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CALIFORNIA DISCOVERIES

GEOLOGY AND ECONOMIC SIGNIFICANCE
of California's 1935-1938 Oil Discoveries

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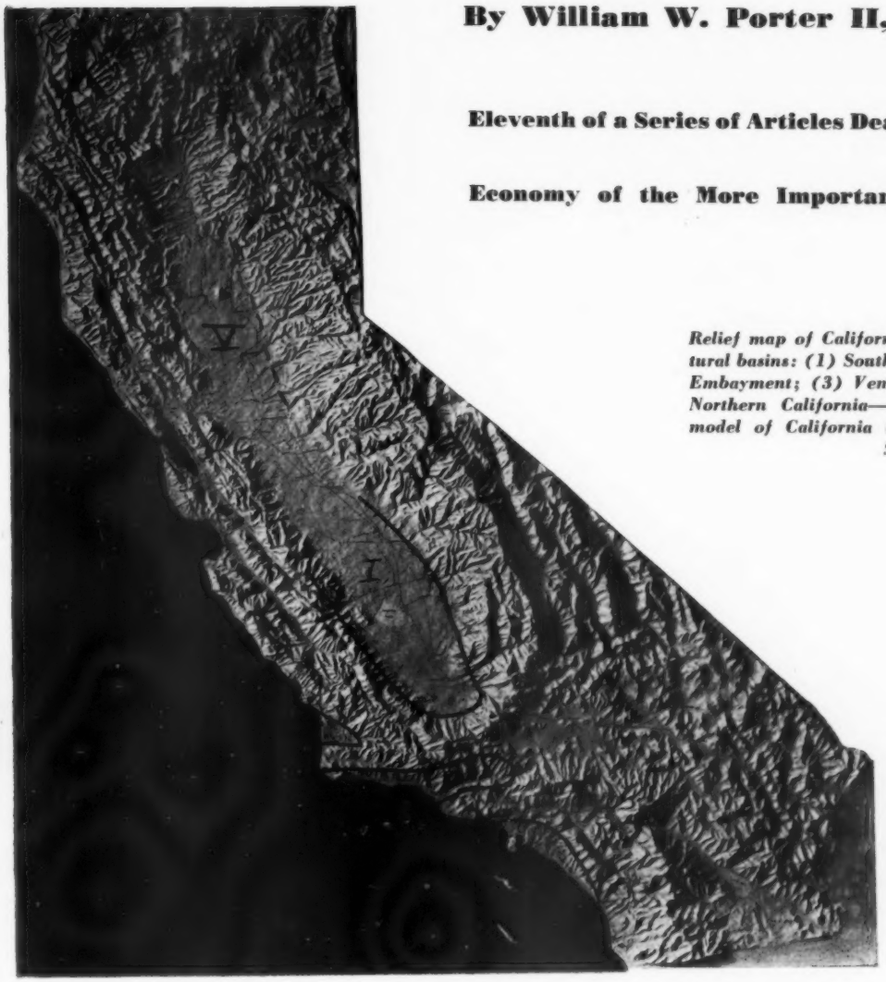
Eleventh of a Series of Articles Dealing With the Geology, Reserves and Economy of the More Important Oilfields Throughout the World.



Relief map of California showing principal oil-containing structural basins: (1) Southern San Joaquin Valley; (2) Santa Maria Embayment; (3) Ventura Basin; (4) Los Angeles Basin; (5) Northern California—Relief map from photograph of relief model of California by N. F. Drake, geological department, Stanford University.

OUTSTANDING as a major discovery era in California oil history is the period from 1935 to the present. During this period 16 important oilfields with total reserves of approximately 1,500,000,000 bbl. of oil were discovered. Several other minor discoveries were made, as well as establishment of extensions and deeper zones in previously proven fields, but only important new developments will be considered in this article.

For several years prior to 1936, the state annually consumed more oil than was discovered and the ratio between known reserves and demand was steadily declining. With the exception of Mountain View, no major discoveries had been made in California since Kettleman Hills and Elwood were located in 1928. From the early part of 1935, the coincidental factors of improved and successful seismograph instruments and executive recognition of the necessity of newer and more costly discovery methods resulted in a campaign of exploration which has added many square miles to the category of lands likely to contain oilfields, and which has materially increased stratigraphic potentialities.

In an attempt to crystallize the effects of this discovery wave, this article will first treat briefly the individual new fields and will then consider the scientific significance and the economic effects related to markets, proration, reserves, excessive drilling and similar matters.

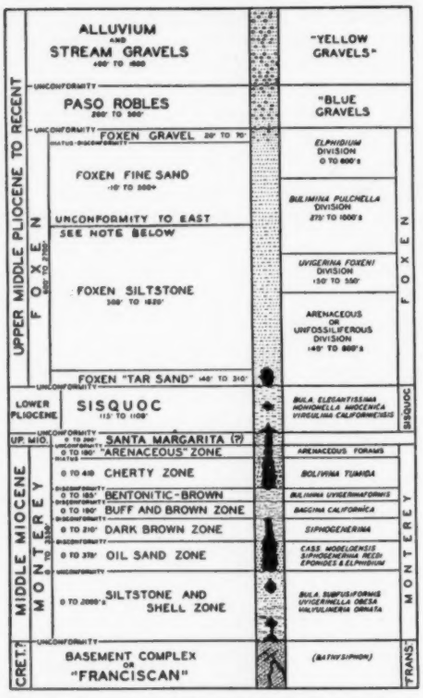
All of the important oil production in California is obtained from four structural basins in which great thicknesses of sedimentary rocks have been downwarped as a whole and then folded and faulted into numerous individual structural traps which underlie the oilfields of the state. These structural basins are the Los Angeles Basin, the Ventura Basin, the Santa Maria Embayment and the San Joaquin Valley. Within the last three years, major discoveries have been made in all four of these structural basins. A fifth district currently attaining prominence is Northern California.

SAN JOAQUIN

In the central part of the southern San Joaquin Valley the stratigraphic section is in general similar in all the fields although it varies considerably in detail, and the minor variations are of great economic importance.

Loosely consolidated sands of the Tulare formation, generally considered Pleistocene in age, are found from the surface to approximately 1,000 ft. Below the Tulare beds occur up to 6,000 to 8,000 ft. of siltstone, claystone and sands of Pliocene age. These beds are equivalent to formations known locally elsewhere as Jacalitos, Etchegoin and San Joaquin clay. The base of the Pliocene is found at depths varying from about 7,100 ft. in the Ten Section area to 8,440 ft. at Wasco.

The brown shale of the Upper Miocene underlies the Pliocene. It consists of approximately 900 ft. of brown shale. The brown shale is underlain in the Ten Section-Greeley area by 1,200 to 1,400 ft. of beds composed predominantly of sand with alter-



Standard stratigraphic section of Santa Maria Valley oilfield by Charles Reiter Canfield. From Bulletin of the A.A.P.G., January, 1939. Reproduced through courtesy of Mr. Canfield and the Association. The section is generally applicable in the district away from the Valley oilfield except that formation lithology and thickness change rather rapidly from place to place. To the east of the Valley oilfield a marked unconformity exists between the Foxen Fine Sand and the Foxen Siltstone. Because of this unconformity field geologists frequently limit the Foxen formation to Canfield's Foxen Siltstone, and map the Foxen Fine Sand as a separate formation for which the name Carreaga Formation has been informally used. The unconformity is great enough that in places the Foxen Fine Sand, or Carreaga, has overlapped as much as 2,000 ft. of underlying beds. An insert has been made by the writer.

the degree of its fracturing. For this reason, allocation of underground reserves are impossible. Initial productions vary from 100 bbl. per day to in excess of 4,000 bbl. per day. To-date, the field is known to have a productive structural relief of at least 2,000 ft. Production seems not confined to definite horizons within the cherty shale, but to come from those segments or, perhaps, kidneys within the cherty zone where fracturing has produced porosity. The field is too young to show any significant decline and the tendency has been noted in some wells for gas pressure and production to increase after several months.

OWNERSHIP—Most of the field is controlled by The Petrol Corporation and Barnsdall-Richfield. The field is poorly defined yet but might prove to extend in excess of 1,000 acres. Judging from apparent structural conditions, the final productive area may be well in excess of this figure but this excess outlying acreage is also held principally by Barnsdall-Richfield and The Petrol Corporation. Smaller amounts of acreage within the field are owned by O. C. Field Gasoline Corporation, The Texas Company, and Moyle Petroleum.

The Barnsdall-Richfield combination has six wells; the Petrol Corporation, five; O. C. Field Gasoline Corporation, two; and Moyle, one; total, 14 producing wells.

PRODUCTION — Although gas pressures have been on the whole low, large volumes of oil can be produced. Experiments conducted by the Engineering Department of The Petrol Corporation with six-inch pump and eight foot stroke have resulted in Gato Ridge's claim to the largest pumping oil wells in the world, one of which pumps in excess of 4,000 bbl. daily of 14 deg. oil.

An unusual feature in drilling is that as much as 1,900 ft. of hole has been drilled with rotary equipment without circulation. Clear water was pumped down but all the fluid, including the cuttings, was lost sidewise in the formation without returning to the surface.

Some of the west end oil from deeper wells is 10 deg. A.P.I. and is consequently more difficult to produce. A production hook-up devised by A. E. Ireland of O. C. Field Gasoline Corporation consists of two strings of tubing with injected distillate. Production from a 4,300 ft. well of 10 deg. oil was increased by the hook-up from 70 bbl. per day to 250 bbl. per day.

VENTURA

The first oil produced in Southern California was in the Newhall area in the eastern part of the Ventura Basin. Many discoveries have since been made, outstanding of which is Ventura Avenue Field. In the Ventura Basin occurs probably the greatest thickness of the Tertiary sediments in the world, the total thickness of the Eocene, Oligocene, Miocene and Pliocene rocks being somewhat over 40,000 ft. The total thickness of all sedimentary rocks from the base of the Cretaceous through the Pleistocene is about 60,000 ft.

In this basin, two important discoveries have been made since 1936. One of these, Newhall Potrero, discovered by Barnsdall Oil Company, is a major field occurring within a few miles of the old, original California oil development near Newhall. The Padre Canyon was discovered by Continental Oil Company and lies northwesterly from Ventura Avenue Field.

Padre Canyon

The Padre Canyon Field lies about six miles northwest of the City of Ventura and is situated about one and a half miles from the ocean. It was discovered by Continental Oil Company, March 22nd, 1936, when Hobson No. 1 well was completed for 570 bbl. daily, 31 deg. oil, cutting 7.7 percent and 200,000 cu. ft. of gas through a 40/64 in. bean from a total depth of 5,501 ft. Tubing pressure was 235 lb., casing pressure 600 lb. The producing zone was encountered from 5,092 to 5,501 ft.

All formations penetrated from the surface through the base of the oil zone are Upper Pico formation of Middle Pliocene age. The oil occurs in generally fine grained sand of good porosity but somewhat low permeability. The average zone penetrated is about 485 ft. thick, of which about 50 percent is oil sand. The oil zone is approximately 1,500 ft. higher stratigraphically than the Miley zone of Rincon Field on the coast to the west, and is about 4,500 ft. higher stratigraphically than the producing zone of San Miguelito Field to the southeast. Principal production is from the main, or Padre zone, but two deeper zones have been encountered in outpost wells and these zones should be productive throughout the field.

To-date, nine wells have been completed in the field and present production is approximately 100 bbl. per well with gas-oil ratio ranging from 750 to 1,100 cu. ft. per bbl. Three of the wells are operated by Continental Oil Company, five by Chanslor-Canfield Midway Oil Company and one by General Petroleum Corporation. Development has not yet been extensive and increased production may be expected from the two deeper zones already encountered in outpost wells and possibly from other deeper zones. The field produced 774,543 bbl. from discovery to January 1st, 1939.

GEOLOGY—It is geologically interesting that the oilfield occurs upon a downfaulted or graben block of the earth's crust. It has been faulted down along the Red Mountain thrust system at an angle of about 80 deg. (northerly) for some 10,000 to 15,000 ft. The southerly boundary of the block is the Madronio thrust fault system, the plane of which dips southerly about 75 deg. Its displacement is approximately 5,500 ft. The discovery of the field is due to carefully applied and interpreted geological study.

Newhall Potrero

The Newhall Potrero Field in the easterly part of Ventura Basin is in Los Angeles County, about six miles west of the town of Newhall. Wells are located in Sec. 26-4N-17 W. The field was discovered by Barnsdall Oil Company in March, 1937. The discovery well, Rancho San Francisco No. 1, was recompleted after deepening to 6,472 ft. on May 30th, 1937, with initial flow of 500 bbl. daily, 35 gravity clean oil. The well has been on production continuously and in January, 1939, still flows clean oil with a cut of 0.6 percent. The

second well was completed in February, 1938. This well established a 1,200 bbl. per day potential. Well No. 3 was completed in July, 1938, and was apparently a much larger well than either of the other two. It was drilled to total depth of 7,264 ft. and bottomed in oil sand. No flow potential was possible because of lack of storage but the well actually flowed 1,780 bbl. of 35.5 gravity clean oil, tubing pressure 1,020 lb., casing pressure 1,200 lb., 20/64 in. bean. Considering performance under these conditions, the per day production would undoubtedly have been several thousand barrels greater than the 1,780 bbl. per day flow. Under proration the well flows about 530 bbl. per day through a 12/64 in. bean, with tubing pressure 1,400 lb., casing pressure 2,150 lb.

Well No. 4 was drilled to 7,352 ft. and completed Dec. 17th, 1938, flowing at 1,100 bbl. per day rate through a 20/64 inch bean.

The field produced approximately 37,755-000 bbl. of oil from discovery to January 1st, 1938. Production during 1938 was 242,441 bbl. The field is currently producing about 720 bbl. daily of 33 deg. A.P.I. average oil, which is moved out of the field through a pipeline to Union Oil Company, and 280,196 bbls. were produced from discovery to January 1st, 1939.

The producing zone as known in well No. 3, which has the greatest penetration, is at least 1,000 ft. thick. At least half or more than 500 ft. is composed of oil sand, which becomes coarser and more permeable toward the bottom. Bottom hole pressures recently made indicate 2,800 lb. The gas-oil ratio is about 700 cu. ft. per bbl. Gas production is about 1,000,000 cu. ft. per day with gasoline content of 1.7 gal. per 1,000 cu. ft. Barnsdall Oil Company expects to build its own plant for treatment of gas. Octane rating of the straight run gasoline is about 69.

It seems probable that in the neighborhood of 1,000 acres will be productive. The field was discovered by detailed geological mapping supplemented by seismograph work, which indicated sub-surface geological conditions upon which the discovery location was made. All the exploration work was done under the direction of R. W. Sherman, consulting geologist, formerly Chief Geologist for Barnsdall Oil Company, and E. Wayne Galliher, formerly Assistant Chief Geologist but Chief Geologist since Mr. Sherman's resignation.

GEOLOGY—The geosynclinal axis of the Ventura Basin trends east-west and lies north of the field. To the south of the field in the Santa Susana Mountains is the prominent Pico anticline. The Newhall Potrero oilfield is situated upon a northwesterly plunging rib of the Pico anticline. An east-

west fault on the south side of the field has trapped the oil and prevented its migration up the plunge toward the top of the Pico anticline. The plunging anticlinal rib, or nose, is apparent at the surface where the outward dipping escarpment rocks bow around the meadow, or *potrero*, in which the field is located. Flank dips are approximately 25 to 35 deg.

Strata from the surface to about 2,000 ft. are composed of Upper Pliocene Pico shale, which comprise hard grey, uniform shale bodies. The position of the basal contact of the Pico with the Repetto is not certainly known. Below the Pico is encountered about 4,000 ft. of Lower Pliocene Repetto formation, which consists of sandy dark grey shale and sands. Top of the Upper Miocene is encountered at about 6,000 ft. and has been penetrated to-date only to depth of about 1,250 ft. The Miocene shale is of platey, organic type and is interbedded with various silty and impermeable sands and with permeable oil sands.

PRODUCING ZONE—The producing zone is the permeable sand member of the Upper Miocene Modelo formation. In well No. 3, the interval from the 8⅝ in. casing shoe at 6,242 ft. to bottom at 7,264 ft. was composed of about 50 percent oil sand, the permeability of which increases with depth. Neither a free gas cap above nor bottom water have been encountered, although a minor amount of connate water was noted in some cores.

DEVELOPMENT—The field is being developed in a slow and orderly manner, with a program of 10 acres per well as the ultimate objective. Two thousand feet of casing is set at the base of the Pico and 8⅝ in. casing at the top of the oil sand, with 5¾ in. perforated liner hung through the producing zone; 2½ in. tubing is used and extends into the liner.

OWNERSHIP—The Newhall Potrero field is unusual in that the entire structure and considerable surrounding country is owned by one land owner, Newhall Land and Farming Company, and the entire 4,000

acres is controlled by one operator, Barnsdall Oil Company, with lease terms uniform throughout the field. Because of this, the field has not in general received interest commensurate with its importance.

Aliso Canyon

Discovery of a new field in the mountains north of San Fernando Valley, Los Angeles County, resulted from exploration by Tidewater Associated Oil Company. The discovery well, Porter No. 1 was completed October 25th, 1938. Initial production was about 650 bbl. per day, but the well rapidly cleaned and flowed 1,320 bbl. per day of 23.8 deg. A.P.I. oil cutting less than 1.0 percent. Total field (one well) production to January 1st, 1939, was 23,416 bbl.

The geology is complicated and as yet imperfectly known. Drilling commenced in the *Valvulinaria colifornica* zone of the Middle Miocene, and passed out of Miocene sediments at the Santa Susana fault plane at 1,895 ft. Below the fault plane which dips northerly at a low angle the Saugus formation of Pleistocene age was encountered. At about 2,400 ft. the well was in Pico, and was bottomed in Middle Pico, Upper Pliocene at 5,391 ft. The oil is produced from sands in the Middle Pico formation. Oil showings were encountered from about 2,900 ft. to bottom, but several tests of upper showings proved unsatisfactory, and present production is from below the 6⅝-in. casing shoe at 4,795 ft. and above the plug at 5,365 ft.

Until much more information is available concerning conditions beneath the Santa Susana fault plane it is impossible to discuss the buried geological conditions, whatever they are, that control the oil accumulation. It seems apparent, however, that an important discovery has been made.

The well is located 2,442 ft. south and 3,010 ft. west from the northeast corner of section 27, Township 3 north, Range 16 west. Elevation 2,180 ft. Adjacent land is held by Standard and Union, but as only one well is on production yet, the value of these holdings is unknown. Both Standard and Union are drilling.

LOS ANGELES

The Los Angeles Basin in a structural classification is the area lying east of the Pacific Ocean and west of the mountain arc which extends from near Santa Monica where the Santa Monica Mountains meet the ocean, in an arc around the Basin, and to the sea again in the neighborhood of San Juan Capistrano.

Many major oilfields, such as Santa Fe Springs, Huntington Beach, Signal Hill and others, have been discovered in this basin. It is of interest that in spite of the density of population and geological scrutiny to which this relative small area has been subjected during the last 40 years, major oilfields continue to be discovered.

Within the period treated in this article, two important fields have been developed in Los Angeles Basin. One of these, Wilmington, is of top rank major importance and the other, El Segundo, might be classed as a major field. Strictly speaking, El Segundo was discovered prior to the period here discussed by a well completed by Republic Petroleum Company in August, 1935. This was the only well in the field until April, 1936, and only four wells had been completed by December, 1936, consequently a brief discussion of the El Segundo Field will be included in this article. Too much has already been written on the Los Angeles Basin to warrant further discussion. It is perhaps ironical that portions of both of these fields were found to exist beneath long held refinery sites of some of the major companies.

El Segundo

On August 24th, 1935, Republic Petroleum Company completed El Segundo No. 1 at a depth of 7,204 ft. flowing 400 bbl. daily, 28 gravity oil. To the end of 1935, this well produced 19,555 bbl. or a daily average of about 160 bbl. Two more wells were subsequently drilled but the existence of an important field was not evidenced until completion in December, 1936, of a well by Richfield Oil Corporation which produced 2,533 bbl. of 27.2 gravity oil. In May of the following year, The Texas Company completed Security No. 1 in the westerly portion of the field for 4,563 bbl. daily. Considerable development subsequently took place, with the result that the field had produced 7,651,147 bbl. of oil from discovery until Jan. 1st, 1939. Production of El Segundo Field is currently between 3,000 and 4,000 bbl. per day.

GEOLOGY—Recent and Pleistocene beds are encountered near the surface, after which the Pliocene extends to a well depth of about 5,200 to 5,500 ft. The Miocene consists of 2,000 ft. to 2,300 ft. of sand, siltstone and shale, the lowermost portion of which is the conglomeratic production zone which varies in thickness from zero up to 100 ft. Directly above the production zone is the Nodular shale. This is a brownish to dark-grey shale containing a number of phospatic nodules which appear as light tan to grey kidneys or eyes up to two inches in diameter. Nodular shale is approximately 200 ft. thick. In the eastern portion of the field, the Nodular shale overlies coarse greenish to grey conglomerate, containing both quartz and schist pebbles up to two inches in diameter. In the conglomerate and associated sections, porosity varies from 16 to 28 percent. Some good production, such as that of Richfield Oil Corporation, El Segundo No. 1 (initial production 2,533 bbl. per day) has been obtained from this basal conglomerate but many wells have been disappointing, being capable of producing only 100 to 150 bbl. Gas-oil ratios in this eastern area average about 650 cu. ft. per barrel.

The above discussed eastern portion of the field is separated from the westerly portion by a northwest trending zone of faulting, west of which the nodular shale rests directly upon the basement schist, the conglomerate being absent. Various chemical and structural factors have induced an erratic porosity in the schist itself. This porosity is variable both above and below about 15 percent and wells fortunate enough to have encountered particularly porous areas in the schist have had yields of up to 4,000 bbl. per day. Apparently the structural relief in the field is about 500 ft. Production from the schist is due merely to the existence of porous reservoir material near a source of Miocene oil and has no significance or bearing on the productive possibilities of basement rocks. The erratic localization of schist porosity and variability of the oil-bearing conglomerate thickness which are indeterminate by any method but drilling make reserve estimates extremely difficult and preclude entirely any possibility of compulsory proration or drilling control based on acreage allotments. L. E. Porter, petroleum engineer for the Richfield Oil Corporation, has stated that "each well must be considered as a semi-wildcat. There are examples of wells producing several thousand barrels per day being offset by wells producing less than 100 bbl. per day."*

Because of the variable productivity within the field, any reserve estimate can have no better standing than a mere guess and perhaps not a good guess, either. To bring out the general category of the field, the writer timidly suggests 20,000,000 bbl.

OWNERSHIP—The Caminol Company, Ltd., Geo. F. Getty, Inc., The Ohio Oil Company, Pacific Western Oil Company, Republic Petroleum Company, Richfield Oil Corporation, Royalty Service Corporation, Standard Oil Company, The Texas Company, and Union Oil Company are the principal lease holders in the field.

Ohio has 11 wells, Richfield six, Standard Republic and Texas five each, and others less than five.

GENERAL—Casing programs ordinarily involve a 13⅜ or 11¾ in. string at 700 to 1,100 ft. with 8⅝ in. or seven inch respectively cemented on top of the oil zone and perforated liners to bottom. Sulphur content of the oil is about 1½ percent and gasoline yield about 28 percent from the 27 to 28 deg. crude. Irregularity of productivity

*L. E. Porter, "El Segundo Oil Field," Transactions Amer. Inst. of Mining and Metallurgical Engineers, Petroleum Division, (Petroleum Development and Technology in 1938).