudal fin | 340 |
| Body girth (as described by Rivas, 1956) | 396 |
| Bony orbital diameter | 48 |
| Tip of bill to origin of dorsal fin | 541 |
| Tip of mandible to origin of anal fin | 1075 |
| Circumference at point of least depth | 135 |
| Origin of first dorsal fin to its insertion | 910 |
| Origin of second dorsal fin to its insertion | 75 |
| Origin of first anal fin to its insertion | 102 |
| Origin of second anal fin to its insertion | 80 |

Measurements and counts of the dorsal and anal elements were made after a taxidermist had removed the fins for mounting. Measurements were made from a point just dorsal to the swollen bases of the elements where they attached to interneural and interhaemal spines.

| | |
|---|---|
| Dorsal elements 53 | |
| Length of 1st dorsal element | 19 mm. |
| " " 2nd " " | 45 |
| " " 3rd " " | 97 |
| " " 4th " " | 249 (greatest length of any dorsal element) |
| " " 7th " " | 222 |
| " " 13th " " | 114 |
| " " 20th " " | 112 |
| " " 25th " " | 114 |
| " " 30th " " | 114 |
| " " 40th " " | 127 |
| " " 45th " " | 93 |
| " " 53rd " " | 26 |
| Anal elements 12 | |
| Length of 1st anal element | 76 |
| " " 2nd " " | 125 (greatest length of any anal element) |

The coloration of the refrigerated day-old fish was blue-black above a horizontal at the upper level of the orbit, extending anteriorly on the head and posteriorly to the caudal base. A light spot appeared over the pineal area. Below the upper darker area the body quickly graded into white which enveloped the ventral portions. No indications of stripes on the body were present. The fins were all dark blue-black without conspicuous markings.

The short bill, slender body, comparatively light weight for an istiophorid this size, and the low undulatory dorsal fin (similar to that pictured by Fowler, 1936) all serve to assign this individual to the genus *Tetrapterus*.

The mounted specimen will be retained by its capturer. Swann (1957) has described the details of the catch and supplied a photograph.

### *Alectis crinitus* (MITCHELL)

On October 30, 1950, Mr. W. Wright obtained a specimen, 138 mm. from east northeast of Port Aransas. The junior author has seen a picture of another specimen from Aransas Bay. This species has been reported in the Gulf only from the Bay of Campeche (Springer and Bullis, 1956).

The specimen is deposited in the collections of the Texas Game and Fish Commission Marine Laboratory.

### *Pomacentrus leucostictus* MÜLLER AND TROSCHEL

There is a single specimen, 71 mm., in the collections of the Institute of Marine Science. It was collected by Mr. M. M. Hayes on March 28, 1954, at a depth of about seventeen fathoms, southeast of Pass Cavallo. The specimen was identified by Dr. H. H. Hildebrand.

### *Halichoeres bivittatus* (BLOCH)

Two specimens have been taken at Port Aransas and deposited in the collections of the Institute of Marine Science. One, 150 mm., on October 14, 1956, from the inlet at Cline's Point, and the other, 154 mm., on April 20, 1957, from the south jetty. The senior author has seen a third specimen also from the vicinity of Port Aransas.

### *Sparisoma radians* (VALENCIENNES)

Leary (1956) has reported a specimen taken from Corpus Christi Bay. There is another specimen in the collections of the Texas Game and Fish Commission Marine Laboratory taken from Port Isabel by Mr. J. Breuer. He reports having taken two others in the same area.

### *Pomacanthus paru* (BLOCH)

One specimen, 67 mm., from Aransas Bay, collected on November 15, 1954, is in the collections of the Texas Game and Fish Commission Marine Laboratory.

### *Holocanthus isabelita* JORDAN AND RUTTER

On August 7, 1957, Mr. B. Reiter of Port Aransas, speared a small blue angel, 129.8 mm. The fish was taken in water fifty-five feet deep at a depth of ten feet. It was feeding about the pilings of an oil rig seven miles south of Port Aransas and about one mile offshore. The specimen had the yellow-margined caudal which distinguished it from *H. ciliaris*, in which the caudal is entirely yellow. On the basis of this character and the nature of the blue spot on the predorsal area (ocellated in *ciliaris;* not ocellated in *isabelita*) the color plates labeled *Angelichthys ciliaris* and *A. isabelita* in the frequently used publication "Guide to the John G. Shedd Aquarium" (fourth edition) should be switched.

Mr. A. R. Brundrett, Port Aransas taxidermist, states that he has seen several other angelfish in previous years. The present specimen will be mounted and retained by its capturer.

*Rhombochirus osteochir* (CUVIER)

One specimen, 97 mm., collected off Port Aransas by a commercial shrimper (date unknown), has been donated to the Texas Game and Fish Commission Marine Laboratory by Mr. E. Holzaphel.

*Lophiomus* sp.

An undescribed species of angler is known from Texas waters. Its description is planned by Dr. R. D. Suttkus. Baughman (1950b) erroneously reported the specimen in the collections of the Texas Game and Fish Commission Marine Laboratory as *Lophius piscatorius*. Springer and Bullis (1956) report this specimen from 27° 56′ N, 94° 00′ W, in Texas waters.

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# The Current Range of the Armadillo *Dasypus novemcinctus mexicanus* in the United States

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Prior to the middle of the last century, armadillos did not occur in the United States, being first recorded in extreme southern Texas by Audubon and Bachman (1854). They have since spread by natural means and transplantation, and now occupy large parts of five southern states and are well established in two others. Buchanan and Talmage (1954) reviewed prior range studies and gave the United States range of the armadillo as of the beginning of 1954. Much of the animal's range had then experienced drought conditions for three years. From then, until the time of this survey, the drought conditions became progressively worse. The present study was undertaken to ascertain what range changes, if any, had taken place during the continued period of sub-normal rainfall.

The method of determining the armadillo's range was the same as used by Buchanan and Talmage (1954). Questionnaires and maps were sent to game wardens in areas in Texas, Oklahoma, Arkansas, Louisiana, Mississippi, Alabama, Georgia and Florida, which bordered on the previous range line. The author is indebted to these men who so kindly answered the questionnaires.

Precise determination of an animal's range is difficult since isolated individuals will always be found beyond the area where the continuous population ceases. This is especially true with animals like the armadillo where curiosity motivates people to transplant a few. Before adjudging the mere presence of an individual animal to represent a range extension, it must be determined how the animal got there and whether it will survive and reproduce. In this report the range limits indicated are those where the continuous population appears to stop. armadillos are reported well beyond these limits but they do not appear to represent established populations.

The notable point about the current range of the armadillo compared to the previous study is the stability it has shown in spite of the extremely dry conditions. About the only range regression seen was in southwestern Texas where the armadillo has retreated from Crockett and Val Verde counties. There has been a range expansion in North Texas along the Red River especially in Red River and Lamar counties.

There has been an appreciable range expansion in southeastern Oklahoma but little movement toward the northern and western part of the state. The isolated population previously reported in north central Oklahoma has disappeared.

Some range extension has occurred in southwestern Arkansas and isolated but established colonies are present in Perry, Montgomery and Polk counties. Sealander (1956) records the armadillo as occurring in the larger portion of the state. Much of the information is based on individual sightings and some of it is dated at a time when the armadillo apparently did occupy parts of northern and northwestern Arkansas (See Talmage and Buchanan, (1954), but there presently appears to be no established population of armadillos in the northern part of the state.

It has been assumed that some armadillos have occurred in western Mississippi for several years and this report confirms that fact. Armadillos are established in southwestern Mississippi in portions of Jefferson, Adams, Wilkinson, Franklin, Amite and Pike counties. They are distributed mostly along stream lines although a portion of the Homochitto National Forest has been invaded.

The small colony of armadillos in Alabama remains fairly stable. Chermock (1956) records armadillos as spreading northward in Alabama, however, no large changes in range have taken place since 1953.

The largest advance in range by the armadillo has occurred in Florida where the animal has increased by half the area it occupies since 1953. Most of the movement has been westward and northwestward in the central lake region. Neill (1952) in a paper not cited in the previous study lists the armadillo as a resident of essentially all of the state except the western panhandle and the swampy southwestern section. While sight records have been obtained from most of the state, the continuous population does not appear to be so extensive. No armadillos appears to have yet become established in Georgia although the Florida population is almost to the state line.

There are persistent reports of armadillos in Kansas. Cockrum (1952) and Hall (1955) record it as a rare resident of the south central portion of the state. These records appear to be isolated animals, however, and it is doubtful if breeding population exists in Kansas, especially since the Oklahoma population shows little northward movement.

SUMMARY

The current United States range of the nine-banded armadillo has been determined and compared to a previous study. In spite of prolonged drought conditions in parts of its range, the armadillo has maintained essentially steady population area. Armadillos occur in most of Texas (except the trans-Pecos and panhandle areas), the southern portion of Oklahoma and Arkansas, essentially all of Louisiana and southwestern Mississippi. Separate populations of armadillos are found in southeastern Alabama and most of Florida except the southernmost and western areas. Most notable range increase is in Florida where the animals have increased their range by about fifty per cent in the past four years.

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# Wildlife and Water Conservation in Texas*

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Water for domestic, municipal, industrial, and agricultural use is receiving more attention today than ever before. New agencies have been created, new plans made and new actions taken, all of which bear witness to public concern over our having a sufficient amount of water at the right place and at the right time.

While we give thought and action to the problems of primary use of water we should not lose sight of the fact that there are other important uses, including wilflife and recreation. Fortunately, these latter uses may generally be gained in the conservation and wise use of water for other purposes.

Watershed protection and flood prevention projects of the United States Department of Agriculture, Soil Conservation Service, in cooperation with Soil Conservation Districts, offer an outstanding example of multiple benefits and uses of water. The purpose of the floodwater retarding structures is to provide temporary detention of floodwater thus protecting areas below from damage by floods. The water release structure, called the principal spillway, is designed to permit downstream flows of less than the capacity of the stream channel below the structure. The storage capacity is designed to contain a greater portion of a flood temporarily and then release this water slowly. An emergency spillway, in addition to the pricipal spillway, is provided for rains of unusual intensities and duration. During the spring rains of 1957, both the principal spillway and emergency spillway ran on many structures, but enough of the water was retarded that severe flooding was averted where a sufficient number of structures had been built on a particular watershed. In addition to the detention storage capacity there is space designed for sediment deposition. These sediment pools are designed to comply with State laws pertaining to water use.

Until the sediment pools are filled with mud, the water held therein

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* Prepared for Texas Academy of Science, Dallas, Texas, December 13 and 14, 1957.

may be used for other purposes such as domestic and livestock supply, fish, wildlife, recreation or other legal uses that landowners may desire. These flood prevention projects are adding to the recreational and wildlife areas in our State. With more leisure time and increased populations, they will become more important in the future.

Under the various projects of the Soil Conservation Service to date 248 waterflow retardation structures have been completed. Work plans completed to date call for 1,200 water retardation structures. At the present rate of construction, however, it will be several years before the total number of planned structures will be built.

The authorized watersheds are the Trinity, Middle Colorado and Washita. To date the Trinity has 906 structures planned with 159 under contract or completed. In the Middle Colorado 121 have been planned with 36 under contract or completed. Planning is in process in the Washita.

The pilot watersheds are Green Creek, Cow Bayou, Calaveras and Escondido Creeks. Forty-four structures are called for under this program with 42 contracted or complete. One hundred and twenty-nine have been planned to date under Public Law 566 Watersheds with 11 under contract or complete.

The value of wildlife on these areas is being recognized by landowners and sportsmen alike. With few exceptions the sediment storage pools of completed structures have been stocked with bass and bluegills or redear sunfish. Many have channel catfish and crappie also. Some landowners charge for fishing privileges while others allow fishing by permission. This is the landowner's choice. At many of these structures doves or waterfowl are hunted. Other landowners do not allow hunting. Again the landowner makes the choice.

Where the landowner is interested in developing a wildlife area adjacent to the water areas, technicians of the Soil Conservation Service assisting the landowners through the local Soil Conservation District can help them. Water alone will not hold waterfowl for long. Food that is attractive, nutritious and really abundant is the key to holding waterfowl or any other wildlife.

Ducks use seeds of many water growing plants such as sago and other pondweeds. Smartweeds and barnyard grasses make good duck foods at the water's edge.

A technique developed in rice fields on the Gulf Coast can be applied to the watershed programs whenever landowners or operators want to manage agriculturally produced foods to feed more ducks. The water level of the sediment pool is lowered by July which will normally happen in most years by summed drawdown. Since the ducks that feed on these seeds can not feed in water over eighteen inches deep, the water needs to be lowered about 2 feet.

The seeds are planted any time in July and the seed crop of 1.000 to 1,400 pounds of seed per acre is produced in 55–60 days. In the fall water would be allowed to cover the area and waterfowl may feed all winter. If desired, the seeding could be carried well above the waterline of the sediment pool. Water on the area for a day or two following winter rains would make the seed available for waterfowl. When the seeds are above waterline, quail, doves and many other birds feed on browntop-millet.

On a recent trip that included the Middle Colorado and Green Creek projects, an interesting variety of birds was observed. There were red heads, pintails, gadwalls, baldpates, bluewing, greenwing and the beautiful little cinnamon teal of the ducks. Other birds included pied-billed grebes, coots, mergansers, sanderlings and an avocet at the water edge. Curlews were on the fields close by. The climax was seeing an Osprey catch a fish in the upper end of Site 5 on Green Creek. Last year it was reported that a whooping crane stopped on a flood prevention structure in this watershed on its migration route.

As one who likes to hunt waterfowl, I am glad to see more opportunities for people from all parts of the State to enjoy the privilege of hunting these wonderful game birds which are afforded by the flood-water retarding structures. Also, as one who likes to observe the myriads of birds that grace our State, I have also enjoyed that privilege by observing the many kinds that are attracted by food and the new areas of water.

Where the landowner wishes to benefit other types of wildlife management is also possible in the area around the pond. Cultivated native foods such as crotons, sunflowers or annual panic grasses make excellent dove, quail and other wildlife foods. The term cultivated native foods is used because disking and fertilization of planned food areas put predictable amounts of food on the ground whereas nature provides unpredictable amonts. A field trial of *Croton capitatus* for doves and quail in the Wood Soil Conservation District showed that disked, fertilized strips produced 300–400 pounds of seed per acre while adjacent untreated strips growing in competition with Bermuda grass produced only a trace amount.

Water, whether retarded for flood prevention or in a farm pond for livestock use, fire protection or any other purpose, is also a recreational asset. Fishing, swimming and boating are additional incentives to manage agricultural waters. Through June 30, 1957, the Soil Conservation Service has furnished technical assistance to Soil Conservation District cooperators on construction of 136,177 farm ponds in Texas. A large portion of these cooperators have also received financial assistance through the Agricultural Stabilization and Conservation program. The primary purpose of most of these ponds is not for wildlife, but wildlife use them. One example of a benefit to wildlife observed during the recent drought was that where quail were able to get to water every day, they carried moisture back to the nest in their feathers. Where the birds were able to do this, they had a much higher hatchability of their eggs than did birds that could not get to water every day. Quail, incidentally, can live without surface water if there is an abundant supply of grasshoppers, succulent plants and occasional dew formations.

Of the ponds constructed more than 33,000 have been stocked with bass, bluegill or redear sunfish. Channel catfish have been added when the landowner desired them. Even with the low production of unfertilized waters, this figure adds up to a lot of recreation and food production. The term, low production, is used because unfertilized waters produce only from 15 to 40 pounds of catchable, usable size fish per surface acre. Many landowners are not satisfied with this low production, however, and use inorganic fetrilizer to raise the poundage of catchable, usable size fish to between 150 and 250 pounds per surface acre. A lot of potential fun, recreation and food for the table are the results of these ponds.

A new type of water management is being studied in the rice farming area; it is a rice-fish rotation. After a rice crop is harvested the field is reflooded and stocked with channel catfish. The fish are left on the field for two years and then the fish are harvested commercially. The soil condition is improved and very little, if any, fertilizer is needed on the following rice crop.

Texans consume about 2 million pounds of channel catfish a year. At this time a good percent of the supply comes from stream fishermen in Louisiana and Arkansas. This type of supply is not as predictable as is a supply grown in rice fields and harvested when demand is best and optimum marketable size is produced. In effect, under the rice-fish rotation plan, an agricultural crop is produced under controlled conditions the same as beef, pork, cotton or corn.

Water management on rice stubble also benefits wildlife. The levees are replugged following rice harvest and rainwater caught. By having the field flooded the 160 to 350 pounds of grain per acre that is lost in the harvesting operation is made available to waterfowl. Many weed seeds are consumed also although waterfowl will not eliminate the weeds that are common in rice culture.

Many rice farmers interested in waterfowl management are planting browntop-millet in idle rice fields for wildlife food. The plant is planted on a drained, idle rice field and fall flooded to make the seeds produced available to waterfowl. In rice culture most farmers produce rice on a piece of land only once every three or four years. The years the land is not in rice it is either grazed, idle or planted to wildlife foods. A recent study by the author showed that rice and weedy plants associated with rice culture are very important waterfowl foods.

The woodland duck pond is another kind of water management. Low levees are constructed in bottomland woodland areas. Water is held on the area during the winter months enabling waterfowl to feed on mast and other seed produced. The area is drained during the spring and summer months so that the trees will not be killed. It improves the timber yield of bottomland hardwoods and makes additional areas available for waterfowl usage. Under this system the management is not to kill the food producing trees. Areas of dead trees are used by waterfowl, but they do not use them to the extent that they do areas where the trees are alive. Food makes the differences as water is on both types of areas.

Irrigation reservoirs help to winter and feed waterfowl, also. The way farmers use water for irrigation helps to produce wildlife food plants. The highest production plants in terms of pounds of food per acre are annuals or low succession perennials. These plants germinate on the wet areas anytime the water is taken out of the reservoir. Although most reservoirs are rarely drained completely, enough areas are exposed to produce food patches of barnyardgrasses, spikesedges and other good food producing plants. After the plants get a few inches high, reflooding will not hurt them and they continue to grow until frost.

Submerged plants such as saga and other pond weeds, stoneworts, watershield, and many others also produce wildlife food, but not as much poundage as cultivation and fertilization produce.

The reservoirs are also important roosting areas for both ducks and geese where food is in fields close by. Snow and Blue Geese on the Gulf Coast roost in many reservoirs although they spend their feeding periods grazing on rice fields, improved pastures or marsh areas.

Most reservoirs that are not drained completely during the crop irrigation season also produce good fishing when stocked with game fish. Arkansas rice farmers are growing commercial crops of buffalo fish in reservoirs. This culture has not yet become popular in Texas because most people in this State consider buffalo a trash fish, but there are indications of growing interest. In the Lavaca Soil Conservation District standards are being developed for production of buffalo fish as another agricultural crop.

Water management for wildlife as an integral part of a soil, water and plant conservation program is practical, profitable and adds greatly to recreational opportunities. Much more can and will be done as conservation becomes established on the farms and ranches in Texas.

# The Meaning and Use of Academic Degrees and Titles[1]

*by* **DOMENIC A. VAVALA,**
*Incarnate Word College*

INTRODUCTION

The American universities of today are heirs to a great educational heritage which, beginning with the Middle Ages, has been transmitted through the centuries via tradition and history to our present universities which are the direct academic lineal descendants of the two original and great archetypal medieval universities, namely, the University of Paris and the University of Bologna.

The traditional and historical significance of academic degrees, both in their origin and development, is rich with meaning and symbolism. The possessor of a college degree should have a knowledge of how his degree came into existence and the traditional and historical meanings of his award of academic achievement. This information should be desired and coveted by all holders of college degrees, and especially by those having a master's or doctor's degree for these titles or degrees were those of the first teachers of the medieval universities.

Ironically, the very knowledge about the university's award of academic distinction, the degree, is strikingly absent from both the curricular requirements and elective courses for academic degrees. This is true both at the undergraduate as well as the graduate levels. A perusal of college catalogs' course offerings and degree requirements will readily confirm this fact. The vast majority of college graduates today have no conception whatsoever regarding the meaning and use of academic regalia, degrees and titles. Should anyone doubt this statement, he has only to go to a college campus and make inquiries both of undergraduates, especially seniors, and of graduate students. The replies would be both apalling and enlightening.

The result is that today the majority of people, both college graduates and non-college people, have an erroneous conception of the meaning and use of academic degrees and titles. If college graduates do not possess this important information, certainly they cannot pass on to others,

[1] Presented at the annual meeting of the Texas Academy of Science, December 12–14, 1957, Dallas, Texas.

their families, acquaintances and friends that which they lack. Thus, both factions are misinformed or grossly uninformed.

A common misconception and error is the notion held by some individuals that the use of the title, "doctor" is the exclusive right of a particular species of doctor. This is absolutely without foundation and has no basis in fact, as will be demonstrated, either in tradition, time or history.

The present paper traces the origin of the academic degrees as well as the meaning and use of academic titles.

*The Medieval Craft and Trade Guilds.* In the early part of the Middle Ages practitioners of the various arts, crafts and trades, having kindred pursuits or common interests or aims, formed associations for their mutual aid and protection. These medieval associations were known as guilds, such as the merchant guild and the trade guild. The members of a guild corporation were divided into three classes, apprentices, assistants and masters (Compayré, 1893). It required a certain number of years to progress from the entry level of apprentice to that of master of the trade or craft. When an assistant was eligible for consideration for admission into the guild as a master, he was required to perform a special task the successful completion of which, upon the judgment of his masters, would entitle him to admittance into the guild as a master tradesman or a master craftsman. The installation of a person as a master was attended with much ceremony and almost always followed by a banquet. By the ceremony of installation the assistant obtained his mastership and the right to freely exercise his trade or craft for the first time together with all the rights of membership in the guild. This, then, was the procedure for attaining the mastership in the craft or trade guild corporations.

*The Masters' Guild in the Universities.* What was the procedure in the university corporations in order to become a master of arts and have the right to follow the teaching profession? One must have spent a certain number of years at the feet of a master, so to speak, serving an apprenticeship in the arts. After fulfilling this requirement he then had to pass an examination before masters of arts, his judges. The successful completion of this step eventually led to the impressive ceremony of freedom from the state of pupillage and admission into the select guild of the masters of arts, followed by a banquet given by the new master, a banquet which lasted for two or three days. Thus, the university corporations set up and followed a system leading to the mastership in arts similar to that leading to the mastership in the craft or trade guild.

*The Earliest Procedure for the Mastership at Paris.* The evidence from early documents (ca. 1150–1170) of the University of Paris, as presented by Boyd, (1921) discloses that in the scholars' guild the student had to serve an apprenticeship of from five to seven years as a disciple of a recognized master in order to qualify for the mastership. At the end of this time he was formally introduced into the society by his master and entrance into its ranks was by the delivery of a probationary or inaugural lecture or disputation which was the ceremony of "inception" or commencement, as we know it today, marking the entrance of the master into the duties of the teaching office (Boyd, 1921). At this time the masters' guild, or university of masters, had no written statutes and no official head.

*Origin of the License to Teach.* As the fame of Paris and Bologna grew and spread students flocked to these centers of learning from all parts of Europe. With the continued increase in the number of students, the number of teachers likewise multiplied. Since pretenders to the teaching office began to appear, it became necessary to protect the scholar as well as the qualified master. Out of such a necessity grew the *licentia docendi*, the license to teach. Studies were beginning to be organized into distinct fields of learning requiring competent teachers in the particular field of study. At Paris, the progression leading to the license was as follows (Boyd, 1921). The student attended the lectures of a member of the masters' guild. After four or five years he became a student-teacher for a further term of years. At the termination of his capacity as student-teacher, he applied to the chancellor of Paris, or the corresponding Church official for a licence to teach. Having received the license he then was presented by his own master to the society of masters as a candidate for admission to their ranks. If approved by the guild, the "inception" followed. At Bologna, by 1219, the same procedure was followed.

*The Licence, a Prerequisite for Teaching.* The licence to teach, as masters and students increased, became a preliminary condition of teaching, a sort of diploma which eventually was absolutely required.

*The Licence, the First University "Degree."* Up to the fourteenth century, licentiate was the only clearly defined university title. Bologna gave the licence to teach law, and Paris gave the licence to teach arts and theology.

*Original Meaning and Use of Title, "Doctor."* Bachelors and doctors, that is, students and professors were much spoken of, but there was neither a bachelorship nor a doctorship at this time. "Doctor" or "master" meant *anyone who exercised the teaching office.* There were doctors of law at Bologna from the twelfth century and doctors of medicine and philosophy from the thirteenth century, but all these were before the examination had been instituted which subsequently gave a right to these titles in their respective fields. "Doctor" and "master" were used at first in a general sense to designate the particular grade of the university hierarchy, and this was before the titles had taken on a definite signification (Compayré, 1893). Compayré states: "it was altogether natural, in fact, that he who had obtained the licence to teach should be called doctor." The word "doctor" is derived from the Latin verb, *docere*, which means to teach. So at this time there were so called "bachelors," apprentices, beginners, although there was as yet no examination corresponding to the first grade of studies.

*Distinction between Teachers and Non-Teachers.* Gradually, with time the honor of mastership came to be desired by those who had no intention of teaching and a distinction came to be made between teachers and non-teachers; *magistri regentes* and *magistri non-regentes* in Paris; *magistri legentes* and *magistri non-legentes* in Bologna. By this distinction, the mastership came to signify the successful completion of a special course of study, and it now became necessary to define the qualifications of the mastership with greater accuracy (Boyd, 1921).

*Bologna Establishes the Bachelorship.* Bologna led the way in defining the qualifications (Boyd, 1921). After five years of attending lectures and giving lectures on a chapter of one of the law books, the student became a bachelor without examination. Two years later, at the end of seven years' study he could apply for the doctorate. This meant being presented to the Archdeacon of Bologna by his master as being fit for the licence after which came a private examination before the college of doctors. If the doctors voted to approve his candidacy, he became a licentiate, but was not given the licence at this time. Graduation was completed by the licentiate's being present at the public examination held in the cathedral with much ceremony. Here he delivered an inaugural lecture or disputation following which he was presented to the Archdeacon and now received his licence to teach. Finally, he seated himself in the magisterial chair, a law book was put in his hand, a gold ring placed on his finger and the doctor's cap placed on his head. He was now a "master" or "doctor" and was escorted or carried triumphantly through the streets by large numbers of students.

*Paris Inaugurates a System Similar to Bologna.* Either independently or in imitation of Bologna, a similar system arose in Paris. By 1215, a definite curriculum of study existed for the degree in arts and by the middle of the fourteenth century the course was divided into three parts: (1) for the baccalaureate—grammar, logic and psychology; (2) for the licence—natural philosophy; (3) for the mastership—

moral philosophy and completion of natural philosophy (Boyd, 1921). The ceremonial admission of the licentiate into the ranks of the doctors was the same at both Paris and Bologna. During the fourteenth century the practices established at Paris became the general rule in most other universities.

*Origin of the Three Academic Degrees.* With the growth of the university the different faculties were constituted, each with its prescribed course of studies and special corps of professors. From the necessity of controlling the work of the students, and of ending the successive periods of study by examinations and by private and public acts, and of celebrating by ceremonies, the system of degrees naturally followed (Compayré, 1893). The three degrees that were distinguished were the bachelorship, the licentiateship, the mastership or doctorship. With reference to the mastership Compayré says:

> To be exact, the mastership was merely a title, the consequence of the licence and its formal consecration. The assumption of the title, master by the licentiate was merely ceremonial introduction into the magistral body.

In the order of time the licentiate was the first academic degree to be established, and it remained the degree *par excellence* even when the custom of preceding it by the baccalaureate had been established (Compayré, 1893).

*The First Doctorates were in Law and Divinity.* As regards the origin, meaning and use of the title, *Doctor*, the evidence is crystal clear and irrefutable.

In the earliest period of the universities of Paris and Bologna, the terms "doctor" and "master" were used interchangeably for the teachers of theology at Paris and for the teachers of law at Bologna. The title of doctor came into common use in the twelfth century when it was conferred for the first time by the Faculties of Law at Bologna (Atkinson, 1945). Compayré also states that "the title of doctor was used only by the Faculties of Law at Bologna."

About 1145, Paris granted the doctorate in the faculty of divinity. In England the degree was introduced in the thirteenth century. Both here and on the Continent the doctorate was for a long time limited to the faculties of law and divinity (Atkinson, 1945).

Rashdall (1936) states:

> From the beginning of the 13th century the documents show that the society or university (of Paris) included masters of three faculties, theology, law and arts. The masters of medicine are not yet mentioned as a distinct element.

*Teachers of Medicine Assume Title of Doctor.* From 1222, there are distinguished three types of physicians, a class styled *Medici Physici,* a title used apparently to distinguish the scientific physicians alike from the ordinary *empirical practitioners* and from the *Medici Vulnerum* or surgeons (Rashdall, 1936). It is not until the second half of the thirteenth century, almost one hundred years after the common usage of "doctor of law" and "doctor of theology" that *teachers of medicine* assumed the title of *Medicinae* or *Physicae Professor* or *Doctor,* and the title implies a distinct imitation of the titles assumed by the *Doctores Legum* (Doctors of Law), (Rashdall, 1936).

Graduation in medicine took place ca. 1260, and this was about the time that a school of medicine was organized after the fashion already established in the schools of law and arts in the universities (Rashdall, 1936). Almost one hundred years after graduation in law, arts and theology had been established, graduation in medicine took place in the faculty of medicine in the university.

*The Doctorate Conferred Only on Teachers.* The meaning and use of the title, *doctor,* could not have been stated any better than Mullinger did in connection with his work on the University of Cambridge (Mullinger, 1884):

> It is evident that, if the statutory course was strictly observed, the doctors of those days could have been no smatterers in their respective departments. The scarlet hood never graced the shoulders of one who was nothing more than a dexterous logician, nor was the honoured title of doctor ever conferred on one who had never discharged the function of a teacher.

## SUMMARY

During the germination period of the medieval universities and for many years after their birth, the master of arts guilds of the two mother-universities of Paris and Bologna imitated the procedure for attaining the coveted mastership in arts which was practiced in the craft and trade guilds in the Middle Ages.

We have seen how the licence became the first degree awarded by the universities to those competent to discharge the duties of the teaching office. This was followed by the establishment of the three academic degrees, the bachelorship, the licentiateship and the doctorship.

Traditionally, and the chronological historical documentary evidence reveals that the first doctorates were those in arts, law and theology. Some one hundred years later, following the procedure and practice already established in the faculties of arts, law and theology, the degree of doctor of medicine was conferred only upon teachers of medicine who taught medicine in the faculty of medicine in the university.

It is absolutely true and correct that for centuries the title of doctor was conferred only upon those discharging the duties of the teaching office. Later on the doctorate was also bestowed as a mark of the highest achievement in a field of knowledge according to established academic procedure arising evidently out of the communicative nature of the teacher. Thus, the title, doctor (1) was and still is essentially—though now related to growth in other fields—teaching (2) was indicative of the degree of perfection and achievement of a profession, teaching—attributed to others.

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## Science in Texas

The first $200.00 scholarship has been awarded by the Field-Franklin Science Education Trust. It went to an outstanding senior at Robert E. Lee High School in Baytown, Texas, who plans a chemical engineering career.

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Appointment of Walter H. Owen as General Manufacturing Superintendent and Earl L. Casey as Manager of Division Services of the Texas Instruments Incorporated Apparatus division, was announced recently by W. F. Joyce, TI Vice President in charge of the division.

Mr. Owen joined TI in 1943 as a manufacturing engineer. Before his new assignment, he had served as Manager of Manufacturing of TI's precision optics facility in Monrovia, Calif., which recently has been moved to Dallas.

A veteran employee, Mr. Casey in 1937 entered the services of Geophysical Service Inc. for work on foreign contracts. Mr. Casey was formerly general superintendent of manufacturing for Apparatus division. In his new assignment, he will be responsible for all plant engineering and office services for the division, reporting directly to Vice President Joyce.

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The Thirteenth Annual Technical Meeting of the South Texas Section of the American Institute of Chemical Engineers will be held at Moody Center, Galveston, October 3, 1958.

A technical program is being drawn up which will include papers on management, computation, statistic, and other technical subjects. Over 800 of the top chemical engineering personnel in the area are expected to be in attendance.

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Contractual research on fish mortality at state hatcheries is being done for the Game and Fish Commission of Texas by the Department of Wildlife Management. Dr. Richard J. Baldauf and Dr. Alvin Peters are conducting studies on the biology and control of trematodes, cestodes, and water molds and their effect on fish production and mortality.

The Texas Herpetological Society held its annual field meet in the lower Rio Grande Valley, 40 miles NW of Laredo, Webb County, Texas, on March 15 and 16, with 87 collectors registered. The Society, as usual, made previous arrangements with local people for permission to collect in a large area surrounding the base camp. Although all reports of collections made on the trip are not yet available, the data compiled so far indicate that at least 10 families, 19 genera, and 29 species and subspecies of reptiles and ambpihians were collected. At least ten of the forms represent new records for the county. New Society officers elected are Richard J. Baldauf (Texas A. and M.), President; Alvin Flury (Mathis, Texas), Vice President; James R. Dixon (Texas A. and M.), Secretary-Treasurer; Jesse Haver (Houston, Texas) and Ernest Tanzer (Texas A. and M.), Executive Board.

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The Department of Wildlife Management at Texas A. and M. College, College Station, Texas, is interested in exchanging preserved specimens of reptiles, amphibians, and fishes. Forms found in Texas and Mexico will be exchanged for certain U. S. and foreign species. Write William B. Davis or Richard J. Baldauf for their Want List.

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San Antonio, Texas—Dr. Louis E. Kidwell, Jr., has recently been named manager of the organic chemistry section of the Department of Chemistry and Chemical Engineering, Southwest Research Institute. He joined the Institute staff last fall as a senior organic chemist. For four years Dr. Kidwell served as a research chemist with the Monsanto Chemical Company, both at Dayton, Ohio, and Nitro, West Virginia, making a study of chemicals which can be added to rubber to prevent its deterioration. Prior to that, he was a research chemist with Shell Oil Company, Houston, conducting research in petroleum cracking, chromatography, and wax stabilization. As a junior engineer with Phillips Petroleum Company in Odessa, he was engaged in studies of the treatment of natural gasoline.

Dr. Kidwell has a B.S. degree in industrial chemistry and an M.S. degree in organic chemistry from the University of Kentucky. He obtained his Ph.D. in organic chemistry on an Air Force fellowship from the University of Texas. The compounds made during his graduate study had potential use as additives for jet fuel.

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Dr. John Andrew Wilson, University of Texas vertebrate paleontologist, has been invited by scientists at Sabadell University in Spain to lecture at a course for international paleontologists. Dr. Wilson, one of two representatives invited from the United States, was at Sabadell from June 29 to July 9. He was in Europe for six weeks to lecture and conduct research at geology museums on a travel grant from the American Philosophical Society. At Sabadell Dr. Wilson lectured on "Miocene Horses and Biostratigraphic Units—Texas Coastal Plain." He presented a statistical study of tooth-measurements of 800 fossil horses to show how those animals evolved during the Miocene geologic period.

After the lecture sessions, the international paleontologists went on a four-day field trip into Northern Spain to observe interbedded marine and continental formations containing fossils of both sea and land vertebrates.

Before going to Sabadell, Dr. Wilson did research at the British Museum of Natural History in London, the Municipal Museum in Basel, Switzerland, and the University of Lyon Museum in France. He studied fossil horses, dogs, and rhineceroses in an attempt to compare the European continental specimens with fossils of the same animals found in North America. These pre-historic animals roamed the two continents during the Miocene Period some 30,000,000 years ago.

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The National Institute of Mental Health has approved a one-year $10,000 study by Dr. Philip Worchel, University of Texas psychology professor, on "The Reduction of Hostility, Anxiety and Guilt." Dr. Worchel will explore various means of reducing those feelings. About 400 University students will be involved in the investigations.

"The studies are designed to test two hypotheses," Dr. Worchel explained. "The first is that reduction of hostility, anxiety and guilt follows communication of feelings (catharsis) and a change in how the threatening situation is seen. The second hypothesis is that the readiness to communicate feelings and to see changes in the nature of the threat is a function of the difference between how a person sees himself and what he would like to be. While a great deal is known about the variables which influence hostility, anxiety and guilt have rarely been studied in an experimental situation," he pointed out. "We must develop adequate methods of reducing these feelings for it is only the extension of these feelings that may lead to the neurotic manifestations of hostility, anxiety and guilt. The first step is to develop a situation which deals with the experimental arousal of these feelings under frustrating conditions. Once these feelings have been arosed, various methods of reducing them can be studied."

A University of Texas geologist, Dr. Edward C. Jonas, has received a $12,305, two-year grant from the National Science Foundation to continue basic research on the effect of clay-eating fish on mineral sediments in Gulf coastal waters. Dr. Jonas, in earlier research, showed that chemical action in clay-filled fish stomachs changes the clay mineral composition of sediments in Gulf coastal bays and estuaries.

The 33-year-old geologist said he hopes to make clay minerals in marine rock more useful as indicators of petroleum-bearing source beds. "If we know hoy to identify marine source beds, then we can hunt for petroleum more effectively," he explained. Dr. Jonas will determine the amount and type of change specific fish cause in various clay minerals and compare those changes in the fish digestive tracts with changes brought about by exposure of clays to sea water alone.

Explaining how marine life changes clay minerals in sediments, Dr. Jonas said that as the clay particles flow downstream and into the Gulf, such filter-feeding marine animals as menhaden, anchovies or shrimp eat the clay particles which are similar in size to their regular diet of algae, bacteria or plankton. In the digestive process the highly-acid chemical enzyme action in the fish's stomach changes the clay particles which are later deposited to form layer after layer of mineral sediment on the ocean floor.

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Oxygen-producing algae may possibly solve man's breathing problems in tightly-closed spaceships. Dr. Jack Myers, University of Texas scientist reported on algae experiments, conducted in the University's Algal Physiology Laboratory, at a national Symposium on Possible Uses of Earth Satellites for Life Science Experiments, in May.

A man flying in a spaceship needs 600 quarts of oxygen a day to sruvive, but the tremendous weight of the oxygen tanks would make it difficult to include them on the spaceship, Dr. Myers explained. A possible alternative would be to set up a photosynthetic gas-recycling system, whereby the man breathes oxygen produced by the algae, and the algae completes the gas-exchange cycle by growing on the carbon dioxide exhaled by the man.

Dr. Myers explained how he and his assistant, Research Scientist Ruth Doney, designed and engineered a photosynthetic gas exchanger containing a tightly-closed spaceship type chamber in which two adult dwarf mice survived 37 days. The mice, still alive and showing no negative signs of their experience, survived on the oxygen produced by the algae. In building the interchange "survival" system, the University scientists created a small compact "world" which contained the biological necessities—oxygen, nutrients and water—to keep the mice alive.

But Dr. Myers emphsized that "no use of this procedure is reasonably foreseen in the immediate future of satellite development. Our research is fundamental, and will contribute to a long range kind of operation." He indicated that it is far cheaper to send up mechanical and electronic equipment, than to send up a man. From the economic and design standpoints, it is is easier to send up the complicated electronic recording equipment than to provide for the necessary survival requirements of man in a space chamber.

For a short space trip, it would be better to carry oxygen as liquid oxygen, and have some absorber to remove the carbon dioxide exhalation, he explained. However, if the space flight is longer, it would be more feasible to equip the chamber with oxygen-giving algae to keep the man alive.

In order to achieve more complete biological balance in their experimental space chamber, Dr. Myers said several "refinements" would be required. First, the protein-rich algae, which reproduces rapidly each day, might also be used as food for the mice. Also other microorganisms could be used to decompose the mice excreta to carbon dioxide nad ammonia which would keep the algae growing to produce more life-giving oxygen for the animals.

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Dr. Harold W. Stevenson, University of Texas associate professor of psychology, has a $26,000 National Institute of Mental Health grant for a three-year study of "Reinforcement Effects in Normal and Retarded Children."

The investigations, aimed at better understanding and training of the feeble minded, will involve normal children and feeble-minded children, all with mental ages of four to six. Dr. Stevenson and his associates will compare normal and feeble-minded children of the same mental age, studying their learning processes and behavior under various types of "reward" situations.

Effects of two types of rewards—prizes and praise—will be compared. Dr. Stevenson's preliminary research indicates that feeble-minded and normal children of the same mental age should be able to do certain practical tasks equally well. But feeble-minded children, in many cases, haven't been given the opportunity to do as much as they could do. "Feeble-minded children usually are given tasks that are too difficult for their mental ages; therefore, they are often frustrated and never experience success or its rewards," Dr. Stevenson points out. When asked to perform tasks appropriate to their mental ages, and when rewarded, especially with praise, many feeble-minded children perform as well as normal children of the same mental ages.

The new research project will not attempt to raise the IQ of feeble-minded children, but seeks techniques for teaching them. The study involves children in the 40 to 70 IQ range, with no brain damage or other physiological defects. Children in this group, with no apparent reason to perform as poorly as they often do, comprise about 70 per cent of all feeble-minded children, Dr. Stevenson says. Cooperating with the study will be local nursery schools and state institutions.

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Dr. Vance E. Moyer, University of Texas meteorologist, has received a $1,100 Texas State Health Department grant to conduct a five-month correlation study to determine the relationship between high temperatures and dental fluorosis, or teeth mottling. Dr. Moyer will work in conjunction with Dr. John W. Stone, State Dental Health director. collecting temperature data while Dr. Stone and his colleagues examine children's teeth in 50 Texas communities. The assumption is that in the hottest part of the day, a child will drink more water and the increase in water intake may increase the mottling. James R. Holmes, College of Engineering faculty member, will serve as consultant on the project and Patricia A. Hocker of Austin, as statistical aide.

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Dr. O. E. Weigang, Jr., Assistant Professor of Chemistry at Texas Lutheran College, Seguin, Texas, has been awarded support of $6,600 from the National Science Foundation toward the purchase of a Beckman recording spectrophotometer. The instrument is to be used in a study of "Solvent Effects on the Spectra of Petroleum-Related Compounds."

Another grant of $7,700 from the Petroleum Research Fund, American Chemical Society, had been awarded recently to support the two year project. The latter grant is for "fundamental research in the petroleum field at the undergraduate level" and is also "designed to stimulate student interest in graduate study."

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A Resarch Conference on *Vertebrate Speciation* will be held at The University of Texas, Austin, Texas, October 27 to 31. The program will include five main topics:

Isolation Mechanisms—Moderator: Ernst Mayr (Harvard University); C. L. Hubbs (Scripps Institute of Oceanography): Isolation mechanisms in fishes; J. S. Mecham (Alabama Polytechnic Institute): Isolation mechanisms in Anura; John A. Moore (Columbia University): Origin of isolation mechanisms; Charles G. Sibley (Cornell University): Hybridization and isolation mechanisms.

Evolution of Behavior—Moderator: Lester Arsonson (American Museum of Natural History); Peter Marler (University of California, Berkeley): Evolution of visual communication; J. A. King (Rosco B. Jackson Memorial Laboratory): Development and behavioral evolution in *Peromysous;* L. T. Evans (Albert Einstein College of Medicine): Structure and organization of populations in reptiles; Keith Dixon (Hastings Reservation, University of California): Habit distribution and niche relationships in North American species of *Parus*.

Polymorphism and Polytypic Species—Moderator: Lee R. Dice (University of Michigan); E. P. Volpe (Tulane): Polymorphism in vertebrate populations; W. F. Pyburn (Arlington State): Polymorphism in cricketfrogs; R. F. Inger (Chicago Natural History Museum): Intraspecific variation.

Population Dynamics—Moderator: Charles M. Bogert (American Museum of Natural History); C. P. Haskins (Carnegie Institution of Washington): Polymorphism and population dynamics in *Lebistes reticulatus;* Henry S. Fitch (University of Kansas): Longevity and size—age groups in some common snakes; Victor C. Twitty (Stanford): Territorial and homing behavior in *Taricha;* W. W. Milstead (Texas Tech): Competitive relations in lizard populations; Frank A. Pitelka (University of California, Berkeley).

Age and Origin of Species—Moderator: E. H. Colbert (American Museum of Natural History); Gunnar Svardson (Institute of Freshwater Research, Drottningholm, Sweden): Young sibling species of fish in northwestern Europe; M. J. Littlejohn (University of Western Australia): Age and origin of some western Australian *Crinia;* R. R. Miller (University of Michigan): Age of species in the American Southwest; C. Kosswig (University of Hamburg): Speciation in the earlier central Anatolian Lake Basin; E. S. Deevey (Yale University): Influence of the Pleistocene.

Travel funds are available for students under a grant from the National Science Foundation. Interested individuals should contact W. F. Blair, Department of Zoology, The University of Texas.

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W. D. Seyfried has been promoted to head Humble Oil & Refining Company's Research and Development Division at Baytown, Texas. He will have in his charge some 100 chemical engineers, chemists and physicists who are engaged in exploratory, product quality, fuels processes, and analytical research. Seyfried replaces Dr. A. A. Draeger who as joined Humble's Marketing Department in Houston as manager of General Office Sales. He is responsible for the sales of chemical and petroleum products. Seyfried has been with Humble 20 years and ass istant head of Research and Development Division since 1948. He participated in the development of analytical techniques and in the organization of the laboratory groups for Baytown Ordnance Works and for the butadiene plant, both operated during World War II by Humble for the government, and now owned and operated by Humble. Seyfried holds the B.S. degree in chemistry from Vanderbilt University. Draegere has headed Research and Development Division since 1947, however, since that time he has served in Humble's Executive Program a year as technical assistant to the Manager of Operations, two years as head of Technical Service Division, and several months as manger of Technical and Research Divisions. He holds the B.S. and M.S. degrees in chemical engineering and the Ph.D. degree in physical chemistry from The University of Texas.

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The University of Texas faculty roster will be enhanced in the fall with the addition of a number of distinguished scholars. Dr. Earl Ingerson, U. S. Geological Survey geochemist and mineralogist in Washington, will join the geology faculty as professor. Dr. Ingerson, selected by President Eisenhower to give a series of lectures in Russia last year, served as chief of the Geological Survey's petrology and geochemistry branch the last 10 years during the intensive investigation of the U. S. uranium resources. He is a Barstow native, majored in chemistry at Hardin-Simmons University and received a Doctor of Philosophy degree from Yale University in 1934. He did postdoctoral research at the University of Innsbruch, Austria.

Dr. Shao Wen Yuan, internationally-known specialist in aerodynamics and structural analysis, will be a new aeronautical engineering professor. Dr. Yuan, who has been in the U. S. for more than 20 years, last year taught at Laval University, Canada. From 1945 to 1957 he taught at Brooklyn Polytechnic Institute. He has extensive industrial and research experience in aerodynamics, and received his training from California Institute of Technology, Stanford University and the University of Michigan.

Dr. Bernard Bruno Kinsey, British atomic physicist, will join the University faculty as physics professor. Dr. Kinsey, authority on neutron scattering, has been with the United Kingdom Atomic Energy Authority's research establishment in Berkshire, and formerly worked on the atomic energy project at Chalk River, Canada.

An internationally-known cancer researcher, Dr. John Julius Biesele, will join the zoology faculty as professor. Dr. Biesele, at the Sloan Kettering Institute for Cancer Research in New York since 1947, received a Ph.D. from the University in 1942.

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Clues to prehistoric Indian cultures that thrived along the Rio Grande about 2500 B. C. will be unearthed by University of Texas archeologists as one phase of a 13-month project to recover Indian artifacts from five dam construction areas. The University has signed a $35,000 contract with the National Park Service to recover remnants of prehistoric Indian villages and campsites before they are lost beneath the reservoirs. The University archeologists, who will dig for Jumano Indian artifacts at Diablo Reservoir near Del Rio, also will seek clues about Tawakoni, Yscanis and Caddo Indian life by excavating at Iron Bridge Reservoir on the Sabine, Blackburn Crossing on the Neches southeast of Tyler, and at the Waco dam enlargement on the Bosque. They will also make a final run on the Ferrell's Bridge damsite near Jefferson before the flood gates are opened next January. Other University archeologists conducted three major excavations there the last two years. Dr. Thomas N. Campbell, anthropology department chairman, will direct the project. Three new research archeologists on the University staff will do the excavating: Edward Jelks, formerly of the National Park Service, who will direct the field work; L. F. Duffield of Tulsa, Oklahoma, and W. A. Davis, former government archeologist.

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Dr. Harold C. Bold, University of Texas botany professor, has been named editor of the American Journal of Botany, official publication of the Botanical Society of America. Dr. Bold, who served as national BSA secretary the past four years, was chosen for a five-year term. He will edit 10 issues each year for a readership of some 5,000 plant scientists. The journal, now in its 45th volume, features scholarly articles that encompass the whole field of botany. Editorial committeemen who will assist Dr. Bold include botanists from Harvard, Duke, and Indiana Universities, and California Institute of Technology. Dr. Bold joined the University faculty last September, after teaching 18 years at Vanderbilt University. He also taught at Barnard College and Columbia University. As author, Dr. Bold achieved acclaim last December with publication of his book, "Morphology of Plants," regarded as "one of the classics of plant science." His research centers around algae of Texas and U. S. soils. He is a member of several organizations, including the Botanical Society of America, American Institute of Biological Sciences, and Phi Beta Kappa, scholastic honor society.

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A four-year course leading to a Bachelor of Science degree in Industrial Engineering has been announced by St. Mary's University. It is the first engineering degree to be offered in the history of higher education in San Antonio. Very Rev. Walter J. Buehler, S. M., president of St. Mary's, said that the senior year of the program will be offered for the first time in 1960. Curriculum for the new department grew out of numerous meetings and detailed studies extending over a period of two years. Distinguished men of industry, the Engineers Council for Professional Development, and educators of this country's leading engineering schools have worked with the St. Mary's faculty to choose a branch of engineering study suited to the needs of San Antonio and the Southwest. Fother Buehler pointed out that the program would "emphasize the importance of the humanities, mathematics and science as the foundation of engineering education. We believe such a program is of maximum benefit to both the student and the business firms he will ultimately serve. The 164-hour course will blend religious and humanistic knowledge with the scientific and technological growth of the student, so that he may progress as a more complete man toward a satisfying professional life."

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Management and technical problems are due for close scruting at the Annual Technical Meeting of the South Texas Section of American Institute of Chemical Engineers to be held in the Moody Center Building, Galveston, Texas, October 3, 1958. A full program promises to give the expected 800-plus attendees a busy but rewarding day. In addition to the general session, symposiums and panels have been scheduled on the following timely topics: "Management and an Individual's Education, Advancement, and Future"; "Modern Computation Methods"; and "Use of Statistics in Research and Production." Dr. J. J. McKetta, University of Texas, will moderate a group discussion on "Professionalism—What Does It Mean" and Dean W. W. Hagerty, also from the University of Texas, will lead a similar discussion on "Present Trends and Planning for the Future in Engineering Curricula." More than 50 exhibits will be set up in Moody Center, displaying the latest equipment for both plant and laboratory. The registration desk opens at 8:00 A.M. and technical sessions begin at 9:30 A.M. General Chairman for this Thirteenth Annual Meeting is K. S. McMahon, Wyatt C. Hedrick Engineering Corp., Houston, Texas.

PANEL—*"Management and an Individual's Education, Advancement, and Future"*

A panel discussion with questions from the audience.

R. W. Ericsson, Vice President and Sales Manager, Texas Butadiene and Chemical Corporation, Houston, Texas.

E. E. Ludwig, Process Engineering Manager, Dow Chemical Company, Freeport, Texas.

B. H. Sloane, Operations Manager, Point Comfort Works, Aluminum Company of America, Point Comfort, Texas.

H. G. Osborne, Senior Vice President, Petrochemicals Development and Research, Continental Oil Company.

SYMPOSIUM—*"Modern Computation Methods"*

"Computers and the Engineer"

J. C. Kaskie, Monsanto Chemical Company, Texas City, Texas.

"Introduction of the Analog Computer"

E. A. Clarke, Jr., Humble Oil and Refining Company, Baytown, Texas.

"Digital Computed Calculations in Distillation"

S. H. Davis, The Rice Institute, Houston, Texas.

"Effects of Vapor-Liquid Equilibria Values upon Distillation Calculations"

J. S. Bonner, Bonner and Moore, Associates, and E. L. Ekholm, The Pace Co., Houston.

SYMPOSIUM—*"Use of Statistics in Research and Production"*

"Using Statistical Methods to Define the Problem"

T. L. Rapp, Union Carbide Chemical Company, Texas City, Texas.

"Power of Statistically Designed Experiments and Results to be Expected"

R. A. Stewart, Shell Oil Company, Houston, Texas.

"Efficient and Economical Means of Determining Optimum Conditions—Through Experimentation"

H. F. Smith, E. I. DuPont de Nemours and Co., La Porte, Texas.

"Determining Optimum Conditions—Through Plant Operations"

P. W. Tidwell, Monsanto Chemical Co., Texas City, Texas.

General Session

"An Improved Absorption Refrigeration Cycle"
E. P. Whitlow and J. S. Swearingen, Southwest Research Institute, San Antonio.

"Improved Process for Fuel Products Deasphalting"
N. P. Peet, J. E. Lawson, J. P. Peet, Humble Oil & Refining Co., Baytown, Texas.

"Formation of Gas Bubbles at Submerged Orifices"
W. B. Hayes, III, and C. D. Holland, A. & M. College of Texas, College Station.

"The Solubility of Inert Gases in Water"
D. M. Himmelblau, The University of Texas, Austin, Texas.

Group Discussions

"Professionalism—What Does It Mean?"
Moderator: Dr. J. J. McKetta, The University of Texas, Austin, Texas.

"Present Trends and Planning For the Future in Engineering Curricula"
Moderator: Dr. W. W. Hagerty, The University of Texas, Austin, Texas.

Banquet

Awards—Best Technical Paper by a Section Member Published in 1957.

Address—Mr. J. A. Gooch, Attorney, Fort Worth, Texas.

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How human beings behave under pressure as representative of opposing groups will be studied by a University of Texas psychology professor. Dr. Robert R. Blake will use a $45,000 grant from the National Institute of Mental Health to make a three-year study of "Representational Behavior in Pressure Situations." Results of his research will have bearing on problems relating to international and military negotiations, labor and management brgiing, iterdepartmental relations in business or industry and in other areas where resolution of group disputes is sought through interactions of representatives. The study is also expected to contribute to theories of group and intergroup relations and representational behavior. Dr. Jane Srygley Mouton, social science research associate of the University's Psychological Research Foundation, will assist Dr. Blake as co-director of the project. Dr. Muzafer Sherif, Turkish-born psychology professor at the University of Oklahoma, will join the Texas faculty in September as a visiting professor and will serve the research project as consultant on systematic problems and experimental designs.

## Affairs of The Texas Academy of Science

The 62nd annual meeting of the Texas Academy of Science will be held at the Houston Medical Center, December 11–13. The headquarters hotel will be the Shamrock-Hilton.

Among special events announced by Dr. Robert C. Sherman of North Texas State College, executive vice president and program chairman, are:

1. A special conference on the health sciences for high school and college students.

2. A major banquet address by Dr. Theodore O. Yntema, vice president for finance, Ford Motor Co. He is an industrialist with a science background and a long-time interest in the education of scientists.

3. A symposium on the education of scientists featuring discussions by three nationally prominent scientists.

4. A special program for wives of Academy members provided by the committee on local arrangements.

The program will begin on Thursday morning, December 11, with an all-day meeting of the Texas Advisory Committee on Conservation Education. D. A. Anderson, head of the department of Research and Education, Texas Forest Service is to preside.

Two meetings are scheduled Thursday night. One is a joint meeting of the Board of Directors, Executive Council, and local arrangements committee. The other is the Board of Science Education, whose chairman is Dr. D. Bailey Calvin, Dean of Student and Curricular Affairs, University of Texas Medical Branch, Galveston.

The Academy is sponsoring the conference on the health sciences Thursday night as a special attraction for high school and college students. This will feature tours of the medical and dental schools, hospitals, and clinics in the Medical Center. Specialists in various areas will be available to explain their work to the students. In charge of the conference is Dr. James R. Schofield, assistant dean, Baylor Medical School, and chairman of the local arrangements committee.

Research papers will be presented at Senior Academy and Collegiate Academy sectional meetings all day Friday and Saturday morning. Members are asked to submit suggestions for papers to Dr. Sherman or to sectional vice presidents. These are:

Section 1, Physical Sciences: Dr. Gordon K. Teal, Texas Instruments, Inc., Dallas.

Section II, Biological Sciences: Dr. Howard L. Gravett, Department of Biology, Texas A. & M. College.

Section III, Social Sciences: Dr. Gordon V. Anderson, Testing and Guidance Bureau, University of Texas.

Section IV, Earth Sciences: Dr. Horace R. Blank, Department of Geology, Texas A. & M. College.

Section V, Conservation: Dr. Omer R. Sperry, Department of Range Management, Texas A. & M. College.

Collegiate Academy: Sister Joseph Marie Armer, Department of Biology, Incarnate Word College, San Antonio.

Sponsor for the Junior Academy sessions, which will meet Friday afternoon and Saturday is Dr. Wayne Taylor, Extension Division, University of Texas.

The Friday morning program will include the annual presidential address by Dr. Paul Witt. The banquet is scheduled that night with Dr. Yntema as the speaker.

Saturday morning the Senior Academy will hear the symposium on the education of scientists. The banquet address and the symposium are designed to attract the intrest not only of Academy members but of local scientific societies, Houston area scientists and engineers, and others with an interest in the problem.

Members will receive by November 1 blanks for making room reservations. The Shamrock-Hilton Hotel is making all the arrangements, which will include the offering of special rates there and the handling of reservation requests from members for all other hotels and motels.

## Instructions for Preparing Manuscripts for the Texas Journal of Science

Each author should check every item below before the final typing of his manuscript. These instructions are to save the editors much needless work and to avoid delay in the publication of articles in the Journal.

1. Manuscripts must be typewritten double-spaced, incuding titles, headings, literature citations, and legends for tables and figures. Underline only when italics are intended.

2. Literature citations must be in the form of recent papers in the Journal. As some science (Physical) differs from others (Biological) in their citation form, please follow the past papers in the same science as the paper to be submitted. Abbreviations should be at a minimum and standardized.

3. Carbon copies or originals on thin paper are not acceptable. Please use heavy paper.

4. Illustrations should be carefully prepared. Only sharp glossy protographs are usable. All drawings and graphs should be prepared in waterproof black ink on white paper or tracing cloth. Lettering should be made with the aid of lettering guides unless the draftsman is of unusual skill.

5. The author's name and scientific address should follow the title.

6. Many kinds of papers are considered for publication in the Journal. From an editorial standpoint they can be grouped into two generalized categories, original research and review papers. Original research papers should include the data on which conclusions are based. Review papers should cite references including the data on which the conclusions are based. Papers combining both of these categories should clearly show what is original data and what is based on other papers.

The final copy should be carefully checked for typing errors.

# THE TEXAS JOURNAL OF SCIENCE

Volume X, No. 3 September, 1958

## Cover Picture

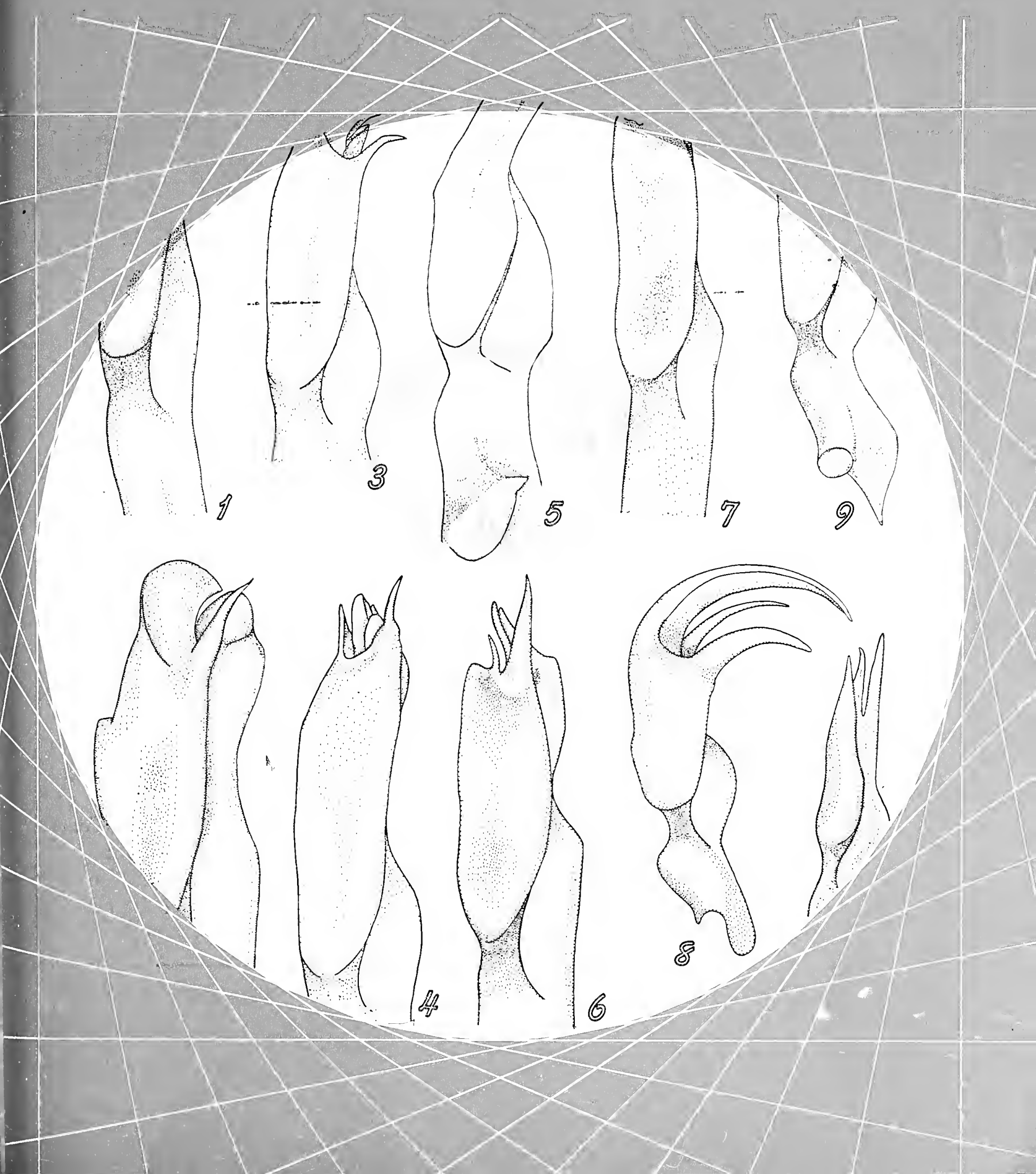
Movements of cricket frogs. The picture is extracted from the center of figure 4 of the article, "Size and Movements of a Local Population of Cricket Frogs *(Acris crepitans)* by William F. Pyburn. For further information on cricket frogs see this paper.

VOL. X, NO. 4 DECEMBER, 1958



# THE TEXAS JOURNAL OF SCIENCE

PUBLISHED QUARTERLY BY THE TEXAS ACADEMY OF SCIENCE



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## GENERAL INFORMATION

MEMBERSHIP. Any person engaged in scientific work or interested in the promotion of science is eligible for membership in The Texas Academy of Science. Dues for annual members are $5.00; sustaining members, $10.00; life members, at least $100.00 in one year; patrons, at least $500.00 in one payment. Dues should be sent to the secretary-treasurer.

TEXAS JOURNAL OF SCIENCE. The JOURNAL is a quarterly publication of The Texas Academy of Science and is sent to all members. Institutions may obtain the JOURNAL for $5.00 per year. Single copies may be purchased from the Editor for $1.25.

Manuscripts submitted for publication in the JOURNAL should be sent to the Editor, Box 7984, University Station, Austin, Texas.

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PUBLISHED QUARTERLY AT AUSTIN, TEXAS (ENTERED AS SECOND CLASS MATTER AT POST OFFICE, AUSTIN, TEXAS, MARCH 30, 1955.)

**Volume X, No. 4** **December, 1958**

# Solution to Some New Destructive Hot-Climate Condensation Problems in Building Wall Insulation[1]

*by* **W. R. WOOLRICH**

*The University of Texas*

The people of the United States have an historical buildup to construct all buildings with adequate facilities for heating the structure. This inertia of designing for warmth has become so much a part of our national way of life that even engineers, and architects of our Federal housing and building projects have been most reluctant to recognize the need to give consideration to cooling problems even in the hot-dry and the hot-humid climates.

Probably ninety per cent of the scientifically sound research that has been done on the heating, cooling and ventilating of the habitats of man both abroad and within the United States have considered him a refugee from cold. Yet two-thirds of the people of this world and one-fourth of the residents of the United States are refugees from heat, not cold, most months of each year.

With the advent of air cooling for homes and other buildings in our national life the industries that had established procedures for the installation of heating facilities and construction, whether they were producers of insulation, paint, building design or air conditioning equipment, discovered they must learn new facets of psychrometrics and psychrometric processes if they would survive in the new march in air conditioning progress.

The air cooling industry is today in the midst of a rapid transition. Suppliers of electrical power, of wall and ceiling insulation, of piping and ducts, of building designs, of control instruments, and even acoustic materials and house paints are encountering some baffling condensation conditions. Heavy financial losses have been sustained by men who were not sensitive to the principles involved in the application of these psychrometric processes.

Probably the one factor that has caused the most concern in this transition to combined cooling and heating of buildings has been that of condensation. The first national conference of the Building Research

[1] Paper prepared for Texas Academy of Science, Dallas, December 12, 13, and 14, 1957.

Advisory Board on Condensation Control in Buildings was held in Washington in February 1952. Subsequent sessions have been conveyed in a coordinated attempt of the entire building industry and related interests to meet the problems as they become aware of them. Each industry involved has come to a realization that they cannot excuse themselves by the continued incrimination of the other productive suppliers of the air conditioning industry involved in the construction of the complete home with its overall facilities installation. The responsibility for condensation control basically belongs to not just one group but must be faced by everyone contributing to a completed building designed for both heating and for comfort cooling.

To make this problem even more difficult than the design and construction of heating installations, the solution of cooling problems for the hot humid climates often differ greatly with those of the hot-dry climates. For example the solution of the cooling problems of Tucson, Arizona, require a different code book than might be used in New Orleans, Louisiana.

*Some New Problems of Condensation Control:* For several decades builders of insulated houses have been advised to install moisture infiltration barriers on the warm side of the building wall to prevent condensation forming within the insulation. In the case of designs of heating for homes and other buildings the warm side was next to the heated room wall. By contrast in the case of the cold storage room the moisture infiltration barrier was placed on the outside of the insulation next to the outer or warmer wall.

The reason given for placing the moisture barrier next to the heated rooms of the insulated home was that the rooms accumulated a high humidity from time to time due to excess moisture during washing, cooking, and partying periods and as the vapor pressure of this warm humid air pushes toward the cold side of the wall with its lower vapor pressure, the migratting air would chill below the dew point. Condensation would result, and this would saturate the insulation with moisture. For a cold storage room the process would be just reversed, especially in summer when the hot outside air, usually with a relatively high absolute humidity, moved inward to the cold room and it likewise would deposit its condensation within the insulation. Thus in each case, the recommended vapor infiltration barrier was placed next to the warm side of the wall.

With the advent of summer cooling of the same rooms that are to be heated in winter, new problems arose. If the owner of a building insisted on cooling his rooms below the dew point of the atmospheric air then he would be faced with the same problem as the cold storage room

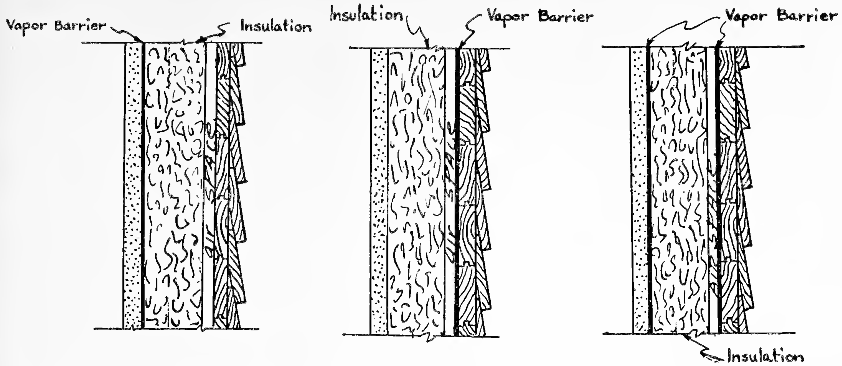


**Fig. 1. LEFT:** ***Insulating for Heating Only.*** **A vapor barrier on the inside of the wall is essential to prevent migration of moisture into insulation from occupied rooms. An additional ventilating air space is a supplementary precaution.**

**MIDDLE:** ***Insulating for Room Cooling Only.*** **A vapor barrier on the outside is essential to prevent migration of moisture into the insulation from the hot out-of-doors. An additional ventilating air space is a supplementary precaution.**

**RIGHT:** ***Insulating for Heating and for Refrigerated Cooling.*** **The modern all year round winter heated and summer cooled room in hot climates needs a vapor barrier on the outside as well as the inside of the wall. Again an additional ventilating air space will be helpful.**

designer and for the summer period his vapor barrier should be at the outer wall. Did this mean that air conditioned buildings should be insulated with vapor barriers on both the inner and outer walls?

*Some Solutions to this Problem:* For the hot-dry climates the most practical solution to prevent condensation is to maintain a room comfort temperature above the dew point of that region. For a climate to be classified as hot-dry, it must have over each 24 hour period a nearly constant wet bulb temperature while its dry bulb will move daily from a low in the morning near that of the wet bulb to some level from 20° to 40° F higher each afternoon. For some regions of the United States for several summer months the total change in wet bulb temperature night and day for those months will not exceed 6 to 10° F. Condensation will not be a summer problem in homes in these areas if the rooms are maintained not lower than 75 or 76 F db during these months. Yet as a case example, the author inspected a $150,000 new home in a hot dry climate coming under the conditions stated above except that the owner had maintained the rooms at 67 to 70 F db. The insulation was installed with the vapor barrier on the inside as if for heating, the panelled walls made up of special kiln dry lumber had been so tightly assembled that they not only buckled in every room but expanded with such force that the brick veneer outer walls were pushed apart with one to two inch gaps at the corners. The insulation in the outside walls adjoining the air cooled spaces was wet with condensation in each instance. The only walls of the mansion occupied less than six months that will not require rebuilding are those that have had the same temperature maintained on each side. The weather records of the past ten years indicate that if these rooms had been held not lower than 75 to 78 F db this home would have remained undamaged.

If a temperature below the dew point is to be maintained in a building or home in any climate then the wall treatment for condensation must be complex. All of the precautions that have been practiced for decades to prevent condensation in house heating must be added to a new list that has been applied for many years to the construction of cold storage rooms. Walls of a room cooled for comfort living to temperatures below the atmospheric dew point should receive treatment similar to that accorded the cold storage rooms.

*Ventilation to Control Condensation:* An uninsulated built-up wall is normally well ventilated and presents few condensation problems within the wall structure. However, if the surface temperature of a room is lower than the inside dew point temperature, condensation will occur and wet walls and ceilings will be the result. The most effective way to eliminate this difficulty is to ventilate the wall surface.

If a wall is to be insulated for both summer air cooling and winter heating, and if the summer cooling is held to a temperature below the atmospheric dew point, then a vapor barrier on both sides of the insulation is desirable.

The principal hazard of two vapor barriers will be the probability of air leakage through inferior barriers and the ultimate collection of moisture within the insulation between the barriers. The principal remedy for this condition is to provide some natural ventilation or chimney effect air movement upward through the insulation. While this will lower the overall insulating value of the insulation, it will be less detrimental than the accumulation of moisture in the insulation.

Should the designer plan on wood panelling within an air cooled room and has some question about the comfort temperature attitude of the resident, he should take the added precaution of specifying that all elements of the panel should be heavily primed on the back side with shellac or varnish before installation. The panel itself should be constructed to permit considerable swelling of the wooden elements without entailing warping due to excessive dimension increase. Even the cross bracing between studding that might become moisture saturated if the barriers fail should be installed at an angle to prevent the edges of the wall from pushing out at the corners.

In some regions, painting contractors are avoiding accepting contracts for both interior and exterior painting of insulated houses. This in itself is a challenge to the architectural engineer to make his moisture barrier specification adequate to protect the interior and exterior walls against moisture migration that might cause blisters and paint peeling at affected points.

*Radiant Cooled Spaces:* Radiant cooling of rooms is rapidly growing in popularity in some regions, as a counterpart to radiant heating. Many of the earlier installations on radiant cooling of rooms were troubled with excessive condensation on the radiant cooling elements and had to be re-designed. The most satisfactory solution has been to admit the make-up air to the space to be radiant cooled through a dehumidifying filter. This should reduce the dew point of the incoming air to a temperature low enough that it does not permit condensation on the surface of the cooling elements. This will require that all of the make-up air shall pass through the dehumidifier. It follows that for such installations the air to be radiant cooled should be maintained under positive pressure to prevent infiltration of air that has not been dehumidified.

*Intermittently Cooled Auditoriums and Churches:* Many auditoriums and churches operate with intermittent air cooling. The air is refrigerated for a few hours before and during a performance, meeting, mass or church service then cut off until another such occasion reequires it. Some unusual condensation patterns may result from a combination of circumstances including nocturnal radiation on the structure roof and internal radiant cooling of the ceiling from the floors, pews and walls during the period the air cooling is supplied.

A case recently examined by the author involved a structural breakdown of the fibres of acoustical tile in critical points of the ceiling although no difficulty was experienced on the side walls which were covered with the same acoustical treatment. The church was refrigerated from Saturday afternoon until noon on Sunday, then Sunday evening the windows were opened for natural ventilation. In this hot-humid climate the Monday morning following a clear night revealed heavy condensation on unventilated sections of the ceiling. The nocturnal radiation on the concrete and tile roof, the internal radiant cooling from below for the Sunday period gave the acoustical tile a resultant temperature below the dew point of the humid air and countless drops of moisture collected in the unventilated sections. This excess moisture surrounded the tile to weaken the supporting fibres and many of the acoustical tile dropped off by their own weight causing certain uneasiness to the worshippers in their pews.

*Sky Cooling:* Only in special cases will condensation in homes and other buildings be definitely traceable to sky cooling and these bona fide cases may occur on any clear night during the heating as well as the cooling season. There is, however, a current trend for some frustrated artisans working in the air conditioning field to attempt to explain unusual condensation phenomena encountered in the cooling of homes and other buildings to a mystical something they would like to interpret as "sky cooling." This discussion is advanced, therefore to give special recognition to condensation problems that are chargeable to sky cooling then proceed to explain some of the other new experiences in condensation incident to the introduction of air cooling into an ever expanding combination of structural and meteorological conditions created in commercial buildings and homes. Quite commonly phenomena other than sky cooling are found to be the responsible agents of excessive moisture troubles, when an engineering analysis of each suspected case is made.

*Nocturnal Sky Radiation:* Radiation from the higher layers of the atmosphere are affected by air temperature, humidity, cloudiness, and the variations in air impurities. Such radiation is operative both night and day, but in the daytime period the heat radiation from the sun is so much greater than the radiant cooling to the higher interstellar atmosphere layers that the radiant cooling is generally ignored.

The formation on a clear night on exposed horizontal surfaces on the earth of dew, and of even frost or ice when the ambient temperatures are several degrees above freezing is an accepted phenomena,

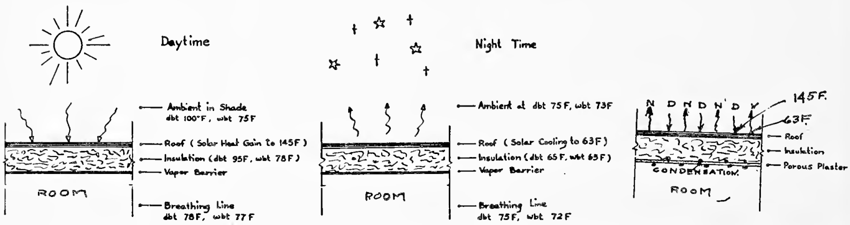


**Fig. 2. LEFT:** ***Daytime Solar Heating. Vapor Barrier Installed.*** **The insulation will remain dry even with highly humid air in the room below.**

**MIDDLE:** ***Night Time Solar Cooling. Vapor Barrier Installed.*** **With the barrier present no moisture migrates from the room to the insulation during the daytime, thus there is no condensation at night even though the cooling may go 8 or 10° F. below the wet bulb temperature.**

**RIGHT:** ***Complete Daytime-Night-Time Cycle with no Vapor Barrier.*** **When vapor barrier is omitted insulation absorbs humid air in the daytme through ceiling porous plaster or board, then this moisture condenses at night when solar cooling lowers temperatures in insulation to dew point to produce ceiling moisture stains or perhaps dripping of condensed water through ceiling into room. On cloudy nights there will be very little solar cooling.**

especially in dry climates. The Egyptians, centuries before Christ, successfully produced ice by a combination of night radiation and evaporative cooling of exposing water surfaces in open areas to fanned air at ambient temperatures of both the dry and the wet bulb well above 32° F. Since such ice was formed when neither the dry or wet bulb temperatures of the ambient air were at or below freezing, it is evident that the Egyptians were putting the phenomena of nocturnal sky radiation to practical use. Night radiation studies indicate that on clear nights temperatures ten to twenty degrees F. below the wet bulb temperature are common in dry climates. At Austin, Texas in the winter season we have repeatedly recorded atmospheric air dry bulb temperatures from 42 to 36 F, and wet bulb temperatures from 38 to 34 F but measured exposed horizontal black surfaces or ice films at actual surface temperatures of 32 to 28 F. The latittude of Austin, Texas and Alexandria, Egypt are approximately the same. H. W. Wexler shows that the surface of newly fallen snow may drop as much as 30° F below ambient air temperature by sky radiation.

Concrete slab roofs in the Southwest on clear nights often show condensation on the under side of the slab which forms a ceiling to an enclosed space of high humidity ambient air. This phenomenon does not exist on cloudy nights when the intervening clouds cut off the low temperature radiation between earth and sky.

G. V. Parmelee and W. W. Aubele report that the radiation received on a horizontal surface from a clear sky can be expressed by the formula

$R_h = R_b(0.55 + 0.33\ P_w)$ But/sq. ft./hr

Where

$R_h$ = energy received on a horizontal surface.

$R_b$ = radiation of a black surface at atmospheric temperature.

$P_w$ = water vapor pressure in inches of mercury at ground elevation.

Further studies are in progress in several areas of North America to establish the cooling capacity of the upper atmosphere by night radiation cooling.

The growers of fruits and vegetables are often successful in protecting their crops from frost damage on clear nights by cutting off the night sky radiation by artificial smoke clouds.

Designers have learned that condensation may take place on surfaces exposed to clear skies at night and where practical, they have provided necessary shielding or dissipated the condensation by ventilation.

Some case studies investigated by the author may give further in-sight into the nocturnal cooling process. A multi-storied building with a concrete slab roof that had been hot mopped on the top with black asphalt as an added moisture barrier was insulated beneath with two inches of fibrous material, then given a room ceiling of dense plaster ¾″ thick. The top floor of this building was used for culinary cooking. After a few weeks of building occupancy, the top floor leasee reported the dense plaster cracked in two areas and observed that after each clear night there would be a dripping between sunrise and 10:00 a.m. of about a half pint of water out of each crack.

The conclusion was reached that there was sufficient vapor pressure in the humid top floor room to saturate the fibrous insulation actually penetrating the dense plaster of the ceiling by its high vapor pressure during the working day then at night the condensation by nocturnal sky cooling would take place above this plaster. The solar heat on the following morning would revaporize this moisture and the initial first result was a pushing out of the plaster to crack it. After cracking of the plaster, the subsequent performance was aggravated by more moisture readily penetrating the insulation and passing up into the cracks each day. This was followed by the condensation on clear nights, with a sufficient vacuum effect by condensation of the vapor to hold it aloof above the plaster until the sun released it from this trap next morning. As the leasee had observed the half pints of water would descend on schedule each morning following a clear night.

One solution to this problem was to coat the black asphalt roof with an aluminum paint to reduce the emissivity, then increase the insulation beneath and finally use a vapor barrier seal for the complete ceiling treatment.

Case number two was a gymnasium and auditorium of a denomination supported University. The roof was a concrete arched reinforced slab treated with black asphalt above as an external moisture seal during rains. Beneath this arched roof the architects plans called for a horizontal sheet rock ceiling with acoustical treatment. This was designed to enclose the structural members from view and to make the auditorium more serviceable acoustically for entertainment.

The contractor completed the job according to specification but before final payment was completed by the University many moisture stains appeared on the sheet rock ceiling. He was advised that he could not receive final payment until he repaired the ceiling to the satisfaction of both the University and the architect.

This was definitely a case of nocturnal cooling of the space above the sheet rock which caused the condensation of the moisture that had infiltrated through the ceiling by vapor pressure during the previous day. Although the contractor was not the responsible party in this controversy, for public relations sake he repaired the ceiling with the agreement on the part of the owner that adequate ventilating fans would be installed to continuously eliminate the entrapped air above the ceiling and thus prevent further condensation.

In conclusion may I re-emphasize that one of the most puzzling problems confronting architects, engineers, paint contractors, insulation installers, acoustical specialists, equipment manufacturers, building contractors, and building financiers is what seems to many to be the unpredictable nature of condensation in building. It is not so unpredictable as it may seem but the many composite patterns of building design originating daily does lend a real challenge to the engineer, the physicist, the meteorologist, and the architect to reason out what will happen when unusual combinations of materials, climate, temperature and humidity demands are imposed upon the designer and builder. Most unusual buildings are still tailor made to suit some specific conditions and this continued trend with ever increasing complexities and personal whims superimposes upon this team of men of science and engineering a never ending challenge to find each answer before the structure and its equipment have been put together to make a useful and satisfactory home or building.

Architects, engineers, builders and suppliers might render a service to the buying public by cautioning them that a building designed for efficient heating may present new problems to the painter, the insulation installer, the acoustical specialist, the carpenter, and the equipment manufacturer when a complete air cooling system is added.

The problem of condensation which was of lesser importance a decade past, is now upon us in full force. It is an engineering problem that will continue in its importance since each building combination of materials and practices presents the possibilities of new complexities in their solution. This will take team work of the interested industries to reach workable solutions.

# The Thermal Decomposition of Inorganic Compounds. II. Metal Nitrates

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INTRODUCTION

This second paper on the thermal decomposition of inorganic compounds (Wendlandt, 1958a) is concerned with the pyrolysis of fifteen metal nitrates. Previous thermobalance studies have been made on the nitrates of the rare earth metals, uranium (VI), zirconium, and thorium (Wendlandt, 1956). Duval (1956) and Peltier and Duval (1948) have studied the thermal decomposition of the nitrates of copper and silver and also a mixture of copper and silver nitrates. A kinetic study of the thermal decomposition of ammonium nitrate (Guiochon and Jacque 1957) and sodium nitrate (Freeman, 1956) have also been reported. Non-thermobalance studies have been made on the thermal decomposition of the uranium (VI) nitrate hydrates (Bridge, *et al.*, 1956; King, *et al.*, 1957).

There are also many reports in the literature concerning the thermal decomposition of other metal nitrates and their hydrates. For example, the heating of $Pb(NO_3)_2$ is a commonly used laboratory preparation for $NO_2$ (Dodd and Robinson, 1954). However, in most cases, the exact temperature limits for the thermal decomposition process of the metal nitrates are not known. It is the purpose of this investigation to determine these temperature limits and also to study the intermediate products formed during the thermal decomposition process.

APPARATUS

An automatic recording thermobalance as previously described by Wendlandt (1958b) was employed. A linear heating rate of 5.4 degrees C. per minute was used, with a maximum furnace temperature limit of about 900° C. The samples were finely powdered and ranged from 70 to 95 mg. in weight. Duplicate, and in some cases, triplicate runs were made on all samples with a resultant agreement to each other of about 1%. A slow stream of air was passed through the furnace during the thermal decomposition run.

### CHEMICALS

The metal nitrates were obtained either in the anhydrous or hydrated forms from commercial sources. They were all of C.P. or reagent grade quality.

### RESULTS AND DISCUSSION

The thermograms of the metal nitrates are given in Figs. 1–3 with the thermal decomposition temperatures being given in Table 1. Each metal nitrate will be discussed individually.

*Lead nitrate* (Fig. 1/A). The anhydrous salt began to lose weight slowly at about 245° C. Evolution of oxides of nitrogen became very rapid about 370° C. to give a break in the curve at 435° C. The composition of the curve at this intermediate break corresponded approximately to basic lead nitrate, $Pb_2O(NO_3)_2$. The stability of this intermediate compound was rather limited since it decomposed rapidly to give the PbO level at 575° C.

*Thallium (I) nitrate* (Fig. 1/B). The salt began to lose a small amount of absorbed water at about 50° C. to give anhydrous $TlNO_3$ at 60° C. The anhydrous nitrate began to lose oxides of nitrogen at 265°

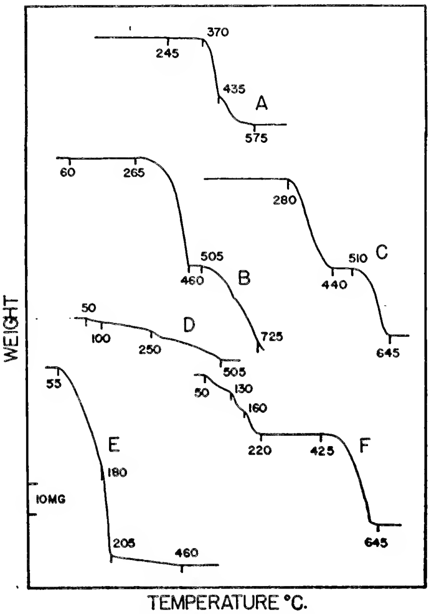


Fig. 1. Thermograms of Metal Nitrates.

A. $Pb(NO_3)_2$
B. $TlNO_3$
C. $Sr(NO_3)_2$
D. $BiONO_3 \cdot 1H_2O$
E. $Be(NO_3)_2 \cdot 4H_2O$
F. $Ca(NO_3)_2 \cdot 4H_2O$

C., about 60° above its normal melting point. A break in the curve and also a horizontal weight level were found from 460° to 505° C. From the composition data, this portion of the curve did not correspond to either of the oxides, $Tl_2O$ or $Tl_2O_3$. Thus, it must be concluded that the composition of the curve in this region is unknown. Further weight loss began at 505° C. with the curve being terminated at about 725° C. The unknown compound in the 460–505° C. region is apparently volatile or else decomposes into volatile products.

*Strontium nitrate* (Fig. 1/C). The anhydrous salt was stable up to 280° C. Above this temperature, there was a period of rapid weight loss, resulting in a break in the curve and then a horizontal weight level from 440° to 510° C. Again, as in the case of $TlNO_3$, the composition of the curve in this region is unknown since it did not correspond to $Sr(NO_2)_2$ nor to a basic nitrate. Further weight loss took place above 510° C. to give the SrO level at 645° C.

*Bismuth oxynitrate 1-hydrate* (Fig. 1/D). The salt began to lose water of hydration at 50° C. but a horizontal weight level corresponding to anhydrous $BiONO_3$ was not observed. Apparently, the salt began to lose oxides of nitrogen before the dehydration process was completed. The $Bi_2O_3$ level began at 505° C.

*Beryllium nitrate 4-hydrate* (Fig. 1/E). The salt began to lose water of hydration at 55° C. with total disruption of the salt taking place

TABLE 1

Thermal Decomposition and Minimum Oxide Level Temperatures for the Metal Nitrates. (Heating rate 5.4° C. per minute).

| Compound | Hydrate | Temperature, ° C. Anhydrous Salt | Oxide Level |
|---|---|---|---|
| $Be(NO_3)_2 \cdot 4H_2O$ | 55 | . . . | 460 |
| $Mg(NO_3)_2 \cdot 6H_2O$ | 60 | 310 | 455 |
| $Ca(NO_3)_2 \cdot 4H_2O$ | 50 | 425 | 645 |
| $Sr(NO_3)_2$ | . . | 280 | 645 |
| $Zn(NO_3)_2 \cdot 6H_2O$ | 40 | . . . | 390 |
| $Cd(NO_3)_2 \cdot 4H_2O$ | 50 | 280 | 435 |
| $Al(NO_3)_3 \cdot 9H_2O$ | 50 | . . . | 460 |
| $Fe(NO_3)_3 \cdot 9H_2O$ | 35 | . . . | 445 |
| $Cr(NO_3)_3 \cdot 9H_2O$ | 55 | . . . | 445 |
| $TlNO_3$ | . . | 265 | . . . |
| $CO(NO_3)_2 \cdot 6H_2O$ | 50 | . . . | 290 |
| $Ni(NO_3)_2 \cdot 6H_2O$ | 50 | 205 | 505 |
| $Cu(NO_3)_2 \cdot 3H_2O$ | 70 | . . . | 325 |
| $Pb(NO_3)_2$ | . . | 370 | 575 |
| $BiONO_3 \cdot H_2O$ | 50 | . . . | 505 |

between 55° and 205° C. The weight loss was much slower beyond 205° C., resulting in the BeO level at 460° C. At no region in the curve was there any evidence for the formation of the anhydrous nitrate.

*Calcium nitrate 4-hydrate* (Fig. 1/F). The salt began to lose water of hydration at 50° C. Breaks in the curve were observed at 130° and 160° C.; corresponding to the compounds, $Ca(NO_3)_2 \cdot 3H_2O$ and $Ca(NO_3)_2 \cdot 2H_2O$, respectively. This was one of the few nitrates studied which possessed hydrates of sufficiently stability so as to be detected in the curve. The anhydrous salt was stable from 220° to 425° C. Above 425° C., the salt lost oxides of nitrogen to give the CaO level at 645° C.

*Zinc nitrate 6-hydrate* (Fig. 2/A). The salt began to lose water of hydration at 40° C. A break in the curve was observed at 160° C. which indicated the transitory existence of anhydrous $Zn(NO_3)_2$. Further decomposition resulted in the ZnO level at 340° C.

*Magnesium nitrate 6-hydrate* (Fig. 2/B). The salt began to lose water of hydration at 60° C. Breaks in the curve were observed at 240° and 310° C.; corresponding to the compounds, $Mg(NO_3)_2 \cdot H_2O$ and $Mg(NO_3)_2$, respectively. The anhydrous salt lost oxides of nitrogen rapidly above 310° C., resulting in the MgO level at 455° C.

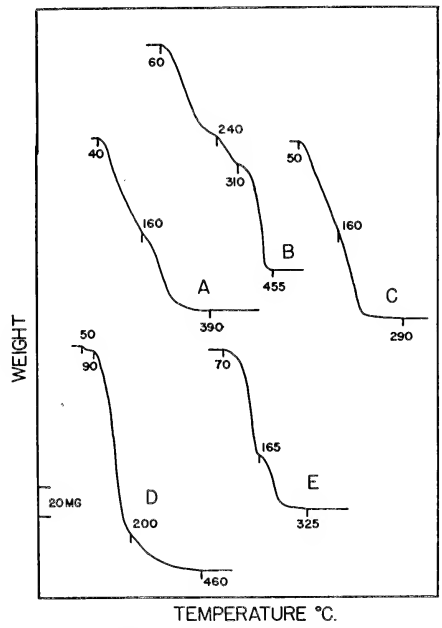


**Fig. 2. Thermograms of Metal Nitrates.**

A. $Zn(NO_3)_2 \cdot 6H_2O$
B. $Mg(NO_3)_2 \cdot 6H_2O$
C. $Co(NO_3)_2 \cdot 6H_2O$
D. $Al(NO_3)_3 \cdot 9H_2O$
E. $Cu(NO_3)_2 \cdot 3H_2O$

*Cobalt nitrate 6-hydrate* (Fig. 2/C). The hydrated salt began to lose water at 50° C. No intermediate breaks were observed in the curves. The $Co_3O_4$ level began at 290° C. The minimum oxide level temperature for cobalt nitrate was the lowest of all of the compounds studied in this investigation.

*Aluminum nitrate 9-hydrate* (Fig. 2/D). The salt began to lose water of hydration at 50° C. The weight loss was slow at first but became very rapid above 90° C. Total disruption of the salt then ensued to give the $Al_2O_3$ level at 460° C. There was no evidence for the formation of anhydrous $Al(NO_3)_3$.

*Copper nitrate 3-hydrate* (Fig. 2/E). The salt began to lose water of hydration at 70° C. After a region of rapid weight loss, a break in the curve was observed at 165° C. The composition of the curve in this region corresponded approximately to a basic nitrate, $Cu_2O(NO_3)_2$. This basic nitrate has previously been discovered by Peltier (1948). Further decomposition resulted in the formation of the CuO level at 325° C.

*Cadmium nitrate 4-hydrate* (Fig. 3/A). The salt began to lose water of hydration at 50° C. After rapid weight loss, the anhydrous $Cd(NO_3)_2$ level was observed from 220° to 280° C. Beyond 280° C. the anhydrous salt rapidly lost oxides of nitrogen to give the CdO level at 435° C.

*Iron (III) nitrate 9-hydrate* (Fig. 3/B). The salt began to lose water of hydration at 35° C. The thermal decomposition proceeded directly to the $Fe_2O_3$ level which began at 445° C. No intermediate hydrate or anhydrous salt levels were observed.

*Chromium (III) nitrate 9-hydrate* (Fig. 3/C). The salt began to lose water of hydration at 55° C. The weight loss was rapid up to 250° C. where a break was observed in the curve. The composition of the curve in this region is not known; it did not correspond to a basic nitrate. Further weight loss took place above 380° C., resulting in the $Cr_2O_3$ level at 445° C.

*Nickel nitrate 6-hydrate* (Fig. 3/D). The salt began to lose water of hydration at 50° C. After a period of rapid weight loss, a break in the curve was observed at 205° C. The composition of the curve in this region corresponded approximately to anhydrous $Ni(NO_3)_2$. Further rapid weight loss took place above 205° C., resulting in the NiO level at 505° C.

*General.* The thermal decomposition of the alkali metal nitrates was also attempted during this investigation. However, the fused nitrates attacked the platinum thermobalance pan so that the thermolysis curves obtained were not a true representation of the thermal decom-

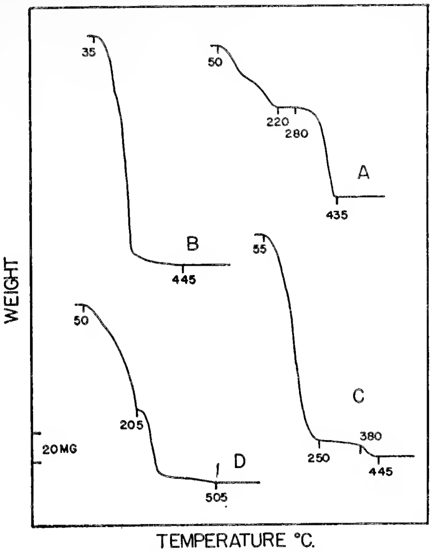


**Fig. 3. Thermograms of Metal Nitrates.**

A. $Cd(NO_3)_2 \cdot 4H_2O$
B. $Fe(NO_3)_3 \cdot 9H_2O$
C. $Cr(NO_3)_3 \cdot 9H_2O$
D. $Ni(NO_3)_2 \cdot 6H_2O$

position process. Thus, to include these compounds in this study would necessitate the use of a non-platinum boat or pan.

All of the hydrated metal nitrates began to lose water of hydration in the 35° to 70° C. temperature range. In the case of the alkaline earth metal nitrates, the anhydrous nitrates possessed sufficient stability so as to be detected in the thermogram. The transition metal nitrates, with the exception of nickel, decomposed directly to the corresponding metal oxides without the formation of intermediate compounds.

The anhydrous metal nitrates began to lose oxides of nitrogen in the 265° to 370° C. temperature range. It is presumed that $NO_2$ is the main decomposition product since the thermal decompositions were carried out in the presence of air.

In two cases, the existence of a basic nitrate was observed. Copper nitrate gave the intermediate, $Cu_2O(NO_3)_2$, previously discovered by Peltier (1948), while lead nitrate gave the intermediate, $Pb_2O(NO_3)_2$. The basic nitrates decomposed eventually to the corresponding metal oxides.

The metal oxide levels were obtained in the 290° to 645° C. temperature range. It is rather surprising that the $Co_3O_4$ level began at 290° C., the lowest found in this investigation.

SUMMARY

The thermal decomposition of fifteen metal nitrates was studied on the thermobalance. The exact temperature limits for the dehydration and decomposition to the corresponding metal oxides were determined. The hydrated salts began to lose water of hydration in the 35° to 70° C. temperature range, while the minimum oxide level temperatures were obtained from 290° to 645° C.

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# Recent Developments in Culture Change at Cochiti Pueblo, New Mexico[1]

*by* **CHARLES H. LANGE**

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The Indians of Cochiti Pueblo, New Mexico, have been the frequent subject of anthropological research. Bandelier, Dumarest, Lummis, and Starr worked there more than a half century ago; Benedict, Boas, Curtis, and Goldfrank gathered data there in the 1920's; and the writer has had contact with the Cochiti since 1946.

From 1946 to 1952, this contact was marked by annual field-work, ranging from a few days to three months of residence in the village. In the five-year period after 1952, contact with the Cochiti was minimal, being limited to sporadic and brief correspondence and second-hand accounts. In the late summer of 1957, however, it was possible to spend a few weeks in and near Cochiti Pueblo.[2]

The primary purpose of the 1957 research was to expand the long-term program of investigation from the fields of historical ethnography and contemporary community study to the archaeological phase of Cochiti culture history, in both its historic and prehistoric aspects.

The plan was to make stratigraphic tests at various sites on Mr. Young's Rancho de la Cañada which adjoins the north boundary of the Cochiti Reservation. During this testing, negotiations were to be conducted so that stratigraphic testing could be carried out within the confines of the present-day village of Cochiti (Figure 1). Past and continuing rapport with an appreciable number of the Cochiti councilmen made this appear quite possible; conversation with the governor soon after our arrival in the field made us optimistic. However, in a session of the full council, the influence of the cacique and the other medicinemen prevailed, and the request was denied. A chance to appear before the council to appeal this decision was deftly thwarted by the governor. Subsequent inquiry into these events, the council meet-

[1] An earlier version of this paper was read at the 56th annual meeting of the American Anthropological Association in Chicago, December 27–30, 1957.

[2] This research was made possible through the cooperation of the Graduate Council and Museum of Southern Illinois University, the Museum of New Mexico, and Mr. James Webb Young.

Fig. 1. Aerial photograph, from the west, of Cochiti Pueblo, March, 1947. Likely stratified deposits occur throughout the area surrounding the plaza—upper center of the picture. (Photo by T/Sgt. Claude E. Fullerton)

ing and associated happenings and relationships, was most revealing as to the nature of various stresses which are involved with culture change at Cochiti—for the most part comprising developments subsequent to our last visit to the pueblo in 1952.

The theocratically oriented political structure of Cochiti is currently under rather severe strain from internal factionalism. The Conservative-Progressive struggle which divided Cochiti with bitter controversies in the early decades of this century now appears to have lost much of its disruptive influence. In its place, a division seems to be growing within the conservative faction itself—resulting in a liberal-archconservative cleavage. The growing impetus from outside employment and more numerous sources of cash income are continuing to weaken the traditional social organization of the tribe in which the emphasis has been upon cooperative rather than competitive activities.

Ramification of these developments may be detected in a number of overt patterns; more significantly, their extension into aspects of the more covert value system is also discernible. Combinations of such factors as more education and military service have continued to foster greater interest in the outside, non-Indian world.

This awareness prepared the way, more than a decade ago, for services under the REA program. In turn, from modest beginnings, this innovation, in essence a Trojan horse, brought in various appliances—washing machines, refrigerators, radios, and, perhaps most influential of all, television (Figure 2). The effects of both programs and advertising, with ideas and concepts acquired both consciously and unconsciously, have been tremendous. While rigorously guarding against such threats as that posed by the request for permission to excavate for stratigraphic sequences in the pueblo dumps, the medicinemen and other archconservatives have come to accept innovations far more devastating insofar as their cultural heritage is concerned. Continual loss, replacement, modification, and innovation can be repeatedly observed in contemporary Cochiti life.

In an earlier analysis of the theocratic structure of Cochiti culture, it was noted that "By the end of 1952, there were only four active medicine men in the three societies." (Lange 1953: 684) Prior to this time, the Giant Medicine Society had consisted—for several years—of the headman and one other member. The elderly headman, although highly venerated, was blind and increasingly senile. The younger man, married to a Spanish-American woman, represented various personality contrasts in comparison with the headman and was a rather constant source of friction in the village. As in the case of at least two other societies with only one or two members each, the question had been asked of informants in 1951–52 as to what would happen in the event of a society's demise. Informants consistently refused to speculate on the question; however, in the interval between 1952 and 1957, it became possible to observe the events subsequent to the end of the Giant Society.

Some time prior to 1952, the younger Giant medicineman had taken a considerable quantity of society and other ritual paraphernalia from the village and had sold it on the west coast. From there it had been purchased by the Denver Art Museum, where, in time, it was discovered by the Cochiti and returned to them. Court proceedings resulted in a short jail sentence for the medicineman, and, more signifi-

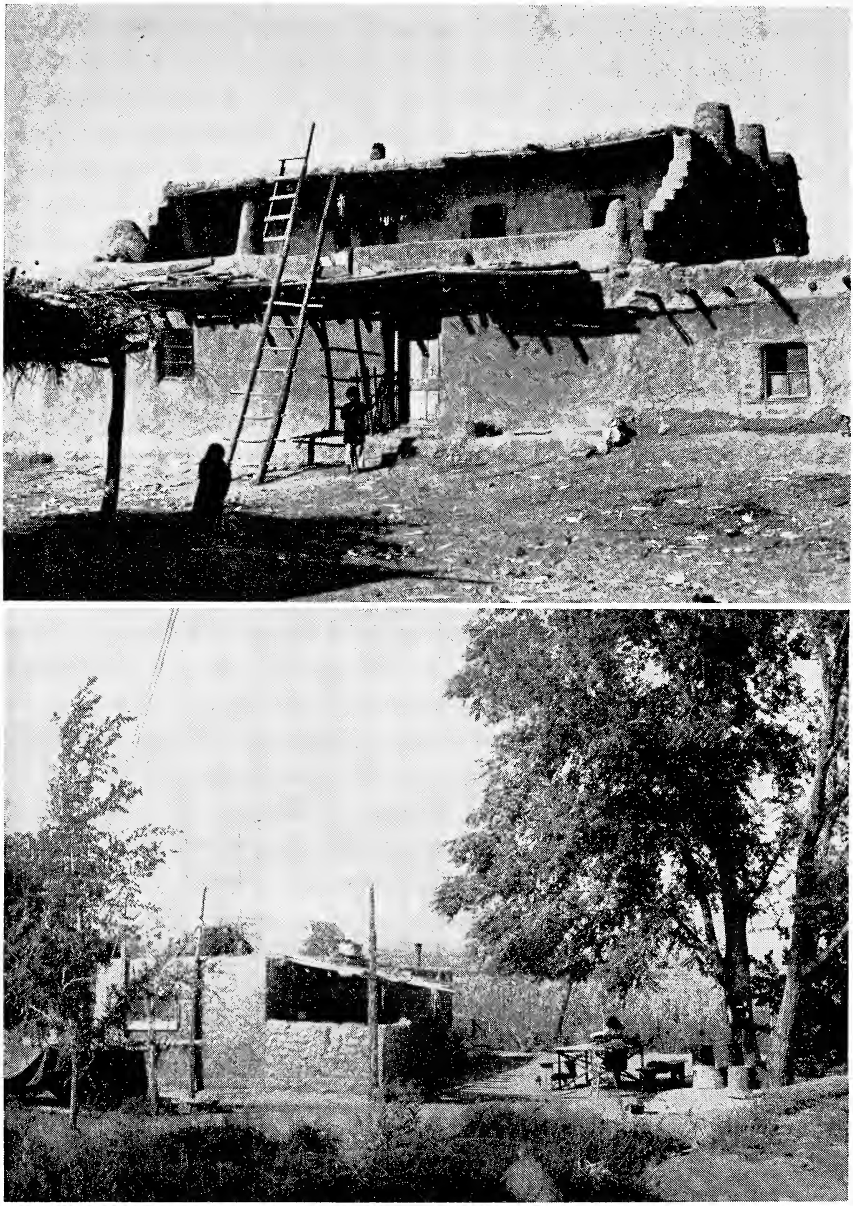

Fig 2. TOP: Former two-storied dwelling at Cochiti. While such multi-storied buildings virtually disappeared from the Cochiti scene in the last quarter-century, there were few other physical changes in the village prior to the introduction of electricity early in 1950. (Photo from the School of American Research, Museum of New Mexico, Santa Fe) BOTTOM: Cochiti ranch house, several miles from the pueblo, 1957. Formerly little more than crude, summer shelters, such buildings have become true summer residences with electricity, refrigerators, radios, television sets, and other appliances. (Photo by the author)

cantly from the cultural point of view, his voluntary request for lifelong banishment from the tribe was granted. These results, especially the banishment, appear to have satisfied the Cochiti though by this time, 1955, with the death of the headman, it meant the extinction of this society in Cochiti.

The traditional functions of medical practice and weather control, both contributing to the general welfare of the tribe, have in part been absorbed by the remaining medicine societies—the Flint and the Shī'kame—and have in part been lost to the Cochiti. The Giant Society's function of naming the governor and lieutenant-governor annually has also been taken over by the Flint and Shī'kame headmen; if either could claim greater influence here, it would be the Flint headman who also serves as cacique and is the person who names the war captain and his lieutenant each year.

Further suggestions of stress within the conservative faction of the tribe were seen in the fact that at the beginning of 1957 it was almost six weeks before a man could be persuaded to accept the governorship. Through the course of at least three centuries, the six major secular offices of the tribe have carried no tangible compensation despite demands on time and effort of the incumbents. Thus, they have never been actively sought; on the other hand, it was virtually without precedent for anyone to decline to serve if named by the medicinemen.

Elsewhere in the political structure, complaint was voiced that younger men, named as assistants to the major officers, were also unwilling to serve. If they found it impossible to escape such duties, they often intentionally neglected their duties so that they would not be chosen again. In other instances, they obtained employment away from the village—thereby leaving duties undone or overburdening the more conscientious ones who were reacting with increasing resentment at this turn of events. Punitive measures merely served to drive such persons, often with their families, from the village with further weakening of the social structure resulting.

The relative youth of the cacique and the Shī'kame headman would seem to indicate a continuation of the traditional theocracy for at least some decades to come. However, support among the conservative faction is diminishing. Aside from the steady attrition through death and the accompanying failure to gain members from among the younger people, an appreciable (and growing) number of the conservatives are voicing disapproval of the cacique's drunkenness and general corruption of the young people.

Thus, in addition to the progressive faction which many years ago ceased to respect the medicinemen in their official capacities, the behavior of the cacique has alienated support among the conservatives of those who find it increasingly difficult to follow the spiritual leadership of the cacique. Occasions of dissenting with him are gaining in frequency. Such attitudes could well bring an end to the cacique's powers before his actual death—assuming no effort to reform on his part. Other factors considered, it may prove difficult, if not impossible, to find a successor, or to secure support for a successor if one should be available.

It appears inevitable that the immediate future will bring further disintegration in Cochiti social structure. Ultimately, some form of tribal constitutional government may evolve to replace the present system. Already, younger men who have had some formal, advanced education, yet have never served as a major officer—the traditional prerequisite for council membership—are being called to consult with the council and, in effect, serve in the council. Similarly, recent years have seen members of the progressive faction, formerly banned for their hostile attitude toward the medicinemen, resuming roles as full-fledged council members.

Changes are occurring at an accelerating pace at Cochiti insofar as basic patterns and covert values are concerned. It is perhaps most regrettable that further disintegration, conflict, and bitterness must inevitably occur before a new system will become acceptable and progress can begin on a solid community foundation.

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# The Tawakoni-Yscani Village, 1760: A Study in Archeological Site Identification

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A number of Indian village sites have been discovered in Texas and adjacent areas which contain objects of European manufacture, certain proof that they were occupied during the period of European contact and settlement. Accounts of early missionaries, explorers, and traders frequently contain first-hand descriptions of Indian villages which they visited in Texas, yet only rarely has there been any effort to identify specific archeological sites with specific documented Indian villages.

Archeologists have attempted, with some success, to relate certain historic archeological complexes to known Indian tribes. The methodological approach of these investigations has consisted of delineating a specific area known to have been occupied by a particular tribe, then searching the area for archeological sites containing European trade items. If several historic sites are found, and if they all contain similar artifacts, a complex of traits is defined and named, and is then identified with the Indian tribe in question.

For example, Krieger has defined the Allen Focus (Suhm *et al.*, 1954: 219–221) and the Glendora Focus (Krieger, 1946: 210–212; Suhm *et al.*, 1954: 221–225), thought to represent the archeological remains of the Hasinai and Kadohadacho tribes respectively; Kelley has related historic components of the Bravo Valley Aspect of the Trans-Pecos area to various tribal groups (Kelley, 1952), the Toyah Focus to the Jumano Indians (Kelley, 1947b: 121), and the Austin Focus to the Tonkawa[1] (Kelley, 1947a); Campbell has hypothesized that the Rockport Focus on the Texas Coast is the archeological equivalent of the Karankawa tribe (Campbell, 1947: 71).

Despite the excellent beginning that has been made in historic archeology in Texas, there has been little if any effort on the part of archeologists to correlate specific sites with specific Indian villages reported in contemporary records. Identification of individual sites with

[1] An alternate proposal equates the Tonkawa with the Toyah Focus rather than with the Austin Focus (Suhm, 1957: 56).

ethnic groups would lend badly needed support to present archeological interpretations and hypotheses.

Several Texas historians have shown keen interest in determining the actual field locations of Indian villages and early Spanish settlements described in early documents. Herbert E. Bolton, the most active of this group, has tentatively identified the sites of a number of Spanish missions and presidios, as well as of several Indian villages (Bolton, 1906, 1914, 1915, 1949). All of Bolton's site identifications, however, were made prior to the development of scientific archeological research in Texas, and consequently he faced the serious handicap of having to work without the benefit of ordered archeological data and taxonomic units. As a result errors were made, such as his location of a Neches Indian village of the early 18th Century at an archeological site subsequently found to be entirely prehistoric in date and centuries too old for the Neches village (Newell and Krieger, 1949: 8).

In short, the problem of historic site identification in Texas has received the attention of historians and, to a lesser extent, archeologists as well. But the archeologists have worked almost entirely from archeological data while the historians' efforts have been based largely on documentary materials.

The evaluation of material data from historic sites is a highly specialized field of research requiring the services of archeologists experienced in historic site analysis and familiar with the archeology of Texas. Use of the documentary sources also requires the services of specialists. Those who would use such documents are hindered by the inaccessibility of these writings, now usually buried in dusty archives in Mexico or Spain. Most of these early records also present formidable problems of translation, composed as they often were by people of little education in an archaic script and style. Fortunately, since the turn of the century many of these documents have been copied in their original language and distributed to several of the leading North American universities where they are available for study.[2] Some of them have also been translated into English, though few of these translations have been published.

Thus accurate historic site determination in Texas depends upon two sets of data: (1) historical documents and (2) archeological finds.

One of the purposes, therefore, of this paper is to encourage the translation and regular publication of historical documents pertaining to the location of Indian villages and early Spanish settlements, so that they may be available in English for the easy use of historians,

[2] The Dunn, Cunningham, and other transcripts and archives at the University of Texas are very useful.

archeologists, and ethnologists. Most of these accounts are in the form of brief letters and official reports, and a single document usually requires no great amount of work in translation; if several individuals could work at translating and publishing them, one by one, in a few years a large body of data would be available for historical and archeological studies. The large amount of ethnographic data contained in the documents would also be welcomed by anthropologists.

It is emphasized that full translations should be published, not just investigators' summaries of original papers, since many mistakes in judgment and in interpretation have occurred in published condensations. This is not to say that the researcher or investigator may not give judgment, opinion, or summary, properly labeled as such, but that when he furnishes a translation of a particular work along with his observations the reader is provided with some means of checking the conclusions and opinions which are expressed.

In the hope of encouraging such a series of publications, the translations of two 18th Century Spanish documents are presented in the following pages, along with the comments and interpretations of the writers. These documents are (1) the journal of Friar Calahorra y Sanz of the Nacogdoches Mission describing his journey to a town of the Tawakoni and Yscani Indians in 1760, and (2) a letter from Calahorra to the Governor of the Province of Texas outlining the circumstances leading up to this trip.

Appreciation is due Dr. R. A. Haynes of the Department of Romance Languages of the University of Texas for freely-given aid in translating the often ambiguous and poorly composed letter and diary of Friar Calahorra. It has not been possible to render a verbatim or near literal translation of the account; an attempt has been made, as nearly as possible, to put the original thoughts and ideas into English idiom and form.

## HISTORICAL SETTING

The principal Indian groups to which Calahorra makes reference are various Wichita speaking tribes, the Hasinai Caddo, and the Apaches. The Tawakoni and Yscani, whom he visited, were members of the so-called "Wichita Confederacy," often referred to in early accounts as the *Norteños* or Nations of the North (*Naciones del Norte*). These Nations of the North—the Wichita Proper, Taovayas, Tawakoni, Yscani, Waco, and other minor groups (Douglas, 1932)—migrated southward, group by group, into northern central Texas from the upper Arkansas River, where they had lived near their kinsmen the Pawnee (Harper, 1953: 268). They settled on Red River and various streams in north-central Texas about the middle of the 18th Century.

The Hasinai Caddo, the allies of the *Norteños*, were a very strong group of tribes located along the Angelina River in East Texas which early came under Spanish influence and control. They had occupied the area for an unknown period of time, presumably since far back into the prehistoric period.

In western Texas lived the Lipan Apaches, and not far to the west in present-day New Mexico, their kinsmen the Mescaleros. It is most likely these groups which are referred to in the accounts of Calahorra. They were much more nomadic than the Wichita groups and depended primarily upon hunting and food-gathering for their sustenance.

In 1757 the Apaches in Texas requested that a religious establishment be provided for them, and Father Alonso Giraldo de Terreros subsequently helped found a mission for their use on the San Saba River (Dunn, 1914). A rumor spread among the Apaches, however, that the Nations of the North (the Taovayas, Tawakoni, and allied tribes) had joined together and were planning to destroy the mission. The Friars had great difficulty, therefore, in persuading the Apaches to settle there in any numbers. On March 16, 1758, the threatened attack came as an estimated 2,000 warriors under the leadership of a Comanche chief descended upon the mission and almost destroyed it.

In 1759, to save face and restore Spanish prestige, the commandant of the San Saba presidio, Colonel Parrilla, headed a punitive expedition to the Red River against the fortified Taovayas city near modern Spanish Fort, but was soundly defeated with the loss of two field pieces captured by the Indians (Allen, 1939).

After this disaster the Spaniards divided into two opposing camps with respect to the next course of action. Some, under the leadership of Colonel Parrilla, wanted the Apache mission to be continued and urged that the *Norteños* or Northern Tribes be subjugated. Others, led by Friar Calahorra of Nacogdoches, long-time friend of the Indians in that area, desired a peaceful settlement of the difficulties, partly because they believed the Northern Tribes too strong at that time to be easily overcome by military might.

In 1760, as the following letter of Friar Calahorra relates, the Tawakoni repeatedly came to him and asked forgiveness for their part in the raid on San Saba, begging for a restoration of peace. The Hasinai, who were close allies of the Tawakoni, interceded on their behalf with Friar Calahorra, and he agreed to make a trip to the Tawakoni village for the purpose of holding a peace conference. His journal contains an interesting but brief account of that visit and his subsequent recommendations to the Governor of Texas. Friar Calahorra made another journey to the Tawakoni village in 1761, but the letter in which he describes this subsequent visit is brief and of no particular value for history, archeology, or ethnography. As a result of the later visit, however, Calahorra recommended that the San Saba Mission be removed to the Tawakoni area to strengthen the Spanish position in northern Texas; but his advice was not followed. Very soon relations between Spain and the Northern Nations became worse, and attacks upon San Saba were vigorously renewed.

### LETTER TO THE GOVERNOR OF THE PROVINCE OF TEXAS, DON ANGEL DE MARTOS Y NAVARRETE, MAY 27, 1760:

"In the name of Jesus, Mary, and Joseph. My Dear Sir: The leading Taguacane [Tawakoni] Indians have been at this mission several times and have repeatedly made known to me, with the most expressive demonstrations of repentance, their strong wish to obtain peace, which they so much desire. They gave evidence of professing the most intimate friendship for the Spaniards. Not only these Indians, but the other tribes which took part in the barbarous offences against San Saba desire peace as well. These peace proposals, though they would lead to a happy conclusion of hostilities and are worthy of much attention, did not seem overly convincing to me, since I have had a great amount of experience with the fickle ways of Indians. I was all the more suspicious since the officials of the neighboring French garrison, don Athanasio de Misiere [Athanase de Mézières] and don Luis de San Denis [Louis de St. Denis], had arrived in this district with the permission of Your Lordship to inquire about the defamatory rumors which one of the Vydais [Bidais] had spread about the aforementioned San Denis, about which, however, not the slightest report has come to my notice before now. This unexpected arrival provided an excuse for the Indians of San Pedro Assinai, Nacogdoches, and Nazones (who probably know of the close friendship which our two nations profess for each other) to come together here and to use the aforementioned French gentlemen as go-betweens in asking me for peace. This they asked for with signs of profound humility in behalf of the previously mentioned Taguacanas, and for the other Indians to whom they are so closely allied. These aforementioned French lords could not help but interpose their influence; nor could I but assure the Indians that I would intercede with Your Lordship on their behalf. I cannot adequately describe the great rejoicing with which they received this promise, nor the obsequious acts of gratitude with which they immediately gave thanks to their mediators. Although I was surprised by everything, I was truly amazed to see the punctuality with which they returned some horses which they had stolen from me on various occasions, and also to see the resolution with which they obligated themselves, and those for whom they spoke [the Tawakoni], to hand over to Your Lordship in the future anyone who should offend in the slightest manner these missions or any Spaniards. These following conditions of peace, besides the above, were decided upon: that they would return the two cannons which had accompanied the expedition of Parrilla, and that they would never practice hostilities against any Apaches who were under Spanish protection and in their good graces. These were finally agreed upon, in the presence of the above-mentioned gentlemen, after a Taguacana chief had arrived, who had come here to the mission the other day. He was extremely pleased with these peace conditions and accepted all of them. He offered to come for me in one moon and to conduct me to the lands of his people so that this agreement would bear more fruit among the leaders of the village. I happily agreed to go, if God does not dispose otherwise. I present to Your Lordship this punctual account relating everything which has occurred here, so that you will condescend to use your effective power of mediation, so that these hapless Indians can obtain from his Excellency the Viceroy that peace which they long for with such passion. I have therefore informed you of all these happenings, knowing that you would consider the universal benefit which would result from them, primarily for these distant and isolated missions which suffer the most—since even in full view our cattle and horses are stolen. If this action is not taken by you some individuals may commit such acts against the Indians that they would become antagonized, and therefore it would cost us much blood and money to pacify them. In the meanwhile it would be a heroic gesture if Your Lordship should decide to take the precaution of having the presidios under your command suspend action against the Indians until such time as you issue orders concerning what they should do about this matter. This action would be the natural outcome of the discreet prudence which is so conspicuous in Your Lordship, whose life I ask God to guard in good health. From Misión de Nuestra Señora de Guadalupe de los Nacogdoches, the twenty-seventh day of May of 1760. Your humble chaplain kisses the hand of Your Lordship, whom he honors."

(signed) Fray Joseph de Calahorra y Sanz; (to) Señor Governador don Angel de Martos y Navarrete.

DIARY OF THE JOURNEY

"In fulfillment of my promise to the Taguacana Indians, made on the twenty-seventh day of May of this present year, I traveled to the city of this tribe. Provisions for this journey were made available by the Governor of the Province of Texas, don Angel de Martos y Navarrete. The sixteenth of September, accompanied by the *Alférez* of the Royal Presidio of the Adais—squad commander Antonio Gallardo, six soldiers, and five other inhabitants, I set out in the direction of the Asinais, who live some eight leagues from this Misión de los Nacogdoches. There we were forced to spend the following day as a result of the bad weather which came unexpectedly upon us. The seventeenth, accompanied by a group of the Tejas and other Indians which in all amounted to some one hundred persons, we continued on our course following the route to the north. After having traveled awhile, proceeding at a rapid gait, we crossed the Angelina River. The land along the river is well supplied with pines, oaks, sassafras, and walnut trees. We encamped for the night at a creek that from that day we called San Francisco Xavier, having traveled some ten leagues. The region around it has an abundance of water, pastures, lumber, and stone. On the eighteenth, following the same route, we traveled to the Netchas [Neches] River which lies some fourteen leagues from the aforementioned creek. The river in those parts is quite wide, and good year-round grass, many fish, and a great abundance of timber and stone can be found in and along its tributaries. Extensive reed growths were also discovered along them, and some admirable grapes and salt pans were encountered two leagues before reaching the river. The road there is good, although the land is hilly and covered at intervals with high ridges which allow one to see for great distances. On the nineteenth we departed from the above-mentioned river and were forced to travel toward the west because of the many turns in the road. After some three leagues, the road turned back toward the north, but it was narrow and difficult to travel upon as numerous little trees had grown up in it. After some fourteen leagues we arrived at a small intermittent creek around which walnut trees and oaks grew in profusion. This we named Santa Barbara. The twentieth we continued our journey in the same direction through these wooded hills, and after traveling four leagues we entered upon some vast, spacious prairies of excellent pasturage, though spotted with small, disformed trees. We continued through these prairies until we arrived at one of the two arms which forms the Río Salinas ["Saline"], where we spent the night. The entire distance traveled that day was twelve leagues. The stream was somewhat dry, but excellent watering places are provided by the pools in it, which support many spots of reed-cane. The passage there is rather incommodious because of the sand and stones that are in it. The day of the twenty-first, the day of the Apostol and Evangelist San Mateo Tectos, we pushed on towards the north through the prairies which were becoming more and more extensive since we had left the above-mentioned creek; we then met Indians that had come out to greet me. After traveling with them some four leagues farther, we entered the town of the Taguascanas, which lies some eleven leagues from the previously mentioned creek. When we entered the town, four chieftains who were awaiting me conducted us to some campaign tents which had been made ready for me and the entire retinue. A mob of Indian men, women, and children gathered and made peaceful signs to us in one accord, and with evident signs of great happiness. They banqueted us splendidly, and continued to do so for the entire eight days which it was necessary for me to detain myself there to receive the obsequious feasts with which they paid homage to me, and in order to give ample time for all the Taguasais [Taovayas] to come together. The aforementioned chiefs alternated in providing the feast, each one, in his own home, bearing all the expenses the day it fell his lot to give the meal. I returned these favors by distributing suitable gifts to these above-mentioned tribes, for which purpose I had been supplied by the Señor Governor. They seemed to be very grateful, and provided us with maize, pinole, and meat for our return trip. The town of the Taguacanas is so close to that of the Yscani that only a street separates them. These towns comprise forty-seven large houses, each with twelve families, and can muster two-hundred fifty warriors. They are governed by four chiefs, who are all brothers. The towns are located on a beautiful meadow at the other side of the other arm of the Sabinas [Sabine] River, and are beautifully arranged with both streets and gardens. Their pasture lands are abundant, are common property, and produce fine breeding horses. Their farm lands, which they prohibit other tribes from using, are black and firm, and are maintained perhaps at a distance of a league from the town. They are accustomed to plant at the proper season all together in one labor. They gather in great abundance their products of maize, beans, and pumpkins[3] and immediately divide them up into equal parts. They were constructing a fort or subterranean passage so they could defend themselves from the Spaniards or any other nation which was making war against them. This aforementioned creek, or arm, is not permanent, but has an abundance of water in pools; its banks are covered with oaks, walnut

[3] The word used in the Spanish is *calabazas*, which can mean "pumpkins," "squash," or any related plant.

trees, good cottonwood trees, nut trees, sassafras, and mesquite. The Taguais [Taovayas], who are those whom Colonel Parrilla fought against, are five days travel to the interior toward New Mexico. They have six hundred warriors and are located on prairie lands much like these, according to the account which the Taguacanas gave me. A chief [a Taovayas] arrived with twenty men and six women in order to greet me in peace in the name of all his people, and they attended to all my wants after some future conferences were agreed upon. They brought up the proposal to return the cannons which they had recovered in the previously mentioned campaign, and I arranged with them to soon make another visit the following summer for the greater strengthening of good feeling and good friendship. I will happily go there since they have promised to conduct me with safety in fifteen days travel to New Mexico, following this feat with a trip to another vast land bordering upon New Mexico, named after the Seauttos, or Apaches Pelones,[4] against whom they are now carrying on war.[5] This, *Señor Governador*, is the diary of my journey and the recounting of everything which has occurred and of all which was found. It is composed in an awkward hand and style, yet dedicated to the truth, to which all those who accompanied me are witnesses. Though I am well advanced in age, I am determined to fulfill the promise which I gave to the Taguacanes to return, though it should cost me my life (if God does not take it beforehand). I do this for the good which must necessarily result from this journey for this province, for Coahuila, and New Mexico, through establishing peace with the Apaches Pelones. This matter depends only upon your making available that which will be necessary for it. In this particular I rely on your well known zeal to the royal service to arrange for this trip, and at the same time I know that you will have the convenient foresight, which such an important and uncertain enterprise requires, to provide for the subjugation[6] of so many barbarians[7] which these vast lands contain, if funds are available for the necessary means.[8] Thus the great riches of

[4] *Pelones* is probably a derogatory term meaning "short-haired" or "hairless" which was originally applied by the early Spanish to various Indian groups north of the Valley of Mexico.

[5] The following year Calahorra did make another trip to the Tawakoni village, intending to go on to the Taovayas city and then to New Mexico, but bad health detained him at the Tawakoni village (Calahorra's letter to Martos y Navarrete, October 18, 1761).

[6] The term used in the Spanish is *la reducción* and may be translated either as "subjugation" or "conversion."

[7] Here Calahorra is most likely referring to the Apaches Pelones.

[8] The word used in the original is *los medios* which may be translated as "means" or sometimes as "troops."

these lands will be made secure for us in every way. I pray God to grant Your Lordship many years of life. Nacogdoches, October the twenty-fourth, 1760. Your humble chaplain kisses the hand of Your Lordship."

(signed) Fray Joseph de Calahorra y Sanz

### INTERPRETATION OF THE DOCUMENT: ETHNOGRAPHIC DATA

The French trader La Harpe visited nine related tribes on the Canadian River in Oklahoma in 1719, referring to the main tribe among them as the "Touacara" (Bolton in Hodge, 1910: 702). It is certain that this was the Tawakoni[9] of later times, since among the others which he listed were the Taoyas (Taovayas), Ousitas (Wichitas), and the Ascanis (Yscani), all definitely known to be close allies of the Tawakoni in later periods.

In 1752 De Soto Vermudez was told by the Nasoni Indians of the Hasinai Confederacy that the "Tebancanas" lived some twenty leagues northwest from the upper Angelina River (Bolton in Hodge, 1910: 702). It is quite possible that the village to which they referred was located on the Sabine River, but if so, it must have been considerably downstream from the village Calahorra visited in 1760 and 1761.

It is interesting to note that Calahorra found the Tawakoni and Yscani living so close together, yet maintaining their separate identities and distinct villages. Such close association is not surprising, however, since these groups spoke mutually intelligible dialects of the same Wichita language, and were members of the loose "Wichita Confederacy."

Evidence of the strong feeling of friendship between the Tawakoni-Yscani group and the Hasinai Caddos is provided in Fray Calahorra's diary, since the Hasinai interceded on behalf of the Tawakoni with Friar Calahorra at the Nacogdoches Mission. This state of friendship and alliance was due in part to the strong cultural and ethnic ties between the two groups, though the Hasinai and Wichita dialects, both of the Caddoan linguistic family, were not mutually intelligible and interpreters had to be used when the two groups communicated with each other (Bolton in Hodge, 1910: 703).

Calahorra related that the Tawakoni were governed by four chiefs, who were all brothers, but does not give any further details. It is

[9] The term *Ta-wá-ko-ni*, according to chief Niastor of that tribe, means "river bank among red sand hills," and was given to them when their village was on the Canadian River many years ago, after they had migrated down from the north (Niaster in Gatschet, 1891).

possible, however, that these were classificatory brothers instead of actual siblings.

The farming lands, said Calahorra, were located about one league from the settlement (though gardens were kept in the village) and such crops as maize, beans, and pumpkins (or squash) were produced, indicating a well-integrated horticultural economy in contrast to the hunting subsistence of the nearby Plains Indians. Furthermore, he noted that planting was done communally, as among the Hasinai (Griffith, 1954: 122), and that the fruits of the harvest were divided up among the people as soon as they were gathered.

Though Calahorra did not describe the houses of the village, he did mention that they were quite large, and it is therefore probable that they were of the usual Caddo-Wichita "beehive" construction. He specified, however, that he and his companions were conducted to some campaign tents *(tiendas de campaña)* when they arrived at the village. It is quite possible that he was here referring to tipis, which were frequently used by the Tawakoni on the hunt.

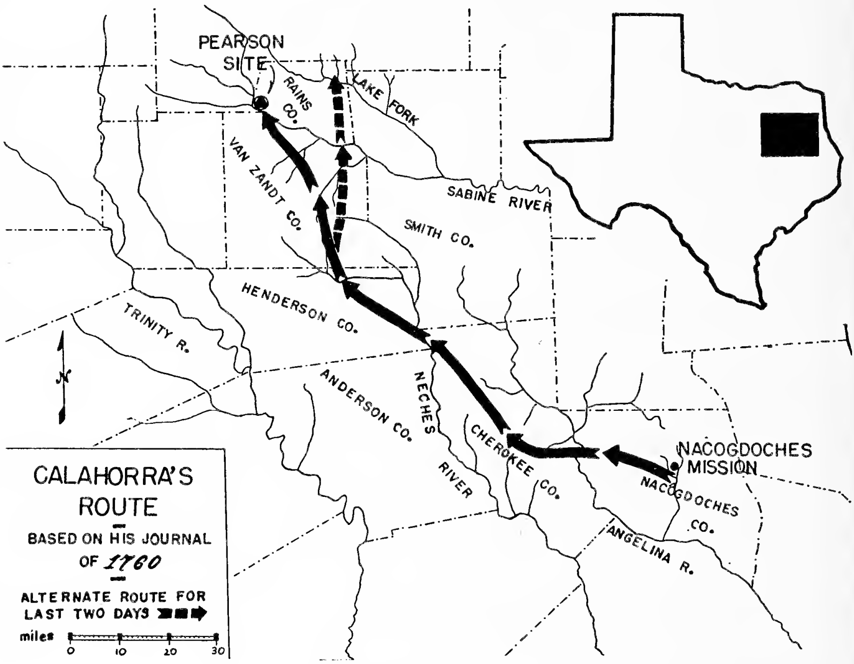
### CALAHORRA'S ROUTE

The following is an attempt to trace the route traversed by Calahorra's party in terms of modern geography. The dangers inherent in such an attempt should be obvious. These early travelers were frequently unfamiliar with the lands in which they found themselves, and quite often they had to rely on hearsay, and sometimes erroneous, information in recording place names, distances between localities, etc. Also, travel was done usually without the aid of compass; likewise the distances traversed could be estimated only approximately. From this it is apparent that it would be somewhat risky to sit down at a map and measure off the directions and indications presented by Calahorra in his journal without some interpretation and modification. For one thing, many explorers of the period expressed directions of travel only as cardinal compass points. Thus north meant not due north, as one might suppose, but rather a general northerly direction, which might be anywhere between northeast and northwest. Furthermore, the distances recorded are not air miles (or leagues), but rather distances of travel *via* winding roads and paths. For this reason we have seen fit to cut Calahorra's estimates of distances by approximately one-third,[10] so that they will correspond more nearly to straight line distances measurable on a map. The Spanish land league of this period,

[10] This figure was decided upon by comparing the actual distances between known locations with the estimated distances given in several travel journals of the 18th Century, describing travel through East and South-central Texas.

which Calahorra used, is equivalent to 2.63 English miles, or 4.24 kilometers.

As a general rule, Calahorra's descriptions are comparatively full and accurate; only when he was in the region of the Sabine River, an area obviously entirely new to him, do his accounts become somewhat confused and ambiguous.




On September 16, 1760, the party set out from Misión de Nuestra Señora de Guadalupe de los Nacogdoches, near the present city of Nacogdoches, and traveled eight leagues (21 road miles, or about 16 air miles) to the land of the Hasinai. This would place them, at the day's end, somewhere in northwest Nacogdoches County east of the Angelina River, perhaps on, or south of, East Fork Creek.

Calahorra said that they were forced to spend the following day in the Hasinai area because of bad weather, but he then proceeded to say that they set out again on the seventeenth. It is obvious that he made an error here in his calendrical reckonings.

The 17th, according to the diary, the party traveled about ten leagues (26 road miles, about 18 air miles) and camped on a creek which they named San Francisco Xavier, having crossed the Angelina River during the day. This would indicate that the actual direction of travel was west of north, not due north, else the party would never have reached the Angelina River at all. They were now probably in northern Cherokee Country, possibly in the area between Rusk and Jacksonville.

On the 18th the party traveled to the Neches River, after having covered some fourteen leagues (36 miles, or approximately 25 air miles). This distance would place them on the river somewhere between the point of confluence of Killough Creek with the river on the south in Cherokee County, and Kickapoo Creek on the north in Henderson County. The description of the terrain along the Neches at this point fits very well with the actual topography (Tharp, 1926, Plate III) since Calahorra related that ". . . the land is hilly and covered at intervals with high ridges which allow one to see for great distances." For this day the direction of travel again had to be northwest instead of due north, or the party would have passed well to the east of the Neches.

On the 19th they left the river and went three leagues west (eight road miles, or about five and a half air miles) and then turned back to the north and traveled some 14 leagues (36 miles, or approximately 25.5 air miles) to a small intermittent stream which they named Santa Barbara, possibly part of the drainage system of present-day Kickapoo Creek. Allowing for the usual northwest inclination of their direction of travel, they were probably now somewhere near the county line between Henderson and Van Zandt Counties.

Up to this point the account is fairly clear and the route not too difficult to follow. Now, however, the picture becomes complicated. On the 20th the party continued in the same direction (which, as previously determined, was somewhat west of north) through the wooded hills, and came out onto prairie land after having traveled some four leagues (ten miles, or about seven air miles). This change in vegetation corresponds nicely with the flora of present day Van Zandt County, since forests and woods give way to rolling, grassy prairies in the western and northern parts of the county (Tharp, 1926, Plate III). Calahorra and his party continued on until they arrived at "one of the two arms which forms the Salinas River," having traveled 12 leagues the entire day (31 road miles, or approximately 22 air miles).

The next day, the 21st, the party pushed on for 11 leagues (28 road miles, or about 20 air miles) and arrived at the Tawakoni-Yscani village which was " . . . located on a beautiful meadow at the other side of the other arm of the Sabinas (Sabine) River."

Two different interpretations of the route followed after the 19th are possible, because of Calahorra's statement that the night of the

20th was spent on one of the two arms which form the Salinas River. If "Salinas" is a misspelling of "Sabinas," then the encampment of the 20th had to be on the main channel of the Sabine, and the Tawakoni-Yscani village itself could only have been on the Lake Fork of the Sabine, well to the north. The alternative possibility is that "Salinas" River is not a misspelling, but refers to one of the tributary streams flowing into the Sabine from the south. In that event the Tawakoni-Yscani village must have been on the main channel of the Sabine rather than on Lake Fork.

The former of these two possibilities has been proposed by Bolton (1915: 92), and while there is some chance that this route may be the correct one, there are nevertheless several objections which should not be overlooked. First, it has already been established that the general direction of travel for the trip was somewhat west of north, and Calahorra stated on the nineteenth that ". . . we continued our journey in the same direction." In order for the party to arrive at the Sabine proper, within the distance specified by Calahorra, it would have been necessary for them to veer considerably and head slightly east of north. Also, in the account of the next day's travel, Calahorra referred back to the "arm" of the Salinas but now employs the term *arroyo*, which means "creek." It would hardly have been proper to employ such a term in referring to the main body of the Sabine River at the point where Friar Calahorra would have crossed it. Finally, it is 11 miles between the main channel of the Sabine and Lake Fork in this vicinity, but Calahorra stated that the distance between the "Salinas" and the Indian village was 11 leagues or approximately 20 miles.[11]

The second possibility—that the village was located on the main stream of the Sabine—is perhaps more probable. This would place the village near the point where Hunt, Rains, and Van Zandt Counties come together, not far from the recently located archeological Pearson Site which will subsequently be discussed. If this possibility is correct, the night of the twentieth must have been spent on one of the large creeks flowing northwest into the Sabine, perhaps Crooked Creek or Grand Saline Creek, both of which have two main branches. Perhaps the name "Grand Saline" itself was derived from the Spanish "Salinas."

[11] Bolton (1915: 92) reported that Calahorra traveled four leagues on the twenty-first. But Calahorra stated that it was four leagues from the point where he met the welcoming Indians on to the village, and later said that the total distance traveled that day was eleven leagues.

### THE PEARSON SITE

In the spring of 1957, an archeological reconnaissance of the area to be affected by Iron Bridge Reservoir on the upper Sabine was undertaken by the National Park Service (Johnson, 1957). The purpose of the reconnaissance was to locate and evaluate any archeological sites in danger of destruction by the reservoir project, so that archeological data could be salvaged by excavation prior to inundation. The field reconnaissance party located a total of 22 archeological sites in the Iron Bridge area, one of which yielded artifacts of European manufacture. This site of the historic period is situated on the east bank of Hooker Creek and on the north floodplain of the Sabine at a distance of about 800 yards from the main stream channel. The archeological site was designated as the Pearson Site after the landowner. The survey report on the site states that "local informants have reported the presence of old trench works in times past in woods on a flat area to the east of Hooker Creek, although these works have been leveled within the last fifty years. At the present there is no surface evidence for the trenches. Likewise, several local inhabitants reported having found numerous firearms and firearm parts in the vicinity" (Johnson, 1957: 11, 12).

The spot where the trenches were reported was grown over when examined by the survey party in 1957, and consequently the surface of the ground was obscured by a mantle of leaves that prevented collection of artifacts from the surface. In a plowed field adjacent to the wooded area, however, a number of artifacts were recovered, including chipped stone implements, potsherds resembling somewhat the ceramics of the historic Womack Site on Red River (Suhm, *et al.*, 1954: 222), several glass beads of European manufacture, a lead musket ball, and many bits of rusted iron. Fragments of burned animal bone were also observed.

Thus the material found at the site seems to date from the historic period, and the topography of the site agrees with that of Calahorra's village. His description of the soils, vegetation, and fortifications also seem to match the Pearson Site.

Calahorra states that the Tawakoni-Yscani village was situated on a branch of the Sabine along whose banks were growing mesquite, cotton wood, oak, sassafras, and walnut trees. The Pearson Site is likewise located in an area where all of these trees are common on the bottom lands. The Pearson Site is in a blackland, prairie region, as was Calahorra's village. What is perhaps of greater importance is Calahorra's statement that earthworks or fortifications were under construction at the time of this visit, and also that local informants reported to the National Park Service survey party that conspicuous trenches had once been visible at the Pearson site before they were filled and leveled in the early part of this century so the land could be used for agriculture. Calahorra states, however, in his letter of October 18, 1761, to the Governor of Texas, that when he returned to the village he had the Indians destroy their fortifications. He said "... *(he) visto demolido el foso en que les hallè enttiendo el viage pasado para defenderse de los Españoles* (I have seen the Indians destroy the earthwork which they were working on, at the time of my last trip, to defend themselves from the Spaniards)." Even though they destroyed their fortifications, it is doubtful that the Indians obliterated all traces of the trenches.

Since the Nations of the North are the only Indians known to have erected earthwork defenses in Texas, these reported fortifications are of significance in identifying the site.[12]

An indisputable identification cannot be made on the basis of the presently known data, but the Pearson Site does satisfy the description in Calahorra's account of the Tawakoni-Yscani villages of 1760. The University of Texas plans to undertake excavation of the Pearson Site in the fall of 1958.

## SUMMARY

These documents and accounts of Friar Calahorra y Sanz have provided some rather interesting ethnographic and historic data, and have made possible the tentative identification of an important archeological site.

It has been our purpose here to show the use to which documentary sources can be put once they are translated and subjected to study. The ethnographic information given by Calahorra, though not abundant, can readily be combined and co-ordinated with other data when more documents have been studied. Also, the historic information herein provided can be used, it is hoped, by historians to good advantage. That documentary sources can aid archeological research is demonstrated by the fact that the information in Calahorra's journal has made possible the identification of the historic Pearson site with a particular Indian group of a definite period, the Tawakoni-Yscani village of the 1760's. It is hoped that similar information can be had from the publication of other documents, and that this field of research will receive the attention which it is due.

[12] The only other Indian earthworks of possible defensive nature are the curious, saucer-shaped depressions with earth heaped around the edges which have been excavated a few miles northeast of Dallas. They are associated with the prehistoric Wylie Focus, and their purpose is not known (Stephenson, 1952).

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# Archeological Remains From the Live Oak Point Site, Aransas County, Texas

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## INTRODUCTION

A number of archeological sites in the central part of the Texas coast have yielded remains of two cultures. One of these cultures, and the earlier of the two, is known as the Aransas Focus, which is characterized by flint spear or dart points, tools and ornaments mainly of shell and bone, and basketry containers (Campbell, 1947, 1952, 1956; Suhm *et al.*, 1954). The other is the Rockport Focus, which is distinguished by several types of pottery and a variety of small projectile points indicating use of the bow and arrow *(ibid.)*. Excavations at the Live Oak Point site have revealed the same two cultures in stratigraphic succession. In the archeological literature dealing with the Texas coast it is often stated that the Rockport Focus is mainly prehistoric in date but survived into historic times, that is, after occupation of Texas by Europeans (Campbell, 1952: 76; Suhm *et al.*, 1954: 119, 125, 127). No documented proof of this has ever been presented. Evidence from the Live Oak Point site clearly shows that the Rockport Focus continued to flourish after the arrival of Europeans, and it also strengthens the linkage of the Rockport Focus with the Karankawa Indians who occupied the central section of the Texas coast until the middle part of the nineteenth century.

## SITE LOCATION AND DESCRIPTION

The Live Oak Point site is located at the extreme northeastern tip of Live Oak Peninsula (Fig. 1), some six miles north of the town of Rockport, Aransas County, Texas. It overlooks Copano Pass, a body of water about two miles wide which separates Live Oak Peninsula from Lamar or St. Charles Peninsula and which also links Copano Bay with Aransas Bay. Today Texas State Highway No. 35 (Corpus Christi to Houston) crosses Copano Pass on a causeway, and the Live Oak Point site lies about 1,200 feet west of the southern end of this causeway.

Live Oak Peninsula lies in the Coastal Plain physiographic province (Fenneman, 1938) and in the Tamaulipan biotic province (Blair,

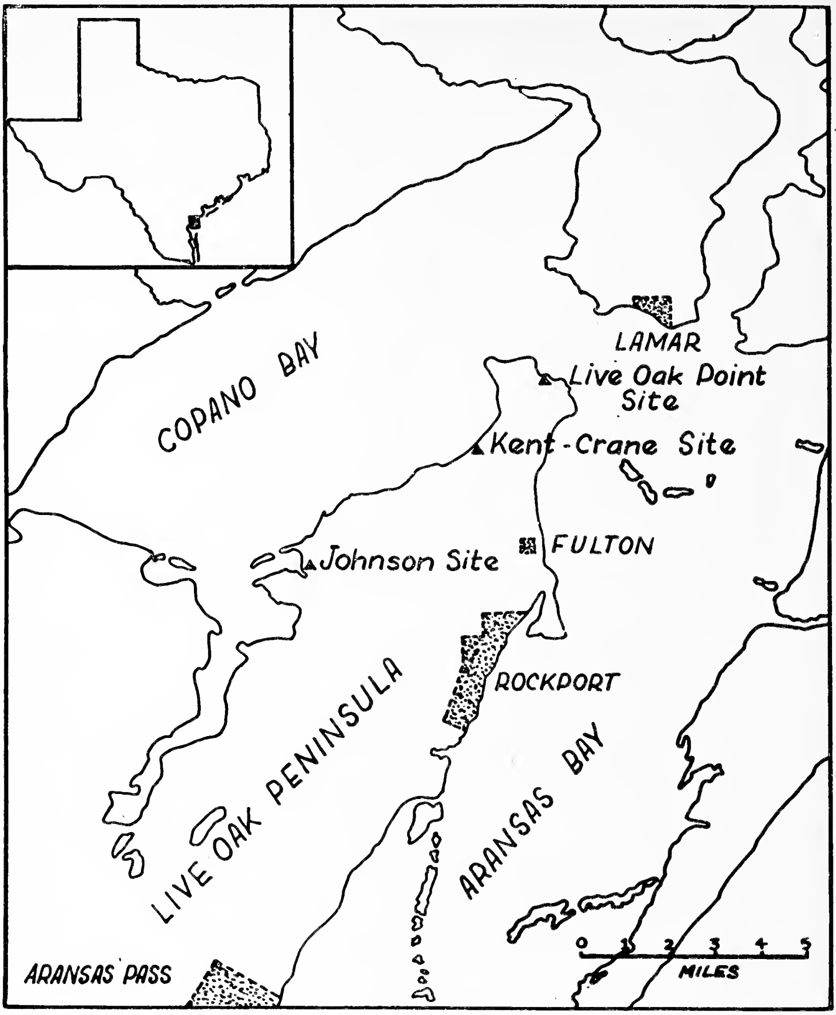


**Fig. 1. Map showing location of Live Oak Point Site and other sites on Live Oak Peninsula.**

1950). Its principal geographic characteristics have been previously described (Campbell, 1952) and will not be repeated here. On Live Oak Peninsula, some seven miles southwest of the Live Oak Point site, is the Johnson site, type site for the Aransas Focus (Campbell, 1947); and about three miles away in the same direction is the Kent-Crane site, which shows an Aransas component overlain by a component of the Rockport Focus (Campbell, 1952).

Martin and Potter visited the Live Oak Point site during their archeological survey of 1927–1929, and in the published report Martin (n.d.: 5, Site 40) describes its main features. It is a beach site lying on the sandy slope of a ridge that rises some 30 to 40 feet above mean sea level, and it extends along the shore for a distance of about 1,000 feet. It is lowest at the southeastern end and highest at the northwestern end. The beach sand rests on a yellowish clay (Beaumont formation), and at several points there are fresh-water seeps at the contact of the two strata. This may have been one factor leading to occupation of the site. At the time of excavation the surface of the site was thinly covered by grasses and weeds, and nearby, though farther inland, were small groves of live oak trees.

Martin reports that flint artifacts and potsherds have been collected from this site for over sixty years. Most of these materials have been collected from the surface of the sandy elevation at the northwestern end of the site, especially after periods of high winds that shift the sand and expose artifacts. Apparently this site has been slowly undergoing destruction by combined wind and wave action, for potsherds and flint flakes may be seen on the shallow bottom of Copano Pass along the shore at times of very low tide. Local people state that during the past fifty years hurricanes have removed some 100 feet from the peninsula at this locality. Possibly the greater part of the site has already been destroyed.

Either on this site or in its immediate vicinity various Anglo-American families lived during the nineteenth century. Huson (1935), a local historian, states that James Power, empresario of the Power and Hewitson Irish colony, built a two-story shell-concrete house on Live Oak Point in 1832 and lived there until his death in 1852. Martin mentions that the Dorothy family lived near the site during the early 1880's. W. Armstrong Price (personal communication, 1947) reports that about the year 1930 he saw a stone chimney still standing near the site. As will be seen later, recent European objects are common at this site, and many of them may be attributed to these Anglo-American residents.

## EXCAVATION

The Live Oak Point site was excavated by a University of Texas-Works Progress Administration expedition (Work Project No. 16770), under the direction of William A. Duffen, during the period of November 7 to December 31, 1940. Duffen's excavation was confined to the northwestern part of the site. Beginning near the high tide mark, a strip 300 feet wide was dug inland to the point of highest elevation in the site. This excavation was carried down to the surface of the clay layer. It soon became apparent that most of the cultural remains were no longer in place. They were scattered in elongated pockets in the upper five feet of the sand layer and consisted of a mixture of shells, animal bones, Indian and European objects. Wind action evidently had formed depressions in the sand; cultural materials had collected in these depressions and later had been covered again by shifting sands. In only one instance was an apparently undisturbed cultural deposit encountered, and this was at a level approximately two feet below the lowest occurrence of mixed Indian and European materials. Here a small deposit of shells, evidently representing a much earlier campsite, contained a few objects attributable to the Aransas Focus. This small find has considerable importance, because the cultural materials overlying it are definitely assignable to the Rockport Focus and to historic European occupation. Thus despite the disturbed condition of the major portion of the Live Oak Point site, it nevertheless yields a modicum of stratigraphic evidence confirming the earlier chronological placement of the Aransas Focus.

### EVIDENCES OF FOOD

From the Live Oak Point site a sample collection of shells and bones was made. The various life forms have been identified and give some indication of the diet of the occupants. Identifications were made at the Museum of Comparative Zoology, Harvard University, the shells jointly by William J. Clench and Richard W. Foster, the bones by T. E. White.

From the lower small shell deposit, which has been identified as belonging to the Aransas Focus, only shells were present. These include conch (*Busycon perversum* Say), Panama shell or Oliva (*Oliva sayana* Ravenel), and oyster (*Ostrea virginica* Gmelin).

From the mixed upper zone both shells and bones were collected, and the various life forms are presented in Table 1. Among the bones of the animals was one fragment of a bison femur showing strong, clean gash marks that appear to have been cut with a metal tool. This agrees with other evidence of the historic dating of the upper zone.

### ARTIFACTS FROM THE LOWER ZONE

In the small shell deposit isolated below the mixed Rockport-European layer were seven objects of shell. Five of these were made of conch shell, one of oyster, and a doubtful one of *Oliva*.

Among the conch shell objects is a small rectangular adz (Fig. 2, d) made from a section of body whorl. It is 4.5 cm. wide, 7.3 long, and has a cutting edge formed by a beveling on the concave face. The opposite or poll end bears part of the spire margin. There is also a

TABLE 1

Faunal Remains, Live Oak Point Site, Upper Zone

| Scientific Name | Common Name |
|---|---|
| *Shells* | |
| *Littorina irrorata* Say | Periwinkle |
| *Polinices duplicata* Say | Moon shell or shark-eye |
| *Pecten gibbus amplicostatus* Dall | Scallop |
| *Ostrea virginica* Gmelin | Common oyster |
| *Dinocardium robustum* Solander | Heart clam |
| *Venus campechiensis* Gmelin | Yucatan little-neck clam |
| *Bones* | |
| *Balistes* | Triggerfish |
| *Pogonias* | Drumfish |
| *Malaclemmys* | Turtle |
| *Amyda* | Soft-shell turtle |
| *Pseudemys* | Fresh-water turtle |
| *Chelonia* or *Carreta* | Marine turtle (very large) |
| *Geomys* | Pocket gopher |
| *Procyon* | Raccoon |
| *Canis* | Probably coyote |
| *Tayassu* | Peccary |
| *Odocoileus* | Deer |
| *Bison* | Bison |

small conch shell hammer (Fig. 2, b) formed by removal of the body whorl, leaving the columella and spire. The margin of the spire is heavily battered, and in the spire itself is a large hole with jagged edges, possibly the result of heavy hammering. The length of this percussion tool is 14 cm. A third object is what appears to be a conch shell container (Fig. 2, c). The greater part of the columella has been removed, and the anterior edge of the whorl shows some traces of grinding. This container has a length of 11.2 cm. and a maximum diameter of 10.5 cm. In addition to the preceding conch shell tools there are two worked sections of body whorl. One is triangular and resembles an adz in size and outline, but it bears no beveled cutting edge; instead the edges have been rounded off. The other body whorl section is longer and rather irregular in outline, having been damaged in places; the undamaged margins have been rounded.

One perforated oyster shell net weight (Campbell, 1958) is included in this small series of objects (Fig. 2, f). It has a large, almost circular hole at its highest point. This hole, which has an average diameter of 2.6 cm., has edges that are smoothly rounded, but this seems to be the result of weathering. The whole shell is well-rounded on all its margins. The last object in the series is an *Oliva* shell with

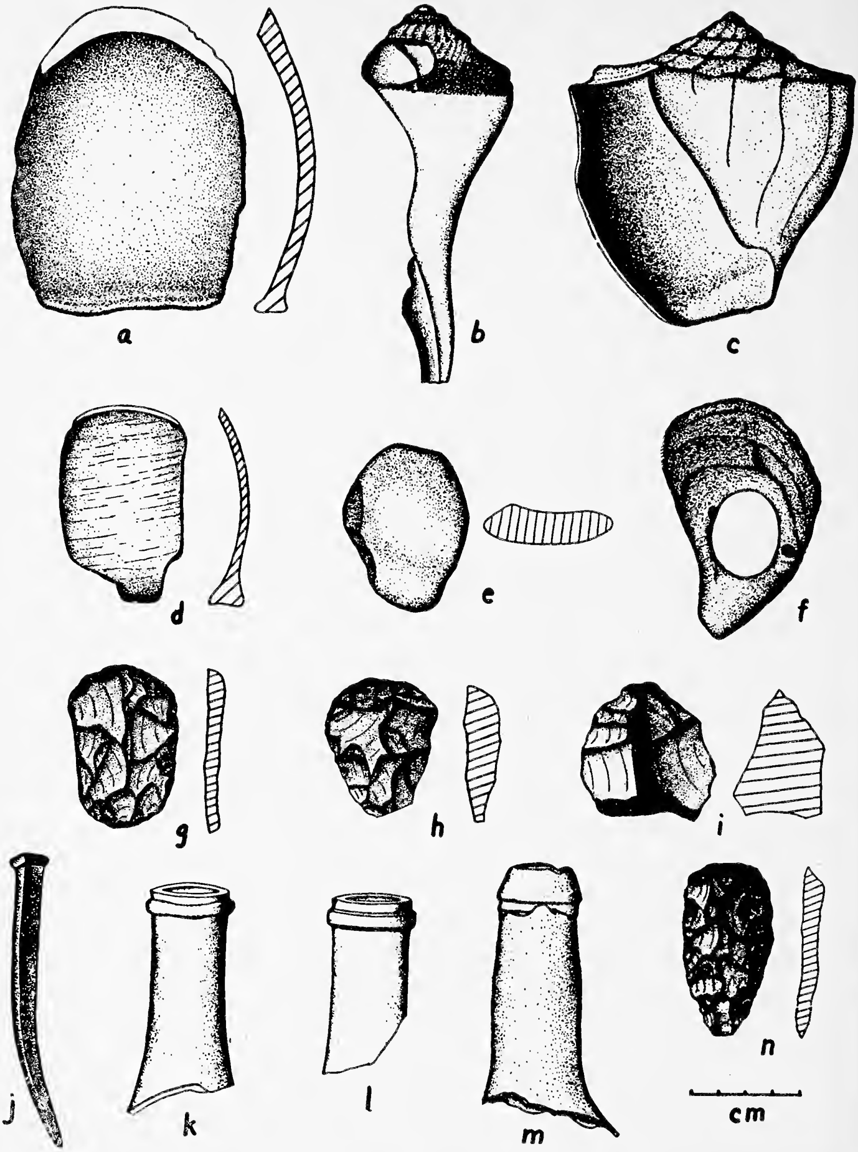


Fig. 2. Shell, stone, and European artifacts from Live Oak Point site. a, d, conch shell adzes; b, conch shell hammer; c, conch shell container; e, sandstone abrader; f, perforated oyster shell net weight; g-h, flint end-scrapers; i, flint chopper; j, brass or bronze nail; k-m, glass bottle necks; n, flint gouge. Provenience: lower zone, b-d, f; upper zone, a, e, g-n.

most of its spire removed. Because of its badly worn condition it is impossible to tell whether or not this was a bead formed by removal of the spire. The somewhat irregular nature of the margin suggests that the spire was probably removed by accidental fracture.

Although this sample is very small, it nevertheless contains three artifacts that are characteristic of Aransas Focus sites in this locality, namely, the conch shell adz, the conch shell hammer, and the perforated oyster shell net weight. Worked conch whorl fragments are also found in Aransas sites. Typical Rockport Focus traits are notably lacking in this series of artifacts from the lower zone.

### ARTIFACTS FROM THE UPPER ZONE

Objects from the upper mixed zone total 5,267 and include artifacts of stone, shell, and bone; lumps of asphaltum, some bearing basketry impressions; potsherds in considerable numbers; and various European objects of metal, glass, and china.

*Stone Objects.* Artifacts of stone from the Live Oak Point site include projectile points, scrapers, gouges, gravers, drills, knives, choppers, and abrading stones. Flint, chiefly in shades of gray and brown, was the material most commonly used for chipped stone artifacts, but green bottle glass was used in the manufacture of three projectile points.

Of the 38 projectile points recovered, all but three are small, their lengths ranging from 1.6 to 3.3 cm., and it may be assumed that they are elements of the bow and arrow complex. These small points are made chiefly from flint flakes by the pressure-flaking technique. About half of them have a plano-convex longitudinal section, one face being formed by the bulbar surface of the original flake, and the only chipping present on this surface is a light marginal retouch. A tendency toward serrated blade edges is observable, but this serration is rarely even and regular on both edges of any one point. In the following pages all identifications of projectile point and pottery types are based on descriptions and illustrations published by Suhm, Krieger, and Jelks (1954).

Among these small projectile points the Fresno type is most common, being represented by 10 specimens (Fig. 3, a-b). These are short and fairly broad and have a straight or slightly concave base. One (Fig. 3, b) is made of green bottle glass, a clear indication that the Fresno point was made in historic as well as prehistoric times in the coastal area. The Young point is represented by five specimens (Fig. 3, c), each having a strongly convex base and a curved plano-convex longitudinal section. This confirms a previous report that

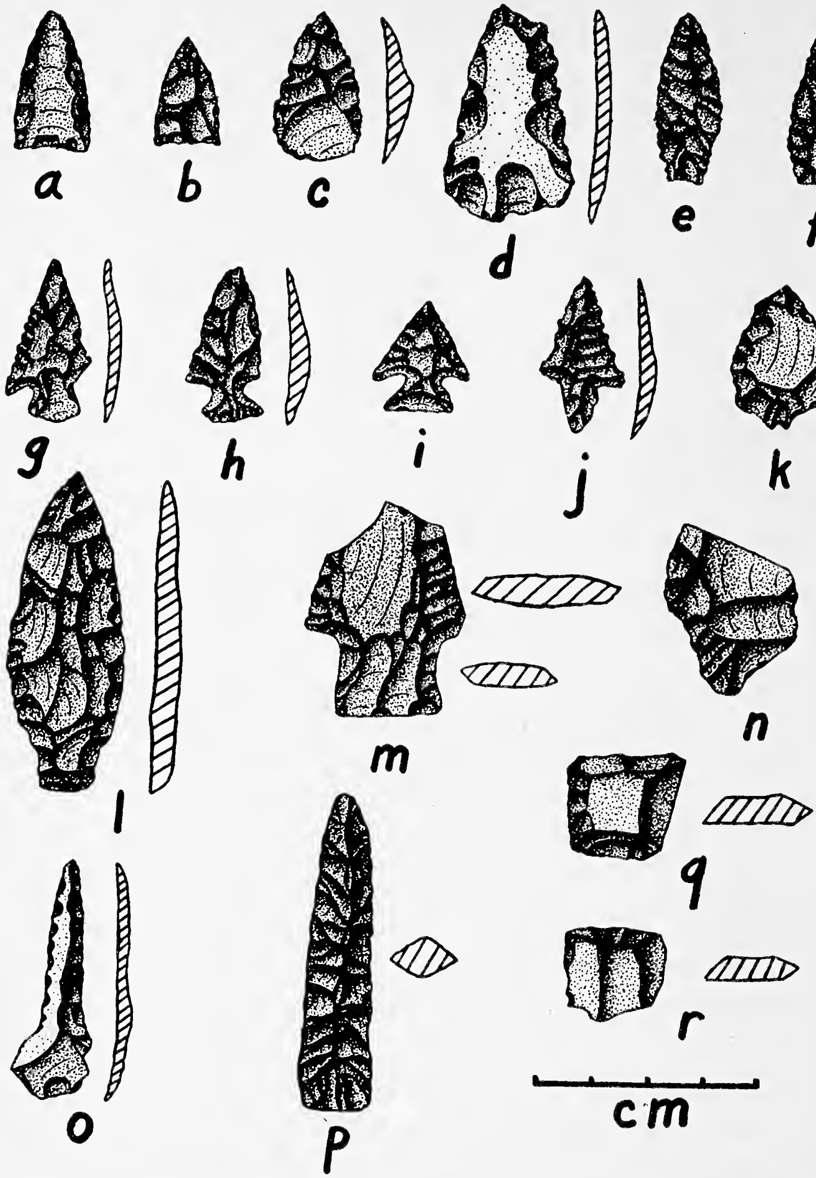


Fig. 3. Chipped flint and glass artifacts from Live Oak Point site. a-k, arrowpoints; l-n, dart points; o-p, drills; q-r, gunflints. Specimens b, d, and f are made of green bottle glass. Provenience: all from upper zone.

Young points occur in the Rockport Focus (Campbell, 1956: 27). The point in Fig. 3, d, is probably best classified as a Young point, but it is made from green bottle glass. It is rather crudely retouched along the margins of both faces, the flake scars being relatively large and irregular in pattern. A large part of both faces consists of unchipped areas that formed the smooth, slightly curved interior and exterior surfaces of the original bottle. Also fairly common is a lanceolate arrowpoint with straight or slightly concave base (Fig. 2, e-f). Six points are of this type, which has not yet received a name, and one of the six (Fig. 3, f) is made of glass. The remainder of the arrowpoints are stemmed: six are Perdiz points (Fig. 3, j), one is a Clifton point (Fig. 3, k), and six are Scallorn points (Fig. 3, g-i).

Three dart points were recovered from the upper mixed zone, and it is believed that these are derived from the earlier Aransas Focus occupation of the Live Oak Point site. One is a Nolan point with alternately beveled stem and blade (Fig. 3, m), another appears to be a fragment of a crudely made Gary point (Fig. 3, n), and the third is a lanceolate point of unknown type (Fig. 3, 1).

Only one object can be classified as a flint knife. It is roughly triangular in outline and is very crudely flaked, most of the flake scars being very large. Its length is 5.1 cm.

The 29 scrapers from this site can be divided into two groups, end-scrapers and side-scrapers, but the distinction is not always clear. The end-scrapers, three in number, are rectanguloid or trianguloid in outline, plano-convex in section, and have at least one steeply retouched edge. Two of these scrapers are relatively large (lengths 5.2 and 6.1 cm. respectively) and have one trait in common: the bulbar face of the original flake is completely covered with flake scars. The first of these (Fig. 2, g) is rectanguloid in outline and is steeply retouched at both ends. One lateral edge is also steeply retouched, but the other lateral edge is chipped evenly from both surfaces, giving a thin, sharp cutting edge. It is evidently a more generalized tool than the second one, which is trianguloid in outline and rather thick (Fig. 2, h). The third end-scraper (Fig. 4, b) differs from the preceding two in that the bulbar face shows no retouching whatever. It is long and narrow, and one end and an adjacent side are steeply retouched. Missing from the Live Oak Point site are the very small end-scrapers reported elsewhere in Rockport Focus components (Campbell, 1956: 12, 28).

The remainder of the scrapers (26 specimens) consists of side-scrapers made principally from long and relatively thin flint flakes which generally have a triangular cross section. The smallest is 1.2 cm. wide and 2.5 cm. long; thickness varies from 1.2 to 3.5 cm. These are retouched along one or both long edges. In 17 specimens the scraping edge is straight to slightly convex (Fig. 4, c-d); in the remaining nine the edges are slightly concave (Fig. 4, a).

One trianguloid tool of brownish gray flint is classified as a gouge (Fig. 2, n). It has practically all of the essential characteristics of the Clear Fork gouge, but it lacks the thickness usually found among the "classic" types described by Ray (1941). This specimen is 3.2 cm. wide, 6.4 long, and .7 thick. It was made from a relatively thin flake, and the bulbar face is covered with flake scars except near the center. Its most distinctive feature is best seen in longitudinal section (Fig. 2, n). This is the "cutting edge" located at the broad end, which is chipped in such a way that instead of forming a gently convex slope, as in an end-scraper, a slightly concave slope is formed. The lateral edges are rather poorly finished. As tools of this type have not yet been clearly associated with the Rockport Focus, it is likely that this particular specimen is derived from an earlier occupation at the Live Oak Point site.

Of the three drills included in the Live Oak Point series, one is long (5.8 cm.) and slender, lacks basal flare, and has a lozenge-shaped cross section (Fig. 3, p.). Its edges are worn and somewhat battered, apparently from heavy usage. The other drills are made from thin flakes (Fig. 3, o) and show the original flake curvature. An unretouched portion of the original flake remains as the "handle." The chipping on the long, slender distal portion is principally on the dorsal surface, the bulbar surface showing only a careless marginal retouch. Small, narrow bipointed flint drills, such as appear in other Rockport Focus components (Campbell, 1956: 15, 30), do not occur in the Live Oak Point series.

Four chipped flint flakes have small, beak-like projections that are unmistakable graver points. These gravers are made from small, rather thick flakes, and the graver point is located at one of the angles of a trianguloid flake (Fig. 4, e) or on one or both long sides of a blade-like flake (Fig. 14, f). The graver point is made by retouching the edge of the flake on both lateral edges of a projection. Flakes are removed from the dorsal surface, leaving a beak-like projection bordered by two slightly concave edges.

Three small, roughly flaked tools may be classified as choppers, for all have a broadly convex cutting edge at one end and a thick butt at the opposite end. One is a pebble with one end chipped to a crude cutting edge, most of the surface being formed by the cortex of the pebble. The two others (Fig. 2, i) show flake scars all over and may

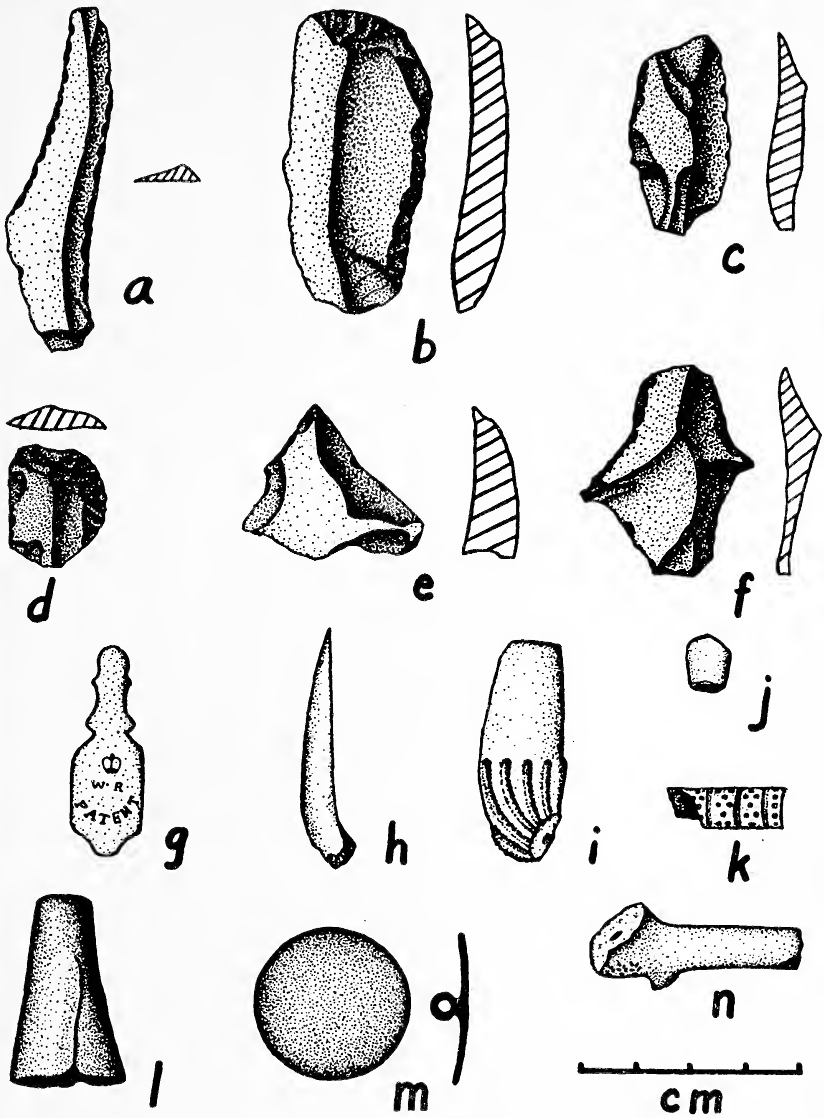


Fig. 4. Stone, bone, and European artifacts from the Live Oak Point site. a, c-d, side-scrapers b, end-scraper; e-f, gravers; g, gunstock plate; h, fish spine, possibly used as a perforator; i, k, n, fragments of white clay pipes; j, bone bead fragment (?); l, unidentified brass object; m, brass button. Provenience: all from upper zone.

be described as of core type. The largest chopper has the following dimensions: length 6, width 4.6, and thickness 3.8 cm.

Four abrading stones were found, two being pieces of sandstone and the remainder of pumice. One piece of sandstone is a small oval pebble (Fig. 2, e) bearing a shallow, elongated basin that seems to have been formed by wear. The other specimen is a rectangular sandstone fragment with one flat abraded surface, and on the opposed face is a long, shallow groove. The pumice fragments show no clear signs of use, although the larger of the two fragments (length 11 cm.) has the general form of an oval hand stone. The smaller specimen is very irregular in shape. Sandstone is found locally on the coast, and pumice may be collected from the beach, to which it is carried by wave action.

*Bone Objects.* Very few objects of bone are included in the Live Oak Point series. They consist of a short section of bird bone (Fig. 4, j) with unsmoothed ends, which may be an unfinished bead; three fish spines, one of which has a slight polish near the point, which suggests use as an awl but may be a natural characteristic (Fig. 4, h); an antler tine fragment; and a section of split mammal long bone with edges ground and polished. This last specimen is broken at both ends, so that its original form cannot be ascertained. It appears to have been some sort of awl, but the surviving portion has a length of 16.6 cm. and shows no indication of tapering toward a point at either end.

*Shell Objects.* Only one shell object was found in the upper zone, a large conch shell adz (Fig. 2, a). It is 8.4 cm. wide and 11.2 cm. long, and it has a strong bevel on the interior surface at one end. There is also slight evidence of grinding on the exterior surface of the cutting edge. The poll has part of the spire margin still attached. This shell adz is badly eroded and in general is very chalky and soft. It is considered to be a survival of Aransas Focus occupation at this site.

*Asphaltum.* This material was used for coating and decorating pottery vessels and possibly for cementing projectile points in their shaft sockets, although there is no direct evidence of the latter. Lumps of asphaltum were found scattered throughout the midden deposit, and in some places quantities were concentrated in small areas. Asphaltum was usually recovered in the form of pellets and lumps that appear to have been squeezed and then rolled between the palms of the hand while in a soft condition. These lumps vary in size from 1 to 6.5 cm. in maximum diameter. About 150 were collected and brought to the laboratory. Of special interest are ten pieces that have textile impressions, some clearly indicating twined basketry. Others show imprints of parallel grass elements. In one spot eight potsherds, including one rim sherd of Rockport Plain ware, were associated with a large mass of asphaltum. These sherds have the same color, surface treatment, and thickness and may be fragments of a single vessel that contained asphaltum. The interior surfaces of all of these sherds are heavily coated with asphaltum.

*Pottery.* Potsherds from the upper zone total 4,746 and can be identified as either Rockport Plain or Rockport Black-on-Gray. Some of the sherds show characteristics that have not previously been reported for these two pottery types.

Rockport Black-on-Gray is represented by 619 sherds, of which 220 are rim sherds and 399 are body sherds. The profiles of the rim sherds indicate bowls with straight or slightly outcurved rims and flat or rounded lips (Fig. 5, b, c, e-l, n, p); wide-mouthed jars with straight rims and flat lips (Fig. 5, m); and globular ollas without necks, all with flat lips (Fig. 5, d, q). Six sherds show a moderate amount of thickening below the lip (Fig. 5, i), and three have an angular projection on the exterior some 10 to 15 mm. below the lip (Fig. 5, j). Lip notching is rather common, 66 rim sherds showing this feature (Fig. 5, l-q). This varies from mere nicks to V-shaped notches 3 to 4 mm. in depth. Most of these notches appear to have been made by taking a sharp-edged implement and cutting the plastic vessel lip diagonally, first on one side and then on the other, removing a small triangular section of soft clay. Occasionally the rim sherds from these notched lip vessels have a small flange-like projection on the exterior of the lip (Fig. 5, n).

The decoration on Rockport Black-on-Gray rim sherds is invariably simple. The most common decoration, noted on 185 sherds, is a painted lip. This sometimes consists of painting the flat portion of the lip, so that the painting is not visible from the side; but more often the painting extends downward on both interior and exterior surfaces for some 2 to 3 mm. (Fig. 5, i, k). Sometimes the paint has run downward, forming tongue-like projections from this band. Thirty rim sherds have lines extending downward from a painted lip. These lines are usually thin and wavy and vertical (Fig. 5, a-b, d), but occasionally they are straight and diagonal (Fig. 5, f-g). A high percentage of this group of painted sherds shows an asphaltum-coated interior. Four sherds, only two of which are rim sherds, have punctation in addition to paintings as an element of decoration (Fig. 5, r-s). This punctation consists of lines formed by a succession of very small punctates. The punctates average about 1 mm. in diameter and appear to have been made by a very sharp-pointed implement, such as a thorn or a fish spine. In one instance the implement was pushed obliquely instead of

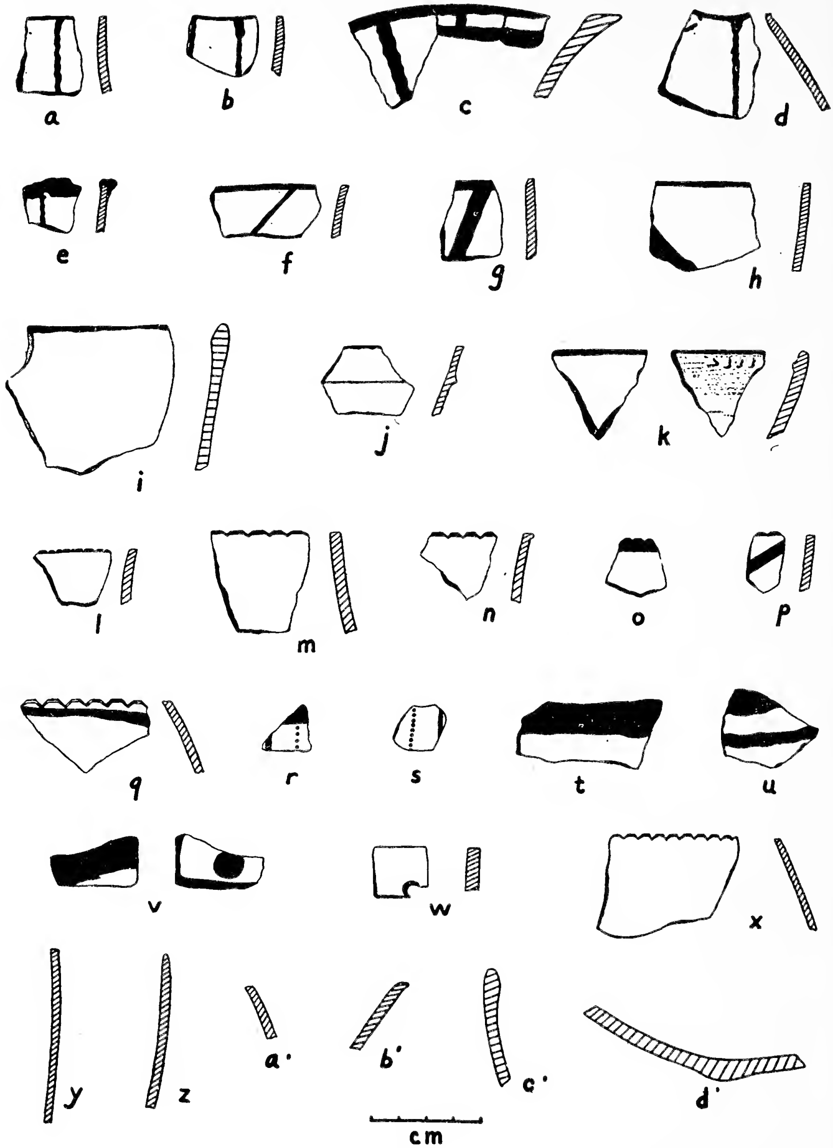


Fig. 5. Pottery fragments from Live Oak Point site. a-v, Rockport Black-on-Gray; w-c', Rockport Plain; d', profile of sherd from base of Rockport ware vessel. In all rim profiles the vessel interior is to the left. Provenience: all from upper zone.

straight into the plastic vessel wall. The lines of punctates alternate with vertical painted lines extending downward from the lip.

Among the body sherds in the Rockport Black-on-Gray group there is a little more variety in the designs. However, 252 sherds out of 399 in this group show one or more wavy lines on the exterior. A broad band type of design element is found on 117 sherds (Fig. 5, t), and in a few additional sherds this is supplemented by a vertical wavy line element. The remainder of the sherds show designs of a bolder sort, such as parallel bands (Fig. 5, u) or large dots (Fig. 5, v). A few sherds, evidently from bowls, have decorated interior surfaces (Fig. 5, u-v). In this large group of body sherds about two-thirds show an interior coating of asphaltum.

Eighty-one rim sherds of Rockport Plain (Fig. 5, w-c′) were collected, and quite a number of these appear to be from the same vessels. It is estimated that about 37 different vessels are represented. The forms are very similar to those of the Rockport Black-on-Gray series at this site, but most seem to be hemispherical bowls. A few pot forms are evident. Rims are straight for the most part (Fig. 5, y-z, b′), but thirteen are incurved (Fig. 5, a′). About two-thirds of the lips are flat, the remainder rounded. Sherds from nine different vessels have notched lips (Fig. 5, x), but only two sherds show any noticeable rim thickening (Fig. 5, c′). Sherds from seven different vessels show interior scoring. One rim sherd shows a crack-lacing hole near the lip (Fig. 5, w), but no sherds in this group exhibit any trace of asphaltum coating.

A very large number of body sherds cannot be identified as either Rockport Plain or Rockport Black-on-Gray. Probably most of these are actually from Rockport Plain vessels, but many undoubtedly represent the undecorated lower zones of Rockport Black-on-Gray vessels. This group of body sherds totals 4,033. Of this group 24% have an asphaltum coating on the interior, 9% on the interior, and 15% on both surfaces.

A small number of these body sherds have certain features of interest. Fourteen show that asphaltum was used for mending cracks, for this material covers one fractured edge, and in one instance a crack-lacing hole is adjacent to this edge. One sherd bears a portion of a round loop handle, indicating that some Rockport vessels have handles. Ten sherds show such small arcs that they must have come from very small-necked ollas or possibly bottles. Three sherds appear to have been used as whetstones; they have a high sand content, and their surfaces bear abraded grooves. Sixteen sherds show interior scoring. Finally, 13 fairly large sherds are from the central portions of vessel bases. All show that the original vessels had rounded bottoms, but nine of them show a slight swelling or boss at the lowest point of the base (Fig. 5, d′). The remains of four basal fragments show an extra thickening, but not enough to produce a perceptible boss. Three sherds in this basal group show an asphaltum coating on both interior and exterior surfaces.

In the Rockport ware from the Live Oak Point site a few features contrast with the same ware in Rockport components at other published sites, particularly Kent-Crane (Campbell, 1952: 74–75) and Indian and Webb islands south of Corpus Christi (Campbell, 1956: 16, 35–41). These include rim thickening just below the lip, more lip notching, less interior scoring, and complete absence of Rockport Incised pottery. These ceramic differences may be due to the chance factor in sampling, to local variation, or even to cultural change through time, for the Rockport component at the Live Oak Point site appears to be later than other known components. The answer to this problem must await further excavation in the area.

*European Objects.* Mention has already been made of arrowpoints made of green bottle glass. In addition 275 objects of European origin were mixed with those of Indian origin. These European materials consist of objects made of flint, iron, copper, brass, lead, glass, stoneware, and china.

Two gunflints were found, both of about the same size and having the same type of cross section, but they are made of two different kinds of flint. One (Fig. 3, q) is made of dark blue flint, and the other (Fig. 3, r) is made of a translucent tan flint. These kinds of flint are not duplicated among any of the other chipped stone artifacts from this site.

Twelve objects of badly rusted iron were obtained from the excavation. Seven of these are unidentificable fragments, but enough remains of the other five to permit identification of the original object. One is a hand-forged nail with rectangular shaft (length 5.8 cm.). Three are fragments of knife blades, one of which is complete enough to show that it had a two-edged dagger-like blade with a length of about 15 cm. and a maximum width of about 4.5 cm. The remaining two blade fragments are just distinct enough in outline to permit reasonably certain identification. The fifth iron object is a two-tined fork with parts of brads still present in the handle. Elsewhere in the site two bone handle coverings were found. These are plano-convex in section, and the convex surfaces are covered with cross-hatching. The width of these handle fragments is approximately the same as that of the fork handle, and it is likely that all three objects came from the same or closely similar types of implements.

Five metal objects are made either of copper or brass. One is a thin copper-plate sheathing from one side of a powder flask. It has the outline of the original flask, narrow at the top and bulging at the bottom. Judging from the dimensions of this metal sheathing, the flask must have been about 10 or 12 cm. long and 8 or 9 cm. wide. On this piece of copper is a scenic design in repousse, the center of interest being a long-haired dog seated under a small tree. Above this scene is a narrow band bearing the legend "P. F. D. F. Paris," with the D reversed, and above this is a panel of latticework and rosettes framed by small bosses at the top and three-lobed leaves on the sides. The metal in this specimen is dark brown in color and shows little patina.

Three other objects in this group are heavily coated with a green patina. One is a square, hand-forged nail (Fif. 2, j) which has an approximate length of 11 cm. Another is a cylindrical cover for the end of some sort of shaft (Fig. 4, 1); one end is mashed flat. A third object is a small plate (length 3.8 cm.) which evidently came from a gun stock (Fig. 4, g). It bears the legend "W. R. Patent" and has a small crown in outline just above these words. The fourth object is a button (diameter 2.65 cm.) with a loop or ring for attachment on the concave side (Fig. 4, m). The front surface may have had a design at one time, but it is now so eroded that no traces remain. Around the loop attached on the reverse side is a circular panel in which "21 Bouver" is faintly visible. The remainder of the lettering has been obliterated.

Seven musket balls of lead were found in the debris. Four of these are flattened or otherwise contorted, obviously from impact after being shot. Three still retain a roughly spherical form and vary in diameter from 6.5 to 15. mm.

Seven fragments of small European trade pipes of white clay are represented in the collection. All appear to be from similar elbow pipes with thin-walled bowls and a short cylindrical stem having a very small bore. These pipes were all made in molds. Measurements of fragments show a bowl with a height of about 4 cm. and a diameter of about 1.5 cm.; the stem is consistently between 7 and 8 mm. in diameter. The remains of these pipes include one bowl fragment with raised ridges at the base (Fig. 4, i); a stem fragment with a raised design of encircling lines and dots (Fig. 4, k); and five plain stem fragments, two of which bear spurs. One of the latter has a very small raised floral design between the spur and the base of the bowl (Fig. 4, n); this design may have continued up onto the bowl.

Six very small glass beads were recovered, four of them blue in color and two a milky white. The blue beads are smaller than the white and also differ from them in shape. The blue beads are like a doughnut in shape, the largest having a diameter of 6 mm., the smallest 3.55 mm. The white beads are spherical in form, have very tiny perforations, and fall between 5 and 6 mm. in diameter.

Projectile points chipped from glass have already been described, and there are six additional small, irregularly shaped green glass fragments that show chipping on their edges. This chipping varies from sporadic to fairly well retouched edges in one specimen, which may be a knife or a scraper. The others show attempts to work the transversely fractured edges down to a cutting edge, in most cases with scant success. The source of this chipped glass is to be found in discarded bottles, fragments of which occurred here and there throughout the jumbled midden deposit. The color, thickness, and curvature of arrowpoints made of glass match that of some of the bottle fragments. The remains of these bottles include 11 necks, one depressed conical bottom, and five sherds of varying sizes, all of blown glass. Nine of these bottle necks have either a rounded or angular collar attached near the lip (Fig. 2, k-l). Two others are of styles shown in Fig. 2, m. The glass in all of these bottles is green in color, varying from light to dark green. That with light green color has the iridescent patina of weathered translucent glass. Judging from the necks and bases, most of the bottles seem originally to have held wine.

Throughout the upper zone of debris at the Live Oak Point site were numerous sherds of china (150) and coarse stoneware (6). The china shows an extraordinary variety in color and design. Thirteen sherds are of interest because they show portions of potter's marks. Mr. Stanley C. Arthur of the Louisiana State Museum, New Orleans, has identified some of it as the product of Mayer, who was making china in Staffordshire, England, in 1784. Other sherds seem to have been made by E. and G. Phillips, who were manufacturers of china in Longport, Staffordshire, from 1822 to 1829. And one piece bears the mark of Henderson and Gaines of New Orleans, a firm which imported pottery and china around the year 1842. The available evidence would appear to date this china as mostly early 19th century, with some of it going back to the late 18th century.

In a site where Indian and European objects are so badly scrambled, it is difficult to determine just which European objects were used by the Indians and which were not. Without much question some of the bottles were used by the Indians as a source of material for chipping arrowpoints and cutting or scraping tools. Likewise there should be little argument about assigning the glass beads to the Indians. The objects associated with firearms (gunflints, powder flask cover, gun plate, and musket balls), the white clay pipes, some of the metal knives, and the brass button could have been used by either group. The square nails, cutlery, china and stoneware were probably used by Europeans only. This is especially true for the china, for records show that Anglo-American families lived at or near the site during the greater part of the 19th century.

## DISCUSSION AND CONCLUSIONS

The Live Oak Point is significant for a number of reasons. It shows cultural stratigraphy, a Rockport component overlying a small remnant of an Aransas Focus site. It provides a large sample of Rockport Focus materials, particularly pottery, and adds new data on Rockport culture traits. It also indicates Rockport occupation at a relatively late historic date, and the inclusion of certain European materials gives a rough impression of the amount of acculturation that had taken place.

The site at one time must have been very extensive. Its location adjacent to both Copano and Aransas bays, and also within easy reach of the mainland opposite, must have attracted human occupation over a long period of time. The present springs at the site suggest that in earlier times an easily available water supply may also have been an attraction. The attractiveness of this location is emphasized by its choice as an occupation site by the earliest Anglo-American settlers.

Unfortunately the evidence at this site is not always as clear as it might be because of extensive disturbance, both natural and human. This disturbance, however, did not succeed in disrupting the stratigraphic sequence completely. The isolated nature of the Aransas materials in the lower zone is clear-cut, and no Rockport materials are mixed with them. Likewise the Rockport materials in the upper zone are relatively free from admixture with Aransas type artifacts. The only important question raised by the disturbance is the relationship of the Rockport materials to the various European materials with which they are mixed. This is important in connection with attempts to assign a date to the Rockport occupation. Historical records and dates of the china fragments, which are almost certainly of Anglo-American origin, give a rough upper date level for Indian occupation. These indicate that the Rockport occupation was at least prior to 1830. The presence of a few European objects of obvious French manufacture suggest that French trade from Louisiana was in operation during the period of Rockport occupation at the Live Oak Point site. Since the French trade with Texas Indians is known to have been most active during the eighteenth century, the best date we can give for the Rockport occupation is from about A. D. 1700 to 1830. As the location of the Live Oak Point site is well within the area occupied by the Karankawa Indians at that time, we can attribute the Rockport occupation to these people.

The Rockport Focus component at the Live Oak Point site differs slightly from other known components. It lacks small end scrapers and small, narrow, bipointed drills, but has fairly large end-scrapers that are chipped on both faces. It has a lanceolate form of arrowpoint (one is made of glass) not previously reported, and it has Fresno and possibly Young points made of glass, indicating survival of these types into the historic period. Ceramic differences include rim thickening, more lip notching and less interior scoring than occurs elsewhere, and absence of incised pottery. Some of these differences may represent changes that occurred in the Rockport Focus during the historic period, but this will have to be demonstrated by further excavation.

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# A List of the Arthropods Found in the Stomachs of Whiptail Lizards From Four Stations in Southwestern Texas

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During the summers of 1951 and 1952, studies of the interrelationships of four species of whiptail lizards (genus *Cnemidophorus*) were made at three stations in southwestern Texas. These stations were: the Black Gap Wildlife Management Area, 60 miles southeast of Marathon, Brewster County; the Sierra Vieja range, 11 miles west of Valentine, Presidio County; and the La Mota Mountain region, 63 miles south of Marfa, Presidio County. The stomachs of the lizards collected during these studies along with the stomachs of lizards collected in the summer of 1949 at a fourth station (the Blackstone Ranch on the Stockton Plateau, 13 miles south of Sheffield, Terrell County) were examined to determine feeding preferences in relation to competition. Of the lizards examined, 1141 had stomachs which contained food. Arthropods constituted over 99% of the food items in both number and volume. The importance of the orders and higher groups of arthropods in the diets of the lizards and the foraging activities of the lizards have been previously reported (Milstead, 1957a, b). This report is a more specific list of the arthropods eaten and is, in effect, also a list of the predominate terrestrial arthropods which are diurnally active during the summer months on the Chihuahuan Desert.

I am indebted to a number of people for aiding in the identifications. Dr. W. J. Gertsch of the American Museum of Natural History identified all of the arachnoids. The late Dr. D. B. Casteel either identified or checked my identifications of all of the families of insects except the orthopterans and dipterans. Drs. O. P. Breland and M. R. Wheeler of the University of Texas and Dr. M. J. D. White of the University of Missouri aided him in this project. Dr. Wheeler identified all of the dipterans. Most of the orthopterans were identified by me through comparison with specimens in study collections which were made by me at the first three stations during the summers of 1951 and 1952. Dr. White identified the grasshoppers in the study collections and the additional ones which were found in the stomachs but not in the collections.

The list given below is a classification of the arthropods which were found in the stomachs of the species of *Cnemidophorus* collected at the four stations in southwestern Texas. The numbers which follow each arthropod or groups of arthropods in the classification indicate the stations and the species of *Cnemidophorus* in which the food organism was found. Roman numerals represent the stations: (I) Black Gap Wildlife Management Area, (II) Sierra Vieja, (III) La Mota Mountain, and (IV) Stockton Plateau. Arabic numerals represent the species of *Cnemidophorus*: (1) *C. perplexus*, (2) *C. sacki*, (3) *C. tessellatus*, and (4), *C. tigris*.

ARTHROPODA

INSECTA
Thysanura—I, 1, 4.
Collémbola—III, 3.
Orthoptera
  Acrídidae
    *Agroecotettix modestus*—I, all; II, 2; III, 4; IV, 2, 3.
    *Arphia aberrans*—II, 2.
    *Bootettix argentatus*—I, 2; II, 1; III, 4.
    *Cibolacris parviceps*—I, 1; III, 4.
    *Clematodes larrae*—I, 4; II, 1, 3.
    *Dactylotum bicolor*—II, 2.
    *Eremiacris virgata*—II, 1.
    *Melanoplus eumera*—II, 3.
    *Mermiria texana*—I, all; II, 2.
    *Phrynotettix robustus*—I, 4; II, 3; IV, 1, 2.
    *Psoloessa texana*—II, 1, 2.
    *Rehnita capito*—II, 1.
    *Trimerotropis citrina*—I, 4; IV, 1, 3.
    Unidentifiable—I and II, all; III, 3, 4; IV, all.
  Tettigonìidae
    *Eremopedes scudderi*—I, 4; II, 2, 3; III, 3, 4; IV, 2.
    *Pediodectes tinklami*—I, 2, 4; II, 1, 3; III, 3; IV, 2.
    Unidentifiable—II, 1, 2.
  Grýllidae—I, 4; II, 3; III, 3.
  Mántidae—I, 2; II, 1, 3; III, 4; IV, 2.
  Bláttidae—I, 2, 4; II, 2; III, 3, 4; IV, 2, 3.
  Unidentifiable—I and II, all; III, 2–4; IV, all.
Isoptera
  Termítidae
    ? *Amitermes sp.*—all species at all stations.
Anopleura—I, 4.
Hemiptera
  Reduvìidae—I, 2, 4; II, 4; III, 4; IV, 2.
  Lygaèidae—II, 1.
  Corèidae—I, 1.
  Unidentifiable—I, all; II, 1; IV, 2, 3.
Homoptera
  Cicàdidae—I, 1, 4; III, 3, 4.
  Cercópidae—I, 1, 4; II, all; III, 3, 4.
  Cicadéllidae—I, 1, 4; II, 1, 2; IV, 1.
  Fulgóridae—II, 1.
  Cóccidae—I, 4.
Neuroptera
  Myrmeleóntidae: larvae—I and II, all; III, 3, 4.
  Myrmeleóntidae: adults—I and II, all; III, 1, 3, 4; IV, all.
Coleoptera
  Cicindélidae—II, 1; IV, 2, 3.
  Carábidae—I and II, all; III, 3, 4; IV, 3.
  Elatéridae—I and II, all; III, 3, 4.
  Bupréstidae—I, 4; III, 3.
  Melòidae—I, 4.
  Tenebriónidae—I, 4; II, 2, 3; III, 3, 4.
  Trógidae—III, 3.
  Scarabaèidae—I, 2, 4; II, all; III, 3, 4; IV, all.
  Cerambýcidae—II, 1; IV, 2.
  Chrysomélidae—II, 1.

Curculiónidae—I and II, all; III, 3, 4; IV, 2, 3.
Unidentifiable—I and II, all; III, 1, 3, 4; IV, 2, 3.
Larvae—I and II, all; III, 3, 4; IV, 2, 3.
Lepidoptera
Larvae—I and II, all; III, 1, 3, 4; IV, all.
Pupae—I and II, all; III, 3, 4; IV, 2, 3.
Adults—I, 2, 4; II, all; III, 3, 4; IV, 2, 3.
Diptera
Bombylìidae—II, 3.
Asílidae—I, 2, 4; II, 1, 3; III, 3; IV, all.
Phóridae—II, 1.
Tachínidae—II, 1.
Sarcophágidae—II, 1.
Larvae—I, 4; II, 1; III, 3, 4; IV, 1.
Pupae—II, 1; III, 4.
Hymenoptera
Tenthredínidae—II, 1.
Mutíllidae—I, 4.
Formícidae—I and II, all; III, 3, 4; IV, all.
Unidentifiable—II, 1, 2.
Larvae—I, 4; III, 3.
Unidentified Insect Eggs—I, 4; II, 2.

ARACHNOIDEA

Scorpionida
Diplocentridae
*Diplocentrus* sp.—I, 2.
Vejovidae
*Vejovis* sp.—I, 2; II, 3; III, 3.
Buthidae
*Centruroides* sp.—I, 2.
Unidentifiable—I, 4; II, 2; III, 3.
Pseudoscorpionida—I, 1.
Phalangida
Phalangiidae
*Trachyrhinus marmoratus*—I, 2.
*Trachyrhinus* sp.—III, 3.
Unidentifiable—III, 3.
Solpugida
Ammotrechidae—I, 2; II, 1.
Eremobatidae
*Eremobates* sp.—III, 3.
*Eremohax magmus*—II, 3.
Unidentifiable—I, 4; II, all; III, 4; IV, 2, 3.
Unidentifiable—II, 1; IV, 3.
Araneae
Filistatidae
*Filistata arizonica*—II, 1, 3; III, 3.
*Filistatoides* sp.—I, 1.
Zoropsidae
*Zorocrates* sp.—II, 3.
Amaurobiidae
*Titanoeca* sp.—II, 2.
Diguetidae
*Diguetia canities*—I, 1; II, 1; IV, 2.
Loxoscelidae
*Loxosceles* sp.—IV, 2.
Theridiidae
Euryopis texana—I, 1.
*Latrodectus mactans*—II, 1, 3; IV, 2, 3.
*Lithyphantes fulvus*—I, 4.
*Lithyphantes pulcher*—II, 1; III, 4.
*Lithyphantes* sp.—II, 1, 2.
Argiopidae
*Tetragnatha laboriosa*—IV, 2.
Lindyphiidae
*Erigone* sp.—II, 1.
Oxyopidae
*Oxyopes* sp.—I, 4; IV, 2.
*Oxyopes tibialis*—I, 1, 4; II, 1, 2; IV, 2.
Lycosidae
*Hesperocosa unica*—II, 1, 2.
*Lycosa antelucana*—II, 2.
*Lycosa retenta*—I, 2, 4; II, 2, 3; III, 3; IV, 2.
*Lycosa* sp.—I, 1, 4; II, 1, 3; III, 4; IV, 2. 3.
*Pardosa pauxilla*—IV, 2.
*Pardosa* sp.—III, 4.
*Geolycosa* sp.—II, 3.
*Schizocosa parallela*—III, 3; IV, 3.
*Trochosa gosiuta*—II, 2.
Gnaphosidae
*Callilepis munda*—I, 4; II, 1.
*Drassyllus* sp.—II, 1, 3.

*Gnaphosa* sp.—III, 4.
*Rachodrassus* sp.—II, 2.
*Zelotes* sp.—II, 2.
*Zelotes* sp.—III, 3.
Unidentifiable—II, 1.
Clubionidae
*Castianeira* sp.—II, 1, 2,
*Micaria* sp.—II, 1.
*Syspira* sp.—I, 4.
Thomisidae
*Misumenops celer*—II, 1.
*Misumenops sp.*—II, 1; IV, 1.
*Thanatus* sp.—II, 1.
*Xysticus funestus*—II, 2.
*Xysticus lassanus*—III, 3.
*Xysticus* sp.—II, 1, 2.
Salticidae
*Habronattus coronatus*—I, 1, 4; II, 1, 2.
*Habronattus elegans*—II, 1.
*Habronattus sp.*—I and II, all; III, 4; IV, 2.
*Metacyrba taeniola*—I, 4.
*Metaphidippus arizonensis*—I, 1; IV, 2.
*Metaphidippus* sp.—I, 4; II, 3.
*Pellenes* sp.—II, 1, 2; IV, 1.
*Phidippus* sp.—I, 2; II, 2.
*Sitticus* sp.—II, 1.
Unidentifiable—I, all; II, 1, 2; III, 3, 4; IV, all.
Unidentified Spider Egg Case—II, 2.
Acarina—II, 1, 3.
CHILOPODA—I, 1, 4; II, 1, 2; III, 3, 4; IV, 3.

Termites formed the bulk of the food items eaten by the lizards at each station. The predominance of other arthropods in the diets varied from station to station, but, in general, orthopterans ranked second, coleopterans third, and lepidopterans fourth. No millipedes or lubber grasshoppers (*Taeniopoda eques*) and only one meloid beetle were found in the stomachs of the lizards. These arthropods are periodically abundant during the summer months on the Chihuahuan Desert and their absence in the diets of the lizards suggests the presence in all three of some mechanism (presumably cantharidine in the beetle) which makes them distasteful to the whiptails. This is somewhat substantiated by the refusal of captive whiptails at the Sierra Vieja station to accept small lubber grasshopper nymphs as food, although they accepted nymphs and adults of other grasshopper species.

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———, 1957b—Observations on the natural history of four species of whiptail lizard, *Cnemidophorus*, in Trans-Pecos Texas. *Southwestern Nat.* 2: 105–121.

# Records of Nasal Mites of the Mourning Dove

*by* **B. L. OWEN**
*Alabama Polytechnic Institute, Auburn*[1]

Crossley (1952) described a mite, *Neonyssus zenaidurae*, from the mourning dove, *Zenaidura macroura* (Linn.). He found these mites to be parasitic in the nasal passages of mourning doves collected in Dickens, Lubbock, and Caldwell Counties, Texas, and Grady County, Georgia. Ten of 19 mourning doves examined by Crossley were found to be infested. He also collected two representatives of this species from the Mexican ground dove, *Columbigallina passerina* (Linn.), from Kleberg County, Texas. Crossley stated that this was probably an accidental infestation, since only 1 of 16 doves was parasitized.

The author examined heads of mourning doves collected in two areas of Alabama in October, 1957, by Dr. J. L. Dusi of the Alabama Polytechnic Institute. Ten doves were taken in Russell County (east central Alabama) and 34 from Baldwin County (southwest Alabama). The dove heads were halved longitudinally with a scalpel and the upper respiratory passages were examined for mites with the aid of small teasing needles and a stereoscopic microscope. Specimens of *N. zenaidurae* were found in doves from both areas. Forty per cent of the doves collected in Russell County were infested with a mean of 1.5 mites per dove; 29.4 per cent of the doves from Baldwin County were infested with a mean of 2.6 mites per individual. This represents the first record of this species from Alabama.

Dr. R. W. Strandtman, Texas Technological College, was most generous in furnishing information regarding a collection of *N. zenaidurae* from mourning doves in Bolivar County, Mississippi, in 1953. This represents the first known record of this species from that state.

LITERATURE CITED

Crossley, D. A., Jr., 1952—Two new nasal mites from columbiform birds. *J. Parasit.* 38(5): 385–390.

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# A Procedure for the Staining and Sectioning of the Heads of Adult Anurans

*by* **RICHARD J. BALDAUF**

*Agricultural and Mechanical College of Texas*

The publication of my studies on the cranial morphology of *Bufo* has brought numerous requests for the technique of sectioning and staining such material. The response suggests the presentation of the procedures in a single reference. The methods are not original, but merely standard procedures, as given in the references suggested below, with occasional modifications and suggestions suited to my needs for studying the bone and cartilage of serially-sectioned adult toads. The use of a sliding microtome for sectioning large, bony specimens, as explained below, should not be tried by those inexperienced in general microtechniques. For this reason I do not take the space to explain some of the more common procedures. All references to alcohol refer to ethyl alcohol.

#### FIXATION

Five to 10% formalin is recommended. Other fixatives are better for special cytological studies, but are not needed for differentiating bone and cartilage.

#### DECALCIFICATION

Perényi's Fluid is excellent and is mixed as follows: 10% $HNO_3$, 4 parts; 95% alcohol, 3 parts; 0.5% chromic acid, 3 parts. An extra bone, such as the femur, can be added to the fluid along with the specimen; this allows some check on the progress of decalcification. A large toad head can be prepared in three days. Familiarity with the material must serve to indicate the need for and the extent of decalcification.

#### EMBEDDING

Delicate structures and extra hard material may require the use of celloidin, but contrary to popular opinion much of this material can be successfully sectioned when embedded in paraffin or Tissuemat. Tissuemat with melting points ranging from 46° – 56°C can be used for sectioning at room temperature during the winter months.

### SECTIONING

The size of the object and its hardness determines the method of sectioning. Small material in a block about one-half inch square can be sectioned on a rotary microtome. Larger specimens and ones with a lot of cartilage or decalcified bone require a sliding microtome. Individual sections cut this way will often come off as a roll. These can be unrolled and spread without distortion. With Tissuemat of m.p. 56°C. the sections can be unrolled by placing on water heated to 35°–38° C. The process of unrolling can be "helped" occasionally with a blunt instrument and a camel-hair brush. Unrolled sections are spread on water heated to 45°C. Each section must be spread for the same amount of time to avoid distortion. This procedure is satisfactory for sections cut at 10, 15, and 20 micra.

### STAINING

A modified Heidenhain's Azan technique (see below) produces good results and yields blue cartilage and red bone. Other straining techniques (Masson's trichrome, picroindigonigrosin, borax-carmine) have equal merit and are described in standard references.

### MOUNTING

Many media are satisfactory. Permount seems to retain its clarity and does not yellow with age as do some natural resins. This point is important only if color photographs are made of the finished sections. (It is more convenient to loan color photographs rather than the original slides.)

### BULK STAINING

There is no special need for bulk-staining, although it does make the sectioned tissue more discernible and, therefore, easier to handle during sectioning, unrolling, and spreading. Bulk staining with borax-carmine, bismark brown, haemalum, and others, as described in standared references, can be added between steps three and four of the following fixation and embedding schedule.

#### SCHEDULE FOR FIXATION AND EMBEDDING

1. Remove lenses from eyes of specimen and fix in formalin—10 days.
*2. Decalcify in Perényi's Fluid—3 days.
3. Wash in running tap water—12 hours.
4. 50% alcohol—2 changes at 12 hours each.

5. 70% alcohol—2 changes at 12 hours each.
6. ½ acetone, ½ 70% alcohol—at least 4 hours.
7. Pure acetone—2 changes at 4 hours each.
8. ½ acetone, ½ cedarwood oil—at least 4 hours.
*9. Cedarwood oil—until specimen is cleared. (Warming speeds the process.)
10. Benzene—at least 4 hours.
*11. ½ Benzene, ½ melted tissuemat—20 hours.
*12. Melted tissuemat—2 changes at 24 hours each.
*13. Embed for sectioning.

* Should be done *in vacuo* for proper infiltration.

SCHEDULE FOR STAINING

| | Step and Constituents | Time |
|---|---|---|
| 1. | Section material and fix to slide. | |
| 2. | Xylol | until all tissuemat is removed. |
| 3. | ½ xylol, ½ absolute alcohol | 5 minutes, maximum. |
| 4. | Absolute alcohol | 5 minutes, maximum. |
| 5. | Run through 95%, 80%, 70%, 50% alcohol to distilled water | 5 minutes, maximum, for each. |
| 6. | Stain in Azocarmine B[1] | 30 minutes. |
| †7. | Wash in 2 changes of distilled water | fast dips to wash off excess azocarmine. |
| †8. | Aniline alcohol[2] | several fast dips. |
| †9. | 95% alcohol plus 3 drops of glacial acetic acid per 100 cc. | several fast dips. |
| †10. | 2% phosphotungstic acid | several fast dips—enough to allow liquid to run smoothly off slide. |
| 11. | Wash in distilled water | 5 minutes, maximum. |
| †12. | Differential staining[3] | 3 minutes. |
| †13. | Wash in water | fast dips to wash off excess blue only. |
| †14. | 50% alcohol | fast dips to wash off excess blue only. |
| †15. | Run through 70%, 80%, 95%, absolute alcohol | fast dips at lower concentrations; the blue stain will not be removed in excess by 80% and higher alcohols. |
| 16. | ½ absolute alcohol, ½ xylol | 5 minutes, maximum. |
| 17. | Xylol | 5 minutes, maximum. |
| 18. | Mount | |

† Must be controlled by visual inspection.

[1] Azocarmine B. Mix 2% aqueous solution plus 15 drops glacial acetic acid per 100 cc. of stain.

[2] Aniline alcohol. 95% alcohol plus 0.3 cc. aniline oil per 100 cc.

[3] Differential staining. Aniline blue (water soluble) .................... 0.5 gr.
Orange G .................................... 2.0 gr.
Glacial Acetic acid ............................ 8.0 cc.

Mix the above in 100 cc. of water. After thoroughly mixed add 200 cc. water.

SUGGESTED REFERENCE

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Gray, Peter, 1954—*The microtomist's formulary and guide.* The Blakiston Co., Philadelphia.

# A Contribution Toward a Knowledge of the Crawfishes of Texas (Decapoda, Astacidae)[1]

*by* **GEORGE HENRY PENN** *and* **HORTON H. HOBBS, JR.**
*Tulane University, and University of Virginia*

During the last three years one of us (GHP) has collected crawfishes in various part of eastern Texas and each of us has identified collections sent from other parts of the state. A sufficient number of interesting distributional records has accumulated that a preliminary account of the crawfishes of Texas is warranted at this time.

Most of the materials examined are in the collection of Tulane University and that of the junior author. All Texas specimens in the United States National Museum, the Academy of Natural Sciences of Philadelphia, and the Museum of Comparative Zoology at Harvard also have been examined by the junior author.

## HISTORICAL STATEMENT

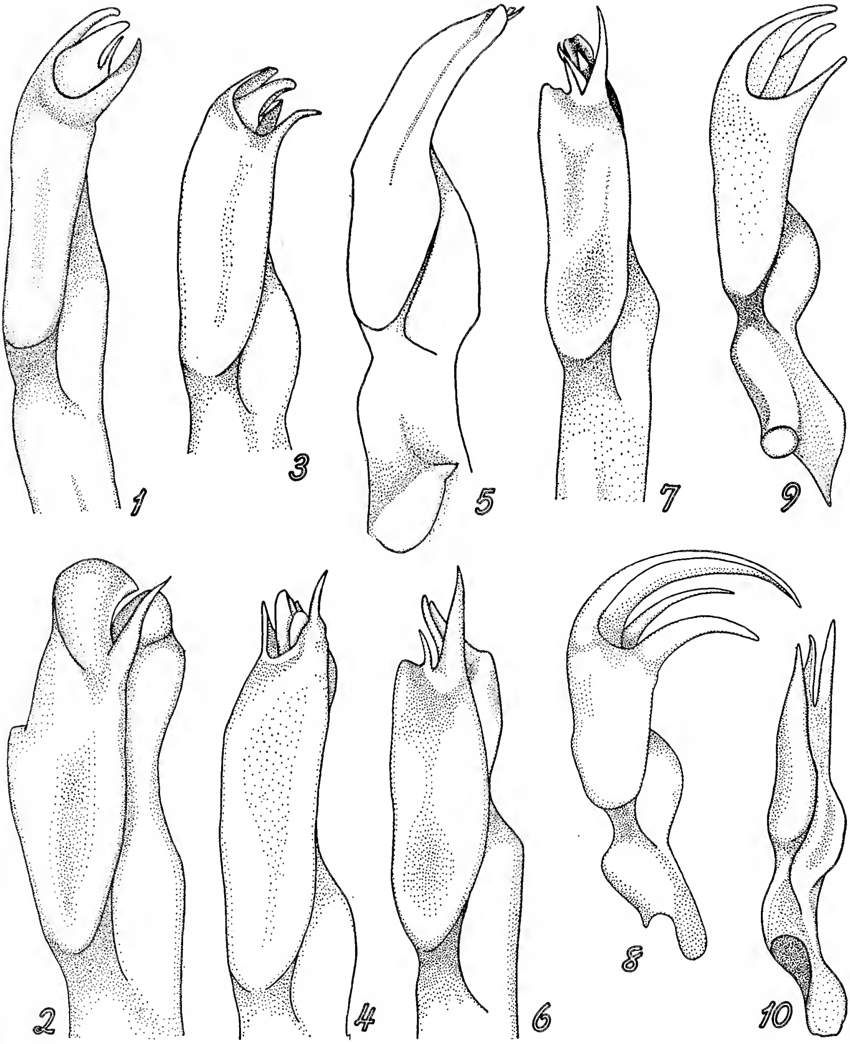
The first scientific report of crawfishes in Texas was published by Girard (1852: 91) who described *Cambarus clarkii* (now in the genus *Procambarus*) from "between San Antonio and El Paso del Norte." Hagen (1870: 102) listed three species, *viz.* "*C. clarkii, C. virilis, C. placidus;* the first occurs near the middle of the state, between San Antonio and El Paso del Norte; of the others the localities are unknown." The latter two species have not been found in Texas again although Faxon (1885a: 168) repeated Hagen's records, and later he (1898: 652) listed *virilis* from Lamar County, Texas. For the present the writers consider Texas records for *virilis* and *placidus* as erroneous.

Records of *Cambarus simulans* and *Cambarus blandingi acutus* (both now in the genus *Procambarus*) were added by Faxon (1884: 112; 1885a: 22). Later (1898: 655, 652) he described a new subspecies, *Cambarus palmeri longimanus* (now in genus *Orconectes*) from the

[1] Specimens from eastern Texas were collected incidental to materials for another study supported by grants NSF–G947 and NSF–G2330 from the National Science Foundation. We acknowledge with thanks also the assistance of Misses Margaret Crumpler and Sue Blackshear in preparing some of the figures.

Red River at Arthur, Texas, and published a record of *Cambarus neglectus* (now in genus *Orconectes*) from the same locality.

In the present century a number of carcinologists and others cited in the text have published additional locality records for some of these species and described four additional new species from Texas local-



Figs. 1–10. Mesial view of first pleopods of form I males; pubescence removed from all structures. 1. *Procambarus blandingi acutus*, 2. *Procambarus clarki*, 3. *Procambarus dupratzi*, 4. *Procambarus natchitochae*, 5. *Procambarus hinei*, 6. *Procambarus simulans simulans*, 7. *Procambarus gracilis*, 8. *Cambarellus ninae*, 9. *Cambarellus puer*, 10. *Cambarellus shufeldti*.

ities. The latter are *Cambarellus puer* Hobbs (1945: 469), *Cambarellus ninae* Hobbs (1950: 89), *Cambarus hedgpethi* Hobbs (1948: 224), and *Procambarus dupratzi* Penn (1953b: 1).

One curious little paper deserves special comment in clearing the record on previously published reports of Texas crawfishes. Parks, Smith and Garrett (1939) claimed to have collected specimens of four species in east Texas, namely: *Cambarus blandingi acutus, C. gracilis, C. diogenes,* and *C. bartoni*. The writers have collected or examined specimens of the first three species from Texas localities, but the fourth definitely must be placed on the spurious list. *C. bartoni* does not occur south or west of Lauderdale County in northwestern Alabama.

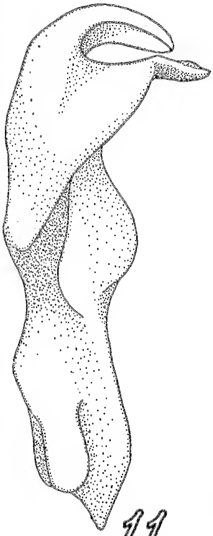
Six genera of crawfishes (Astacidae, Cambarinae) occur in North America east of the Rocky Mountains (Hobbs, 1942a); four of these genera are represented by species within the borders of Texas: *Procambarus, Cambarellus, Cambarus, and Orconectes.*

## TAXONOMIC CHARACTERS

Adult male crawfishes of the subfamily Cambarinae (including all Texas species) exhibit two distinctly different and usually alternating morphological forms. These are referred to as forms I and II (or, first and second form) males. The form is related directly to the reproductive cycle: males of form I are capable of copulation, those of form II (and juveniles) are not. The form I male is distinguished by a corneous (yellowish) condition of one or more of the apical elements of the first pair of pleopods and the presence of well-developed hooks on the ischiopodites of the second and third, third, or third and fourth pereiopods (Fig. 18). In form II males all of the apical elements of the first pair of pleopods and the hooks of the pereiopods are comparatively less well-developed and never corneous.

Although there are considerable differences in the shape and proportions of the apical elements of the first pair of pleopods of the different species they have all been homologized with a hypothetical four-parted structure by Hobbs (1942b). All apical elements are present, though variable in development, in most species of *Procambarus* (Figs. 1–7); the cephalic element is lacking in species of *Cambarellus*

**Figs. 11–17. Mesial view of first pleopods of form I males; pubescence removed from all structures. 11. *Cambarus hedgpethi*, 12. *Orconectes lancifer*, 13. *Orconectes neglectus neglectus*, 14. *Orconectes palmeri longimanus*, 15. *Orconectes difficilis*, 16. *Orconectes nais*, 17. *Orconectes clypeatus*.**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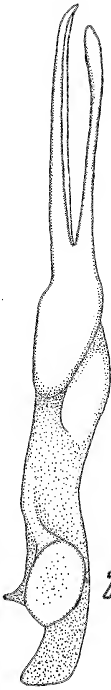
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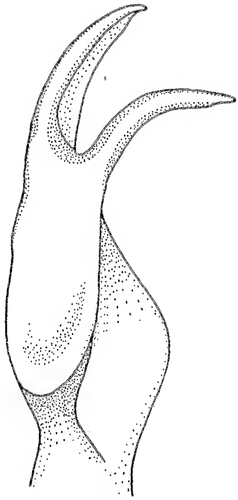
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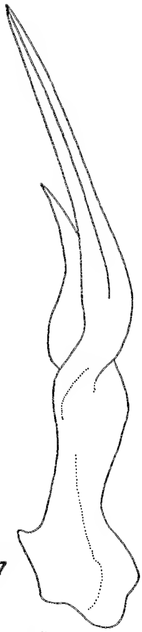
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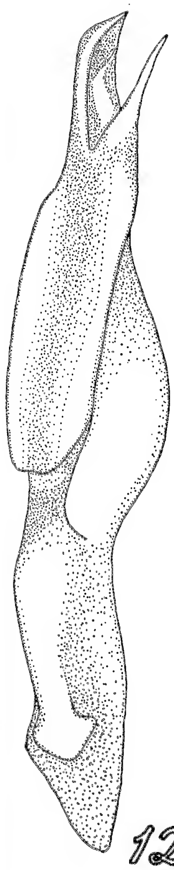
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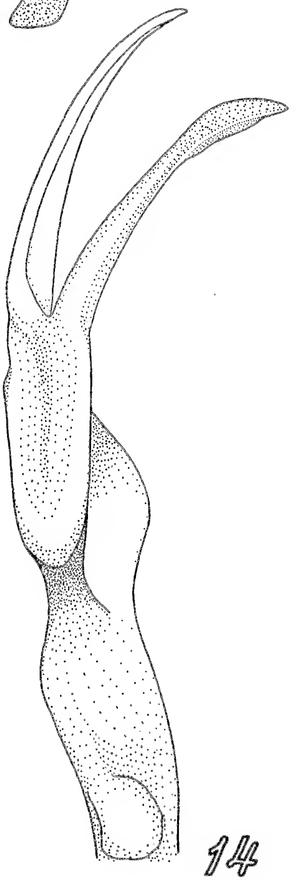
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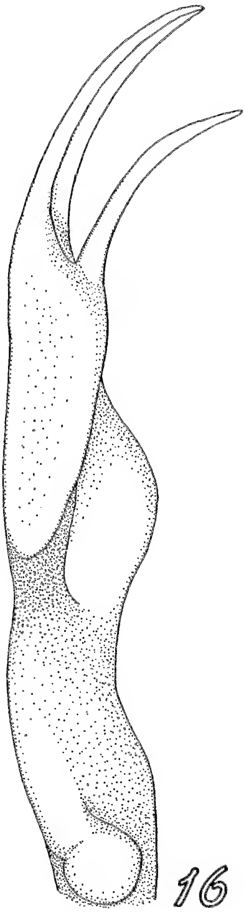
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(Figs. 8–10); and, only the mesial process and central projection persist in species of *Cambarus* (Fig. 11) and *Orconectes* (Figs. 12–17).

Other characters useful in crawfish taxonomy and that are used in the following key and species diagnoses include the following (Fig. 19): (1) *rostrum* (length relative to cephalothorax length; and, with

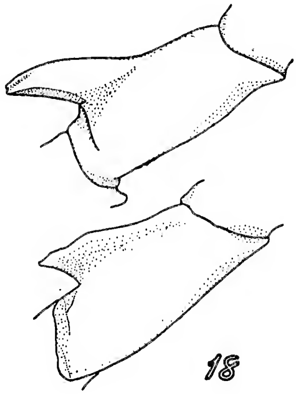


Fig. 18. Hooks on ischiopodites of third and fourth pereiopods of *Procambarus hinei.*

or without lateral spines); (2) *lateral spines of cephalothorax* (present or absent; number); (3) *areola* (length relative to length of cephalic region of cephalothorax; whether open or obliterated; and, if open, the length/width ratio); (4) *chela* (length/width ratio; number and arrangement of the tubercles on the palm and fingers); (5) *annulus ventralis*, or sperm receptacle of the female (Figs. 20–34) length/width ratio; sculpture of the surface).

## KEY TO FORM I MALES OF TEXAS CRAWFISHES

1. First pleopod terminating in three or more distinct parts .................. 2
   First pleopod terminating in only two distinct parts .......................... 11
2. Hooks present on ischiopodites of the 3rd, or 3rd and 4th pereiopods (genus *Procambarus*) ..... ................................................ 3
   Hooks present on ischiopodites of 2nd and 3rd pereiopods (genus *Cambarellus*) ........................................................................ 9
3. Hooks present on ischiopodites of 3rd and 4th pereiopods .................. 5
   Hooks present on ischiopodites of 3rd pereiopods only ..................... 4
4. Areola narrow, obliterated at least in the middle (fig. 40). .................................. *Procambarus gracilis* (Bundy)
   Areola wider, never obliterated in the middle (fig. 39) ............................ *Procambarus simulans simulans* (Faxon)

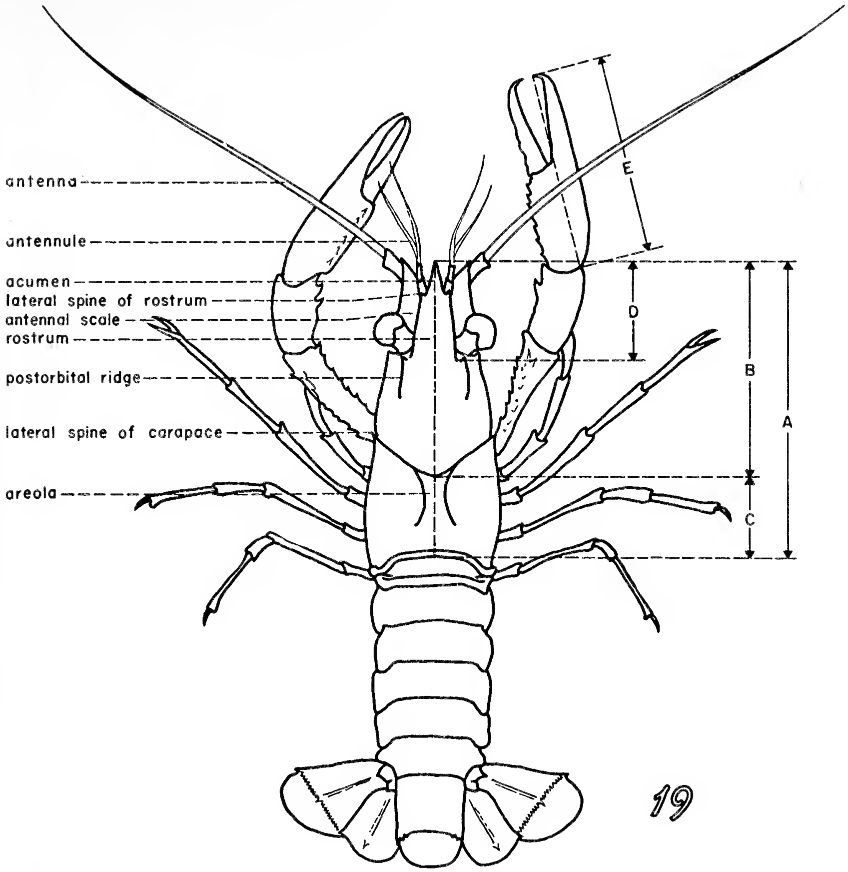
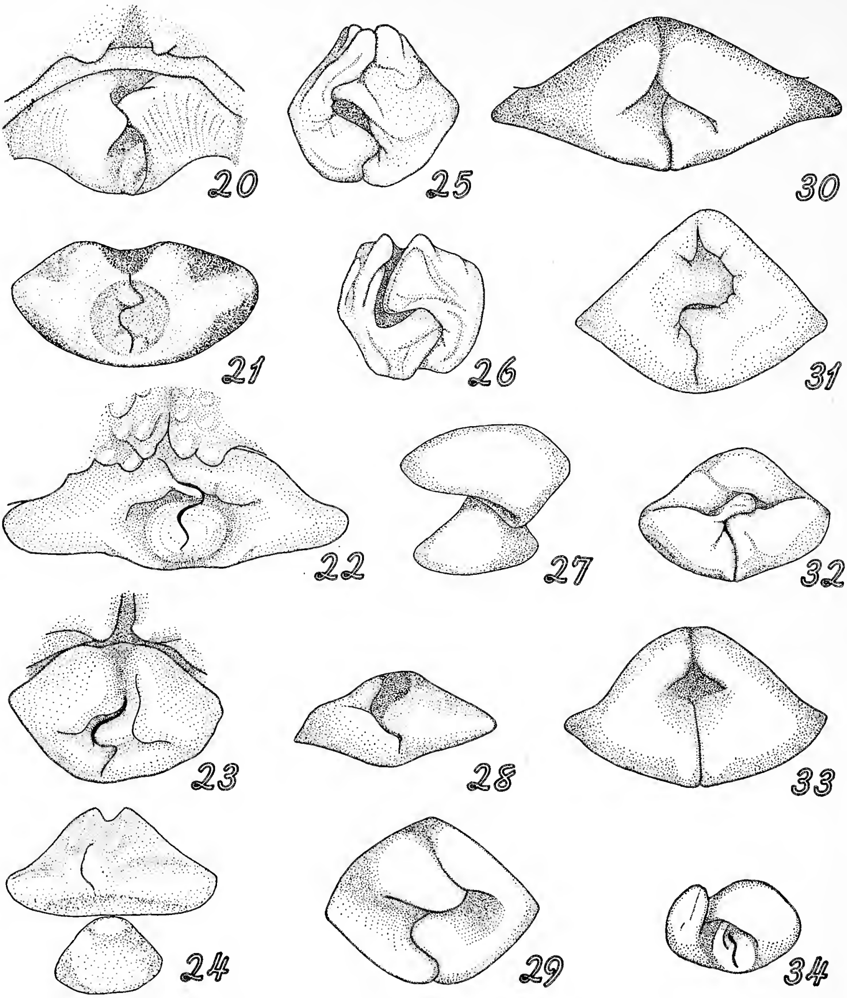



**Fig. 19. Crawfish terminology. A=cephalothorax, B=cephalic region of cephalothorax, C=areola, D=rostrum, E=chela.**

5. Areola obliterated or very narrow (width less than one-tenth length of areola) ........ 6
   Areola wide (width greater than one-fourth length of areola) ........ 7

6. First pleopod with a distinct shoulder on cephalic surface near apex; cephalic process large, compressed, rounded cephalodistad but angular on candodistal margin (fig. 2) ........ *Procambarus clarki* (Girard)
   First pleopod lacking a shoulder; cephalic process bladelike, corneous and directed caudodistad (fig. 1) ........ *Procambarus blandingi acutus* (Faxon)

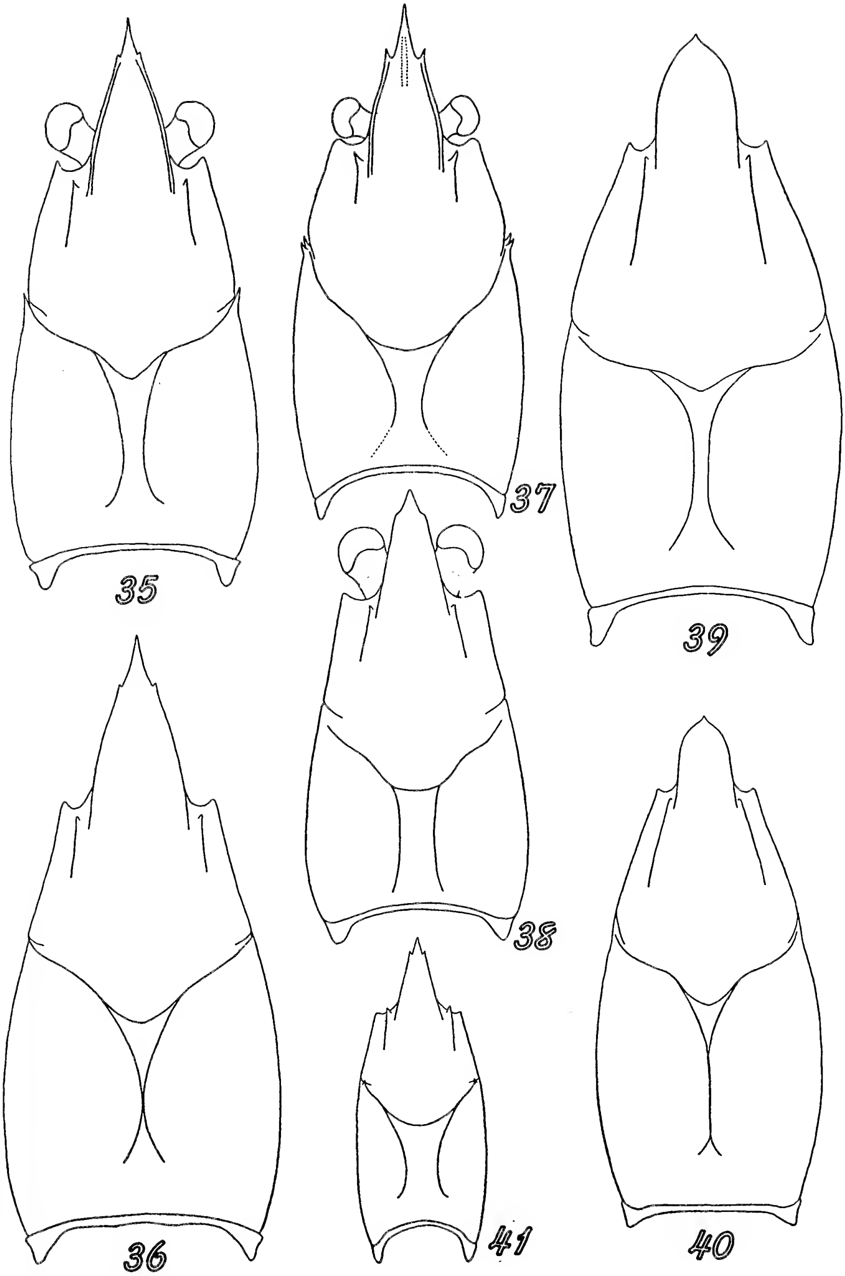
7. Cephalothorax with two lateral spines on each side; rostrum with lateral spines ........ 8



Figs. 20–34. Annuli ventrali of mature females. 20. *Procambarus blandingi acutus*, 21. *Procambarus clarki*, 22. *Procambarus dupratzi*, 23. *Procambarus natchitochae*, 24. *Procambarus hinei*, 25. *Procambarus simulans simulans*, 26. *Procambarus gracilis*, 27. *Cambarellus shufeldti*, 28. *Cambarus hedgpethi*, 29. *Orconectes lancifer*, 30. *Orconectes neglectus neglectus*, 31. *Orconectes palmeri longimanus*, 32. *Orconectes difficilis*, 33. *Orconectes nais*, 34. *Orconectes clypeatus*.

Cephalothorax without lateral spines, or at most with one small spine on each side; rostrum without lateral spines (fig. 38) ........ *Procambarus hinei* (Ortmann)

8. Terminal parts of first pleopod bent caudad at about a 40° angle to the shaft of the appendage (fig. 3) ....... *Procambarus dupratzi* Penn

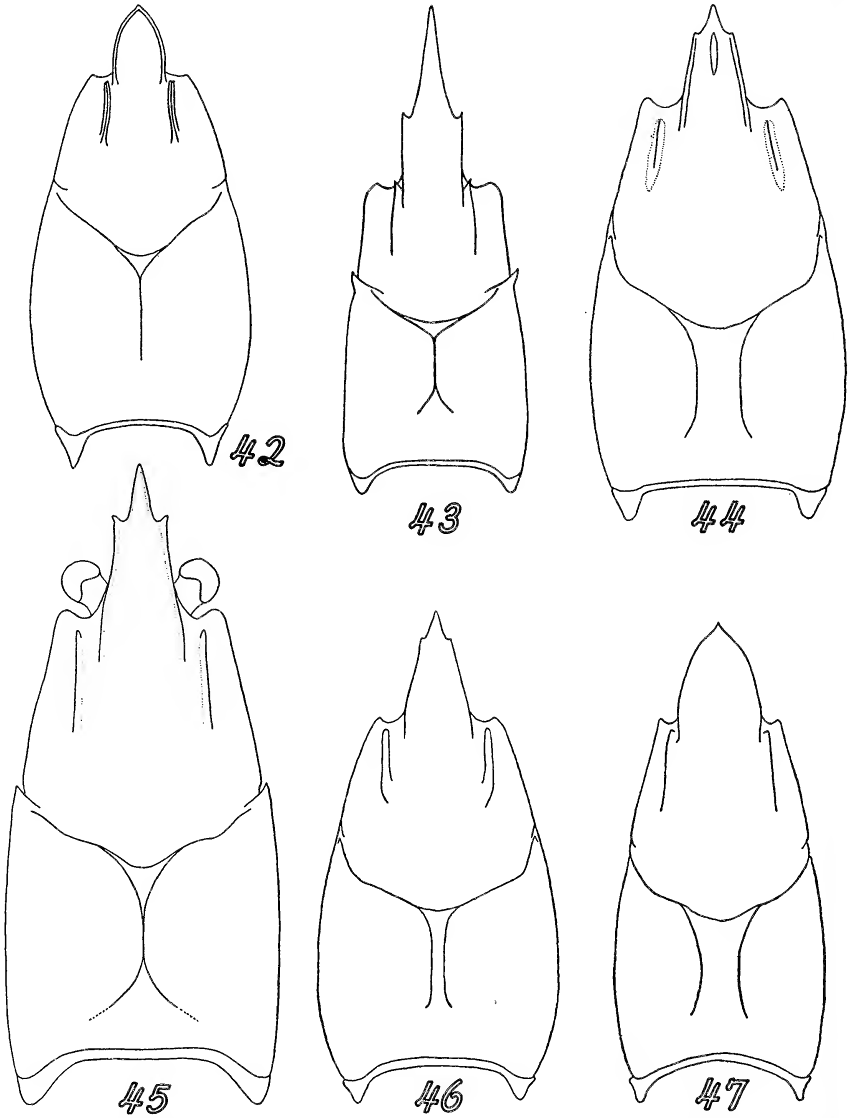



**Figs. 35–41. Cephalothoraxes of form I males. 35. *Procambarus blandingi acutus*, 36. *Procambarus clarki*, 37. *Procambarus dupratzi*, 38. *Procambarus hinei*, 39. *Procambarus simulans simulans*, 40. *Procambarus gracilis*, 41. *Cambarellus shufeldti*.**

Terminal parts of first pleopod extend straight distad or nearly so (fig. 4) .............................. *Procambarus natchitochae* Penn

9. Terminal parts of first pleopod extend straight distad or nearly so (fig. 10) .............................................*Cambarellus shufeldti* (Faxon)

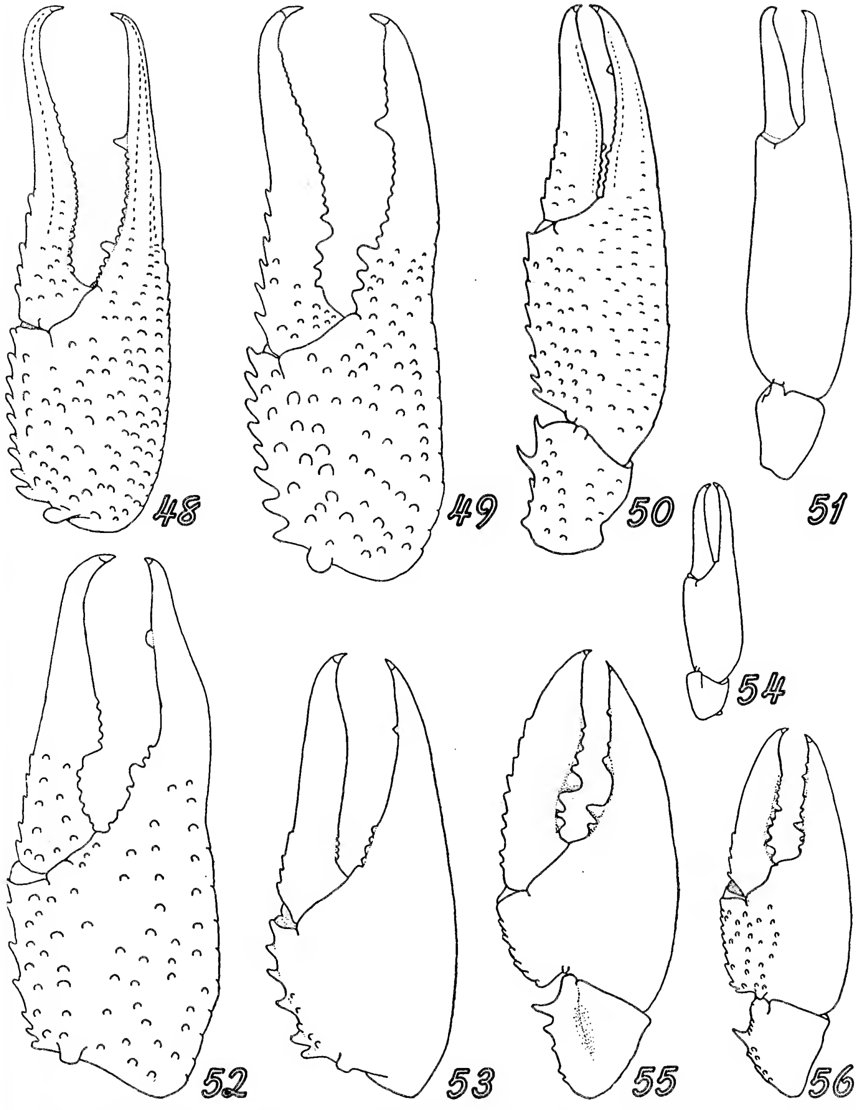
Terminal parts of first pleopod bent caudad .................................. 10




**Figs. 42–47. Cephalothoraxes of form I males. 42. *Cambarus hedgpethi*, 43. *Orconectes lancifer*, 44. *Orconectes neglectus neglectus*, 45. *Orconectes palmeri longimanus*, 46. *Orconectes nais*, 47. *Orconectes clypeatus*.**

10. Central projection of first pleopod extending further caudad than other terminal elements (fig. 8); areola broad, never more than three times as long as wide .......................... *Cambarellus ninae* Hobbs

Central projection of first pleopod never extending further caudad than other terminal elements (fig. 9); areola narrower, five to




**Figs. 48–56. Chelae of form I males; pubescence removed from all structures. 48. *Procambarus blandingi acutus*, 49. *Procambarus clarki*, 50. *Procambarus dupratzi*, 51. *Procambarus hinei*, 52. *Procambarus simulans simulans*, 53. *Procambarus gracilis*, 54. *Cambarellus shufeldti*, 55. *Cambarus hedgpethi*, 56. *Cambarus diogenes diogenes*.**

six times as long as wide ........................ *Cambarellus puer* Hobbs

11. Two terminal parts of first pleopod generally short and bent caudad at a 90° angle to the shaft; entire appendage short and heavy (fig. 11) (genus *Cambarus*) ........................ 12

    Two terminal parts of first pleopod short or long, but never both bent caudad at a 90° angle to the shaft; both terminal elements slender, and in most cases setiform (figs. 12–17) (genus *Orconectes*) ........................ 13

12. Immovable finger of chela with only one prominent tubercle on opposable margin (fig. 56); mesial process of first pleopod somewhat bulbous, does not appear twisted; antennal scale length/width ratio over 2.6 ........................ *Cambarus diogenes diogenes* Girard

    Immovable finger of chela with two prominent tubercles on opposable margin (fig. 55); mesial process of first pleopod not bulbous, appears somewhat twisted (fig. 11); antennal scale length/width ratio 2.2 or less........................ *Cambarus hedgpethi* Hobbs

13. The two rami of the first pleopod subequal in length; rostrum with lateral spines; areola open or closed ........................ 14

    The two rami of the first pleopod distinctly unequal in length (central projection nearly three times as long as the mesial process) (fig. 17); rostrum without lateral spines (fig. 47); areola broad, width about one-fourth length (fig. 47) ........................ *Orconectes clypeatus* (Hay)

14. Rostrum antennal scale exceptionally long; length of acumen equal to or greater than width of rostrum at base (fig. 43); the two rami of the first pleopod short, not setiform (fig. 12) ........................ *Orconectes lancifer* (Hagen)

    Rostrum and antennal scale not exceptionally long; length of acumen less than width of rostrum at its base; the two rami of the first pleopod longer, more-or-less setiform ........................ 15

15. Areola open (length/width ratio not greater than 10) ........................ 16

    Areola usually obliterated in middle (rarely it may be slightly open, but length/width ratio never less than 20) ........................ 17

16. Rami of first pleopods nearly straight, sometimes the central projection slightly curved caudad, but never in the same direction as the mesial process (fig. 13) ........................ *Orconectes neglectus neglectus* (Faxon)

    Rami of first pleopods both curved caudad (fig. 16) ........................ *Orconectes nais* (Faxon)

17. Central projection of first pleopod longer than distal mesial shaft (fig. 14); pleopod reaching to coxo-

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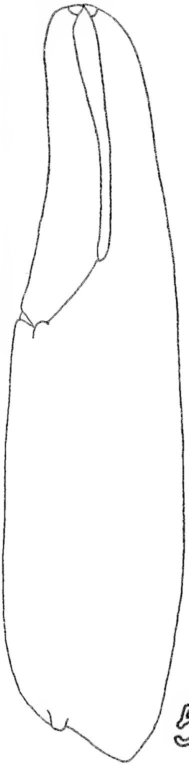
**Figs. 57–62. Chelae of form I males; pubescence removed from all structures. 57. *Orconectes lancifer*, 58. *Orconectes palmeri longimanus*, 59. *Orconectes neglectus neglectus*, 60. *Orconectes difficilis*, 61. *Orconectes nais*, 62. *Orconectes clypeatus*.**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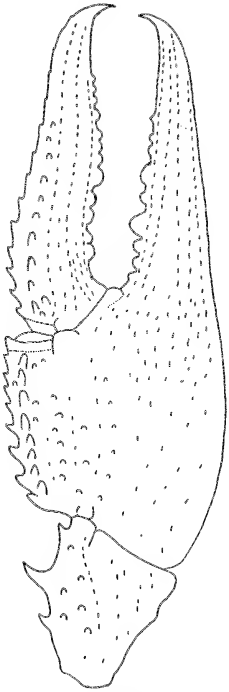
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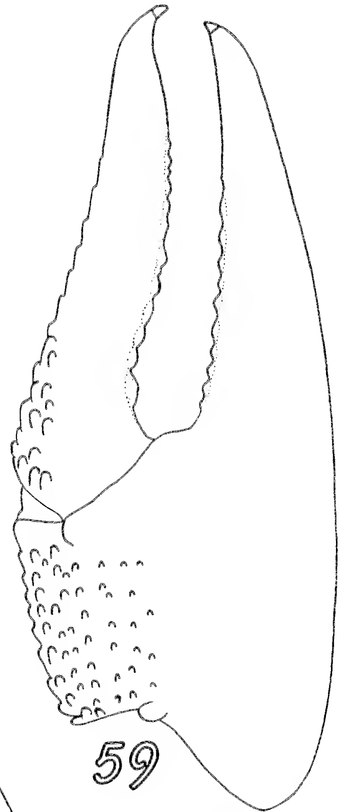
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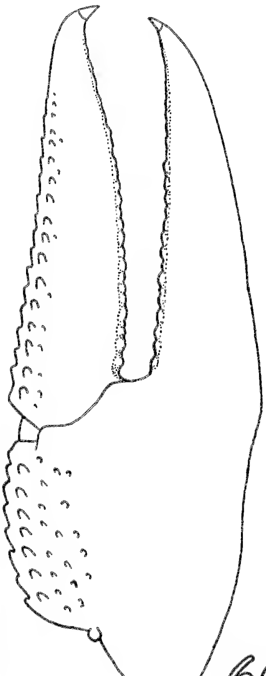
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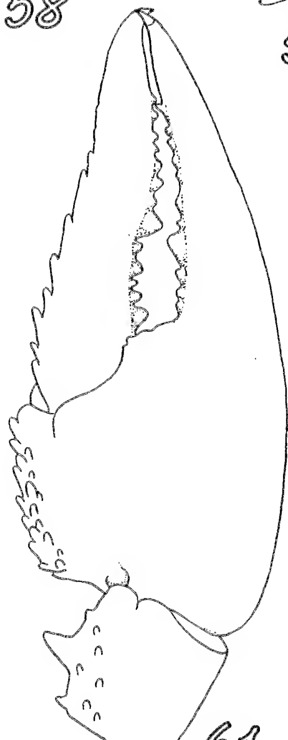
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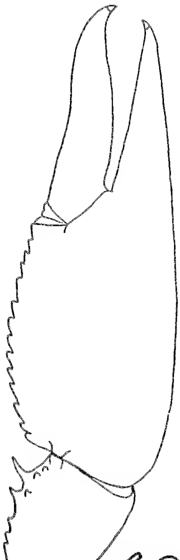
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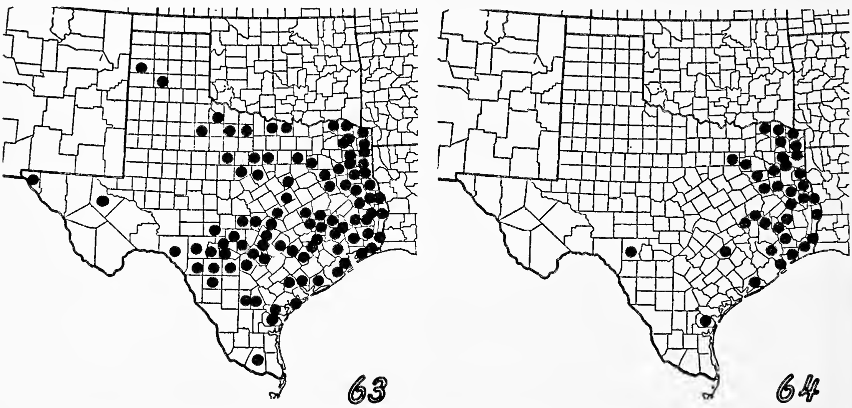
podite of 2nd pereiopod ....*Orconectes palmeri longimanus* (Faxon)
Central projection of first pleopod shorter than distal mesial shaft (fig. 15); pleopod reaching to coxopodite of 3rd pereiopod ........................................*Orconectes difficilis* (Faxon)

### *Procambarus blandingi acutus* (FAXON)

(Figures 1, 20, 35, 48, 64)

*Diagnosis.*—Rostrum with very small lateral teeth near tip (absent in some specimens); areola narrow, but definitely open; one lateral spine on each side of cephalothorax. Chela long and slender. First pleopod of form I male reaching to coxopodite of third pereiopod and ending in four distinct parts: mesial process long and spiniform and directed laterodistad; cephalic process blade-like, corneous, compressed, and directed caudodistad; caudal element and central projection acute, blade-like, corneous, compressed, and directed caudodistad.

*Specimens examined.*—This crawfish occupies a wide range (Fig. 64), but apparently it is not common in any part of Texas. We have seen 276 individuals distributed by drainage systems and counties, west to east, as follows: Nueces River (Edwards and Nueces counties), Lavaca River (Fayette county), Matagorda Bay (Matagorda county), Colorado River (Matagorda county), Brazos River (Brazos county), Buffalo Bayou (Harris county), Galveston Bay (Chambers, Galveston, and Liberty counties), San Jacinto River (Walker county), Trinity River (Dallas, Kaufman, Madison, Polk, and Walker counties), Neches River (Anderson, Cherokee, Henderson, Jefferson, Nacog-




**Figs. 63–64. Distribution of Texas collection by counties. 63. All collecting sites combined, 64. *Procambarus blandingi acutus*.**

doches, Orange, San Augustine, Shelby, and Smith counties), Sabine River (Newton, Panola, and Sabine counties), and Red River (Bowie, Cass, Lamar, Marion, Red River, Titus, and Upshur counties).

Previously it had been recorded from the Nueces River (Nueces county, Faxon, 1898, 1914), Buffalo Bayou (Harris county, Ellis, 1919), Galveston Bay (Liberty county, Hobbs, 1945), Trinity River (Dallas county, Faxon, 1885a; Polk and San Jacinto counties, Parks *et al.*, 1939), and Red River (Lamar county, Faxon, 1898, 1914).

*Associates.*—In Texas *P. b. acutus* has ubiquitous habits, hence it was found associated with a wide variety of other crawfishes. However, in 49 percent of the 55 collections examined it was not associated with other crawfish. In order of decreasing frequency the associates in the remaining 51 percent of the collections were *P. s. simulans*, *P. clarki*, *P. dupratzi*, *C. puer*, *C. hedgpethi*, *P. natchitochae*, *P. hinei*, *C. d. diogenes*, *O. p. longimanus*, and *O. difficilis*.

*Life history notes.*—Apparently the seasonal cycle in Texas is comparable to that described for *P. b. acutus* in Louisiana by Penn (1956), although we had less than a third as many individuals with collection dates for analysis. Ovigerous females were not seen, but Penn (*op. cit.*) suggested that egg laying occurs in Louisiana from September through December. The seasonal data from Texas are summarized in the following table.

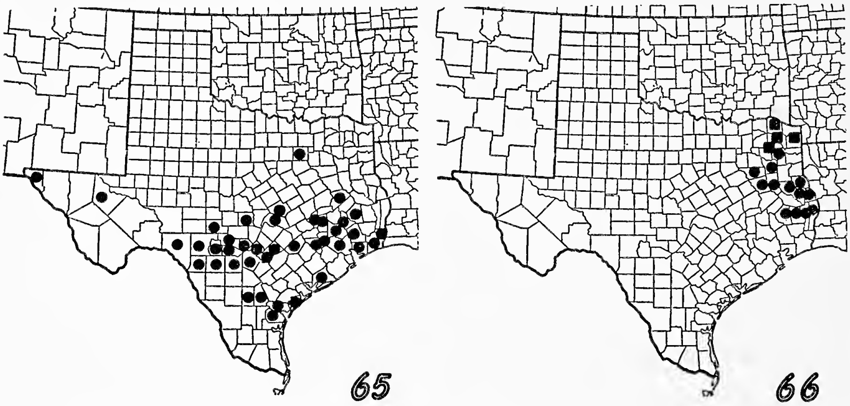
| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ♂♂ I | .. | 1 | 1 | 4 | 1 | 9 | 4 | .. | 1 | .. | .. | .. | 21 |
| ♂♂ II | 3 | .. | .. | 5 | 9 | 7 | 2 | .. | 5 | 1 | .. | 2 | 34 |
| ♀♀ | 6 | 3 | .. | 3 | 6 | 7 | 2 | 1 | 1 | .. | 2 | 4 | 35 |
| ♂♂ juv | 1 | 24 | 1 | 6 | 1 | 6 | 1 | .. | .. | .. | 2 | 40 | 82 |
| ♀♀ juv | .. | 28 | .. | 5 | .. | 9 | 1 | 4 | .. | .. | 2 | 39 | 88 |
| Totals | 10 | 66 | 2 | 23 | 17 | 38 | 10 | 5 | 7 | 1 | 6 | 85 | 260 |

*Ecological observations.*—Hobbs and Marchand (1943) pointed out the ubiquity of ecological tolerance of populations of *P. b. acutus* in various parts of its widespread geographic range. This observation is corroborated by an analysis of the data on 48 Texas collections in the table below.

The various physical and biological factors in all habitats combined

| Habitat | Percent of Total Collections |
|---|---|
| Creeks and rivers | 54 |
| Ponds and lakes | 23 |
| Ditches (mostly roadside) | 23 |

may be summarized in the statement that *P. b. acutus* occurs more frequently in shallow water, *i.e.* less than 15 inches deep (54%), that is turbid (52%), permanent (77%), flowing (54%), and exposed to full sunlight (71%). Two of the collections were from obviously polluted streams (one each with garbage and manure). The greatest current recorded was 1.3 ft/sec at the surface. Most of the collections were from habitats with mud bottoms (62%) and without aquatic vegetation present (57%).




**Figs. 65–66. Distribution of Texas collections by counties. 65. *Procambarus clarki*, 66. *Procambarusdupratzi* (dots), and *P. natchitochae* (closed squares).**

## *Procambarus clarki* (GIRARD)

(Figures 2, 21, 36, 49, 65)

*Diagnosis.*—Rostrum with small lateral spines or tubercles (absent in some specimens); areola obliterated, or slightly open; chela moderately long with palmar area somewhat broadened and bearing a row of six to nine tubercles along mesial margin; a single lateral spine or tubercle present on each side of the cephalothorax. First pleopod of form I male reaching to middle of coxopodite of third pereiopod; apex with a distinct shoulder on the cephalic surface, and terminating in four distinct parts: mesial process spiniform, extending distad only slightly beyond the other elements; cephalic process large, compressed, rounded cephalodistad but angular on the caudodistal margin; caudal process almost spatulate, making up the distal caudolateral portion of the appendage; central projection lying between and slightly mesiad of the cephalic process (somewhat overhung by the cephalic process), entirely corneous, acute, and the least conspicuous of the four parts.

*Specimens examined.*—This is one of the commonest crawfishes in Texas. We have seen 505 individuals distributed by drainage systems and counties, west to east (Fig. 65), as follows: Rio Grande River (El Paso, Reeves, and Val Verde counties), Nueces River (Bandera, Edwards, Kerr, Kinney, Live Oak, McMullen, Nueces, San Patricio, Real, and Uvalde counties), Aransas Bay (Aransas county), Guadalupe River (Comal, Guadalupe, Hays, Kendall, Kerr, and Medina counties), San Antonio River (Bexar county), Colorado River (Bastrop, Kimble, Llano, and Matagorda counties), Brazos River (Austin, Bell, Brazos, Grimes, and Williamson counties), Buffalo Bayou (Harris county), San Jacinto River (Liberty and Montgomery counties), Galveston Bay (Chambers and Jefferson counties), Trinity River (Dallas, Liberty, Polk, and San Jacinto counties), and Neches River (Anderson, Jefferson, and Orange counties).

Previously it had been recorded from the Rio Grande (Val Verde county, Ortmann, 1905), Nueces River (Kinney county, Faxon, 1898, 1914; Ellis, 1919; Hobbs and Zinn, 1948; Nueces county, Faxon, 1914), Guadalupe River (Hays and Guadalupe counties, Faxon, 1914), Brazos River (Waller county, Faxon, 1885a), Neches River (Angelina River and Jefferson county, Faxon, 1914), Buffalo Bayou, (Harris county, Faxon, 1914), and "between San Antonio and El Paso del Norte" by Girard (1852).

*Comments.*—Faxon (1885a: 26) noted that in specimens from San Antonio "the carapace is smoother than in the form commonly received from New Orleans and Mobile, with more prominent lateral and postorbital spines. The rostrum tapers much less than in the form farther east, the sides being more nearly parallel. The areola, moreover, is not entirely obliterated in the middle, but forms a linear area. . . . The male sexual appendages do not differ from those of the Louisiana specimens. This is probably the form described by Girard."

*Associates.*—*P. clarki* occurred without associates in 84 percent of the 101 collections studied. In the remaining 16 percent of the collections its associates, in order of decreasing frequency were *P. b. acutus, O. p. longimanus, P. s. simulans, C. puer, C. hedgpethi,* and *P. hinei.*

*Life history notes.*—The seasonal cycle of *P. clarki* has been studied extensively in coastal Louisiana (Viosca, 1939, 1953; Penn, 1943) and in Japan (Suko, 1955) where it became an economic pest following its introduction in 1930. In west Texas some difference may be expected in association with differences in habitat and climate. The seasonal data from Texas are summarized in the following table.

*Ecological observations.*—In Louisiana, where it occurs in its great-

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ♂♂I | .. | 1 | .. | 15 | 2 | 8 | 1 | .. | 2 | .. | .. | 3 | 32 |
| ♂♂II | 2 | 3 | 4 | 31 | 2 | 5 | .. | .. | 1 | .. | 3 | 4 | 55 |
| ♀♀ | 1 | 3 | 1 | 27 | 6 | 9 | .. | 1 | 4 | 2 | 3 | 9 | 66 |
| ♀♀ eggs | .. | .. | .. | .. | .. | 1 | .. | .. | .. | 1 | .. | .. | 2 |
| ♂♂ juv | 17 | 28 | 1 | 29 | 4 | 27 | 2 | 2 | .. | 1 | 7 | 13 | 131 |
| ♀♀ juv | 22 | 23 | 1 | 28 | 6 | 30 | 4 | .. | .. | .. | 2 | 8 | 124 |
| Totals | 42 | 58 | 7 | 130 | 20 | 80 | 7 | 3 | 7 | 4 | 15 | 37 | 410 |

est abundance, *P. clarki* is an inhabitant of marshes, swamps and other lentic bodies of water of semipermanent nature (Penn, 1956). However, in Texas the species is found more frequently in lotic situations. The table below summarizes the data from 76 collections in Texas.

| Habitat | Percent of Total Collections |
|---|---|
| Creeks and rivers | 62 |
| Springs | 17 |
| Ponds and lakes | 13 |
| Ditches and borrow pits | 8 |

The various physical and biological factors in all habitats may be summarized in the statement that *P. clarki* occurs more frequently in deeper water, *i.e.* over 15 inches deep (59%), that is clear (54%), permanent (75%), flowing (75%), and exposed to full sunlight (68%). Four of the collections were from polluted waters (all industrial wastes). Most of the collections were from habitats with either sand and gravel (37%) or mud bottoms (37%) and with aquatic vegetation present (90%).

### *Procambarus dupratzi* PENN

(Figures 3, 22, 37, 50, 66)

*Diagnosis.*—Rostrum with a pair of lateral spines; areola about four times longer than wide; two lateral spines on each side of cephalothorax. Chela elongate with mesial margin of palm bearing a row of eight tubercles. First pleopod of form I male reaching to middle of coxopodite of third pereiopod and terminating in four parts that as a unit extend caudad at about a 40° angle to the shaft of the pleopod: mesial process spiculiform, basal two-thirds directed caudodistad at about a 45° angle, apical third bent so that it extends straight caudad; cephalic process corneous, subacute, excavate and directed caudodistad; caudal element consists of three parts: (a) caudal knob in lateral aspect inconspicuous, subacute, noncorneous, (b) caudal process corneous, acute and directed caudomesiad, and (c) accessory process corneous, forming an inconspicuous, thin, transverse ridge caudad of the central projection; central projection corneous, subacute, and directed caudodistad.

*Specimens examined.*—We have seen 338 specimens distributed by drainage systems and counties, west to east (Fig. 66) as follows: Trinity River (Anderson county), Neches River (Anderson, Henderson, Jasper, Nacogdoches, Polk, Rusk, San Augustine, Shelby, Smith, and Tyler counties), and Sabine River (Newton, Panola and Upshur counties).

Previously it had been recorded from the Trinity River (Anderson county, Penn, 1953b), Neches River (Anderson, Nacogdoches, and Shelby counties, Penn, 1953b; Nacogdoches, Penn, 1957a), and Sabine River (Panola county, Penn, 1953b).

*Associates.*—Restricted to streams of eastern Texas, *P. dupratzi* has few associates. Twenty-two collections were studied; in 59 percent of these it had no associates. In the remaining 41 percent of collections four crawfishes were associated (listed in order of decreasing frequency): *P. s. simulans*, *P. b. acutus*, *O. p. longimanus*, and *C. d. diogenes.*

*Life history notes.*—Including the Louisiana and Arkansas data, collections have been made in only six months: March through July, August and November. Form I males are present in April, May, June and August; mature females from March through July. By months the spermplug percentages are: March (0%), April (12.5%), May (69%), June (25%), and July (50%). The Texas data are summarized in the following table.

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ♂♂ I | .. | .. | .. | 1 | 9 | 27 | .. | .. | .. | .. | .. | .. | 40 |
| ♂♂ II | .. | .. | .. | 12 | 3 | 20 | .. | .. | .. | .. | .. | .. | 35 |
| ♀♀ | .. | .. | 1 | 17 | 12 | 67 | .. | .. | .. | .. | .. | .. | 97 |
| ♂♂ juv | .. | .. | .. | 3 | 6 | 70 | .. | .. | .. | .. | .. | .. | 79 |
| ♀♀ juv | .. | .. | .. | 5 | 4 | 75 | .. | .. | .. | .. | .. | .. | 84 |
| Totals | .. | .. | 1 | 41 | 34 | 259 | .. | .. | .. | .. | .. | .. | 335 |

*Ecological observations.*—In Texas as well as throughout its range, *P. dupratzi* has been found exclusively in permanent, flowing streams; rate of surface flow was recorded for nine of the 24 collections: range, 0.33 to 1.5, mean 0.95 ft/sec. Water in these streams at the sites of collections was either clear or turbid (50% each), colorless (95%), shaded or exposed to sunlight (50% each), over 15 inches deep (52%), without aquatic vegetation (58%), and with sandy-mud to mud (53%) or sand to sand and gravel bottoms (47%).

### *Procambarus natchitochae* PENN

(Figures 4, 23, 66)

*Diagnosis.*—Rostrum with a pair of lateral spines; areola about four times longer than wide; two lateral spines on each side of the cephalothorax. Chela elongate with mesial margin of palm bearing a row of eight or nine tubercles. First pleopod of form I male reaching to cephalic side of coxopodite of third pereiopod, and terminating in four parts: mesial process spiculiform and directed laterodistad; cephalic process corneous, acute, excavate caudad and extending straight distad; caudal element consisting of three parts: (a) caudal knob in lateral aspect subacute and noncorneous, (b) caudal process corneous, subacute, and directed mesiodistad, and (c) accessory process forming a thin transverse, corneous ridge caudad of the central projection; central projection corneous, truncate, and somewhat beaked distad.

*Specimens examined.*—Not previously recorded from Texas. We have seen 160 individuals, all from the Red River drainage (Fig. 66) as follows: Cass county (Black Cypress Bayou, 8.4 mi. w. Linden, TU 3412, 3434), Red River and Titus counties (Sulphur River, 3.3 mi. s. Johntown, TU 3435), and Upshur county (Little Cypress Creek, 9 mi. e. Gilmer, TU 3411).

*Associates.*—In the four Texas collections *P. natchitochae* was associated with *P. b. acutus* each time, and with *P. s. simulans*, *C. d. diogenes*, *O. p. longimanus*, and *O. difficilis* once each.

*Life history notes.*—The Texas specimens were collected in June and July only, but if these data are added to those from Louisiana (Penn, 1956) we have collections from February through August available for analysis. Form I males are present from April through August, and mature females from March through July. In April, May and June about one-third of the females have sperm plugs; in July, 94 percent of the annuli are plugged. Ovigerous females have not been observed.

*Ecological observations.*—In all respects *P. natchitochae* resembles *P. dupratzi* in being exclusively a lotic species and in having the same ecological tolerances in the streams inhabited.

### *Procambarus hinei* (ORTMANN)

(Figures 5, 24, 38, 51)

*Diagnosis.*—Rostrum tapering sharply, with slight indication of lateral spines; areola wide; without lateral spines on cephalothorax (or, only one small spine on each side in some specimens). Chelae subcylindrical, palm longer than fingers. First pleopod of form I male reaching to coxopodite of third pereiopod, and terminating in three parts: mesial process noncorneous, spiculiform and extending laterodistad; cephalic process corneous, lying near to and mesiocaudad of the mesial process, truncate near apex, and directed laterodistad; central projection corneous, acute and somewhat compressed; caudal process not developed. A shoulderlike hump is present on the cephalomesial part of the apex of the pleopod.

*Specimens examined.*—We have seen only 39 specimens from the southeastern corner of Texas as follows: Harris county (Houston, TU 1795), Liberty county (7 mi. w. Dayton, HHH 1–241–1a; 10.4 mi. s. Deevers, TU 3388), and Jefferson county (2.9 mi. sw. Fannett, TU 3386). Previously it had been reported from Liberty county by Hobbs (1945).

*Associates.*—In the four Texas collections *P. hinei* was associated with five other crawfishes; listed in order of decreasing frequency these are *P. b. acutus*, *C. puer*, *P. clarki*, *P. s. simulans*, and *C. hedgpethi*.

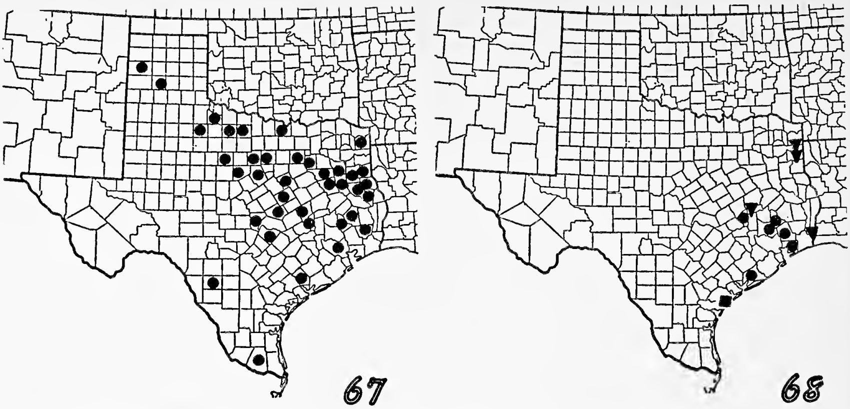
*Life history notes.*—From Texas we have seen specimens collected in only January, February and June. Form I males are present in January and June. Presumably the seasonal cycle will be found similar to that described for the species in Louisiana (Penn, 1956); spawning in the early spring (February through April) and copulation extending from December through the early part of the egg-laying period.

*Ecological observations.*—Three of the four Texas collections were from roadside ditches, the fourth from a small pond. As far as these data go they are in agreement with those given by Penn (1956) for *P. hinei* in Louisiana, *i.e.* primarily in semipermanent lentic bodies of water.

### *Procambarus simulans simulans* (FAXON)

(Figures 6, 25, 39, 52, 67)

*Diagnosis.*—Rostrum with or without angular emargination near tip; areola less than one-tenth as long as wide; a small lateral spine or




**Figs 67–68. Distribution of Texas collections by counties. 67. *Procambarus simulans simulans*, 68. *Cambarellus puer* (dots), *C. shufeldti* (closed triangles), *C. ninae* (closed square).**

tubercle on each side of cephalothorax. Chela elongate with inner margin of palm bearing seven to nine tubercles. First pleopods of form I male reaching to cephalic margin of third pereiopod and terminating in four parts: mesial process elongate, spiculiform, somewhat compressed proximad; cephalic process directly cephalad of mesial process and mesad of central projection, acute, less than half the length of the mesial process; caudal element consisting of an angulate caudal knob capped laterodistad by the caudal process that extends as a distal oblique (cephalomesad to caudolaterad) corneous ridge; central projection corneous, acute, and extending somewhat cephalolaterad.

*Specimens examined.*—This is one of the commonest of Texas crawfishes and perhaps also the most widespread (Fig. 67). We have seen 329 individuals distributed by drainage systems and counties, west to east, as follows: Rio Grande River (Hidalgo county), Canadian River (Oldham county), Nueces River (Zavala county), Lavaca River (Jackson county), Colorado River (Burnet and Travis counties), Brazos River (Bell, Brazos, Eastland, Erath, Hill, McLennan, Palo Pinto, Robertson, and Shackelford counties), Buffalo Bayou (Harris county), Trinity River (Archer, Cooke, Dallas, Kaufman, Parker, Polk, and San Jacinto counties), Neches River (Anderson, Cherokee, Hardin, Henderson, Nacogdoches, Rusk, San Augustine, Shelby, and Smith Counties), Sabine River (Panola county), and Red River (Archer, Baylor, Cass, Foard, King, and Randall counties).

Previously it had been recorded from the Canadian River (Oldham county, Penn, 1953a), Colorado River (Travis county, Faxon, 1885b), Trinity River (Dallas county, Faxon, 1884, 1885a; Goodnight, 1940), and Neches River (Hardin county, Faxon, 1914).

*Associates.*—*P. s. simulans* ranks immediately below *P. b. acutus* in number and variety of associates; however, in 65 percent of the 59 collections studied it had no associates. In order of decreasing frequency the associates in the remaining 35 percent of the collections were *P. b. acutus*, *P. dupratzi*, *P. clarki*, *O. p. longimanus*, *C. d. diogenes*, *C. hedgpethi*, *P. natchitochae*, *C. puer*, and *P. hinei*.

*Life history notes.*—We have seen Texas specimens collected in all months except October, but most of the material was collected from February through August. Ovigerous females have not been collected in Texas, but they have been reported in early September in Oklahoma by Creaser and Ortenburger (1933), in burrows in May in southern Nevada by Harris (1903), in August in south-central Kansas by Harris (1902); females carrying young were found in April in Kansas by William and Leonard (1952). The seasonal data for Texas are given in the following table.

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ♂♂I | .. | .. | 2 | 1 | .. | 1 | 3 | 1 | .. | .. | 1 | 1 | 10 |
| ♂♂II | .. | 4 | 5 | 6 | .. | 1 | 1 | 4 | 1 | .. | .. | 3 | 25 |
| ♀♀ | .. | 2 | 1 | 9 | .. | 1 | 2 | 9 | 1 | .. | 1 | 3 | 29 |
| ♂♂juv | 1 | 16 | 4 | 29 | 7 | 36 | 9 | 12 | .. | .. | 1 | .. | 115 |
| ♀♀juv | 1 | 26 | 2 | 36 | 6 | 41 | 12 | 6 | 1 | .. | .. | 2 | 133 |
| Totals | 2 | 48 | 14 | 81 | 13 | 80 | 27 | 32 | 3 | .. | 3 | 9 | 312 |

*Ecological observations.*—Williams and Leonard (1952) pointed out the ubiquity of habitats occupied by populations of *P. s. simulans* in the northern part of its range where it occurs primarily in temporary lotic bodies of water. Penn (1956) recorded it in western Louisiana primarily from permanent lentic bodies of water. The data in the following table for 49 Texas collections are similar to those from Louisiana.

| Habitat | Percent of Total Collections |
|---|---|
| Creeks and rivers | 73 |
| Ditches (mostly roadside) | 19 |
| Ponds, lakes, pools | 8 |

The various physical and biological factors in all habitats combined may be summarized in the statement that specimens of *P. s. simulans* are found more frequently in bodies of water that are permanent

(77%), flowing (73%), colorless (90%), shaded or exposed (50% each), clear or turbid (50% each), with or without aquatic vegetation (50% each), and shallow or deep (50% each). The greatest rate of surface flow recorded was 1.3 ft/sec. Three collections were from decidedly polluted streams (one each: garbage, manure, industrial wastes). Substrate was various: mud to sandy-mud, or sand to sandy gravel (50% each).

Two of the specimens examined were collected from Longhorn Cavern in Burnet county by Mr. James K. Baker. Unidentified crawfish had been reported previously from the same cave by Law (1933). He wrote that "in the pools . . . in the Big Room numerous yellow-white crayfish dash about as if frightened by the advent of light. They appear to have normal eyes and some are still unblanched. They may be immigrants into the cave from streams into which the cave empties." Mr. Baker informed the senior author (personal communication) that he has seen crawfishes in a number of other Texas caves, but no specimens have been preserved.

*Procambarus gracilis* (BUNDY)

(Figures 7, 26, 40, 53)

*Diagnosis.*—Rostrum without lateral spines, sides subparallel, converging sharply to form short acumen; areola obliterated at middle. Chela relatively short with inner margin of palm bearing a row of eight tubercles forming a subcristiform row. First pleopods of form I male reaching to anterior margin of coxopodites of third pereiopods, and terminating in four parts: mesial process elongate, curved, noncorneous; cephalic process shorter, noncorneous; central projection corneous, long and curved; caudal element consisting of an extremely small corneous caudal process with an accessory lateral point, and adventitious caudolateral bladelike process bent in a right angle with lateral side in line with sagittal plane of the body, and a small caudal process within the angle formed by the adventitious process.

*Speciments examined.*—One female from 6 miles north of Saint Jo, Montague county (HHH 8–151–1). Parks *et al.* (1939) recorded specimens from Polk county, but we believe these records are based on misidentifications and in all probability were specimens of *P. s. simulans*.

Previously published authentic records place this species in southern Oklahoma (Johnston county) (Creaser and Ortenburger, 1933; Williams, 1954), hence this Texas record is a slight southern range extension.

### *Cambarellus shufeldti* (FAXON)

(Figures 10, 27, 41, 54, 68)

*Diagnosis.*—Areola relatively narrow, four to five times longer than wide. Hooks on second pereiopods of form I male truncate, those on third pereiopods bituberculate. First pleopod of form I male terminating in three acute elements, all straight or nearly so.

*Specimens examined.*—Not previously recorded from Texas. We have seen 51 individuals from the Red River drainage (Fig. 68) in Harrison county (Caddo Lake State Park, TU 1400, 1402) and Marion county (3 mi. n. Smithland, TU 1406; Caddo Lake, TU 1929). Three specimens (1 ♂ II, 2 ♀ ♀) from a pond adjacent to the Neches River at Beaumont, Orange county (HHH 9–2653–1a) and one form I male from the Trinity River drainage (4 mi. sw. Midway, Madison county, TU 2932) are from areas out of the expected range of the species, which should reach only the northeastern corner of Texas. We postulate that these latter records resulted from recent introductions by human agency; this species has been introduced successfully outside its original range at least once (Penn, 1942).

*Associates.*—*C. shufeldti* lacked associates in five collections, and was found with *P. b. acutus* in the sixth.

*Life history notes.*—Observations by the senior author in Louisiana (Penn, 1942, 1950) indicate that this crawfish spawns the year around with peaks in the early spring and late summer.

*Ecological observations.*—Specimens of *C. shufeldti* are found most frequently and most abundantly in lentic bodies of water that are shallow, permanent, exposed to sunlight and with abundant aquatic vegetation (Penn, 1950).

### *Cambarellus puer* HOBBS

(Figures 9, 68)

*Diagnosis.*—Areola relatively narrow, five to six times longer than wide. Form I male with bituberculate hooks on third pereiopods. Lateral spines on cephalothorax weak or absent. First pleopod of form I male reaching coxopodite of third pereiopod, and terminating in three curved elements; mesial process directed caudoventrad at about an 80° angle to the shaft of the appendage.

*Specimens examined.*—We have seen 344 specimens from the southeastern corner of Texas (Fig. 68) as follows: Brazos county (11 mi. se. Bryan, HHH 12–453–1a), Chambers county (3.2 mi. w. Stowell, TU 3387), Liberty county (7 mi. w. Dayton, HHH 1–241–1b, TU 25;

Romayor, TU 2760, 2833; 10.4 mi. s. Devers, TU 3388), Matagorda county (4 mi. s. Bay City, TU P-649), Montgomery county (0.25 mi. s. New Caney, HHH 3–1151–1), and San Jacinto county (6 mi. sw. Shepherd, TU 3394). Previously it was recorded from Liberty county by Hobbs (1945).

*Associates.*—In the ten Texas collections, *C. puer* lacked associates in only three; in the other seven it was associated with *P. b. acutus, P. hinei, P. clarki, C. hedgpethi,* and *P. s. simulans.*

*Life history notes and ecological observations.*—The same statements made for *C. shufeldti* also apply to *C. puer* according to the observations by Penn (1950).

### *Cambarellus ninae* HOBBS

(Figures 8, 68)

*Diagnosis.*—Areola broad, never more than three times as long as wide. Form I male with bituberculate hooks on third pereiopods. Lateral surface of cephalothorax devoid of spines. First pleopod of form I male extending to coxopodite of third pereiopod and terminating in three distinct parts all of which are bent caudad at angles less than, equal to, or greater than a right angle.

*Specimens examined.*—This crawfish has been recorded to date from only the type locality, the Aransas Refuge, Aransas county. All known records are listed by Hobbs (1950).

*Associates.*—This crawfish was associated with *C. hedgpethi* in six of the ten collections.

*Life history notes and ecological observations.*—Ovigerous females have been collected in February and March only, form I males in January, March and April (Hobbs, 1950). The only habitat data include Hobbs' statement that the type series was collected from a roadside ditch.

### *Cambarus diogenes diogenes* GIRARD

(Figure 56)

*Diagnosis.*—Rostrum without lateral spines, concave above; areola obliterated. First pleopod of form I male reaching coxopodite of third pereiopod and terminating in two short, stout parts bent at right angles to the shaft of the appendage; mesial process slender and corneous, central projection bladelike. Chela broad, immovable finger with one prominent tubercle near base.

*Specimens examined.*—Hitherto not recorded from Texas. We have seen only ten specimens (8 of them juveniles) as follows: Cass county

(Black Cypress Bayou, 8.4 mi. w. Linden, TU 3412), Dallas county (2 mi. e. Dallas, TU 2622), Harris county (Houston, TU 1796), Orange county (Beaumont, HHH 3–2153–1), and San Augustine county (Carrizo Creek, 1.5 mi. e. San Augustine, TU 3401).

*Associates.*—Adults of *C. diogenes diogenes*, because of their burrowing habits, are rarely taken with associates; however, the juveniles (which remain in bodies of water) have been found associated with specimens of *P. b. acutus*, *P. s. simulans*, *O. p. longimanus*, *P. dupratzi*, and *P. natchitochae*.

### *Cambarus hedgpethi* HOBBS

(Figures 11, 28, 42, 55)

*Diagnosis.*—Rostrum without lateral spines; areola obliterated in the middle. Chela strongly depressed with a pominent tuft of plumose setae along base of immovable finger; opposable margin of immovable finger with two prominent tubercles near base. First pleopod of form I male reaching to posterior margin of coxopodite of third pereiopod and terminating in two parts bent at right angles to the shaft of the appendage; mesial process so grooved as to appear slightly twisted; central projection bladelike.

*Specimens examined.*—We have seen 249 individuals from Texas as follows: Aransas county (Aransas National Wildlife Refuge), Brazoria county (Brazoria), Harris county (Houston, Bellaire, 0.5 mi. s. Channelview), Matagorda county (4 mi. s. Bay City, 6.4 mi. s. Magnet), San Jacinto county (6 mi. sw. Shepherd), Titus county (2 mi. e. Mt. Pleasant), Victoria county (Victoria), and Walker county (Huntsville).

It was recorded previously from Aransas, Brazoria and Victoria counties by Hobbs (1948).

*Associates.*—In two-thirds of the 21 collections studied, this crawfish was without associates. In the remaining seven it was associated with specimens of *C. ninae*, *P. b. acutus*, *P. clarki*, *P. s. simulans*, *C. puer*, and *P. hinei*.

*Life history and ecological notes.*—We have seen specimens collected in only six months (January through April, June and December). Form I males are present in January, February, April and December; mature females in January, February, April and June. The overwhelming majority of the individuals examined are juveniles collected in February and March, indicating that egg-laying occurs in January and February. One ovigerous female was collected on February 22, 1948. The Texas seasonal data are given in the following table.

This species is a burrower as recorded previously by Hobbs (1938).

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ♂♂I | 3 | 1 | .. | 1 | .. | .. | .. | .. | .. | .. | .. | 1 | 6 |
| ♂♂II | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 |
| ♀♀ | 1 | 3 | .. | 1 | .. | 1 | .. | .. | .. | .. | .. | .. | 6 |
| ♀♀eggs | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 |
| ♂♂juv | .. | 59 | 60 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 119 |
| ♀♀juv | .. | 61 | 56 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 117 |
| Totals | 4 | 125 | 117 | 2 | .. | 1 | .. | .. | .. | .. | .. | 1 | 251 |

### *Orconectes lancifer* (HAGEN)

(Figures 12, 29, 43, 57)

*Diagnosis.*—Rostrum with lateral spines; rostrum and antennal scale decidedly elongate; areola obliterated; hooks on ischiopodites of third pereiopods only. First pleopod of form I male reaching to middle of coxopodite of second pereiopod and terminating in two short, recurved rami of which the central projection is bladelike.

*Specimens examined.*—Previously not recorded from Texas. We have seen only seven individuals from one locality: a tributary of the Red River, 8.1 mi. n. Clarksville, Red River county (TU 3436). Associated with specimens of *O. p. longimanus.* This locality is a westward range extension of approximately 150 miles from the nearest previously known westernmost locality: Natchitoches Parish, Louisiana (Penn, 1952).

### *Orconectes neglectus neglectus* (FAXON)

(Figures 13, 30, 44, 59)

*Diagnosis.*—Rostrum with poorly defined lateral spines, usually with a median carina; areola wide (length about 3.8 times narrowest width). Chela heavy, fingers conspicuously gaping at base. Hooks on ischiopodites of third pereiopods only. First pleopod of form I male reaching to coxopodite of third pereiopod and terminating in two elongate, nearly straight rami: central projection longer, corneous, with rounded shoulder on cephalic margin near base; mesial process noncorneous, flattened on distal third, and broadened near apex.

*Specimens examined.*—We have seen no Texas specimens; this subspecies is included here dubiously on the basis of the record by Faxon (1898: 652): "There are specimens . . . in S. E. Meek's collection from . . . Red River, Arthur, Texas." The nearest authenticated localities to this are in the Arkansas River drainage in northeastern Oklahoma (Creaser and Ortenburger, 1933; Williams, 1954).

### *Orconectes palmeri longimanus* (FAXON)

(Figures 14, 31, 45, 58)

*Diagnosis.*—Areola obliterated or nearly so; rostrum with well-defined lateral spines; cephalothorax with one prominent lateral spine on each side. First pleopod of form I male reaching to coxopodite of second pereiopod and terminating in two setiform rami both of which are gently recurved caudad. Chela elongate, usually nearly as long as the cephalothorax in form I males.

*Specimens examined.*—We have seen 290 individuals from Texas distributed by drainage systems and counties, west to east, as follows: Guadalupe River (Kerr county), Colorado River (Kimble and Gillespie counties), Trinity River (San Jacinto county), Neches River (Polk, San Augustine, and Shelby counties), and Red River (Franklin, Red River, and Titus counties).

It was recorded previously from the type locality in Lamar county by Faxon (1898) and from unspecified localities in drainages of the Colorado, Guadalupe, Neches, Red, San Jacinto, and Trinity rivers by Penn (1957b).

*Associates.*—In the 19 collections studied, *O. p. longimanus* was without associates in six collections; in the remaining 13 it was associated with *P. clarki*, *P. dupratzi*, *P. b. acutus*, *P. s. simulans*, *C. d. diogenes*, *P. natchitochae*, and *O. lancifer*.

*Life history notes.*—In Texas, specimens of this subspecies have been collected in only six months. Ovigerous females have not been collected anywhere in the range of the subspecies. The seasonal data for Texas collections are given in the following table.

*Ecological observations.*—Williams (1954) recorded specimens in Arkansas and eastern Oklahoma in what he considered a "wide range

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ♂♂ I | .. | .. | 1 | .. | 3 | 3 | .. | .. | .. | .. | .. | 1 | 8 |
| ♂♂ II | .. | .. | .. | .. | 5 | 2 | 16 | 1 | .. | .. | .. | .. | 24 |
| ♀♀ | .. | .. | .. | .. | 4 | 5 | 16 | .. | .. | .. | .. | 1 | 26 |
| ♂♂ juv | .. | .. | .. | .. | 2 | 50 | 60 | 3 | .. | .. | .. | .. | 115 |
| ♀♀ juv | .. | .. | .. | .. | 2 | 63 | 61 | .. | .. | .. | .. | .. | 126 |
| Totals | .. | .. | 1 | .. | 16 | 123 | 153 | 4 | .. | .. | .. | 2 | 299 |

of habitats ranging from that of swiftly flowing rocky streams to that of slowly moving mud-bottomed streams." We have examined data from twenty Texas collections: 18 (90%) are from flowing streams, two from potholes in dry creek beds. Undoubtedly some of these flowing streams are reduced to series of potholes in dry beds during the summer droughts. The various physical and biological factors affecting these habitats are: exposed to sunlight (82%), colorless (100%) clear water (53%), shallow (64%), without aquatic vegetation (64%), and with substrate of mud to sandy-mud (64%), or sand to sand and gravel (36%).

### *Orconectes difficilis* (FAXON)

(Figures 15, 32, 60)

*Diagnosis.*—Rostrum with well-defined lateral spines; areola obliterated in the middle; cephalothorax with one prominent lateral spine on each side. Pleopod of form I male reaching to anterior margin of coxopodite of third pereiopod and terminating in two short rami, both curved caudad at nearly a 90° angle to the shaft of the appendage.

*Specimens examined.*—Hitherto not recorded from Texas. We have seen only seven individuals from one collection in the Red River drainage: Little Cypress Creek, 9 mi. e. Gilmer, Upshur county (TU 3411). Associates were specimens of *P. b. acutus* and *P. natchitochae.*

The nearest records previously published are in the Canadian River system in Pittsburgh and Latimer counties, Oklahoma (Creaser and Ortenburger, 1933; Williams, 1954). The Texas locality thus represents a slight southwestern range extension.

### *Orconectes nais* (FAXON)

(Figures 16, 33, 46, 61)

*Diagnosis.*—Rostrum with lateral spines; areola narrow, but clearly open. Chela broad and flattened, immovable finger usually densely bearded near base. First pleopod of form I male reaching to posterior margin of coxopodite of second pereiopod and terminating in two parts, both gently curved caudad.

*Specimens examined.*—Previously unrecorded from Texas. Two form II males were collected from a tributary of the Red River, 6.8 mi. w. Gainesville, Cooke county (USNM 93204). It has been known from southern Oklahoma (Creaser and Ortenburger, 1933; Williams, 1954), hence this record represents a slight range extension southward.

## *Orconectes clypeatus* (HAY)

(Figures 17, 34, 47, 62)

*Diagnosis.*—Rostrum without lateral spines and barely a trace of an acumen; areola broad. Chela with inflated, subcylindrical palm, fingers about equal in length to the palm. First pleopod of form I male reaching coxopodite of first pereiopod and terminating in two rami: central projection very long, slender, subcylindrical and corneous; mesial process very short (one-third to one-half the length of the central projection), acute and noncorneous; the two pleopods overlap apically *in situ*.

*Specimens examined.*—Previously not recorded from Texas. We have seen only two individuals (one form I male and one mature female) from the Red River drainage in the northeastern corner of the state: 2 mi. e. Jefferson, Marion county (TU 1404). This record together with the one from LeFlore county in southeastern Oklahoma by Creaser and Ortenburger (1933) probably represent the westernmost geographic limits of the species.

*Life history and ecological notes.*—Specimens of this species are abundant in Louisiana where Smith (1953) studied the life cycle. She recorded spawning in September and October in association with a burrowing habit of the females. Penn (1952) recorded a summary of ecological tolerances for this crawfish in Louisiana. Largest populations occupy a wide variety of temporary and permanent lentic habitats, fewer individuals are found in lotic water.

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# Mating Call and Stage of Speciation of Two Allopatric Populations of Spadefoots (*Scaphiopus*).

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Comparison of closely related, disjunctly allopatric populations in respect to potential isolation mechanisms provides the best means of determining their stage of speciation. Comparison of their degree of divergence in morphological characters, degree of divergence in attributes that may be potential isolation mechanisms, and degree of divergence in genetic compatibility should give clues as to the possible sequence of events in the speciational process.

The two disjunct allopatric populations of spadefoots of the eastern and southern U.S. coastal plains that have been variously referred to as *Scaphiopus holbrooki* and *S. hurteri* or as subspecies of the former present an excellent case for analysis at this time. Smith (1937) and Zweifel (1956) have compared the cranial morphology in the two populations. Wasserman (1958) has determined the degree of genetic compatibility of the two and contributed to the knowledge of their spatial relations and morphological differentiation. In addition, we have recently succeeded in recording and analyzing the mating call in representatives of both populations so that they can now be compared in respect to divergence in this potential isolation mechanism.

## MATERIAL

Tape recordings of *holbrooki* were made in a small breeding aggregation on March 6, 1958. This aggregation was found in a temporary pool on the floodplain of the Flint River in Mitchell County, Georgia, opposite the town of Newton. There had been heavy rain during the day and early evening. The air temperature was 18.0°C., and the water temperature in the breeding pool was 16.0°C. John W. Crenshaw, M. J. Littlejohn, and W. H. McAlister assisted with the recording.

Tape recordings of *hurteri* were made about 7 miles southwest of Huntsville, Walker County, Texas, on March 2, 1957. These were made in a roadside pool following heavy rainfall in the late evening.

The air temperature was 16.0° C., and the water temperature was 16.0°. In addition to these, calls from a population of *hurteri* in Gonzales County, Texas, have been described by Blair (1955).

Characteristics of the calls in the two allopatric populations as measured by the sound spectrograph are shown in Table 1. Comparison of the Huntsville *hurteri* and Newton *holbrooki* is simplified by the fact that the water in which both groups were floating and calling had identical temperatures, which eliminates possible temperature effects on the characteristics of the call from consideration.

The calls in the two populations, as represented by the samples, are notably undifferentiated. The call of these spadefoots, as described and figured earlier by Blair (1955) for *hurteri* is a noise-like groan characterized structurally by a series of closely spaced harmonics of which certain ones are emphasized. The Huntsville and Newton samples could have come from the same population insofar as dominant frequency and duration of the call are concerned (Table 1). In addition, the same harmonics tend to be emphasized in both populations.

TABLE 1

Measurements of mating calls of 4 *Scaphiopus h. holbrooki* from Georgia and 3 *S. h. hurteri* from Texas. Made from sound spectrograms and "sections."

| Sample | Air °C. | $H_2O$ °C. | Dominant frequency (cps) | Duration (sec.) | Emphasized harmonics |
|---|---|---|---|---|---|
| *S. h. holbrooki* ...... | 18.0 | 16.0 | 1550 | 0.62 | 10, 11, 12, 31, 32 |
| Newton, Georgia ... | ... | ... | 1350 | 0.58 | 7, 8, 9, 28, 29 |
| | | | 1300 | 0.52 | 7, 8, 9, 27, 28 |
| | | | 1300 | 0.56 | 7, 8, 9, 28, 29 |
| *S. h. hurteri* ....... | 16.0 | 16.0 | 1400 | 0.62 | 7, 8, 9, 29, 30, 31 |
| Huntsville, Texas ... | ... | ... | 1710 | 0.62 | 7, 8,9, 10, 29, 30, 31 |
| | | | 1325 | 0.62 | 8, 9, 10, 11, 29, 30, 31 |

The population of *hurteri* previously reported by Blair (1955) shows more differences from the Huntsville *hurteri* than that population does from the Newton *holbrooki*. There are two possible explanations for the difference in the *hurteri* samples, which are mainly differences in duration, but adequate material is not yet available to show which of these is most likely. First, the Gonzales County *hurteri* were calling in water 3.5°C. warmer than were the Huntsville *hurteri*, but from work with other species (Blair, 1958) this difference should have had minor effects. Secondly, the former sample is from an area of sympatry with *S. couchi*, and the shorter call of the Gonzales County *hurteri* could represent reinforcement of the principal call difference (duration) between these sympatric species. The Huntsville *hurteri* are from an area in which no other member of the genus occurs, as is also the entire population of *holbrooki*.

## DISCUSSION

Analysis of these allopatric populations gives some indication of the sequence in which the various changes associated with speciation have occurred. As Wasserman (1958) has theorized, it seems likely that geographical isolation of these populations dates from the Pleistocene, and as Wasserman has pointed out a soil barrier in the Mississippi Embayment appears to be the critical factor enforcing this separation today. It should be inserted parenthetically that Wasserman (1958) has shown Zweifel (1956) to be in error in reporting sympatric occurrence of these two populations. Available information indicates that the two are separated by the Mississippi Embayment. It seems likely that the separation of the two populations occurred as late as the Wisconsin glacial stage, but it cannot be proved that it did not occur earlier.

The two populations have diverged morphologically to the extent that some recent workers (Smith, 1937; Zweifel, 1956) have considered them to be distinct species on the basis of morphological criteria. The differences involve the width of the fronto-parietal region of the skull and the presence in *hurteri*, absence in *holbrooki*, of a bony interorbital boss, as well as some differences in external color, pattern, and texture (Wasserman, 1956). There seems little doubt that as fossils, or in the absence of other than morphological criteria, these might be regarded by most workers as good species.

Other evidence gives a somewhat different picture of the evolutionary status of these populations. Wasserman (1958) has shown that these populations have retained a high degree of genetic compatibility. His hybrids from both reciprocals of the cross showed viability comparable to that of the controls. Hybrid males from the cross of *hurteri* ♀ × *holbrooki* ♂ proved fertile in backcrosses to both parent types. A hybrid female proved fertile when backcrossed to a *hurteri* male. An $F_1$ male from *holbrooki* ♀ × *hurteri* ♂ proved fertile when backcrossed to a *hurteri* male. The other hybrids were not tested, but all of his evidence indicates a high degree of genetic compatibility between the two populations. This is not unexpected, since sympatric species commonly retain interfertility and are maintained as separate breeding systems by complexes of ethological and ecological isolation mechanisms. The absence of genetic incompatibility is important in the present instance, because in the absence of ethological and ecological isolation mechanisms the population would be able to interbreed successfully if they should ever come in contact.

When potential isolation mechanisms of an ethological and ecological nature are considered, it seems doubtful that any barrier to interbreeding of *hurteri* and *holbrooki* would exist if one or both populations succeeded in surmounting the soil barrier that presently separates their ranges. The mating call, differentiation of which constitutes the most important ethological isolation mechanism in anuran amphibians, is essentially identical in the two populations if our samples are representative. Both are inhabitants of sandy soils, so there is no indication of any possible ecological isolation by soil type such as Wasserman (1957) found in *hurteri* and *couchi*. Both are opportunistic breeders, aggregating in temporary pools after heavy rains. The Huntsville *hurteri* and Newton *holbrooki* were found breeding at almost identical times of the year and under almost identical temperatures.

In these two allopatric populations we have a situation, then, of considerable morphological distinction but no indication of incipient isolation mechanisms. This situation is open to two possible interpretations, neither of which can be proved. Morphological differences, including skeletal ones, may have evolved faster in geographical separation than did behavioral differences that might function as incipient isolation mechanisms. The alternative explanation would be that the morphological differences represent wholly or in part racial differences that existed before the postulated Pleistocene fragmentation of the ancestral range, thus creating an illusion of faster differentiation in morphological than in behavioral characters. The present evolutionary stage of these populations appears to be one short of separation into biologically distinct species, in which our interpretation agrees with that of Wasserman (1958).

## SUMMARY

Analysis of sample mating calls from the allopatric populations of spadefoots commonly referred to as *Scaphiopus holbrooki* and *S. hurteri* on the sound spectrograph reveals no differences between the two populations. Furthermore, all available evidence points to the absence of any potential isolation mechanisms, including genetic incompatibility, between these two populations. Thus, in spite of morphological divergence that has led some workers to regard these as distinct species, they do not appear to have reached the stage of evolutionary diverg-

ence at which they would maintain their distinctness if they should transgress the present soil-type barrier separating them.

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# Occurrence of the Amazon Molly, *Mollienesia formosa*, at San Marcos, Texas

*by* **GEORGE E. DREWRY, EXALTON A. DELCO, JR.,** *and* **CLARK HUBBS**

The University of Texas

The amazon molly, *Mollienesia formosa* (Girard), has long been known to occur in extreme southern Texas. Its type locality is at Palo (mispelled Paolo) Alto (Girard, 1859), presumably the Palo Alto Battlefield east of Brownsville. Hubbs and Hubbs (1932 and 1946), Meyer (1938), and Hubbs (1955) have pointed out that it ranges from south Texas to the vicinity of Vera Cruz, Mexico. No authors have suggested any appreciable northerly increase in its known range, *i.e.*, in the United States, *M. formosa* is known only from Hidalgo, Willacy, and Cameron counties, Texas. As this species is the only known essentially gynogenetic vertebrate in nature and only one natural phenotypic male is known (Hubbs, Drewry, and Warburton, in press) any range extension is of interest.

Three collections obtained from the San Marcos River just east of the Southland Ice Plant in San Marcos during October, 1958, have contained specimens of *M. formosa*. The authors together with Mrs. Drewry and Robert Beyers variously participated in the collection operations. An addition sample was made during the suring of 1958 by Mr. William F. Hettler. He obtained two living *M. formosa* from the San Marcos region, but the precise locality is uncertain. In the laboratory these females had several broods that were all females of uniform size, which called our attention to the fish and we noted that they were *M. formosa*. Subsequently we collected the fish on which this report is based.

Earlier collections from the vicinity have been reexamined and none include *M. formosa*. Thereby, it is possible that *M. formosa* has recently been introduced at San Marcos and that the introduction was successful. Brown (1953) considered that the only other northern molly, *M. latipinna* LeSueur, was also introduced at San Marcos, supporting our conclusion that *M. formosa* was introduced.

There is little doubt of the identity of these fish as *M. formosa*. In addition to the unique uniform size of the all female broods, the morphology is similar to that of *M. formosa* from the type locality. There are 11 dorsal rays, the modal number for *M. formosa*. There are 10 scale rows between the dorsal origin and occiput, a number typical of female *M. formosa*. The dorsal base is contained 2.5 times in the predorsal length. In all of these criteria the fish differ from *M. latipinna* and *M. sphenops* (Cuvier and Valenciennes), the only species of *Mollienesia* ranging as far north as northern Mexico. Likewise the *M. formosa* from San Marcos have lateral spots like those of *M. formosa* from Palo Alto as well as other typical *M. formosa* colors. The San Marcos fish have a slightly heavier build than South Texas *M. formosa*, but this is probably due to environmental factors, such as better food and/or colder temperatures during ontoeny. Hubbs and Springer (1957) thought that either or both of these factors were responsible for heavier builds in experimental stocks of species of *Gambusia*.

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## Science in Texas

A further advance into the nucleonic sciences has been taken by Texas A. and M. College with the addition of a 256 channel analyzer to the present AGN 201 reactor facility being operated for the College by the Texas Engineering Experiment Station for education and research. By use of the analyzer in conjunction with the nuclear reactor and card punch units from the digital computer, most solid and liquid substances can be analyzed qualitatively and quantitatively in a matter of minutes without chemical separation. The machine accomplishes with extreme accuracy while one waits what otherwise requires hours or days of analytical effort in a laboratory. It is capable of identifying as many as 50 unknown elements in the sample, according to Dr. Richard E. Wainerdi, coordinator of the reactor program.

Because of its extreme accuracy and speed the facility is expected to have immediate application in the many fields of science represented in the College and in the industries of Texas. Most obvious applications are those of medicine and geology.

Dr. Wainerdi says, "samples received for analysis are first put in the reactor in the presence of neutrons. After bombardment they are brought out in front of a scintillation probe attached to the analyzer. The probe has a sodium iodide crystal. The sample emits gamma rays, some of which go into the probe and the crystal luminesses and produces light emissions which in turn cause electrical impulses. A pulse is produced for each gamma ray entering the crystal of the probe. The machine's converter then sorts the pulses into what corresponds in 256 channels as stored memory. The pulses, in addition to being in the memory, can be displayed in electro-magnetic spectrum on the cathode ray tube. In addition, a strip chart recorder records what is in the memory and shown in the spectrum. Final identification is accomplished by interpreting the displayed and plotted information by comparing it with established nuclear activation reference data on chemical elements."

Computer card punch units are being used alongside the analyzer to mechanize identification. Eventually, a computer will tie directly into the analyzer and recognition of elements will be accomplished almost simultaneously with avoidance of reference work.

Dr. Frederick A. Matsen, chemist-physicist at the University of Texas, was one of six scientists from the United States and Europe invited to lecture at the University of Upsala international summer school on quantum mechanics at Valadalen, Sweden. Three scientists from the United States and three from England, Germany and Sweden conducted the school.

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Dr. Louis S. Kornicker, marine geologist at the University of Texas Institute of Marine Science at Port Aransas, was awarded a grant of $14,000 by the National Science Foundation last summer for a two-year study of living ostracods in Texas bays. Ostracods are small, shell-covered marine animals with no backbones. Dr. Kornicher's findings will help marine geologists in their interpreations of dead ostracod content in sediments in Texas bays and older strata. Study of modern sediments as a means of explaining geological patterns is a recent advancement in geologic strata identification.

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Dr. Bassett Maguire, University zoologist, has received $8,000 from N. S. F. for a three-year study of how small aquatic organisms are transported from one body of water to another across dry land. His findings will aid evaluation of current theories on what happens when animal populations in one area are suddenly found thriving in an isolated region. He will try to determine the characteristics which enable some organisms to be transported alive to a new area, colonize it, and then persist in that area, while other organisms are unsuccessful at survival.

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A grant of $87,350 was made by the Atomic Energy Commission to The University of Texas this fall for purchase of a new subcritical reactor, a neutron source-producing accelerator or Van de Graaf "atom smasher," and other nuclear science and engineering equipment. It will be used primarily for undergraduate and early graduate training. The subcritical reactor is designed to be relatively simple so that students on the junior level will find it easier to use and understand, Dr. Little, acting Physics Department chairman noted. It is almost as useful a tool as a nuclear reactor, and it doesn't produce enough radioactivity to be dangerous.

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A new building to house the Central Research Laboratory of Texas Instruments, Inc., has recently been started. It will be located on T. I.'s 300-acre north central expressway site in Dallas. Completion is expected in early 1959. The research building will be of steel, masonry and glass construction. Design will be in keeping with the activity it will house. Construction costs will be about $3,000,000.

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Beginning this fall, A. and M. College offers a Ph.D. program in Meteorology. A large scale training program has been offered by the College for forty years. Extension of this program to the Ph.D. level is expected also to help combat the serious shortages of adequately trained meteorologists in the country. In the past, students from Texas and neighboring states have had to travel to Los Angeles, Chicago, or to the East, if they were interested in training for professional meteorology.

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Dr. Royston M. Roberts, University of Texas chemist who discovered a new type of molecular rearrangement has received $16,800, from the National Science Foundation to support two years of basic research on "unsettled molecules." Dr. Roberts, after observing a "reshuffle" of atoms within the molecule, advanced a new theory to explain his unusual observations. He will use the research grant to continue his experiments and retest every facet of the theory.

Radioactive carbon—Carbon 14—is used to trace the changes in position the carbon atom takes during a molecular rearrangement. The University chemist "tags" the carbon atom with radioactive isotopes so he can trace the changes in the atom's position.

Knowledge of molecular rearrangements played a part in increasing the production of high octane gasoline from crude oil and helped produce the material for nylon. Dr. Roberts will work directly with organic compounds called alkylbenzenes, studying how they are affected by Lewis acids—acids sometimes used as catalysts to speed up chemical reactions.

★ ★ ★ ★

Nuclear physicists at The University of Texas will search for new facts about "atom splitting" and "neutron scattering" on a $50,000 contract from the Atomic Energy Commission. The new contract runs for nine months through March 31, 1959. The 1957–58 contract, $45,-804, was for 12 months. The funds will support basic research at the Nuclear Physics Research Laboratory.

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Texas A. and M. College has received an $800,000 four-floor building at Galveston, for use as a research and teaching center for oceanography and meteorology. The structure, built in 1947, and 2.87 acres of land near the beach have been transferred to Texas A. and M. College by the U. S. Department of Health, Education and Welfare.

The building at Galveston provides the Department of Oceanography and Meteorology with permanent quarters for continuing research and teaching work carried on since 1949. The new facility provides space for offices, laboratories and quarters for visiting scientists and for administrative offices for research relating to the ships used by the department. These vessels, the A. A. Jakkula, the Elena, and the Hidalgo, are owned by the Texas A. and M. Research Foundation.

The Hidalgo, a 126-foot motor vessel, valued at $90,000, was given this past summer by the Pan American Petroleum Corporation, Houston to the Foundation for use in oceanographic research.

Foundation director, Archie M. Kahan, says the motor vessel, "Hidalgo," is particularly well suited to both in-shore and long-range work in the Gulf of Mexico. Powered by two 500-horsepower engines, it has an 11-knots cruising speed, 14-knots top speed and a range of 4,000 miles. The vessel will accommodate 21 scientists and crew members.

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The Surgeon General's Office of the U. S. Army has granted approximately $83,000 to finance two studies using some of the nuclear science facilities of the Texas Engineering Experiment Station, to investigate influences of low intensity radiation on rats and mice. The research will be a cooperative work with the Texas A. and M. Research Foundation, which negotiated the contracts with the Surgeon General's Office, the nuclear science facilities of the Texas Engineering Experiment Station, and members of the staff of the college's Department of Biology, staff of the Biological Research Laboratory of the Research Foundation, and the School of Household Arts and Sciences of Texas Women's University. Directing the research here is Dr. Sidney O. Brown, professor of zoology at Texas A. and M. College.

Dr. Brown will direct over-all operations of two projects, one of which is aimed at finding out how continuous, low-level, not immediately lethal radiations affect albino rats and mice. In this experiment, rats will be exposed to radiations from Cobalt 60, in a specially-constructed 30 x 30 foot radiation chamber to be built on the campus this summer. Records will be kept and analyzed, on weight gains, general appearance and experimental procedures will be carried out to determine what effects the radiations have on wound healing, bone growth, and recovery from shock conditions. Some of the animals will be put on protein and vitamin deficient diets, and then subjected to radiation, in another effort to find out just how these diets and radiation will affect the animals.

Nuclear science facilities and staff of A. and M. will also be used in cooperation with a research work now under way at Texas Women's University. This project is one headed by Dr. Pauline B. Mack, and is aimed at studying the influence of radiation on bone development in rats and mice. The animals will be placed in the radiation chamber and removed at intervals for X-rays. The X-ray plates will then be developed and analyzed in a densiometer, by Dr. Mack. Here, the work is aimed at finding out the effects of continuous radiation on bone growth and density.

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Electrical Engineering Research Laboratory engineers from The University of Texas are using a 1435-foot television tower in Dallas to study the "low level jet," high speed winds which occur at low levels and pose possible threats to jet planes during take-off and landing. EERL engineers are engaged in a three-year investigation at the request of the U. S. Air Force Cambridge Research Center, which awarded $45,000 for the first year's research. John Randolph Gerhardt, EERL assistant director, is in charge of the project.

"In this meteorological study of wind and temperature variations with height, our particular emphasis will be on the 'low level jet'," Gerhardt said. This "low level jet," winds whirling up to a maximum velocity of 40 miles an hour, is usually found at about the 1,000-foot level, for example. The winds at ground level and at 2,000 feet may, in contrast, be blowing at about 10 miles per hour. Such unexpected high wind speeds at 1,000-foot levels "could be hazardous" for planes during take-off, because jet planes especially are sensitive to erratic wind speed changes.

Gerhardt also indicated the possibility that the "low level jet" may be involved in a number of unexplained airplane crashes. "This possibility should be investigated," he added. Such rapidly moving winds at 1,000-foot levels may serve as a "trigger mechanism" for night thunderstorms or squall lines, or to form heavy hail storms, he continued. The "low level jet" may conceivably be associated with tornado activity.

The "low level jet" appears to be only a nighttime phenomenon, but EERL engineers will measure the wind speeds around-the-clock in order to obtain enough comparative data on the wind speed variations. The data will be recorded on tapes or punched cards after it is relayed from the tower instruments to the transmission buildings.

Dr. Kenneth A. Kobe, University of Texas chemical engineering department chairman, has recently patented a new process which produces vinyl chloride more quickly and more economically. Vinyl chloride serves as a "building block" for a group of plastic resins which are volume leaders in the plastic industry. Polyvinyl chloride resins are used to make such items as tablecloths, shower curtains, electrical insulation, shoes, phonograph records, food containers and upholstery materials. Dr. R. Emerson Lynn, Jr., Akron, Ohio, is co-owner of the patent. With the Kobe-Lynn process vinyl chloride is made directly from dilute acetylene gases.

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A 60-foot aluminum tower has been erected at Texas A. and M. College for use in the initial phase of a research project being conducted by the Texas Transportation Institute of the Texas A. and M. College System for the State Highway Department. Charles J. Keese, professor of civil engineering, A. and M. College, and research engineer, Texas Transportation Institute, is in charge of the research project, an investigation of the effects of highway lighting on traffic operation.

Purpose of the investigation, which Professor Keese says will probably continue for at least a year, is to determine the effects of different degrees of intersectional lighting on traffic behavior. The tower, located near Highway 6 will be used to perfect the procedure for making motion pictures of highway traffic at night.

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The most effective spray and solids distribution system for serving recognized needs in agricultural aviation is being sought for the new Grumman Ag-Cat in a special research endeavor at the Texas Engineering Experiment Station, Texas A. and M. College. The work is being conducted under the supervision of Joseph C. Brusse and involves considerable test flying over the Texas Engineering Experiment Station's spray and dust measuring platform in the Brazos river bottoms which is inset with 21 delicate balances for extremely accurate distribution gauging.

The Ag-Cat is a biplane with a wing span of 35 feet, 8 inches; an overall length of 24 feet, 4 inches; and low power (220 to 300 horsepower). It weighs 2079 pounds empty and carries a payload (spray or solids) of 1000 pounds. Its maximum gross weight with pilot, fuel, and load is 3500 pounds. It permits a maximum speed (level) of 115 miles per hour and a stall speed of 38 miles per hour.

Dr. George Willard Watt (a University of Texas chemistry professor) has received a $21,704 Atomic Energy Commission contract to continue his basic research into the nature of the mysterious forces that hold atoms together. Dr. Watt, who worked on the now-famous "Manhattan Project" which produced the atomic bomb, will study the mechanism of chemical reactions in order to learn more about what bonds hold atoms together after reactions. A better understanding of atomic bonding will enable chemists to predict the roles of catalysts in chemical reactions.

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An effort to reduce the tremendous losses of surface water supplies through evaporation is being taken by scientists of the Texas A. and M. College System. The State Board of Water Engineers is financing a $25,000 project concerned with evaporation control on water reservoirs. Members of the staff of the A. and M. College Chemical Engineering department and the Texas Agricultural Experiment Station will conduct the research.

Dr. W. D. Harris, professor of chemical engineering, stated that "a chemical film has been developed and proved for reducing evaporation and we are trying to devise a practical and economical method of placing it on the surface of the water." The chemical film is a commercial compound that has been tested by the U. S. Food and Drug Administration for this specific purpose. Tests have shown the chemical to be harmless to people, fish and livestock. The chemical is a white, flaky compound and when placed on the water it produces a film that is one molecule thick. That would be much less than the thickness of the paper used in the printing of newspapers.

"Placing on the surface of ponds and lakes, the chemical covering will reduce evaporation by as much as 60 or more per cent," Dr. Harris said. This would result in a great saving of water as data from the Texas Agricultural Experiment Station indicates that evaporation losses in Texas, even in a year of normal rainfall, just about equals the total consumption for all purposes in the state. Before such a saving will ever materialize, however, many problems will have to be solved. For instance, the scientists must determine the most feasible method of distributing the film on bodies of water and they must find out how long the film will remain on the water. Weeds and grass will soak up some of the compound and some will be blown off the water by wind. Over a certain period of time, a small amount of the chemical will dissolve in the water. Dr. Harris said the film spreads over the surface of the water like oil, but, unlike oil, it will not shut off the supply of oxygen.

Studies to solve the problem of evaporation are not new. There have been numerous projects, both in this country and abroad. But despite these numerous projects, the principal drawback is that no economical method of placing the film on the water has been developed.

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As compared with similar systems previously developed, a gas-fired absorption refrigeration system developed by Southwest Research Institute shows a 50% improvement in the coefficient of performance, a 30% reduction in fuel consumption and a 25% reduction in cooling water requirements. The announcement was made in a paper by Drs. Eugene P. Whitlow, chairman of the Department of Chemical Engineering and Judson S. Swearingen, technical director, Petroleum Technology, Southwest Research Institute, read at a meeting of the American Institute of Chemical Engineers, in Galveston October 3. The system can also be used for heating and thus provides year-round air conditioning. It was invented and developed as SWRI in a two-year research program for the American Gas Association.

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Dr. Frank N. Edmonds, University of Texas astronomer, has received a $3,000 National Science Foundation grant for research on the sun's bubbling hydrogen gases.

The gases may cause the phenomenon of "temperature reversal" in the sun's atmosphere. At the sun's surface, the temperature is 6,000 degrees centigrade, a drop of millions of degrees from the heat at the sun's center. Yet. going out from the sun's surface into the chromosphere and on to the corona, the outermost layer of the sun's atmosphere, the ttemperature zooms back to one million degrees.

Dr. Edmonds will try to learn about the temperature fluctuations by investigating solar garnules, bright spots on the sun's surface which are presumably convection in which currents of turbulent gases are rising and falling. This convection occurs in the solar hydrogen convection zone just under the sun's surface and plays an important part in the transport of energy from the hot solar interior outward to the surface, Dr. Edmonds said. He hopes to calculate the amount of heat energy being brought to the sun's surface by this convection. These data will help astronomers determine more accurately the physical conditions (temperature, density, pressure) on the sun's surface and in the hydrogen convection zone.

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Drs. Charles G. Skinner and William Shive, University of Texas biochemists, have discovered a new combination of plant growth chemicals which significantly speeds up lettuce seed germination.

In experiments at the Clayton Foundation Biochemical institute, they are believed to be the first to find that lettuce seed will germinate faster if pre-soaked in a chemical solution combining the powerful "kick" of gibberellin and certain purine derivatives. Lettuce seed will not usually germinate in the dark and at warm temperatures, but seed pretreated with the two chemicals will grow under these adverse conditions, Dr. Skinner noted.

Gibberellin alone increases the rate of lettuce seed germination, just as certain purine derivatives also speed up initial plant growth. In combination, the two chemicals "pack a powerful wallop" by inducing rapid initial plant growth. This cooperative or "synergistic" action significantly increased the speed of lettuce seed germination with several varieties tested.

Gibberellin is a powerful plant growth booster found in a certain type fungus. Purine derivatives are nitrogen-containing compounds essential for both plant and animal growth processes.

The University scientists also studied effects of gibberellin and purine derivatives alone and in combination upon carpet grass and clover seed. They noted an "appreciable increase" in growth, but not as great an increase as with the lettuce seed.

Pretreatment with gibberellin and purine derivatives causes lettuce seed to burst into immediate and rapid growth, Dr. Skinner continued. "We could possibly make the plant grow faster earlier in the growing season when there is more rain. Then when the dry part of the growing season arrives, the plant may have reached a stage of maturity which will insure its survival." These effects, however, have been observed only in laboratory experiments. Field tests have not been made.

"Man's knowledge of plant germination and chemical effects on biological growth is meager," Dr. Skinner said. "In our experiments, we hope to learn more about what biochemical actions take place when the seed suddenly bursts from dormancy into growth."

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Dr. Gunnar Gjerstad, University of Texas specialist in the science of medicinal drugs, recently received a $2,300 U.S. Public Health Service grant to investigate the effect of gibberellic acid—a powerful plant growth booster—on certain drug plants.

Results of this research may lead to reduction of the high costs of certain medicines produced from plant extracts.

"Gibberellic acid makes plants grow to phenomenal sizes," Dr. Gjerstad pointed out. He will analyze what happens to the active medicinal ingredient as the plant grows larger than usual, and will experiment with several drug plants which thrive in Texas, growing the plants under greenhouse conditions and in the drug garden.

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The Texas A. and M. Research Foundation has been awarded a grant of $16,400 by the National Science Foundation for the support of basic research of the oceanographic environment of the West Mississippi Delta area. The research study will be under the direction of Dr. R. G. Bader, associate professor in the Department of Oceanography and Meteorology, Texas A. and M. College. The grant became effective Aug. 27, 1958, and is for a two-year study.

Objective of the study is to determine the interrelationships between the despositional and physical oceanographic environment of the Western Mississippi Delta area.

The grant from the National Science Foundation is for the evaluation of data already on file from the U. S. Army Corps of Engineers, the Office of Naval Research, the cruise program of the Oceanography and Meteorology Department and from an Atomic Energy Commission research project that Dr. Bader directs.

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Slag from burned Texas lignite may be a part of the quiet, non-skid highway surfaces of the future. This by-product of the combustion of lignite in power plant boilers at Alcoa's Rockdale Works is being tested at Texas A. and M. College as a potential street and highway paving material.

Bob M. Gallaway, who is in charge of the research project, says tests up to now have shown that mixes made with the slag will compete economically with paving materials in present use. "Test strips have already shown that the material has high, non-skid qualities and provides an exceptionally quiet riding surface," Gallaway said.

Two test strips have been laid. One of these is 24 feet wide and 400 feet long—a part of Highway 6 just south of College Station. The other is a 600-foot section of Oak Lawn Street in Bryan. Gallaway believes the real application of the material would probably be for city streets because of its quiet, non-skid features. It can be put down in layers as thin as a quarter of an inch provided the structure of the street is sound.

Non-skid characteristics were increased in tests by the addition of limestone screenings. Differential in rate of wear resulted when one part of limestone was mixed with three parts of slag. The limestone screenings are softer, therefore the non-skid surface is renewed as the pavement wears. Alcoa's plant at Rockdale produces its power by burning lignite. About 450 tons of slag is collected each day. The company has been stockpiling the slag for five years and now has about a half million cubic yards on hand. Source of supply for this new paving material is assured for many years as many parts of the state have lignite resources. During a period of years prior to the discovery of large oil and gas deposits in the eastern part of the state, Texas was producing more than a million tons of lignite annually. Should lignite be used on a wide scale in the future, large tonnages of this paving material will be made available.

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Gerardo Senz, of Ballinger, pursuing research in Mexico during the summer of 1958, discovered the exact birth date of an important Mexican poet, who died in 1934. The discovery was headline news in Mexico City's three largest daily newspapers. Working on his doctoral dissertation research in Romance Languages at the University of Texas, Mr. Senz found Luis G. Urbina's baptismal certificate in the Sagario (parish) of the Cathedral in Mexico City. Urbina's birth date was given as February 8, 1864, "not in 1867, 1868 or 1869 as many writers say. And apparently Urbina himself was not sure of his birth date, for even in declarations for various documents and interviews, he was vague about it, and never came anywhere near 1864," Saenz reports. "This was due largely to the fact that he was born of a humble family and the forgetting of a birth date is not unusual under such circumstances."

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Announcement was made during the summer of 1958 of award by the Civil Aeronautics Administration of a contract to Texas Instruments, Incorporated, in the amount of $5,928,000 for airport surveillance radar systems to be installed at 19 different sites. Installations will be made in Texas, eleven other states, and the District of Columbia.

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A number of staff changes have been announced recetnly by Texas Instruments, Incorporated, of Dallas. Cecil Covington has been named Manager of Government Contracts Administration; Rear Admiral (ret.) Chester W. Nimitz, Jr., succeeds him as Controller of the Apparatus Division. J. S. Dufford has been assigned to the newly created position of Assistant Vice President, Head of Quality Assurance and Industrial Engineering. Walter H. Owen has been named Manager of Manufacturing. Effective this fall, E. C. Karnavas was appointed Manager of the Capacitor department of T. I.'s Semiconductor Components division.

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## Cover Picture

Pleopods of several crawfishes in Texas. Crawfish pleopods are used in copulation and serve as excellent diagnostic aids in species identifications. For further information on crawfishes, see "A contribution toward a knowledge of the crawfishes of Texas (Decapoda, Astacidae)" by George Henry Penn and Horton H. Hobbs, Jr. The picture is taken from figs. 1–10 of their paper.