OCCURRENCE OF LOWER OLIGOCENE MAMMAL-BEARING BEDS NEAR DEATH VALLEY, CALIFORNIA

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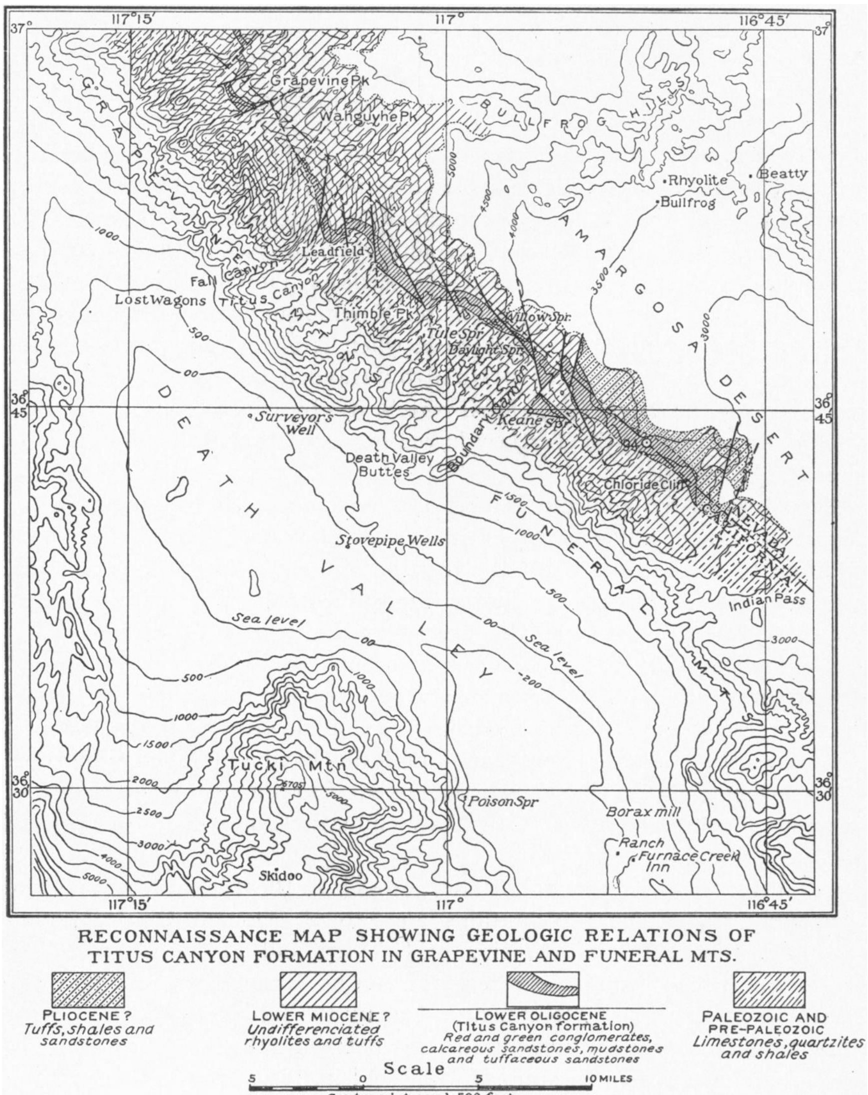
Introduction.—It is a curious fact that while the White River deposits with their wealth of vertebrate fossils are widely distributed in the western Great Plains and occur also in certain of the intermontane basins of the Cordilleran province, no horizon, recognized on the basis of land mammals as equivalent in time to the lower Oligocene or Titanotherium Zone, has been found beyond these areas on the North American continent.[1] All the more unusual does this fact seem when it is realized that since the definition of the White River Group by Hayden in 1862 and the early researches on the White River fossil vertebrates by Leidy, Cope and Marsh, field investigations in the Tertiary have progressed broadly and intensively over the Far West.

Discovery of a significant record of this stage of the Oligocene in the Amargosa range, adjacent to Death Valley, not only brings a welcome addition to our knowledge of the distribution and relationships of lower Oligocene faunas, but also possesses important implications with regard to the early Tertiary history of this portion of the western Great Basin.

The region, due in large measure perhaps to its inaccessibility and desolateness, has received in the main only reconnaissance study. However, the early investigations of the geology of the Grapevine and Funeral Mountains by Gilbert,[2] Spurr and by Ball elucidated much important information as part of the noteworthy contributions made by these surveys to an understanding of the stratigraphy and structure of southern Nevada and eastern California.

Credit for the discovery of vertebrate fossils in the Tertiary series of the Grapevine and Funeral Mountains goes to H. Donald Curry, former graduate student in the Division of Geology and Paleontology at the California Institute and more recently Acting Ranger-Naturalist at the Death Valley National Monument. During the fall of 1934, Mr. Curry, while traveling over the little-used road between Rhyolite, Nevada, and the now deserted mining camp of Leadfield in Titus Canyon, Grapevine Mountains, saw and collected, in an outcrop of maroon or chocolate-colored, calcareous mudstones exposed in the face of a road-cut, a portion of a titanothere jaw with teeth. Later, excavations at this locality (Locality 253 Calif. Inst. Tech. Vert. Pale.) revealed additional lower jaw material as well as a splendidly preserved skull of a titanothere. Subsequent investigations conducted by field parties from the California Institute have been generously permitted by the National Park Service.

History of Geologic Studies in Region.—The first detailed description of



RECONNAISSANCE MAP SHOWING GEOLOGIC RELATIONS OF TITUS CANYON FORMATION IN GRAPEVINE AND FUNERAL MTS.

PLATE 1

Tertiary sediments in southwestern Nevada was made by H. W. Turner[3] in 1900. Turner described a succession of conglomerates, sandstones, tuffs and associated flows of rhyolite and andesite in the vicinity of the

Silver Peak Range, 100 miles northwest of the Grapevine Mountains, and named the series the Esmeralda. The basal beds of the series were found to lie unconformably on Paleozoic rocks. Although a probable Miocene age was given to the series, it was recognized that a range in age from Eocene to Pliocene might well be represented.

Spurr[4] in the same year referred the Esmeralda to the late Eocene or early Miocene because part of this series occurs beneath the oldest rhyolite in the Silver Peak Range, which he regarded as of Eocene age. Three years later Spurr[5] described the sediments occurring along the east side of the Amargosa Range and in Death Valley, referred them to the Esmeralda, and reiterated his earlier statement that this formation is late Eocene to early Miocene in age. In 1905 Spurr[6] described the Siebert Tuff at Tonopah, Nevada, and referred this deposit to the middle or late Miocene, distinguishing it from the Esmeralda, which he regarded as older.

In 1907 Ball[7] gave a more detailed description of the Tertiary sediments on the east side of the Amargosa Range and in Death Valley. Ball noted that conglomerates exposed in the vicinity of Boundary Canyon contained boulders of rhyolite. Believing that these boulders were derived from an early Miocene rhyolite, exposed in the immediate vicinity, Ball referred the conglomerates to the middle Miocene and correlated them, as well as the borax-bearing sediments in Death Valley with the "Siebert Lake Beds," the Siebert Tuff of Spurr. In reality, however, the rhyolite boulders in the vicinity of Boundary Canyon have their origin in rocks belonging to an older period of vulcanism, and the sediments in this area observed by Ball are older than and lie beneath his early Miocene rhyolites.

Occurrence.—The sedimentary series containing fossil vertebrates outcrop in a narrow, almost continuous, belt along the eastern side of the Grapevine and Funeral Mountains. Position of this belt coincides roughly with the California-Nevada state boundary in this region and extends from a point a few miles northwest of Grapevine Peak southeasterly to a point approximately five miles southeast of Chloride Cliff. The beds comprise quartzite conglomerates, sandstones, calcareous mudstones, algal limestones and tuffaceous sandstones. At the base is a limestone breccia. This series of sediments is here designated the *Titus Canyon formation*, from its typical occurrence in Titus Canyon near Leadfield, California. The Titus Canyon formation dips in an E to NE direction off the east flank of the Grapevine and Funeral Mountains and lies with marked unconformity upon Paleozoic sediments, frequently with a strike nearly at right angles to the structure discerned in the older rocks. It is overlain unconformably by 400–500 feet of conglomerate, which is interbedded with and lenses upward into rhyolite flows unquestionably the correlative of Rhyolite No. 1, the lowermost volcanic flow recognized by Emmons and Garrey in the Bullfrog Hills, Nevada. In the vicinity of Titus Canyon

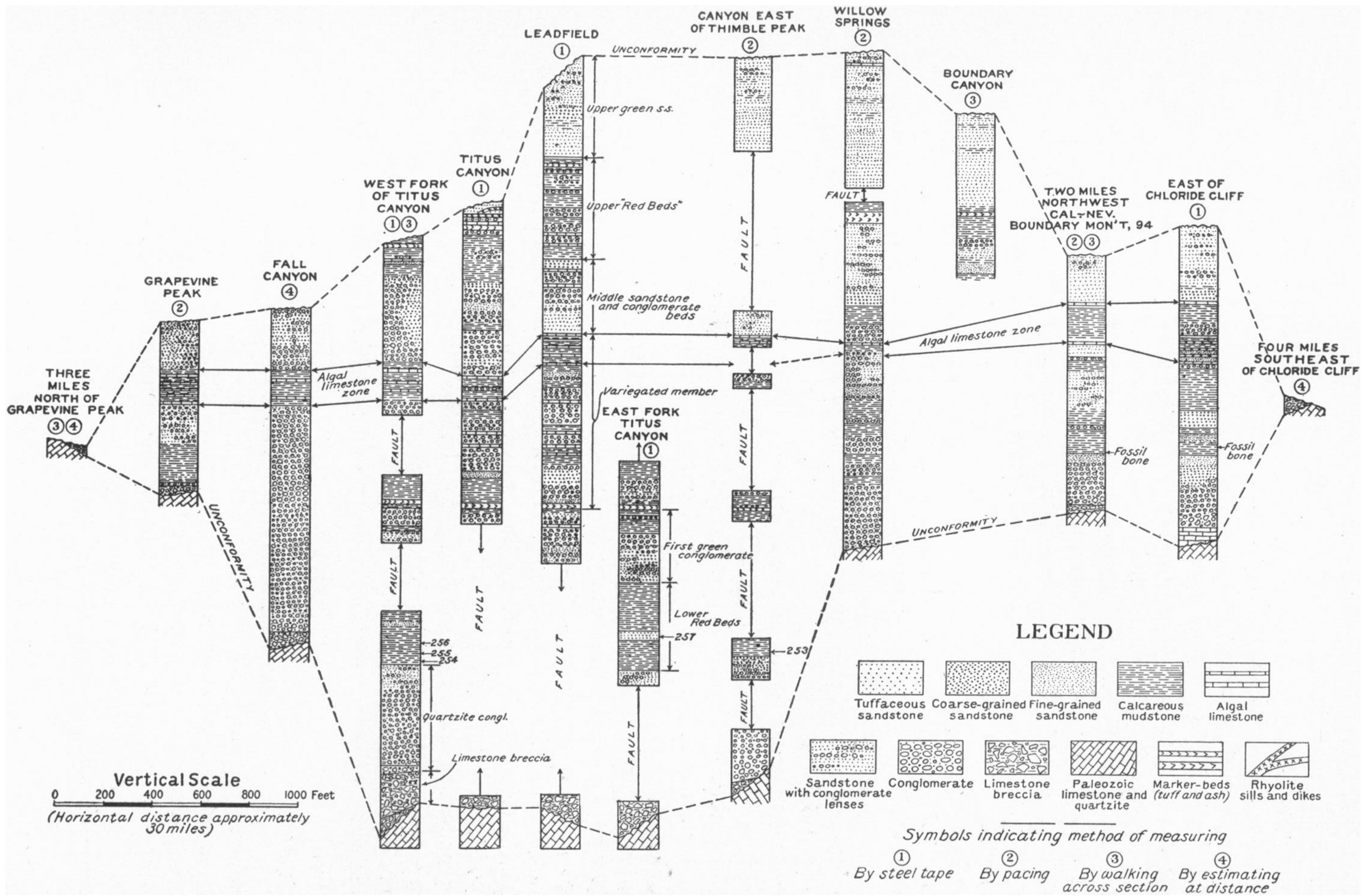


PLATE 2

Columnar sections of lower Oligocene Titus Canyon formation in Grapevine and Funeral Mountains, California. Nos. 253–257 refer to Calif. Inst. Tech. Vert. Pale. Coll. localities.

these volcanics and associated sedimentary tuffs have a total thickness of more than 7000 feet.

The stratigraphic succession of lithologic types is indicated in the columnar sections on the accompanying chart. Outcrops of the basal limestone breccia show angular blocks of Paleozoic rocks like those now exposed in the Paleozoic section immediately to the southwest. Angular blocks of limestone near the base of this member occasionally have a diameter of nearly 20 feet. Laterally, the limestone breccia thickens and thins rapidly and field evidence indicates apparently that it filled depressions in the surface on which the Titus Canyon formation was deposited. The poor sorting, frequent large size and angularity of constituent boulders indicate that the source of this material was not far away. The upper part of this member contains a few well rounded quartzite boulders and grades upward into the quartzite conglomerate. In texture, the limestone breccia resembles most closely recent talus material found in the vicinity of limestone cliffs. While it is difficult to recognize the extent of lateral variation in a direction normal to the strike of the sediments, the limestone breccia is seen to pinch out southwesterly under the quartzite conglomerate on the northwest wall of Titus Canyon.

The general character of the quartzite conglomerate and of all overlying conglomerates is that of fluviatile gravels. The conglomerates contain an abundance of well rounded, highly polished, quartzite boulders. Limestones are common and, it is important to note, that rhyolite, granite and quartz monzonite boulders are present although rare. The thickness and lithology of the calcareous mudstones and algal limestones are rather constant along the strike. Consequently these beds make excellent stratigraphic markers. In the middle part of the section, the succession of deposits is markedly irregular. Frequently an algal limestone bed is found intercalated in two thick strata of coarse conglomerate.

A distinctive horizon of yellow and blue-gray algal limestones and of red or maroon, calcareous mudstones near the upper middle of the section has been termed the Algal Limestone Zone. This zone occurs but once in every section measured along the lateral extent of the deposits. Its characters are so distinctive and constant as to preclude the possibility of confusion with sediments elsewhere in the stratigraphic sequence. For this reason the beds, although now encountered in discrete sections on individual fault blocks, are regarded as having accumulated simultaneously throughout the area, and correlation of the various sections has been made largely on the basis of position of this zone.

The upper part of the section in Titus Canyon consists of red conglomerates and red and green calcareous mudstones, overlain by massive, usually well sorted, green, tuffaceous sandstones and pebble conglomerates. The uppermost member of this group is present only in the region between

PLATE 3A

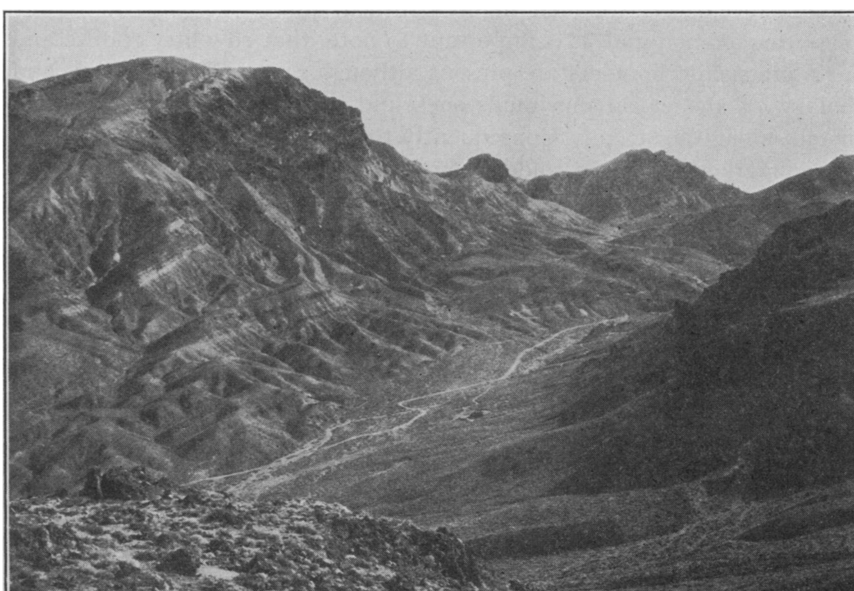


PLATE 3B

(Description of Plate 3 on opposite page.)

Titus and Boundary Canyons. Elsewhere it has been removed by erosion prior to the extravasation of the rhyolites. The green tuffaceous sandstones at the top of the section east of Chloride Cliff have been correlated with a similar unit in Titus Canyon, immediately overlying the algal limestone zone, rather than with the uppermost green sandstones, on the basis of position of this zone in the Chloride Cliff section.

A distinct angular discordance is present between the Titus Canyon formation and the overlying conglomerates and associated rhyolites northwest of Leadfield as well as at the top of the section in Titus Canyon. A similar angular discordance is seen in the area east of Chloride Cliff where the overlying volcanics cut across the Titus Canyon formation and rest directly on pre-Tertiary rocks. At other localities, however, no angular discordance has been observed. Correlations by means of the algal limestone zone indicate that in the vicinity of Grapevine Peak and Chloride Cliff more than 1000 feet of the upper part of the Titus Canyon formation was removed prior to deposition of the rhyolites and accumulation of their basal conglomerate. Presence in the overlying conglomerates of boulders derived from the underlying Titus Canyon also favors existence of an unconformity. Localization of an angular discordance suggests that prior to accumulation of the overlying rhyolite the area was compressed in a north-south direction, causing local folding with development of axes normal to this direction and an elevation of the northern and southern ends of the region to an extent sufficient to allow the removal of 1000 feet of sediments in these areas. A few small faults were found extending up to, but not cutting the contact above, the Titus Canyon formation.

Fauna and Age.—Fossil mammalian remains have been found in the lower portion of the Titus Canyon formation where they usually occur in red calcareous mudstones. All of these occurrences are below the algal limestone zone. The fauna comprises the horse, *Mesohippus*, titanotheres representing presumably two types, hyracodont rhinoceroses, several distinct types of artiodactyls including the genus *Agriochoerus*, and a sciuromorph rodent. The titanotheres, in stage of evolution, are more nearly related to the genera *Brontops*, *Brontotherium* and *Menodus*,

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DESCRIPTION OF PLATE 3

A. View of Titus Canyon formation in area east of Chloride Cliff, Funeral Mountains, California. Unconformable contact with overlying conglomerates parallels sky-line in right background.

B. Exposures of Titus Canyon formation in vicinity of Leadfield, Grapevine Mountains, California. Basal limestone breccia lies on Paleozoic rocks seen in right wall of canyon. Lower red beds concealed beneath alluvium of canyon bottom; middle and upper parts of section exposed on mountain face at left. Overlying volcanics form left sky-line. Difference in elevation between top of mountain on left and canyon bottom is more than 3000 feet.

known from the Titanotherium Beds of the White River group, than to Eocene types. The hydracodont rhinoceroses may represent types more primitive than those recorded from the White River. The Titus Canyon fauna is certainly later in age than the Duchesne River assemblage and the Uppermost Eocene fauna recorded from the Sespe of California, and is earlier than the Oreodon and Leptauchenia zones of the White River. Characters exhibited by the titanotheres and presence of *Mesohippus* furnish the principal evidence for recognition of a close age relationship between this horizon and the Titanotherium Zone. Since the latter has been generally regarded as belonging to the lower Oligocene, this age may likewise be assigned to the Titus Canyon formation.

Concluding Remarks.—Discovery of a fossil vertebrate fauna in the Grapevine Mountains and recognition of the Titus Canyon formation in which this assemblage occurs, has considerable significance in that (1) lower Oligocene land mammals are recorded for the first time in the Great Basin Province and far from previously known areas of occurrence, and (2) a definite age determination can be made for the lowermost formational unit in the Tertiary rock sequence of the Grapevine and Funeral Mountains.

Further, since the basal limestone breccia of the Titus Canyon formation consists of material which has undergone little transportation and has been derived from Paleozoics in the immediate vicinity and since prevailing dips on planes of cross-bedding in the sandstones and conglomerates are toward the northeast, the suggestion is strongly given that the material comprising the Titus Canyon formation was derived from rocks exposed not far to the west. Presence of algal limestone beds in the upper portion of the formation indicates that some of the deposits accumulated in standing water. The conglomerates, however, appear to have been deposited under fluviatile conditions.

Present evidence seems to indicate that the basal part of the lower Oligocene formation accumulated along the flanks of a mountain range the position of which was somewhat like that of the present Grapevine and Funeral Mountains. Following an accumulation of sediments sufficient to bury many of the irregularities of the pre-existing land surface below the Titus Canyon formation, lacustrine conditions prevailed. The deposition of algal limestones and calcareous mudstones was, however, frequently interrupted by an introduction of coarser sediments carried in by streams from the bordering range. Determination of these lower Oligocene topographic features for an area that roughly coincides with a region displaying similar land forms at the present time suggests an age for the present Basin Range topography in at least this portion of the Great Basin.

[1] Recent studies by Stock (see *Proc. Nat. Acad. Sci.* 1932–1935) have shown the presence of an uppermost Eocene mammalian fauna in the Sespe deposits, north of the Simi

Valley, Ventura County, California. In the history of North American mammal life this fauna has a position immediately antecedent to that of the Titanotherium Zone. Above this stage in the Sespe is a considerable thickness of land-laid material and some of these deposits are without much doubt lower Oligocene in age although in the absence of fossil remains this cannot be definitely proved at the present time.

[2] Gilbert, G. K., *U. S. Geog. Surv. West 100th Mer., Wheeler Surv.*, **3**, 33 (1875).

[3] Turner, H. W., *U. S. Geol. Surv. 21st Ann. Rpt.*, Pt. 2, 197–208 (1900).

[4] Spurr, J. E., *Jour. Geol.*, **8**, 633 (1900).

[5] Spurr, J. E., *U. S. Geol. Surv. Bull.*, **208**, 19, 185 (1903).

[6] Spurr, J. E., *U. S. Geol. Surv. Prof. Pap.* **42**, 51–70 (1905).

[7] Ball, S. H., *U. S. Geol. Surv. Bull.*, **308**, 32–34, 165–166 (1907).

ADOPTION OF THE METER-KILOGRAM-MASS-SECOND (M.K.S.) *ABSOLUTE SYSTEM OF PRACTICAL UNITS BY THE INTERNATIONAL ELECTROTECHNICAL COMMISSION* (I.E.C.), *BRUXELLES, JUNE, 1935*

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At its plenary meeting in June, 1935, in Scheveningen-Bruxelles, the I.E.C. unanimously adopted the M.K.S. System of Giorgi, as a comprehensive absolute practical system of scientific units.

The last preceding international action of a similar character was in 1881, when the International Electrical Congress of Paris[1] adopted the centimeter-gram-second (C.G.S.) system.

Commencing with that action in 1881, various International Electrical Congresses, up to that of 1893 at Chicago,[2] and since then, the I.E.C.,[3] have adopted, by successive steps, the well-known series of nine practical electromagnetic units (*ohm, volt, ampere, farad, coulomb, joule, watt, henry* and *weber*). These practical units are recognized as not pertaining to the C.G.S. system; but as being derived therefrom through a corresponding series of decimal multiples (10^9, 10^8, 10^{-1}, 10^{-9}, 10^{-1}, 10^7, 10^7 and 10^8). It was pointed out by Clerk-Maxwell,[4] that the series might be considered as belonging to a practical absolute system having for its fundamental units the length of an earth-quadrant, (10^9 cm.), the mass of an eleventh-gram (10^{-11} g.) and the mean solar second of time (Q.E.S.). In the Q.E.S. system, the numerical value of μ_0 space permeability, was unity, the same as in the C.G.S magnetic system. The units of length and mass in the Q.E.S. system are so awkward that neither Maxwell, nor any unitologist since his time, has ever seriously proposed the practical adoption of the Q.E.S. system. It has remained an academic curiosity.

In 1901, however, Prof. G. Giorgi of Rome[5] showed that if the numerical