Figure 1. Looking North into Black Star Canyon from the Baker-Black Star Divide. The "Skyline Drive" Between the Towns of Corona and Orange Winds along the Slope to the Left of the Gorge of Blackstar Creek.

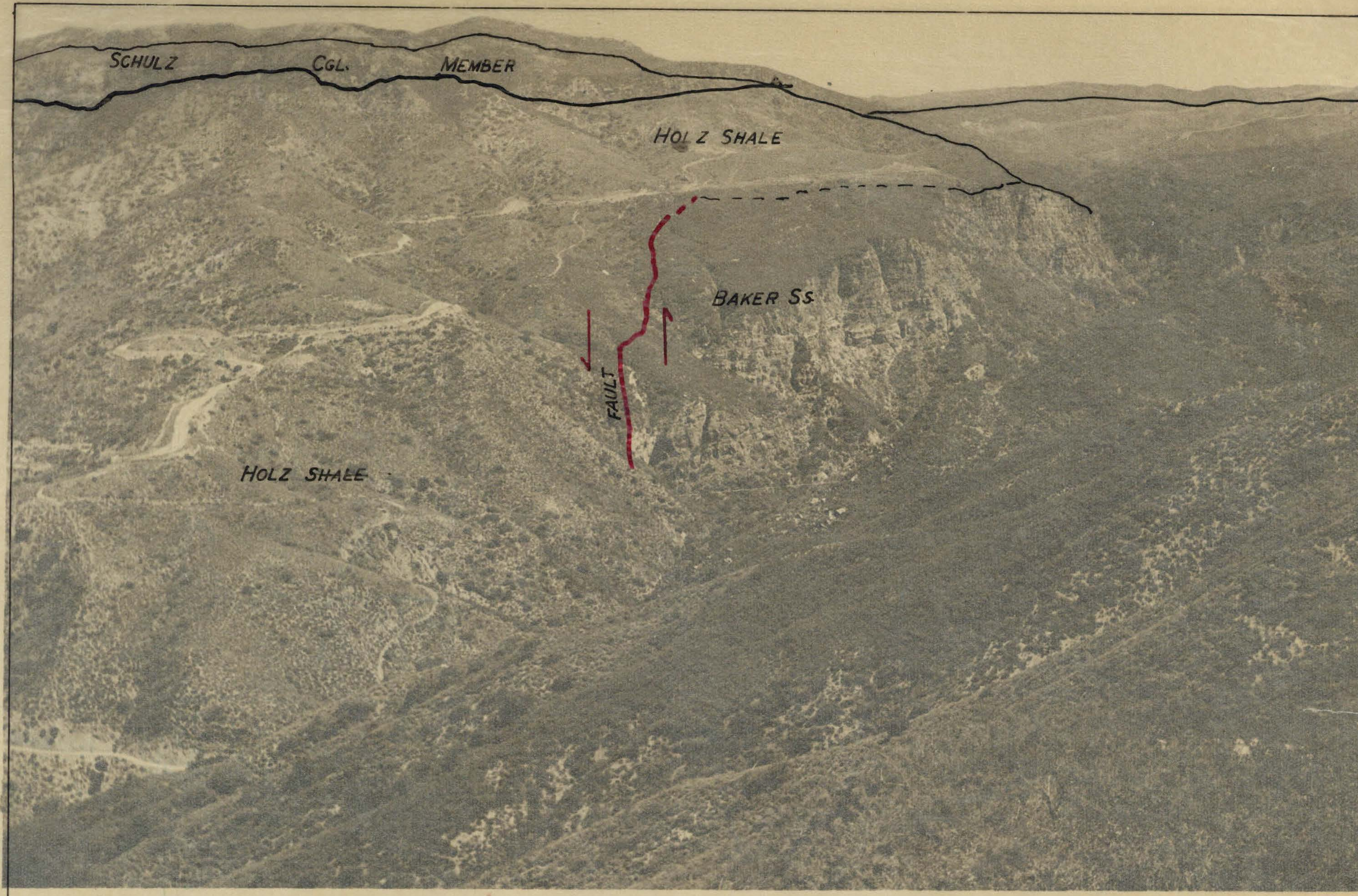

Figure 1. Looking North into Black Star Canyon from the Baker-Black Star Divide. The "Skyline Drive" Between the Towns of Corona and Orange Winds along the Slope to the Left of the Gorge of Blackstar Creek.

THE UPPER CRETACEOUS STRATIGRAPHY AND PALEONTOLOGY OF THE NORTHERN SANTA ANA MOUNTAINS.

by

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy,

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ILLUSTRATIONS

SUMMARY

The Upper Cretaceous deposits of the Santa Ana Mountains in the area between Trabuco and Santa Ana Canyons are divisible into three formations, each of the two upper formations being further divisible into two members. The Trabuco formation at the base has an estimated average thickness of 250 feet. It lies unconformably upon a basement complex made up of metamorphosed Triassic sedimentary rocks, and later intrusive igneous rocks. The Trabuco formation is a red, soft, incoherent, boulder conglomerate, is unfossiliferous, and may be of continental origin. The Trabuco formation is apparently conformably overlain by the Ladd Formation, which has a maximum thickness of at least 1700 feet, and which is divided into the Baker sandstone and conglomerate member below, and the Holz shale member above. The Baker member, approximately 200 feet thick on the average consists of hard, well-cemented, gray, unfossiliferous boulder conglomerates below grading into thick-bedded to shaly highly fossiliferous sandstones above. The Holz shale member has a maximum observed thickness of approximately 1500 feet, is composed principally of silty, micaceous, gray shale. The lower half of the shale is almost unfossiliferous. The upper half yields a prolific molluscan fauna. The Williams formation rests upon the Holz shale with a slight unconformity. It is divided into the Schulz conglomerate and sandstone member below, and the Pleasants sandstone member above. The Schulz member is unfossiliferous, composed of well-worn and rounded pebbles and boulders alternating with arkosic sandstones. It is approximately 200 feet thick. The Pleasants member consists of thin-bedded, rather shaly, light-colored micaceous sandstones, alternating with coarse, calcareous sandstones. It is highly fossiliferous.

Two faunal zones are distinguished. The fauna of the Baker member, or Acataeonella oviformis zone of Packard, is not certainly known elsewhere in California, but is probably in part represented in the basal beds of the Rogue River Valley Upper Cretaceous of Oregon. The Glycymeris veatchii zone includes the upper part of the Holz shale member, and all of the Williams formation. It is divisible into three subzones from below upward (a) the subzone of Turritella chicoensis, typical variety, (b) the subzone of Turritella chicoensis, giant variety, (c) the subzone of Metaplacenticeras pacificum.

Fossiliferous Cretaceous beds in the Simi Hills and the Santa Monica Mountains of southern California are probably to be correlated with the subzone of Metaplacenticeras pacificum, and to be somewhat younger than the Upper Cretaceous beds at Chico Creek, Butte County.

A fauna of approximately one hundred ten species is listed and discussed, a number of new species are described and figured, and new facts concerning the systematic position of a number of previously described fossils are presented.

INTRODUCTION

Study of the Upper Cretaceous deposits of the Pacific Coast constitutes one of the most promising pioneer fields of research yet remaining in North American stratigraphy and paleontology. It is now nearly three-quarters of a century since Gabb disclosed the considerable extent of beds of this age in California and Oregon, and gave some hint of the richness and excellent preservation of the contained faunas. In the last decade of the nineteenth century other workers added some details of specific sections, and described a number of new fossil species. Since the end of the last century work in this field has been largely incidental to areal studies of other and later formations. It has seldom passed the reconnaissance stage; and has usually consisted in mapping the areal limits of exposures known to be Upper Cretaceous and assigning them to the "Chico formation".

As a result of these conditions and methods, the stratigraphic subdivisions and faunal successions of the Upper Cretaceous of the West Coast are yet imperfectly known. Areas in which deposits of this age are known to occur have been fairly well determined, and their surface exposures have been demarcated in many regions. The faunas contained in these beds however are but imperfectly known, or in many instances are entirely unknown in so far at least as published reports go. The age relationships of the Upper Cretaceous deposits in different parts of the Pacific Coast region have not been established, while the position of these deposits in the standard Cretaceous time-scale of the world has been subject to the most diverse interpretations.

At the beginning of this study, it was hoped that a correlation might be made between the Cretaceous of the Santa Ana Mountains and the Cretaceous of other parts of the Pacific Coast region, particularly with the section exposed on the east side of the upper Sacramento Valley. Work had not long been under way however, before it was realized that no satisfactory comparison could be made with the Cretaceous as developed elsewhere in the West Coast region, because no general standard section had ever been worked out for this area. This forced a reversal in the object of the research. Instead of attempting to correlate the Cretaceous of the Santa Ana Mountains with a standard section developed elsewhere in the Pacific Coast Cretaceous, the attempt has been to set up a tentative section based on a detailed study of the stratigraphy and fauna of the Santa Ana Mountains deposits. With this section may be compared the stratigraphic sequence and faunas of other regions as detailed work makes them known.

This thesis, then, should be regarded as a progress report in a detailed stratigraphic and faunal study of the Upper Cretaceous of the Pacific Coast. I hope to be able to take part in and forward this study in other areas than the one here treated. It will doubtless not be the privilege of any one person to complete a program so vast. Careful work done in any part of the Pacific Coast section can scarcely fail to be of value, however; and continued effort in this direction will ultimately afford as precise paleontologic and stratigraphic information of the West Coast Cretaceous section as is now available for Upper Cretaceous deposits elsewhere in North America.

CONDUCT AND RESULTS OF THE RESEARCH

In the conduct of this investigation, especial emphasis has been laid upon obtaining as nearly complete a collection of the fossil fauna as has been possible in the time available. Exact location of each collection has been stressed, and so far as possible, the comparative stratigraphic position of each assemblage has been determined. The subdivisions of the Upper Cretaceous of the area have been mapped in greater detail than in any study previously published. The base maps used have been airplane photographs with an approximate scale of 1500 feet to the inch. Structural and physiographic problems in the area studied have been treated only incidentally, and only as they have been necessary to an understanding of the stratigraphy.

Accompanying the work upon the field problems, has been a detailed preliminary review of the fauna. In the systematic part of this thesis, many changes have been suggested in the specific, generic, and even family designations in which some of the fossils have previously been included. Relationships with Cretaceous forms elsewhere have thus been determined that had not been recognized before. Especial attention has been paid to working out details of dentition and other internal structures of the pelecypods. The hinge-structures and other important features of diagnostic value of many of these forms have been entirely unknown, even since the time of Gabb, for the resistant matrix in which the fossils are embedded has prevented the working out of these delicate structures. It was found possible in this work to grind away the matrix, nearly to the surface of the shell, with a dental carborundum wheel, and to clean the remaining rock away from the fragile hinge-teeth and other delicate structures with a sharp needle under high magnification. The work has been both arduous and exacting, but the results attained have justified manyfold the time and patience expended. As a result of this work, the affinities of many well-known but misappraised species have been determined. These discoveries will permit a closer comparison of these forms with those found elsewhere in the Cretaceous of the world. It is not to be inferred from this that paleontological work on the Santa Ana Mountains Cretaceous fauna is complete. Many new gastropods are present in this fauna, and the study and description of these difficult forms is yet to be done. It is hoped that it may soon be begun. The fauna of the Baker member of the Ladd formation should be studied in detail; for this assemblage is not only one of the most distinct faunal groups known in the California Upper Cretaceous, but is imperfectly known. I hope to take up this study also soon.

It is believed that the stratigraphy and faunal succession of the Upper Cretaceous of the Santa Ana Mountains has been fairly well established. It must remain for future work in other parts of the Pacific Coast region to show what part of the succession here is local in its character, and what part is characteristic of the faunal succession of the Cretaceous of the Californian region as a whole. The larger problems outlined have their own difficulties, and likewise their own rewards. I hope to be one of those permitted to advance the solution.

ACKNOWLEDGMENTS

In the course of preparation of this thesis I have had assistance from many people, and have received many courtesies and kindnesses that have materially aided my work. The project has been carried forward under the general supervision of Dr. J. P. Buwalda, Chairman of the Division of the Geological Sciences, and Dr. Chester Stock, Professor of Paleontology, of the California Institute of Technology. From both of these, I have received much good advice and encouragement in all stages of the work. Dr. W. P. Woodring of the United States Geological Survey first suggested the problem to me, and in the course of study has aided me in many ways, and has critically reviewed the completed manuscript. Dr. L. W. Stephenson, Dr. J. B. Reeside, and Dr. Ralph Stewart, also of the United States Geological Survey, have helped me often in the systematic determination of many fossil species, and have given me much good counsel in the general conduct of the study. Dr. G. H. Anderson, of the California Institute of Technology has accompanied me to the field on a number of occasions, and has helped me materially in the working out of some of the puzzling problems I have encountered there. Dr. Frank M. Anderson, of the California Academy of Sciences, has offered identifications of a number of the ammonite species found in the area studied. Dr. B. N. Moore of the United States Geological Survey permitted me to use the large collections of Upper Cretaceous fossils that he collected in the Santa Ana Mountains some years ago.

In the systematic study of the fauna, I have had the cordial cooperation of the heads of the Paleontological Museums of the University of California, of the California Academy of Sciences, of the Leland Stanford

Junior University and of the United States National Museum. These institutions have made their fossil collections available to me and have from time to time made comparisons of material sent them with types in their possession, and have offered their opinions as to the relationships involved.

I have had many courtesies and kindnesses from land owners and residents of the areas in which I have worked. I wish to mention particularly the kindness of Mrs. Jennie Johnson of Santiage Canyon, the Shady Brook Camp of Silverado Canyon, T. C. Peterson of Baker Canyon, and J. N. Beek of Blackstar Canyon. These friends have freely given permission to camp upon their property, and have offered me many kindnesses during my stay with them. Finally, I wish to record the cordial cooperation I have had at all times from the officials of the United States Forest Service in Cleveland National Forest.

HISTORY OF PREVIOUS WORK

GOODYEAR [/1] in 1888 made the first reference I have found to the presence

/1 Goodyear, W. A., Calif. State Mining Bureau, 8th Ann. Rept. State Mineralogist, pp. 337-338, 1888.

of marine Cretaceous in the Santa Ana Mountains. He gave a very brief account of a reconnaissance taken in company with Dr. J. G. Cooper in the neighborhood of Aliso Creek, where Cretaceous fossils were found in the bed of the creek.

FAIRBANKS [/2] in 1892 noted the presence of Cretaceous rocks on the western

/2 Fairbanks, H. W., Calif. State Mining Bureau, 11th Ann. Rept. State Mineralogist, pp. 115 et seq., 1892.

slope of the Santa Ana Mountains, and briefly mentioned the conglomerates developed in these beds. Most of his discussion is confined to the metamorphics.

COOPER [/3] in 1894 discussed the fossils collected by Stephen Bowers in the

/3 Cooper, J. G., Calif. State Mining Bureau, Bull. no. 4, pt. 4, pp. 34-35, et. seq., 1894.

Santa Ana Mountains. Cooper regarded the fossils as older than "Chico-Tejon" because of the paucity of ammonites, but younger than the Shasta group, and younger than the Cretaceous beds exposed in the old coal mine on Point Loma, San Diego County. He described one species, *Cucullaea bowersiana* from this region.

SMITH [/4] in 1900 mentioned the presence of *Placenticeras pacificum* in "the

/4 Smith, J. P., The Phylogeny and Development of *Placenticeras*, Calif. Acad. Sci., Proc., (3), vol. 1, no. 7, p. 210, 1900.

lower Chico beds of Silverado Canyon near the old coal mine". The horizon represented was believed to be Cenomanian in age.

ANDERSON /5 in 1902 selected as a typical "Lower Chico" locality, the Cre-

/5 Anderson, F. M., Cretaceous Deposits of the Pacific Coast, Calif. Acad. Sci., Proc., (3), vol. 2, no. 1, 1902.

taceous beds of Silverado Canyon, Santa Ana Mountains (p. 26) and cited on pp. 27-32, a long list of species from this locality or from its nearby stratigraphic equivalents. On pp. 73 et seq. he described a number of new species from this locality, including Pholadomya anaana, Pectunculus pacificus, Mactra gabbiana, Baculites fairbanksi and Acanthoceras compressum.

DICKERSON /6 in 1914 mentioned briefly some of the features of the Cre-

/6 Dickerson, R. E., University of Calif. Pubs., Bull. Dept. Geol., vol. 8, no. 11, 1914.

taceous of this region. A concise summary of the general Cretaceous geology is contributed on pp. 262-263 by E. L. Packard.

PACKARD /7 in 1916 discussed the fauna of the Upper Cretaceous of the Santa

/7 Packard, E. L., University of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, 1916.

Ana Mountains in some detail. He listed one hundred thirty-one forms of Invertebrates from this region, and distinguished three faunal zones which he named after characteristic molluscan fossils. He considered the uppermost faunal zone to be the approximate equivalent of the type Chico of Chico Creek.

PACKARD /8 in 1922 described and figured thirty four new species of fossils

/8 Packard, E. L., University of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10, 1922.

from the Upper Cretaceous beds of the Santa Ana Mountains, and gave a brief resume of the faunal subdivisions of this part of the section.

ENGLISH [/9] in 1926 published a report and geologic map including the northern end of the Santa Ana Mountains as far south as Silverado Canyon. The discussion of the Cretaceous beds of this area is adapted almost entirely from the previously cited articles by Packard. English's map offers some interpretations of the areal geology different from those given by Packard and Dickerson.

/9 English, W. A., U. S. Geol. Survey Bull. 768, 1926.

MOORE [/10] in 1930 mapped the Cretaceous beds of the area between Silverado and San Juan Canyons in the course of a general geological study of this portion of the Santa Ana Mountains region. Moore considered the Trabuco formation of Packard to be a leached or weathered basal phase of the basal Cretaceous conglomerate. He mapped four lithologic divisions in the Cretaceous, and briefly discussed some of the faunal characteristics of the beds.

/10 Moore, B. N., Ph.D. Thesis, Calif. Inst. Technology, 1930.

ANDERSON and HANNA [/11] in 1935 referred the upper cephalopod-bearing Cretaceous beds of the Santa Ana Mountains to Campanian age, correlating them with the Panoche formation of Mt. Diablo, with the Pt. Loma beds at San Diego, and with the Ariyalur series of India. The "Lower Fossil Beds" of the Santa Ana Mountains were referred to a lower Turonian age. These references were part of a tentative correlation chart of the West-Coast Upper Cretaceous.

/11 Anderson, F. M., and Hanna, G. D., Calif. Acad. Sci., Proc., (4), vol. XXIII, no. 1, 1935.

LOCATION AND GENERAL GEOLOGIC FEATURES

The Santa Ana Mountains

The Santa Ana Mountains are a rugged mountain mass rising about fifty miles southeast of Los Angeles, in southwestern Riverside and northeastern Orange Counties. The common boundary of these two counties lies along the crest of the range. The northern boundary of the mountains is fixed by the canyon of the Santa Ana River; the steep northeastern scarp of the range overlooks the Elsinore trough, in which lie the towns of Corona and Elsinore; the gentler southwestern slopes of the range merge gradually into the fertile orchard lands of the southwestern end of the Los Angeles Basin in the region around the towns of Orange, Santa Ana, Tustin, and El Toro. The southeastern limit of the mountains is indefinite, but may be taken as corresponding roughly with the San Diego-Orange County line. The general trend of the range is northeast-southwest.

Location of the Upper Cretaceous Area

The Cretaceous beds whose study forms the subject of this thesis outcrop in a rudely triangular area lying upon the southwest slope of the Santa Ana Mountains in the region between Trabuco and Santa Ana Canyons. The apex of this triangle is situated a short distance north of Trabuco Canyon, and about nine miles northeast of the small town of El Toro. The base of the triangle extends from a point about one mile north of the mouth of Sierra Canyon obliquely northeast across the mountains to intersect Santa Ana Canyon six miles west of Corona. The northeastern line of the triangle lies near the crest of the range in the vicinity of Blackstar and Sierra Canyons but passes progressively farther to the south and west of the crest as it approaches Trabuco Creek. The southwestern side of the Cretaceous outcrop roughly parallels the course of Santiago Creek from Harding Canyon to its northwestern end. Throughout most of this distance, the Cretaceous-Tertiary contact lies from one-eighth to one-half mile east of the bed of Santiago Creek, except in the vicinity of the mouth of Sierra Creek, where Cretaceous beds form both walls of Santiago Canyon.

Vegetation and Culture

Little of the area underlain by Cretaceous beds is suitable for cultivation, and only the narrow valley floors can be satisfactorily farmed. The shale series in the middle part of the section usually supports a good growth of grass and sage-brush. Some of this region is fenced for grazing. The coarser sediments outcropping in the upper and lower parts of the section support a dense growth of heavy brush. Roads have been built along the floors of several of the principal canyons, making these easy of access. Recently, a number of good dry-weather fire control roads have been built by the U. S. Forest Service, and by the State, across the inter-canyon divides. These have not only made the whole region much more accessible, but have made some valuable fresh rock exposures. Small farms and orchards have been established in the broader parts of the canyon bottoms, and a number of homes and resorts have been built along the streams. On the whole, however, the region is quite rugged, and is not easily traversed away from the roads.

Physiography of the Area

As remarked above, the Santa Ana Mountains present a steep scarp to the northeast overlooking the Elsinore Trough, and a much gentler slope to the southwest. The crest of the range thus lies very near the northeast boundary. The gentler southwestern slope is drained by a number of large creeks tributary to Santiago Creek. These streams head near the crest of the range, flow more or less directly down the southwestern slope through rather deep incised canyons, and join Santiago Creek near the contact between the Cretaceous and Tertiary beds. These canyons thus cut directly across the Cretaceous outcrop exposing good natural sections every two or three miles along the strike. The Cretaceous beds dip to the southwest or west in the same direction as the general slope of the mountain face and the courses of the streams. Resistant beds outcropping in the Cretaceous have given rise to a small scale hogback physiography with a latticed drainage pattern and the development of a system of small subsequent and obsequent gullies. This pattern is particularly well marked at the base of the Cretaceous where a resistant gray conglomerate overlies an easily eroded red conglomerate. Subsequent gullies developed along the outcrop of the basal red conglomerate have undercut the resistant beds overlying, which stand up as a northeastward facing cliff that may be traced for a distance of more than ten miles. The slope of the Cretaceous outcrop to the southwest is more gentle, thus reproducing in miniature the general contour of the range as a whole.

Structure of the Cretaceous Beds

The structure of the Cretaceous of the Santa Ana Mountains is broadly rather simple, though locally it is rather complex. South of Blackstar Canyon the beds show a regular homoclinal dip to the southwest or west and outcrop in long narrow roughly parallel strips trending north or northwest. From Blackstar Canyon south to Silverado Canyon, the prevailing strike is

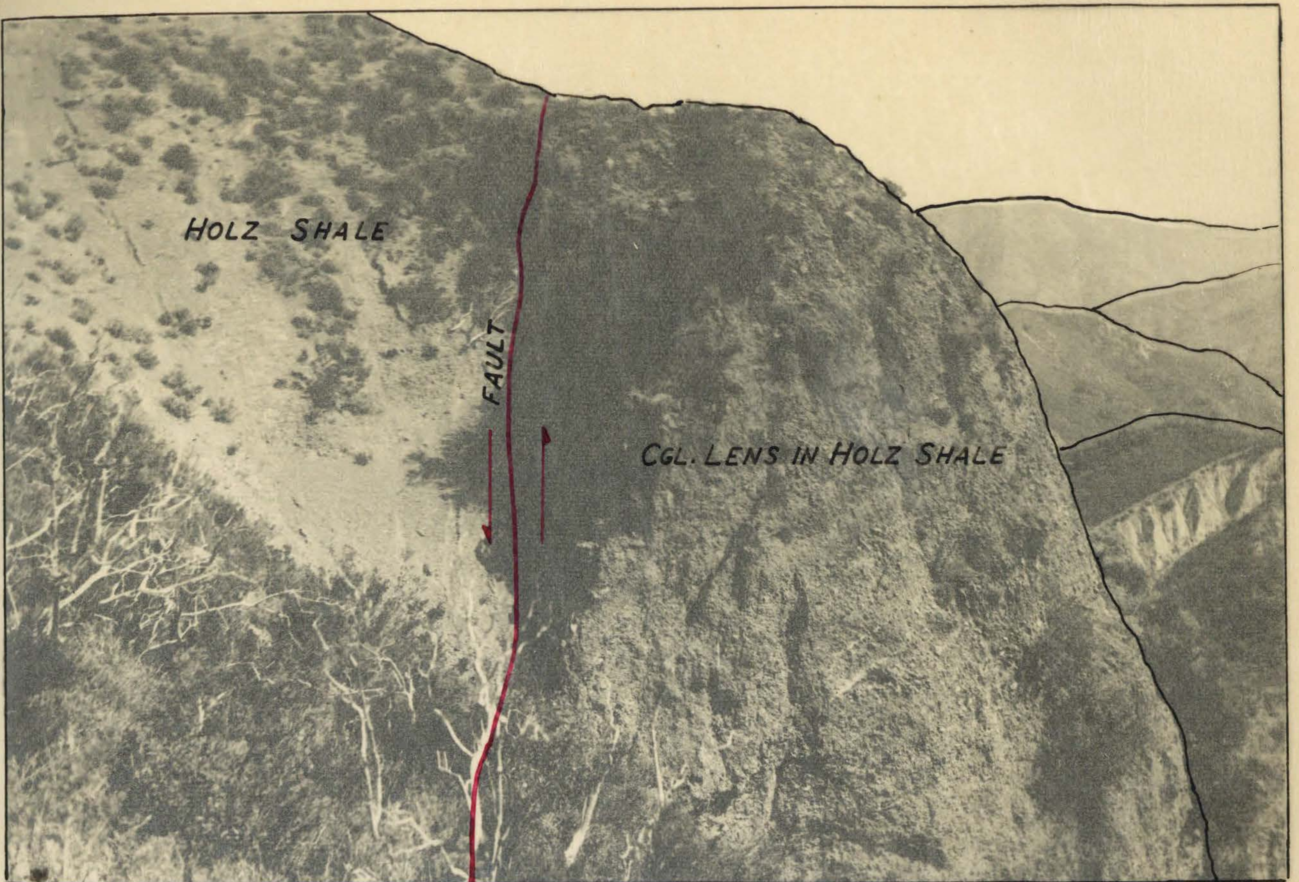

Fig. 1. Small Fault in the Basal Part of the Holz Shale. The Fault is Probably a Branch of the Large Fault Shown in the Figure Below. View Looking North, about one-quarter Mile North of Harding Canyon.

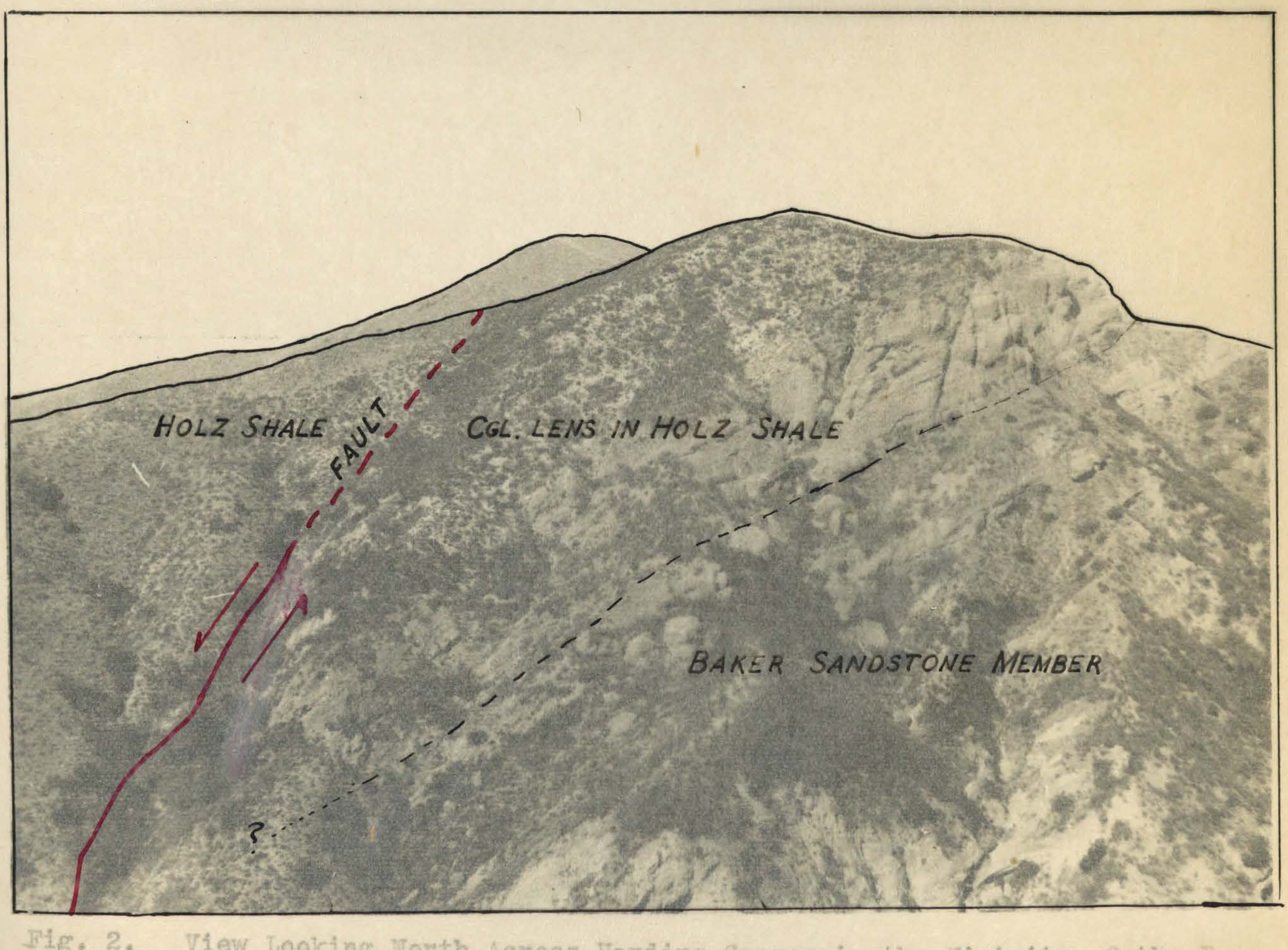

Fig. 2. View Looking North Across Harding Canyon in the Vicinity of the Dam.

Fig. 1. Small Fault in the Basal Part of the Holz Shale. The Fault is Probably a Branch of the Large Fault Shown in the Figure Below. View Looking North, about one-quarter Mile North of Harding Canyon.

Fig. 2. View Looking North Across Harding Canyon in the Vicinity of the Dam.

nearly north-south, and the dip between twenty and thirty degrees to the west. From Silverado Canyon south, the strike of the beds tends to turn more and more to a westerly direction, being almost due northwest in the vicinity of Harding Canyon. Near the southern tip of the outcrop the strike is nearly N 75° W. The prevailing dip of the beds throughout most of this area does not exceed 35 degrees and is usually 25 degrees southwest. Near the southern end of the outcrop in the region between Harding and Trabuco Canyons, the dip increases, especially near the Cretaceous-Tertiary contact, which here is a fault contact. Dips of from 60 to 70 degrees are found in this area and in one place observed, the strata next to the fault are overturned.

Four faults have been recognized in the area south of Blackstar Canyon. One of these has been traced with reasonable certainty from about one mile south of Harding Canyon to the vicinity of Baker Canyon, a distance of six miles. The fault-plane is apparently nearly vertical. The downthrow is to the west. Its trend is slightly oblique to the prevailing strike of the beds through which it passes, except in the region south of Harding Canyon, where it cuts through younger and younger rocks, finally passing into the Tertiary beds. Throughout the distance in which it has been traced, this fault is bounded on one side or the other by the shales of the middle part of the section. Along a great deal of its course, the fault trace lies wholly within the shales. North of the Baker-Silverado Canyon divide, this fault passes into the coarse conglomerates developed here in the basal part of the shales. It has not been traced with certainty beyond this point, though it may be represented in the Blackstar Canyon area.

East of the main outcrop of the Cretaceous between Silverado and Harding Canyon, portions of the basal Cretaceous section have been duplicated by two low angle faults with downthrow to the east, that have dropped Cretaceous on the east side of the fault plane against the basement rock on the west. The easternmost dislocation has involved only two isolated and narrow strips of the lowermost member of the Cretaceous - the red Trabuco conglomerate. One of these strips may be seen along the high ridge forming the south wall of Harding Canyon at a point about one-half mile above its mouth; the second strip is to be seen along the crest of the divide between Harding and Williams Canyons, about three-quarters of a mile east of the basal contact of the main Cretaceous outcrop in this region. The westernmost fault of this pair has not only dropped a block showing the entire thickness of the Trabuco formation, but all of the gray marine conglomerate and sandstone overlying, and a considerable thickness of the gray shales that occupy the middle part of the section. At its upper contact, the shale dips directly against the Triassic andesite along a very sinuous trace, and a few rods to the west of this contact, the basal beds of the Trabuco conglomerate may be seen resting in normal contact on the andesite.

The fourth important fault of this area forms the boundary between the Cretaceous and Tertiary from about one and one-half miles southeast of the mouth of Harding Canyon southeast to the tip of the Cretaceous outcrop in the Trabuco Canyon region. This fault is also nearly vertical in attitude and the downthrow is to the southwest. The total displacement is unknown, but must be considerable, for a great thickness of the middle shale series of the Cretaceous and all of the upper sandy and conglomerate series are missing. If the original thickness of the Cretaceous at this place be assumed to be the same as that exposed between Harding and Williams Canyons, fully seventeen hundred feet of Cretaceous beds have been cut out by this fault; and as some of the base of the Tertiary has also been cut out the total displacement may be considerably more.

The structure of the Cretaceous north of Blackstar Canyon is much more complicated than in the region just discussed, and because of poor exposures, massive character of the rock, and absence of good horizon markers, is much more difficult to decipher. In its larger features, this northern portion may be characterized as a broad open syncline with its axis trending slightly west of north, broken by two large faults and many small ones, and modified on its western limb by one or two obscure small folds. The axis of this syncline is believed to lie near a line connecting the mouth of Blackstar Canyon on the south with a point slightly west of the mouth of Bedrock Canyon on the north. In general, the faults in this region are roughly parallel to the synclinal axis. Most of these appear to be nearly vertical and to have the downthrow to the west, though in one or two instances, this direction appears to be reversed. It is probable that the Triassic-Cretaceous contact from Tick Canyon north to Bedrock Canyon is a fault-contact, for here, the entire lower part of the Cretaceous is absent from the section, and the middle shales rest against the Triassic basement. North of the head of Tick Canyon, the basal Cretaceous beds again appear, resting upon the Triassic apparently in normal depositional contact.

THE UPPER CRETACEOUS STRATIGRAPHY OF THE SANTA ANA MOUNTAINS

General Features

The Upper Cretaceous strata of the Santa Ana Mountains may be divided on a lithologic basis into five mappable units. Except for local areas where parts of the section are missing due to faulting or overlap, each of these units may be distinguished from end to end of the outcrop, with only minor changes in lithology. These five units are here grouped into three formations, the upper two of which are each divided into two members. In descending order, the stratigraphic classification here adopted is as follows:

3.	Williams formation	(Pleasants sandy shale member (Schulz conglomerate member
2.	Ladd formation	(Holz shale member (Baker conglomerate and sandstone member
1.	Trabuco formation	

The Cretaceous rocks of this region are almost entirely clastic. Coarsely clastic sediments are common, and in places predominate. Individual beds that are calcareous enough to be called impure limestones are present, but are rare. In parts of the section, particularly in the middle portion silty clay shales are developed in great thickness. The most striking, if not the thickest sediments in the area are the coarse sandstone and conglomerate beds that occur both in the lower and in the upper parts of the section. In the territory south of Silverado Canyon these coarse deposits compose approximately half of the Cretaceous rocks exposed. North of Silverado Canyon these coarse sediments predominate.

Detailed Stratigraphy

1. The Trabuco Formation

The basal member of the Cretaceous rocks from Blackstar Canyon south to the southern tip of the outcrop is a soft massive red boulder conglomerate averaging perhaps two hundred fifty to three hundred fifty feet in thickness. This rock unit was first distinguished as a separate formation by Packard (1916, p. 140), who named it the Trabuco formation. In composition, this formation is quite variable. It is characteristically a mass of ill-sorted, angular, deeply weathered boulders that range in size from small pebbles to huge blocks more than a foot in diameter within a very small area, and in composition from angular blocks of sandstone, chert, and nodular limestone to deeply decayed fragments of coarse-grained plutonic rocks. Occasional lenses of coarse red sands occur. Wherever bedding is discernible in these, cross-bedding is common. Except for these sand lenses however, bedding is hardly ever to be seen in the Trabuco, and for this reason, calculations of the attitude and thickness of the formation are difficult. Assuming that the Trabuco formation has the same strike and dip as the beds immediately overlying, the thickness of the formation is estimated to be approximately three hundred feet. The conglomerate is nearly everywhere deeply weathered. The weathering extends usually even into the center of the most resistant boulders, tingeing them with the striking red color so characteristic of the rocks of the formation, and decomposing them so that they usually crumble under slight stress. Perhaps the predominant rocks among the boulders are of sedimentary origin - sandstones, quartzites, slates, concretionary limestones and cherts. These closely resemble the sediments present in the metamorphic Triassic rocks that form a considerable part of the basement upon which the Trabuco was deposited. Other important rock types represented among the Trabuco boulders include andesitic rocks that are not distinguishable megascopically from much of the andesite that in places forms the basement rock; and a coarse-grained dioritic rock similar to that found on the east side of the Elsinore Valley of this region.

The Trabuco rests upon a basement of metamorphosed Triassic sediments and of igneous rocks intruding the Triassic, with a profound unconformity that has been noticed and mentioned by nearly every geologist who has worked in this area. This unconformity is strikingly shown in many places. In the vicinity of Baker and Blackstar Canyons the Trabuco lies upon Triassic slates; in the region of Silverado Canyon and Ladd Canyon, the basement rock is an andesite, which, according to Moore /1 is intruded into the metamorphics.

/1 Moore, Bernard N., Geology of the Southern Santa Ana Mountains, Ph.D. Thesis, Calif. Inst. Technology, 1930, pp. iv, 32, etc.

About three-quarters of a mile east of the Trabuco-andesite contact in the Ladd Canyon region, a considerable thickness of Cretaceous has been faulted down with a portion of the underlying basement. The normal depositional contact of the Cretaceous with the basement is clearly shown here. The basement rock below the contact is seen to be Triassic slate, which dips at a high angle to the northeast, while the Trabuco, as shown by the inclination of the surface upon which it rests, dips at nearly as high an angle to the west. Near the Baker Canyon-Silverado Canyon divide the line of the Trabuco-Basement contact truncates the contact of the Triassic slates and the andesites of the basement series. From this point north to Tick Canyon the Trabuco rests again against the slates in depositional contact.

The Trabuco conglomerate is considerably less resistant to erosion than is either the underlying basement rock or the overlying basal member of the Ladd formation. For this reason, it forms a non-resistant zone that has been excavated by small subsequent gullies into a depressed zone bounded on the west by the conglomerate cliffs of the Baker member of the Ladd formation, and on the east by the steep dip slopes of andesite or slate. The gullies formed in this depressed strip meet the larger consequent streams that cut across the strike almost at right angles. These smaller gullies usually develop in pairs, flowing toward their master stream from opposite directions, but entering the master canyon at almost the same point along its course.

The Trabuco conglomerate has thus far yielded no fossils, and no accurate determination of its age can be made. It appears to be essentially conformable with the undoubted marine Cretaceous overlying. Since it is profoundly unconformable with the Triassic below, its deposition post-dates the orogenic disturbances during which the Triassic sediments were intruded, tilted, and eroded. A late lower Cretaceous or early Upper Cretaceous age has generally been assigned to it, and this estimate is probably nearly correct.

Packard [/2] and Moore [/3] have studied the origin of the Trabuco and have

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/2 Packard, E. L., U. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, p. 141.

/3 Moore, B. N., op. cit., pp. ix, 52-54.

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come to diametrically opposite conclusions in regard to it. Packard, in defining the formation, wrote: "The peculiar color, the angular form of most of the pebbles and sand-grains, and the lack of marine fossils suggests that the Trabuco formation was deposited on a narrow coastal plain by torrential streams arising in a mountainous region but a short distance to the eastward. After about two hundred feet of this material had been laid down, marine conglomerates of the basal Chico accumulated within the waters of the transgressing sea". Moore, in 1930, wrote: "The red basal conglomerate called the Trabuco formation is clearly only a basal conglomerate and of less formational value than some of the other lithologic zones of the Cretaceous which have here been mapped" (p. v) and on page ix remarks: "The red beds of the .... Trabuco.... are in reality altered marine deposits rather than continental beds". Farther on, on pages 52, et. seq. Moore explains his opinions in a discussion somewhat too long to quote, but which is based on an interpretation of the Trabuco as a basal phase of the marine Cretaceous conglomerate, altered and weathered to its present red color and state of decomposition by agents active long after the conglomerates had been deposited. He concludes his argument with these words: "A full consideration of the available evidence leads me to the belief that the red color and the apparent continental nature of the deposit are due not to a different and non-marine mode of deposition, but to alteration of a coarse, porous, arkosic material. The mechanism of the alteration is unknown. Whatever type it was it is certain, because of the evident oxidation of the iron, that oxygen bearing meteoric waters were involved. In the process of alteration the more porous parts were most easily oxidized. Some parts were evidently so slightly porous as to prevent much alteration". After some discussion of the structural relations between the Trabuco and gray conglomerates overlying, Moore epitomizes his opinion with these words: "In view of the close relationship of this basal series to the overlying Cretaceous, it is believed that it has no status as a distinct formation".

The question of the origin of the Trabuco is of importance in the consideration of the stratigraphy and the paleogeography of the Upper Cretaceous in this part of California. If the Trabuco is marine and represents only an altered lower portion of the basal conglomerate, interpretation of geologic events taking place in this region in early Upper Cretaceous or late Lower Cretaceous time will be far different from the diagnosis suggested by the evidence for a thick mantle of detrital continental beds mantling the land surface over which the Cretaceous sea transgressed. The Trabuco has yielded no fossils. The attack upon the problem thus must be from the standpoint of petrology. Such an investigation is now in progress, and it is hoped, may suggest which of the two opposing views quoted is more probably correct.

2. The Ladd Formation

The Ladd formation is defined as the series of Cretaceous beds of the Santa Ana Mountains included between the top of the red Trabuco conglomerate below and the base of the Williams formation above. The type locality of the formation is the region west of the mouth of Ladd Canyon, for which the formation is named. The greatest measured thickness of the formation approximates seventeen hundred feet. The contact of the Ladd formation with the Trabuco is probably conformable and may be gradational; its contact with the Williams formation above is abrupt wherever observed, and is believed to be disconformable if not actually unconformable. The Ladd formation is divided into two members - the Baker conglomerate and sandstone member below, and the Holz shale member above.

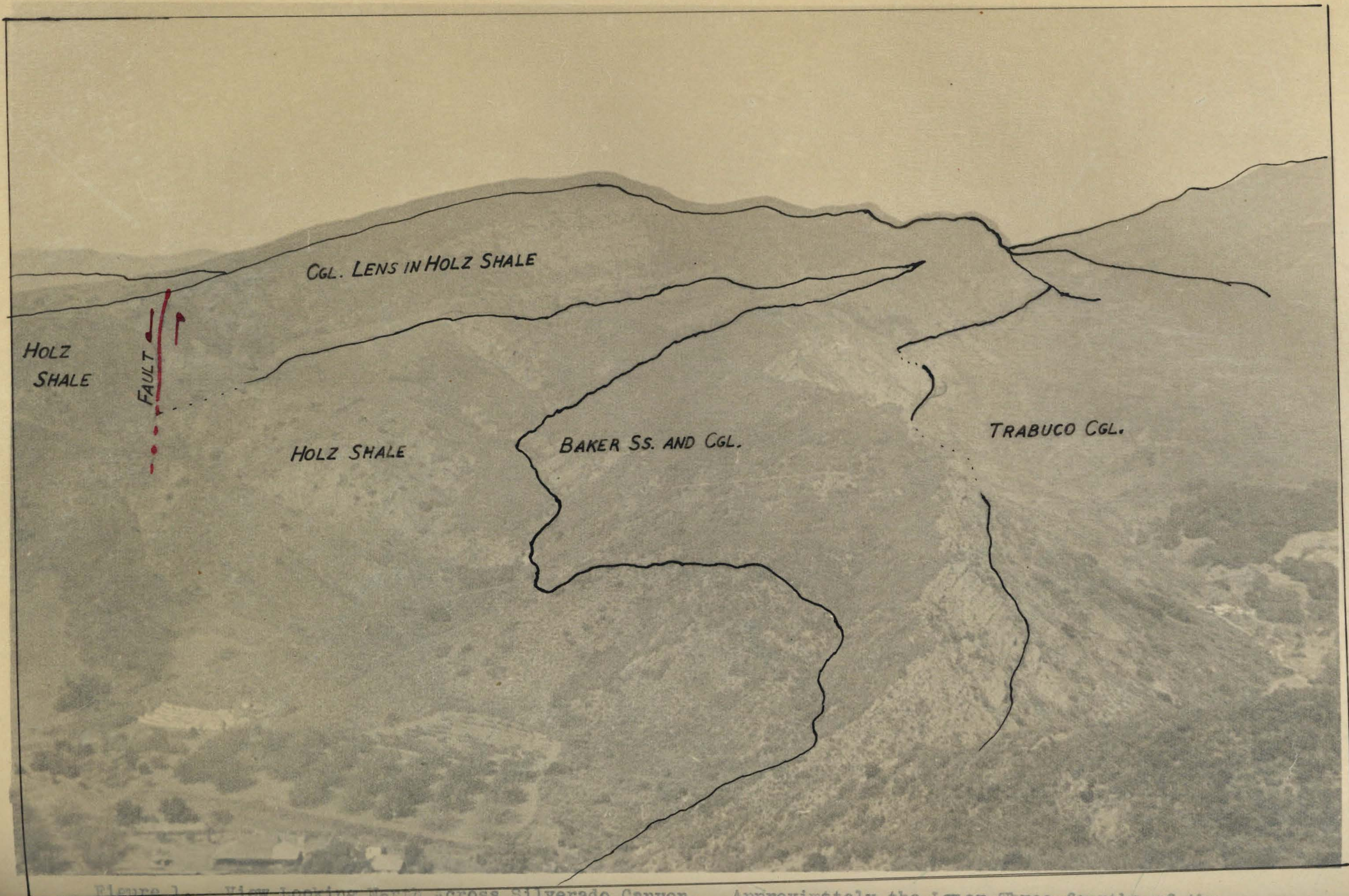

Figure 1. View Looking North Across Silverado Canyon. Approximately the Lower Three-fourths of the Cretaceous Section at this point is shown in the Picture. The Holz Ranch is in the Left Foreground.

Figure 1. View Looking North Across Silverado Canyon. Approximately the Lower Three-fourths of the Cretaceous Section at this point is shown in the Picture. The Holz Ranch is in the Left Foreground.

The Baker Conglomerate and Sandstone Member

This member, named for its great development in the type region in Baker Canyon, includes the gray conglomerates and greenish-gray overlying sandstones that immediately overlie the Trabuco formation and underlie the thick gray shale section in the Santa Ana Mountains Cretaceous. The thickness of the member probably approximates two hundred fifty or three hundred feet. This member is the resistant series that forms the scarp on the westward side of the Trabuco lowland, extending from the southern tip of the outcrop north to the Baker-Blackstar Canyon divide. It characteristically consists of a coarse, hard, gray, almost massive boulder conglomerate below, grading up into a thick-bedded coarse, sometimes calcareous, arkosic sandstone above. The conglomerates meet the Trabuco conglomerate below with a contact that is usually quite abrupt, although in places, the contact seems gradational. In comparison with the Trabuco, the upper conglomerate is much better consolidated, far less weathered, the boulders composing it are generally fresh and hard, show better sorting, smaller average boulder size, higher percentage of volcanic rocks, and considerably smaller percentage of sedimentary rocks. The individual fragments composing the upper conglomerate are likewise better rounded. The sedimentary rocks contained in it are of more resistant types such as quartzites and cherts. Topographically, the conglomerate usually outcrops along a bold, bare, and steep cliff-face overlooking the longitudinal valleys carved in the Trabuco formation. No fossils other than a few indeterminate Gryphaea-like or oyster-like forms have been found in this member. Its thickness in the neighborhood of Silverado Canyon and farther south averages about one hundred feet. North of Silverado Canyon, as will be explained, it becomes much thicker.

This gray conglomerate grades up into, and in places is interbedded with a thick-bedded gray-green sandstone that forms the upper part of the Baker member. This sandstone is typically coarse, hard, well-cemented, thick-bedded and highly arkosic near the transition zone into the conglomerate below, but becomes progressively finer and more shaly toward its top where it grades into the Holz shale member. Occasional thin stringers and lenses of pebbles occur among the sandstones, and some soft shaly and limey thin-bedded bands occur interbedded with the more massive phases. The thickness of the sandstone is extremely variable. At places, as for example just north of Williams Canyon, but little sandstone is present, the transition from conglomerate to shale taking place within a vertical distance of forty or fifty feet. In other regions, as for example in the territory south of Harding Canyon, the sandy beds appear to attain a thickness of two hundred fifty feet. The transition from sandstone to shale is usually gradual and determination of the contact between the two members is thus somewhat arbitrary, and a question of individual judgment. The lenticular character of the sandy phase makes it extremely probable that some of the beds mapped here as uppermost sandstone are synchronous in the deposition with beds mapped elsewhere as basal shale.

The sandstones of the Baker member are at places highly fossiliferous, though the fossil occurrences are usually sporadic and very unevenly developed. While in some places the fossils occur in distinct beds, each bed containing only a few species, there is little evidence that any of these species are confined to distinct levels within the sandstone. The fauna may well be considered as a unit. In general, the faunal assemblage is quite distinct in character, differing strikingly from the fauna of the beds overlying, and resembling but little other known faunal horizons in the California Cretaceous. By far the greater proportion of new species described from the Cretaceous of this region come from these beds. Forms occurring here that have been found elsewhere in California include Trigonia evansana Meek, Syncyclonema operculiformis (Gabb), Aphrodina ? arata (Gabb), Turritella cf. T. hearnii Merriam MS. Other species common in this zone but little known elsewhere include Clisocolus corrugatus n.s., Glycymeris pacificus Anderson, Trigonarca californica Packard, Astarte sulcata Packard, Liopistha anaana Anderson, Crassatella gamma n.s., and many others. Three species of small Prionotropid ammonites similar to if not identical with forms described by F. M. Anderson from the Rogue River Valley and Siskiyou Mountains Cretaceous, occur in the Baker sandstone in abundance, and indicate the probable correlation of this member with part of the Cretaceous section of southern Oregon.

The Holz Shale Member

Lying above the Baker sandstone and conglomerate member is a thick series of gray sandy shales that here are called the Holz shale from their excellent exposures at the type locality in the neighborhood of the Holz Ranch in Silverado Canyon. The Holz shale is the most persistent member of the Cretaceous of this region; for it may be followed in unbroken exposure from end to end of the outcrop. In area of exposure, the shale also probably exceeds any other member in the section. At its greatest thickness it approximates one thousand five hundred feet, considerably thicker than all of the rest of the Cretaceous section combined.

The predominating rock of this member is a soft brownish-gray micaceous rather sandy clay shale, but variations from this lithology are numerous and extreme. Thin beds of concretionary limestone are common locally. Rather persistent, though thin, beds of gritty sandstone are not rare; and lenses of coarse conglomeratic sandstone or heavy conglomerate are numerous and striking in their development within the shale.

As has been stated, the contact of the Holz shale with the Baker member below is gradational, and the designation of the contact is largely a matter of arbitrary choice. The only exception to this statement is found in the neighborhood of Harding Canyon. Here, a huge conglomerate lens developed at the base of the shale immediately overlies the fossiliferous sandstones of the Baker member. At the upper limit of this lens, the transition from conglomerate to shale is quite abrupt, taking place within a few feet. On the other hand, the contact of the Holz shale with the basal beds of the overlying Williams formation is usually very abrupt. Good exposures of this contact may be seen in a number of places. New roadcuts made along the fire control roads in the Santiago Canyon and Silverado Canyon areas show these abrupt contacts excellently; an almost unbroken series of good exposures extends from Baker Canyon to the Blackstar-Sierra Canyon divide; the contact is again well shown on the north wall of the north fork of Sierra Canyon where a newly cut fire control road winds down the steep side of the canyon wall. The lithologic change at this contact is very pronounced, the silty shales of the Holz member giving way in the space of a few inches to coarse conglomerates and gritty sandstones. There is also a rather pronounced faunal break in the fossil assemblages above and below the contact. These changes suggest an unconformity. This is further suggested by the gradual thinning out to the north and the final disappearance of a prominent fossil bed at the top of the shale, that in the Williams Canyon-Harding Canyon interstream area is about one hundred feet thick. Between Williams and Silverado Canyons, this bed thins rapidly northward. Along the fire control road just south of Silverado Canyon, this bed is not more than four or five feet thick, with the sharp contact with the overlying Williams formation truncating its upper surface. North of Silverado Canyon, the fossil bed has been cut entirely from the section.

While this contact is believed to represent an unconformity and a probably erosion surface, it is not believed that the unconformity represents a very long time interval. The faunas above and below the contact, while fairly distinct, show no marked change such as might be expected if a long unrecorded interval separated the times in which they lived in the region. There is no discernible discordance in the bedding above and below the unconformity, and it is probable that it represents no more than a local and minor oscillation of the sea bottom.

The greatest measured thickness of the Holz shale is to be found in the area between Harding and Williams Canyons, where a total thickness of nearly one thousand five hundred feet is indicated. This figure is probably too small, for part of the shale section has been cut out by a persistent longitudinal fault that involves the shale section on one or both sides of its trace from Baker Canyon to about one mile south of Harding Canyon, where the fault passes into the Tertiary beds. The total displacement of this fault is unknown, but it is at least one hundred fifty feet, and may be much more. South of the point where this fault leaves the shale section, the Tertiary beds are dropped against the shales by an intersecting fault that has cut out of the section the entire Williams formation at this point and a considerable thickness of the upper Holz shale as well.

The presence of conglomerate lenses in the shales has already been mentioned. Many of these lenses do not exceed more than a few feet in thickness

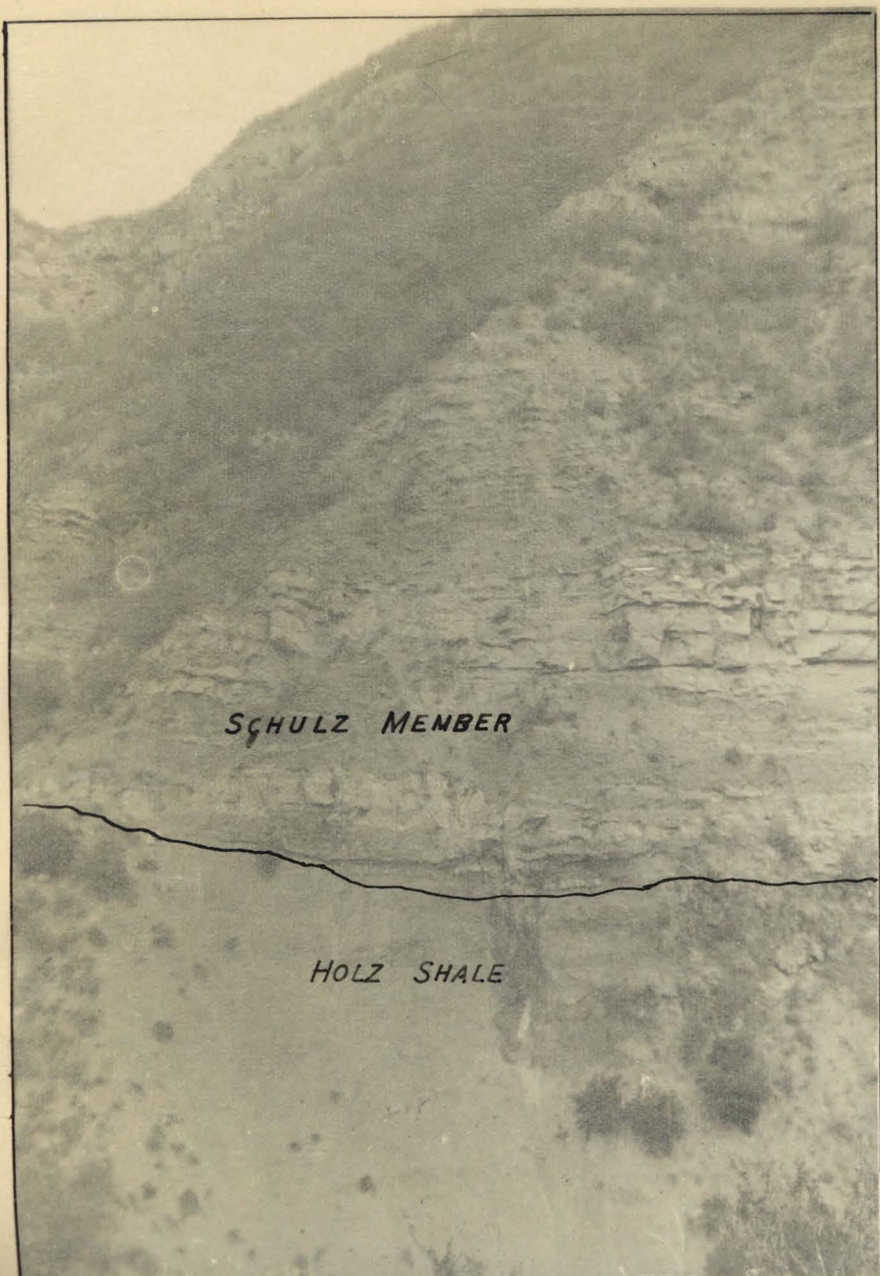

Figure 1. The Ladd Formation-Williams Formation Contact on the West Wall of Blackstar Canyon. The Rock Above the Contact is a Thin-Bedded Quartz Sandstone.

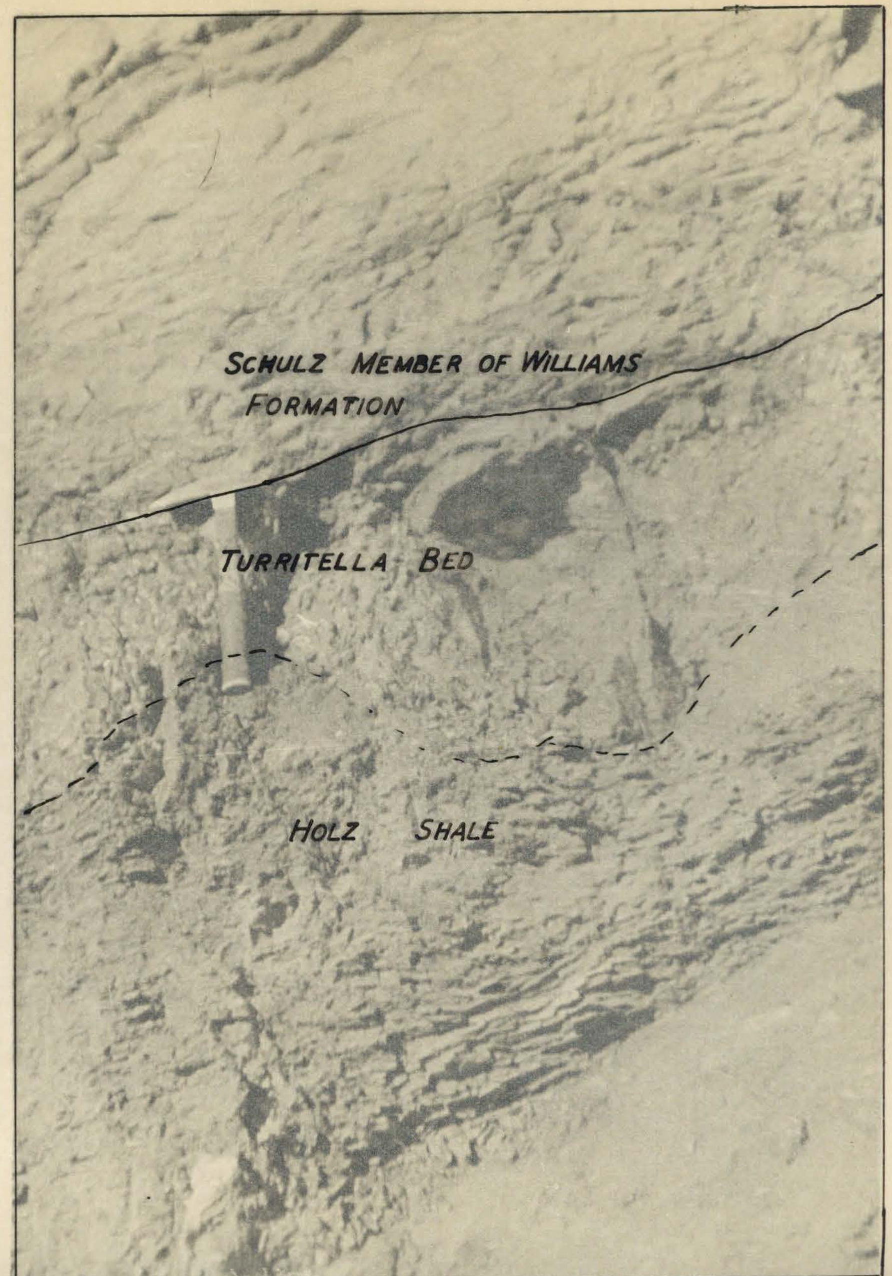

Figure 2. The Ladd Formation-Williams Formation Contact in a Forest Service Roadcut on the South Side of Silverado Canyon. The Turritella bed is not found North of this Region.

Figure 1. The Ladd Formation-Williams Formation Contact on the West Wall of Blackstar Canyon. The Rock Above the Contact is a Thin-Bedded Quartz Sandstone.

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and a few yards in length. Some of them however are huge. A large lens about three thousand feet long and perhaps seventy-five feet thick in its middle portion is found at about the middle of the exposed shale section on the north side of Williams Canyon. Many of the boulders in this lens exceed a foot in diameter. In the Aliso Canyon region, a second thick lens of coarse boulders and gritty sandstones is found in the midst of the shale section. At the only place measured, this lens is one hundred forty feet thick. Its exposed length exceeds one mile. Its original length probably was much greater, for it is truncated on both ends by faults. Reference has already been made to the conglomerate lens developed in the basal part of the shale in the neighborhood of Harding Canyon. The maximum measured thickness of this conglomerate exceeds one hundred feet, and is probably much more for part of it is cut out by a fault in the shale section. Its length exceeds one mile. The most remarkable conglomerate in the shales is the lens that is developed in the basal part of the shale section beginning in the high bluff to the north of the Holz ranch, in Silverado Canyon and extending north to a short distance beyond the Baker Canyon-Blackstar Canyon divide - a distance of more than three miles. The total thickness of this deposit is as yet unknown, but probably is not less than one thousand feet. It is composed of massive beds of gritty feldspathic sandstone in great thickness alternating with boulder beds carrying fragments ranging in size from small pebbles to great angular blocks three or four feet in diameter. In general, the mass is firmly consolidated. The terrane it underlies is clothed with a thick tangle of brush, which, except in a few places where trails have been cut through it, is virtually impassible; and the streams that transect the lens flow through gorges so choked with brush, so strewn with boulders and so set with waterfalls and potholes that exploration of their courses is exceedingly difficult. Throughout most of its extent this lens merges below with the Baker sandstone and conglomerate member, and has been mapped with it.

North of Tick Canyon on the east side of Blackstar Canyon, the whole basal series including the Trabuco Conglomerate, the Baker member, and the great conglomerate lens described above, pinch out and disappear. A few hundred yards north of Tick Canyon, the Triassic slates and the Holz shale occur within a few yards of one another, though no actual contact is visible. From this point north to the Bedrock Canyon-Sierra Canyon divide, the shale appears to be in direct contact with the basement rock. North of this divide nearly to Santa Ana Canyon, a soft reddish or brownish boulder conglomerate appears on the east wall of Bedrock Canyon in normal depositional contact with the Triassic and apparently in fault contact with a thin strip of Holz shale above. This lower conglomerate may represent a part of the Trabuco, or the Trabuco plus part of the Baker member.

The question of the origin of the conglomerate lenses developed in the shales is of considerable interest in sedimentation. They are doubtless in part marine, for they carry marine fossils. They may have developed along the bases of high sea-cliffs that descended into fairly deep water and mingled their talus with the detritus brought down by streams that drained the area to the east. The coarseness of much of the material in the lenses would indicate that it could not have been borne far.

The terrane underlain by the shales weathers into smoothly rounded grassy slopes on which good exposures are rare. In the southern part of the area the outcrop is broad. The slopes here have been greatly incised by numerous subparallel gullies that head near the Holz-Baker member contact, and flow westward across the strike of the beds to Santiago Creek. This dissection results in an extremely rugged topography in this part of the area. In the area north of Baker Canyon, the shale outcrop is narrow, and is largely confined to the lower slopes of the steep valley walls that are capped by the resistant basal beds of the overlying Williams formation.

From Baker Canyon south, the shales are fairly fossiliferous. Individual fossil beds generally cannot be traced more than a few yards however, the fossils occurring in lenticular sandy and conglomerate beds and not usually directly in the shale itself. Faunally the Holz shale may be divided into three rather vague zones. The lower zone includes perhaps the basal hundred feet of the shale, and bears a fauna that in general is very much like that of the Baker sandstone below, together with a few forms that seem prenuncial of the assemblages of higher horizons. The shales above this zone are barren for several hundred feet. The second zone occurs in the upper half of the shale beds up to about one hundred feet from the top of the member, as developed in Williams Canyon. Fossil occurrences are scattered and few in this part of the section, but have yielded some good faunas. Characteristic species include Etea triangulata Packard, Tenea inflata Gabb, Opis. cf. triangulata, Turritella chicoensis, typical variety, and a few other forms that appear to be restricted to this part of the section. Many other species that occur here are also common in the zones above. From the south side of Silverado Canyon to about one and one-half miles south of Harding Canyon the top of the shale section is occupied by a series of sandy beds that attain a thickness of nearly one hundred feet in the Williams Canyon region. These beds contain an abundant but not particularly varied fauna especially characterized by the presence in great

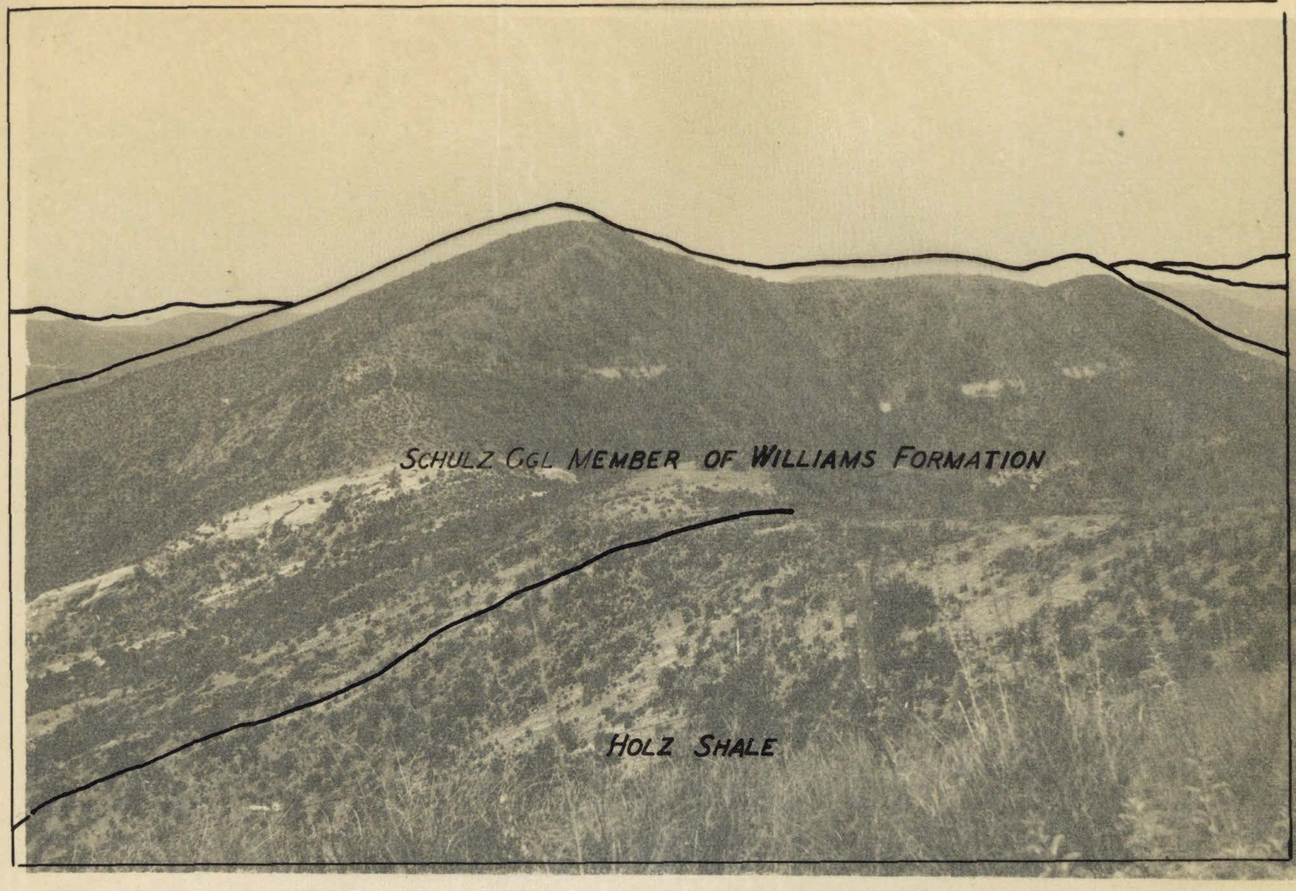

Figure 1. Low Ridge formed by Schulz Member at Contact with Holz Shale. View Taken Looking West about one-quarter Mile South of Harding Canyon. The Ridge in the Foreground is Part of the Santiago-Aliso Divide.

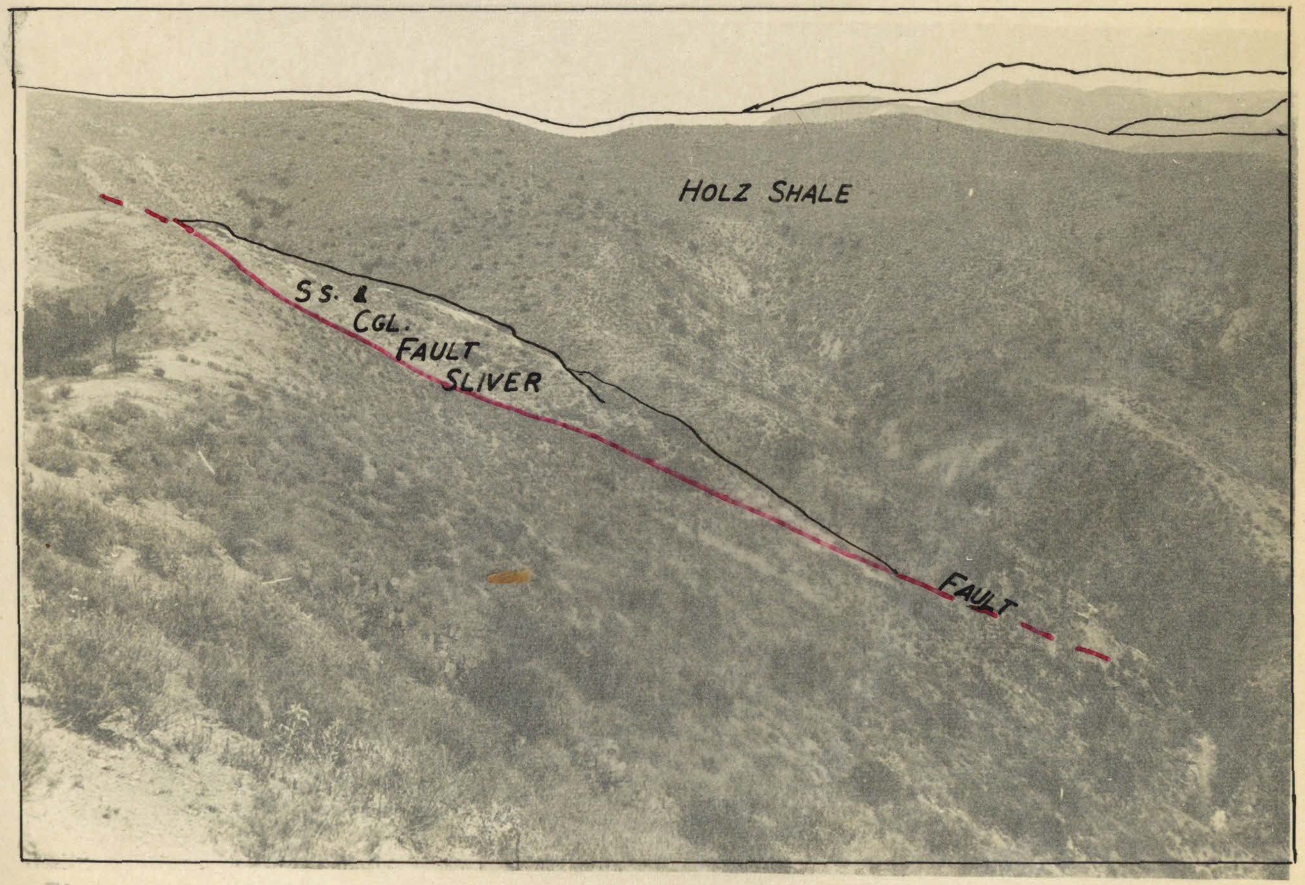

Figure 2. Conglomerate Fault Sliver in the Holz Shale, about One Mile South of Harding Canyon. The Beds Dip Toward the Observer.

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numbers of giant specimens of Turritella chicoensis and Crassatella lomana. A rather striking feature of the shale faunas in general is the scarcity of ammonites, in contrast to the rather abundant occurrence of these fossils in the Baker member below and the Williams formation above.

3. The Williams Formation

This formation, named from characteristic exposures at the type locality about one-quarter mile above the mouth of Williams Canyon, forms the summit of the Upper Cretaceous section in the Santa Ana Mountains. The formation here is approximately five hundred feet thick. At its base is usually found a rather thin series of boulder conglomerates and coarse, light colored, highly feldspathic and micaceous, soft, cross-bedded sandstones, the Schulz sandstone and conglomerate member. At higher levels in the section, the sandstones become finer grained and less feldspathic, and occasional limy beds begin to appear, often so calcareous as to form sandy limestones. Near the top of the section the prevailing matrix becomes very fine-grained, and might with almost equal correctness be designated a sandy siltstone or a fine-grained shaly sandstone. The color of the rocks of the whole formation is prevailingly light. Pinkish shades induced by extensive limonite stain are very characteristic. The outcrop is almost everywhere covered with a stubborn growth of thick and resistant brush, which contrasts strikingly with the smooth grass-covered slopes of the shales below.

The Schulz Sandstone and Conglomerate Member

The type locality of the Schulz member is approximately one-quarter mile above the mouth of Williams Canyon near the west boundary of the Schulz ranch. The member is composed of coarse light-colored soft cross-bedded arkosic sandstone with subordinate boulder beds. The boulders in the conglomerate are usually of rather small size, individual fragments as large as one foot in diameter being quite rare. The boulders are nearly all well-rounded and quite fresh. They vary in consistency from cherts and quartzites to volcanic and plutonic igneous rocks of a variety of types. Quartz pebbles are abundant. The coarse sandy matrix in which these boulders are embedded breaks down readily, and the conglomerates weather out into subdued rocky ridges quite different in appearance from the bold conglomerate cliffs of the Baker member at the base of the section. The arkosic sandstone beds that characterize the upper part of the member usually form rather thick, cream-colored layers of soft rock that in Baker Canyon and north compose the striking bluffs that cap the soft and dark shale slopes. Where they outcrop over a considerable area, as in the northern half of the Cretaceous exposure, these sandstones weather out into immense monolithic blocks that lie scattered about on the crests of the bluffs they cap like so many unfinished Stonehenges.

The lithology of this member at its contact with the Holz shale varies greatly from place to place, but an abrupt change in character from the rock below is everywhere apparent. In the vicinity of Harding Canyon, comparatively little conglomerate is present in this member, the rock at the contact being a soft pebbly sandstone; farther north in Williams Canyon coarse conglomerates occur immediately above the contact with the shale; at Silverado Canyon on the south side the beds just above the shales are of soft silty sandstones succeeded immediately by boulder beds; on the north side of Silverado Canyon the basal beds of the Schulz member are again coarsely conglomeratic; along the west walls of Baker and Blackstar Canyons the Schulz member just above the contact is usually a coarse sandstone, in places feldspathic and in places composed of nearly pure olive-colored quartz sand. Fragments of shale resembling the Holz shale below are common in the lowermost few feet of the beds above the contact.

The Schulz member thickens somewhat north of Baker Canyon. In this region it shows a general tendency to cavernous weathering, and a tendency to form joints perpendicular to the bedding-planes, a characteristic that gives a fluted or columnar appearance to the bluff faces that it forms.

With the exception of one collection (locality no. 1066) no fossils have been found in this member. This one exception may represent reworked boulders in the base of the member. It is presumed however from the gradational contact between the Schulz member and the overlying Pleasants fossiliferous beds that the Schulz represents the basal conglomerate of the advancing sea in which the fossiliferous beds were later laid down.

The Pleasants Sandstone Member

This member is named for its excellent development at the type locality in the neighborhood of the Pleasants ranch at the mouth of Williams Canyon. It consists in general of very fine-grained and thin-bedded ferruginous micaceous shaly sandstone, with which are interbedded numerous thick layers of false-bedded calcareous sandstone or sandy limestone. These limy beds weather out on the surface into large concretion-like blocks that occasionally carry a good fossil fauna. The first appearance of the characteristic limy blocks in ascending the section has been taken as the base of the member in mapping.

PLATE 6

Characteristic Exposure of Arkosic Sandstones of the Schulz Member of the Williams Formation, Exposed on Ridge Crest of West Wall of Baker Canyon. Note the Tendency to Cavernous Weathering of the Sandstones.

View Taken Looking Southwest.

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Characteristic Exposure of Arkosic Sandstones of the Schulz Member of the Williams Formation, Exposed on Ridge Crest of West Wall of Baker Canyon. Note the Tendency to Cavernous Weathering of the Sandstones.

View Taken Looking Southwest.

The Pleasants member is rather discontinuous in its distribution, being cut out of the section in a number of localities by faulting or overlap. From the southern tip of the Cretaceous exposure north to about one and one-half miles south of Harding Canyon, the entire Williams formation has been cut out by a fault that drops the Tertiary beds against the Holz shale. In the vicinity of the mouth of Harding Canyon, the basal Tertiary beds entirely overlap the Pleasants member, resting upon the Schulz conglomerate and sandstone. The Pleasants member is hidden here for a distance of perhaps one-half mile. North of Silverado Canyon, the Pleasants member is again entirely overlapped by the basal Tertiary beds for a distance of perhaps three-quarters of a mile. Perhaps one of the best examples of the overlap of the Tertiary upon the Cretaceous is shown on the north wall of the north fork of Sierra Canyon near its head. Along the Bedrock Canyon-Sierra Canyon divide, the Martinez Paleocene beds may be seen resting upon characteristic beds of the Pleasants member. As this contact is traced to the east, the Pleasants is overlapped and the Martinez rests upon the Schulz conglomerates and sandstones. About one-quarter mile to the east at the head of Bedrock Canyon, the Schulz member also is overlapped, and the Martinez beds rest directly on the Holz shale.

The Pleasants member is represented only in discontinuous and isolated areas north of Blackstar Canyon. In this region it was not differentiated from the underlying Schulz member.

Determination of the thickness of the members of the Williams formation is difficult, owing to the overlaps and the faulting which have affected these members from end to end of the Cretaceous outcrop. The best calculation made based on measurement of the section in the neighborhood of

Williams Canyon gives an approximate thickness of two hundred feet for the Schulz member, and about three hundred twenty feet for the thickness of the Pleasants sandstones. It is probable that farther north, the Schulz member may exceed this thickness.

The fauna of the Pleasants sandstone is striking and characteristic. It is marked by numerous specimens of _Calva major_, _Cymbophora ashburnerii_, _C. gabbiana_, _Margarites ornatissimus_, _Meekia navis_, and _Metaplacenticeras pacificum_. The latter species is especially useful as an index fossil, for it not only is confined to this member in the Santa Ana Mountains region, but is easily recognized even in fragments, and has been found almost everywhere that the Pleasants member is exposed. It has also been recognized throughout a wide geographic range in Cretaceous beds in California and southern Oregon. As its stratigraphic range appears to be restricted, it may be regarded as a criterion for correlation of considerable value.

On the whole, the fauna of the Pleasants member is widespread, but in only a few localities, is it either well-developed or well-preserved. One prolific locality on the west slope of the ridge just east of the Pankratz ranch house has furnished by far the largest and best-preserved collection from the member. Over fifty species have been obtained at this place. At almost every other locality where the Pleasants member is exposed, fossils are obtainable but are neither in comparable abundance nor in such a good state of preservation.

THE UPPER CRETACEOUS FAUNA OF THE SANTA ANA MOUNTAINS

Introduction

One hundred and eight species and varieties of mollusks are listed in the accompanying table upon which the following discussion is based. This fauna includes sixty-seven species of Pelecypods, thirty species of Gastropods, thirteen species of Cephalopods, and one species of Scaphopods. Approximately ninety-five of these species have been either specifically determined, compared to closely related described species, or described as new species. In addition to these one hundred and eleven species and varieties, the fauna contains five or six Pelecypod species and perhaps forty Gastropod species that have not been even generically determined, and probably are all new species. Nearly all of this latter assemblage is represented by rare or solitary specimens. Two species of "worms" are present in the fauna, but have neither been described nor discussed. Foraminifera, Bryozoa, and Crustacea are known to occur in this assemblage, but are represented by indeterminate forms in the main. I have not distinguished herein any specimens referable to the Echinoderma, Brachiopoda, or corals.

The fauna of the Cretaceous of the Santa Ana Mountains is divisible into two distinct assemblages that have very few species in common. The first assemblage is that found in the Baker sandstone member of the Ladd formation, and in three small lots of fossils obtained from beds at the very base of the Holz shale overlying. It is this faunal group that Packard named the Actaeonella oviformis zone. The second faunal assemblage includes all of the fossils of the Holz shale member of the Ladd formation, excepting the three collections just mentioned (C. I. T. cat. nos. 92, 454, 1064), and all of the fauna of the Pleasants member of the Williams formation

Thickness	FORMATIONS	MEMBERS	FAUNAL ZONES OF PACKARD, 1916	FAUNAL UNITS OF THIS THESIS
300'	WILLIAMS FORMATION	Pleasants shaly sandstone member	Tellina ooides zone	Glycymeris veatchii zone: Subzone of Metaplacenticeras pacificum
200'		Schulz arkosic sandstone and conglomerate member		Glycymeris veatchii zone: Barren beds
200'	LADD FORMATION	Holz shale member	Turritella pescaderoensis zone: Shallow-water phase	Glycymeris veatchii zone: Subzone of Turritella chicoensis, giant variety
600'			Turritella pescaderoensis zone: Shallow-water phase ?	Glycymeris veatchii zone: Subzone of Turritella chicoensis, typical variety
700'			Turritella pescaderoensis zone: Deeper-water phase ?	? Barren beds
200'		Baker sandstone and conglomerate member	Actaeonella oviformis zone	Actaeonella oviformis zone
300'	TRABUCO FORMATION			

Generalized Columnar Section Showing Relationship of Rock Units to Faunal Units, Upper Cretaceous of the Santa Ana Mountains
Drawn Approximately to Scale

To simplify subsequent discussions, I shall call this second faunal group the zone of Glycymeris veatchii, as this species occurs abundantly throughout this stratigraphic range, and does not occur in the Baker sandstone.

The faunal subdivisions as adopted in this thesis, together with the corresponding subdivisions of Packard (1916, p. 144), and their approximate stratigraphic position, are shown on the chart facing page 36.

The Actaeonella oviformis Zone

The fauna of the Baker sandstone, or "Actaeonella oviformis zone" is large. At least fifty of the species included in the fossil list occur in this member, and of this number but few are found in the higher beds. The zone includes by far the majority of those forms that have been described as new species from this region. Many of these species have not been found elsewhere on the Pacific Coast, or at least have not been so reported in publications. Of the species found in this zone that are known elsewhere in the Pacific Coast Cretaceous, a considerable proportion occurs in Gabb's fauna from Cottonwood Creek, Shasta County, suggesting that Gabb's locality is probably correlative with the Baker sandstone.

The more abundant and characteristic fossil species occurring in this zone include Aphrodina ? arata (Gabb), Calva regina n.s., Clisocolus corrugatus n.s., Corbula traskii ? Gabb, Crassatella gamma n.s., Cucullaea sp. cf. C. gravida (Gabb), Flaventia zeta n.s., Glycymeris pacificus (Anderson), Inoperna n.s., Isocardia delta n.s., Lima beta n.s., Liopistha anaana (Anderson), Syncyclonema operculiformis (Gabb), Tenea inflata (Gabb) small variety, Actaeonella oviformis Gabb, Ampullina pseudoalveata (Packard). Anchura cf. falciformis ? (Gabb), Pugnellus sp. cf. P. manubriatus Gabb, "Siphonalia" dubius Packard, Turritella sp. cf. T. seriatimgranulata Gabb non Roemer, "Nautilus" sp., "Schloenbachia" sp. cf. "S" knighteni (Anderson), "S" sp. cf. "S". phoenixense Anderson, "S" sp. cf. "S". siskiyouensis Anderson, and Baculites fairbanksi Anderson. All of the forms above mentioned with the exception of Anchura cf. falciformis ? (Gabb), appear to be restricted in their occurrence to the Baker sandstone. Anchura cf. falciformis ranges up into the lower portions of the overlying Holz shale. Of the few other species found in the lowermost zone, but usually more characteristically developed in the beds higher in the section may be mentioned Trigonia evansana, Opis triangulata, Acila demessa, Trinacria cor, Parallelodon brewerianus, and Oligoptycha obliqua. Of these, the Trigoniae in the beds above the Baker sandstone are very poorly preserved, and while they are very closely related to T. evansana there is reason to believe that they may be a separate species - probably T. inezana Packard. Parallelodon brewerianus is a species that elsewhere is characteristic of the lower portion of the West Coast Upper Cretaceous, and is even reported from the Horsetown group (Lower Cretaceous)(Diller and Stanton, 1894, pp. 439, 443). It is not surprising to find this species ranging through a considerable thickness of beds in this section also. The other species mentioned are either comparatively long-ranging forms, or are forms that are characteristic of the lower portion of the overlying shales, and are usually represented in the Baker sandstone by single individuals from one or two localities.

The Glycymeris veatchii Zone

The faunas of the "Glycymeris veatchii zone" show a considerable amount of uniformity from top to bottom of the section, and show a great change from the assemblage of the Baker sandstone. They may be subdivided, however, into three fairly well marked subzones, all of which were recognized by Packard, and were designated by him the "deeper-water phase of the Turritella pescaderoensis zone", the "shallow-water phase of the Turritella pescaderoensis zone", and the "Tellina oöides zone", from bottom to top (Packard, 1916, p. 145). The two lower subzones are found in the Holz shale. The uppermost subzone includes the fossiliferous portion of the Williams formation. For reasons that will appear subsequently, these subzones are designated in this paper, from below upwards (1) the subzone of Turritella chicoensis, typical variety; (2) the subzone of Turritella chicoensis, giant variety, /1 and (3) the subzone of Metaplacenticeras pacificum.

/1 Dr. Charles Merriam of Cornell University who has monographed the Turritellas of the Pacific Coast Cretaceous and Cenozoic deposits, informs me (personal note, Jan. 1934) that he regards Turritella pescaderoensis Arnold, and the giant Turritella from the Santa Ana Mountains as separate subspecies of typical T. chicoensis Gabb, and will so describe them in his forthcoming monograph of this genus. Upon publication of these descriptions, the varietal name can be used to designate the middle subzone of the Glycymeris veatchii beds.

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1. Subzone of Turritella chicoensis, Typical Variety

It has been pointed out in the chapter on stratigraphy that the Holz shale in the region between Silverado and Harding Canyons consists of silty shales with occasional conglomerate and sandstone lenses interbedded, and with a highly fossiliferous sandy phase at the top. The maximum computed total thickness of the shale section is in the neighborhood of one thousand five hundred feet. The subzone of Turritella chicoensis, typical variety, occurs in the upper half of this shale section below the sandy beds at the summit. The lower half of the shale is barren of fossils or nearly so. The fossils occur in limy, sandy, or conglomeratic lenses interbedded with the shales, and seldom in the shale itself - an occurrence that suggests that the character of the fauna is not solely a feature of facies control. The fossil occurrences are usually isolated and of small lateral extent. Few of the fossiliferous beds may be followed along the strike more than a few yards.

These species seem most characteristic of this subzone in the shale: Turritella chicoensis, typical variety; Parallelodon brewerianus; Tenea inflata (large form), Opis cf. triangulata, Ampullina packardi, Etea angulata, and Volutoderma santana. A number of other forms are common in this subzone, but also are found abundantly in beds higher in the section. These include Glycymeris veatchii, Clisocolus cordatus, Crassatella lomana, Flaventia lens, Euspira shumardiana, "Fulgur" hilgardi, and Volutoderma averillii. Ammonites are very rare, and usually are poorly preserved.

Very little in the character of the fauna would suggest a deep-water condition of deposition of these shale beds. The occurrence in the section of conglomerate lenses and sandstone beds suggests a fairly shallow sea. The concept of a shallow sea with a mud bottom would account for the characteristics of this deposit satisfactorily.

2. The Subzone of Turritella chicoensis, Giant Variety

The sandy beds at the top of the Holz shale, and just below the basal conglomerate of the Williams formation include this subzone. The beds of the subzone probably reach their greatest thickness in the region between Williams and Harding Canyon, where they are about one hundred fifty feet thick. They are cut out of the section about a mile south of Harding Canyon by faulting, and are overlapped by the basal beds of the Williams formation north of Silverado Canyon.

The fauna of this subzone is distinguished by the association of species rather than by their restriction in range. A considerable number of the abundant forms found in this subzone occur also in greater or less abundance in the subzone below; and similarly a number of species that first appear at this horizon pass upward into the *Metaplacenticeras* subzone above. Probably the most striking feature of the fauna is the robust appearance of many forms which in their earlier or later appearance are of more modest size. The giant variety of *Turritella chicoensis* is probably the best example of this. This species occurs not only in great size in this subzone but also in great numbers, in many places making up a considerable portion of the bulk of the rock in which it occurs. Were this evidence of optimum living conditions the only characteristic feature of these beds, it would not be sufficient basis for distinguishing a separate faunal division. The combination of species is however distinct.

Beside the giant forms of *Turritella chicoensis*, the following species are both abundant and characteristic in this subdivision: *Crassatella lomana*, *Clisocolus cordatus*, *Cucullaea youngi*, *Cymbophora ashburnerii*, *Flaventia lens*, *Glycymeris veatchii*, *Trinacria cor*, *Acila demessa*, *Euspira shumardiana*, *Lysis californiensis*, and *Baculites chicoensis*.

3. The Subzone of *Metaplacenticeras pacificum*

The basal member of the Williams formation, the Schulz conglomerate, has yielded but one fossil collection (C. I. T. locality no. 1066). The fauna of this collection shows no great difference from the faunas of the giant *Turritella* beds, which here are overlapped. With this exception, all of the fossils obtained from the Williams formation have been found in the limy and shaly sandstones of the upper or Pleasants member. This member has yielded a fauna of more than fifty species. By far the best preserved and most abundant collections of the subzone have been derived from a small area south of Harding Canyon and northeast of the Pankratz ranch.

Elsewhere along the outcrop of the Pleasants member, fossils are sparsely distributed and poorly preserved. It has usually been possible to obtain sufficient fossils almost everywhere to identify the member, however.

The most characteristic and useful fossil of this subzone is the ammonite species Metaplacenticeras pacificum (J. P. Smith). This form is distributed throughout the outcrop of the member, and though seldom abundant is generally present in localities that furnish any fossils at all. It is easily recognized, even when poorly preserved, and has so far not been found in any horizon lower than the Pleasants sandstones. The species is found in both middle and northern California, and in southern Oregon, where it appears to have a restricted range. It thus represents a criterion for correlation of unusual interest and importance. This ammonite is suggested as the zone-fossil for this horizon, rather than the species "Tellina" oöides Gabb as suggested by Packard, as the latter form is less abundant, harder to recognize, and probably of wider stratigraphic range.

Next to Metaplacenticeras the most important and characteristic fossil of this subzone is Calva nitida var. major (Packard). It occurs rarely in the subzone below, but is most abundant and best developed in the Metaplacenticeras beds. Other forms that occur abundantly at this horizon include Cymbophora ashburnerii (Gabb), C. gabbiana (Anderson), the ubiquitous Glycymeris veatchii, "Fulgur" hilgardi White, Gyrodes expansa Gabb, Margarites ornatissimus (Gabb) and Oligoptycha obliqua (Gabb). As will readily be seen, the fauna of this subzone and the subzone below differ little, and the conclusion is justified that the two subzones are not widely separated in time. An unconformity separates the beds in which the two subzones are developed, but it probably does not represent a very considerable break in deposition.

The general aspect of the fauna of the "zone of Glycymeris veatchii" is much like that found on the east side of the Upper Sacramento Valley at Chico Creek, Tuscan Springs, Penz's Ranch and Cow Creek. Nearly every species found in the upper zone at the Santa Ana Mountains is also represented in the fauna from Chico Creek, especially from the upper beds.

PLATE 8. Table Showing Stratigraphic Range of Santa Ana Mountains Cretaceous Fossils

Species	BAKER SANDSTONE	HOLZ SHALE: Typical T. chicoensis beds	HOLZ SHALE: Giant T. chicoensis beds	WILLIAMS FORMATION
Corbula sp. A.	—			
Gryphaea ? sp.	—			
Pleuromya ? papyracea Gabb	—			
Pteria sp.	—			
Bittium sp.	—			
Clisocolus corrugatus n.s.	—			
Cyprimeria moorei n.s.	—			
Lima sp. cf. L. suciensis Whiteaves	—			
Liopistha hardingensis (Packard)	—			
Nuculana ? sp.	—			
Ostrea crescentica Packard	—			
Plicatula sp.	—			
Spondylus rugosus (Packard)	—			
Bullaria tumida Packard	—			
"Siphonalia"dubius Packard	—			
"Nautilus" sp.	—			
Schloenbachia" sp. cf."S" knighteni Anderson	—			
"Schloenbachia" sp. cf."S" siskiyouense "	—			
"Schloenbachia" sp. cf."S" multicosta "	—			
Turritella iota n.s.	—			
Aphrodina ? arata (Gabb)	—			
Astarte sulcata Packard	—			
Calva regina n.s.	—			
Corbula traskii ? Gabb	—			
Flaventia zeta n.s.	—			
Glycymeris pacificus(Anderson)	—			
Inoperna bellarugosa n.s.	—			
Pinna calamitoides Shumard	—			
Syncyclonema operculiformis (Gabb)	—			
Tenea inflata (Gabb), small variety.	—			
Ampullina pseudoalveata (Packard)	—			
Pugnellus sp. cf. P. manubriatus Gabb	—			
Turritella sp. cf. T. seriatimgranulata Gabb	—			
Baculites fairbanksi Anderson	—			
Crassatella gamma n.s.	—			
Cucullaea sp. cf. C. gravida (Gabb)	—			
Isocardia delta n.s.	—			
Liopistha anaana (Anderson)	—			
Trigonarca californica Packard	—			
Actaeonella oviformis Gabb	—			
Lima beta n.s.	—	—		
Anchura sp. cf. A. falciformis Gabb	—	—	—	
Trigonia evansana Meek	—	—	—	—
Opis triangulata ? Cooper	—	—		
Parallelodon brewerianus (Gabb)	—	—	—	
Protocardia sp.	—	—		
Eriphyla ovoides (Packard)	—	- - -	—	
Acila demessa Finlay	—	—	—	—
Panope californica Packard	—	- - -	—	—
Trinacria cor n.s.	—	—	—	—
Oligoptycha obliqua (Gabb)	—	—	—	—
Cylichnina sp. cf."C" costatus Gabb	—	—	- - -	—
Volutoderma averillii (Gabb)	? —	—	—	—
Baculites chicoensis Gabb	? —	- - -	—	—
Clisocolus dubius Gabb		—		
Cucullaea litata Packard		—		
Eriphyla lapidis (Packard)		—		
Ostrea sp. A.		—		
Acteonina ? sp.		—		
Tessarolax distorta Gabb		—		
Canadoceras sp.		—		
Etea angulata (Packard)		—	—	
Tenea inflata (Gabb), large variety.		—	- - -	—
Turritella chicoensis Gabb, typical variety		—	— ?	
Ampullina packardi n.s.		—	—	
Volutoderma santana Packard		—	—	— ?
Crassatella lomana Cooper		—	—	—
Cucullaea youngi Waring		—	—	—
Glycymeris veatchii(Gabb)		—	—	—
Turritella ossa n.s.		—	—	—
Lithophaga ? sp.		—	—	
Clisocolus cordatus Whiteaves		—	—	—
Flaventia lens (Gabb)		—	—	—
Anomia ? lineata?Gabb		—	—	—
Euspira shumardianan (Gabb)		—	—	—
Lysis californiensis Packard		—	—	—
"Fulgur" hilgardi White		—	—	—
Gyrodes expansa Gabb		—	- - -	—
Perissitys brevirostris (Gabb)		—	—	—
Inoceramus whitneyi Gabb			—	
Spondylus subnodosus (Packard)			—	
Puzosia ? sp.			—	
Turritella chicoensis Gabb, giant round-whorled variety.			—	
Calva major(Packard)			—	—
Cymbophora gabbiana (Anderson)			—	—
Cymbophora ashburnerii (Gabb)			—	—
Corbula sp. B.			—	—
Ampullina n. sp.			? —	—
Brachidontes bifurcatus n.s.				—
Legumen ooides (Gabb)				—
Margarites ornatissimus (Gabb)				—
Leptosolen ? sp.				—
Linearia ? sp.				—
Lembulus striatula Forbes				—
Martesia clausa Gabb				—
Meekia navis Gabb				—
Mytilus sp.				—
Siliqua ? alisoensis Packard				—
"Tellina" sp. A.				—
"Tellina" sp. B.				—
Acteon normalis (Cooper)				—
"Odostomia" sp.				—
"Odostomia" santana Packard				—
Desmoceras ? sp.				—
Turritella chicoensis Gabb, giant flat-whorled variety.				—
Metaplacenticeras californicum (Anderson)				—
Metaplacenticeras pacificum (J.P.Smith)				—

Comparative breadth of the horizontal black lines indicates approximate comparative abundance of specimens in each horizon.

NOTES ON OTHER UPPER CRETACEOUS DEPOSITS IN SOUTHERN CALIFORNIA

In the course of the past year, the California Institute of Technology acquired a number of fossil collections from Cretaceous beds in the Santa Monica Mountains, and in the Simi Hills of Los Angeles and Ventura Counties. These faunas are listed here. Their stratigraphic occurrences are briefly outlined and their relationships to the Cretaceous faunas of the Santa Ana Mountains are discussed.

Upper Cretaceous of the Simi Hills

Stratigraphy

According to Kew (1924, pp. 11-12) the Cretaceous sediments of the Simi Hills are divisible into two members: the lower member consists of a calcareous sandstone about two hundred fifty feet thick below, and a gray, soft shale about equally thick above; the upper member consists of approximately fifty-five hundred feet of massive brown sandstone, with numerous thin shale seams interbedded. All, or nearly all of the fossils obtained from the Cretaceous of this region are derived from the lowest beds exposed - the calcareous sandstone.

Fauna

The localities from which the fossils are obtained are listed as follows with their California Institute of Technology Invert. Paleontology locality numbers:

1154. SE side of the Simi Hills, spur between north and south branches of Dayton Canyon, north side of spur, two hundred feet above the canyon floor. From limy sandstone underlying massive sandstone.

1155. Limy sandstone beds in sandy shales, south side of south fork of Dayton Canyon, Simi Hills, Calabasas quadrangle, Ventura County, Calif.

1156. Sandstone outcropping on crest of ridge, about three hundred feet southwest of sta. no. 1155.

1157. Southeast slope of the Simi Hills, north bank of Bell Canyon, in shale bluffs above stream channel about fifty feet below the base of the massive Cretaceous sandstone. One mile straight west of the Los Angeles-Ventura County line on the boundary, (extended) between townships 1 and 2 north. Calabasas quadrangle.

1158. Approximately same horizon as locality no. 1157, but about one-eighth mile west.

1159. Prominent fossil bed on crest of spur between forks of Dayton Canyon, about four hundred feet east of the Los Angeles-Ventura County line, and six thousand feet N 23° W of the SE corner of sec. 33, T 2 N, R 17 W, Calabasas sheet.

Species	C. I. T. loc. no.	1154	1155	1156	1157	1158	1159
Margarites ornatissimus (Gabb)		x		c		c	a
Euspira shumardiana (Gabb)					r	a	r
Gyrodes expansa Gabb		x		r		c	r
Lysis californiensis Packard						r	c
Turritella chicoensis Gabb (giant)		r		r	va		r
Turritella ossa n.s.					a		
Perissitys brevirostris (Gabb)			r		r	a	
Volutoderma averillii (Gabb)						r	r
Oligoptycha obliqua (Gabb)		a		va	c	va	va
Acila demessa Finlay		r	r	c		r	r
Glycymeris veatchii (Gabb)		c	c	a	c	va	va
Cucullaea youngi Waring		r	r	r	?		va
Cucullaea truncata ? Gabb						r	
Parallelodon brewerianus (Gabb)					r	va	va
Trinacria cor n.s.		c		r			r
Trigonia evansana ? Meek		r	r		c	r	a
Anomia lineata Gabb		r	r	r			
Inoceramus whitneyi ? Gabb		a	c	a		r	
Meekia navis Gabb		c		r			r
Crassatella lomana Cooper				r			va
Crassatella n.s. ?					a	r	
Eriphyla ovoides (Packard)						c	
Eriphyla lapidis (Packard)						r	
Clisocolus cordatus Whiteaves		r		r		r	a
Calva nitida major (Packard)		r	c	c		?va	va
Tenea inflata ? (Gabb)		r	r			c	
Flaventia lens (Gabb)		c		c		r	va
Cymbophora ashburnerii (Gabb)		c	c	va	r	va	a
Cymbophora gabbiana (Anderson)		r	c	a		r	r
Baculites chicoensis Trask				c			a
Metaplacenticeras californicum (Anderson)		a	c	a			c

The stratigraphic relationships of these various localities to one another are as follows: localities 1154, 1155, and 1156 are nearly at the top of the calcareous sandstones, and probably represent essentially the same horizon. Locality no. 1159 is somewhat lower stratigraphically than the three listed above. The exact stratigraphic interval separating the two horizons is not known, but probably does not exceed one hundred fifty feet. Localities no. 1157 and 1158 are separated from the four discussed above by a distance of more than a mile. In Kew's map of this region, several considerable faults are shown cutting the area between the Dayton Canyon and Bell Canyon localities; and evidence of faulting is strong in the immediate vicinity from which the Bell Canyon fossil collections were made. It is not possible to say at this time just what the stratigraphic relations of localities 1157 and 1158 may be to the Dayton Canyon section. The fossils suggest a somewhat greater age, but the evidence is by no means conclusive.

If the fossil lists from the Santa Ana Mountains be compared to those from the Simi Hills, these relationships become apparent: none of the characteristic fossils from the "Actaeonella oviformis zone" - the Baker sandstone - are found in the Simi Hills assemblage. Beds of Baker age are probably entirely absent in the Simi Hills. Such fossil species as Etea angulata, Opis triangulata, and Tenea inflata, that are especially characteristic in the zone of Turritella chicoensis (typical variety) are also absent from the Simi Hills collections. It seems probable that this horizon also is absent in the Simi Hills. The abundant forms from the Simi Hills include such species as Metaplacenticeras californicum, Cucullaea youngi, Turritella chicoensis (giant variety), Cymbophora ashburnerii, C. gabbiana, and Clisocolus cordatus. Such an assemblage is particularly characteristic of the uppermost beds of the Holz shale, and of the Williams formation in the Santa Ama Mountains, and it seems very likely that the calcareous sandstones at the base of the exposed section in the Simi Hills are to be correlated in whole or in part with the two uppermost faunal horizons of the Santa Ama Mountains. If this correlation be correct, the entire fifty-five hundred feet of massive sandstone at the top of the Cretaceous section in the Simi Hills is younger than any beds exposed in the Santa Ana Mountains section studied. It has been thought that part of these sandstones might be Eocene in age. Kew (1924, p. 12) includes them with the Upper Cretaceous, however, on the basis of their conformable relationships with the fossiliferous Cretaceous below, and their unconformable relationships with Martinez (Paleocene) beds above. Since the time of Kew's report *Baculites* has been reported from the top of the sandstone series directly beneath the Martinez contact, apparently confirming Kew's conclusions.

One or two differences in faunal occurrence between the Simi Hills fossiliferous beds, and the fauna of the Williams formation may be mentioned. *Metaplacenticeras pacificum*, the most characteristic fossil of the Williams formation is not present in the collections from the Simi Hills; while *M. californicum* is abundant in the collections from Dayton Canyon, but is very sparingly represented in the Santa Ana Mountains, where it is associated with *M. pacificum*. Elsewhere in California and Oregon, these two species have almost always been found together. In the Santa Monica Mountains, about twenty miles south and southwest of the Simi Hills, *M. pacificum* also occurs, but does not appear to be associated with M. *californicum*. These discrepancies suggest a slight age difference between the Williams formation, and the *Metaplacenticeras* beds of the Santa Monica

Mountains on the one hand and the calcareous sandstone of Dayton Canyon on the other. The ranges in time of the two ammonite species probably overlap somewhat. Their occurrence together in middle and northern California is explainable in this way. Differences in facies or geographic range are hardly admissable as explanations for the facies are similar in all three localities, and the geographic differences are insignificant compared to the known range of both species.

Upper Cretaceous of the Santa Monica Mountains

The latest comprehensive report available on the geology of the Santa Monica Mountains of Los Angeles County, is the work of H. W. Hoots (U. S. G. S. Prof. Paper 165-C). The stratigraphic data offered in the following discussion are derived from Hoots' report. The remarks upon the fauna are partly made on the basis of collections by Dr. Hoots and Dr. W. P. Woodring and now in the California Institute of Technology, and partly upon collections that I made in the summer of 1935.

Stratigraphy

Hoots has distinguished two areas of Cretaceous rocks in the Santa Monica Mountains. The first area is found in the Reseda quadrangle, about two to three miles east of the upper part of Topanga Canyon. The Cretaceous rocks outcrop in a roughly triangular strip that lies on both sides of Mulholland Drive, and measures approximately three miles in length by one mile or less in width. At the base of this section, the Cretaceous rests with an apparently depositional contact on the Santa Monica slates. The basal member of the Cretaceous here is a thick, soft, red, incoherent, greatly decomposed boulder conglomerate, and conglomeratic sandstone. At its greatest development, this member is about seven hundred fifty feet thick. Above this red conglomerate is a member composed principally of hard massive fairly well indurated brown conglomerate, with a subordinate amount of hard dark-gray shale and occasional thick beds of conglomeratic sandstone and of limestone. The total thickness of this member approximates twenty-five hundred feet. A few fossils have been obtained from this upper member, but except that they show the rocks to be marine and Cretaceous in age, have little to offer indicative of the exact relationships of the deposits of the region with the Cretaceous as found elsewhere. Lithologically, the Cretaceous rocks of this area greatly resemble the red Trabuco conglomerate and the overlying Baker conglomerates and sandstones as developed in the Baker Canyon region of the Santa Ana Mountains. The stratigraphic succession is similar in the two areas, and the relationships to the basement rocks are also similar. It is tempting to consider the two sections as probable correlatives, but at present very little direct evidence is available to support this view.

The second Cretaceous area of the Santa Monica Mountains is included in the Topanga Canyon quadrangle. A large part of the lower reaches of Santa Ynez, Temescal, and Topanga Canyons is underlain by Cretaceous rocks. The relationships of the Cretaceous and Martinez (Paleocene) in this region are so complicated, and the terrane so difficult for detailed mapping, that they have been mapped together as "Chico-Martinez". In general, the known Cretaceous rocks are dominantly hard massive coarse brown conglomerates associated with dark-gray shales and dark-gray sandstones. The sandstones are often highly fossiliferous. In the area of Temescal Canyon, the Cretaceous rocks are mostly cobblestone conglomerates with well-rounded boulders, and a matrix of clean gray to greenish-gray sandstone. The total thickness of this conglomerate approaches eight thousand feet in Temescal Canyon.

Fauna

Fossils obtained by Hoots and Woodring (supra, p. 91) from the first area described above include Scaphites, Inoceramus, and Baculites, none of which appear specifically determinable. At one locality (C. I. T. loc. 22), were found Glycymeris veatchii, Trigonia evansana, and Cymbophora gabbiana. This assemblage, while meager, suggests a horizon above the "Actaeonella oviformis zone" of the Santa Ana Mountains, and probably a horizon at least as high as the top of the Holz shale. This locality occurs very near the top of the Cretaceous section in this area. The fauna from the Cretaceous of the Temescal Canyon-Santa Ynez Canyon area is considerably more abundant and diagnostic. Owing to the fact that the Cretaceous and Tertiary of this area have not been critically separated, the exact stratigraphic relationships of these Cretaceous faunas are considerably in doubt. The fossil list submitted, therefore, represents a composite of the collections made in this area by Hoots, Woodring, and myself. I have altered the nomenclature in this list from that given in Hoots' report, to accord with the fossil names used elsewhere in this paper. The composite list of species follows:

Pelecypods:
- Cucullaea youngi Waring
- Parallelodon brewerianus (Gabb)
- Glycymeris veatchii (Gabb)
- Inoceramus sp.
- Trigonia evansana Meek
- Trigonia leana Gabb
- Pholadomya sp.
- Meekia navis Gabb
- Crassatella sp. A
- Crassatella sp. B
- Protocardia sp.
- Calva nitida major (Packard)
- Cymbophora gabbiana (Anderson)
- Corbula sp.

Gastropods:

Gyrodes expansa ? Gabb
Margarites ornatissimus (Gabb)
Turritella chicoensis Gabb
Conchothyra rotunda ? (Waring)
Volutoderma averillii (Gabb)
Oligoptycha obliqua (Gabb)

Cephalopods:

Eutrephoceras sp.
Baculites sp.
"Pachydiscus" sp. A (giant species)
"Pachydiscus" sp. B
"Pachydiscus" sp. C
Metaplacenticeras pacificum (Smith)*
Metaplacenticeras californicum (Anderson)

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* The ammonite species listed by Woodring in Hoots' report as Metaplacenticeras sanctaemonicae (Waring) is here referred to M. pacificum (J. P. Smith). I have had the opportunity of comparing the specimens from the Santa Ana and Santa Monica Mountains and here referred to Smith's species with the type of M. sanctaemonicae at Stanford University. I am inclined to believe that Waring's species upon careful comparison with a good suite of specimens of M. pacificum, will prove to be a variant of this latter species.

The specifically determined fossils listed here all appear in the Williams formation of the Santa Ana Mountains with the exception of Parallelodon brewerianus, and Conchothyra rotunda. The species of Pachydiscus listed are not certainly known to occur elsewhere, at least in those collections available to me. The species of Metaplacenticeras however are both abundant and characteristic in the Williams formation of the Santa Ana Mountains. The Williams formation then, is probably correlative of the Metaplacenticeras beds in the Santa Monica Mountains.

The stratigraphic relationships of the Metaplacenticeras beds of the Santa Monica Mountains to the remainder of the Cretaceous section of this region are not well known. Hoots (supra, p. 93) states that beds carrying Metaplacenticeras pacificum occur near the top of the eight thousand foot thick section of conglomerate in the Temescal Canyon region. The distribution of other localities containing this fauna, suggests also that most of the fossils occur high in the exposed Cretaceous section. Perhaps much of the Cretaceous stratigraphic column, as represented by the Trabuco and Ladd formations of the Santa Ana Mountains, is present in these thick clastic beds below the Metaplacenticeras beds of the Santa Monica Mountains. Much more detailed work in this latter region is necessary however, before this relationship is proved or disproved.

Tentative Correlation of the Cretaceous Section of Southern California

On the basis of the faunal evidence given above, the following tentative correlation is suggested for the Cretaceous deposits of the Santa Ana Mountains, the Simi Hills, and the Santa Monica Mountains:

The Metaplacenticeras beds of the Santa Monica Mountains are correlated with the Williams formation of the Santa Ana Mountains. The calcareous sandstones at the base of the exposed Cretaceous section of the Simi Hills are in part equivalent to the subzone of Turritella chicoensis (giant form) at the top of the Holz shale of the Santa Ana Mountains, and in part (the Metaplacenticeras californicum beds) may be equivalent to the Williams formation. The massive sandstones at the top of the section in the Simi Hills are probably all or nearly all younger than any part of the Cretaceous section of the Santa Ana Mountains. The equivalents of the lower subzone of the Holz shale and of the Baker sandstone and Trabuco formation of the Santa Ana Mountains are absent from the Simi Hills, but may be present in the Santa Monica Mountains. Direct evidence for this latter view is very meager.

It should be emphasized here that the correlations offered above are tentative, rather than the expression of a settled opinion. They are made on the assumption that the ranges and distributions of species are similar in the three areas discussed. So far as available evidence goes, this assumption appears justified. It remains to test this assumption by critical stratigraphic and paleontologic work in a number of areas in the Upper Cretaceous of southern California before it can be regarded as established.

NOTES ON THE UPPER CRETACEOUS DEPOSITS OF THE PACIFIC COAST

Insofar as published information goes, the work done on the Upper Cretaceous of the Pacific Coast is still in the category of pioneer and reconnaissance work. During the last thirty-five years, when the search for petroleum has tremendously accelerated critical study of the Tertiary deposits of the Coast Ranges, the study of the Upper Cretaceous has languished. Only within the last few years have geologists again turned their attention to these latter deposits as promising field for study; and the results of this tardily reawakened interest are but now beginning to appear in publications. Because of this state of knowledge, it is difficult to judge the relationships of the Upper Cretaceous deposits of the Pacific Coast to one another, and to the Upper Cretaceous elsewhere in the world. It is proposed in the next few pages to review some of the attempts that have been made in the last forty-five years to correlate the Pacific Coast section with the later Cretaceous rocks of other parts of the world, and to refer it to a standard section.

DILLER and STANTON [1] in a discussion of the Cretaceous rocks of northern

/1 Diller, J. S., and Stanton, T. W., The Shasta-Chico Series, G. S. A. Bull. no. 5, p. 460, 1894.

California, remark: "It is a significant fact that the most abundant ammonites of the Chico belong to the genus Schloenbachia (in the broad sense in which the name is used in Europe). Ammonites chicoensis, Ammonites tehamaensis, and two undescribed species belong here, and these are all found in the upper beds of the Chico. In other American Cretaceous localities this genus does not pass above the top of the Colorado formation and its equivalents, and in Europe it seems not to occur above the "Emscher Mergel" or lowest Senonian. Ammonites turneri, which was found neat Mt.

Diablo associated with Anchura californica and other lower Chico species is an Acanthoceras closely related to European species that occur in the Cenomanian. The other ammonites known from these beds do not resemble those characteristic of the latest Cretaceous. The two abundant species of Trigonia, T. evansana, and T. Leana likewise have their nearest relatives in the lower part of the Upper Cretaceous of Europe."

KOSSMAT[/2] in the course of a critical study of the ammonites from the Upper

/2 Kossmat, Franz, Untersuchungen über die südindische Kreideformation, Beiträge zur Geolog. unt Paleontol., vol IX, pp. 97-203, 1894-95, vol. XI, pp. 89-148, 1897.

Cretaceous rocks of south India, compares a number of Indian ammonite species with those occurring in the "Chico" formation of California, and with those found in the Nanaimo group of Vancouver Island and the San Juan Islands. These comparisons are significant: Phylloceras nera Forbes (Senonian) with Ph. ramosum Meek (considered identical) from the Nanaimo group of British Columbia; Lytoceras kayei Forbes (Upper Senonian) near L. jukesii Whiteaves (Nanaimo group, Vancouver Island); Hamites rugatus Forbes (Upper Senonian, Valudayur group) near H. aff. cylindraceus Dep. from the Nanaimo group, Vancouver Island); Baculites vagina (typical)(Upper Senonian) near B. occidentalis Meek (Nanaimo group); B. vagina var. simplex near B. chicoensis from "Californien"; Acanthoceras turneri White (Upper Cenomanian, Utatur group) identical with A. turneri ("Chico" beds, Mt. Diablo, Calif.); Pachydiscus otacodensis Stol., (Upper Senonian, Ariyalur group) identical with P. otacodensis (Nanaimo group, Vancouver Island); Desmoceras diphylloides Forbes (Upper Senonian, Ariyalur group) near D. selwynianum Whiteaves, (Nanaimo group, Vancouver Island); Hauericeras gardeni Baily (Upper Senonian, Ariyalur group) identical with H. gardeni from the Nanaimo group, Vancouver Island. These comparisons indicate a close relationship of the Nanaimo group of British Columbia and Sucia Island with the Valudayur and Ariyalur groups of India - groups that are considered well up in the Senonian by Kossmat, and by other European students.

SMITH[3] in studying the development and phylogeny of Metaplacenticeras

/3 Smith, J. P., The Development and Phylogeny of Placenticeras, Calif. Acad. Sci. Proc., Ser. (3), vol. 1, no. 7, pp. 181-229, 1900.

pacificum (Smith) and M. californicum (Anderson), states in regard to these species and the fauna associated with them (p. 204): "It is fair to assume that P. californicum is characteristic of the lower Chico, or Cenomanian portion of the formation", and on p. 210, says: "This fauna almost undoubtedly indicates the lower part of the Chico formation, Cenomanian, Upper Cretaceous".

ANDERSON[4] in a survey of all of the Cretaceous deposits of the Pacific Coast,

/4 Anderson, F. M., Cretaceous Deposits of the Pacific Coast, Calif. Acad. Sci. Proc., Ser. (3), vol. 2, no. 1, pp. 1-152, 1902.

divided the Upper Cretaceous or Chico group into Upper and Lower Chico. Representative localities with Lower Chico faunas include those of Phoenix, Ore., Henley, Siskiyou County, Calif., Silverado Canyon, Santa Ana Mountains, Calif., and San Diego, Calif. Typical Upper Chico localities include the famous Gabb localities of Tuscan Springs, Texas Flat, Chico Creek, and Penz's Ranch, all from the east side of the Upper Sacramento Valley, Calif. The "Lower Chico beds" are correlated with the Nanaimo Group of Vancouver Island and adjoining islands, with the uppermost Utatur beds of India, and the major part of the overlying Trichinopoly beds of India, and with the Turonian horizon of the standard section of Europe. The "Upper Chico" beds are considered the equivalent of the Senonian of Europe, the upper Trichinopoly beds and lower Ariyalur beds of India, and the Montana group of the Great Plains region of North America. Metaplacenticeras, in accord with the earlier view of Smith, is believed a "Lower Chico" form, but probably either uppermost Cenomanian or lowermost Turonian in age.

DE LAPPARENT [5] refers the California Cretaceous beds with Schloenbachia chicoensis and Acanthoceras of the rotomagense group to the Cenomanian. No Turonian beds from the Pacific Coast are recognized, nor are the lower divisions of the Senonian (Emscherian) mentioned. The Aturian or Upper Senonian is believed present at Vancouver Island (Nanaimo group), and in California by beds containing Pachydiscus newberryanus, Baculites chicoensis, Pugnellus, Gyrodes, Trigonia evansana, etc. It is evident from De Lapparent's lists that he has confused the faunal character of the "Chico" as some of the forms quoted as illustrative of the Cenomanian occur in the same beds with forms believed to represent the Aturian.

/5 De Lapparent, A., Traite de Geologie, Paris, 1906, pp. 1408, 1466.

STANTON [6] in a general discussion of the Upper Cretaceous faunas of the United States remarked: "In time range the Chico formation apparently began somewhat earlier and continued somewhat later than the Colorado fauna of the interior seas, but did not extend to the end of the Cretaceous, and latest Cretaceous time is probably not represented by marine deposits on the Pacific Coast." The time range indicated extends from approximately late Cenomanian to middle Senonian in terms of the European standard scale.

/6 Stanton, T. W., Later Mesozoic Invertebrate Faunas of North America, Jour. Geol., vol. 17, 1909, pp. 418-419.

SMITH [7] in discussing the Upper Cretaceous of California, remarks: "The

/7 Smith, J. P., The Geologic Formations of California, Calif. State Mining Bureau. Bull. no. 72, p. 34, 1916.

Upper Cretaceous of California includes only the Chico formation which is distributed along the West Coast from Puget Sound to Lower California, chiefly in the Coast Ranges and on the west side of the Great Valley, but overlaps on the western flank of the Sierra Nevada near Oroville, in Butte County. It may be divided paleontologically into: lower Chico with Schloenbachia oregonensis; and upper Chico with Placenticeras. The lower Chico is probably upper Cenomanian and Turonian in age, equivalent to the Colorado formation, while the upper Chico is probably Senonian, equivalent to the Montana formation". This is the first published reference known to me recognizing the occurrence of "Placenticeras" (Metaplacenticeras of this paper) in the upper part of the Upper Cretaceous section of California, and in beds younger than Cenomanian.

PACKARD /8 in discussing the fauna of the Upper Cretaceous of the Santa Ana

/8 Packard, E. L., Faunal Studies in the Cretaceous of the Santa Ana Mountains of Southern California, Univ. of Calif. Pubs., Bull. Dept. Geol. vol. 9, no. 12, p. 150, et. seq. 1916.

Mountains correlates the uppermost zone (Williams formation of this paper) with the "Type Chico" of Chico Creek. The fauna of the "Type Chico" taken for comparison was collected by Studley (M. S. thesis, Univ. of Calif., 1914) from horizons rather high in the exposed section at Chico Creek, Butte County. Packard regards the fauna of the shales ("Turritella pescaderoensis zone") of the Santa Ana Mountains Cretaceous as being probably in part equivalent to the Chico Creek fauna, and considers that the fauna of the lowest zone in the Santa Ana Mountains, or the "Actaeonella oviformis zone" (Baker sandstone of this paper) is older than anything represented at Chico Creek, but probably not as old as the Horsetown beds. No comparison is made with the European section.

HAUG [9] apparently basing his conclusions upon the article by F. M. Anderson

[9] Haug, Emile, Traite de Geologie, vol. 2, part 2, pp. 1290, 1346-47, 1922.

cited above, refers the "Lower Chico" "incontestably" to the Cenomanian, and refers the "Upper Chico" together with the Nanaimo group of Vancouver Island with similar certitude to the Maestrichtean. Haug suggests that strata of intervening age (Turonian and lower Senonian) are lacking or at least have not been proven to be present in the California area.

ANDERSON [10] described Fagesia californica, F. shastensis, and S. Siskiyou-

[10] Anderson, F. M., The Genus Fagesia in the Upper Cretaceous of the Pacific Coast, Jour. of Pal., vol. 5, no. 2, pp. 121-126, June 1931.

ensis from Upper Cretaceous beds of northern California and southern Oregon. This genus he regards as Turonian in age, and refers the three species described above respectively to middle, lower, and uppermost Turonian in age. The second species described, F. shastensis is stated to occur in association with "Schloenbachia" knighteni Anderson, which also occurs in the Baker sandstone of the Santa Ana Mountains.

SPATH [11] in reviewing the contribution by Anderson above, disputes the as-

[11] Spath, L. F., Palaeontologisches Zentralblatt, Band 1, p. 54, no. 182, 1932.

signment of Fagesia to middle and upper Turonian, and restates his opinion that the genus is characteristic of basal Salmurian (lowermost (?) Turonian) age.

HANNA, TAFF, and CROSS [12] in presenting a paper before the Geological Society

[12] Hanna, G. D., Taff, J. A., and Cross, C. M., Chico Cretaceous at the Type Locality, List of Papers with Abstracts, 34th Ann. Meeting, Geol. Soc. Amer., 1935, p. 32.

of America state that the two thousand feet of Upper Cretaceous strata exposed in the canyon of Chico Creek, Butte County, represent a formational and faunal unit. The predominating cephalopods are referred to the "Schloenbachia group" and are considered to indicate a Cenomanian age. The Panoche and Moreno formations of the Diablo Range of California are believed younger than the type Chico.

ANDERSON and HANNA /13 describe the geology of Cretaceous deposits in Lower

/13 Anderson, F. M., and Hanna, G. D., Cretaceous Geology of Lower California, Calif. Acad. Sci. Proc. (4), vol. XXIII, no. 1, pp. 1-34, December 23, 1935.

California, and describe or discuss in detail twenty-four species of invertebrates including Parapachydiscus catarinae n.s., P. ootacodensis (Stoliczka), P. peninsularis n.s., Nostoceras sternbergi n.s., "Hamites" vancouverensis Gabb, and a number of gastropods and pelecypods. A tentative correlation chart for the Upper Cretaceous of the Pacific Coast is included in the discussion. These points may be noted in connection with this correlation chart: (1) The Catarina formation (Lower California) is correlated with the upper part of the Panoche formation of the Diablo range, with the Cretaceous beds at Pt. Loma, San Diego County, with the upper part of the section in the Santa Ana Mountains (Williams formation ?), and with the Campanian, or uppermost Senonian of Europe. The type Chico fauna is considered to range from approximately lower Cenomanian to middle or upper Turonian age.

The review of opinions given above, beside indicating the confusion of ideas prevailing on the age relationships of the local Cretaceous section shows some interesting developments. We may first note the accumulation of opinion that deposits at least as young as Campanian (Upper

Senonian) are present in the Pacific Coast Upper Cretaceous. Second may be noted the abandonment of the idea of "Upper Chico" and "Lower Chico" as subdivisions of the local section. The original conception responsible for this subdivision apparently was not based upon actual knowledge of the stratigraphic succession of the Cretaceous fauna, but was based upon a mistaken interpretation of faunal lists. As a result, forms as widely separated in time as Senonian and Cenomanian were combined in the "Lower Chico" fauna, and the actual succession of species was in some cases inverted. It is hardly to be wondered at that this composite fauna should be confusing in its aspect. Since it contained both Cenomanian and Senonian elements, it was quite natural to regard the "Lower Chico" as Turonian. Such correlations and stratigraphic assignments as have been attempted have been made almost entirely on the basis of comparison of local faunas with those in Asia or Europe, and less attention has been paid to a careful determination of the local faunal succession. In practice, the testimony offered by the gastropod and pelecypod elements of the fauna has been largely ignored and only the ammonites have been relied upon for correlation. Ammonites are rare in the California Upper Cretaceous section, however, except in sporadic occurrences, and while they are of great value should be used in addition to other testimony rather than to exclusion of it.

These remarks may suggest profitable fields for research in the Upper Cretaceous of the Californian region. Perhaps most necessary of all is a careful study of the stratigraphy of these deposits, with a determination of faunal succession. Next may be suggested a systematic study of the Cretaceous faunas, with careful discrimination of species. A necessary if prosaic part of the work consists of describing and figuring new species with attention to their relationships in Cretaceous deposits elsewhere.

If such work should be prosecuted in "key" regions such as along both borders of the Sacramento Valley, in the Rogue River Valley of Oregon, and in the Diablo Range of middle California, considerable clarification of knowledge of all phases of Upper Cretaceous geology should result.

SYSTEMATIC CATALOG OF THE FAUNA

Introduction

In the following section is offered a catalog of the determined species of the Upper Cretaceous fauna of the Santa Ana Mountains. Partial synonymies are given for the species discussed, listing those references in which descriptions, figures, or critical discussions of the species are given. Usually references giving only the fossil name in a faunal list have been omitted. Any pertinent observations on the relationships or occurrences of these species are included. In the case of new species, beside the formal description, types are named and figured, type localities are designated, and full dimensions of the specimens are given.

Especial attention has been paid in this study to determination of the systematic position and characters of many pelecypods whose exact generic and family relationships had been hitherto in doubt. While the attempt has been made to place every pelecypod species studied in its correct genus, no attempt has been made to adjust purely nomenclatorial tangles. It is regretted that it has not been possible in the time available to treat the gastropods and cephalopods with similar completeness. This is perhaps less important however, for the cephalopods are receiving attention from other workers, and the gastropods are considerably less well known and at present of not such importance in correlation, for that reason. It is hoped that it will be possible to prosecute a critical review of the gastropod fauna of this region in the near future.

The classifications used follow the system of Dall /1 in the pelecypods,

/1 Dall, W. H., in Zittel-Eastman Textbook of Paleontology, 2nd ed., pp. 422-507.

and Pelseneer[1] in the gastropods. In most instances the generic allocations of Stewart[2] have been accepted, except where newly discovered facts have dictated otherwise.

It was originally intended to quote occurrences of species outside of the Santa Ana Mountains area. The present confused state of information in regard to California Cretaceous stratigraphy however would make such citations essentially meaningless, however, and they are omitted. Full lists of occurrences of all species within the Santa Ana Mountains, with stratigraphic range are given. The symbols given in connection with the distribution-lists indicate the relative abundance of each species at each locality where it occurs; that is, "r" ="rare" or less than four specimens in a collection from one locality; "c" indicates "common", i.e. from four to twenty specimens, "a" or "abundant" indicates in excess of twenty specimens from a single locality, and "va" or "very abundant" indicates a species whose individuals compose a considerable proportion of the total number of specimens present in one lot of fossils.

Catalog of Species

PHYLUM MOLLUSCA

CLASS PELECYPODA

Order Prionodesmacea

Superfamily Nuculacea

Family Nuculidae

Genus Acila Adams

/1 Pelseneer, Paul, Lankester's Treatise on Zoology, part V, Mollusca.

/2 Stewart, Ralph, Gabb's Calif. Fossil Type Gastropods, Acad. Nat. Sci. Phil. Proc. vol. LXXVIII, pp. 287-447. Gabb's Calif. Cretaceous and Tertiary Type Lamellibranchs, Acad. Nat. Sci. Phil. Spec. Pub. no 3.

Acila demessa Finlay

1864 Nucula truncata, n.s., Gabb, Paleontology of California, vol. 1, p. 198, pl. 26, fig. 184, 184a, b.

1866 Nucula (Acila) truncata Gabb, Gabb, Am. Jour. Conch., vol. 2, pp. 88, 92.

1871 Nucula (Acila) truncata Gabb, Stoliczka, Pal. Indica. ser. VI, vol. iii, p. 327.

1876-1903 Nucula (Acila) truncata Gabb, Whiteaves, Geol. Sur. Canada, Mes. Fos., vol. 1, pp. 162, 232, 289.

1916 Acila truncata (Gabb), Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, p. 146.

1927 Acila demessa n.n., Finlay, Trans. and Proc., N. Z. Inst. vol. 57, p. 522.

1930 Acila demessa Finlay, Stewart, Acad. Nat. Sci. Phil., Special Pub. no. 3, p. 45, pl. 3, fig. 6.

1934 Acila (Truncacila) demessa Finlay, Schenk, Bull. du Mus. Hist. Nat. de Belgique, T. X, no. 20, p. 42.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. no. 1164(r).

Holz shale member; 94(r), 982(r), 983(c), 985(r), 1057(c), 1059(r), 1162(r).

Williams formation; 974(c), 975(r), 976(c).

Discussion: Acila demessa is one of the very few Cretaceous members of the genus. It is very abundant and widespread in the Upper Cretaceous of the Pacific Coast, and as nearly as may be judged has also a considerable stratigraphic range. It is represented in the Baker sandstone of the Santa Ana Mountains, as well as in the higher members of the section. It thus is one of the very few species that appears in all members of the section.

Family Nuculanidae

Genus Lembulus Risso

Lembulus striatula (Forbes)

1846 Leda striatula n.sp., Forbes, Geol. Soc. London, Trans. ser. 2., vol. 7, p. 148, pl. 17, fig. 14.

1871 Yoldia striatula (Forbes), Stoliczka, Pal. Indica., ser. VI, vol. 3, p. 323, pl. IV, fig. 2, pl. XVII, fig. 6.

1879 Yoldia striatula (Forbes), Whiteaves, Geol. Sur. Can., Mes. Foss., vol. 1, p. 162, pl. 18, fig. 9.

Distribution: Williams formation; C. I. T. loc. nos. 974(c), 975(r).

Discussion: This little shell is referred to Forbes' species with some misgivings. I can find no grounds for separation however, in comparing the Santa Ana Mountains specimens with Forbes' and Whiteaves' descriptions and figures.

Stewart (supra, p. 53) refers to Lembulus those equilateral nuculanids having wavy sculpture that trends slightly oblique to the shell borders. "Leda" translucida Gabb and "Yoldia" arata Whiteaves, both of the Pacific Coast Cretaceous are also referred to this genus by Stewart. The former species differs from L. striatula in having a pointed rather than a truncate posterior border, and in having no posterior umbonal angulation. Similarly "Yoldia" arata is triangular in shape and pointed posteriorly.

Superfamily Arcacea

Family Parallelodontidae

Genus Parallelodon Meek and Worthen

Parallelodon brewerianus (Gabb)

1864 Arca breweriana n.s., Gabb, Pal. Calif., vol. 1, pp. 193, 235, pl. 25, fig. 181.

1879 Nemodon vancouverensis (Meek) ?, Whiteaves, Geol. Sur. Can. Mes. Foss., vol. 1, pp. 163, 392, pl. 19, figs. 1, 1a.

1917 Nemodon (Arca) breweriana (Gabb), Waring, Calif. Acad. Sci. Proc. (4), vol. VII, no. 4, p. 57, pl. 7, figs. 5, 6.

1930 Parallelodon brewerianus (Gabb), Stewart, Acad. Nat. Sci. Phil. Special Pub. no. 3, p. 69, pl. 3, fig. 1.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 79(r), 1062(c).

Holz shale member; 453(c), 454(c), (489(r), 982(r), 1053(va), 1054(r), 1055(r), 1063(c), 1064(r), 1160(r), 1162(c), 1163(r), 1166(r), 1170(a), 1171(c), 1172(r), 1173(a).

Discussion: Parallelodon brewerianus appears to be a species with a long range in time and a wide distribution geographically. It is widespread throughout the Upper Cretaceous of the Pacific Coast and has even been reported from the Horsetown beds. It is probably of subordinate value as an index fossil. In the Santa Ana Mountains, it has not been reported from the Williams formation, but apparently occurs in beds in the Santa Monica Mountains that are approximately of Williams age.

Genus Cucullaea Lamarck

Cucullaea youngi Waring

1917 Cucullaea youngi n.sp., Waring, Calif. Acad. Sci. Proc. (4), vol. VII, no. 4, p. 59, pl. 8, fig. 12.

1922 ? Cucullaea ponderosa Whiteaves, Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10, p. 416.

1922 ? Cucullaea (?) cordiformis n.sp., Packard, op. cit., p. 417, pl. 24, fig. 1.

1916 ? Cucullaea truncata Gabb, Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, p. 146.

Distribution: Ladd formation, Holz shale member; 83(c), 93(r), 94(?r), 95(a), 453(r), 455(a), 982(r), 983(r), 985(r), 1053(va), 1054(c), 1055(r), 1059(r), 1060(r), 1063(r), 1163(r), 1169(r), 1170(r), 1173(r).

Williams formation; 974(c), 1052(r), 1056(r), 1066(r).

Discussion: *Cucullaea youngi* may prove to be conspecific with *C. ponderosa* Whiteaves, from the Nanaimo Division of Vancouver Island, B. C. Specimens of the latter species appear to be rare, and I have not seen any. In his description of *C. ponderosa*, Whiteaves remarks (1900, p. 294): "Anterior side short.......posterior side broader, and a little longer than the anterior" and he gives as the dimensions of a large specimen - "maximum length, 117 mm.; height, inclusive of either umbo 86 mm.". This characterization suggests a decided difference from the features of *C. youngi*, which in a number of good specimens measured shows height and length of the valves approximately equal, and which also shows the posterior side of the shell to be shorter than the anterior side. For these reasons, *C. youngi* is believed to be distinct from *C. ponderosa*.

It seems probable that most of the references to occurrences of *Cucullaea truncata* Gabb in the Santa Ana Mountains represent young specimens of *C. youngi* Waring. A number of specimens of a large *Cucullaea* in the California Institute of Technology collections from Cottonwood Creek, just below the mouth of Hulen Creek, Shasta County, agree almost exactly with the shape, proportions, and sculpture of the specimen figured by Stewart (1930, pl. 2, fig. 7) and are believed to represent typical *C. truncata*. This species may readily be separated from *C. youngi* by its longer hinge-line and posterior dorsal margin, by its prominent radial sculpture, and by its lower beaks. I have not yet certainly distinguished *C. truncata* in southern California.

Cucullaea sp. cf. *C. gravida* (Gabb)

1916 ? *Cucullaea decurtata* (Gabb), Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, p. 146.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 82(va), 301(r), 1062(c), 1164(va).

Holz shale member; 454(a), 1064(va).

Discussion: This species is a rather small plump shell with delicate radial ribbing in which every third rib is slightly larger than the two succeeding ones. In appearance it resembles Gabb's figure of "Arca" gravida, though according to the figure and to the dimensions of Cucullaea gravida by Stewart (1930, p. 77) the shells from the Santa Ana Mountains will average larger than C. gravida and are proportionally slightly higher and not quite so thick. Stewart suggests (supra) that C. decurtata is probably a synonym of C. gravida; but the actual characters of C. decurtata appear to be in doubt. The type is evidently very poorly preserved, and in view of this condition, many of the identifications of this species from California and Oregon Cretaceous localities may be questioned.

Cucullaea lirata Packard

1922 Cucullaea lirata n.sp., Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10, p. 417, pl. 24, fig. 2, pl. 25, fig. 3.

Distribution: Ladd formation, Holz shale member, C. I. T. loc. nos. 453(r), 455(r).

Discussion: This rather low elongate form with anteriorly placed umbones and sculpture of prominent close-set radial ribs is probably to be referred to Packard's species. I have found no record of the occurrence of this form except in the Santa Ana Mountains.

Family Arcidae

Genus Trigonarca Conrad

Trigonarca californica Packard

1922 Trigonarca californica n.sp., Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10, p. 418, pl. 25, figs. 2a, 2b.

1922 ? Trigonarca excavata n.sp., Packard, op. cit., p. 418, pl. 25, figs. 1a, 1b.

1922 Trigonarca sectilis n.sp., Packard, op. cit., p. 419, pl. 27, figs. 1a, 1b, 1c.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 80(va), 84(c), 87(a), 456(a), 978(r), 979(c), 981(va), 986(c), 1058(a), 1067(c), 1068(a), 1069(a), 1070(c), 1071(c).

Discussion: Packard (supra) described three species of Trigonarca from the Baker sandstone of the Santa Ana Mountains. These three species differed in shape and size, but apparently were similar in sculpture. I have examined more than two hundred specimens of Trigonarca from the Santa Ana Mountains in the course of this study, and am unable to find any character or group of characters in this assemblage by which more than one species may be discriminated. Forms corresponding to all of Packard's three species are present in this suite of specimens; but these appear to be connected with one another by every degree of transition of form. This suggests that T. sectilis and T. excavata should be considered as variants of of T. californica (the dominant form) rather than as separate species. They are so treated here.

Stewart (1930, p. 77) has suggested that Trigonarca californica does not represent true Trigonarca. I was able recently to compare several specimens of Trigonarca californica from the Santa Ana Mountains with a good specimen of T. maconensis (genotype of Trigonarca) from the Upper Cretaceous of Georgia. The following differences may be noted: (a) T. maconensis is strongly inequilateral with the beaks placed posterior to the mid-length of the shell; T. californica has the beaks slightly anterior to the mid-line of the shell in most individuals, but because of the variability in shape mentioned above has the beaks strongly anterior in some individuals and nearly at the mid-length in others; (b) T. maconensis is apparently opisthogyrate, though the beak is eroded somewhat, and its actual orientation is uncertain; T. californica is essentially orthogyre; (c) the cardinal area of T. maconensis is about four-fifths anterior to the beaks; the cardinal area of T. californica is about equally divided by the beaks. The differences noted here seem scarcely sufficient to justify generic division of these two species.

Trigonarca californica is one of the most abundant and characteristic fossils of the basal beds of the Cretaceous of the Santa Ana Mountains. The species is apparently restricted to the lower portion of these sandstones, and is not well represented in the beds just below the shale contact, where its place appears to be taken by Cucullaea cf. C. gravida. Packard (supra) reports Trigonarca sectilis from the Upper Cretaceous of Oregon, but I know of no other citation of the occurrence of the genus elsewhere on the Pacific Coast.

Genus Glycymeris da Costa

Glycymeris veatchii (Gabb)

1864 Axinaea veatchii n.s., Gabb, Pal. Calif., vol. 1, p. 197, pl. 25, figs. 183, 183a.

1900 Pectunculus veatchii Gabb, Whiteaves, Geol. Sur. Canada, Mes. Foss., vol. 1, p. 391, pl. 47. figs. 3, 4.

1902 Pectunculus veatchii Gabb, Anderson, Calif. Acad. Sci. Proc. (3), vol. II, no. 1, p. 35.

1917 Glycymeris veatchii (Gabb), Waring, Calif. Acad. Sci. Proc. (4), vol. VII, no. 4, p. 61, pl. 8, figs. 2, 7, 8.

1930 Glycymeris veatchii (Gabb), Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, p. 70, text fig. 1, pl. 1, fig. 7.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 83(va), 93(c), 94(c), 95(c), 453(c), 455(r), 489(r), 982(va), 983(va), 985(c), 1053(a), 1054(va), 1059(a), 1060(r), 1061(c), 1057(r), 1063(r), 1160(r), 1162(r), 1163(r), 1166(r), 1168(a), 1169(a), 1170(r), 1171(r).

Williams formation; 86(r), 974(va), 975(c), 976(c), 1052(a), 1066(r).

Discussion: Anderson (1902, p. 35) suggests that at least two varieties and perhaps one closely related new species are to be distinguished among the forms that have been referred to Glycymeris veatchii on the Pacific Coast. Stewart (1930, p. 71) suggests that specimens referred to this species from Tuscan Springs, the type locality, probably are specifically different from specimens from Penz.

The Santa Ana Mountains forms compare well in all particulars with specimens in the California Institute of Technology collections from Tuscan Springs, and are believed to represent the typical form. Most of the specimens from the Santa Ana Mountains are small, averaging perhaps fifteen to thirty millimeters in altitude. Occasional giant forms appear in the collections with altitudes of fifty to sixty millimeters. No basis has been found except that of greater size, by which the giant forms could be separated specifically from the normal ones; and they are believed to represent true veatchii. The giant forms have no stratigraphic individuality, for they occur usually in the same bed that yields many specimens of the smaller forms. Examination of collections from the Cretaceous from middle and northern California shows that this species exhibits this peculiarity of growth elsewhere as well as in the Santa Ana Mountains.

Glycymeris pacificus (Anderson)

1902 Pectunculus pacificus sp. no., Anderson, Calif. Acad. Sci. Proc., vol. II, no. 1, p. 74, pl. VII, fig. 159.

1916 Glycymeris pacificus (Anderson), Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, p. 146.

Distribution: Ladd formation, Baker member; C. I. T. loc. nos. 80(va), 82(r), 87(c), 981(r), 1058(r), 1065(r), 1068(c), 1069(a), 1070(r), 1164(c).

Holz shale member; 92(c), 1064(r).

Discussion: This shell is to be distinguished from Glycymeris veatchii by the character of its sculpture, which consists of bundles of very fine radial striae. In shape, the shell is inflated, and nearly circular in outline. It apparently is confined to the lower fossiliferous zone in the Santa Ana Mountains. In northern California and southern Oregon, the species is found also at horizons near the base of the Upper Cretaceous section.

Family Limopsidae

Genus Trinacria Mayer

Trinacria cor n.s.

Plate 9, figs. 1 - 3.

Description: Shell large and massive for the genus, high, short, angular. Beaks small, sharply incurved, opisthogyrous. Dorsal anterior margin concave directly in front of the beaks, merging thence into the tumid anterior margin; ventral margin slightly curved to nearly straight; posterior margin abruptly truncate back of the beaks, separated from the lateral portions of the shell by a sharp umbonal angulation, lateral and ventral surfaces of the shell meeting at nearly a right angle; posterior margin back of the angulation nearly flat. Sculpture of fine growth-lines with occasional deeper incised concentric grooves marking resting stages of growth. Very fine, rather widely spaced radial lines appear on well-preserved specimens. Area short, amphidetic, shallow, directly beneath the beak. Dentition of about five minute chevron-shaped teeth on each side of the beaks. Muscle scars and pallial line unknown.

Type Locality: C. I. T. Invertebrate Paleontology loc. no. 974.

Holotype: C. I. T. Invertebrate Paleongology cat. no. 3418.

Dimensions of holotype: Height, 14.0 mm., length, 16.0 mm., thickness, 6.4 mm.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. no. 1058(r).

Holz shale member; 83(c), 92(r), 94(c), 982(c), 983(r), 985(c), 1060(r), 1061(c), 1168(c).

Williams formation; 974(a), 975(r), 976(c), 1066(r).

Discussion: This species has also been found in the Upper Cretaceous of the Simi Hills and of the Santa Monica Mountains, and has been found in the "type Chico" beds of Chico Creek, Butte County.

One other species of Trinacria (T. galeata) has been reported from the Cretaceous (Holzzapfel, 1889, p. 213), but the genus finds its greatest development in the Eocene, where it is rather common in Alabama and in the Paris Basin. It has been reported from the Oligocene of Washington by Clark, (1925, p. 81) and from the Miocene Alum Bluff group of Florida by Dall (1898, p. 604) and Gardner (1926, p. 22), but Stewart has questioned the reference of these species to Trinacria. If these references be incorrect, the known range of the genus will be Upper Cretaceous and Eocene.

Trinacria cor differs from all other specimens or illustrations of members of the genus I have seen by its relatively large, massive shell, its high beaks, and by the very abruptly truncated posterior border. It is from two to three times longer than any other member of the genus for which I have found dimensions.

Superfamily Pteriacea

Family Pinnidae

Genus Pinna Linnaeus

Pinna calamitoides Shumard

1858 Pinna calamitoides n.sp., Shumard, Acad. Sci. St. Louis. Trans., vol. 1, p. 124.

1879 Pinna calamitoides Shumard, Whiteaves, Geol. Sur. Can., Mes. Foss., vol. 1, p. 167, pl. 20, figs. 1, 1a, 1b.

1916 Pinna cf. C. calamitoides Shumard, Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9. no. 12, p. 147.

1917 ? Pinna calamitoides Shumard, Waring, Calif. Acad. Sci. Proc., (4), vol. VII, no. 4, p. 64, pl. 9, fig. 4.

1930 Pinna calamitoides Shumard, Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, p. 134.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 87(r), 456(r), 986(r), 1062(r), 1069(r).

Holz shale member; 92(r), 454(r).

Discussion: This species is represented in the main by very poorly preserved fragments from the lower sandstone of the Santa Ana Mountains. One specimen from locality number 92, however, is nearly complete, showing the sculpture and shape well, and showing also the muscle scars where the shell has been peeled away from the cast in two places. In form and ornamentation this specimen accords well with the specimen figured by Whiteaves (supra), but differs from the specimen figured by Stewart (1930, p. 133, text fig. 4) as *Pinna breweri* in having only one or two radial ribs present on the ventral half of the shell, and in having the ventral diagonal undulations much more closely spaced as is suggested in Whiteaves' figure. This lends support to Stewart's suggestion that *Pinna breweri* and *P. calamitoides* are distinct.

Family Pernidae

Genus Inoceramus Parkinson

? *Inoceramus whitneyi* Gabb

1869 *Inoceramus whitneyi* n.sp., Gabb, Pal. Calif., vol. 2, pp. 193, 247, pl. 32, fig. 91.

1917 *Inoceramus whitneyi* Gabb, Waring, Calif. Acad. Sci. Proc., (4), vol. VII, no. 4, p. 62, pl. 8, fig. 9.

1930 *Inoceramus whitneyi* Gabb, Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, p. 105, pl. 2, fig. 1.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. no. 982(r).

Discussion: The identity of the lone specimen of *Inoceramus* in the California Institute of Technology collections from the Santa Ana Mountains with *I. whitneyi* is not certain. It agrees well with better preserved material from the Simi Hills, and these latter specimens in turn agree well with the type of *I. whitneyi* figured by Stewart (supra). *I. pembertoni* Waring (1917, p. 61) may prove to be only an unusually large representative of this species.

Superfamily Trigoniacea

Family Trigoniidae

Genus Trigonia Bruguiere

Trigonia evansana Meek

1858 Trigonia evansana Meek, Trans. Albany Inst., vol. 4, p. 42.

1864 Trigonia evansii Meek, Gabb, Pal. Calif., vol. 1, p. 189, pl. 25, fig. 177.

1917 Trigonia evansana Meek, Waring, Cal. Acad. Sci., Proc., (4), vol. VII, no. 4, p. 65, pl. 8, fig. 6.

1921 Trigonia evansana Meek, Packard, Univ. of Oregon Pub., vol. 1, no. 9, p. 25, pl. 9, figs. 5, 6.

1930 Trigonia evansana Meek, Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, p. 93.

Distribution: Ladd formation, Baker sandstone member; 79(r), 80(r), 82(c), 84(r), 97(r), 99(r), 301(r), 302(r), 1062(r), 1068(va), 1069(a), 1070(va).

Holz shale member; 83(c), 93(r), 453(r), 455(r), 489(r), 985(r), 1053(r), 1054(c), 1055(r), 1057(r), 1060(r), 1063(r), 1162(r), 1163(r), 1167(r), 1168(c), 1169(r), 1170(r), 1173(c).

Williams formation; 86(c), 974(c), 975(r), 976(r), 1052(r), 1066(r).

Discussion: As shown by reference to the distribution list above, the forms here referred to T. evansana range throughout the section in the Santa Ana Mountains Cretaceous. Well-preserved specimens occur in a number of localities in the Baker sandstone, and appear to represent true evansana. The identity of the Trigoniae of the Holz shale and Williams formation with those in the Baker sandstone is not beyond question however. It has proved almost impossible to get well-preserved specimens of this genus from the upper portion of the section. Most of the specimens collected at these levels are internal casts or badly decorticated individuals. So far as may be made out, the specimens collected from higher horizons than the Baker sandstone appear to have slightly coarser sculpture than typical T. evansana, and appear to be larger and more inflated in shape. They may represent T. inezana Packard, which Dr. Packard states has been confused with *T. evansana* in many localities and many fossil lists (supra, p. 25, 27).

Trigonia leana Gabb

1864 *Trigonia gibboniana* Lea ?, Gabb, Pal. Calif., vol. 1, p. 190, pl. 17, fig. 178, pl. 31, fig. 262.

1876 *Trigonia leana* n.s., Gabb, Acad. Nat. Sci. Phil. Proc., p. 312.

1921 *Trigonia leana* Gabb, Packard, Univ. of Oregon Pub., vol. 1, no. 9, p. 20, pl. 5, figs. 1, 2, 3, 5, 6, pl. 6, fig. 1, pl. 7, fig. 1.

1930 *Trigonia leana* Gabb, Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, p. 92.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. no. 1169(r).

Discussion: A single specimen of this species has been selected in the course of this investigation. The species appears also to occur in the Santa Monica Mountains *Metaplacenticeras* beds.

Superfamily Pectinacea

Family Pectinidae

Genus Syncyclonema Meek

Syncyclonema operculiformis (Gabb)

1864 *Pecten operculiformis* n.s., Gabb, Pal. Calif., vol. 1, p. 201, pl. 26, fig. 188.

1930 *Syncyclonema operculiformis* (Gabb), Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, pp. 120, 121.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 79(r), 80(r), 84(r), 99(r), 978(c), 981(r), 1058(r), 1062(c), 1065(r), 1069(r), 1070(r).

Discussion: This small pecten is restricted in the Santa Ana Mountains to the Baker sandstone. Elsewhere it has been reported from localities in middle and northern California that seem to represent the lower parts of the Upper Cretaceous section. The actual range of this fossil, like that of most other West Coast Upper Cretaceous species is very uncertain, however.

Family Limidae

Genus Lima Bruguiere

Subgenus Limatula Wood

Lima (Limatula) sp. cf. L. suciensis Whiteaves

Plate 9, fig. 4.

Description: Shell small, thin, slightly inequilateral, slightly higher than broad, outline gibbous; anterior dorsal slope slightly concave from the umbo to about one half the distance from the umbo to the ventral border; ears approximately equal, small; beaks low and pointed; sculpture on the posterior half of the shell of very fine radiating lines crossed by fine growth lines producing a minute cancellation; sculpture on the anterior portion of the shell of low smooth sharp-crested ridges separated by interspaces several times the width of the ridge; anterior dorsal slope unornamented except for growth-lines.

Dimensions of a specimen: height, 18.0 mm., length, 17.2 mm., thickness of one valve approximately 4.0 mm.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 1068(r), 1069(r).

Discussion: The subgenus Limatula to which this species is referred includes straight or slightly oblique forms with pronounced sculpture on the middle portion of the valves, and with the posterior and anterior slopes of the valves smooth or finely sculptured.

This species of Lima is represented in the collections by two individuals, both right valves, and both imperfect. The figured specimen is broken along the ventral border, but shows the sculpture and outline of the shell excellently. The other specimen has been distorted by pressure, but is nearly perfect insofar as the shell substance is concerned.

This Lima agrees fairly well in outline and in size with Whiteaves' figure of L. suciensis (Whiteaves, 1903, p. 399, pl. 51, fig. 2) and may be conspecific with it. Whiteaves' description includes the following remarks: "Surface markings consist of small narrow radiating ribs that are everywhere crossed by concentric striae or lines of growth. From eleven to fourteen of these ribs are a little larger than the rest, and in testiferous specimens the spaces between them when examined with a lens are seen to be occupied by from four to six close-set minute radiating ridges". These features suggest the subgeneric characters of Limatula, but unfortunately Whiteaves' figure of the species is not sufficiently good to determine the characters completely.

I find no reference to any other Lima from the Pacific Coast Cretaceous resembling this Santa Ana Mountains species.

Subgenus Acesta H. and A. Adams

Lima (Acesta) beta n.s.

Plate 9, fig. 5.

Description: Shell moderately large, thin, fragile, pyriform, slightly convex; beaks low; anterior margin nearly straight, excavated dorsally;

anterior ear very slightly developed; posterior and ventral margins forming a sweeping regular curve; posterior ear small, obliquely truncate; sculpture of narrow radiating ribs toothed on the crests and separated from one another by concave interspaces three or four times wider than the ribs; interrib areas ornamented only by fine growth-lines; resilium pit oblique toward the posterior side.

Holotype: C. I. T. Invertebrate Paleontology cat. no. 3424.

Type Locality: C. I. T. Invertebrate Paleontology loc. no. 1069.

Dimensions of type: height, 35.3 mm., length, 27.3 mm., thickness of one valve, approximately 5.0 mm.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 80(c), 82(a), 87(r), 99(c), 302(c), 456(c), 981(r), 1058(a), 1062(r), 1065(c), 1068(va), 1069(a), 1070(c), 1164(c).

Holz shale member; 455(r).

Discussion: The subgenus Acesta to which this species is referred includes Limas with straight anterior margins, small to obsolete anterior ears, and with oblique ligament pits extending under the posterior ear.

Of the other West Coast Cretaceous Limas, only L. microtis Gabb bears any resemblances to L. beta. In his diagnosis of L. microtis, Gabb remarks: "Ornamented by numerous flat radiating entire ribs, not dichotomous, the interspaces forming shallow grooves serrated on the sides and marked in the middle by a series of small pits or punctations". In contrast to this description, the ribs of Lima beta are sharp-crested and denticulate on top. No sign of punctations or serrations appears on the interspaces.

Family Spondylidae

Genus Plicatula Lamarck

Plicatula sp. cf. P. variata Gabb

1864 ? Plicatula variata n.s., Gabb, Pal. Calif., vol. 1, p. 203, pl. 26, fig. 90.

1916 ? Plicatula n.s., A., Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, p. 147.

1930 ? Plicatula variata Gabb, Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, p. 114, pl. 6, figs. 3, 4, 5.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 981(c), 1067(r).

Discussion: This species resembles the figures given by Gabb and Stewart (supra) for Plicatula variata, and may well prove to be identical with it. Gabb's material came from "Cottonwood Creek", a locality that has furnished several others forms close to or identical with species found in the Baker sandstone of the Ladd formation.

Genus Spondylus Linnaeus

Spondylus subnodosus (Packard)

1922 Lima subnodosa n.s., Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 13, no. 10, p. 421, pl. 28.

1922 Spondylus striatus n. s., Packard, op. cit., p. 422, pl. 29.

Distribution: Holz shale member of the Ladd formation; C. I. T. loc. no. 95(c).

Discussion: The only specimens of this interesting species in the California Institute of Technology collections are from a faulted block of Cretaceous outcropping in Bee Canyon, about five miles southwest of the Cretaceous outcrops in the Harding Canyon-Santiago Canyon areas. The stratigraphy of this region is not clear, and the relationships of the fossils contained therein with those in the Cretaceous sequence to the northeast are yet uncertain. The remainder of the fauna from the Bee Canyon beds suggests that of the top of the Holz shale member, however.

Two or three nearly perfect specimens of this species are in the California Institute of Technology collections. Some of these have both valves together. The left valves of these Spondyli accord almost exactly with Packard's figure and description of Lima subnodosa, and there can be little doubt that Packard's specimen is identical specifically with them. It has been possible to expose the hinge of the left valve of one of the Bee Canyon forms. The revealed dentition is that of a typical Spondylus.

The following notes will supplement Packard's original description of this form: right valve roughly oval in outline, very thick and heavy; valve surface concave dorsally, nearly flat ventrally; hinge region very heavy with a large triangular area; sculpture of broad low rounded ribs, each rib consisting of a bundle of seven or eight flat-topped riblets; ventral exterior of shell overlain with crude discontinuous concentric undulations or rugosities.

With the exception of another species of Spondylus described by Packard from the Santa Ana Mountains, and of a dubious indeterminate species listed by Whiteaves (1903, p. 400) from British Columbia, I find no other record of the appearance of this genus in the Upper Cretaceous rocks of the Pacific Coast. Spondylus calcaratus Forbes from the Trichinopoly group of India suggests S. subnodosa in shape and sculpture but is not so large.

? Spondylus rugosus Packard

1922 Spondylus rugosus n.s., Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10, p. 422, pl. 27, fig. 3, pl. 30, fig. 3, pl. 31, fig. 3.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 79(r), 84(r).

Discussion: The specimens doubtfully referred to this species are two in number. The specimen from locality 84 has the left (upper) valve well preserved. The general shape of this specimen agrees fairly well with the left valve figured by Packard (op. cit., pl. 31, fig. 3), though Packard's specimen is evidently considerably larger than the form I have studied. The sculpture of the *Spondylus* from locality 84 is well preserved and consists of numerous fine crowded wavy irregular radiating ribs. The hinge shows a narrow resilifer with sockets on either side and blunt dorsally curved teeth outside of the sockets. The right valve of this specimen is not well preserved.

The specimen from locality 79 is smaller than the one from locality 84. Both valves are preserved, though the sculpture is not well shown on either. The sculpture of the right valve is composed mainly of rather irregular growth-lines, though there is a suggestion of radial lines where the surface shelly layer has been eroded.

Superfamily Anomiacea

Family Anomiidae

Genus Anomia Miller

? *Anomia* cf. *A.* *lineata* Gabb

Distribution: Ladd formation, Holz shale member; 94(c), 489(r), 1059(r), 1060(r), 1061(r).

Williams formation; 975(r), 1052(r), 1066(r).

Discussion: The specimens doubtfully referred to *Anomia* are almost all lacking the outer shelly layer, and are otherwise poorly preserved.

They compare fairly well with specimens from Clover Creek, Shasta County, which presumably represent A. lineata, but judgment on the identity of the species will be withheld until better material is available.

Superfamily Mytilacea

Family Mytilidae

Genus Inoperna Conrad

Inoperna bellarugosa n.sp.

Plate 9, figs. 6, 7.

Description: Shell of moderate size, elongate, compressed, gently concave on the ventral and convex on the dorsal margin, margins diverging gently posteriorly; beaks low and small, markedly anterior but not terminal; anterior end smoothly rounded into the ventral side; posterior end also smoothly rounded with no marked posterior truncation; posterior umbonal angulation low and broad, extending from the umbo to the ventral posterior margin; sculpture consisting of narrow concentric lamellae paralleling the border of the shell, and of strong undulations developed upon the dorsal posterior border, paralleling the growth lines dorsally, but dying out at the posterior umbonal angulation; undulations variable in their development on different individuals; internal characters of the shell unknown.

Holotype: C. I. T. Invertebrate Paleontology cat. no. 3420.

Paratype: C. I. T. Invertebrate Paleontology cat. no. 3421.

Type Locality: C. I. T. Invertebrate Paleontology loc. no. 1068.

Dimensions of type: Height, 18.7 mm., length, 42.3 mm., thickness, 13.9 mm.

Discussion: Inoperna bellarugosa resembles Volsella siskyouensis (Gabb) somewhat in the character of the sculpture, but may easily be distinguished from this latter species by the characteristic dorsal posterior undulations, by its more smoothly rounded posterior margins, and by the more gently tapering outline of the shell. Inoperna bellarugosa probably represents those forms from the Santa Ana Mountains that have been referred to V. siskiyouensis.

Inoperna flagellifera (Forbes) from the Valudayur group of India (Stolieska, 1871, p. 379) and the Upper Greensands of England (Woods, 1900, p. 99) is longer and more slender than I. bellarugosa. Inoperna carolinensis Conrad from the Ripley formation of Coon Creek, Tennessee, and the Black Creek formation of North Carolina apparently has the dorsal undulations somewhat smaller and more numerous.

Woods (supra, p. 99) states that "Modiola" flagellifera belongs to a molluscan group characteristically developed in the Jurassic rocks.

Genus Brachidontes Swainson

Brachidontes bifurcatus n.sp.

Plate 10, fig. 2.

Description: Shell small, thin, inflated; beaks low, incurved, markedly anterior; anterior end narrow, inflated, rounded; dorsal margin straight, two thirds the length of the entire shell; posterior margin gently convex, obliquely truncate; ventral margin very slightly emarginate; posterior umbonal ridge sharply angular near the beaks, becoming progressively lower and more broadly rounded toward the posteroventral border; sculpture consisting of numerous radial flat-topped ribs separated by interspaces as wide as the ribs, strongly developed on the posterodorsal slope of the shell and on the umbonal ridge, abruptly ceasing slightly anterior to the umbonal angulation; sculpture on the anterior portion of the shell of growth-lines only, or with exceedingly fine radial striae in addition; radial ribs occasionally bifurcating along the umbonal ridge; internal shell border crenate; dentition unknown.

Type: C. I. T. Invertebrate Paleontology cat. no. 3425.

Type Locality: C. I. T. Invertebrate Paleontology loc. no. 974.

Dimensions of the type: length, 8.0 mm., height, 5.0 mm., thickness of one valve, 2.0 mm.

Distribution: Williams formation; C. I. T. loc. nos. 974(c), 1056(r).

Discussion: This species is placed in the genus *Brachidontes* on the basis of the shape and sculpture of the shell, and the crenate inner margin, which is visible in broken specimens. If the generic designation be correct, this is the first record of the appearance of *Brachidontes* in the Cretaceous of the Pacific Coast, nor do I find reference to the appearance of this genus elsewhere in the North American Cretaceous. Woods (1900, p. 101 et seq.) has recognized this genus in the Cretaceous of England.

Order Anomalodesmacea

Superfamily Anatinacea

Family Pleuromyacidae

Genus Pleuromya Agassiz

? *Pleuromya papyracea* Gabb

1869 *Pleuromya papyracea* n.s., Gabb, Pal. Calif., vol. 2, pp. 178, 235, pl. 29, fig. 66.

1930 Pleuromya (?) papyracea Gabb, Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, p. 303, pl. 2, fig. 5.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. no. 978(r).

Discussion: A single fragmentary specimen from the Baker sandstone is doubtfully referred to Gabb's species. The type of the species comes from "Cottonwood Creek", Shasta County, and the species has been reported from the Horsetown beds.

Superfamily Poromyacea

Family Poromyacidae

Genus Liopistha Meek

Section Psilomya Meek

Liopistha (Psilomya) hardingensis (Packard)

Plate 9, fig. 8, plate 10, fig. 16.

1922 Homomya hardingensis n.sp., Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10, p. 423, pl. 32, figs. 1a, 1b.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 79(r), 87(r), 456(r).

Discussion: This large shell is a Liopistha of the group of L. superba (Stoliczka) and L. gigantea (Sowerby). These notes supplement the original description of the species: sculpture of L. hardingensis consists of rather coarse concentric growth lines; of undulatory concentric ridges strongly developed at the beaks but becoming progressively weaker ventrally to a distance of three or four centimeters from the beaks where they vanish; and of radial lines, strongly developed at the beaks but appearing on the ventral part of the shell as rows of rather widely spaced raised granules.

Where the granules are broken off, their bases appear as shallow pits. Dentition not well shown but consists apparently of two lamellar teeth in the right valve, the anterior tooth being smaller, and oblique; one rather small tooth in the left valve separates the sockets that receive the right cardinals; ligament external and rather short; a pronounced ridge extends from the beak to the anterior extremity delimiting a concave anterior dorsal area devoid of sculpture except for growth-lines; anterior end apparently close; posterior end narrowly gaping.

As suggested above, Liopistha hardingensis is much like L. superba (Stoliczka) from the Trichinopoly group of India, and L. gigantea (Sowerby) from the Upper Cretaceous beds of Blackdown, England. L. hardingensis differs from both of these latter species in having a narrower and more pointed posterior extremity. I have found no other reference of the presence of the section Psilomya elsewhere in the Cretaceous of America.

Liopistha anaana (Anderson)

Plate 10, figs. 1, 3.

1902 Pholadomya anaana sp. nov., Anderson, Calif. Acad. Sci. Proc., (3), vol. II, no. 1, p. 73, pl. VII, fig. 151.

1916 Liopistha anaana (F. M. Anderson), Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, p. 146.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 80(a), 84(c), 978(a), 979(a), 981(r), 1058(a), 1065(r), 1067(a).

Discussion: The following notes may be added to the original description: hinge of the left valve consisting of two teeth; posterior tooth rather oblique, and strong; anterior left cardinal parallel to the hinge margin, smaller than the posterior cardinal; dentition of right valve consisting of one rather blunt oblique cardinal situated close up under the anterior hinge margin, and bounded above and below by sockets that receive the left cardinal teeth; right anterior cardinal broken; ligament external, narrow; posterior dorsal slope unornamented except for growth-lines; strong radial ribs occur immediately anterior to the posterior dorsal slope continuing to the anterior region of the shell, where they become progressively finer and more close-set; valves apparently close in front, gaping behind; fine undulatory concentric ridges show on the umbonal regions of well-preserved specimens.

Liopistha anaana is probably to be referred to Liopistha s.s., as outlined by Meek. Certainly, the radial sculpture is the more prominent element in the ornamentation of the shell. There is a suggestion of concentric undulations in the umbonal region, but this is seldom discernible far down on the sides of the valves. The radial sculpture is more prominent on the posterior part of the valves, but sometimes as many as twelve or fifteen radial ribs growing weaker anteriorly are discernible.

Dr. L. W. Stephenson of the United States Geological Survey informs me (oral communication) that the specimens of Liopistha s.s. that he has studied from Atlantic Coast and Western Interior Cretaceous localities all show fine denticulations on the radial ribs. This feature is not shown on any of the specimens I have seen from the Santa Ana Mountains. Its absence from these may be due to preservation. I am inclined to believe, however, that these denticulations were never present. On the other hand, a few well-preserved specimens from the Santa Ana Mountains show what appear to be radial rows of broken-off tubercles, suggestive of the sculpture of the section Psilomya, mentioned in the discussion of L. hardingensis above.

No other species of _Liopistha_ known to me appears to be closely related to _L. anaana_.

Family Verticordiidae ?

Genus Meekia Gabb

Meekia navis Gabb

1864 _Meekia navis_ n.s., Gabb, Pal. Calif., vol. 1, p. 192, pl. XXV, fig. 180.

1916 ? _Meekia sella_ Gabb, Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, p. 146.

1930 _Meekia navis_ Gabb, Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, p. 307.

Distribution: Williams formation; C. I. T. loc. nos. 974(c), 975(r).

Discussion: The family relationships of _Meekia_ are yet considerably in doubt. Gabb (op. cit.) considered the closest relationships of the genus to lie with _Tancredia_, a genus generally placed in the Lucinacea. Meek, Fischer, Dall, Pelseneer, and some others agree with Gabb in considering _Meekia_ and _Tancredia_ to be closely related. Stoliczka considered _Meekia_ to be similar and related to _Schizodus_ and _Trigonia_ of the Trigoniidae. Stewart (op. cit.) doubtfully places the genus in the Verticordiidae, a procedure that is followed here.

Meekia has been recognized in many Cretaceous localities throughout the upper Cretaceous of the Pacific Coast, and has been found in the Cretaceous of Japan (Yabe and Nagao, 1928, p. 86).

Order Teleodesmacea

Superfamily Cypricardiacea

Family Pleurophoridae

Genus Etea Conrad

Etea angulata (Packard)

Plate 10, fig. 4.

1922 Meretrix angulata n. sp., Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10, p. 425, pl. 33, fig. 5.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 92(c), 453(a), 455(r), 982(r), 983(r), 1053(c), 1054(c), 1055(c), 1163(c), 1168(r), 1169(r), 1173(r).

Discussion: The following notes supplement the original description of the shell: dentition of the right valve consists of two cardinal teeth and two lateral sockets; right anterior cardinal very thin, laminar, oblique, lying close up under the lunular border; right posterior cardinal long, obliquely ventrally directed, bifid, the anterior element of the bifid tooth being short and splint-like; anterior socket deep, short, close to the anterior cardinal; posterior socket deep, narrow, long, situated midway between the umbo and the posterior end of the shell; dentition of the left valve consisting of two cardinal teeth, and two lateral teeth; anterior cardinal stout, triangular, weakly bifid, situated directly beneath the beak; posterior cardinal long, thin, laminar, close up under the nymph; anterior lateral close to the beaks, short, stout, prominent; posterior lateral long and thin, distant from the beaks; ligament rather short, narrow, external; pallial line simple.

Etea was erected by Conrad as a subgenus of Veniella. It has usually been so considered, but Dr. L. W. Stephenson has informed me (oral communication) that in his forthcoming monograph on the Navarro fauna of Texas he will accord Etea generic rank. It is so considered here. In comparison with Veniella as typified by Veniella mortoni Conrad, Etea has a much thinner shell and lighter hinge, is generally smooth instead of having a sculpture of coarse concentric corrugations and costae, has the posterior lateral teeth farther removed from the beaks, and apparently lacks the transverse striations of the posterior laterals. The two groups may well represent distinct genera.

Etea has not been reported elsewhere on the Pacific Coast, and I have found no reference to it elsewhere in the Cretaceous literature of the Indo-Pacific region. The genus is represented in a number of localities in the Upper Cretaceous of the Atlantic and Gulf Coastal Plain area, but none of the species I have seen are so robust as E. angulata.

Etea angulata is characteristic of a zone in the Holz shale comprising several hundred feet of beds near the middle of the section. At this horizon it is abundant and widespread. It has also appeared rarely in beds both near the top and near the bottom of the Holz shale.

Superfamily Astartacea

Family Astartidae

Genus Astarte Sowerby

Astarte sulcata Packard

Plate 10, figs. 5 - 8.

1922 Astarte ? sulcata n. sp., Packard, Univ. of Calif. Pubs., Bull Dept. Geol. Sci., vol. 13, no. 10, p. 424, pl. 33, fig. 6.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 84(r), 978(r), 981(a), 1067(va), 1071(a).

Discussion: The following notes are added to the original description of this species: lunule and escutcheon both well-marked, rather broad, long and devoid of sculpture; ligament small and short, inserted in a narrow trough; dentition of the right valve, one strong trigonal posterior tooth immediately below the beaks, and one very small laminar anterior tooth directed obliquely toward the ventral anterior border, and situated close up under the lunular margin; dentition of the left valve consisting of one strong central trigonal cardinal; dorsal anterior margin of right valve and dorsal posterior margin of left valve fit into long, narrow, and shallow grooves on the corresponding margins of the opposite valves; pallial line simple; internal ventral margins of valves smooth.

The genus Astarte s.l. has been divided into many sections and subgenera of which the distinctions and the definitions are both confused and confusing. The subdivision to which A. sulcata should be referred is uncertain. The species agrees fairly well with a species figured and discussed by Meek (1876, p. 124) as Eriphyla gregaria M. and H. Meek questions the reference of this latter species to Eriphyla, and it seems impossible that it should belong to this genus. A. sulcata appears to agree rather well also with the Astarte subcostata group as figured by Woods (1906, p. 109, et. seq.). Small Astartes of this general type appear rather widely distributed in the Upper Cretaceous of Europe. I find no very closely allied forms in the American Interior or East Coast Cretaceous beds, however.

Genus Eriphyla Gabb

Eriphyla ovoides (Packard)

Plate 10, figs. 9, 10.

1864 ? Venus lenticularis n.s. Gabb, Pal. Calif., vol. 1, p. 162, pl. 30, fig. 246.

1922 Astarte ovoides n.sp., Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10, p. 424, pl. 30, fig. 1.

1930 "Venus" lenticularis Gabb, Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, p. 219, pl. 1, fig. 12.

1888-89 not
Eriphyla lenticularis (Goldufss), Holzapfel, Paleontographica, Band 35, p. 195, pl. 14, figs. 5, 5a, 6, 7.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 94(r), 982(?).

Baker sandstone member; 302(c).

Discussion: The following notes may be added to the original description; dentition consisting of two cardinal teeth in each valve, of a posterior lateral tooth in the right valve and a corresponding posterior lateral socket in the left valve; right posterior cardinal heavy, trigonal, oblique; right anterior cardinal narrow, thin, situated perpendicularly beneath the beak; right posterior lateral long, straight, rather heavy; left anterior cardinal rather heavy, situated nearly perpendicularly beneath the beak; right posterior cardinal long, curved, thin, set close up under the nymph; posterior lateral socket long, narrow, shallow; ligament external, rather long; lunule deeply impressed; edge of left lunular margin projecting, fitting into a narrow elongate socket just below the lunule of the right valve.

Eriphyla has been regarded as a subgenus of Astarte by many writers, and as a genus of the Astartidae, by as many others. Dall (Proc. U. S. Nat. Mus., vol. XXVI, p. 933) considers Eriphyla more nearly related to the Crassatellidae. In the procedure followed here, Eriphyla is considered a genus, tentatively placed with the Astartidae. Stoliczka (1871, p. 156) referred the genus to the Veneridae, near Dosinia. Meek (1876, p. 122) questioned the generic position of the species referred to Eriphyla by

Stoliczka, largely on account of the presence in Stoliczka's forms of a slightly sinuous pallial line. Meek admitted that Stoliczka's specimens otherwise agreed well with Gabb's definition of the genus. Since that time Woods (1906, pls. XVI, XVII) has figured specimens of *Eriphyla* showing a sinuous pallial line, as has Holzapfel (op. cit.). Specimens of *Eriphyla* in the California Institute of Technology collections from Upper Cretaceous beds of Clover Creek, Shasta County, also show the gently sinuous pallial line plainly. This feature should be sufficient to separate *Eriphyla* from *Astarte*.

Eriphyla lapidis (Packard)

Plate 10, figs. 11, 12.

1922 *Astarte lapidis* n.sp., Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10, p. 423, pl. 30, figs. 4a, 4b.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 453(c), 1053(a), 1162(a), 1163(r).

Discussion: Hinges of both valves of this species have been revealed, and agree fully with Gabb's diagnosis of *Eriphyla*. They also agree fully with the dentition of *Eriphyla ovoides* (supra), and with hinges of specimens from Clover Creek, Shasta County now in the Institute collections, believed to represent *E. umbonata* Gabb.

Eriphyla lapidis bears considerable resemblance to *E. umbonata* in general form and sculpture. Better material than that now available may show the two to be conspecific. *E. lapidis* seems to average larger than *E. umbonata* in size, and in shape is slightly more ovoid in outline, however.

Genus Opis Defrance

Opis sp. cf. O. *triangulata* (Cooper)

1894 Corbula triangulata n. sp., Cooper, Calif. State Mining Bureau, Bull. no. 4, p. 49, pl. 2, fig. 42.

1896 Opis triangulata (Cooper), Stanton, U. S. Geol. Sur., Bull. 133, p. 59.

1897 Opis triangulata (Cooper), Cooper, Calif. Acad. Sci. Proc. (2), vol. 6, p. 332, pl. XLVII, figs. 7, 8, 9.

1916 Opis triangulata (Cooper), Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, p. 147.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 302(r), 1069(r).

Holz shale member; 453(c), 1055(a), 1063(r), 1170(a), 1171(c), 1172(r), 1173(va).

Discussion: Opis cf. triangulata ranges through nearly the entire thickness of the Holz shale below the zone of the giant Turritella, i. e. up to within one hundred or one hundred fifty feet of the top. It has been found also sparingly represented in two localities in the Baker sandstone near the shale contact.

Whiteaves (1879, p. 158) describes Opis vancouverensis from the beds of the Nanaimo group of Denman Island, Straits of Georgia, British Columbia. The description and figure are based on a single imperfect specimen. Neither fixes the individuality of the species sufficiently to determine whether O. cf. triangulata is, or is not, the same as O. vancouverensis. In size and outline Whiteaves' species compares well with many of the specimens from the Santa Ana Mountains, and the likelihood that the two forms may prove conspecific may be borne in mind.

The specimens from the Santa Ana Mountains compared with O. triangulata attain considerable size, some of the larger specimens reaching an altitude of from sixty to seventy millimeters although the average is somewhat less. Considerable variability in proportions also exists, some of the forms being high, and narrow at the ventral border, and others within the same suite of specimens are much broader proportionally at the base of the shell. The altitude given here for the forms from the Santa Ana Mountains exceeds the altitude of Cooper's Point Loma specimens (the types of O. triangulata) by more than four times, although the sculpture and outline of Cooper's forms agree well with the sculpture and outline of the umbonal portions of larger specimens from the Santa Ana Mountains. The two probably represent the same species, the original description of the species probably being based upon immature or dwarfed individuals.

Opis is a genus widespread in the Upper Cretaceous of Europe, and Asia. It does not seem to be well represented in the Cretaceous of North America except upon the Pacific Coast.

Family Crassatellidae

Genus Crassatella Lamarck

Subgenus Pachythaerus Conrad

Crassatella lomana Cooper

Plate 11, figs. 2, 3.

1894 Crassatella lomana n.sp., Cooper, J. G., Calif. State Mining Bureau, Bull. no. 4, p. 48, pl. 3, fig. 47.

1916 Crassatella lomana Cooper, Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, p. 146.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 83(va), 93(r), 94(c), 95(a), 489(r), 982(a), 983(va), 985(a), 1053(a), 1054(c), 1055(c), 1057(r), 1059(va), 1060(c), 1061(c), 1063(a), 1166(r), 1167(va), 1168(c), 1169(a), 1170(a), 1171(c), 1173(va).

Williams formation; 976(r), 1066(a).

Discussion: Crassatella lomana is at once the most abundant, the most characteristic, and the most widely distributed fossil of the upper part of the Holz shale. It is present in abundance in nearly every fossil collection from this part of the section, and occurs at but few other horizons.

Crassatella lomana was originally described from the Cretaceous shales at Point Loma Peninsula, San Diego. Dr. Cooper, in his original description, stated that the fossil lacked the concentric ridges of C. tuscana, being sculptured only by coarse lines of growth. In well-preserved specimens, these growth-lines show a considerable regularity, and appear to differ from the more finely chiseled ornamentation of C. tuscana more in degree than in kind. The only specimens of C. tuscana now available to me are from Sucia Island. These show a smaller shell than C. lomana, with finer sculpture, somewhat more inflated shape, and shorter posterior end, with a broader dorsal slope. The two species are probably closely related but are undoubtedly distinct.

Crassatella gamma n.sp.

Plate 10, figs. 13 - 15, plate 11, fig. 1.

Description: Shell of moderate size, rather high, short, compressed, angular in outline; beaks not very prominent, slightly anterior to the middle of the shell, prosogyrate; lunule depressed, long, narrow, about two-thirds the length of the anterior dorsal border; anterior dorsal border nearly straight; anterior portion of ventral border rounded; posterior part of ventral border nearly straight; posterior end abruptly truncate nearly at right angles to the ventral border; posterior dorsal slope comparatively broad, plane, bounded below by an abrupt umbonal angulation; escutcheon long, narrow; sculpture of fine concentric closely set rather irregular ridges; dentition of right valve; one strong trigonal posterior cardinal tooth directly beneath the beak, bounded anteriorly by a narrow oblique socket, and posteriorly by a rather deep triangular socket; anterior cardinal tooth nearly obsolete; ligament pit a triangular depression in dorsal half of hinge plate immediately behind the posterior cardinal tooth; anterior dorsal border bears a shallow lateral socket situated ventrally to the forward part of the lunule; posterior lateral tooth long, narrow, straight; dentition of the left valve; anterior cardinal tooth narrow and oblique; posterior cardinal tooth short and rather thick; bounded above by the chondrophore; anterior lateral tooth short and narrow, situated below the anterior end of the lunule; posterior lateral socket long, narrow, extending nearly the full length of the escutcheon.

Holotype: C. I. T. Invertebrate Paleontology cat. no. 3433.

Paratypes: C. I. T. Invertebrate Paleontology cat. no. 3434.

Type Locality: C. I. T. Invertebrate Paleontology loc. no. 1069.

Dimensions of type: Height, 26.0 mm., length, 30.5 mm., thickness of both valves, 17.1 mm.

Distribution: Ladd formation, Baker sandstone member; 79(c), 82(r), 87(r), 99(c), 1062(a), 1068(va), 1069(a), 1070(r), 1164(r), 302(r).

Holz shale member; 80(r), 1064(r).

Discussion: This *Crassatella* is common in, and characteristic of, the very basal portion of the Holz shale, and of the uppermost part of the Baker sandstone. It appears to have a limited stratigraphic range. It is somewhat similar to *Crassatella tuscana* but appears to differ from that form in being higher, more compressed laterally, more sharply truncate posteriorly, with straighter ventral and dorsal margins, a longer and narrower lunule, and in general, greater angularity of form. I do not know of the occurrence of this species elsewhere than in the Santa Ana Mountains.

Superfamily Cardiacea

Family Cardiidae

Genus Protocardia Beyrich

Protocardia sp. cf. *P. translucida* (Gabb)

Plate 11, figs. 4 - 6.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 92(va), 1053(c), 1064(a).

Williams formation; ? 974(r).

Discussion: Two species of Protocardia were described by Gabb in 1864 from the California Cretaceous deposits - *P. translucida* and *P. placerensis*. These have been refigured and discussed by Stewart, who suggests the probability that the two are conspecific.

Judging from the figures both of Gabb and of Stewart, the species from the Santa Ana Mountains is probably distinct, and represents a new species. The posterior end appears to be higher and more broadly truncate than in Gabb's species, and the ventral median region of the shell is smooth in the species from the Santa Ana Mountains and apparently concentrically striate in the northern California forms. It is judged better to withhold description of the forms from the Santa Ana Mountains until these apparent differences can be verified, however.

Superfamily Isocardiacea

Family Isocardiidae

Genus Isocardia Lamarck

Isocardia delta n.sp.

Plate 11, figs. 7, 8, 11.

Description: Shell of medium size, thin, fragile, inflated; beaks very high, prominent, distant, spirally enrolled, prosogyrous; anterior dorsal margin deeply concave below the beaks; anterior extremity obtuse and rounded; ventral margin broadly curved; posterior extremity meeting the ventral margin at an abrupt angle, and merging with the dorsal posterior border in a sweeping curve; dorsal posterior slope and lateral face of shell meeting along a rounded curving angle extending from the beaks to the ventral posterior border; ligament narrow, rather short, external; lunule and escutcheon undefined.

Dentition of the right valve consisting of two curved laminar teeth arranged parallel to the hinge line, situated one above the other, separated by a groove that receives the ventral cardinal tooth of the left valve; left valve also with two laminar horizontal cardinal teeth, the posterior and dorsal one extending from the hinge-line obliquely posteroventrally; anterior and ventral cardinal parallel to the hinge border directly below the beaks, separated from the hinge border by a narrow groove; anterior tooth grooved on the ventral side; lateral teeth apparently absent.

Holotype: C. I. T. Invertebrate Paleontology cat. no. 3436.

Paratypes: C. I. T. Invertebrate Paleontology cat. nos. 3437, 3438.

Type Locality: C. I. T. Invertebrate Paleontology loc. no. 1164.

Dimensions of type: Height, 39.6 mm., length 34.0 mm., thickness of both valves 34.6 mm.

Distribution: Ladd formation, Baker sandstone member; 82(r), 99(r), 302(a), 979(r), 1062(c), 1067(r), 1068(a), 1069(a), 1071(r), 1164(r).

Discussion: Isocardia delta occurs in a narrow zone essentially including the uppermost beds of the Baker sandstone and the lowest beds of the Holz shale. The species is very fragile, and few of the specimens collected have escaped crushing and distortion. Isocardia delta is probably at least subgenerically distinct from Isocardia cor, the genotype, for the Cretaceous species lacks the characteristic posterior lateral teeth that are present in the genotype, and in all of the other Tertiary and Recent Isocardias that I have seen. Isocardia delta was recognized by Packard, but was not described.

A few species of Isocardia have been described from Upper Cretaceous deposits both in the Atlantic Coastal Plain and in Europe. The genus is not well represented in the Cretaceous, however. I. delta appears to be the first authentic record of the genus in the Cretaceous of the Pacific Coast, for Isocardia chicoensis Waring apparently is a Clisocolus, probably C. cordatus Whiteaves.

Genus Clisocolus Gabb

Clisocolus cordatus Whiteaves

1879 Clisocolus cordatus Meek and Hayden, Whiteaves, Geol. Sur. Can., Mes. Foss., vol. 1, p. 157, pl. 18, figs. 3, 3a, 3b.

1903 Clisocolus cordatus Whiteaves, Whiteaves, op. cit., p. 384.

1916 Clisocolus dubius Gabb, (in part ?), Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, p. 146.

1917 Isocardia chicoensis n.s., Waring, Calif. Acad. Sci. Proc., (4), vol. VII, no. 4, p. 62, pl. 8, fig. 3.

1930 Clisocolus cordatus Whiteaves, Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, p. 157.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 83(c), 93(r), 94(r), 95(c), 453(r), 982(r), 983(r), ? 1053(a), 1172(r), 1173(r).

Williams formation; 974(c), 975(r), 976(r), 86(r).

Discussion: The Santa Ana Mountains specimens here referred to Clisocolus cordatus have been compared directly with specimens of the latter species now in the Institute collections from Sucia Island. There is no discernible difference in the forms. I have been unable to get good specimens of Clisocolus dubius Gabb with which the Santa Ana Mountains forms may be compared. Judging from available descriptions and figures, the principal differences separating C. dubius and C. cordatus lie in the fact that the former species is a small form with fine concentric ribbing, while the latter species tends to be large, usually smooth, but with occasional deep concentric sulcations developed on the ventral part of the shell due to resting stages in growth. The specimens from locality 1053 (above) are all or nearly all finely concentrically striate, and may represent C. dubius. Some of the other smoother specimens from the Santa Ana Mountains show fine concentric lines upon the umbonal region of the shell, but become smooth ventrally. Moreover, the fine concentric umbonal sculpture is quite variable in its development upon different individuals, being absent in some and strongly developed in others. It may prove to be a varietal feature, and Clisocolus dubius and C. cordatus may be only varietally distinct. Better material of undoubted C. dubius must be available before such an opinion can be verified or disproved.

Clisocolus cordatus appears to be limited in its range to the upper portions of the Holz shale and to the fossiliferous beds of the Williams formation. Its position in the lower part of the section is taken by Clisocolus corrugatus n.sp., described below. C. cordatus is also abundant in the limy sandstones at the base of the exposed Cretaceous section in the Simi Hills.

Clisocolus is usually referred to the Isocardiidae, but its actual systematic position is highly problematical, as Stewart (1930, p. 189) has suggested.

Clisocolus corrugatus n.sp.

Plate 11, figs. 9, 10, 12.

Description: Shell of medium size, highly inflated, gibbous in outline; shell substance rather thick; beaks high, prominent, prosogyrous, sharply incurved; outline of shell-margin below the beaks nearly circular to slightly oval; lunule and escutcheon undefined; ligament external, lodged in a rather deep narrow furrow; hinge edentulous, but with a slight thickening of the hinge line below the beaks, and with a shallow pit centrally placed, and dorsal to the thickened part; lateral teeth absent; sculpture consisting of rather coarse raised concentric corrugations, spaced at approximately 2.0 mm. intervals on the median portion of the mature shell; character of muscle scars and pallial line unknown.

Holotype: C. I. T. Invertebrate Paleontology cat. no. 3439.

Type Locality: C. I. T. Invertebrate Paleontology loc. no. 302.

Dimensions of type: Height 31.5 mm., length 31.5 mm., thickness of one valve 14.4 mm.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 82(r), 302(c), 1062(r), 1068(r), 1069(r), 1070(r).

Discussion: Clisocolus corrugatus is easily distinguished from C. cordatus Whiteaves by the character of its coarse, widely spaced concentric sculpture. In general, the latter species is larger, higher, and more gibbous in outline than C. corrugatus also. I do not know of the appearance of any form similar to C. corrugatus anywhere outside of the Santa Ana Mountains.

Superfamily Veneracea

Family Veneridae

Genus Cyprimeria Conrad

Cyprimeria moorei n.sp.

Plate 11, fig. 13, plate 12, figs. 1, 2.

Description: Shell rather small, thin, fragile, compressed, oval in outline, slightly longer than high; beaks low, slightly anterior; margin very slightly concave just in front of the beaks, elsewhere smoothly curved in a broad ellipse; ornamentation of fine regular growth-lines only; no lunule or escutcheon; ligament external, deep-seated, long, and very narrow; pallial line with a very shallow sinus.

Dentition of three cardinal teeth in each valve; left anterior cardinal long, very thin, thickening slightly anteriorly, strongly oblique to the shell-margin above and the ventral hinge-plate margin below, bounded above and below by deep narrow sockets; median left cardinal short, broad, trigonal, high behind, beveled in front, situated directly beneath the beak; posterior left cardinal rather long, thin, slightly curved, diverging at an acute angle from the nymph, which it underlies; anterior and median right cardinals rather thin and long, extending obliquely forward from the beaks, subparallel, but diverging slightly anteriorly; posterior cardinal narrow, slightly curved, extending obliquely posteroventrally from the beaks, thickening slightly toward the posterior end, deeply cleft along the crest; lateral teeth absent.

Cotypes: C. I. T. Invertebrate Paleontology cat. nos. 3440.

Type Locality: C. I. T. Invertebrate Paleontology loc. no. 92.

Dimensions of cotypes: (right valve) length, 27.3 mm., height, 21.6 mm., thickness of one valve, approximately 4.2 mm., (left valve) length, 24.4 mm., height, 19.6 mm., thickness of one valve approximately 2.3 mm.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 92(a), 454(r).

Discussion: I am glad to name this beautiful shell for Dr. B. N. Moore, of the United States Geological Survey. Dr. Moore collected all of the material upon which this species is based, and generously made his collections available for this study.

Cyprimeria moorei is apparently the first species of *Cyprimeria* reported from the Upper Cretaceous of the Pacific Coast. Whiteaves (1903, p. 379) has referred to *Cyprimeria* several specimens which he at first identified as "*Meretrix*" *lens* Gabb, a species since shown by Stewart to belong to the genus *Flaventia* (1930, p. 247). It has been possible to expose the hinges of several specimens of *Flaventia lens* from the Santa Ana Mountains, northern California, and from the Sucia Islands. The hinge characters as there shown agree almost exactly with those illustrated by Woods of *Flaventia ovalis* (Sowerby), genotype of the genus *Flaventia* (Mon. Cret. Lam. Eng., vol. II, p. 191, pl. 24, figs. 19 - 26). The dentition of these forms also agrees well with the figure and hinge of "*Cyprimeria*" *lens* as figured by Whiteaves. A second species cited by Whiteaves from the Upper Cretaceous of British Columbia, *Cyprimeria* ? *tenuis* Meek is neither described nor figured, and its actual relationships remain very dubious.

Genus Tenea Conrad

Tenea inflata (Gabb)

Plate 12, figs. 3 - 5.

1864 Dosinia inflata n.s., Gabb, Pal. Calif., vol. 1, p. 168, pl. 23, fig. 149.

1916 Dosinia inflata Gabb, Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, p. 146.

1930 "Dosinia" inflata Gabb, Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, p. 231.

Distribution: Small variety; Baker sandstone member of the Ladd formation; C. I. T. loc. nos. 79(c), 82(c), 99(?), 301(c), 1062(a), 1069(c), 1164(c). Giant variety; Ladd formation, Holz shale member; 93(r), 95(c), 489(r), 982(c), 1055(r), 1057(c), 1063(r), 1084(r), 1160(va), 1170(c), 1171(c), 1173(c).

Williams formation; 1052(r).

Discussion: The following notes may be given on the dentition of this species: right anterior cardinal very small, slender, short, diverging slightly from the hinge-margin directly anterior to the beak, extending only half-way across the hinge-plate ventrally; median right cardinal rather heavy, low, trigonal; right posterior cardinal rather heavy, long, slightly curved, situated close up under the nymph from which it is separated by a narrow groove; a thin lamellar ridge rising from the floor of the socket separating the anterior and median right cardinals, extends about half-way from the ventral edge of the hinge-plate toward the beak; left anterior and median cardinal teeth short, slender, joined to one another dorsally, diverging ventrally at a high angle; posterior left cardinal long, laminar, oblique, situated just below the nymph; lateral teeth apparently absent; pallial sinus long, narrow, pointed, ascending, directed toward the beaks.

Tenea has not been reported hitherto from the West Coast Cretaceous, but is known from several localities in the Atlantic and Gulf Coast Cretaceous of the eastern United States. The genotype is from the Cretaceous of New Jersey (Conrad, Amer. Jour. Conch., vol. 6, pp. 72, 73). *Cyclina magna* Wade from the Ripley formation of Coon Creek, Tennessee is probably to be referred to this genus (personal communication from L. W. Stephenson) as may also be *Cyclina parva* Gardner of the Monmouth formation of Maryland. Holzapfel (Palaeontographica, vol. 35, p. 168, pl. XII, figs. 9 - 12) figures a form identified as *Cytherea tumida* Goldfuss, which is almost certainly to be referred to Tenea, and it is quite probable that many other Cretaceous specimens that have been described as "*Dosinia*" will be found referable to this genus.

The systematic position of *Tenea* has appeared doubtful to many writers who have discussed the subject. Conrad originally suggested the relationship of *Tenea* to *Taras* [*Diplodonta*] and many other writers including Dall, Fischer, and Weller have doubtfully or confidently placed this genus in the Ungulinidae. Whitfield on the other hand placed the genus in the Veneridae, comparing it to *Dosinia*. It is my belief that *Tenea* is a Venerid genus, and that it is closely related to *Dosinia* and *Cyclina*, though it is quite distinct from either. The reasons for this decision rest in the typically Venerid characters of the hinge, especially of the right valve, and in the slender, pointed, ascending pallial sinus, so similar to the sinus as developed in *Cyclina* and *Dosinia*.

Tenea inflata is represented by many excellent specimens from the middle and upper parts of the Holz shale and from the upper part of the Baker sandstone. Those specimens found in the shale member become usually quite robust and large, some of the individuals attaining a height of thirty-five millimeters. The forms in the Baker sandstone, conversely, are invariably small, thin, and fragile. Few specimens from this part of the section will attain an altitude of twenty millimeters. The individuals from the lower beds are so uniformly small and thin-shelled, and those from the upper beds are so uniformly large and thick-shelled that one is tempted to believe that two species are represented; and this view is strengthened by the fact that very few species appear to be common to both the Baker sandstone, and the higher horizons of the Holz shale. Nevertheless, I have been unable to find any basis for separation of these two forms other than that of size, and this seems hardly sufficient criterion.

Genus Flaventia Jukes-Brown

Flaventia lens (Gabb)

Plate 12, figs. 4.

1864 Meretrix lens n.s., Gabb, Pal. Calif., vol. 1, p. 164, pl. 23, fig. 143.

1879 Cyprimeria lens (Gabb), Whiteaves, Geol. Sur. Canada, Mes. Foss., vol. 1, pt. 2, p. 152, pl. 17, figs. 15, 15a. ibid, p. 379, (1903).

1930 Flaventia ? lens (Gabb), Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, p. 247, pl. 4, fig. 6.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. no. ? 84(r).

Holz shale member; 83(c), 93(r), 94(c), 95(r), 982(r), 983(a), 1054(r), 1060(c), 1061(r), 1166(c), 1168(c), 1169(a), 1170(r), 1173(r).

Williams formation; 974(r), 976(r), 1052(r), 1056(c), 1066(r).

Discussion: Whiteaves (op. cit.) was apparently the first to call attention to the hinge structure of Flaventia lens, or at least was the first to publish his observation. He referred the species to Cyprimeria, but comparison of his figure of the hinge of the left valve with a hinge of Cyprimeria suggests an error. Stewart (op. cit.) first called attention to the similarity of the hinge of F. lens with that of F. ovalis (genotype of Flaventia) and suggested the relationship. It has been possible in this study to expose several complete hinges of this species from the Santa Ana Mountains, from northern California, and from the Sucia Islands. The following notes on the hinge structure are offered: right anterior and median cardinals close together, diverging ventrally, directed obliquely anteriorly; right posterior cardinal long, heavy, deeply bifid, the anterior element being the shorter; left anterior and median cardinals short and strong, close together, diverging ventrally at a large angle; posterior cardinal long, thin, situated directly beneath the nymph; ligament external, moderately long, slightly submerged; lunule and escutcheon undefined; pallial sinus triangular and ascending; lateral teeth absent.

Flaventia lens, as shown by the distribution table, is most abundant in the upper part of the shale section of the Santa Ana Mountains, though a few forms appear in the Williams formation. The single individual doubtfully reported from the Baker sandstone may have been misplaced during preparation of the collections.

Flaventia zeta n.sp.

Plate 12, figs. 9, 10, 11.

Description: Shell of medium size, strong, moderately inflated, elongate-oval; beaks not very prominent, situated slightly in advance of the median line of the shell; anterior dorsal slope nearly straight from just before the beaks to the anterior end; ventral border smoothly curved between the anterior and posterior ends of the shell, forming nearly the arc of a circle; posterior dorsal border slightly arched, meeting the ventral border with a blunt angulation; ligament external, about one-half the length of the posterior dorsal border; lunule undefined; escutcheon spindle-shaped, long, narrow; ornamentation of growth-lines only, fine on the dorsal region of the shell, but more coarse toward the ventral border; pallial sinus short, broadly triangular, wide open at the base, ascending.

Hinge of three cardinal teeth in each valve and no laterals; right median and anterior cardinals short, slender, subparallel but diverging slightly distal to the beaks, anteriorly obliquely directed from the beaks; right posterior cardinal strong, rather long, trigonal, strongly bifid, the anterior element of the tooth being the shorter and weaker one; very oblique, diverging at a small angle from the nymph; left anterior and median cardinals short and thin, approximately equal in size, diverging from one another at a moderate angle directly ventral to the beaks; posterior left cardinal long, narrow, slightly curved, underlying and slightly diverging from the nymph; hinge plate of both valves slightly excavated in front of the anterior teeth.

Holotype: C. I. T. Invertebrate Paleontology cat. no. 3444.

Paratypes: C. I. T. Invertebrate Paleontology cat. no. 3445.

Type Locality: C. I. T. Invertebrate Paleontology loc. no. 1068.

Dimensions of type: Height, 33.2 mm., length, 44.7 mm., thickness of both valves 18.0 mm.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 80(c), 99(c), 456(a), 973(c), 979(c), 1058(c), 1065(r), 1068(a), 1069(c), 1070(r), 1164(r).

Holz shale member; 92(va), 1053(a).

<u>Discussion</u>: <u>Flaventia zeta</u> is to be distinguished from <u>F. lens</u> principally by its more elongate outline and by its higher beaks. Most of the mature specimens of <u>F. lens</u> are nearly equidimensional in length and height, while <u>F. zeta</u> is longer than high in the ratio of four to three. The shapes of the individuals of the two species are somewhat variable, and end members of the variable series approach one another in shape. Stratigraphically, the two species are complementary, <u>F. zeta</u> being common in the Baker sandstone and rare in the lower part of the shale; while <u>F. lens</u> is common in the upper part of the shale and rare in the sandstones of the Williams formation. The two species have not been found together.

<u>Flaventia zeta</u> is not certainly known to occur elsewhere than in the Santa Ana Mountains. It may reasonably be expected elsewhere in the lower beds of the Upper Cretaceous of the Pacific Coast, and may be represented in the fossil lists by forms that have been identified as <u>F. lens</u>.

Genus Legumen Conrad

<u>Legumen ooides</u> (Gabb)

Plate 12, figs. 8, 12.

1864 <u>Tellina ooides</u> n.sp., Gabb, Pal. Calif., vol. 1, p. 157, pl. 22, figs. 135, 135a.

1909 <u>Tellina</u> ? <u>ooides</u> Gabb, Arnold, Paleon. Coalinga Dist., U. S. G. S. Bull. 396, p. 11, pl. 1, fig. 3.

1916 <u>Tellina ooides</u> Gabb, Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 9, no. 12, p. 147.

1930 "<u>Tellina</u>" <u>ooides</u> Gabb, Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, p. 202, pl. 3, fig. 3.

<u>Distribution</u>: Williams formation; C. I. T. loc. nos. 974(c), 975(r), 976(r).

Discussion: Packard (op. cit.) has taken this species as the zone fossil for the uppermost faunal zone of the Santa Ana Mountains. Legumen ooides apparently is restricted to this zone (the Williams formation), but I have not found it abundant, and it does not seen widely distributed in this locality. I have suggested elsewhere the ammonite species Metaplacenticeras pacificum (Smith) as an abundant, widely distributed, and important zone fossil for the horizon of the fossiliferous beds of the Williams formation.

Complete hinges of both valves of Legumen ooides have been worked out in this study. These features have been determined: cardinal teeth three in each valve; lateral teeth absent; right anterior and median cardinals short, slender, prominent, subparallel, situated almost directly beneath the beaks; right posterior cardinal long, moderately prominent, subparallel to the nymph which it underlies, bifid, the anterior element of the tooth being short and splint-like. Left anterior and median cardinals also short, slender, and prominent, but diverging from one another ventrally at an angle of approximately sixty degrees; left posterior cardinal long and thin, joined to the ventral border of the nymph; hinge plate slightly excavated immediately in front of the anterior teeth; lunule undefined; ligament submarginal, about one-half the length of the posterior dorsal margin of the shell; pallial sinus rather short, broad, blunt, directed toward the anterior adductor scar.

The characters of the dentition, ligament, lunule and pallial sinus of Legumen are very similar to those features in Flaventia. The principal differences are (a) the species of Flaventia tend to have rather heavy shells, either equal in length and height, or not much longer than high; (b) the right posterior cardinal tooth of Flaventia is comparatively larger than the same tooth in Legumen, is more deeply bifid, and the anterior element of the bifid tooth is longer and stronger. These differences may be of not more than subgeneric importance. Flaventia might then be considered a subgenus of Legumen. A critical review of the forms referred to these two groups is advisable before such grouping is determined, however.

Stephenson (1923, p. 319) suggests that Baroda Stoliczka is probably generically identical with Legumen. If this be so, Legumen is represented by many species widely distributed in the Upper Cretaceous faunas of the world. I have not seen the hinge of Baroda, and those illustrations of the hinge available do not show whether or not the right posterior tooth is bifid. Jukes-Brown (Malac. Soc. London, Proc., vol. 8, 1908, p. 171) describes this tooth as "entire". Since the bifid right posterior cardinal appears to be a constant character in the American species of Legumen, Baroda is probably at least subgenerically distinct.

Genus Calva n. genus

Genotype Species: Calva regina n.sp.

Genosyntypes: Calif. Inst. Technology Invertebrate Paleontology cat. no. 3447.

Generic Diagnosis: Venerid pelecypods of medium to large size, with heavy shells, characteristically ornamented by fine concentric lines with occasional irregularly spaced deeper concentric grooves; shape usually moderately elongated; beaks prominent and high; lunule usually circumscribed by an impressed line, somewhat depressed; hinge bearing three cardinal teeth in each valve, left anterior and posterior lateral teeth, and corresponding right posterior and anterior lateral sockets; left anterior lateral tooth parallel to the forward border of the nymph, smooth, rather long;

left posterior lateral tooth formed by a slightly salient projection of the hinge line; right posterior lateral socket long, narrow, moderately deep, distant from the beaks; right posterior cardinal tooth weakly bifid.

Within this genus will fall all, or nearly all, of the forms formerly referred to "Venus" varians Gabb, "Meretrix" nitida Gabb, and the varieties listed in connection with these names, and in addition most, if not all, of the Cretaceous species hitherto referred to the genus Dosiniopsis Conrad.

Dosiniopsis was erected in 1864 by Conrad (Acad. Nat. Sci. Phil., Proc. xvi, p. 213, text fig.) with Dosiniopsis meeki from Eocene deposits near Washington, D. C., as genotype. D. meeki was later declared to be simply a variant of D. lenticularis (Rogers) by Clark and Martin (Md. Geol. Sur., Eocene, p. 171). Meek (1876, p. 179) apparently first mentioned the presence of a posterior lateral tooth in this genus. Cossman (1886, Coq. Foss. del'Eoc. des Env. de Paris, p. 113) recognized Conrad's genus and placed therein three species previously described by Deshayes from the Eocene of the Paris Basin - D. fallax, D. bellovacensis, and D. orbicularis (Edwards). Cossman does not mention the presence of a posterior lateral tooth in these forms, but in the illustrations of these species given in the "Iconographie Coquilles Fossiles de Paris" of Cossman and Pissarro, all views showing the interior of the right valve show the posterior lateral plainly. Of Cretaceous forms referred to Dosiniopsis may be mentioned Cytherea caperata Sowerby, and Cytherea subrotunda Sowerby, referred to Dosiniopsis by Jukes-Brown (Malac. Soc. London, 1908, p. 151) and figured and described later in the same year by Woods (Pal. Soc. Mon., vol. 62, pp. 181-2, pl. 28, figs. 1 - 10). Palmer (Pal. Amer., vol. 1, no. 5, p. 6) has referred Meretrix umzambiensis Woods of the Upper Cretaceous of Pondoland to Dosiniopsis, and Meek

(1876, p. 184) described Dosiniopsis nebrascensis from the Fort Pierre and Fox Hills groups of the Dakota Upper Cretaceous.

A review of the descriptions and figures of the above species, together with the study of the Pacific Coast Cretaceous "Venus" varians - "Meretrix" nitida group indicates that all of the Eocene species of Dosiniopsis, including the genotype have striated anterior lateral teeth and sockets, heavy, strongly bifid, right posterior cardinal teeth, and in general a lenticular form. The Cretaceous species referred to Dosiniopsis uniformly seem to have smooth anterior lateral teeth and sockets, weakly bifid posterior right cardinals and in general, elongate form. These differences, correlated with the age difference, appear to be sufficient to distinguish a new genus.

To the genus Calva then, are tentatively referred the following species:

Venus varians Gabb
Meretrix nitida Gabb
Meretrix umzambiensis Woods
Meretrix nitida var. major Packard
Cytherea subrotunda Sowerby
Cytherea caperata Sowerby
Callista pseudoplana Yabe and Nagao
Dosiniopsis nebrascensis Meek

Undoubtedly, other species will be found referable to this genus upon further study.

Calva major (Packard)

1922 Meretrix nitida Gabb, var. major Packard, Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10. p. 425, pl. 31, fig. 2.

1930 Aphrodina varians (Gabb), Woodring, in Hoots, U. S. G. S. Prof. Paper 165-C, p. 91.

1935 Aphrodina major (Packard), Anderson and Hanna, Calif. Acad. Sci. Proc., (4), vol. xxiii, no. 1, p. 28.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 93(c), 94(r), 95(c).

Williams formation; 86(c), 974(va), 975(a), 976(va), 1052(c), 1056(r), 1066(r).

Discussion: Calva major differs from the northern California forms usually referred to "Meretrix" nitida and "Venus" varians by being considerably larger and heavier, in general having a more elongate form, and in having a more deeply concave anterior dorsal margin.

The actual relationships between "Venus" varians and "Meretrix" nitida are yet obscure. Stewart (1930, p. 251) suggests that the two are conspecific, and I am much inclined to agree. Both of these species doubtless belong to the genus Calva. A number of collections from northern California in the California Institute of Paleontology show considerable suites of this genus. In almost any one of these assemblages, considerably more variation is to be noticed than Gabb permitted in the separation of these two species, and it scarcely seems practicable to consider them as distinct.

Calva regina n.sp.

Plate 12, figs. 6, 7, 13, 14.

Description: Shell of moderate size, nearly as high as long, inflated, rather heavy; beaks prominent, high, anterior to the middle line of the length of the shell, prosogyrous; anterior dorsal border strongly concave; anterior end rather sharply rounded; ventral border broadly arched; posterior end bluntly truncate vertically; posterior dorsal border rather short, slightly arched; posterior dorsal slope nearly flat, broad, marked off from the lateral part of the shell by a low rounded angulation extending from the beak to the posterior ventral border; escutcheon faintly delimited extending the length of the posterior dorsal border; lunule heart-shaped, sunken, circumscribed by a fine line, length about one-half that of the anterior dorsal slope; ornamentation of even, moderately fine growth-lines only; ligament rather short, and sunk below the shell margin; character of the muscle scars and pallial line unknown.

Dentition: right anterior and median cardinals short, narrow, prominent, close together, slightly divergent ventrally, situated directly beneath the beaks; right posterior cardinal tooth long, straight, shallowly bifid, subparallel to the nymph; anterior lateral socket long, narrow, moderately deep, smooth, parallel to the lunular border of the shell; posterior right lateral socket deep, posterior to the rear end of the ligament, bounded below by a projecting, rather large tooth; left anterior cardinal prominent, very slender, aligned almost vertically below the beak; left median cardinal rather more strong than the anterior, trigonal, directed obliquely backward; left posterior cardinal very oblique, continuous with the ventral side of the nymph, but little longer than the two other teeth, not very heavy; anterior lateral tooth quite long, slightly wedge-shaped, parallel to the hinge border below the lunule, smooth; posterior lateral tooth, a slightly salient portion of the shell margin just to the rear of the posterior end of the nymph.

Cotypes: C. I. T. Invertebrate Paleontology cat. no. 3447.

Type Locality: C. I. T. Invertebrate Paleontology loc. no. 1164.

Dimensions of a cotype: Height, 34,4 mm., length, 36.5 mm., thickness of one valve, approximately 8.5 mm. Dimensions of a second cotype: height, 33.2 mm., length, 37.0 mm. (approximately), thickness of one valve approximately 10.8 mm.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 302(c), 981(r), 1062(r), 1068(r), 1069(r), 1070(r), 1164(r).

Discussion: Calva regina is fairly widespread but not abundant in the Baker sandstone. It may be distinguished from Calva major (Packard) by the abruptly truncated posterior and the rather high, short posterior dorsal slope. In general C. regina is considerably smaller than C. major also.

Specimens greatly resembling C. regina occur near the base of the Upper Cretaceous section in the Siskiyou Mountains and the Rogue River Valley of Oregon. The species may not be identical with C. regina, but may well be only varietally removed from it.

Genus Aphrodina Conrad

Aphrodina ? arata (Gabb)

Plate 12, figs. 15, 16.

1864 Meretrix arata n.s., Gabb, Pal. Calif., vol. 1, p. 166, pl. 30, fig. 250.

1916 Meretrix arata Gabb, Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. vol. 9, no. 12, p. 146.

1930 ? Meretrix arata Gabb, Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, p. 247, pl. 1, fig. 4.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 79(r), 80(r), 84(r), 87(r), 99(c), 302(r), 456(r), 979(r), 981(c), 1062(r), 1065(c), 1068(va), 1069(va), 1070(r), 1164(c).

Discussion: It is with some misgivings that this shell is referred to Aphrodina. It has not proved possible to expose the hinge of this species without some breakage of the teeth. The best hinges so far exposed apparently are identical with the hinges of Aphrodina tippana Conrad (genotype of Aphrodina), except that the anterior lateral tooth and socket, which are rather long and are striated in A. tippana are comparatively shorter and seem to be smooth in A. arata. These differences seem scarcely important enough to justify more than subgeneric separation of the two forms.

Aphrodina arata is especially characteristic of the Baker sandstone. It apparently does not occur at higher horizons, and within this horizon is to be found in nearly every fossiliferous locality. It is interesting to note that this species was originally described from material from "Cottonwood Creek", Shasta County, a locality from which Gabb derived a number of other species that in the Santa Ana Mountains appear to be confined to the horizon of the Baker sandstone.

Callista (Aphrodina ?) tenuis Meek and Hayden (Meek, 1876, p. 188) appears to be a form similar to A. arata, as does Cytherea minutula Stoliczka from the Ariyalur group of south India.

Superfamily Tellinacea

Family Tellinidae

Genus Tellina Linnaeus

"Tellina" sp. A.

Distribution: Williams formation; C. I. T. loc. no. 974(r).

Discussion: Two valves of this species, one right and one left, each show two minute divergent teeth. The shells are long and low, somewhat in the form of the recent genus Gari. The material is too poor to describe or figure. It has not proved possible to discover enough diagnostic characters to definitely determine the genus represented.

"Tellina" sp. cf. "T". parilis Gabb

Distribution: Williams formation; C. I. T. loc. no. 974(r).

Discussion: This small Tellinid is represented by two valves from a single locality. It is probably identical with a species represented in the Institute collections by many specimens from localities on the east side of the Sacramento Valley. It is possibly to be identified with "Tellina" parilis Gabb. I have been unable to make out sufficient features of dentition or other internal characters to justify a definite determination of this species.

Superfamily Mactracea

Family Mactridae

Genus Cymbophora Gabb

Cymbophora ashburnerii (Gabb)

Plate 13, fig. 1.

1864 Mactra ashburnerii n.s., Gabb, Pal. Calif., vol. 1, p. 153, pl. 22, fig. 127.

1869 Cymbophora ashburnerii (Gabb), Gabb, Pal. Calif., vol. 2, pp. 181, 236, pl. 29, fig. 69.

1903 Cymbophora ashburnerii (Gabb), Whiteaves, Can. Geol. Sur., Mes. Foss., p. 374.

1909 Mactra ashburnerii Gabb, Arnold, U. S. Geol. Sur., Bull. 396, p. 11, pl. 1, fig. 4.

1916 Spisula ashburnerii (Gabb), Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 18, p. 298, pl. 26, figs. 4, 5, pl. 27, fig. 1.

1930 Cymbophora ashburnerii (Gabb), Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, p. 212, pl. 5, fig. 6a.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 93(c), 94(r), 982(c), 983(r), 985(r), 1060(r).

Williams formation; 86(c), 974(a), 975(r), 976(c), 1052(c), 1056(r), 1066(r).

Discussion: The hinge of Cymbophora ashburnerii was figured by Gabb (op. cit.) and this figure was reproduced by Packard (op. cit.). In neither figure however is the dentition fully represented. Stephenson (1923, pl.lxxxv, figs. 5, 6) has figured both valves of Cymbophora trigonalis. The dentition of this species appears to agree in every particular with the hinge of C. ashburnerii as revealed in this study. The following notes are offered on the dentition of a left valve of this species: chondrophore rather narrow and shallow, its floor almost flush with the inner face of the hinge plate; on the anterior border of the chondrophore is a very thin laminar tooth (accessory lamella ?) which is separated from the posterior limb of the bifid cardinal tooth by a very narrow slit; anterior dorsal shell margin straight, and abruptly truncate at a point immediately opposite the beak, which is situated slightly to the left of the hinge-margin; back of this truncation, the posterior dorsal margin of the shell extends slightly obliquely to a point opposite the anterior end of the posterior lateral; this leaves a slight gap between the valves directly back of the beaks and above the position of insertion of the ligament; the lateral teeth are rather heavy for a Mactrid, and are close to the beaks.

Cymbophora gabbiana (Anderson)

Plate 13, fig. 2.

1864 Mactra ashburnerii n.s., (in part), Gabb, Pal. Calif., vol. 1, p. 153.

1879 Cymbophora ashburnerii Gabb, Whiteaves, Can. Geol. Sur., Mes. Foss., p. 141, pl. 17, fig. 8; p. 373 (1903), not p. 374.

1902 Mactra gabbiana sp. nov., Anderson, Calif. Acad. Sci. Proc., (3), vol. 2, no. 1, p. 74, pl. 7, fig. 156.

1916 Spisula gabbiana (Anderson), Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 16, p. 299, pl. 27, fig. 2.

1930 "Mactra" gabbiana Anderson, Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, p. 211.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 83(r), 93(c), 95(r), 1169(r).

Williams formation; 86(a), 974(va), 975(c), 976(va), 1052(r).

Discussion: Cymbophora gabbiana is especially well represented in the Williams formation. Few considerable collections may be made from this horizon without getting this species in abundance. Those localities in the Holz shale from which the species has been obtained are high in the section near the Holz-Williams contact. The fossil seems thus to be a good marker for the higher beds, at least in this region. Its abundance in certain localities in the Upper Cretaceous of the Simi Hills and of the Santa Monica Mountains probably has considerable significance in correlation.

The hinge of this species has neither been described nor figured heretofore. These notes on the dentition may therefore be of interest: in the right valve are two cardinal teeth, joined at their dorsal extremities; anterior cardinal tooth very oblique, close up under the dorsal anterior shell margin; posterior cardinal aligned almost vertically beneath the beak; chondrophore shallow, rather narrow, bounded dorsally by a narrow, oblique posterior lamina which includes between it and the hinge line a deep narrow cavity; posterior and anterior lateral teeth heavy and rather short, close to the umbonal region of the shell, separated from the dorsal border by a deep socket; lunule and escutcheon undefined; lateral teeth very lightly striated; in the left valve is one strongly bifid (inverted V-shaped) anterior cardinal tooth, separated from a narrow, prominent laminar posterior tooth (accessory lamella ?) by a narrow vertical slit; chondrophore and subumbonal cartilage groove as in the right valve; anterior and posterior lateral teeth single and strong.

The hinge of this species accords in all ways with that of C. ashburnerii. It is doubtless true Cymbophora, for the difference in sculpture can hardly be of more than specific importance. Whiteaves (supra, p. 142) and Stewart (supra, p. 211) have called attention to the similarity of C. gabbiana to Mactra tripartita G. B. Sowerby of the Trichinopoly group of India.

Superfamily Myacea

Family Corbulidae

Genus Corbula Lamarck

Corbula traskii ? Gabb

1864 Corbula traskii n.s., Gabb, Pal. Calif., vol. 1, p. 149, pl. 22, figs. 121, 121a.

1879 Corbula traskii ? Gabb, Whiteaves, Can. Geol. Sur., Mes. Foss., vol. 1, pt. 2, p. 138, pl. 17, fig. 3.

1930 Corbula traskii Gabb, Stewart, Acad. Nat. Sci. Phil., Special Pub., no. 3, p. 289.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 79(r), 82(r), 99(c), 456(r), 978(c), 1062(c), 1065(r), 1069(r), 1164(c).

Discussion: This species is referred to Corbula traskii with many misgivings. It may represent a new species. It is fairly common and widespread in the Baker sandstone, but has not been found above that horizon.

Corbula sp. A.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. no. 1067(r).

Discussion: This species is represented by a single cast of one valve. The shell is markedly high-beaked and short, and has coarse concentric sculpture. The specimen doubtless represents a new species, but is too imperfect to describe.

Corbula sp. B.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 83(r), 454(r), 1061(r).

Williams formation; 974(r), 1066(r).

Discussion: This species, represented by fragmentary and poor material, is somewhat similar to the species above referred to *Corbula traskii*. It differs from this latter species in being straight, or nearly so, along the ventral border, instead of rounded as is the ventral border of *C. traskii* ?. The material at hand does not justify description or figuring.

Family Saxicavidae

Genus Panope Menard

Panope californica ? Packard

1922 *Panope californica* n.s., Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10, p. 427, pl. 34, fig. 1.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. no. 82(r).

Holz shale member; 83(r), 95(r).

Williams formation; 975(r).

Discussion: All of the material listed above is scanty, poorly preserved and fragmental. From such features as can be made out, the specimens appear referable to *Panope californica*, but the identifications are far from certain.

Superfamily Adesmacea

Family Pholadidae

Genus Martesia Leach

Martesia clausa Gabb

1864 *Martesia clausa* n.s., Gabb, Pal. Calif., vol. 1, p. 145, pl. 22, fig. 115.

1879 *Martesia clausa* Gabb, Whiteaves, Geol. Sur. Can., Mes. Foss., vol. 1, pt. 2, p. 137, pl. 17, figs. 2, 2a, 2b.

1930 *Martesia clausa* Gabb, Stewart, Acad. Nat. Sci. Phil., Special. Pub., no. 3, p. 295, pl. 4, fig. 2.

Distribution: Williams formation; C. I. T. loc. nos. 974(r), 975(r).

CLASS CASTROPODA

SUBCLASS STREPTONEURA

Order Pectinibranchia

Suborder Taenioglossa

Family Pyramidellidae

Genus Odostomia Fleming

"*Odostomia*" *santana* Packard

1922 *Odostomia santana* n.sp., Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10, p. 428, pl. 36, fig. 2.

Distribution: Williams formation; C. I. T. loc. nos. 974(r), 975(r).

Discussion: This species is probably not *Odostomia* for polished longitudinal sections show no spiral welt on the columella. It may be *Eulima*. The species is also found in the Upper Cretaceous beds near the top of the section at Chico Creek, Butte County.

Family Trochidae

Genus Margarites Gray

Subgenus Atira Stewart

Margarites (Atira) ornatissimus (Gabb)

1864 Angaria ornatissima n.s., Gabb, Pal. Calif., vol. 1, p. 121, pl. 20, fig. 78.

1879 Margarita ornatissima (Gabb), Whiteaves, Geol. Sur. Can., Mes. Foss., vol. 1, pp. 128, 368.

1927 Margarites ornatissimus (Gabb), Stewart, Acad. Nat. Sci. Phil., Proc., LXXVIII, p. 315, pl. XXIV, fig. 1.

Distribution: Williams formation; C. I. T. loc. nos. 974(c), 975(c), 976(r), 1052(r), 1056(r).

Discussion: This species does not appear below the horizon of the Williams formation in the Santa Ana Mountains, but is found in the Cretaceous beds on the east side of the Sacramento Valley throughout a considerable range.

Family Naticidae

Genus Gyrodes Conrad

Gyrodes expansa Gabb

1864 Gyrodes expansa n.s., Gabb, Pal. Calif., vol. 1, p. 108, pl. 19, figs. 62a, 62b, 62c.

1879 ? Gyrodes excavata Michelin, Whiteaves, Geol. Sur. Can., Mes. Foss., vol. 1, pt. II, pp. 224, 365, pl. 16, figs. 2, 2a.

1916 Gyrodes expansa Gabb, Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, p. 148.

1917 Gyrodes canadensis Whiteaves, Waring, Calif. Acad. Sci. Proc., (4), vol. 7, no. 4, p. 66, pl. 9, fig. 7.

1927 Gyrodes expansa Gabb, Stewart, Acad. Nat. Sci. Phil., Proc., LXXVIII, p. 328, pl. XXII, fig. 1a, 3.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. no. 1053(r).

Williams formation; 974(a), 975(r), 976(c), 1052(r), 1056(r).

Discussion: Dr. Packard has reported this species from the Baker sandstone, but it does not appear in the collections from this member at the California Institute of Technology. With the exception of the single occurrence at locality 1053, I have found no specimen of the genus lower than the Williams formation.

Whiteaves (supra, p. 165) refers specimens of *Gyrodes* from various localities in the Upper Cretaceous of Vancouver Island to *G. excavata* Michelin, and later describes these same forms as the new species *G. canadensis* (supra, p. 365). In his later reference Whiteaves remarks: "Shell always much smaller than *Natica excavata* and the typical *G. conradiana* and differing from the latter also in having the upper edge or margin of the outer volution narrowly truncated and flattened downward next to the suture above". Waring in 1917 referred to Whiteaves' species forms that he found in the Simi Hills of Ventura and Los Angeles Counties.

Abundant specimens of *Gyrodes expansa* from northern California are in the Institute collections, as are additional numerous specimens of *Gyrodes* from Waring's Simi Hills locality, and from Sucia Islands, Straits of Georgia. It is difficult to see in what way the specimens from the two latter localities may be separated from *Gyrodes expansa* of the Sacramento Valley area. While I have not seen Whiteaves' types, his figure and description of *G. canadensis* fit *G. expansa* perfectly. *G. expansa* also occurs at Sucia, although Whiteaves' does not list it from there. The fossils described under the two names are almost surely conspecific, and Gabb's name, being the earlier, has precedence.

Genus Euspira Agassiz

Euspira shumardiana (Gabb)

Plate 13, fig. 3.

1864 Lunatia shumardiana n.s., Gabb, Pal. Calif., vol. 1, pp. 106, 224, pl. 19, fig. 61.

1917 Gyrodes compressus n.s., Waring, Calif. Acad. Sci. Proc., (4), vol. VII, no. 4, p. 67, pl. 9, fig. 6.

1922 Gyrodes californica n.s., Packard, Univ. of Calif. Pubs., Bull Dept. Geol. Sci., vol. 13, no. 10, p. 429, pl. 35, figs. 2, 2a.

1927 Polinices shumardianus (Gabb), Stewart, Acad. Nat. Sci. Phil., Proc., LXXVIII, p. 325, pl. XXI, fig. 11.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 83(a), 94(r), 454(r), 455(r), 982(r), 983(c), 1054(r), 1055(r), 1057(r), 1059(r), 1060(c), 1061(r), 1167(r), 1169(r), 1173(r).

Williams formation; 974(c), 975(r).

Discussion: Packard, in describing Gyrodes californica differentiated it from G. compressus Waring on the basis of the presence of a compressed zone below the suture in the latter species, and its absence in the former. I have been able in this study to compare rather large collections of both species from the type localities of each. It is found that in any collection containing as many as half a dozen individuals that some forms will show this depressed subsutural zone and some will not. In other respects no feature upon which the specimens can be separated is discernible. The presence or absence of this depression is believed to be a feature of individual variation, and of less than specific importance.

Gyrodes, to which this species has been referred, was established by Conrad in 1860 as a subgenus of Natica. Since that time, it has been treated as a distinct genus by nearly every worker who has had occasion to study the group. In reviewing Gyrodes Meek remarked (1876, p. 309): "This genus is readily distinguished by its thin shell, wide open umbilicus, bounded by an angular more or less crenate margin and without a trace of callosity within, as well as by the truncated, slightly concave, and more or less wrinkled upper edge of its volutions - a combination of characters unknown in any other type of the Naticidae". An examination of the specimens here referred to Euspira shumardiana shows that every characteristic mentioned by Meek as characterizing Gyrodes is absent from E. shumardiana. It can in no way be considered to belong to Gyrodes. It may be referable to Polinices as Stewart has suggested. Its narrow, almost closed umbilicus, and the umbilical callosity that is truncate below the umbilicus and broad above are so similar to the characteristics of Euspira that I have tentatively referred it to that genus.

As shown by the distribution table, E. shumardiana appears to be limited in the Santa Ana Mountains to the higher portion of the Holz shale and to the Williams formation. The individuals from the latter horizon are much smaller than are those from the shale, but there seems no other good criterion for separating them.

Genus Ampullina Lamarck

Ampullina pseudoalveata (Packard)

1922 Amauropsis pseudoalveata n.sp., Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 13, no. 10, p. 429, pl. 35, figs. 1a, 1b, 3.

1927 Ampullina pseudoalveata (Packard), Stewart, Acad. Nat. Sci. Phil., Proc., LXXVIII, p. 334.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 79(r), 80(r), 302(r), 456(r), 979(r), 981(r), 1058(c), 1065(c), 1067(c), 1068(c), 1069(r), 1164(r).

Holz shale member; ? 92(a), ? 454(r), ? 1064(r).

Discussion: Dr. Packard listed this species from all three of his zones. It is believed that three separate species are represented. A. pseudoalveata as described and figured by Packard is apparently restricted to the Baker sandstone and to the basal beds of the shale.

Ampullina packardi n.sp.

Plate 13, figs. 4, 5.

Description: Shell small to medium size, robust; spire rather short; bodywhorl very large, about seven-eights the height of the shell; suture linear, bordered by a narrow sloping shoulder; whorl just below the shoulder markedly impressed with a shallow encircling sulcus; remainder of body whorl nearly globular; anterior apertural margin only slightly produced; columella excavated anteriorly and covered with a smooth heavy callus that entirely conceals the umbilicus; anterior apertural margin rather broadly rounded, with a conspicuous fasciole; aperture narrow posteriorly; ornamentation of fine growth-lines with occasional development of fine, narrow, incised, regularly spaced axial lines.

Holotype: C. I. T. Invertebrate Paleontology cat. no. 3453.

Type Locality: C. I. T. Invertebrate Paleontology loc. no. 1054.

Dimensions of type: Length, 24.1 mm., diameter of last whorl, 20.8 mm.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 453(r), 455(r), 983(r), 1054(c), 1055(r), 1057(r), 1061(r).

Discussion: Ampullina pseudoalveata is to be distinguished from A. packardi by these features: A. pseudoalveata has a broad, flat or channeled, shoulder to the whorl, is nearly flat to slightly concave below the suture, has a rather produced and peaked anterior apertural margin, and averages at least half again as large as A. packardi. A. packardi has a narrow rather sloping shoulder to the whorl, a pronounced spiral sulcation below the shoulder, and a rather short and rounded anterior apertural margin. In distribution, the latter species is confined to the middle and upper part of the Holz shale. A. pseudoalveata on the other hand is practically limited to the Baker sandstone, and the shale beds immediately overlying.

There is little doubt that the two species are closely related. Some difficulty may be experienced in separating these forms especially when the specimens are badly weathered. A. packardi may be a descendant of A. pseudoalveata for its small and immature members resemble the larger and geologically older species considerably in outline.

Family Fossariidae

Genus Lysis Gabb

Lysis californiensis Packard

1922 Lysis californiensis n.sp., Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10, p. 431, pl. 37, figs. 2, 3.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 83(c), 94(c), 982(c), 983(c), 985(r), 1059(r), 1061(r), 1163(r), 1167(r), 1168(c), 1169(c).

Williams formation; 1066(r).

Discussion: Four species of Lysis have been described from the Upper Cretaceous of the Pacific Coast, with the probability that a fifth form (Stomatia intermedia Cooper) may belong to this genus. The described species are: Lysis duplicosta Gabb, type of the genus, from Texas Flat; L.

suciensis Whiteaves, from the Sucia Islands; L. oppansus White from Penz Ranch; and L. californiensis Packard from the Santa Ana Mountains.

Packard (supra) in describing L. californiensis stated that the species was unornamented except for rather coarse lines of growth, though one cast showed spiral sculpture. Conversely, almost every one of the specimens I have seen from the Santa Ana Mountains exhibits a marked spiral sculpture, except in the case of those individuals that are obviously badly worn. This sculpture varies considerably in detail. In the majority of examples, it consists of moderately fine spiral raised lines alternating with groups of two or three much finer spirals; in one or two individuals the ornamentation becomes quite coarse; and in one specimen that does not seem badly worn, the sculpture is practically obsolete, except that a few obscure spirals may be made out with difficulty. Except for this variable ornamentation, the shells show few differences that could be used for specific discrimination.

It is significant that in the descriptions of several other of the species listed above, mention is made of the variability in sculpture shown within the species. It is also significant that a Lysis, now in the Institute collections from Penz Ranch, closely resembles the more coarsely sculptured specimens from the Santa Ana Mountains. Close comparison of topotype material may show several synonyms among the described species of the genus, and demonstrate that one or two species instead of five are present in the Pacific Coast Upper Cretaceous deposits.

Family Turritellidae

Genus Turritella Lamarck

Turritella chicoensis Gabb

Plate 13, figs. 7, 9, 10.

1864 Turritella chicoensis n.s., Gabb, W. M., Pal. Calif., vol. 1, p. 133, pl. 21, fig. 91.

1908 ? Turritella pescaderoensis n.s., Arnold, Ralph, U. S. Nat. Mus. Proc., vol. xxxiv, p. 358, pl. xxxi, fig. 7.

1916 Turritella pescaderoensis Arnold, Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, pp. 142, 143, 145, 148.

1927 Turritella chicoensis Gabb, Stewart, Acad. Nat. Sci. Phil., Proc., LXXVIII, p. 348, pl. 21, fig. 1.

Distribution: Typical dwarf form; Ladd formation, Holz shale member; C. I. T. loc. nos. 94(r), 453(a), 455(r), 489(r), 1053(va), 1054(a), 1055 (va), 1057(a), 1063(c), 1160(a), 1162(c), 1163(r), 1166(r), 1168(r), 1170 (a), 1171(c), 1172(r), 1173(a). Giant form, round-whorled; Ladd formation, Holz shale member; 83(va), 93(c), 95(a), 982(r), 983(a), 985(a), 1059(va), 1060(c), 1061(r), 1167(c), 1169(a). Giant flat-whorled form; Williams formation; 1052(va), 1056(a).

Discussion: Turritella chicoensis, one of the most persistent and abundant fossils of the upper portion of the Holz shale, was selected by Packard as the zone fossil of this part of the section. The species appears in three well-characterized horizons, each signalized by a distinct mutation. The lowermost horizon is that of the more shaly members of the Holz shale, extending from about the middle half of the shale section to within two hundred feet of the top of the section; the second horizon includes the sandy beds at the top of the Holz shale in the region between Silverado and Harding Canyons; the third horizon is that of the uppermost beds of the Williams formation.

The mutation of Turritella chicoensis characteristic of the horizon mentioned first above is the typical or dwarf form so abundantly found in the Canyon of Chico Creek, Butte County. It is a medium-sized shell with rounded whorls, rather depressed suture, four or five raised, rather widely spaced spirals on each whorl, and a narrow unornamented zone on either side of the suture. The mutation of Turritella chicoensis found in the second zone at the top of the shale is a giant form occasionally attaining a length of one hundred millimeters, or twice the length of the largest specimens found in the zone below. Except for their robust size, these giants do not differ in character from the typical dwarf variety of the species. In the upper levels of the Williams formation occurs the third mutant - a giant variety that has developed a flat-sided whorl in many individuals, due to the formation of strong spirals close to the suture line on both sides. This change in sculpture and whorl shape of this species would justify its description as a new species were it not for the fact that fully one-half of the giant forms from the highest horizon are exactly like the round-whorled giants found in the uppermost beds of the Holz shale. Again, some of the flat-whorled giants develop round whorls with sunken sutures on the last whorl or two of the shell, though the earlier formed whorls may have typically straight sides.

Turritella cf. T. seriatimgranulata Gabb non Roemer.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 79(r), 82(c), 981(c), 1065(r), 1068(c), 1069(c), 1164(va).

Discussion: This Turritella is a form with straight-sided whorls, linear suture barely impressed, sculpture of four or five rather strong, usually beaded spirals, with numerous fine spirals separating the principal ones. It strongly resembles T. seriatimgranulata Gabb, in shape and sculpture, though the forms from the Santa Ana Mountains are much larger than the specimens of T. seriatimgranulata figured by Gabb (1864, pl. 20, fig. 88) and Stewart (1927, pl. xxi, fig. 2). This is probably the form that has been referred to T. seriatimgranulata from the Santa Ana Mountains.

Dr. Charles Merriam of Cornell University has kindly examined the specimens of this species from the Santa Ana Mountains and compares them to a new species of Turritella to be described in his forthcoming monograph on the Turritellas of the Pacific Coast. Until this monograph is published, this species will be left undescribed.

Turritella iota n.sp.

Plate 13, fig. 8.

Description: Shell of medium size, rather slender; whorls slightly concave along the posterior four-fifths of the whorl, the sides diverging to a definite keel or shoulder near the anterior suture, and sloping abruptly from the keel to the suture; sculpture of three or four strong beaded spirals separated by numerous fine spirals developed between the principals.

Holotype: C. I. T. Invertebrate Paleontology cat. no. 3457.

Type Locality: C. I. T. Invertebrate Paleontology loc. no. 984.

Dimensions of type: Length (incomplete), 37.6 mm., diameter, 8.6 mm.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 92(r), 984(c), ? 1064(r).

Discussion: This form resembles somewhat Turritella sp. cf. T. seriatimgranulata discussed above, but differs from it in the pronounced keel present on the anterior part of the whorls, and on the slightly concave outline of the whorls back of the keel.

The holotype of this species is derived from a loose boulder near a fault in the Cretaceous section, which has cut the Baker sandstone entirely out of the section, and has dropped the Holz shale against the basement rocks.

The boulder in which the Turritella is found is associated with similar boulders bearing an entirely different assemblage of Cretaceous fossils. The Cretaceous age of the Turritella is unquestionable for in the boulder with it are found Trigonia, Oligoptycha obliqua, Tenea inflata, a small ammonite and other forms that recall a horizon well down in the Holz shale. The specimens rather doubtfully referred to this species from localities ninety and one thousand sixty-four occur also low down in the shale section. The stratigraphic position of this species is thus fairly well established.

Turritella ossa n.sp.

Plate 13, fig. 6.

Description: Shell small, rather slender; apical angle about 18°; whorls gently convex anteriorly, concave posteriorly, slightly inflated just posterior to the suture, constricted at the suture; suture linear; side and base of whorl meeting in a smoothly rounded curve; base oblique, gently convex, ornamented with a few very faint spiral lines most prominent at the juncture of side and base of the whorl; aperture quadrate, slightly higher than wide; sculpture of growth-lines only, or of very faint spiral lines in addition to the growth-lines; growth-lines inclined away from the aperture on the posterior part of the whorl, toward the aperture on the anterior part of the whorl, and crossing the base in almost a straight line.

Holotype: C. I. T. Invertebrate Paleontology cat. no. 3458.

Paratypes: C. I. T. Invertebrate Paleontology cat. nos. 3459, 3460.

Dimensions of a holotype: Length (incomplete), 20.0 mm., diameter, 9.4 mm.

Dimensions of a paratype: Length, 26.0 mm., diameter, 9.4 mm.

Type Locality: C. I. T. Invertebrate Paleontology loc. no. 984.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 1054(va), 1060(r), 1066(va), 1168(c), 1169(va).

Discussion: This small Turritella may at once be distinguished from any other described California form by its very faint or obsolete sculpture, and the shape of its whorl. In its distribution, it is confined almost entirely to the upper part of the Holz shale. While it occurs in but few localities, it is usually abundant when found at all.

I have found no record of the occurrence of this species outside of the Santa Ana Mountains, and know of no other California Turritella that resembles this species or is related to it.

Family Struthiolariidae

Genus Pugnellus Conrad

Pugnellus sp. cf. P. manubriatus Gabb

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 84(r), 978(r), 979(r), 1062(c), 1164(r).

Discussion: This species is closely related to Pugnellus manubriatus Gabb from the Upper Cretaceous of Northern California. The Santa Ana Mountains forms are so imperfect that comparison is difficult. Only two specimens show the shell preserved satisfactorily, and these two do not show the anterior canal. Incipient development of axial wrinkles is apparent on the shoulders of the whorls, but these wrinkles appear coarser than on typical P. manubriatus. Better material than is at present available is necessary to definitely determine the species.

Family Aporrhaidae

Genus Anchura Conrad

<u>Anchura</u> <u>falciformis</u> ? (Gabb)

1864 <u>Aporrhais</u> <u>falciformis</u> n.s., Gabb, Pal. Calif., vol. 1, p. 127, pl. 20, fig. 83.

1868 <u>Aporrhais</u> <u>falciformis</u> Gabb, Gabb, Amer. Jour. Conch., vol. 4, p. 145, pl. 14, fig. 14.

1916 <u>Alaria</u> <u>falciformis</u> (Gabb), Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 9, no. 12, pp. 148, 154.

1927 <u>Anchura</u> <u>falciformis</u> (Gabb), Stewart, Acad. Nat. Sci. Phil., Proc., LXXVIII, p. 360, pl. xxii, fig. 9.

<u>Distribution</u>: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 79(a), 82(c), 84(r), 301(c), 1062(r), 1069(r), 1164(c).

Holz shale member; 453(r), 454(c), 1053(c), 1054(r), 1057(r), 1060(r), 1064(r).

<u>Discussion</u>: The forms from the Santa Ana Mountains referred to this species appear to differ somewhat from the typical representatives of the species from northern California. It may later be necessary to describe the southern California <u>Anchura</u> as a new species. In general, the Santa Ana Mountains specimens have slightly coarser axial sculpture extending from suture to suture, while the axial ribs of the northern California forms become faint or obsolete near the posterior side of the whorl. Usually also, the spiral sculpture of <u>A. falciformis</u> consists of about ten fine low ridges, while the Santa Ana Mountains forms show four or five coarser spirals. These characteristics appear fairly constant. <u>Anchura condoniana</u> Anderson resembles the southern form considerably as far as can be judged by the figure. I have as yet no comparative material of this latter species available.

Genus Tessarolax Gabb

Tessarolax distorta Gabb

1864 Tessarolax distorta n.s., Gabb, Pal. Calif., vol. 1, p. 126, pl. 20, figs. 82, 82a, 82b.

1868 Tessarolax distorta Gabb, Gabb, Amer. Jour. Conch., vol. 4, p. 146, pl. 14, figs. 18, 19.

1927 Tessarolax distorta Gabb, Stewart, Acad. Nat. Sci. Phil., Proc., lxxviii, p. 363, pl. xxiii, figs. 4, 5.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 1053(r), 1168(r).

Discussion: A few fragmentary specimens from the above localities comprise the only reported occurrence of this species in southern California.

Family Turbinellidae ?

Genus Perissitys Stewart

Perissitys brevirostris (Gabb)

1864 Perissolax brevirostris n.s., Gabb, Pal. Calif., vol. 1, p. 91, pl. 18, fig. 43.

1903 Perissolax brevirostris Gabb, Whiteaves, Can. Geol. Sur., Mes. Foss., vol. 1, pt. 5, p. 356, pl. 43, fig. 3.

1909 Perissolax brevirostris Gabb, Arnold, U. S. Geol. Sur., Bull. 396, p. 11, pl. 1, fig. 2.

1916 Perissolax brevirostris Gabb, Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, p. 148.

1927 Perissitys brevirostris (Gabb), Stewart, Acad. Nat. Sci. Phil., Proc., lxxviii, p. 426, pl. xx, fig. 4.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 94(r), 983(r), 1057(r), 1060(r), 1063(r).

Williams formation; 974(c), 975(r).

Discussion: Perissitys brevirostris is one of the most ubiquitous species of the Upper Cretaceous of the Pacific Coast, being found from southern California to British Columbia, and appearing in nearly every fossil list given from the east side of the Sacramento Valley. Nevertheless, the species appears to have a rather restricted range stratigraphically. In the Santa Ana Mountains it is limited to the Williams formation and to the higher levels of the Holz shale; in northern California, it appears in localities in a position believed to be fairly high in the section.

The systematic position of this fossil is a matter of considerable doubt, as Stewart (supra, p. 426) indicates. Most observers have placed it near Tudicla in the Turbinellidae, a proceeding that is followed tentatively here.

Family Neptuneidae

Genus Siphonalia H. and A. Adams

"Siphonalia" dubius Packard

1922 Siphonalia dubius n.sp., Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10, p. 431, pl. 35, fig. 5.

Distribution: Baker sandstone member of the Ladd formation; C. I. T. loc. nos. 301(r), 1062(r), 1069(r), 1164(r).

Discussion: This form probably is not Siphonalia, though it may be related to that genus. There are no specimens in the collections showing a complete anterior canal. It appears to be nearly straight judging from the growth-lines. There is little suggestion of a siphonal fasciole. The inner lip is smooth.

Genus "Fulgur" Montfort

"Fulgur" hilgardi White

1889 Fulgur hilgardi n.s., White, C. A., Bull. 51, U. S. G. S., p. 22, pl. III, figs. 2, 3.

1902 Fulgur hilgardi White, Anderson, F. M., Calif. Acad. Sci. Proc., (2), vol. II, no. 1, p. 29.

1916 Fulgur hilgardi White, Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, p. 149.

1927 "Fulgur" hilgardi White, Stewart, Acad. Nat. Sci. Phil., Proc., lxxviii, p. 426.

Distribution: Ladd formation, Holz shale member; 1054(c), 1057(r), 1059(r).

Williams formation; 974(c), 975(c), 976(c), 1056(r).

Discussion: This species was originally described from Penz Ranch, and was reported later from Phoenix, Oregon, and from "Silverado Canyon, Orange County" by Anderson. Packard did not find the species in the Santa Ana Mountains.

Family Volutidae

Genus Volutoderma Gabb

Volutoderma averillii (Gabb), ver. magna Packard

1922 Volutoderma magna, Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10, p. 432, pl. 57, fig. 1.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 83(c), 93(r), 302(?), 454(r), 1054(r), 1057(r), 1169(r).

Williams formation; 86(c), 974(c), 975(r), 976(r), 1052(c).

Discussion: I am inclined to believe that Packard's species V. magna represents a giant form of V. averillii (Gabb). In his discussion and figure of this latter species, Stewart (1927, p. 409) states that Gabb's holotype is an immature specimen. Small individuals in the collection from the Santa Ana Mountains are not to be distinguished from the figured specimens of V. averillii, and their association with the giant Volutoderms leaves little doubt that they represent youthful forms of the same species.

The mature forms of V. averillii var. magna show below the suture of the last whorl, a sloping shoulder that is nearly devoid of sculpture. At the angle of the shoulder, widely spaced, indistinctly nodose, low spiral ridges appear. Toward the anterior part of the body whorl, these ridges become lower, smoother and more oblique to the columella. In the oldest and largest specimens, the shoulder of the last whorl becomes more pronounced, and the outer lip is expanded and flaring, as Packard described it.

Volutoderma santana Packard

1922 Volutoderma santana n.s., Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10, p. 432, pl. 37, fig. 1.

Distributions: Ladd formation, Holz shale member; C. I. T. loc. nos. 94(c), 95(r), 455(c), 983(r), 1053(c), 1054(c), 1055(r), 1170(r), 1172(r), 1173(r).

Williams formation; ? 974(r).

Discussion: Volutoderma santana is a robust form with a broader and more inflated shell than V. averillii magna. The shoulder of the whorl especially on larger and older specimens is rather narrow and square, and the ornamentation on the shoulder is of coarsely nodose spirals. The spiral sculpture on the posterior part of the body whorl is of prominent nodes spirally arranged, the interspaces separating the nodes being as broad as the nodes. The sculpture of the anterior portion of the body whorl is of rather low spiral raised cords.

Except for the doubtful individual referred to this species from locality nine hundred seventy-four, V. santana is confined to the Holz shale, and with exception of one locality is not represented in the collections in horizons higher than the subzone of typical Turritella chicoensis. I know of no record of the species outside of the Santa Ana Mountains.

Subclass Euthyneura

Order Opisthobranchia

Family Actaeonidae

Genus Actaeon Montfort

? Actaeon normalis Cooper

1894 Tornatella normalis n.sp., Cooper, Bull. no. 4, Calif. State Mining Bureau, pt. V, p. 46, pl. III, figs. 36, 37.

Distribution: Williams formation; C. I. T. loc. no. 974(r).

Discussion: So far as may be judged from the original description and figure, this species accords well with Dr. Cooper's "Tornatella" normalis. I have not seen actual specimens of the latter species.

Genus Actaeonella d'Orbigny

Actaeonella oviformis Gabb

1869 Actaeonella oviformis n.sp., Gabb, Pal. Calif., vol. 2, p. 173, pl. 28, fig. 58.

1916 Actaeonella oviformis Gabb, Packard, Univ. of Calif. Pubs., Bull. Dept. Geol., vol. 9, no. 12, pp. 144, 147.

1922 Actaeonella oviformis Gabb, Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10, pl. 36, fig. 4.

1927 Actaeonella oviformis Gabb, Stewart, Acad. Nat. Sci. Phil., Proc., lxxviii, p. 432, pl. xxi, fig. 13.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. noc. 84(va), 981(a), 986(va), 1071(a).

Discussion: This huge opisthobranch is restricted in the Santa Ana Mountains to a level slightly below the top of the Baker sandstone. It is very irregular in its distribution, occurring in some limited localities in tremendous numbers. A short distance along the strike from a prolific locality, it may be entirely absent. It is most abundant in the region between Williams Canyon and Aliso Canyon. Here it is doubtless the dominant form of the Baker sandstone.

Packard (1916, p. 144, et. seq.) has designated this fossil as the representative species of the faunal zone of the Baker sandstone.

Family Ringiculidae

Genus Oligoptycha Meek

Oligoptycha obliqua (Gabb)

1864 Cinulia obliqua n.sp., Gabb, Pal. Calif., vol. 1, p. 111, pl. 19, figs. 64, 64a, 64b, 64c.

1917 Cinulia obliqua Gabb, Waring, Calif. Acad. Sci., Proc., (4), vol. 7, no. 4, p. 66, pl. 9, fig. 2.

1927 Oligoptycha obliqua (Gabb), Stewart, Acad. Nat. Sci. Phil., Proc., lxxviii, p. 436, pl. xxiv, fig. 14.

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 83(c), 454(r), 983(r), 1053(c), 1057(r), 1063(r), 1160(r), 1166(r), 1167(r), 1168(c), 1169(c).

Williams formation; 974(va), 975(c), 976(a), 1052(a), 1056(r).

Discussion: This species is one of the most abundant, ubiquitous, and characteristic fossils in the Upper Cretaceous of the Pacific Coast. It ranges at least from Lower California to British Columbia. Its stratigraphic range is not well known, but it appears to range through a considerable part of the section, and thus to be of lesser value as a horizon fossil.

In the Santa Ana Mountains it occurs from beds well down in the shale section, and is found from that level continuously up to the top beds of the Williams formation.

Genus "Bullaria" of authors

"Bullaria" tumida Packard

1922 Bullaria tumida n.sp., Packard, Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., vol. 13, no. 10, p. 433, pl. 37, fig. 2.

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 456(c), 986(r), 1067(c).

Holz shale member; 92(r).

Discussion: Dr. Packard, in his original description of this species, stated that its zonal position is uncertain. It apparently is restricted in range to the Baker sandstone and the very base of the Holz shale.

Bullaria is said by Grant and Gale (1931, p. 451) to be an exact synonym for Scaphander. "B." tumida certainly does not belong to this latter genus. The proper generic designation for "B." tumida is as yet uncertain. It may represent a new genus.

Genus Cylichnina Monterosato

Cylichnina sp. cf. "Cylichna costata" Gabb

Distribution: Ladd formation, Holz shale member; C. I. T. loc. nos. 454(r), 1053(c).

Williams formation; 974(c), 976(c), 1052(r).

Discussion: This species is probably the same as the Cretaceous forms included by Gabb under Cylichna costata, for it appears to be well represented in the Upper Cretaceous collections from the east side of the Sacramento Valley. As suggested by Stewart, (1927, p. 440) the forms appear to belong to *Cylichnina*, for they have a perforated apex without callus, and the columella bears a weak anterior fold.

There are in the collections from the Santa Ana Mountains, perhaps forty gastropod species that have not been treated here. They apparently are all new. Many of the genera represented are new to the Pacific Coast Cretaceous, and a number of them may be new to Paleontology. Most of these forms are rare, being generally found at only one or two localities, and in many instances are represented by solitary specimens. Effective treatment of these gastropods will involve a virtual overhaul of the rather scanty and unsatisfactory literature on Cretaceous Gastropoda, and possibly the erection of a number of new genera. I hope to take up the work some time in the near future.

CLASS SCAPHOPODA

Genus Dentalium Linnaeus

Dentalium whiteavesi Anderson and Hanna

1864 *Dentalium cooperi* n.s., Gabb, Pal. Calif., vol. 1, p. 139 (in part).

1879 *Entalis cooperi* (Gabb), Whiteaves, Geol. Sur. Can., Mes. Foss., vol. 1, pt. 2, p. 133, pl. 16, figs. 10, 10a.

1935 *Dentalium whiteavesi* n.sp., Anderson and Hanna, Calif. Acad. Sci., Proc., (4), vol. XXIII, no. 1, p. 27, pl. 6, fig. 5.

Distribution: Ladd formation, Baker sandstone member; ? 79(r), ? 84(r). Holz shale member; 83(r), 92(r), 1061(r).

Williams formation; 974(a), 975(c), 976(r), 1052(r).

CLASS CEPHALOPODA

Order Ammonoidea

Genus Metaplacenticeras Spath

Metaplacenticeras pacificum (J. P. Smith)

1900 *Placenticeras pacificum* sp. nov., Smith, J. P., Calif. Acad. Sci., Proc., (3), vol. 1, no. 7, p. 207 et. seq., pl. xxiv, figs. 1-21, pl. xxv, figs. 9-11, pl. xxvi, pl. xxvii, figs. 1-13, pl. xxviii, figs. 1-5.

1902 *Placenticeras pacificum* J. P. Smith, Anderson, Calif. Acad. Sci., Proc., (3), vol. 2, no. 1, p. 79, pl. viii, figs. 162-164, 171-172, pl. ix, fig. 180.

1917 *Placenticeras pacificum* Smith, Waring, Calif. Acad. Sci., Proc., (4), vol. 7, no. 4, p. 70, pl. 9, figs. 18, 19.

1917 ? *Placenticeras sanctaemonicae* new species, Waring, op. cit., p. 70, pl. 9, figs. 20, 21.

1926 *Metaplacenticeras pacificum* (J. P. Smith), Spath, Geol. Mag., vol. LXVIII, no. 740, p. 79.

1927 *Metaplacenticeras pacificum* (Smith), Reeside, J. B. Jr., U. S. Geol. Sur., Prof. Paper 147, pp. 1, 2, pl. 1, figs. 8-12, pl. 2, figs. 6-10.

Distribution: Williams formation; C. I. T. loc. nos. 86(r), ? 95(r), 974(va), 974(r), 976(r), 977(r), 1093(r), 1094(r), ? 1095(r), 1097(r).

Discussion: Three species of *Metaplacenticeras* have been described from the Upper Cretaceous beds of the Pacific Coast. These are: *Metaplacenticeras pacificum* (Smith); *M. californicum* (Anderson); and *M. sanctaemonicae* (Waring). The type locality for the first two species is Henley, California. The third species was first described from material collected on the south slope of the Santa Monica Mountains, Los Angeles County.

M. pacificum and *M. californicum* have been reported from a number of localities in southern Oregon, and in northern, middle, and southern California. These two species have generally been found associated with one another. They are probably good horizon markers, for they appear to have a rather narrow stratigraphic range and are widely, though not abundantly, represented in the section. They may thus be considered to yield a basis for correlation of considerable importance.

In the Santa Ana Mountains, Metaplacenticeras pacificum appears to be confined to the horizon of the Williams formation. It is present in nearly every collection of any size made from this formation. It is easily distinguished, even when worn and fragmentary, and thus forms one of the most useful fossils for stratigraphic purposes that the formation affords.

Most of the individuals of this species so far found are small, usually measuring less than seventy millimeters in diameter, though two or three specimens have been collected that will exceed one hundred millimeters. The species is abundant in only one locality in the Santa Ana Mountains - number 974, which has yielded more than thirty good individuals.

Considerable variation in form and sculpture is to be noted in the individuals of this latter assemblage. The majority of the specimens show a moderately coarse ribbing, the ribs varying somewhat in number and spacing. In the latter characteristic considerable variation may be noted in the spacing of the ribs shown on the whorl flanks of a single individual. A similar variation is to be seen in the size and character of the nodes that form at the ends of the ribs, both upon the umbilical and the ventral borders. These different sculptural features differ independently from one another. Thus while the forms with the strongest ribbing on the flanks of the whorl show also the strongest ventral and umbilical nodes, some individuals with strong ribbing and strong umbilical nodes will show only low ventrolateral keels. Others, with well-developed umbilical nodes, have practically obsolete ventrolateral keels and smooth whorl flanks. Several other combinations of these variable characters might be cited. The number of ribs in one whorl also varies considerably in shells of the same size. Most of the specimens will show about twenty coarse ribs in half a whorl; some others show perhaps twenty-five in a half-revolution; while in others, as has just been mentioned, the ribbing is obsolete.

These observations show that M. pacificum is a species with considerable individual variation. For this reason, M. sanctaemonicae is included in the synonymy as a variant of M. pacificum. I have inspected the type of the former species. It seems to fall within the assemblage of characters noted in the variants of M. pacificum. It may also be noted that a considerable suite of specimens of M. pacificum collected in the Santa Monica Mountains, and now in the California Institute of Technology collections, shows the same variable characters that have just been described from the Santa Ana Mountains assemblage.

Metaplacenticeras pacificum is found in the Santa Monica Mountains; in the Arroyo del Valle, southeast of Livermore, Alameda County; in the sandstones above the Fagesia-"Schloenbachia" beds west of Henley, Siskiyou County; and in southern Oregon. It is probable that the horizon of the Williams formation is present in each of these localities. Unfortunately, little is known about the position of this fossil in the local section of each of these general regions, and less has been published about the species associated with this ammonite. More precise knowledge of both the position and association of this form will aid in correlating the beds in which it occurs.

Metaplacenticeras californicum (Anderson)

1900 Placenticeras californicum Anderson (MS), Smith, J. P. Calif. Acad. Sci., Proc., (3), vol. 1, no. 7, p. 203, et. seq., pl. xxv, figs. 1-8, pl. xxviii, fig. 6.

1902 Placenticeras californicum sp. nov., Anderson, Calif. Acad. Sci., Proc., (3), vol. 2, no. 1, p. 78, pl. viii, figs. 173-177.

1917 Placenticeras californicum Anderson, Waring, Caliv. Acad. Sci., Proc., (4), vol. 7, no. 4, pp. 57, 70, pl. 9, figs. 16, 17.

1927 Metaplacenticeras californicum (Anderson), Reeside, U. S. Geol. Sur., Prod. Paper 147, pp. 1-2, pl. 2, figs. 14-16.

Distribution: Williams formation; C. I. T. loc. nos. 974(r), ? 975(r).

Discussion: Like Metaplacenticeras pacificum, with which it is almost always associated, this species is found in the Santa Ana Mountains only in the Williams formation. I have not found it in the Santa Monica Mountains, although Waring (supra) reports it from this region. In the Simi Hills at a horizon perhaps one hundred feet stratigraphically below the base of the massive Cretaceous sandstones, M. californicum occurs in abundance. Peculiarly, it does not seem to be associated with M. pacificum in this region, although almost everywhere else that one of these species has been found, the other occurs also. This may suggest that the two species have slightly different stratigraphic ranges, but that the ranges overlap. The possibility of facies control being responsible is apparently excluded, for the two species occur in close geographic proximity in very similar sediments.

M. californicum differs from M. pacificum principally in its coarser ribbing, its somewhat thicker whorl-section compared to its diameter, and in its tendency to develop a series of nodes on the falcate ribs a short distance above the ventral shoulder of the whorl. These lateral nodes develop rather early in the youth of the animal and furnish an excellent criterion for separating young M. californicum from M. pacificum.

Genus Schloenbachia Neumayr s.l.

"Schloenbachia" sp. cf. S. knighteni Anderson

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 79(c), 301(r), 979(r), 1062(c), 1164(c).

Discussion: This species accords well with Anderson's description and figure of "S." knighteni, and may be identical with the latter form. The two appear at any rate to be closely related. Unfortunately, no good examples of S. knighteni are available for direct comparison in this study.

Little published information is available to show the distribution or range of this species. In the Santa Ana Mountains, it is restricted to the Baker sandstone. The only other occurrence cited is at Phoenix, Oregon, from where this fossil was first described by Anderson (1902, p. 28).

"Schloenbachia" sp. cf. "S". siskiyouensis Anderson

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. nos. 79(r), 84(r), 301(r), 302(r), 1062(c), 1067(r).

Discussion: This species is also fairly common and widespread in the Baker sandstone. It is usually found associated with "S". cf. knighteni described above.

In its coarsely tuberculate ventral keel, flat-sided whorls, and simple straight ribs, this species recalls the features of Prionotropis, as defined by Meek (1876, p. 455). This form differs from Meek's genotype in the character of the ribs. These, in Prionotropis woolgari, the genotype, are simple, straight, and continuous from umbilicus to ventral shoulder. In "Schloenbachia" cf. siskiyouensis, only each third rib reaches the umbilicus. The two intervening taper to a point and disappear along the dorsal region of the whorl flank. If the California form does not belong to Prionotropis it is closely related to that genus.

Schloenbachia sp. cf. "S". multicosta Anderson

Distribution: Ladd formation, Baker sandstone member; C. I. T. loc. no. 1067(c).

Discussion: This species resembles closely specimens in the Institute collections identified as S. multicosta Anderson. This latter species was originally described from beds of the Rogue River Valley in southern Oregon. The horizon is believed to be low in the Upper Cretaceous section of that area. I know of no other record of the occurrence of this species.

In common with all of the other Schloenbachia-like ammonites of the Santa Ana Mountains, this species has been found only in the Baker sandstone.

A few species of ammonites, mostly represented by poorly preserved and immature individuals are listed briefly here, with the stratigraphic position in which they occur. I am indebted for these tentative identifications to Dr. Frank M. Anderson, of Berkeley, California.

Williams formation:

Desmoceras sp. juvenile

Parapachydiscus ? sp.

Ladd formation, Holz shale member:

Puzosia ? sp.

Ladd formation, Baker sandstone member:

Scaphites sp.

Hamites ? sp.

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PLATE 9

All figures Natural Size Except as Otherwise Stated.

Figs. 1 - 3. Trinacria cor, new species. Cotype. 2x natural size. (1) Exterior of left valve; (2) umbonal view of left valve; (3) hinge of left valve.

Fig. 4. Lima sp. cf. L. suciensis Whiteaves. 2x natural size. Exterior view of right valve.

Fig. 5. Lima beta, new species. Holotype. Exterior of right valve.

Fig. 6 - 7. Inoperna bellarugosa, new species. (6) Exterior of left valve (holotype); (7) fragment of right valve showing coarse undulations on dorsal posterior border (paratype).

Fig. 8. Liopistha (Psilomya) hardingensis (Packard). View of complete specimen from the left side.


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PLATE 10

All Figures Natural Size Unless Otherwise Stated

Figs. 1, 3. Liopistha anaana (Anderson). $1\frac{1}{2}$x natural size. (1) Hinge of left valve; (3) hinge of right valve.

Fig. 2. Brachidontes bifurcatus new species. 3x natural size. Exterior view of right valve (holotype).

Fig. 4. Etea angulata (Packard). 2x natural size. Hinge of right valve of immature specimen.

Figs. 5 - 8. Astarte sulcata Packard. 2x natural size. (5) Exterior of left valve; (6) hinge of left valve; (7) hinge of right valve; (8) umbonal view of complete specimen.

Figs. 9, 10. Eriphyla ovoides (Packard). (9) Hinge of left valve; (10) hinge of right valve.

Figs. 11, 12. Eriphyla lapidis (Packard). (11) Hinge of right valve; (12) hinge of left valve.

Figs. 13 - 15. Crassatella gamma, new species. (13) Umbonal view of complete specimen (holotype); (14) exterior of right valve (holotype); (15) hinge of left valve (paratype).

Fig. 16. Liopistha (Psilomya) hardingensis (Packard). Umvonal view of complete specimen, showing concentric sculpture around the beaks.

PLATE 10

PLATE 11

All Figures Natural Size Unless Otherwise Stated

Fig. 1. *Crassatella gamma*, new species. Paratype. Hinge of right valve.

Figs. 2, 3. *Crassatella lomana* Cooper. (2) Hinge of left valve; (3) hinge of right valve.

Figs. 4 - 6. *Protocardia* sp. cf. *P. translucida* (Gabb). (4) Exterior of left valve; (5) hinge of right valve; (6) hinge of left valve.

Figs. 7, 8, 11. *Isocardia delta*, new species. (7) Anterior view of complete specimen (holotype); (8) exterior of left valve (holotype); (11) hinge of left valve (paratype).

Figs. 9, 10, 12. *Clisocolus corrugatus*, new species. (9) Umbonal view of left valve (holotype); (10) lateral view of left valve (holotype); (12) hinge of left valve (holotype).

Fig. 13. *Cyprimeria moorei*, new species. Cotype. 2x natural size. Hinge of right valve.

PLATE II

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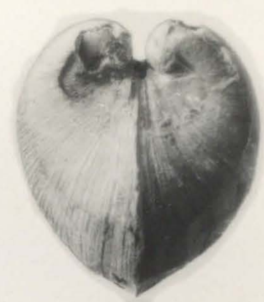

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PLATE 12

All Figures Natural Size Unless Otherwise Stated.

Figs. 1, 2. *Cyprimeria moorei*, new species. Cotypes. 2x natural size. (1) Exterior of right valve; (2) hinge of left valve.

Figs. 3, 5. *Tenea inflata* (Gabb). (3) Hinge of right valve; (5) hinge of left valve.

Fig. 4. *Flaventia lens* (Gabb). Hinge of right valve of a specimen from Butte Creek, Butte County, Calif.

Figs. 6, 7, 13, 14. *Calva regina*, new genus and species. Genosyntypes. (6) Hinge of right valve; (7) hinge of left valve; (13) exterior of right valve; (14) exterior of left valve.

Figs. 8, 12. *Legumen ooides* (Gabb). (8) Hinge of right valve; (12) hinge of left valve.

Figs. 9, 10, 11. *Flaventia zeta*, new species. (9) Exterior of right valve (holotype); (10) hinge of left valve (paratype); (11) hinge of right valve (paratype).

Figs. 15, 16. *Aphrodina ? arata* (Gabb). (15) Hinge of right valve; (16) hinge of left valve. 2x natural size.

PLATE 12

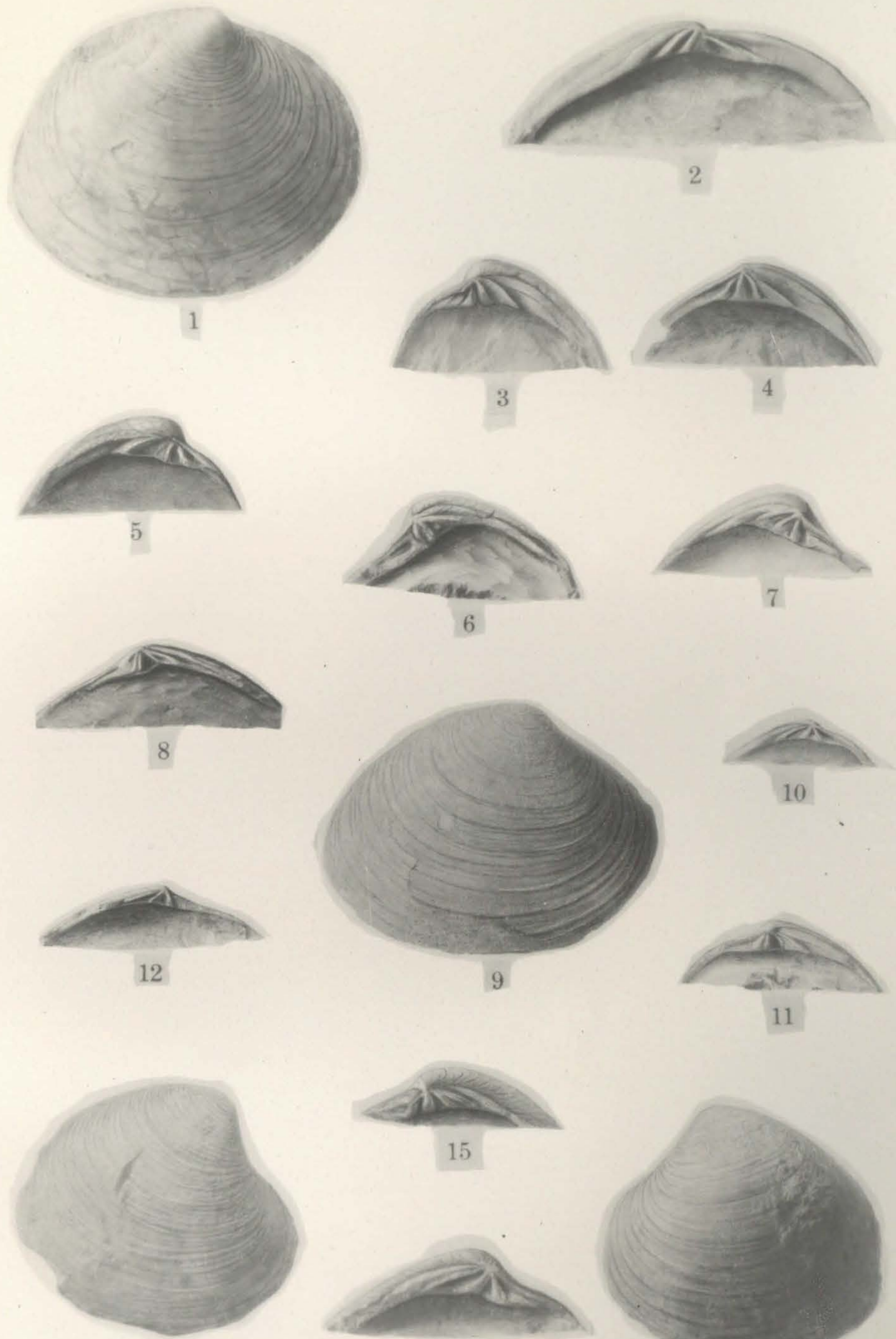

PLATE 13

All Figures Natural Size Unless Otherwise Stated.

Fig. 1. *Cymbophora ashburnerii* (Gabb). Hinge of left valve. $1\frac{1}{2}$ times natural size.

Fig. 2. *Cymbophora gabbiana* (Anderson). Hinge of right valve.

Fig. 3. *Euspira shumardiana* (Gabb). Apertural view.

Figs. 4, 5. *Ampullina packardi*, new species. Holotype. (4) Apertural view; (5) view of body whorl.

Fig. 6. *Turritella ossa*, new species. Holotype. $1\frac{3}{4}$x natural size.

Fig. 7. *Turritella chicoensis* Gabb. Typical variety.

Fig. 8. *Turritella iota*, new species. Holotype.

Fig. 9. *Turritella chicoensis* Gabb. Giant round-whorled variety.

Fig. 10. *Turritella chicoensis* Gabb. Giant flat-whorled variety.

PLATE 13