The STRATIGRAPHY and FORAMINIFERAL FAUNA of the SANTA SUSANA FORMATION

by

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ABSTRACT

The Santa Susana formation on the north side of the Simi Valley, Ventura County, California consists of 2360 feet of marine sediments. Macro-fossils found by previous workers indicate that the formation represents the Meganos Eocene. As these fossils came from the upper 300 feet of the formation, nothing was known concerning the correlation of the remainder of the section.

Abundant and well preserved foraminifera have been found by the writer through the entire section, with the exception of the lower 275 feet. These micro-fossils indicate that the lower portion of the Santa Susana is also of Meganos age.

The fauna has been found to consist of three distinct faunules which form the basis for the same number of zones. The validity of this zoning must be tested by checking the present section with others in this and other localities. This has not as yet been possible.

The foraminifera indicate that the Santa Susana formation represents two stages of the Gulf Coast Eocene succession, the upper Midway and the overlying Wilcox. Approximately fifty per cent of the total species present in the lower two zones are present in the

upper Midway of Texas. The correlation of the upper zone with the Wilcox of Alabama is less certain.

Six lithologic members are present in the section which show that the beds become gradually finer from the basal conglomerate upward into the middle shale member and then becomes coarser from the top of the shale member upward. These lithologic members do not correspond with the faunal divisions.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

THE STRATIGRAPHY AND FORAMINIFERAL FAUNA OF THE SANTA SUSANA FORMATION

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INTRODUCTION

The California Eocene has been the subject of a considerable portion of the literature on the west coast Tertiary since T. A. Conrad[1] recognised the fossils in a boulder from Grapevine Canyon at the extreme southern end of the San Joaquin Valley as Eocene in age. Since that notable discovery our knowledge of the marine Eocene has increased until the "Cretaceous 'B'" of Gabb[2] has been divided into four principal formations. These are, in ascending order, the Martinez, the Meganos, the Domengine and the Tejon formations. Within the last few years yet higher Eocene beds have been found in the western Santa Ynez range but as yet little has been published concerning the relation of these beds to the Tejon

1) Conrad, T. A., Preliminary report pacific railroad surveys, Paleontology, 1855; Pacific railroad reports 4to, vol. 5, pp. 317-329, 1856.
2) Gabb, W. M. in Whitney, J. D., Geological survey of California. Paleontology, preface, 1864.

formation.

The macrofauna of the marine Eocene has absorbed practically the entire attention of paleontologists studying these beds. However the correlation of many thick bodies of shale has remained largely a matter of conjecture due to their lack of macrofossils of stratigraphic value. A detailed study of many of these finer sediments has revealed the presence of perceptibly different foraminiferal assemblages which appear to have important stratigraphic value. Although the study of these microscopic forms involves a rather time consuming and specialized technique, micropaleontology has been of great value in the solution of many stratigraphic problems, especially in those formations in which the finer sediments predominate.

Probably the most complete and best exposed section of middle Eocene marine strata in California is to be found on the north side of the Simi Valley a few miles north-east of the town of Santa Susana, Ventura County, California. In this vicinity more than 4000 feet of beds of this age are found. The lower part of this series of beds, the Santa Susana formation, is largely composed of shales in which very few macrofossils have been found, except for those in a few sandy beds near the top. The results of a detailed study of this portion of the section are presented in

this paper.

As only a small portion of the vast literature on foraminifera was available for this study many of the names assigned to species may be open to question. However the intention of the present study is to use the foraminifera for stratigraphic purposes and thus even numbers assigned to the different species would serve very well. The conclusions drawn as to the correlation of the different outcrops are based entirely on comparisons of the Santa Susana forms with species from the other localities discussed, and are therefore independent of the names used to designate the species.

ACKNOWLEDGEMENTS

The writer is greatly indebted to Mrs. Helen Jeanne Plummer of Austin, Texas, for her generosity in supplying comparative material from many Gulf Coast localities, especially from the Texas Midway formation and for many helpful suggestions during the course of the work. Mr. Dale Sparks of Los Angeles greatly facilitated the author's work in permitting the use of his extensive collections from the Southeastern United States and Mexico. Special appreciation is due to Mr. A. E. May of

Bakersfield, California for the loan of his collections from the type section of the Meganos formation, and to Mr. E. R. Atwill of Alhambra, California for the loan of his collections from the Eocene section north of Coalinga, Fresno County, California. Dr. Hubert G. Schenck was also very kind in supplying material for comparative purposes. Messrs. D. D. Hughes, Boris Laiming and Dr. Paul P. Goudkoff of Los Angeles, California cooperated in various ways to encourage the writer's interest in the work. The writer also wishes to thank his associates at the California Institute of Technology for their cooperation and advice in the course of this study.

LOCATION AND GENERAL GEOLOGY

The section described lies along the lower portions of Las Llajas and Poison Oak canyons in eastern Ventura County a few miles northeast of the town of Santa Susana, and about 40 miles northwest of Los Angeles. A small scale map of a part of southern California and the portion of the Santa Susana quadrangle shown in figures 1 and 2 will serve to locate the area.

The strata studied in detail lie between the upper shales of the Martinez formation (Paleocene)

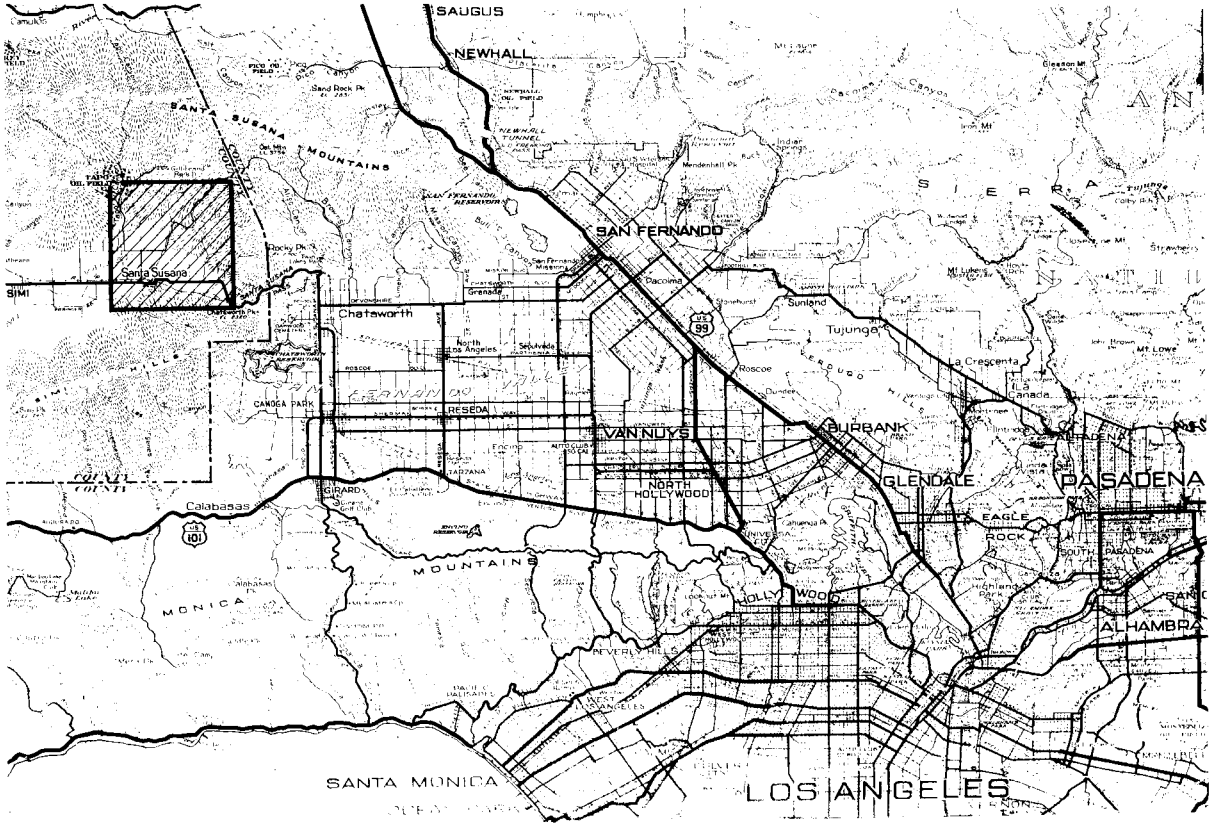
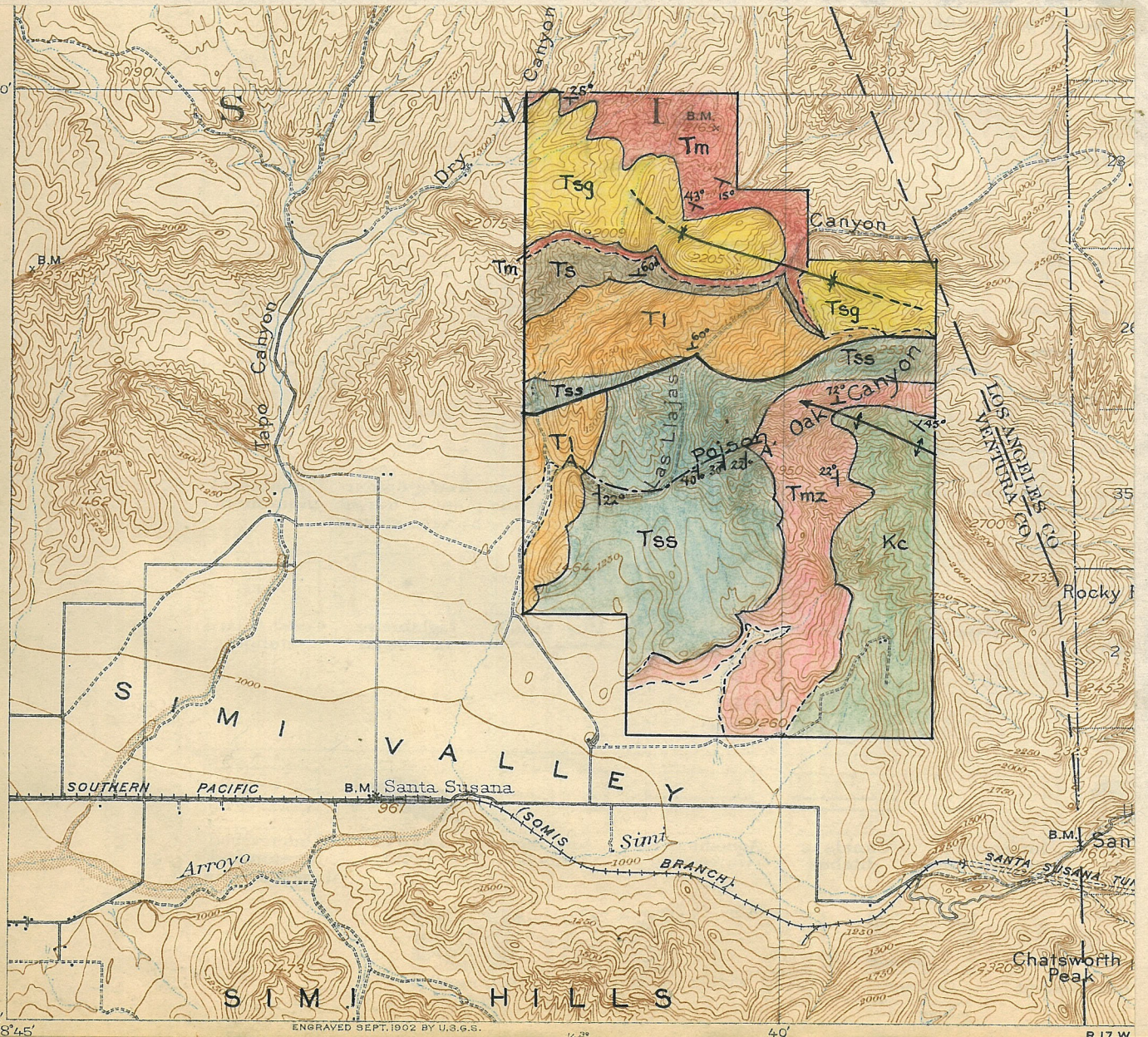


Fig. 1. - Map of a portion of southern California showing the location of the area of the map in figure 2.

Figure 2. - Portion of the Santa Susana quadrangle showing location of section and the geology in the vicinity. Section made along line AA'.



EXPLANATION

Pliocene & Pleistocene		Tsg	Saugus formation
Miocene		Tm	Modello formation
Oligo-cene	Eocene	Ts	Sespe formation
		Tl	Llajas formation
		Tss	Santa Susana formation
Pal-eocene		Tmz	Martinez formation
Cret-aceous		Kc	Chico (?) formation

Dip & Strike 25°
Contacts
Fault
Anticline
Syncline

and the basal conglomerates of the Llajas formation (Domengine Eocene). These beds have received the local name of the Santa Susana formation but have been considered by recent workers[1] to be equivalent to the Meganos of the type section. The beds along the course of the section dip rather uniformly to the west at angles of 20 to 50 degrees. The section is unbroken by faulting. The areal geology in the immediate vicinity is shown in figure 2 which is based on the unpublished maps of W. A. Findlay and F. D. Bode, members of the 1929 summer camp in field geology of the California Institute of Technology.

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1) Stewart, Ralph B., oral communication.

METHOD OF INVESTIGATION

Stakes were placed at measured intervals of from fifty to two hundred feet in the bottoms of Poison Oak and Las Llajas canyons. Rock samples were collected at intervals of approximately fifty feet or less throughout the length of the exposed section and were located by means of a steel tape extended between two consecutive stakes. Approximately 400 samples were collected. On completion of the sampling, a plane table traverse was carried along the line of stakes so as to accurately locate each one. Then with the aid of the measured distances, the position of each sample was located on the plane table sheet and a structure section prepared. During the course of the following year these samples were examined and about fifty of the original number were selected and prepared for a study of their microfaunal content.

HISTORICAL REVIEW

The first published reference to the Eocene of the Simi Valley region is apparently that by Dickerson[1]. He states: "A typical collection of Martinez fossils was made by the 1910 Stanford University class in geology forty miles northwest of Los Angeles in the Calabasas quadrangle". Although Dickerson at that time recognised two divisions of the California Eocene no mention is made of the occurrence of the upper one, the Tejon, in the Simi Valley.

In 1917, C. A. Waring,[2] a member of the 1910 Stanford field party, published a geologic map of a portion of the Calabasas quadrangle with a description of the fossil species collected from the Eocene and Cretaceous of southern California. The Eocene was divided into two formations, the Tejon conformably overlying the Martinez, the latter including the Santa Susana formation as recognized in this report.

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1) Dickerson, R. E., Fauna of the Martinez Eocene of California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 8, p. 6 9, 1914.
2) Waring, C. A., Stratigraphic and faunal relations of the Martinez to the Chico and Tejon of southern California, Calif. Acad. Sci. Proc., 4th ser., vol. 7, pp. 41-124, pls. 7-18, 1917.

During the following year a new division of the California Eocene, the Meganos Group, was proposed by B. L. Clark[1]. He divided the Eocene of the Simi Valley section into three parts, placing portions of both the Tejon and Martinez as mapped by Waring into his Meganos (middle Eocene). Clark[2] has a note on the Eocene of the Calabasas quadrangle as follows:

> "The Tejon of this section rests unconformably on the Meganos, the unconformity being indicated by an irregular contact, a marked difference in strike and a possible difference in dip, together with a basal conglomerate. A very good typical Tejon fauna was obtained above this contact."

A year later, W. S. W. Kew[3] published a more detailed map of the Simi Valley area than that of Waring, but still retained the two-fold division of the Eocene into the Tejon and Martinez formations. In a later report Kew[4] accepted Clark's three-fold

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1) Clark, B. L., Meganos group, a newly recognised division in the Eocene of California, Bull. Geol. Soc. America, vol. 29, pp. 281-296, 1918.
2) op. cit., p. 295.
3) Kew, W. S. W., Structure and oil resources of the Simi Valley, southern California, U. S. Geol. Survey Bull. 691, pp. 323-355, 1919.
4) Kew, W. S. W., Geology and oil resources of a part of Los Angeles and Ventura counties, California, U. S. Geol. Survey Bull. 753, pp. 14-30, 1924.

division of the California Eocene and mapped the three formations in the Simi Valley region. According to Kew, the Martinez formation consisted of 1,500 to 3,000 feet of marine sediments unconformably overlying the Cretaceous. Nearly all of the Tejon of the earlier report was mapped as Meganos. These deposits consisted of 2,000 to 3,500 feet of marine sediments overlying the Martinez with apparent conformity. The Tejon was recognized only on the south side of the Simi Valley, directly south of the town of Simi. Here this formation consisted of about 2,000 feet of probably marine strata resting on the Meganos with marked unconformity and overlapped by the Miocene near the west end of the Simi Hills. The fossils on which the age of these strata was based were poorly preserved and few in number but were identified by Dr. B. L. Clark as of typical Tejon age.

In 1925 R. N. Nelson[1] proposed the name "Santa Susana shale" for a lithologic member of the Eocene section overlying the Martinez in the Simi Hills.

1) Nelson, R. N., A contribution to the paleontology of the Martinez Eocene of California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 15, p. 4-2, 1925.

According to Nelson it consisted "predominantly of light gray shale with some fine grained sandstone and a lens of conglomerate at the base near its eastern end". These beds were believed to be conformable with the Martinez. The fauna of the Santa Susana shales was found to be closely related to that of the Meganos but contained "several distinctive genera such as Corbis and Velates, which are new to the California Eocene". Nelson mapped the beds overlying these shales as Domengine formation, "(the name Domengine was proposed by F. M. Anderson and is now used by B. L. Clark for the upper part of his Meganos group.)"

In 1926 Dr. B. L. Clark[1] proposed a fourth division of the California Eocene, namely the "Domengine horizon". In this paper the Santa Susana shales of Nelson were termed the Santa Susana formation and were described as lying disconformably on the Martinez. These beds were tentatively correlated by Clark with the Meganos of the type locality. Clark[2] states further:

> "As found at the east end of the Simi Valley this formation (Santa Susana) has a thickness of about 1800 feet, consisting of light colored shales

1) Clark, B. L., The Domengine horizon, middle Eocene of California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 16, pp. 99-118, 1926.
2) op. cit., p. 109.

and sandy shales. Here at the base is a conglomerate containing boulders of Martinez fossils, e. g., Retipirula crassitesta Gabb. - - - - In Llajas Canyon the upper 300 feet of shales, which are locally very sandy, are fossiliferous. A fairly large distinctive fauna has been obtained from the Santa Susana formation, a considerable number of species of which are new and have not been found either in the Martinez horizon below or in the Domengine above. The fauna includes among others Ficopsis N. sp., Turritella n. sp., Lyonsia n. sp. which are found in the deposits of the type locality of the Meganos. The presence of these species together with the stratigraphic position of the formation, is the evidence for correlating it with the Meganos".

Briefly then, according to the existing literature, four divisions of the California Eocene have been reported from the Simi Valley region. These are the Martinez formation, the Santa Susana formation (correlated with the type Meganos), the

Domengine (locally known as the Llajas formation[1]) and Tejon (?). B. L. Clark[2]) states concerning the presence of Tejon strata "At the present time, (1926), because of the meagerness of the fauna, it seems best to question the correlation of these beds with those of the Tejon of the type section though the writer is of the opinion that when a larger fauna has been obtained from these beds they will prove to be Tejon."

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1) The term Llajas formation was first suggested by Dr. Ralph B. Stewart. It was used by the 1929 summer camp in field geology under the direction of Dr. W. P. Woodring of the California Institute of Technology. Although the name has not been formally proposed as a formational designation it has found its way into the literature and is commonly employed by geologists and paleontologists.

2) Clark, B. L., The Domengine horizon, middle Eocene of California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 16, p. 110, 1926.

STRATIGRAPHY

General Character

The Santa Susana formation in the area studied lies unconformably on the Martinez shales. The evidence for the unconformity consists of boulders in the basal conglomerate of the Santa Susana formation which carry Martinez fossils, an exceedingly sharp break in lithology from clay shale to heavy conglomerate, the presence of angular to subangular pebbles of the underlying shale in the conglomerate which range in size up to boulders over ten feet in length, and an apparent difference in dip of about ten degrees. There is no difference in strike between the two formations and no dips were obtainable in the Martinez within 100 feet, stratigraphically, of the contact. For these reasons the angular discordance of the two formations is uncertain. Further study in adjoining areas will be necessary to determine the exact nature of the unconformity and its areal extent.

The Santa Susana formation is composed of 2360 feet of marine sediments in the section studied. The beds become gradually finer from the basal conglomerate upward through the lower 1730 feet of the section

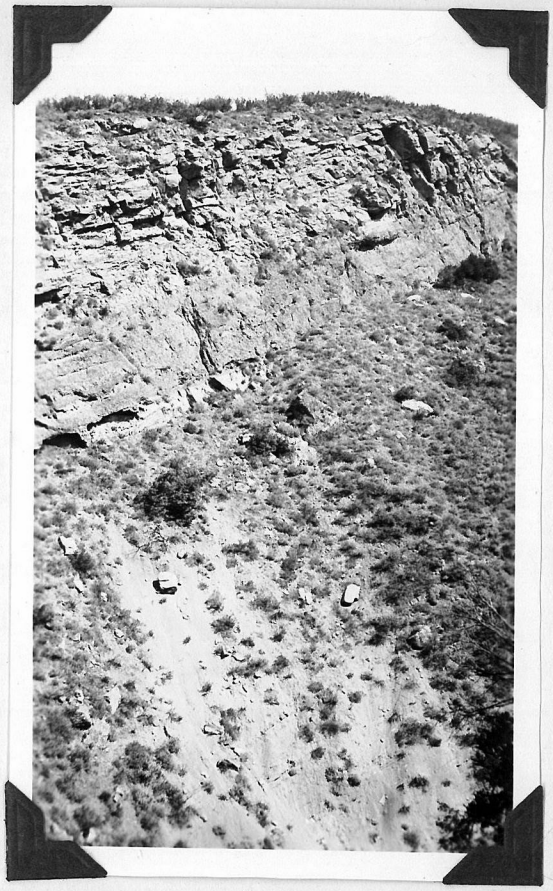
and from that point upward the sediments become gradually coarser. The uppermost beds are fine to medium grained sandstone. A columnar section is shown on plate IV.

The contact with the overlying Llajas formation is believed to be conformable. Near the mouth of Las Llajas Canyon the contact is very well exposed for a distance of several hundred feet and the lower beds of the Llajas conglomerate were shown to lens along the strike grading into the medium grained sandstones of the upper Santa Susana. The presence of blue-gray shale fragments in the basal portion of the Llajas conglomerate might be taken as evidence for disconformity but this is not believed to be a good criterion. Also, there is no reason to exclude the possibility that these shale fragments were derived from the Martinez shales which are very similar to those of the Santa Susana. The microfauna is also much more closely related to that of the overlying Llajas formation than would be expected if an erosional interval of any significance were present.

Lithology

The Santa Susana formation, as exposed in the section studied, may be roughly divided into six lithologic members as follows:

PLATE I



(A)

(B)

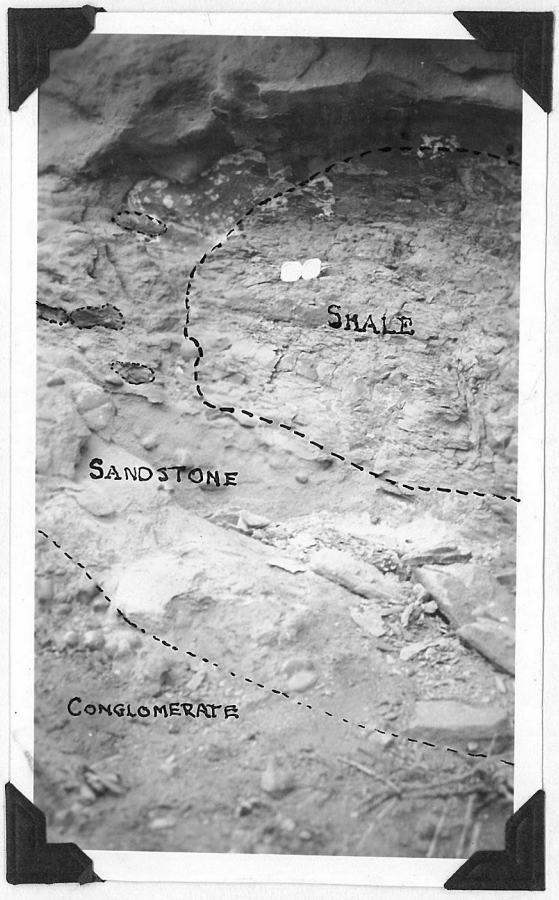
A. Contact between Martinez shales and the overlying Santa Susana Formation in Poison Oak Canyon.
B. Closer view of the same contact as (A).

Generalized Section along Las Llajas and Poison Oak Canyons.

Llajas Formation - conglomerate and interbedded sandstone.
Santa Susana Formation.
Upper sandstone - - - - - - - - - - - - - 250'
Upper sandstone - shale transition. - - 350'
Middle shale- - - - - - - - - - - - - - -1500'
Lower sandstone - shale transition- - - 125'
Lower sandstone - - - - - - - - - - - - 50'
Basal conglomerate- - - - - - - - - - - 75'
Martinez Formation - clay shale. Total -2350'

Basal Conglomerate. - The basal portion of the Santa Susana formation as exposed in Poison Oak Canyon is composed of 35 feet of heavy, well cemented, gray conglomerate with lenses of coarse arkosic sandstone. The conglomeratic material is composed of about sixty-five percent gray-green and red andesite porphyry, fifteen percent granite and related rocks, ten percent quartzite and the remaining ten percent is blue-gray clay shale, gray, richly fossiliferous sandstone and gneissic rocks. The conglomeratic material ranges up to about two feet in diameter and averages about two inches. The matrix consists of coarse angular arkosic sandstone. Pebbles and boulders above one inch in diameter are well rounded but the smaller pebbles and granules are in general subangular to subrounded. For this reason some of the finer portions of the conglomerate, especially near the top of the member, appear to be more angular than other portions.

PLATE II

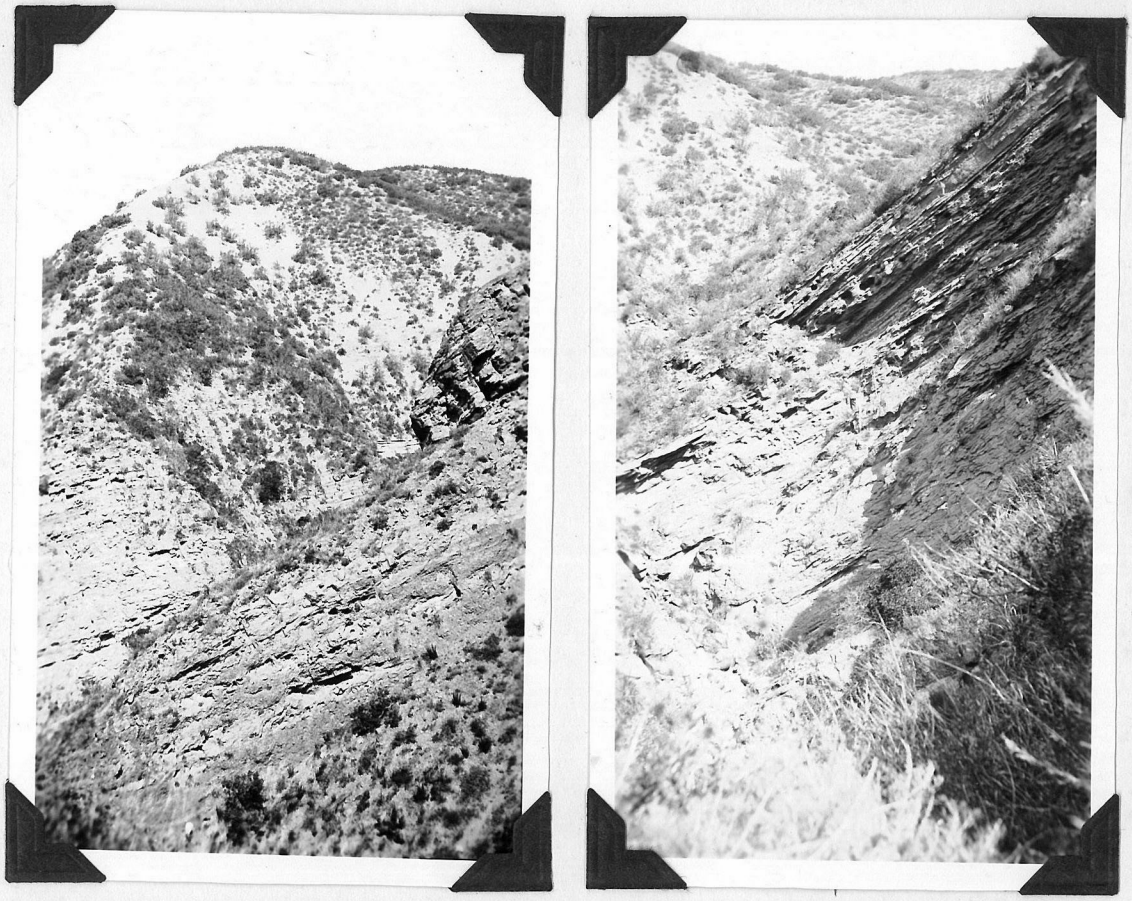


Large boulder of Martinez shale in sandstone lens of Santa Susana basal conglomerate.

The Santa Susana conglomerate can be easily distinguished, in the section studied, from the Llajas conglomerate on the relative consolidation and the proportions of andesite and quartzite pebbles. The Llajas conglomeratic material is composed of about fifty percent quartzite and thirty percent andesite. The plutonic rocks and gneiss are much more decomposed in the Llajas conglomerate which is poorly cemented and has a larger proportion of matrix than the Santa Susana basal beds.

Possible sources for this material have not been studied but the high percentage of quartzite pebbles suggests that the ultimate source of the material was the western bed rock complex. The immediate source, however, is probably the Martinez conglomerate or the Cretaceous conglomerates or both. No attempt has been made to locate the original source of the andesites. That some material was furnished by the eastern bed rock complex is shown by the presence of granitic rocks. It is hoped that a study of the heavy minerals in the matrix of this and the other conglomerates of the area will furnish some more definite clue as to the source areas for these rocks.

PLATE III



(A) (B)

A. View looking north-west up a small tributary to Poison Oak Canyon showing basal conglomerate in the foreground and the middle shale member in the background.

B. Closer view in the same tributary as (A) showing the lower sandstone and the sandstone-shale transition members.

Perhaps the most interesting feature of this member is a lenticular bed of arkosic sandstone about 25 feet above the Martinez contact which carries a great number of blocks of blue-gray clay shale. These blocks were undoubtedly derived from the underlying series of Martinez shales with which they appear to be lithologically identical. Some of these masses of shale reach dimensions of more than ten feet in length and four feet in thickness. The random orientation of these fragments precludes the possibility that they were deposited as a shale filling of channels or depressions at some stage in the depositional history of the sandstone. Even granting the derivation of these huge blocks of shale from the underlying Martinez formation, the manner of their emplacement in the sandstone is almost beyond conjecture. Although the contact surface between the two formations shows evidence of erosion, it is extremely regular as far as could be observed. This would not suggest that there was a region of any great relief prior to the deposition of the sandstone lens. For the present at least, no satisfactory explanation of these blocks can be offered.

Lower Sandstone.- Overlying the basal conglomerate are beds of massive, medium to coarse grained gray sand-

stones, which, with some thinly bedded material of the same nature, have a thickness of about 50 feet. These beds are well indurated and have a calcareous cementing material. Concretions are fairly common but are mostly of small size. The material is arkosic and carries abundant mica flakes some of which are almost one-fourth of an inch across.

At some horizons this sandstone is vaguely laminated and in some places this laminated material is highly contorted on a small scale. Differential weathering of alternate laminae causes the contortion to be very obvious on these weathered surfaces. As the overlying beds are undisturbed this contortion is believed to be due to contemporaneous deformation. The more massive beds in the laminated sandstones were evidently too competant to fold so that they have fractured and the small blocks so formed have been rotated into positions as much as 30 degrees from their normal attitude. This gives the beds an appearance which may be easily mistaken for cross bedding as the overlying beds have normal attitudes and are undeformed.

Lower Sandstone - Shale Transition. - The next 120 feet of sediments as one goes higher in the section form the transition from the underlying sandstones

to the thick shale section immediately above. These beds consist of interbedded sandstone similar to those just described and sandy shales. This member may be further divided into two divisions of approximately equal thickness. The lower is characterized by brownish weathering sandy shales interbedded with the sandstone which ranges from coarse to medium grade. The upper half of this member carries interbedded shales which are blue-gray in color, less sandy and much better indurated. The sandstone of this upper portion is generally fine to medium grained.

Middle Shales. - This member is composed of about 1460 feet of blue-gray clay shale of very uniform character. These compact, dense, tough shales form a very monotonous section broken only by thin limy beds and slight differences in the degree of lamination. The lowermost portion of this member is in part sandy and carries fairly abundant foraminifera preserved partly as casts and partly in their original condition. The preservation of the micro-fossils becomes gradually better upward in the section until near the top of this member and in the overlying beds the foraminifera are in an excellent state of preservation.

In spite of the tough, compact character of these shales and their general rather limy character, the surface of the exposures reached by the sun, slakes to a very crumbly sediment which is rather easy to wash in preparing samples for foraminiferal examination. However on fresh exposures, in shady canyon bottoms and a very few inches below the surface of an outcrop, the shale is found to be very hard and tough. For this reason many samples known to carry foraminifera have not as yet been examined microscopically.

The preservation of the tests of the foraminifera in the lowermost beds, the Loxostomum applini zone, is interesting in that the forms which originally had calcareous tests of their own secretion are filled with calcite, while those which possessed agglutinated tests with calcareous cement have been filled with granular silica and have had the calcareous cement replaced by siliceous material. This selective replacement and filling appears to be due to the quartz grains in the tests composed of agglutinated arenaceous material acting as centers of crystallization, attracting the silica dissolved in the circulating ground waters while the calcareous material in the secreted tests acted similarly in forming centers for crystallization of calcite. The arenaceous

tests should be filled with relatively coarsely crystalline quartz is a matter difficult to explain. Normally these tests would be filled with chalcedony or opal. This appears to be a matter worthy of further study.

Upper Sandstone - Shale Transition. - This member is composed of about 365 feet of interbedded brown, micaceous sandy silts, shaly fine sands and clay shales similar to those of the middle shale member. Fairly well preserved macro-fossils and abundant, well preserved foraminifera are present in some beds of this member. On the whole these beds are poorly exposed in Las Llajas canyon due to their slightly indurated condition.

Upper Sandstone. - The uppermost member of the Santa Susana section studied consists of 290 feet of brownish to light gray, medium to fine grained, fairly well sorted sandstones. These sediments are thin bedded and on the whole are rather poorly indurated. Foraminifera were found in these sands a few feet below the contact with the Llajas formation. Limonite staining, affecting the micro-fossils especially, is very common.

FAUNA

General Character

The foraminiferal fauna of the Santa Susana formation in the section studied is composed of three distinct assemblages. In ascending order these are: the Loxostomum applini zone; the Verneuilina triangularis zone; and the Hemicristellaria zone. Further division of these zones on the basis of restricted ranges of individual species is possible with the data at hand, but due to the limited knowledge of the stratigraphic and areal distribution of the individual species it seems best to leave more detailed zoning for further study.

In general the fauna is characterized by the dominance of the Lagenidae, the scarcity of pelagic forms such as the Globigerinidae and the Globorotaliidae, and the almost total absence of the Miliolidae. This distribution suggests a deep nearly landlocked or epeiric sea. The evidence for such a statement is admittedly very inadequate but the suggestion seems important in view of the possibility of a western source area for these sediments.

The character of the forms found in the three zones suggests very deep or cool water at the begin-

ning of the shale deposition, that is in the beds carrying the Loxostomum applini faunule, with a gradual shallowing higher in the section. The Llajas conglomerate is apparently the culmination of this shallowing and marks a return to somewhat deeper water conditions. The fauna of the overlying Llajas shales is one suggesting the warm, rather shallow water faunas of the present ocean.

The total number of species found in the Santa Susana section thus far is in excess of one hundred. Eighty-two of these are shown in the check list on plate IV, the others being omitted because of their extremely rare occurrence, doubtful generic determination, or extremely poor preservation. More complete lists accompany the descriptions of each faunal zone. Study of additional material from this section and others will undoubtedly greatly increase this number.

Loxostomum applini Zone.

This faunule has been found only in the lowermost beds of the middle shale member. It was first encountered 75 feet above the base of the member or 275 feet above the Martinez shales in Poison Oak Canyon, and extends upward through about 125 feet of sec-

tion. This range will probably be extended upward into the lower part of the overlying "barren zone" which has yielded only a few poorly preserved foraminifera thus far.

The assemblage of this zone is characterized by Loxostomum applini (Plummer), Gaudryina indentata Cushman and Jarvis, Pulvinulinella culter (Parker and Jones) var., Nodosaria pomuligera (Stache), Nodosaria vertebralis (Batsch), Silicosigmoilina californica Cushman and Church, and several other species of more limited occurrence. This faunule is very distinct in the section studied as only nine species of the fifty listed below are found higher in the section. This faunule can be correlated with that of the "G" division[1] of the type Meganos. Other California localities at which this assemblage has been noted are: the lower half of the shale body underlying the Domengine sands in the Tumey Gulch section[2] north of Coalinga, Fresno County, California; and the lower Eocene beds of San Nicolas Island.

1) Clark, B. L. and Woodford, A. O., The geology and paleontology of the type section of the Meganos formation (lower middle Eocene) of California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 17, p. 72, 75, 1927.
2) Atwill, E. R., Stratigraphy and micropaleontology of the Eocene in the Cantua Creek-Tumey Gulch area, California, paper read before the Pacific Section of the Soc. Econ. Paleon. Mineralogists, Nov. 3rd, 1932.

As far as can be determined from the rather meager knowledge of the ecology of the foraminifera this faunule indicates either relatively deep water or very cool shallow water conditions. Deep water which of course would necessitate relatively low temperature, appears to be the better explanation due to the character of the sediments, and the uniformity of faunal character over large areas. Whether temperature or depth of water is the ecologic control of foraminifera still remains an unsettled question. In shallow and moderately deep waters of the present oceans, temperature is apparently the chief control but with increasing depth the temperature soon ceases to vary an appreciable amount, while character of the microfauna continues to change. Therefore it seems apparent that temperature is not an important factor in deeper water, while depth assumes a very important control. It also seems logical to say that depth is a more or less constant influence with temperature coming into effect with decreasing depth and finally assuming the major control. The combined effect of the two variables should produce greater variations in shallower water faunas and such seems to be the case. In

stratigraphic work the micropaleontologist finds the deeper water assemblages excellent markers over large areas while the shallow water faunas are of value, generally, only within a single basin of deposition.

The following species have been found in the Loxostomum applini zone from six localities in Poison Oak Canyon:

Ammobaculites triangularis n. sp.
Ammodiscus incertus d'Orbigny
Anomalina grosserugosa Gumbel
Bathysiphon (?) sp.
Bolivina incrassata Reuss var. limonensis (?) Cushman
Bulimina inflata Seguenza
Bulimina obtusa d'Orbigny
Bulimina sp. 1
Ceratobulimina sp. (?)
Clavulina humilis var. mexicana Cushman
Cornuspira involvens Reuss
Lponides tenera (H. . Brady)
Epistomina elegans (d'Orbigny)
Gaudryina infentata Cushman and Jarvis
Gaudryina sp. (?) of Cushman[1]
Gaudryina sp. 1
Glandulina manifesta (Reuss)
Glandulina radicula (Linnaeus)
Globigerina cf. compressa Plummer
Globigerina triloculinoides Plummer
Globorotalia sp. (?)
Gyroidina soldanii (d'Orbigny) var. subangulata Plummer
Gyroidina sp. 1
Gyroidina sp. 2
Gumbelina sp. (?)
Haplophragmoides cf. canariensis (d'Orbigny)
Haplophragmoides sp. (?)
Lagena cf. apiculata (Reuss)
(?) Lenticulina orbicularis (d'Orbigny)
(?) Lenticulina sp. 1
(?) Lenticulina sp. 2
Loxostomum applini (Plummer)

1) Cushman, J. A., Foraminifera of the Velasco Shale, Bull. Am. Assoc. Petroleum Geologists. vol. 10, p. 583, pl. 16, figs. 11a,b. 1926.

Marginulina glabra d'Orbigny
Nodosaria adolphina d'Orbigny
Nodosaria granti Plummer
Nodosaria latejugata Gumbel
Nodosaria pomuligera (Stache)
Nodosaria spinulosa (Montagu)
Nodosaria vertebralis (Batsch)
Nodosaria sp. (?)
Nonion umbilicatulus (Montagu)
Pleurostomella alternans Schwager
Pulvinulinella culter (Parker and Jones) var.
Quinqueloculina ferussacci d'Orbigny
Silicosigmoilina californica Cushman and Church
Silicosigmoilina sp.
Spiroplectamina sp. 1
Textularia agglutinans d'Orbigny
Trochamina (?) sp.
Verneuilina sp. (?)

Verneuilina triangularis Zone

The faunule found in Poison Oak and Las Llajas Canyons 1345-1495 feet above the base of the Santa Susana formation is designated the Verneuilina triangularis zone. The range given above may be extended downward into the so-called "barren zone", (see plate IV) when further samples from the underlying strata are examined. Characteristic species are Verneuilina triangularis n. sp., and Siphonina cf. wilcoxensis Cushman. Other forms such as Valvulineria meganosensis n. sp., Anomalina ammonoides (Reuss) var. acuta Plummer, and Eponides exigua (H. B. Brady) are also confined to this zone but appear to have restricted ranges within the interval mentioned.

A few species from a sample 1500 feet above the Martinez shales are included in the faunal zone for convenience, although this assemblage carries none of the species mentioned above as characteristic.

The Verneuilina triangularis zone faunule has not been seen elsewhere in California by the writer. The following species have thus far been recorded from this zone in the four samples studied:

Anomalina ammonoides (Ruess) var. acuta Plummer
Cibicides cf. rigida (Schwager)
Discorbis infrequens Plummer
Epistomina elegans (d'Orbigny)
Gyroidina soldanii (d'Orbigny) var. subangulata Plummer
Eponides exigua (H. B. Brady)
Eponides tenera(?) (H. B. Brady)
Nodosaria gracilis Neugeboren
Siphonina cf. wilcoxensis Cushman
Valvulineria meganosensis n. sp.
Verneuilina triangularis n. sp.

The following were noted in the 1500 foot sample mentioned above:

Cibicides mexicana Nuttall var.
Haplophragmoides eggeri Cushman
Nodosaria soluta Ruess
Robulus kemperi(?) (Hanna)

Hemicristellaria Zone

This zone is characterized by several species of the genus Hemicristellaria, as well as Anomalina umbonata Cushman, Eponides lotus (Schwager), Uvigerinella triangularis n. sp., an abundance of Cibicides, and several others.

Although the faunule as whole is large, the number of species is a function of the number of samples examined. The species named above are the only ones which hold together this variable fauna. In all probability further work will show more than one zone to be present. The presence of molluscs and the character of the foraminiferal faunule indicate relatively shallow water conditions of deposition for these beds.

The writer has not seen this faunule elsewhere in California. However, Dr. Paul P. Goudkoff[1] has noted Uvigerinella triangularis n. sp. in a well section north of Coalinga, California and believes this species to have a very restricted range. The molluscs from the upper portion of this zone have been correlated with the type Leganos by recent workers[2].

The following species have been found in the Bonicristellaria zone as exposed in the lower portion of Las Llajas Canyon:

Anomalina umbonata Cushman
Buliminella sp. (?)
Cibicides ungeriana (d'Orbigny)
Cibicides sp. 1
Cibicides sp. 2
Dentalina communis d'Orbigny
Dentalina sp.
Dentalina sp. (?)

1) Goudkoff, Paul P., oral communication.
2) Stewart, Ralph E., oral communication.

Elphidium susanaensis n. sp.
Eponides lotus (Schwager)
Eponides sp. (?)
Gaudryina laevigata Franke
Gaudryina sp. (?)
Glandulina manifesta (Ruess)
Globigerina triloculinoides Plummer
Haplophragmoides sp. (?)
Hemicristellaria compressa n. sp.
Hemicristellaria marrensis n. sp.
Hemicristellaria plummeri n. sp.
Hemicristellaria sp. 1
Hemicristellaria sp. 2
Lenticulina articulata (Ruess) var. texana Cushman and Applin
Lenticulina convergens (Bornemann)
Lenticulina sp. (?)
Nodogenerina sagrinensis (Bagg)
Nodosaria affinis d'Orbigny
Nodosaria colinata Cole
Nodosaria arundinea Schwager
Nonion umbilicatulus (Montagu)
Nonion sp. (?)
Robulus n. sp. (?)
Robulus sp. (?)
Robulus sp. (?)
Siphonina aff. jacksonensis Cushman and Applin
Textularia ligulatum (Schwager)
Uvigerinella triangularis n. sp.
Valvulineria marrensis n. sp.
Valvulineria susanaensis n. sp.

Correlation with the Gulf Coast Section

The lower faunal zone shows striking affinities to the upper Midway fauna of Texas. Of the fifty species listed from the Loxostomum applini zone, twenty-two are recorded by Mrs. Plummer[1] from the upper Midway of Texas.

1) Plummer, Helen Jeanne, Foraminifera of the Midway formation in Texas. Univ. Texas Bull., No. 2644, 1926.

Among the species believed to be in common with the upper Midway are four which were considered by Mrs. Plummer as confined to that part of the Texas section. These are Bulimina obtusa d'Orbigny (= Bulimina quadrata Plummer), Globigerina compressa Plummer, Eponides tenera (H. B. Brady) of Plummer and Pulvinulinella culter (Parker and Jones) of Plummer. Other species such as Loxostomum applini (Plummer), Ammodiscus incertus (d'Orbigny), Bulimina inflata Seguenza (=Bulimina aculeata d'Orbigny of Plummer), Glandulina radicula (Linnaeus), (?) Lenticulina gibba (d'Orbigny), Globigerina triloculinoides Plummer, Epistomina elegans (d'Orbigny), and Gyroidina soldanii (d'Orbigny) var. subangulata (Plummer) are common Texas upper Midway forms.

Of the species from the Vernonilina triangularis zone, seven out of a total of twelve have been recorded from the upper Midway including in addition to some of those mentioned above, Discorbis infrequens Plummer and Eponides exigua (H. B. Brady) which are regarded as restricted species by Mrs. Plummer. Also Anomalina ammonoidea (Reuss) var. acuta Plummer is a common but not a restricted midway form. Since the publication of Mrs. Plummer's paper, Eponides exigua has been recorded from the Wilcox Eocene of Alabama[1]. This with the presence

1) Cushman, J. A. and Ponton, Gerald M., An Eocene foraminiferal fauna of Wilcox age from Alabama, Contr. Cush. lab. Foram. Res., vol. 8, pp. 51-72, 1932

of Siphonina cf. wilcoxensis Cushman, suggests a correlation with the Wilcox stage. Although the bulk of the evidence favors the Midway correlation, there are other factors which make it impossible to eliminate the Wilcox correlation. First, the faunule from the Verneuilina consists of only twelve forms. Second, the Wilcox faunas are not very well known. Third, the Wilcox stage is represented by largely non-marine strata in Texas so that the upper range of many of the Midway forms is not definitely known.

The faunule of the Hemicristellaria zone also shows affinities to both the Wilcox and the upper Midway stages. However, in this case the bulk of the evidence favors the Wilcox correlation. Uvigerinella triangularis n. sp., and Eponides lotus (Schwager) have not been noted to occur in other than the Santa Susana formation and the Alabama Wilcox stage by the writer. Although some forms common in the upper Midway of Texas are also present, there are also a number of forms recorded from the Jackson (uppermost Eocene) of the Gulf Coast.

The correlation chart shown in figure 3 summarizes the writers ideas of the relationships of the Pacific and Gulf Coast sections. Except for the Santa Susana correlation the relationships are based on preliminary

studies only .

Fig. 3. Tentative Correlation Chart of California and Gulf Coast Eocene Sections.

Simi Valley	General California Section	Gulf Coast Section
		Jackson
	Type Tejon	CLAIBORNE Yegua
Llajas Fm.	Type Domengine	Cook Mt. Mt. Selman
SANTA SUSANA FM.	TYPE MEGANOS	WILCOX Hatchetigbee Bashi Tuscahoma Nanafalia
Homicristellaria zone		
Verneuilina triangularis zone		
Loxostomum applini zone	"C" Division	Upper Midway

Note: Only the marine strata are included in this chart.

CONCLUSIONS

The Santa Susana formation carries abundant foraminifera which have been found throughout most of the section exposed in Poison Oak and Las Llajas canyons. The fauna consists of three distinct faunules which should be of great value in correlating various sections throughout California. Many species appear to have restricted ranges which should be of value in making local detailed correlations.

The lowest of the three faunules shows strong affinities to the assemblage from the "C" division of the type Meganos. The two higher assemblages have not been noted by the writer elsewhere in California and but one distinctive species from the higher zone has been reported elsewhere in the state.

The two lower zones appear to be equivalent to the upper midway formation of Texas, while the upper faunule shows affinities to the Wilcox Eocene of Alabama.

In the area studied the rather distinctive tough blue-gray, shales of the Santa Susana formation are believed to have been deposited in water varying from very deep for the basal portions to moderately deep or shallow water for the uppermost portion. This conclusion is based on faunal as well as lithologic evidence.

COLUMNAR SECTION AND CHECK LIST OF FORAMINIFERA OF THE SANTA SUSANA FORMATION