SEDIMENTARY PETROGRAPHY OF THE EOCENE SERIES ON THE NORTH SIDE OF MOUNT DIABLO CALIFORNIA

by

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ABSTRACT

The area under discussion is situated in the Coast Ranges of Central California, on the north side of Mt. Diablo about 30 miles northeast of San Francisco. Formations of late Cretaceous and Tertiary age are tilted upward with a general NE dip and rest upon a basement of Franciscan rocks, which forms the core of Mt. Diablo. The formations are primarily of sedimentary origin and have a prevailing strike approximately N 70 W. They are intersected by NW-SE trending thrust faults and cut by smaller, normal, adjustment faults whose general trend is northeast.

This report deals primarily with an investigation of the sedimentary petrography of the formations belonging to the Eocene. These consist from older to younger of the following formational units: Martinez, Meganos, Capay, Domengine, and the Markley group. The latter is composed of medium-grained, micaceous sandstone containing lithologic sub-divisions designated as the Nortonville and Sidney shales. These shale units contain an abundant fauna of Foraminifera and Radiolaria. The results of the paleontologic investigation are not included in this report, but await further

field and laboratory studies.

Detailed stratigraphic sections were measured with plane table and alidade control. The rock and fossil samples are tied in to their respective beds in the columnar section. The rock samples were studied in the sedimentary petrography laboratory of the University of Washington, where petrographic determinations were made of the mineral grains. The samples were crushed, washed, screened, and the mineral grains were separated into heavy and light suites by bromoform with a specific gravity of 2.90. The heavy and light minerals were immersed in oils of known indices of refraction and studied under the petrographic microscope. The grade-size curves were constructed on 3-cycle, semi-logarithmic paper, based on data obtained from the screen analysis. The curves are plotted on the columnar section in accordance with the stratigraphic position of the sample.

SEDIMENTARY PETROGRAPHY OF THE EOCENE SERIES ON THE NORTH SIDE OF MOUNT DIABLO CALIFORNIA

I

INTRODUCTION

The area under investigation is situated in the Coast Ranges of Central California, on the north side of Mt. Diablo, approximately 15 miles south of the junction of the San Joaquin and Sacramento Rivers, 30 miles east of San Francisco, and 50 miles southwest of Sacramento.

The problem undertaken is a study of the sedimentary petrography and petrology of the Eocene Series on the north side of Mt. Diablo, California. The problem will be a contribution to the understanding of the stratigraphy and paleontology of the Mt. Diablo area.

The Eocene section of the north side of Mt. Diablo represents one of the most complete Eocene stratigraphic and formal sequences in western North America, and will be of value as a standard for comparison with other established Eocene sections of the Coast Ranges and other sections through-out the world. This area is important because it contains thick deposits of marine Eocene sediments representing almost continuous deposition from the beginning to the close of Eocene time. These sediments were tilted and brought above sea level, and now form somewhat rugged topography consisting of ridges and intervening valleys possessing a general northwest and southeast trend. These strata toward the northeast pass beneath the alluvium of the San Joaquin Valley, where in certain areas they are economically important because of their gas and possible oil content. Therefore it becomes important to have an understanding of the stratigraphic details, lithologic variations, and faunal content of the units which enter into the Eocene rocks. Farther south in the Coast Ranges of California, detailed investigations have been made and published concerning the Eocene lithologic and faunal sequence. These sections are used for correlation purposes and in interpreting the subsurface stratigraphy of the southern part of the San Joaquin Valley. The sequence of Eocene sediments on the north side of Mt. Diablo contain stratigraphic and faunal evidence for building up a detailed section which could serve as a standard for correlation of Eocene deposits in the Coast Range of Central California and the sections obtained by drilling beneath the floor of the San Joaquin and Sacramento valleys. The present investigation was undertaken for the purpose of establishing such a section for the Eocene on the north side of Mt. Diablo. This investigation will include detailed areal mapping of several stratigraphic Eocene units, a study of the lithology, and the sedimentary petrography of each unit, and the coordination of the paleontologic evidence based on molluscan, echinoid, and foraminiferal faunas. This problem will lay emphasis on the sedimentary petrography and petrology of the Eocene formations on the north side of Mt. Diablo. Many contributions have been made to the Tertiary geology and paleontology of this area, but no detailed published information is available which could serve for the establishing of a standard section of the Eocene, to be used for correlation purposes of the Eocene rock in the surrounding areas of Central California. It is hoped that this contribution will serve as a guide to other investigations in Central California, where an interpretation of Eocene geologic history is necessary.

The writer spent 10 weeks in the area south and west of Martinez during the early summer of 1946 studying the stratigraphic and structural relations of the Eocene rocks to the underlying Cretaceous formations and the overlying Oligocene. Later, 6 weeks were spent during the summer and fall in the area north of Mt. Diablo in geological mapping, construction of cross-sections and collecting foraminifera and rock samples for sedimentary analysis. Additional field work was undertaken during December for the purpose of checking previous data and the collection of additional fossils and rock material for sedimentary analysis. A period of 8 months have been devoted to the laboratory investigation of the samples obtained.

These preliminary investigations are to be followed by several months of field work in order that the area investigated may be extended eastward to the San Joaquin valley.

II

PREVIOUS INVESTIGATIONS

The first organized geologic work in California began in December 1860, after the California state legislature authorized the office of state Geologist and created a state Geological Survey. In 1864, the Geological Survey of California published volume I of the Paleontology of California, based on four years field work by Gabb & Meek.

Gabb[1] divided his recognized cretaceous into an upper and lower division, which he called Cretaceous A and Cretaceous B. He included in the former, the beds now known as

Chico, Horsetown, and Knoxville. The upper division, Cretaceous B, was called Tejon. Later in 1869 Gabb[2], after studying the Tertiary faunas and collecting from more extensive areas, revised his previous classification. He subdivided Cretaceous A into the Shasta and Chico groups and division B he named Tejon. He provisionally placed the Martinez beds between the Chico and Tejon and because of the small geographical extent of the Martinez beds, Gabb suggested that they might be a sub-division of the Chico. The determination of the fossils collected by Gabb from the Martinez beds suggested that the Martinez fauna was a possible transition from Chico to Tejon. Later when the Tejon was regarded as Eocene, the age of the Martinez beds became an important factor in determining the geologic history of California. The first age determination of any part of the Chico-Tejon series was made by Conrad[3] in 1855, when he described a few species of molluscan, fossils sent to him by Blake from Canada del Uvas near Fort Tejon. These fossils collected by Blake were referred to as Eocene in age.

Prior to 1896, the general assumption concerning the classification of beds on the north side of Mt. Diablo was a two-fold division, the upper called Tejon and the lower the Martinez.

The confusion concerning the age relationship of the Tejon, the Chico, and the Intermediate Beds of the Martinez were largely cleared up in a paper on the "Cretaceous and the Eocene of the Pacific Coast" by Stanton[4]. He reorganized the earlier classifications; based on the results of more detailed study of the Chico, Tejon and Martinez faunas. In this new arrangement, he divided the Martinez group of Gabb into two parts, on the basis of its faunal and stratigraphic relations. He placed the lower part in the Chico and the upper part in the Eocene, designating it as the lower Tejon.

The following year Merriam[5] was able to show that the Martinez fauna was quite distinct from the Chico and the Tejon. Only a few species were found in common with them. He separated the Martinez beds from the adjoining formations on faunal and lithological basis. These beds were referred to as lower Eocene in age and recognized as a geological formation distinct from the Tejon.

In 1905 Weaver[6] described many new species of Mollusks collected from the type section of Martinez formation. On the basis of his detailed faunal study, he was able to divide the Martinez formation into two groups, the upper and the lower. The lower division was considered as lowermost Eocene in age; later the upper division was designated as Domengine.

The stratigraphic and faunal relations of the Martinez formation to the Chico and Tejon formations on the north side of Mt. Diablo were described by Dickerson[7] in 1911. He recognized faunal and stratigraphic breaks existing between the Martinez and Chico formations and suggested that an unconformity separated the two formations. He found that similar conditions existed between Martinez and Tejon.

Following the work on the Mt. Diablo area, Dickerson[8] studied the faunal and stratigraphic relationship of the Tejon formation at Marysville Buttes. A faunal assemblage different from the Martinez and the Tejon faunas of Mt. Diablo was recognized and described. The Marysville Butte fauna was considered by Dickerson upper Eocene in age and younger than the Martinez and Tejon faunas of Mt. Diablo.

Dickerson[9] later investigated the known Tejon on the south side of Mt. Diablo. As a result of this work four faunal zones were recognized based on poorly preserved fossils. The fourth or uppermost zone was considered the equivalent of the Marysville Buttes fauna.

Later, after studying the Martinez fauna at the type section, Dickerson[10] was able to divide the Martinez fauna into 3 zones. The unconformable relations of the Martinez formation to the overlying Tejon and the underlying Chico were recognized.

Dickerson[11] in 1916 recognized four faunal zones in the Tejon formation, based on the faunal studies of the known Tejon localities. These zones were established on the basis of poorly preserved molluscan fossils.

Clark[12] in his paper entitled "The San Lorenzo Series of middle California", named and described the Markley formation on the north side of Mt. Diablo. He recognized this new formation as San Lorenzo (Oligocene) in age, based on the stratigraphic position of this formation, to the known Tejon of that area. Later the Markley formation was proved to be Eocene in age by Clark and others.

During the summer of 1917, while studying the Tertiary formations on the north side of Mt. Diablo, Clark[13] recognized the existence of a marked stratigraphic break between two members formerly considered as Tejon in age. On the basis of areal mapping and detailed biologic and evolutionary study of the fauna, Clark was able to show the presence of a new stage of deposition in the California Eocene, and named it the Meganos group. It is divided into five stratigraphic divisions called Meganos A, B, C, D, and E. Division E, the youngest, is unconformably overlain by the Tejon Formation. Later in a paper entitled "The Faunal Relations of the Meganos Group," Clark[14] recognized the wide distribution of the Meganos group throughout the Coast Ranges of California. The study of the Meganos fauna collected over a wide area, showed that the fauna described by Dickerson from Marysville Buttes, belonged to the same stage of deposition as the fauna of division D and E of the Meganos. As a result of this work the Eocene of California was recognized as a three-fold division consisting of Martinez, Meganos, and the Tejon formations in ascending order.

After a detailed biologic study of the evolutionary development of the Eocene faunas, collected from numerous localities in the Coast Ranges, Clark[15] was able to recognize the existence of a fourth stage in the Eocene. This newly recognized stage was called the Domengine horizon, with the type section located on Domengine Ranch, north of Coalinga on the west side of the San Joaquin Valley. The Domengine fauna was found in beds stratigraphically below those bearing the typical Tejon fauna, and above beds containing the newly recognized meganos fauna.

After the recognition of the Domengine horizon at Coalinga, Clark restudied the Mt. Diablo area and found that the beds which were formerly considered as Tejon in age contained a fauna very similar to that of the type Domengine. Thus the fourth Eocene stage was recognized on the north side of Mt. Diablo.

The fifth stage of the Eocene was recognized by C. W. Merriam and F. E. Turner[16] based on a study of the fauna collected by T. H. Crook and J. M. Kirby[17] from their newly recognized Capay formation. The Mega fauna of the Capay formation closely resembles the fauna described by Dickerson from Marysville Buttes and the micro fauna from the latter place correlates with division E of the Meganos formation on the north side of Mt. Diablo. The recognition of the Capay stage is based on biological differences of the Capay fauna compared with that of the Domengine and the Meganos. At the present time a five fold division of the Eocene is recognized throughout California. The oldest of the Eocene formations is the Martinez, and above it in sequence are the Meganos, Capay, Domengine and Tejon.

III

FIELD INVESTIGATIONS

The geological data obtained as a result of field work was plotted on a base map, enlarged from the Mt. Diablo topographic Sheet published by the United States Geological Survey. The original map is on the scale of 1:62,500, and was enlarged to approximately 1000 feet to the inch to facilitate areal mapping. Auxiliary air plane photo maps were also used, making it possible to more accurately determine the places where the observations were recorded. Early in the investigation a triangulation network system was established and the higher peaks and points along the contacts between the formations were tied into it. The locations where the samples were taken were tied in by plane table and telescopic alidade to the triangulation network. This method produced a greater accuracy in field mapping than reliance on the more general topographic map and the air plane maps that vary in scale from place to place. Thus the localities where rock or fossil samples were taken are fairly accurate.

A detailed stratigraphic cross-section was made with the aid of a plane table and steel tape, at right angles to the general strike of the strata. The variation in the lithologic details from the bottom to top of each formation along the line of cross section has made it possible to construct a columnar section. The rock samples for sedimentary analysis and the shale samples containing foraminifera were taken along the line of cross section affording material on which the laboratory work is based.

The foraminifera studies are to be reported in future reports. The main purpose of this paper is an investigation of the lithologic details of each formation by sedimentary petrography methods.

During the last twenty five years, rapid advances have been made in the field of micropaleontology. The establishing of foraminiferal zones farther south in the Coast Ranges have been especially helpful in the correlation and age determination of strata encountered in drilling, in connection with investigations for petroleum. There are many workers engaged in research work on the Tertiary forminifera along the

Pacific Coast of North America and especially in Southern California. Since this paper deals primarily with the discussion and analysis of the sedimentary petrography of the Eocene formations on the north side of Mt. Diablo only a few brief notes are given.

After a detailed study of the micro faunal relations in all key Eocene sections of Southern California, supplemented by additional data on assemblages built up from core samples, Laiming[18] was able to divide the Eocene into 12 faunal zones, each characterized by a distinct faunal assemblage, with one or several species restricted to it. These zones starting from the top of the Eocene are designated; R, A-1, A-2, A-3, B1-A, B-1, B-2, B-3, B-4, C, D, and E. Zones A-1, A-2, and A-3 are correlated with the Tejon stage, B-1A, and B-1 are correlated with the Domengine stage, B-2, B-3, B-4, and C are correlated with the Capay stage, zones D and E are correlated with the Meganos and Martinez stages respectively. Of the above listed foraminiferal zones only the R zone is absent on the north side of Mt. Diablo.

Laiming's correlation system was developed for use by Oil Company paleontologists, for determining the age of strata while drilling operations were in progress. Thus the zones are listed in reverse order from the conventional manner of listing faunal horizons.

It is often difficult to correlate molluscan fauna with the microfauna of the same basin of deposition, because key fossils of either fauna rarely occur together. Before age correlation of the two types is possible, it is necessary to have a very detailed areal map in order to determine the stratigraphic sequence of the faunal horizons. The relationship between ecological conditions and the presence or absence of certain foraminiferal assemblages are not fully known. The phylogeny in most cases is not completely known, and the transition from one genus to another complicates the classification. At the present time it is extremely difficult to build up a classification system of foraminiferal zones on a world-wide basis. Until this is accomplished, correlation based of molluscan and foraminifera cannot be very definite.

The formations studied, measured, and sampled in stratigraphic ascending order, include the Martinez, Meganos, Capay, Domengine, Nortonville, and the Markley. 186 samples of rock were collected from the major stratigraphic and faunal units of each of these formations. These samples usually were taken along the line of cross section, but in several places samples were taken along the strike of certain beds, some distance to the east or west of the section. Additional samples were taken from rock layers a considerable distance away from the cross section in order to check minor changes in lithology and mineral content against those in the main cross section.

The columnar section was constructed from the measured thickness of each formation, and the samples taken are tied into their exact stratigraphic position within the columnar section. The grade-size curves for all of the samples are inserted in the columnar section.

Mechanical Analysis

The samples taken for study were first crushed, cleaned by bathing in dilute (6N) hydrochloric acid, decanted, washed and dried. The clean sample was then weighed and screened. The weight of the sample taken for screen analysis, depended upon the grade size of the rock to be analyzed. The coarser the material, the larger the sample taken. The average weight of the sample taken was approximately 70 grams. The weighed sample was graded through Tyler standard no. 5, 24, 42, 80, and 170 mesh screens. The screens were rotated and tapped until no further visable separation took place. The contents of each screen was carefully removed and weighed. Only the residue remaining on the 170 mesh screen (.175-.088mm) was saved for microscopic examination.

Accumulation grade-size curves were constructed on three-cycle, semi-logarithmic paper. The percentage of the sample that would be retained on any single screen, if used alone, is shown on the curve by a small circle. The circle representing the highest percentage indicates the amount of sample that would be retained on the 170 mesh screen. The lower circles represent the 80, 42, and the 24 mesh screens respectively. The accumulation grade size curves were plotted with the 24 mesh screen value normal to the columnar section and opposite the sample number in order to show the variation of sorting from one formation to the other. The portion of the sample remaining on the 170 mesh screen (.175-.088 mm in diameter) was treated with bromoform (Ap. G. 2.90) for separation of heavy and light minerals.

Microscopic Study of the Sediments

The heavy and light minerals studied with the aid of the petrographic microscope, were immersed in oils of known index of refraction. The binocular microscope was found to be very useful in picking minerals for study under the petrographic microscope.

Mineral percentages were determined by actual count and by estimation after several counts were made. The mineral percentage curves for the Markley formation were constructed to show the relative percentage of the minerals throughout the formation. These values represent percentage of the mineral in the heavy mineral suite but not in the sample as a whole. The mineral percentage curves for the Markley formation are shown on Plate 5.

IV

MARKLEY FORMATION

The Markley formation was first described and placed on record by Clark[12] in 1918. It was at that time recognized as San Lorenzo (Oligiocene) in age, based on the evidence of poorly preserved molluscan fossils and thought to be the equivalent of the overlying Kirker fauna. Formerly these beds were regarded by Clark as Tejon in age. In 1930 Bailey[20], while working in Potrero Hills north of Suisun Bay, discovered a Tejon fauna in beds of the same stratigraphic position as the Markley formation, on the north side of Mt. Diablo. On the basis of the fossil evidence presented by Bailey, the age of the Markley formation became recognized as upper Eocene and equivalent to the Tejon formation, at the type section in Southern California.

Lithology of the Markley Formation

The Markley formation is approximately 3800 feet thick and consists of three cartographic units, based on lithology. The lowermost unit will be referred to as the Lower Markley Sandstone; the middle unit, The Sidney Shale Member; and the upper unit, The Upper Markley Sandstone.

The lower Markley sandstone consists of 1600 feet of fine to medium-grained, light buff-tan, loosely consolidated, micaceous sandstone. Interbedded with it are very loosely consolidated, silty, friable sandstone and layers of varying thickness, of silty, carbonaceous, micaceous, chocolate-brown clay shale. Several of the sandstone beds are characterized by reddish-brown limonitic stained, often caliche coated, elongate concretions, which in some cases range from 3 to 5 feet in length. The concretionary beds generally contain a higher percentage of calcite and silica cement, but do not differ greatly in hardness from the non concretionary layers that are cemented with limonite, calcite and minor amounts of silica and gypsum. Cavernous weathering is common throughout the lower sandstone members. The concretionary beds weather out as steep, cliff-like, convex faces, and may be traced the entire distance of the exposed lower Markley. All of the sandstone beds in the Markley formation are characterized by the occurance of large flakes of muscovite mica, commonly 3 to 4 mm. in diameter.

The beds of silty clay shale vary from 3 to 5 feet in thickness near the base to 2 to 4 inches in thickness near the top of the lower Markley sandstone. These beds grade into the sandstone beds above and below, and are characterized by a large amount of carbonized material and quantities of Marine diatoms and radiolaria.

Interbedded with the sandstone and clay shale already described are two very massive, soft beds of silty sandstone. The upper bed is approximately 125 feet thick and occurs 175 feet below the top of the lower Markley sandstone. The other bed is approximately 200 feet thick and occurs 500 feet below the top. These beds outcrop in two very poor, deeply weathered exposures.

The lower sandstone beds contain a very few poorly preserved, limonitic casts of molluscan fossils. The occurence of these fossils in addition to the Marine diatoms and radiolaria indicate a marine origin for the lower sandstone beds of the Markley formation.

The lower Markley sandstone rests with apparent conformity upon the Nortonville Shale at the type section in Markley Canyon. A view of the Lower Markley sandstone beds, looking southeast across the former site of the old coal mining village of Sommersville is shown on Figure 1, Plate 1. Note the apparent northeast dip of these beds. The Nortonville Shale is exposed in the gullies along the west central edge of the picture.

The upper portion of the lower Markley sandstone grades upward into the very dark, massive, sandy, basal shale called the Sidney shale member. The lower 300 feet of the Sidney shale is characterized by dark argillaceous, massive shale containing an abundance of carbonaceous material. Above the dark, massive shale is approximately 165 feet of lighter colored, much harder shale making fairly conspicuous outcrops. The shale of this horizon varies from chocolate-brown in color to almost pure white. Some of the layers, especially near the base are rather thick and massive. Higher up they are thinner bedded and in places form a typical paper shale. Marine diatoms are abundant in the lower beds, the genus COSCINODISCUS being the dominate genus. Impressions of leaves and rushes are rather common in upper part of this shale member. Diatoms are conspicuous by their absence. The character of the shale in the upper portion of the horizon just described is shown in Figure 2, Plate 1. Note the small fault shown in the lower part of the picture. The light colored shales grade upward into carbonaceous shale with alternating layers of medium-grained micaceous grey to yellowish brown sandstone and thin beds of light and dark colored shale. Toward the top of the Sidney shale member, the sandstones and sandy shale become more prominent. The beds of shale vary from a few inches to

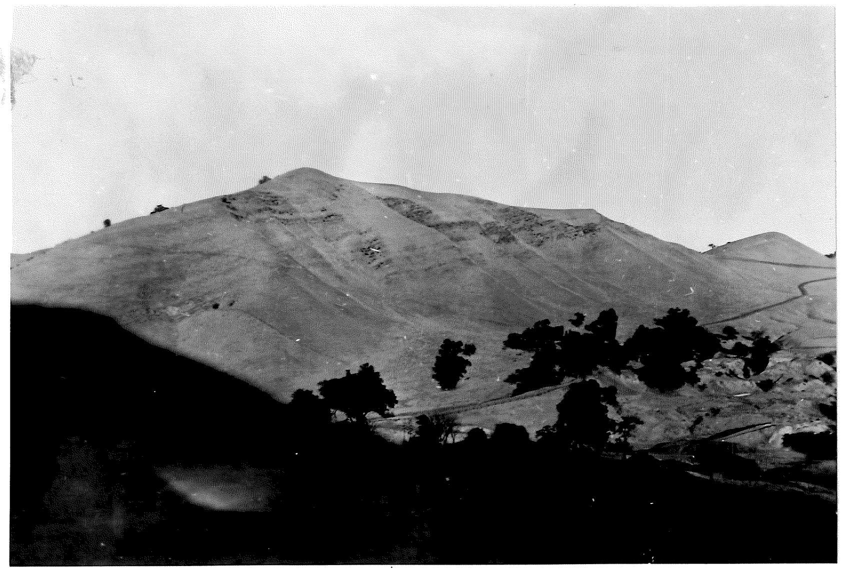


Figure 1. Outcrop of the lower Markley sandstone.

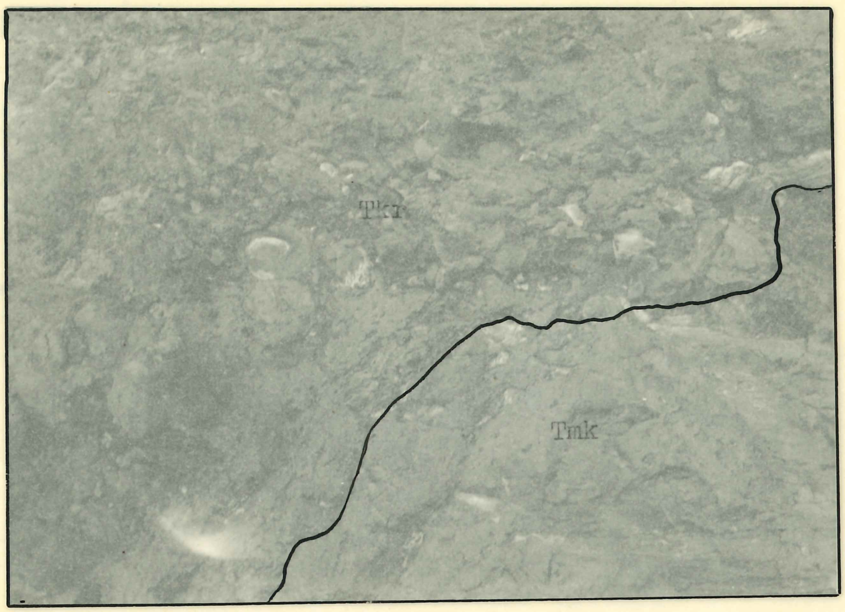
Figure 2. Sidney shale

PLATE I

several feet in thickness; some layers are white and fairly hard, some are black, while others are reddish brown in color. Leaf impressions and carbonized material are abundant in these beds. The total thickness of the Sidney shale is approximately 1100 feet in Markley canyon.

The presence of Marine diatoms and radiolaria indicate a marine origin for the Sidney shale member of the Markley formation. The Sidney shale is generally known by micro-paleontologists as the type locality of Laiming's A-1 zone, characterized by the presence of Plectofondicularia jenkinsi.

The upper part of the Sidney shale grades into massive, light-buff-tan micaceous sandstone almost identical in character to that of the lower Markley sandstone. Interstratified with this sandstone are thin beds varying from a few inches to a foot in thickness, and composed of light and dark colored, thinly bedded, almost paper shale, similar to the shale which is characteristic of the middle portion of the Sidney shale member. These sandstone beds with minor amounts of shale are approximately 250 feet thick in Markley canyon where they are terminated by a well developed angular unconformity. In Kirker canyon, to the north-west, the upper Markley sandstone beds are approximately 500 feet thick. Figure 3, Plate 2 shows the unconformable relations between the Kirker (Oligocene) and the underlying Markley formation. The boulders at the base of the Kirker formation were derived



Tkr Kirker Formation

Tmk Markley Formation

Figure 3. Kirker - Markley Unconformity

PLATE II

from the underlying Markley sandstone beds.

Petrography of the Markley Formation

The megascopic description of the samples taken from the upper and lower sandstone divisions of the Markley formation, are in every case, almost identical. The samples are medium to fine-grained, buff-colored, limonitic stained, micaceous, sandstone, loosely to moderately-cemented with limonite and calcite. Quartz constitutes 90 per cent of the visible minerals in the hand specimen. The accessory minerals that are readily recognized are muscovite, biotite, and hornblende. The muscovite occurs in large flakes 2 to 4 mm. in diameter, and characterized the Markley formation throughout Northern California.

The microscopic study of the grains .175-.088 mm. in diameter, reveal that quartz constitutes 90 per cent of the light minerals (Sp. G. less than 2.90), muscovite 6 per cent, albite (Ab9-An1), microcline and orthoclase 2 per cent, calcite, limonite and chlorite the remainder. Most of the quartz present is characterized by many clear angular fragments with inclusions of apatite, rutile and to a lesser extent sillimonite. Other quartz grains are cloudy and nearly opaque due to carbonaceous inclusions. Many of the muscovite flakes, albite, orthoclase, and microcline fragments contain inclusions of apatite and chlorite. The albite fragments are slightly altered to sericite. The orthoclase and microcline are altered kaolin and are generally more altered than the albite.

The heavy mineral suite of the Markley formation contains a large number of mineral species. In the upper part of the formation, anthophyllite constitutes 80 percent of the heavy minerals present. The percentage of this mineral decreases in the lower beds and finally drops to zero at the base of the formation. Hornblende represents 15 percent of the heavy minerals in the upper beds, drops to less than 2 percent in the lower beds. Garnet and zircon represent 5 percent of the heavy mineral assemblage in the upper beds, but increases to 30 percent in the lower beds. Biotite and chlorite constitute 50 percent of the heavy minerals with tourmaline, actinolite, magnetite, ilmenite, kyanite, titonite, limonite and leucoxine making up the remainder. Two varieties of hornblende are present in the Markley formation. The type most common in the upper beds is pleochoric in light green to brown, with an extinction angle of 23 degrees. The second type is more common in the lower beds and is pleochoric in light green to yellow green with an extinction angle of 18 degrees. The zircon present is the colorless, normal elongate, prismatic variety, commonly including apatite. Yellow-orange tourmaline is present in very small amounts in the upper Markley sandstone beds but increases in percentage in the lower beds. Magnetite and ilmenite are present in about the same percentage throughout the formation and they are partially altered to limonite and leucoxine. The biotite present in the Markley formation is largely altered to chlorite.

Megascopically the sandstone samples of the Sidney shale member differ from the lower and upper Markley members, in that the former are finer grained, and are characterized by alternating bands of light and darker gray, layers. The visable mineral composition is approximately the same. Microscopically the mineral composition and percentage are nearly identical for the three divisions of the Markley formation. The quartz in the sandstone of the Sidney shale member is characterized by the high percentage of an included clay-like material, rendering the grains nearly opaque. Albite (Ab9-An1) and microcline show greater alteration to sericite and kaolin than do the same minerals of the other divisions of the Markley formations. The heavy mineral assemblage of the Sidney sandstone beds differ greatly from those of the other two divisions of the Markley formation. Anthophyllite, hornblende, Kyanite, actinolite, and titanite are absent. Magnetite, ilmenite, and pyrite constitute 70 percent of the heavy minerals present. Biotite, zircon, garnet and small amounts of tourmaline constitutes the remainder of the heavy mineral assemblage. The pyrite is secondary in origin and coats quartz and other minerals. Magnetite and ilmenite are altered on the surface to limonite and leucoxine; the biotite is almost completely altered to chlorite. Some of the quartz, hornblende, mica, garnet and zircon occur frequently in the euhedral crystaline shapes.

All of the mineral fragments of the Markley formation are characterized by very angular and sharp shapes. No frosted grains were observed in any of the samples, thus indicating that the sediment had not been transported great distances or reworked from pre-existing sedimentary rocks.

Figure 4, Plate 3 is a photomicrograph of the light mineral assemblage from the Markley sand stone beds. Note the sharp angular fragments of quartz and the clear unaltered albite in contrast to the altered microcline and orthoclase fragments. The heavy minerals of the Markley formation are shown on Plate 3, Figure 5. Note the angularity of the anthophyllite and hornblende. A photomicrograph of the heavy minerals of the Sidney sandstone appear on Plate 4, Figure 6. The heavy mineral suite of the Sidney sandstone contains considerably more opaque grains than the Markley sandstone beds.

The accumulation grade size curves for the Markley formation are shown on Plate 5. It is evident from the study of the grade size curves that the Markley formation is very uniformly sorted from top to bottom.

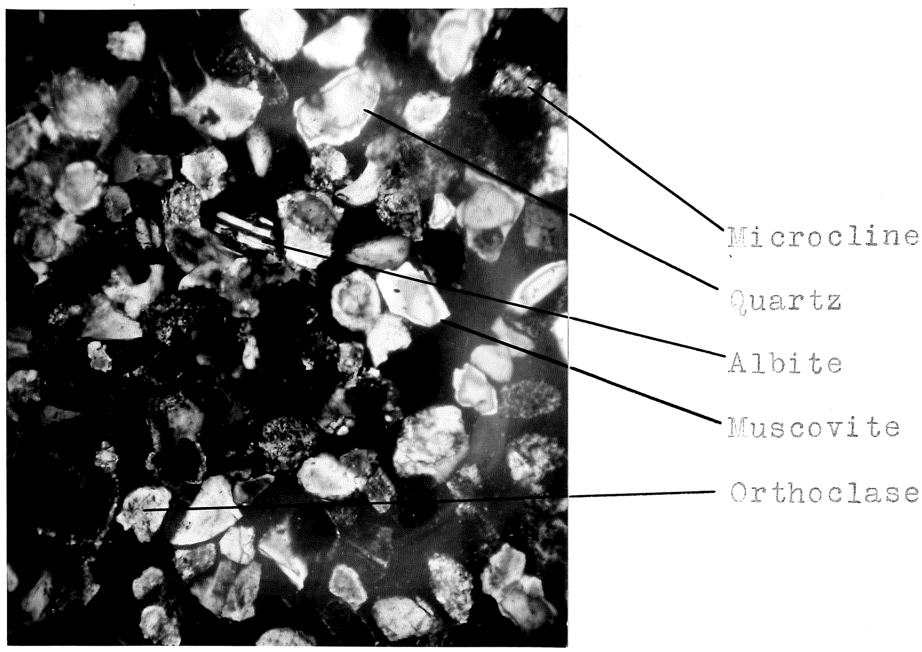


Figure 4. Light minerals of Markley Sandstone. Crossed-Nicols, 45 diameters.

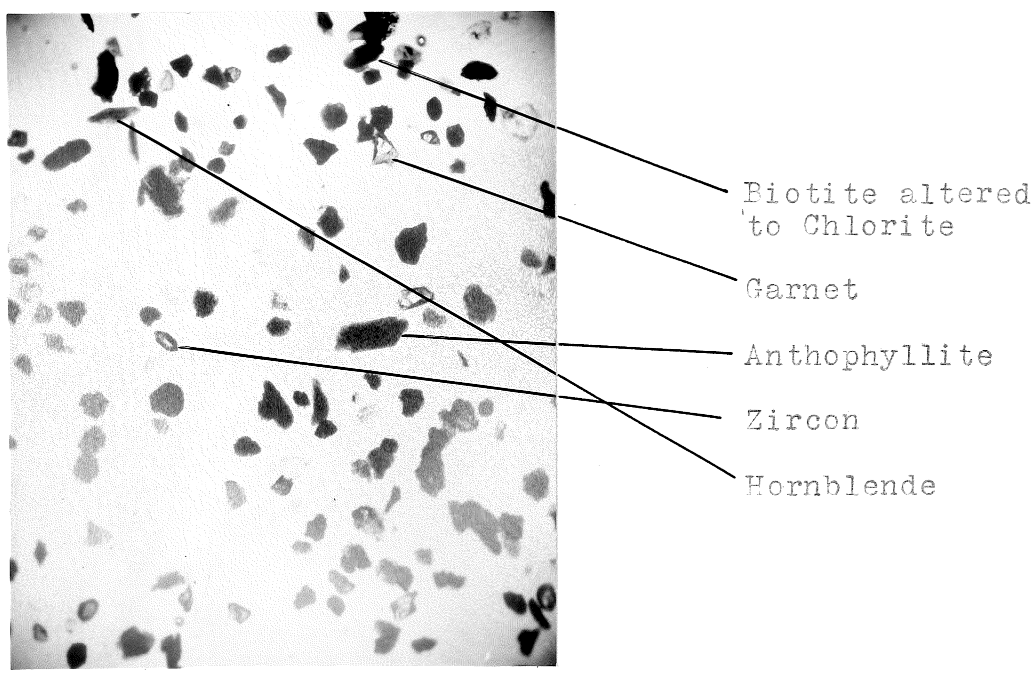


Figure 5. Heavy minerals of the Markley Sandstone, plane light 20.5 diameters.

PLATE III

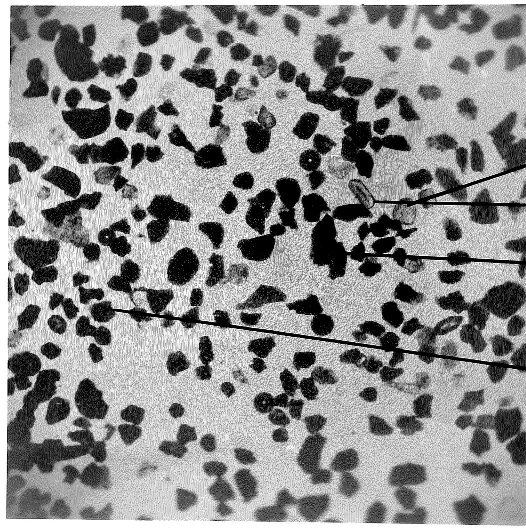


Figure 6. Heavy minerals of the Sidney sandstone. Plane-light 20.5 Diameters.

PLATE IV

V

NORTONVILLE SHALE

The Nortonville shale was formerly referred to as the Tejon shale on the north side of Mt. Diablo. Later it became generally regarded as a lower shale member of the Markley formation. Still later it was separated from the Markley formation on the basis of a contained microfaunal assemblage corresponding to the A-2 zone of Laiming.

The type section of the Nortonville shale is located on the north side of Mt. Diablo between the two former mining towns of Nortonville and Somersville. It is approximately 700 feet thick and consists of massive, chocolate-brown clay shale, interbedded with sandstone and sandy clay shale. The basal beds of the Nortonville shale rest with apparent conformity upon the upper beds of the Domingine formation. The relationship of the contact of the Nortonville Shale and the Domengine formation is shown on Plate 6, Figure 7. The picture was taken looking east, in a gully west of the former village of Sommersville. The lower 150 feet of the Nortonville Shale consists of fossiliferous, massive, chocolate-brown shale, weathering in a concretionary manner, with the weathered surfaces light-grey in color, and with limonite. The shale of this horizon is badly jointed and the joint planes are coated with limonite, and in places crusted with small gypsum crystals. Large, authigenic, generally twined gypsum crystals occur scattered throughout this horizon.

Stratigraphically above the shale beds just described, occurs a massive, buff-tan, fine to medium-grained, micaceous sandstone. This sandstone bed is approximately 25 feet thick and is almost identical to those occurring in the lower and upper Markley sandstone. Stratigraphically above the sandstone is approximately 500 feet of massive, concretionary weathered, fossiliferous, chocolate-brown shale, which is very similar in every respect to the lower shale beds already described. These upper shale beds are locally disturbed by small minor faults. The surfaces often show slickensides, and are sometimes coated with limonite and gypsum. Large euhedral, often twinned crystals of gypsum also occur frequently through these beds. The upper 50 feet of the Nortonville shale consist of alternating beds of silty, micaceous, sandstone, sandy clay shale, and chocolate-brown clay shale. Rusty, soft, lenticular concretions are common in the more sandy beds. In the lower portion of this zone a few poorly preserved, thin-shelled, molluscan fossils have been collected.

Petrography of the Sandstone Beds in Nortonville Shale

Samples of the sandstone beds of the Nortonville shale cannot be separated by megascopic examination from the lower and upper Markley sandstone samples. The color, visable mineral content, percentage, degree of induration and grade size are almost identical. Microscopic examination reveals the close similarity between the mineral composition and percentage of the light minerals present in the Nortonville sandstone beds and the overlying Markley beds. Quartz constitutes 90 to 95 per cent of the light minerals. It is very similar to the quartz fragments of the Markley formation in that they are predominately clear, very angular, often including apatite, rutile and in a few cases sillmanite. Muscovite, albite (Ab9-An1), orthoclase, and microcline make up the remainder of the lights. The fragments of microcline, orthoclase and albite occasionally include apatite and show slight alteration to sericite and kaolin. The heavy mineral suite of the Nortonville sandstone, differs somewhat from the heavy mineral assemblage in the lower and upper Markley sandstone beds. Anthophyllite is absent in the Nortonville samples. Zircon and garnet constitute 40 percent of the mineral assemblage. Biotite and chlorite 40 percent, hornblende 10 percent, magnetite, ilmenite, kyanite and tourmaline making up the remainder. The garnet, zircon, brotite and tourmaline are identical in character to those described in the Markley formation. The hornblende present is predominately the light green to yellow-green variety. Magnetite and ilmenite are frequently altered to limonite and leucoxine. Apatite is commonly included in the garnet, tourmaline and to a lesser degree, biotite.

The photomicrograph of the heavy mineral assemblage of the sandstone beds of the Nortonville shale appears on Plate 7, Figure 8. Note the large altered flakes of altered biotite, and the smaller fragments of zircon, hornblende and garnet. Compare Figure 8 with Figures 5 and 6 for angularity and mineral content.

The grade size curves for the sandstone beds of the Nortonville shale are shown on Plate 5. From the examination of these curves it is evident that the sandstone beds of the Nortonville shale show practically the same sorting and grade size as the Markley formation.

Based on close similarities of grade size, sorting, mineral composition and percentage of the upper and lower Markley divisions to the sandstone beds of the Sidney and Nortonville shale. The writer suggests the name Markley group to be applied to these stratigraphic units.

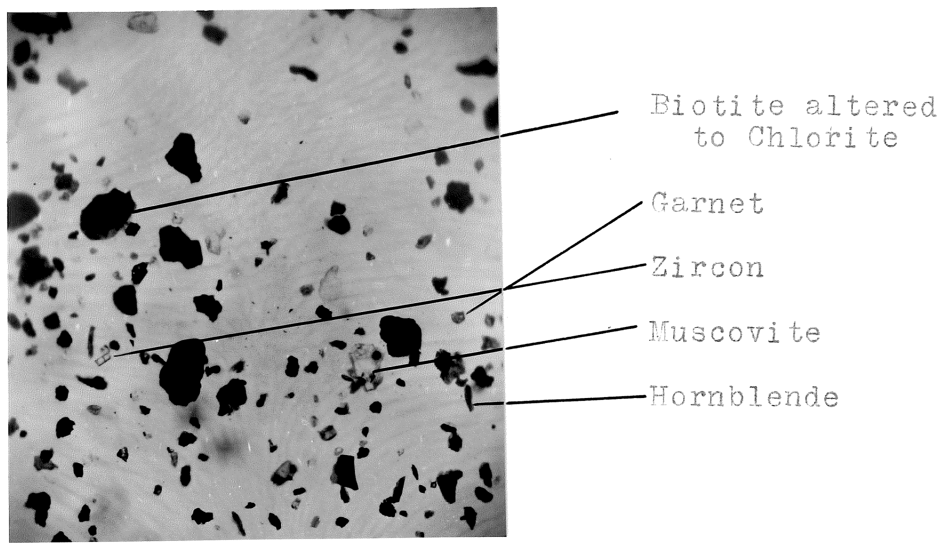


Figure 8. Heavy minerals of the Nortonville sandstone. Plane-light, 20.5 diameters.

PLATE VII

VI

STRATIGRAPHY OF THE DOMENGINE FORMATION

The term Domengine was first applied by Clark[15] in 1926, to the fossiliferous beds exposed on the Domengine Ranch, north of Coalinga, California. Clark was able to separate the Domengine fauna from the Tejon and Meganos, on the basis of biologic differences. He found that only a few species were common to the three formations.

The Domengine formation on the north side of Mt. Diablo is approximately 720 feet thick. It unconformably overlies division E of the Meganos, or the Capay, and is conformably overlain by the Nortonville shale. The lower 50 feet of the formation consists of light colored, limonitic stained, coarse grained, massive sandstone, with interbedded cobble conglomerate. It is made up of approximately 90 percent well rounded, white to grey quartzite pebbles and 10 percent dark-colored, well rounded quartzite pebbles, in a matrix of fine to medium-grained almost white sandstone.

Stratigraphically above the conglomerate and coarse sand of the basal Domengine, are approximately 50 feet of thinly bedded, chocolate brown, carbonaceous shales, that are in places very ashy. The shales weather to a yellowish white in color and when fresh give off an odor of gas. This shale contains sufficient carbonaceous material and gas that it will burn when placed in a fire. Interbedded with the chocolate brown shale are thin lenticular layers of soft, white limonitic stained, coarse-grained sandstone. Near the top of this horizon occurs a four foot bed of coal, locally known as the Black Diamond vein. Above the chocolate-brown shale is approximately 150 feet of light-grey to white, coarse to medium-grained, cross-bedded sandstone with minor amounts of chocolate-brown carbonaceous shale. Within this horizon are two coal beds, one two and a half feet thick, and the other three feet thick. They are locally known as the Little vein and the Clark vein respectively. Overlaying the Clark coal vein is approximately 200 feet of massive, white to light-grey, almost pure quartz sandstone. The white almost pure quartz sand is locally called the glass sands, and are correlated by Clark[22] with the Ione glass sands of the east side of the San Joaquin valley. The lower more silty sandstone beds of this horizon, contain a high amount of iron oxide sufficient to color the sandstone a reddish-brown. The weathered surfaces and the soil derived from these beds are rusty brown in color. The presence of the red-brown soil makes it possible to trace this zone throughout the formation. The overlying beds seem to contain less and less iron oxide stratigraphically upward. Clark[15] considered the iron oxide as primary in origin, based on the wide areal extent of its occurrence. Later underground workings in the sand mines of the area indicate that the iron oxide is present as a cementing agent, coating the sand grains, rather than being primary grains of iron oxide deposited with the sand. The writer suggests a secondary origin for the iron oxide, possibly being formed by leaching of the overlying beds which now contain only a very small percentage of heavy minerals. The ground water level, prior to the uplift may have been responsible in controlling the concentration and areal extent of this zone. Overlying the glass sands are approximately 190 feet of fine to medium-grained buff-colored fossiliferous sandstone, containing dark calcareous and siliceous blue-grey concretions with well preserved molluscan fossils. The soft, buff-colored sandstone contains numerous poorly preserved casts of molluscan fossils. The fossil assemblage of this horizon is very similar to the fauna of the Domengine at the type locality near Coalinga.

The Domengine formation of the north side of Mt. Diablo is of economic importance from the standpoint of the glass sand deposits. At the present time there are three mines in operation, mining the loose almost pure quartz sand. This sand is used as molding sand in the steel mills and for the manufacture of glass and ceramic glazes. The three coal layers namely the Clark, Little Vein and Black Diamond veins were formerly mined, but coal mining operations shut down in the Mt. Diablo area in the early 1900's due to the cost of mining and the lack of markets.

Petrography of the Domengine Formation

Megascopically, all of the Domengine samples are fine to coarse-grained, light buff-tan to almost pure white in color, soft, loosely compact, non-cemented sandstone. Quartz constitutes 98 percent of the visible minerals present. Magnetite and Biotite make up the remainder.

Microscopic examination of the light mineral assemblage reveals that quartz constitutes 92 percent of the light minerals, orthoclase 5 percent, with albite, microcline, and a few pieces showing micrographic intergrowt making up the remainder. The quartz fragments are very angular and sharp and often include apatite and rutile. The albite and microcline are slightly altered to sericite, and the orthoclase is altered to kaolin. The Domengine samples are characterized by the very small percentage of heavy minerals with respect to the lights. The heavy mineral suite consists of small amounts of zircon with included apatite, garnet, tourmaline and very small quantities of magnetite and ilmenite. All of the heavy minerals show the same characteristic as those described in the Markley formation.

Photomicrographs of the heavy and light mineral assemblages of the Domengine formation appear on Plate 8. Figure 9 shows the predominately quartz character and the angularity of the mineral fragments of the Domengine formation. The heavy mineral suite of the Domengine formation is shown in

Figure 10, the mineral grains pictured show approximately the same characteristics as the heavy minerals of the other formations.

The accumulation grade size curves for the Domengine formation are plotted on Plate 5. The grade-size curves show that the beds of the Domengine formation are not as uniform in sorting and grade-size as the beds in the Markley formation.

VII

LITHOLOGY OF THE MEGANOS FORMATION

The name Meganos group was first applied by Clark[13] in 1918 to rocks formerly considered as Tejon in age. The type section of the Meganos is located on the north side of Mt. Diablo where it is divided into five lithologic units.

The Meganos formation, at the type section is approximately 3100 feet thick, resting unconformably upon the Martinez formation and unconformably below the Domengine.

The lower 50 feet of the Meganos formation is known as division A. It consists of heavy conglomerate and coarse grained sandstone. The conglomerate is made up of well rounded pebbles of vein quartz, red, green and white chert, white and

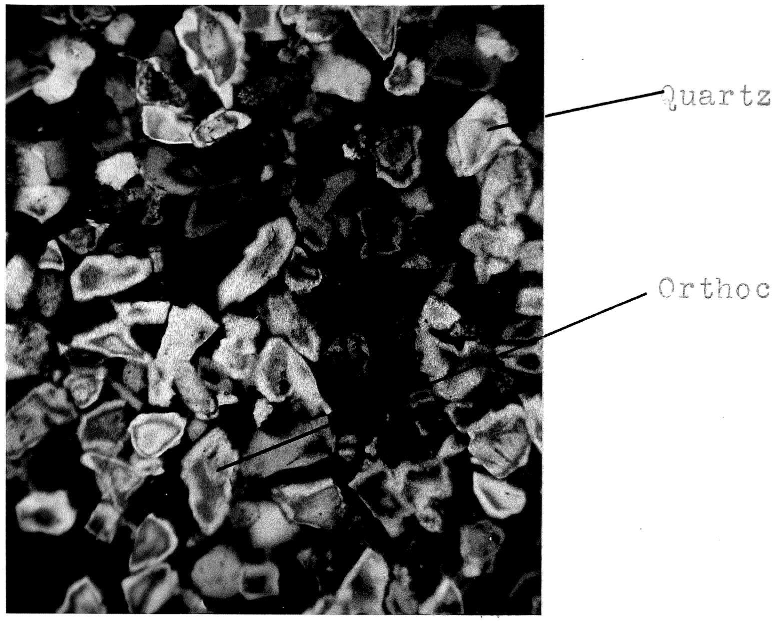


Figure 9. Light minerals of the Domengine formation, crossed Nicols, 45 diameters.

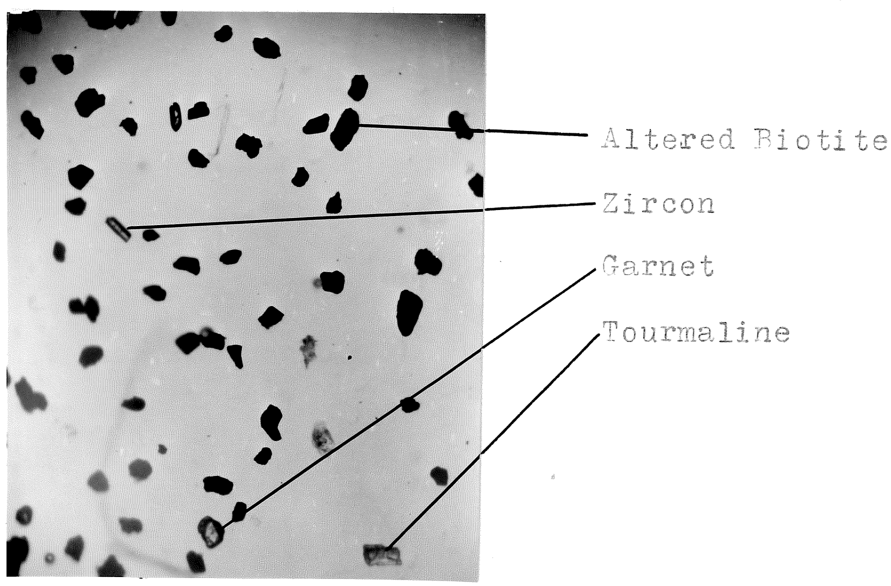


Figure 10. Heavy minerals of the Domengine formation. Plane-light, 20.5 diameters.

PLATE VIII

black quartzite, gniess, limestone and a few angular blocks of brown, medium-grained sandstone filled with upper Cretaceous (Chico) fossils. The conglomerate is best developed in the western part of the area, and when followed along the strike to the southeast, the conglomerate thins and grades into a course grained sandstone.

Overlying the basal conglomerate of division A, are approximately 700 feet of massive, coarse to fine grained, grey to grey-brown, micaceous, locally cross-bedded sandstones of division B.

Stratigraphically above the massive sandstones are the basal beds of division C. The lower 75 feet of this division is characterized by dark slate grey carbonaceous shale, with indistinct bedding and weathering in a concretionary manner. Interbedded with the shale are elongate, calcareous nodules and thin lenses. Overlying the slate-grey shale is approximately 110 feet of fine to coarse grained, light tan-buff colored, poorly consolidated, sandstone. Locally this sandstone becomes very gritty and contains thin clay lenses and in places contains considerable amounts of carbonaceous material. Stratigraphically above the sandstone just described are approximately 300 feet of dark slate grey, carbonaceous, nodular clay shales. This shale has fairly distinct bedding and weathers in a concretionary manner. The shale of this horizon contains a few hard bluish-grey, calcareous nodules and lenses.

The shale just described is the uppermost lithologic unit of division C.

Overlying the upper shales of division C are approximately 300 feet of massive, fine to coarse-grained grey, loosely cemented sandstones of division D. The basal beds of this unit are complexly cross-bedded, fine grained, massive, uncemented sandstone which is broken by two or three persistent one foot beds of white or bluish grey shale. The complex cross-bedding in the lower portion of this horizon suggests possible near shore eolian conditions existing at the time of deposition. The sandstone beds of the middle part of this horizon are medium grained, massive, yellow-brown to grey in color often cross-bedded, containing large flakes of biolite mica and three inch rusty concretions. Locally there are vague casts of fossils, probably marine mollusks. The upper sandstone beds of this horizon are massive medium-grained, grey to tan-brown in color, often grading laterally into pebbly lenses. The upper sandstone beds of this horizon contain hard lenses and reefs of calcareous, fossiliferous sandstone. Almost all of the molluscan fossils described by Clark[14] were collected from localities along the reefs in the upper portion of division D.

Overlying division D are approximately 1500 feet of clay shales and sandstone. The lower part of this horizon is composed of fine grained, massive silty, poorly indurated, buff-colored sandstone. The upper portion of this horizon is predominately medium-grey, massive, deeply weathered, clay shale with minor amounts of soft, silty, sandstone. The weathered surfaces of the clay shale are light-grey in color and are locally stained with limonite. The exposures of this division are very poor and in most cases deeply weathered and covered with vegetation. The basal conglomerate of the Domengine formation overlays the upper Meganos division E.

Petrography of the Meganos Formation

The Meganos sandstone is very similar, megascopically to the overlying Domengine formation already described. All of the Meganos samples are fine to course-grained, soft, friable, light-grey sandstone. Quartz constitutes 65 to 90 percent of the lights and is predominately clear. Some fragments include apatite, rutile chlorite, iron oxide and carbonaceous material often rendering them nearly opaque. Orthoclase makes up 25 percent in the lower beds. Microcline, andesine or oligoclase and muscovite are present in small percentages. The microcline and plagioclose are partially altered to sericite.

The percentage of minerals heavier than bromoform vary from 2.5 to 8 percent throughout the formation. The heavy mineral assemblage is composed of 30 percent green-hornblende, approximately 30 percent zircon, 15 percent black tourmaline (schorite), and small percentages of tremolite, garnet, titanite, magnetite, ilmenite, and yellow-orange tourmaline making up the remainder. Ilmenite and magnetite are sometimes altered to limonite and leucoxine; tremolite is frequently altered to talc. The mineral fragments as a whole are less angular than those of the Markley formation, but are more angular than those of the Martinez formation.

Figures 11 and 12 on Plate 9 are photomicrographs of the mineral fragments contained in the Meganos formation. The light mineral assemblage is shown in Figure 11. Note the close similarity in mineral composition and angularity to the light mineral assemblage shown in Figure 4. The heavy mineral suite of the Meganos formation is shown in Figure 12. Note the greater abundance and variety of the heavy mineral suite of the Meganos formation.

A comparison of the grade-size curves shown on Plate 10 indicate less uniform sorting in the Meganos beds in contrast with the Markley formation, but more uniformly sorted than the Domengine and Martinez beds.

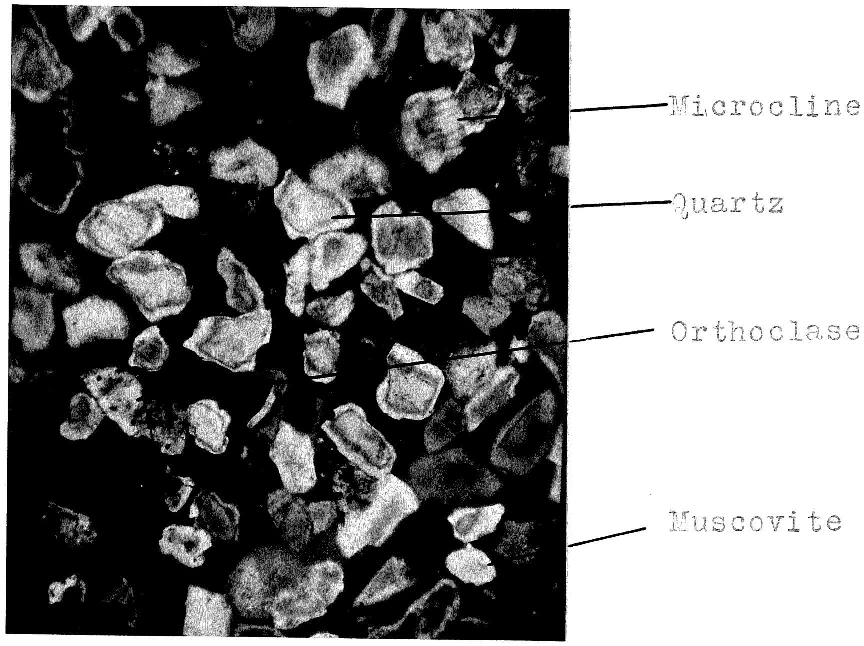


Figure 11. Light minerals of the Meganos Formation, crossed Nicols, 45 diameters.

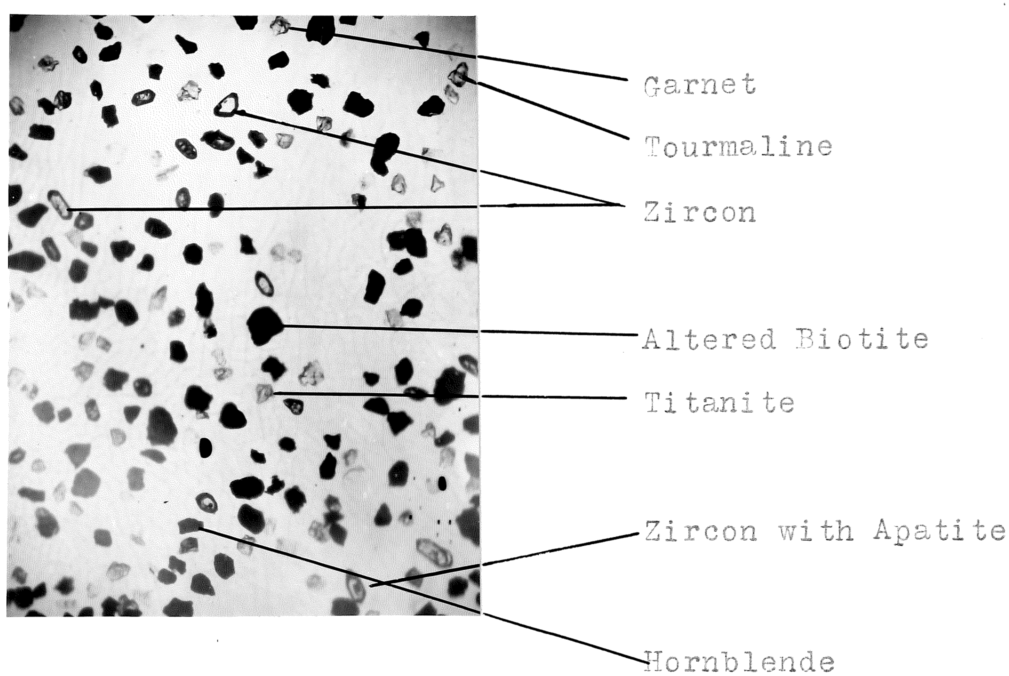


Figure 12. Heavy minerals of the Meganos Formation, Plane light, 20.5 diameters.

PLATE IX

VIII

STRATIGRAPHY OF THE MARTINEZ FORMATION

The term Martinez group was first applied by Gabb[1] in 1864, to the series of strata overlying the Chico(Cretaceous) formation in the Martinez, California area.

The Martinez formation on the north side of Mt. Diablo is approximately 700 feet thick and consists of five stratigraphic units. The lowermost or basal unit consists of approximately 50 feet of hard, well-consolidated, dark-brown, fossiliferous conglomerate, made up of well rounded pebbles and cobbles of red, green, brown, and yellowish white chert, white vein quartz, dark and white quartzite, dark bluish grey limestone nodules and a few angular dark-brown slabs of gritty sandstone, all in a matrix of medium-grained, gritty, hard calcareous, medium-brown sandstone. In the vicinity of Oil Creek this basal conglomerate contains the well known lower Eocene, Meretrix dalli fauna. The basal conglomerate of this horizon unconformably overlies the Chico (Cretaceous) shale. The upper portion of the basal conglomerate grades upward into a very gritty to coarse-grained sandstone containing rounded granules, similar in composition to the pebbles in the conglomerate.

Overlying the basal conglomerate and gritty, coarse-grained sandstone beds are massive light-brown sandy shales interbedded with minor amounts of lenticular, silty, grey-green, fine-grained sandstone. This horizon is approximately 100 feet thick and contains a well preserved Paleocene microfauna.

Stratigraphically above the shale horizon are alternating beds of sandstone with minor amounts of shale, approximately 250 feet thick. Some of the sandstone beds of this horizon when followed south eastward along the strike, thicken and split into several beds. The lower portion of this horizon is characterized by soft, buff-tan colored, fine-grained, non-fossiliferous sandstone. Interbedded between the sandstone just described and next to a massive sandstone bed is 6 feet of grey-green badly weathered shale. Above the shale bed is a massive coarse-grained, gritty, grey-buff-tan, limonitic-stained, sandstone. Above this coarse-grained sandstone is a thin bed of deeply weathered poorly exposed, grey-green shale. The shale bed is in turn overlain by a massive, very gritty, hard, light-tan-brown sandstone. The grits are similar in composition to the pebbles in the basal conglomerate. The upper sandstone beds of this horizon are generally finer-grained, usually harder, and darker in color than the sandstone beds of the lower portion of the horizon. The upper finer-grained sandstone beds contain the middle Martinez, Trochocyathus zitteli faunal zone.

Overlying the sandstone horizon just described are approximately 300 feet of massive marine grey-green fossiliferous, sandy shale, with indistinct bedding and weathering in a concretionary manner. This shale is exposed in the western part of the area where it is overlain unconformably by the Meganos basal conglomerate. Elsewhere the exposures are very poor and deeply weathered. Throughout most of the area the shale beds are covered by a thick mantle of soil and adobe.

The light mineral assemblage of the Martinez formation consists of 90 percent quartz, 6 percent gypsum and calcite, 3 percent albite-oligoclase and approximately 1 percent muscovite. The quartz fragments are made up of both clear and opaque grains showing more roundness than in other formations. Apatite is very commonly included with the quartz fragments. Calcite and gypsum are both authigenic in origin. Microcline, albite and oligoclase are usually badly altered to sericite and kaolin.

The heavy mineral suite of the Martinez formation consists of 40 percent yellow-orange tourmaline, 30 percent zircon with included apatite, 10 percent garnet, magnetite, ilmenite, biotite, chlorite, and leucoxine, making up the remainder. All the minerals present in the heavy mineral assemblage are similar to those already described. The mineral fragments of the martinez formation show less angularity and more roundness than do the minerals of the other Eocene formations. A few of the zircons are smooth and frosted indicating that they are probably reworked from an earlier cycle of deposition.

The mineral glauconite has been reported as a characteristic mineral of certain beds of the Martinez formation on the north side of Mt. Diablo at the type section, and at other localities throughout California. None of the samples collected from the so called glauconitic beds on the north side of Mt. Diablo contained the mineral glauconite.

The accumulations grade size curves for the Martinez formation are plotted on Plate 10. The sorting and grade-size of the Martinez beds differ considerably from the overlying Meganos formation.

Photomicrographs of the light and heavy mineral suites of the Martinez formation are shown on Plate 11, Figures 13 and 14 respectively. Note the angularity and the similarity of mineral content in both the light and heavy mineral assemblages of the Martinez to the other Eocene formations.

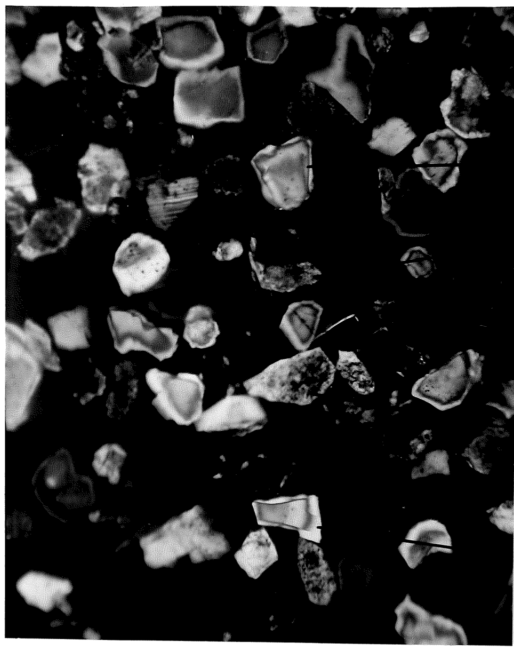


Figure 13. Light minerals of the Martinez formation, crossed Nicols, 45 diameters.

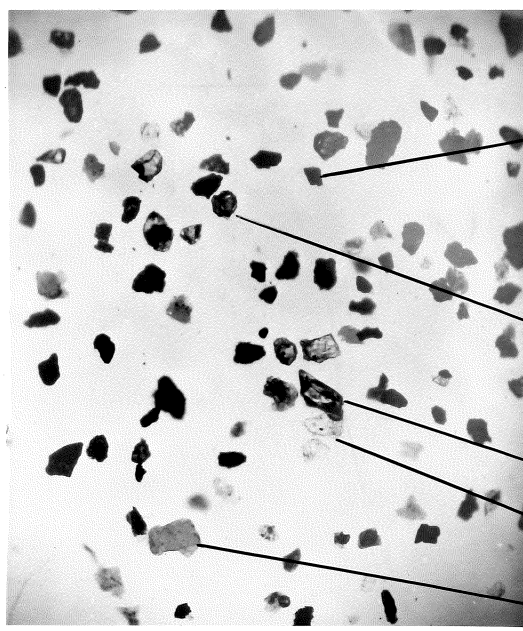


Figure 14. Heavy minerals of the Martinez formation, plane light, 20.5 diameters.

PLATE XI

IX

IDENTIFYING CHARACTERISTICS OF THE EOCENE FORMATIONS

The Eocene formations on the north side of Mt. Diablo may be separated on the basis of mineral content and lithology. The presence of large flakes of muscovite mica distinguish the Markley group from the other Eocene formations on the north side of Mt. Diablo, and in other Eocene localities in central California. The upper and lower Markley sandstone units may be separated from the Sidney and Nortonville members by the presence of anthophyllite. This mineral is more dominant in the upper portion of the formation than in the lower.

The Domengine formation is characterized by the lack of muscovite mica, the very small percentage of heavy minerals and by its distinctive lithology. Fragments showing micrographic intergrowth of quartz and feldspar were found only in the Domengine formation. However the presence or absence of the micrographic intergrowth cannot be used to identify the formation.

The Meganos and Domengine formations are very similar in both lithology and mineral content, but differ greatly in the percentage of heavy minerals. The Domengine formation contains .5 to 2 percent heavy minerals in contrast to the

3 to 6 percent contained in the Meganos formation. Hornblende and tremolite are present in the Meganos formation but are absent in the Domengine beds. The lower Meganos beds are characterized by the presence of large flakes of biotite mica.

The Martinez formation is readily recognized from other Eocene formations by its distinctive lithology. The mineral assemblage and percentage of the Martinez formation is similar to the overlying formations. Small, well-rounded frosted grains of chert and zircon are fairly common throughout the Martinez formation, but were not seen in the Domengine or Meganos formations. The mineral fragments of the Martinez formation are generally more rounded and show more wear than do the fragments of the other Eocene formations. Some of the beds of the Martinez formation in other localities of California are characterized by the presence of the mineral glauconite. This mineral was not found in any of the samples collected on the north side of Mt. Diablo.

Source of Sediments

The source of the sediment that constitutes the Eocene formations on the north side of Mt. Diablo has been a subject for discussion for a number of years. It is generally recognized by most California geologists, that the sediments were derived from a landmass located to the west of Mt. Diablo.

Clark[19] in discussing the character of the Markley formation states, "The arkosic character together with the great abundance of mica apparently shows that these sediments were derived in part directly from igneous rocks." The euhedral shapes of the minerals and the angularity of the fragments in the Markley formation definitely indicate that the sediment was not transported a great distance. The only source of igneous or metamorphic rock located to the west of Mt. Diablo, are west of the San Andreas fault, in the Sur Series. The sediments being derived from this landmass would have to be transported by streams 40 to 50 miles to the basin of deposition. It is very doubtful if the hornblende and the feldspars of the Markley formation could have survived the trip and still maintained the possessed angularity. The presence of anthophyllite and Kyanite definitely indicate that the Markley formation was not derived from an igneous landmass but more probably from rocks of metamorphic origin.

The Sierra Nevada mountains to the east contain metamorphic rocks from which the sediments could have been derived. The distance of the landmass from the basin of deposition may again be the objectionable factor.

A third possibility for the source of the material is from the Great Valley Granite-like mass now buried beneath the alluvium in the San Joaquin Valley east of Mt. Diablo. The position of this mass is more favorable from the standpoint of its location near the basin of deposition, but insufficient knowledge of the character of this mass renders it questionable.

Based upon the similarities of the mineral content, the grade size and the angularity of the sediments making up the Markley Domengine and Meganos formations, the writer believes that all three formations were derived from the same landmass. A possible metamorphic origin is indicated presence of tremolite in the sediments of the Meganos formation. The heavy, dark colored minerals of the Domengine formation may have been removed by weathering prior to deposition.

Clark[22] in discussing the Meganos formation states, "Apparently, the Meganos sediments were derived from plutonic, Franciscion and Chico areas. The basal conglomerate indicates nearby Chico and Granciscion source and probably a more distant granitic source rock. The more abundant larger angular pebbles are in the western portion of the line of outcrop suggesting a western site for the area of erosion. The principle source rock for the Meganos sediments seems to have been granite. The abundance of feldspars, biotite and hornblende, the unrounded characters of the minor accessories, and the coarseness of grain, sometimes greater than that of the underlying Chico, all point to a predominately direct origin the plutonic source rock. That the derivation was not indirect, via the Franciscion, is further indicated by mineralogic distinctions. The Meganos sandstone contains abundant hornblende, which is only occasionally seen in the Franciscan sandstone and is rare or missing in other Franciscan rocks. Further more, the Franciscan sandstone is at least sometimes higher in soda-lime than in potash feldspar.

The Chico formation on the north side of Mt. Diablo and in the Martinez area is composed of 90 percent shale and 10 percent sandstone. The sandstone is fine to medium grained, silty and dark brown in color. All of the Chico sandstone beds studied by the author are finer grained than the Meganos sediment, and therefore can be eliminated as a source for the Meganos sediments.

The sediments making up the Martinez formation bear close resemblance to the mineral content and grade size to the Chico and Franciscan sandstones. Many of the fragments show considerable wear and indicate a possibility of a second cycle of erosion and deposition. The basal conglomerate beds and the grit of some of the sandstone beds are made up of well rounded fragments of chert, limestone and quartzite that are characteristic of Chico and Franciscan formations. The presence of similar material composing the grit and pebbles in the basal conglomerate, suggest that the Chico and possibly the Franciscan formations contributed sediment to the Eocene basin during Martinez time.

X

CONCLUSIONS BASED ON SEDIMENTARY PETROGRAPHY

1. The Markley, Domengine and Meganos formation were derived from the same landmass.

2. The sediments were derived from rocks of metamorphic origin.

3. The sediments were derived from a landmass near the basin of deposition.

4. The source of material may have come from the granite-like landmass now buried beneath the San Joaquin Valley.

5. The Martinez formation was in part derived from Chico and Franciscan rocks.

XI

STRUCTURE

For several years the structure of Mt. Diablo has been the subject of a great deal of discussion and comment among California geologists. The first description of the structure of Mt. Diablo was made by Clark[15] in 1924. He described the structural relations of the Tertiary formations as exposed members of the eastern limb of a major, breached, northwest-southeast trending anticline. After considerable study in the Mt. Diablo area and other localities throughout California Clark advanced the idea of a complex system of low-angle overthrust faults. The problems involved in the recognition and mechanism of the low-angle thrust faulting was discussed in several papers by Clark and others. At the present time there are several major northwest-southeast trending thrust faults recognized in Central California.

The Mt. Diablo thrust fault lies on the west side of Mt. Diablo and is responsible for much of the structural control in that area. The Jurassic and Cretaceous rocks now exposed on Mt. Diablo were formerly buried beneath the Tertiary strata of the San Joaquin Valley.

Late in the Pliocene, the Jurassic and younger rocks were faulted and shoved up westward at a steep angle onto the Tertiary formations. The Tertiary formations on the northeast were dragged upward with the overthrust mass.

The faults shown on the areal map, Plate 12, are secondary thrust faults and normal adjustment faults, closely associated with the major Mt. Diablo fault system.

The strike of the Tertiary rocks on the north side of Mt. Diablo vary from N 45° W to east-west, with an average dip of 36° to the northeast. In the vicinity of Oil Creek the Martinez formation strikes N 89° W, and dips 45° to the northeast. Farther to the south the strike swings N 75° W, with a dip of 35° to the northeast. The overlying Meganos formation strikes N 45° W to N 70° W and dips 33° to 43° to the northeast.

The difference in strike and dip are due to the unconformable relations of the two formations. The beds of the Domengine formation in the southern part of the area strike N 50°-70° W and dip 30° to 33° to the northeast. In the northern part of the area, the Domengine formation appears to have the same dip and strike as the overlying Markley group. Northwest of Nortonville the Lower Markley sandstone strikes N 76° W and dips 35° northeast. In Markley Canyon the lower sandstone beds strike N 68° W and dip 48° to the northeast. The Upper Markley sandstone beds strike N 73° W and dip 39° to the northeast.

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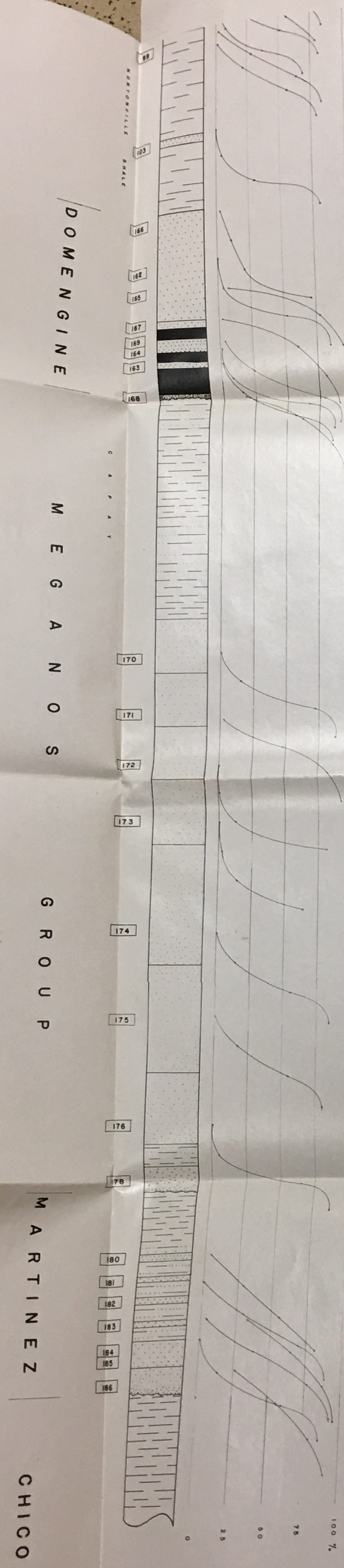


MINERALS OF THE DOMENGINE FORMATION

85-99 %	QUARTZ
.5-2	ALBITE
	MICROCLINE
1-10	ORTHOCLASE
	SERICITE
	KOALIN
98-99	LIGHT MINERALS
	GARNET
	ZIRCON
	TOURMALINE
	MAGNETITE
	ILMENITE
	LEUCOXINE
.2-1	HEAVY MINERALS

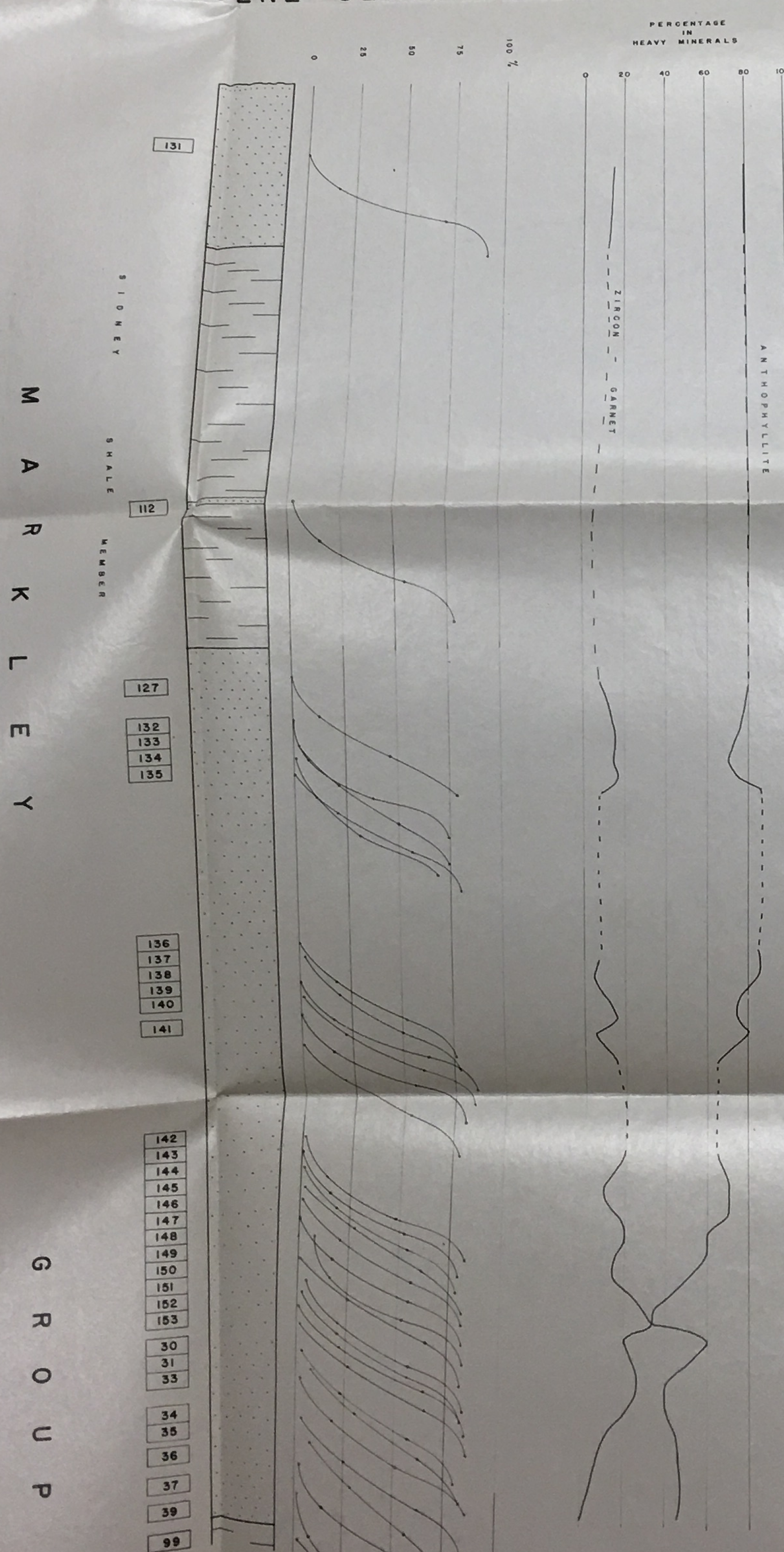
MINERALS OF THE MEGANOS FORMATION

70-90 %	QUARTZ
1-22	ORTHOCLASE
1-3	OLIGOCLASE-ANDESINE
	MICROCLINE
	MUSCOVITE
	SERICITE
94-97	LIGHT MINERALS
1-5	BIOTITE-CHLORITE
1-3	GREEN HORNBLENDE
1-3	ZIRCON
	TREMOLITE
	TITANITE
	GARNET
	RUTILE
	SILLIMONITE
	TOURMALINE (BROWN)
	TOURMALINE (YELLOW)
	MAGNETITE
	ILMENITE
	LEUCOXINE
3-6	HEAVY MINERALS

MINERALS OF THE MARTINEZ FORMATION

90%	QUARTZ
5	GYPSUM
	CALCITE
1-3	ALBITE-OLIGOCLASE
	MUSCOVITE
	SERICITE
94-95	LIGHT MINERALS
1-3	TOURMALINE
1-2	ZIRCON
.5-1	GARNET
	MAGNETITE
1-3	BIOTITE
	ILMENITE
	LEUCOXINE
	LIMONITE
5-6	HEAVY MINERALS

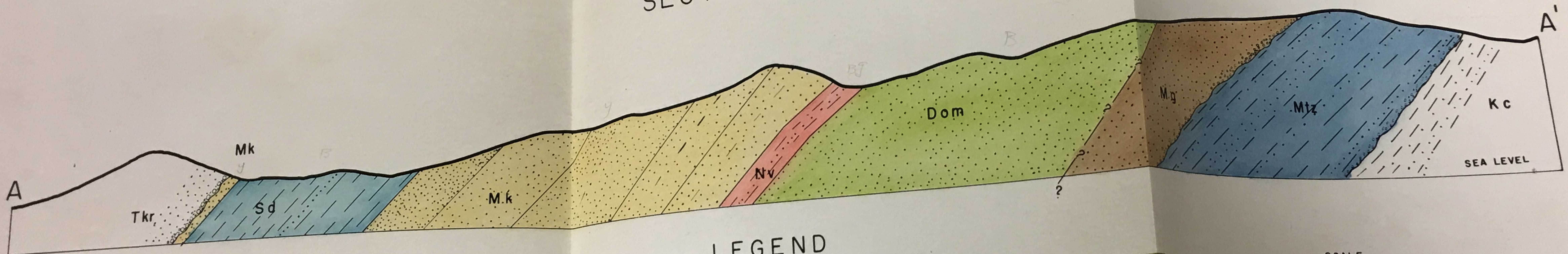
COLUMNAR SECTION OF THE EOCENE SERIES ON THE NORTH SIDE OF MT. DIABLO



MINERALS OF THE MARKLEY GROUP

90-93 %	QUARTZ
1-3	MUSCOVITE
1-2	ALBITE
1-2	ORTHOCLASE
	MICROCLINE
	CALCITE
93-94	LIGHT MINERALS
.5-1	HORNBLENDE
0-4	ANTHOPHYLLITE
1-3	GARNET
.5-3	ZIRCON
	TOURMALINE
	KYANITE
	TITONITE
	ACTINOLTE
1-3	BIOTITE
	MAGNETITE
	ILMENITE
	PYRITE
	LEUCOXINE
	LIMONITE
2-7	HEAVY MINERALS

SECTION A – A'



LEGEND

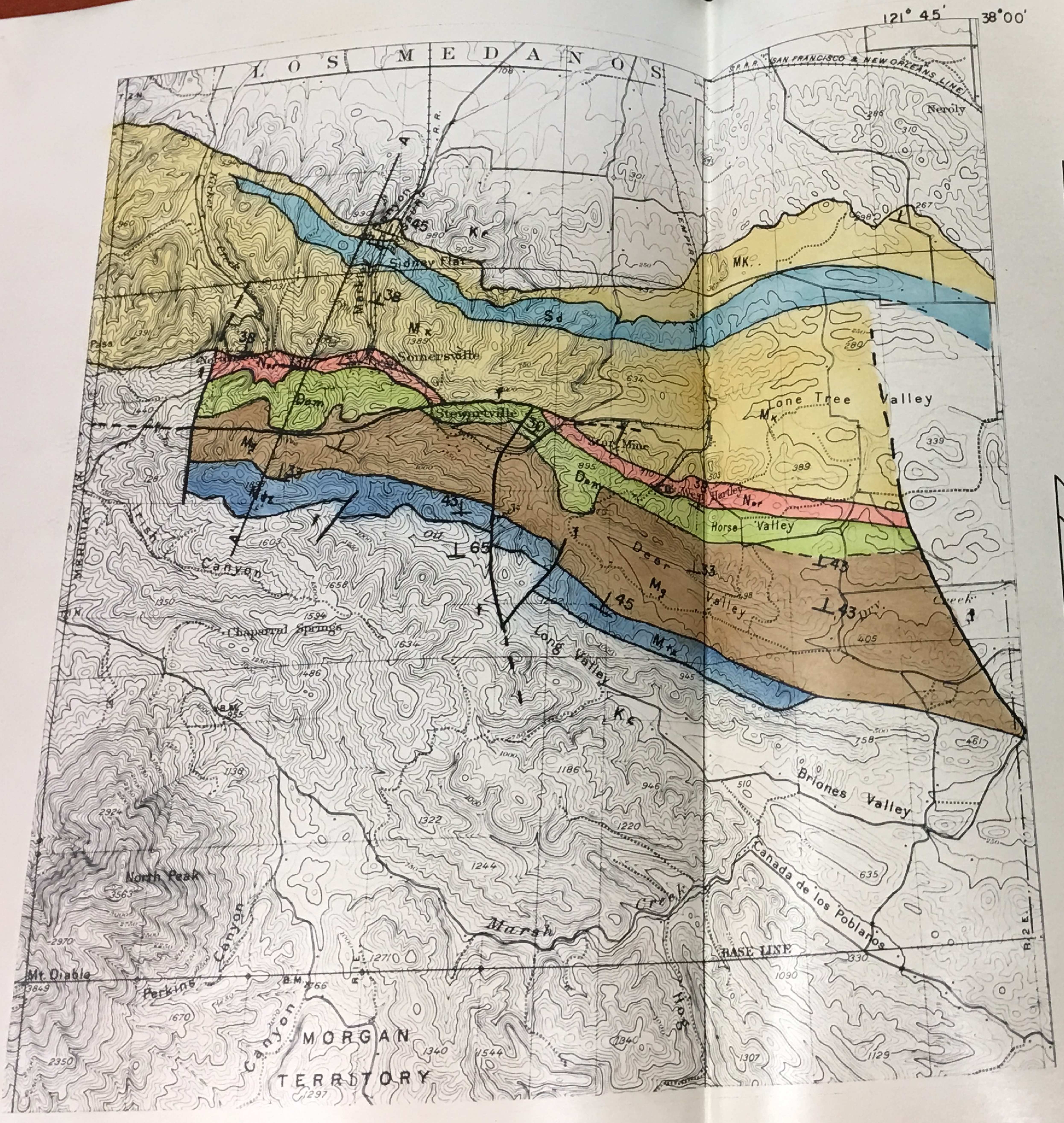
	KIRKER FORMATION	Tkr
MARKLEY GROUP	MARKLEY FORMATION	Mk
	SIDNEY SHALE	Sd
	NORTONVILLE SHALE	Nv
	DOMENGINE FORMATION	Dom
	MEGANOS FORMATION	Mg
	MARTINEZ FORMATION	Mtz
	CHICO FORMATION	Kc

SCALE

HORIZONTAL ├──┤ = 5000'

VERTICAL ├──┤ = 5280'

PLATE XIII



GEOLOGIC MAP

LEGEND

MARKLEY FORMATION	Mk
SIDNEY SHALE	Sd
NORTONVILLE SHALE	Nor
DOMENGINE FORMATION	Dom
MEGANOS FORMATION	Mg
MARTINEZ FORMATION	Mz

FAULT — — f

SCALE

1 MILE

PLATE XII