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A STRATIGRAPHIC STUDY IN THE MOUNT DIABLO
RANGE OF CALIFORNIA

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PREFACE.

The systematic study of the field covered by this paper, and its stratigraphy, was begun for purely economic and private purposes and not for publication; nevertheless, so much data and material of a scientific interest have been gathered, and so much information has been acquired, part of which, though of a practical nature, it is permissible to make public, that some of the more general facts are here offered as a contribution to the geological literature of California.

The matter and conclusions set forth are the result of a field-study extending over a period of more than two years, made partly alone, and partly with the coöperation and aid of Mr. Josiah Owen, whose knowledge of the field is both extensive and practical to a high degree, and to whom are due many of the stratigraphic observations here presented.

The advantages for a stratigraphic and faunal study offered by this field are in most respects unsurpassed anywhere. The aridity of the climate, and the soft and crumbling nature of the younger sediments, together with the action of the wind, combine to give excellent and accessible exposures of rock, while in many cases the almost perfect preservation of the shells and other fossils renders the task of identification satisfactory. The structure of the rocks, moreover, is generally simple, and strata are readily followed to almost any extent, particularly along the eastern flanks of the range, to which most of the field-work was naturally confined.

In this connection it is proper to mention the generous interest taken in this work by Professor E. T. Dumble and the many facilities afforded through his kind coöperation.

The fossils collected during the field explorations, aggregating several thousand in number, were donated to, and have become the property of the California Academy of Sciences.

INTRODUCTION.

In order that one of the main purposes of this paper may be understood, it is necessary, at the outset, to make the following statement. It is believed that during the Neocene periods, if not throughout the Tertiary, there were a number of more or less separated basins, or minor faunal provinces, along the Pacific border, two of which are represented within the confines of California.

The California *interior basin* was bounded approximately by the outer Coast Range, the Tehachapi Range, and the Sierra Nevada. At the south the barrier described a broad curve, following the axis of the Santa Cruz and Santa Lucia ranges along the present coast, thence turning eastward to Pine Mountain and the Tehachapi Range, which united it to the Sierra Nevada. The interior basin thus occupied the region of the Great Valley of California and the intermontane valleys between that and the coast.

The basin thus bounded and outlined is clearly distinguished from that of the open ocean of the time, the littoral deposits of which form a narrow fringe at intervals along the present coast, or fill the narrow coastal valleys, especially at the south.

The present paper is concerned especially with the deposits of the interior basin of California, which are believed to be typically represented in the Mount Diablo Range and in a few other localities within the Great Valley.

The Mount Diablo Range, as defined by Whitney,¹ extends along the southwestern border of the Great Valley of California, from Mount Diablo, near the Straits of Carquinez, southeasterly to Pine Mountain, where it unites with the Tehachapi Range, which links it with the Sierras. Thus the valley of the San Joaquin is surrounded by a continuous barrier of ranges on the east, south, and west, while it is separated by the Mount Diablo Range from the rest of the interior basin occupied by the Salinas and the Carisa valleys. In other words the Mount Diablo Range divides the basin of

¹ Geol. Surv. Calif. Geol. v. 1, pp. 8-60.

the California interior somewhat centrally, presenting at the same time magnificent stratigraphic sections that are unsurpassed anywhere in the West in their exposures.

DIVISIONS OF THE MOUNT DIABLO RANGE.

Whitney divided the Mount Diablo Range into six more or less distinct sections separated by certain low passes, some of which at least are notable breaks in the range, and though the region was not so well known then as now, it is still useful to observe some of these divisions.

The San Carlos Division of Whitney embraced that portion of the range between the Panoche Pass on the north and the Estrella (or Cottonwood) Pass on the south, thus including most of the western border of Kings and Fresno counties, or the territory adjacent to the Devil's Den, Coalinga, and "Oil City" petroleum districts. It is this division of the range which is chiefly the subject of the present paper, the various features of which will serve to illustrate the facts and conditions prevailing throughout the range.

Rocks of various kinds are found among the formations of this section ranging in age from Paleozoic to Recent, and embracing both sedimentary and igneous elements, though the latter are of only minor importance. For the most part the formations are arranged in roughly concentric fashion about the two principal centers of this division, one of which lies to the south and the other to the northwest of the Coalinga district. On the eastern slope of the range the structure is usually monoclinical, the strata dipping at varying angles toward the Great Valley, generally toward the east or north. The Cretaceous and early Tertiary beds stand at a high angle, while the younger strata often have a much gentler inclination.

The general topographic features of the Mount Carlos Division of the range are similar to those of other portions, and vary according to the underlying formations. The concentric arrangement of the rocks above referred to gives rise to similarly concentric series of hills and dales that have

developed in accordance with the character and hardness of the rocks affected. The higher portions of the range are rocky and rugged, while the lower eastern slopes are often formed of gently undulating hills extending in parallel ranks and gradually sinking below the plain to the eastward.

The principal streams of this section, flowing toward the Great Valley, are the Panoche, San Carlos, Cantua, Los Gatos, and Alcalde creeks, each of which cuts deep canyons into the softer formations near the valley, but heads high up on the rocky ridges in the central parts of the range. Farther south are the Sunflower and Antelope valleys with converging streams.

STRATIGRAPHIC SERIES.

FRANCISCAN AND ASSOCIATED ROCKS.

The oldest rocks met with in the San Carlos Division of the range are those generally referred to the Franciscan series, including not only the well known sedimentary factors, but also certain basaltic and other igneous rocks closely connected or involved with them. It is perhaps sufficient to say that the entire series, including the eruptives, are in point of age pre-Cretaceous, though they have been variously assigned by different authors, wholly or in part, to the Paleozoic, Jurassic, or Cretaceous periods.

The sedimentary members of the Franciscan series represented in this field include the rocks ordinarily found associated in this formation, such as radiolarian jaspers, sandstones, slates, and schists, and perhaps certain conglomerates.

Closely connected with the Franciscan rocks territorially are the serpentines of the range. While it is not likely that the connection is anything more than territorial, as in point of age the serpentines are of more recent origin and therefore more closely connected with the succeeding series, still, as their association with the Franciscan rocks is habitual even outside this district, they may be better classed with these than with any other formations.

The geologic and topographic features of the series are the same as everywhere in the coast ranges both north and south of the Bay of San Francisco. In this field the series is confined in its occurrence to the axis of the chief range extending west of the Coalinga district, or, more accurately, to a few prominent areas within that range.

There are two or three principal areas of Franciscan and serpentine rocks, separated to a considerable extent by an area of Cretaceous strata. One of these lies to the south of the upper tributaries of Alcalde Creek (or Warthan Canyon), and extends from there southeasterly to Cottonwood Pass; another extends from the upper branches of Los Gatos Creek northward toward the Panoche Valley and the tributaries of the San Benito River, and therefore includes the New Idria quicksilver district and the San Carlos and San Benito peaks.

The most extensive formation in this area is undoubtedly serpentine. To the south and west of New Idria, serpentine is almost the only rock to be seen for many miles. The sedimentary rocks of the Franciscan series are mostly confined to the southern and western borders of the area.

CRETACEOUS STRATA.

Lying along the eastern margins of the Franciscan areas and filling wide spaces between, are Cretaceous rocks, forming a stratified series of great thickness and dipping steeply toward the Great Valley. An important area of Cretaceous rocks is that between the Alcalde and Los Gatos creeks near Coalinga.

The Cretaceous strata include both the Knoxville and Chico divisions, with the intervening Horsetown Beds apparently omitted. The usual nonconformity between these members has not been proved in this field directly, though there are abundant grounds for believing that it exists.

The Knoxville consists of a thick series of dark clay shales and thin-bedded sandstones, lying next to the Franciscan rocks. They have been particularly noted along the head waters of Alcalde Creek, near the Fresno Hot Springs, on

least suspected by Gabb, as shown in Whitney's¹ discussion of the region.

The stratigraphic members of the Eocene, then, are the following:

Domijeau Sands
Kreyenhagen Shales
Avenal Sandstone

The lack of continuity of these members along the entire range is to be attributed partly to their nature and manner of origin, and partly to their degradation previous to the laying down of the succeeding Miocene or Pliocene strata; naturally, therefore, this lack affects chiefly the lower and upper members, while the intermediate member is more uniform in its character and at the same time more persistent in its occurrence.

The preceding lists of fossils contain representative Eocene species such as indicate that the beds are to be correlated rather with the Tejon than with the Martinez division of the Eocene, and this accords with the fact that the latter horizon has been considered local in its occurrence, or extending only northward from the latitude of Mount Diablo, and also with the fact that the Tejon Beds are found at New Idria and other points only a few miles north of the limits of our own observations.

MIOCENE FORMATIONS.

Rocks of the Miocene period do not enter extensively into the stratigraphy of the San Carlos Division of the range north of Alcalde Creek, but south and east of this stream they are more in evidence. Miocene strata occur in somewhat disconnected belts running parallel with the Eocene, and to some extent parallel with the Cretaceous. The greatest thickness of Miocene rocks found in any part of the range is near McKittrick and Temblor, although thicker aggregations of strata are found elsewhere, as on the western border of the Carisa Valley.

¹ Geol. Surv. Calif. Geol. v. 1, p. 57.

The most representative section of the Miocene that has been observed anywhere in the range south of the Cantua Creek is to be seen at Temblor and Canara Springs in western Kern County. Though no detailed study of these strata was undertaken, a general statement will be found interesting and instructive. The most conspicuous member of the Miocene in this section is the Monterey Shales, which have here an aggregate thickness of more than five thousand feet. For the most part this member consists of light colored shaly strata, the material of which is evidently largely organic, but in which three or more elements are easily recognizable; viz., foraminiferal limestone, siliceous organic beds, clay shales, and supposedly volcanic dust and ash.

The limestone occurs in thin lenticular bands, gray or yellowish in color, in which Foraminifera are readily seen through a good lens. These yellow or light gray bands occur in groups or singly, scattered through the entire thickness. The siliceous portion of the Monterey Shales predominates, and generally shows remains of Diatomaceae and other siliceous organisms, with bones and scales of fishes.

Near the top of the series the strata become more chalky and softer. *Pecten peckhami* has been found at both the top and bottom of this member at Canara Springs and eastward. The Monterey Shales, apparently, in undiminished thickness, make up the mass of the main range west of McKittrick, but they have not been traced easterly much beyond the Sunset district.

Underlying the Monterey Shales at Canara Springs and Temblor are sandstones and sandy shales which make up an additional thickness of fifteen hundred feet. The entire series of Miocene rocks at this point is about as follows:

| | ft. |
|---|------|
| Monterey Shales..... | 5500 |
| Sandstones with <i>Astrodapsis</i> | 100 |
| Siliceous and clay shales with interstratified sandstone..... | 600 |
| Sandstones with numerous fossil species..... | 800 |
| | 7000 |
| Total thickness..... | 7000 |

The sandstone with *Astrodapsis* contains in addition *Pecten nevadensis*, *Pecten discus*, and a few fragments of oysters and

barnacles. The lower fossiliferous sandstones yielded the following species of invertebrates:

| | |
|------------------------------------|------------------------------|
| <i>Lucina borealis</i> Linn. | <i>Pecten</i> sp. |
| <i>Lucina richthofeni</i> Gabb | <i>Solen</i> sp. |
| <i>Yoldia cooperi</i> Gabb | <i>Tapes</i> sp. |
| <i>Mytilus mathewsoni</i> Gabb | <i>Macoma</i> sp. |
| <i>Chione mathewsoni</i> Gabb | <i>Ballanus</i> sp. |
| <i>Dosinia mathewsoni</i> (?) Gabb | <i>Neverita callosa</i> Gabb |

In the light of stratigraphic studies farther north it is evident that the entire series of sands and shales below the Monterey Shales should be regarded as a distinct member of the Miocene, and the name *Temblor Beds* is suggested to embrace this aggregate of strata, while for the first sandy beds below the Monterey at Temblor the name "Button beds" has been used on account of the great numbers of small discoidal sea urchins (*Astrodapsis*) which characterize them here and elsewhere.

The Temblor Beds are often characterized by sands, more or less distinctly stratified, which are usually rendered highly calcareous by great numbers of fossil invertebrates. Echinoderms are sometimes so abundant that certain beds become almost a limestone. Occasionally pebbly layers are encountered, and at other points the sandstones become noticeably shaly.

As will be noticed further on, it is not rarely that the Monterey Shales are found resting on older rocks without any appearance of the Temblor Beds intervening. In some places there is a distinct overlapping of the Monterey Shales beyond the borders of the Temblor Beds.

North of the Canara Springs there is no similar thickness of Miocene strata anywhere in the Mount Diablo Range as far as known to the writer. In the vicinity of the Devil's Den and northward the section is materially reduced, chiefly by the reduction of the Monterey Shales.

Nowhere north of the Antelope Valley have these shales been found to exceed one thousand feet in thickness, though otherwise they are identical and appear to represent the basal portion of the shales occurring in the Canara Springs section.

Miocene strata describe a broad curve around the eastern side of the Sunflower Valley, but at most points only the Monterey Shales are visible. On the northern border of the Sunflower Valley, at Tar Springs, the Miocene section is about as follows:

| | |
|--------------------------------------|------|
| | ft. |
| Monterey Shales..... | 900 |
| Temblor Sandstones with fossils..... | 800 |
| White sandy shales..... | 400 |
| Total | 2100 |

This section is representative of the Miocene occurrences at most points between the Antelope Valley and Alcalde Creek. The Miocene rocks rest indiscriminately upon the Eocene, the Cretaceous, or older rocks as the case may be, though not always with an appearance of unconformity. The dip is always toward the Great Valley at some angle between 20° and 90°. At Tar Springs the dip is above 75°. At the Devil's Den on the south side of the Sunflower Valley the dip is in some places anticlinal, and to the west of the valley the Monterey Shales rise upon the flanks of the main range, overlying the Cretaceous without any appearance of the Temblor Beds.

The topographic aspect of the Temblor Beds is striking. They stand out in bold relief along the whole range from McKittrick northwestward to near Coalinga, and form a species of serrated wall along the front of the hills through which the canyons emerging into the Great Valley have cut their ways. This is particularly noticeable along the northern border of the hills extending west from Tar Springs, and in many other parts of the country. This feature is shown in some degree on plates xxviii and xxix.

The following fossil species have been collected from the Temblor Beds at different points:

Tar Springs.

- | | |
|---|--|
| <p><i>Scutella</i> sp. <i>Astrodapsis merriami</i> n. sp. <i>Pecten discus</i> Conrad <i>Pecten crassicardo</i> Conrad <i>Turritella ocoyana</i> Conrad</p> | <p><i>Neverita callosa</i> Gabb <i>Dosinia matthewsoni</i> (?) Gabb <i>Crepidula praerupta</i> Conrad <i>Ballanus</i> sp.</p> |
|---|--|

Kreyenhagen Wells.

| | |
|--|--------------------------------------|
| <i>Astrodapsis merriami</i> n. sp. | <i>Zirphaea</i> sp. |
| <i>Pecten discus</i> Conrad | <i>Natica</i> sp. |
| <i>Pecten estrellanus</i> Conrad | <i>Mactra</i> (<i>Spisula</i>) sp. |
| <i>Turritella ocoyana</i> Conrad | <i>Ostrea</i> sp. |
| <i>Agasoma gravidum</i> Gabb | <i>Hemifusus wilkesana</i> n. sp. |
| <i>Neverita callosa</i> Gabb | <i>Lucina acutilineata</i> Conrad |
| <i>Mactra densata</i> Conrad | <i>Arca montereyana</i> Osmont |
| <i>Venus</i> (<i>Chione</i>) <i>temblorensis</i> n. sp. (rel. <i>C. guidia</i> .) | <i>Ballanus</i> sp. |

Sulphur Springs, Zapata Chino Creek.

| | |
|--------------------------------|---|
| <i>Mactra densata</i> Conrad | <i>Lucina</i> sp. |
| <i>Mactra</i> sp. | <i>Venus</i> (<i>Chione</i>) <i>temblorensis</i> n. sp. |
| <i>Arca montereyana</i> Osmont | <i>Astrodapsis merriami</i> n. sp. |
| <i>Tapes</i> sp. | |

The species given in the preceding lists are characteristic of the Lower Miocene as it occurs in the Great Valley of California, and perhaps that of all the interior valleys of the State.

The more northerly belt of Miocene rocks in the Coalinga district begins a few miles to the northwest of Coalinga, on the north side of Sec. 2, T. 20 S., R. 14 E., and extends in a broad curve northeasterly, northerly, and northwesterly for many miles, or quite beyond the Cantua Creek.

It is fairly well shown on the Coalinga geologic map prepared for this paper (Pl. xxxv). The dip of the strata is always toward the Great Valley at angles varying from 20° to 35°, and in directions normal to the strike. In a few cases only, and notably in one or two cases, is the structure complicated. In the main the structure of all the Tertiary rocks is monoclinical. But on the S. E. ¼ of Sec. 20, T. 19 S., R. 15 E., the Miocene rocks are exceedingly crushed and distorted by compression, and to some extent this distortion extends also to the Eocene and the Pliocene rocks.

Two members of the Miocene have been detected in the Coalinga district proper, but possibly others occur a few miles to the northwest. For the most part the Temblor Beds are not present, and the following members only are in

evidence, as in the vicinity of the Kimball wells, where the following members occur:

| | |
|------------------------------|-------|
| (?) Contra Costa Beds | ft. — |
| Monterey Shales | 800 |
| Domijean Sands (Eocene)..... | 1200 |

Ashy beds near the top of the Miocene resemble both lithologically and faunally beds on the bay-shore north of Pinole Station, Contra Costa County. The following species were collected from these Miocene beds on the west side of Sec. 19, T. 18 S., R. 14 E.:

Ashy beds.

Leda oregona (?)
Tellina congesta (?)

Monterey Shales.

Pecten peckhami Gabb
Callista (?) sp.

The Miocene rocks show little evidence of being bituminous as they are followed northward toward the Cantua Creek, and in fact there is but slight direct evidence that they are bituminous at any point between Coalinga and the Cantua.

The noteworthy facts about the Miocene series north of Coalinga as far as followed are the absence of the Temblor Beds and the greatly reduced thickness of the Monterey Shales. Strata of apparently the horizon of the Temblor Beds occur in the Walnut Creek Valley west of Mount Diablo, as described by Dr. Merriam.¹

LATER NEOCENE BEDS.

By far the most important series of strata in the Mount Diablo Range from the view-point of economic geology are the late Tertiary strata, including the probable equivalents of the San Pablo Beds and others with which they are unconformably related. In this collection of strata the following members are distinguishable, either stratigraphically or faunally:

¹ Bull. Dept. Geol. Univ. Calif. v. 3, pp. 377-381.

rocks is exposed with a dip of 40° to 60° to the northeast. The series consists of alternating horizons of sandstone and siliceous shales, the former of which greatly preponderate.

The lowest fossil horizon near the base of the series, and the second one some thirteen hundred feet above the base contained very nearly the same fauna, from the latter of which the following species were collected:

| | |
|---|---------------------------------------|
| <i>Turritella ocoyana</i> Conrad | <i>Cytherea (Callista) mathewsoni</i> |
| <i>Trochita filosa</i> Gabb | Gabb |
| <i>Agasoma gravidum</i> Gabb | <i>Dosinia mathewsoni</i> Gabb |
| <i>Crepidula grandis</i> Conrad | <i>Mytilus mathewsoni</i> Gabb |
| <i>Crepidula praerupta</i> Conrad | <i>Lucina richthofeni</i> Gabb |
| <i>Neverita callosa</i> Gabb | <i>Pecten estrellanus</i> Conrad |
| <i>Fusus (Hemifusus) wilkesana</i> n. sp. | <i>Pecten</i> sp. |
| <i>Scaphander jugularis</i> Conrad | <i>Glycimeris estrellanus</i> Conrad |

A third fossiliferous horizon within twenty-five hundred feet of the top of the Miocene series yielded essentially the same fauna with one or two additional forms, as *Pecten nevadensis*, *Oliva californica* n. sp., and an undescribed species of *Dosinia*, etc. This horizon is well exposed about four miles southeast of La Panza Springs on the east side of the San Juan River. It is overlain by shaly beds with a fauna resembling that of the Monterey Shales.

KERN RIVER BEDS.

Although this locality was not specially studied, and lies without the Mount Diablo Range, still it has long been known, and lies within the interior basin of California. The locality is on Kern River, two to six miles east of Oil City, Kern County. The strata are mainly sands and sandy clays, dipping gently toward the west. The entire thickness of the strata exposed along the river aggregates about three thousand feet, of which the lower two-thirds belongs to the Miocene. Toward the base they become very fossiliferous, containing numerous species of invertebrates, teeth of sharks, and bones of fishes and other marine vertebrates.

The following species were collected in the vicinity of Barber's ranch, chiefly north of the river:

| | |
|---|---|
| <i>Agasoma gravidum</i> Gabb | <i>Cancellaria simplex</i> n. sp. |
| <i>Agasoma kernianum</i> Cooper | <i>Cancellaria dalliana</i> n. sp. |
| <i>Agasoma sinuatum</i> (?) Gabb | <i>Cytherea</i> (<i>Callista</i>) <i>mathewsoni</i> |
| <i>Conus oweniana</i> n. sp. | Gabb |
| <i>Neverita callosa</i> Gabb | <i>Venus</i> (<i>Mercenaria</i>) <i>pertenuis</i> |
| <i>Turritella ocoyana</i> Conrad | Gabb |
| <i>Cuma biplicosta</i> Gabb | <i>Venus</i> (<i>Chione</i>) <i>temblorensis</i> n. sp. |
| <i>Oliva californicus</i> n. sp. | <i>Dosinia mathewsoni</i> Gabb |
| <i>Scaphander jugularis</i> Conrad | <i>Dosinia</i> sp. |
| <i>Trophon kernensis</i> n. sp. | <i>Maetra</i> (<i>Spisula</i>) <i>falcata</i> Gould |
| <i>Dentalium substriatum</i> Conrad | <i>Maetra</i> sp. |
| <i>Dentalium</i> sp. | <i>Pachydesma inezana</i> Conrad |
| <i>Pleurotoma</i> (<i>Clathurella</i>) <i>dumbleana</i> | <i>Pecten discus</i> Conrad |
| n. sp. | <i>Solen sicarius</i> Gould |
| <i>Nassa arnoldi</i> n. sp. | <i>Solen</i> sp. |
| <i>Trochita filosa</i> Gabb | <i>Tellina ocoyana</i> Conrad |
| <i>Crepidula praerupta</i> Conrad | <i>Tellina</i> sp. |
| <i>Purpura lima</i> Martyn | <i>Yoldia impressa</i> Gabb |
| <i>Sigaretus scopulosus</i> Conrad | <i>Lucina richthofeni</i> Gabb |
| <i>Terebra cooperi</i> n. sp. | <i>Arca montereyana</i> Osmont |
| <i>Bullia</i> (<i>Molopophorus</i>) <i>anglonana</i> | <i>Corbicula dumbleana</i> n. sp. |
| n. sp. | <i>Leda oregona</i> Shumard |
| <i>Cancellaria pacificus</i> n. sp. | <i>Cytherea</i> sp. |
| <i>Cancellaria joaquinensis</i> n. sp. | <i>Homomya</i> sp. |
| <i>Cancellaria condoni</i> n. sp. | <i>Pectunculus</i> sp. |

Many yet undescribed species occur in this collection, and the locality is well worth a more exhaustive study. On the whole it probably better represents the Lower Miocene fauna of the California interior than any other locality that has been described.

CORRELATIONS.

It is not at present possible to correlate with much accuracy the Tertiary beds of the Mount Diablo Range with others occurring in distant parts of the Coast or of the State. For the Pliocene, and perhaps also the Miocene periods, a number of minor provinces must be recognized along the Pacific border, corresponding to the physical geography of the time. North of the Klamath Mountains the Miocene and Pliocene faunas are in a measure specifically different from those of Central California, while these are in turn somewhat unlike those of the southern coast of California.

The exact line of separation between the Californian provinces of the later Neocene appears to follow very nearly the line of the outer Coast Ranges as far south as the head waters of the Salinas Valley drainage, and follows in turn the axis of the Santa Cruz and the Santa Lucia ranges, turning eastward to Pine Mountain and the Tehachapi Range at the latitude of Moro Bay. The Pliocene beds of the coastal valleys south of the Santa Lucia Range are faunally more closely related than any of them are with the Pliocene of the interior valleys. The interior basin of the Pliocene includes not only the Great Valley, but the Salinas and Carisa valleys and other small valleys of the Coast Ranges, probably extending as far north as Lake and Tehama counties.

Within these provincial limits a faunal and stratigraphic correlation of Pliocene deposits, at least, is likely to be more successful than are present attempts at a detailed correlation of deposits within two or more provincial basins.

In the Salinas Valley occur late Tertiary beds that can be satisfactorily compared and correlated with those of the Mount Diablo Range. At Santa Margarita and on the Nacimiento River, at La Panza Springs, and on the Estrella and San Lorenzo rivers, are beds that are entirely similar. At Santa Margarita these beds have been mapped and described by H. W. Fairbanks¹ as the Santa Margarita Formation.

It is quite likely that a correlation of the Miocene beds, or at least of some of them, will have to be restricted within the same territorial limits. The Vaquero sandstones described by Dr. H. W. Fairbanks as occurring within the drainage of the Salinas River lack thus far any fauna² description, and his correlation of these with beds occurring south of the Santa Lucia Range is not supported by any faunal evidence. On the other hand the fauna occurring at the base of the Miocene near San Luis Obispo is characteristic over the whole extent of the coast border, especially south of that point.

¹ San Luis Folio, U. S. Geol. Surv. no. 101.

CONCLUSIONS.

The conclusions to be arrived at from the stratigraphic study of this field are not at variance with, but are mainly confirmatory of much that has been written during the last decade. The Tertiary formations of California have thus far been too little studied and analyzed, though for general scientific as well as for economic reasons they richly deserve attention. In the present contribution to the literature it is believed that the following points are either made clear or are at least clearly indicated:

1. Stratigraphic nonconformities exist in the Mount Diablo Range between all of the chief periodic series, and in some instances between different members of the same series.

2. The Eocene strata are capable of being divided into several distinct members, of which the Tejon portion contains, at least locally, two sandy members separated by one of shale.

3. The Neocene deposits of California can be separated into two or more basins or minor provinces, those of the Mount Diablo Range belonging to the California interior basin and being characteristic of the same.

4. In the Mount Diablo Range two clear stratigraphic nonconformities exist within the Neocene, dividing these deposits into three groups, lower, middle, and upper. The lower and older of these groups contains the well recognized Miocene strata of Central California; the later and younger group, the strata which have been described as Etchegoin or San Pablo, and which are believed to be of Pliocene age; while the intervening or middle group, on account of its faunal resemblance to the older Miocene, is more logically classed in this period than in the period following.

5. In the older Miocene two distinct members are to be recognized; viz., the Monterey Shale and the Temblor Sandstone.

6. The most complete and therefore the most typical fauna of the Lower Miocene of the California interior is that

of the Kern River Beds on the southeastern border of the San Joaquin Valley.

7. The most complete and typical development of the San Pablo strata is not found in the locality from which it takes its name, but along the northeastern flanks of the Mount Diablo Range, as in western Fresno County, where the series attains more than four times the thickness stated in its original description.

8. The Etchegoin series is capable of being subdivided, at least locally, into two or more separate members, each of which has a greater stratigraphic thickness than was originally given for the entire body of similar beds occurring on San Pablo Bay, which are altogether embraced in the lower division, the Etchegoin Sands.

9. The uppermost stratigraphic unit of the Mount Diablo Range is one of fresh-water origin, and is perhaps equivalent to the Orindan Formation of the Berkeley Hills, as described by Dr. Lawson.

10. The Neocene faunas of California are far from being completely known; they offer a rich field for study, and it is believed that such study would yield results of great value to students of stratigraphic geology.

DESCRIPTIONS OF SPECIES.

Among the many fossils collected in the Mount Diablo Range and the California interior during the field-study represented in the foregoing paper, many new species have been discovered, some of which are here described.

While undescribed forms have been obtained from both Cretaceous and Tertiary strata, the latter only are illustrated in the following pages. The list of new forms from each of the Tertiary horizons might be considerably extended by the use of fragmentary and imperfect materials, but the description of such material is not only unsatisfactory but results in much harm to paleontologic science.

Many of the California Tertiary invertebrates were originally described in literature that has become inaccessible, and

some of the accessible literature contains only unsatisfactory figures and descriptions; therefore it is highly desirable to have re-descriptions and better drawings made when authentic material can be obtained and properly identified. The species figured and described by Conrad in the Pacific Railroad Reports can rarely be identified except from the type localities, and then only by the utmost care and reservation; the same is often true of the species described by Gabb in the Paleontology of California. Much of the confusion and uncertainty in stratigraphic determination in the Pacific Coast Tertiary originates in such faulty descriptions. Correct specific determinations cannot be made from much of the literature upon California paleontology that is accessible to students of the subject, and until these can be made, trustworthy determinations of faunal horizons are likewise impossible.

Where any departure has been made from the current paleontological nomenclature it has been with deference to the classification proposed by Zittel in his *Handbuch der Paläontologie*, and it must be confessed that such a standard should have been adopted throughout. An attempt to do this would, however, involve a considerable amount of work in revising the Pacific Coast nomenclature, and that is beyond the purpose of this paper.

The paleontological materials that form the basis of this study have been largely collected by the writer; they have become the property of the California Academy of Sciences, and are a part of its permanent collections.

FORAMINIFERA.

Eocene.

PLATE XIII, FIGS. 9-29.

For the purpose of calling attention to the many well preserved forms of Foraminifera in the Eocene rocks of the Mount Diablo Range, and to illustrate some of the more common genera, a few have been figured without any attempt

Scaphander jugularis *Conrad.*

PLATE XV, FIGS. 56 AND 57.

Bulla jugularis Conrad, Pac. R. R. Rept. v. 5, p. 328, pl. VII, figs. 62
a and *b*.

Shell not large, 1-1½ inches in length, width ½ as great; contracted toward the posterior end; aperture wide, ovate; inner lip crusted; whorl loosely convolute, narrowing behind; surface ornamented by revolving lines crossed by oblique lines of growth. The revolving lines consist of flattened ridges and rounded grooves of equal width.

Conrad's figure lacks sufficient description to make absolute identification possible, but as the localities are contiguous and the horizon practically the same, there can be little doubt as to identity.

Occurrence.—Lower Miocene beds on Kern River, a few miles south of Ocoya Creek.

Oliva californica n. sp.

PLATE XV, FIGS. 54 AND 55.

Shell moderate in size, 1-1½ inches long, width more than half as great, ovate, narrowing below; spire low and rounded; aperture narrow, inner lip somewhat crusted; columella bearing 2 principal spiral plications, with finer lines both above and below; suture impressed and sharply defined on adolescent and mature shells; surface marked only by lines of growth.

Occurrence.—Lower Miocene beds of Kern River, Barker's ranch, etc.

Oliva futheyana n. sp.

PLATE XV, FIG. 53.

Shell similar in many respects to the preceding, but narrower, and having a more elevated spire, and more graceful outline.

Occurrence.—This shell occurs with the preceding.

Conus oweniana n. sp.

PLATE XV, FIGS. 58 AND 59.

Shell small, conical; spire moderate, conical; whorls flattened, or concave above; suture impressed on young shells; aperture narrow, and straight; surface marked by distant, fine revolving lines.

This species is unlike *C. californica* Gabb in having a lower and less rounded spire, a less ovate outline, and a narrow straight aperture.

Occurrence.—This shell occurs in the Lower Miocene beds of Kern River.

***Purpura lima* Martyn.**

PLATE XV, FIGS. 62 AND 63.

Purpura lima Martyn, Conch. fig. 47.

Purpura lima (Mart.) Tryon, Man. Conch. v. 2, p. 175, pl. LIII, figs. 156, 158, 159, and 161.

Among the many molluscan species originally described in obscure or inaccessible literature is the above. Authentic samples of this shell are in the collections of the California Academy of Sciences, and the identification of the fossil species is from a comparison with these. The fossil specimens are a little shorter, with a less elevated spire, but the difference seems to be insignificant.

Occurrence.—The four or five samples of this species that have been found fossil are from the Lower Miocene beds of Kern River.

***Trophon kernensis* n. sp.**

PLATE XVI, FIGS. 64 AND 65.

Shell rather large, length from 2-3 inches, width $1\frac{1}{2}$ inches; graceful in outline, narrowing rapidly before; spire rather short, conical, and angular, but sloping above, bearing tubercles, or very short spines on the angles, more prominent on very young shells; surface ornamented chiefly by lines of growth, but bearing faint spiral lines on the lower part of the whorl, noticeable especially in young shells; aperture pear-shaped, and narrowing to a long canal; inner lip crusted; canal long and narrow.

This species is only distantly related to *T. ponderosum* Gabb, but more nearly related forms are found in the Pliocene of California.

Occurrence.—This shell is from the Lower Miocene beds of Kern River.

EXPLANATION OF PLATE XV.

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| <i>Cancellaria dalliana</i> n. sp. Figs. 39-42. | 199 |
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