THE GEOLOGY OF THE MERCED HILLS, LOS ANGELES COUNTY, CALIFORNIA, with a section on the RADIOACTIVITY OF THE OILS AND WATERS

Thesis by

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In partial fulfillment of the requirements
for the degree of Master of Science

California Institute of Technology

Pasadena, California

1931

CONTENTS

ILLUSTRATIONS

(Note. Plates 2 and 4 were copied from Summary of Operations, California Oil Fields, v. 5, n. 11, 1920.)

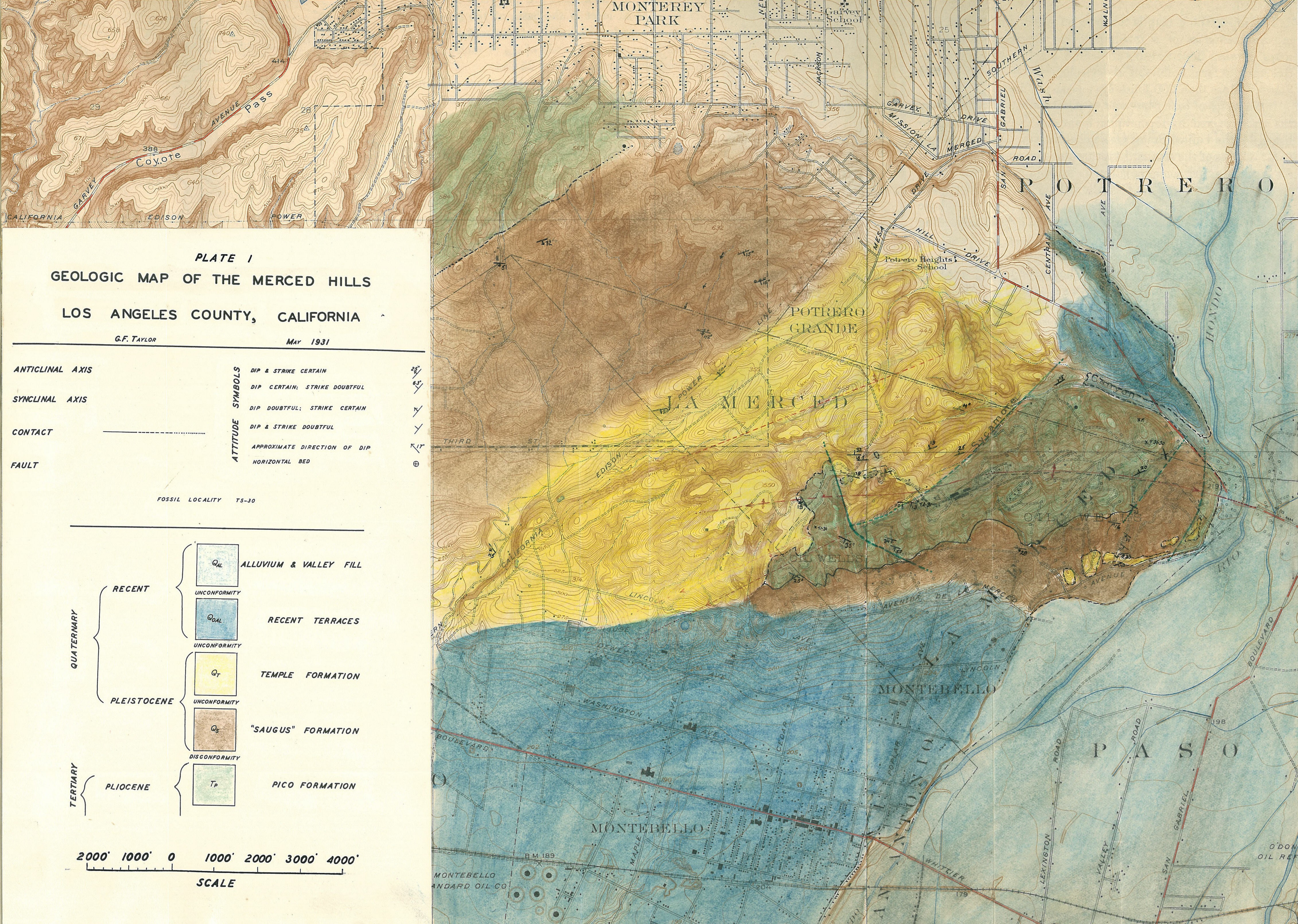

PLATE I
GEOLOGIC MAP OF THE MERCED HILLS
LOS ANGELES COUNTY, CALIFORNIA

G.F. TAYLOR — MAY 1931

THE GEOLOGY OF THE MERCED HILLS, LOS ANGELES COUNTY, CALIFORNIA

INTRODUCTION

The area discussed in this paper lies in the Merced Hills about 9 miles east of the center of Los Angeles, California. To the east lie the Rio Hondo and the San Gabriel River and east of the valley containing these rivers are the Puente Hills. The western edge of the area mapped merges into the Repetto Hills which extend west nearly to the Los Angeles River. The oil field, from which samples of oil and water were obtained for the radioactive measurements, is located along the south-eastern margin and in the eastern portion of the Merced Hills and is called the Montebello Field, after the town of that name about a mile south of the field.

This general area has been mapped by geologists of several oil companies, but the information thus obtained has not been made public. The Puente Hills, several miles east of the Merced Hills, were mapped in 1926 by Walter A. English[1/], and the Los Angeles Region, several miles west, was mapped in 1906 by Ralph Arnold[2/]. Dr. W.S.W.Kew is at present engaged in preparing a geologic map of Los Angeles City for the United States Geological Survey, and will include in it the area discussed in this paper.

Geologic mapping was done on a scale of a

1/ English, Walter A., U.S.Geological Survey Bull. 768, 1926.
2/ Arnold, Ralph, U.S. Geological Survey Bull. 309, 1907.

thousand feet to the inch on an enlargement of portions of the Alhambra and El Monte quadrangles of the United States Geological Survey.

Relief in the area mapped is approximately 430 feet, with elevations ranging from about 200 feet at the eastern end of the Merced Hills to 632 feet at their summit about a mile and a half northwest of the Standard Oil Company's camp.

This work was carried on under the immediate supervision of Mr. Rene Engel of the California Institute geological staff. Mr. Robley D. Evans, graduate student in the California Institute physics department, extended the greatest cooperation in the use of apparatus which he was completing at the time this research was being prosecuted. Dr. W.S.W. Kew, geologist with the Standard Oil Company of California, extended many courtesies, especially in connection with work at the Montebello Oil Field, where his company controls a large amount of property. Mr White, petroleum engineer at the Standard Oil Company's Montebello office, very kindly assisted in the sampling, and was of great help in discussing the underground conditions and the properties of the oil well fluids.

STRATIGRAPHY

Pico Formation

The oldest formation exposed in the area mapped is the Pico Formation 1/ of Pliocene age. As exposed on the surface, this consists of a series of light grey to yellowish grey, well bedded, marine sandstones and sandy shales. The base is not exposed in the area, but the thickness has been found to be 5400 feet in the Repetto Hills, a few miles west of the area mapped, in a section measured by Mr. Driver of the Standard Oil Company. 2/

A molluskan fauna, obtained in the Merced Hills, shows Pico affinities, while foraminifera, present both in well cores and in surface outcrops in the Montebello Field, indicate the Pico age of this formation.

1/ Clark, B.L., Jour. Geology, vol. 29, pp. 608-9, 1921.
2/ Driver, Herschel L., Holman, W.H., Ferrando, A., Foraminiferal Section in the Repetto Hills: Ms. presented before the Society of Economic Paleontologists and Mineralogists, Los Angeles, Cal., Dec.,28,1928.

Faunal List of Pico Formation in Merced Hills

	T31-30	T1-31	T2-31
Gastropoda:			
Alectrion sp.	X		
Calliostoma sp.	X		
Calyptraea sp.	X		
Conus californicus Hinds	X		
Crepidula princeps Conrad	X		
Crepidula sp.	X		
Neverita recluziana Petit	X	X	
Turritella cooperi Carpenter	X	X	
Pelecypoda:			
Cardita ventricosta Gould	X		
Marcia cf. subdiaphana Carpenter	X		
Ostrea vespertina Conrad	X		
Pecten bellus hemphilli Dall		X	
Pecten sp.	X	X	
Phacoides cf. annulatus Reeve			X
Solen sp.	X		

"Saugus" Formation

Lying concordantly on well bedded sandstones of the upper part of the Pico formation is the non-marine "Saugus" formation. 1/ A basal conglomerate of the "Saugus", an erosion surface at the top of the Pico, a sudden change from marine conditions to non-marine conditions, all point to a distinct time break between these formations. The marine aspect of the Pico formation is indicated by foraminifera and mollusks, both of which persist to within a few feet of the top. Non-marine conditions is "Saugus" time are indicated by poor sorting, indistinct bedding, cross bedding, lack of any fossils except land plants.

Since no fossils were found with which to date the "Saugus" formation, it was possible to place it in the Southern California stratigraphic section only by its relation to the underlying Pico and to the overlying terrace deposits. It is composed of material similar to that in the Saugus formation at its type section, and bears the same relation to the Pico formation as that near Saugus. For these reasons it is believed that the "Saugus" formation in the Merced Hills is of approximately the same age as the Saugus formation at its type locality.

Light grey to buff and occasionally reddish, sandstones, shaly sandstones and conglomerates with

1/ Hershey, O.H., Some Tertiary Formations of Southern California; Am. Geologist, v. 29, pp. 349-372, 1902.

sub-angular to fairly-well-rounded pebbles, cobbles and boulders, compose the "Saugus" formation in the area mapped for this report. Cross-bedding, indicative of rapid deposition of sediments, possible also of fluviatile conditions, characterizes the "Saugus" as well as younger Quaternary deposits. Occasional thin beds composed almost exclusively of heavy minerals, such as magnetite and ilmenite, were discovered near the middle of the formation near the Potrero Grande. These accumulations varied from less than a millimeter to about five millimeters in thickness.

Since the top of the "Saugus" formation cannot be located with certainty within the area mapped, the thickness of the formation can be stated only approximately. Assuming an average dip of 35 degrees for the beds as exposed along Garfield Avenue and a width of outcrop of 6000 feet, the thickness in the region would be about 3450 feet. Approximately the lower 1000 feet and the upper 1000 feet are highly conglomeratic with occasional sandy lenses, while the middle of the formation is predominantly sandy.

The relation of the "Saugus" formation to the overlying Temple formation is obscure throughout much of the area because of general lithologic similarity. The central and southwestern parts of the area had so few outcrops that definite conclusions as to the relations of these Quaternary deposits were not reached. In general, the older "Saugus" formation has suffered deformation to the same extent as the underlying Pico formation, while the Temple formation has undergone much less folding. When the "Saugus" and Temple formations are in close proximity, therefore, the degree of folding is generally sufficient to separate them. When the outcrops of the formations are over a few hundred yards apart, however, this criterion fails, and separation is practically impossible, although beds deformed and tilted to as much as 45 degrees may be reasonably assigned to "Saugus" or older age. This means, that in the writer's judgement; post-"Saugus" folding was not sufficient to produce dips of over 45 degrees.

Temple Formation

The name Temple formation is proposed for the thin series of conglomerates and conglomeratic sandstones which overlie unconformably the "Saugus" formation. It is probable that the Temple formation is approximately equivalent to the San Pedro formation in age, but,in the absence of any definite means of correlation, it is thought desireable to give it a local name

The thickness of the Temple formation is not known accurately, but it is probably not over a few hundred feet.

Recent Terraces

Resting unconformably on the Templo formation is the nearly flat series of very poorly sorted conglomerates, representing a fanglomerate, deposited in sub-recent to recent time by the Rio Hondo and San Gabriel river. This series forms a terrace sloping gently southward wherever encountered in the area mapped. It is not believed feasible to correlate this terrace with terraces elsewhere in the general region because of the strong probability that faulting on various blocks has resulted in widely varying elevations of identical terraces. The recent terraces have undergone slight, if any, folding, but, as indicated elsewhere in the general region, have been faulted rather extensively.

Alluvium and Valley Fill

Unconsolidated material which has been deposited in the present stream courses is mapped under the general heading of alluvium and valley fill. This series, poorly sorted and indistinctly bedded, is typically fanglomeratic.

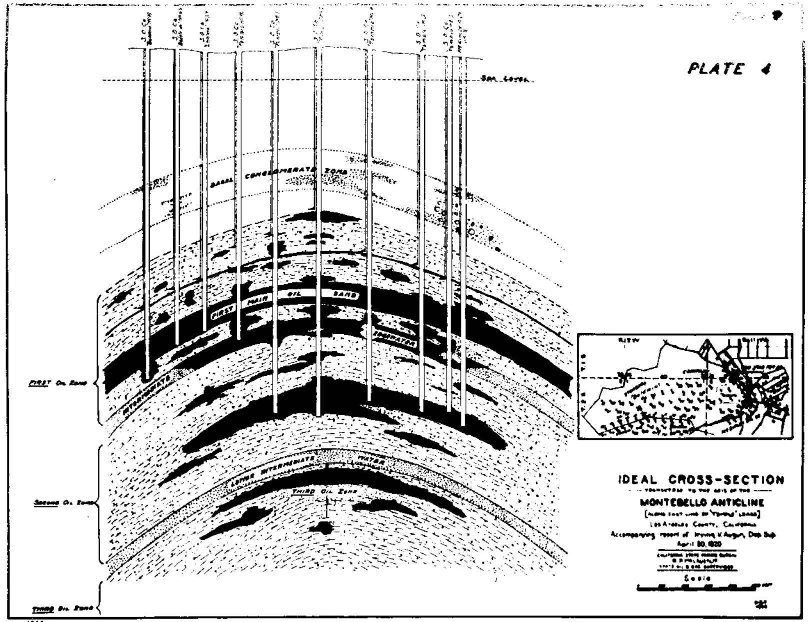
PLATE 4
Sea Level
BASAL CONGLOMERATE ZONE
FIRST MAIN OIL SAND
LOWER INTERMEDIATE WATER
THIRD OIL ZONE
FIRST OIL ZONE
SECOND OIL ZONE
THIRD OIL ZONE
IDEAL CROSS-SECTION
MONTEBELLO ANTICLINE
Los Angeles County, California
Accompanying report of Irving V. Augur, Dep. Sup.
April 30, 1920
Scale

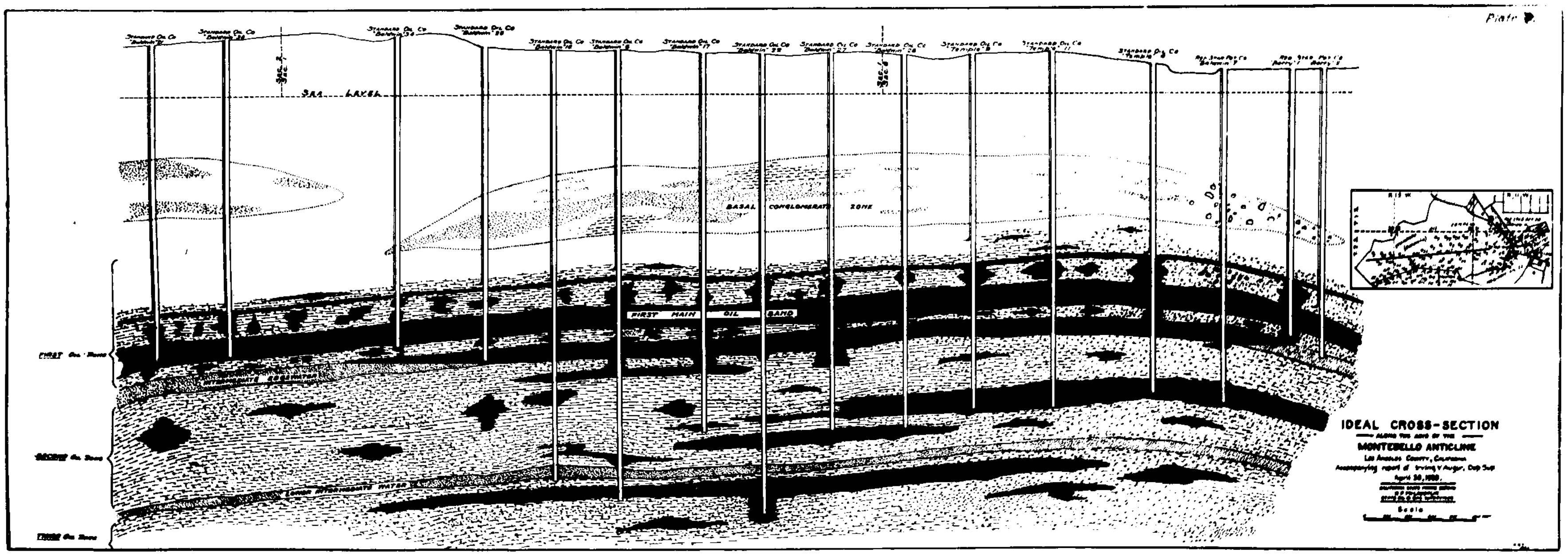
Plate
SEA LEVEL
BASAL CONGLOMERATE ZONE
FIRST MAIN OIL SAND
LOWER INTERMEDIATE WATER
FIRST OIL ZONE
SECOND OIL ZONE
THIRD OIL ZONE
IDEAL CROSS-SECTION
ALONG THE AXIS OF THE
MONTEBELLO ANTICLINE
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April 30, 1920
Scale

STRUCTURE AND GEOLOGIC HISTORY

The Merced Hills are the direct result of uplift along the Merced Anticline during the Pleistocene epoch. The greater part of the movement took place between the deposition of the"Saugus" formation and that of the Temple formation. Uplift continued, however, into the Recent,as is evidenced by tilting of all but the most recent deposits. As may be seen from Plate 1, the Merced anticline follows the topographic crest of the Merced Hills quite closely, although its structural summit is located somewhat east of the topographic summit of that portion of the hills. Toward the west, the anticline branches, and the topography flattens so that the geomorphic relations are obscured.

After discussing the underground structure of the Montebello oil field with Mr. White, of the Standard Oil Company, and others, it was decided that it would be entirely futile to attempt to draw an accurate geologic cross section in the region; for it is the opinion of those familiar with the underground structure,that the surface structural irregularities do not extend to an appreciable depth. On the other hand, the underground structural conditions are remarkably uniform. They are shown in Plate 2, a copy of an illustration appearing in a publication on the Montebello field by the California State Mining Bureau. 1/

The westward extension of the Merced Anticline has been proved unproductive, but the southern branch of it has developed a fairly high production.

Since the various faults mapped on the surface, with the exception of the north to northwest striking one in the western part of the oil field, are not found at any great depth, it is obvious that their influence on oil accumulation has been negligible. The fault mentioned above may be found in well logs, but apparently has a different magnitude of throw at several thousand feet than at the surface. It is even possible that it also dies out completely at five to six thousand feet depth.

The structure in the northern part of the Merced hills is very obscure because of poor outcrops and the presence of much recent terrace material; it is believed, though, that no major structures are present north of the Merced Anticline. Since the depth of alluvial fill and terrace material is about the same over the whole general region, at any particular distance from the San Gabriel Mountain front, structural features of equal magnitude and effect should show approximately similar geomorphic relations. The height of the Merced Hills toward the northern part of the

1/ Auger, Irving V., Summary of operations, California Oil Fields, v.5, n.11, 1920.

area mapped is due, in very large part, to differential erosion, with the hard conglomerates of the "Saugus" and Temple formations forming the crest of the ridge. The higher portions of the hills in the vicinity of the Montebello Oil Field, on the other hand, are largely soft sandstone and sandy shale.

THE RADIOACTIVITY OF THE OILS AND WATERS

INTRODUCTION

The fact that many geologic materials contain radioactive substances in measureable quantities has long been recognized. The rather lengthy bibliography appended to Ambronn's text on geophysics 1/ bears testimony to this as well as to the fact that most of the investigation ralative to radioactivity of soils, rocks, waters and oils has been carried on in Europe. It has also been recognized for some time that certain relations exist between the geologic structure of rocks and their radioactive content. Ambronn, for example, found that an increase in the alpha-radiation of the soil was detectable in the vicinity of faults. 2/

The present investigation was undertaken with the purpose of determining whether any relation existed between the radioactivity of the fluids from oil wells and geologic structure of the oil field. It was thought desireable to investigate a region in which the areal geology is well exposed and comparatively simple so that conclusions as to relationships between structure and radioactivity would be readily demonstrable. The Montebello oil field appeared to fulfill this condition, and was chosen for study. Geologic field work, however, has shown: first, that the structure is rather complex in detail, and second, that the surface geology

1/ Ambronn, R., Elements of Geophysics, 1928.
2/ Idem, p. 127.

does not correspond at all closely with the sub-surface geology.

The conclusions reached, therefore, are at the best tentative, and it is suggested that further investigation be undertaken at localities where there can be no doubt as to the geologic relations.

THEORY

The radioactive substance in the liquids investigated during this research is Radium Emanation or Radon. This is the first decay product of Radium, and has a half-life of 3.85 days.[1/] Radon further passes through several transformations, Radium A, Radium B, Radium C, Radium C', Radium D, Radium E, Polonium, to Lead (with an atomic weight of 206). All of these substances, with the exception of Radon, are solids, with half-lives ranging from 10^{-6} second for Radium C' to 16.5 years for Radium D. Lead, of course, is the stable end-product of the radioactive transformation series. The presence of these various substances wherever Radon is found introduces very complicated equilbrium relations, but with the technique employed in this research, their effect is negligible.

Radon is an inert gas, boiling at -65 degrees Centigrade and having an atomic weight of 222. The radioactive unit of Radon is the Curie, which is that quantity of Radon in equilibrium with 1 gram of Radium. A smaller unit, the Eman, is equal to 10^{-6} Curie, and the Mache unit of concentration is equal to 3.64 Emans per liter.

It has been determined experimentally [2/] that

1/ Meyer, St., und von Schweidler, E., Radioaktivitat, 1916, p.334.
2/ Bohn, J. Lloyd, Radioactive properties of rocks, soils and waters of the Southern California region, p.6,: California Institute of Technology Thesis, 1928.

the maximum activity in the ionization chamber obtains in the period from three to three and one-half hours after admitting the Radon. Therefore, all measurements, both calibration and determination, were made in that period. This time corresponds to the attaining of equilibrium between Radon and its dissociation products.

DETERMINATIONS

Procedure in determining the Radon in Oils and Waters.

Sampling was done in all cases directly at the well to be investigated. Since the gas pressure in the Montebello field is relatively low, rarely exceeding 100 pounds per square inch, the samples were collected in an open contained held under a valve on the pump line. For determinations of the Radon content of the total fluid, 2400 cc. of the above liquid were collected and poured into a three liter Florence flask in which boiling was subsequently done. The entire sampling operation, thus outlined, took less than five minutes. A small sample of the total fluid was also taken to determine the percentage of water and the density of the oil.

When it was desireable to make separate determinations of the Radon content of the oil and water, the fluid as it came from the well was allowed to settle for about fifteen minutes in the container. The water and oil were then drawn off separately through a cock in the bottom of the container, measured and immediately transfered to the large flasks.

The sampling flask was sealed as soon as it was filled, by a rubber stopper in which were inserted two short glass tubes terminated by short pieces of rubber tubing, closed by screw clamps. The lower end of one of the glass tubes was ground at an angle to facilitate refluxing in the boiling operation. The stoppers were wired into the flasks and all joints were sealed with Ambroid cement.

The time at which the sample was taken, and the time elapsing between taking the sample and sealing the flask, were noted.

As soon as convenient, the Radon was determined in the laboratory. Since the half-life of the Radon is 3.85 days, it is desireable to make the determination within a week in order to have an appreciable quantity to measure. The disintegration may be easily computed from a table given by Meyer and Schweidler [1].

At the time samples were taken, a small quantity of pure Barium Chloride was added to precipitate Carbon Dioxide and prevent its passing into the ionization chamber. It was necessary to eliminate Carbon Dioxide from the ionization chamber, for it would hydrolize any water vapor present and tend to break down the insulation about the electrode leading to the electroscope. The insulation was kept dry by a quantity of dehydrating agent placed near it, and by passing all gasses entering the ionization chamber through a Sulfuric Acid cell.

The elimination of the Radon from the sample was performed as follows: 1/

A sampling flask, sealed as brought in from the field, was placed in position with one of the rubber outlet tubes (the larger one) connected with the lower end of the reflux column. The entire system, except the flask was then evacuated with the water aspirator. Clamp A was then closed, clamp B nearly closed, and clamp C opened fully, and heating was started. The sample was heated rapidly until it began to boil and was then allowed to boil as vigorously as possible, without excess foaming or bumping, for about a half hour. During the latter part of the boiling, clamp B was opened completely, so that equilibrium was established throughout the system. The fire was then removed, and a supply of thoroughly boiled tap water was allowed to enter the flask through one of the rubber outlet tubes and completely fill the flask and reflux column. The ionization chamber was then sealed by closing clamp B, and the time noted.

Three hours after the above operation was completed, the ionization chamber was connected to the electroscope and the rate of discharge of the fibers during the next half hour was observed.

1/ See Plate 3.

As soon as possible, the entire apparatus, including the ionization chamber, was thoroughly cleared of Radon by passing fresh air through in large quantities. By performing this operation immediately after making the determination, very little of the Radon has an opportunity to dissociate and but a small quantity of its dissociation products is deposited in the ionization chamber. The presence of this active precipitate in the rest of the apparatus is without significance, since none of them yield gaseous products. The zero leak of the ionization chambers must be occasionally checked, for the gradual accumulation of active products may cause a slow increase of apparent zero leak. The ionization chamber may be safely used for a determination about an hour after the preceding run is ended and the chamber cleared. In this time the first three decay products, RaA, RaB, RaC, will be reduced to a small fraction of their original activity.

Considerable difficulty was encountered in boiling mixtures of oil and water, due to emulsification of the oil by steam, and foaming of the mixture. Pure oil or water were boiled without difficulty.

It has been determined experimentally, 1/ that the maximum activity in the ionization chamber obtains in the period from three to four hours after

1/ Op. cit., Bohn, J. Lloyd, p. 6.

admitting the Radon. There is some variation in the activity in the chamber depending on the time consumed in boiling , since the decay products of the Radon begin depositing as soon as some gas in admitted to the chamber. The activity is quite constant for an hour or more after the three hour period, however, so the time for accumulation of activity may be reckoned from the sealing of the chamber. Since the gas in the chamber is in equilibrium with that in the flask up to the moment of sealing the chamber, the correction for disintegration of the emanation is calculated from the moment of taking the sample to the sealing of the ionization chamber after boiling.

The electroscope was charged several minutes before readings were taken in order to eliminate any error that might be introduced by reactions to the sudden movement of the quartz fibers in charging them.

In calculating the amount of emanation present in the sample at the time it was taken, the following corrections were made:

a. disintegration of the Radon during the time clapsing from sampling to sealing of the ionization chamber,

b. Radon retained in the apparatus during boiling,

c. zero leak of the electroscope-ionization chamber system.

Corrections were not made for the following sources of error:

a. Radon lost to the air when taking the sample,

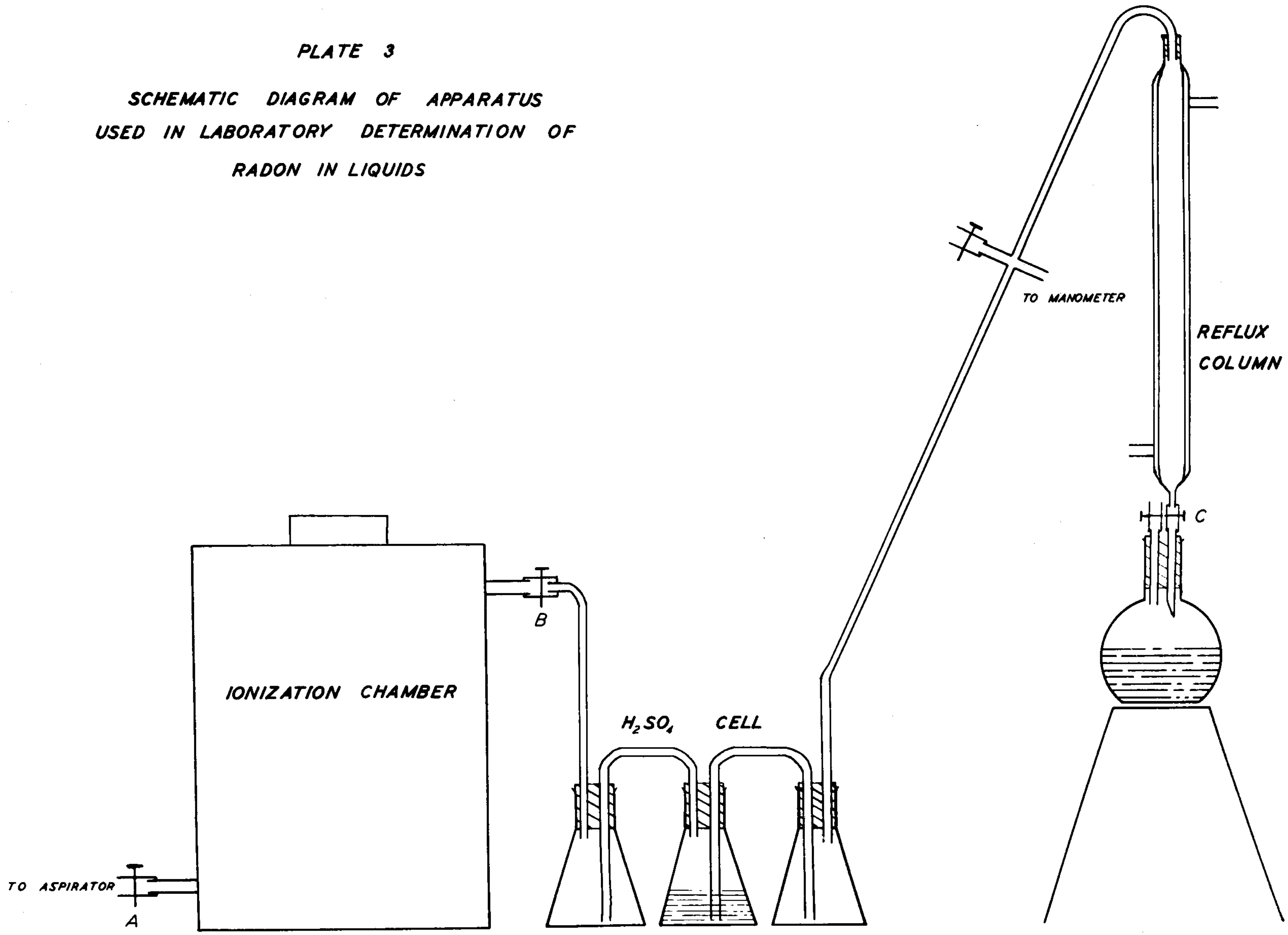
b. Radon contained in dissolved gas,

c. varying times of boiling, affecting the quantity of disintegration products in the ionization chamber.

Since the quantity of Radon in the escaping gas is small due to its high solubility in oil, and since the gas-oil ratios in all of the wells studied vary greatly, it is believed impossible to take into account the Radon present in the oil well gasses. The fact that the activity curve of the ionization chamber is quite flat for some time after three hours makes the effect of varying times of boiling slight.

PLATE 3

SCHEMATIC DIAGRAM OF APPARATUS USED IN LABORATORY DETERMINATION OF RADON IN LIQUIDS



APPARATUS

The apparatus used in the laboratory for measuring the Radon consists of a reflux column, a sulfuric acid drying cell, a mercury manometer, a vacumn pump and an electroscope with removable head.

The reflux column, about 32 inches long, was designed to allow boiling mixtures of oil and water, with the accompanying foaming, without danger to the remainder of the apparatus. Its inner tube was divided into a series of constrictions and enlargements to allow reflux action to take place readily.

In order to allow fluctuations of pressure to take place either way through the sulfuric acid cell, it was designed as shown so that the acid could not find its way into the ionization chamber or reflux column.

An ordinary water aspirator was found entirely satisfactory for evacuating the system prior to boiling the sample, and for drawing fresh air through the system to eliminate the Radon.

The electroscope was designed by Mr. R.D. Evans, of the California Institute Physics department, especially for use in determining radioactivity of geologic materials. 1/ In consists of two parts, an ionization chamber where the gases to be measured

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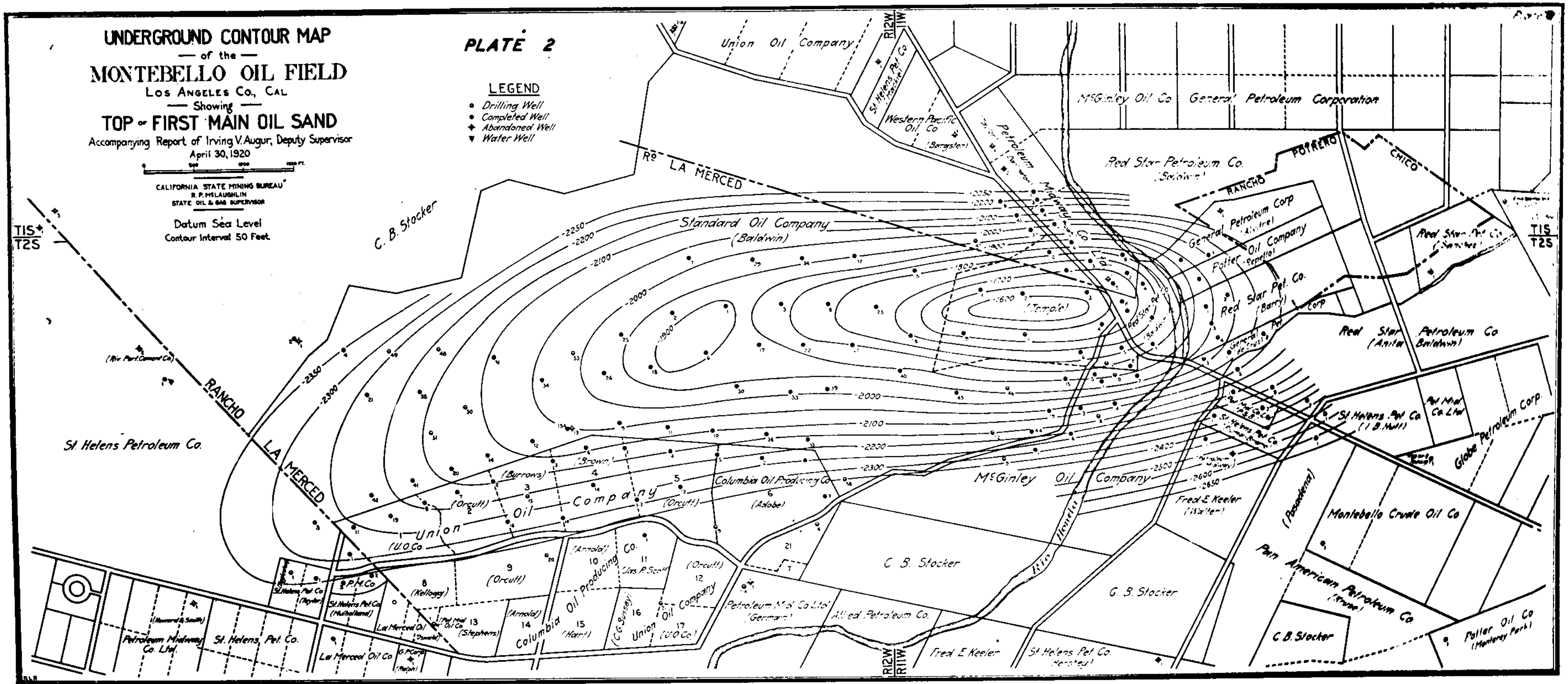
1/ Evans, R.D., Unpublished manuscript.

are placed, and a removable head, containing the electroscope. This electroscope is of bifilar, quartz fiber design, and will be described in detail within a short time, by Mr. Evans. The advantage of the removable head is apparent, when it is considered that a number of ionization chambers may be used in conjunction with it, reducing the total cost considerably when it becomes necessary to make a number of measurements.

The apparatus for boiling the sample was made as simple as possible, both in order to keep the volume small, and to facilitate cleaning. The volume was kept small for several reasons. First, to keep the correction factor for the volume of apparatus outside of the ionization chamber low. Second, to provide but little room for accumulation of the solid disintegration products of Radon. Third, to provide little area for absorption of the Radon by the glass. This last factor is of little importance with glass 1/ although it is of considerable importance with other substances, notably rubber.

1/ Curie, P., Traite de Radioactivite, p. 259, 1910.


UNDERGROUND CONTOUR MAP
of the
MONTEBELLO OIL FIELD
LOS ANGELES CO., CAL
Showing
TOP of FIRST MAIN OIL SAND
Accompanying Report of Irving V. Augur, Deputy Supervisor
April 30, 1920
CALIFORNIA STATE MINING BUREAU
R. P. McLAUGHLIN
STATE OIL & GAS SUPERVISOR
Datum Sea Level
Contour Interval 50 Feet
PLATE 2
LEGEND
Drilling Well
Completed Well
Abandoned Well
Water Well
Union Oil Company
McGinley Oil Co
General Petroleum Corporation
Red Star Petroleum Co.
Standard Oil Company
(Baldwin)
C. B. Stocker
St. Helens Petroleum Co.
RANCHO LA MERCED
RANCHO POTRERO CHICO
McGinley Oil Company
Columbia Oil Producing Co.
Montebello Crude Oil Co
Pan American Petroleum Co
Globe Petroleum Corp
Potter Oil Co
Fred E. Keeler
Allied Petroleum Co.
G. B. Stocker
St. Helens Pet. Co.
Western Pacific Oil Co
Petroleum Midway Co.
T1S
T2S
R12W
R11W

MEASUREMENTS

Well	Date Collected	Time Collected	Fluid	Emans per Liter	Sample
SOB 49	5-2-31	10:02A	Total	1.18	1
SOB 49	5-7-31	11:54A	Total	0.97	5
SOB 48	5-7-31	12:06P	Total	1.17	6
SOB 47	5-19-31	5:50P	Total	2.47	13
SOB 28	5-26-31	2:30P	Total	1.57	15
SOB 28	5-26-31	2:42P	Total	1.09	16
SOB 17	5-15-31	4:30P	Total	3.00	7
SOB 17	5-15-31	4:40P	Water	0.25	8
SOB 17	5-15-31	4:45P	Oil	4.25	9
SOB 14	5-4-31	4:42P	Total	0.92	4

CONCLUSIONS

It was believed from the first that the large number of variable conditions present in oil wells would make it difficult to obtain comparable results by measuring radioactivity. After a few preliminary measurements, samples 15 and 16 were taken within a few minutes of one another, from the same well, in order to discover if any constancy of radioactivity existed in a particular well. The variation, ammounting to thirty percent, disproves at once any correlation theory based on an assumption of fairly constant radioactivity in individual wells.

Separate determinations on the oil and water from the same sample were made in the case of samples 8 and 9, with the result that the oil showed an activity of 17 times that of the water. It is impossible to say whether the Radon had had an opportunity to attain equilibrium between the oil and water; probably it had not done so. Earlier workers have pointed out the greater solubility of Radon in petroleum than in water, a fact which the above figures support.

The following factors, each one of importance in determining the Radon content of oil well fluids, vary independently:

a. Total fluid production.

b. Gas-oil ratio.

c. Water-oil ratio.

d. Strata contributing to gas production.

e. Strata contributing to oil production.

f. Strata contributing to water production.

g. Density of oil.

If any four of these could be held constant, or if they varied slowly, it is possible that some definite results would be obtainable from measurements of Radon content of oil field fluids; but since all seven factors listed above vary widely, and independently, it seems futile to expect such measurements to lead to results of value in correlation.

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(Note: The reader is also referred to the bibliographies in Ambronn, Bohn and McMillan)