GEOLOGY OF THE DEL VALLE AREA, LOS ANGELES COUNTY, CALIFORNIA

by

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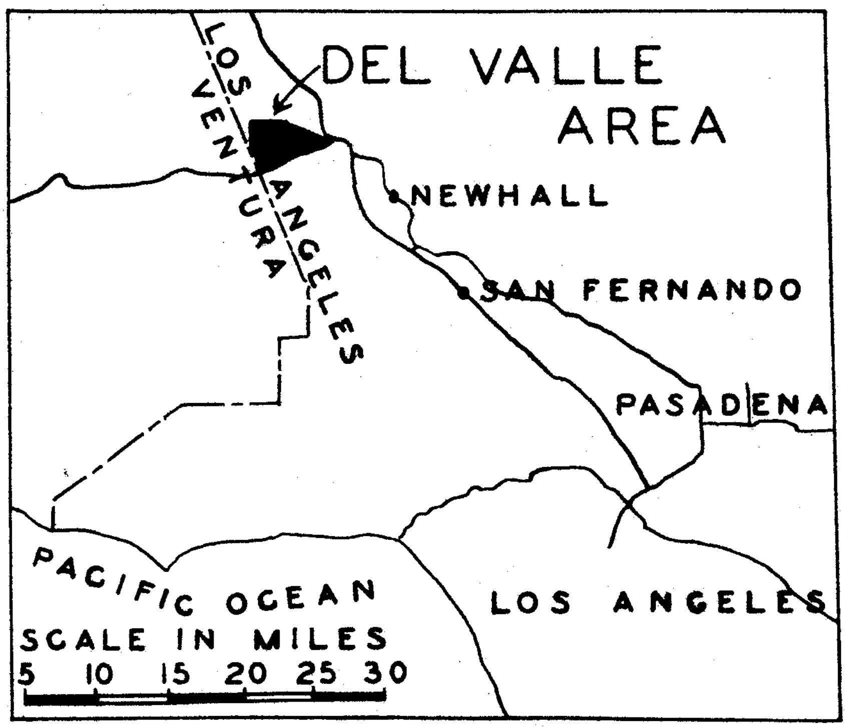
ABSTRACT

The Del Valle area is a part of an east-west synclinal basin located near the eastern end of the Ventura Basin. It is also a part of the Transverse Range region of southern California and its structural trends are therefore predominantly east-west. The area is characterized, structurally, by folding and overthrust faulting with some minor normal faulting. The formations consist entirely of sedimentary rocks ranging in age from Miocene to Recent. Beds of the Saugus, upper and lower Pico, and Repetto formations are exposed at the surface, and consist of sands, sandstones, siltstones, and shales. Local terrace sands and gravels and alluvial deposits are also present. Two productive oil fields, the Del Valle and Ramona oil fields are located within this area.

INTRODUCTION

The Del Valle area is in the western part of Los Angeles County, about 40 miles north of the center of the city of Los Angeles and 4 miles west of Castaic Junction on the north side of the Santa Clara River. The area discussed in this report, roughly triangular in shape, is approximately 12 square miles in extent and is bounded on the west by Longitude 118° 42' West, on the north by Latitude 34° 28' North, by Hasley Canyon on the northeast and by the Santa Clara River Valley on the south



LOCATION OF DEL VALLE AREA

and southeast. The Del Valle oil field itself occupies sections 15, 16, 17, and 18, T. 4 N., R. 17 W. The Ramona field is immediately north and west of the Del Valle field; however, only that part of it which is necessary for the explanation of the geology of the area as a whole is included in this report. The area is moderately rugged, with differences in relief of more than 1000 feet. The highest elevation in the area is more than 2200 feet above sea level, with the lowest being less than 875 feet above sea level.

The entire area drains to the south into the Santa Clara River. Intermittent streams from the San Martinez Grande Canyon and the San Martinez Chiquito Canyon drain into the northeast-southwest flowing Santa Clara River.

The types of vegetation found here depend upon the soil types. The vegetation is commonly more pronounced on the north side of the hills where it does not receive the direct rays of the sun. Grass is found on the siltstones and sandy siltstones of the lower Pico and Repetto formations, whereas mainly chaparral and cactus grow on the sandstones of the upper Pico and Saugus. Some of the chaparral on the north slopes is so thick that it is almost impossible to penetrate it.

Outcrops are excellent in this area in cliffs, canyons, and gullies. The numerous road cuts found here also greatly vacilitated the geologic mapping. Two rather large areas of poor outcrops are the two areas of slump (see map), one in the Repetto and one in the lower Pico.

The area is easily accessible by roads in Hasley Canyon, San Martinez Chiquito Canyon, and San Martinez Grande Canyon. Even more important than these, however, not only for accessibility but for fresh roadcuts, are the roads leading to the oil wells in the productive part of the area.

The settlement of Valverde is located in San Martinez Chiquito Canyon. A small refinery operated by R. E. Havenstrite has been constructed on the river terrace between San Martinez Grande Canyon and San Martinez Chiquito Canyon immediately north of the Santa Clara River.

This report covers field and laboratory work, the purpose of which was to determine the structure and stratigraphy of the Del Valle field and adjacent area by means of surface mapping and interpretation of well logs. The base map used for field mapping was an enlargement (1/12000) of the U.S.G.S. Castaic Quadrangle (1/24000). Aerial photographs supplemented this in the field. The field work was started October 18, 1946 and completed May 3, 1947. A total of 30 days was spent in the field.

The writer wishes to thank the Standard Oil Company of California for the use of their well logs from their Sepulveda lease of the Del Valle field, and Drs. R. H. Jahns and J. W. Durham for their guidance and supervision.

STRATIGRAPHY

General:

The formations in the Del Valle area consist entirely of sedimentary rocks ranging in age from Miocene to Recent. The rocks exposed at the surface in the area are Pliocene sands, sandstones, siltstones, and shales, with local Pleistocene sands and gravels. No igneous or metamorphic types are to be found except as conglomeratic boulders.

Modelo formation, upper Miocene:

"The Modelo is not exposed at the surface in the Del Valle area though it is penetrated by the wells and is productive. The oldest sediments penetrated in the Ramona and Del Valle fields are the brown shales and sands of the Mohnian stage of the upper Miocene. Over 2000 feet of Mohnian beds have been penetrated in the area. R. E. Havenstrite's Barnes No. 2 well, which was drilled to 9867 feet, (Structure Section B-B') and the Superior Oil Company's and the British-American Oil Producing Company's Handy no. 1, (Structure Section C-C') drilled to 10,097 feet, are the deepest stratigraphic penetrations to date in the area"/[1]...........and both penetrate the Mohnian.

"Uppermost Miocene Delmontian stage beds overlie the rocks of the Mohnian age. Since paleontologists disagree as to the exact position of the top of the Miocene in the area, the exact

1. Matter, J. E. and Wrath, W. F., Del Valle and Ramona Oil Fields, Los Angeles and Ventura Counties, California, Field Trip Guide Book, joint annual meeting of AAPG, SEG, SEPM, pp. 37-38; March, 1947.

thickness of Delmontian age beds is uncertain. Depending upon the point used for the top of the Delmontian, between 1500 to 2200 feet of brown shales, sandstones, and conglomerates are assigned to this stage."/[2]

Tarbet/[3] studied the upper lithologic member of the Modelo formation on the Temescal anticline, immediately west of the area studied, and found that it "comprises about 1300 feet of interbedded gray and brown silty shale and sandstone with lenticular rusty brown pebble and cobble conglomerate. The lower part of this member varies from well bedded and laminated brown shale and gray sandstone with a few calcareous-cemented beds to rather massive gray and brown silty shale and sandstone. The upper part of this member varies from well bedded gray and brown silty shale and gray sandstone to massive gray and brown sandy siltstone and gray sandstone. Very lenticular sandy conglomerate strata are present throughout the member, but they are more numerous in the upper and middle parts. Lenticular oil saturation is present in the sandstone and conglomerate strata of this member on the south flank of the Temescal anticline. The lowermost part of this lithologic member is in the Mohnian paleontologic time stage, and the upper part is in the Delmontian stage, as defined by R. M. Kleinpell."

Both the Mohnian and Delmontian stage of the Modelo con-

2. Matter, J. E. and Wrath, W. F., op. cit., p. 38, 1947.
3. Tarbet, L. A., Geology of Del Valle Oil Field, Los Angeles County, California, AAPG Bull. 26, pt. 1, p. 189, 1942.

tain oil in commercial quantities that is now being produced. "The Bering zone is the lowest stratigraphic producing zone in the field and is in beds of the Mohnian stage of the upper Miocene. It consists of fine to coarse sands of varying lithology. The producing zone consists of roughly the upper 200 feet of a predominantly sandy section which is some 1100 to 1200 feet thick. The lower portion of this sandy section is wet. The top of the zone ranges in depth from 7600 to 7900 feet."/[4]

There are oil producing zones in both the lower and upper Delmontian stage. "The top of the Del Valle zone is some 1200 to 1400 feet above the top of the Bering zone in beds of the lower Delmontian stage of the upper Miocene. The general portion of the section occupied by the zone is highly lenticular with shales being replaced by sands very rapidly."/[5] The Videgain, Vasquez, and Vasquez 13 zones (the Vasquez 13 is not shown on the structure sections) are considered to be of uppermost Miocene age (uppermost Delmontian stage). The producing sands average about 100 feet in thickness, separated generally by shales.

Tarbet/[6] states that "a study of foraminiferal samples indicates that a slight angular unconformity and overlap mapped on the east plunge of the Temescal anticline is equivalent to the Pliocene-Miocene foraminiferal division used in the Del

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4. Matter, J. E. and Wrath, W. F., op. cit., p. 39, 1947.
5. Matter, J. E. and Wrath, W. F., Idem, 1947.
6. Tarbet, L. A., idem, 1942.

Valle.....oil field and the Pliocene-Miocene contact at the type section of the Modelo formation." He further states that this unconformity is not sufficient to alter greatly the Modelo structure as interpreted from the overlying Pliocene sediments.

Repetto formation, lower Pliocene:

The amount of Pliocene penetrated by the wells depends, of course, on the position on the structure, but about 5700 feet seems to be the maximum. This includes both Repetto and Pico. The section as described by some geologists for the same locality contains approximately 500 feet of Saugus in formations penetrated by the same wells. The writer could find no basis for this if the division between the Pico and Saugus is limited to the marine-non-marine basis.

The Repetto formation crops out at the surface in the producing area west of the San Martinez Grande Canyon. It has been carried to the surface here by the Del Valle thrust fault (see geologic map and Structure Section C-C'). The top of the Repetto is placed by the writer at the base of a conglomerate bed that represents a stratigraphic break between the Repetto and lower Pico. 800 to 900 feet of Repetoo is exposed here, where it consists of siltstones, brown, and gray-brown. Sands grade upward into the massive gray siltstones and sands of the lower Pico. The Repetto is characterized by slumping-even on relatively moderate slopes. In fact, the slumping is to such an extent that the mapping in these areas is of no structural value. Between 2200 and 2400 feet of Repetto seem to be represented on the well logs in the Del Valle area. This corresponds rather closely to the 2150 feet reported by Tarbet[7] in the same area. It should be noted here that Kew did not recognize the Repetto in this area and assigned the whole Pliocene to the Pico formation (see Correlation Table).

There is one producing zone in the Repetto, the Sepulveda zone, which is considered to be in the lowermost Pliocene. It is the highest zone stratigraphically in the Del Valle area.

Pico formation, upper Pliocene:

The lower Pico is exposed south of the Repetto on the Del Valle thrust sheet, south and west of San Martinez Grande Canyon and on the Ramona anticline. It consists of a basal conglomerate overlain by gray-brown siltstone with local interbeds of buff to gray sandstone. Between the Del Valle and Ramona faults the Pico exposed is chiefly a sandstone unit with some of the lower Pico's siltstone outcropping also. This sandstone unit is approximately 2000 to 2300 feet thick and is upper Pico. The top of the Pico as seen along Structure Section A-A' is a thin, very fossiliferous siltstone, grading into a sandstone. Beneath this are white to buff, creme sandstones, well-bedded, sorted and cemented, medium to coarse grained. Some 400 feet below the top of the formation is an

7. Tarbet, L. A., op. cit., p. 190, 1942.

Ostrea bed that appears to be quite consistent throughout the Del Valle area south of the Ramona fault. There is a question in the writer's mind as to how much of the top of the Pico is missing owing to the disconformity between the Saugus and the Pico.

Farther east, in the vicinity of Elsmere and Pico Canyons, Kew/[8] describes an overlap type of disconformity between the Pico and Saugus formations. Although the exposures are not good, this overlap does seem to be present in the Del Valle area south of the Ramona fault (see Structure Section A-A'). However, it was not possible to detect an overlap north of the fault.

Below the Ostrea bed are more sandstones, coarse grained, white to buff, massive, poorly sorted and fossiliferous with some cross-bedding. These grade into the lower Pico, which is estimated by the writer to be about 1000 feet thick. The lower Pico exposed between the two Canyons is identical with the lower Pico exposed by the Del Valle thrust, except that the basal conglomerate is not seen at the surface.

The sandstone unit (upper Pico) contains numerous mega-fossils horizons of Pliocene age. A few species found here are: Dendraster diegoensis Kew, Anadara camuloensis, Ostrea lurida Carpenter, Ostrea vespertina Conrad (?), Pecten bellus Conrad, Patinopecten caurinus (Gould), Chlamys (?) hastatus

8. Kew, W. S. W., Geology and oil resources of a part of Los Angeles and Ventura Counties, California, U.S.G.S. Survey Bull. 753, pp. 86-89, 1924.

(Sowerby), *Venericardia californica* Dall, *Fusinus kobelti* Dall, *Polynices reclusianus* (Petit), *Turritella cooperi* Carpenter, and *Neptunea humerosa* Gabb (?).[9]

Saugus formation, upper Pliocene and Pleistocene:

Some 2000 feet of the lower beds of the Saugus formation is exposed on the Hasley anticline. Here the Saugus consists of buff to almost white, reddish and brown sandstones and conglomerates. These sandstones and conglomerates are interlayered with the sandstones predominating. These sandstones are, for the most part, medium to coarse-grained, with few fine-grained sandstones found. The Saugus in this area was deposited under terrestrial conditions and contains no marine fossils. Many of the sandstones are arkosic and cross-bedded. Strata of the Saugus formation are quite easily recognizable in the field on the basis of their color, detrital character, lack of marine fossils, and what may be called a terrestrial look. Where the Saugus beds are overlain by terrace gravels of a later age, it is almost impossible to separate the two formations unless an angular discordance can be observed. This can be seen very well on the west side of the Del Valle anticline in San Martinez Grande Canyon where just such a situation exist.

Terrace deposits, Pleistocene:

Bench gravels, probably of late Pleistocene age, are well

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9. Personal communication from H. B. Allen.

developed especially in the Havenstrite area of the Del Valle anticline. They overlie the Saugus and Pico formations with a nonconformity, are generally flat or dip gently toward the Santa Clara River, and represent alluvial deposits that have been uplifted and dissected. These benches consist of unsorted boulders, gravels, and finer clastic sediments. Some boulders two feet and more in diameter have been observed.

Alluvial deposits, Recent:

The floors of all the canyons and valleys are covered with fluviatile deposits that range in thickness from a few feet to more than fifty feet.

GEOLOGIC STRUCTURE

General:

"The Del Valle area is in a faulted and folded east-west synclinal basin at the eastern end of the Ventura basin of deposition"[10]........and is situated in the Transverse Ranges in which the structural trends are predominantly alligned in an east-west direction. In the Del Valle area the faults trend generally in an east-west direction whereas the folded structures plunge slightly south of east.

Two major thrust faults, the Del Valle[11] and the Ramona[12]

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10. Tarbet, L. A., idem, 1942.
11. R. W. Sherman named this thrust the Videgain thrust and San Martinez fault. Sherman, R. W., Del Valle oil field, California State Division of Mines, Bull. 118, p. 410, 1943.
12. Sometimes called the San Martinez Chiquito Canyon fault, or Holser Canyon fault.

divide the district into three distinctly separate structural blocks that will be considered individually. These blocks are: (1) the Del Valle thrust block, or the area south and west of the Del Valle fault; (2) the Ramona thrust block, or the area south of the Ramona fault and north of the Del Valle fault and the Santa Clara River; and (3) the Hasley fault block, or the area north of the Ramona fault and south of Hasley Canyon.

At least two periods of diastrophism have taken place. The first, at the close of the Miocene, was not regional in scope. In this part of the Ventura Basin, it amounted to little more than a short break in the Miocene sedimentation, perhaps accompanied by a brief uplift of the northern part of the district and followed by subsidence. No deformation is apparent. Elsewhere uplift and distortion must have been more profound because there were conglomerates deposited in the lower Pliocene horizons. Also, angular discordances have been noted (see section on the stratigraphy of the Modelo formation). The second period of movement was of major importance with shortening by folding and thrusting taking place. This orogeny is probably related to the Pasadenian Disturbance that began in late Pliocene or early Pleistocene, culminated in the middle or late Pleistocene, and probably is still active. The recency of movement is evidenced by the presence of Quaternary bench gravels found at varying elevations above the present local base levels.

(1) <u>Del Valle thrust block</u>:

From the western edge of the map the Del Valle fault parallels the San Martinez Grande Canyon first with an east-west strike and then swings abruptly south, crossing the Canyon near the road north of the Santa Clara River. The fault is an overthrust from the south with a large displacement bringing the lower Pico and Repetto to the surface here, overriding the upper Pico. The fault plane is plainly visible just east of the Standard Oil Company's well Sepulveda No. 9. The fault zone here is narrow, 18 inches to 2 feet wide, and is filled with a black clay-like gouge. It has a south dip of 50° that can be measured and this is confirmed in the well logs. Gas seeps and oil stained sands are present at the surface trace with the gas actually bubbling through the narrow zone of gouge. The fault is not as clear cut as this over the entire area and generally consists of a wide zone of fracture. The fault takes on a strike-slip component in the north-south trending part of the San Martinez Grande Canyon. In other words the fault changes in the curve (see geologic map) rather abruptly from a south dip, where the fault trends westward, to a southwesterly and then nearly vertical dip where it strikes southeastward.

The surface trace of the fault is plainly visible at only two points (in the area mapped) - at the location mentioned above and just north of the Santa Clara River where it crosses the San Martinez Grande Canyon road. The fault has an approximate 4500-foot displacement according to Tarbet/[13] and Matter and Wrath/[14]. This stratigraphic displacement can be seen on Structure Section C-C'.

Sherman/[15] believes that instead of one large overthrust with a local strike-slip component that there are two faults; an overthrust, which he calls the Videgain thrust, and a strike-slip fault that he named the San Martinez fault. He estimates that the beds on the west side of the strike slip fault have been pushed north as much as 3000 feet,/[16] and it is his contention that these faults are separate, although contemporaneous. He further believes that his San Martinez fault extends to enough depth to account for the "erratic and poor production characteristics of offset wells in the Videgain area" (productive area on the Del Valle anticline west of the San Martinez Grande Canyon). Sheldon/[17] and Tarbet have pointed out, however, that the stratigraphic changes from sand to shale may partly account for this difference in production.

The effect of the Del Valle fault on accumulation of oil in the Del Valle anticline will be discussed later on. In the south central part of the block a north-south fault, probably with normal displacement, offsets the basal Pico conglomerate. The displacement is about 600 feet, with the western side of

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13. Tarbet, L. A. op. cit., p. 191, 1942.
14. Matter, J. E. and Wrath, W. F., op. cit., p. 37, 1947.
15. Sherman, R. W., idem, 1943.
16. Sherman, R. W., idem, 1943.
17. Sheldon, D. H., Development of the Del Valle oil field, AIME, Los Angeles Meeting, Petroleum Division, October, 1941.

the fault upthrown. An anticline, plunging to the southeast is the controlling surface structure of the thrust block. This fold is approximately 7300 feet long and plunges into the Del Valle fault (see geologic map). This structure controls the dips and strikes of all the strata on this part of the fault block. It is the opinion of Dr. J. P. Buwalda/[18], who has done extensive work in this area, that the folding here was separate from and prior to the thrusting. If this is true, certainly the thrusting steepened the dips on the north flank of the anticline, at least at depth. This anticline is not the surface expression of the underlying Del Valle anticline as can be seen in Structure Section C-C'. The two folds are definitely separate, and unrelated. There is no known oil production in the upthrown side of the Del Valle fault - all wells south of the surface trace go through the Repetto and into the Pliocene for production from the underlying Del Valle anticline. The amount of Repetto penetrated before reaching the Del Valle anticline, of course, depends upon the position of the well south of the fault. Some wells also go through the Miocene before again entering the Pliocene.

(2) Ramona thrust block:

The Ramona fault itself is a steeply dipping overthrust from the south, similar to the Del Valle thrust. The surface trace strikes approximately east-west through San Martinez Chiquito Canyon, then southwest through Holser Canyon to the

18. Personal communication.

west. To the east of San Martinex Chiquito Canyon it follows the east-west trending unnamed valley, and thence swings south-east under the Santa Clara River. The fault plane dips 50 to 60 degrees south. The fault has a dip of 50 degrees where it intersects the Shell Oil Company's well No. "Daugherty" 1, which is just south of the fault in the east-west trending part of San Martinez Chiquito Canyon. The exact displacement is not known. Tarbet[19] states that "there may be as much as 4000 feet of duplicated beds, but there is probably less than 2000 feet". Matter and Wrath[20] estimate the displacement at 3000 feet. Sherman[21] found a duplication in the electric log of Havenstrite's well No. "Lincoln" 10 (see Structure Section B-B') between 6700 and 6800 feet that would indicate a thrust of about 500 feet.

Structure Section C-C' indicates a displacement of at least the magnetude of Tarbet's 4000 feet and probably more.

The thrust places the lower Pico formation over the lower Saugus formation. The fault plane can be seen in Holser Canyon and springs and other topographic indications of faulting are present in the unnamed valley east of the San Martinez Chiquito Canyon. The springs are mapped and define the fault in this part of the area (see geologic map). The fault is generally traced, however, by the contact between the lower Pico and the lower Saugus. The trace of the fault is in a syncline with

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19. Tarbet, L. A., idem, 1942.
20. Matter, J. E. and Wrath, W. F., idem, 1947.
21. Sherman, R. W., idem, 1943.

the Pico beds dipping into the fault from the south side and the Saugus beds dipping into it from the north side. Kew/[22] believes that the Ramona fault is an extension of the San Gabriel fault.

There is evidence that the unnamed valley to the east of the San Martinez Chiquito Canyon is a graben with the Ramona fault on the south side and at least one normal fault on the north side. This normal fault is easily traced and has a displacement of at least 350 to 400 feet. This fault probably joins the Ramona fault as indicated on the map.

South of the graben valley (heretofore called the unnamed valley) the Ramona fault exhibits imbricate structure for some 5000 feet. The small block just south of the valley, containing the anticline, was dragged up during the thrusting (see Structure Section A-A'). The greater displacement is on the segment of the fault immediately south of the anticline, where the upper Pico is brought against the Saugus west of the easternmost north-south fault. Lower Saugus instead of upper Pico is faulted up against the Saugus (lower?) east of the easternmost north-south fault due to the downdropping of the block along this fault. This will be further explained later in this section.

Another east-west fault, probably with normal displacement, is located in North Syncline. It strikes east-west across the

22. Kew, W. S. W., *op. cit.*, geologic map, 1924.

north end of the Del Valle anticline, disappears to the west, probably under the Del Valle thrust, and dies out rapidly to the east in the syncline. In all, it is traceable for about 10,000 feet. The fault, as nearly as can be determined, is downthrown in the south side approximately 50 to 100 feet, and probably dies out rapidly at depth. There is no evidence to the writer's knowledge of any indication of this fault on the electric logs.

Sherman/[23] states that "it is questionable whether or not this synclinal fault extends to sufficient depth to be an important feature in the control of the area of accumulation"... ....in the Del Valle anticline. Probably it does not. The almost straight east-west trend of the fault as it cuts the dipping beds in the syncline indicates that it is probably a steep normal fault.

A series of at least 5 and possibly more faults complicate the structure in the northeast section of the Ramona fault block. These are best discussed later in relation to the folds that they cut.

The two most important structures in the Ramona fault block from an economic standpoint are the Del Valle and Ramona anticlines.

The axis of the Del Valle anticline trends nearly east-west in the productive area and then swings southeast and finally

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23. Sherman, R. W. Idem, 1943.

plunges out about 18,000 feet/[24] (across the Santa Clara River) from the discovery well - R. E. Havenstrite's "Lincoln" well No. 1. The western section of the anticline is obscured by the Del Valle thrust block which overrides it, and therefore its western limits are not accurately known. 7100 feet of the anticlinal axis is visible from where it disappears under the Del Valle fault to where it is cut by highway 126. It extends for at least another 6000 to 8000 feet west under the thrust block. The fold is asymmetric in San Martinez Grande Canyon where the axis in inclined northward. It is more symmetrical to the east and west. Dips vary from 6 to 20 degrees.

Structure Sections B-B', C-C', and D-D' give about as accurate a picture of the surface and subsurface structure of the anticline as is possible with the limited number of electric logs that were available to the writer.

As seen in the sections the anticline is quite narrow. Note also that the western productive section, represented by C-C', is some 300 feet higher structurally than the eastern section (B-B').

Tarbet/[25] reported in 1941 that the "surface geology indicates that the productive limits of the Del Valle field are controlled on the north by the Holser (Ramona) fault, on the east by the easterly plunge of the folded sediments, and on the south by the south flank of the Del Valle anticline.... ....There are several features capable of causing the trap on

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24. Tarbet, L. A., op. cit., p. 191, 1942.
25. Tarbet, L. A., Idem, 1942.

on the west side of the Del Valle field. The producing zones may lens out toward the west to form a stratigraphic trap, north-south-trending cross faults may offset the producing zones sufficiently to form a fault trap, or there may be a reversal of plunge on the Del Valle anticline, with the western end of the anticline plunging westward under the Del Valle fault to form a structural trap............."

After this was written many more wells were drilled and much more learned about the field. Matter and Wrath/[26] report (1947) that there is "....both structural and stratigraphic closure contributing to the total amount of effective closure. The western half of the field appears to have definite structural closure while the closure on the eastern half of the field seems to be a combination of up-dip stratigraphic changes and probable faulting..........." As mentioned before, Sherman/[27] favored the fault hypothesis, having a vertical strike-slip fault cutting the anticline, while Sheldon/[28] favors the stratigraphic change idea.

The Del Valle thrust fault does not affect the accumulation of oil in the Del Valle anticline, nor does the Ramona fault appear to have much affect, at least in the top producing horizons. The Ramona fault cuts the upper zones on the north side of the anticline outside the area of closure. It is pro-

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26. Matter, J. E., and Wrath, W. F., op. cit., p. 39, 1947.
27. Sherman, R. W., op. cit., p. 410, 1943.
28. Sheldon, D. H., Idem, 1941.

bable that in the deeper zones, the Bering and Del Valle zones in the eastern area of production in the Mohnian and Delmontian respectively, and the Bering in the western area of production, that the accumulation is affected by the fault. The writer did not have access to the electric logs of these two deep wells. It is entirely possible that not enough deep wells have been drilled to date to definitely know if the fault affects accumulation at this depth. As shown in Structure Sections B-B' and C-C' these zones should definitely be affected by the faults. However, if the displacement of 500 feet on No. "Lincoln" 10 is correct (as described by Sherman), it is entirely possible that the fault is rapidly dying out at depth, and hence that there may not be enough displacement at depth to seriously affect the deep zones.

Stockman/[29] described a situation at the Newhall-Potrero field where it was thought that the Newhall-Potrero fault, which cuts across the axis of that structure (much in the same way that the Ramona fault cuts the Del Valle anticline), would limit production in the Miocene. It was later found that this fault did not extend down into the productive measures of the Miocene. A similar situation may exist at Del Valle. The Ramona fault may not extend down into the Miocene deeply enough or it may die out quickly enough not to exert any affect on the deepest zones

Another possibility is that the fault may plunge deeply enough in places to preserve thick measures of the Miocene.

29. Stockman, L. P., Petroleum Geology of the Del Valle Field, Los Angeles County, California, Oil and Gas Jour., vol. 41, no. 51, pp. 95-97, April 29, 1943.

North Syncline separates the Del Valle anticline and the Ramona anticline. It has an east-west trend and as mentioned above, is faulted at the surface except in its eastern section where the synclinal fault dies out. Its western end is obscured by the Del Valle thrust, and it probably extends under the thrust for some distance. It is easily traced to the east where it is cut by the Santa Clara River and in all 16,000 feet of this asymmetrical syncline is mapable. As seen on the map and the Structure Sections B-B' and C-C' the dips are more steep on the north flank of the syncline.

West and south of the San Martinez Chiquito Canyon the Ramona anticline is the most prominent structural and topographic feature in the Ramona fault block. The beds, especially the more prominent sandstones of the Pico, may be seen dipping quite steeply away from the axis into North Syncline. The anticline closely parallels the Ramona fault and has all the aspects of a large drag fold. However, as mentioned before, it is probable that the north flank has merely been steepened by drag.

The anticline is generally asymmetric, with steeper dips in the north and a roughly east-west and then southwest trend, which may be traced for 16,000 feet in the area mapped by the writer. It plunges along its axis to form the Ramona field and dies out to the east across the San Martinez Chiquito Canyon in a very complicated structural situation that will be discussed later.

Although it is not within the scope of this paper some of the subsurface structure of the Ramona field as taken from Matter and Wrath/[30] will be quoted here to round out the general picture in the Del Valle area. "Production in the Ramona Field is confined to the east plunge of the Ramona anticline. In the vicinity of the field the anticline is a very tight fold. Dips on the south flank average 47° and are as high as 80° on the north flank in outcrop. Closure is provided to the east by the plunge of the anticline and a continuation of the strike into the Holser Canyon fault (Ramona fault). The producing zones are closed to the west up the nose of the anticline by a very rapid change from sand to tight siltstones and shales. The Holser Canyon thrust fault (Ramona fault) forms the closure to the north. In the vicinity of the field the fault ranges in dip from 53° to 70°."

In the northeast quarter of the Ramona fault block a series of faults complicates the structure, and these have been reserved for discussion until this point in order not to confuse the general picture. Here is a series of northwest trending anticlines and synclines cut by at least 4 north-south normal faults and at least one major east-west normal (?) fault.

The beds north of the east-west trending fault were dropped down to some extent but the main movement was a rotary one with

30. Matter, J. E. and Wrath, W. F., op. cit., p. 41, 1947.

the beds on the north side of the fault being tilted to the east. During the rotary movement a small slice was dropped down between the two blocks. This was further complicated by the north-south trending faults. The block (north of the east-west fault) with the highest elevation, i.e. 1675', remained almost stationary after the tilting movement. The block to the east of it was, however, dropped down a minimum of 400 feet (stratigraphic displacement). All the beds on the west side of the fault are stratigraphically lower than those on the east side. The stratigraphic displacement can be measured where the Saugus-Pico contact dips into the fault. Here the Ostrea bed, which is about 400 feet below the top of the Pico, is in contact with the upper Saugus formation.

The two blocks to the west of the stationary block also were dropped down. The block immediately adjacent was dropped down approximately 200 feet (stratigraphic displacement) and the westernmost block at least 100 feet (stratigraphic displacement). This was sufficient to preserve a wedge of Saugus against the fault in this block. The westernmost north-south fault completed the adjustment of the forces by dropping the block down on the east side of the fault. The total displacement on this fault is difficult to determine but it is in the neighborhood of 300 to 400 feet and probably more. Lower upper Pico beds are exposed in a roadcut in the block on the east side of the San Martinez Chiquito Canyon whereas upper lower Pico beds are found on the west side.

Due to the down-faulting on its four sides the block that is highest topographically is a horst, and the downfaulting on its west side by the series of three faults could be described as step faulting.

All these faults appear to be normal. The east-west fault tilting the beds north of the fault east occured first and probably represents an adjustment of this part of the Ramona fault block during the overthrust movement. Thus the rotary movement along this fault was probably given by the overthrusting. The normal north-south faults then represent a relaxation of tensional forces caused by the thrusting and rotary movement. At the outset these north-south faults would appear to be simple tear faults that occured during the overthrust movement. However, that they occured after the tilting (and thus after the east-west fault) is proved by the fact that the beds in all the separate small fault blocks are tilted to the east. This would not appear to be possible had the north-south faults occured first. Also, with the possible exception of the easternmost north-south fault, there is no evidence of horizontal movement along the faults. This would all point to normal faulting following the thrusting and rotation.

The best interpretation that could be made in the field is that given above. The east-west fault appears to die out very rapidly to the east in the syncline and the north-south faults seem to stop at their contact with the east-west fault.

Structure Section A-A' gives as accurate a picture as possible of the structure through the small horst block. Here , as is shown, the northwest-southeast trending anticline was cut by the east-west fault (south side up) and a small slice dropped down a minimum of 100 feet. The greatest movement, the rotary motion, was impossible to show in the structure section.

The northwest-southeast trending anticline, broken by the three faults, is approximately 8500 feet long and originates on the flank of the Ramona anticline on the west and begins to plunge out near the Santa Clara River on the east. It is asymmetrical with the steeper dips on the south side west of the easternmost north-south fault and on the north east of this north-south fault. As shown by the Structure Section A-A', it is a question as to whether this anticline should be represented as two separate folds with a break where it is broken by the faults. However, as it is genetically all one fold it has been represented this way on the map.

The syncline paralleling it to the north, however, has been broken into two distinct sections by the tilting along the east-west fault and the down dropping of the eastern block by the easternmost north-south fault. Some north-south horizontal movement may be present here also but is difficult to confirm. The westernmost segment is about 2500 feet long and is slightly asymmetrical with steeper dips on the north side. It originates on the nose of the Ramona anticline and is cut off by the easternmost north-south fault at its east end. The axis of the larger segment is some 600 feet south of the axis of the western segment. It is 5500 feet long to the point where it is cut by the Santa Clara River and is asymmetrical with the steeper dips on its southside.

(3) <u>The Hasley fault block:</u>

The Hasley fault block is separated from the Ramona block by the Ramona fault and is characterized by simplicity of structure as compared to the other two blocks. The controlling feature is the Hasley anticline which (in this area) is principally a long northwest trending anticlinal nose plunging out to the southeast in the vicinity of the Ramona fault. Only a part of the anticline (some 14,500 feet of it) is in the area mapped by the writer. Here the nose appears to be quite symmetrical. The structure becomes more anticlinal as it disappears off the north edge of the map and just before it plunges out to the southeast.

A smaller anticline is seen plunging out to the east on the northwest corner of the map with a syncline just north of it,

The strata dip gently down the nose of the Ramona anticline with only a slight change in strike marking the axis of the nose.

The Saugus-Pico contact may be seen here and is much more gradational than south in the Ramona fault block. Thick, massive, and cross-bedded sandstones of the upper Pico grade into the lower Saugus almost imperceptibly and the top of the Pico here greatly resembles the lower Saugus. The lower Saugus and

and Mioc beds gently dip down the nose of the anticline but become more steeply dipping as they disappear into the Ramona fault.

The general trend of the beds south of the anticline is northeast. This changes to almost due north along the anticlinal nose and then to a northwest direction on the north flank of the nose.

Explanation of structure sections:

Structure Sections A-A' and E-E' need no clarification. However, B-B' and C-C' have wells projected into the plane of the sections that may give the reader an eroneous impression. In the areas from which these wells are projected the Ramona fault evidently plunges deeply enough to preserve a thick section of Miocene that is faulted out in the wells in the plane of the sections, or the fault may be dying out. In other words the position of the fault in respect to the two deep wells, R. E. Havenstrite's Barnes No. 2 well and the Superior Oil Company and the British-American Oil Producing Company's Handy No. 1, is not known, therefor the fault was drawn short of the wells. This is not intended to give the impression that the fault lies out here. It may do so, but this is purely conjecture and is not the impression that is meant to be given by the structure sections.

The dips at depth were taken from the well logs where possible. The locations of the productive zones were all taken from the logs.

Control for the Structure Section D-D' was obtained from the wells through which it was drawn, plus a subsurface contour map by Matter and Wrath/[31] drawn at the top of the Miocene (or top of the Vasquez Zone).

The depth that the Ramona fault intersects the Havenstrite No. "Lincoln" 10 (Structure Section B-B') was obtained from a similar section drawn by Sherman./[32]

GEOMORPHOLOGY

This part of the Ventura Basin is probably in late youth. There has not been a complete adjustment of the landforms to the underlying structure. In fact so little erosion has taken place that only in several folds do we have examples of inversion of relief, i.e. synclines with greater topographic expression than the anticlines. North Syncline in its eastern section is one example and is a major topographic expression in this part of the area rising to almost 1500 feet above sea level. Another example of inversion in relief is found in the parallel flexures in thevicinity of the east-west fault south of the Ramona fault. Here the anticline in its eastern section has been almost entirely disected and is low topographically in comparison to the syncline which has become the prominent feature. Disection of the prominent anticlines in the area has not been carried to a very great extent. The semi-arid climate,

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31. Matter, J. E. and Wrath, W. F., op. cit. p. 39, 1947.
32. Sherman, R. W., idem, 1943.

of course, is the controlling factor on the rate of erosion.

The base level for the drainage is the Santa Clara River and all the intermittent streams which are consequent to the present folding drain southward into it. The Santa Clara River itself appears to be antecedent to the present system of folds.

The terraces along the Santa Clara River reflect the minor uplifts that followed the folding. Here, the terraces, formed by the river after the folding, have been uplifted and disected and are now some 200 to 300 feet above the present stream level.

GEOLOGIC HISTORY

The history of this section of the Ventura Basin of deposition is found, for the most part, in the marine beds of the Miocene and Pliocene and in the terrestrial sediments of the Saugus formation that were deposited in the basin. The oldest sediments exposed or found in the well cores are the Mohnian and Delmontian stages of the upper Miocene or Lower Neogene.[33] The brown organic shales of these two stages reflect the widespread, relatively quiet seas that covered the area at this time. Some orogenic movements in the upland areas are reflected by some sands and conglomerates. These widespread seas with their large content or organic matter were ideal for

33. Reed, R. D., California's record in the geologic history of the worls, Calif. State Div. of Mines Bull. 118, pp. 116-118, 1943.

deposition of beds that were later important for oil genesis.

The slight angular unconformity and overlap at the Miocene-Pliocene contact reflects a rather large scale uplift that in this local part of the Ventura Basin amounted to little more than a short break in the Miocene sedimentation perhaps accompanied by a brief uplift of the northern part of the district followed by subsidence. This orogeny marked the end of the Miocene and corresponds to the transition from Lower to Upper Neogene.[34] No real deformation is apparent, and the unconformity is not sufficient to alter greatly the Modelo structure as interpreted from the overlying Pliocene sediments. Elsewhere uplift and distortion was profound because of the conglomerate deposited in the lower Pliocene horizons. In the large embayments, such as the Ventura basin, the seas persisted; but the increase in area, the elevations of the uplands, and the decrease in size of the areas of deposition led to an increase in the clastic content of the sediments and to a cessation of deposition of the shale that characterized the upper Miocene.

The brown and gray-brown siltstones of the Repetto reflect the conditions of the seaward margins of the Ventura basin. Here were recieved large accumulations of highly organic silts during earliest Upper Neogene time.

The basal conglomerate that marks a break in the siltstone sedimentation of the Repetto and lower Pico probably reflects a local uplift in the surrounding uplands that did not affect

34. Reed, R. D., Idem, 1943.

the beds being deposited, and no angular discordance is noted.

During the later stages of the Neogene although the Ventura basin was subsiding the upland or mountain areas were rising at a rate sufficient to produce marine sediments that were more clastic, and finally the basin filled to the extent that terrestrial sediments were deposited. Thus the transition is from the organic siltstones of the Repetto to the siltstone and sand stage of the lower Pico to the upper Pico where thick beds of sandstone and some conglomerates were deposited under marine conditions. These grade into the terrestrial sediments of the Saugus.

Following this subsidence of the basin and the more or less accelerating rise of the uplands came a period of strong folding and overthrust faulting, the Pasadenian disturbance, which affected not only the mountainous areas but also the margins of the basins of deposition. It began in the late Pliocene or early Pleistocene and reached its peak in middle Pleistocene and is still active.

Once the terrestrial sediments were being deposited and the Ventura Basin began to have a system of exterior drainage, the major rivers, such as the Santa Clara River became established. This was followed by folding which was probably late Pliocene or early Pleistocene. Thus the main drainage is antecedent to the folding and the minor drainage subsequent to the folding.

The overthrust faulting was post folding. The time that elapsed between the faulting and the folding is unknown, or at least it was not evident in the area studied by the writer. However, if the compressive forces that caused the folding also caused the faulting the time that elapsed between the two was probably not great. If the faulting was due to a completely different set of compressive forces that formed after the folding (but acted in the same direction) the possibility exists that considerable time could have passed before the faulting occured.

Minor uplifts followed the folding. This is shown by the benches or terraces along the Santa Clara River that were formed by the river after the folding and have been uplifted and disected. These benches are now 200 to 300 feet above the present level of the river.

The normal faulting in the area probably followed the overthrusting and was due to the tension formed by the relaxation of the compressional forces that caused the overthrusting.

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