A TERTIARY MAMMALIAN FAUNA
FROM THE SAN ANTONIO MOUNTAINS
NEAR TONOPAH, NEVADA

Thesis

by

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ABSTRACT

A collection of mammalian fossils from near Tonopah, Nevada, contains nineteen species, six of which have been reported from no other locality. With more than 225 individuals in the collection, the assemblage approaches a true representation of the numerical frequency of species in a plains fauna. Abundance of skeletal elements of Hypohippus and Merychippus affords material for detailed osteological comparison.

Geological reconnaissance in the area about California Institute of Technology Vertebrate Paleontology Locality No. 172 led to the discovery of a contemporary inland lake faunal facies containing diatoms, molluscs and fish. The occurrence of the mammalian fossils in gravels and cherts, as well as in clays, indicates that the bones were deposited near the entrance of a stream into a saline lake. The small stratigraphic extent of the quarry, the close association of the bones, and the limited morphological variation within abundantly represented species suggests that the fauna is unmixed.

The mammalian assemblage is correlated with the uppermost Barstow and is designated as Upper Miocene in age.

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INTRODUCTION

Discovery of fossil mammals near Tonopah, Nevada, affords opportunity not only to date significant geologic events in the west-central part of the state, but also to recreate the plains life of the region during Upper Miocene time. The fauna contains nineteen species, six of which are known from no other locality. Close association of the mammalian assemblage with remains of diatoms, molluscs and fishes in the stratigraphic record establishes a definite correlation in time between these groups. The value of the discovery as a record of Upper Miocene life is greatly enhanced by the simultaneous occurrence in a limited area of these two entirely different and complementary facies of contemporary faunas. This occurrence of faunal facies representing arid plains and inland lake furnishes interesting and detailed information as to the paleogeography of the region. Abundance of individual mammals from a quarry of narrow horizontal and vertical limitations provides a large unmixed fauna on which to base paleoecological studies.

The fossil mammal occurrence in the San Antonio Mountains was discovered in 1922 by H. G. Ferguson of the U. S. Geological Survey. A letter from Mr. Ferguson under date of March 9, 1940 gives

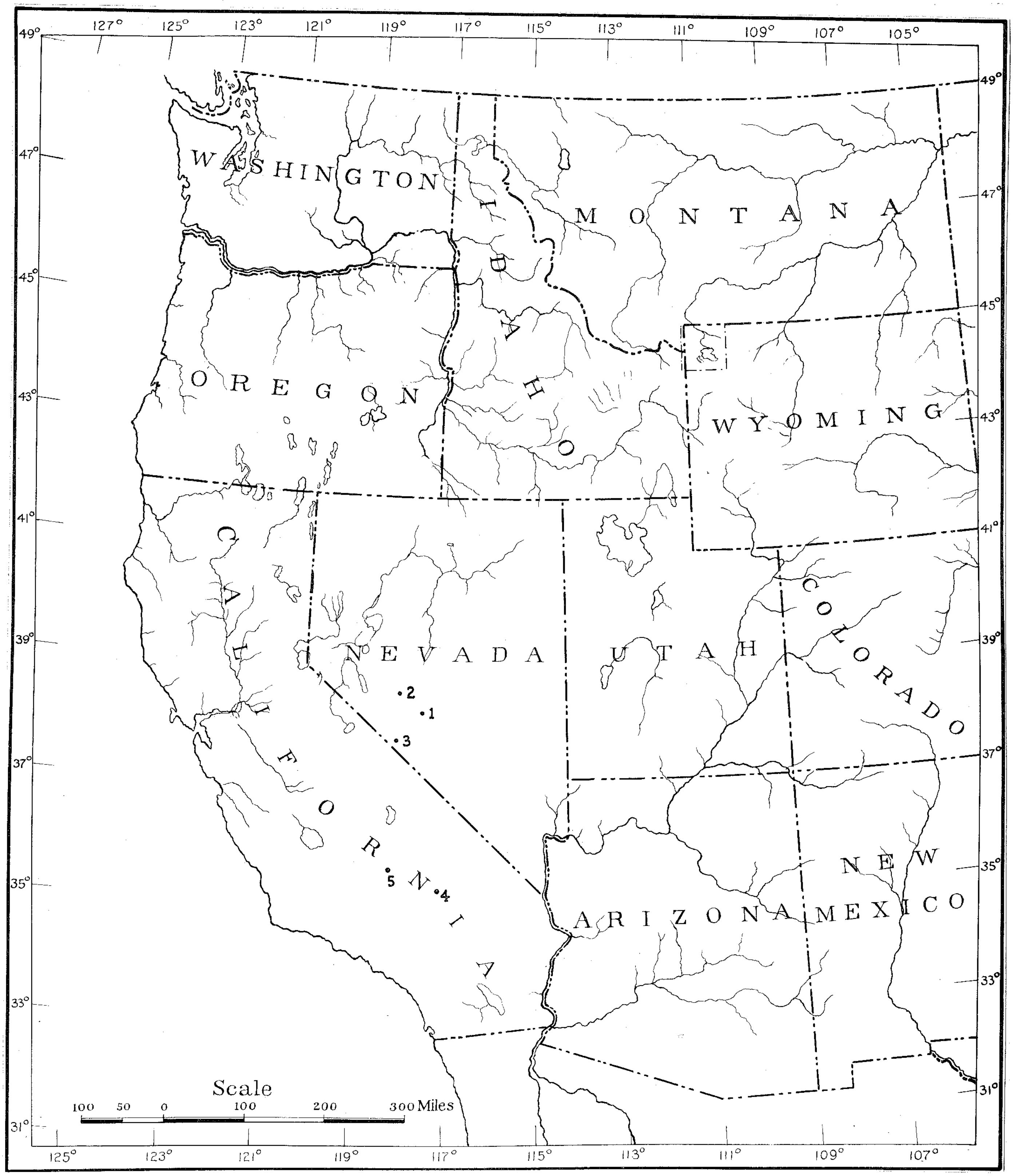

Fig. 1 - Locations of Upper Miocene and Lower Pliocene vertebrate fossil localities of the western United States.

1. Tonopah
2. Cedar Mountain
3. Fish Lake Valley
4. Barstow
5. Ricardo

the following interesting statement concerning the discovery and development of this fossil site:

> "I found the locality in the summer of 1922 during the course of reconnaissance mapping of the Tonopah quadrangle. The discovery was purely accidental, and not the result of any systematic search. The fossils were abundantly exposed at the surface in a bed of greenish marl about two feet thick and traceable along the strike for something over 100 feet. Someone, probably a prospector, had been there before me, as there was a shallow hole cut with a pick. Evidently he was not interested. I made a small collection, chiefly of teeth, and these were later identified by Dr. Gidley. Later in the season another collection was made . . . I later gave Dr. Stock a note as to the locality and still later showed the place to Mr. H. C. Clinton, a mineral collector at Manhattan, Nevada. Mr. Clinton collected at the site before Dr. Stock's party, and I believe exchanged fossils for minerals with different museums and universities. When I revisited the site in 1937 with Professor Muller of Stanford, I was astonished at the large scale mining done by the California Tech. party."

In 1931 and 1932 field parties of the California Institute of Technology carried on quarrying operations in the most productive portions of the fossil-bearing horizon. In 1939 in the course of a brief geological reconnaissance of the area, A. B. Drescher relocated an invertebrate horizon nearby which had been described by Spurr. In addition, Drescher discovered the fossil remains of fish at approximately the same horizon.

ACKNOWLEDGMENTS

It has been my great pleasure and good fortune to have in Dr. Chester Stock, an adviser whose keen perception, invaluable counsel, indispensable aid and critical reading of the manuscript have been a constant source of encouragement and inspiration. I am indebted to E. L. Furlong who prepared much of the material and furnished many valuable suggestions. R. W. Wilson kindly contributed a statement regarding the fossil rodents and lagomorphs in the collection. For their courtesy, cooperation, and helpful suggestions I am obligated to the staff of the Museum of Paleontology, University of California.

LOCATION

The fossil material in the Tonopah collection was found at the California Institute of Technology Vertebrate Paleontology Locality No. 172. The locality lies on the western flank of the San Antonio Mountains, approximately nine miles north of Tonopah, Nevada. The area where the fossiliferous strata are exposed is located at a point 3.67 miles N. 39° W. of the U.S.G.S. B.M. 206, U.S.G.S., topographic map "Tonopah Quadrangle," Nevada, edition 1908, reprinted 1922.

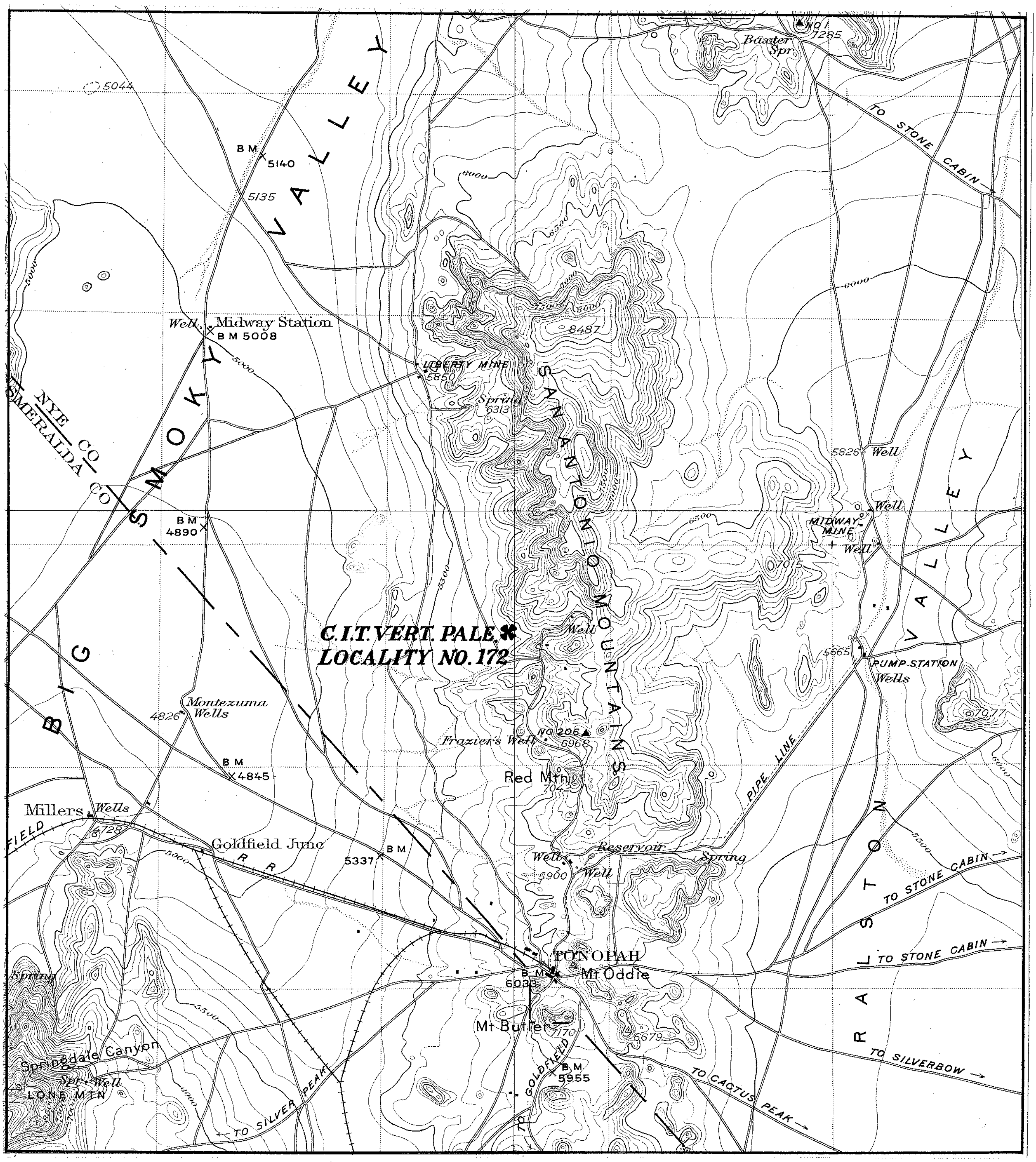

Fig. 2 - Southeastern portion of the United States Geological Survey Tonopah Quadrangle showing the location of the California Institute vertebrate fossil locality in the San Antonio Mountains. Scale 1:250000. Contour interval, 100 feet.

HISTORICAL REVIEW

In 1866 William P. Blake read before the California Academy of Sciences a short notice pointing out that "fossilized fish are found in a light colored clay shale in the mountains a few miles north of Silver Peak." He displayed a few of the specimens, but did not venture to identify them.

The first published notice of extensive fresh-water deposits in the Silver Peak region appears to be that of M. A. Knapp, a mining engineer. Knapp (1897) described particularly the coal deposits occurring in beds at the north end of the Silver Peak Range. Molluscan remains collected by Knapp near the coal beds were examined by Dr. J. C. Merriam of the University of California. Dr. Merriam found the following four species in the collection:

Campeloma sp.

Unio sp.

Planorbis, like *spectabilis* Meek

Ancylus, like *undulatus* Meek

He suggested that the shells were early Miocene or late Eocene in age.

H. W. Turner (1900A) named and briefly described the Esmeralda formation. He states that "in Esmeralda County, Nevada, there are extensive deposits of Tertiary sediments which contain at some points abundant plant and animal remains." Along with the freshwater lake deposits occur beds of Tertiary coal, possibly Miocene in age. "The beds of the Esmeralda formation are inclined at most points, dipping usually from 10° to 40°. No absolutely continuous section of the entire series was obtained, but the total thickness may be several thousand feet.

"The base of the series as seen near the coal mines is composed of sandstone chiefly, with some shale, aggregating perhaps 2000 feet. In this terrane occur the coal, the dicotyledonous leaves and most of the fossil shells.

"Above the sandstones is a considerable thickness of buff shales containing at a few points very abundant fossil fish." On the east side of Big Smokey Valley well-cemented heavy-bedded breccias and conglomerates of Paleozoic detritus overly the buff shales and are interbedded with the sandstone of the Esmeralda formation.

"The top of the series is made up of lacustral marls and white shales, containing fish bones, and at some points these beds are capped by rhyolitic and basaltic lavas and tuffs. There are also some layers of rhyolitic and andesitic tuffs lower down in the formation, and these volcanic layers frequently contain silicified wood. Faulting has displaced the beds at many points and it is therefore difficult to estimate the entire thickness of the formation."

In his more complete report published later in the year, Turner (1900B) described the stratigraphy and structure of the Esmeralda formation in detail. He estimated the total thickness of the beds at 14,800 feet. Turner mentions the occurrence of calcareous tufa at one locality in the series.

F. H. Knowlton (1900) examined a florula collected by Turner at two localities in the Esmeralda formation. These fossil plants embraced fourteen forms, all but one of which were regarded as new. Most of the new forms were found referable to well-known living genera.

List of Fossil Plants

Gleichenia? obscura Knowlton

Dryopteris? gleichenoides Knowlton

Spathyema? nevadensis Knowlton

Salix angusta? Al. Br.

Salix vaccinifolia Knowlton

Salix sp.

Salix? sp.

Quercus turneri Knowlton

Quercus argentum Knowlton

Ficus lacustris Knowlton

Chrysobalanus pollardiana Knowlton

Cercis? nevadensis Knowlton

Chonchidium? turneri Knowlton

Rhus? nevadensis Knowlton

Indet.

Knowlton assigned no geological age to the florula.

F. A. Lucas (1900A and B) described as a new species, <u>Leuciscus turneri</u>, a small fish obtained by Turner in the Esmeralda deposits of the Silver Peak Quadrangle. In the title of one of the published notices (1900A), Lucas suggested that the species was Miocene in age.

J. E. Spurr (1905, pp. 51-55) in the study of the Tonopah mining district defined the Siebert tuff (lake beds) as consisting of white stratified tuffs, beautifully and uniformly bedded, and composed of well sorted material. He noted that where beds of conglomerate occur the pebbles are perfectly rounded. The principal deposits include several hundred feet of lake beds of consistent fine-grained character containing fresh-water infusoria. Sandy and cross-bedded sediments were considered to represent shore and delta facies. Spurr concluded that the lake must have been of considerable size from the fact that over 600 feet of lake beds are exposed on Siebert mountain, with neither top nor bottom exposed. He hypothesized that the lake basin originated from a crustal depression that followed volcanic activity and was perhaps coupled with a climatic change to increased rainfall. The sedimentary materials were derived mostly from glassy dacites and rhyolites. Limited deposits of volcanic ash and small lava flows indicate that mild vulcanism continued during deposition of the lake beds. Upper beds of river gravels, some of which contain petrified wood, indicate uplift and renewed erosion of the highlands and mark the conclusion of lacustrine deposition.

From some of the tuffs Spurr collected infusoria which were identified by R. M. Bagg, Jr. as follows:

List of Diatom Species

Gallionella granulata Bailey

Gallionella varians Ag.

Coscinodiscus radiatus Ehrenberg

In the same publication, Spurr (1905, pp. 66-67) mentions a locality 8 miles north of Tonopah and one mile west of the little mining camp of Ray where there occurs a series of folded gravels, tuffs, lavas and some white, thin limestones carrying numerous Eocene fossils. W. H. Dall noted that the fossils are like those from the Wasatch or Bear River Laramie Eocene of White and Meek.

List of Mollusca

Vivipara near V. couesi

Planorbis utahensis Meek

Ancylus? sp.

Corbicula? cf. Sphaerium idahoense Meek

Of Corbicula Dall remarked that "the specimens are merely internal casts, but if they are really Corbicula they may prove to be C. occidentalis Meek. Their condition is too imperfect to be certain even of the genus, but the form closely approaches that of the figures of S. idahoense." Spurr states further that: "These (beds) overlie the Paleozoic limestones near Hay. Similar beds were noted at several places between Hay and Sodaville. They are probably continuous with a part of the Tertiary deposits of the Silver Peak and Monte Cristo mountains.

Following Spurr's intensive study of the Tonopah region, S. H. Ball (1907), F. L. Ransome (1907 and 1909), and later Adolph Knopf (1921) applied the term Siebert formation to a series of volcanics and lake beds in widely scattered localities throughout west-central Nevada and eastern California. H. G. Ferguson (1924) has pointed out that all of these authors failed to restrict the name Siebert formation to Spurr's definition. All of them broadened the formation to include equivalents of Spurr's underlying Fraction breccia. Ferguson suggested that the Esmeralda formation of Turner is the approximate equivalent of the Fraction breccia and Siebert tuff combined.

Harold Hannibal (1912) summarized the Recent and Tertiary fresh-water mollusca of the Californian province. He included a number of species recorded from the Truckee Lake beds, Nevada. For the new species which he described as _Viviparus turneri_ Hannibal cited several localities in the vicinity of Silver Peak.

Junius Henderson (1935, p. 225) in reviewing the fossil non-marine mollusca of North America points out with regard to Hannibal's contribution of 1912 that "his synonymies and classification in this paper are notably erroneous." Henderson deleted all species of indefinite locality from Hannibal's list of forms from the Truckee beds and combined the remainder with the molluscan fauna reported by Turner from the type Esmeralda.

List of Mollusca (Henderson, 1935, p. 46)

Esmeralda beds, Silver Peak region, Nevada

Unio sp.

Sphaerium catharinae Hannibal

Planorbis cordillerana (Hannibal)

Lanx like *undulatus* (Meek)

Viviparus turneri Hannibal

Truckee beds, Hawthorne, Nevada

Pisidium? meeki Hannibal

J. P. Buwalda (1914) described the Esmeralda formation in considerable detail as it occurs in Stewart and Ione Valleys in the vicinity of Cedar Mountain, Nevada. He discussed the distribution, lithology, thickness, stratigraphic relations and structure of the formation. Mammalian fossil material collected from the Esmeralda by Buwalda and Baker was studied by Professor J. C. Merriam. The fossil mammalian remains according to Buwalda (1914), "are most abundant in sandstones and in ashy deposits; a portion of a single connected skeleton was found in limestone. A few specimens were found in beds of coarse angular terrestrial material." The age of the fauna was determined as approximately Upper Miocene. Buwalda identified four species of fresh-water molluscs in the collections from the Esmeralda beds in Ione and Stewart Valleys.

List of Mollusca

Helisoma cordillerana Hannibal

Viviparus turneri Hannibal

Melania, near *sculptilis* Meek

Corneocyclas meeki Hannibal

Buwalda traced the beds in Ione Valley by continuous outcrops to the type Esmeralda locality, and found the first two of the molluscan species given in the above list occurring in abundance in the type section.

Buwalda states that the scattered distribution and occasional coarse strata of the lake sediments suggest moderate topographic relief at the time of their deposition. The fact that the sediments first started to accumulate in the Upper Miocene indicates that the local drainage had been external prior to that time. Pure ash layers in the sediments were derived from contemporaneous outbursts of vulcanism. An abundance of leaves, silicified wood, and remains of herbivorous mammals indicates local conditions of abundant plant growth and a fairly moist climate. The occurrence of a large lake in a region which now contains only small playa basins further suggests a somewhat greater rainfall in the area during Miocene time. The presence of camels and grazing horses was interpreted as indicating a vegetation of the plains type rather than a forest cover.

Merriam (1916A) reported on the fauna of the Cedar Mountain region collected by Buwalda and Baker. The literature on the region was reviewed. Merriam drew largely on the published observations of Buwalda's geological reconnaissance for his information on the Cedar Mountain beds and the relation of the fauna to its environment. Mention was made of two fishes examined by Professor J. O. Snyder, a salmon-like form and a cyprinoid; a testudinate, possibly *Chlemmys*; and three ducks identified by L. H. Miller as *Nettion carolinense* (Gmelin), *Marila collaris* (Donovan) and *Querquedula cyanoptera* (Vieillot)?. In his discussion of the faunal relationships, Merriam noted that the mammals included elements of both primitive and advanced types, and suggested that more than one fauna might be represented. He compared the stage of the fauna to that of the Barstow and Santa Fe.

In 1924 S. H. Cathcart assembled a small collection of fossil plants from the Esmeralda. The fossils were taken from a coal prospect 4 miles southeast of Morgan Ranch and 15 miles west of Hawthorne, Mineral County, Nevada. E. W. Berry (1927) examined this flora and in the light of better and more abundant material was able to revise and add to the earlier lists by Knowlton.

Revised Flora of Esmeralda Formation

Azolla tertiaria Berry

Dryopteris obscura Knowlton

Typha lesquereuxi Cockerell

Potamogeton knowltoni Berry

Salix inquirenda Knowlton

Salix knowltoni Berry

Salix sp. Knowlton

Salix? sp. Knowlton

Populus lacustris (Knowlton)

Quercus simulata truncata Berry

Quercus turneri Knowlton

Quercus argentum Knowlton

Ceratophyllum fossilium Berry

Castalia? sp. Berry

Chrysobalanus pollardiana Knowlton

Cercis? *nevadensis* Knowlton

Rhus? *nevadensis* Knowlton

Sapindus lancifolius Lesquereux

Trapa americana Knowlton

Vaccinium ellipticum Berry

Vaccinium vaccinifolia (Knowlton)

Cinchonidium? *turneri* Knowlton

Six of the plants in this flora are hygrophilous, while two are stream or lakeside in habitat. These water-loving plant types, coupled with an abundance of very large fragments of silicified wood, fairly thick coal beds, and wide distribution of diatomaceous beds, furnish evidence that the climate of the region was considerably more moist at the time of deposition than it is at present. On the other hand, four members of the flora are characteristic of semi-arid regions. Berry considered that the known "flora does not furnish conclusive evidence regarding the regional environment." He compared the Esmeralda flora with that of Florissant, Mascall, Latah and Payette, and concluded that the Esmeralda is "not older than Middle Miocene and is almost certainly Upper Miocene."

Further collecting in the Cedar Mountain area and discovery of fossiliferous strata in Fish Lake Valley renewed interest in the faunas of the Esmeralda beds. Reports on various finds followed in quick succession (Matthew 1929; Burt 1929; Hall 1929; Stirton 1929 and Hall 1930 B and C). Stirton (1932) summarized the results of a study of the new material in conjunction with a restudy of the earlier University of California collections. He found that at no single locality does a mixed fauna occur. A lense of brown sandstone containing fossils of the older Merychippus fauna occurs at a locality distinct from those characterized by the younger Pliohippus-Hipparion fauna. Stirton noted that the fossils of the older fauna give evidence of having been reworked. The older Cedar Mountain fauna was designated Middle Miocene in age. The Fish Lake Valley fauna was considered Lower Pliocene and equivalent to the Upper Snake Creek of Nebraska. A comparison of the Fish Lake Valley and late Cedar Mountain faunas indicates that these assemblages are the same or are closely related in age.

In subsequent publications Stirton (1933; Teilhard and Stirton 1934; Stirton 1936,) employed the old name Esmeralda to designate the Lower Pliocene mammalian remains from the Fish Lake Valley and Cedar Mountain areas. Stewart Spring was suggested as a name for the Middle Miocene fauna obtained at U.C. Locality 2027

(Teilhard and Stirton, 1934, p. 285) in the Cedar Mountain area. At the same time, Stirton stated definitely that "*Merychippus* teeth clearly indicate that the Stewart Spring fauna is, approximately, equivalent to the Virgin Valley and not as advanced as the Santa Fe."

The California Institute of Technology Locality 172 which was discovered by Ferguson, has yielded an abundant fauna. Furlong (1934) briefly commented on the locality and described two new species of *Merycodus* in the fauna.

Bode (1934, pp. 56 and 59) compared the crown-heights of upper and lower merychippine cheek-teeth obtained in faunas from the Mascall, Merychippus zone at Coalinga, Barstow, and Tonopah.

In a paper read before the Paleontological Society, Pacific Coast Branch, Stock (1934) described the skull and dentition of *Pseudaelurus intrepidus* from Tonopah. Stock (1935, p. 1067, fig. 2c) compared the lower deciduous molars of *Merychippus calamarius* (C.I.T. No. 1827) from Tonopah with those in a section of jaw of *Pliohippus tehonensis* taken from a well core in the Chanac formation, California.

In the present study a description is given of the remaining species in the fauna as represented by the collections of the California Institute of Technology. An attempt is also made to demonstrate the relationships of the fauna to other Tertiary mammalian assemblages of western North America.

GEOLOGIC OCCURRENCE

AND

NOMENCLATURE OF FOSSIL BEDS

The deposits containing the mammalian fauna are those which Spurr visited and described (1905, pp. 66-67) 8 miles north of Tonopah and one mile west of the mining camp of Ray (see above). Though Spurr missed the vertebrate fossils, he collected shells from the nearby Tertiary limestones.

Stratigraphy.--Approximately a mile east of C.I.T. Vertebrate Paleontology Locality 172 the Tertiary lake beds are found in fault contact with Paleozoic limestones. At several localities in the cores of anticlinal folds in the immediate vicinity of the mammalian fossil deposit, the beds can be seen to overlie pre-Esmeralda lavas.

The section at Locality 172 was estimated from nearby exposures to be approximately 40 feet thick.

Thickness of beds (in feet)	Lithology
2 - 3	Dendritic calcareous tufa.
4 - 5	Gray-green silts, gravelly sandstone, occasional chert. Extremely abundant mammalian remains.
25	Gray tuffaceous sediments.
5 (estimated)	Conglomerate with pebbles of green and red volcanic rocks in green matrix.
Base	Unknown.

The locality where Spurr collected fossil invertebrates is located approximately three-quarters of a mile due east of C.I.T.

Locality 172. The section containing the invertebrates is somewhat thicker.

Thickness of beds (in feet)	Lithology
1	Dendritic tufa tubes and pipes.
30	Punky gray shale.
20	Alternating thin layers of light gray tuffaceous sandstone, light gray punky shale, white coquina, fine angular gravel, light colored calcareous sandstone. Very great abundance of invertebrate fossils.
30 (estimated)	White to gray soft shale.
Base	Unknown.

A third roughly measured section is located on the south side of the first important wash to the south of C.I.T. Locality 172. It lies slightly more than one-half mile south of C.I.T. Locality 172, and is approximately three-quarters of a mile southwest of Spürr's invertebrate locality. The section here is even thicker than at Spurr's locality.

Thickness of beds (in feet)	Lithology
4 - 6	Dendritic tufa domes and pipes.
35	Light gray, poorly bedded shales.
0.75	Resistant gray sandy tuff.
15	Light gray shale.
1	Dense, resistant, gray-white, tuffaceous shale. Marker bed.
85	White, thin-bedded to laminated, diatom-bearing shale.
Base	Andesitic volcanics cut by breccia dikes.

At about one-quarter of a mile northeast of the locality where the third section was measured, the basal shales exhibit a gray-buff facies not so thinly bedded as the laminated shales of the measured section. Thirty feet below the resistant one-foot Marker Bed these gray-buff shales contain abundant fish remains along with some fossil grasses.

At still another locality situated almost equidistant from the localities of the three measured sections, fish remains similar to those mentioned above occur intimately associated with invertebrates of the types which are found at Spurr's locality.

In the vicinity of all the fossil-bearing localities, the weather-resisting dendritic tufa beds form the highest remaining horizon. To the west of C.I.T. Locality 172 lies a considerable thickness of gently tilted buff sandstones which are thought to be younger than the thin fossiliferous series.

Structure.--C.I.T. Locality 172 lies near the north side of a basin which reaches into the west flank of the San Antonio Mountains. The basin is slightly over a mile wide and about three miles long. Esmeralda sediments cover most of the area within the basin. A few scattered outcrops of pre-Esmeralda lavas are exposed in the main wash where down-cutting and lateral planation have stripped away the overlying lake beds. The eastern end of the basin is bounded by a fault contact with the Paleozoic rocks. To the north of the basin the Esmeralda sediments are overlain with erosional and angular unconformity by Pliocene (?) andesite. On the south the narrow basin is bounded by a rhyolite which Ferguson regards as post-Esmeralda Upper Miocene in age.

The fossil-bearing strata have been folded along east-west axes into two synclines and an anticline. The steepest dips are less than 25°. All of the flexures plunge gently eastward toward the main front of the San Antonio Mountains.

Several minor transverse faults striking west of north have locally displaced the folded strata. A longitudinal fault along which the south side has moved east a few hundred feet lies almost on the axial plane of the anticline. This minor faulting probably occurred at the time of the folding of the sediments.

Molluscan and piscine faunas.--In addition to the mammalian remains, the fossils obtained from the Tertiary lake beds north of Tonopah comprise a considerable number of molds and casts of four species of freshwater molluscs. The anterior portion of one fossil fish, an abundance of fish bones and scales were also found.

The mollusca have been tentatively identified. They represent the same four species which Spurr collected and Dall identified.

Revised List of Mollusca

Pisidium? meeki Hannibal

Planorbis cf. cordillerana (Hannibal), small, diameter 16 mm.

Lanx cf. undulatus (Meek), large, length 20 mm.

Viviparus turneri Hannibal

All of these species are apparently lacustrine in habitat (Hannibal 1912).

These mollusca are closely allied to, although not identical with, the members of the molluscan fauna described by Buwalda (1914) from the Esmeralda of Ione and Stewart Valleys. *Planorbis* near *utahensis* differs from *Heliosoma cordillerana* in its smaller size and more deeply umbilicate shell. A similar close relationship yet lack of identity exists between this San Antonio Mountain fauna and the molluscan fauna of the type Esmeralda which was examined by Merriam (Turner 1900B, pp. 203-204).

A single fossil fish in the collection has been referred to *Leuciscus turneri* Lucas. Absence of the caudal and anal fins, and the poor preservation of the remaining skeletal parts render impossible any detailed comparison with the type of the species from near Silver Peak.

On the basis of extensive geological reconnaissance of the area, H. G. Ferguson includes all of these deposits in the Esmeralda formation. Ferguson remarks that "the beds have the same position relative to older and younger formations as in Turner's type locality, though, of course, there is not continuous outcrop between the two areas."

The similarity of the molluscan and piscine fauna of the San Antonio Mountain Esmeralda beds with the corresponding assemblage of the type Esmeralda adds support to the correlation made by Ferguson.

OCCURRENCE AND PRESERVATION OF FOSSIL MATERIAL

Local correlation.--The mammalian fossil material was recovered from stratified beds of gray-green silt and sandy silt in which occur lenses of gravelly sandstone and occasional beds of chert. Although the fossil mammal horizon is limited in vertical extent to less than ten feet, fossil remains representing float materials were found continuously along the weathered outcrop for more than one-half mile to the southwest and south of the producing quarries. This strict stratigraphic limitation of the fossil-bearing horizon proclaims the purity of the mammalian fauna. The invertebrates and fishes are likewise strictly limited as to stratigraphic horizon. The invertebrate-bearing marls and light gray shales total not more than twenty feet in thickness. All of the fossiliferous localities, both vertebrate and invertebrate, occur stratigraphically beneath the dendritic tufa layer, and presumably lie not far above the local base of the Esmeralda sediments. It is believed that the faunas of all of these San Antonio Mountain localities are essentially contemporaneous.

Lacustrine facies.--The large extent of the sedimentary deposits and the considerable thickness of diatom-bearing beds indicate the existence of a lake of considerable size in Upper Miocene time. The light-colored shales and marls of the fish and invertebrate localities must have been deposited far enough out in the lake to escape admixture with coarser stream-borne sediments. Sporadic volcanic activity showered the lake and surrounding country with fine gray ash, much of which was incorporated in the offshore sediments of the lake. The marl, diatomite, and tufa of the lacustral beds were deposited by organic and chemical action.

Salinity of the Miocene lake.--The layer of dendritic tufa noted at the top of each measured section appears to be identical in its character to similar deposits of Lake Lahontan, described in detail by Russell (1885). Tufa tubes, pipes, and hollow domes are extremely common in the horizon. For similar structures in Mono Lake and the Lahontan basin, Russell suggested two possible modes of origin: "First, by the direct precipitation of calcareous tufa about nuclei. Second, from the precipitation of the same material from springs rising in lakes that are highly charged with mineral matter in solution." From the presence of abundant normally developed molluscan shells embedded in the dendritic tufa, Russell concluded that the waters of Lake Lahontan were not strongly alkaline or saline when that deposit was laid down. By analogy the Upper Miocene Esmeralda lake may have been somewhat saline but not greatly so when the dendritic tufa was formed.

The presence of the freshwater mollusca and fish indicates that at least occasionally the waters were not too saline for animal life to exist. Under the heading "Syntonis" Hannibal (1912, pp. 114-116) discusses the effect of various salines upon molluscan life. He notes that while magnesium compounds produce remarkable physiological effects and act as poisons, even high concentrations of sodium, potassium and calcium salts exert little effect. Hence, waters saline enough to form precipitates (e.g. dendritic tufa and chert) may still support normal or almost normal molluscan faunas.

Though *Leuciscus* is dominately a freshwater fish in both Europe and North America, many members of the genus are found in brackish waters of the Baltic Sea and in bays of the eastern and western shores of the Atlantic. Accordingly, it is assumed that although *Leuciscus turneri* may be primarily a freshwater type, this fish could persist for a time at least under conditions of increasing salinity.

Delta facies.--The gray-green silts, sands, gravels and occasional cherts enclosing the mammalian fossils are indicative of a near shore deposit, perhaps deltaic in character. The occasional layers of chert interbedded with the silts may provide significant evidence as to the nature of the environment at time of deposition. According to Twenhofel (1939) the normal environment for chert interbedded with clastic sediments, particularly clays and silts, is an area where fresh silica-bearing waters mingle with saline water. Ideal conditions for such a deposit would be found adjacent to an entrance of a stream into a saline lake.

Preservation of the fossils.--All of the fossil material from C.I.T. Locality 172 is highly silicified. Most of the unweathered specimens are tinted a distinctive green color of the surrounding sedimentary formation.

A few of the teeth in the collection are definitely rounded as though they were rolled and abraded either by stream transportation or by wave action near a lakeshore. Most of the fossil material, however, shows no postmortem wear whatsoever. In many cases, delicate tooth structures have been preserved with great fidelity.

The fossil material consists almost entirely of dentitions and limb bones. Out of a collection representing more than 225 individuals only a single cat skull and a few antelope frontlets were preserved well enough to merit description. Equally noteworthy is the almost complete absence of vertebrae and ribs in the collection.

During the course of excavation at C.I.T. Locality 172 two maps of the major quarry site were carefully made on a scale of one inch to one foot. All fossil finds within the first six feet below the surface were plotted on one map, while finds from six to ten feet below the surface were recorded in the second. These maps form an important record of the fossil occurrence. The productive portion of the quarry covered an area of approximately 40 feet on the strike of the beds and 50 feet down the dip. Over 80 percent of the fossils were derived from the upper horizon of the quarry, a three foot zone extending from three feet to six feet below the surface of the ground. The maps give no indication of any special orientation of the fossil bones, nor is there any suggestion of channels determining the localization of bone within the quarry. It must be remembered, however, that the entire quarry may represent a channel of concentration forty feet wide in the half-mile outcrop of sparsely fossiliferous to barren beds.

The quarry maps do reveal the relatively high degree of association of the fossil bones. Dentitions and limb bones of the same individual were not found in association except in a few doubtful cases. Associations of maxillae and rami and of various bones of the same limb, however, are frequent. Invariably the lateral metapodials of the feet of horses are intimately associated with the medial metapodial. Furthermore, the metapodials are often closely associated with carpals and tarsals and occasionally with portions of the upper limb bones. The dentitions, though still associated, are more widely scattered. For example the left maxilla and dentition of a rhinoceros was separated by a distance of two feet from the left ramus and dentition, while a single tooth from the right ramus of the same individual was found eight feet away in the same horizon.

Association and distribution of the kind noted appears to indicate that the osseous material arrived at the locality still held together by ligaments. Furthermore, burial must have been relatively rapid to prevent any wide scattering of the osseous material.

FAUNAL CENSUS AND ENVIRONMENT

Of the 225 specimens in all stages of growth represented in the collections of the California Institute of Technology, 195 are herbivores. Except for one insectivore and a number of uncounted rodents and lagomorphs, the remainder of the fauna consists of carnivores. Less than 20 of the individuals represent young animals.

Census of Tonopah Mammalian Fauna

Genus	Number of individuals
Metechinus	1
Tomarctus	9
Leptocyon	6
Aelurodon	4
Amphicyon	2
Brachypsalis	3
Pseudaelurus	5
Merychippus	110
Hypohippus	12
Aphelops?	3
Alticamelus?	8
Merycodus	62

(Note: Rodentia and Lagomorpha were not counted.)

This representation of genera approaches the normal conditions of a plains habitat. In contrast, attention may be directed to the faunas of Rancho la Brea (Stock 1929) and McKittrick (Schultz 1938) where an unnatural preponderance of carnivores occurs. The tarpools of Rancho la Brea most certainly functioned as baited traps for unwary carnivores. The McKittrick assemblage approaches more normal ecological conditions, although here the concentration of carnivores is still extremely high. Hence, McKittrick likewise must have acted to some extent as a carnivore trap. The Tonopah fauna, on the other hand, probably comes close to furnishing a normal cross-section of the mammalian life as it existed at a given stage when the deposits were laid down. However, the balance appears still to remain in favor of the predators, for there are eleven individuals in the fauna representing Aelurodon, Amphicyon, and Pseudaelurus.

In attempting to reach an estimate of the normal number of herbivores which ought to be present in the assemblage on the basis of the carnivore population certain assumptions are perhaps permissible. For example, at least one major kill had to be made each day to satisfy the hunger of the predatory group. We may assume also that the horses and antelopes, which furnished most of the food, produced offspring but once a year. On this basis therefore a normal population for a given moment in time must contain more than 365 herbivores for every eleven large carnivores. Yet in the Tonopah fauna we find a ratio of only 195 to 11. It may be concluded therefore that in the collections from Tonopah the carnivore-herbivore ratio is still abnormally high. Probably the smallest representation occurs in the antelope family. This ordinarily prolific group is represented by only 60-odd individuals.

The abundance of grazing horses (Merychippus) and antelopes, coupled with the occurrence of camels and long-limbed rhinoceroses, indicate without question that the environment was one of grassy, perhaps shrub-covered plains. It has often been suggested that *Hypohippus* was a browser, not a grazer. The proportional representation of this genus is small. Perhaps the hypohippines foraged in stream-bottoms or along the edges of the lake where doubtless there flourished shrubs and trees to their liking.

CONDITIONS OF ACCUMULATION AND BURIAL

Summarizing the conclusions drawn from the geological and faunal evidence, we find that the fossils occur in delta deposits along the shores of a large saline lake. The mammals probably died near their burial place. The bones were quickly covered before they could be scattered far. The species represented in the fauna are predominantly of a plains-dwelling type.

A saline lake and a plains fauna suggest aridity of climate. In an arid region, the occurrence of occasional droughts is extremely probable. During a severe drought the larger mammals are forced to congregate about the more permanent water holes. The lake, or the lower reaches of a stream entering the lake, furnish the last available sources of water in the district. As time elapses without rain, an ever thinning stream of stragglers trails in from the dusty plains. Many arrive at the watering place too emaciated to survive. Among the thousands of animals congregating near the lakeshore disease and undernourishment take a steadily mounting toll. The depredations of the Carnivora strike sharp notes of terror in this tragic theme of famine. The lakeshore becomes a veritable charnel house with widespread destruction and death until once again the rains fall to quench a parched and sunbaked earth. Seeds of grass quicken and push their tender shoots up through the moistened ground. The grazing mammals that have survived make off for hill and plain and in their wake stalk the carnivores.

But what of the dead that are left behind? With the coming of the rain the streams revive their flow and bring silts and sands. The least amount of scattering, quickest burial and best preservation occur where carcasses and bones lie in the stream channels. Doubtless the opportunities for preservation are better under these circumstances than under those presented along the lakeshore. Bones not in the channels disintegrate and are widely scattered before burial. Hence, there is an apparent concentration of fossils in the old stream channels. Perhaps in this manner was formed the rich concentration of fossil material unearthed at a quarry forty feet wide in a sparsely fossiliferous horizon more than one-half mile in length.

COMPOSITION AND STAGE OF EVOLUTION OF FAUNA

Representatives of the family Erinaceidae are rare in the later Tertiary record of North America. Only two species have been described thus far, Metechinus nevadensis Matthew (1929) and Meterix latidens Hall (1929) from the Fish Lake Valley Lower Pliocene of California. Metechinus fergusoni differs from all other erinaceids (Leche 1902) except M. nevadensis in the extreme reduction of its tooth-row. M. fergusoni parallels M. nevadensis in many details of the dentition and tooth-structure. On the basis of the less complete reduction of the upper premolars in M. fergusoni, the Tonopah form is regarded as slightly more primitive than M. nevadensis from Fish Lake Valley.

In his introductory statement concerning the Tonopah Rodentia and Lagomorpha Wilson (this paper) states that this part of the fauna is late Miocene or early Pliocene in age. The content and relationships of the faunule, namely "Mylagaulus" sp., cf. Eutamias ateles Hall; cf. Peromyscus longidens Hall, or possibly a n. sp., and Hypolagus sp., suggest that it is most closely related to the Barstow.

Tomarctus paulus from Tonopah differs from Matthew's Tomarctus confertus (1918), and from material referred to that species by Matthew (1924) in slightly larger size and in the more slender proportions of the teeth. It is doubtful whether C.I.T. No. 1229 is closely related to the Lower Snake Creek type. Even if close relationship between the two species were established it would still be difficult to determine the relative stage of advancement of each form.

Tomarctus? *kelloggi* of the Tonopah fauna agrees closely with the type specimen (Merriam 1911) from Virgin Valley. The only possibility of determining the phylogenetic position of this species rests on the questionable assumption that the second lower molars U.C. No. 10651 and U.C. No. 12542 of the Virgin Valley and Thousand Creek mammal beds respectively are correctly referred to *T. kelloggi*. Without the accompanying lower carnassials it is impossible to demonstrate that these teeth are "relatively large" and "extraordinarily developed." If Merriam (1911) was correct in referring both these teeth to *T. kelloggi*, the following argument may bear a little weight. $\overline{M2}$, C.I.T. No. 789 is slightly smaller overall and is slightly more constricted between trigonid and heel than is U.C. No. 10651 from Virgin Valley. $\overline{M2}$ from Thousand Creek, U.C. No. 12542, referred by Merriam to *T.* near *kelloggi*, shows even more constriction and is still smaller. If this constriction crown and diminution in size of $\overline{M2}$ mark an evolutionary trend, the Tonopah form lies between *T. kelloggi* of Virgin Valley and *T.* near *kelloggi*, of Thousand Creek.

Tomarctus brevirostris, represented in the Tonopah collection by a canine and a single lower carnassial tooth, conforms almost exactly to Pawnee Creek and Lower Snake Creek material which has been referred to Cope's species.

Leptocyon vafer shows no specific difference from Leidy's type, and agrees perfectly with Matthew's (1918) description of the

Lower Snake Creek form. The Tonopah material is smaller than the referred specimen from Ricardo (Merriam 1919) which differs further in having an entoconid in $\overline{M1}$.

On the basis of evidence discussed in detail below, the varietal form, Aelurodon wheelerianus asthenostylus, differs markedly from typical Aelurodons of the Ricardo, Esmeralda and Barstow faunas. The Tonopah variety appears to approximate an undescribed Aelurodon from Barstow. The variety seems to be closely allied to Cope's relatively primitive type Ae. wheelerianus from Santa Fe. Ae. wheelerianus asthenostylus is differentiated by extreme weakness of the parastyle on $\underline{P4}$.

The Amphicyon metapodials are directly comparable to some undescribed material in the Pawnee Creek collection of the University of California. Since canid metapodials change relatively slowly in character, it is doubtful whether further light could be shed on the position of the Tonopah Amphicyon even if similar material were present in other faunas.

Brachypsalis pachycephalus of the Tonopah represents an evolutionary stage close to that of B. modicus Matthew (1918) of Lower Snake Creek. The Nevada form appears to be cospecific with Cope's type from the Loup Fork Upper Miocene. An undescribed specimen from the Barstow collection of the University of California (U.C. No. 35447) closely resembles C.I.T. No. 1231.

Pseudaelurus intrepidus is very closely allied to Leidy's type from Niobrara River. Referred specimens from Lower Snake Creek (Matthew 1918, 1924) are similar. The Barstow material differs in being more massive. A lower jaw from the Avawatz Mountains is definitely more advanced.

Hypohippus near affinis may be slightly more primitive than referred material from the Burge of Gordon Creek, Nebraska (McGrew 1938), and is perhaps more advanced than referred material in the University of California Niobrara River collection.

The relationships of Merychippus calamarius are discussed at length below. The form has close affinities with the same species from Barstow, but seems a little more advanced in its greater crown-height and more complex enamel pattern. On the basis of its highly complex enamel pattern, the Santa Fe type (Cope 1877) may be more advanced in turn than the Tonopah form.

Aphelops? cristalatus n. sp. is apparently definitely more advanced than the Pawnee Creek A. megalodus (Cope), and considerably more primitive than A. mutilus Matthew from the Coffee Ranch and Higgins Quarry A.

The peculiar Alticamelus? stocki n. sp. presents a difficult problem in phylogenetic position. It may correspond roughly in evolutionary stage to A. leptocolon Matthew in the Lower Snake Creek (1924) and the Pawnee Creek (1901) faunas.

The relationships of the unusual and primitive merycodonts,

<u>Merycodus loxocerus</u> Furlong and <u>Merycodus hookwayi</u> Furlong, are likewise difficult to demonstrate. These species have no counterparts in either the Barstow or the Ricardo faunas. In fact, no similar forms have been reported from any part of the North American Tertiary. In view of the fact that they are both characterized by primitive dentitions coupled with a previously unrecorded type of horn-core, it appears that these forms represent an aberrant development from a primitive type which persisted locally.

RELATIONSHIPS OF FAUNA

Great Basin.--The wealth of material in the Tonopah collection renders feasible detailed comparisons with other well represented faunas of southeastern California and western Nevada.

The Tonopah rodent and lagomorph faunule "is closest perhaps to the Barstow." Tomarctus brevirostris may be near the Barstow T. near temerarius. At least one of the Barstow Aelurodons resembles closely the Tonopah Ae. wheelerianus asthenostylus. Pseudaelurus sp. of the Barstow differs somewhat in its more massive jaw from the Tonopah form. An undescribed Brachypsalis from Barstow has close affinities with the slightly smaller Tonopah specimen. Hypohippus, near affinis, occurs in the Barstow fauna, but the fragmentary nature of the material precludes any conclusive determination of relationship. The most advanced merychippines of the Barstow are certainly very close to Merychippus calamarius from Tonopah. Alticamelus alexandrae seems more advanced than the primitive appearing A? stocki of Tonopah. The Tonopah merycodonts are likewise relatively primitive, more so perhaps than any of the Barstow forms except Ramoceros (Merriamoceros) coronatus.

In summary, the only demonstrable difference which may be indicative of the relative geologic ages of the Tonopah and Barstow faunas appears in the Equidae. Merychippus calamarius constitutes one of the most advanced merychippine forms to be recorded from the North American Tertiary, but the advance of this form beyond the stage represented by the Barstow species is very slight. It is interesting to note that an undescribed series of merychippine upper cheek-teeth found in one of the uppermost horizons of the Barstow by Mr. Clair Steggall of the University of California at Los Angeles is as advanced as M. calamarius in crown height, although it lies in the M. intermoutanus line.

Detailed comparison demonstrates clearly that the Fish Lake Valley fauna (Esmeralda of Stirton 1932) represents a stage of evolution more advanced than that of the Tonopah. Interest centers in the occurrence of an insectivore in the Tonopah fauna because this type appears to be closely related to Metechinus nevadensis Matthew (1929.) M. fergusoni shows considerably less reduction of the premolar teeth and consequently seems definitely more primitive than M. nevadensis. The rodent and lagomorph faunule of Tonopah appears to be slightly more primitive than the Fish Lake Valley assemblage. Aelurudon haydeni from Fish Lake Valley exhibits larger size and perhaps more progressive characters than the Tonopah Aelurudon. Hypohippus near affinis displays characters in which it is assuredly more primitive than, if not directly ancestral to, H. near nevadensis of Fish Lake Valley. Neohipparion cf. occidentale and Pliohippus cf. leidyanus of Fish Lake Valley are much more advanced than Merychippus calamarius from Tonopah. The primitive camel and merycodonts of the Tonopah fauna show no close affinities to the fragmentary Fish Lake Valley material.

Without exception, the members of the Ricardo mammalian assemblage patently display an advance in evolutionary stage over comparable species from Tonopah. _Canis? vafer_ of the Ricardo is larger than the Tonopah species. The Ricardo _Aelurodons_ typically bulk much larger than _Ae. wheelerianus asthenostylus_. One undescribed Ricardo Aelurdon of slightly larger size than the Tonopah species, is unfortunately too fragmentary to permit a close comparison with the Tonopah form. The relatively large lower jaw of _Aphelops_ sp. (Stock and Furlong 1926) from the Ricardo represents a form probably more advanced than the Tonopah species. The Ricardo Equidae include several species of _Hipparion_ and _Pliohippus_ and typifies a stage of evolution considerably later than that of _M. calamarius_ from Tonopah. Fragmentary camelid material from Ricardo affords no satisfactory comparison with _Alticamelus? stocki_. _Merycodus_ (_Paracosoryx_) _furlongi_ is much more advanced in its dentition than either of the Tonopah species.

Tomarctus kelloggi from Tonopah may be roughly equivalent to _T._ near _kelloggi_ from Stewart Spring (Stirton 1932; Teilhard de Chardin and Stirton 1934, p. 285.) The Stewart Spring Equidae, however, consist of _Hypohippus_ near _osborni_ and _Merychippus isonesus_, and are much more primitive than _H._ near _affinis_ and _M. calamarius_ respectively from Tonopah.

Pacific Coast.--No forms in the Mint Canyon fauna (Maxson 1930; Stirton 1933) are at all comparable to the Tonopah species. The Nevadan fauna is considered as definitely younger than the Tick Canyon (Jahns 1939), and it appears to be older than the _Hipparion_ zone of the Upper Mint Canyon. Further finds in the Mint Canyon series may reveal a faunal zone comparable to that occurring near Tonopah.

The Quatal Canyon fauna (Gazin, Cuyama, 1930) offers no comparable species.

The Chanac fauna (Merriam 1915, 1916B; Stock 1935) has been divided on the basis of its Equidae into an upper and lower portion (Stirton 1939A, p. 135). The Lower Tejon Hills (Drescher, in press), characterized by Nannipus tehonensis and Pliohippus tehonensis, seems definitely more advanced than Tonopah.

The Lower Pliocene fauna of the San Francisco Bay region (Merriam 1913, 1917; Stirton 1935, 1939B) corresponds closely to that of the Tejon Hills and accordingly is definitely younger than the assemblage from Nevada.

Great Plains.--In absence of any revision of the Santa Fe fauna it is impossible to make a satisfactory comparison at this time. Frick (1933) states that the Santa Fe beds, as determined by mammalian fossils, ranges in age from the Middle Miocene to the Pleistocene. Aelurudon wheelerianus asthenostylus is smaller and not identical with the type Ae. wheelerianus of Santa Fe. Aphelops meridianus from New Mexico seems more primitive than the Tonopah A? cristalatus. The Tonopah Merychippus calamarius appears almost identical with Cope's type from the Santa Fe. Out of the abundance of merycodont types reported by Frick from the Santa Fe, none belongs to the subgenus Merycodus (Paracosoryx) into which both of the Tonopah species seem to fall. Future exploration in the valley of the Rio Grande will doubtless reveal a series of distinct faunas, some of which may well be contemporary with Tonopah.

On the basis of the distinctly more primitive forms, Aphelops ceratorhinus and Merycodus agilis, the Madison Valley fauna of Montana (Douglass 1900) is regarded as pre-Tonopah in age.

Specimens of the Niobrara River namely, Hypohippus cf. osborni, Merychippus republicanus, M. insignis, and M. perditus, in the collections of the University of California are all more primitive than H. near affinis and M. calamarius from Tonopah.

The Burge fauna in the collections of the University of California and which inclues Hypohippus affinis, Neohipparion coloradense, Nannipus cf. retrusus and Pliohippus cf. supremus typifies an evolutionary stage more advanced than that of the Tonopah. Both the Niobrara River and the Burge faunas include members of the genus Metechinus. If future exploration yields more diagnostic material representing the latter genus, it will be of some significance to determine in detail the relationships of the Great Plains species to the Tonopah and the Fish Lake Valley material.

The relationships of the Tonopah fauna to other Tertiary mammalian assemblages known from North America are shown in the following chart:

Relationship of the Tonopah Fauna to Miocene-Pliocene Vertebrate

Horizons of Western North America

Age	Nevada	California	New Mexico	Montana	Nebraska
Lower Pliocene	Esmeralda	Lower Ricardo	Santa Fe		Burge
Upper Miocene	Tonopah Stewart Springs	Barstow	Santa Fe	Madison Valley	Niobrara R.

Faunal Lists

Tonopah Fauna

Insectivora

Metechinus fergusoni n. sp.

Rodentia

"Mylagaulus" sp.

Cf. Eutamias ateles Hall

Cf. Peromyscus longidens Hall
or possibly a n. sp.

Lagomorpha

Hypolagus sp.

Carnivora

Tomarctus paulus n. sp.

Tomarctus? kelloggi (Merriam)

Tomarctus brevirostris Cope

Leptocyon vafer (Leidy)

Aelurodon wheelerianus asthenostylus n. var.

Amphicyon sp.

Brachypsalis pachycephalus Cope

Pseudaelurus intrepidus Leidy

Perissodactyla

Merychippus calamarius (Cope)

Hypohippus near affinis (Leidy)

Aphelops cristalatus n. sp.

Tonopah (cont.)

Artiodactyla

Camelidae

Alticamelus stocki n. sp.

Antilocapridae

Merycodus loxocerus Furlong

Merycodus hookwayi Furlong

Barstow Fauna

Insectivora

Limnoecus tricuspis Stirton

Rodentia

Eutamias ateles Hall

Perognathoides cf. tertius Hall

Perognathoides sp.

Heteromyid gen. and sp.

Peromyscus longidens Hall

Peromyscus sp.

Peromyscus sp.

Lagomorpha

Hypolagus cf. vetus L. Kellogg

Hypolagus sp.

Carnivora

Tomarctus near temerarius (Leidy)

Canid (Canis?) sp. small

Aelurodon near wheelerianus Cope

Aelurodon, Dinocyon, or Amphicyon sp.

Brachypsalis sp.

Machaerodont sp. a

Machaerodont sp. b

Machaerodont sp. c

Felid? indet.

Pseudaelurus sp.

Proboscidea

Tetrabelodon? sp.

Perissodactyla

Hypohippus near affinis (Leidy)

Parahippus? mourningi Merriam

Merychippus (Protohippus) intermontanus Merriam

Merychippus calamarius stylodontus Merriam

Merychippus sumani Merriam

Protohippus? or Pliohippus?, sp.

Artiodactyla

Tayassuidae

Prosthennops?, sp.

Merycoidodontidae

Merycochoerus buwaldi Merriam

Camelidae

Procamelus, sp. a

Procamelus, sp. b

Pliauchenia, sp.

Alticamelus alexandrae Davidson

Cervidae

Dromomeryx or Cervus?, sp.

Antilocapridae

Ramoceros (Paramoceros) brevicornis Frick

Ramoceros (Merriamoceros) coronatus (Merriam)

Merycodus (Paracosoryx) alticornis (Frick)

Meryceros joraki Frick

SYSTEMATIC DESCRIPTION

ERINACEIDAE

Part of a shattered left maxillary with the anterior portion of the zygomatic arch, and most of a left ramus of the same individual, comprise the insectivore material from Tonopah. The teeth which have been preserved include C and $P\underline{4}$ and $P\overline{4}$-$M\overline{2}$. All of these teeth are excellently preserved. The teeth show resemblance to those of a hedgehog and more particularly to those of the genus *Metechinus* from the Fish Lake Valley beds. On the basis of apparent differences in tooth structure, the material is described as belonging to a new species.

Metechinus fergusoni, n. sp.

Type specimen. - A portion of the left maxillary, C.I.T. No. 2817, and a part of the left ramus bearing most of the tooth-row, C.I.T. No. 2818. The maxillary portion shows part of the alveoli for two incisors, C, the roots of $P\underline{3}$?, $P\underline{4}$, part of the alveolus of $M\underline{1}$, and the anterior portion of the zygomatic arch. The lower jaw exhibits three anterior alveoli, one of which is partially closed, $P\overline{4}$, $M\overline{1}$, $M\overline{2}$, and part of the lower posterior portion of the ramus.

Specific characters. - Small size. Upper canine with two distinct roots. $P\underline{3}$, present, not caducous. $P\underline{4}$ with very high, large metacone blade. $P\overline{4}$, well-developed, with two distinct roots, and slightly complex crown. $M\overline{1}$ with very long trigonid.

Skull. - The infraorbital foramen lies just anterior to P4. The anterior portion of the zygomatic arch arises from the maxillary at a point just external to the anterior root of M1.

Mandible. - The lower border of the mandible is almost flat beneath P4-M2, curving gently upward anteriorly and posteriorly. The portion of the ramus posterior to M2 is long, while that in front of this tooth is considerably shortened. Though the major part of the ascending ramus is missing, the ridge at the lower anterior edge of the ascending ramus makes a sharp anterior boundary for the masseteric fossa. The inferior boundary of this fossa is very weak. A large mental foramen lies below P4. The mandibular foramen lies in the almost smooth internal surface of the ramus.

Measurements (in millimeters)

	2818
Depth of the mandible below M1	2.8
Width of mandible below M1	1.7

Upper dentition. - A sharp-cusped tooth with small anterior basal cusp and strong basal heel cusp is tentatively regarded as a canine. Low cingula border the base of the tooth near these cusps. The tooth has two distinct roots.

P3 is represented by two roots set diagonally in the jaw. The anteroexternal root is larger than the posterointernal.

In P4 the long metacone blade is almost as high as the backward-sloping sharp-pointed paracone, and is approximately equal to it in total bulk. The metacone blade extends very strongly posteroexternally. The two inner cusps, which are of equal height, arise from a common internal platform and are further connected by a low internal cingulum. The posterior border of the cingulum curves well back giving a large areal extent to the posterior portion of the internal platform.

Two upper incisors appear to be represented by the internal borders of their alveoli. Of $\underline{M1}$ only the alveolus of the antero-external root is present. Since $\overline{M2}$ is present in the mandible a second molar must have been present in the upper series, although no trace of it is preserved.

<u>Lower dentition</u>. - $\overline{P4}$, supported by two separate roots, is set obliquely in the jaw. The moderately high principal cusp suggests that in its unworn state the tip was divided into two very small cuspules. The posterior cuspule was located slightly external to the anterior one. The cingulum, rising high and strong on the anterior and posterior borders of the crown, forms almost an anterior basal cusp and a cusp on the heel.

$\overline{M1}$ has a long trigonid and is a relatively very large tooth. The long, slender paraconid blade is curved gently inward, and is more anteroposterior than transverse in position. The protoconid is strong, high and separated from the almost equally large metaconid by a very shallow valley. The lowset heel is basined and bears a hypoconid and entoconid of equal size. A moderately strong cingulum extends along the external side of the tooth from the anterior portion of the protoconid to the middle of the base of the hypoconid.

M2 is a much smaller tooth than M1 and bears a short paraconid with anteroposterior shear. The protoconid and metaconid cusps are of equal size. The small heel is narrower than the trigonid. The hypoconid equals the entoconid in size. A low cingulum lies along the external side of the tooth and extends from the anterior end to the middle of the base of the hypoconid.

Of the three anterior alveoli, the very large, oval, almost horizontal one is considered to be for I2; the small partially closed alveolus contained a caducous I3; and the large round alveolus immediately anterior to P4 held the lower canine. These assumptions are open to question, but they are in accord with such information as is available on loss of teeth in the family Erinaceidae (Leche, 1902). M3 is absent.

Measurements (in millimeters)

K , Upper dentition:	C.I.T. 2817	U.C. 29600	
C , anteroposterior diameter	1.2		
C , transverse diameter	.7		
P4, anteroposterior diameter	3.2	4.5	
P4, transverse diameter	2.3	4.2	

K , Lower dentition:	C.I.T. 2818		
Length of series P4 - M2	6.2	10.1	composite
P4, anteroposterior diameter	1.4	1.5	
P4, transverse diameter	1.1		
M1, anteroposterior diameter	3.0	5.3	
M1, transverse diameter	1.7	2.7	
M2, anteroposterior diameter	1.9	3.6	
M2, transverse diameter	1.2	2.2	
M2, width of heel	.9	1.9	

Relationships. - The position of *Metechinus fergusoni* from Tonopah is definitely within the family Erinaceidae. Detailed comparison with the modern *Erinaceus europaeus europaeus* from Germany and *Neotetracus sinensis* from Ho-mu-shu Pass, China, reveals many striking similarities and a few important differences in dentition.

Meterix latidens Hall (1929) bulks larger in size and has a much more nearly complete dental battery. Also this form from Fish Lake Valley differs in having two mental foramina and a strong ridge on the posterointernal face of the ramus.

Metechinus nevadensis Matthew (1929) from Fish Lake Valley exhibits a close similarity to the Tonopah form. The latter agrees with *M. nevadensis* in the reduction of the Premolars and the posterior molars, and in the corresponding enlargement and specialization of $\overline{M1}$. The dental formulae in the two species are probably identical. That in specimens No. 2817, No. 2818 may be recorded as follows:

$$\frac{?\ 2 \cdot 1 \cdot 2 \cdot ?}{2 \cdot 1 \cdot 1 \cdot 2}$$

In *M. fergusoni* as well as in *M. nevadensis* $\overline{M2}$ is much smaller than $\overline{M1}$ and $\overline{M3}$ is absent. All of these points of agreement are in characters designated by Matthew as of generic rank. The forms differ in two generic characters given by Matthew: (1) $P\underline{3}$ of *M. nevadensis* is caducous, while this tooth is less reduced in C.I.T. No. 2817, and (2) $\overline{P4}$ of *M. nevadensis* is small and simple: in the Tonopah erinacid it is larger and more complex.

Some of the other minor differences between C.I.T. No. 2817 and *M. nevadensis* include the lesser degree of reduction and more complex pattern in the upper canine from Tonopah. $P\underline{4}$ is relatively longer and narrower on the C.I.T. specimen. The metacone blade of $P\underline{4}$ is relatively higher and larger in C.I.T. No. 2817. $\overline{P4}$ from Tonopah is much less reduced and slightly more complex. Except for the slightly longer paraconid blade and the external cingulum in $\overline{M1}$ from Tonopah, the two molars of both species are in close agreement. Of course, the most obvious difference between the two forms is that of size, C.I.T. Nos. 2817 and 2818 being only about 60 per cent of the size of *M. nevadensis*.

All of these differences are of minor importance. Perhaps none of them can be considered of generic rank. All but two of the differences lie in the same direction, i.e. increase in total size accompanied by reduction of anterior premolars and posterior molars, perhaps indicative of an evolutionary trend from the Tonopah species to *Metechinus nevadensis*. The two features in *M. Fergusoni* which seem relatively more advanced than *M. nevadensis* are really one and the same: the relatively greater anteroposterior length (1) of $P\underline{4}$ and (2) of $\overline{M1}$ on C.I.T. Nos. 2817 and 2818 respectively.

Though the Tonopah form may later be given generic distinction, temporarily at least it is referred to Matthew's genus *Metechinus*.

RODENTIA AND LAGOMORPHA

by Robert W. Wilson

This small and fragmentary collection includes three rodents and a lagomorph. In age, the Tonopah assemblage is closest perhaps to the Barstow fauna, but identification of the several types is tentative. A late Miocene or early Pliocene age is suggested rather strongly by the "fauna". A provisional list of forms is as follows:

"Mylagaulus" sp.
Cf. Eutamius ateles Hall
Cf. Peromyscus longidens Hall, or possibly a n. sp.
Hypolagus sp.

"Mylagaulus" sp.

A mylagaulus is represented by a palate with P4, M2-M3 of both sides, and several isolated cheek-teeth. Until a thorough revision of the mylagaulids is undertaken, a more specific determination is hardly possible.

Cf. Eutamius ateles Hall

The presence of a small sciurid is recorded by several isolated cheek-teeth, an incisor fragment, and two pieces of ramus each with a single cheek-tooth. The Tonopah species apparently is closer to *Eutamius ateles* of the Barstow than to any other form, although it is not certain that the two are co-specific. Chipmunks are rare as fossils, and the present occurrence apparently is only the second record of these squirrels in the North American Tertiary. Perhaps it is open to question whether either of these records pertains to the living genus.

Cf. Peromyscus longidens Hall, or possibly n. sp.

A cricetid type, close to the Barstow *Peromyscus longidens*, but possibly representing a new species, is known by the following: skull fragment with incisor and $M\underline{1}$ - $M\underline{3}$, maxillary fragment with $M\underline{1}$ - $M\underline{2}$, two isolated molars, and several bits of rami with not more than a single cheek-tooth in each.

Hypolagus sp.

A partial skull with dentition, a cheek-tooth series comprising right $P\underline{2}$ - $M\underline{1}$, a left ramus with $P\overline{3}$ - $M\overline{3}$, and various individual teeth are to be assigned to the very common later Tertiary leporid, *Hypolagus*. In size, the material indicates a species smaller than *H. vetus*, and more nearly agreeing with *H. limnetus* from the Hagerman and *H. cf. vetus* from the Fish Lake Valley beds. The Tonopah species probably represents an undescribed if not hitherto unknown form. In several characters of the dentition, such as relatively simple enamel folding of the upper cheek-teeth, it apparently is somewhat more primitive than middle Pliocene and later leporids. However, the species is no more primitive than its stratigraphic position would suggest.

CANIDAE

Fossil remains of the Canidae in the Tonopah collection represent a surprisingly large variety of forms. The well preserved, almost complete dentition of a young adult described as the species *Tomarctus paulus* is the best specimen in the collection. Part of a lower jaw and a few lower teeth are referred to the species *Tomarctus kelloggi*. *Tomarctus brevirostris* and *Leptocyon vafer* are represented by more or less fragmentary material. Two jaws, part of a palate, and a few separate teeth are designated as a new variety, *Aelurodon wheelerianus asthenostylus*. An interesting pair of large canid metacarpals and a phalanx are referred to *Amphicyon*. If properly assigned to this genus, they furnish the first real clue to the foot structure of that type.

Tomarctus paulus n. sp.

Type specimen.--A palate with well-preserved, complete dentition; a complete lower jaw of the same individual with all teeth except $\overline{I1}$ and $\overline{M3}$, C.I.T. No. 1229.

Referred material.--A few separate upper teeth and a number of partial rami complete the collection. No skeletal parts have been referred to this species. A minimum population count based upon rami totals five individuals.

Specific characters.--Size of *T. confertus* (Matthew.) $\underline{P4}$ elongate with protocone set very far forward. Upper molars very wide transversely. Lower dentition differs from *T. confertus* type in narrower premolars with only moderately high cusps. $\overline{M1}$ short, not compressed. $\overline{M2}$ moderately long and narrow.

Skull.--All that can be determined from the poorly preserved skull material is that the posterior part of the palate was relatively wide compared to that of *C. latrans* (47 mm. least overall diameter across the palate immediately posterior to $\underline{P4}$.) The infraorbital foramen lies over the anterior end of $\underline{P4}$.

Mandible.--The mandible is fairly well-preserved except for the anterior portion of the symphysis, the tip of the coronoid process of the right ramus, and the ascending left ramus. The ramus is slender, but not so slender as that of a fox or coyote. The lower border of the ramus is smooth from symphysis to angle. The angle projects back strongly, but is a little weaker than that of _C. latrans._ The masseteric fossa extends forward to a point below the alveolus of $\overline{M3}$. The anterior mental foramen lies below $\overline{P1}$; the posterior below the middle of $\overline{P3}$.

Measurements (in millimeters) of mandible

	1229	1232
Length from condyle to alveolus for $\overline{I1}$	90 _ap_	
Minimum overall diameter from lower border of ramus to tip of coronoid process	35 _ap_	
Depth of ramus below $\overline{M1}$	14.7	17.3
Width of ramus below $\overline{M1}$	7.3	8.5

_ap_. approximate

Note: Although the mandible of C.I.T. No. 1232 is of an older individual and is much more massive than No. 1229, the dentition is of same size.

Upper dentition.--The incisors are small. All of these teeth, even $\underline{I3}$, characteristically bear accessory tubercles on either side of the principle cusp, and a cingulum behind. The canine is short and slightly stouter than that of _C. latrans._

All of the premolars have a slight backward cant to the principle cusp. The single-rooted $\underline{P1}$ has a small posterior accessory cusp but no anterior one.

$\underline{P2}$ and $\underline{P3}$ are both double-rooted and have small heel cusps as well as posterior accessory cusps. $\underline{P3}$ bears a definite anterior accessory cusp on the internal side, while $\underline{P2}$ has no such cusp.

The carnassial is long, but relatively not so narrow as in *C. latrans*. A small parastyle lies on the anterior border of the tooth. The strong protocone is sharply set off from the rest of the tooth and stands well forward of the anteroexternal border of the tooth.

$M\underline{1}$ and $M\underline{2}$ are very similar to the form displayed by these teeth in *Canis*, with the exception that their heels are slightly larger.

Lower dentition.--The small incisors resemble those of *Canis* in every way. The canine is proportionally shorter and stouter.

Single-rooted $\overline{P1}$ has a simple conical cusp. $\overline{P2}$, $\overline{P3}$ and $\overline{P4}$ are all double-rooted. All bear a posterior accessory cusp and a heel cusp; $\overline{P4}$ has a slight suggestion of an anterior accessory cusp.

$\overline{M1}$ is dog-like in almost every respect. The tooth is less elongate than in *Canis*, and the metaconid is proportionally slightly larger.

$\overline{M2}$ is proportionally larger than in *Canis*. It bears the distinguishing paraconid, and its entoconid is well-developed.

$\overline{M3}$ bears an anterior paraconid crest, well-marked protoconid and metaconid cusps, and a posterior hypoconid-entoconid crest. The roots of the tooth have coalesced to form a single root which is extremely elongate antero-posteriorly.

Measurements (in millimeters)

Length of series $\underline{I1}$ - $\underline{M2}$	60 ap
Length of series $\underline{P1}$ - $\underline{M2}$	45.5
$\underline{C}$, anteroposterior diameter	6.4
$\underline{C}$, transverse diameter	3.9
$\underline{P1}$, anteroposterior diameter	3.6
$\underline{P1}$, transverse diameter	2.2
$\underline{P2}$, anteroposterior diameter	6.0
$\underline{P2}$, transverse diameter	3.2
$\underline{P3}$, anteroposterior diameter	7.5
$\underline{P3}$, transverse diameter	3.5
$\underline{P4}$, anteroposterior diameter on external side	13.0
$\underline{P4}$, anteroposterior diameter on internal side	14.9
$\underline{P4}$, transverse diameter	6.5
$\underline{M1}$, anteroposterior diameter	9.8
$\underline{M1}$, transverse diameter	13.2
$\underline{M2}$, anteroposterior diameter	5.0
$\underline{M2}$, transverse diameter	9.6
Length of series $\overline{I1}$ - $\overline{M3}$	65 ap
Length of series $\overline{P1}$ - $\overline{M3}$	51 ap
$\overline{C}$, anteroposterior diameter	4.1
$\overline{C}$, transverse diameter	4.1
$\overline{P1}$, anteroposterior diameter	2.9
$\overline{P1}$, transverse diameter	2.0
$\overline{P2}$, anteroposterior diameter	5.4
$\overline{P2}$, transverse diameter	3.0
$\overline{P3}$, anteroposterior diameter	6.5
$\overline{P3}$, transverse diameter	3.5
$\overline{P4}$, anteroposterior diameter	7.7
$\overline{P4}$, transverse diameter	4.0
$\overline{M1}$, anteroposterior diameter	15.0
$\overline{M1}$, transverse diameter	6.0
$\overline{M2}$, anteroposterior diameter	7.6
$\overline{M2}$, transverse diameter	5.0
$\overline{M3}$, anteroposterior diameter	4.0
$\overline{M3}$, transverse diameter	3.0

ap, approximate.

Relationships.--Comparisons show that a close relationship exists between *Tomarctus paulus* and *Tomarctus confertus* (Matthew 1918, pp. 188-189, fig. 1) from the Snake Creek *M. paniensis* zone. *T. confertus* has a slightly shorter tooth-row, and possesses smaller teeth. The premolars of *T. confertus* are slightly shorter and wider. $\overline{M1}$ is much more compressed in the type. On the other hand, $\overline{M2}$ is slightly larger than the comparable tooth in C.I.T. No. 1229. In a skull referred to the species *T. confertus* (Matthew 1924, pp. 96-97) the upper dentition is slightly smaller than in C.I.T. No. 1229. $\underline{P4}$ is less elongate and the protocone does not stand so far forward as in *T. paulus*. The upper molars of A.M.N.H. No. 18253, although approximately of same anteroposterior diameter are much shorter transversely than in C.I.T. No. 1229.

If the specimen shown in Leidy's figure (1869, pl. 1, fig. 12) were taken as the type of *T. temerarius* as Matthew suggests (1924, p. 98), then all material which corresponds to the larger upper jaw fragment described but unfigured by Leidy would be excluded from the species. However, on the basis of page priority, it is deemed advisable to consider the larger unfigured upper jaw material as the type of Leidy's species *T. temerarius*. Hence, the relatively large jaw from Barstow referred by Merriam (1919) to *T.* near *temerarius* does resemble the type and is certainly not co-specific with *Tomarctus paulus*.

On the other hand, C.I.T. No. 1229 agrees very closely in size and cusp arrangement with Leidy's figure of $\overline{M1}$. Furthermore, the depth of ramus below $\overline{M1}$ of Leidy's figure falls between the values recorded for *T. paulus*.

Tomarctus? kelloggi (Merriam 1911) differs in much larger size with the premolar teeth not so closely spaced, and anterior premolars simple and without accessory cusps. The anteroposterior diameter of $\overline{M2}$ is more than 70 percent of that of $\overline{M1}$, as compared to only 50 percent in *T. paulus* from Tonopah.

All other material referred to *Tomarctus* represents species of much larger size.

Tomarctus? kelloggi (Merriam)

A partial ramus bearing $\overline{P1}$ - $\overline{M1}$ (C.I.T. No. 1235), a ramal fragment with $\overline{M1}$ and $\overline{M2}$ (C.I.T. No. 789), separate $\overline{M1}$ and $\overline{M2}$ differ in several important respects from other canids of this group. At least three individuals are represented by this material.

Mandible.--The ramus, deep beneath $\overline{P1}$, becomes still deeper below $\overline{M2}$. To some extent this depth is attributable to the advanced age of the individual. In spite of its depth, the mandible does not attain very great thickness. The symphyseal region appears to have been relatively small. The masseteric fossa does not reach so far forward as $\overline{M2}$.

Measurements (in millimeters)

Depth of mandible below $\overline{P3}$	22.0
Depth of mandible below $\overline{M2}$	26.0
Thickness of mandible below $\overline{M2}$	9.2

Lower dentition.--The lower teeth are well spaced and uncrowded. The moderate-sized premolars have suffered little reduction. $\overline{M1}$ appears relatively short, while $\overline{M2}$ seems inordinately long.

$\overline{P1}$, single-rooted and peglike, is nevertheless rather large. $\overline{P2}$, $\overline{P3}$ and $\overline{P4}$ are all two-rooted and progressively increase in size. $\overline{P2}$ is simple. $\overline{P3}$ bears a small heel-cusp. $\overline{P4}$ possesses a small posterior accessory cusp as well as a strong heel-cusp.

$\overline{M1}$ in C.I.T. No. 1235 is much worn on its external side by a crushing and grinding action without much shear. A referred unworn specimen (C.I.T. No. 789) is of almost identical size. C.I.T. No. 789 bears a short blunt paraconid, a blunt, heavy protoconid, and a relatively very large rounded metaconid high up on the protoconid cusp and closely appressed to it. On the heel the large entoconid, which closely resembles the hypoconid in size, occupies a more elevated position than the latter. A small tubercle lies between the base of the protoconid and the hypoconid. The external base of the heel is expanded, making the heel the widest part of the tooth.

The extremely large second lower molar is almost 80 per-cent as long as $\overline{M1}$, but appears to be characteristically canid. A protoconid of moderate size, a paraconid almost as strong as the protoconid, and a very large and elevated metaconid constitute the trigonid. The long basined heel bears the hypoconid and entoconid cusps, both well-developed. A small tubercle lies in the valley betwen the protoconid and the hypoconid. The cingulum is developed into a prominent ridge on the anteroexternal side of the trigonid. Between trigonid and heel, the external wall is strongly indented and the internal wall is slightly indented giving the tooth a pronounced "waist." The enamel of the posterior face of the tooth is abraded slightly due to contact with a third molar.

Measurements (in millimeters)

	C.I.T. 1235	C.I.T. 789	*T. kelloggi* U.C. 11562 Virgin Valley
Length of series $\overline{P1}$ - $\overline{M1}$	45.6		
$\overline{P1}$, anteroposterior diameter	3.9		
$\overline{P1}$, transverse diameter	2.5		
$\overline{P2}$, anteroposterior diameter	6.5		6.0
$\overline{P2}$, transverse diameter	3.4		
$\overline{P3}$, anteroposterior diameter	7.3		6.7
$\overline{P3}$, transverse diameter	3.6		
$\overline{P4}$, anteroposterior diameter	8.4		8.4
$\overline{P4}$, transverse diameter	4.7		
$\overline{M1}$, anteroposterior diameter	13.5	13.0	15.0
$\overline{M1}$, transverse diameter	6.9	6.6	7.0
$\overline{M2}$, anteroposterior diameter		10.5	10.5
$\overline{M2}$, transverse diameter		5.9	6.7

Relationships.--The completely canid appearance of the lower dentition combined with presence of a well-developed paraconid in $\overline{M2}$ correspond to the characteristic features of the genus *Tomarctus*. The most striking peculiarities are depth of ramus, simplicity of the premolars, the anteroposterior shortness of $\overline{M1}$, and relatively great length of $\overline{M2}$.

Although *Tomarctus temerarius* and *Tomarctus paulus* approach C.I.T. No. 1235 in size, they differ strikingly in the proportions of $\overline{M1}$ and $\overline{M2}$. In fact, all but one of the species assigned to the genus *Tomarctus* have a large to very large lower carnassial and a small to very small $\overline{M2}$. The one species *T? kelloggi* (Merriam 1911), differs from all others in having an $\overline{M2}$ "relatively large and extraordinarily developed." Merriam's species from Virgin Valley agrees closely with the Tonopah material. The jaw is "relatively heavy in the posterior half." The jaw of C.I.T. No. 1235 is still heavier, but it has been mentioned already that the extreme depth of jaw (for a canid) of No. 1335 may be partially explained by the age of the individual. The premolars are slightly larger and more massive in C.I.T. No. 1335. $M\overline{1}$ and $M\overline{2}$ of C.I.T. Nos. 1235 and 789 agree in almost every detail with the type of the species. The paraconid of $M\overline{1}$ is not quite so long as is that cusp in U.C. No. 11562.

The posterior portion of a lower carnassial, U.C. No. 19767, from Stewart Spring (Merriam 1916) is certainly co-specific with the Tonopah material although slightly smaller.

Any comparison with referred $M\overline{2}$'s U.C. No. 10561 from Virgin Valley and U.C. No. 12542 from Thousand Creek (Merriam 1911) would have limited value in view of the fact that such reference is far from indisputable.

On the basis of presence of an extremely long and slender $M\overline{2}$, and the low-crowned $M\overline{1}$ with pairs of subequal cusps, the species <u>T? kelloggi</u> may be regarded as generically distinct from <u>Tomarctus</u>. Additional material, especially of the maxillary dentition, will undoubtedly throw further light on this question.

Tomarctus brevirostris Cope

A much worn $\overline{M1}$, C.I.T. No. 774, possesses a size like that of a coyote molar and appears to represent a species related to Tomarctus brevirostris. The tooth is moderately large and differs from other members of the genus in its exceptionally long heel. Tooth-wear has undoubtedly accentuated the heel length.

A long, slender upper canine tooth has also been referred to this species.

Measurements (in millimeters)

C, upper anteroposterior diameter	5
C, upper transverse diameter	2.5
C, upper distance from tip of crown to end of root	3.8
$\overline{M1}$, anteroposterior diameter	19.5
$\overline{M1}$, transverse diameter	7.6
M1, anteroposterior diameter of heel	6.8

Relationships.--T. rurestris (Condon) is distinctly larger than this form from Tonopah. T. kelloggi is much smaller. T. temerarius has a considerably smaller $\overline{M1}$ and this tooth possesses a shorter heel. Of the canids described from the Great Plains region, Tomarctus brevirostris Cope (1873B; Matthew 1924, pp. 88-96, figs. 11-16) is nearest to the specimen from Tonopah. From the point of view of size, proportions, metaconid development and heel-length, a specimen from Barstow (U.C. No. 19402) shows very close resemblance. The Barstow specimen was referred by Merriam (1919, pp. 462-464) to T. near temerarius. Matthew remarks that the type upper jaw of T. temerarius belongs to an animal only slightly smaller than the small variant <u>T</u>. <u>brevirostris</u>. C.I.T. No. 774 which is a little larger than U.C. No. 19402 from Barstow, agrees almost exactly with M$\overline{1}$ of <u>T</u>. <u>brevirostris</u> from the Pawnee Creek and Lower Snake Creek.

Leptocyon vafer (Leidy)

Both rami of a lower jaw, C.I.T. No. 780, with some teeth missing combine to provide a series from C to M$\overline{2}$ complete except for P$\overline{4}$. Another lower jaw fragment, C.I.T. No. 2815 bears P$\overline{4}$. Additional lower jaw fragments, the posterior half of P$\underline{4}$, and a few milk teeth (poorly preserved C - Dm$\overline{4}$) make up the rest of the material representing this species. Five adults and one young individual are represented in the collection.

<u>Mandible</u>.--The jaw is long, slender, shallow and fox-like in appearance. The anterior mental foramen lies between P$\overline{1}$ and P$\overline{2}$, the posterior below the posterior end of P$\overline{3}$. The masseteric fossa reaches forward almost to a level with the alveolus for M$\overline{3}$.

Measurements (in millimeters)	780
Depth of mandible below middle of M$\overline{1}$	10.5
Thickness of mandible below middle of M$\overline{1}$	5.2

<u>Lower</u> <u>dentition</u>.--The long, slender canine is relatively larger than that in <u>T</u>. cf. <u>confertus</u>. P$\overline{1}$ is single-rooted and simple-cusped. All the remaining premolars are double-rooted. P$\overline{2}$ has a simple cusp. A posterior accessory cusp characterizes P$\overline{3}$. P$\overline{4}$ has a slight anterior basal cusp, a strong posterior accessory cusp, and a marked posterior basal cusp.

$\overline{M1}$ differs from this tooth in T. paulus in size and in presence of a low marginal entoconid crest rather than a strong entoconid cusp. This crest bears a very small entoconid.

$\overline{M2}$ likewise differs strikingly from the corresponding tooth of T. paulus. It is characterized by an almost complete lack of paracone and by a low entoconid crest bearing a minute entoconid.

$\overline{M2}$ is followed by an alveolus for a single-rooted $\overline{M3}$.

Measurements (in millimeters)

	780	2815
Length of series C - $\overline{M2}$	52.5	
C, anteroposterior diameter	4.3	
$\underline{C}$, transverse diameter	3.0	
$P\underline{1}$, anteroposterior diameter	2.2	
$P\underline{1}$, transverse diameter	1.4	
$P\underline{2}$, anteroposterior diameter	5.4	
$P\underline{2}$, transverse diameter	1.8	
$P\underline{3}$, anteroposterior diameter	6.6	
$P\underline{3}$, transverse diameter	2.0	
$P\underline{4}$, anteroposterior diameter		7.5
$P\underline{4}$, transverse diameter		3.0
$M\underline{1}$, anteroposterior diameter	10.5	10.8
$M\underline{1}$, transverse diameter	4.2	4.3
$M\underline{2}$, anteroposterior diameter	6.4	6.8
M2, transverse diameter	8.5	7.4

Relationships.--Although Leidy's type specimen Leptocyon vafer (1869, pl. 1, fig. 11.) differs from the Tonopah form in having slightly larger proportions throughout, no apparent specific difference can be found to distinguish the two.

Canis? vafer from the Ricardo as described and figured by Merriam (1919, pp. 533-535, fig. 138a-b) is slightly larger and possesses an entoconid in $\overline{M1}$ which "is relatively small but prominent."

C.I.T. No. 780 is larger than Canid, indet. C.I.T. No. 2308 from the Avawatz Mountains (Henshaw 1939, p. 17, pl. 2, figs. 2 and 2a).

On the basis of the peculiar heel in $\overline{M1}$ of the Tonopah material, the author agrees with Matthew (1918, p. 190) that although the foxes parallel L. vafer in proportions of the jaw, they are "too closely related in dentition to Canis to be separately descended from Leptocyon instead of Tephrocyon" (Tomarctus), or from Cynodesmus, see McGrew (1935, p. 310).

Aelurodon wheelerianus asthenostylus, n. var.

The posterior portion of a palate with P4, M1 and M2 C.I.T. No. 781; two jaws, the best of which, C.I.T. No. 2816, is complete with the exception of absence of the incisors, M3, and the ascending rami; a few separate teeth including a milk upper carnassial; a fragment of a radius and part of a calcaneum comprise the material representing the genus Aelurodon in the Tonopah collection. At least three individuals are recorded.

Mandible.--The mandible is short, deep, and thick for a canid. Three mental foramina can be observed, the first a small one beneath I3, the second and largest beneath the anterior portion of P2, and the third beneath the posterior portion of P3. The deep masseteric fossa extends forward to a point below the posterior root of M3.

Measurements (in millimeters)	2816
Depth of mandible below middle of M1	32.0
Thickness of mandible below middle of M1	12.9

Upper dentition.--The upper carnassial tooth is relatively much shorter and stouter than P4 of Canis. The tooth bears a parastyle in the form of a tiny tubercle which is not set off from the anterior portion of the paracone. The strong protocone, located directly medial to the parastyle, does not project in front of the anteroexternal border of the tooth. A pronounced cingulum is present on the internal side of the heel of the tooth.

M1 is short anteroposteriorly and wide transversely, and has the same proportions as in Canis. The heel is large, but there is no protoconule. The metaconule is relatively strong, being almost as well-developed as the protocone. The hypocone crest is likewise well-developed. A moderately strong cingulum traverses the anterior, external and part of the posterior border of the tooth.

M2 is relatively longer anteroposteriorly and shorter transversely than the comparable tooth in Canis. Hence it is slightly more robust. All of the cusps are small. In the heel only the protocone and hypocone are developed. A weak cingulum borders the antero-external portion of the tooth.

A large trenchant upper milk carnassial possesses the characteristic features of this tooth in canids. The tooth bears only the faintest suggestion of a parastyle.

Lower dentition.--The canine is shorter-crowned, stouter, and with heavier roots than in Canis. The anterior and posterior crests are placed similarly to those of Canis.

The lower premolar teeth are larger and are somewhat more crowded than in Canis. They tend to have a slight backward pitch. Individually these teeth show slight reduction in size. The premolars are somewhat compressed and retain their cutting function, although they are not nearly so compressed as the corresponding teeth in Canis.

P1 in C.I.T. No. 2816 is a small single-rooted tooth very much as in Canis.

$\overline{P2}$ and $\overline{P3}$ are moderately large, double-rooted teeth, subequal in size. They are characterized by a large, conical main cusp and a small heel cusp, between which lies a distinct and moderately large posterior accessory cusp. There is a very small anterior accessory cusp on both teeth.

$\overline{P4}$ resembles $\overline{P2}$ and $\overline{P3}$ in form but is larger in size. The anterior end is toed in very slightly giving the tooth an orientation not quite parallel to the jaw. The heel of the tooth differs from that in $\overline{P2}$ and $\overline{P3}$ in slightly greater transverse diameter.

$\overline{M1}$ resembles _Canis_ in every respect including development of metaconid and relative size of heel. This tooth is relatively wider than $\overline{M1}$ in _Canis_.

$\overline{M2}$ is like that in _Canis_ except that a small paraconid is present.

$\overline{M3}$ is not preserved but one ramus bears two small alveoli for its roots.

All teeth, both upper and lower, are moderately worn. There is little evidence of a shearing wear on the camassials.

Measurements (in millimeters)

Upper dentition	*A. wheelerianus* No. 8307(1) A.M.N.H.	No. 781 C.I.T.	*A. saevus* No. 8305(2) A.M.N.H.
P4, external anteroposterior diameter	23.2	21.2	23.8
P4, greatest transverse diameter	13 ap	12.6	12.5
M1, external anteroposterior diameter	14.8	15.6	17.6
M1, greatest transverse diameter	21.0	21.0	22.2
M2, external anteroposterior diameter	7.4	8.1	6 ap
M2, greatest transverse diameter	12.0	13.3	14.0
		No. 790	
Dm3, anteroposterior diameter		16.8	
Dm3, greatest transverse diameter		9.0	
Lower dentition		No. 2816	
Length of series C - M2	96	100 ap	103
C, anteroposterior diameter at base of crown	12 ap	11.0	10.1
C, transverse diameter at base of crown	10 ap	8.8	8.5 ap
P1, anteroposterior diameter	6.3	5.5	4.0
P1, transverse diameter	4.6	3.9	3.3
P2, anteroposterior diameter	10.8	9.2	9.1
P2, transverse diameter	6.2	5.4	5.1
P3, anteroposterior diameter	12.6	10.9	11.5
P3, transverse diameter	7.4	6.5	6.5
P4, anteroposterior diameter	16.4	14.2	16.1
P4, transverse diameter	9.4	8.3	9.4
M1, anteroposterior diameter	26.8	25.0	27.3
M1, transverse diameter	12.4	10.2	11.5
M2, anteroposterior diameter	11.0	11.8	12.8
M2, transverse diameter	8.2	7.9	8.6

ap, approximate measurement.
(1) Matthew 1904, figs. 3 and 4.
(2) Cope and Matthew 1915, pl. 118.

Relationships.--*Aelurodon wheelerianus asthenostylus* of the Tonopah fauna falls apparently within the genus *Aelurodon* (see Matthew and Stirton 1930, p. 182). The anterior premolars are slightly reduced, retaining a more or less compressed form and cutting function. The upper molars closely resemble those of *Canis*. $\overline{P1}$ is present. $\overline{P2}$ and $\overline{P3}$ are two-rooted. $\overline{P4}$ possesses a weak accessory cusp and a distinct posterior accessory cusp. The heel cusp in this tooth is only moderately wide. $\overline{M1}$ is patterned as in *Canis*. $\overline{M2}$ resembles the comparable tooth in *Canis* except that a weak paraconid occurs in C.I.T. No. 2816. In all the above mentioned characters *Aelurodon wheelerianus asthenostylus* agrees with *Aelurodon*. Only in the fact that the parastyle in $\underline{P4}$ is very weak does *Ae*. *w*. *asthenostylus* differ from the strong-styled type.

A very close relationship appears to exist between *Ae*. *wheelerianus asthenostylus* and the type *Ae*. *wheelerianus* Cope from Santa Fe, (Cope 1877, pl. 69, type figs. 2, 2a, 2b; Cope and Matthew 1915, pl. 119a; and refiguration, Matthew 1904, figs. 3 and 4.) C.I.T. Nos. 781 and 2816 approximate the referred specimens very closely in size. *Ae*. *w*. *asthenostylus* has premolars that are slightly reduced and molars that are slightly enlarged. The anterior accessory cusps in the lower premolars are a little weaker in C.I.T. No. 2816 than they are in the referred material A.M.N.H. No. 8307. $\underline{P4}$ of *Ae*. *wheelerianus* bears a strong parastyle, distinct from the anterior blade of the paracone. In *Ae*. *w*. *asthenostylus* the parastyle, no longer distinct, forms a weak anterior ridge on the paracone.

The ramus of the type *Aelurodon saevus* (Leidy 1869, pl. 1, fig. 9; also Cope and Matthew 1915, pls. 118-119; Matthew 1904, figs. 3 and 4) is longer, more slender, and its premolars are more widely spaced than in C.I.T. No. 2816. The anterior mental foramen lies below the posterior root of $\overline{P2}$ in *Ae. saevus*. *Ae. saevus* has been regarded by Matthew and Stirton (1930, p. 188) as a progressive derivative of *Ae. wheelerianus*. This species shows in its dentition the same evolutionary trends as *Ae. w. asthenostylus*. These trends are carried out to a greater extent in *Ae. saevus* than they are in the Tonopah form. *Ae. saevus*, likewise, ranks close to *Ae. w. asthenostylus* in size. The premolars of *Ae. saevus* are still more reduced; the molars are further enlarged. Anterior accessory cusps have disappeared completely; posterior accessory cusps are weaker. $\underline{P4}$, however, does bear a parastyle.

Thus *Ae. wheelerianus asthenostylus* with its weak parastyle seems to lie on a side branch near the primitive end of the direct line of evolution between *Ae. wheelerianus* and *Ae. saevus*.

Two rami from Barstow, U.C. Nos. 19398 and 21231 (Merriam 1919, p. 465, figs. 10 and 11), have been referred to *Aelurodon* near wheelerianus Cope. Both are larger, more massive, but similar in proportions to *Ae. asthenostylus*. $\overline{M2}$ and $\overline{M3}$ of U.C. No. 19398 are proportionally very small; $\overline{M2}$ of U.C. No. 21231 is large. An undescribed *Aelurodon* from Barstow, U.C. No. 35295, is represented by a jaw which, although closely comparable to C.I.T. No. 2816, is slightly smaller, more slender, with teeth slightly smaller, more trenchant, and not so closely spaced. This ramus bears only one mental foramen.

Aelurodon haydeni, U.C. No. 29638, from the Esmeralda of Fish Lake Valley, close to Leidy's type (1869, pl. 1, fig. 10), is more than one-third larger than *Ae. wheelerianus asthenostylus*.

Aelurodon aphobus Merriam (1919) is much larger than *Ae. wheelerianus asthenostylus*. A single undescribed lower jaw, U.C. No. 22472, from the Ricardo, though slightly larger, approximates C.I.T. No. 2816 in size. Unfortunately the comparison can be carried no further, since the dentition of U.C. No. 22472 has not been preserved.

Amphicyon? sp.

Metacarpals III and IV, C.I.T. No. 767, the distal end of another metapodial, C.I.T. No. 783, and a phalanx, C.I.T. No. 777, are characterized by very large size, massive appearance, and rugose surfaces. These foot elements are canid in appearance. Although the proximal ends have large lateral articular facets, they do not have the extreme overlap which is characteristic of the Felidae. The proximal articular surface of metacarpal III is smooth and slopes with a slight groove on the dorsal side. Immediately distal to this articular surface, on the dorsal side, lies a deep pit for the insertion of a ligament. Another pit is located near the proximal end, distal to the volared surface for articulation with metacarpal II. The shaft is slightly convex dorsally in its long diameter. Near the distal end of the shaft are two very large lateral eminences for attachment of ligaments, a cat-like feature. The dorsal side of the distal articular surface presents a surface which is more nearly hemisphericalthan hemicylindrical, another cat-like character. Although the distal keel is strong, it is not so long and narrow as it is in either Felis or Canis.

In metacarpal IV the proximal articular surface is smooth and sloping. The dorsal articular facet for metacarpal III is flat, in contrast to the slight projection of the surface in Canis and to the very strong projection in Felis. The entire proximal half of the volar side of metacarpal IV is covered by an upraised, wide, flat, rough area for attachment of a ligament. The shaft is straight, not curved as in Felis. The distal end resembles that of metacarpal III.

The proximal end of the phalanx presents a deep, smooth hemispherical cup. The wide, flattened shaft is dorsally convex. Deep lateral pits for insertion of ligaments lie on either side of the broad distal end.

Measurements (in millimeters)

	Metacarpals 767 III	Metacarpals 767 IV	Phalanx 777
Length	97	98.5	54
Proximal end AP	37.5	33.5	28
Proximal end Tr	21.5	27.5	19.5
Distal end AP	22.7	23.5	14.3
Distal end Tr	25.8	26.5	21.8
Least dimensions of shaft AP	13.9	14.5	9.8
Least dimensions of shaft Tr	15.0	15.8	17.5

AP, anteroposterior diameter.
Tr, transverse diameter.

Relationships.--Although the foot structure of Amphicyon is at present unknown (Matthew, 1924, p. 115), it is believed that these elements from Tonopah are of that genus. The material is not strictly comparable to the metapodials described by Schlosser (1899) as Amphicyon. The latter metapodials from Eckingen near Ulm, as Matthew has already noted "belong to a much smaller animal, very different in foot proportions"

A series of metapodials found in definite association with skull and dentition of Amphicyon from Pawnee Creek occurs in the collections of the U.C. Museum of Paleontology. These Pawnee Creek metapodials are almost identical with C.I.T. No. 767.

MUSTELIDAE

Part of an upper dentition, two mandibular fragments, and several individual teeth clearly belong to mustelids. The minimum mustelid population within the one species which occurs in the Tonopah fauna consists of three individuals, a young adult, and two adults of more advanced age.

Brachypsalis pachycephalus Cope

An almost complete maxillary C.I.T. No. 1231, with P1 to P4 in place, a loose M1, two loose P4's, a ramus C.I.T. No. 1230, with worn C, and P3 - M2, another partially preserved ramus and individual canine teeth are believed to represent this species.

Skull.- The maxillary is short and high. The anterior rim of the orbit lies above the anterior root of P4. The lachrymal foramen is large and round. The infraorbital foramen opens over the middle of P3. The malar forms a very massive zygomatic arch.

Measurements (in millimeters)

	No. 1231 C.I.T.	No. 8338 A.M.N.H.
Least depth of malar below orbit	13.0	11.8
Least distance from rim of infraorbital foramen to orbital rim	11.8	12.7

Mandible.- The short, heavy mandible deepens posteriorly. Three small mental formamina lie in a horizontal line below the region between P3 and C. The masseteric fossa reaches forward to a point below the anterior end of M2.

Upper dentition.- Alveoli show that the incisors were large. The upper canines are of relatively very large size, with short crown and very massive root. The crown is grooved anteriorly from wear against the lower canines. P1 is a small single-rooted, peg-like tooth.

P2 and P3 are fairly short and wide and are so worn that the original characters of their cusps are difficult to determine. P2 was set slightly diagonally. P3 may have had a small heel cusp.

P4 is likewise short and wide. The very large protocone projects strongly forward and inward. A small parastyle is present. A low cingulum lies along the posterior internal base of the metacone. Although the shear of the unworn tooth appears high, the tooth wears to a low cutting edge.

M1, which has been referred to this species, is characterized by a small paracone, a still smaller metacone, a large ridge-like protocone, almost no sign of metaconule, which may be due to wear, a parastyle crest, a metastyle crest and most important of all a very strong anterointernal flange which makes the heel of the tooth wider than the outer edge. There is no indication in the specimens available of an alveolus for M2.

Lower dentition.- The canines are comparable in size to those in the upper dentition. P1 probably was present in the young animal, since the first premolar is still present in the upper dentition. From its alveolus P2 appears to be single-rooted, although the two roots may have been closely appressed.

P$\overline{3}$ and P$\overline{4}$ are rather short and wide like the upper premolars, and have lost all other characters because of wear. A shattered P$\overline{4}$ in specimen C.I.T. No. 778 suggests that there was a posterior accessory cusp on the crown of this tooth.

M$\overline{1}$ is also short and wide, and is characterized by a very strong metaconid, short heel with small entoconid crest rather than an entoconid cusp, and the surface is worn to a low angle of shear.

M$\overline{2}$ is small, almost round in outline, and with a very short basined heel.

Comparative measurements (in millimeters)

Upper dentition	B. pachycephalus No. 1231 C.I.T.	B? hyaenoides No. 8338 A.M.N.H. Republican R.	B. matutinus No. 18921 A.M.N.H. L. Sheep Crk.	B. modicus No. 17210 A.M.N.H. L. Snake Crk.	B. pristinus No. 18268 A.M.N.H. U. Snake Crk.
Length, P2 - P4	35.0	32.7			
C , anteroposterior diameter	13.1				
C , transverse diameter	8.8				
P1, anteroposterior diameter	2.4				
P1, transverse diameter	2.3				
P2, anteroposterior diameter	7.3	7.0			
P2, transverse diameter	5.0	4.6			
P3, anteroposterior diameter	9.3	8.8			
P3, transverse diameter	6.5	5.8			
P4, internal anteroposterior diam.	15.4	14.1	13.9	15.5	16.7
P4, greatest transverse diameter	10.6	10.0	9.0	11.0	12.8 ap
M1, greatest transverse diameter	12.5	13.0	12.4	14.4	14.3
M1, width of heel	8.0	7.8	6.5	8.0	10.0

Lower dentition	No. 1230 C.I.T.	B. pachycephalus No. 8544 A.M.N.H. U. Mio. Niobrara	No. 18921 A.M.N.H.	No. 17209 A.M.N.H.	No. 18922 A.M.N.H.
Depth of jaw at M2 - M3	23.2	25.3		20.0	18.9
Length, C - M2	64.0			62.4	
C , anteroposterior diameter	11.0			10.7	
C , transverse diameter	7.6			8.0	
P3, anteroposterior diameter	8.0			8.4	
P3, transverse diameter	5.0			5.8	
P4, anteroposterior diameter	11.0		8.3	10.2	9.6
P4, transverse diameter	6.9		5.7	6.5	5.2
M1, anteroposterior diameter	14.0	14.4 ap	12.7	15.7 ap	17.5
M1, transverse diameter	7.5	7.8 ap	5.6	7.5	8.8
M2, anteroposterior diameter	7.1		6.4		
M2, transverse diameter	6.2		4.6		

ap, approximate measurement.

Relationships.- The form and construction of the teeth, especially $P\underline{4}$ and $M\underline{1}$, reveal the affinities of C.I.T. Nos. 1230 and 1231 with the *Paroligobunis* - *Brachypsalis* group of mustelids (Matthew 1924, p. 129).

Brachypsalis modicus Matthew (1918 figs. 4 and 5) from the Lower Snake Creek approximates C.I.T. No. 1231 very closely in size. The protocone of $P\underline{4}$, C.I.T. No. 1231, projects farther forward than in A.M.N.H. 17210. This projection is more apparent than real, however, because the parastyle in $P\underline{4}$ of C.I.T. No. 1231 is entirely worn away and this has shortened in appearance the anteroposterior diameter taken through the outer section of the tooth. $M\underline{1}$ of C.I.T. No. 1231 has a smaller paracone than in A.M.N.H. 17210. The advanced age of C.I.T. No.1231 partly accounts for such differences in the lower jaw as loss of $P\overline{1}$, constriction of aveolus of $P\overline{2}$, and increased heaviness and depth of jaw. For the most part the lower dentitions are similar.

Brachypsalis pristinus (Matthew 1904; Matthew 1924) differs from C.I.T. No. 1231 in its much larger $P\underline{4}$ with no parastyle. $M\underline{1}$ is also much larger and bears a strong posterior heel crest. The lower jaw of this Upper Snake Creek species is not so deep as in C.I.T. No. 1230, but $M\overline{1}$ bulks larger, especially in the heel region. $P\overline{4}$ of A.M.N.H. 18922 is distinctly more slender than P4 of the Tonopah form.

B. matutinus Matthew (1924) of the Lower Sheep Creek is much smaller all around, and has a more elongate $M\overline{2}$.

B. obliquidens Sinclair (1915) from the Upper Snake Creek is characterized by large teeth, greatly crowded in the lower jaw so that $P\overline{2}$ and $P\overline{3}$ are set obliquely in the jaw.

B. marshalli Martin (1928) from Edson, Kansas, differs in its larger size, and in its relatively shorter, wider teeth.

B. angustidens Hall (1930) from the Kern River Pliocene is much smaller than the Tonopah species.

The skull fragment with superior dentition, A.M.N.H. No. 8338, the type of Aelurodon hyaenoides Cope from Driftwood Creek, Nebraska (Cope 1881, p. 388; 1883, p. 244, fig. 11c; Cope and Matthew 1915, pl. 119a, fig. 5) was considered by Matthew (1918, p. 195-196) to represent B. pachycephalus. This form, though slightly smaller than C.I.T. No. 1231, resembles it closely in character of the dentition. In both forms P1 is a peg, P2 is set slightly oblique, and the protocone of P4 projects rather far forward. M1, though similarly constructed, is a little larger transversely in A.M.N.H. No. 8338.

The type of B. pachycephalus Cope (1890) A.M.N.H. No. 8544 from the Loup Fork Upper Miocene, resembles C.I.T. No. 1230 in length of tooth-row and apparently in size of lower carnassial. Unfortunately, the type is fragmentary and the teeth are either absent or, as in the case of M1, badly broken. The jaw of the type is slightly deeper and more massive.

Although the type material is poorly preserved the referred specimen, A.M.N.H. No. 8338, exhibits several characters. If this reference by Matthew is correct, then the relationships of the Tonopah species are with B. pachycephalus Cope.

An undescribed maxillary dentition, U.C. No. 35447 from Barstow, closely resembles C.I.T. No. 1231, although P2 - P4 are slightly more massive than comparable teeth in C.I.T. No. 1231.

FELIDAE

The cats appear to be represented in the Tonopah collection by remains of at least five individuals. The skull and lower jaw material was described in detail by Stock (1934). Although the specimens varied somewhat in size and slightly in characters, Stock referred all of them to *Pseudaelurus intrepidus* Leidy.

Pseudaelurus intrepidus Leidy

Relationships.--Stock has pointed out that C.I.T. No. 791 is closely similar to the Old World *Pseudaelurus*, while it differs from *Metailurus* Zdansky (1924) in premolar dental formula and in possessing an alisphenoid canal.

Pseudaelurus marshi Thorpe (1922) agrees closely with C.I.T. No. 1233 in size, but differs in a number of minor respects (see Stock 1934.) Except for smaller size of the lower jaw material, the Tonopah felid agrees closely in all respects with the type *P. intrepidus*.

A portion of a lower jaw without teeth (U.C. No. 21516) from the Barstow beds is larger, deeper and heavier than No. 1233. Fragmentary material from the Avawatz Mountains (C.I.T. No. 2309) represents a type larger in all measurements with more crowded teeth, and with a smaller heel-cusp in $\overline{M1}$ than in No. 1233. Specimens from the Cedar Mountain region (Merriam 1916) and from Thousand Creek (Merriam and Stock 1928) are too fragmentary to be of any diagnostic value.

EQUIDAE

Remains of the Equidae comprise the bulk of the fossil collection from Tonopah. Isolated teeth and foot bones are preserved in greatest abundance. Maxillary and mandibular tooth-rows make up a considerable part of the collection, but there are no complete skulls. Curiously, while many individuals are represented by this material only a few poorly preserved vertebrae were found.

All of the equid material may be divided into two distinct groups, the hypohippine and merychippine. A population count based on astragali and teeth indicates a minimum of approximately 10 adult and 2 young hypohippine individuals and 100 adult and 10 young of *Merychippus*.

All the specimens referable to *Hypohippus* appear to fall into a single species.

The merychippine material, although extremely abundant, shows surprisingly little variation. Hence, the specific and subspecific differentiation, which was encountered in the Sheep Creek, Pawnee Creek, Snake Creek and Barstow faunas, stands in contrast to a stability of type in the Tonopah assemblage.

Hypohippus near affinis (Leidy)

Skull. - The infraorbital foramen lies directly above the anterior portion of $P\underline{4}$. The diastema between $I\underline{3}$ and C ranges from 12 to 15 mm. in length, while the diastema between C and $P\underline{1}$ falls between 27 and 22 mm. in length.

Mandible. - A single specimen representing the symphyseal region indicates that the diastema between C and P2 approximates 42 mm. in length. The mental foramen is located below the posterior part of the diastema.

Measurements (in millimeters)

	680	1881
Anteroposterior diameter of symphysis measured on inferior border from notch to base of crown of I1	65.6	
Least width of symphyseal region	24.0	
Least depth of symphyseal region	22.5	
Depth normal to alveolar border anterior to P2	35 ap	
Depth normal to alveolar border anterior to M1		46

ap, approximate measurement.

Upper permanent dentition.- The incisors are large, short-crowned, deeply cupped, but uncemented. A strong break occurs between the thickly enameled crown and the root. While the large short canine displays a rounded exterior surface, a strong median ridge occurs on the inner surface.

P1 is a relatively large, short-crowned, double-rooted tooth. It appears to be cupped on the occlusal surface, and is suboval in outline.

In striking contrast to those of *Merychippus*, the molariform teeth are by no means subequal in size. The teeth of the premolar row increase steadily in size from P2 to P4, the latter being the largest of the cheek-teeth. The molar teeth decrease rapidly in size from M1, which is almost as large as P4, to M3, by far the smallest of all the cheek-teeth.

The large protocone displays a characteristic subconical shape with anterior border flattened, and is greater in size than the hypocone. A strong cingulum anterior to the protocone usually disappears on the median border of the base of the protocone. In teeth of one premolar series (C.I.T. No. 1879) the cingulum continues across the median border of the base of the protocone. In P3, P4, and M3 the internal basal border of the protocone lies lingual to that of the hypocone.

Normally the protoloph remains separate from the ectoloph. Generally speaking the anterior premolars show greatest separation of protoloph from ectoloph. The extent of this separation decreases progressively toward the posterior molars. With increased wear the protoloph tands to become attached to the ectoloph. Such attachment has been observed in several specimens of M1, but in only one example of P4. In a few cases the protocone is separate from the protoconule, but the two cusps are usually joined together.

The hypocone is slightly smaller than the protocone and is not so perfectly conical in shape. A small cingulum may be present at the medial end of the valley between protocone and hypocone (usually on P2, sometimes on P3, never on the other teeth). In well-worn teeth the hypocone and hypostyle are connected.

The metaloph is attached to the ectoloph in almost all permanent teeth of Hypohippus in the collection. P2 in C.I.T. No. 1239 forms a single exception. The transverse crest which makes the connection curves anteriorly from the hypocone, then swings back to join the ectoloph at a point opposite the mesostyle.

The large hypostyle is generally cupped posteriorly. With wear, the cup or infold disappears. The hypostyle generally remains discrete, though with wear it does become connected with the hypocone. A moderately strong cingulum borders the tooth between the hypostyle and the hypocone. In one premolar series (C.I.T. No. 1879) the cingulum actually traverses the base of the hypocone and is continuous with the cingulum of the protocone.

A narrow ridge joins the hypostyle with the metastyle. This tenuous connection is completed at a later stage of wear than is that between hypocone and ectoloph, but is usually earlier than the than the connection between protocone and ectoloph.

Crochets reaching forward from the metaconule, appear on several third molars. The fossettes are rarely closed, and then only when the tooth has been greatly worn. In some specimens a few plications have been observed on the metaloph in the prefossette and postfossette areas.

Strong, massive, external styles characterize the teeth. Cement is completely absent. The occlusal surface of the permanent upper cheek-teeth varies in shape. It may be square or rectangular with transverse width much greater than the anteroposterior.

The following measurements (in millimeters) give the maximum heights of the low, strongly curved crowns:

	1879		1239		1404
P2	17.0	M1	17.2	M3	16.5
P3	18.5 est	M2	17.7		
P4	19.0				

est, estimated measurement.

Upper deciduous dentition.- Only two teeth, both representing Dm2, occur in the collection. In these the protoloph is not connected with the ectoloph, and the protocone is separated from the protoconule in C.I.T. No. 2845. The cingulum, though well developed along the anterior side of the teeth, is absent on the inner base of both protocone and hypocone.

The separation of metaloph from ectoloph forms an important diagnostic character. A small transverse ridge points inward from the ectoloph at the posterior end of the paracone crescent. The outer end of the metaloph ridge terminates just anterior to the transverse ridge of the ectoloph. The two ridges overlap and come very close to each other, but they are not joined together except perhaps at the very base.

The hypostyle is much more suppressed than in permanent teeth. The shape of the occlusal surface of Dm2 is like that of P2: Antero-posterior diameter along outer border, 29 millimeters; greatest transverse diameter, 26.5 millimeters. The crown height in Dm2 is 14 to 15 millimeters.

<u>Lower permanent dentition</u>.- The incisors (C.I.T. No. 680) are long-rooted, short-crowned, and not so procumbent as are the merychippine lower incisors. A strong dividing line distinguishes the upraised, thickly enameled crown from the root. Very shallow uncemented cups occur near the posterior border of the occlusal surface.

$P\overline{1}$ (C.I.T. No. 2847) is a small single-rooted tooth which from root to crown is concave anteriorly. The crown is laterally compressed, with a faint anterior tubercle and a large posterior tubercle.

As with upper cheek-teeth, $P\overline{4}$ is the largest and the remaining teeth are successively smaller in either direction from $P\overline{4}$.

In the molariform teeth the metaconid-metastylid column bears no pronounced gutter on its inner wall. There is sometimes a very slight groove near the summit of the column. With wear the column increases very rapidly in anteroposterior diameter.

The posterior lobe of $M\overline{3}$ is relatively small. The triangular entoconid becomes square with wear. The external walls of the protoconid and hypoconid display a strongly curved finely fluted enamel surface. A very deep valley lies between the protoconid and hypoconid. No cement is present on the teeth.

A strong cingulum, which arises high on the anterior border of the tooth, skirts the external basal border of the protoconid. A second cingulum originates in the protoconid-hypoconid valley, skirts the external basal border of the hypoconid, then rises sharply to the posterior border of the tooth.

The occlusal surfaces are relatively short and wide.

Ratios of anteroposterior diameter to transverse diameter

$\overline{P3}$	$\overline{P4}$	$\overline{M1}$	$\overline{M2}$	$\overline{M3}$
1.20-1.40	1.15-1.36	1.25-1.30	1.23-1.39	1.60-1.70

The maximum crown height for all of the lower molariform teeth is approximately 20 millimeters.

Lower deciduous dentition.- The milk-teeth resemble the permanent dentition in every respect except height of crown.

Measurements (in millimeters)

2848	AP	Tr	Crown height
$\overline{Dm3}$ or $\overline{Dm4}$	28	18	12

Hypohippus osborni Gidley (1907, p. 930) is considerably smaller than the largest H. near affinis, although only slightly smaller than the smallest individuals referable to this species.

Hypohippus near affinis from Tonopah falls short of the type H. affinis (Leidy) in size. Material from Big Spring Canyon (A.M.N.H. No. 10834), which was assigned to the type H. affinis by Gidley (1906, p. 135), shows that the lower teeth of H. affinis are somewhat larger than those of the Tonopah form.

A molar series, P3 - M3 U. C. No. 32019, from the Niobrara River U. C. Locality Little Beaver A V336, is smaller than the corresponding teeth from Tonopah. In this specimen there is a firmer connection between metaloph and ectoloph, and a small conical cuspule is present at the lingual end of the protocone-hypocone valley of all the teeth. A small crochet is developed in P4. The protocone and the protoconule show a tendency to remain separate in the premolars. In this latter character and in size, the Niobrara River specimen appears a little more primitive than H. near affinis; while on the basis of metaloph-ectoloph connection the Tonopah form may be slightly more primitive. H. near affinis is interpreted to be more advanced but situated on a closely allied side branch which retained the primitive separation of metaloph and ectoloph.

Well preserved series of upper and lower permanent teeth and upper milk teeth of Hypohippus affinis in the Burge fauna have been illustrated by McGrew (1938). These teeth agree closely in size with those of H. near affinis. A partially erupted M1 in U. C. No. 28842

Measurements (in millimeters)

Upper dentition	1404	1401
Length of series P1 - M3	164	145
Length of series P1 - P4	92	82
Length of series M1 - M3	72	63
P1, anteroposterior diameter	14.2	15.7
P1, greatest transverse diameter	8.2	10.4
P2, AP along outer border	30.0	26.5
P2, AP protoconule-hypostyle	24.0	20.0
P2, greatest transverse diameter	27.4	26.4
P3, AP along outer border	29.2	25.0
P3, AP protoconule-hypostyle	26.0	23.0
P3, greatest transverse diameter	32.5	29.8
P4, AP along outer border	30.5	25.5 ap
P4, AP protoconule-hypostyle	27.2	23.2
P4, greatest transverse diameter	33.8	32.5 ap
M1, AP along outer border	28.5	24.9
M1, AP protoconule-hypostyle	25.0	22.1
M1, greatest transverse diameter	32.5	30.5
M2, AP along outer border	28.8	23.0
M2, AP protoconule-hypostyle	24.2	21.0
M2, greatest transverse diameter	31.4	27.5
M3, AP along outer border	23.2	20.4
M3, AP protoconule-hypostyle	22.5	19.0
M3, greatest transverse diameter	25.4	25.0
I1, greatest diameter	14.4	
I1, least diameter	11.6	
I2, greatest diameter	12.8	11.6
I2, least diameter	10.3	8.5
I3, greatest diameter	9.7	9.2
I3, least diameter	7.9	5.4
C , greatest diameter	11.4	
C , least diameter	8.7	
I3 - C diastema	18 est	14
C - P1 diastema	23 ap	28 ap

AP, anteroposterior diameter.
ap, approximate measurement.
est, estimated measurement.

Measurements (in millimeters)

Lower dentition	1880	1881	2847
Length of series P$\overline{2}$-M$\overline{3}$	148		
Length of series P$\overline{3}$-P$\overline{4}$	74.5		
Length of series M$\overline{1}$-M$\overline{3}$	73.5		
P$\overline{1}$, anteroposterior diameter			9.1
P$\overline{1}$, transverse diameter			6.0
P$\overline{2}$, anteroposterior diameter	24.0		23.6
P$\overline{2}$, transverse diameter	16.3		17.3
P$\overline{3}$, anteroposterior diameter	24.2	23.2	
P$\overline{3}$, transverse diameter	17.5	19.2	
P$\overline{4}$, anteroposterior diameter	24.8	24.0	
P$\overline{4}$, transverse diameter	19.5	20.9	
M$\overline{1}$, anteroposterior diameter	23.8	23.9	
M$\overline{1}$, transverse diameter	18.4	19.0	
M$\overline{2}$, anteroposterior diameter	24.0	22.5	
M$\overline{2}$, transverse diameter	17.3	18.3	
M$\overline{3}$, anteroposterior diameter	23.5	25.5	
M$\overline{3}$, transverse diameter	14.7	15.0	

I$\overline{1}$, greatest diameter			9.4
I$\overline{1}$, least diameter			9.0
I$\overline{2}$, Greatest diameter			9.0
I2, least diameter			8.3

Relationships.- Hypohippus nevadensis Merriam (1913A) of the neighboring Esmeralda fauna presents several characters which find analogies in H. near affinis from Tonopah. The former species was first described from the Esmeralda (U. C. Locality 1980) near Cedar Mountain, Nevada. Further material from Fish Lake Valley, Nevada, was assigned to this species by Stock (1926). A detailed comparison between the Tonopah species and H. nevadensis reveals a similarity in characters, but a discrepancy in size. Unfortunately for the sake of comparison, the material of the type H. nevadensis consists of deciduous upper cheek-teeth and M1. Dm2 from Tonopah is much smaller than Merriam's type (U. C. No. 21056) and somewhat smaller than the specimen from Fish Lake Valley (U. C. No. 27116). The largest M1 in the Tonopah collection is much smaller in all dimensions including height of crown than M1 (U. C. No. 27116) from Fish Lake Valley. The deciduous teeth of H. near affinis resemble those of the Cedar Mountain species in separation of metaloph from ectoloph, in which respect they differ also from the Fish Lake Valley form. While the metaloph and ectoloph are separate in M1 of U. C. No. 27116 from Fish Lake Valley, these crests are joined in all permanent cheek-teeth from Tonopah except P2, C. I. T. No. 1239. A crochet is present in Dm2 and Dm3 (U. C. No. 27116), but it is weak in Dm4 and absent in M1. In the Tonopah collection only one tooth, an M3, bears a crochet. A cingulum traversing the entire inner border of the upper cheek-teeth may be present or absent in the material from the three Nevadan localities.

Lower teeth of H. near affinis resemble those from Fish Lake Valley in every respect except size. The latter lower teeth are larger by about the same amount as are the upper teeth.

Limb elements of the Tonopah species closely approximate in size those of U. C. N. 21056 from Cedar Mountain. It must be remembered, however, that the limb elements of H. near affinis are those of a large adult, whereas U. C. No. 21056 represents a very young individual.

In summary, the major difference between the Tonopah form and Hypohippus nevadensis from Cedar Mountain and Fish Lake Valley is one of size. The latter averages one-sixth to one-eighth larger lineally than the former. In Hypohippus nevadensis the importance of separation of metaloph from ectoloph and the development of a crochet may be overestimated. Merriam (1913) based the new subgenus Drymohippus on this separation of lophs. After reviewing the Fish Lake Valley material, Stock (1926, p. 64) commented: "If the form from the Fish Lake Valley region has been correctly assigned to Merriam's species, this character appears to be subject to individual variation and cannot, therefore, be considered as distinguishing Drymohippus. Likewise, the development of a crochet in the milk teeth would not then offer a constant character distinguishing Drymohippus from other members of the Hypohippus group." (See also McGrew 1938, p. 314.) In the figure of Hypohippus equinus Scott (1895) on P2 the metaloph is apparently separate from the ectoloph. The Tonopah material, with metaloph and ectoloph joined in all except two milk teeth and in P2, bears out the contention that such variations may be common to many hypohippines.

Hypohippus osborni Gidley (1907, p. 930) is considerably smaller than the largest H. near affinis, although only slightly smaller than the smallest individuals referable to this species.

Hypohippus near affinis from Tonopah falls short of the type H. affinis (Leidy) in size. Material from Big Spring Canyon (A.M.N.H. No. 10834), which was assigned to the type H. affinis by Gidley (1906, p. 135), shows that the lower teeth of H. affinis are somewhat larger than those of the Tonopah form.

A molar series, P3 - M3 U. C. No. 32019, from the Niobrara River U. C. Locality Little Beaver A V336, is smaller than the corresponding teeth from Tonopah. In this specimen there is a firmer connection between metaloph and ectoloph, and a small conical cuspule is present at the lingual end of the protocone-hypocone valley of all the teeth. A small crochet is developed in P4. The protocone and the protoconule show a tendency to remain separate in the premolars. In this latter character and in size, the Niobrara River specimen appears a little more primitive than H. near affinis; while on the basis of metaloph-ectoloph connection the Tonopah form may be slightly more primitive. H. near affinis is interpreted to be more advanced but situated on a closely allied side branch which retained the primitive separation of metaloph and ectoloph.

Well preserved series of upper and lower permanent teeth and upper milk teeth of Hypohippus affinis in the Burge fauna have been illustrated by McGrew (1938). These teeth agree closely in size with those of H. near affinis. A partially erupted M1 in U. C. No. 28842 indicates that the Burge form is much higher crowned. The tooth pattern of U. C. No. 28840 differs in presence of a crochet on metaloph, in better connection of metaloph and ectoloph, and in development in the last two molars of a small conical cuspule at the lingual end of the protocone-hypocone valley. The lower molars U. C. No. 28840 are similar in pattern to those of *H.* near *affinis*, but are somewhat higher crowned, and have a larger posterior lobe in M_3.

Known material of *Hypohippus* from Barstow is too fragmentary to afford any comparisons of value. On the basis of broken lower teeth U. C. Nos. 21215 and 35421, the Barstow form appears larger than the *H.* near *affinis*, yet in all probability it, too, lies near that species.

Hypohippus near *affinis* from Tonopah may have been ancestral to *Hypohippus nevadensis*. The former type represents a stage of development which is slightly more primitive than that shown in *H. affinis* from the Burge of Gordon Creek, and is more advanced than *H.* cf. *osborni* from the Niobara River of U. C. Loc. Little Beaver A V 336.

Merychippus calamarius (Cope)

Skull.- Only a few minor characters are determinable from the sparse and fragmentary skull material. The infraorbital foramen lies directly above the posterior portion of P$\underline{3}$ and the anterior border of P$\underline{4}$. The anterior border of the orbit reaches as far forward as the plane of contact between M$\underline{3}$ and M$\underline{2}$. While the diastema between I$\underline{3}$ and C ranges from 19 to 24 millimeters in length, the diastema between C and P$\underline{1}$ varies inversely in length from 32 to 26 millimeters.

Mandible.- Although symphyseal sections and horizontal parts of rami were preserved in considerable abundance, no material is available to illustrate the region of the angle and the ascending ramus. The canine occurs immediately posterior to I$\overline{3}$, and the diastema between C and P$\overline{2}$.is from 43 to 49 millimeters long. The mental foramen is located halfway between C and P$\overline{2}$. In young animals the tooth-size and the diastemal length is the same as in adults. Growth in the mandible takes place by deepening the jaw from 40 mm., just posterior to Dm$\overline{4}$ in a young foal (C. I. T. No. 2833), to 50 mm., between P$\overline{4}$ and M$\overline{1}$ in a young adult (C. I. T. No. 2834). The mandible is also thickened by growth. However, the greatest increase in size and in length takes place in the molar region, as the ascending ramus is pushed back to make room for the molar teeth.

Measurements (in millimeters)	2834	678	656
Anteroposterior diameter of symphysis measured on inferior border from crotch to root of I1	50 ap	49	40
Least width of symphyseal region	28.4	23.0	19.0
Least depth of symphyseal region	22.0	20.4	16.5
Depth normal to alveolar border anterior to P2	32.9	31.0	21 ap
Depth normal to alveolar border anterior to M1	51.4	43 est	22 est

ap, approximate measurement.
est, estimated measurement.

Tooth wear.- Advanced stages of wear efface details of the enamel pattern and destroy the original proportions of the occlusal surface. Hence, well-worn teeth tend to lose many of the characters on which specific determinations are made. For this reason, in the following discussion, all remarks apply to teeth which are approximately one-third worn except where noted to the contrary. Teeth which are unworn to one-third worn are designated as unworn, teeth which are more than one-third worn are termed worn. The state of wear of any given tooth was determined by comparing the height of crown with the maximum crown height for that tooth.

Upper permanent dentition.- The incisors are strongly curved and relatively long-crowned with no sharp break between crown and root. The enamel gradually becomes thinner and disappears toward the root. In each incisor the grinding surface is deeply cupped and the enamel infold is filled with cement.

The upper canine is a strongly curved, peg-like tooth. Occasionally the piercing end of the tooth, instead of being circular in cross section is somewhat flattened on the lingual side of the anterior and posterior edges. Hence, the tooth appears as a small curved blade supported by a column on the lingual side.

P1 is a small, short-crowned, double-rooted tooth located immediately anterior to P2. It is generally well-worn at an early stage and is often lost soon after maturity. Because the angle of the surface of wear on this tooth may vary greatly, its enamel pattern appears in a number of diverse forms. Basically it consists of a prominent outer border, a strong metaconule, and a partially enclosed prefossette opening toward the front.

Separation of the protocone from the protoconule occurs in almost 90 per cent of the unworn molariform teeth. Only 14 per cent of the unworn teeth have rounded or oval protocones. In the rest the protocone has a spur projecting toward the protoconule. The protocone is generally inflated although it may be flattened on the lingual side. Indented protocones rarely occur. The long axis of the protocone is oriented for the most part anteroposteriorly. The protocone usually lies lingual to the posterior half of the prefossette. In some cases, however, it is more posterior, extending back to a position lingual to the metaconule. The protocone in M3 always has this posterior position. The protocone is always larger, more inflated, and more lingual in position than the hypocone.

The hypocone is practically always united with the metaconule. It is generally flattened, although it may be rounded in some specimens. The long axis of the hypocone is almost never oriented anteroposteriorly.

The pli-caballin is generally a single, acutely pointed plication, sometimes a single rounded plication, and rarely a bifid or double plication. The hypostyle has sometimes no plications, but commonly possesses a single acute plication and rarely has a double plication.

The fossettes are usually closed in all teeth except P2. The various plications range in number from none to quadruple folds. On the whole, the complication of the fossette borders would be called moderately to highly complex for a merychippine form. There appears to be a direct correlation between protocone separation and degree of complexity of the enamel pattern. The earlier and more complete the separation, the more complex the pattern.

The external styles are strong. Moderately heavy to heavy cement covers most of the teeth.

In M1 and M2 the ratios between anteroposterior and transverse diameters vary from 1.18-1.10 in absolutely unworn teeth to .90-.76 in very worn teeth. Because of the cement covering on most of the teeth, inaccuracies enter into the measurements of the transverse diameters (Bode 1931, p. 122).

The crowns of the molariform teeth are strongly curved. In unworn teeth the radius of curvature of the external styles generally falls between 40 and 50 mm. The radius of curvature of the lingual side of the protocone ranges between 12 and 18 mm. In unworn upper teeth the maximum crown height is greater than in any merychippine species previously recorded.

Measurements (in millimeters)

	A	B
P1	9	
P2	35	37
P3	39	41
P4	42	45
M1	40 ap	43 ap
M2	44	47
M3	36	41

ap, approximate measurement.

These measurements were taken of separate unworn teeth and of unerupted teeth in maxillary batteries. In list A crown height is considered to be the shortest distance from root to grinding surface taken just anterior to mesostyle, with the notch between the external roots furnishing one measuring point and the indentation on the external wall of the tooth between paracone and metacone furnishing other measuring point.

The measurements in list B were taken by the method used by Bode in compiling data for a table comparing the crown height of merychippine forms from Mascall, Coalinga, Barstow and Tonopah (Bode 1934, p. 56). The measuring points in this case were the base of the anteroexternal root and the tip of the paracone cusp.

Upper deciduous dentition.- The incisors are large, deeply cupped teeth without cement. The canine (C.I.T. No. 1312) is flattened particularly on the inner side. Dm1, as it appears in C.I.T. No. 2835, is a slightly longer tooth than P1. The metaconule is poorly developed, hence the tooth is blade-like in appearance and shows no tendency toward developing fossettes.

Character for character the molariform deciduous teeth resemble closely the permanent premolars, except for the expected differences between deciduous and permanent teeth. In the molariform deciduous teeth the protocone remains free until the crowns are more than half-worn. The fossette borders are a little more complexly plicated than they are in the permanent series. Also in the deciduous teeth the cement varies from a thin film on the outer walls, and none in the fossettes to a moderately thick external coating and a thin film in the fossettes. The following maximum crown-height was measured from the roots to the notch between the paracone and metacone cusps.

Measurements (in millimeters)

Dm3	16 ap
Dm4	17 ap

ap, approximate measurement.

Lower permanent dentition.- A symphyseal section of the jaw with incisors and canines complete (C.I.T. No. 2836) shows that the lower incisor teeth like the uppers are relatively long-crowned and have no sharp break between crown and root. Likewise, the grinding surface is characterized by deep cement-filled cups. The lower incisors differ from the upper in their more procumbent position and the crowns are therefore not so sharply curved.

The lower canine is less curved than the upper. The root of the tooth is circular in cross section. The piercing end of the tooth is flattened on the buccal as well as on the lingual side along the anterior and posterior edges. This gives the tooth the appearance of a central cone with anterior and posterior flanges.

P1, based on a single separate tooth, C.I.T. No. 2837, referred to this position is very small with two rounded roots closely appressed. In an anteroposterior direction the tooth is pinched in where the crown and roots join. The crown is strongly compressed laterally with sharp anterior and posterior edges.

The stout premolars tend to be a little shorter anteroposteriorly and much wider transversely than the molars. In the molariform teeth the anteroposterior length of the metaconid-metastylid column is relatively great. The values for the ratio metaconid-metastylid length to anteroposterior length for P3 thru M2 ranges from .35 to .53, while the mean values for each of these teeth fall between .41 and .45.

	Measurements (in millimeters)						Ratios of measurements		
	Max. AP	Min. AP	Mean AP	Max. MCS	Min. MCS	Mean MCS	Max. M/A	Min. M/A	Mean M/A
P2 (separate)	25.5	21.8	24.0	6.7	5.0	5.9	.28	.20	.243
P3 (in place)	24.2	21.4	23.2	11.2	8.5	9.9	.48	.35	.429
P3 and P4 (separate)	25.0	20.5	22.8	11.8	8.4	10.2	.53	.38	.448
P4 (in place)	25.2	20.3	23.1	11.5	8.8	10.3	.50	.37	.444
M1 (separate)	25.0	19.3	22.6	10.5	8.0	9.3	.49	.36	.413
M2 (separate)	26.4	19.5	22.9	11.0	7.7	9.5	.46	.36	.417
M3 (separate)	27.5	24.0	26.1	8.7	6.5	7.7	.33	.26	.294

AP....anteroposterior length of tooth
MCS...anteroposterior length of metaconid-metastylid column
M/A...ratio of MCS to AP

In $\overline{P2}$ the metaconid occasionally stands as a small separate column halfway between the metastylid and parastylid. In such cases the anteroposterior diameter across the metaconid and metastylid column is much greater than it is when the two are joined into one column, and the mean ratio of metaconid-metastylid length to anteroposterior length becomes .36.

The gutter on the inner wall of the metaconid-metastylid column is sharply incised to rounded. Though the gutter disappears with wear, it is always of pronounced depth in unworn teeth. $\overline{P2}$ characteristically possesses a small gutter and a metastylid which is often more highly developed than the metaconid. In all other teeth the metaconid surpasses the metastylid in size. The posterior lobe of $\overline{M3}$ is greatly extended.

The parastylid swings inward lingual to a plane tangent to the lingual side of the metaconid-metastylid column.

While the entoconid may be in any form from triangular (often indented) to rounded, to almost rectangular, it is generally rounded and strongly inflated.

The posterior extension of the entostylid, while commonly strong in unworn teeth and especially strong in the molars, varies considerably from one tooth to another. With increased wear the entostylid decreases in size.

The external walls of the protoconid and hypoconid are strongly curved in unworn teeth. One or two unworn teeth and a few worn teeth in the collection show a slight tendency toward flattening of the outer walls of these cusps. The sharp, deep V of the valley between the cusps generally points anteriorly. With wear the valley becomes more shallow and open.

As in the upper dentition, the lower teeth sometimes have little or no cement on the external walls, but most of the teeth would be characterized as moderately to heavily cemented.

The antero-external fold is present on more than 75 per cent of the lower teeth. It rarely appears in teeth less than one-fourth or more than three-fourths worn.

As in the upper cheek teeth, the shape of the occlusal surface varies primarily with the stage of wear of the tooth. Measurements on loose unworn teeth and on worn teeth in the jaw yielded the following results.

Ratios of anteroposterior diameter to transverse diameter

	Unworn Teeth			Worn Teeth
	Minimum	Maximum	Average	Average
P2	1.81	2.26	2.01	
P3 and P4	1.60	1.98	1.76	1.57
M1	1.93	2.50	2.23	1.47
M2	2.04	2.60	2.36	1.81
M3	2.46	3.27	2.90	

The extent of plication of the enamel walls of the lower cheek teeth is very slight, hence the pattern would be termed simple.

On unworn lower teeth the maximum crown height is greater than in any merychippine previously recorded.

Measurements (in millimeters)

P1, crown height 8.5
P2, crown height 32
P3, crown height 47
P4, crown height 47
M1, crown height 41
M2, crown height 38
M3, crown height 38

These measurements were made on loose unworn teeth and on unerupted teeth in the mandible. The measuring points were taken as the notch between the roots on the external side and the notch between the metaconid and metastylid cusps.

<u>Lower deciduous dentition</u>.- The incisors are large, deeply cupped and uncemented. A symphyseal section of a new-born foal (C.I.T. No. 2838) bearing only the first incisors and canines reveals that $\overline{Dc}$ is similar to $\underline{Dc}$ but smaller. $\overline{Dm1}$ (C.I.T. No. 660, left ramus) appears as a small peg-like tooth.

In the molariform deciduous teeth the ratio metaconid-metastylid length to antero-posterior diameter of the tooth is very constant. This constancy probably arises from the shortness of crown and hence almost identical stage of wear on all individuals measured.

Ratios of metaconid-metastylid length to anteroposterior diameter

	Minimum	Maximum
Dm2	.36	.39
Dm3	.45	.50
Dm4	.42	.45

These ratios for Dm$\overline{3}$ and Dm$\overline{4}$ correspond closely to similar ratios determined for the permanent premolars P$\overline{3}$ and P$\overline{4}$. The ratio for Dm$\overline{2}$ is higher than all ratios for normal P$\overline{2}$, although it is identical with the ratio determined for the second premolars in which the metaconid stands as a separate column from the metastylid.

In Dm$\overline{3}$ and Dm$\overline{4}$ the metaconid-metastylid column has about the same strength as it has in P$\overline{3}$ and P$\overline{4}$. The column is normally stronger, however, in Dm$\overline{2}$ than in P$\overline{2}$.

The gutter on the inner wall is sharply incised and of about equal depth for all three deciduous molars, hence the gutter in Dm$\overline{2}$ is relatively much deeper than the gutter in P$\overline{2}$.

As in permanent premolars the metastylid in Dm$\overline{2}$ is more highly developed than the metaconid, while the reverse is true of Dm$\overline{3}$ and Dm$\overline{4}$. In contrast to the entoconid in permanent teeth, the milk entoconid is triangular to strongly indented. Only after considerable wear does the entoconid appear rounded. In Dm$\overline{2}$ and Dm$\overline{3}$ the entostylid is strong and is sharply curved lingually. In Dm$\overline{4}$ the very strong entostylid projects posteriorly with only a slight inward curvature. The strongly curved external walls show no flattening. The enamel surface displays a distinctive finely fluted surface. The very deep valley between protoconid and hypoconid points anteriorly. While a few of the teeth lack cement almost completely, most of them are thinly coated with it, and some might be termed moderately cemented. The anteroexternal fold is very well developed toward the base of the crown in Dm$\overline{3}$ and Dm$\overline{4}$. It is slightly to moderately developed in Dm$\bar{2}$. In approximately two-thirds of the milk-teeth in the collection, the external tubercle between protoconid and hypoconid is moderately developed to well developed. Lacking cement to round it off, the occlusal surface is very rough, even sharp-pointed in an unworn stage. Variations in shape of crown may be expressed by ratios between the anteroposterior diameter and the transverse diameter.

Ratios of anteroposterior diameter to transverse diameter

	Minimum	Maximum
Dm2	1.98	2.31
Dm3	1.69	1.90
Dm4	1.74	2.05

The enamel pattern of the lower milk molars is simple. The maximum crown height is expressed as follows:

Measurements (in millimeters)

Dm1	5
Dm2	16
Dm3	18
Dm4	22

The measurements were made on unworn milk-teeth. The measuring points were taken on the posteroexternal face of the tooth from the base of the hypocone to the crest of the hypocone cusp.

Measurements (in millimeters)

Upper dentition	2839	669	1311	2840	2841	Merychippus calamarius Type Specimen
Length of series P2 - M3		135	133	142	134	129.0
Length of series P2 - P4	76.6	73.5	71.3	74.7	71.7	67.8
Length of series M1 - M3		61.4	61.9	67.2	61.9	61.0
P1, anteroposterior diameter	14.9	13.5				
P1, transverse diameter	8.4	7.2				
P2, anteroposterior diameter	29.3	27.5	27.0	27.0	27.4	25.0
P2, transverse diameter	16.9	17.5	17.4	18.2	17.9	17.8
P3, anteroposterior diameter	24.0	23.0	22.0	24.1	22.3	21.5
P3, transverse diameter	20.0	20.5	20.0	20.5	22.1	21.0
P4, anteroposterior diameter	23.3	23.0	22.3	23.6	22.0	21.0
P4, transverse diameter	21.0	21.9	21.1	21.5	22.8	20.5
M1, anteroposterior diameter	21.0	19.7	19.8	21.2	20.7	19.4
M1, transverse diameter	19.6	21.4	20.8	21.8	24.2	19.6
M2, anteroposterior diameter	22.5	21.2	19.8	23.0	21.2	21.2
M2, transverse diameter	20.5	21.6	21.3	21.8	24.2	18.9
M3, anteroposterior diameter		20.5	22.3	23.0	20.0	19.1
M3, transverse diameter		17.9	20.1	19.0	21.4	17 ap

I1, greatest diameter	13.4	13.5	11.5
I1, least diameter	8.1	8.0	8.0
I2, greatest diameter	13.8	14.5	13.6
I2, least diameter	7.0	7.3	7.8
I3, greatest diameter	11.7	13.6	11.4
I3, least diameter	5.8	6.3	6.4
C , greatest diameter	10 ap	10.7	10.1
C , least diameter		7.0	7.3
I3 - C diastema	23.0	19.0	21.9
C - P1 diastema	27.5	31.3	

ap, approximate measurement.

Measurements (in millimeters)

Lower dentition	2834	2842	678	2837	Merychippus calamarius Type Specimen
Length of series P2 - M3	144	140	133x		
Length of series P2 - P4	73.4	70.2	67		
Length of series M1 - M3	70.6	69.4	65x		
P1, anteroposterior diameter				8.7	
P1, transverse diameter				5.0	
P2, anteroposterior diameter	24.6	24.4	22.9		
P2, transverse diameter	11.6	11.5	11.8		
P3, anteroposterior diameter	23.2	22.9	22.8		20.0
P3, transverse diameter	13.6	12.8	14.5		13.2
P4, anteroposterior diameter	24.3	23.1	20.3		21.4
P4, transverse diameter	14.7	13.7	14.7		12.7
M1, anteroposterior diameter	21.4	22.0	21.0		19.5
M1, transverse diameter	12.8	11.5	12.0		10.5
M2, anteroposterior diameter	21.3	23.3	20.0		18.6
M2, transverse diameter	12.3	10.0	11.0		
M3, anteroposterior diameter	27.7	26.0	20.8x		24.8
M3, transverse diameter	10.9	9.7	9.7		8.9

				2836
I1, greatest diameter				11.3
I1, least diameter				8.0
I2, greatest diameter			12.4	12.8
I2, least diameter			7.8	7.5
I3, greatest diameter				12.3
I3, least diameter				6.7
C , greatest diameter	8.8			8.8
C , least diameter	7.0			6.8
C-P2, diastema	42		49	

x, measurement does not include posterior lobe of M3.

Measurements (in millimeters)

Upper milk dentition	2843	2844
Length of series Dm$\underline{2}$ - Dm$\underline{4}$	82.5	80.3
Dm$\underline{1}$, anteroposterior diameter		12.0
Dm$\underline{1}$, transverse diameter		7.0
Dm$\underline{2}$, anteroposterior diameter	34.0	30.5
Dm$\underline{2}$, transverse diameter	19.0	18.2
Dm$\underline{3}$, anteroposterior diameter	23.7	22.9
Dm$\underline{3}$, transverse diameter	21.7	21.4
Dm$\underline{4}$, anteroposterior diameter	25.0	24.5
Dm$\underline{4}$, transverse diameter	21.4	21.7
Di$\underline{1}$, greatest diameter		12.7
Di$\underline{1}$, least diameter		5.2
Di$\underline{2}$, greatest diameter		11.5
Di$\underline{2}$, least diameter		5.1
Di$\underline{3}$, greatest diameter		9.7
Di$\underline{3}$, least diameter		4.7

Lower milk dentition	656	660
Length of series Dm$\overline{2}$ - Dm$\overline{4}$	82.4	77.3
Dm$\overline{1}$, anteroposterior diameter		3 <u>ap</u>
Dm$\overline{1}$, transverse diameter		4 <u>ap</u>
Dm$\overline{2}$, anteroposterior diameter	29.9	26.6
Dm$\overline{2}$, transverse diameter	13.8	12.4
Dm$\overline{3}$, anteroposterior diameter	24.6	24.0
Dm$\overline{3}$, transverse diameter	14.0	14.2
Dm$\overline{4}$, anteroposterior diameter	26.6	25.9
Dm$\overline{4}$, transverse diameter	13.3	13.5
Di$\overline{1}$, greatest diameter	12.3	
Di$\overline{1}$, least diameter	5.5	
Di$\overline{2}$, greatest diameter	12.3	
Di$\overline{2}$, least diameter	5.2	
Di$\overline{3}$, greatest diameter	9.0	
Di$\overline{3}$, least diameter	5.5	

<u>ap</u>, approximate measurement.

Relationships.- Unfortunately the neighboring Esmeralda localities (Stirton 1936, p. 183) contain very scant protohippine remains. Of these only an $\overline{M3}$ (U. C. No. 19825, Merriam, 1916, pp. 187-188, fig. 21) offers diagnostic characters which approach those of *Merychippus calamarius*. The occlusal surface of this tooth is short. The antero-posterior diameter of the metaconid-metastylid column and of the posterior lobe are relatively much shorter than the corresponding features in third molars from Tonopah. The relative transverse width of the posterior lobe of $\overline{M3}$ surpasses that of *M. calamarius*. The inflation of entoconid and absence of an anteroexternal fold in this instance signify little as to the evolutionary stage of the tooth when comparisons are made with teeth from Tonopah. The crown height of 36 mm. may be considered extremely high for a merychippine tooth as worn as this one is. In summary, the strong development of the third lobe and the relatively great height of crown may be taken as evidence that this specimen (U.C. 19825) probably belongs to a primitive form of the genus *Protohippus* or *Pliohippus*. Merriam (1916, p. 188) stated that the tooth "represents a protohippine horse of approximately the stage of evolution seen in the form of *Merychippus* near *calamarius* of the Barstow fauna." To the author the tooth appears to be more advanced than *M. calamarius*, though its geologic age relative to the Tonopah merychippine horses can not be stated with any surety.

Merychippus intermontanus Merriam (1915, 1919) from the Barstow fauna falls within the size limits of the largest individuals from Tonopah. A simple enamel pattern and early attachment of the protocone distinguish the upper cheek-teeth and milk-dentition from those of *M. calamarius*. None of the lower teeth of *M. intermontanus* carries the anteroexternal fold which develops so commonly in lower cheek-teeth of *M. calamarius*.

Though the upper cheek-teeth of *Merychippus sumani* Merriam (1911, 1915, 1919) from the Barstow show a complexity of enamel pattern equal to that of *M. calamarius*, the teeth of this species are considerably smaller.

Merychippus calamarius stylodontus Merriam (1915, 1919) from the Barstow fauna closely approximates the Tonopah form in size, although it is considerably smaller. Furthermore, the enamel pattern of the Tonopah form is slightly more complex than that of the Barstow *M. calamarius stylodontus*. Merriam states (1919, p. 484) that *M. calamarius stylodontus* differs from the typical *M. calamarius* "in relative simplicity of enamel folds of the walls bordering the fossettes. ......It is considerably smaller than the typical form and the crowns seem narrower. The apparent difference in width may be due in part to differences in stages of wear of specimens compared, or to method of measurement." The author wishes to point out that the measurements previously recorded (Cope 1877, p. 322; Merriam 1919, p. 489) for *M. calamarius* obviously do not correspond to measurements made on the original plate (Cope 1877, pl. 75, fig. 1). Thus discounting the question of width, it becomes apparent that M. calamarius stylodontus differs from the type M. calamarius in precisely the same manner as it does from the Tonopah merychippine species.

The teeth of the type Merychippus calamarius (Cope, 1875) from the Santa Fe do not differ from those of its equivalent from Tonopah in any important character. The upper teeth of the Santa Fe type may be described as slightly smaller and slightly more complex than typical Tonopah specimens. The lower teeth from Santa Fe show a relatively smaller posterior lobe in M3 and they do not carry any anteroexternal fold.

Plication	Tonopah	Santa Fe
pli-caballin	generally single	single or double
pli-protoloph	single, rare	single, rare
pli-protoconule on P2	absent	present
on other teeth	single	single
pli-prefossette on P2	single	single
on other teeth	generally single	double to quadruple
pli-postfossette	double or triple	double or triple
pli-hypostyle	absent or single	single or double

The material from Quatal Canyon (Gazin 1930) which was designated Merychippus sumani Merriam suggests but does not approach the M. calamarius. The upper teeth from Quatal Canyon are smaller, less cemented, and lower crowned than those of M. calamarius. The lower teeth in the Quatal Canyon collection differ from M. calamarius in having a more shallow inner gutter, a deeper, more rounded external valley, and a smaller position lobe on M3.

No teeth from the Mint Canyon fauna (Maxson 1930; Stirton 1933) approach those of M. calamarius in appearance.

The Ricardo species *Pliohippus tantalus* Merriam (U.C. No. 19434, 1913c, fig. 4; 1919, fig. 189) and *Pliohippus fairbanksi* Merriam (U. C. No. 19789, 1915, fig. 8; 1919, fig. 185) have both larger and higher crowned teeth than in *Merychippus calamarius*. *Pliohippus* near *mirabilis* (U.C. No. 21323, 1919, fig. 188) is of about the same size as *M. calamarius*, but its enamel pattern is simpler and the tooth-crown appears to be higher.

None of the protohippine horses of the Great Plains region approaches very closely *M. calamarius* from Tonopah. The bulk of the Equidae from the Snake Creek was at first tentatively referred to *Merychippus* cf. *insignis* Leidy (Matthew and Cook 1909). Later, when the formation was divided into zones, ninety to ninety-five per cent of the Equidae from the Lower Snake Creek were referred to *Merychippus paniensis* Cope (Matthew 1924). The type for *M. insignis* consists of Dm2 and Dm3. These teeth differ from *M. calamarius* in being noticeably smaller and in lacking cement. The type *M. paniensis* is smaller and relatively low-crowned, though Matthew does state that some of the specimens in the fauna are as large and progressive as *M. calamarius*.

Among the Niobrara River (sensu McGrew and Meade 1938) protohippines in the undescribed collections of the University of California, *Merychippus insignis* appears much smaller and perhaps more primitive than *M. calamarius*. A second species represented by U. C. No. 33068 (perhaps *M. republicanus*) differs in its constant protoconal separation, smaller size and slightly more complex enamel pattern. A third species, which may represent *M. perditus*, appears longer crowned and shows definite connection between protocone and protoconule at a very early stage of wear.

Pliohippus supremus, U.C. No. 32285, from the Burge (McGrew 1938) is somewhat similar to *M. calamarius* in size and in enamel pattern, but it is longer crowned and the protocone becomes attached at a much earlier stage of wear. Teeth of *Pliohippus pernix*, U.C. No. 32501, are larger and simpler than those of *M. calamarius*, and display an attachment of the protocone at an earlier stage of wear.

Comparative Osteology of Hypohippus and Merychippus

Skeletal parts.- For the sake of convenience in discussion, the skeletal elements of *Merychippus calamarius* and *Hypohippus* near *affinis* are described together. Very few of the larger bones have been preserved completely. The hypohippine material occurs in a poorer state of preservation and specimens are much less abundant than those of the merychippine type. The ratio of frequency of occurrence is 2 to 10 merychippine elements to every one of *Hypohippus*.

For the most part the skeletal material resembles that of *Equus* very closely in all features except size. Only those differences from *Equus* which appear in form and in the proportions of elements are described below at some length.

Scapula.- In this element of the shoulder girdle the spine differs from that of *Equus* in its downward slope toward the neck without suggestion of an acromion.

Measurements (in millimeters) of scapula

	Merychippus	*Hypohippus*
Anteroposterior diameter from tuber to posterior border of glenoid cavity....	68	77.5
Transverse diameter across glenoid cavity...	40	49
Anteroposterior diameter across glenoid cavity..............................	44	56

Humerus.- The head is similar to the head in the humerus of *Equus*. In every other feature the humerus of *Merychippus* differs from that of the modern horse. In the first place, the bicipital groove is single, not double as in Equus. Secondly, the anterior portion of the lateral tuberosity is strongly produced so as to curve medially. It overhangs the bicipital groove. A large inner tuberosity extends posteriorly toward the articular surface of the head. The comparatively slender shaft is twisted. Compared to the corresponding feature in Equus, the deltoid ridge is inconspicuous and localized, having no crests extending out from it. The lateral condyloid crest is moderately developed. The coronoid fossa is not so deep as in Equus. The medial condyle is large and tapers from the medial border toward the synovial fossa. The lateral condyle is much smaller than the medial one. Medially, the lateral condyle is characterised by a low, rounded ridge. The lateral portion of the lateral condyle is cylindrical rather than conical on its bearing surface. The forms of the medial and lateral condyles give the distal extremity a much more pronounced appearance of obliquity than is characteristic of Equus.

In all of these characters in which the humerus of Merychippus differs from that of Equus, a strong similarity is shown to the humerus of a Recent artiodactyl such as the ox.

In the later evolution of the horses from the merychippine stock there has developed in the humerus a double bicipital groove with formation of a median convexity (Osborn 1930, p. 754; Scott 1895, p. 101). The curved and overhanging prominence of the anterior portion of the lateral tuberosity has been subdued and finally lost. The deltoid ridge and its accompanying proximal and distal crests have become strongly developed.

Only the distal ends of several humeri of *Hypohippus* are available in the Tonopah collections. These differ from the merychippine type and approximate closely in form that displayed by *Equus*. The lateral condyloid crest is fairly well developed. The medial condyle does not taper so strongly as it does in *Merychippus*, yet it is not quite so gently tapering as it is in *Equus*. The lateral condyle is marked by a pronounced shallow groove and is conical, increasing in diameter toward the lateral border as in *Equus*. The distal extremity of the humerus differs from that of *Equus* in having a rounded border at the median side of the medial condyle, whereas in *Equus* the bearing surface of the median condyle is separated from the median border by a very sharp angular break.

Measurements (in millimeters) of humerus

	Merychippus	*Hypohippus*
Total length	223	
Smallest diameter of shaft:		
anteroposterior	27	
transverse	22	
Transverse diameter, proximal end	62	
Transverse diameter, distal end	50	59

Radius.- The humeral articular surface as well as the distal end of the radius of *Merychippus* differs from that of *Equus* in being proportionally narrower transversely. The sagittal ridge of the proximal end is a little more pronounced than it is in *Equus*. The dorsal surface of the shaft is strongly curved but the volar surface is flat.

Measurements (in millimeters) of radius

	Merychippus	Hypohippus
Total length	227	265 ap
Proximal end, anteroposterior diameter	27.0	33.5
Proximal end, transverse diameter	47.5	59.0
Distal end, anteroposterior diameter	27.0	32.0
Distal end, transverse diameter	44.5	49.5
Narrowest part of shaft, anteroposterior diameter	19	
Narrowest part of shaft, transverse diameter	26	

ap, approximate measurement.

Ulna.- Only fragments of the proximal end of the ulna are preserved. The structural characters of the proximal end are similar to those in the corresponding portions of the ulna in *Equus*.

Carpus.- The scaphoid does not differ markedly from that of *Equus*. In the merychippine form this element has rounder articular surfaces and more concave borders. The lunar resembles that of *Equus* very closely. The proximal articular surfaces of the cuneiform are relatively farther apart than in *Equus*. These surfaces are always distinct from each other with a non-articular area between them. The anterior proximal articular surface and the distal articular surface are relatively narrower than those of *Equus*. The pisiform is longer anteroposteriorly than in *Equus*. It has two distinct surfaces for articulation with the cuneiform and one surface which articulates with the ulnar portion of the fore-leg bone. The trapezium was not preserved. The trapezoid is a wedge-shaped bone with less articulating surface than that of *Equus*. It never has a posterior facet for articulation with the magnum. It may or may not bear a posterior facet for articulation with the trapzium. The magnum is much narrower tranwversely than the corresponding bone in Equus. The unciform resembles that of Equus. However, the posterior surface for articulation with the magnum is smaller than in the modern horse. A small posterior articular surface for metacarpal V is usually present.

In summary, the carpal bones of Merychippus and Hypohippus differ but little from each other in shape and proportions. In the course of evolution from Merychippus to Equus the carpals were shortened anteroposteriorly, widened transversely, and flattened proximo-distally.

Measurements (in millimeters) of carpals

	Merychippus			Hypohippus		
	AP	Tr	PD	AP	Tr	PD
Scaphoid	26.0	17.5	19.7	29.3	20.0	23.6
Lunar	24.1	19.4	19.0	27.0	19.7	23.0
Cuneiform	24.0	11.2	15.0	32.5	15.3	20.0
Pisiform	31.4	7.6	20.9	35 est	8.0	22
Trapezoid	12.9	12.5	12.4	15.5	14.0	16.0
Magnum	23.9	25.2	16.5	30.3	30.0	19.7
Unciform	18.5	11.7	16.2	22.4	12.2	20.4

AP, anteroposterior diameter.
Tr, transverse diameter.
PD, proximal-distal diameter.
est, estimated measurement.
All measurements are minimum over all diameters.

Metacarpus.- The proximal end of metacarpal III in both Merychippus and Hypohippus is not so broad as in Equus. For both Miocene types the angle between the magnum and unciform articular facets varies from 107° to 120° and averages 116° (cf. 160° in Equus). Merychippine metacarpal III is broadly grooved on its volar surface between the rough areas for attachment of lateral metacarpals. The volar groove appears deeper in Hypohippus. In both Merychippus and Hypohippus the keel on the distal articular surface of metacarpal III is strong posteriorly, but weak to totally absent on the anterior surface. In *Equus* this keel is strong all the way around.

The lateral metacarpals II and IV are well-developed in both *Merychippus* and *Hypohippus*. The hypohippine side metacarpals are readily distinguished from the more slender merychippine forms by their massiveness. In both genera metacarpal II bears a facet for articulation of the trapezium. On the posterior side of its proximal end, metacarpal IV carries a small facet for the articulation of metacarpal V. Below this small facet and parallel to the main axis of the metacarpus is a broad, flat, slightly roughened area against which lay metacarpal V.

Measurements (in millimeters)

				(1)			(2)
			Merychippus			*Hypohippus*	
Metacarpal		II	III	IV	II	III	IV
Length		153	163	147	177 *est*	192	173 *est*
Proximal end AP		12	19	14	13	22	15
Proximal end Tr		9	26	10	12	28	13
Distal end AP		15	20	15	18	22	19
Distal end Tr		8	25.5	7	11	27.5	11
Least Dimensions of shaft	AP	7	14	8	12	15	12.5
	Tr	6	18	4	6	22	6

est, estimated measurement.
AP , anteroposterior diameter.
Tr , transverse diameter.
Note: These measurements were made on mounted specimens. All approximations are controlled by measurements of unmounted specimens of the same general size.

(1) Merychippine metacarpal III varies in length between 160 and 186 mm., and averages about 180 mm. long. Hence, this mounted specimen is much smaller than average for the Tonopah collection.

(2) Hypohippine metacarpal III varies in length from 183 to 192 mm., and averages 186 mm. The mounted specimen is therefore larger than average.

<u>Pelvis</u>.- The acetabulum is the only part of the pelvic girdle which has been preserved. The merychippine acetabulum appears to resemble closely that of *Equus*. A single hypohippine acetabulum appears to be deeper and more nearly hemispherical than the others.

Measurements (in millimeters) of acetabulum

	Merychippus	Hypohippus
Anteroposterior diameter	42.0	46.5
Transverse diameter	33.0	46.8

<u>Femur</u>.- No complete femora are preserved in the collection. The proximal and distal ends of the femur of Merychippus closely resemble those of *Equus*. The shaft of the femur is proportionately more slender than that of *Equus*, but the lesser trochanter and the third trochanter are well developed.

A distal end of a *Hypohippus* femur displays a trochlea proportionately much narrower than that of *Equus*. The lateral condyle of the femur in *Hypohippus* is much larger than the medial condyle, whereas in *Equus* the lateral condyle is only slightly larger.

Measurements (in millimeters) of femur

	Merychippus	Hypohippus
Length, estimated	275	
Distal end, transverse diameter	61.5	76.5

<u>Tibia</u>.- The tibia of *Merychippus* closely resembles that of *Equus* throughout. The shaft is slightly larger than that of *Equus* in proportion to the size of the extremities. The articular grooves of the distal end are slightly deeper and sharper in the tibia of *Merychippus*.

The distal end of a hypohippine tibia resembles that of *Equus* in every feature except in a proportionately broader intermediate ridge on the articular surface.

Measurements (in millimeters) of tibia

	Merychippus	*Hypohippus*
Length	283	
Distal end, transverse diameter	45	57

Patella.- Patellae of *Merychippus* and *Hypohippus* resemble the knee-cap of *Equus*, except that the base is slightly more produced and the medial angle is less produced. These proportions give the bone the appearance of an elongate rhomb, when viewed from the front, rather than that of a square as in *Equus*.

Measurements (in millimeters) of patella

	Merychippus	*Hypohippus*
Anteroposterior diameter	25	28
Transverse diameter	41	45
Proximal-distal diameter	46	55

Tarsus.- A deep, narrow groove bordered by narrow, high ridges characterizes the trochlea of a merychippine astragalus in which respect the principal element of the tarsus resembles that in *Equus*. The hypohippine astragalus, in contrast, has a trochlea with broad, shallow groove bounded by low, wide ridges. The merychippine astragalus further resembles that of *Equus* in having on the navicular facet a well-defined non-articular depression. This non-articular depression is either poorly represented or entirely absent in the hypohippine astragalus.

In the merychippine calcaneum, and to a lesser extent in the hypohippine, there is a deeper groove between the tuber calcis (proximal part of the body) and the sustentaculum tali (medial process) than in Equus. The articular facet for the cuboid is slightly more steeply inclined upward and backward than the corresponding facet in Equus.

The astragalar facet of the navicular has a shallow non-articular depression in the merychippine form and no depression in the hypohippine. Only one specimen in more than 60 naviculars of Merychippus has a surface for articulation with the calcaneum. This articulation occurs commonly in Equus. On the distal surface there is no non-articular groove separating the two surfaces of articulation for the ectocuneiform. Likewise on the distal surface there is no non-articular groove between the ecto- and meso-cuneiform surfaces. Both of these grooves are commonly found in naviculars of Equus. Finally, in Merychippus the ento-mesocuneiform surface is continuous and rounded, not broken by an angle as in Equus. The fused ento-mesocuneiform form bone in Hypohippus differs little from that of Equus.

In only 3 out of 42 merychippine ecto-cuneiform bones does the non-articular groove completely cross the proximal surface. The distal non-articular groove may vary in shape, but is never large as in Equus. Both of these non-articular grooves are far less developed in Hypohippus than in Merychippus. The proximal posterior articulation for the cuboid appears to make a fairly constant angle with the proximal posterior articulation for the navicular for any given type of horse. Large series of measurements yield the following values; *Merychippus* 100°, *Hypohippus* 105°, and *Equus* 110°.

The cuboid of *Merychippus* differs from that of *Equus* in having the anterior surface for articulation with metatarsal IV relatively larger than the facet for metatarsal III. The posterior lateral surfaces for articulation with the navicular and ectocuneiform make a prominence which projects inward from the middle of the medial surface. In *Equus* this prominence lies near the posterior end of the medial surface. The cuboid of *Hypohippus* is shorter anteroposteriorly and more cuboid in shape than that of either *Merychippus* or *Equus*. Furthermore, all of the articular surfaces on the hypohippine cuboid appear larger, especially the facet for metatarsal IV. In the cuboid bone of both *Merychippus* and *Hypohippus* the tuberosity for attachment of the plantar ligament is much larger than in *Equus*.

Measurements (in millimeters) of tarsals

	Merychippus			*Hypohippus*		
	AP	Tr	PD	AP	Tr	PD
Astragalus	28	35	42	32	42	44
Calcaneum	35	33	84	42	37	93
Navicular	26	30	10	31	31	12
Ento-mesocuneiform	11	25	14	15	29	18
Ectocuneiform	24	27	10	29	31	11
Cuboid	28	17	21	30	19	26

AP, anteroposterior diameter.
Tr, transverse diameter.
PD, proximal-distal diameter.
All measurements are minimum over all diameters.

Metatarsus.- In both *Merychippus* and *Hypohippus* the proximal end of metatarsal III presents a nearly circular anterior outline, in contrast to the oval outline in Equus. While a facet for the articulation of the mesocuneiform is always present in metatarsal III of Equus, in Merychippus the facet appears in only 2 out of more than 70 specimens. On the other hand, this mesocuneiform facet seems to be constantly present on all seven well-preserved hypohippine third metatarsals. In both Merychippus and Hypohippus the distal keel, though prominent on the posterior surface, dies away on the anterior surface. The transverse diameter of the distal end of metatarsal III is relatively much greater in Hypohippus than in Merychippus.

The lateral metatarsals II and IV are well-developed in both Merychippus and Hypohippus. The merychippine side toes are much more slender than the hypohippine, especially near the distal end. The proximal end of metatarsal IV is very massive in both forms, and is characterized on the posterior side by a large sloping surface for the attachment of ligaments.

Measurements (in millimeters)

			(1) Merychippus			(2) Hypohippus	
Metatarsal		II	III	IV	II	III	IV
Length		170	183	171	202	217	203
Proximal end AP		15	24	20	18	27	26
Proximal end Tr		8	26	12	11	32	12
Distal end AP		14	19	14	22	24	23
Distal end Tr		8	25	7	12	33	14
Least dimensions of shaft	AP	6	16	5	13	18	15
	Tr	2.5	18	3	5	24	5

AP, anteroposterior diameter.
Tr, transverse diameter.

Note: These measurements were made on mounted specimens. All approximations were controlled by measurements on unmounted specimens of the same general size.

(1) Merychippine metatarsal III varies in length between 182 and 216 mm., and averages 202 mm. Hence, this mounted specimen, almost the smallest in the collection, is much smaller than the average.

(2) Hypohippine metatarsal III varies in length between 212 and 221 mm., and averages 216 mm. This mounted specimen is a little larger than average.

Phalanges.- Owing to the variation in growth stages represented by the equids in the collection, the phalanges show considerable variability in size and proportions. Since no phalangeal series were found in undoubted association with upper limb bones, it is deemed undesirable to make distinction between the phalanges of the fore limb and those of the hind limb.

Digit III.- The first phalanx of Merychippus is proportionally more slender than that of Equus, especially at the distal end. Hypohippine phalanx I, notably in the shaft, is much more robust than that of Equus. In the case of both Tonopah equids the median groove of the proximal articulation becomes shallower and disappears anteriorly. In Equus the groove is strong anteriorly as well as posteriorly. A single abnormal merychippine first phalanx in the collection bears large lateral tuberosities or spurs which apparently functioned as aggrandized eminences for attachment of the collateral ligament. The form is in all likelihood a sport.

The merychippine second phalanx is longer and more slender than that of Equus. Proportionally, the second phalanx of the Hypohippus approximates that of Equus in length and breadth, but falls short of this equine form in thickness of the distal end.

The third or ungual phalanx of Merychippus tends to be more slender and pointed than that of Hypohippus. Both are longer and narrower than the third phalanx of Equus. In the Tonopah forms the articular surface continues out toward the wings to make a bell-shaped pattern, as compared to the semicircular shape of the articular surface in the ungual phalanx of *Equus*. In the Miocene equids the wings, or angles, were either undeveloped or unossified to the extent that they are in *Equus*. A well-marked terminal cleft characterizes the ungual phalanges of both *Merychippus* and *Hypohippus*. The angle of inclination between the ground plane and the anterior slope of the phalanx ranges from 33° to 35° in the Miocene forms in contrast to approximately 50° in *Equus*.

The proximal sesamoids differ little except in size from those of *Equus*. No distal sesamoids were found in the entire collection.

Measurements (in millimeters) of Digit III

	Merychippus			*Hypohippus*		
	AP	Tr	PD	AP	Tr	PD
Phalanx I			42			43
Proximal end	22.5	30		25	36	
Distal end	14	34		16	30	
Least diameter of shaft	11.5	20		12.5	27.5	
Phalanx II			30			34
Proximal end	19	30		21	35	
Distal end	15	26		17.5	33	
Least diameter of shaft	12.5	22.5		14	29	
Phalanx III	37	37	24	41	40	25.5

AP, anteroposterior diameter.
Tr, transverse diameter.
PD, proximal-distal diameter.
Note: These measurements were made on individual specimens in the collection and represent average sized adults.

Digits II and IV.- The lateral phalanges are small and more variable in size than those of digit I. The hypohippine first phalanx is deeper proximally, much broader throughout, and slightly longer than that of *Merychippus*. The second phalanx of *Hypohippus* is longer and slightly larger than that of *Merychippus*. No lateral ungual phalanges are included in the collection.

Measurements (in millimeters) of Digits II and IV

	Merychippus			Hypohippus		
	AP	Tr	PD	AP	Tr	PD
Phalanx I			24.5			25.5
Proximal end	14.5	10.0		18.4	12.6	
Distal end	9.7	8.8		11.5	11.5	
Phalanx II	10.0	9.5	17.5	12	10.3	23.0

AP, anteroposterior diameter.
Tr, transverse diameter.
PD, proximal-distal diameter.

Note: These measurements were made on individual specimens in the collection and represent average sized adults.

RHINOCEROTIDAE

This family of the Perissodactyla is represented in the Tonopah fauna by relatively few specimens. The only well-preserved material consists of first premolars followed by milk-teeth in both upper and lower dentitions, along with a few skeletal elements. Based upon the teeth, a population count of the rhinocerotids in the collection totals three individuals, one adult and two young. In the highly cristate pattern of its deciduous upper molars and in its retention of a large crested $P\underline{1}$ and a large simple $P\overline{1}$, the Tonopah rhinocerotid appears distinct from any species previously described and is designated as follows:

Aphelops? cristalatus n. sp.

<u>Type specimen</u>.--A portion of the left maxillary, C.I.T. No. 2806, and a portion of the left mandible, C.I.T. No. 2807. Specimen 2806 includes an unworn $P\underline{1}$ and the slightly worn $Dm\underline{2}$ - $Dm\underline{4}$. All of the teeth are in good condition except for the middle portion of the anterior end of $Dm\underline{2}$ which has been lost. Specimen 2807 possesses the lower dentition which corresponds to that of the type maxillary, <u>i.e</u>. an unworn $P\overline{1}$ and slightly worn $Dm\overline{2}$ - $Dm\overline{4}$. All are in good condition except $Dm\overline{3}$. No. 2807 was found in the same horizon and only two feet from the maxillary. Undoubtedly it represents the lower jaw of the same individual.

Referred material.--Dm$\underline{2}$ and Dm$\underline{3}$ No. 762; part of a ramus, No. 2808, bearing Dm$\overline{2}$ and Dm$\overline{3}$; a ramus, No. 2809, with Dm$\overline{2}$ - Dm$\overline{4}$; tibia, fibula, calcaneum, two astragali, 3 lateral metapodials and a phalanx.

Specific characters.--P$\underline{1}$, large, only slightly reduced, bearing an internal crest and three transverse cristae. Upper deciduous molars with several cristae always present, very strong crochet and moderate to strong antecrochet, union of crochet and crista occurring almost always. P$\overline{1}$, large, almond-shaped. Dm$\overline{2}$, long, very narrow, no protoconid-hypoconid valley. Limbs and feet normally proportioned as in modern rhinoceroses, not shortened as in *Teleoceras*.

Mandible.--The young mandible, Nos. 2807 and 2809, is quite slender and possesses very little depth. Much of this lack of depth may be ascribed to the youth of the individual, but the character reflects in part a customary shallowness of jaw in *Aphelops*.

Measurements (in millimeters) of mandible No. 2809

Depth of inner side normal to alveolar border, posterior to Dm4	53
Height from lower border of angle to condyle.	146

Upper dentition.--P$\underline{1}$ (1) is a small tooth with very simple crown consisting of an outer crest along the length of the tooth and a parallel inner crest which is restricted to the posterior portion of the tooth. Three cristae run transverse to these crests.

(1) Since the crown is not yet fully erupted and the following milk molars show considerable wear, the tooth is considered a P$\underline{1}$. See Matthew 1932, Note on p. 423.

A large anterior crista and a small intermediate crista arise from the external crest, while the small posterior crista originates on the internal crest.

Dm2, a molariform tooth, is more elongate than the posterior deciduous teeth. The anterior border of the tooth is diagonal and curved, giving the tooth an almost triangular outline. The outer wall of the tooth is convex externally, and smooth except for a low style (parastyle fold) external to the paracone. The protoloph remains separate from the ectoloph until a very advanced stage of wear is reached. At this advanced stage a connection tends to be made by means of the median crest as well as by the anterior crest which projects inward from the ectoloph. There is no antecrochet arising from the protoloph; the prefossette is open. The relatively large metaloph is connected with the ectoloph. The metaloph bears a very strong crochet which joins the posterior crista from the ectoloph and closes off a median fossette. At least two small cristae from the ectoloph and one small crista from the crochet project into this median fossette. The post-fossette is open. A low cingulum traverses the entire anterior, internal and posterior border of the tooth. An internal tubercle small to large in size, lies on the internal border of the tooth in the protocone-hypocone valley.

Dm3 is wider transversely than Dm2 and is larger and more nearly square in outline. The parastyle fold is much larger than in

Dm$\underline{2}$ and relatively much farther forward because the parastyle is not so greatly produced anteriorly. The protoloph is firmly joined to the ectoloph and bears a bulky, rounded, but short antecrochet. The metaloph, slightly smaller than the protoloph, is firmly joined to the ectoloph by the posterior crista. A long relatively strong crochet folds forward from the metaloph. A union between the crochet and one of the two median cristae from the ectoloph is not consummated in one specimen (No. 2806) and only tenuously effected in another (No. 762.) A few small cristae project into the region of the median fossette. None of the fossettes is really closed. A low cingulum and internal tubercle tend to develop as in Dm$\underline{2}$. In No. 2806 a very small median ridge runs along the bottom of the protocone-hypocone valley.

Dm$\underline{4}$ in No. 2806 is almost identical in pattern and structure with Dm$\underline{3}$ of No. 762. In size, especially in crown-height, Dm$\underline{4}$ bulks somewhat larger than Dm$\underline{3}$.

Lower dentition.--In the ramus, No. 2807, P$\overline{1}$ is just emerging. This tooth is almond-shaped. Instead of coming to a point, however, the occlusal surface is marked by an elongate fossette which opens into a groove on the internal side of the tooth. Two very small folds lie on the external wall of the tooth.

Dm$\overline{2}$ in No. 2808 is a long, very narrow triangular-shaped tooth with lophoid pattern. It differs from permanent P$\overline{2}$ of other aphelopines in its length. The absence of any marked valley on the external wall differentiates the tooth from the second lower deciduous teeth in other aphelopines.

$Dm\overline{3}$ and $Dm\overline{4}$, both relatively long-crowned, consist of two lophs arranged as in typical rhinocerotids. The only anomaly is a small internal cusp which lies in the posterior valley of $Dm\overline{4}$.

Measurements (in millimeters)

Upper Dentition	2806	762
Length of series P1 - Dm4	154	
Length of series Dm2 - Dm4	138	
P1, anteroposterior diameter	27.0	
P1, transverse diameter	21.5	
P1, crown height	28 ap	
Dm2, anteroposterior diameter	46.0	50.0
Dm2, transverse diameter	43.0	48.4
Dm2, crown height	24.5	30.0
Dm3, antroposterior diameter	48.0	53.6
Dm3, transverse diameter	47.0	52.0
Dm3, crown height	28.0	34.0
Dm4, anteroposterior diameter	54.0	
Dm4, transverse diameter	52.5	
Dm4, crown height	38.0	

Lower Dentition	2807	2809
Length of series P1 - Dm4	155	
Length of series Dm2 - Dm4	133	135
P1, anteroposterior diameter	16 est	
P1, transeverse diameter	8 est	
P1, crown hieght	22 ap	
Dm2, anteroposterior diameter	35 ap	38
Dm2, transverse diameter	17.8	18.5
Dm2, crown height	23.0	27.0
Dm3, anteroposterior diameter	47.0	45.5
Dm3, transeverse diameter	22.0	22.0
Dm3, crown height	29.0	32.0
Dm4, anteroposterior diameter	46.0	49.0
Dm4, transverse diameter	25.2	24.0
Dm4, crown height	34.0	37.0 est

ap, approximate measurement.
est, estimated measurement.
All measurements are minimum overall diameters.

<u>Scapula</u>.--The massive scapula bears no acromion. The tuber is large and rugose with a short heavy coracoid process.

Measurements (in millimeters) of scapula No. 2811

Anteroposterior diameter from tuber to posterior border of glenoid cavity	123
Transverse diameter across glenoid cavity	69
Anteroposterior diameter across glenoid cavity	88

<u>Tibia and fibula</u>.--The thick-set tibia differs little from the characteristic rhinocerotid form. Only the extremities of the fibula are preserved. The tibial facet of the distal extremity makes a very obtuse angle (approx. 145°) with the astragalar facet, in contrast to a presumably more acute angle on the teleocerine form.

Measurements (in millimeters) of tibia No. 1310

Length	400
Distal end, transverse diameter	101

<u>Astragalus</u>.--The trochlear surface which is long anteroposteriorly has a characteristic deep and broad groove. The fibular facet is almost vertical. The external calcanear facet presents a strongly concave and convex surface and is separated from the internal calcaneal facet by a deep nonarticular groove. The internal calcaneal facet is rounded in outline. The navicular facet is relatively short anteroposteriorly. The cuboid facet makes a low angle with the navicular facet and is long, narrow and diagonal in position. The posterior

region of the line of junction between cuboid and navicular facets bears a distally projecting prominence.

Calcaneum.--A short tuber calcis and a large astragalar facet which curves up onto the anterior side of the cochlear process characterize the calcaneum. The outline of the astragalar facet on the sustentaculum tali is rounded. The surface for articulation with the cuboid is strongly concave.

Measurements (in millimeters)

761	AP	Tr	PD
Astragalus	54	90	78
Calcaneum	72	86	131

AP, anteroposterior diameter
Tr, transverse diameter
PD, proximo-distal diameter

Cuboid.--The most striking feature of the cuboid is the extremely large size of the tuberosity for the plantar ligament.

Metapodials.--Three metapodials in the collection appear to represent metatarsal II (2 specimens) and metatarsal IV (1 specimen). These metatarsals are relatively long, slender, smooth, and strongly keeled distally.

Phalanx.--A single side-toe phalanx I, though short, appears to be relatively narrow and high.

Measurements (in millimeters)

Metatarsal 2810	II	IV
Length	142 - 162	141
Proximal end AP	38	40
Proximal end Tr	30	43
Distal end AP	40	41
Distal end Tr	31	31
Least dimension of shaft		
AP	21	22
Tr	23	26

2812	Length	Proximal end		Distal end	
Digit II or IV		AP	Tr	AP	Tr
Phalanx I	37	37	37	26	29

AP, anteroposterior diameter.
Tr, transverse diameter.

Relationships.--The affinities of *Aphelops? cristalatus* clearly lie with *Aphelops* and *Peraceras* rather than with *Teleoceras*. In absence of adequate skull material, however, the generic status of the Tonopah rhinoceros must remain tentative.

Aphelops malacorhinus Cope (Cope and Matthew 1915, pl. 141) compares closely with *A.? cristalatus* on the broader points of size, tooth-pattern, strong crochet and weak antecrochet. *A. malacorhinus* differs in having no cristae, and hence no union of crochet and crista to form a medifossette.

Aphelops mutilus Matthew (1924 and 1932) is considered a progressive mutation of *A. malacorhinus*. *A. mutilus* averages somewhat larger than *A.? cristalatus* in length of premolar tooth-row and in transverse diameter of the teeth. The latter difference may be due in large part to the fact that the comparison is made between permanent teeth of one species and deciduous of the other. The teeth of *A.? cristalatus* are far more cristate than those of *A. mutilus*. This again may be a normal difference between milk and permanent teeth. Pl of *A.? cristalatus*, however, is distinguished by a long external crest, a moderately long inner crest, and three transverse cristae. Pl of *A. mutilus* and all other comparable rhinocerotids bear two internal cusps, of which the larger is posterior, rather than a single long crest. Transverse cristae are single or absent.

In view of these similarities and differences, Aphelops? cristalatus, progressive in tooth-pattern but primitive in retaining well-developed $P\frac{1}{1}$, is regarded as an offshoot of the line which gave rise to A. malacorhinus from the Republican River bed (exact fauna not known, Stirton 1936, p. 188) and to A. mutilus from the Coffee Ranch Quarry and from Higgins Quarry A of Texas.

Aphelops ceratorhinus Douglass (1903) differs from A.? cristalatus in smaller size and in absence of antecrochets and cristae.

Aphelops megalodus (Cope 1873; Cope and Matthew 1915) from Pawnee Creek is much smaller and distinctly more primitive in all its tooth characters.

Aphelops meridianus (Leidy) and material from New Mexico assigned to the species by Cope (1877, pp. 317-319, pls. 73 and 74), is likewise a small and primitive form.

Until Aphelops jemezanus Cope (1877, pl. 73) is represented by better and more abundant material it will be impossible to determine any but its broadest relationships. No satisfactory comparison can be made between A. jemezanus and A? cristalatus.

An upper milk molar from the Valley of the Niobrara River was described and illustrated by Leidy (1858, p. 28; 1869, pl. 23, figs. 4 and 5). The tooth resembles Dm3 (C.I.T. No. 2806) very closely in pattern. The Niobrara River tooth is of indeterminate genus and species (Matthew 1918, p. 207, without any specific reasons refers the tooth to T. fossiger.)

Aphelops sp. Matthew (1918, fig. 13, A.M. 17222), consisting of P1 - Dm4 represents a form which is much smaller with simpler tooth-pattern than that from Tonopah. The inner crest of so-called Dm1 (probably P1), consists of two rudimentary cusps rather than an elongate crest. No cristae are present, hence in no tooth of the series does the crochet unite with a crista to form a medifossette. A not far distant ancestor of Aphelops? cristalatus may have resembled this (Lower?) Snake Creek Aphelops sp. very closely.

As Matthew has conclusively demonstrated (Matthew 1932, pp. 433-435.) "among the Old World Rhinocerotidae the group of species assembled by Ringstrom under Chilotherium make the nearest approach to the American Aphelops." An illustration of the milk dentition of Chilotherium anderssoni Ringstrom (1924, pl. 3) emphasizes the similarity between this Asiatic rhinocerotid of the Hipparion fauna and the American Aphelops? cristalatus. The milk-teeth of Chilotherium anderssoni are of same length as those of the Tonopah form, but they are narrower transversely and are progressively higher crowned from P1 through Dm2 to Dm4. The outer crest and three transverse cristae of P1 resemble A? cristalatus in form, but the metaloph is a conical cusp as in all species of Aphelops except A? cristalatus. In each of the milk molars, Dm2 to Dm4, the main medial crista is well-developed, but there are no minor cristae such as appear in A? cristalatus. The antecrochet and the posterior portion of the cingulum are more strongly developed in _Chilotherium_ than in _Aphelops_. In the lower jaw, $P\overline{1}$ is a peg-like tooth which is absent in most cases in contrast to the relatively well-developed $P\overline{1}$ of _A? cristalatus_. $Dm\overline{2}$ to $Dm\overline{4}$ are almost identical with the corresponding teeth of the Tonopah species, except that there is a strong protoconid-hypoconid valley in $Dm\overline{2}$, a feature which is characteristically absent in _A? cristalatus_.

On the basis of dentition alone the following relationships seem indicated:

Aphelops mutilus
Pattern complex (3)
$P\underline{1}$ reduced, simple
$P\overline{1}$ lost

Chilotherium anderssoni
Pattern moderately complex (2)
$P\underline{1}$ reduced, slightly cristate
$P\overline{1}$ strongly reduced

Aphelops? cristalatus
Pattern very complex (4)
$P\underline{1}$ slightly reduced, cristate
$P\overline{1}$ slightly reduced

Aphelops megalodus
Pattern simple (1)
$P\underline{1}$ relatively well-developed
$P\overline{1}$ unknown

(1) Simple: No crista; no crochet; weak antecrochet.
(2) Moderately complex: Crista present or absent; strong crochet; moderate to strong antecrochet; occasional union of crochet and crista on premolars.
(3) Complex: Crista always present; strong crochet; moderate to strong antecrochet; union of crochet and crista on premolars almost always.
(4) Very complex: Several cristae always present; very strong crochet; moderate to strong antecrochet; union of crochet and crista on premolars almost always.

An astragalus, U.C. No. 19824, from the Esmeralda can be assigned questionably to Aphelops.

Some fragmentary teeth from High Rock Canyon, U.C. No. 11619, suggest that their crown pattern was cristate when unworn. This material, though slightly larger, is comparable in size to C.I.T. No. 2807. Since the High Rock Canyon material represents adults, however, a direct comparison with the youthful A? cristalatus is almost meaningless.

CAMELIDAE

The family is sparingly represented in the Tonopah fauna. A fairly well-preserved palate and a single partial ramus with $P\overline{2}$ - $M\overline{3}$ provide the only moderately complete dentitions in the collection. The remainder of the collection consists of maxillary and mandibular fragments, isolated teeth, an axis, a few complete limb bones, many carpals, tarsals, and phalanges, a few metatarsals but no complete metacarpals, and an abundance of more fragmentary skeletal material.

An estimate based upon the occurrence of astragali and teeth indicates that the fauna contained as a minimum population at least eight camelids, two young and six adults.

Alticamelus? stocki n. sp.

<u>Type specimen</u>.--A palate with $P\underline{1}$ - $M\underline{3}$ of both sides complete (except both $P\underline{2}$'s broken off), left C, right $I\underline{3}$, both $I\underline{2}$'s and the alveoli for both $I\underline{1}$'s, C.I.T. No. 1434. A ramus with $P\overline{2}$ - $M\overline{3}$ complete, C.I.T. No. 2819.

<u>Referred material</u>.--A palate C.I.T. No. 764, symphyseal section of jaw No. 2820, milk teeth $Dm\underline{3}$ and $Dm\underline{4}$ No. 2821, $Dm\overline{3}$ and $Dm\overline{4}$ No. 2822, ulnoradii Nos. 2823 and 2824, tibia No. 2825, metatarsi Nos. 2826 and 2827, and all (except perhaps the very largest) camelid carpals, tarsals and phalanges in the Tonopah collection.

<u>Specific characters</u>.--$I\underline{1}$ and $I\underline{2}$ retained in fully adult individual. Premolars slightly more reduced than in other species

of **Alticamelus**. Limb bones large and long, but proportionally not quite so long as in other alticamelids. I take pleasure in naming this species for Dr. Chester Stock.

Skull.--In the best-preserved palate, C.I.T. No. 1434, the posterior palatine foramen lies just medial to the middle of P3. This position is more anterior than observed for the foramen in the second palate, No. 764. The relative shortness of all of the diastemata constitutes an important diagnostic character.

Measurements (in millimeters) of diastemata

	1434	764
I3 - C	11.5	16.0
C - P1		15.0
P1 - P2	12.0	19.0

Mandible.--The manibular material is too fragmentary to display any important characters. A large mental foramen lies below P1, while a second and smaller foramen is situated between P4 and M1.

Measurements (in millimeters) of mandible

	2819
Depth of mandible below M1	41
Width of mandible below M1	23
Diastema I3 - C	15
Diastema C - P1	19
Diastema P1 - P2	18 est

est, estimated measurement.

Upper dentition.--There is a deep conical alveolus for a moderately large I1 which projects anterolaterally. I2 is somewhat smaller than the first incisor and the crown is perhaps nonfunctional. The tooth curves inward. I3 is large, strong and caniniform. The recurved canine bulks approximately as large as

I$\underline{3}$. Caniniform P$\underline{1}$ is a little more recurved than the canine and has a shorter crown, but its single root is just as massive as that of the canine.

The long, narrow and double-rooted P$\underline{2}$ is relatively large and bears cingulum-like ridges on the internal wall at either end of the tooth. P$\underline{3}$ is similar to P$\underline{2}$, but the internal ridge is developed along the whole internal wall of the tooth so that it closes off a long narrow fossette. In P$\underline{4}$ the internal wall reaches full development, being thick and strongly convex lingually. The premolars do not appear to be greatly reduced.

The molar teeth are large, simple and typically camelid with their moderately high crowns (26 mm. on external side of an unworn tooth C.I.T. No. 2831, measured from root to highest point in intercusp valley), very strong styles and strong fold on the external enamel wall.

Lower dentition.--The three strongly procumbent lower incisors are spatulate when unworn. The large canine and single-rooted P$\overline{1}$, both caniniform, approximate each other in size.

P$\overline{2}$ is slender, simple, moderately large and double-rooted. Its anterior portion does not triturate with any upper teeth. P$\overline{3}$ and P$\overline{4}$ are relatively little reduced. The molars may be described as large, simple and moderately high-crowned.

Milk dentition.--Dm$\underline{3}$ is submolariform with a strong anterior style, a narrow anterior crescent, and a posterior crescent. Dm$\underline{4}$ is slightly higher crowned than Dm$\underline{3}$. It is completely molariform although smaller and lower crowned than the true molars.

Dm3 is a long and very slender tooth characterized by two deep infolds in its external wall, one in its external wall and a small enclosed posterior fossette. Dm4 with its three crescents is long, slender and only moderately high-crowned.

Measurements (in millimeters)

Upper dentition (see note)	1434
Length of series P2 - M3	149
Length of series P2 - P4	53
Length of series M1 - M3	96
I3, anteroposterior diameter	11 ap
C , anteroposterior diameter	11.5
C , transverse diameter	9.5
P1, anteroposterior diameter	12.4
P1, transverse diameter	8.2
P2, anteroposterior diameter	14 ap
P2, transverse diameter	7.5 ap
P3, anteroposterior diameter	19.0
P3, transverse diameter	11.4
P4, anteroposterior diameter	18.0
P4, transverse diameter	17.5
M1, anteroposterior diameter	27.0
M1, transverse diameter	22.0
M2, anteroposterior diameter	35.5
M2, transverse diameter	24.0
M3, anteroposterior diameter	36.8
M3, transverse diameter	21.0

ap, approximate measurement.

Lower dentition	2819
Length of series P2 - M3	144
Length of series P2 - P4	44
Length of series M1 - M3	100
P2, anteroposterior diameter	11.4
P2, transverse diameter	5.3
P3, anteroposterior diameter	15.6
P3, transverse diameter	6.4
P4, anteroposterior diameter	17.7
P4, transverse diameter	9.2
M1, anteroposterior diameter	24.5
M1, transverse diameter	15.5
M2, anteroposterior diameter	32.3
M2, transverse diameter	19.1
M3, anteroposterior diameter	42.5
M3, transverse diameter	16.1

Measurements (in millimeters)

Upper milk dentition	2821
Dm3, anteroposterior diameter	25.0
Dm3, transverse diameter	13.0
Dm4, anteroposterior diameter	24.0
Dm4, transverse diameter	14.0

Lower milk dentition	2822
Dm3, anteroposterior diameter	17.0
Dm3, transverse diameter	7.3
Dm4, anteroposterior diameter	33.0
Dm4, transverse diameter	10.5

Note.--All measurements are made approximately at wearing surface of teeth. In measuring anteroposterior diameters of molars and milk molars, the parastyle was not included. No. 1434 (upper dentition) represents a fully adult camelid, in which anterior crescentic infold of M1 has already partially disappeared with wear. No. 2819 (lower dentition) is so worn that anterior crescent infold has disappeared in M1 and is almost completely worn away in M2. The milk dentitions, both upper and lower, are little worn.

Skeletal parts.--In relation to the size of the dentition the skeletal parts in the camelid collection appear inordinately large. Yet since but one type of camelid is found in the fauna, these dentitions and skeletal parts are presumed to be of the same species.

Axis.--The second cervical vertebra though large is not particularly elongated for a camel of this size. The odontoid process is spout-like.

Measurements (in millimeters) of axis

	2828
Length of centrum	200
Transverse diameter at anterior end	79

Ulnoradius.--The radius and ulna are as firmly fused together as in Recent *Lama*. Two examples of this bone are preserved in the collection, one moderately large, presumably a young animal, the other a very large adult.

Measurements (in millimeters) of radius

	2823	2824
Total length	448	575
Proximal end, transverse diameter	67	74
Distal end, anteroposterior diameter	47	55
Distal end, transverse diameter	65	77

Carpus.--The carpal elements differ little from those of Recent *Lama*, except in their somewhat larger size. Although the size of the carpals varies somewhat, there do not appear to be any distinctive characters by which the elements can be segregated.

Measurements (in millimeters) of carpals

	AP	Tr	PD
Scaphoid	39	22	30
Lunar	38	24	34
Cuneiform	40	24	33
Pisiform	49	24	38
Trapezoid	22	16	21
Magnum	33	24	19
Unciform	46	26	28

AP, anteroposterior diameter.
Tr, transverse diameter.
PD, proximal-distal diameter.

Note.--All measurements are minimum overall diameters. The series which was measured is relatively only moderately large.

Metacarpus.--No complete metacarpal elements occur in the collection. The proximal end of a large cannon-bone corresponds in size with the large carpals and the large ulnoradius. This large metacarpus is strongly fused as in an adult. A pair of smaller metacarpals, agreeing in size with the smaller radius and carpals, is not completely fused into one bone and hence may represent a young individual. The step down from the proximal articular surface of metacarpal III to the articular surface of metacarpal IV is pronounced.

Measurements (in millimeters) of metacarpus

	2839
Proximal end, anteroposterior diameter	46
Proximal end, transverse diameter	59

Tibia.--The long fairly slender tibia of a young individual shows no noteworthy features. The lateral malleolus is similar to that of *Lama*.

Measurements (in millimeters) of tibia

	2825
Total length	495
Distal end, transverse diameter	66

Patella.--The patella resembles that of *Lama*.

Measurements (in millimeters) of patella

Anteroposterior diameter	30
Transverse diameter	38
Proximal-distal diameter	80

Tarsus.--The tarsal bones of a young individual appear to correspond very closely to those of *Lama*. The astragalus is relatively narrow.

Measurements (in millimeters) of tarsals

	AP	Tr	PD
Astragalus	37	40	64
Calcaneum	48	42	130
Navicular	39	25	23
Cuboid	50	31	27
Ectocuneiform	28	26	18

AP, anteroposterior diameter.
Tr, transverse diameter.
PD, proximal-distal diameter.

Metatarsus.--The metatarsal bones of a young individual demonstrate that at first fusion is incomplete near the distal end of the shafts. Fusion is completed in an older slightly larger individual. A few very large distal extremities of metapodials constitute some of the material which may represent a larger and different species of camelid. In Recent *Lama* the distal ends of the metacarpals are larger than the distal extremities of the metatarsals. Hence these large fragments need not necessarily represent another species, but may belong to the fore-feet of an especially large individual.

Measurements (in millimeters) of metatarsus

	2827	2830
Total length	407	
Proximal end, transverse diameter	51	
Distal end, transverse diameter		
metatarsal, normal	28	
metapodial, very large		36

Phalanges.--In Recent *Lama* the phalanges of the manus may measure as much as one-ninth (11%) larger in every dimension than do the phalanges of the pes. It is to be noted, however, that they maintain similar proportions in both manus and pes. Hence, in a collection of fossil camelid phalanges of a given species there should be little variation in proportions even though the size range seems considerable. On this account a few disproportionately massive phalanges may be associated with the metapodial material to represent a larger camelid.

Measurements (in millimeters) of phalanges

	AP	Tr	PD
Phalanx I (normal specimen)			96
Proximal end	28	29	
Phalanx II (large specimen)			99
Proximal end	34	39	

AP, anteroposterior diameters.
Tr, transverse diameter.
PD, proximal-distal diameter.

Relationships.--At present the distinctions between the various Upper Miocene-Lower Pliocene camelids appear to be very poorly defined. Matthew (1901) reviewed th bases upon which these distinctions are made. In comparing the structural features of the Tonopah camelid with Matthew's revised list of generic characters (1918) the Nevadan type is found to differ from Pliauchenia and Megatylopus in possessing a complete dentition. The latter two genera have each but one incisor while the premolar formula is $\frac{3}{2}$ and $\frac{2}{2}$ respectively. Miolabis is much smaller and more primitive.

The Tonopah form differs from Procamelus in its complete dentition with not quite so much reduction of the premolars. The limb bones of the Tonopah camelid are relatively longer and larger.

Protolabis resembles Alticamelus? stocki only in the retention of its upper incisors. It differs decidedly in its small, short limb-bones and in the separate to imperfectly united metacarpals.

According to Stirton (1929, p. 293) there are a number of characters in which *Alticamelus* may be distinguished from *Procamelus*. The Tonopah material exhibits the following features diagnostic of *Alticamelus*:

(1) The premolars are slightly less reduced than in *Procamelus*.

(2) The parastyle, mesostyle, and the anterior external rib are more prominent.

(3) The diastemata between P$\underline{1}$ and P$\underline{2}$ and between C and P$\underline{1}$ are relatively short.

(4) The $\overline{P1}$ - $\overline{P2}$ diastema (estimated) is much less.

(5) The caniniform teeth are heavier than in *Procamelus*. (The upper canines in C.I.T. No. 1434 are about the size seen in *Procamelus*, but I$\underline{3}$ and P$\underline{1}$ are larger. All of the caniniform teeth are very large in No. 754.

(6) The first premolars, upper and lower, show no tendency to develop double roots.

(7) The inner side of the lobes of the lower molars are slightly convex anteroposteriorly, but not much more so than in *Procamelus*.

All of the characters listed above appear to be valid. Since the Tonopah camelid lies in or near the alticamelid group with respect to each of these characters, it apparently should be referred to the genus *Alticamelus*. However, if the absence of the first and second upper incisors be considered a definite character of *Alticamelus*, then No. 1434 as a fully adult specimen with complete dentition, cannot be of that genus. In his description of Alticamelus giraffinus Matthew (1901, p. 430, A. altus; Matthew and Cook 1909, p. 402, renamed A. giraffinus) states that "the first and second upper incisors are represented by small crownless stumps, perhaps the remains of the milk dentition." The first two incisors in No. 1434 are much reduced in size and may have had little function, but their reduction is not so great as that described by Matthew and they are probably not milk teeth. Matthew (1924, fig. 54) has referred a figured specimen, A.M.N.H. Nos. 18350 and 18869, to Alticamelus cf. leptocolon. The specimen is undescribed. The figure shows alveoli for all three incisors, but the specimen might be of the genus Protolabis.

Ratios of premolar reduction have been calculated by dividing the length of series $M_1 - M_3$ by $P_2 - P_4$, and also by dividing length of series $\overline{M1} - \overline{M3}$ by $\overline{P2} - \overline{P4}$. These reveal that in all but one species of Alticamelus the premolar teeth are relatively less reduced than in Nos. 1434 and 2819 from Tonopah. The one exception is an Alticamelus referred to leptocolon A.M.N.H. Nos. 18350 and 18869 by Matthew (1918). This ratio does not distinguish Alticamelus? stocki from Protolabis and Procamelus.

A second ratio was calculated to determine the limb proportions of the various Upper Miocene camelids. This ratio was derived by dividing the length of the series $\overline{M1} - \overline{M3}$ into the length of the metacarpal. Where these measurements were not available, length

M_1 and M_3 and length of metatarsal were used. It must be remembered that while the use of both of these "substitute" measurements give approximately the same ratio, the use of only one "substitute" may affect the ratio as much as several tenths of a point. Shortening of the tooth-row with wear is another important source of error. This ratio actually does set apart the alticamelid group from the genera *Protolabis* and *Procamelus*. *Protolabis* has a much lower ratio. That of *Procamelus* is still lower. *Procamelus* with its moderately long limbs should have a higher ratio than available measurements indicate. Although additional material will probably yield higher ratios for *Procamelus*, these new ratios will undoubtedly remain distinctly lower than those for Alticamelus. In limb proportions *Alticamelus? stocki* falls nearest to the *Alticamelus* group, although it can not be definitely included within that group.

Comparative measurements (in millimeters) and ratios

	A? stocki	A. alexandrae	A. procerus	A. sp. No. 1	A. giraffinus	A. leptocolon
		No. 26015	No. 14070	undesc.	No. 9109	No. 18350
	C.I.T.	U.C.	A.M.N.H.	(Davidson 1923)	A.M.N.H.	A.M.N.H.
Lengths	Tonopah	Barstow	L. Snake Crk.	Snake Crk.	Pawnee Crk.	Pawnee Crk.
$P\underline{2} - M\underline{3}$	149	117.5	157			111
$P\underline{2} - M\underline{4}$	53	46.5	63			34
$M\underline{1} - M\underline{3}$	96	74.5	98		87	74
$P\overline{2} - M\overline{3}$	144	130	164	143	154	
$P\overline{2} - P\overline{4}$	44	45.5	55	48	49	
$M\overline{1} - M\overline{3}$	100	84.5	108	95	105	
Axis	200	172			250	
Radius	448-575	480		494		417-464
Metacarpus		390		399 (see note)		362-389
Metatarsus	403		552		624.4	355
Ratios						
Upper, m/pm	1.81	1.60	1.55			2.18
Lower, m/pm	2.18	1.85	1.93	1.98	2.14	
Metapodial / Molar tooth row	4.2	4.6	5.6	4.2	7.1	4.8

Note.--A metacarpus recorded for Alticamelus sp. No. 1 (Davidson 1923, p. 406) with length of 484 mm. is evidently not to be associated with a radius of lengths of 494 mm. Hence the metacarpus described as of A. sp. No. 2 by Davidson and having a length of 399 mm. is employed instead.

Alticamelus alexandrae Davidson (1923) from the Barstow Miocene has no I1 and I2. The tooth-row is shorter, premolars are less reduced, and the limb bones are more elongate than in A? stocki The length of the axis is proportionally the same in both forms.

Alticamelus procerus Matthew and Cook (1909) from the Lower? Snake Creek differs from A? stocki in absence of I1 and I2, in longer tooth-row, in less reduced premolars and in possessing more elongate limbs.

Alticamelus giraffinus Matthew (1901, A. altus) from Pawnee Creek, an old individual with a longer tooth-row and less reduced premolars, differs strikingly from the Tonopah species in the extreme elongation of its limb elements and of its neck (cf. the axis.) This species, the type of the genus, possesses the stumps of I1 and I2.

The skull mentioned above, which was referred by Matthew (1924, fig. 54) to A. cf. leptocolon, has a much shorter tooth-row than in No. 1434, but I1 and I2 are present. Because of lack of further illustrations and detailed description of this Snake Creek camelid, the two forms cannot be closely compared. Limb bones which have been designated A. leptocolon Matthew (1901, fig. 30; 1909, p. 115) are of the same proportions as the specimens from Tonopah, but are somewhat smaller.

Some undescribed alticamelid species from Snake Creek (Davidson 1923, pp. 402 and 406) approximate in measurements the Tonopah material. The premolars of the Snake Creek form are somewhat less reduced. Alticamelus priscus Matthew (1924, p. 187) lacks sufficient description for any detailed comparison.

ANTILOCAPRIDAE

A large number of merycodont remains, including skull parts and horn-cores, have been described from the Tonopah locality (Furlong, 1934.) On the basis of this material, two new species were established: (1) Merycodus loxocerus Furlong represented by no less than sixty individuals of all ages, and (2) Merycodus hookwayi Furlong known by the remains of possibly more than three individuals.

Considerable variation in size and pattern of merycodont horn-cores can be noted in a collection of this kind of material from a given locality. Sometimes several distinct types are represented. More commonly the types grade by small variations from one to the other. With such variations possible it would seem logical to use minor structural differences in horn-core development to distinguish species or varieties of a particular species. It is deemed advisable to reserve for generic distinction the differences in dental characters and the major differences only in the horn-cores.

Furlong has already pointed out the characters of horn-core and dentition which serve to distinguish the two Tonopah species from all others. No attempt was made, however, to determine the phylogenetic position of these species.

The best criteria for establishing the relationships of merycodonts are not found in the form and size of the horn-cores, but in the length of the postsymphyseal diastema, the reduction of the premolars, crown pattern of $\overline{P4}$, and in the lengthening of the molar tooth-crowns.

Frick has indicated the relative length of the postsymphyseal diastema by recording the ratio of the anteroposterior diameter of $\overline{M3}$ to the diastema length. The selection of the length of $\overline{M3}$ as dividend in the ratio, though moderately satisfactory for determining specific differences, is peculiarly unfortunate from the point of view of demonstrating the relative diastema length in species. The evolutionary trend in merycodonts is shown by an increase in size of $\overline{M3}$ as well as by an increase in length of diastema. Hence, with both values increasing in the normal evolution of the family, the ratio between $\overline{M3}$ and diastema length may remain constant, even though both are greatly elongated relative to the rest of the tooth-row. Therefore, to emphasize more correctly the relative increase in diastema length, the writer has used the ratio postsymphyseal diastema length to anteroposterior diameter of $\overline{M1}$ rather than $\overline{M3}$.

The ratio of length of premolar tooth-row to length of molar tooth-row has been employed to indicate the amount of shortening in the premolar series.

The phylogenetic significance of the crown-pattern of $\overline{P4}$ was discussed in a previous paper (Henshaw 1938, pp. 65-67).

The length of the molar tooth-crowns is probably the most important character in determining phylogenetic relationships. Though well shown in Frick's illustrations (Frick 1937, figs. 41-47), this character unfortunately has not been considered in any large measure by other students of the merycodont antelope group.

Merycodus loxocerus Furlong

Relationships.--Measurements taken on C.I.T. Nos. 713 and 1298 indicate that the postsymphyseal diastema is relatively extremely short, only those of Ramoceros coronatus (Merriam) (Frick 1937, p. 437) and Merycodus sabulonis (Matthew and Cook 1909, p. 411) being shorter. The premolar-molar tooth-row ratio in M. loxocerus indicates less reduction of the premolar tooth-row than for any other merycodont except the primitive Merycodus agilis Douglass from Madison Valley. The crown-pattern of P4 retains the primitive fived-lobed form. The molar crown-height on unworn teeth is very low in relation to antero-posterior length of tooth, e.g. in $\overline{M3}$ approximately 12 millimeters crown-height to 12 millimeters anteroposterior length.

All of these characters emphasize the primitive nature of Merycodus loxocerus. The type of horn-core found in this species agrees closely with some of those from the Barstow, e.g. Merycodus alticornis (Frick 1937, p. 347 and fig. 38A) described as "shaft unusually slender and elongate." The lower teeth of the Tonopah form, however, appear more primitive than those of the Barstow (Frick 1937, figs. 46 and 47.)

Merycodus hookwayi Furlong

Relationships.--Measurements taken on the paratype, C.I.T. No. 712, show that the postsymphyseal diastema of Merycodus hookwayi is relatively shorter than in all species except Ramoceros coronatus, Merycodus sabulonis, M. loxocerus and M. agilis. The slight premolar shortening exceeds that of only the primitive forms M. agilis and M. loxocerus, while it equals that in Ramocerus coronatus and Merycodus sabulonis. The crown-pattern of P4, as in M. loxocerus, is of the 5-lobed type. Height of crown of M3 is 16 millimeters on an unworn tooth 14.5 millimeters long.

Merycodus hookwayi represents a primitive merycodont which is slightly more advanced than Merycodus loxocerus. Frick placed M. hookwayi, in the genus Meryceros, yet he characterized that genus as having muzzle and diastema elongate. Furthermore, the horn-cores of typical Meryceros all appear to be short-shafted. M. hookwayi, with its long, though moderately heavy-shafted horn-core, and above all its shortened diastema and heavy premolars, appears to be more closely related to Frick's subgenus Paracosoryx.

For reasons previously discussed (Henshaw 1939, pp. 25-26) this Tonopah species is referred to the genus Merycodus. The subgenus Paracosoryx appears to be valid.

Among Frick's figured specimens the one which appears closest to M. hookwayi is F.A.M. 31159 (Frick 1937, fig. 39A; also p. 347). Frick referred this Barstow specimen to M. (Paracosoryx) alticornis, but made special note of the fact that the specimen appeared "as heavy, but considerably shorter than type." Unfortunately there are no teeth associated with this specimen from the Barstow.

M. (Paracosoryx) furlongi (Frick) U.C. No. 26795 (Furlong 1927, pl. 26, fig. 1; Frick 1937, p. 348) differs in having forward tilting horn-cores with longer tines, and in having a much more advanced type of ramus and lower dentition.

Neither M. loxocerus nor M. hookwayi appear to have any counterpart among recorded merycodonts. They may represent a primitive type which developed into localized aberrant forms.

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Plate I

Panorama of the western slope of the San Antonio Mountains, looking S 45°W to W from a point ten miles north of Tonopah, Nevada. The southern end of Big Smokey Valley lies in the distance with Lone Mountain beyond.

The locations of quarries "A" and "C" of C.I.T. Vert. Pale. Locality No. 172 are indicated on the photograph.

PLATE

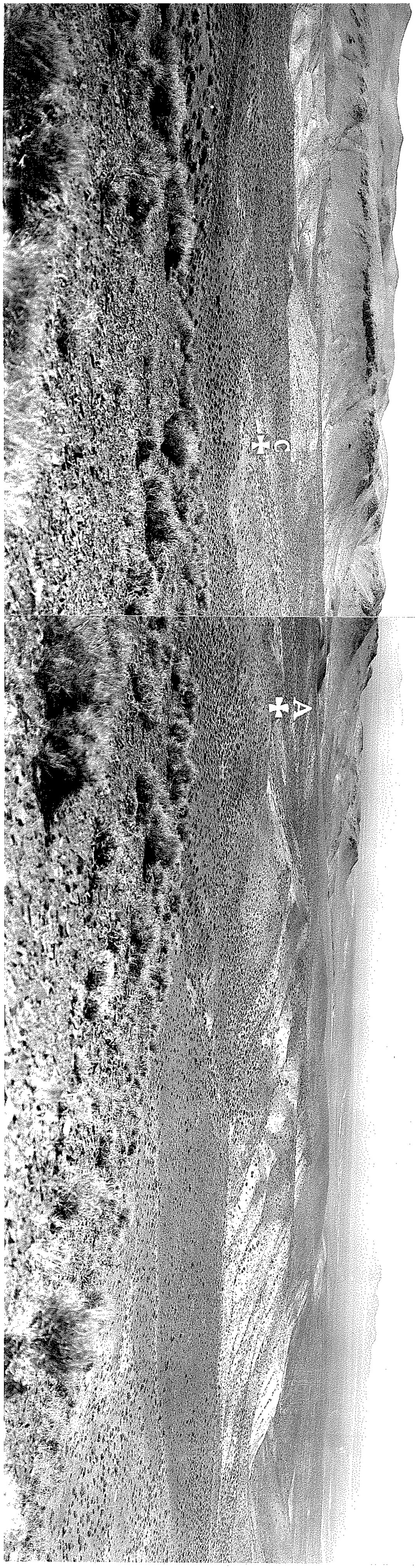


Plate II

Fig. 1 - View of Quarry A from the northwest. Quarry A is the cut on the side of the hill in the middle center-ground. Quarry C lies out of sight on the back slope of the same hill. Both quarries lie on approximately the same stratigraphic horizon. This horizon has been offset by minor faulting.

Fig. 2 - Blasting to loosen overburden at Tonopah Quarry C. View from the east. The fossiliferous strata dip gently southward.

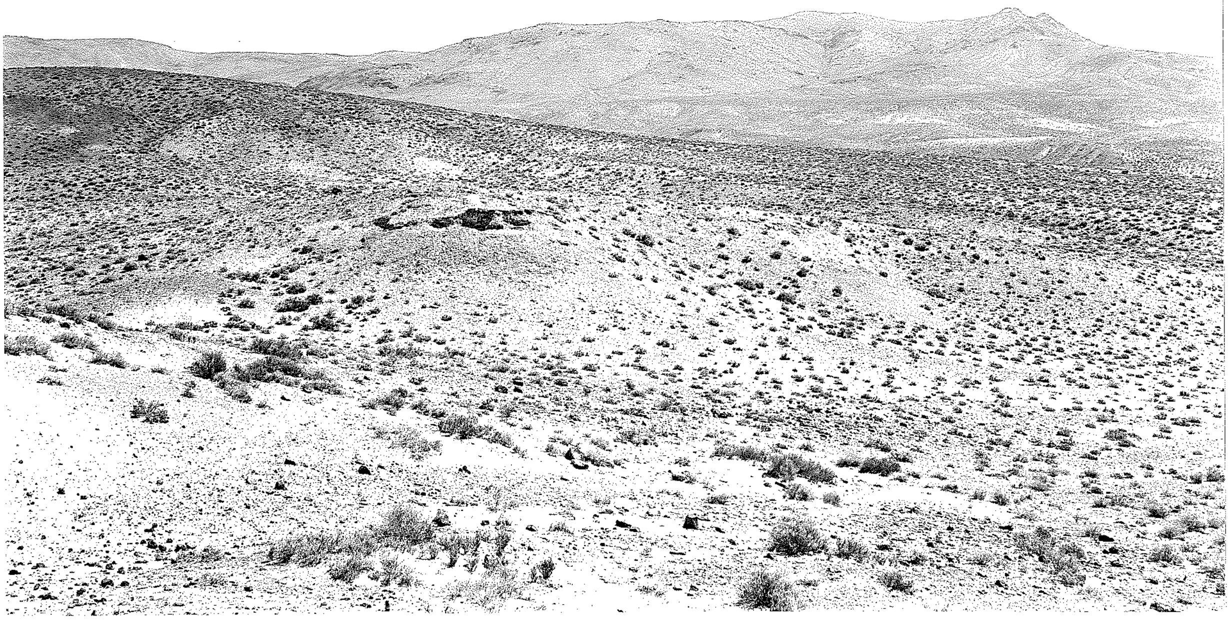


Fig. 1

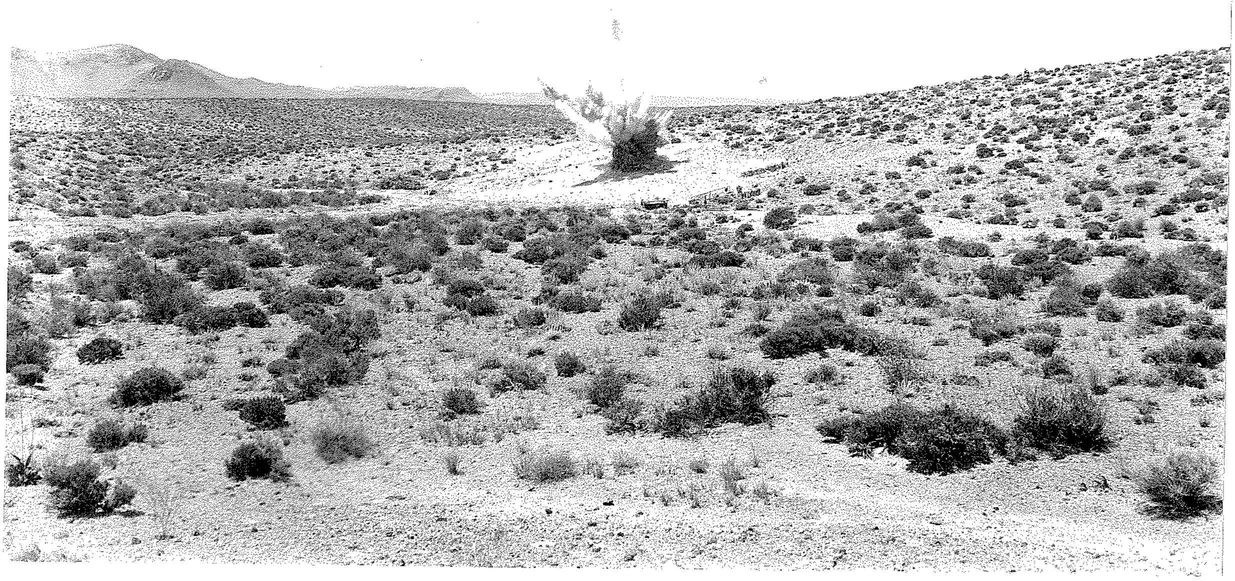


Fig. 2

GEOLOGY AND MINERAL DEPOSITS

OF THE

CARGO MUCHACHO MOUNTAINS

IMPERIAL COUNTY, CALIFORNIA

Thesis

by

Paul C. Henshaw

IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA

1940

CONTENTS

ILLUSTRATIONS

ABSTRACT

The study of the Cargo Muchacho Mountains presents the first account of the geology of southeasternmost California. In these mountains pre-Mesozoic kyanite schist and arkosite are intruded by a series of granitoid rocks probably Mesozoic in age. The two youngest rocks of this series were formed by granitization of arkosite. Andesite dikes of minor importance intruded the area probably in Tertiary time. Remnants of a once extensive flow of olivene basalt cover a few outlying hills. Alluvial deposits of three distinct ages occur in the area. Two of these, which are pre-basalt in age, offer evidence that the Colorado River formerly flowed through the region.

The Cargo Muchacho Mountains constitute an important gold mining district. The occurrence of the ore is shown to have been controlled by the regional structure. The ore deposits are mesothermal and are locally characterized by extreme alteration of the wall rock. Kyanite and sericite are also mined in the district. The record of mining activity and production of the district is brought up to date.

GEOLOGY AND MINERAL DEPOSITS
OF THE
CARGO MUCHACHO MOUNTAINS
IMPERIAL COUNTY, CALIFORNIA

INTRODUCTION

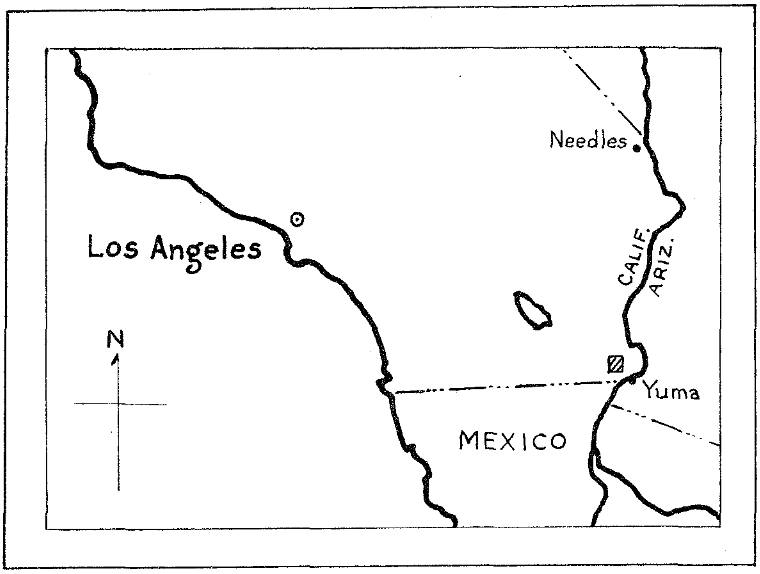
Location and Extent of Area

The Cargo Muchacho Mountains are defined as the small range, including outlying hills, which covers the central portion of the northern half of the Yuma Quadrangle, California-Arizona. These mountains lie immediately to the northeast of the town of Ogilby on the Southern Pacific Railroad line. Their southeastern extremity is about nine miles NNW of Yuma, Arizona. The area which has been mapped geologically (Plate II) is located approximately between W. Longitude 114°42' 00" to 114°50' 30" and N. Latitude 32°48' to 32°56'.

Settlement and Industries

The principal industries carried on in the area are the mining and milling of gold ores. At the height of its development in the latter part of the nineteenth century, the town of Hedges supported a population of several thousand. It now numbers about thirty. When work revived recently at the American Girl mine, the town of Obregon temporarily attained a population of over 300 inhabitants. The town of Ogilby has a population of about 100 and is located on the railroad.

Plate II



Map of Southern California showing the location

of the Cargo Muchacho Mountains: ▨.

Routes of Access and Transportation

The main line of the Southern Pacific Railroad passes through Ogilby which lies by rail about 15.5 miles from Yuma and 250 miles from Los Angeles.

An improved county road leads northward to Blythe from a point on U.S. Highway 80 just east of the Sand Hills and about 12 miles west of Yuma. Ogilby lies on this county road, four miles north of U.S. Highway 80. An improved road connects Ogilby with the town of Obregon. Around the mountains is a network of unimproved roads leading in all directions between mines, prospects, and main roads.

Previous Geological Work in the Area

Although mining has been carried on in the Cargo Muchacho Mountains ever since the latter part of the eighteenth century, no detailed geological map has been made of the district. A few brief geological descriptions of the area have appeared in the broader surveys of the region.

In 1853 W. P. Blake, geologist in Lieut. Williamson's Pacific Railroad Exploration party, visited the south end of the Cargo Muchacho Mountains. He reported[1] that the rock consists of "compact gneiss or gneissose granite . . . . Several white quartz veins from three inches to a foot or two in thickness were seen."

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1. Blake, Wm. P. Geological Report (Williamson's reconnaissance in California). U.S. Pacific R.R. Expl. vol. 5. 1856.

Also Blake noted the desert pavement of "rounded agates and carnelians, and a mass of rolled and water-worn flint, which contained small fossil shells, apparently carboniferous or cretaceous."

J. S. Brown of the U.S. Geological Survey carried on field work in the Salton Sea Region during the winter of 1917-1918. His Water Supply Paper[1], covering over 10,000 square miles in southeastern California, necessarily makes only the broadest generalized statements concerning the geology of any given locality in the region. He attributes the granites and schists of the Cargo Muchacho range to the oldest series of Pre-Cambrian rocks in the district. As evidence for this conclusion Brown states[2] that these rocks have suffered the greatest metamorphism, and have been intruded or overlain by all other series of the region; that they are similar to the Pre-Cambrian rocks of the Grand Canyon and other parts of Arizona; and that, although thick series of sedimentary beds are exposed, no fossils have ever been found within them.

Reports of the California State Mineralogist, with their accounts of mining activity, aided greatly in surveying the history of the Cargo Muchacho District. The geological descriptions, however, which are included in these reports, are very sketchy and include little material of value.

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1. Brown, J. S. The Salton Sea Region, California. U.S.G.S. Water Supply Paper 497. 1923.

2. Brown, J. S. op. cit. p. 43.

A series of private reports on the American Girl mine is limited in subject almost entirely to problems regarding the economics of mining and milling. The few statements regarding the geology of the mine are compiled in a report by Marshall Draper[1]. These statements consist of guesses as to the metamorphic nature of the wall rock, brief descriptions of the southward-dipping attitude of the main fault, and mention of the sulphide nature of the mineralization.

Field work by the writer was begun in June 1937 and continued at intervals during 1938 and 1939. In all, the writer spent a little more than three months in the area.

Purpose and Scope of Present Work

The purpose of the writer's geological work in the Cargo Muchacho Mining District was to assemble general facts regarding the geology and mineral deposits of the whole region, and to make a detailed study of the American Girl Mine.

The area was mapped geologically on an enlargement taken from the Yuma Quadrangle of the Topographic Atlas of the United States. All important mineral deposits of the area were examined. Faults, wallrock alteration, and ore of the American Girl mine were studied in considerable detail.

The geology of the kyanite-bearing Vitrefrax formation presents some of the most interesting problems of the whole area. The notes on this formation included below do not pretend to offer an adequate

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1. Draper, M. Private report on the American Girl mine. 1911.

discussion of the complexities involved. The formation has been mentioned by way of completing the picture of the regional geology. It has no direct bearing on the metallization of the district which is the main concern of this thesis.

Acknowledgments

The writer was ably assisted in the field by Messrs H. Victor Church, William M. Fiedler, and Howard Smith.

To all the mine owners, managers, engineers and other men interested in mining in the Cargo Muchacho District, my sincere thanks are due for their cordial cooperation. Particularly do I desire to express my appreciation for the many courtesies and sincere support extended by the owners and staff of the American Girl Mine.

To Doctor Ian Campbell and Doctor H. J. Fraser of the California Institute of Technology, who supervised the field work and critically read the manuscript, I am deeply grateful.

Surface Forms and Drainage

The Cargo Muchacho Mountains are low but extremely rugged. The range rises sharply above an alluvial fan which is continuous with the gently sloping surface of the Colorado River delta. The range is divided almost evenly in half by the deep east-west Obregon Valley, the highest point of which lies less than 900 feet above sea level.

The highest peak of the district (2225 feet elevation) lies in the northern half of the range. This northern portion of the mountains includes a considerable area of high, rugged hills off to the east. Stud Mountain (2130 feet elevation) dominates the southern half of the range. Both the northern and southern halves are dissected by a number of deeply incised valleys which contribute to the extreme ruggedness of the country. A compact group of hills lies about a mile to the south of the range.

The drainage divide between the Colorado River and the Salton Sea Basin passes down the crest of the range from northeast to southwest. Through the outlying hills to the northeast and to the south of the range are cut valleys which drain away from the main mountain mass. No perennial streams or flowing wells exist in the area.

Climate

The climate of the Cargo Muchacho district is typical of the Sonoran Desert region. According to records kept at Yuma[1] for the past

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1. Weather Bureau Bulletins. U.S. Department of Agriculture.

fifty-three years the mean annual temperature is 71.9° Fahrenheit with an absolute maximum of 120° and an absolute minimum of 22°. July is normally the hottest month.

The mean annual precipitation at Yuma is 3.38 inches. Ogilby has a mean annual precipitation of approximately 1.1 inches[1]. In summer rain often falls in violent local showers which in a few minutes change dry arroyos into raging torrents.

Smith[2] states that the natural evaporation possible at the Yuma Citrus Station, eight miles southwest of Yuma, amounts to 121.4 inches of water per year.

Records kept at Yuma for sixty-one years indicate a prevailing north wind for the winter months and a west to southwest wind for the rest of the year.

Flora and Fauna

On the dry rocky mountain slopes, pediments and alluvial slopes, scattered barrel cactus, cholla, ocotillo, and creosote are present. Palo verde and ironwood flourish in the dry washes. Near rock tanks and charcos which are able to hold water for long periods of time between rains, mesquite and occasionally reedy grasses maintain a precarious existence.

Animals are very scarce in the Cargo Muchacho Mountains. Small

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1. Brown, J. S. The Salton Sea Region, California. U.S.G.S. Water Supply Paper 497, p. 13. 1923.

   McAdie, A. G. Climatology of California. U.S. Dept. Agr. Weather Bureau Bull. L. 1903.

2. Smith, H. V. Climate of Arizona. Univ. of Ariz. Exp. Sta. Bull. 130. 1930.

mammals, buzzards, quail, hummingbirds, lizards, rattlesnakes and a few insects make up the fauna.

Historical Sketch

For an account of the early explorers who passed through the Yuma region, the reader is referred to the excellent condensation of F. L. Ransome's history of Arizona modified by Kirk Bryan and published in Bryan's memorable paper on The Papago Country, Arizona.[1]

The best bibliography of the History of Exploration of the Colorado Delta region is the annotated and classified bibliography by Godfrey Sykes.[2]

The Yuma region was first visited by the Spaniards in 1540. Occasional explorers and missionaries visited there over the next two hundred twenty-five years. With the establishment of a short-lived settlement from 1780-81 mining was first carried on in the region.[3] The rich placer deposits at the Potholes on the west bank of the Colorado River near the site of Laguna Dam were worked. At the same time mining activity extended to the Cargo Muchacho district, and centered round placer grounds of Jackson Gulch and rich oxidized ores of Madre Valley.

Mining activity in the Cargo Muchacho district was resumed after the establishment of the Mexican Republic. Evidence of old

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1. Bryan, Kirk The Papago Country, Arizona.
   Ransome, F. L. Historical Sketch of Arizona. U.S.G.S. Water Supply Paper 499, pp. 3-33. 1925.

2. Sykes, Godfrey The Colorado Delta Amer. Geographical Society Special Pub. no. 19. 1937. Also Carnegie Instn. of Wash. Pub. no. 460. 1937.

3. Browne, J. Ross Reports upon the Mineral Resources of the United States, p. 13. Gov't Printing Office, Wash. 1867.

Mexican workings and arrastres is abundant. Reputedly it was at this time that two young Mexican lads, who were playing at prospecting, in imitation of their fathers, came into camp one evening with their shirts loaded with gold. From this incident the district received its name Cargo Muchacho or Loaded Boy.

During the period of Mexican occupation American explorers began to take interest in the region of the lower Colorado. After the Mexican war, Yuma assumed importance as a fort and way station along the southern route from the east to California. American miners began to work in the Cargo Muchacho district.

The end of the Civil War applied a major stimulus to mining throughout the Southwest. Mining in the Cargo Muchacho District was established on a firm basis when in 1877 the Southern Pacific Railroad between Yuma and the coast was completed.

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Production

Figures for the total mineral production of the Cargo Muchacho mining district for years prior to 1892 are very incomplete. For the most part they are concealed in the returns for the whole of old San Diego County. Reliable figures give a minimum total of almost $2,500,000. Conservative estimates indicate a production of more than $4,000,000 worth of gold, of which $2,500,000 to $3,000,000 were derived from the Golden Cross group of claims alone.

Note: In the following table, only those years have been quoted for which actual figures or reliable approximations could be obtained. The omission of a year from the table does not necessarily mean that there was no gold production that year, but merely indicates that no reliable statistics of production were available.

Table 1. Gold Production of the Cargo Muchacho Mining District

1892	$ 60,000	approximate
1893	24,374	
1895	225,000	approximate
1897	300,000	approximate
1898	350,000	approximate
1899	100,000	approximate
1905	94,299	
1911	98,044	
1913	31,794	
1914	219,389	
1915	14,411	
1916	23,493	
1917	924	
1924	259	
1926	325	approximate
1927	260	
1930	148	
1931	649	
1932-33	15,230	
1934	9,486	
1935	59,406	
1936	44,391	
1937	308,994	
1938	456,884	
Total	2,437,760	

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PETROLOGY

Metamorphosed sediments, granitoid intrusives, volcanics, and alluvium comprise the bulk of the rocks which occur in the Cargo Muchacho district. The areal geology and a structure section are given in Plate I.

Metamorphic Rocks

The metamorphic rocks of the district are divided into two distinct groups which occur in separate areas.

Vitrefrax Formation

Definition and distribution.--This formation is named from its best developed exposure in the Bluebird quarry on Vitrefrax Hill, (Plate I, no. 17, Plate III, no. 2). The formation covers only a very small area of the district, notably Vitrefrax Hill itself and Micatalc Hill to the north.

Lithologic character.--The Vitrefrax formation comprises several indefinitely bounded lithologic units. The lowermost of these units is white quartzite which grades into sericite schist or quartz-mica schist. Above this lies talcy sericite schist, which in turn grades upward into kyanite-bearing quartz-sericite schist, thence into white kyanite-bearing quartzite, thence into sericite schist with abundant magnetite metacrysts, and finally into kyanite-bearing quartz-sericite schist. Texture is fine to medium-grained for the most part, yet where the kyanite is best developed the crystals occur in large matted aggregates and in radiating groups several inches long.

Origin and metamorphism.--The presence of strikingly different rock types in a limited area, the layered character of these rock types, and the close resemblance of the total composition of these rock types to that of silty sandstone point toward the theory that the Vitrefrax metamorphics were derived from sediments. The quartzite and its variations were undoubtedly formed from sandstone. The talcy sericite layers were derived by metamorphism perhaps from dolomitic beds, although a basic igneous rock would be an equally adequate initial type. In the kyanite-bearing quartz-sericite schist, the completely random orientation of the kyanite crystals coupled with the vuggy nature of the sugary quartz matrix militates strongly against a regional dynamic metamorphic origin for the deposit. Hydrothermal solutions working on a more aluminous member of the series is suggested as the most likely agent in causing this metamorphism. Ferruginous clay shales may have been the original material from which was produced the magnetite sericite schist.

Evidence of later pneumatolytic action is also present in the area. About 900 feet directly south of Micatalc Hill, near the fault zone separating metamorphics from biotite granite, a considerable amount of euhedral black tourmaline crystals are disseminated through the kyanite-bearing quartz-sericite schists. The tourmaline also occurs in fine-grained veinlets cutting the schists. Accompanying the tourmaline are waxy green to white steatite, often filling the interstices of broken tourmaline needles. A small amount of pyrite is irregularly scattered through portions of the Vitrefrax formation.

In the same limited locality small dikes and veins of quartz-feldspar pegmatite containing specular hematite crosscut the tourmalinized and steatized kyanite schist. One quartz vein containing a seam of specular hematite occurs undistrubed in a fault zone filled with talcy gouge.

Note: The controversy concerning the origin of kyanite centers about the question of whether or not new material has been added to the country rock by the agency of hydrothermal solutions. A few of the classic and a number of more recent references on this subject are cited below.

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Wilson, E. D. An occurrence of dumortierite near Quartzite, Arizona. Amer. Min., vol. 14, pp. 373-81. 1929.

Related series.--Another group of metamorphic rocks may be included with the Vitrefrax formation. These outcrop on the extreme eastern border of the southern half of the range. The occurrence is very much confused by abundant aplitic intrusions in the form of small dikes and irregular plugs.

One horizon of these metamorphics outcrops discontinuously along ridge tops for over a quarter of a mile in a more or less straight line, striking N10°E and dipping 50°SE. This ridge-forming rock varies from an extremely hard white quartzite, which occasionally bears epidote, to a rock bearing abundant wollastonite and occasional coarsely crystalline calcite. The outcrop has weathered to form a rough solution-pitted surface like a normal limestone under desert conditions. The rock probably originated from the metamorphism of a calcareous sandstone.

A fine to medium-grained dense gray rock occurring nearby commonly displays laminae and bedding. It appears to be a strongly metamorphosed feldspathic sandstone.

A third variety consists of a fine-grained black biotite-hornblende schist. Although sometimes only slightly folded, this schist is often very strongly contorted, especially when it is near a contact or is in fairly large inclusions in quartz monzonite. The origin of this schist is uncertain. On the basis of lithologic similarity, this schist may be the source of the inclusions in the quartz monzonite on the southeast side of the range.

Tumco Formation

Definition and distribution.--This name is applied to the metamorphic terrane lying in the Tumco Valley and extending north and south therefrom for about a mile. A strip of this formation can be traced through the northern part of the range over to the east side where there lies another considerable area of metamorphosed sediments. With neither top nor bottom exposed, the minimum stratigraphic thickness of the formation is more than 6000 feet.

Lithologic character.--Arkosite. Gray to pinkish gray, highly indurated, massive and closely to sparsely jointed arkosite is the type rock of the formation. In texture the rock is fine-grained. It consists dominantly of quartz and feldspar with small amounts of hornblende and biotite. Minor variations in mineral composition and in grain size produce a slight effect of banding in the arkosite. The main joints parallel the bedding planes, while the next most important joints stand vertically and strike roughly N-S.

Under the microscope the rock is fine to medium-grained. The principal minerals include feldspars, 50%, (approximately equal amounts of orthoclase and microcline); quartz, 45%, rounded grains; biotite, 4%, large, strongly pleochroic grains often showing parallel alignment; and hornblende, a few medium sized grains, pleochroic yellow-green to blue-green. Accessory minerals consist entirely of magnetite, apatite and zircon.

The Tumco formation is not uniform in appearance. Most important of the variations are those due to differences in the original materials from which the rocks were formed, giving two main types, arkosite (described above) and hornblende schist.

Lithologic character.--Hornblende schist. Green-gray, schistose rock characterized by its thin-bedded nature and its large hornblende phenocrysts. It occurs in unjointed layers a few inches up to a foot thick at wide stratigraphic intervals throughout the arkosite series.

Microscopically this hornblende schist appears holocrystalline, with large crystals of hornblende and biotite scattered through a fine-grained feldspar and quartz groundmass. Feldspar varies from 20% medium-grained orthoclase in the one extreme, to 20% orthoclase and 20% medium-grained microcline in the other. Quartz, 45%, occurs in medium-sized grains, often elongated parallel to the schistosity. In thin section under the microscope with nicols crossed most of the quartz grains display wavy extinction. Hornblende, 5%, appears as characteristically large grains, pleochroic from yellow-green to blue-green and parallelling the schistosity. Biotite, exhibiting strong pleochroism, varies in amount from 18% to 2% inversely with the amount of microcline present. Epidote, 8%, occurring in small scattered crystals, is found persistently throughout the schist. Apatite and magnetite are the dominant accessory minerals.

Origin and metamorphism.--In composition the typical arkosite does not differemuch from an ordinary granite. The thin fissile hornblende layers interstratified with the arkosite, and the slight but regular textural and compositional banding of the arkosite appear to be indications of sedimentary origin. This stratigraphic banding is especially evident where the rock has been folded by small sill-like intrusions.

The texture of the mineral grains of which the rock is composed points to sedimentary origin. Feldspars with their rounded to irregular grains may have been sedimentary grains slightly recrystallized by metamorphic forces. Well-rounded quartz grains, on the other hand, could be only detrital in origin, though they may have been slightly elongated and somewhat strained by metamorphic activity.

Thinness of its beds and extremely fine-grained nature of its matrix, suggest a tuffaceous origin for the hornblende schist. The subhedral hornblende and biotite crystals in this schist were probably formed by mild metamorphism.

North of Tumco Valley the formation is very abundantly cut by dikes and penetrated by lit-par-lit sills which are granitic to pegmatitic in character. Intrusions increase in abundance as the contact between arkosite and leucogranite is approached. The actual contact is a very indefinite zone in which hundreds of sills finger into the arkosite. On the map (Plate I) the contact is drawn to represent the locus at which sills predominate over arkosite in a ratio of approximately 60% to 40%.

In the contact area between Tumco arkosite and leucogranite a number of suggestive features have been noted.

Rocks with typical fine-grained texture of the arkosite can be traced along a single stratigraphic horizon until they have changed by a series of minute variations to completely granitoid leucogranite.

Coincident with gradual textural change is an equally gradual compositional change. Fine-grained gray to pinkish-gray feldspars in arkosite give way to light gray and white feldspars in leucogranite. Biotite content which is quite high in some of the arkosite near the contact area, decreases considerably as gradual transition is made into leucogranite. Magnetite occurs in inverse proportions to biotite.

Likewise there is a gradual loss of sedimentary structure as the contact is traversed from arkosite into leucogranite. This loss of sedimentary structure occurs even more slowly than do the variations in texture and composition. Hence, in many cases where the rock is both texturally and compositionally leucogranite, it still bears evidence of structural similarity to stratified arkosite. This stratified appearance is caused by differences in mineralogy, texture, color or hardness of different layers of leucogranite. Very commonly the small amount of biotite in the leucogranite is in parallel alignment with the regional structure of the arkosite. Weathering of the rock surface generally aids in accentuating the minor differences between layers and hence emphasizes the sedimentary appearance of this type of leucogranite.

Throughout the leucogranite are abundant arkosite inclusions. North of the leucogranite-arkosite contact, the inclusions decrease in number and in size, and are more completely digested. On the map (Plate I) a few of the largest inclusions are represented by attitude symbols placed within the leucogranite proper. All of the major inclusions are oriented parallel to the regional trend of the arkosite.

Two textural anomalies occur in the arkosite and in the granite of the contact area. It can be observed under the microscope that while type Tumco arkosite contains a considerable amount of microcline, this microcline occurs characteristically in small, somewhat rounded, slightly kaolinized grains. As the contact with the leucogranite is neared, however, large irregular microcline crystals, many of which are considerably kaolinized, become increasingly abundant. This same relationship has been noted, but not so commonly, in the case of orthoclase.

In type leucogranite, most of the quartz is in small to moderate-sized angular to irregular-shaped grains. However, some quartz in the leucogranite, most notably in the contact area, consists of small rounded grains, a few of which are actually included in large microcline and orthoclase crystals. These phenomena are evidence that the leucogranite was formed by the granitization of original arkosite in the area.

The textural change might have been brought about by an increase of temperature and pressure.

The compositional change is not important in terms of total composition. The reworking of the feldspars converted gray tinted feldspars in arkosite into clear feldspars in leucogranite. It has been suggested[1] that the clouded gray effect of many feldspars is

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1. Anderson, G. H. Granitization, albitization, and related phenomena in the northern Inyo Range of California-Nevada. Bull. G.S.A., vol. 48, pp. 1-74, 10 pls., 11 figs. 1937.

caused by the presence of dustlike inclusions of ferruginous material, chiefly hematite, or, less abundantly, magnetite. The segregation of this ferruginous material as well as partial breakdown of biotite and hornblende may account for the slightly greater amount of magnetite in the granite.

The gradual loss of sedimentary structure accompanies more complete digestion of the arkosite by the granitizing solutions.

The varying stages of digestion of the inclusions as well as their parallelism of orientation suggests infiltration and penetration by replacing solutions rather than forcible intrusion of a displacing magma.

The large feldspar crystals in the arkosite of the contact area are interpreted as metacrysts representing the first stages of granitization.

The quartz inclusions in the feldspars of the leucogranite are interpreted as being the last undigested remnants of the original arkosite.

Igneous Rocks

The igneous rocks of the district have been tentatively mapped as several types. A series of four major igneous intrusions makes up the bulk of the range and extends almost continuously along the center of the range from south to north. The rocks vary from an extremely dark quartz diorite in the south to an almost white granite in the north. They seem to be a related sequence of successive intrusions into the metamorphic terrane.

Quartz Diorite

Quartz diorite occurs in the southern part of the range in a belt lying to the south of the Madre Valley, extending eastward to Jackson Gulch and thence northward to Obregon Valley.

The rock is dark in appearance, containing abundant biotite and hornblende. The quartz and feldspar are gray. Texture is generally granitic, though locally it becomes gneissoid.

Microscopically the rock is holocrystalline and fine to medium-grained. Andesine (An 46) makes up 25% of the rock. Orthoclase, 5%, is present in the form of large highly kaolinized crystals. Quartz occurs to the extent of 20% in fairly well-preserved grains interstitial to the feldspars. Biotite in strongly pleochroic euhedral crystals forms 20% of the rock. Hornblende, likewise 20%, occurs as strongly pleochroic yellow to dark green crystals, partly resorbed by later quartz grains. Epidote, 8%, is formed as small euhedral crystals scattered in the feldspars. Accessory minerals include apatite, zircon and occasionally magnetite.

In its northeastward extension the diorite bears numerous dark schistose inclusions. Many of these inclusions contain abundant microscopic hairs of sillimanite.

Quartz Monzonite

Quartz monzonite makes up the whole eastern portion of the southern half of the range, as well as the hills to the south of the range. This quartz monzonite may eventually be mapped as two or three rock types, for its mineral content varies considerably.

It is characterized megascopically by grains and aggregates of dark biotite and hornblende sharply contrasting with light colored feldspar and quartz. The texture of this rock is typically granitoid, but in a number of isolated spots it is gneissic, having been subjected either to primary flowage or to secondary localized shearing or compression.

Upon examination under the microscope, the quartz monzonite appears holocrystalline, subequigranular and with granitoid texture. Feldspar comprises about 55% of the rock. Of this, 10% is orthoclase, 20% microcline; the remaining 25% consists of andesine (An 45). 20% of the rock is quartz, mostly in small grains. Euhedral, strongly pleochroic biotite makes up 18% of the rock. Other minerals include hornblende together with the accessory minerals, apatite, magnetite and zircon. Sericite occurs as an alteration of the feldspars.

Epidote, which may attain considerable proportions locally, is found both in veins and as disseminations.

In its less typical phases, the quartz monzonite may become either aplitic or porphyritic in texture. The porphyritic phase contains large orthoclase phenocrysts in the form of Carlsbad twins up to four inches long. This porphyritic type occurs in small dikes, one to fifteen feet wide, cutting the main body of the quartz monzonite. While the adjacent normal quartz monzonite bears abundant dark inclusions, the porphyritic facies bears none.

Biotite Granite

This rock occupys the southeastern quarter of the northern half of the range. It varies somewhat in appearance. A closely related rock type outcrops in the area immediately to the south of the American Girl Mine. Scattered stocks of biotite granite intrude the quartz diorite on the south edge of Obregon Valley.

Megascopically this rock is characterized by the abundant occurrence of coarse pink to gray feldspar as well as by the presence of biotite as the major dark mineral.

Under the microscope the composition of a typical specimen is seen to be 50% orthoclase and microcline, 40% quartz and 8% biotite with a little hornblende. Accessory minerals include zircon, magnetite, and a few grains of apatite and garnet. The texture of the rock appears characteristically holocrystalline, fine to coarse-grained.

The large feldspars are believed to be metacrysts, and much of the quartz occurs as small rounded grains. The presence of these small rounded quartz grains scattered throughout the rock strongly suggests that the biotite granite in its present form was derived from a quartzitic sediment by granitization.

Between the American Girl Mine and Micatalc Hill the rock has been so thoroughly altered that it has assumed a dense greenish black appearance relieved only by scattered feldspar metacrysts. The rock contains orthoclase, 20%, in large pink Carlsbad twins, quartz 50% in small subrounded grains, biotite 18%, hornblende 5%, and epidote 8%. Accessory minerals are apatite and zircon.

Leucogranite

The whole northernmost part of the range and the northeastern portion of the outlying hills to the northeast of the range are composed of granite. Several small granite stocks were observed in the eastern portion of the southern half of the range. This granite contains few dark minerals. Its texture varies from even-grained granitoid to gneissic.

A typical specimen contains about 52% feldspar, of which 30% is orthoclase in irregular slightly kaolinized grains, 20% is microcline and 2% is oligoclase, both of which are also in small irregular grains. Quartz in subrounded grains, suggestive of sedimentary origin, makes up 47% of the rock. Highly pleochroic and partially resorbed biotite crystals are present and show a slight tendency towards alignment. Accessory minerals include apatite, zircon and magnetite.

Closely associated with the granite, and often obviously emanating from it, are numerous pegmatitic and aplitic sills and dikes. These are composed of 98% quartz and feldspar, with small red garnets making up the remainder. Often hand specimens of the dike and sill rock cannot be distinguished from the leucogranite.

Origin of the Granitoid Igneous Rocks

The igneous rocks discussed in the preceding pages have many characters in common. Only broad types were distinguished in mapping, though more detailed study would certainly justify further subdivision of some of these types. In the field the leucogranite and less commonly the biotite granite are locally characterized by an alignment of minerals and a bedded appearance which are not found in the quartz monzonite and quartz diorite.

From field evidence the quartz diorite seems to be the oldest of the intrusives. Its relationship to the older metamorphics can be demonstrated at only a very few localities. On the east end of Micatalc Hill the diorite intrusive contact cuts across the schistosity of the earlier Vitrefrax formation. To the south and west of Kyanite Hill another contact between these two formations can be seen. At this latter locality, however, the alluvium-mantled outcrops are not continuous enough to give a clear-cut picture of the relationships.

At the east end of Madre Valley and again in the area just north of Jackson Gulch, the intrusive relationships between the quartz diorite and the younger quartz monzonite are well displayed. Narrow stringers of quartz monzonite penetrate the quartz diorite. At the same place, the quartz monzonite contains abundant xenoliths of quartz diorite.

The dike-like bodies of porphyritic quartz monzonite and aplitic quartz monzonite which occur in the southeastern portion of the range cut the main body of the quartz monzonite with many stringers and apophyses. Accordingly these minor facies are younger than the rest of the quartz monzonite. Their relationships to each other and to any of the supposedly subsequent rocks are unknown. Similarity of composition provides the only reason for supposing that these dikes intruded immediately after rather than long after the emplacement of the main body of quartz monzonite.

The mode of intrusion of the biotite granite differed from that of the earlier intrusions in that replacement rather than displacement of the country rock began to assume an important role. These relationships may be observed best at the eastern end of Tumco Valley. There the biotite granite definitely cuts across the earlier Tumco Arkosite. At the same time, however, especially in its alignment of minerals, the biotite granite contains hints of structural parallelism with the arkosite. On the other hand, the small stock-like masses of biotite granite in the southern part of the range show no structural parallelism whatsoever. These latter masses undoubtedly displaced or stoped out the pre-existing country rock.

Subsequent to the emplacement of the biotite granite, the leucogranite intruded the northern part of the area. A number of textural and structural features which can be observed in the leucogranite, suggest that this igneous rock granitized or replaced rather than displaced the Tumco Arkosite.

Along with the intrusion of the leucogranite, the entire area, especially in the north, was shot through with aplitic and pegmatitic sills and dikes. These relationships can best be seen on the west side of the mountains about one mile north of Tumco Valley.

Andesite

Andesite may be observed in a number of outcrops too small to map in and along the western border of the biotite granite north of Obregon Valley and in a single large dike-like outcrop on the west end and skirting the north side of Micatalc Hill. The rock is extremely fine-grained, appearing almost aphanitic. The matrix is a compact mass of very fine needles and laths. A peculiar feature about this andesite is the scattered occurrence of angular to well-rounded pebble-like fragments of milky white quartz. These fragments are generally small, but may at times be as large as two inches long. Occasional aggregates of biotite occur in the rock. Fresh andesite appears greenish gray and dense. It weathers to a pale earthy brown. It shows no indications of metamorphism.

Under the microscope the andesite is fine to medium-grained with andesitic groundmass. Tabular and lath-shaped crystals of andesine are most common, 50%. Quartz, 2%, occurs as small granular inclusions.

Biotite, 30%, is found in patches of strongly pleochroic grains. Augite, 8%, develops as large, euhedral, almost colorless phenocrysts. Magnetite 2%, hornblende 1%, and glassy groundmass 7%, make up the rest of the rock.

Olivine Basalt

Olivine basalt caps three hills within the area mapped. All are small hills set apart from the main range (Plate III, no. 1). One hill lies at the east end of Obregon Valley; the second at the west end of the same valley, while the third is located on the west end of the hills to the south of the range. The cap varies in thickness from about seventy-five feet on the round-topped hill east of the mountains, down to nothing where it wedges out in the southern hills. The facts that scattered basaltic debris is to be found in the alluvium all over the district and that just outside the area there are several other hills which are capped similarly to those here described, testify to the former magnitude of areal extent of these flows. The writer suggests that they may at one time have been continuous with flows which cover the Chocolate Range from 12 to 20 miles to east and north. At least there is no evidence of any nearer source.

The basalt is fine-grained and highly vesicular near both top and bottom of the flows. No structures were encountered which would afford evidence of direction of flow. The basalt is dark gray in color and bears a scattering of brownish crystals of olivine. Under the microscope the rock is seen to be holocrystalline with basaltic texture. Laths of labradorite make up 60% of the rock, olivine in large euhedral crystals 12%, augite in small crystals 25%, and magnetite 2%.

Alluvium

In the area mapped there are present at least three ages of alluvium. The oldest type has been observed in only one locality. This is a high ridge consisting solely of alluvial material and lying about a quarter of a mile northwest of the lava-capped round-topped hill to the east of the mountains. Poorly sorted, angular or only slightly rounded pebbles and boulders characterize the material. Although occasional boulders attain a size of two or three feet across, most of the material ranges from one to six inches in diameter. The fragments are heterogenous in character, the bulk (about 80%) are of schist, while the remainder are mostly of quartz and granite. Some of the large boulders consist of dense fine-grained dumortierite,[1] others are of kyanite schist, while in a few boulders kyanite is found in conjunction with dumortierite.

Because of the great size of the boulders involved, and because of the angular to subrounded character of the material, this oldest alluvium appears to have suffered but little transportation. On the other hand, this alluvium contains an abnormally high content of schist boulders for which no apparent local source exists. For

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1. Mackay School of Mines Staff. Dumortierite. Univ. of Nevada Bull., vol. 22, no. 2. 1928.

example, the presence of dumortierite-bearing boulders, some of which are identical with those described by Wolff[1] from ten miles north of the Cargo Muchacho Mountains, places the boulder source possibly that far away. According to O. R. Grawe[2] the Imperial County dumortierite appears to have had a common origin with the boulders from Clip, Arizona. (The town of Clip was located over thirty miles to the north of the Cargo Muchacho Mountains near the present camp of Cibola, Arizona.) If there was a common source for all of these boulder deposits of dumortierite and dumortierite with kyanite, it remains unknown. The agent which distributed them was probably the Colorado River flowing in a long since abandoned course which led across the area now occupied by the Chocolate and Cargo Muchacho Mountains. On the other hand, there may have been several independent local sources which have been eroded away or covered by alluvium.

A second type of alluvium consists dominantly of ellipsoidal pebbles, extremely well waterworn and well sorted. This alluvium lies on the flat area to the east of the mountains and in long alluvial ridges between the washes south of the southeastern part of the range. Where it occurs near the older schist-bearing alluvium this pebble alluvium forms terraces which overlap the older type. The

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1. Wolff. work cited 1930.

2. Mackay School of Mines. work cited 1938.

ellipsoidal pebbles are very constant in their composition, almost all being of chalcedony or jasper, with a few of flint and quartz. One chert pebble was found which bore the impression of a large crinoidal stem. This material is certainly not local in origin because: (1) there exists no local source for such material and (2) the material must have been transported far to be so well polished and sorted. It is believed that this alluvium, likewise, was deposited by the Colorado River when it was flowing on a now abandoned course. In their early explorations in the region both Blake[1] and Newberry[2] noted this pebble alluvium. Each assigned a Carboniferous age to the source rock. J. S. Newberry says the fossiliferous pebbles "derived, as I subsequently ascertained, from the Carboniferous limestone many miles above."

A third type of alluvium is the Recent slabby, angular, locally derived material which covers most of the fan area around the Cargo Muchacho Mountains. To the south of the mountains this alluvium can be seen overlying the rounded pebble type of alluvium.

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1. Blake, Wm. P. Geological Report (Williamson's reconnaisance in California) U.S. Pacific R.R. Expl. vol. 5, pp. 112, 117-118, 230-232. 1856.

2. Newberry, J. S. Report upon the Colorado River of the west, by Lt. Joseph C. Ives, Washington, D. C. 1861.

CHAPTER III

STRUCTURAL GEOLOGY

Subsequent to the emplacement of the intrusions described above, faults played the dominant role in the development of the structure of the Cargo Muchacho Mountains. Faults are numerous and fault blocks are characteristic structural units. Folding, on the other hand, was of only slight significance in the structural history of the range.

Intrusions

The earlier igneous intrusions in the range exhibit the characteristic features of typical stocks. The intrusive bodies have partly folded and partly cut across the country rocks. So far as could be determined the intrusions have steeply inclined, relatively smooth walls with no floor visible. Localities where inclusions are more abundant than the intrusive represent roof and border phases where the invading magma was commencing to stope the country rock.

The intrusion of the leucogranite exhibits clearly some features which are commonly observed in connection with stock-like intrusions and others which are commonly associated with replacements. In the first place, the metamorphic rocks are intruded by the granite and dip away from the supposed center of intrusion, (Plate IV, nos. 1 and 2.)

Secondly, within the leucogranite are a great many actual inclusions of the metamorphics. Far more abundant than actual inclusions are the relic structures of the Tumco arkosite within the leucogranite (discussed above). In every case these inclusions and relic structures maintain the regional dip of the invaded Tumco arkosite. That is, the country rock was not displaced, beyond perhaps a regional up-bowing, centering on a point to the northeast of the northern end of the range.

Thirdly, associated with the intrusion are a tremendous number of sills which are remarkably persistent (Plate IV, no. 5). These sills range from a few inches up to eight or ten feet in thickness. Those which are about two or three feet thick are most common. Above and below some of these sills which lie to the southwest of the granite, the metamorphics have been deformed by little drag folds which are of such a nature as to indicate intrusion coming from the southwest at depth and traveling in a northeastwardly direction or toward the center of the granite outcrop.

Among the minor intrusive features is the lenticular appearance of some of the sills in the metamorphics. In this case, the metamorphics obviously have been displaced and not replaced, for the layers of the Tumco arkosite can be seen to pinch and swell as they lap around the lenses of pegmatitic sills. Upon examination of detached blocks of rock containing these sills it can be shown that the pinches in the sills are localized points, not ridges or waves. That is, in three dimensions the sill is "tufted", like a quilt formed by pinching only single points together.

A fourth feature of importance is the vast number of dikes, both granitic and pegmatitic, which occur in the northern part of the range and which are probably connected very closely with the origin of the sills and granitic stock itself. These dikes do not appear as systematic swarms, but criss-cross the country in every direction, (Plate IV, no. 3.) For the most part they are steep-dipping to vertical. The facts: (1) that the dike rock is often indistinguishable in composition and texture from the leucogranite, (2) that the dikes become increasingly abundant as the leucogranite is neared, and (3) that no dikes have been found cutting the leucogranite itself, are interpreted as evidence that the source of the dike material was the leucogranite.

Another minor feature is the abundant ptygmatic folding of very small dikes, usually less than an inch thick. Such dikes, though occurring in relatively unfolded rocks, are highly irregular in all three dimensions, and are probably a replacement phenomenon rather than the result of open space filling.

All of these features emphasize the facts that the topography cuts the very top of the granitic intrusion and near the tops of the older intrusions and that the features here exposed might be termed acrobatholithic.[1]

The structure of the outlying hills on the northeast of the

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1. Emmons, W. H. Metalliferous lode systems and igneous intrusives. TAIME, vol. 74, pp. 29-70. 1926.

range duplicate the acrobatholithic structure of the north end of the range precisely. Hence, instead of being a separate but contemporaneous intrusion, the rocks in these hills may constitute a down-faulted extension of the same structure which dominates the northern end of the mountain mass.

Folds

In the metamorphic rocks of the Cargo Muchacho Mountains folding does not rank as a prominent structural feature. In fact, there is but a single major fold in the whole range, namely the broad warp which the Tumco arkosite makes as it dips off to the west and south away from the granite intrusive in the north (Plate IV, nos. 1 and 2). There a swing from a strike of N 45° W to a strike N 45° E is spread out over two miles.

Small drag folds have been noted in the Obregon Valley, as well as at numerous points underground in the American Girl Mine. The largest one observed in the mine involved a shortening of only two or three feet, while the largest seen in the field might have caused a shortening of about thirty feet. The significance of these drag folds will be pointed out under the discussion of faults.

Faults

Thrust faults.--Thrust faults mark most of the major east-west trending valleys in the area. These faults are best observed and traced in mine entries and prospect pits. At least four such thrusts are known in Tumco Valley; one is known in Obregon Valley; two are believed to occur in the Madre Valley. Undoubtedly more exist, perhaps some in the northern part of the range and perhaps others in the valleys already cited. The faults strike mainly between E-W and N 60° E, though local variations swing far outside of these limits. Likewise, dips are relatively limited, ranging between 20° and 40° south. It cannot be proven that the movement on all these faults has been in the nature of a thrust. However, drag folds in the American Girl Mine and small faults and drags observed in the walls of the Golden Cross glory hole in conjunction with a low angle fault of major proportions are indisputable evidence of thrusting.

N-S Faults.--Among the many N-S faults there are at least two of major importance. The greatest of these appears as a broad vertical gouge zone striking west of north which lies along the northeast side of the main mountain mass.

The other important fault of this type lies immediately to the west of Pasadena Peak and may readily be traced in the valleys and notches. It strikes about N 35° E and appears to be vertical. It is characterized by a shattered zone ten to twenty feet wide which has been subsequently mineralized. The dominant minerals in the fault zone are epidote, brown calcite, silica, malachite, and limonite. On the northwest side, the rock is all biotite granite, while that on the southeast is quartz diorite, bearing very dark inclusions. Farther down the valley to the southwest, the fault zone ceases to mark the contact between these two rock types. Likewise, to the northeast the contact swings away from this fault. Thus the fault has displaced the igneous contact between the biotite granite and the quartz diorite, locally making a fault contact between the two.

From areal relationships the fault is considered of the strike-slip variety, the west side having moved northwestward offsetting the intrusive contact between the biotite granite and quartz diorite. If this hypothesis is correct, a slip of more than 2000 feet is indicated. The implications involved in such a fault have a direct bearing on the problems connected with the American Girl Mine, for the block which was moved northward is the hanging wall block of the mine.

Joints

Joints in the region have reached far greated development in the igneous rocks than in the metamorphics. No single jointing system prevails over any great area. Three jointing systems appear to be more prominent than any others: (1) parallel to the range and steeply dipping, (2) transverse to the range and steeply dipping, and (3) variable strike and very shallow dip, giving a bedded sedimentary appearance to the rocks where best developed.

Basin-Range Structure

To consider the possibility that the mountains owe their elevation to differential erosion would be to bring up the whole question of the origin and structure of the Basin and Range Physiographic Province.

Sidestepping this controversy the author merely states his belief that the role of differential weathering as a cause of the relative elevation of the Cargo Muchacho Mountains is negligible. Hence, some other cause must be sought.

Since within the range faults are prominent and folding is subordinate, it is probable that the mountains owe their present elevation to faulting. Though no means are at hand to prove this assumption, the range is thought to be a raised "slice" between two major faults, perhaps of the strike-slip variety. Such an hypothesis would make the Cargo Muchacho Mountains similar in origin to the Mecca and Indio Hills which lie to the northwest, on the east side of the Salton Basin.

PHYSIOGRAPHY

The processes and the land forms produced by weathering and erosion under arid conditions have been analysed in detail by Lawson, Bryan and others.

Approximately one mile to the south of the range lies a compact group of hills which are completely traversed by valleys draining to the south. In a similar manner, at least one small valley cuts northeastward through the lower hills which lie to the northeast of the main range. These valleys must have been either superposed or antecedent. Coupled with this phenomenon is the fact that in the southern portion of the range the valleys which drain to the north may be observed to be long, of gentle gradient, and relatively open in contrast to the short precipitous steep-walled canyons draining southward. Furthermore, the older types of alluvium stand as much as seventy-five feet above the present alluvial surface. Overlying this older alluvium are remnants of what may once have been a single flow of basalt.

All of these facts may be coordinated by hypothesizing that the streams flowing away from the range gained their courses on a cover surface of old alluvium or perhaps even on the basalt and maintained these same courses as the subjacent rock was exposed.

GEOLOGIC AGE AND CORRELATION

No means are at hand for determining the exact geologic age of the rocks of the Cargo Muchacho district. The lithologic units are similar in nature to the rocks of adjacent areas which have been described, *e.g.* Eagle Mountains, California, 80 miles to the northwest,[1] various mountains of southern Yuma County, Arizona,[2] Tinajas Altas, Tule and O'Neil ranges[3] fifty miles and more to the southeast, and S. H. or Kofa Mountains[4] sixty miles to the northeast.

In each case the author cited admits that his dating of the rocks is based upon similarity of rock type and degree of metamorphism to corresponding features in rocks of known date of other areas. In no case was it possible to date by paleontological evidence or by direct continuity of outcrop.

The same lack of adequate evidence as to geologic age prevails in the Cargo Mucahcho district. Accordingly the following tabulation of geological events is accompanied by hypothetical age assignments.

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1. Harder, E. C. Iron-ore deposits of the Eagle Mountain, California. U. S. Geological Survey Bull. 503. 1912.

2. Wilson, Eldred D. Geology and mineral deposits of southern Yuma County, Arizona. Univ. of Ariz., Ariz. Bur. of Mines Bull. 134. 1933.

3. Bryan, Kirk The Papago Country, Arizona. U. S. Geological Survey, Water Supply Paper 499, pp. 58-59. 1925.

4. Jones, E. L. Jr. A reconnaissance in the Kofa Mountains, Arizona. U. S. Geological Survey Bull. 620, p. 155. 1915.

Geologic History

1. A great thickness of quartz sandstone and arkosic sandstone was deposited, either preceded or followed by the formation of limestone beds and silty quartz sandstone strata. Probably pre-Mesozoic.

2. A series of granitoid rocks intruded the area, commencing with quartz diorite in the south and terminating with leucogranite, aplite, and pegmatite in the north. Probably Mesozoic.

3. Hydrothermal solutions accompanying the intrusions recrystallized the sediments, locally developing metamorphic minerals.

4. Shortly after the intrusion, the area was faulted by thrusts from the south. Solutions rose along the faults and mineralized part of the area.

5. Minor andesitic intrusion. Probably Tertiary.

6. Erosion almost to the present stage.

7. Deposition of old coarse boulder alluvium.

8. Deposition of fine rounded jasper and quartzite pebble alluvium.

9. Basalt flow. Probably Quaternary.

10. Erosion to the present stage and development of outwash alluvial deposits.

ECONOMIC GEOLOGY - METALS

General Character of Resources

Gold is the most important single resource of the region. In the past it has been mined on a fairly large scale. At present all activity is restricted to a number of small scale operations. Copper was produced along with the gold at the American Girl Mine. Other mineral products of the district are talcy sericite and kyanite.

Structure of the Gold Veins and Lodes

The gold deposits of the Cargo Muchacho district are all confined to the western side of the range. Although some mines are located in the far north and others in the far south, those in the Tumco Valley region have been most productive. All of the lodes have certain characters in common. They are all tabular bodies, usually associated with a definite foot wall or a definite hanging wall, but rarely with both. All but three of the lodes trend east and west, parallel to the major thrust faults of the area. Locally, of course, strikes widely at variance with this may be found. Dips of the lodes are fairly limited in their scope. With extremes at 16°S and 52°S, most of them lie between 20°S and 40°S. The three major lodes which do not trend E-W are the easternmost mines of the district, the Pasadena, Guadaloupe, and Cargo Muchacho. They all trend roughly east of north and dip steeply to the east, parallel to some of the major N-S faults of the area. Ore zones have been traced for considerable distance along the strike. Though the values may pass below an economic mining limit the structure continues. The same is true in following the ore at depth. Hence, the structure at any rate may be regarded as persistent.

The influence of fracturing on ore deposition is very important. Equally noteworthy is the close relationship between fracturing and rock type. Where a major fault traverses granite or quartz monzonite, the rock remains unfractured. On the other hand, a major fault in the metamorphic rocks or in quartz diorite shatters the rock. Though numerous prospects and even mines have been started on promising veins in the granite and in the quartz monzonite, none of these has ever proved valuable. Every mine in the district which has produced or is now producing gold on an economic basis occurs in metamorphics or quartz diorite. This influence of fractured country rock is brought out strikingly in the case of the Cargo Muchacho mine, in which the vein was exceedingly rich wherever it lay in quartz diorite. Where the structure passed southeastward into the quartz monzonite, however, the values disappeared.

A low angle fault, whether it be hanging wall or footwall, generally forms one limit to the ore. The other limit is usually determined by assay rather than by any structural feature. Nevertheless, the values seem to be concentrated in a definitely bounded zone. These zones are abundantly fractured, although often the fractures are microscopic. The amount of ore occurring as fissure filling is negligible.

Almost all of the ore appears to have been deposited by replacement, although, of course, the ore-bearing solutions entered along definite fracture channels.

Ore Shoots

In most of the mines in the district the ore shoots appear to trend roughly north-south, or northeast-southwest as in the case of the American Girl Mine. The shoots are broadly related to zones of approximately north-south fractures.

Ores

Two main types of ore are known from the Cargo Muchacho district. In the more common and more extensively worked, the gold is free milling. In the second and less common type, the gold is included in disseminated pyrite.

Composition and Value

Gold (and its included silver) and copper are the only minerals extracted from the Cargo Muchacho district ores. In the mines from which free milling gold is obtained the values run from $15. to $150. per ton. The copper content in this sulfide ore normally more than pays for freight and smelting charges on the concentrate.

Mineralization

Mineralogy

Mineral species which occur, or are associated with, the metallic ore deposits of the Cargo Muchacho district are listed below.

Brief mention of their occurrence is also given:

Gold:	native gold	Lead:	galena
Silver:	native silver	Zinc:	sphalerite
Copper:	chalcopyrite covellite chalcocite malachite azurite chrysocolla cuprite native copper	Gangue:	quartz calcite sericite biotite chlorite fluorite
Iron:	pyrite magnetite hematite limonite		

Gold occurs (1) as microscopic grains disseminated through the country rock; (2) as wire gold and grains in quartz veins; (3) as microscopic grains in disseminated pyrite, and (4) as placer nuggets, grains, and colors. All of this gold contains some silver.

The only silver in the district occurs as alloyed with gold.

Chalcopyrite, the most abundant of the copper-bearing minerals, occurs sparingly in the American Girl Mine. It was probably the primary source for most of the oxidized copper which can be seen in scattered outcrops all over the district.

Among the supergene copper minerals are covellite, chalcocite, malachite, azurite, chrysocolla, cuprite and copper, all in minor amounts.

Pyrite is the most abundant sulfide in the region. It occurs as a primary mineral in veins and in disseminated deposits.

Magnetite has been found occurring as a primary vein mineral in very small amounts at several isolated spots in the workings of the American Girl Mine.

Hematite has been collected as shiny gray mirror-like plates from a number of mineralized veins throughout the whole district. It is most commonly found penetrating calcite crystals along their cleaveage planes.

Limonite occurs in the oxidized zone wherever there has been mineralization.

Galena and small amounts of sphalerite have been identified as occurring along with chalcopyrite in the ores of the American Girl Mine.

Quartz is the most abundant gangue mineral of the whole district. It forms the bulk of most of the vein deposits and is an important constituent in all disseminated deposits.

Calcite, and much less commonly fluorite, occurs in minor amounts as a gangue mineral in conjunction with most of the mineralization in the area.

Sericite and biotite occur in mineralized zones as small fresh looking crystals with subparallel orientation. They also occur in large micaceous lenticular masses locally along the main fault of the American Girl Mine.

Chlorite is generally found in the mineralized zone in veinlets with calcite or quartz, though some of it appears disseminated.

The best opportunity to study the mineralization was provided by the American Girl Mine. Consequently, the remarks in the following few pages are strictly applicable to that mine only, although they apply in general to the other prospects and mines.

Wall rock alternation

The country rock in the American Girl Mine has undergone considerable alteration by mineralizing solutions. The country rock has been somewhat sheared but the extent to which this shearing brought about mineralogical changes is not great, except perhaps in the close proximity of the shears themselves. This general but weak dynamic metamorphism may be observed persistently throughout the mine. Locally, especially along the main fault, shearing stresses acting in combination with a small amount of introduced material succeeded in producing non-persistent lenses of talcy sericite.

To a later phase belong the solutions which produced the major alterations and metallization. Chloritization and sericitization are the most important types of alteration, particularly in the metamorphic rocks. Feldspars and some quartz have also been introduced into the arkosite. Areas of alteration of quartz diorite are rare.

The typical barren wall rock throughout most of the American Girl Mine is green-gray, generally fine-grained but occasionally porphyritic containing large gray to pink crystals of feldspar. The porphyritic variety of alteration is best observed in the footwall drift of the 500 level of the mine. In the hand specimen (C.M. No. 43) the nature and origin of the rock remains highly uncertain. In thin section under the microscope, however, this wall rock appears holocrystalline and porphyritic.

Principal minerals:

Orthoclase, 35%, occurs in roughly rounded grains of small to medium size. It is partly altered to kaolin and in places very small flakes of sericite have developed in the crystals.

Microcline, 16%, small to medium sized gray grains which are distinct from the large pink metacrysts described under alteration minerals.

Andesine, 3%, appears as small rounded grains scattered throughout the ground mass.

Quartz, 30%, most commonly occurs as small rounded grains. Quartz also occurs to a very small extent as an alteration mineral.

Accessory minerals:

Include zircon, apatite, sphene and topaz.

Alteration minerals:

Chlorite, 8%, is the only important dark mineral in the rock. Characterized by its ultra-blue abnormal interference color, it probably represents the variety penninite.

Microcline, 4%, occurs as large pink metacrysts which replace the earlier mineral grains indiscriminately. The metacrysts often bear inclusions of quartz and occasionally of the less common minerals.

Quartz occurs in one or two small veinlets penetrating the microcline metacrysts.

Calcite and pyrite are present as a few grains replacing the country rock.

Sericite and kaolin are developed to a small extent in the feldspars.

The rock was derived from an arkosic sediment, probably identical with Tumco arkosite. Hydrothermal alteration has changed the megascopic appearance of the rock considerably with little effect on its chemical composition and structure. Original dark minerals (probably mostly biotite) have been entirely chloritized. Microcline has been introduced or reworked in place to form medium to large-sized pink metacrysts. Minor amounts of quartz likewise have been introduced or reworked. A few grains of pyrite and calcite give evidence of the actual infiltration of mineralizing solutions. The sericitization of the feldspars may have occurred at the time of this later mineralization. (There is no proof of the time of sericitization in the wall rock under discussion. For evidence that sericitization may have been closely related to ore deposition, see below.) Kaolin in the feldspars may have been developed either by the action of supergene ground waters or by hydrothermal action. Chloritized rock of the type described above is common in all of the workings of the mine whether in rich ore or barren waste, whether in hanging wall or in foot. The degree of intensity of chloritization decreases with increased distance from the ore-bearing area.

In contrast to the widespread weak chloritization of the wall rock is localized and intensive alteration to sericite and biotite. This sericite-biotite alteration occurs in the American Girl Mine only in areas in close proximity to the main fault or to minor subparallel faults. All of the wall rock which was altered in this manner constituted economically profitable ore. Perhaps almost half of the total ore of the mine was derived from these heavily metallized sericite-biotite alteration zones.

In the hand specimen (C.M. No. 45) the ore appears to consist of abundant euhedral pyrite crystals in a very fine-grained, dark-gray indistinctive ground mass. Numerous fine stringers cut the rock. Under the microscope the groundmass is seen to be holocrystalline and fine-grained. Apparently none of the original minerals of the rock have been left unaltered, except perhaps apatite.

Accessory minerals:

Apatite, 1%, occurs in small rounded grains, and is scattered all through the rock.

Alteration minerals:

Sericite, 57%, makes up the bulk of the groundmass. It is very fine-grained and almost completely lacking in any crystal alignment.

Biotite, 30%, occurs in small fresh-looking crystals with subparallel orientation. They are very rarely replaced or altered in any way.

Quartz, 2%, calcite, 4% and chlorite occur in veinlets and also disseminated throughout the rock.

Magnetite, occurs as a dust disseminated through the rock.

Pyrite, 5%, forms large euhedral crystals which cut across the other minerals, replacing rather than displacing them.

The magnetite as well as apatite may have been an original rock mineral, but it must have suffered recrystallization. All of the other minerals are the products of wall rock alteration. From the nature of this highly altered specimen (C.M. No. 45) there is no clue to the original character of this ore-bearing rock.

Veins

In addition to the quartz, calcite and chlorite veinlets which penetrate the wall rock, several strong veins occur in the American Girl Mine. All of these major veins follow faults along which the wall rock is shattered on either side. The dominant vein mineral is quartz. Pyrite, chalcopyrite, galena and magnetite have been observed in these veins. Vein pyrite is rarely in euhedral crystals, in contrast to euhedral pyrite in the altered wall rocks. Perhaps the sphalerite and pyrrhotite reported in the concentrates were also derived from these metal-bearing quartz veins. Pink orthoclase and deep purple fluorite have been occasionally noted in vein quartz. Most commonly the veins are massive and single, but occasionally they occur as composite veins or lodes. A few very thin veins have minor cavities and vugs lined with quartz and euhedral pyrite. Others contain calcite.

Metallization

Along with the wall rock alteration there were introduced a number of metallic elements, mostly in the form of sulfides. All data on metallization was obtained from a report by the American Cyanamid Company.[1] The flotation concentrate includes pyrite, chalcopyrite, chalcocite, covellite, bornite, sphalerite, galena, pyrrhotite, magnetite, hematite, limonite and gold.

Table 2. Assays of the flotation concentrate

	American Cyanamid Co.	Smelter
Gold	6.75 oz. per ton	6.88 oz. per ton
Silver		3.5 oz. per ton
Copper	2.85%	3.05%
Iron	31.93%	30.5%
Sulphur	32.93%	32.5%
Lime		1.5%
Alumina		4.1%
Silica		20.6%
Insoluble	25.90%	

(*Note*: The percentage of copper in both samples is lower than average. 5% copper is usual.)

Assays of the different mesh sizes after screen analysis reveals that most of the values fall into the minus 325-mesh group. The minus 325-mesh contained 54.74% of the total gold, 70.65% of the copper, 45.81% of the iron, and 27.81% of the insoluble material.

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1. American Cyanamid Company. Ore Dressing Laboratory. Microscopical examination of a flotation concentrate from the American Girl Mine. Private Report. 1938.

Examination of the flotation concentrate under the microscope showed that the metallic mineral constituents occurred in both free and locked mineral grains. Pyrite was the most abundant mineral constituent. Most of the pyrite occurred in apparently free mineral grains. An appreciable proportion of the pyrite contained inclusions of other mineral constituents, especially chalcopyrite, sphalerite, limonite and quartz.

Of the copper-bearing minerals, about 66% were chalcopyrite and about 34% were chalcocite, along with a little covellite and bornite. About 76% of the copper metal content occurred in apparently free mineral grains and about 24% occurred in locked mineral particles, especially as minute inclusions of chalcopyrite in pyrite.

Occurrences of gold were noted in free mineral grains and in locked particles. Locked gold particles 1 to 30 microns in diameter were most common in pyrite and chalcopyrite. Gold was also found both in limonite and quartz. The limonite was generally pseudomorphous after pyrite.

Four panner products and a slime product were obtained from a sample of the concentrate on a Haultain super-panner. These products were all assayed for gold, copper, iron and insoluble material. 21.94% of the gold was panned out as free gold. The panner iron concentrate assayed 6.04 oz. of gold per ton and carried 38.40% of the gold. The panner copper concentrate assayed 10.24 oz. of gold per ton and carried 17.82% of the gold. 4.10% of the gold occurred in the panner tailing, which assayed 1.32 oz. of gold per ton. In the slime portion of the sample was 17.74% of the gold. The slimes assayed 5.28 oz. of gold per ton.

The study of the ore minerals has not been carried far enough to permit detailed discussion of the paragenesis of the ore minerals. Since most of the gold occurs as minute locked particles in the pyrite and chalcopyrite, the interpretation that is placed upon these relationships (whether inclusion or replacement) will determine in a large measure the nature of any hypothesis of paragenesis.

A series of drawings made from photographs of polished sections of the concentrates[1] illustrates the nature of the occurrence of the metallic minerals and their relationships to each other (Plate VIII).

Omitting for lack of evidence, any statement regarding the paragenetic relationships of gold and quartz, these drawings seem to show the following mineral paragenesis:

Earliest: pyrite
chalcopyrite
Latest: sphalerite

Relationship between wall rock alteration, veins, and metallization

Surrounding the main break and some of the minor breaks of the American Girl Mine lies an aureole of chloritized and feldspathized country rock. Bodies of rock highly altered to dense fine-grained

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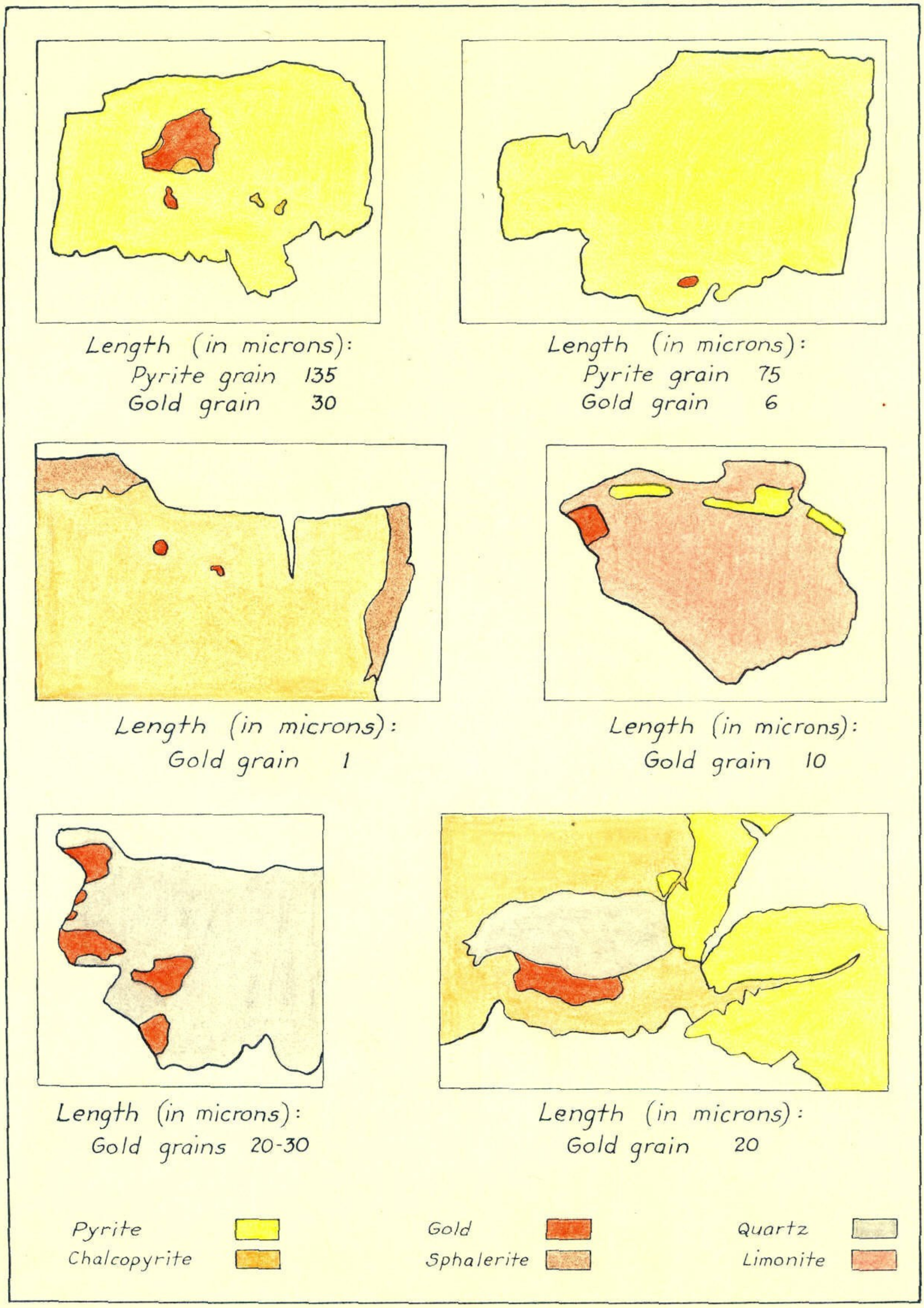
1. American Cyanamid Company. work cited. 1938.



AMERICAN GIRL MINE CONCENTRATES

Drawn from photomicrographs of polished sections.

American Cyanamid Company report

masses of sericite and biotite crystals occur in shoots and lenticular deposits in close association with the breaks. Almost all of the alteration took place in the arkosite wall rock to the west of the American Girl shaft. Nothing beyond a little chloritization occurred in the quartz diorite which lies to the east.

Whether these two types of alteration represent successive stages or different phases of the same stage of mineralization, the metallization occurs dominantly with the sericite and biotite. Massive quartz veins, which occasionally carry inclusions of sericite-biotite ore, were deposited during the next stage. More pyrite and gold, along with the less common sulfide minerals and fluorite were deposited in the quartz veins. The exact time of deposition of the relatively unimportant calcite stringers was not determined, though it is suggested that they followed the period of metallization.

Origin of the Ores

While some of the materials involved may have been derived from the decomposition of the country rock, most of the chemical elements were introduced. Furthermore, the source of these introduced elements was probably a cooling magma. Sericitization, which represents the most intensive type of alteration, is considered to be indicative of the alkalinity of the solutions.[1]

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1. Graton, L. C. Nature of the ore-forming fluid. Econ. Geol., vol. 35, supplement to No. 2, pp. 197-358. 1940.

The metallization, wall alteration, and vein structure, as discussed above are typical of mesothermal ore deposits.

Age of mineralization

Mineralization in the American Girl Mine was obviously controlled by the main fault and its subsidiary faults. In every case, wall rock alteration and metallization decreases with increasing distance from these breaks. Hence the mineralization is post-faulting. In several places in the footwall in the American Girl Mine small sulfide-bearing veins have been found cutting pegmatite dikes. Hence, the ore mineralization occurred after the pegmatites intruded. In the Sovereign East mine of Tumco Valley the pegmatite dikes are seen to be offset by the main thrust fault in the mine.

From these structural relationships it is concluded that the ore is post-faulting and the faulting is post-pegmatite. The pegmatites are known to be the youngest of the coarsely crystalline rocks. Hence the ore mineralization is younger than the main period of intrusion. Though at present there is no apparent means of telling how much younger, it is believed that these mesothermal gold-bearing quartz veins, like those of southern Yuma County, Arizona,[1] may be of late Mesozoic Age.

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1. Wilson, E. D. Geology and mineral deposits of southern Yuma County, Arizona. Univ. of Arizona, Ariz. Bur. of Mines Bull. 134, p. 46. 1933.

Gold Placers

Distribution

The alluvial gravels of Jackson Gulch and the Padre Madre Valley are reported to have yielded rich returns in placer gold. Pits and dump piles testify that these two alluvial areas were thoroughly explored and exploited. At the present time there is very little gravel left which has not been worked at least once.

Gold Content

Rumour has it that these placer deposits were very rich. However, no estimate can be made of their total yield. In Jackson Gulch the writer witnessed the dry washing of about one-half a cubic yard of previously undisturbed gravel. This gravel yielded approximately $5.00 in gold, most of which was in the form of small relatively unworn nuggets. The preponderance of larger pieces was probably due to the loss of the fine colors in the dry washing.

Tailings

The three major tailings piles of the district have all been reworked to a greater or less degree. The Tumco tailings are being cyanided in a small scale operation.[1] Old tailings and dumps of the American Girl were extensively milled and concentrated by O'Brien Mines, Inc. Cargo Muchacho tailings have been reworked more than once. Holmes and Nicholson were the last to operate on them.

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1. Calif. State Mineralogist's Report, vol. 34, p. 9. 1938.

METAL MINES

Mines in the Leucogranite

Mineralized zones occur on faults in or near metamorphic inclusions. The altitude of the faults is parallel to the relic structure of the inclusions. The mineralization consists essentially of quartz veins bearing pyrite, a little chalcopyrite, specular hematite and gold.

La Colorada mine, Plate I, no. 1. Nine claims owned by Mr. and Mrs. Mike Muller and Earl Goff of Calexico, California. The vein strikes E-W and dips 30° - 35°.

Golden Queen prospect, Plate I, no. 2. Owned by a Mr. Miller. The vein lies on a flat lying fault of variable strike, which averages roughly NW, while the dip is less than 20° SW.

Mines in the Tumco Arkosite of Tumco Valley

Mineralized zones occur on and near faults parallel to the regional structure. Perpendicular transverse faults form a minor ore control, as in the Golden Cross Mine. Drag folds in the hanging wall also localized the deposition of the ore, e.g. the large scale drag folds in the 450 stope and 700 stope of the Golden Queen Mine. The mineralization consists of quartz, pyrite, chalcopyrite and gold. In the past some of these mines were operated on a very large scale.

Coffee Pot prospect, Plate I, no. 3. Six claims owned by Eddie Coffee, J. L. Hardy, Henry Stroud, Mike Olathe, Henry H. Austin, and Jose Davis. Vein attitude is N84°E 34°S. A winze had been sunk

65 feet down the dip in January 1939.

King mine, Plate I, no. 4, differs from other mines in this group in its steep dip near the surface. The attitude of the main fault is N72°W 52°S.

Golden Cross group of mines now under the control of Thomas L. Woodruff of Ogilby had a total production estimated at over $3,000,000. All were large mines with inclined shafts extending down the dip of the main fault for over 1000 feet, and with many thousands of feet of workings. Ore occurred disseminated in the hanging wall. All were mined by shrinkage stoping.

Golden Queen mine, Plate I, no. 5. The attitude of the footwall is N52°E 26°S. For workings see map Plate VI. Pegmatite stringers in the hanging wall are shown in a picture of the shaft, Plate IV, no. 6.

Golden Cross mine, Plate I, no. 6. Footwall attitude is N57°E 37°S.

Golden Crown mine, Plate I, no. 9. Footwall attitude is N86°W 22°S.[1]

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1. California State Mineralogist's Reports, vol. 12, pp. 240-241. 1893-1894.
vol. 13, pp. 331, 337-339. 1895-96.
vol. 14, pp. 726-728. 1913-1914.
vol. 22, pp. 257-258. 1926.

Draper, M. Private Report on the American Girl Mine. 1911.

U. S. Bureau of Mines. U. S. Department of Commerce.
Mineral resources of the U. S. Washington. 1924-1931.
Minerals yearbook-review. Washington. 1932-1933.

U. S. Bureau of Mines. U. S. Department of Interior.
Minerals yearbook-reviews. Washington. 1933-1939.

U. S. Geological Survey. Mineral resources of the U. S.
Washington. 1882-1923.

Sovereign mines, east and west, Plate I, nos. 7 and 8, also Plate V, no. 4, owned by Thomas L. Woodruff. Total production for 1937-38 over $50,000. The property is still being operated (1940). Ore occurs in the footwall under a fault of variable attitude: strike N72° 30°E, dip 20° 30°S. In the Sovereign East mine, workings extend more than 200 feet down the dip and over 350 feet along the strike. Free gold occurs in a quartz vein 20 to 70 inches thick and averages $10. to $15. per ton.[1]

Other properties in the Tumco arkosite include Banner mine, Delta prospect, and Desert King mine.[2]

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1. California State Mineralogist's Report, vol. 34, p. 9. 1938.
   U. S. Bureau of Mines. U. S. Department of Interior.
   Minerals yearbook-reviews. 1938 and 1939.

2. California State Mineralogist's Report, vol. 13, pp. 331-332. 1895-96.
   vol. 14, p. 729. 1913-1914.
   vol. 22, pp. 255-256. 1926.

American Girl Mine

This mine, Plate I, no. 12, is covered by eighteen claims which also include the American Boy mine, Plate I, no. 13. The American Girl was recently operated by O'Brien Mines, Inc. Early in 1939 these holdings were incorporated with properties controlled by Sidney B. Wood, Jr. to form Allied Mines Inc., with Mr. Wood as general manager. Operation of the mine ceased in the summer of 1939. An estimate of the total production of the American Girl mine from July 1936 to May 1, 1939 is 119,000 tons of ore mined, yielding $575,000 in gold, silver, and copper. Earlier production had yeilded:

1892-1900	30,000 tons	$105,000 gold.
1913-1916	20,000 tons	$131,000 gold.

A well drilled in alluvium to the southwest of the range about 2.5 miles from the mine supplied water for the mine and mill, (for analysis see Appendix A). Water for domestic use was trucked from Irvin well in Ogilby.

A plan of the underground workings (Plate VII) shows the extent of operations. The ore occurs on and near a thrust fault which dips 30°S near the surface and 25°S at depth. Minor cross faults which intersect the main thrust fault have locally shattered the wall rock and have determined to a considerable extent the localization of intense wall rock alteration and metallization. The nature of the wall rock, wall rock alteration, and metallization have been discussed above. The Tybo shaft of the mine is shown in Plate V, no. 1.[1]

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1. California State Mineralogist's Reports, vol. 13, p. 331. 1895-96.
vol. 14, pp. 728-729. 1913-14.
vol. 22, p. 255. 1926.
vol. 34, p. 9. 1938.

Draper, Marshall Private report on the American Girl Mine. 1911.

The American Boy mine differs from the American Girl in distribution of wallrock types. The entire hanging wall consists of quartz diorite; the footwall, of metamorphosed arkosite. The structure is similar to that of the American Girl, but wall rock alteration and metallization are not so intense.

Nearby properties similar in geology include the Ogilby group, the Mayata and Englewood claims, and the Yuma and Arizona claims.[1]

Guadaloupe Mine

This mine, owned by Nat Kenison, is located near the east end of Obregon Valley, Plate, no. 14. Disseminated pyrite occurs in a large quartzitic inclusion in quartz diorite along a fault which parallels the orientation of the inclusion. The fault strikes N7°W and dips 52°E.[2]

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1. California State Mineralogist's Reports, vol. 14, p. 729. 1913-14.
   vol. 22, p. 269. 1926.

2. California State Mineralogist's Reports, vol. 14, p. 729. 1913-14.
   vol. 22, p. 255. 1926.

Mines in Quartz Diorite

Within this rock quartz veins occur along minor generally steep-dipping faults and shear zones. Wall rock alteration in the form of chloritization is intense in the mines of Madre Valley, but is of limited extent elsewhere. Hematite is common. Gold occurs free or in pyrite. Although the values are generally spotty a few of these mines have been very productive.

Pasadena mine, Plate I, no. 24. An ore-bearing silicified shear zone, with an attitude of N30°E 33°SE, has been prospected by five adits at different levels.[1]

Cargo Muchacho mine, Plate I, no. 23, was leased and worked by Holmes and Nicholson in 1936 and again in 1939. Quartz veins occur in a silicified shear zone 2 to 8 feet wide. Its attitude is approximately N4°E 48°E. To the south the mineralized zone crosses the contact from the quartz diorite into quartz monzonite. Values occur only where quartz diorite is the wall rock.[2]

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1. California State Mineralogist's Reports, vol. 11, p. 386. 1891-1892.
   vol. 12, p. 242. 1893-1894.
   vol. 13, pp. 341 and 343. 1895-1896.
   vol. 14, p. 729. 1913-1914.
   vol. 22, p. 260. 1926.

2. California State Mineralogist's Reports, vol. 6, p. 81, Pt. I. 1886.
   vol. 11, pp. 385-386. 1891-92.
   vol. 12, p. 239. 1893-1894.
   vol. 13, pp. 333-334. 1895-96.
   vol. 14, p. 729. 1913-1914.
   vol. 22, p. 255. 1926.
   vol. 34, p. 9. 1938.

Blossom mine, Plate I, no. 18 and Plate V, no. 2, is an old property which was reopened in 1938-39 by a Mr. Stubbins. The quartz diorite country rock is abundantly sheared and highly chloritized. There are many small quartz stringers in the mine, but none of them are persistent. The 200-foot Valencia shaft and several hundred feet of drift explore a mineralized fault zone with an attitude of N15° - 25°W 50°SW.[1]

Padre and Madre mines, Plate I, nos. 19-21 and Plate V, nos. 3 and 5, are owned and operated on a small scale by the Holmes and Nicholson Mining Company. The ore occurs in or near a dull gray quartz vein which follows a fault of variable attitude. Its strike ranges from N50°W to N50°E. Dip remains almost constant at approximately 24°S. A persistent breccia dike a few inches to a foot thick occurs generally in the footwall parallel to the vein.[2]

1.	Calif. State Mineralogist's Reports,	vol. 12, p. 238.	1893-94.
		vol. 13, p. 332.	1895-96.
		vol. 14, p. 729.	1913-14.
		vol. 22, p. 255.	1926.
	Register of Mines and Minerals.	San Diego Co., p. 6.	1902.
2.	Calif. State Mineralogist's Reports,	vol. 12, p. 242.	1893-94.
		vol. 14, p. 729.	1913-14.
		vol. 22, p. 259.	1926.
		vol. 34, p. 9.	1938.

Other properties in the quartz diorite include Occidental mine, south of Pasadena mine; Gray Eagle prospect, east of Pasadena mine; and Little Bear prospect, Plate I, no. 22. Gray Eagle, owned by C. J. Creese has an attitude of N57°E 36°SE. Little Bear is owned by Roy Bennett and others of Yuma, Arizona. It is characterized by a zone of numerous small quartz stringers with an attitude of N60°E 45°SE.

A number of prospects have been opened in quartz monzonite on small veins similar to those which occur in quartz diorite. None of them has developed into a mine.

Whitecap prospect, Plate I, no. 15, five claims owned by J. D. Northcott, J. H. Williams, R. van Patten and B. J. Hanna. Vein attitude N33°W 51°E.

Tee Wee prospect, Plate I, no. 16, three claims owned by Alex Crawford, may represent an extension of the Whitecap vein.

ECONOMIC GEOLOGY - NONMETALS

General Description

The non-metallic products of the Cargo Muchacho District consist of talcy sericite and kyanite. Though both of these minerals have been mined extensively in the district, their production is sporadic and follows closely the demands of the market. Five talcy sericite quarries have been opened up and two kyanite deposits have been worked. Most of the production has come from one talcy sericite quarry and from one kyanite quarry.

The mineralogy and general geology and possible origin of these deposits have been discussed above.

NONMETAL MINES

Sericite in Tumco formation

Occasionally near pegmatite dikes in the Tumco arkosite the country rock is completely altered to talcy sericite. This grades outward first into a sericite schist bearing large feldspar augen, then to a biotite feldspar schist, and finally into normal Tumco arkosite.

A prospect pit in the bottom of an arroyo a few hundred feet north of the Golden Queen mine and a few sporadically active quarries, Plate I, no. 10, at the southwest end of Tumco Valley exemplify this type of occurrence.

Sericite in the Vitrefrax Formation

This occurrence of talcy sericite has been briefly described above. The largest and most active talcy sericite quarry in the district is located on Micatalc Hill, Plate I, no. 11. An open cut has been worked since about 1930 by Micatalc Inc., under C. E. Allebrand of Los Angeles.

Kyanite in the Vitrefrax Formation

The geology of the kyanite deposits has been briefly discussed above.

Several small quarries have been worked on Micatalc Hill and in its vicinity.

Ogilby Kyanite Deposits, 10 claims owned by Vitrefrax Corp., 5050 Pacific Boulevard, Los Angeles. A large open cut on Vitrefrax Hill, Plate I, no. 17, supplies an average of 100 tons per year of kyanite. The best ore in the mine averages 40% kyanite. The kyanite is separated from the quartz by crushing and screening in the Micatalc mill, Plate V, no. 6.[1]

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1. California State Mineralogist's Reports, vol. 13, p. 333. 1895-1896.
vol. 22, pp. 268-270. 1926.
vol. 27, pp. 451-452, 455-457. 1931.

California State Div. of Mines Bull. 99, pp. 87, 121-122. 1928.

Riddle, F. H. Minerals of the sillimanite group. Eng. and Mining Jour., vol. 133, no. 3, p. 141. 1932.

WATER SUPPLY

Ground Water Level

The only available water in quantity in the district occurs as ground water in the alluvial fan to the west of the range.

A series of well records (See Appendix B) indicates that the ground water level is highest near the Colorado River. Hence it is concluded that the Colorado River is the source of supply for the ground water of the Ogilby region. With an intake point at a high of around 150 feet above sea level, for example at El Oro on the Colorado, the ground water level drops away to the north and west. The fact that the water table does not rise as the mountains are approached indicates that almost no ground water is contributed from the mountains.

Amount and Type of Ground Water

Not one of the wells listed in the Appendix has ever been pumped dry, or for that matter ever had its level lowered appreciably. Hence, the gravels penetrated by the wells must be highly permeable as well as adequately supplied with ground water.

All of the wells around Ogilby, except for the American Girl company well, yield water fit for domestic use. The first water struck in drilling the American Girl well was sweet, but insufficient in quantity. Deeper drilling gave an unlimited supply of saline water satisfactory for all except drinking purposes, (see Appendix A for analysis).

APPENDIX A

Analysis of Water from the American Girl Well

Dissolved Solids

Silica	1.30	grains per U.S. gal.
Aluminum oxide	0.25	
Iron oxide	0.01	
Calcium	24.41	
Magnesium	0.90	
Sodium	82.64	
Sulphate	21.16	
Chlorine	156.52	
Carbonate	None	
Bicarbonate	2.14	
Total solids	289.36	
Total non-volatile solids		288.27
Total hardness as $CaCo_3$		64.74

Hypothetical Combinations

Silica	1.30	grains per U.S. gal.
Aluminum oxide	0.25	
Iron oxide	0.01	
Calcium bicarbonate	2.84	
Calcium sulphate	29.98	
Calcium chloride	41.30	
Magnesium bicarbonate	None	
Magnesium sulphate	None	
Magnesium chloride	3.53	
Sodium bicarbonate	None	
Sodium carbonate	None	
Sodium sulphate	None	
Sodium chloride	210.15	
Total solids	289.36	

Determinations

Carbon dioxide uncombined in p.p.m.	2.0
Hydrogen sulphide in p.p.m.	None
Specific electric conductance	Not determined
Hydrogen Ion concentration	7.7
Boron in p.p.m.	0.4
Color (filtered)	None
Odor	None
Taste	Saline
Turbidity (filtered)	None

Smith-Emery Co. Chemical analysis of water from the American Girl well. Private report, March, 1936.

APPENDIX B

Well Records

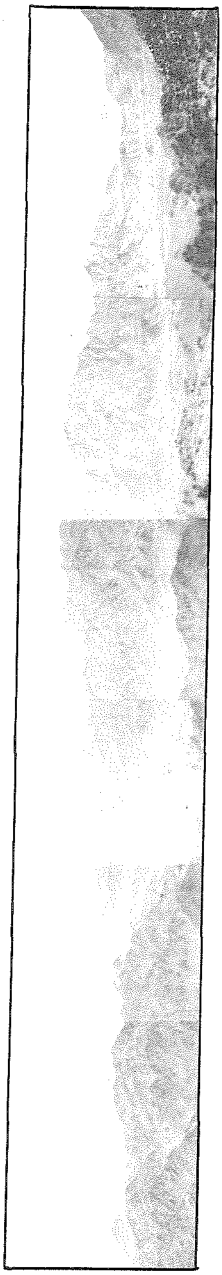
Well	Location	Elevation	Depth Water Stands	Depth Water Struck	Total Depth Well	Ground Water Elev.	Type of Water
Walker	T15S R20E Sec 4	460	410	410	521	50	Domestic
American Girl	T15S R20E Sec 23	450	368	325	475	82	Saline
Irvin	T15S R20E Sec 34	310	220		390	90	Domestic
Maxey	T16S R21E Sec 26	200	110		150	90	Domestic
Highway Maint.	T16S R20E Sec	170	100	100	190	75	Domestic
Buttercup Valley	T16S R20E Sec	180	90	90	90	90	Domestic
Gray	T16S R20E Sec 32	170	90	90	120	80	Domestic
Gordon	T16S R19E Sec 36	165	90		125	75	Domestic
Old County	T16S R20E Sec 32	170	110		120	60	Domestic
New County	T17S R18E Sec 1	125	80		140	45	Domestic
Glamis	T13S R18E Sec 28	350					Saline
Amos	T12S R16E Sec 24	259	268	268	550	9	Saline

PLATE III

1. Panorama looking north from Pasadena Peak. Note Vitrefrax Hill on the extreme left; low lava-capped hill at west end of Obregon Valley; town of Obregon in the valley; round lava-capped hill at east end of Obregon Valley.

2. Panorama looking northeast from a low hill southwest of Vitrefrax Hill. Note low lava-capped hill at west end of Obregon Valley on the extreme left; Micatalc Hill in the center ground; Vitrefrax Hill with the large cut of the Bluebird quarry.

Plate III



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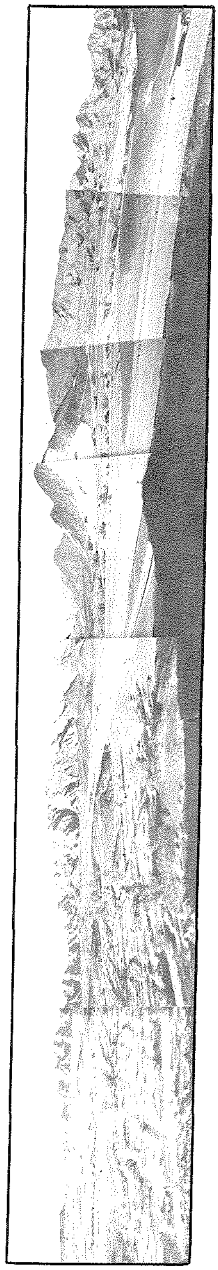


2.

PLATE IV

1. On the left the silled Tumco formation can be seen dipping to the southwest. View northwest from Coffee Pot prospect.

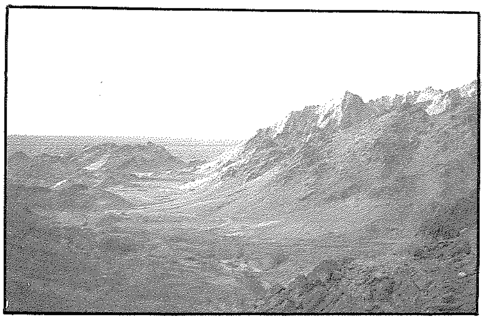
2. Tumco formation in right centerground dips away from leucogranite in left centerground. View southeast from the northwest corner of the area mapped.

3. Pegmatite dikes in the Tumco formation. View northeast from a point near the lava-capped hill at the west end of Obregon Valley.

4. Lava-capped hill at the west end of Obregon Valley. View northwest.

5. Tumco formation containing abundant pegmatitic sills. View northeast from Coffee Pot prospect.

6. Pegmatitic veins in the arkosite of the hanging wall. Golden Queen mine, Tumco Valley.



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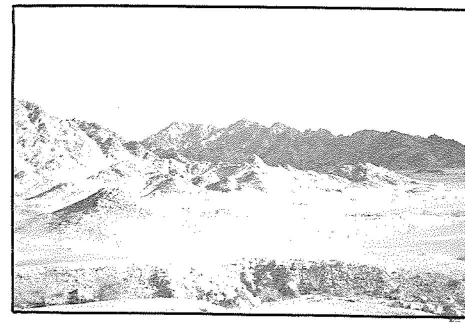

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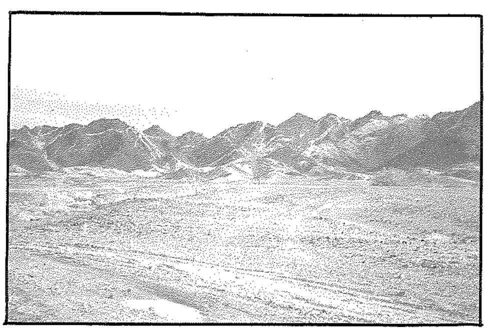

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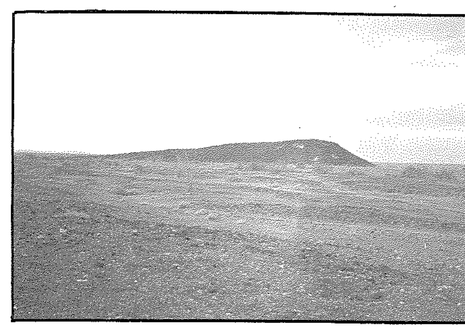

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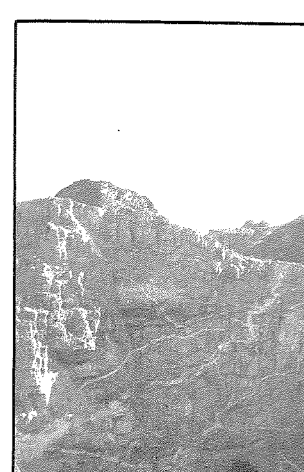
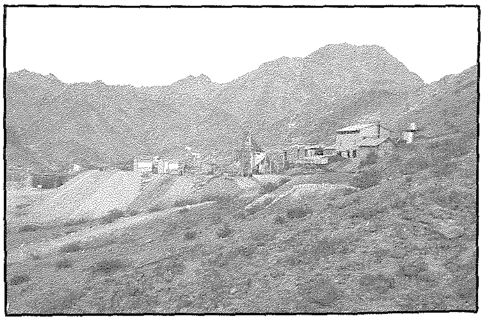


6.

PLATE V

1. Tybo shaft of the American Girl Mine. Pasadena Peak in the background.
2. Valencia shaft of the Blossom mine.
3. Madre Number Two shaft.
4. Sovereign mill from the west.
5. Madre Number One shaft.
6. Micatalc mill.

Plate V



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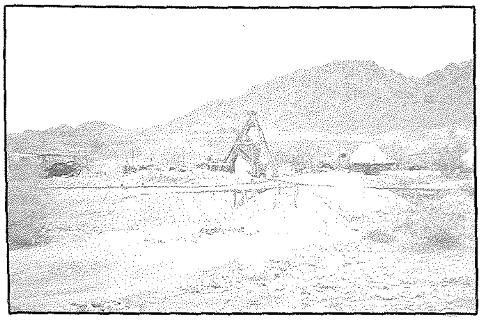

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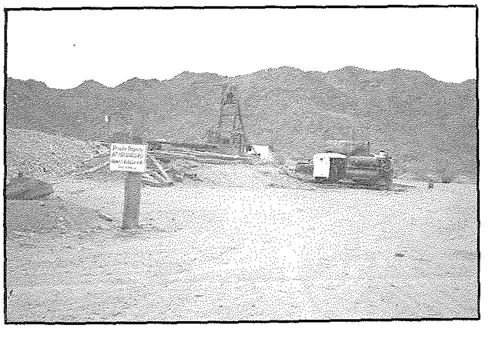

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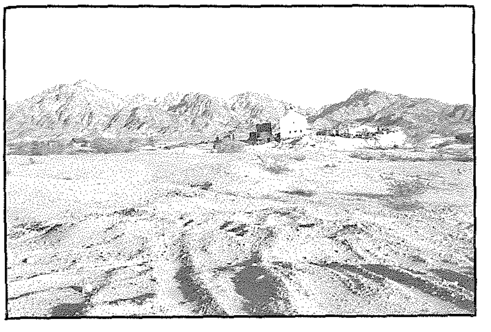

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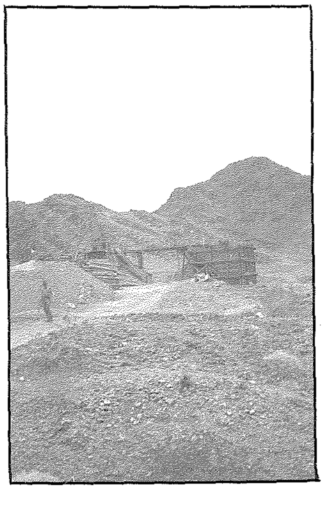

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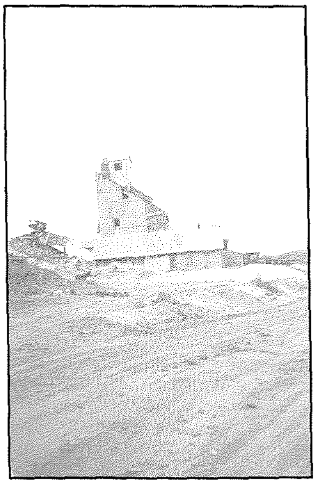

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