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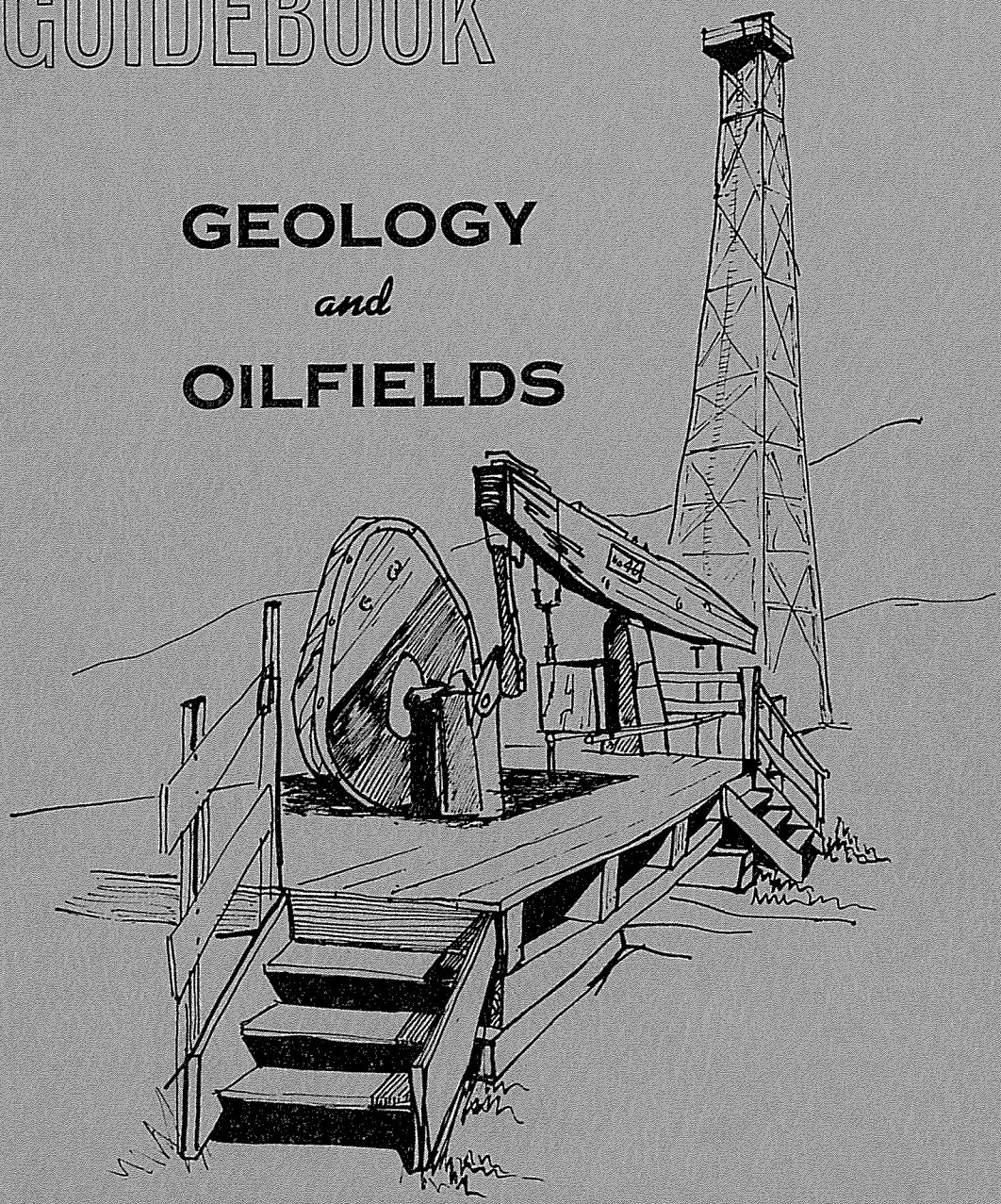
1968 GUIDEBOOK

GEOLOGY *and* OILFIELDS



WEST SIDE SOUTHERN SAN JOAQUIN VALLEY

PACIFIC SECTIONS AAPG SEG SEPM

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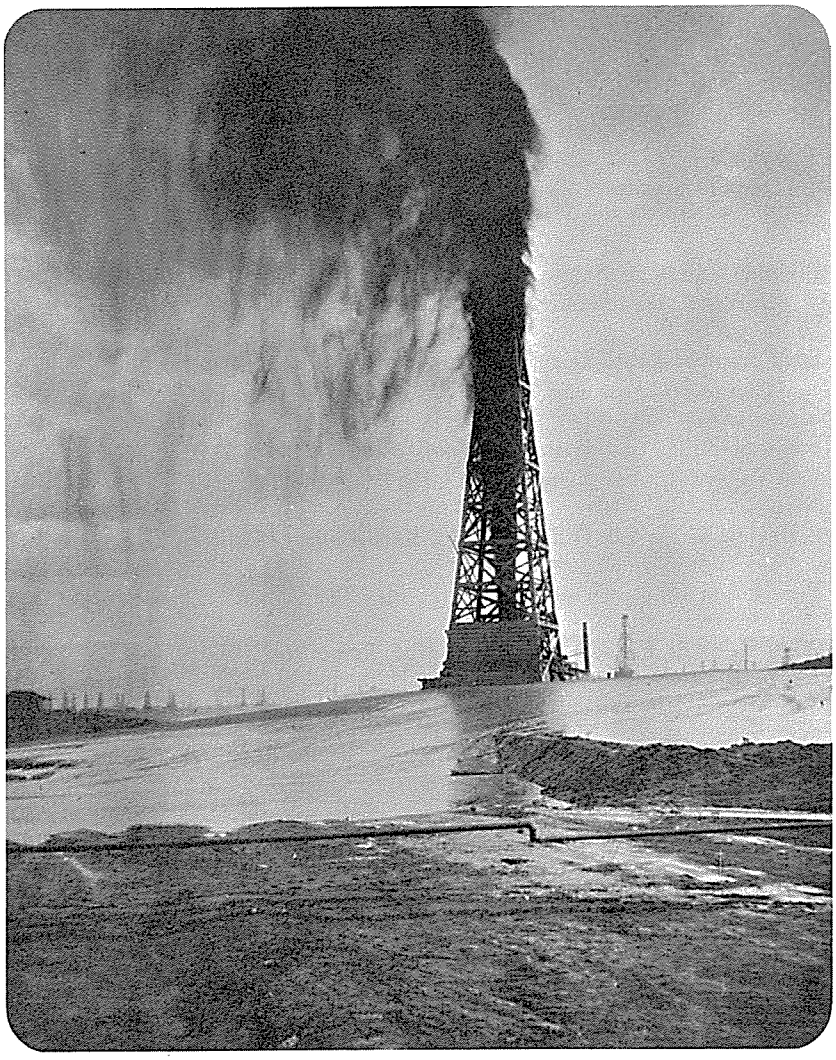

LAKEVIEW No. 1

43rd ANNUAL MEETING

PACIFIC SECTIONS AAPG SEG SEPM

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GUIDEBOOK

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INTRODUCTION

Oil has been produced from the west side of the southern San Joaquin Valley for the past 70 years and despite the 21,000 wells that have been drilled in this basin, there still remains many potentially productive areas.

Ten thousand wells produce 68 million barrels of oil annually with a cumulative production of two and a third billion barrels of petroleum from 21 fields.

To say this all began with the discovery of Lakeview No. 1 in 1910 would be incorrect, but certainly the Lakeview gusher focused world attention on a little known corner of the Great Valley. From that day on, the West Side gained its place among the giants. This year, Midway-Sunset Field will join the exclusive "billion barrel club" and Elk Hills, considered to be the third largest field in the United States, has an estimated billion barrels in reserve. Two and a half trillion cubic feet of gas contributed to the economy of the West Side and an estimated 1.2 trillion cubic feet of gas are in reserve. Though the figures are impressive, the story is not ended. Within the past five years, four new fields or areas and four new pools have added 15 million barrels of oil to 1967 production figures.

The West Side may never see another Lakeview gusher but as new recovery methods are devised and exploration techniques developed, today's geologist will continue to add to West Side production, petroleum reserves that rival that produced by Lakeview #1.

Many of the West Side reservoirs are closed by stratigraphic changes as well as structure. Most of the producing zones crop out along the Temblor Range, and provide an excellent opportunity to observe the significant lateral and vertical changes in these formations.

At Carneros Creek and Chico Martinez Creek, the nearly complete section from Eocene through Pliocene will be seen. It is one of the most continuous unfaulted exposure of Upper Tertiary formations in the southern San Joaquin Valley.

Tectonic movements will be viewed in the form of an active thrust fault on the main field trip route. If alternate routes are followed, several additional areas of active tectonism in the southern San Joaquin Valley can be seen and studied.

The route selected traverses many of the West Side oil fields in an attempt to relive part of the colorful history and to give a better understanding of the size and distribution of many of the West Side fields.

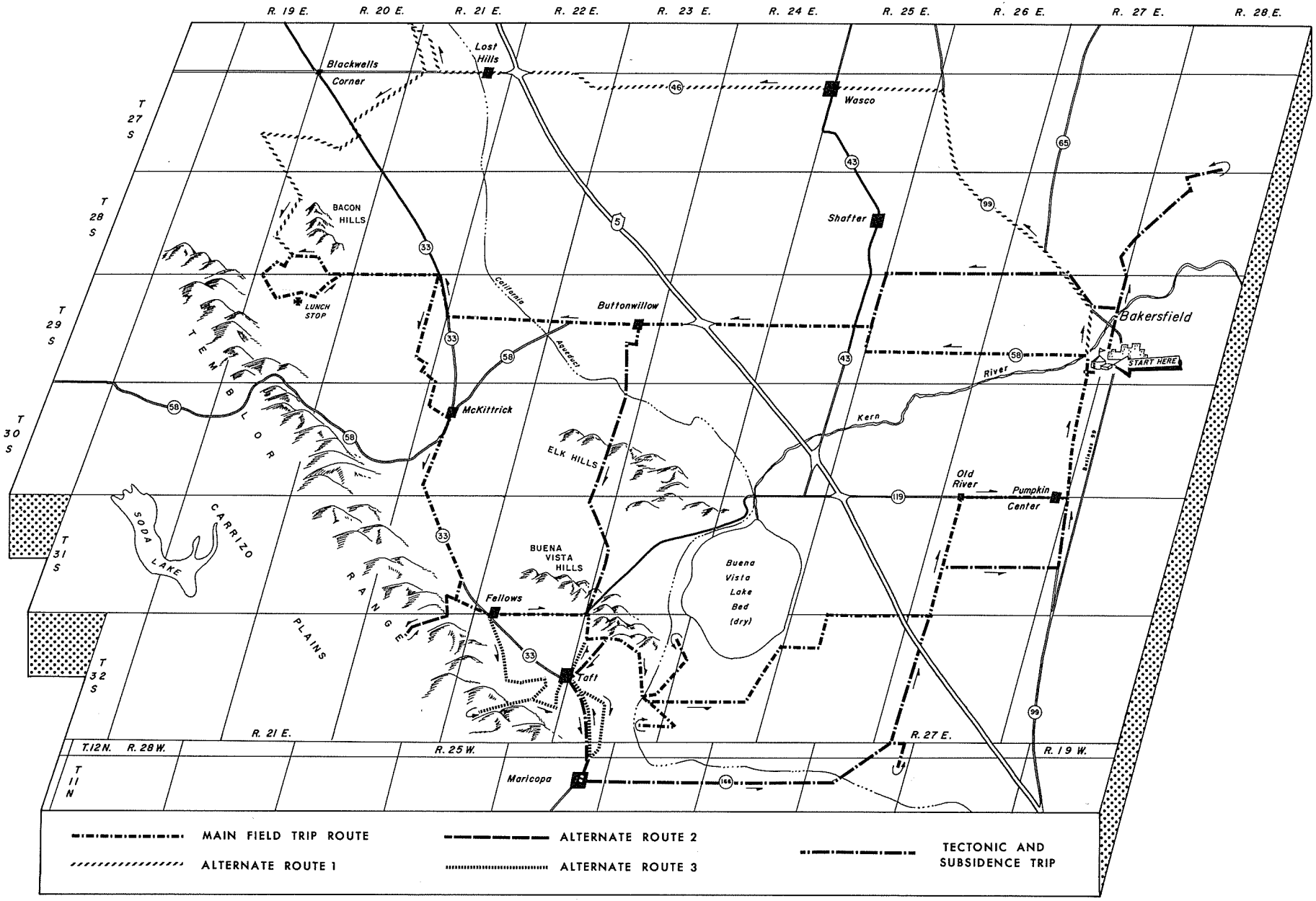
Another giant, the California Aqueduct, will be seen on this trip. Due for completion in 1970, this multi-million dollar project will bring water to the dry, thirsty West Side and with it a new growth. In the near future sage brush and tumbleweed will give way to truck farms and citrus groves. The now dry aqueduct will carry one and a third million acre feet of water annually to West Side farms and to Southern California. The site of a pumping plant where water will be raised 205 feet to continue its journey south will be one of our several stops. The effect of this water on land in the form of subsidence has created many problems for the engineer and geologist alike, and if time permits this area will be studied in greater detail.

Only the highlights of this intriguing area can be seen on a one-day visit. Historical, cultural and technical features by-passed on the main trip are included on alternate guides to be visited at your "leisure." We hope you enjoy our route.

GENE TRIPP
BILL ELLIOTT
ED KARP

ORIENTATION MAP

SOUTHERN SAN JOAQUIN VALLEY
WEST SIDE



WHEN THE WEST SIDE BOOMED[1]

WILLIAM RINTOUL[2]

One day about 60 years ago the city attorney of Bakersfield contemplated an oil lease he had bought for $5, sadly noted the 1,000-foot dry hole that subsequently had been drilled nearby, and quietly sold out, considering himself lucky to get as much as he had paid for the ill-starred property.

It was not long afterward that a group of Los Angeles investors took a hopeful look at the same lease, decided it had possibilities, and incorporated themselves for the purpose of drilling a well under the name Lakeview Oil Co. Unfortunately, the well consumed time and money in greater amounts than anticipated, and the hard-pressed backers cast about for help.

Help was forthcoming in the form of a neighbor with production. Union Oil Co. of California wasn't necessarily sold on the Lakeview well; in fact, according to a later admission, the real lure was the land on which the well was being drilled: the company saw it as a dandy spot to build tanks for storage of oil to be shipped through a pipeline then under construction. But the Lakeview-Union agreement was a package deal: in return for the land, the right to build tanks, and a controlling interest in Lakeview Oil Co., Union took a commitment to continue drilling the Lakeview well — as crews could be diverted from other projects considered more pressing.

Drilling proceeded, and so did expenses, requiring an occasional assessment in the form of a dime-a-share dun of Laveview stockholders. One stockholder named Maria Addis soon qualified for membership in the club begun by the city attorney of Bakersfield. Tiring of assessments, she sold her 200 shares at public auction to Clarence H. White for $20. The sale was consummated on Nov. 12, 1909, some four months before the Lakeview gusher blew in as, in the words on the California Historical Landmark plaque that marks the site, "America's most spectacular gusher."

The column of dark brown oil that shot up from the Lakeview gusher on the morning of March 15, 1910, demolished the wooden derrick, sprayed the countryside for miles around, and encouraged the formation of 39 new oil companies in two weeks.

An army of upward to 400 men labored to contain the gusher's oil. In the ranks were newcomers hastily recruited from as far away as Suisun City, 300 miles to the north. For many, home in the oil fields was a bedroll thrown down on hard ground. More than one newcomer proved fair game for the practical jokes of old hands. A favorite trick was to conceal a rope under the newcomer's bedroll. At nightfall, the newcomer would be treated to much talk of rattlesnakes and their prevalence in the oil fields. Later, after the impressionable newcomer had settled uneasily into his bedroll, someone would grab the rope and yank, excitedly shouting "snake." The prank was guaranteed to empty a bedroll in a hurry.

Fondness for practical jokes among the Lakeview hands apparently was equaled if not surpassed by the men's desire to see that holidays were properly celebrated. Orval O. McReynolds, a consulting engineer who represented original backers of the Lakeview gusher, touched on such a celebration in a report he wrote to Messers. Charles Off and R. D. Wade in Los Angeles on July 7, 1910, three days after the nation had noted its independence day. "Progress during the past week has been somewhat slow," McReynolds reported, "for the reason that the entire Maricopa field had been celebration mad. We are just beginning to settle down to work again after a week of debauch."

While the Lakeview gusher and its uncontrolled flow of an estimated nine million barrels of oil solved the problem of respectability for the Midway-Sunset field, there still remained a matter of status for the West Side's redoubtable Sunset Railroad, built jointly in 1902 by Southern Pacific Co. and Santa Fe Railway Co. to connect the embryo oil fields with Bakersfield, some 45 miles away.

Though the Sunset's $100,000 a month hauling business made it one of the most profitable branch lines in the United States, the line's image left much to be desired. Most West Siders knew the Sunset mainly for its lack of speed in carrying passengers to their destinations. One passenger had indignantly requested that the railroad either speed up the run or add sleeping cars and a diner. Another, a man on crutches, had enacted what must stand as the epitome of protest to passenger service on any rail line. Some 13 hours out of Bakersfield on what had been billed as a two-hour-and-ten-minute run, while the train was stopped on a siding near Buena Vista Lake, the angry passenger had climbed off and begun hobbling toward the tents and shacks of Taft on his crutches, leaving the train behind.

It was not long after the Lakeview gusher ceased to flow that the Sunset attained the status of every self-respecting western railroad. The train was robbed of a gold shipment.

It happened on Dec. 9, 1911. The first sign of trouble came when the afternoon train rolled to a stop in Taft. The agent approached the express car, rapped on the door, and received no answer. Alarmed, he forced his way inside to find the express messenger lying bound, gagged and unconscious beneath sacks of mail. An open strongbox told the story. A $20,000 gold shipment to meet oil payrolls was gone.

It was the following morning before the messenger pulled himself together sufficiently to tell, from a hospital bed, a story of being accosted by two robbers, one of whom pistol-whipped him when he tried to pull the bell cord. Somebody recalled seeing two men riding exhausted horses into the hills near Glenville on the other side of the valley, and a possee rode off in pursuit, to no avail. The reason became clear several days later. Further questioning developed discrepancies in the messenger's story. The messenger confessed that he and his brother had stolen the gold and that he had bumped his head to make his story seem authentic. Authorities found the gold in a shallow hole beside the tracks, and the train robbers were sent to an institution where, one wag predicted, the passage of time would seem as unhurried as a ride on the Sunset railroad.

If the Sunset achieved its standing at the hands of a dubious hold-up, the same could scarcely be said of the communities that grew to supply

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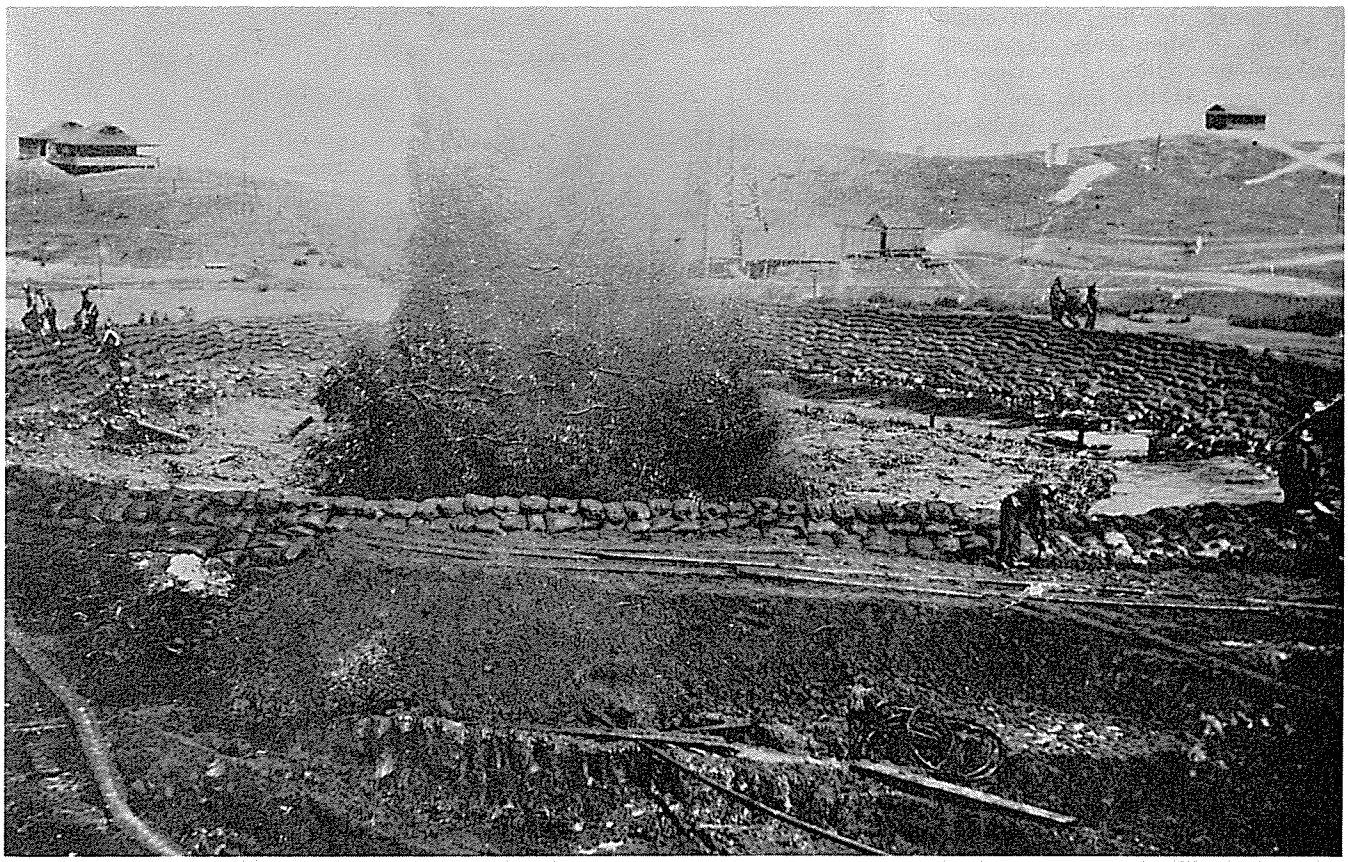
[1]Manuscript submitted September 1967.
[2]Oil Columnist, Bakersfield, California.

Taft celebrated the Fourth of July, 1911, with a parade down Center Street.



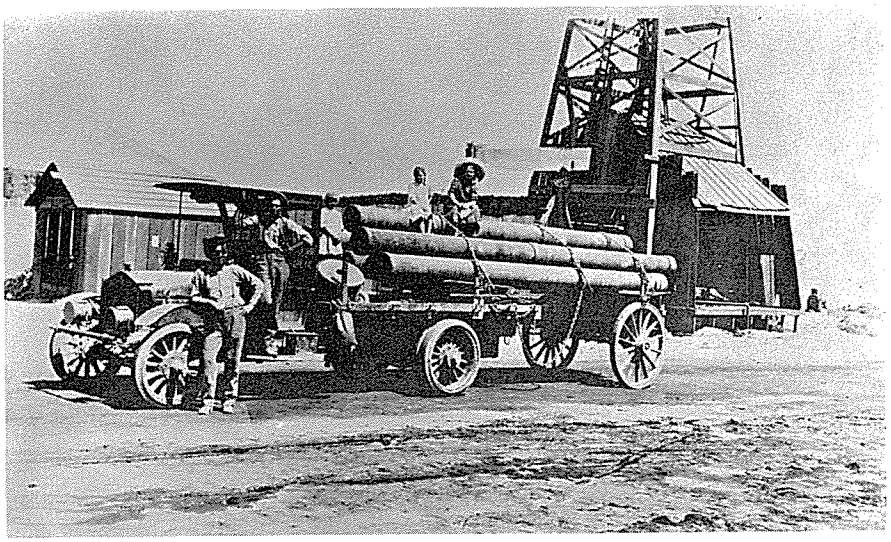
Enveloped in oily spray, workmen at the Lakeview gusher were in constant danger.

the oil fields. There's a legend that says of western mining towns—and the West Side communities were based on mineral wealth no less certainly than the Whiskey Flats and Hangtowns of the Mother Lode—that drunkenness, shootouts and stern privation were the prevailing mode of life. Certainly such things as shootings for example, did occur—and still occur even in the best of towns—but whether they should be regarded as the whole story is debatable.

What of life in the West Side oil communities? For housewives, life was not without its conveniences. The women of tiny Reward, for example, cooked with natural gas a full five years before piped-in gas was available to their counterparts in proud Los Angeles. In the oil fields, gas served not only for cooking and house heating but also for such luxuries as gas lights and even for irons. It was the practice to connect the iron to the gas source with a flexible hose. The woman ironing could choose by regulating the flow of gas between a warm, medium or hot iron.

And when washday arrived, there was the blow-off box, an oil field laundromat. At each boiler house, a pipeline led away to deadend at a reasonable distance from the boilers. Through the line, steam could be blown off when there was excess pressure—or clothes to be cleaned. At the end of the line would be found a sturdy box with holes bored through its sides and a lid that fastened tightly on top. Even the oiliest of oil-staned clothes, with perhaps an assist from pre-soaking in distillate, came away thoroughly cleansed after a lively session with steam in the blow-off box.

For men, life in the oil camps was not without its comforts. Notable was the way they handled hot weather at a bunkhouse on the C. J. Berry lease. The bunkhouse consisted of a wooden frame over which wire screen had been nailed; covering the latter was a layer of burlap. Topping the structure was a trough from which water dripped, dampening the burlap. The bunkhouse stood apart from other buildings to catch any and all breezes. It provided cool quarters in which night crews slept during summer days. The same arrangement on a more modest scale served for the coolers in which early residents of the West Side guarded their perishables before the installation of community ice-making machines.



TOP: Running casing was a family affair in the early days of the West Side oil fields. BOTTOM: Fire drill at Fellows, circa 1912.

While burgeoning communities of the West Side offered entertainment ranging from cultural offerings at the Blaisdell Opera House in Taft to near-championship boxing matches in Taft and McKittrick featuring such men as Jack Johnson, who later became world's heavyweight champion, and Sam Langford, the famous Boston Tar Baby, for many West Siders the center of social life remained the oil company lease. Highlights of lease life were the annual community picnic in the spring and the gala Christmas party in the winter. In the absence of Christmas trees, or any other trees for that matter, men would trek into the Temblor Range, cut a tree—be it oak or scrub—that showed promise, and by judicious pruning shape it in traditional form. Once decorated, the tree served its purpose without complaint from any of the celebrants, least of all the children, who received gifts of candy, raisins and nuts.

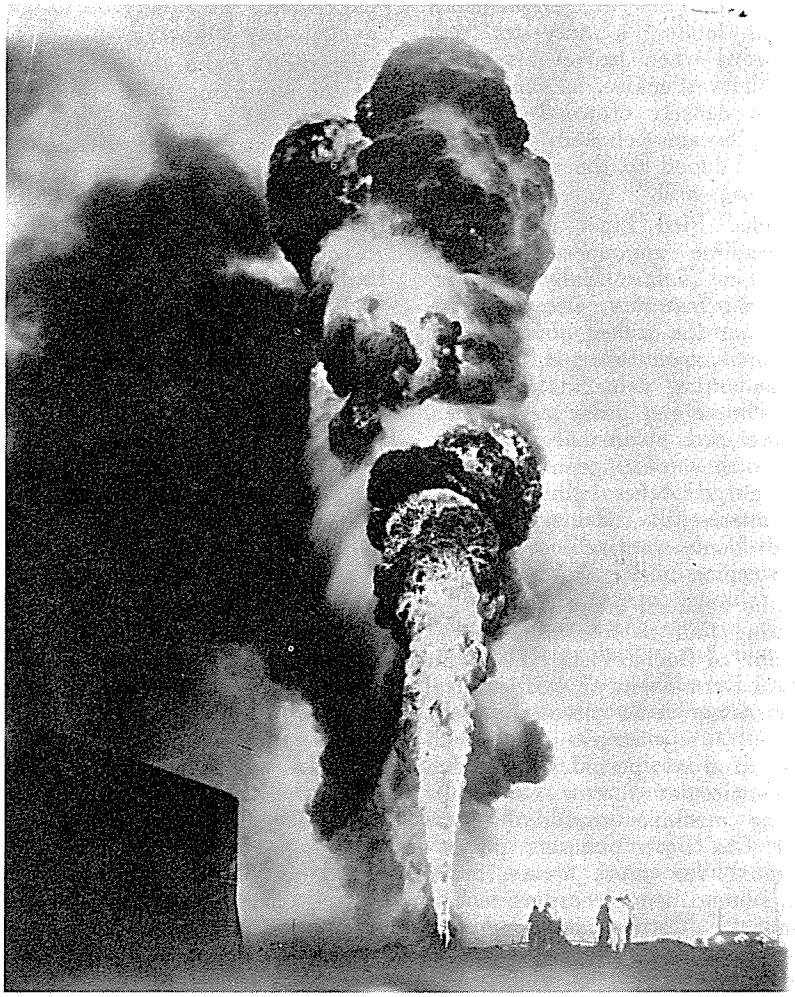
If the bounty of nature furnished a reason for existence on the West Side, nature had more ways of evidencing itself than the gift of rich oil sands. On the wintery Monday morning of Jan. 17, 1916, a gale blew out of the southwest, buffeting the West Side for more than three hours. The gale began with a bang: wind blew the crown block from a derrick on the San Francisco & McKittrick lease, sending it smashing into a boiler, causing the boiler to explode. Ground, softened by rain, proved an unsteady base; in West Side fields more than 400 wooden

derricks toppled. Fortunately, no one was killed, though one man fell from a derrick and broke his ankle, another working on a rig suffered a deep gash in his arm.

A motion picture crew from Los Angeles arrived the following day to film the devastation, taking pictures of collapsed tanks, unroofed houses and derricks in all stages of delapidation. Loss was estimated at more than $740,000. Teams were in more demand that trucks because they didn't bog down as easily in the morass. A call for rig builders went out, and men responded from as far away as Texas. More than 100 carloads of lumber were ordered at McKittrick the day following the windstorm. Perhaps the man who came through best was L. P. Guiberson, who less than two weeks earlier had taken out policies with the Heath Agency insuring ten of his derricks, seven of which were wrecked.

Ten days later the headlines in The Bakersfield Californian announced: "60-Mile Gale Sweeps Valley; Wires Out, Trees Down; West Side Isolated." Another gale had struck, taking with it many of the derricks that had survived the first blast. Damage on the West Side was set at over $1 million. A lineman for San Joaquin Light & Power Co., while climbing a pole to attempt to restore service, was hit by corrugated iron and suffered several broken ribs. Two salesmen from Oil Well Supply Co. were brought to a grinding halt on the highway when wind dropped dead wire on their car, neatly tangling them. A Fellows man suffered a broken leg while walking along the community's wooden sidewalk; the wind picked up the walk and flayed him.

What nature had been unable to accomplish, embattled men succeeded in doing: they shut down the West Side's wells. The shutdown came at midnight on Sept. 11, 1921, when upward to 8,000 San Joaquin Valley oil workers struck some 425 companies, affecting not only West Side fields but Kern River and Coalinga as well. In Kern County, the strike affected some 213,000 b/d production, most of it on the West Side.



One that got away, circa 1911, prevented the Sunset Railroad's trains from traveling the last five miles of track for two months.

Six weeks earlier, operators had announced they would not renew an agreement with the International Association of Oil Fields, Gas Well and Refinery Workers when the agreement expired at the end of August. In addition, operators said, because of "decreased cost of living" they would slash wages $1 a day.

The union, reluctantly accepting the wage cut, which for lower categories amounted to a 17 per cent slash, struck against further reductions, demanding that operators agree, with the federal government as a party to the agreement, to a memorandum of terms that for one year would preclude the possibility of additional wage cuts or other changes in working conditions. (Some union men feared a return to the 12-hour work day.)

Three days after the strike began, the first skirmish came at Pentland Junction near Maricopa. More than 2,000 strikers and sympathizers turned back a Southern Pacific special carrying men from San Francisco to the oil fields. The union called them strikebreakers; operators said they were guards. Sheriff D. B. Newell promptly banned the sale of firearms and ammunition in Kern County.

The union, proclaiming it would maintain law and order, combed its ranks for ex-servicemen; organized them into patrols, identified by red, white and blue badges; and promptly expelled several IWW organizers. Operators hotly claimed the patrols the union let it be known it would were in fact pickets. At one point, tolerate no foolishness. A union spokesman said: "If any of the boys on strike secure a drink of liquor, the committee (Law and Order Committee) will find out where it was secured and the place will be raided by police operatives." Bootleggers took the hint and went on vacation.

Amid reports strikebreakers were being recruited in San Francisco and Los Angeles, oil operators met in secret session at the Palace Hotel in San Francisco. Out of the meeting came the Oil Producers Association of California. Stoutly rejecting any hint of government mediation, the Association rallied under the battle cry: "More business in government, less government in business."

In the weeks that followed, pay-

ments were started from the strike benefit fund: $10 a week to single men, $15 a week to married men. Businessmen of Taft subscribed $4,000 to the fund. Merchants of Maricopa issued a statement supporting the strikers: "All the oil workers are after is a square deal for all." Strikers requested a government probe of the strike, declaring that operators were painting them "worse than Russian soviets." The number of deputies in the oil fields increased to 1,075, and strikers asked for troops, protesting many deputies were lease superintendents and foremen. Strikers paraded through the streets of Taft, 1,000 strong; a McKittrick oil worker hung himself. Friends said he was despondent over the course of the strike.

Operators, professing to see mediation as the opening wedge in government control, rejected overtures from the union for a "settlement without victory." They warned they would hold Kern County responsible for any violence or damage to their properties; filed more than 100 suits in Kern County Superior Court to force the eviction of strikers and their families from lease houses; and met in Los Angeles "to explore ways and means of resuming production."

In the long run, the strike hinged on one question: what would happen to a well that was shut in. The state mineralogist had warned from San Francisco that wells might suffer damage. As the strike progressed, some wells were quietly returned to production by non-strikers. It developed the wells had suffered no damage.

Early in November, two months after it had begun, the strike ended. Against a background of complaints of wholesale firing of men who had struck, an attempt to burn bridges on Highway 119 linking the West Side oil fields with Bakersfield, and sporadic shooting, wells were returned to production. Before the month ended, normal production had been resumed.

Conflict of a different sort erupted some five years later when the West Side became the target for one of the most bizarre attacks in history.

On the dark night of Nov. 24, 1926, the advance column of an unlikely army moved out of the rain-soaked bed of Buena Vista Lake, aiming its assault at the West Side. The task force, composed of thousands of house mice, was the vanguard of an army that would number more than 30 million—larger than any force put together by men. The target as mice scurried from muddy burrows was the town of Taft, seven miles away, by then a community of 5,000 population.

If anyone had suggested hardy citizens of Taft might soon tremble at the sight of mice, the person making the suggestion would have been greeted with derision. The reaction, predictably, when the first column of mice hit outlying oil camps between Taft and the lake bed was to regard the attack as an uproarious joke. It was rumored on Center Street, where oilworkers gathered in off-duty hours, that women were frantically making plans to start a stilt factory.

After mice invaded beds and nibbled the hair of horrified sleepers, chewed through the sides of wooden storehouses to get at food supplies, and crawled boldly into children's desks at Conley School, apprehensive Taftians cast worried glances at the rodents' staging area, wondering when the attack would cease. From the lake bed, where 11,000 acres of barley and milo maize furnished plentiful fodder, a harvester sent back word when he set his cutter low to harvest maize, he came upon mice so densely crowded that the blades "became choked with fur, flesh and blood to the resemblance of a sausage mill."

"Fabled Pied Piper Needed," a sub-headline announced over an article in Taft's Daily Midway Driller on Saturday, Dec. 4, 1926. Describing the influx of mice, the town newspaper reported "there is a considerable demand for mouse traps, cheese and pussy cats." Cats, it developed, were scarcely the scourge they were reputed to be. Once gorged, the felines showed little interest in rodents. One disgusted homeowner discovered 16 mice sleeping under two cats.

In the field, oil crews cut furrows extending four to five miles across the point of Buena Vista Hills. Whit Barber, Kern County's horticultural commissioner, led a platoon into the trenches to sow strychnined wheat. In a three-day period one trench alone—acircular furrow cut by a ditching machine around Midway Oil & Gas Co.'s pumping plant—accounted for more than 75,000 mice, among them, according to The Bakersfield Californian, "genuine rats wearing shaggy winter coats." It appeared as if the mice war were won. Weary men left trenches to spend Christmas at home.

Though defenders had won a battle, they had not yet won the war. Early in January, mice in even greater numbers aimed massive thrusts not only at Taft but also at Maricopa; at Elk Hills, its oil camps and the community of Tupman to the north; and at Paloma Ranch and the newly-seeded farm fields to the east. Bolstering the attackers were millions of meadow mice, a hardier specimen than house mice that had carried the attack before. Among the newcomers were numbers of exceptionally large individuals — a not uncommon situation after periods of inordinate increase.

Advancing to the southwest, mice killed a sheep and devoured the carcass in less than a day. A column slipped past poison-filled trenches to touch off an exodus of women from Ford City, an unincorporated community adjoining Taft. Another column captured the Petroleum Club golf course after token opposition from fleeing golfers. To the north, hordes swarmed over the Taft-Bakersfield Highway, where thousands were ground to death under car wheels, making the highway dangerously slippery.

It didn't calm those in the path of the squeeking mice when a University of California zoologist pointed out one pair of mice could in a year's time produce 16,146 mice, nor did it help when estimates placed size of the rodent army between 30 and 100 million mice, indicating attacking mice outnumbered residents of Taft by a conservative margin of at least 6,000 to 1.

While defenders feverishly cut new trenches, advice poured in from all quarters. The Army Chief of Chemical Warfare suggested use of poison chlorine gas. An Orange County woman suggested vats filled with water and lye be placed in the path of the mice. After mice had swam through, she said, they would lick their feet and die. A Rushville, Mo., man suggested establishment of a state colony of skunks. Skunks, he said, would soon clear out the mice —and the town, too, added a Taftian.

A federal poisoner from the Bureau of Biological Survey arrived on Jan. 22, 1927, to take command. His name was Piper — Stanley E. Piper—and he was a tall, serious man who took immediate offense at being hailed by newspapers as the Pied Piper. It was a joke he'd undoubtedly heard before for he had successfully turned back a smaller mice migration at Lovelock, Nevada, in 1907-1908. Piper set up a base

camp on Pelican Island in the northern portion of the dry lake bed, outfitted the camp with living quarters and cookhouse, and recruited a force of 25 men—promptly dubbed the Mouse Marines—to carry the battle to the rodents' redoubt.

Nature, as if belatedly mindful of an obligation to preserve its balances, provided unexpected help. More than a thousand ring-billed gulls appeared, diving out of the sky to destroy mice. Straggling companies of short-eared owls flocked into the mice redoubt, making nights at the Pelican Island base melodious with their clear calls. Ravens and hawks joined the airborne attack. Other birds participated in lesser numbers, including great blue herons, road runners, white-rumped shrikes and at least two golden eagles.

Beset by man and birds, mice fell back to short blind excavations little resembling their normal systems of runways and tunnels. Advancing exterminators found evidence of cannibalism in the mice army. Epidemic disease, believed caused by bacillus of mouse septicemia, suddenly spread through rodent ranks. The great mice war ended in mid-February with losses calculated at more than 30 million mice.

Such was life on the West Side: a wild well hailed as America's most spectacular gusher and a train that seldom arrived on time, blowout boxes that cleansed clothes and gales that flattened derricks, a bitter strike and a determined assault by mice. All, and more, are early chapters in the saga of the West Side's prolific oil fields and the communi ties they spawned.

AN INTRODUCTION TO THE FLORA AND VEGETATION OF THE WESTERN SAN JOAQUIN VALLEY[1]

ERNEST C. TWISSELMANN[2]

When one writes of the flora and vegetation of the Western San Joaquin Valley and the neighboring Tamblor Range for visitors from other regions, almost automatically Mary Austin's warning, written long ago, comes to mind:

"You will do well to avoid that range uncomforted by singing floods. You will find it forsaken of most things but beauty, and madness and death and God. Many such ranges quicken the imagination with a sense of purposes not revealed, but the ordinary traveller brings nothing away from them but an intolerable thirst."

It is safe to assume, I think, that the members of the American Association of Petroleum Geologists are anything but ordinary travellers. So it is a pleasure to introduce you to the flora and vegetation of one of California's lands of little rain.

Except briefly during spring, the route you will follow does, indeed, have little of interest for Mrs. Austin's casual visitor. But, for the more perceptive, the tour traverses an unusual and perhaps even unique region that presents a diversity of botanical and other phenomena with varied and often profound implications for other fields and disciplines. These seemingly monotonous plains and arid hills can richly reward the enquiring mind. With diverse soils, unstable climate, and history of rapid and continuing geological change, they are a singularly rich laboratory for the student of plant migration, evolution, and adaptation.

The flora is notable for its rapid and continuing development in response to increasing aridity. This process began, at least in the region the plants now occupy, no earlier than the Pliocene, when the entire region was submerged. Since that time, except for possible interruptions during the wetter and cooler periods during the Pleistocene, the California flora has developed as an assemblage of plants adapted to rapid growth in winter and tolerance for drouth, erratic climate, and fire. Much of this highly specialized plant assemblage developed in the highlands of northwest Mexico in the Tertiary and slowly migrated to the northwest. However, other species evolved through natural selection from ancestral boreal species in response to increasing aridity, a process that is actively continuing. A few originated as hybrids; these have drouth tolerant qualities possessed by neither of their ancient parents. Some of these ancestral plants that once grew together are now widely separated, others are extinct. Finally, a few, even in the arid San Joaquin Valley and the Temblor Range, are not adapted to drouth and survive only in very local highly favorable places.

The trend toward dryness has greatly accelerated since the close of the Pleistocene; considerable data supports the theory that the present extremely arid climate developed only in the last 1200 years. Evidence of this recently increased aridity is the relict flora of the Temblor Range. Shrubs that are common in the Coast Ranges to the west are often represented in the Temblor by only one or two isolated usually senescent colonies. These include the holly-leaved cherries *(Prunus ilicifolia)* in Temblor Canyon, wooly yerba santa *(Eriodictyon tomentosum)* that reaches its southwestern limits on Ross Ridge, and the only Kern County occurrence of two widespread coastal shrubs and one tree: the colony of California gooseberries *(Ribes califoruicum)* at Joe Messa Spring at the head of Black Canyon, the old fungus-ridden colony of toyon or Christmas berry *(Photinia arbutifolia)* in Don's Can-

[1]Manuscript submitted Feb. 1968.
[2]Rancher and Plant Taxonomist, Cholame, California.

yon, a fork of Cedar Canyon, and the grove of coastal live oaks *(Quercus agrifolia)* at Bill Little Spring in upper Chico Martinez Canyon. The original roots of the Bill Little oaks form a platform well above the present soil level, a measure of wind and other erosion during the life of the trees.

Less obvious although of far greater significance are a group of plants restricted to a narrow climatic belt along the lower eastern slope of the inner south Coast Ranges that extends far to the north, terminating at Corral Hollow in distant Alameda County. Cytogenetic and other studies show that these plants, typically smaller in all parts than the same species at only slightly higher and moister elevations, are not depauperate merely because of scant moisture but are the product of genetic drift, in which new species slowly develop from old ones. Many of the changes are not visible to the naked eye, but a few plants, such as the Temblor clarkia *(Clarkia tembloriensis)* have already emerged as distinct species with well established fertility barriers separating them from the closely related species from which they evolved.

Thus, the arid flora of the region is rich in evolutionary significance; a fuller understanding of the processes at work will have widespread implications not only for the botanist but in all fields of biology.

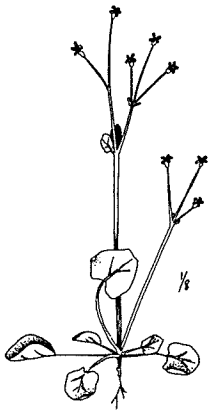
The vegetation of the San Joaquin Valley and the lower portions of the surrounding ranges is extremely xeric or drouth tolerant. Weather and climate, rather than soils or other factors, are by far the most important factors determining its character. As a result, it is a region of winter annuals that grow rapidly, flower early, and mature quickly. All of these are traits that enable the vegetation to use the scant rainfall to the greatest possible advantage. The native plants are largely colorful annuals, such as the sky lupine *(Lupinus nanus* var. *Menkerae)* that once formed a blanket of blue covering several thousand acres in the Arvin region southeast of Bakersfield, California poppy *(Eschscholzia californica)*, and the cheerful little yellow daisy, goldfields *(Baeria chrysostoma)*, and many others. The native flora was greatly supplemented soon after the coming of the white man by accidentally introduced annuals from the arid regions about the Mediterranean; several of the most common plants were originally immigrants. These include slender wild oats *(Avena barbata)*; the valuable little Arabian or sheep grass *(Schismus arabicus)*; that economic main-stay of the livestock industry, red-stemmed filaree *(Erodium cicutarium)*; and Russian-thistle *(Salsola Kali)* (the summer weed widely but erroneously called "tumble weed" in Kern County, that is only in part Russian and not at all a thistle); and the two most common grasses, common foxtail *(Horseum glaucum)* and red brome *(Bromus rubens)*.

Of these, Arabian grass has special interest. This important little grass was first found in California in the Kettleman Hills in the 1930's.

"Temblor Clarkia" "Arabian Grass"

While its exact mode of arrival is unknown, even that long ago Kettleman Hills had oil workers who travelled to the Near East and may have carried the seed home in their gear. Botanists had long wondered how the Mediterranean annuals could have spread so rapidly and become so thoroughly established so soon after the expeditions of the first Spanish explorers. The spread of Arabian grass furnishes an answer; it continued to be known only as a rare weed until the great drouth that persisted through the late 1940's. This extended dry period was highly favorable for this non-competitive but extremely drouth resistant annual of the dunes of the Near Eastern deserts. In a few short years, the species literally exploded and became common over hundreds of thousands of acres of arid California, Arizona, and northwestern Mexico where it is now an established and economically important part of the vegetation.

However, most of the annual plants of the upper San Joaquin Valley and the Temblor Range are not adapted to active growth in dry soil, unlike such true desert plants as the cactuses of North America and the euphorbias of Africa, few have special moisture conserving mechanisms. They succeed in this arid land by their ability to make rapid growth in the brief periods of favorable moisture and by intricate and not fully understood mechanisms that allow germination to take place in any favorable time but on a selective basis that insures against disaster for the species, whatever may happen to the unfortunate seedlings caught in an extended drouth. Some seeds will germinate with a half inch of rain, another group with an inch, and yet another following a two inch storm. Similarly, some will germinate only after warm rains, others only during cold storms. Thus, if drouth or other unfavorable conditions wipe out one crop, another and still another is always assured. It is said the soil at any time has a fifty year supply of wild oat seed.



"Temblor Buckwheat"

A few annuals are true xerophytes and thrive in seemingly completely dry soil. Your trip will take you down Chico-Martinez Canyon, the home of the few known colonies and the type locality of the annual Temblor buckwheat *(Eriogonum temblorense)* (located along the Carl Twisselmann ranch road on the east side of the canyon). This annual germinates late, grows after all the other plants have dried, and flowers when the bleak Chico Martinez slopes are at their most forbidding. If one accepts the dicta of plant physiologists, no plant can make active growth in soil so lacking in moisture as the slopes where this plant grows. (It is evident the buck-

wheat has not read the books or heard the lectures.) While it is not known for sure that the plant requires shale, at least five of the six known colonies do occur in fractured beds or in talus slides of this rock.

Another plant that has evolved a remarkable method for coping with drouth is the gypsum larkspur *(Delphinium gypsophilum)* (a misnamed plant that has no particular preference for gypseous soils), a perennial with tall white flowering stalks. Its venomous qualities make it the leading livestock killer of the region. Instead of growing and wilting in dry years, this tough-rooted perennial survives by its ability to remain dormant over long periods, forming leaves only in response to safe levels of soil moisture. During the great drouth of the 1940's staked plants at Olig (near McKittrick) failed to form even basal leaves for eight years; the ninth year had good rains and the plants formed basal rosette leaves before withering; 1952 was meterologically a vintage year; the marked plants grew flowering stalks more than two and one-half feet tall.

The California shrubby flora, which you will barely reach on your loop from Carneros Rocks to Chico Martinez Canyon, is not only xerophytic, or drouth adapted, it is also pyrophytic, or adapted to fire. This is especially true of the vast expanses of chaparral in the Coast Ranges, a vegetation rather feebly represented at the higher elevations of Messa Ridge. Most of the many chaparral species are shrubs that grow rapidly and are relatively short lived. Many are invigorated by fire and new growth from the roots of burned plants is prompt and vigorous. Fire-killed species have seed that germinates only after exposure to fire; seedlings that have not been seen for decades sprout prolifically following the first rain after a brush burn.

Finally, the vegetation is superbly adapted to grazing, even fairly heavy grazing. This is essential to encourage both the economically valuable as well as the scientifically interesting native plants. Poorly grazed lands are quickly taken over by such weedy annuals as rip-gut *(Bromus rigidus)*, wild oats *(Avena barbata* and *A. fatua)*, and various weedy members of the mustard family. This is not surprising when one considers the very large number of San Joaquin antelope and tule elk that roamed the region in primitive times, as well as the impact of grazing of animals that became extinct only during the late Pleistocene or perhaps even more recently. The devastating grazing common during prehistoric drouths can easily be imagined if one recalls that the mechanics of population control for the elk and antelope in such times was simple starvation.

The soils of the region are almost entirely derived from sedimentary rocks and are most rich and fertile. In arid regions, the native flora has a tolerance for a wide range of edaphic conditions; in regions with more rainfall plants can afford to be more demanding of their habitat. Thus, there are only a few plants with obligatory specialized soil requirements. The most obvious of these are the plants of alkali sinks that require sodium chloride or other alkaline salts; these are usually shrubby perennials with fleshy leaves. However, experimental plantings show that most of those that are found only in certain kinds of soil are not restricted because of any highly specialized soil needs but because they are unable to compete with the fast growing plants that are at home in better or richer soils. This is true of many of the plants of the alkali sinks that do not have fleshy leaves, including almost all of the "alkali" annuals as well as most of the annuals usually found on shale or sandstone with little top soil or those that seem to demand the peculiar qualities of gypseous soils. These gypsum-tolerating plants include one of the several local species of firewood or fiddleneck *(Amsinckia tessellata)*, San Joaquin blazing star *(Mentzelia pectinata)*, which color many slopes a rich coppery yellow when other plants have begun to dry, and yellow-flower *(Mentzelia dispersa)*, which is especially common in grain fields or other disturbed places with gypsum-bearing soil. Knowledge is lacking, but it seems certain most native plants have a tolerance for boron far greater than that of many commercial domestic plants; this may have complex implications for those developing farm lands in the new west-side irrigation districts.

But, unlike that of many other regions, the flora is orientated to its need to cope with an unpredictable supply of moisture. While many species are especially adapted for growth in soil with good, fair, or poor drainage, it doesn't usually seem to be of critical importance what sort of soil or rocks affords this drainage.

In summary, the region has an annual flora and vegetation, often colorful when in bloom, that is superbly adapted to the erratic climatic conditions of the region. Although part of it evolved from the Tertiary boreal flora that has now retreated to cooler moister regions, the greater part is derived from ancestral species that migrated from far to the southeast.

It is something of a challenge on a cold frosty day in mid-December to predict what floral displays will greet you in late March. Early rains give promise of the possibility of a spectacular spring, such as those of 1952 and 1958. On the other hand, early rains are often portents of extended drouths to come. But it is pleasant on this wintry day to think large thoughts and assume the hills will be a blaze of color for your visit. It is, of course, impossible to discuss or even list the approximately 844 kinds of plants that grow along your route. So all that will be attempted here is to note some of the more colorful or interesting ones. With this as an introduction, perhaps you will be inspired to get a copy of one of the references in the bibliography and come back another day for a holiday from geology as you become more intimately acquainted with the flora.

"Salt Bush"

The only widespread shrub on the valley plains is the common salt bush *(Atriplex polycarpa)*, in Kern County widely but wrongly called sagebrush (a plant not at all closely related to salt bush). This is the dominant shrub of the Lower Sonoran Life Zone in the upper San Joaquin Valley (and much of the arid southwest). It is the most important browse plant in its range for livestock, exceeding even alfalfa in protein content, is an excellent soil

holder in "blow" areas, and is vital for food and cover for wild life. This true desert shrub can endure the dryest of soils, becoming dormant not seasonally but when soil moisture is no longer available. On the other hand, in times or places with ample moisture, it grows luxuriantly. Just as most garden shrubs benefit from pruning, so do those in the wild from browsing by wild animals or domestic livestock. Thus, salt bush is an important element in the region's range economy.

"Gold-fields"

The first flower you will see in abundance when you leave the farm lands west of Buttonwillow is the cheerful little bright yellow daisy-like gold-fields *(Baeria chrysostoma)*. It is common in much of California, tolerating a wide range of soil conditions. Gold-fields is a rather poor competitor and thus is at its best in poor light soils, even those that are subalkaline, and is especially common following winters with less than average rainfall. It sometimes forms small golden blankets in shallow soil pockets on the rocks at Carneros.

"Red-stem Filaree"

Red-stemmed filaree *(Erodium cicutarium)*, a member of the geranium family and native to the deserts about the Mediterranean, was thoroughly naturalized in the San Joaquin long before the first settlers arrived. (John Fremont wrote of its abundance in the dry year of 1844 in the low foothills between what is now Porterville and Bakersfield.) The plant has decumbent to prostrate stems, small rosy pink flowers, and grows virtually everywhere in Kern County below the regions of severe winter cold. It is of prime importance to livestock people because the plant gives exceptional nutrition to the sparse grazing of the arid regions where it grows. In addition to its great nutritional value, it grows best when well grazed. Red-stemmed filaree has remarkable ability to develop depauperate seed-bearing plants in times of drouth; plants 1.5 inches tall produce viable seeds. However, in highly favorable situations, robust plants with stems 36 inches long develop.

Sky lupine *(Lupinus nanus* var. *Menkerae)*, a plant endemic to the upper San Joaquin Valley, in good years forms patches or even fields of bright blue on the higher plains. It is often abundant near the gate leading to Carneros Rocks.

No one will need to be introduced to the California poppy, our state flower *(Eschscholzia californica)* In favorable years, another and much more rare species grows in Chico Martinez Canyon. This is the Lemmon poppy *(E. Lemmonii)*, a plant of relatively barren or rocky soils in the inner south Coast Ranges. It can be distinguished from the California poppy by its larger yellower petals and the lack of a collar (tarus rim) below the flowers.

In the light well-drained soils on the arid hillside and locally on the valley floor hundreds of acres are covered with gray plants with bright yellow daisy-like flowers. These are the hilltop daisy *(Monolopia lanceolata)*. When one sees this flower in spectacular abundance in a good year on the west side slopes, it is difficult to believe that phytogeographically it is a plant of limited range, occurring primarily in the south inner Coast Ranges, and much less commonly through the upper San Joaquin Valley, becoming rare at the western borders of the Mojave Desert.

Two plants that occur widely in California but reach their greatest abundance on the slopes around the San Joaquin Valley are the common fireweeds or fiddle necks *(Amsinckia Douglasiana* and *A. intermedia)*. These species are about equally common in this region; their ranges thoroughly overlap. The somewhat larger and more intensely orange flowered *A. Douglasiana* is primarily a cismontane plant; *A. intermedia* a desert species. Both occasionally concentrate nitrates in the first good year following extended drouths; the results are serious for livestock people. A third Amsinckia, *A. vernicosa*, is a rare plant; it grows in shale in Chico Martinez Canyon and is occasional in similar places in the south Coast Ranges. This species can be distinguished from the others by its smooth almost glossy leaves and by the much larger flowers. In common with several plants of the

"Fiddleneck"
Amsinckia Douglasiana

interior, its range is probably limited by its extreme sensitivity to mildews prevalent in the less arid regions.

One of the striking floral displays at Carneros Rocks are the mounds of the buff flowers of the interior bush monkey flower *(Diplacus calycinus)* against the tan sandstone. Interior golden bush *(Haplopappus linearifolius)* is also common at Carneros and in the foothills generally; it is a viscid shrubby perennial often covered with yellow daisy-like flowers in the early spring.

"Bush Monkey-flower"

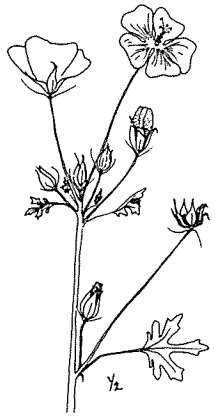
Blue-flower *(Phacelia ciliata)* grows in dense colonies in heavy soils at slightly higher elevations than your trip will reach. In a good spring, it and the hilltop daisy form the spectacular masses of blue and yellow for which the region is noted. Blue-flower prefers heavier soil with less sharp drainage than does the hilltop daisy, As a result, the two often form a pattern with the upper portions of a hillside brilliant yellow and the lower part solid blue.

Beautiful designs are often found, sometimes with a pattern of varied checks, lines, or angles, all of which are caused by differences in soils.

In good years, large colonies of light yellow marigold-like flowers

"Wild Marigold"

grow in the valley in light sandy soils; these are particularly common between Carneros and Middlewater and in the wind-deposited soils in the Belridge region. This is the wild marigold *(Malacothrix californica)*, closely related to the widespread species that grow in similar soils in the Mojave Desert; both are probably recent derivatives from the same ancestor (although the Mojave plant also occurs in the valley at such places as Sand Ridge near Edison and at Blackwells Corner, and hybrids between the two have not been observed).



"Parry Mallow"

Parry mallow *(Eremalche Parryi)*, known in the west side oil fields as farewell-to-spring, a name generally used for an unrelated plant, is another dweller in wind-modified soils. This plant with prostrate stems blooms after all the other annuals are nearly dry, often in great drifts of lavender-blue. A white-flowered species, *Eremalche kernensis*, probably originally a hybrid between a species now confined to the Mojave Desert and Parry mallow, is a rare endemic, known only from small colonies along Salt Creek south of Belridge and from the Soda Lake region of San Luis Obispo County.

In fairly heavy soils with more than average moisture, especially on the flats below Carneros Rocks, you may see colonies of owl's clover *(Orthocarpus purpurascens)*, a plant with dense spikes of rosy pink flowers. Tom-cat clover *(Trifolium tridentatum)* is common everywhere but is most common in good rich soils; this is one of the important forage plants of the region. The yellow flowered bur clover *(Medicago hispida)* is a European immigrant that is also common and important livestock feed.

As you travel up Messa Ridge from Carneros Rocks and swing

"Tom Cat Clover"

back down Chico Martinez Canyon, you will note that many of the hillsides, particularly the rocky ones, are densely covered with low gray shrubs. This is the extremely drouth tolerant gray California buckwheat, that occurs from the Temblor Range and Cuyama Valley east to the Mojave Desert. This plant, with three distinctive varieties, is a classic example of evolutionary adaptation for drouth. The typical variety grows only along the coast; there the leaves are larger and green and microscopic examination will show that both the lower and upper leaf surfaces have stomata that transpire moisture and absorb air. The second variety, occurs away from the heavy rainfall belt of the immediate coast, extending inland to such regions as the northern Temblor Range. This form has slightly smaller leaves that are green above but are gray below. All of the stomata are on the lower surface, a moisture conserving character for arid climate. Finally, the desert gray form has leaves that are quite small and are gray on both surfaces. There are very few stomata and the edges of the leaves are curled downward to protect these from hot dry winds. The coastal plants are undoubtedly the ancestral form. With the passage of time, selective genetic processes will further isolate the interior forms, and all three varieties will eventually become established as distinct species.

Another perennial Eriogonum, the McKittrick buckwheat, is a plant of bare, graded, serpentine, or other unusual or peculair soils of the inner south Coast Ranges from Merced County south to Maricopa. This perennial with markedly inflated stems reaches by far its best development with a noteworthy colony of robust plants on the otherwise barren asphaltic soil just west of McKittrick; it is easily observed from the Taft-McKittrick highway. (The wild buckwheats are the plants most typical of arid western North America; the west has at least 160 species; more than 103 grow in California and 46 in Kern County. From the desert plains to the subalpine peaks, at least one and often several grow in practically every plant association except the alkali sinks and the marshes.)

One of the widespread San Joaquin Valley perennials you will see throughout your trip is black loco *(Astragalus lentiginosus* var. *nigricalycis)*, a variety endemic to the upper San Joaquin Valley. This mounded plant with decumbent to prostrate stems survives as a result of its very deep and extensive root system and by promptly responding to even light rain, often blooming in January. It is a member of a remarkably plastic species of the western United States; there are more than forty named varieties in the complex, occupying such diverse habitats as the San Joaquin Valley, the deserts, and extending even to the alpine regions of the western mountains. While each of the many varieties of *Astragalus lentiginosus* is distinct enough in its typical form, all merge impercetibly at the borders of their ranges. The species demonstrates the remarkable ability of one genetic pool to furnish forms for coping with many different soils, climates, and other factors.

Along your route you may see scattered colonies of the bushy Diablo loco *(Astragalus oxpyhuysus)*; unlike black loco, which furnishes excellent forage, Diablo loco is poisonous to livestock. Despite

decades of control, it is still fairly common on the high plains along the borders of the valley. A third Astragalus is the lavender flowered annual dwarf loco, often abundant on the west side plains. This little plant, which superficially resembles a vetch, is one of the prime forage plants of the region. It does best in years with early, heavy rains and warm winters.

A single shrub of the Mojavean Cooper desert thorn *(Lycium Cooperi)* grows just off your route near Gould Hill; it is also rare in the Elk Hills. This is an example of a Mojavean shrub with isolated San Joaquin Valley occurrences. Such occurrences of Mojave plants in the valley are unusual; this is somewhat surprising when one considers the similar low rainfall of these two desert regions and the easy path Tehachapi Pass offers for plant migration. There are a number of reasons for this scant representation of species of the Mojavean flora west of the mountain crest. First, the evolution of the San Joaquin desert flora is recent and neither its flora or fauna is yet stable. That of the Mojave Desert probably became well established sometime early in the Pleistocene; the Mojave was a relatively arid region even in the Pliocene. Secondly, the winter climate of the San Joaquin Valley is warm; that of the nearby Mojave is cold and not conducive to early plant growth. Finally, there are substantial differences in the qualities of the sedimentary soils of the valley and the coarser less fertile ones of the Mojave Desert.

In the late spring, when most of the annuals are dying, the sticky odorous San Joaquin tarweed *(Hemizonia pallida)* often grows around the valley borders and the neighboring low hills densely enough to color large areas pale yellow. This species is closely related to the Red Rock tarweed, known only from one small colony along the seep above the freeway in the Mojave Desert's Red Rock Canyon. One can easily speculate that the Red Rock tarweed was widespread in the Mojavean woodland of the Pliocene and was progressively restricted by increasing aridity until finally only the one station remains. It is most likely that the San Joaquin tarweed and the Red Rock plants evolved from a single species as a result of isolation by the uplift of the Tehachapi Mountains.

Other colorful plants include baby blue eyes *(Nemophila Menziesii)*; in wet years colonies are locally common on the flats between Middlewater and Carneros. Its intense blue flowers have been called "bits of the sky drawn down to the earth." Scattered colonies of the pale to rich yellow cream cups *(Platystemon californicus)* grow in favorable places. Just west of Carneros Rocks, as you start up the grade, is an extensive colony of a rare mariposa tulip, perhaps not yet quite in bloom, which has petals that are a deep yellow of unusual depth and clarity. Another member of the lily family is blue dicks or pignut *(Brodiaea pulchella)*, common in medium to heavy soils. Colonies of a deep violet wild onion *(Allium peninsulare)* grow on shaded north slopes.

These, then, are some of the colorful, interesting, or important plants you may see if the winter rains are good. While the spectacular displays of the Temblor and upper San Joaquin Valley spring wildflowers are notable throughout California, of more permanent interest are the plants' intricate, complex, and poorly understood mechanics for adaptation and speciation for survival in a generally hostile environment. The flora and the vegetation are highly specialized; in order to cope with the region, man and his economy has had to become equally specialized and adaptable. It is hoped that this brief and inadequate introduction will spur your interest to develop a further and more intimate knowledge of the plants of California's lands of little rain.

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PETROLEUM PAPERS

HABITAT OF OIL ON THE WEST SIDE, SAN JOAQUIN VALLEY, CALIFORNIA[1]

DAVID C. CALLAWAY[2]

INTRODUCTION

The area to be discussed is designated the "West Side," and is defined as that portion of the San Joaquin Valley bounded by the Coalinga Oil Field on the north; the San Andreas Fault Zone on the west; and on the east and south by a line from the northeast tip of Coalinga, through the east edges of Kettleman Hills, Lost Hills, Elk Hills and Midway Sunset, then due south to intersect the San Andreas Fault. Geologically the discussion is restricted to the time interval from the beginning of Upper Eocene to the beginning of the Pleistocene.

GEOLOGY

DISCUSSION

The San Joaquin basin of deposition in the past was probably very similar in size and shape as today's basin would be if water covered the valley floor. The sediments deposited were either shales or sands. The shales are rarely found to be fissle, but generally fall in a siltstone, claystone, mudstone category which can be siliceous, cherty, calcareous or diatomaceous. The sands range from conglomeratic to silty often wedging out into the basin and shaling out laterally.

UPPER EOCENE AND OLIGOCENE

The source of sediments on the "West Side" of the San Joaquin Basin during Upper Eocene time was the southerly extension of the Diablo Uplift adjacent to the San Andreas Fault between Townships 23 South and 28 South. The basin had two access routes to the ocean; Murray A. Nadler, Consulting Geologist (personal communication October 1961), the shallow and narrow Vallecitos Channel to the north and the very deep Taft Trough to the south in the area of Townships 32 South, 12 North and 11 North; and Range 23 East.

The western edge of the basin was quite steep sided and deep in the Coalinga area. A thin, shallow shelf in the Jacalitos/Reef Ridge area quickly expanded to approximately 20 miles in width and apparently extended as far east as Lost Hills, South Belridge and Railroad Gap. The shelf dropped off to rapidly deepening water along a northwest to southeast line south of Belgian Anticline. Deposition of Upper Eocene Point of Rocks thick regressive beach sands, was restricted to this wide shelf. This was followed by basin subsidence and the laying down of transgressive Upper Eocene Kreyenhagen Shale, and apparently without interruption, Oligocene Tumey Shale. Two Oligocene sands are found on the "West Side." A bar type deposit, the "Oceanic" sand, occurs on the shelf in an area running from North Belridge to Belgian Anticline. To the north, between Coalinga and Kettleman Hills, the regressive "Leda" sand is found at the top of the Oligocene. Uplifting adjacent to the San Andreas Fault at the end of the Oligocene was locally severe, raising and extending the Diablo Uplift much farther to the north. It caused severe deformation in a small area centering in the east half of Township 29 South, Range 21 East and the vicinity of the Belgian Anticline. Portions of the Coalinga Nose and western Jacalitos were affected to a lesser degree. On the western margin of the basin (i.e. the south flank of Shale Point), the unconformity onlapped by younger sediments may be the result of this uplift. (See Plate I)

LOWER MIOCENE

As the basin subsided, the initial Miocene sedimentation occurred in the Kettleman Hills area. The basal Vaqueros sands were quite likely furnished by the Vallecitos Channel. Their transgressive onlapping was followed by "Salt Creek" shale deposition. To the south, where the "Salt Creek" shale overlies older beds, a thin sandy grit locally represents the base of the Miocene. The shallow shelf that existed during the Upper Eocene was again evident after the basin was completely submerged. The shelf was covered by regressive "Phacoides" sands. On the outer shelf edge the "Phacoides" is composed of three members, each regressive, each terminated at the top by a local transgressive shale. At North Belridge, these three members are known as the "Bloemer," "Belridge 64" and "Gibson" sands. The "Phacoides" was overlain by the transgressive "Lower" Santos shale which was then followed by a remarkedly similar regressive cycle that deposited the Agua sand. On the outer edge of the shelf, the Agua, like the "Phacoides," is also composed of three sand members. At McDonald Anticline they are called the "2A," "Upper" Agua and "Lower" Agua sands. The "2A" sand was overlain by transgressive "Upper" Santos shale.

Prior to the end of the Lower Miocene, brief severe uplift occurred on the basin margins. Strong local uplifting, compression and erosion took place from Pyramid Hills to Shale Point, at Belgian Anticline, and at the West Recruit Pass area of the Temblors. The inner basin area centered around Beer Nose and North Belridge was much less affected. The basin subsided and Carneros sand was deposited.

On the northern portion of the shallow western shelf, the lower Carneros sands are transgressive and the upper sands are regressive. A misidentification of sands is found in the literature concerning the basal, transgressive Carneros sand at Blackwells Corner. The sand has been

[1]Manuscript submitted Feb. 1968.
[2]Atlantic Richfield Oil Company, Bakersfield, California.

called Agua, but both paleo and depositional environment appear to refute this. To the south, in the neighborhood of Cymric and Santos Creek, the character of the Carneros sand changes. It has the appearance of a channel sand and a channel environment is reasonably inferred for the area of deposition south of the surface McDonald Anticline. Further to the south, the Carneros (Temblor) again changes to a deltaic deposit on the fairly steep flanked basin edge, due west of Midway Sunset. Widespread subsidence ended the Lower Miocene with transgressive Media Shale deposition. At the end of the Lower Miocene, uplift occurred which elevated the area west of Reef Ridge and Coalinga and was locally quite severe, affecting the innter basin from Elk Hills to Coalinga.

MIDDLE MIOCENE

The Diablo Uplift and a small, local high area at Shale Point were sources of Middle Miocene sediments.

The Vallecitos Channel, although still open, may have been very shallow and narrow. The Taft Trough, which became somewhat constricted at the end of the Lower Miocene, widened and deepened during the Middle Miocene.

The shallow "West Side" shelf shifted slightly to north and became severely reduced in width from North Belridge to Pyramid Hills. In the area of Kettleman Hills, where the persistent basin "deep" had previously occurred, a cross basin shelf developed. This very shallow shelf, almost a tidal flat, had an edge coincident with the present Fresno/Kings County boundary line.

Deposition of the basal Middle Miocene was transgressive. Gould shale and the "Buttonbed" sand onlapped the Lower Miocene. The term "Buttonbed" sand is commonly applied to the sand locally found at the base of the Middle Miocene and associated with buttons of *Scutella merriami*. This type of usage is misleading as the basal "Buttonbed" sand in one place may be the third sand up from the base in another place due to onlap. The transgressive phase during which Gould shales and sands were deposited, shifted to a regressive phase and deposition of Devilwater shales and sands took place. The Middle Miocene transgressive sands may have been cannibolized from adjacent uplifted Carneros sands in the Pyramid Hills/Devils Den area.

At the end of the Middle Miocene, the northern portion of the basin edge, from Devils Den to Coalinga, was uplifted and eroded. The southern portion of the basin edge, between the San Andreas Fault and the Belgian Anticline, and between the San Andreas Fault and Midway Sunset, was also subject to intense uplifting and erosion. Accompanying these two areas of uplift was a general downwarp through the McDonald Anticline and Shale Point area.

UPPER MIOCENE

Sediments of Upper Miocene age were derived from the Temblor Uplift between the San Andreas Fault and the Belgian Anticline and Midway Sunset Fields. This source contributed large amounts of clastic sediments throughout the Upper Miocene. The Diablo Uplift to the north contributed little or no clastics to the basin at this time. With uplifting adjacent to the San Andreas, the Taft Trough was closed off and the channel shifted to the north through the McDonald Anticline/Shale Point downwarp. The shallow northern portion of the basin effectively closed the Vallecitos Channel. The western edge of the basin was relocated during the Upper Miocene to what had previously been the bottom of the basin. The old, "deep," portion of the basin became a steep flank on the southwest.

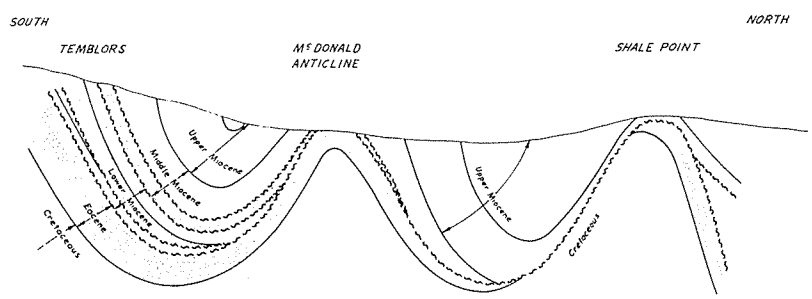
Deposition in the southern portion of the "West Side" during the Upper Miocene consisted of localized minor river deltas which fed coarse clastics into the basin as the deeper portions filled with McDonald and Antelope shale. To the north, McClure shale (i.e. Antelope shale and McDonald shale equivalent), filled the basin. Continued and increasing rates of uplift adjacent to the San Andreas dumped massive amounts of Spellacy/Monarch sands and conglomerates onto the basin flank while Upper Antelope shale filled the remainder of the basin. Local minor river channels redeposited cannibolized Spellacy sands in the Midway Sunset area.

Toward the end of the Miocene, minor uplift and erosion began before Reef Ridge Shale was deposited. After Reef Ridge Shale deposition, uplift reached a maximum that marked the end of the Miocene. It caused extensive and severe basin edge deformation in the Midway Sunset/Elk Hills/Cymric area. The centers of uplift which had a general northward movement during Lower and Middle Miocene shifted back to the south at the end of the Miocene.

PLIOCENE

The Temblor Uplift area remained the major source area for sediments of the Pliocene and Pleistocene. The opening to the ocean migrated farther north to occupy a position approximately between Pyramid Hills and Kettleman Hills. The southwest edge of the basin had a fairly uniform and shallow slope.

Deposition during the Pliocene was generally transgressive as the basin filled with Etchegoin and San Joaquin sands and shales which overlapped Miocene sediments. A minor exception to this was the del-



DIAGRAMMATIC SECTION ACROSS McDONALD ANTICLINE AND SHALE POINT

Plate I

taic Olig/Potter sand deposited between Belgian Anticline and Cymric.

The period of uplift at the end of the Pliocene represented the final phase of uplift and erosion in this basin and resulted in the withdrawal of the sea.

OIL ENTRAPMENT

Oil traps on the "West Side" are found on almost every buried structural anomaly with available porosity.

Oil is structurally trapped on closed anticlines and on faulted homoclines and noses. It is stratigraphically trapped on the flanks and noses of anticlines, in the bottom of synclines, and on monoclines where the productive sands are open to outcrop.

STRUCTURAL TRAPS

Structures within the "West Side" are both tightly and broadly folded and tend to be assymetrical. These structures are the result of locally severe, uplifting adjacent to the San Andreas Fault. Crustal shortening and structural growth is caused by a combination of basin subsidence parallel to the basin edge and compression perpendicular to the axis of the basin.

SUBSIDENCE as restricted to the shallow "West Side" shelf, whether called subsidence or compaction, is considered an example of deposition that controlled deformation and instigated the formation of anticlines such as North Belridge, Cymric, Northeast McKittrick and Elk Hills.

COMPRESSION as reflected by tightness of folding is directly related to proximity to the San Andreas Fault. Laterally, along the fault, severity of faulting pinpoints the area of maximum compression. On the south, in the vicinity of Midway Sunset, Buena Vista Hills and Elk Hills, faulting is un-important to non-existent. In the center, from Belgian Anticline to Pyramid Hills, faulting dominates. Thrust faults generally parallel to structural trends, as well as high angle normal faults perpendicular to structure, complicate intensely folded areas. The thrusting is usually south over north on south structural flanks, and north over south on north structural flanks. On the north, from Lost Hills to Coalinga, faulting again becomes rare, although there is a profusion of exposed tension faults at Kettleman Hills.

Examples of structural traps as found on the "West Side" are:

CLOSED ANTICLINES—Buena Vista Hills, Elk Hills, North Belridge, Lost Hills, Kettleman Hills.

FAULTED HOMOCLINES — Antelope Hills, Cymric Sheep Springs, Belgian Anticline.

FAULTED NOSES—McDonald Anticline, Cymric Salt Creek, Northeast McKittrick, Belgian Anticline.

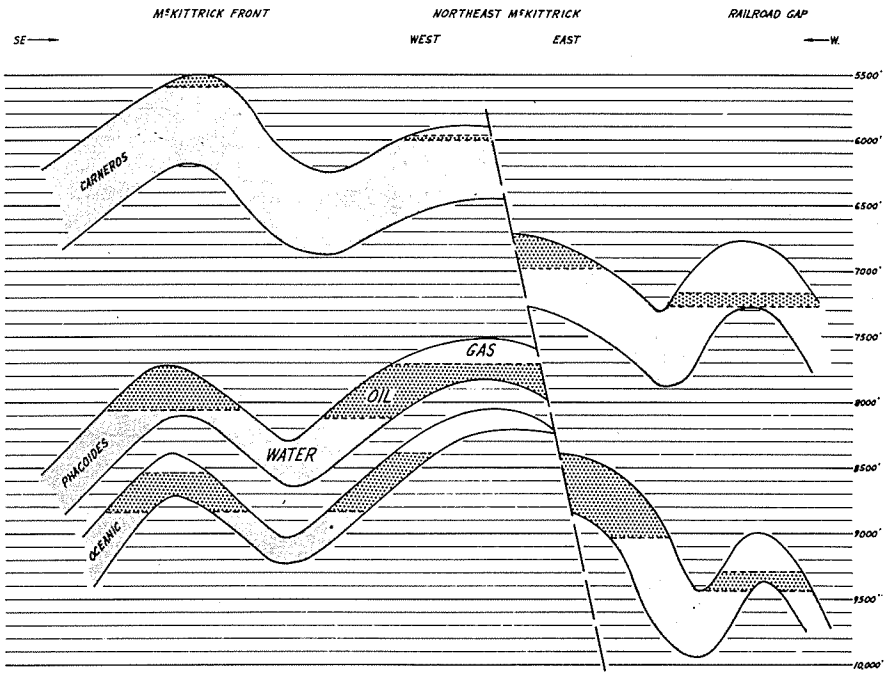


Plate II, DIAGRAMMATIC CROSS SECTION

STRATIGRAPHIC TRAPS

From the flanks and noses of anticlines to the bottom of synclines, the complete gamut of stratigraphic traps is represented on the "West Side." Shale out, wedge out, buttress or onlap, offlap, truncation and permeability barriers, are all to be found. A few examples are:

TRUNCATION ACROSS FLANKS OR NOSE — Buena Vista Hills ("555" Pool), North Antelope Hills, Belgian Anticline, Asphalto.

ONLAP—Midway Sunset (Pliocene Pool), Antelope Hills.

SHALE OUT—Midway Sunset (Republic Pool), McKittrick (Asphalto sand).

SYNCLINAL—Midway Sunset (Potter sand), (Lakeview sand).

PERMEABILITY BARRIERS — East Coalinga.

Statistically, the structural entrapment of oil is more important than stratigraphic entrapment. Plate II indicates that 4.4 billion barrels* of oil has been produced from "West" Side oil fields, and 2.0 billion barrels, or 44% is directly related to unconformities. This 44% can be broken down to the percentage of production that is directly related to the following periods of uplift.

a. Post Oligocene/pre Miocene	2.2%
b. Middle Lower Miocene	1.0%
c. Post Lower Miocene/pre Middle Miocene	14.3%
d. Post Middle Miocene/pre Upper Miocene	trace
e. Post Miocene and post Pliocene	26.5%
Total	44.0%

The high percentage of oil related to the Post Miocene and Post Pliocene Uplifts are the result of the better reservoir preservation that would occur in onlapping beds deep in the basin.

**Gas quantities have been converted to oil quantities on the basis of value using an average value of $3.00 per barrel of oil and $.30 per Mcf of gas. Thus, 10,000 Mcf of gas equates to 1000 barrels of oil.*

OIL MIGRATION AND ACCUMULATION

On the assumption that oil is formed soon after sediment deposition and compaction and is then rapidly concentrated in a water filled porous media (primary migration), its subsequent movement (secondary migration is subject to hydrodynamic forces (Gussow, 1967). The force of bouyancy is initially the most important hydrodynamic vector.

In the circumstance of the deposition of a porous sand body on a shallow shelf, there is a subsiding structural condition between the shore line and the hinge line of the

shelf that is caused by the weight of the sediments being deposited. Subsidence here may be coincident with compaction. When oil within the porous sand becomes movable, secondary migration acting under the force of bouyancy, will be toward the high shore line (Hoots *et al*, 1954), and the high hinge line. Shore lines are usually subject to repeated uplift and erosion which generally eliminates the oil traps that are nearest to the shore line. Traps along the hinge line are most commonly preserved. The hinge line, a high and therefore general focal point or focal area for oil to migrate to, may be broken into numerous smaller local areas by basin deformation, perhaps the same deformation that allowed the oil at the shore line to escape. These primary traps are affected by later basin deformation and hydrodynamic activity that causes readjustments to, and in rare cases, escape from the traps. The larger oil accumulations of the "West Side" are related to the hinge line.

The migration of oil after initial accumulation is perceived in many oil fields and pools. The best known example is the East Coalinga Oil Field. This two domed oil field with a common oil water interface, had gas trapped in the northern, downdip dome, 1600′ below the top of the southern dome where there is no gas trapped. A north tilting, 90 ft/mile, hydraulic gradient has modified the oil accumulation. According to Gussow gas and oil moved into the northern dome first and then overfill oil spilled into the higher southern dome. Later hydrodynamic activity again moved the oil.

Hydrodynamic movement of oil is quite common throughout the "West Side." This movement is generally evidenced by a tilt of the oil/water interface. At Midway Sunset, in Section 18, Township 32 South, Range 23 East, five wells are producing from the Upper Miocene Republic sand on the small anticlinal closure known as the Westates Pool. The Republic sand outcrops less than 4000′ from this pool. A good case can be made to indicate a very steep northeasterly dipping oil/water interface, which would be very logical if water flowed from the outcrop and across this structure.

The McKittrick Front (Weddle, 1966), Northeast McKittrick (Weddle, 1965), Railroad Gap (Hardoin, 1965) structural trend is another example of oil migration after accumulation. These three anticlinal fields lie in a general west to east alignment. Fault complexities divide Northeast McKittrick, the central field, into the west and east halves. The Lower Miocene Carneros and "Phacoides" producing horizons are common to all three fields (all four accumulations). Oligocene "Oceanic" sand occurs only to the McKittrick Front and Northeast McKittrick (west) Fields.

OIL FIELD	POST OLIGOCENE	POST MID. L. MIOCENE	POST L. MIOCENE	POST M. MIOCENE	POST MIO. & PLIO.	CUM. PROD. TO 1-67
	MILLIONS OF BARRELS					
Midway Sunset					855.9	1008.2
Buena Vista Hills					23.7	652.0
Elk Hills			*	*	1.0	291.6
Asphalto					17.4	17.4
Belgian Anticline	28.8		*	*		50.4
McKittrick					119.3	119.3
Railroad Gap			*	*	.1	5.4
McKittrick N.E.			*	*	1.0	15.2
Cymric Welport	27.0				26.9	58.1
Salt Creek						20.1
Sheep Springs	1.1				2.2	4.7
Temblor and West Salt Creek	3.8					3.8
South Belridge					124.6	124.6
North Belridge		12.6			6.1	68.2
McDonald Anticline	3.3		3.0		*	9.5
Antelope Hills	*		12.0		*	12.1
N. Antelope Hills	*		3.0		*	3.0
Blackwells Corners		1.0			*	1.0
Pyramid Hills, Devils Den		*	2.0	2.0		7.0
Lost Hills						109.1
Kettleman Hills		29.4				715.3
Guijarral Hills	36.3					53.3
Pleasant Valley	*					13.2
East Coalinga	*	*				453.1
Coalinga		*	590.2			590.2
Jacalitos		*	22.3			22.3
Totals Percent	100.3 2.2%	43.0 1.0%	632.6 14.3%	2.0	1178.2 26.5%	4428.1

PLATE III Chart relating production from "West Side" oil fields to associated periods of uplift.

* Denotes uplifting & erosional affects, but no associated production

From Plate III, a diagrammatic cross section through these fields, two relationships can be seen:

1. The McKittrick Front Field has no gas cap in the Carneros sand even though it is structurally higher than Northeast McKittrick (west) which has a thin gas cap. This same relationship occurs in the Carneros and "Phacoides" sands between Northeast McKittrick (east) and Railroad Gap.

2. The oil and gas column at Northeast McKittrick in the "Phacoides" sand is much greater than at either McKittrick Front or Railroad Gap and the oil and gas column at Railroad Gap in the Carneros sand is much greater than at the other two fields.

These observations can be interpreted to show that hydrocarbons migrated into Railroad Gap first. When that structure filled with gas, overspill was into the higher Northeast McKittrick field and from that into McKittrick Front. In the time between the filling of the Phacoides and the Carneros, uplift and faulting probably occured which allowed some "Phacoides" oil at Northeast McKittrick to spill back into the enlarged Railroad Gap structure. Faulting then prevented Carneros overfill oil at Railroad Gap from getting to Northeast McKittrick (west).

The consideration of early oil migration with regard to the presence of structural high areas has provoked the following observation: Structural trends such as Kettleman Hills/Lost Hills, North Belridge/South Belridge and Pyramid Hills/Blackwells Corner all have a common denominator; the northern ends of these structural trends have oil trapped in the older beds while the

southern ends have oil trapped in younger beds. This relationship suggests that these structural trends have persisted throughout a long period of time, but the emphasis of the relative high area within trends has shifted, through time, from north to south.

COMMENTS

The previous statement that oil traps are found on almost every buried structural anomaly with available porosity must now be qualified. There have been a number of dry holes drilled in places that were good traps with good reservoirs present. In light of today's knowledge and theories on oil exploration, these dry holes were assumed valid tests and a theory was developed to explain why the oil wasn't there. Excuses like "late structure," "leaky reservoir," "poor oil source," and "hydrodynamically wrong" are still employed for prospects i.e., Lower Miocene sands on Beer Nose, Spellacy sand on Globe Anticline (Callaway, 1962), Carneros sands on the McDonald Anticline flank, and the "Oceanic" sand at Cymric Salt Creek. Perhaps these reasons are valid or maybe newer theories will turn these "dry" traps into oil fields.

In some multizone oil fields (i.e., Cymric/Welport, Northeast McKittrick, Elk Hills and Midway-Sunset), there is a tendancy for areas of shallow production to appear as a "halo" surrounding deeper structures. These "halos" represent stratigraphic traps due to truncation or shale out or decrease in permeability. In some cases "halos" were evident for years before deeper investigation was attempted.

After review of "West Side" oil fields, it becomes obvious that structure plays the major role for oil and gas accumulation.

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OILFIELD WATERS IN SOUTHWESTERN SAN JOAQUIN VALLEY, KERN COUNTY, CALIFORNIA[1]

JAMES R. WEDDLE[2]

INTRODUCTION

This investigation covers the waters of the oil fields that lie in a narrow band about 75 miles long and 10 miles wide along the southwestern side of the San Joaquin Valley, Kern County, California. The towns of Maricopa, Taft, and McKittrick are within this area and are connected by State Highway 33 which traverses it lengthwise (Plates I and II).

The following illustrations accompany this report:

Plate I. Location map

Plate II. Map showing distribution of water samples analyzed

Plate III. Map showing water analysis graphs for the Etchegoin formation

Figure 1. Composition of selected waters with Tickell analysis graphs

Figure 2. Graph showing salinity vs. depth for selected fields

Figure 3. Water production and injection graphs

The author expresses his appreciation to the operating companies for making their water analysis data available and to Carl Fieber, chemical engineer of Standard Oil Company of California, for his advice.

REVIEW OF LITERATURE

Few papers have been written on the subject of oilfield waters in the southwestern San Joaquin Valley. Several early reports on oil fields include some mention of the occurrence and composition of the brines; most important of these is one by Rogers (1919). Tickell in 1921 presented a paper on a method for the graphical interpretation of water analysis, in which he used examples from the Midway-Sunset region. In 1934 Jensen wrote on California oilfield waters and discussed, among others, some of the fields covered by this paper. Little was written until 1961 when Bailey and others covered the composition of a few oil zone waters in Cymric field.

METHODS AND DEFINITIONS

Presented in Table 1 are composite or average values from analyses of oilfield zone waters tabulated by fields, areas, and zones. These analyses were obtained from the files of the California Division of Oil and Gas and oil companies. The samples are average in all respects as they have been taken over a wide range of time, conditions, and methods, and have been analyzed by a num-

[1]Manuscript submitted September 1967; this report is also presented in California Division of Oil and Gas, Summary of Operations—California Oil Fields, Vol. 53, No. 1.

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TABLE 1

ANALYSES OF OIL ZONE WATERS

Field / Area / Zone	Formation or member	Anions (parts/million)				Cations (Parts/million)			Boron (ppm)	Total solids (ppm)	pH	Resistivity ohms/M at 77°F	Salinity g/g NaCl	Number of samples
		Chloride	Sulfate	Carbonate	Bicarbonate	Sodium + Potassium	Calcium	Magnesium						
Antelope Hills														
Tulare	Tulare	483	66	0	1,098	710	29	8		2,394	8.2	3.350	47	1
IA Gas	Devilwater-Gould	4,300	29	174	2,379	3,787	14	15		10,699	8.4		414	1
Button Bed	Temblor	2,540	95	86	2,498	2,674	32	12		7,936			244	2
Agua	Temblor	1,533	144	195	2,797	2,353	19	7	4	6,500	8.6	1.176	148	7
Antelope Hills, North														
Agua	Temblor	11,307	0	0	2,373	7,862	112	64	48	20,222	7.5	0.306	1,088	2
Asphalto														
Stevens	Stevens	13,145	34	0	3,821	9,863	71	37	114	26,929	7.7	0.263	1,266	15
Belgian Anticline														
Main, R-K, and Telephone Hills Areas														
Phacoides	Temblor	8,036	26	97	1,701	5,775	122	37	84	16,033	8.1	0.291	773	5
Oceanic	Tumey	7,083	30	0	2,179	5,093	245	77	91	14,871	7.9	0.365	682	7
Point of Rocks	Kreyenhagen	999-10,922	7-87	0	307-3,574	655-6,443	88-1,044	9-70	20-225	2,347-18,658	6.7-8.2	3.100-0.328	96-1,053	10
Northwest and Forbes Areas														
Phacoides	Temblor	10,992	5	0	689	6,776	360	88	44	19,078	7.7	0.322	1,059	2
Oceanic	Tumey	10,362	51	0	750	6,263	508	94	70	18,071	7.0	0.335	998	2
Point of Rocks	Kreyenhagen	11,160	75	0	474	5,763	1,256	104	165	19,024	7.0	0.329	1,074	5
Belridge, North														
Fractured Shale	Antelope	22,642	14	0	1,111	14,817	150	66		38,845			2,188	2
Temblor	Button Bed	24,379	737	0	686	14,648	1,111	228		41,951	6.5		2,347	8
Bloemer	Phacoides	12,855	819	0	685	8,476	356	44	tr.	23,295			1,239	3
Belridge 64	Phacoides	12,144	624	0	725	7,664	355	57		21,790	7.5		1,167	13
Y Sand	Oceanic	5,079	9	0	1,227	3,633	70	24	33	10,042	7.8	0.490	494	1
Belridge, South														
Upper Tulare	Tulare	2,719	147	94	1,701	2,277	40	113		7,099	8.0	1.062	262	18
Lower Tulare	Tulare	10,338	15	0	2,929	6,986	180	261	54	20,832	6.9	0.398	995	15
Etchegoin	Etchegoin	14,950	8	4	645	9,015	298	262	32	25,590	7.6	0.230	1,452	2
Belridge Diatomite	Monterey	19,518	59	0	5,120	13,093	716	373		38,878	7.5		1,520	5
Fractured Shale	Monterey	14,940	27	0	7,236	12,192	99	67		34,562	7.5		1,440	4
Blackwells Corner														
Agua	Temblor	8,191	19	0	3,404	5,877	192	269		17,978	7.3	0.410	788	1
Buena Vista														
Front														
Sub-Scalez	San Joaquin	19,729	20	0	343	10,968	1,053	403	35	32,699	7.2	0.201	1,900	12
Mulinia	Etchegoin	21,712	34	0	364	11,706	1,473	450	40	35,760	7.3	0.181	2,091	3
Hills														
Sub-Scalez (Top Oil)	San Joaquin	21,296	11	0	484	11,700	1,122	534	24	35,177	7.1	0.189	2,055	25
Sub-Mulinia	Etchegoin	24,678	59	0	262	12,992	1,691	634	54	40,317	7.2	0.162	2,340	1
Wilhelm-Gusher	Etchegoin	20,489	148	0	240	11,658	1,046	356	53	34,080	7.3	0.190	1,985	4
Calitroleum	Etchegoin	20,055	14	0	690	12,250	513	238	40	33,799	7.3	0.195	1,929	11
99-9D	Etchegoin	16,271	273	0	709	10,144	439	159		27,995	7.3	0.230	1,567	9
Basal Etchegoin	Etchegoin	19,062	78	0	2,103	12,278	242	267	113	34,214	7.2	0.188	1,834	8
Stevens	Monterey	14,380	28	0	2,519	10,203	69	41	126	27,430	8.1	0.269	1,386	4
Fractured Shale	Antelope	15,515	12	0	1,586	10,150	282	101	145	27,680	7.5	0.228	1,489	18
Cymric														
Cymric Flank														
Carneros	Temblor	3,723	511	0	2,886	3,612	82	21		10,835	7.9	0.642	358	1
McKittrick Front														
Amnicola	Tulare	1,048	40	61	2,167	1,410	43	55	5	4,844	7.8	1.900	101	3
Olig	Reef Ridge	10,935	23	0	4,703	8,173	337	186		14,448			1,053	1
Carneros	Temblor	13,011	12	0	2,697	9,366	52	19	75	25,176	8.1	0.266	1,253	2
Phacoides	Temblor	7,757	84	0	1,600	5,140	100	50		14,232	7.2	0.454	699	1
Oceanic	Tumey	6,247	151	0	2,308	4,884	50	27		13,668	7.2	0.494	602	1
Salt Creek, Main														
Etchegoin	Etchegoin	11,133	166		2,650	7,766	171	112	80	22,721	7.8	0.298	1,072	1
Carneros	Temblor	11,356	8	0	2,245	7,460	397	139	121	21,487	7.5	0.274	1,092	8
Phacoides	Temblor	14,438	15	0	352	7,001	1,798	233	204	23,862	7.2	0.273	1,370	3
Sheep Springs														
Phacoides	Temblor	13,682	73	0	442	7,222	1,045	346		22,814	7.2	0.260	1,319	1
Welport														
Tulare	Tulare	3,042	48	0	2,621	2,689	90	101	33	8,598	7.1	0.891	293	3
Amnicola	Tulare	7,928	72	0	3,002	5,512	232	282	55	17,052	7.6	0.411	764	1
Fitzgerald	Etchegoin	12,380	30	0	3,041	8,842	122	173	124	24,573	7.6	0.305	1,192	3
Fractured Shale	Antelope	12,304	6	0	5,059	9,598	100	90	96	27,172	7.7	0.264	1,185	1
Carneros	Temblor	13,316	40	0	2,947	9,469	181	47	79	25,967	7.7	0.259	1,282	3
Agua	Temblor	13,000	46	0	1,485	8,180	462	160	230	23,334	7.4	0.284	1,252	2
Phacoides	Temblor	9,170	44	0	1,550	6,153	245	63	96	17,228	7.5	0.366	883	3
Oceanic	Tumey	11,533	37	0	590	6,917	452	150	150	19,686	7.2	0.323	1,111	4
Point of Rocks	Kreyenhagen	12,776	90	0	186	3,946	3,894	78		21,380	6.7	0.328	1,254	10
1-Y Gas														
McKittrick Sand	Reef Ridge	5,238	194	0	2,429	4,197	124	44	52	12,226	7.6	0.585	504	3
Devils Den														
Alferitz														
Point of Rocks	Kreyenhagen	4,970	31	6	1,132	3,520	112	34		9,806	7.5	0.601	478	1
Old														
Point of Rocks	Kreyenhagen	4,346			665	2,813	470	1,243		9,537	7.2		418	1
Elk Hills														
Mya (Gas)	San Joaquin	28,850	12	0	410	14,278	2,134	1,138	12	46,842	6.6	0.136	2,778	3
Above Scalez	San Joaquin	21,328	18	0	222	11,158	1,506	552	22	34,824	6.8	0.188	2,053	4
Sub-Scalez	San Joaquin	21,365	24	0	338	11,493	1,289	534	25	35,028	7.0	0.187	2,067	34
Mulinia	Etchegoin	19,689	9	0	343	10,644	1,098	532	21	32,347	7.1	0.195	1,896	5
Sub-Mulinia	Etchegoin	20,109	70	0	904	11,205	1,029	581	21	33,939	7.3	0.189	1,936	11
Bittium	Etchegoin	20,742	15	0	1,166	11,709	997	553	34	35,186	8.0	0.192	1,998	1
Wilhelm-Gusher	Etchegoin	17,723	282	0	622	9,931	1,023	375	54	29,872	7.4	0.220	1,706	9
Olig	Reef Ridge	15,686	55	0	5,287	11,104	586	220	110	32,942	6.9	0.218	1,511	1
Stevens	Antelope	11,723	63	0	3,718	8,830	107	49	95	24,500	7.7	0.288	1,127	16
Carneros	Temblor	7,779	67	0	2,971	6,166	24	7	38	17,033	8.0	0.389	749	1
McDonald Anticline														
Theta (2nd Devilwater)	Devilwater	2,653	9	0	2,050	2,276	104	54	8	7,146	7.4	0.800	256	1
Tolco (7th Devilwater)	Devilwater	1,456	22	12	3,302	2,888	50	15	14	7,759	8.4	0.841	140	3
Button Bed	Temblor	244	28	105	3,664	1,707	18	5	2	5,890	8.2	1.457	24	3
Agua	Temblor	359	22	79	3,860	1,773	25	8	12	6,178	8.3	1.585	34	2
Point of Rocks	Kreyenhagen	1,334	20	144	720	1,267	4	1	16	3,500	8.7	2.200	129	1

TABLE 1

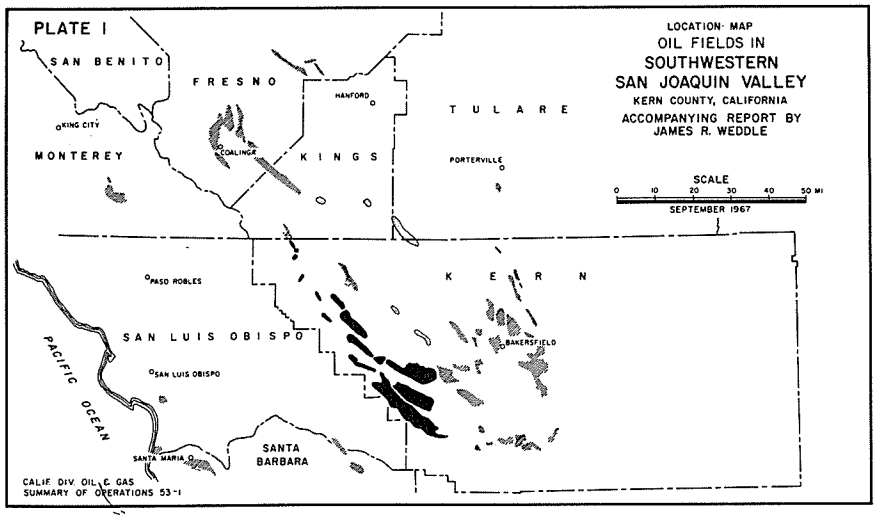
ANALYSES OF OIL ZONE WATERS

Field Area Zone	Formation or member	Anions (parts/million) Chloride	Sulfate	Carbonate	Bicarbonate	Cations (parts/million) Sodium + Potassium	Calcium	Magnesium	Boron (ppm)	Total solids (ppm)	pH	Resistivity ohms/M at 77°F	Salinity g/g NaCl	Number of samples
McKittrick														
Main														
Olig	Reef Ridge	4,636	4	0	2,542	3,959	70	56	33	11,612	7.8	0.950	447	7
Stevens	Antelope	12,516	3	0	5,065	9,810	117	43	111	27,634	7.8	0.251	1,206	3
Northeast														
Amnicola	Tulare	751-	25-		421-	568-	2-	22-		1,975-	7.6-	0.623-	72-	
		4,331	58	0	3,252	4,033	56	45		11,785	8.2	3.260	417	2
Antelope	Monterey	14,892	22	0	2,734	10,224	152	162	194	28,213	7.2	0.238	1,434	1
Carneros	Temblor	12,763	18	0	2,985	9,272	99	12		25,152	7.5	0.277	1,229	3
Phacoides	Temblor	5,876	34	0	2,519	4,729	46	16	36	13,260	8.1	0.512	566	4
Oceanic	Tumey	7,062	90	0	1,672	5,138	83	10	.	14,056	7.7	0.449	680	1
Point of Rocks	Kreyenhagen	13,827	47	0	420	6,068	2,604	48		23,014	6.9	0.283	1,331	1
Midway-Sunset														
Central														
Top Oil	San Joaquin	22,221	6	0	304	11,892	1,378	563	59	36,405	7.6	0.168	2,139	3
Kinsey	Etchegoin	19,100	47	0	368	10,400	962	565		31,442	7.4	0.202	1,857	1
Wilhelm	Etchegoin	21,785	34	0	245	11,671	1,478	466	34	35,732	7.6	0.180	2,098	1
Gusher	Etchegoin	14,998	94	0	1,580	8,022	545	274		25,514	8.0	0.248	1,444	1
Calitroleum	Etchegoin	21,221	11	0	482	10,297	1,058	389	48	35,183	6.8	0.186	2,043	7
Lakeview	Reef Ridge	17,497	14	0	1,934	10,985	397	388	88	31,108	6.5	0.222	1,675	8
Sub-Lakeview	Reef Ridge	4,514	26	0	3,672	4,209	47	33	58	12,503	7.6	0.589	435	7
Monarch	Antelope	483-	0-	0-	1,802-	1,173-	2-	8-	33-	4,074-	7.3-	2.230-	47-	
		14,254	94	120	3,697	10,344	248	75	112	27,814	8.2	0.247	1,373	8
Exeter	Antelope	11,495	48	0	1,959	8,074	78	30	104	26,696	7.9	0.292	1,107	1
Globe Anticline														
Tar	Tulare	1,809-	5-		755-	1,441-	26-	1-	31-	4,234-	7.0-	1.470-	174-	
		7,318	152	0	5,397	5,849	150	189	56	17,845	7.9	0.416	705	4
Top Oil	San Joaquin	22,400	tr.	0	1,342	12,200	1,184	788	23	38,071	7.1		2,155	1
Etchegoin	Etchegoin	16,294	38	0	1,031	9,770	549	302	38	28,010	7.0	0.251	1,568	3
Potter	Reef Ridge	35-	0-	0-	246-	391-	13-	2-	6-	1,553-	7.0-	5.460-	3-	
		3,600	355	450	3,853	2,827	242	313	45	9,438	8.7	0.570	347	19
Marvic	Reef Ridge	440	935	22	2,467	1,688	21	1		5,575	7.7	1.870	43	1
Old Belgian Anticline														
Tulare	Tulare	4,502	441	0	2,861	4,062	41	52		11,958	7.6	0.600	434	1
2nd Mya (Tar)	San Joaquin	2,650	7	0	2,695	2,701	60	36	26	8,314	7.7	0.980	256	1
Potter	Reef Ridge	1,794-	5-		242-	1,710-	36-	2-	26-	5,558-	7.6-	1.822-	173-	
		4,150	230	0	5,612	3,626	272	58	44	10,829	8.4	0.503	400	5
Republic														
Republic	Antelope	700	28	0	3,930	1,850	14	46		6,568	8.4		67	1
Santiago														
Metson	Antelope	8,200	tr.	0	2,855	6,215	104	55	50	17,622	7.7		789	2
Leutholtz	Antelope	5,761	12	0	2,600	4,334	288	24	44	13,110	7.8	0.518	555	4
Sunset														
Tulare	Tulare	9,877	150	0	4,941	7,625	41	355	118	21,344	7.9	0.338	951	1
Top Oil	San Joaquin	15,459	6	0	1,856	9,448	425	357	47	27,583	7.4	0.243	1,488	5
Kinsey	Etchegoin	15,628	6	0	794	9,096	528	387		26,443	7.2	0.243	1,505	2
Wilhelm	Etchegoin	17,780	22	0	385	10,800	570	535		30,156	7.1		1,710	1
Gusher	Etchegoin	16,360	36	0	2,712	11,106	235	145		30,753			1,575	1
Calitroleum	Etchegoin	16,858	15	0	1,161	10,243	712	176	110	28,967	7.8	0.251	1,624	2
10-10	Antelope	9,396	51	47	1,802	6,802	9	12	71	18,131		0.366	905	1
Monarch	Antelope	8,416	171	0	3,595	6,602	160	85	59	18,487	7.8	0.356	810	5
Rass	Antelope	10,105	25	76	1,431	7,077	50	15	123	18,779	8.3	0.343	973	1
Obispo (frac. shale)	Antelope	10,046	37	0	3,697	7,631	132	56	91	21,639	7.4	0.351	967	3
Moco	Antelope	10,187	56	92	3,009	7,672	76	51	55	21,220	7.4	0.400	982	4
Uvigerina C	Antelope	7,508	14	0	3,726	5,814	131	67	80	17,228	7.5	0.420	733	3
Pacific (frac. shale)	Antelope	6,267	124	4	2,621	4,913	138	27	16	14,091	6.9	0.505	604	3
Leutholtz	Antelope	1,934	34	41	2,871	2,330	32	12		7,259	8.1	1.090	186	3
Railroad Gap														
Amnicola	Tulare	2,232	220	0	1,046	1,888	65	26		5,578	7.8	1.199	224	2
Olig	Reef Ridge	9,917	63	0	2,350	7,091	127	58		19,607	7.4	0.335	955	1
Valv Foraminite	Devilwater	19,009	100	0	8,350	15,301	131	37		42,929	7.7	0.183	1,831	1
Carneros	Temblor	15,890	55	0	1,880	10,758	199	28		28,809	7.7	0.230	1,530	1
Phacoides	Temblor	3,384	511	0	2,639	3,610	19	4		10,165	7.5	0.751	326	2

ber of different laboratories by an even larger number of chemists. The author realizes the drawbacks from using data of such a diverse nature, rather than data collected and analyzed under controlled conditions, but it is felt that the averages presented are of value because, in spite of these variances, the results for any one zone are remarkably consistent. In some cases where there is a wide disparity of values, only a range is given. The values presented in Table I are from 519 of the more than one thousand separate water analyses studied; values that were felt to be out of line were eliminated. Plate II shows the distribution of the samples used.

The averages for particular ions or elements are from a varying number of samples. The analyses used were from single zones and preference was given to lead line samples taken from oil wells several months after completion to production. Data from drill stem tests were considered reliable only if there had been a substantial entry of fluid or the values fit with those from lead line samples. Gullikson and others (1960) reported that there was little difference between analyses of water that had been treated with chemical emulsion breakers and those not; therefore, treated samples were given equal weight. Care was taken to use samples from wells that had not been used for steam injection, from wells prior to the start of a water-flood project, or from wells not yet reached by the flood front. Samples from wells involved in fire-flood projects were screened for abnormalities.

The ions, elements, and properties listed on Table I are those that are almost universally given in lab reports. The value for sodium is calculated and includes potassium; resistivities are converted to a temperature of 77°F (25°C) by the International Critical Tables; total solids are calculated by summation of the constituents. The units of measurement are those in common practice: parts per million (ppm) for ions and elements, ohms per meter (ohms/M) for resistivity, and grains per gallon (g/g) for salinity.



Salinity in the strict sense is defined as the "total amount of solid material in grams contained in one kilogram of sea water when all the carbonate has been converted to oxide, the bromine and iodine replaced by chlorine and all the organic matter completely oxidized" (Pearse and Gunter, 1957). Salinity as used in this paper is the theoretical sodium chloride present if all the chlorine ions could combine with sodium. It is calculated by dividing the chloride concentration in ppm by a conversion factor of 10.38 and is expressed as g/g NaCl. Salinity in g/g NaCl is a convenient and consistently reproducible parameter of measurement.

GRAPHIC PRESENTATION

There are several commonly used methods of graphically depicting the composition of waters; all have special qualities that suit them for specific purposes. Analysis graphs show the relative concentration of ions in a solution and therefore make comparisons of samples possible without regard to total concentrations. Probably the most widely used graph today is that originated by Tickell (1921), which is the handiest for quick visual interpretation and comparison of analyses. It is constructed on six equally spaced axis with each axis being 50 units long, which represents 50 percent. Reacting values percent, that is the percentage of the total concentration based on the equivalent weights of the particular ions, are plotted on the proper axis and connected by lines. Because certain ions are related, they are grouped together. (See Figure I and Plate III.) In the past, a principal objection to Tickell graphs was that there was no way to show the concentration of total solids. D. E. Silcox, a former Standard Oil Company of California chemist, is believed to have originated the use of a circle, centered on the graph, that showed the concentration of total solids in ppm by the length of its radius. For greater ease of comparison of graphs, he also added an arc with a radius equal to the concentration in sea water (35,000 ppm).

GEOLOGY

The geologic setting of the area investigated is that of the thick section of folded and faulted clastic sedimentary rocks along the western edge of the Maricopa and Tulare basins adjacent to the Temblor Range. Most of the Tertiary and Quaternary Systems from Eocene to Recent are represented. A chart showing the general stratigraphy and occurrence of oil zones is included on Plate II but no thicknesses are implied; nomenclature is that used in the California Division of Oil and Gas publication, *California Oil and Gas Fields, Maps and Data Seets, Part 1* (1960).

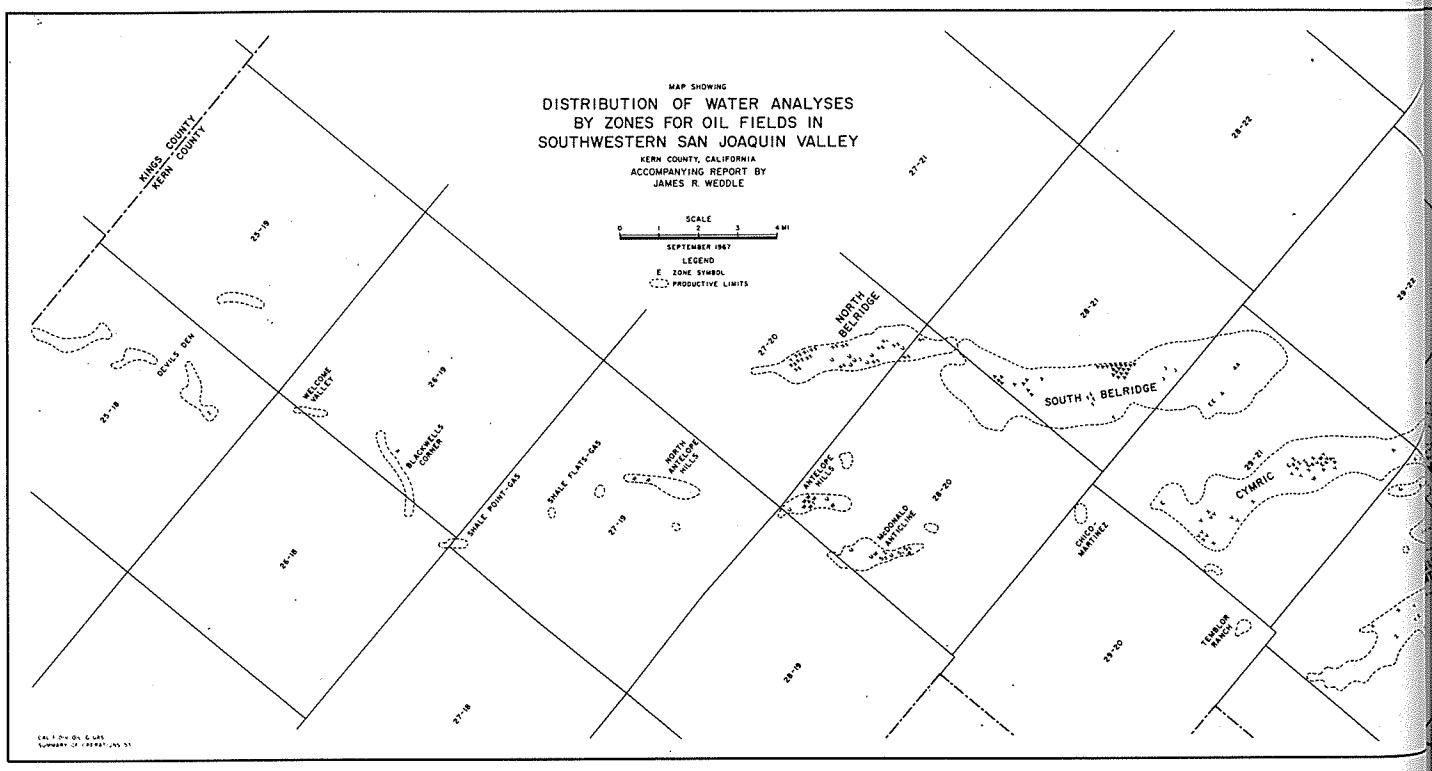
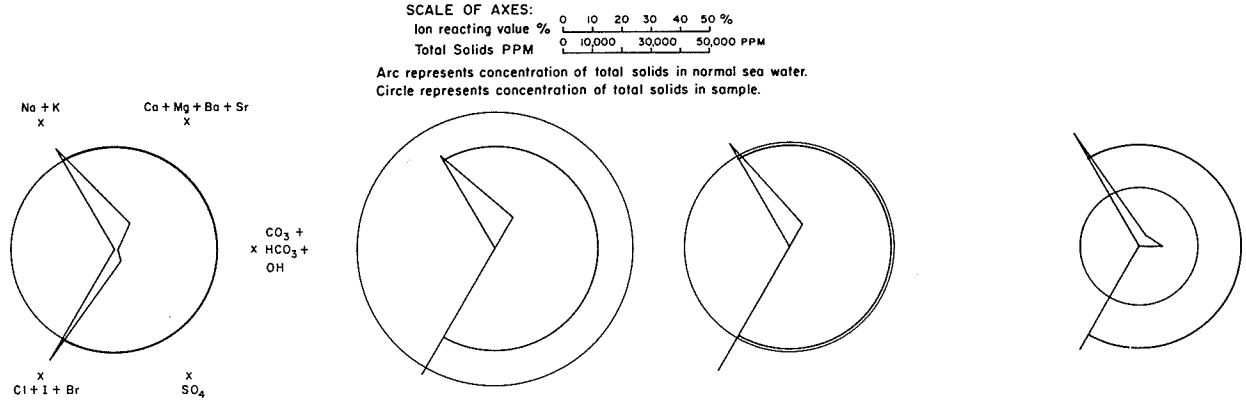


FIGURE I

COMPOSITION OF SELECTED WATERS WITH TICKELL ANALYSIS GRAPHS



CONSTITUENT	SEA WATER *	MYA (Elk Hills Field)	TOP OIL (Buena Vista Field)	CARNEROS (Cymric Field)
CHLORIDE	19,353	29,500	22,054	9,751
SULFATE	2,700	5	1	6
CARBONATE	---	0	0	0
BICARBONATE	142	162	141	3,217
IODIDE	0.05	14	39	10
SODIUM and POTASSIUM	11,156	14,363	11,900	6,851
CALCIUM	408	2,505	1,340	203
MAGNESIUM	1,297	1,033	488	241
BORON	4.7	4	20	126
TOTAL SOLIDS	35,061	47,607	35,973	20,280

* After Jensen (1934) and Goldberg as quoted by Ordway (1966)

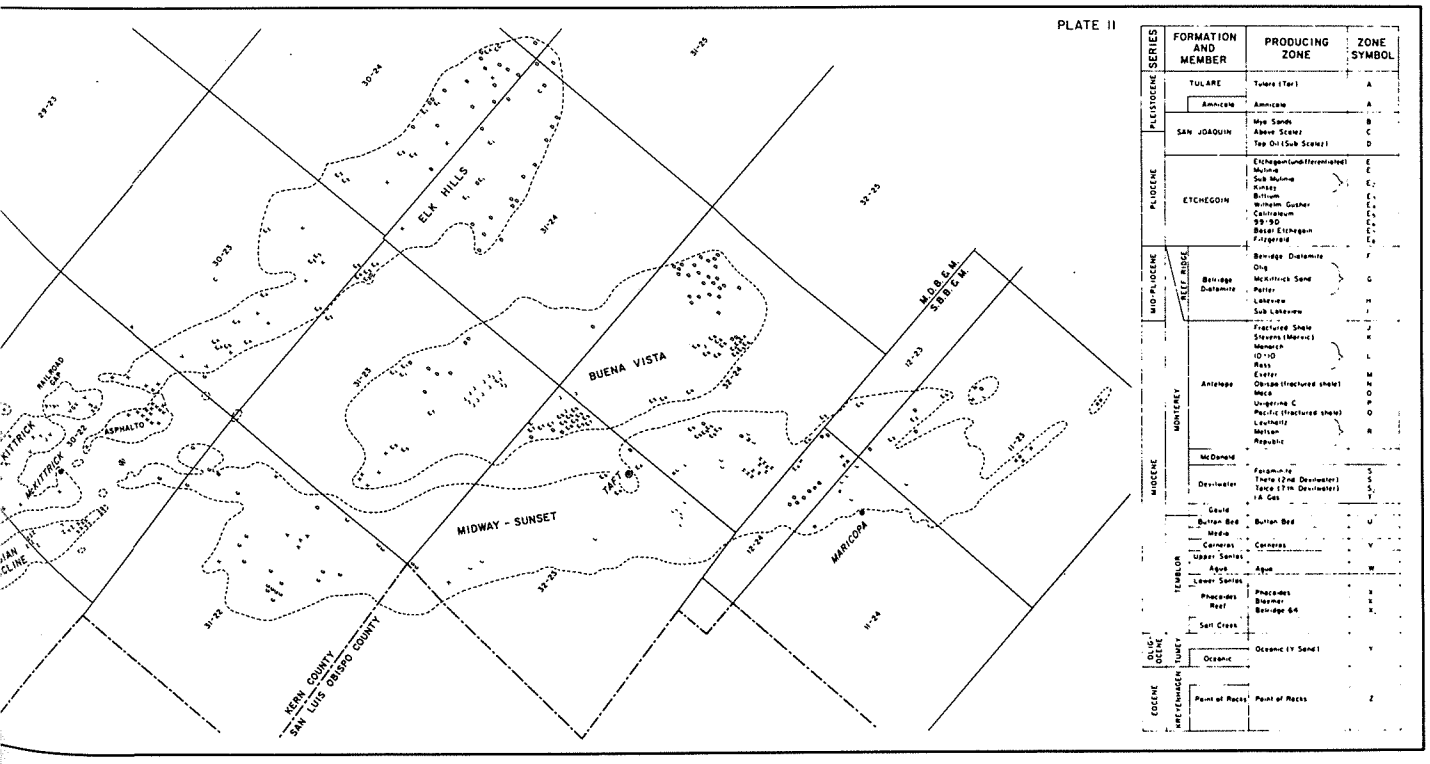
DISTRIBUTION

All the oil zones in the area contain water; a great volume, more than 158 million barrels, was produced with the oil during 1966 from the fields shown on Plate II. Along most of the western portion of the area there is no water above the oil zones, but valleyward meteoric and connate waters do occur above the oil measures. Minor fresh water aquifers are present in Buena Vista Valley and the Belgian Anticline area.

COMPOSITION

Most of the oilfield brines in this area are of a sodium chloride type, notably lacking in sulfate. The range in salinity is from less than 5 g/g in the Potter zone of Midway-Sunset to about 2,850 g/g in the Mya gas zone of Elk Hills; total dissolved solids range from about 1,500 ppm to 48,000 ppm in these same fields. Iodine, though not generally determined, is present in more than trace amounts in most brines. The Sub-Mulinia zone at Elk Hills showed the highest reading—350 ppm. Sev-

PLATE II

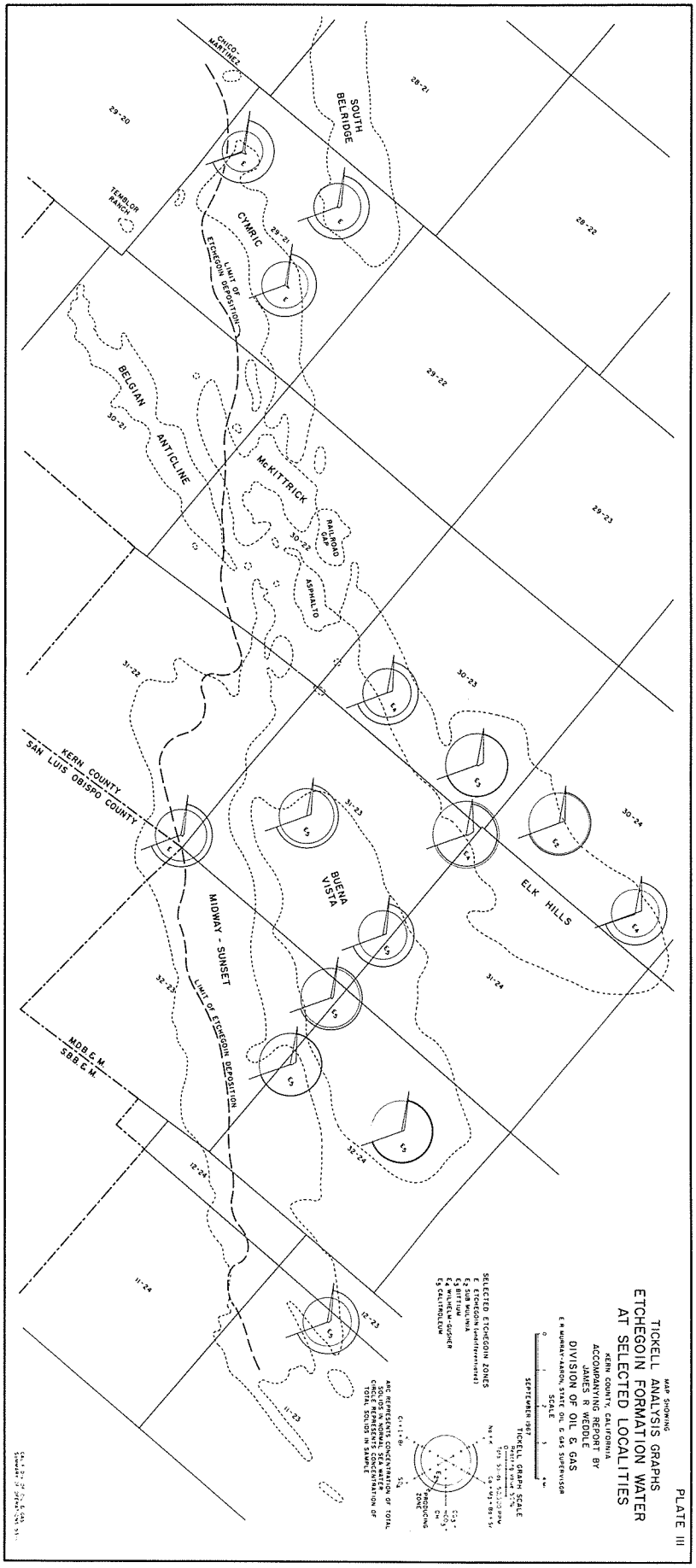


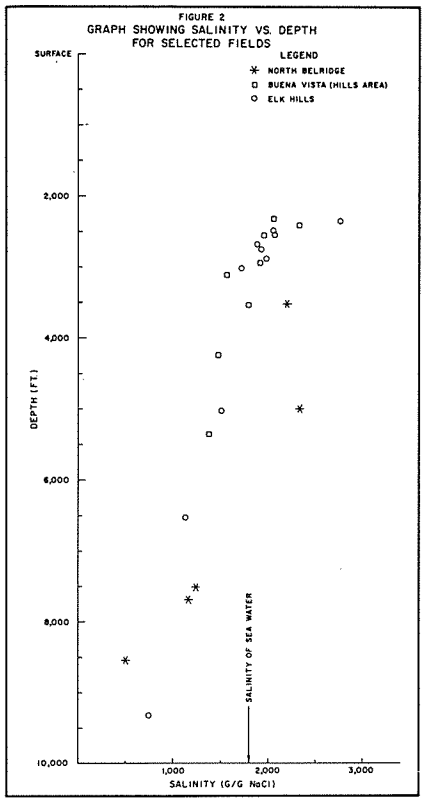
eral workers (White, 1965; Collins, 1967) have noted that calcium concentration decreases and iodine increases with depth; this is generally true here also with the radical exception being the Point of Rocks zone. Boron is found in all brines in significant quantities with the highest recorded value being 251 ppm in the Point of Rocks zone at Belgian Anticline field. An analysis for this element is commonly made because boron has a deleterious effect on plant growth in concentrations higher than 2 ppm; thus its quantitative presence is particularly important when evaluating waste disposal methods.

Many of the brines have been diluted and altered by the influx of meteoric water through present or ancient outcrops. This is well documented in the paper by Rogers (1919) on the Midway-Sunset region, in which he presents diagrams showing the increase of chloride and solids and the decrease in carbonate as the distance from the outcrop is greater. This mechanism seems to explain the anomaly of markedly fresher water in Miocene zones than in the overlying Pliocene Etchegoin Formation. (See Table 1, Midway-Sunset, Central and Sunset areas). In this example, there is a widespread angular unconformity at the top of the Miocene which indicates that these zones could have been exposed to the effect of meteoric water. Further, these Miocene zones seem to become more saline farther from the contact.

A striking anomaly is the general decrease in salinity and dissolved solids with increased depth and age of the sediments. (See Figure 2.) Some workers attribute all reduction, of these concentrations to less than that of sea water, to dilution by meteoric water (De Sitter, 1947; Chave, 1960). In fields near the outcrops there is no reason to doubt this hypothesis, but for those fields shown on Figure 2 the distance is substantial; this same trend has been noted in other California oil fields. If dilution were the sole reason for the decrease, it would seem that there would be more high and low values scattered throughout the column, as the individual units have been exposed in outcrop in varying amounts and periods of time.

There are a number of cases where total dissolved solids are much greater than in sea water (Belridge, Temblor zone; Bunea Vista Hills, Sub-Mulinia zone; Elk Hills, Mya zone; and Railroad Gap, Valv Fora-





minite zone). The accepted explanation for this condition is that fine-grained sediments are semipermeable membranes which permit the selective escape of certain ions and water molecules, thus tending to concentrate the solution (White, 1965). In the case of water from the Mya zone, the efficiency of this salt-sieving action is especially impressive as the depositional environment was a brackish water sea of early Pleistocene age (Barbat and Galloway, 1934).

ORIGIN OF ZONE WATERS

A comparison of oilfield brines with sea water shows several obvious similarities and differences in composition (Figure 1). Both are basically sodium chloride types, and the total solids in the brines seldom exceed that of sea water. Four major differences of brines from sea water are (1) the low amount of sulfate; (2) the calcium - magnesium ratios are reversed or near 1:1; (3 and 4) both boron and iodine are in much larger amounts.

Krejci-Graf (1930), as quoted by Rankama (1950), suggested that the high iodine content is due to marine organisms, the brines are formed by the same processes which are responsible for the formation of petroleum and that the brines are the main product, whereas oil occurs only in subordinate amounts. The migration of the brines together with petroleum accounts for the small content of magnesium and the high content of calcium in oil zone waters. Most workers do not feel that these differences in composition are great enough to suggest a different origin but they do indicate that the waters have been modified.

The fact that oil field brines are typically low in sulfates has been explained by Rogers (1919) as the result of the reduction of sulfate to sulfide or hydrogen sulfide and oxidation of hydrocarbon material to form carbonate or carbon dioxide. Subsequent work (Ginter, 1934; Chave, 1960; White, 1965) suggests that the sulfate reduction involves the action of anaerobic bacteria in the presence of oxidizable organic material resulting in the formation of hydrogen sulfide and carbon dioxide; most of the hydrogen sulfide precipitates as metal sulfides, chiefly iron pyrite.

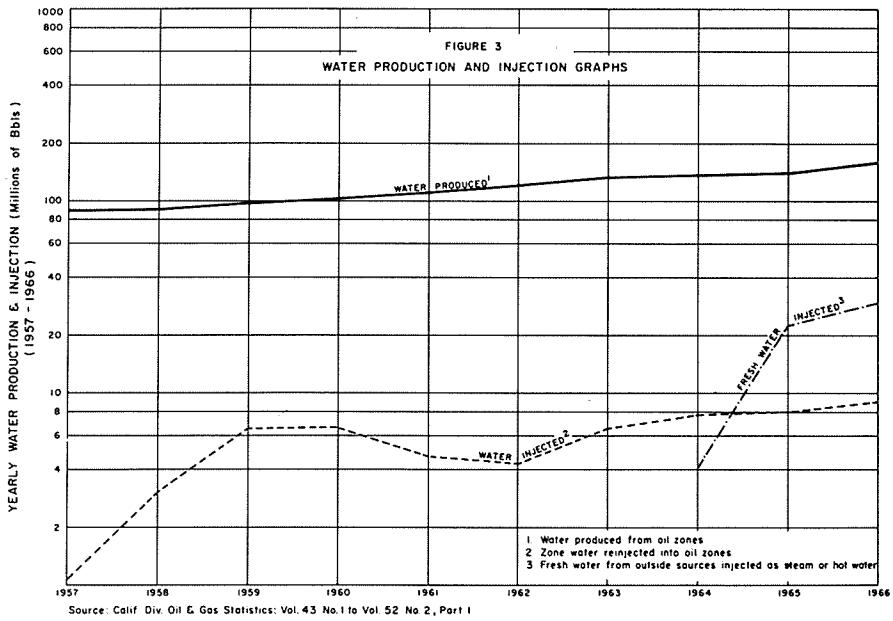
In recent time the most significant alteration of the brines has been done by man. Figure 3 shows the history of water production and injection over the past decade. The large quantity of water that has been injected in flood projects (9 million barrels in 1966) is in a great measure waste water from foreign zones. During the last few years wells have been drilled for the sole purpose of getting brines for injection. In addition, ever increasing amounts of fresh water (29 million barrels in 1966) are being injected as steam or hot water.

Fire floods also have an effect on zone waters. It seems obvious that the intense heat would cause changes in the composition not only by making the water a better solute but by the breaking down of minerals in the rocks thereby supplying more matter to be dissolved.

Certainly there is an interplay of many forces, physical and biological, that change the composition of the original water entrapped during the deposition of the rocks. The chemical changes that have taken place are complex and the explanations for these are often highly speculative. Two mechanisms for change that seem to have general acceptance are (1) the reduction of sulfate, and (2) the concentration of a water by the salt-sieving action of the shales.

APPLICATIONS OF ANALYTICAL DATA

With the advent of various logging tools and sophistication of paleontologic knowledge, little attention is given to the use of water analyses for correlation purposes. This should not mean, however, that there is no application for water data. Equivalency of rock units in local areas can be shown by these data. Because in most of California the geologic structure is disrupted by faults and erosion and the basins of deposition are restricted, regional correlations on the basis of water analysis are impractical. Plate III illustrates by means of Tickell water analysis graphs the variances found in the Etchegoin Formation water over the subject area. In Wyoming, however,



according to Crawford (1940), regional correlations can be made by the utilization of water analyses.

In order to properly interpret electric logs, accurate electrical resistivities of zone waters are necessary. The expedient of taking a salinity and calculating empirically a resistivity is not satisfactory for fine work. The electrical characteristics of a water are derived from all the ions in their specific proportions. It is not accurate to calculate water quality, except in a gross way, by electrical resistivity.

Water analyses can show when a breakthrough in a flood project occurs, provided that the injection and zone waters are different; this is demonstrable in Elk Hills and Buena Vista fields. A knowledge of the vertically distributed composition of water can be a factor in finding the source of water entry, particularly breaks in casing. Waters above the first oil zone are commonly high in sulfate; so if a well goes wet, an inexpensive first look at the problem would be a water analysis. The effectiveness of water shut-offs could occasionally be assessed this way.

More complete information as to the composition of waters is needed in the search for suitable injection fluids. The graph in Figure 3 shows the rapid increase of the volume used.

CONCLUSIONS

Application of water analysis data to regional correlations in California is impractical; local correlations can have validity. As a tool for source of water entry these data have great value.

Because the water in an oil zone is a part of the environment of the oil, it deserves more study. Most of the reports are written on either very small areas or on the broad subject of oilfield brines in general. Many reports are based on only a few samples.

Although the information presented here is for 118 zones from 15 oil fields, there are many gaps to be filled; little data was obtainable from the northern portion of the area. (See Plate II.) If the high rate of injection into the oil zones continues, within a few years it will be nearly impossible to gather virgin samples. The author welcomes comments and hopes that subsequent workers can refine the data and remove some of the uncertainties surrounding the origin of the zone waters.

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STRATIGRAPHY OF THE WEST SIDE SOUTHERN SAN JOAQUIN VALLEY[1]

CHARLES D. FOSS[2] and ROBERT BLAISDELL[3]

Many of the topics that will be discussed are controversial, but the stratigraphic units selected are believed to be in the most use by geologists studying the west side of the San Joaquin Valley. The various units are described chronologically from youngest to oldest, as has been done in some previous guidebooks. For ease of reference, each formation is described under the following topics in the same order: 1) type locality, 2) characteristics and lithology, 3) fauna and age, 4) stratigraphic relationships, 5) divisions, and 6) oil and gas. The fauna and age section has been written by Robert Blaisdell.

TYPE LOCALITY AND ACCEPTANCE

Under type locality it will be found that some of the names are informal without a definitely described type section. Also, some of the stratigraphic units are mainly faunal zones without a characteristic lithology. Many of the names were probably used by petroleum geologists before they appeared in print. Equivalent names to the stratigraphic unit discussed are considered under 5) divisions.

The degree of acceptance of the formations and members named is placed in three categories: 1) formal units accepted by the U.S.G.S. in the Lexicon (1966), such as: Tulare, San Joaquin, Etchegoin, etc., 2) informal units listed in the Lexicon (1966), such as: Antelope shale, McDonald shale, Devilwater siltstone, etc., 3) units not listed by the U.S.G.S., but used locally and informally are placed in quotation marks, such as: "Button bed," "Phacoides sand," "Salt Creek shale," "Oceanic sand," etc.

STRATIGRAPHIC NOMENCLATURE

Since the units picked are not all accepted as formations, a brief mention of the stratigraphic nomenclature may be in order. The Pleistocene and Pliocene units used: the Tulare, San Joaquin, and Etchegoin, have all been accepted as formal formation names. The Miocene units used, on the other hand, are members, or smaller stratigraphic units, that are mostly informal. The Miocene has been divided into two formal formations: 1) the Monterey Formation replacing the term Maricopa shale, which has been abandoned, and 2) the Temblor Formation.

The Monterey Formation is mostly shale in the type section of its members: Reef Ridge, Antelope, McDonald, Devilwater, and Gould. Lithologically, these members can be separated in their typical areas, but they are carried beyond their lithologic limits by micro faunal assemblages. Beyond the limits of the faunal zones, new member names are given. As an example, typically the Reef Ridge is a blue shale or a diatomaceous shale, the Antelope is a gray-brown rhythmically bedded siliceous to cherty shale, the McDonald a massive chocolate brown siltstone, the Devilwater a grayish siltstone, and the Gould is a massive siliceous shale. To the north, the Antelope and the McDonald members are included in the McLure brown shale member because they cannot be separated by either lithology or fauna.

The Temblor Formation is mostly sand with some shale in the type section of the Temblor Ranch. The members and beds included under it are: the "Button bed"; Media shale member; Carnerous sandstone member; Santos shale member, which includes the "Upper Santos," Agua sandstone, and "Lower Santos"; the "Phacoides"; and "Salt Creek shale." The Vaqueros in the Salinas Valley is the approximate equivalent to the Temblor in the San Joaquin Valley. However, when both the terms are used in the San Joaquin Valley, the Temblor refers to the Turritella ocoyana zone or the Saucesian and younger beds, whereas the Vaqueros refers to the Turritella inezana zone or the Zemorrian beds. It will be found that the type locality for all Miocene units listed, except the Reef Ridge, is in the Chico Martinez area which will be visited on the field trip.

It is believed the Oligocene Tumey should be treated as a formation, although in places north of Devils Den it has been considered as a member of the Kreyenhagen Formation.

The Upper Eocene consists of two formations that interfinger into each other: 1) Kreyenhagen Shale in the Coalinga district in the north, and 2) The Tejon Formation of mostly sands and some shale at the south end of the valley. The Point of Rocks sandstone is a tongue of the Tejon Formation in the Kreyenhagen Shale that extends as far north as Pyramid Hills. On the other hand, the Welcome formation (Upper Kreyenhagen) and the Canoas shale are tongues of the Kreyenhagen above and below the Point of Rocks.

SEQUENCES

Unfortunately, some formations like the Temblor have unconformities within them, or some formations are a part of all of a certain succession of lithologies between unconformities. For this reason, and also to attempt to formulate a stratigraphic pattern for this area, the concept of sequences is introduced for the westside, although its application is somewhat speculative. Since this term has not been used previously in the literature on the West Side, it is explained more fully below. A sequence is defined as the beds between the more important unconformities and their continuation into conformable beds. The term sequence was used by Sloss, Krumbein, and Dapples (1949) for strata

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between major regional unconformities in the interior of North America. Compared to that, the sequences referred to here are local and of short duration, but possibly contain equivalent thickness of strata.

The sequences have a certain tectonic and depositional succession. On the West Side there seems to be two types of sequences: 1) a thin sequence with a thin erratic post unconformity sand, a middle shale, and a thick but truncated upper pre-unconformity sand; 2) the thick sequence is thicker, but otherwise similar with the addition of a middle sand incased in an upper and lower shale, and the upper pre-unconformity sand is thin or absent.

The stratigraphy of the West Side is tentatively divided into 9 sequences listed below:

1. Tulare thick sequence—Tulare Formation.
2. Pliocene thick sequence — San Joaquin and Etchegoin Formations.
3. Feed Ridge thin sequence — Reef Ridge.
4. Monterey thick sequence—Antelope, McDonald, Devilwater and Gould members of the Monterey Formation, and the "Button bed" unit of the Temblor Formation.
5. Saucesian thick sequence—Media, Carneros, "Upper" Santos.
6. Lower Santos thin sequence—Agua and "Lower" Santos.
7. Salt Creek thin sequence — "Phacoides" and "Salt Creek."
8. Oligocene thin sequence — Tumey and "Oceanic."
9. Kreyenhagen thick sequence — Kreyenhagen, Point of Rocks, and Canaos.

The names are temporary and, if the concept is usable, more formal names may be presented.

Thick sequences are characterized by a thick middle sand incased in shale. Examples of a thick sequence are as follows: The Kreyenhagen sequence has the erratic post unconformity sand, the Mabury; and the thick midle sand, the Point of Rocks, incased in the Canoas and Kreyenhagen shales. There is no pre-unconformity sand. The Saucesian sequence is similar with the middle sand, the Carneros, incased in the "Upper" Santos and Media shales. The Monterey sequence has the post unconformity sand, the "Button bed" and, in places, the numerous overlapping Devilwater sands. The middle sand, the Stevens, is incased in the Antelope shale. There is no pre-unconformity sand. In the Pliocene sequence the Bates and other sands are the post unconformity sands. The middle sandy section, the Upper Etchegoin, is incased in the Lower Etchegoin and San Joaquin clayey sections. The Tulare sequence consists of fluvial sands between the upper and lower lacustrine beds.

The significance of the middle sands is that they were deposited when the West Side and the Temblors were a deeply sinking basin and the sands were derived from uplifts elsewhere.

The thin sequences, except for the Oligocene sequence, are characterized by a thick and rapidly truncated pre-unconformity sand. Examples of a thin sequence are as follows: The Salt Creek sequence has the erratic basal post unconformity "grit" followed by the "Salt Creek shale," and the thick pre-unconformity sand, the "Phacoides" or "Belridge 64." The Lower Santos sequence is similar with the basal sand, the "Bloemer" followed by the "Lower" Santos shale and the pre-unconformity sand, the Agua. The Reef Ridge sequence also has basal sands followed by shale and the pre-unconformity sand, the Olig-Potter. On the crest of the Temblor the probably correlative fine Santa Margarita Sand is overlain by the pre-unconformity granite conglomerate. In the case of the Oligocene sequence, the basal post unconformity sand, the "Oceanic" is the most prominent. This is followed by the Tumey shale, but the pre-unconformity sand is missing.

The significance of thin sequence sands is that they are derived from the uplifts of the Temblor Range that produced the unconformities.

UNCONFORMITIES

Since the principle unconformities are the basis for separating the sequences, a brief mention will be made of them.

The Eocene unconformity is the most prominent in the south where it is on basement and disappears to the north of Coalinga where the beds are more or less conformable. This unconformity is a result of uplift in the Transverse Range. The base of the Oligocene unconformity is also more prominent in the south as at Belgin Anticline and disappears north of Devil's Den where it is conformable on the Upper Eocene Kreyenhagen Shale.

Most of the Miocene unconformities, on the other hand, are more prominent in the north and disappear in the southern portion of the Temblor Range where the Miocene is conformable, except for the Reef Ridge. The general tendency is for the progressively younger Miocene unconformities between sequences to migrate southward, closing off the seaway across the southern portion of the Temblor Range. The various Miocene unconformities truncate each other so their original distribution is altered.

The base of the Miocene unconformity is a transitional type, being present in both the Transverse Range at the south end of the valley and in the central Temblor Range.

The base of the Lower Santos, base of the Saucesian unconformities, are present in the central Temblor Range and adjacent areas. The most prominent one is the base of the Upper and Middle Miocene unconformity which shows prominent overlapping and truncation in the central Temblor Range area. The base of the Reef Ridge unconformity is present mainly in the southern Temblor Range.

The base of the Pliocene unconformity is present on the flanks of the southern and central Temblor Range, but it is especially prominent in the Cymric Field. North of Devil's Den it is represented by conformable beds.

The base of the Tulare unconformity is present mostly around the flanks of the valley and such uplifts as Lost Hills and South Belridge.

TYPES OF SAND BODIES

In summary, it appears there are mainly three types of sand, each with its particular type of geometry: 1) the post unconformity sand is either overlapping or erratic, 2) the pre-unconformity sand is wedge shape, often becoming coarser at the top, 3) the middle sand is a thick series of sands that interfingers into shale.

CORRELATION PROBLEMS

Correlation still remains the biggest problem. This makes the discussion of stratigraphic relationships somewhat speculative and subject to different interpretations. For instance, do the Potter, Olig, and Fitzgerald sands belong in the top of the Reef Ridge Miocene, in the basal Pliocene, or both? A choice has had to be made in order to synthesize the stratigraphy and to know which unit to describe them under.

FORMAT

An outline of the items discussed under the various stratigraphic units follows. However, not all items are discussed under each unit.

STRATIGRAPHIC UNIT (AGE)

TYPE LOCALITY.

Type area, type section, or type well. Formal, informal, or local use. What named after, named by whom, subsequent revisions, and references.

CHARACTERISTICS AND LITHOLOGY.

What distinguishes the formation. Boundaries, internal markers. Lithology at the type section, lithology in general, and lithofacies.

FAUNA AND AGE.

Discussion of megafossil zones and microfossil zones with age determination.

STRATIGRAPHIC RELATIONSHIPS.

Distribution. Position in sequence. The area of maximum thickness and thick axis with the conformably overlying and underlying stratigraphic units and those it grades into laterally. Toward the edges, wedging, onlapping unconformably, amount of onlapping or duration of the unconformity, and beds truncated. Where unit is truncated by an overlying unconformity. Outcrops.

DIVISIONS.

Equivalent names for the same unit. Subdivisions of the unit. Facies names. Named oil sands.

OIL AND GAS.

Trends and gravity variations.

TULARE FORMATION

PLEISTOCENE

TYPE AREA: East Flank of Kettleman Hills adjacent to Tulare Lake. F. M. Anderson (1905) p. 181. Type section suggested as La Ceja in Section 35-21S/17E by Woodring, Stewart & Richards (1940) pp. 13-26. Formally accepted.

CHARACTERISTICS AND LITHOLOGY: The main characteristics are buff colored sediments and fragments of older sediments. The type area consists of 1000 feet of gypsiferous sands and clays. In general, it consists of fluvial sands which are silty, pebbly, and conglomeratic and, in the upper and lower portions, are lacustrine clay, silt, fine grained sandstones, tuff, limestones, gypsum, and diatomite. Near the front of the Temblor Range it consists of fragments of older sediments.

FAUNA AND AGE: The Tulare Formation is non-marine in origin and considered Pleistocene in age from stratigraphic position and contained Mollusca. In some places the Tulare contains abundant, well preserved, re-cycled Eocene and Miocene foraminifera.

The boundary with the underlying San Joaquin Formation in the Kettleman Hills area, which has been regarded as the type region, has been placed at the top of the "Upper Mya" molluscan assemblage of the San Joaquin and below the "Lower" Amnicola Molluscan assemblage of the Tulare.

Beds of the Tulare contain a goodly number of Mollusca representing fresh water snails and mussels and a few brackish water clams. Fresh water diatoms are also present. The fauna have been divisible in the Kettleman Hills area into an "Upper" and a "Lower" Amnicola assemblage, both assemblages characterized by an abundance of fresh water gastropods, belonging to the Amnicolidae (Flumincola, Pyrgulopsis, Calipyrgula, Littoridina, Amnicola, Hydrobia and Brannerillas). For a listing of the mollusks and the diatoms, the reader is referred to Woodring, et al (1940) listing opposite page 78, and to Arnold (1909) on pages 91 to 101.

STRATIGRAPHIC RELATIONSHIPS: This formation includes the entire Tulare sequence. It occurs mainly on the west side of the San Joaquin Valley with the thick axis of around 4500 feet extending from San Emgidio Nose through the Kettleman Hills, along which it is conformably overlain by the Alluvium and underlain by the San Joaquin Formation. Eastward, it grades into the Kern River Formation. To the west, the Tulare unconformably overlaps formations as old as the Eocene. It outcrops in the Temblor foothills, Kettleman Hills, at North Belridge, Elk Hills, etc.

DIVISIONS:

CORCORAN CLAY MEMBER. Upper Tulare lacustrine member. Type well is a test hole in Section 15-15S/14E. It is 50-120 feet thick and covers 4000 square miles. Frink and Krues (1954), pp. 2357-2371.

"AMNICOLA SAND" is an important oil sand named after the numerous small gastropods that are found in this sand.

OIL AND GAS: 12 to 15° gravity oil is found in a belt extending from the South Lost Hills, S. E. North Belridge, South Belridge, Cymric, McKittrick to Midway Sunset. The oil is principally in the lacustrine beds of the lower Tulare where it overlaps San Joaquin, Etchegoin, Reef Ridge, and Antelope oil bearing sands. Possibly it is a lake shore line accumulation.

Gas is trapped by the pinch out of thin gas sands in the Dudley Ridge Field.

SAN JOAQUIN FORMATION

UPPER PLIOCENE

TYPE AREA: Eastside of the north dome of Kettleman Hills Section 23-22S/18E. Named by F. M. Anderson (1905) p. 181. It was further defined by Barbat & Galloway (1934) pp. 476-499. Formally accepted.

CHARACTERISTICS AND LITHOLOGY: Characterized by blue and green fine grained rocks that are more persistent than the overlying or underlying formations. Principally fine grained silty sands, silt, and clay. Somewhat rhythmic, green, barren, varved clays; blue Mya-Elphidium clays; and the brown Pecten clays.

FAUNA AND AGE: The San Joaquin Formation is predominantly marine in origin and many of the coarser grained beds contain marine molluscan fossils. Some of the finer grained beds appear to be non-marine in origin; at least marine fossils have not been found in many of them, and the remains and land plants and fresh water shells are present in some. The San Joaquin is considered late Pliocene and, possibly, early Pleistocene in age from stratigraphic position and contained Mollusca.

The largest marine faunas are generally found in sand, sandstone and conglomerate. These beds are distinctive by the fossil and lithic components, but most of these show stratigraphic change along strike and, therefore, the only member recognized is the Cascajo Conglomerate at the base of the formation.

Contact with the overlying Tulare is placed above an "Upper Mya" molluscan assemblage. There are several other faunule zones within the San Joaquin characterized by species of Pecten, Acila, Anadara, Mya, Trachycardium, Dendrasters (sand dollars) and numerous representative gastropods. Some of the more characteristic species are: *Pecten coalingensis, Ostrea vespertina* and *Dendraster coalingensis.* For a more complete listing of the mollusks the reader is referred to

Woodring, et al (1940) listing opposite page 78. A listing of diatoms recorded from the formation may be found on page 41 of Woodring.

STRATIGRAPHIC RELATIONSHIPS: This formation is the upper shaley part of the Pliocene sequence. It occurs mainly on the West Side of the San Joaquin Valley, with the thick axis of around 4200 feet extending from San Emigdio nose northward through the Coalinga District along which it is conformably overlain by the Tulare and underlain by the Etchegoin. Eastward, it grades into the Kern River Formation. It wedges to the west and, in places, overlaps on to the Miocene. Also to the west, it is truncated by the basal Tulare unconformity.

DIVISIONS:

CASCAJO CONGLOMERATE Member occurs in the Kettleman Hills. Woodring, et al (1940).

OIL AND GAS: The oil is heavy on the west and grades to gas in the center of the basin. It is 15-23° gravity at Midway Sunset, 18-36° at Buena Vista Hills, 18-39° at Elk Hills with a gas cap. The center of the valley has gas sands from Semitropic to Paloma. Possibly these are shore line sands and sands on the flanks of growing structures.

ETCHEGOIN FORMATION

LOWER PLIOCENE

TYPE AREA: Etchegoin Ranch and vicinity, NW/4 Section 1-19S/15E at the north end of the Coalinga Field. Named by F. M. Anderson (1905) pp. 178-181. Barbat & Galloway (1934) restricted the Etchegoin. Formally accepted.

CHARACTERISTICS AND LITHOLOGY: Massive blue and brown sandstones, poorly sorted blue or bluish gray shales, and pebble conglomerates. In places variable, making correlations difficult. The Lower Etchegoin (Jacalitos) is more shaley and it has a basal sand, also some diatomite and punky shale.

FAUNA AND AGE: The Etchegoin Formation is predominantly marine in origin and strata of the formation contain marine Molluscan faunal assemblages that lend themselves to faunule zonation. However, some of the beds within the formation do contain fresh water mollusks or a mixture of marine and fresh water mollusks. The Etchegoin is considered early Pliocene in age from stratigraphic position and contained Mollusca.

At Kettleman Hills Woodring, et al (1949) have delineated nine milluscan faunule zones within the Etchegoin. The most satisfactory horizon is these is the Littorina faunule assemblage which is near the top of the formation. This faunule assemblage is used to help delineate the Etchegoin from the overlying San Joaquin.

Some of the more characteristic molluscan fossils found in the Etchegoin are: *Arca trilineata, Mytilis Coalingensis, Littorina mariana, Pseudocardium gabbi, Pseudocardium densatum* and *Siphonalia kettlemanensis.* For a more complete listing of the mollusks the reader is referred to Woodring, et al (1940) listing opposite page 78. A listing of diatoms recorded from the formation may be found on pages 67, 75 and 78 of Woodring (1940).

STRATIGRAPHIC RELATIONSHIPS: This formation includes the middle sand, the lower shale, and the basal sand part of the Pliocene sequence. It occurs mainly on the westside of the San Joaquin Valley with the thick axis in the center of the valley, reaching a maximum thickness of 4730 feet at North Dome Kettleman Hills. Northward, the thick section trends between Pyramid Hills and Coalinga, indicating a probable connection with the sea. In this central area it is conformably overlain by the San Joaquin and underlain by the Reef Ridge. Eastward it grades into the Kern River Formation. It wedges to the west and, in places, is overlapped by the San Joaquin. Also to the west, it truncates beds as old as the Cretaceous (Coalinga) and, in turn, it is truncated by the basal Tulare unconformity.

DIVISIONS:

JACALITOS FORMATION named from Jacalitos Creek, 21S/15E, south of Coalinga, by Arnold and Anderson (1908). It is considered equivalent to the Lower Etchegoin.

"BITTERWATER CREEK FORMATION" named from Bitterwater Creek (Section 32, 33-11N/24W) by Dibblee (1962). It is a semi-siliceous shale facies up to 3000 feet thick, grading northwest into marine sandstones.

"PANORAMA HILLS FORMATION." Non-marine pebble gravel in lower part grades southeast through marine sandstone into the Bitterwater shale. It is adjacent to the San Andreas fault. Dibble (1962) S.J.G.S. Guidebook "Geology of The Carrizo Plains & San Andreas Fault."

OIL SANDS in the Upper Etchegoin are the Bitumen, Wilhelm, and Gusher sands; and in the Lower Etchegoin, Calitroleum, etc.

BATES SAND, the basal Etchegoin sand on the east flank of Devil's Den.

FITZGERALD SAND is the basal Etchegoin sand in the Cymric area.

OIL AND GAS: Lower gravity (13-18°) oil is found near the truncation and shore lines, and higher gravity (18-40°) oil basinward. Gas is found in the center of the basin. Oil and gas trends are similar to the San Joaquin.

MONTEREY FORMATION

REEF RIDGE SHALE MEMBER UPPER MIOCENE DELMONTIAN

TYPE LOCALITY: At the base of the Reef Ridge north of the Pyramid Hills Field. Named by Barbat and Johnson (1933), Gester and Galloway (1933) pp. 1174-1176. It outcrops on the flanks of the Diablo and Temblor Ranges. Restricted by Siegfus (1939). Formally accepted as a formation, informally as a member of the Monterey.

CHARACTERISTICS AND LITHOLOGY: Blue shale in the vicinity of the type section. White, gray, or brown diatomaceous sandy, thin bedded shale with poorly sorted granitic sands and conglomerate to the south.

FAUNA AND AGE: The foraminifer, *Bolivina obliqua,* found in the Reef Ridge, is an index fossil for Kleinpell's (1938) Delmontian stage of the Upper Miocene. Some other foraminifers reported from the Reef Ridge Shale in the Belridge and Kettleman Hills area are: *Nonion belridgensis, Nonionella miocenica, Buliminella elegantissima, Buliminella dubia, Bulimina pseudotora, Virgulina californiensis, Virgulina subplana, Bolivina brevoir* and *Eponides exigua.*

The Chico Martinez (Belridge) diatomite of the Chico Martinez Creek area is of Mio-Pliocene age by lithologic correlation with the Belridge diatomite in the subsurface at South Belridge where *Elphidium hughesi,* which is common in the Pliocene, has been found in the upper part of the diatomite and *Bolivina obliqua* is abundant in the lower part.

STRATIGRAPHIC RELATIONSHIPS: This represents the entire Reef Ridge sequence. The thickest section is probably 2200 feet in the Midway

Sunset area. In its axial area it is conformably overlain by the Etchegoin and underlain by the Antelope Shale. Eastward, it grades into the Chanac. Toward its periphery it is essentially regressive with shale at the base with an overlying pre-unconformity sand becoming increasingly coarse toward the top, such as the Olig, Potter, etc. It is truncated by the basal Pliocene and the basal Tulare unconformities to the west.

DIVISIONS:

BELRIDGE DIATOMITE is a facies of the Reef Ridge. Siegfus (1939).

OIL SANDS are the Olig, Potter, Lakeview, and Marvic sands.

OIL AND GAS: Oil in this formation has been found mainly in the McKittrick-Midway Sunset area.

ANTELOPE SHALE MEMBER UPPER MIOCENE-UPPER MOHNIAN

TYPE LOCALITY: Probably informally named by petroleum geologists from outcrops in the Temblor Hills adjacent to the Antelope Valley. First appeared in print in an article by E. B. Noble (1940) on the Rio Brova Field p. 1332 (fig. 1), and by Simonson and Grueger (1942) p. 1611 (fig. 2) p. 1617. Informal

CHARACTERISTICS AND LITHOLOGY: This is a member of the Monterey Shale and grades into the McLure Shale Member to the north. The lower Antelope is mainly cherty and siliceous shale; whereas, the Upper Antelope has a brown shale facies, a cherty and siliceous shale facies (Chico Martinez) and a sand and shale facies (Stevens).

FAUNA AND AGE: The Antelope is probably Upper Miocene, Upper Mohnian by stratigraphic position.

The foraminifers *Buliminella elegantissima, Bolivina seminuda, Nonionella miocenica, Nonion* sp., *Uvigerina subperegrina, Virgulina* sp. and *Globigerina bulloides* are found in the lower part of the Antelope along with the mud pecten *Pecten peckami. Pecten peckami* is an important subsurface fossil.

The Chico Martinez cherts (McLure of Prof. Paper 195) contain relatively non-diagnostic arenaceous foraminifers, including Cyclamminas and Trochamminas. These beds are Delmontian or Upper Mohnian by stratigraphic position.

STRATIGRAPHIC RELATIONSHIPS: This formation is in the upper part of the Monterey sequence. It contains the middle sand of the sequence, the Stevens and the siliceous shale portion. The thickest section is probably in the outcrop section adjacent to the Midway Sunset Field, where it is conformably overlain by Reef Ridge and underlain by the McDonald shale. Eastward, it grades into the upper Fruitvale shale and Santa Margarita sands. It is possibly locally unconformable with the overlying and underlying formations. It outcrops on the eastern flank of the Temblor Range.

DIVISIONS:

UPPER AND MIDDLE MCLURE. The Antelope grades into the upper brown shale and the middle siliceous and cherty shales of the McLure.

CHICO MARTINEZ apparently first appeared in print in the S.J.G.S. Guidebook on Chico Martinez Creek (1959). It is apparently equivalent to the Upper Antelope Haplophragmoides arenaceous zone. Some geologists consider it in part Reef Ridge. This formation changes from siliceous shale and chert at the type locality (Section 11-29S/20E) to brown shale to the north.

STEVENS SAND was named after the Stevens Station on the Sunset Railroad as an informal subsurface name. It first appeared in print in Hoots (1938) pp. 701-718. The central valley Stevens sand is an interfingering blanket sand with a cementation barrier adjacent to the Coles Levee and Paloma Fields, possibly due to commingling of the eastern and western waters.

The westside sands equivalent to the Stevens sand are composed of off structure linear sand bodies. The northern one goes under various names such as the McKittrick Stevens sand, Asphalto sands, "555" sand at Buena Vista Hills, and the Elk Hills Stevens sands. In the Midway Sunset area, these sands may be roughly divided into: 1) upper Antelope Monarch, Contact, Gibson, Hoyt, Beverly, 10-10, and Essex sands; 2) upper middle Antelope Webster, Signal, Exeter and 29-D sands; 3) lower middle Antelope Moco, Uvigerina C, Obispo, and Metson sands; and 4) lower Antelope Republic, Williams, and Leutholtz sands.

OIL AND GAS: Oil is found in the Stevens and related sands. It is higher gravity basinward. Oil is also found in the fractured shales. It is more prolific in the fractured chert facies adjacent to Stevens sand production.

McDONALD SHALE MEMBER UPPER MIOCENE-LOWER MOHNIAN

TYPE LOCALITY: Probably informally named by petroleum geologists from outcrops southwest of the present McDonald Field. First appeared in print as equivalent to the Pulvinulinella gyroidinaformis zone in an article by Cushman and Goudkoff (1930) p. 1. This unit is within the Monterey Shale, and grades into the basal portion of the McLure Shale Member. It is described as a member of the Monterey Shale in Simonson and Krueger (1942) pp. 1616-1617. Informal.

CHARACTERISTICS AND LITHOLOGY: In Temblor Range the McDonald shale is characterized as a massive chocolate brown silty shale in contrast to the buff and tan Devilwater-Gould and the siliceous well-bedded light brown shale of the Antelope. In places, it has a cherty and siliceous shale member, and a sand member often basal.

FAUNA AND AGE: The McDonald is considered to be Lower Mohnian in age on the basis of its stratigraphic position and contained microfauna.

Upper McDonald shales are representative of Kleinpell's (1938) *Bulimina uvigerinaformis* zone of the late Lower Mohnian stage age. Some of the foraminifers found in these upper shales are *Pulvinulinella gyroidinaformis, Bolivina sinuata sinuata alisoensis, Uvigerina hootsi.* In the Chico Martinez Creek area, the uppermost McDonald carries rare occurrences of *Uvigerina segundoensis.*

Cassidulina monicana, Eponides keenani, Gyroidina montereyana (obesa), Bolivina californica, Bolivina parva and *Uvigerina joaquinensis* are some of the foraminifers found in the lower McDonald shales. The assemblages place these shales in the *Bolivina modeloensis* zone of early Lower Mohnian stage age. Lower McDonald shales that were laid down in deep water carry a fauna characterized by *Pullenia moorei* and *Rotalia becki* (see discussion by C. H. Rudel in the guidebook).

STRATIGRAPHIC RELATIONSHIPS: This formation is in the middle part of the Monterey sequence. It is the shale below the middle sand of the sequence. The thickest section is probably in the outcrops in the Temblor Hills adjacent to the Mid-

way Sunset Field (2250 feet) where it is conformably overlain by the Antelope Shale and underlain by the Devilwater siltstone. Eastward, it grades into the Lower Fruitvale shale and northward, into the lower McLure shale. In the northern part of the area adjacent to the Temblor Range, the McDonald forms the basal member of the sequence with the Packwood as the basal sand, truncating beds as old as the Eocene Point of Rocks. The McDonald outcrops along the front of the Temblor Range.

DIVISIONS:

LOWER MCLURE. The McDonald grades into this portion of the McLure.

TWISSELMAN SAND type section on the Twisselman Ranch in Section 14-27S/18E. Heikkila and MacLeod (1951) p. 12.

PACKWOOD SAND is in the vicinity of the North Antelope Field and is named after Packwood Creek.

OIL AND GAS: A small amount of oil has been produced from the Packwood sand and fractured shales.

DEVILWATER SILT MEMBER
MIDDLE MIOCENE-LUISIAN

TYPE LOCALITY: Probably informally named by petroleum geologists from outcrops in Devilwater Creek west of the Antelope Hills Field. First appeared in print Bailey (1939) pp. 66-71. Informal.

CHARACTERISTICS AND LITHOLOGY: It is a buff to dark gray sandy siltstone with a greenish cast. In the vicinity of the McDonald and Antelope Hills Field it has numerous sands.

FAUNA AND AGE: The Devilwater silt contains foraminifers typical of the Luisian stage of the Middle Miocene.

The late Luisian *Siphogenerina collomi* zone of Kleinpell (1938) is not represented in the Devilwater in the Chico Martinez Creek area but, elsewhere, in the subsurface it is characterized by the foraminifers: *Valvulineria californica* ss., *Siphogenerina collomi, Baggina californica, Bolivina advena striatella, Anomalina salinasensis* and *Pullenia miocenica.*

The upper portions of the Devilwater silt in the Chico Martinez Creek area contain foraminifers indicative of the *Siphogenerina nuciformis* zone of the Luisian. Some of these are: *Baggina californica, Bolivina advena striatella, Bolivina imbricata, Anomalina salinasensis, Dentalina quadrulata, Hemicristellaria beali, Pullenia miocenica, Siphogenerina nuciformis, Valvulineria californica.*

Foraminifers in the lower portions of the formation in the Chico Martinez Creek area are representative of the early *Luisian, Siphogenerina reedi* zone. Some of these are: *Bolivina advena ornata, Bolivina californica, Valvulineria californica* ss and var. *obesa, Siphogenerina reedi* and *Siphogenerina nuciformis.*

STRATIGRAPHIC RELATIONSHIPS:

This formation is in the upper lower part of the Monterey sequence. The thickest section, up to 1500 feet, is probably the one west of the Midway Sunset Field, where it is conformably overlain by the McDonald shale and underlain by the Gould Shale Member. Eastward, it grades into the Round Mountain silt and northward, into non-marine beds. The thick interval of overlapping sands in the McDonald-Antelope Hills area indicates the rather long duration of the base of the upper and middle Miocene unconformity. It outcrops in the Temblor Hills.

DIVISIONS:

ALFERITZ FORMATION (informal) named by Van Couvering and Allen (1943) pp. 496-500. This is equvalent to the Devilwater. In spite of this being the first description of the surface beds, it is little used. Devil's Den District.

OIL SANDS in the McDonald Anticline Field are the "Theta" or "2nd Devilwater Sand" and the "Tolco" or "7th Devilwater Sand."

OIL AND GAS: The oil production is mostly limited to the sands mentioned above in the McDonald Field. There is some gas at Antelope Hills and oil in the Foraminite zone at Railroad Gap.

GOULD SHALE MEMBER
MIDDLE MIOCENE-RELIZIAN

TYPE LOCALITY: Probably informally named by petroleum geologists from Gould Hill south of Chico Martinez Creek. The type locality extends from center W/2 Section 14-29S/20E to southeast side of Chico Martinez Creek. Cunningham and Barbat (1932) pp. 417-421.

CHARACTERISTICS AND LITHOLOGY: The most characteristic lithology is hard, silicified, locally cherty and resistant platy tan shale. In some places, it is more massive and siliceous. The siliceous shales distinguish it from the Devilwater. At Belgian Anticline it is brown siltstone. Where it is a clay shale or siltstone, its presence is determined by paleo or electric log correlations. The thicker sections have the siliceous shale facies.

FAUNA AND AGE: The Gould Shale is placed in the late Relizian stage of the Middle Miocene, both by the contained foraminifers and stratigraphic position.

Such foraminifers as *Baggina robusta, Bolivina imgricata, Gyroidina reliziana, Nonion costiferum, Siphogenerina branneri* and *Valvulineria californica* vars. *obesa* and *appressa* found in the Gould are representative of the Kleinpell's (1938) *Siphogenerina branneri* zone of the Relizian.

STRATIGRAPHIC RELATIONSHIPS: This formation is in the lower part of the Monterey sequence. The thickest section of up to 1500 feet is probably west of the Midway Sunset Field. It is conformably overlain by the Devilwater and underlain by the "Button bed." Eastward, it grades into the Round Mountain silt.

SUBDIVISIONS:

LAYMAN 2 SAND is productive at the McDonald Field.

OIL AND GAS: Oil production is limited to the above sand.

TEMBLOR FORMATION

"BUTTON BED" MEMBER
BASAL MIDDLE MIOCENE

TYPE LOCALITY: Carneros Creek is given by Heikkila and MacLeod (1951) p. 10, as the type locality. It was first mentioned in print by F. M. Anderson (1905) p. 170, who said it was the top member of the Temblor. It is named after the button-like sea urchins *Scutella merriami.*

CHARACTERISTICS AND LITHOLOGY: The fossil mentioned above is the most characteristic feature at the type locality, but these are not present in many places. It is a medium gray to brown massive sand.

FAUNA AND AGE: Abundant specimens of the small, "button-like" echinoid, *Scutella merriami,* as well as the characteristic *Pecten estrellanus* and *Pecten andersoni,* occur in the Button Bed sands. The Molluscan assemblages, referable to the Molluscan *"Turritellaocoyana"* zone, as well as some of the microfossils found in the siltier parts of the stratigraphic unit, place the unit in the early Middle Miocene.

Some of the foraminifers found in the stratigraphic unit are: *Bolivina advena striatella, Nonion costi-*

ferum, Nonionella miocenica, Valvulineria miocenica, Siphogenerina branneri and *Siphogenerina hughesi.* The foraminifers are characteristic of the *Siphogenerina hughesi* zone of Kleinpell (1938). Abundant Sporbo (phosphatic oolites) are also found in the siltier parts of the stratigraphic unit.

STRATIGRAPHIC RELATIONSHIPS: This is the basal portion of the Monterey sequence. The thickest section is probably 800 feet in the outcrops in Sections 17, 20, 21-27S/18E. It is conformably overlain by the Gould Shale and underlain by the Media Shale, and grades into Gould Shale. It onlaps beds as old as the Eocene Point of Rocks. In the outcrop it is an erratic sandstone varying from zero to 800 feet from 26S/17E to 29S/20E. In the subsurface it appears to consist of several basal transgressive sandstones.

DIVISIONS:
None.

OIL AND GAS: Oil is produced in the North Antelope and Antelope Fields where it truncates and overlaps the Agua sand. Oil is also found at the McDonald Field.

MEDIA SHALE MEMBER LOWER MIOCENE-UPPER SAUCESIAN

TYPE LOCALITY: First mentioned by Cunningham and Barbat (1932) pp. 417-421. Probably named after Media Agua Creek west of the McDonald Field. Informal.

CHARACTERISTICS AND LITHOLOGY: It ranges from a platy tan silty shale to a light colored siliceous shale. The most characteristic feature in outcrop is the presence of numerous 3 foot buff colored limestone beds.

FAUNA AND AGE: The foraminifers of the Media shales are representative of Kleinpell's *Uvigerinella obesa* zone of the late Lower Miocene Saucesian stage. Some of the more characteristic foraminifers are: *Bulimina inflata alligata, Cibicides floridanus, Eponides mansfieldi, Nodogenerina koina, Nodosaria parexilis, Nonion costiferum, Plectofrondicularia miocenica directa, Planulina appressa, Robulus simplex, Uvigerinella obesa impolita* and *Siphogenerina transversa.*

In the Chico Martinez Creek area the first 50 feet of a sandy silt interval referred to as Media, which underlies the Button Bed sand in the area, contains Lower Relizian *Siphogenerina hughesi* zone foraminifers. Some of the species noted are: *Anomalina salinasensis, Uvigerinella californica, Valvulineria miocencia* and *Siphogenerina branneri. No Siphogenerina hughesi* were found.

STRATIGRAPHIC RELATIONSHIPS: This is the upper part of the Saucesian sequence. The Media is thickest in the Temblor Range where Carneros is thin or absent and it rests directly on the "Upper" Santos shale. In Cedar Canyon, it is 2300 feet thick. In the axial area it is conformably overlain by the "Button bed" and underlain by either the Carneros sand or "Upper" Santos shale. It grades into the Carneros sand and, on the eastside, into the Freeman silt. It is unconformably truncated by the "Button bed" in the Antelope Hills and other areas. It outcrops on the flanks of the Temblor Hills.

DIVISIONS:
None.
OIL AND GAS: None.

CARNEROS SANDSTONE MEMBER LOWER MIOCENE SAUCESIAN

TYPE LOCALITY: Carneros Creek west of the Chico Martinez Oil Field. Cunningham and Barbat (1932) pp. 417-421. Probably first named by H. G. Schenck, May and Gilboe (1931). Informal.

CHARACTERISTICS AND LITHOLOGY: The lithology varies from a very hard lumpy calcareous sandstone to a well-bedded platy calcareous sandstone to a buff colored friable sandstone.

FAUNA AND AGE: *Pecten miguelensis* and *Scutella merriami* are some of the more characteristic mollusks found in Carneros sands. The Mollus assemblage is relatable to the Molluscan "*Turritella ocoyana*" zone and perhaps within the "Vaqueros-Temblor Transition" of Loel and Corey. Stratigraphic relationship of the Carneros (lying between the two Saucesian stage age shales — the Media and the Upper Santos) places the unit in the Lower Miocene Saucesian stage.

STRATIGRAPHIC RELATIONSHIPS: This is the middle sand in the Saucesian sequence. It is incased by Media and "Upper" Santos shale. There are three bodies of Carneros sand: 1) a northern one extending as far south as North Belridge with a maximum thickness of 2390 feet in the Bates area; 2) the middle or main Carneros sand body extending from the type section to Elk Hills, with a maximum thickness of 2000 feet; 3) the southern one in the Temblor Hills west of Midway Sunset, extending from Crocker Canyon to the Pioneer area, with a maximum thickness of 5000 feet. The Carneros is overlain and grades into the Media shale, and it is underlain and grades into the "Upper" Santos shale. It outcrops in the Temblor Range.

DIVISIONS:

ANDERSON SAND in the Welport area is probably equivalent to the 1st and 2nd Carneros to the south.

WESTON 3 SAND in the Welport area is probably equivalent to the 3rd Carneros sand to the south.

OIL AND GAS: The middle or main Carneros sand body has the bulk of the oil from fields such as Salt Creek, Welport, Railroad Gap, and Elk Hills. Railroad Gap has the largest gas cap. The southern sand body in the Temblor Hills has the thickest sands but only small fields with 20-30° oil. Also the northern sand body has only small accumulations of 12-23° oil.

"UPPER" SANTOS SHALE MEMBER LOWER MIOCENE-LOWER SAUCESIAN

TYPE LOCALITY: Santos Creek, Gester and Galloway (1933) and May and Gilboe (1931). The term "Upper" Santos shale was mentioned by Goudkoff (1934). Santos informal. "Upper" Santos local usage.

CHARACTERISTIC AND LITHOLOGY: Light gray shales with thin sand lenses, and tan, platy, siliceous and calcareous shales with lenticular limestones and sandstones. Usually less silty than the Media shale.

FAUNA AND AGE: The microfauna of the "Upper" Santos shales represent Kleinpell's (1938) *Siphogenerina transversa* and *Plectofrondicularia miocenica* zones of the Lower Saucesian stage of the Lower Miocene.

Bolivina marginata adelaidana, Cibicides americanus, Siphogenerina transversa, Siphogenerina tenua, Siphogenerina mayi, Baggina robusta var., abundant Sporbo (phosphatic oolites) and fish remains are some of the microfauna normally found in these shales.

STRATIGRAPHIC RELATIONSHIPS: This is the lower shale of the Saucesian sequence. The maximum thickness of 1500 feet occurs in the Bitterwater Creek outcrop area where little, if any, Carneros is present. It is conformably overlain and grades into the Carneros sandstone. In places, it is overlain by the Media shale. In the axial area it is underlain conformably by the Agua sand.

It also unconformably overlaps beds as old as the Tumey shale. It outcrops in the Temblor Hills.

DIVISION:

None.

OIL AND GAS: None.

AGUA SANDSTONE MEMBER LOWER MIOCENE-UPPER ZEMORRIAN

TYPE LOCALITY: Named informally in an abstract by Clark and Clark (1935) p. 137, with no type section given, but that it occurred between Carneros Creek and Cedar Canyon. Named after Media Agua Creek. Heikkila and MacLeod (1951). Informal.

CHARACTERISTICS AND LITHOLOGY: This sandstone is medium to coarse grained and gritty with muscovite and glauconite.

FAUNA AND AGE: *Bulimina carnerosensis, Buliminella subfusiformis, Siphogenerina transversa, Siphogenerina mayi* and *Uvigerinella sparsicostata* are found in the shale and silt interbeds in a sand body in the Chico Martinez Creek in the approximate stratigraphic position of the Agua sand of Media Agua Creek. This fauna is representative of the *Uvigerinella sparsicostata* zone of Kleinpell, which is the upper division of the Zemorrian stage of the Lower Miocene.

STRATIGRAPHIC RELATIONSHIPS: This is the pre-unconformity sand in the Lower Santos sequence. The maximum thickness is around 400 feet in the Antelope Hills area. It is conformably and unconformably overlain by the "Upper" Santos shale and underlain by and probably grades into the "Lower" Santos shale. It is truncated by the base of the Saucesian unconformity in the Beer Nose area. To the south, in the Antelope Hills Field, it is truncated by the base of the "Button bed" unconformity. It has small outcrops in the Temblor Hills, but it is mainly subsurface.

DIVISIONS:

None.

OIL AND GAS: North Antelope 15° oil, Antelope Williams 17° oil, McDonald 25° oil, and North Belridge 45° oil.

"LOWER" SANTOS SHALE MEMBER LOWER MIOCENE ZEMORRIAN

TYPE LOCALITY: Santos Creek, Gester and Galloway (1933) and Gilboe (1931). The term "Lower" Santos shale was mentioned by Goudkoff (1943). Santos informal, "Lower" Santos local usage.

CHARACTERISTICS AND LITHOLOGY: Dark brown to gray brown shale and gray brown silt with interbedded shale.

FAUNA AND AGE: Foraminifers contained in the upper shales of the "Lower" Santos are representative of Kleinpell's (1938) upper division of the Lower Miocene Zemorrian stage, the *Uvigerinella sparsicostata* zone. Some of the species reported by Kleinpell in the Zemorra Creek section are: *Bulimina carnerosensis, Gyroidina soldanii, Saracenaria schencki, Siphogenerina mayi* and *Uvigerinella sparsicostata.*

Uvigerina gallowayi, Uvigerina kernensis, Uvigerina "pseudoatwilli" and *Pseudoglandulina gallowayi* are found in the lower shales of the "Lower" Santos. The foraminifers place these lower shales in the lower division of the Zemorrian stage, the *Uvigerina gallowayi* zone.

STRATIGRAPHIC RELATIONSHIPS: The Lower Santos sequence has an erratic basal sand, the "Bloemer," the "Lower" Santos shale and, finally, the massive Agua sand which, in places is truncated by an unconformity. The maximum thickness of the "Lower" Santos shale is probably 375 feet at N. E. McKittrick. It is conformably overlain by the Agua sand and underlain conformably and unconformably by the "Phacoides sand." In the vicinity of uplifts, it is unconformably overlain by the "Upper" Santos shale and by the "Button bed." It outcrops in the Temblor Range, but it is overlapped northward by the "Upper" Santos shale.

DIVISIONS:

BLOEMER SAND named after the Ohio Bloemer Lease, Section 36-27S/20E. It is a basal Lower Santos sand found at North Belridge and elsewhere. There is a correlation difficulty in that the Bloemer probably correlates with the thin "Phacoides" in the Antelope Hills area. Unfortunately, the type "Phacoides" may belong here rather than with the "Phacoides" described subsequently.

OIL AND GAS: Bloemer sand at North Belridge and possibly the thin "Phacoides" sands elsewhere.

"PHACOIDES SAND" MEMBER LOWER MIOCENE-LOWER ZEMORRIAN

TYPE LOCALITY: Kleinpell (1938) p. 107, Goudkoff (1943) p. 250, mentions that the "Phacoides" Reef is exposed in Salt Creek and in Chico Martinez Creek. However, the name "Phacoides" is now used for a sand that is probably underneath this one. Local usage.

CHARACTERISTICS AND LITHOLOGY: Light gray sandy siltstones at the base, grading to massive sand with thin hard gray lenses becoming coarser and having glauconite at the top.

FAUNA AND AGE: Molluscan assemblages containing *Pecten (Chlamys) sespeensis, Pecten branneri, Bruclarkia (Agasoma) barkeriana, Lucina acutilineatus, Amantus mathewsoni, Clementia pertenuis* and *Ostrea* sp. found in the Phacoides "reefs" are relatable to the molluscan "*Turritella inezana*" zone and placed in the Zemorrian stage of the Lower Miocene by Kleinpell (1938). The Phacoides stratigraphic relationship would further place the Phacoides in the lower division of the Zemorrian stage.

In the calcareous and glauconitic Phacoides sand in the vicinity of Chico Martinez-Zemorra Creek area, the following microfossils were found: *Cibicides floridanus, Robulus inoratus, Uvigerinella obesa impolita, Elphidium* sp. and Sporbo and sponge spicules.

STRATIGRAPHIC RELATIONSHIPS: This is the pre-unconformity sand in the Salt Creek sequence. The maximum thickness is in excess of 400 feet. It is conformably and unconformably overlain by the "Lower" Santos shale and underlain and interfingers into the "Salt Creek shale." It is unconformably truncated by the incompletely known base of the Lower Santos unconformity.

DIVISIONS:

BELRIDGE "64" SAND is named after the Belridge #64 well in Section 27-27S/20E. The type Phacoides may correlate with Bloemer in the previously described unit.

OIL AND GAS: The principle areas of production are the North Belridge and N. E. McKittrick-Railroad Gap area.

"SALT CREEK SHALE" MEMBER LOWER MIOCENE-LOWER ZEMORRIAN

TYPE LOCALITY: Mentioned by Goudkoff (1943) in the subsurface. Presumably named after Salt Creek southwest of the Cymric Field. Named by J. R. Williams (1936) in Div. Oil & Gas. Calif. Oil Fields Vol. 21, No. 4 called the "Salt Creek"—shale between the Bloemer and Belridge "64" sand. Local usage.

CHARACTERISTICS AND LITHOLOGY: Greenish black to black sandy silts with thin sands and an erratic basal sand. Also a massive brown shale.

FAUNA AND AGE: The microfossil assemblage contained in the Salt Creek shales have a high percentage of arenaceous foraminifers. The foraminiferal assemblages are considered to be Lower Miocene, Lower Zemorrian in age. Some of the foraminifers found in these shales are: *Buliminella curta, Glandulina laevigata, Globigerina bulloides, Gyroidina soldanii, Plectofrondicularia vaughani, Cyclammina incisa, Haplophragmoides translucens, Ammobaculites* sp. and coarse *Trochammina* spp.

STRATIGRAPHIC RELATIONSHIPS: This is the basil portion of the Salt Creek sequence consisting of a shale and an erratic basal sand. Maximum thickness of the Salt Creek is probably 825 feet on the east flank of the Devil's Den area. It is conformably overlain and grades into the "Phacoides sand," and underlain by the Tumey shale. It unconformably overlaps formations from the Tumey to as old as the Eocene. It outcrops in the central portion of the Temblor Range.

DIVISIONS:

GIBSON SAND is named after the Union Gibson lease in Section 36-27S/20E. This name conflicts with the Gibson sand of Upper Antelope age in the Midway Sunset area.

OIL AND GAS: Very little production. Shows in the Gibson sand. Some production in the basal grit.

TUMEY FORMATION

TUMEY SHALE MEMBER

OLIGOCENE-REFUGIAN

TYPE LOCALITY: Tumey Gulch, S/2 Section 16-16S/13E, north of Coalinga, by Atwill (1935) pp. 1192-1204. A more complete section is found just south of the type area in the Arroyo Ciervo, 16S/13E. Cushman and Simonson (1944). Informal. The Lexicon (1966) treats it as a member of the Kreyenhagen Formation.

CHARACTERISTICS AND LITHOLOGY: Lithofacies in the south end of the valley (Tecuya) are non-marine beds consisting of red and green silts, coarse granular sandstone, massive conglomerates. In the Devil's Den district (Wagonwheel formation) it consists of fossiliferous sandstone with an overlying siltstone. Northward to Tumey Gulch it consists of thick shale with lenticular sands.

FAUNA AND AGE: Characteristic foraminifers of the Tumey, exclusive of the Leda and Transition zones of Cushman and Simonson (1944), are: *Plectofrondicularia packardi* and var. *multilineata, Plectofrondicularia garzaensis, Bolivina jacksonensis, Cibicides hodgei, Uvigerina garzaensis, Uvigerina atwilli, Uvigerina cocoaensis, Bulimina* cf. *schwageri* and *Guttulina irregularis.* These foraminifers are indicative of the Oligocene Refugian stage.

STRATIGRAPHIC RELATIONSHIPS: This is the upper part of the Oligocene sequence. The maximum thickness of 1600 feet extends from the east flank of Devil's Den north to the type section. Southward it is 500 feet or less. It is conformably and unconformably overlain by the "Salt Creek shale" and conformably underlain by the "Oceanic sand" and the Kreyenhagen shale. It is unconformably truncated by the base of the Miocene unconformity and the base of the Saucesian unconformity. The Tumey outcrops at the type section, and in the Devil's Den area, and at the south end of the valley.

DIVISIONS:

WAGONWHEEL FORMATION is used in the Devil's Den district as the equivalent to the Tumey shale. Named by H. R. Johnston (1909), Smith (1956). Although this name predates the Tumey and is closer to the oilfields, it is little used.

TECUYA FORMATION, Stock. Univ. Calif. Geol. Dept. Bull. Vol. 12 (1920) pp. 267-276. Named after Tecuya Creek near the Grapevine.

OIL AND GAS: Heavy oil occurs in the fractured shales of the Tumey in the Welcome Valley Field. Some lenticular sands on the east flank of Devil's Den also have small accumulations.

"OCEANIS SAND" MEMBER

OLIGOCENE

TYPE LOCALITY: The "Oceanic sand" (subsurface only) was named after the Oceanic lease in the Cymric Welport area, Section 22-29S/21E. Local usage.

CHARACTERISTICS AND LITHOLOGY: Light brown, fine to medium grained sand with some kaolin.

FAUNA AND AGE: Only molluscan fragments have been recorded from the Oceanic sands. Stratigraphic position (lying between the Refugian Tumey shales and uppermost Narizian age Kreyenhagen shales) places the Oceanic sands as probable Lower Refugian Oligocene in age.

STRATIGRAPHIC RELATIONSHIPS: The "Oceanic sand" is the basal portion of the Oligocene sequence. It extends from the Belgian Anticline-N. E. McKittrick area to the North Belridge - Blackwells Corner area. The maximum thickness is probably less than 200 feet. It is conformably overlain by and grades into the Tumey shale; and it is conformably and unconformably underlain by the Kreyenhagen shale. It has no outcrops because it is always truncated by the base of the Miocene and other unconformities before reaching the surface.

DIVISIONS:

None.

OIL AND GAS: 32-36° oil is produced from the northeast flank of Belgian Anticline, NW end of N. E. McKittrick, McKittrick Front, Cymric Welport and Sheep Springs areas, and the north end of North Belridge. Also a small amount of 20° oil was produced at the Bacon Hills area of the McDonald Field.

KREYENHAGEN FORMATION

EOCENE

TYPE LOCALITY: It was named by F. M. Anderson (1905) p. 163, from the Kreyenhagen wells located in Sections 32, 33-22S/16E, south of Coalinga. Formal. In local usage the Kreyenhagen shale is used also as a member of the Kreyenhagen Formation overlying the Point of Rocks.

CHARACTERISTICS AND LITHOLOGY: Dark brown to medium gray fissile shale with fish remains, sponge spicules and radiolaria. Typically lavender brown siliceous splintery siltstone and shale with some sands and limestones.

FAUNA AND AGE: "Restricted" Kreyenhagen (drawn at the Refugian-Narizian contact) encompasses the *Bulimina corrugata* and *Amphimorphina jenkensi* zones of the Upper Eocene Narizian stage of Mallory (1959). Some of the foraminifers reported from the "restricted" Kreyenhagen shale are: *Amphimorphina jenkensi, Bulimina corrugata, Anomalina garzaensis, Asterigerina crassiformis, Bulimina microcostata, Eponides umbonata, Planularia markleyana, Gyroidina soldanii octocamerata, Robulus welchi, Uvigerina garzaensis* and *Uvigerina churchi.*

STRATIGRAPHIC RELATIONSHIPS: It is the upper shale member of the Kreyenhagen sequence, the maxi-

mum thickness of which is about 1500 feet. It is conformably and unconformably overlain by the Tumey and the "Oceanic," and underlain and grades into the Point of Rocks sandstone. It is truncated on top by the base of the Miocene, base of the Saucesian, base of the Upper and Middle Miocene, and base of the Tulare unconformities. The main outcrops of the Kreyenhagen shale are north of the Pyramid Hills Field.

DIVISIONS:

WELCOME MEMBER of the Kreyenhagen Formation was named by Van Couvering and Allen (1943) p. 496. This is a tongue of the Kreyenhagen shale where it overlies the Point of Rocks sandstone in the Devil's Den district. Although it is little used, according to the Code (1961) and Lexicon (1966) it should be used in preference to Kreyenhagen shale member.

REED CANYON SILT. Probably equivalent to the Kreyenhagen at the south end of the valley.

OIL AND GAS: Small amounts of oil were produced from fractured shale in the Middle Dome Kettleman Hills.

POINT OF ROCKS SANDSTONE MEMBER EOCENE

TYPE LOCALITY: The Point of Rocks was originally designated as a unit of the Tejon Formation, but is here discussed under the Kreyenhagen Formation. Named by Reed and Hollister (1936) p. 1566, on a columnar section from the Point of Rocks northwest of the Welcome Valley Field, Section 2-26S/18E. Informal.

CHARACTERISTICS AND LITHLOLGY: Massive, coarse to medium grained arkosic sandstone with "cannonball" concretions.

FAUNA AND AGE: The Point of Rocks sandstones encompass most, if not all, of the Upper Eocene *Bulimina microcostata* zone of the Lower Narizian and extend through the *Amphimorphina californica* zone and at least down into the *Vaginulinopsis mexicana* zone; both of these latter zones are of Middle Eocene age and belong to Mallory's (1959) Ulatisian stage. Shale and silt interbeds in the Point of Rocks sands contain such forms as: *Uvigerina churchi, Bulimina corrugata, Dorothia principensis, Gyroidina orbicularis planata* and *Cibicides "pygmaea."*

STRATIGRAPHIC RELATIONSHIPS: This is the middle sand of the Kreyenhagen sequence. The maximum thickness is in excess of 5000 feet. It is conformably overlain and grades into the Kreyenhagen shale and conformably underlain and grades into the Canoas shale. It outcrops in the Temblor Range from the Cymric Field northward.

DIVISIONS:

None, but it is divided into several separate sands at Belgian Anticline and Pyramid Hills.

OIL AND GAS: Belgian Anticline, Cymric Welport (30°), Antelope Hills (17°), Shale Point South, Devil's Den Alferitz (37°) and Pyramid Hills Field (16-17°). The heavy oils are associated with unconformities.

CANOAS SILTSTONE MEMBER EOCENE

TYPE SECTION: Named after Canoas Creek about 20 miles south of Coalinga. Mentioned in Calif. Div. of Mines. Bull. 118 by Clark, p. 187, and Chambers, p. 487; and by Cushman and Siegfus (1942). Type locality is Garza Creek, Kings County. Formal. Basal member of the Kreyenhagen.

CHARACTERISTICS AND LITHOLOGY: Gray claystone locally silty with some thin glauconitic sandstone. The basal lenticular Mabury sand is a massive, medium to coarse grained to pebbly sand with glauconite near the base.

FAUNA AND AGE: The siltstones in the basal Kreyenhagen in the Coal Mine Canyon and Cantua Creek area develop locally into a unit referred to as the Canoas siltstone. The foraminifers contained in these siltstones are Middle Eocene in age and are placed by Mallory (1959) in the *Amphimorphina californica* zone of the Upper Ulatisian. Some of the foraminifers characteristic of the Canos are: *Vaginulinopsis asperuliformis, Martinotiella* cf. *petrosa, Bifarina nuttalli, Pleurostomella nuttalli* and *Anomalina dorri aragonensis.*

STRATIGRAPHIC RELATIONSHIPS: This is the lower shale and basal sand if the Kreyenhagen sequence. It is conformably overlain and grades into the Point of Rocks sand. It is underlain conformably and unconformably by the Domengine and older beds. It outcrops west of the Chico Martinez area, at Devil's Den, and further north.

DIVISIONS:

The correlation and the possible equivalents need further study because of the confusion in the literature. Tentatively, these units are considered as part of the Canoas horizon.

"MUD PIT SHALE" is an equivalent name for the Canoas Siltstone now no longer used.

GREDAL. Van Couvering and Allen (1943) Devil's Den district. Equivalent to the Canoas silt. D.O.G. Sum. Oper., Vol. 43, No. 1 (1957). Variegated, green-red claystone containing occasional sandstone beds and considerable glauconite. Mallory (1959) refers to the Gredal as a member of the Lodo formation.

MABURY SAND is the basal sand member of the Canoas. There are also other sands in the Canoas. Van Couvering and Allen (1943) pp. 496-500. Named after the Mabury Hills where it outcrops in Sections 10, 11-26S/18E. Coarse tan sandstone with black chert pebbles, containing *Spiroglyphus tejonensis.*

OIL AND GAS: Gas occurs in the Mabury sand at Shale Point, Shale Flat and Bolton areas in 27S/19E. Oil occurs in lenticular sands in the Norris area and the Orchard area of 24S/18E. The traps are near the pinch outs of the sands.

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SOME SOLUTIONS TO LOGGING PROBLEMS ON THE WEST SIDE OF CALIFORNIA'S SAN JOAQUIN VALLEY[1]

ARMOUR KANE[2]

Production on the west side of the southern San Joaquin Valley is from shaly sands. While the degree of shaliness varies, truly clean sands are rarely encountered. Further characterization of the producing formations requires classification by depth. In the deeper producing sands the formation waters are brackish to salty; in the shallow zones the waters are fresh. Porosities are generally higher in the shallower unconsolidated sands. Log evaluation of the shallow sands, already made difficult by shaliness, fresh water, and lack of compaction, is further complicated by the common occurrence of low-gravity, high-viscosity crude oils. The special interpretation methods for these shallow zones will be covered following discussion of the more common methods used for the deeper sands.

LOG EVALUATION OF THE DEEPER HORIZONS

The minimum logging program for the deeper sands consists of an Induction-Electrical Survey and either a Sonic Log or a Formation Density Log. The Induction-Electrical Survey (IES) provides correlation control for subsurface mapping and structural studies. In addition, the resistivity values from the IES are used with porosity data to find and evaluate oil- and gas-bearing zones.

While either sonic or density logs provide porosity control to augment the IES, the choice of which to use depends on the primary problem to be solved. The IES-Sonic combination provides the most reliable identification of hydrocarbon-bearing shaly sands. The pessimistic effect of shaliness on resistivity measurements is offset by an optimistic effect on sonic-derived porosities. However, if accuracy of porosity measurements is the more important, the better combination

[1]Manuscript submitted Feb. 1968.
[2]Schlumberger Well Services, Bakersfield, California.

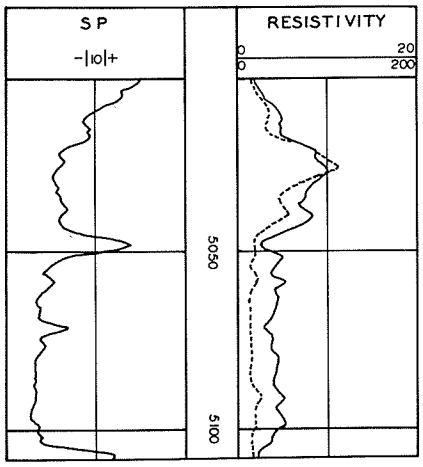

Fig. 1 Induction Electrical Survey recorded in Kern County, California.

is IES-Density. Density logs provide more accurate measurement of effective porosity since they are not optimistically affected by shaliness as are sonic logs.

Log evaluation of these shaly sands is enhanced when, in addition to an IES, both sonic and density logs are recorded. This provides not only more accurate values of porosity and water saturation, but also an evaluation of the shaliness or relative clay content of the shaly sands (Alger *et al.*, 1963). This latter information is important in appreciating the relative "producibility" of the sands. The greater the clay content of a sand, the lower its permeability will be.

The benefits of evaluation based on IES, sonic and density logs are best realized with foot-by-foot computations through the zones of interest (Morris and Biggs, 1967). While the equations used are not overly complex, manual computation of many levels is cumbersome and time-consuming. Thus, the work is best handled by computer.

Programs have been developed to not only rapidly compute the log values, but also to provide a machine plot of the computed results. This log-type presentation of the computed results simplifies both qualitative and quantitative appraisals of zones of interest.

The IES section of Fig. 1 was recorded in a Kern County well. Data from the IES, and from sonic and density logs through the same massive sand section, were processed by computer to obtain the computed Bulk Volume Analysis (BVA) presentation in Fig. 2 (Morris and Biggs, 1967). In the left-hand track of the computed presentation, values of "Q" and density-derived porosity are plotted to produce continuous curves. The "Q" value is the computed fraction of the sand porosity occupied by dispersed clay. The density-derived porosity value is the porosity indicated by the density data; it is assumed to be the effective porosity of the sand. Other factors being equal, the more permeable sand sections exhibit high values of density-derived porosity and low values of "Q." To emphasize the apparent "producibility" of the sands, the area between the "Q" and the density-derived porosity curves is cross-hatched when "Q" is to the left of density-derived porosity. Thus, the width of the cross-hatched area provides an index of the producibility of the zone; the wider the area, the higher the permeability. When the "Q" curve crosses to the right of density-derived porosity, the intervening area is not cross-hatched—and the zone is considered too "tight" for production.

In the middle track of the Bulk Volume Analysis Log three curves define the bulk volume fractions of water, hydrocarbons, and dispersed clay or shale. The highest reading curve, sonic-derived porosity, represents total sand porosity. The middle curve is derived from density data and is considered to be effective porosity. Thus, the area between these two porosity curves represents the amount of dispersed clay or shale in the sand. The lowest-reading of the three curves represents the percent of bulk volume occupied by water; it is computed by multiplying the effective porosity by the computed water saturation. Finally, then, the area between the bulk volume fractions of water and effective porosity represents the bulk volume fraction occupied by hydrocarbons.

The third track of the Bulk Volume Analysis Log contains a curve of the computed values of water saturation. The equations used in determining the values of water saturation correct for the pessimistic effect that clay minerals have on formation resistivities in shaly oil or gas sands.

With the Bulk Volume Analysis Log the continuous presentation of reservoir parameters simplifies and enhances avaluation. For example, the oil sand above 5,050 feet in Fig. 2 is readily apparent. It is equally apparent that the sand below 5,050 feet would not produce oil. However, there are other advantages of the BVA that may not be so apparent. The pay section is shalier than the water sands below. There is apparently a transition zone (i.e., a zone not at irreducible water saturation) below 5,030 feet which, if perforated, would increase the possibility of water production. Low permeability

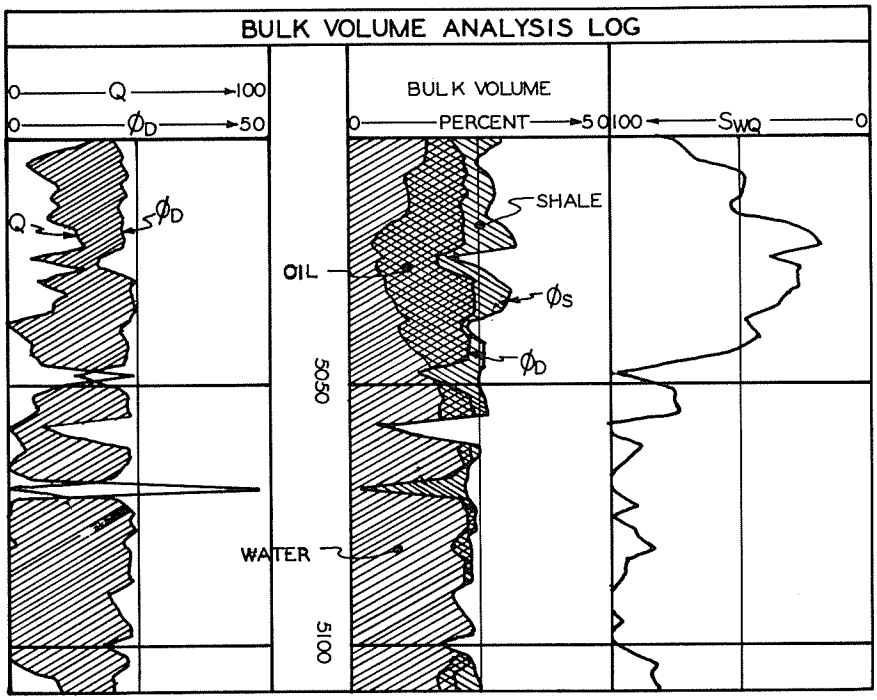

Fig. 2 Machine-computed and plotted Bulk Volume Analysis Log from Fig. 1.

zones are indicated at 5,048, 5,058, and 5,070 feet. While these permeability barriers may be relatively unimportant in this well, such knowledge is often important in planning completions and production. Furthermore, from the BVA, the sand between 5,008 and 5,018 feet is obviously of a finer grain than the sand between 5,020 and 5,030 feet. This is indicated by the drop in bulk volume water at 5,018 feet.

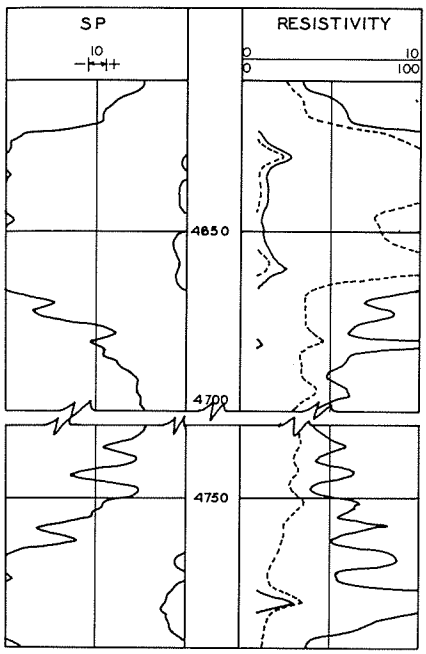

Fig. 3 Induction Electrical Survey from southern Kern County, California.

Another example is from a well in southern Kern County. Sections of the IES are presented in Fig. 3. The BVA on this well is shown in Fig. 4. From the IES one might be led to believe the sand is simply hard and tight from the top to 4,640 and from 4,655 to 4,663, with wet sand below. Reference to the BVA discloses that this is not the case; there is one comparatively hard streak at 4,628 and an almost zero porosity streak at 4,660. The remainder of the sand is oil bearing with a bulk volume water saturation averaging about 5%. Below the shell streak at 4,660 the sand is again seen to be oil-bearing but with the bulk volume water averaging 9-10%. Because of the relatively uniform bulk volume water percentages, these two zones are both above transition, or at irreducible water saturations. The shale content is seen to be greater in the lower zone and that fact, combined with the higher Sirr, suggests the lower sand to be less permeable than the upper one.

Below 4,750 can be seen the beginning of a transition zone leading to prohibitively high water saturation. It can also be seen that the shale content of the sand decreases as we go deeper into the wet zone.

The Bulk Volume Analysis Log is able to show many formation characteristics which are not obvious from a study of the resistivity and porosity logs, and can save many hours of hand computation which is quite slow and tedious.

SIDEWALL NEUTRON POROSITY AIDS INTERPRETATION

A recently introduced tool called the Sidewall Epithermal Neutron Porosity Log (SNP) is rapidly proving its value as an aid in formation evaluation (Tittman *et al.*, 1966). This log presents a direct recording of a neutron-derived porosity on a linear scale. Since neutron-derived porosity in shaly sands approximates a measure of "total" porosity as does the sonic log, it can be used together with density-derived porosity in the computation of a BVA. At this writing, the technique has been employed several times in West Side wells and results have been satisfactory. Unfortunately, the examples are not available for publication. The SNP can be used in the very soft, uncompacted shallow formations as well as in the deeper zones, and thus gives promise of more complete evaluation for the shallow formations of the west side of the San Joaquin Valley.

A very useful application of the SNP is for gas detection when combined with either the sonic or density logs. In unconsolidated gas sands the sonic log records a higher apparent porosity than in fluid-filled sands of the same true porosity. The SNP is essentially responsive to hydrogen content, and since gas has a lower hydrogen content than either oil or water, the tool records an appreciably lower apparent porosity in gas. Thus, if the sonic log is compared with the SNP, gas zones are readily identified. Such a comparison is shown in Fig. 5, the cross-

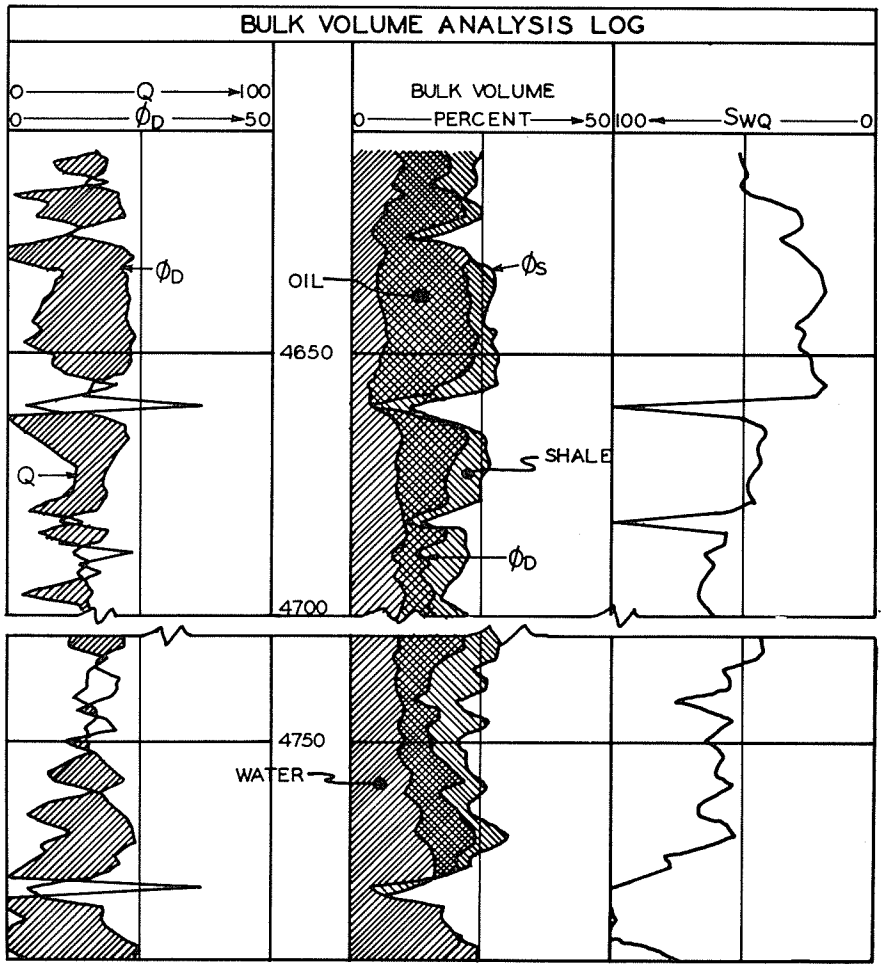

Fig. 4 Bulk Volume Analysis Log computed from Fig. 3.

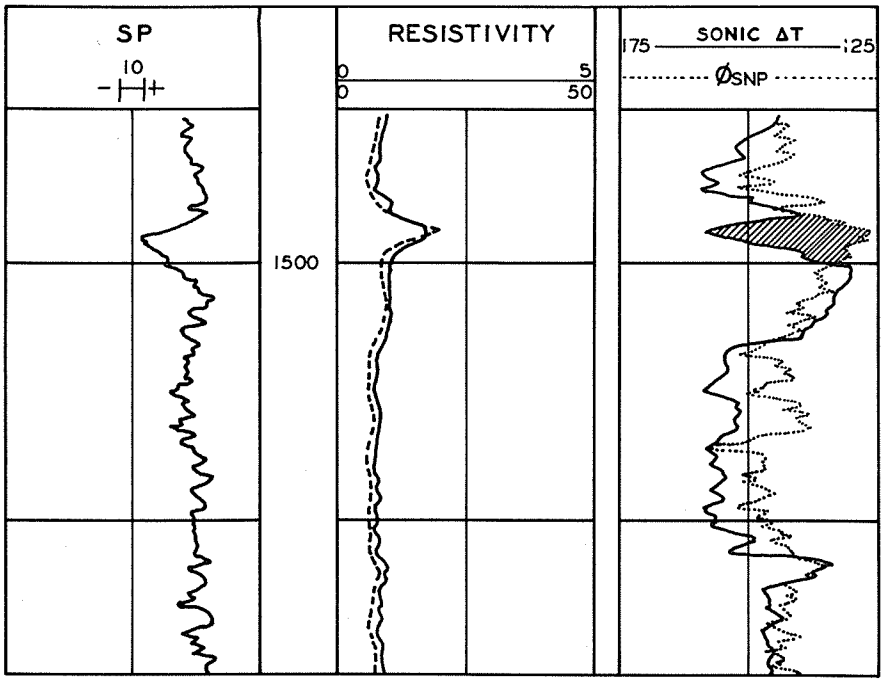

Fig. 5 I-ES, Sonic and Sidewall Neutron Logs in gas sand, Kern County, California. Cross-hatched zone points out gas.

hatched area indicating the gas zone.

A similar technique may be used in very shallow zones were the sonic log is rendered ineffective by the lack of compaction. Since both the SNP and FDC logs are effective in the very soft formations, the porosity values obtained from these two logs may be compared to detect the presence of gas. In the shaded areas of Fig. 6 the density porosity shows an increase due to the low density gas in the pore space and the SNP indicates a lower apparent porosity due to the low hydrogen content of gas. In hard streaks both curves move to the right. The "hour-glass" appearance of the curves when compared with each other, whether sonic-SNP or density-SNP, is a reliable indication of the presence of gas. Despite its very recent appearance upon the scene, the SNP has already solved a number of evaluation problems and is gaining wide acceptance among the oil companies.

SPECIAL PROBLEMS IN SHALLOW PRODUCING HORIZONS

Log evaluation of the shallow producing horizons is more difficult than for the deeper horizons. In addition to the problems caused by shaliness, there are added complications caused by lack of compaction, fresh waters, and high-viscosity oils. We have already mentioned the inefficinecy of sonic measurements in these uncompacted formations. Thus, the Sonic Log is not recommended. Early results with the SNP indicate that it provides a good value of total porosity to augment interpretations of IES and density data.

Standard interpretation methods, based on a minimum program of IES and FDC (density) logs have given excellent results in many shallow wells. Fig. 7 presents IES and FDC logs from shallow Tulare sands in a well drilled on the west side of the San Joaquin Valley. While the thick sand at 900 feet appears to be a pay sand, the fresh waters found in these shallow sands can be misleading. However, in this example, the 900 foot sand is an oil sand, and

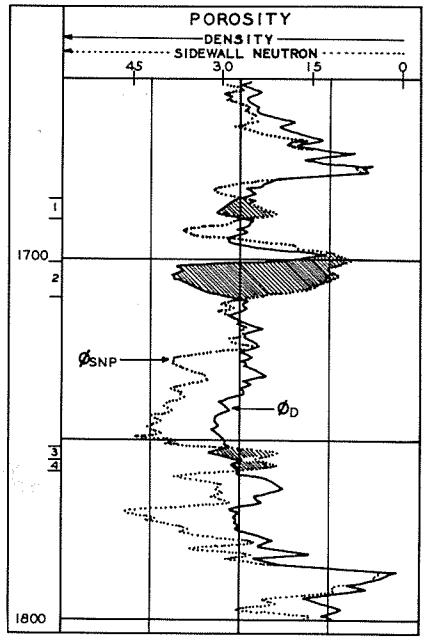

Fig. 6 FDC porosity log compared with SNP Porosity curve. Zones marked 1, 2, 3 and 4 are gas-bearing.

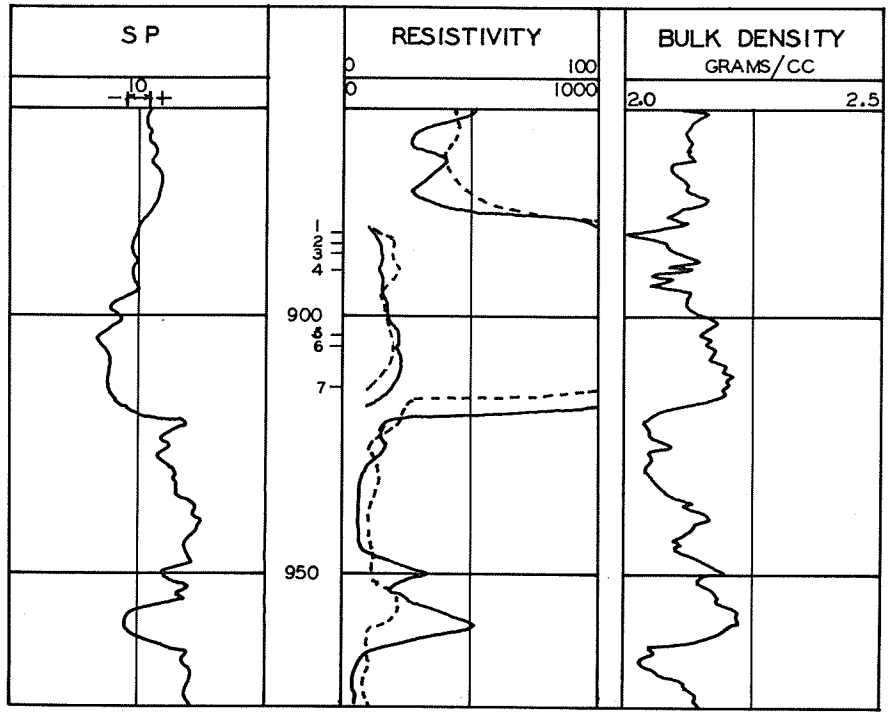

Fig. 7 Logs recorded in shallow Tulare sands of west side of San Joaquin Valley, California.

as shown in Fig. 8, the coherent cross plot of porosity and water saturation values indicates the sand to be at irreducible water saturation (Morris and Biggs, 1967). Thus, production from this sand should be water-free.

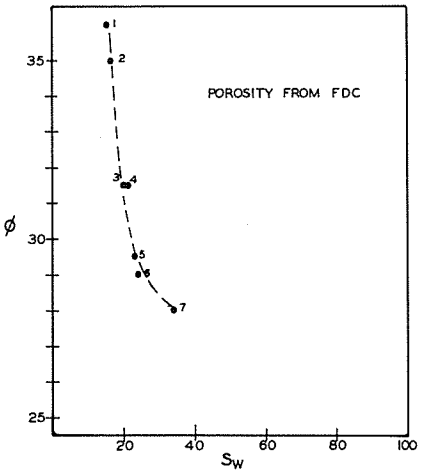

Fig. 8 Cross-plot of Sw vs. Density-derived Porosity values computed from logs of Fig. 7 showing coherent pattern indicating sand to be at irreducible water saturation.

MOVEABLE OIL PLOT FOR VISCOUS OIL

As valuable as a knowledge of Sw and porosity may be, it is many times insufficient to tell whether a reservoir is capable of producing, especially in the low-gravity crude zones. A technique called a Moveable Oil Plot (MOP) has recently been used with considerable success in the shallow zones on both the east and west sides of the San Joaquin Valley (Doll and Martin, 1954; Tixier, 1962; Lindley, 1961). For best results this technique requires that the drilling mud be salted to the point where the resistivity of the mud filtrate (Rmf) is less than Rw. Three logs are run, a Laterolog, a Microlaterolog (MLL), and an FDC density log. The actual porosity, as determined from the density log, is compared with water-filled porosities computed from the Laterolog and the Microlaterlog.

The Microlaterolog has a shallower depth of investigation than the Laterolog; most of the MLL response is from the zone immediately surrounding the borehole, where flushing by mud filtrate is most effective. When the water-filled porosity computed from the MLL is greater than that from the Laterolog it is evidence that the process of invasion swept oil away from the well bore. Thus, the zone contains moveable oil.

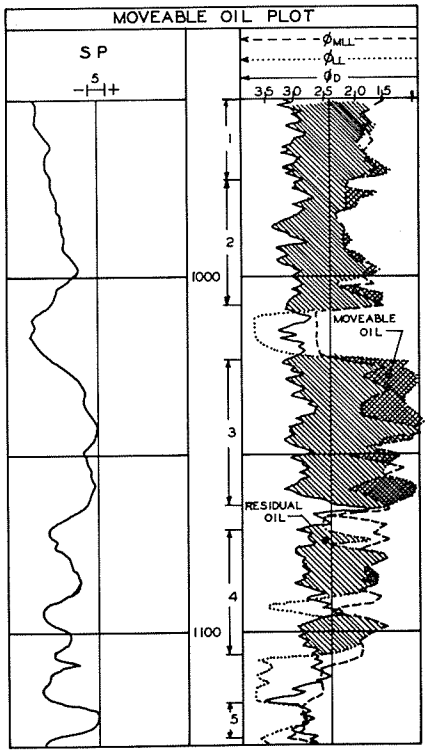

Fig. 9 Moveable Oil Plot computed from a Kern County well. Note SP is positive (moves to right in sands) due to fresh interstitial water and salty mud. Courtesy Tenneco Oil Co.

When the Laterolog and Microlaterolog-derived porosities are plotted on the density log porosity curve, as in Fig. 9, the water sands and oil sands can be seen at a glance, and the movable oil and residual oil are also evident. In Zone 5, which is a wet sand, the porosity curves are seen to match rather closely; Zones 1 and 4 indicate oil saturation but very little moveable oil; Zone 2 indicates oil with a small portion that is moveable; Zone 3 indicates the best oil saturation, a considerable portion of which is moveable. This is shown by the separation between MLL-derived porosity and LL-derived porosity.

Such plots are extremely valuable in these low-gravity crude reservoirs to indicate zones where primary production can be expected (moveable oil) or where steaming would be necessary for any production.

NML IDENTIFIES WATER-PRODUCTIVE ZONES

Frequently not only bottom water but intermediate water as well is encountered in the shallow producing horizons. Intermediate water is very difficult if not impossible to detect with standard logging tools in formations of the type encountered on the West Side. With the advent of the Nuclear Magnetism Log (NML) these difficulties have mostly been resolved. It is beyond the scope of this paper to describe the theory and operation of this highly complex tool, but the primary signal received is a Free Fluid Index (FFI) which is an indication of the amount of fluid in the pore space which is free to move. In low-gravity crudes (less than about 15° or 16° API) no signal is received from the viscous oil, thus any FFI recorded on the log represents free water in the formation. Local experience determines an FFI cut-off level, that is, an FFI level below which clean production can be expected and above which the water cut would be excessive. The value of critical FFI varies from about 4% to 8% depending upon the area (Nikias and Eyraud, 1963).

Fig. 10 is an example of an IES and an NML from a Kern County well. The sands down to 1,500 feet exhibit high values of FFI, ranging from 6% to 12%. These values are well above the cut-off point for this particular field. In the sands below 1,500 feet, the FFI values

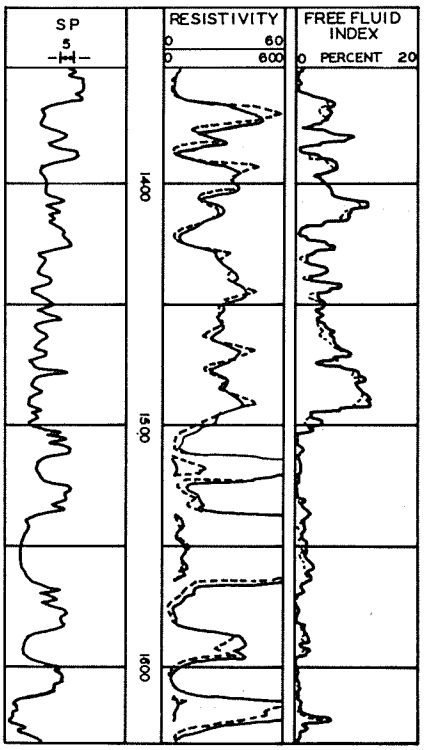

Fig. 10 I-ES and Nuclear Magnetism Log in Kern County, Calif., well.

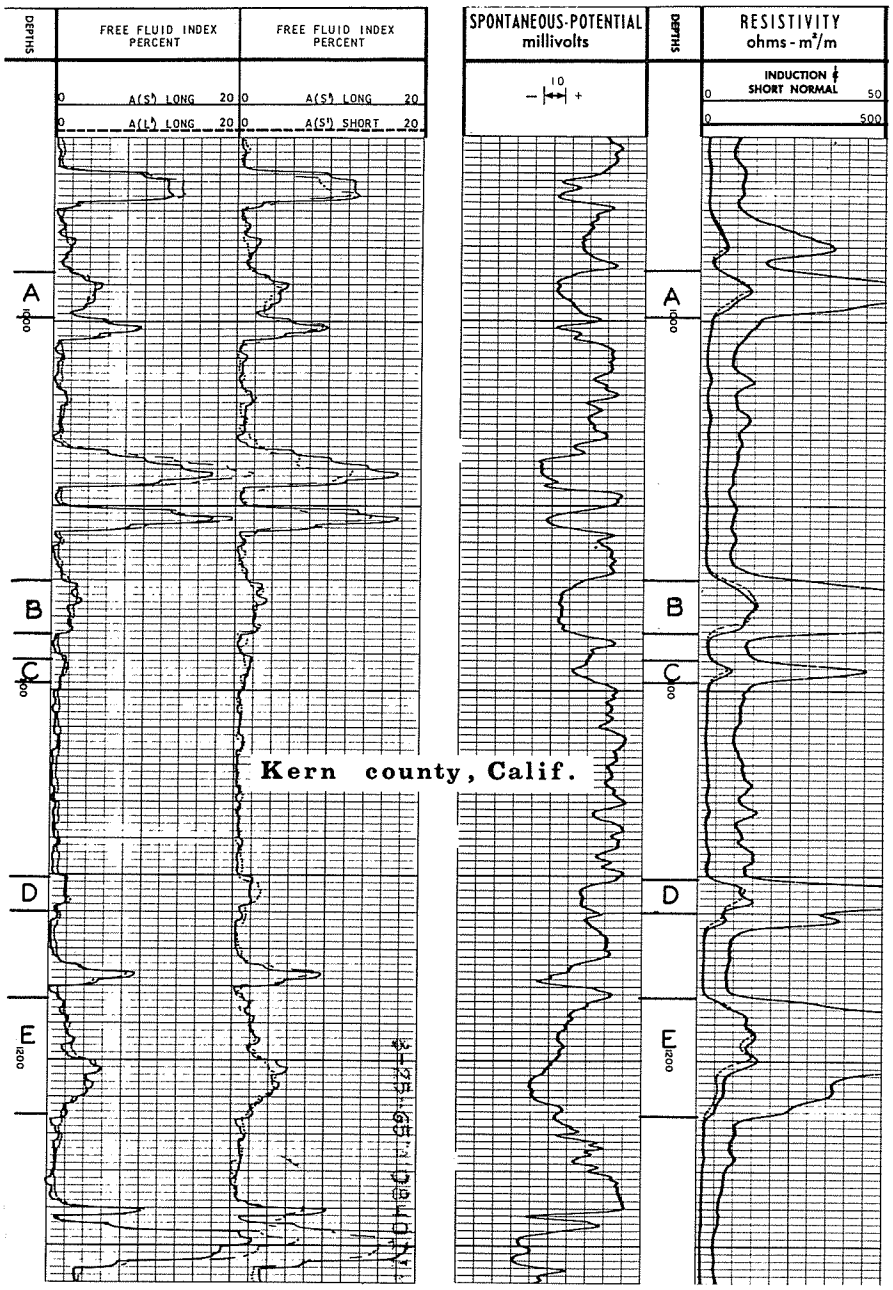

Fig. 11 I-ES and Nuclear Magnetism Log recorded in shallow zone on west side of San Joaquin Valley, California.

are uniformly low, indicating very little free water. In the lowermost sand, an FFI value of over 5% can be seen in the lower portion of the sand, suggesting excessive free water. The well was completed above this sand to exclude the indicated water.

Fig. 11 shows an IES and NML on a well in another part of Kern County. Here may be seen some very high FFI values, in excess of 20%; only water would be produced from these sands. Sands B, C, and D exhibit low FFI and should produce oil with a minimum of water. Sand A displays an FFI of just about critical value, while Sand E indicates a low FFI in the top 16 feet grading to an above-critical value in the lower 12 feet.

This particular logging combination, IES together with NML, has been widely used to good advantage by both major oil companies and independent operators in excluding unwanted water.

SUMMARY

Due to difference in compaction, shaliness, porosity, water salinity and oil gravity, the formations of the west side of the San Joaquin Valley may be classified into two groups: the shallow zones which would roughly encompass the sands above the Etchegoin; and the intermediate to deep group from the Etchegoin on down. Since the logging problems differ in the two groups, different logging programs have been discussed to help in the solution of water saturation, porosity, gas detection, shaliness and permeability problems.

As a minimum program for evaluation of the shallow zones a combination of IES and Density Log has been suggested, together with the NML for detection of both intermediate and bottom water in the low gravity crude zones. For further evaluation the Moveable Oil Plot, utilizing Laterolog, Microlaterolog and Formation Density Log, has been described as a method of determining the presence of "producible" oil.

For the deeper horizons, a combination of IES and Sonic Log or FDC would constitute a minimum program. For more complete evaluation, the machine-computed analysis of values from IES, Sonic and FDC, forming the Bulk Volume Analysis Log, is capable of a complete evaluation of the formation characteristics. From the BVA may be seen at a glance effective porosity, water saturation, shale content and those zones which are too shaly to produce. The recently introduced Sidewall Epithermal Neutron Porosity Log may be used in both shallow and deep zones as a porosity tool and gas detection device.

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A REVIEW OF THE ELK HILLS OIL FIELD, KERN COUNTY, CALIFORNIA[1]

ROBERT J. LANTZ[2]

INTRODUCTION

The Elk Hills oil field—Naval Petroleum Reserve No. 1—is located in the prolific "west side" area of the southern San Joaquin Valley that contains many giant oil fields (see fig. 1). The field is situated on and named for a hilly area about 17 miles long and 7 miles wide that lies between the cities of Taft and Bakersfield in southwestern Kern County. The hills have a maximum altitude of 1,551 feet and stand 1,000 feet to 1,200 feet above the nearly flat floor of the surrounding San Joaquin Valley. The Elk Hills are relatively barren of vegetation and are disected by many steep-sided canyons and gullies forming fairly rugged topography. The Elk Hills field has produced more than 275 million barrels of oil and has reserves estimated at more than one billion barrels. It is generally regarded as ranking third in size among the oil fields of the United States; only the East Texas and Wilmington fields are larger.

This paper will briefly review the development of this giant oil field and outline the geologic conditions of accumulation. Capt. R. E. Sparks, John C. Maher, Ernest E. Glick, and R. Stanley Beck aided its preparation with their comments and criticisms.

DEVELOPMENT

The Naval Petroleum Reserves were established during the early 1900's, when conservation became an important political issue (Bates, 1963, p. 2). Conservationists or "Progressives" established a strong lobby in Washington, and widely circulated pamphlets and editorials expressed the general fear that the remaining public lands, mostly in the western states, would disappear into private ownership. The natural resources of the public domain were said to be dwindling rapidly as a result of homesteading, patenting of mining claims, granting of land to states to support public schools and to railroad companies to help finance construction of new railroads.

About this time, the navies of the world were converting to oil because of its many advantages over coal. The United States Navy was hesitant about using the superior fuel, owing to the difficulty experienced in supplying its then small needs at a satisfactory price. Partly as a result of these circumstances, President Theodore Roosevelt directed the United States Geological Survey to investigate the remaining government lands and recommend for withdrawal from all forms of entry areas thought to contain oil. On the basis of recommendations submitted by the Survey, President Taft, who succeeded President Roosevelt, signed an executive order on September 27, 1909, withdrawing some of the public lands from entry. The public lands in the Elk Hills were included in the withdrawal. (Ragland, 1944, p. 28.)

The order of 1909 was issued barely in time. Oil seeps and tar deposits in the foothills along the southwest border of the San Joaquin Valley had been known since about 1870, and some open pits had been dug around the site of McKittrick before 1890 (Pack, 1920, p. 63). Exploration drilling began shortly after 1890, and by 1900 sixteen oil wells had been drilled in the McKittrick area (Watts, 1900, p. 125). Further development of the oil-producing area southeast of McKittrick was delayed by lack of water and transportation, and by the discovery of oil in the Kern River field on the east side of the valley. Crude oil prices fell as a result of the flush production from the new Kern River field, and the low prices retarded west-side activity until about

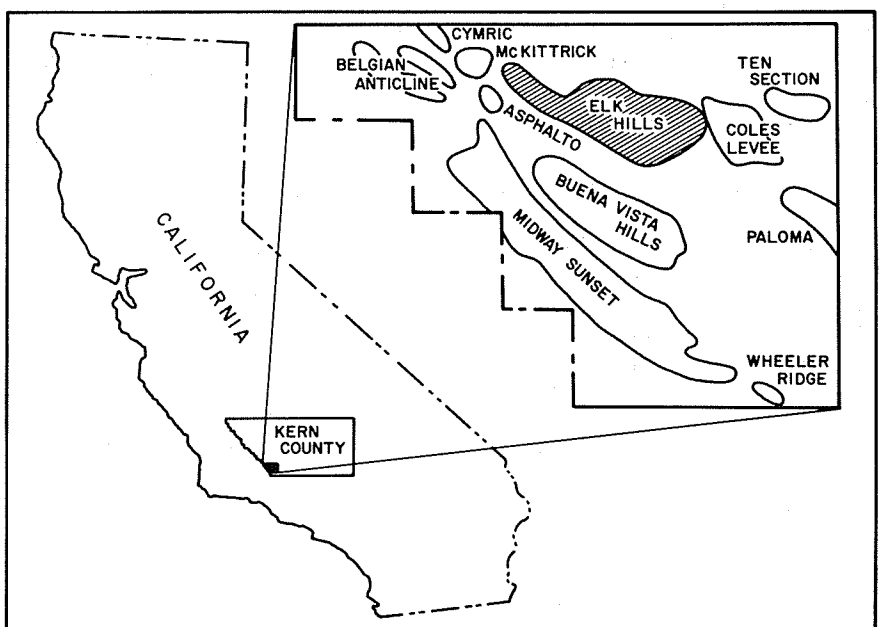

FIGURE 1—OIL FIELDS IN SOUTHWESTERN KERN COUNTY, CALIFORNIA

[1]Publication authorized by the Director, U.S. Geological Survey, and Director, Naval Petroleum and Oil Shale Reserves. Manuscript received Jan. 1968.

[2]U.S. Geological Survey

1907. Development of the oil-lands in western Kern County accelerated during 1907 as a result of increased prices for oil and the completion of railroad facilities. Prospecting spread northward from the Sunset-Midway area, and by 1909 had reached Buena Vista Hills. The next logical move was into the Elk Hills, but the public lands there were withdrawn from entry in September of 1909.

Most of the support for the public land withdrawals came from eastern states, where there was little, if any, public land remaining. People living in the western public land states were generally opposed to the action, which they considered unfair. Western oil operators were especially outspoken in their opposition, and in many cases drilled wells on withdrawn land in violation of the withdrawal orders. More than 20 wells were started in the Elk Hills in 1010, and several others in 1911, but only three reported oil. The first well that produced oil was drilled by the Associated Oil Company in sec. 26, T. 30 S., R. 23 E.; it was completed in March 1911 for about 75 barrels of oil a day. All of the wells reporting oil were evidently noncommercial, as they had produced a total of less than 10,000 barrels of oil by September 1912.

On June 28, 1912, the Secretary of the Navy asked the Secretary of the Interior for aid from the U.S. Geological Survey in locating oil-bearing public lands sufficient to ensure a supply of 500 million barrels of petroleum. The first area recommended by the Survey was Elk Hills, now designated Naval Petroleum Reserve No. 1. The second was Buena Vista hills, called Naval Petroleum Reserve No. 2. President Taft issued an executive order dated September 2, 1912, setting aside the public lands within a designated area as Naval Petroleum Reserve No. 1. The area so designated was in the Elk Hills and included approximately 37,760 acres (see dotted line on figs. 3, 4 and 5). Following the designation of the area as a Naval Petroleum Reserve, all operations in the Elk Hills were suspended as a result of suits brought by the government to clear title to the land. There is little doubt, however, that the Elk Hills oil field would have been developed by 1912 or 1913 if the public lands had not been withdrawn (Woodring, Roundy and Farnsworth, 1932, p. 47).

Activity began again in 1918 after the Standard Oil Company of California acquired title to a state school land section situated near the center of the Reserve (sec. 36, T. 30 S., R. 23 E.). Standard's first well, the Hay No. 1, was completed in January 1919, with an average daily production of 225 barrels of 37° gravity oil. This well is generally regarded as the discovery well of the Elk Hills oil field. The Standard Oil Company also obtained leases on other lands situated outside, but immediately adjacent to, the east end of the Reserve. In February 1920, Standard completed the Tupman No. 1, in sec. 36, T. 30 S., R. 24 E., flowing 5,400 barrels of oil a day. Several other wells followed in this area the same year with initial production ranging from 4,000 to 8,000 barrels of oil a day (Ragland, 1944, p. 120).

The government was slow in protecting the Reserve from drainage. By the time the first well on government land was completed in September 1921, more than 21 million barrels of oil had been produced from the Tupman area immediately adjacent to the east end of the Reserve. Two rows of offset wells were drilled around the Tupman area in an effort to prevent drainage. Unfortunately, these wells prevented drainage only at the expense of producing the very oil that the government wished to conserve (Pemberton, 1929, p. 59).

In June 1938, Congress granted the Navy additional statutory powers to ensure the integrity of Naval Petroleum Reserves as strategic reserves of oil. The Navy was empowered to exchange lands, leases, and royalties in Naval Petroleum Reserve No. 2, a part of the Buena Vista field (see fig 1), for leases that were within or offset and drained Naval Petroleum Reserve No. 1. This exchange of equal-value leases was not attainable because many tracts within the Elk Hills Reserve had not been drilled, and none had been explored for deeper (Monterey and lower) production. Values for untested lands could not be established (Department of the Navy, 1964 p. 5).

On October 18, 1942, President Franklin D. Roosevelt signed an Executive Order enlarging the limits of the Naval Petroleum Reserve No. 1 to include the then-known geologic limits of the Elk Hills oil field. The

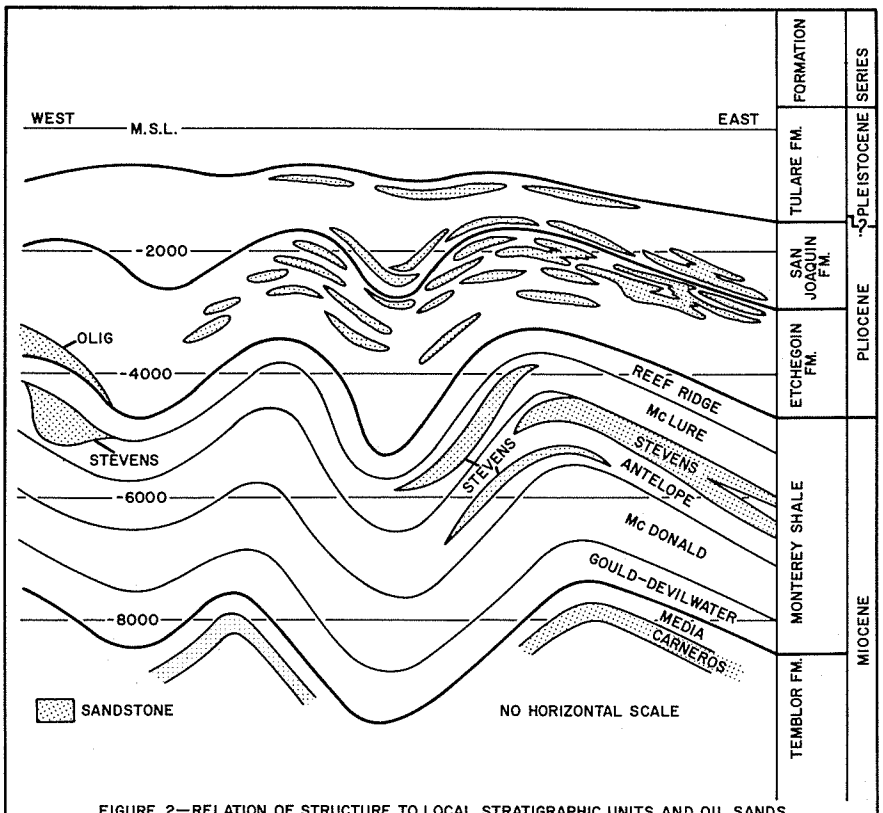

FIGURE 2—RELATION OF STRUCTURE TO LOCAL STRATIGRAPHIC UNITS AND OIL SANDS ELK HILLS, KERN COUNTY, CALIFORNIA

order added about 5,840 acres of land to the Reserve (see solid outline, figs. 3, 4 and 5). By this time, Standard Oil Company of California was the only owner of private lands inside Naval Petroleum Reserve No. 1, and unitizing the operation of the entire field seemed to be the most equitable arrangement. Consequently, Standard Oil Company and the Navy signed a unit contract in November 1942. At the time the contract was signed, more than 400 wells had been drilled in the field, and more than 160 million barrels of oil had been produced, mostly from the eastern part of the field.

During negotiations for the unit contract, 21 exploratory wells were drilled. This deeper drilling resulted in the discovery of oil production from the so-called Stevens sand within the Monterey Shale. During World War II, 317 wells were drilled in the field, and only four were abandoned as dry holes. A zone in the Temblor Formation, the Carnerous Sandstone Member of Cunningham and Barbat (1932), was found to be productive in 1951; it has not yet been fully developed. There are at present some 985 producible wells in the Elk Hills oil field, and wells are added at the rate of about six to eight per year.

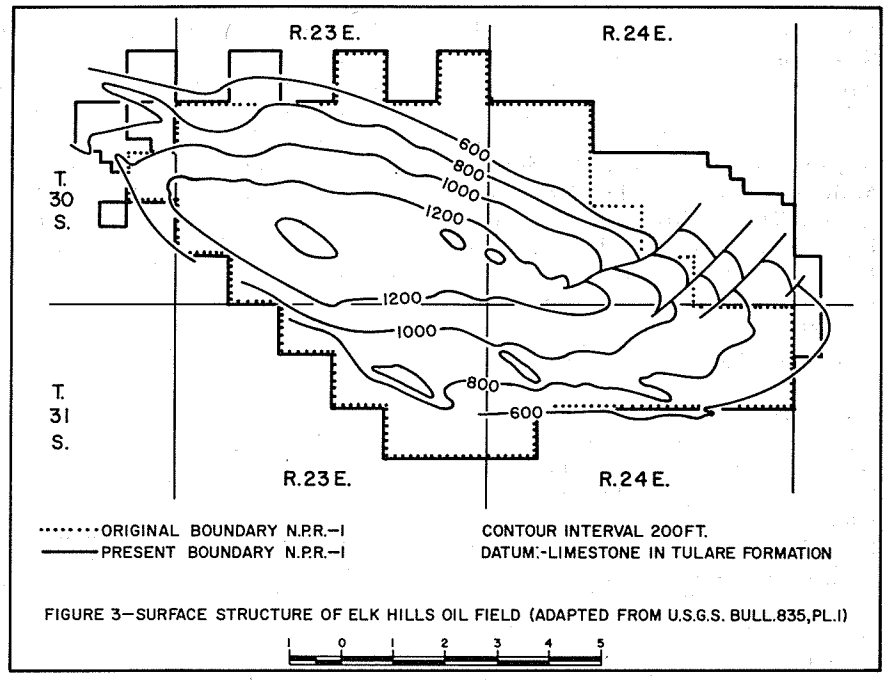

FIGURE 3—SURFACE STRUCTURE OF ELK HILLS OIL FIELD (ADAPTED FROM U.S.G.S. BULL.835,PL.I)

STRATIGRAPHY

The Tulare Formation of Pliocene and Pleistocene age is the only formation exposed on the Elk Hills structure. Lower Miocene rocks are the oldest yet penetrated by wells in the Elk Hills. Deep wells nearby have penetrated Oligocene and Eocene rocks, however. This suggests that similar rocks underlie Elk Hills. The Eocene section is estimated to be at least 3,000 feet thick and thought to consist of both shale and sandstone. The Oligocene rocks are believed to be less than 1,000 feet thick, and to consist primarily of shale. Parts of the Miocene, the Pliocene, and the Pleistocene rocks are shown diagrammatically on figure 2.

In general, the rock-stratigraphic classification used herein follows that of Woodring, Roundy and Farnsworth (1932). Five formations, the Temblor, Monterey, Etchegoin, San Joaquin, and Tulare, are recognized in the subsurface. Most petroleum geologists working in the area recognize further subdivisions based on faunal, lithologic, or petroleum-bearing characteristics. Although often informally employed, the units are useful in understanding the subsurface stratigraphy of Elk Hills.

TEMBLOR FORMATION

The oldest rocks penetrated by wells in the Elk Hills oil field belong to the Temblor Formation, which is locally of early Miocene age. The Temblor is estimated to be about 3,500 feet thick under the field. Most petroleum geologists working in the Elk Hills area subdivide the Temblor Formation into seven members or units. In ascending order these are: the Salt Creek Shale Member (McMichael, 1959, p. 12); the "Phacoides" sandstone member (McMichael, 1959, p. 10); the lower Santos Shale Member (Gester and Galloway, 1933, p. 1169); the Agua Sandstone Member (Clark and Clark, 1935, p. 137); the upper Santos Shale Member (Gester and Galloway, 1933, p. 1169); the Carneros Sandstone Member (Cunningham and Barbat, 1932, p. 419); and the Media Shale Member (Cunningham and Barbat, 1932, p. 419). The so-called button beds or Button Bed Sandstone unit reported at the top of the Temblor Formation in the Temblor Mountains is not present at Elk Hills.

One well, located at the extreme west end of the field, was drilled to a depth sufficient to penetrate all members except the Salt Creek Shale Member. The Salt Creek Shale Member is present in wells drilled adjacent to the Reserve, and is assumed to underlie the Elk Hills field. The "Phacoides" sandstone member, which does not now produce oil within the limits of the Elk Hills field, has been penetrated by only this one well. Oil may be found in the "Phacoides" when more deep wells are drilled. The one deep well does produce oil from sandstone stringers in the upper Santos Shale Member. The Carneros Sandstone Member is productive on the Elk Hills structure, but has not been fully developed.

MONTEREY SHALE

The Monterey Shale, locally of middle and late Miocene age, rests on the Temblor Formation. The Monterey, about 4,000 feet thick, consists of six members at Elk Hills. The members are, from bottom to top: Gould Shale Member (Cunningham and Barbat, 1932, p. 418); Devilwater Silt Member (Simonson and Krueger, 1942, p. 1616); Antelope Shale Member (Simonson and Krueger, 1942, p. 1617); McLure Shale Member (Henny, 1930, p. 403); and the Reef Ridge Shale Member (Barbat and Johnson, 1934, p. 8).

Outcrops of the Monterey Shale have been divided into different units at different places on the basis of weathering characteristics and outcrop patterns. These units are valid for surface mapping, but most difficult to trace across basins in the subsurface on the basis of lithology and electric-log character. The lithology and thickness of the Monterey changes considerably down the depo-

sitional dip, and the characteristics that define outcropping units disappear in the basin. The gross brown, diatomaceous, cherty appearance of the Monterey is distinctive and easy to recognize, but individual beds are not. Foraminiferal zones have been established that seem to be consistent in the Elk Hills area, but some of these zones are too thick to be very useful.

Rock types constituting the Monterey Shale in the Elk Hills include mudstone, claystone, diatomite, siliceous mudstone, and siltstone. Lenses of sandstone and conglomerate, each locally called the Stevens sand, are also present. These lenses, the major reservoirs of the Elk Hills field, appear to be generally at a lower stratigraphic position at the east end of the field than at the west. Some oil production has also been developed from fractured shale zones within the Monterey Shale.

ETCHEGOIN FORMATION

The Etchegoin Formation, of Pliocene age, rests on the Monterey Shale. The thickness of the Etchegoin Formation differs across the field, but averages about 2,200 feet. The Etchegoin consists primarily of greenish-gray and gray clay and claystone with many irregular lenses of unconsolidated or poorly consolidated sand, all of which may have been deposited in a shallow marine environment. The thin sand lenses contain oil and are collectively referred to as the "shallow oil zone." Local names applied to the oil sands are, in ascending order, the Olig sand (Zulberti, 1956, p. 52); the Calitroleum oil sand (Woodring, Roundy and Farnsworth, 1932, p. 48); the Gusher sand (Woodward, 1945); the Wilhelm sand (Woodward, 1945); the Bittium sand (Woodward, 1945); the sub-Mulinia sand (McMasters, 1943, p. 518); and Mulinia sand (McMasters, 1943, p. 518).

SAN JOAQUIN FORMATION

The San Joaquin Formation, also of Pliocene age, lies on the Etchegoin Formation. The San Joaquin is mostly nonmarine in character, although marine beds are present in the lower 300 to 500 feet. The formation consists of about 1,000 feet of light-colored clay that contains sand lenses. Some sand lenses contain petroleum, and the two lowest lenses are important reservoirs in the Elk Hills field. A widespread brown shale layer that contains an unusual fossil called *Scalez petrolia* —generally regarded to be the operculum of an undiscovered gastropod —lies a short distance above the zone that contains these two lower sand lenses (Woodring, Roundy and Farnsworth, 1932, p. 33). The local names applied to the sand units are: Second sub-Scalez sand (McMasters, 1943, p. 517); and First sub-Scalez sand (McMasters, 1943, p. 517). They are included in the "shallow oil zone."

TULARE FORMATION

Immediately above the San Joaquin Formation is the Tulare Formation of Pliocene and Pleistocene age. It is the youngest formation found on the Elk Hills structure, and is the only formation that crops out on it. The Tulare Formation consists mostly of lenses of sand and mudstone that were deposited in a nonmarine environment. It ranges in thickness from about 300 feet to more than 1,000 feet and is thinnest on the crest of the structure where part of it has been removed by erosion.

STRUCTURE

The southwestern edge of the San Joaquin Valley is bordered by the Temblor Range, the easternmost of the Coastal Ranges in this region. The Temblor Range trends in a northwesterly direction; the individual folds that make up the Temblor Range do not parallel the mountainous area, but trend in a more east-west direction. In the western part of the Temblor Range, the folds are crowded and closely compressed; they are more open to the east in the foothills adjoining the San Joaquin Valley. Some of the larger folds in the foothills extend southeastward into the Valley. The Elk Hills structure is situated on the extension of one of these folds—it is relatively broad and open at the east end, but is narrower and more steeply folded in the western part (Pack, 1920, p. 57).

Surface mapping indicates that the Tulare Formation has been warped into two large *en echelon* anticlines with several small auxiliary anticlines on the flanks. Figure 3, adapted from Woodring, Roundy, and Farnsworth (1932, pl. 1), shows about 400 feet of closure on the surface beds. The folding in the subsurface rocks, as shown by a structure map on the top of the Etchegoin Formation (fig. 4, modified from unpublished maps prepared by the Elk Hills Unit Operator), is sharper than that of the outcropping Tulare beds. Folding at the top of the Monterey Shale (fig. 5, adapted from unpublished maps prepared by the Elk Hills Unit Operator) is still sharper. The impression is gained from these maps (figs. 3, 4 and 5) that the structure was evolving from at least late Miocene through Pleistocene time.

Maps of deeper horizons are not possible with existing well data. About a half-dozen wells have been drilled to a depth sufficient to penetrate the Carneros Sandstone Member, but mechanical difficulties

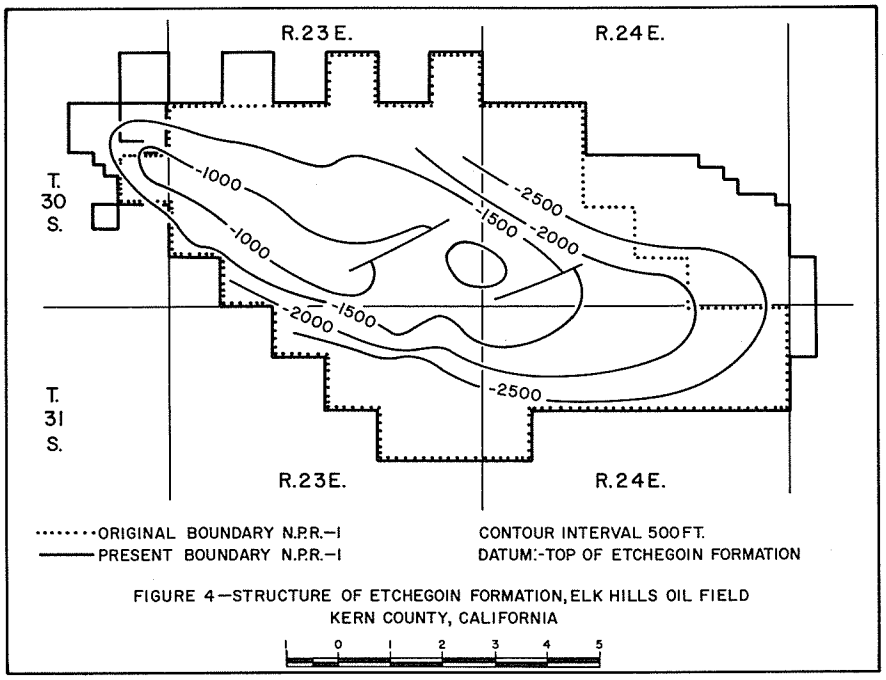

FIGURE 4—STRUCTURE OF ETCHEGOIN FORMATION, ELK HILLS OIL FIELD KERN COUNTY, CALIFORNIA

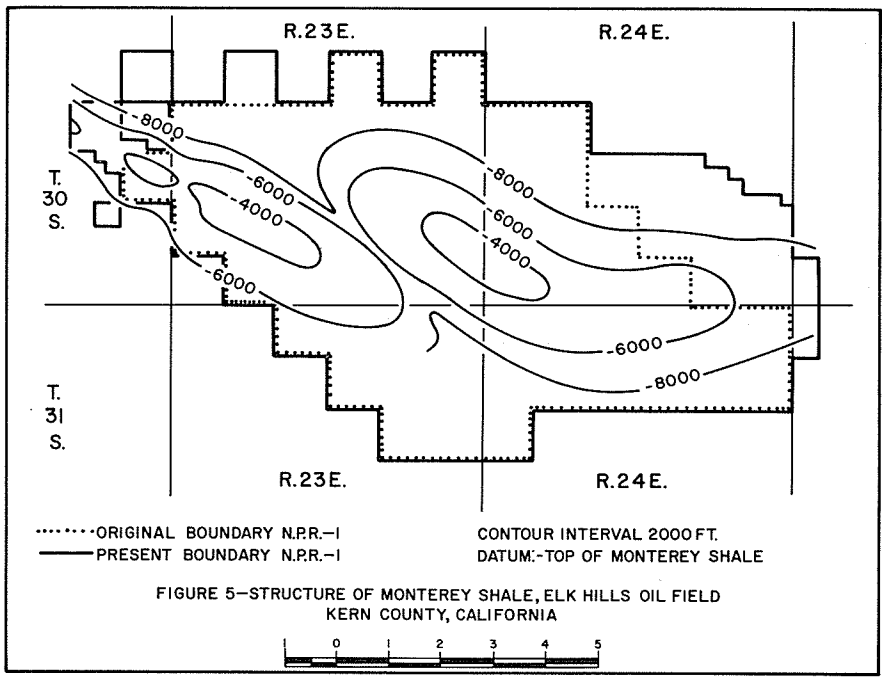

FIGURE 5—STRUCTURE OF MONTEREY SHALE, ELK HILLS OIL FIELD KERN COUNTY, CALIFORNIA

caused poor logging results or prevented the logging tools from reaching the total depth. Available data suggest that the folds are tighter in the Carneros Sandstone Member than in the Monterey Shale, and also that the porosity and permeability of the Carneros decreases toward the eastern end of the Elk Hills oil field.

OIL ACCUMULATION AND PRODUCTION

The Elk Hills oil field is situated on a great anticlinal axis. The folds are large, not only in amount of structural relief but also in areal extent. Structure has dictated the location of the oil field, but sand distribution has determined the position of the oil on the structure. Sand conditions influence well volumes more than structural position. All known productive horizons except the Carneros Sandstone Member are lenticular. The "shallow oil zone" sands of Pliocene age and the Stevens sand of Miocene age are the major reservoirs of the field and both are extremely lenticular (see fig. 2). The Pliocene sands are rarely more than 30 feet thick, and most are isolated lenses distributed through the upper two-thirds of the Etchegoin Formation. Many of these isolated lenses contain individual accumulations of oil. Oil-saturated sands are found below water-bearing sands, sometimes at the same stratigraphic horizon. The distribution of the Stevens sand is much more restricted than the Pliocene sands. The distribution of the lenticular Miocene sands is extremely erratic; one lense of sand in the western part of the field thickens from a wedge to more than 700 feet and is wedged out again in a distance of less than three-fourths of a mile. Certainly stratigraphic conditions played an important part in trapping hydrocarbons in the Elk Hills field.

Current production from the Elk Hills oil field is primarily the result of various equipment-testing programs, and most of the oil is produced from the "shallow oil zone." During 1966, the average daily production was 9,248 barrels a day. The cumulative production to January 1, 1967, was 282,142,666 barrels. The estimated remaining recoverable reserves as of January 1, 1967, were 1,025,853,634 barrels of oil. Thus, the ultimate total reserves as of the same date were 1,307,996,300 barrels of oil.

The concept of naval petroleum reserves has been modified considerably over the years, and the original idea of an assured source of oil for naval vessels has been changed. Naval Petroleum Reserve No. 1 is presently regarded as a reserve of oil to be available for any strategic military purpose should an emergency arise. The Elk Hills field could be an important factor in replacing west coast imports should an emergency situation shut them off. Present west coast imports range from 200,000 to 250,000 barrels of oil a day; with additional surface equipment, production from the Elk Hills field could replace imported oil.

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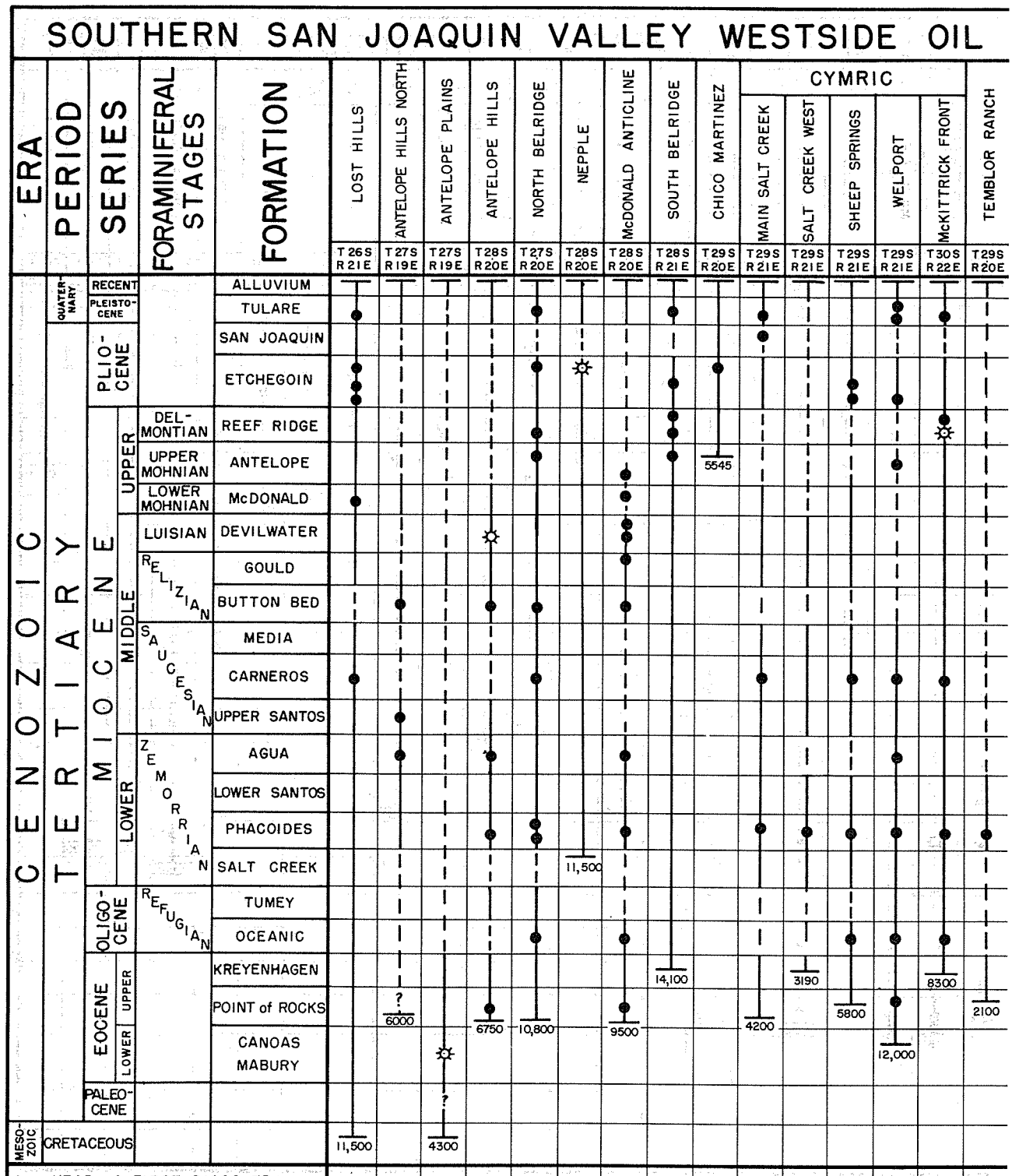
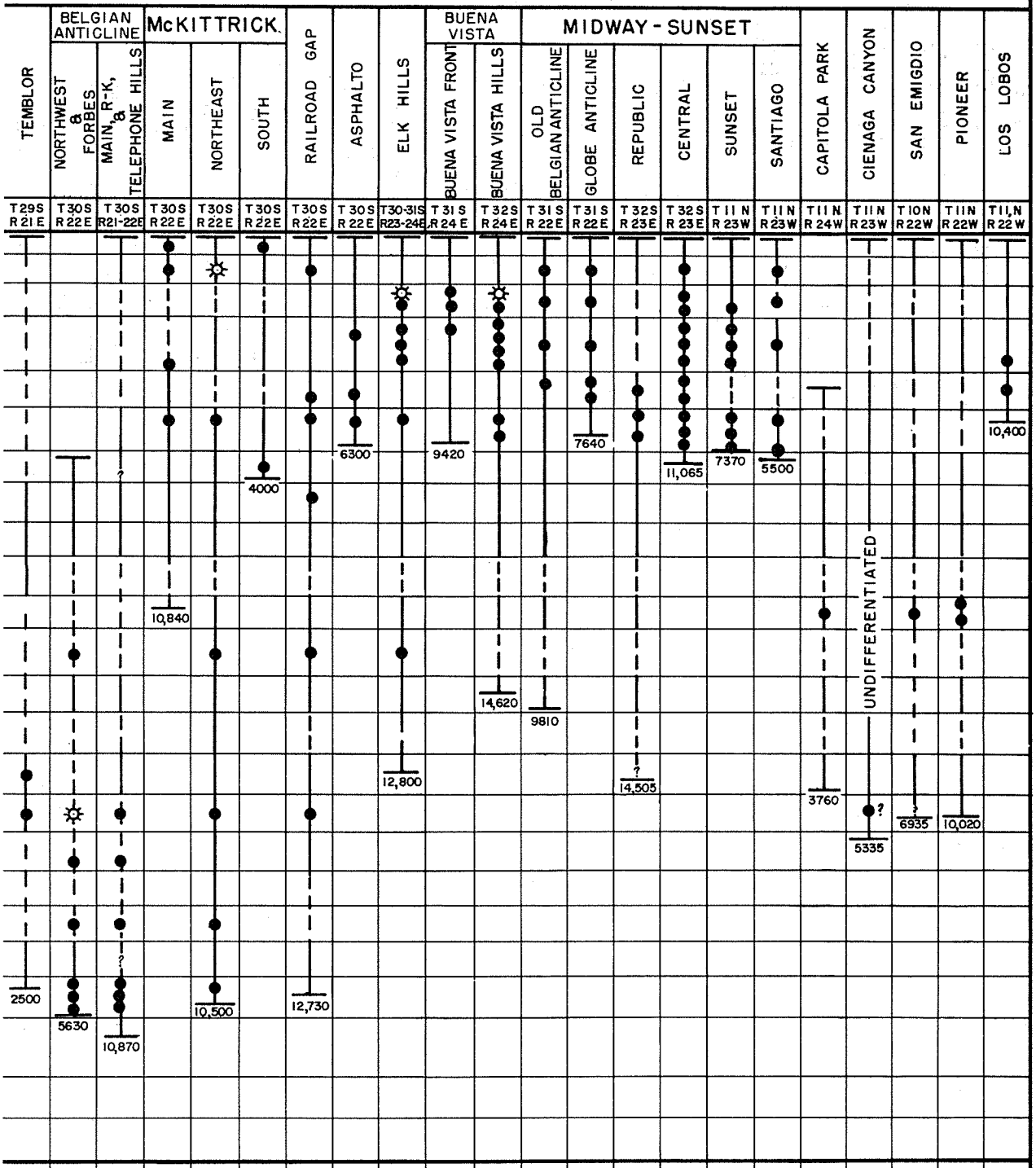
SOUTHERN SAN JOAQUIN VALLEY WESTSIDE OIL



	LOST HILLS	ANTELOPE HILLS NORTH	ANTELOPE PLAINS	ANTELOPE HILLS	NORTH BELRIDGE	NEPPLE	McDONALD ANTICLINE	SOUTH BELRIDGE	CHICO MARTINEZ	MAIN SALT CREEK	SALT CREEK WEST	SHEEP SPRINGS	WELPORT	McKITTRICK FRONT	TEMBLOR RANCH
YEAR of FIRST DISCOVERY	1910	1950	1949	1942	1915	1955	1945	1911	1927	1946	1951	1944	1916	1909	1900
PRODUCING WELLS 8-1-67	1063	21	Abd	66	94	Abd	68	2576	16	39	48	42	337	314	8
CUMULATIVE GAS PRODUCTION. (Mil. MCF) 1-1-67	95	18.5	35	7	465	155	0.89	18.2	—	0.02	0.8	4.3	63.4	12.4	—
OIL PRODUCTION 1966 (Thous Bbls)	2746	40	—	456	435	—	728	7571	4	440	115	88	1659	3341	17
CUMULATIVE OIL PRODUCTION (Thous Bbls) 1-1-67	99,476	2953	—	11,272	68,156	—	8987	124,637	126	20,154	2664	4254	51,558	22,418	1032
BARRELS PRODUCED per ACRE	26,670	11,300	—	30,450	34,900	—	15,200	15,500	1800	N/A	N/A	N/A	N/A	N/A	11,500
OIL GRAVITY	12-40	15	—	17, 31	10-52	—	13-38	12-25	12	12-30	19-24	16-41	13-50	11-20	16
TYPE of TRAP	A	TH	FA	FA	A,S	FN	FA	FN	N,S	FN	FA	FN,S	FA,S	TH,A	FA

KEY: A = Anticline; N = Anticlinal Nose; TH = Truncated Homocline; B = Anticlinal Flank; F = Faulted;

FIELDS PENETRATION AND PRODUCTION CHART

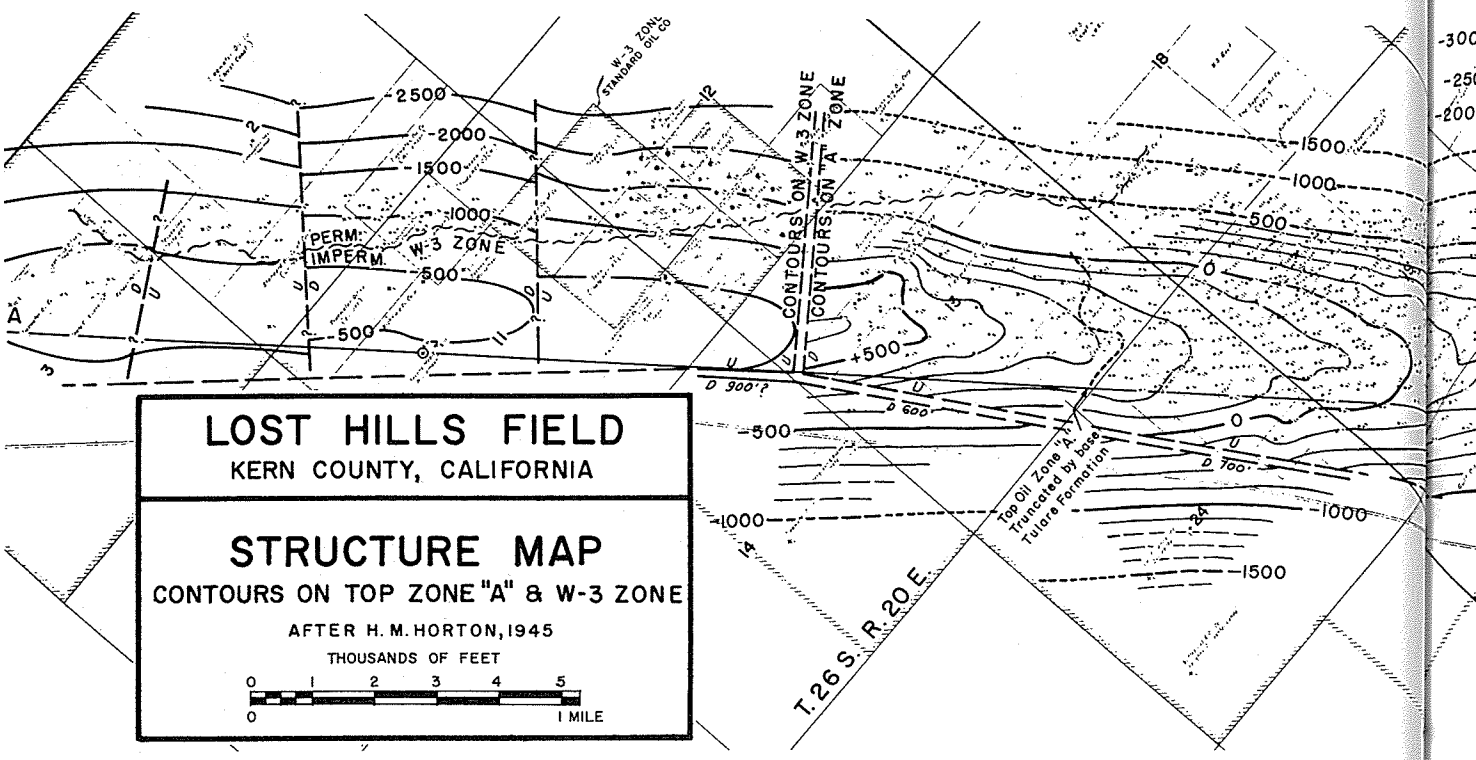


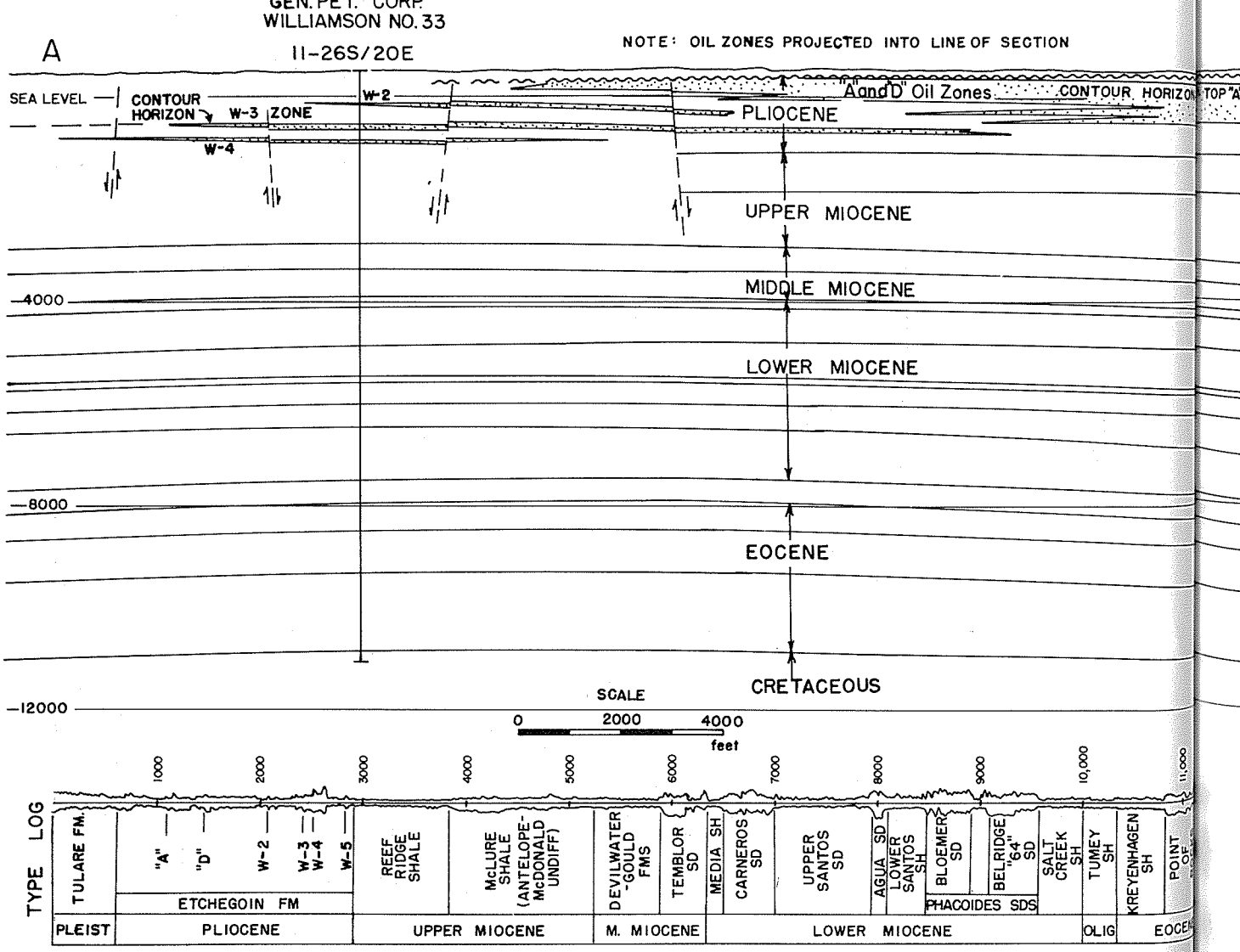
1953	1951	1947	1887	1944	1938	1964	1962	1919	1912	1909	1916	1912	1928	1901	1900?	1911	1960	1926	1948	1959	1952
Abd	53	72	627	118	Abd	51	53	120	177	1129	4692*	—	—	—	—	—	1	Abd	Abd	2	2
—	22.5	95.8	13.1	21.6	0.08	17.3	18.1	151.5	56.9	717.3	466*	—	—	—	—	—	—	—	—	0.2	1.2
—	211	713	4058	7356	—	1270	3607	2071	732	6805	26,099*	—	—	—	—	—	1	—	—	8	17
2.6	14,949	23,614	119,264	13,009	17.6	3386	15,613	276,060	120,537	454,034	961,641*	—	—	—	—	—	9	2.1	1.8	107	2714
—	N/A	N/A	81,000	N/A	17,600	N/A	N/A	14,000	26,000	38,000	30,900*	—	—	—	—	—	—	—	—	1300	9000
20	29-43	32-39	12-32	12-55	20	13-42	18-40	11-44	14-18	23-36	11-36*	—	—	—	—	—	26-27	33	28	40	15-25
FB,S	FN,S	FA	TH,FA	FA	FB	A	S	FA	B,S	A	FN	FN	FA	TH,S,N	FN,S	FTH,S	A	FA	FTH	FA	TH,S

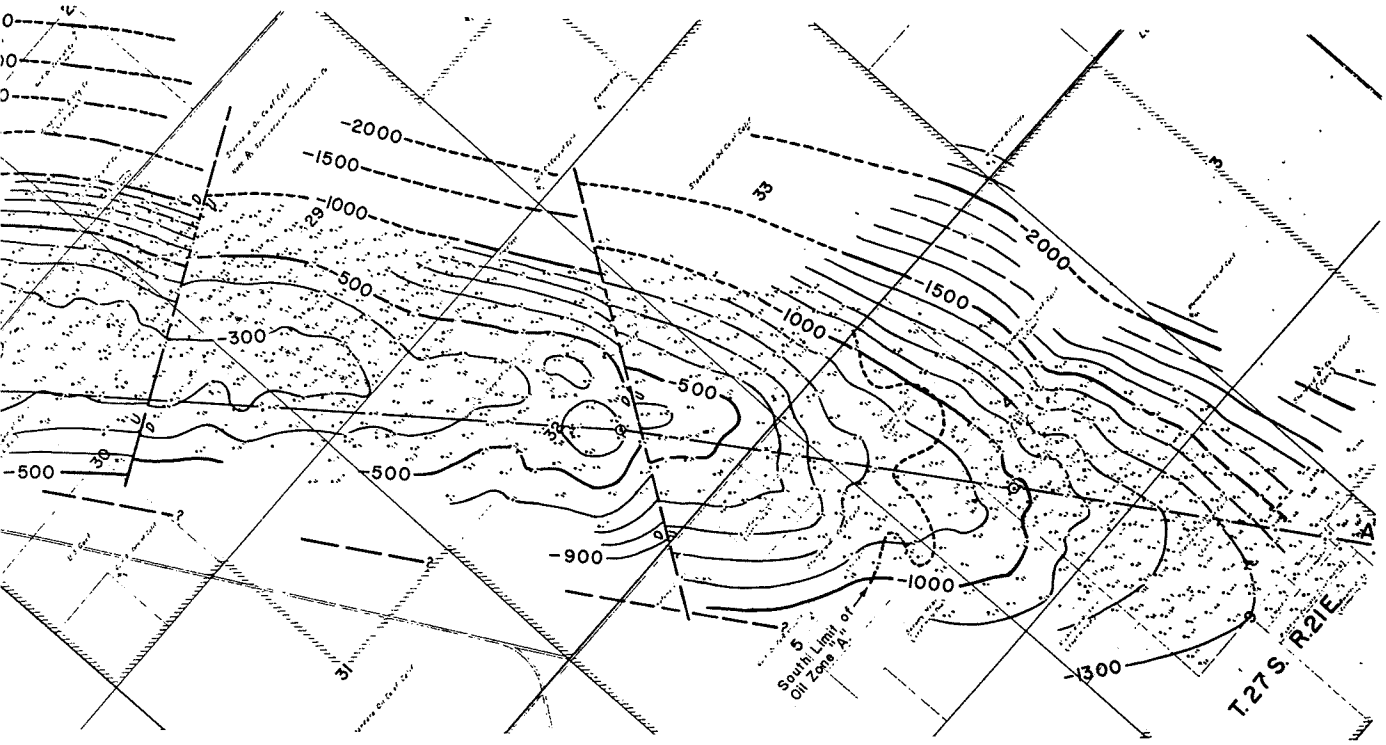
S = Stratigraphic .

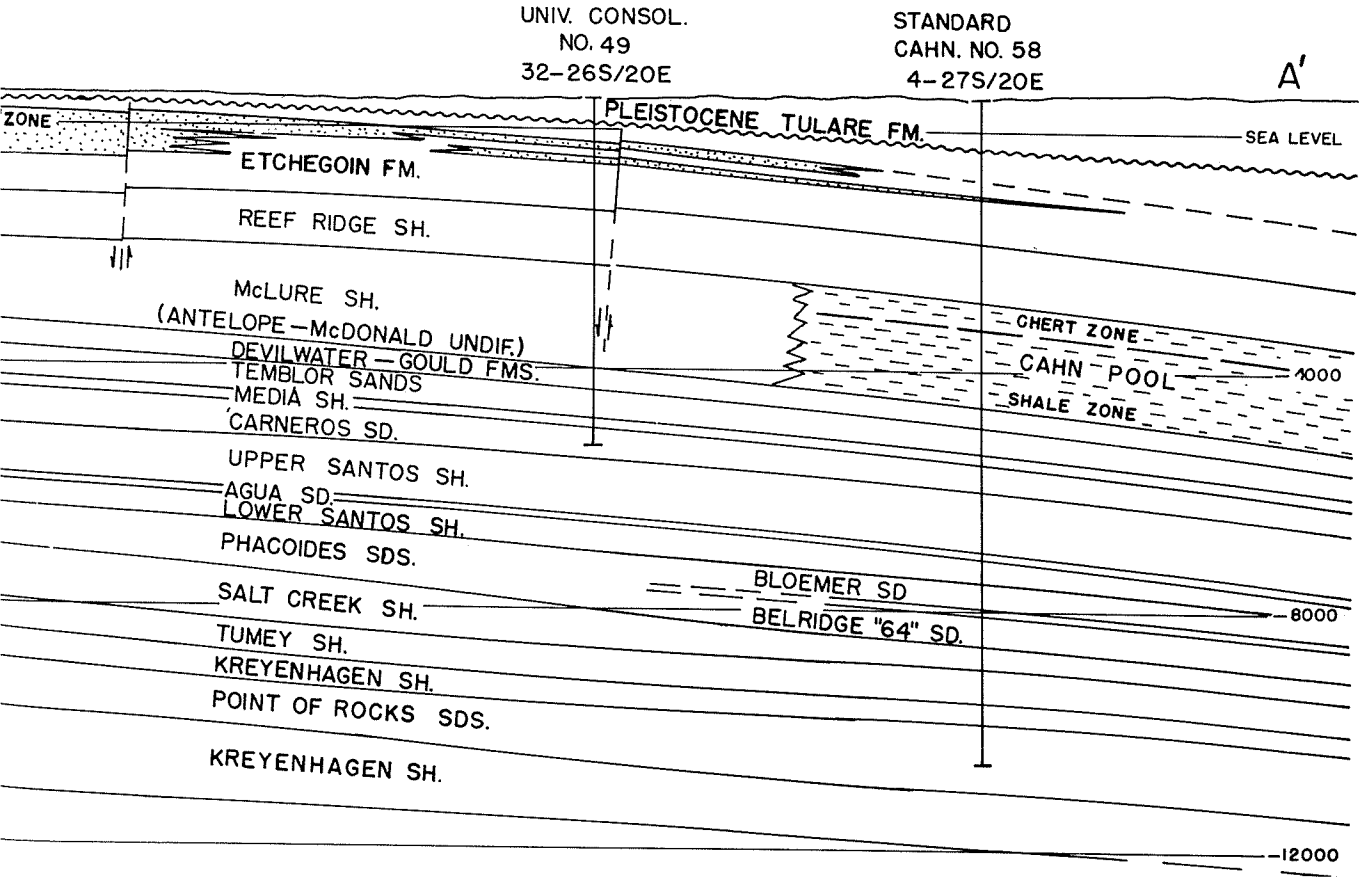
* Totals For Entire Midway - Sunset Field

Compiled by T.L. Fyock, Texaco Inc., from published sources


LOST HILLS FIELD
KERN COUNTY, CALIFORNIA
STRUCTURE MAP
CONTOURS ON TOP ZONE "A" & W-3 ZONE
AFTER H. M. HORTON, 1945
THOUSANDS OF FEET
0 1 2 3 4 5
0 1 MILE
PERM. IMPERM.
W-3 ZONE
W-3 ZONE STANDARD OIL CO
CONTOURS ON W-3 ZONE
CONTOURS ON "A" ZONE
Top Oil Zone "A" Truncated by base Tulare Formation
T. 26 S. R. 20 E.
A


GEN. PET. CORP.
WILLIAMSON NO. 33
11-26S/20E
A
NOTE: OIL ZONES PROJECTED INTO LINE OF SECTION
SEA LEVEL
CONTOUR HORIZON
W-3 ZONE
W-2
W-4
"A" and "D" Oil Zones
CONTOUR HORIZON TOP "A"
PLIOCENE
UPPER MIOCENE
MIDDLE MIOCENE
LOWER MIOCENE
EOCENE
CRETACEOUS
-4000
-8000
-12000
SCALE
0 2000 4000
feet
TYPE LOG
TULARE FM.
"A"
"D"
W-2
W-3
W-4
W-5
ETCHEGOIN FM
REEF RIDGE SHALE
McLURE SHALE (ANTELOPE-McDONALD UNDIFF)
DEVILWATER-GOULD FMS
TEMBLOR SD
MEDIA SH
CARNEROS SD
UPPER SANTOS SD
AGUA SD
LOWER SANTOS SH
BLOEMER SD
BELRIDGE "64" SD
PHACOIDES SDS
SALT CREEK SH
TUMEY SH
KREYENHAGEN SH
POINT OF
PLEIST
PLIOCENE
UPPER MIOCENE
M. MIOCENE
LOWER MIOCENE
OLIG
EOCE





LOST HILLS OIL FIELD - PRODUCTION DATA

Main Field - 1966 - 2,529,000 bbls.
Cumulative to 1/1/67 - 89,640,000 bbls
Williamson Area - 1966 - 87,000 bbls.
Cumulative to 1/1/67 - 5,543,000 bbls.
Cahn Pool - 1966 - 88,000 bbls.
Cumulative to 1/1/67 - 2,322,000 bbls.
Other Zones - 1966 - 47,000 bbls.
Cumulative 1/1/67 - 2,068,000 bbls.
Totals - 1966 - 2,751,000 bbls.
Cumulative to 1/1/67 - 99,574,000 bbls., 95,014 MMCF

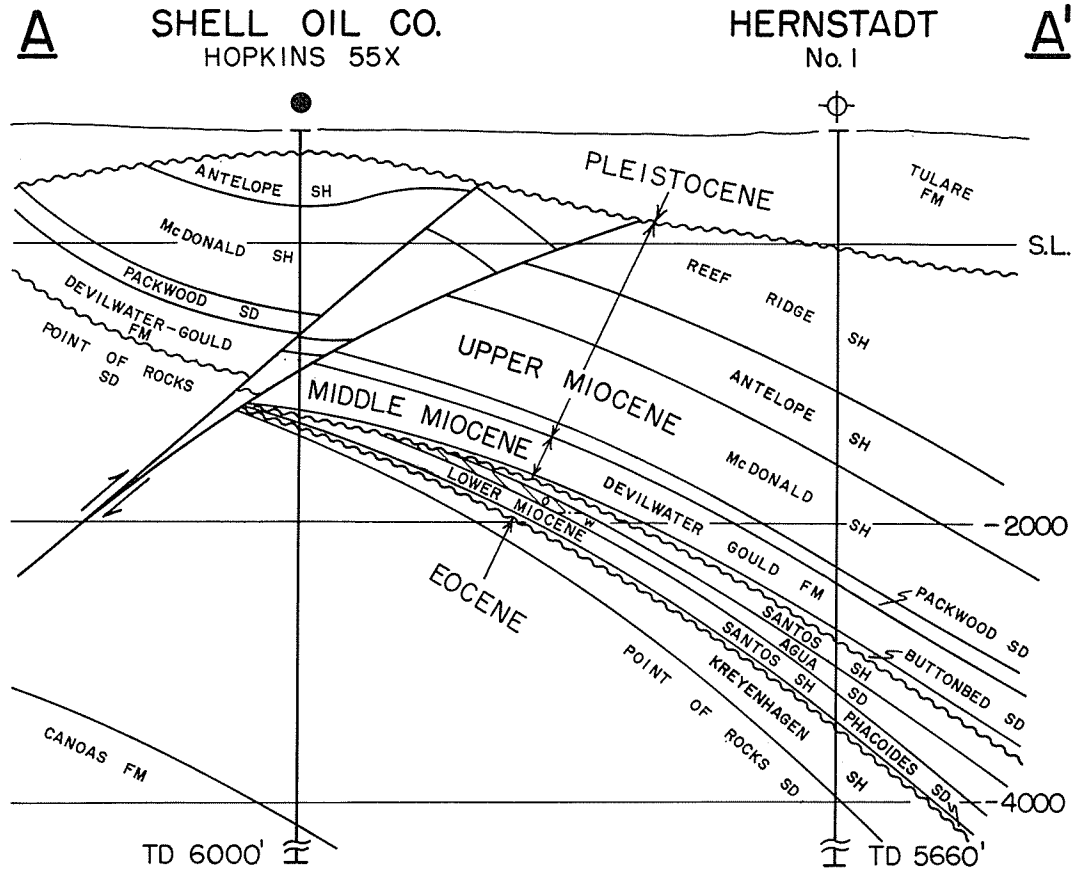
DISCOVERY DATA

The main field was discovered by the Martin and Dudley (now Gulf Oil Corp.) #1, near the N/4 corner of Section 30, T. 26 S., R. 21 E., July 20, 1910. The well was drilled as a water well but encountered 15° gravity oil sand from 472-530 feet.

Williamson Area - Baker and Henshaw #2, near the SW corner of Section 12, T. 26 S., R. 20 E., June 1916. Initial production was 300 B/D of 12° gravity oil from 1205-1230' (W-4 zone).

Cahn Pool (fractured chert and shale) - Standard Oil Co. of Calif., Cahn #9, NE/4 NE/4 of Section 9, T. 27 S., R. 20 E., August 25, 1913. Initial production was 60 B/D 30° gravity oil from 3100-4550 feet.

NORTH ANTELOPE HILLS OIL FIELD



DISCOVERED BY

SHELL OIL CO.
HOPKINS "B" No. 63X
SEC. 23 - T. 27 S. - R. 19 E.
JUNE, 1950

PRODUCTION DATA

LOWER MIOCENE AGUA SAND
CUMUL. PROD. TO 1/1/67: 2,953,000 Bbls
OIL GRAVITY: 15°
POROSITY: 27 %
PERM: 400 md

PROVED AREA

260 ACRES

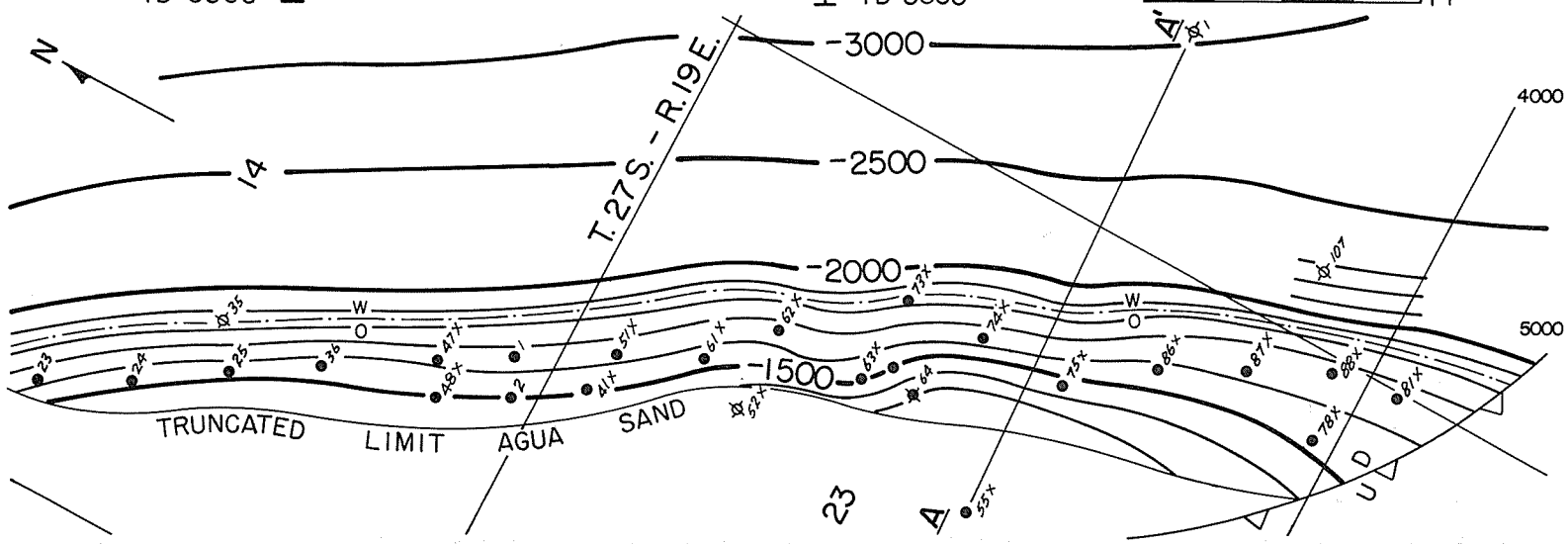
PRODUCTION FOR 1966

40,000 Bbls

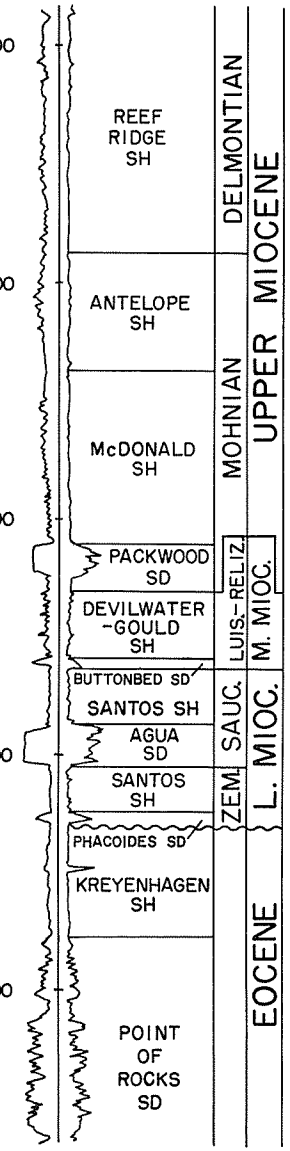
CONTOURED ON TOP AGUA SAND

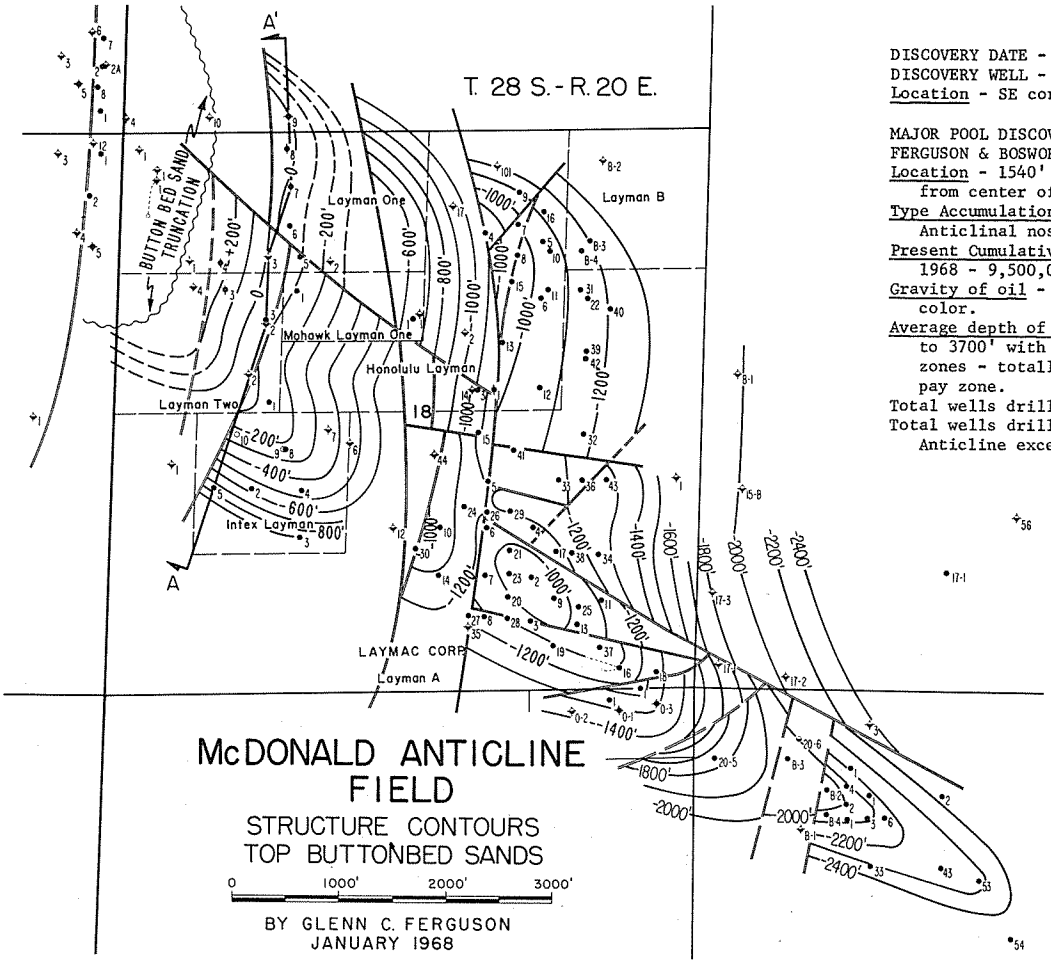
C. I. = 100' & 500'

SCALE
0 1000 2000 FT



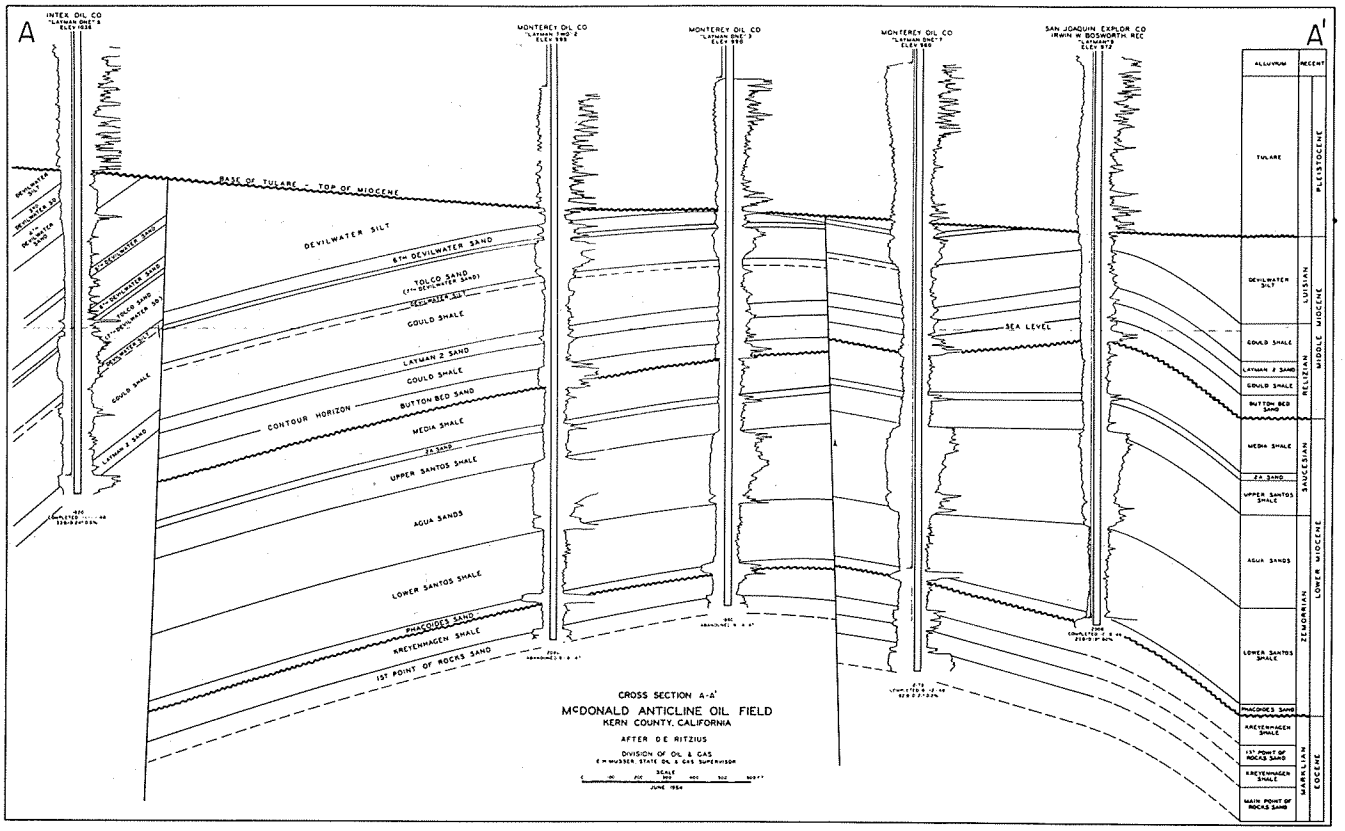
TYPE LOG

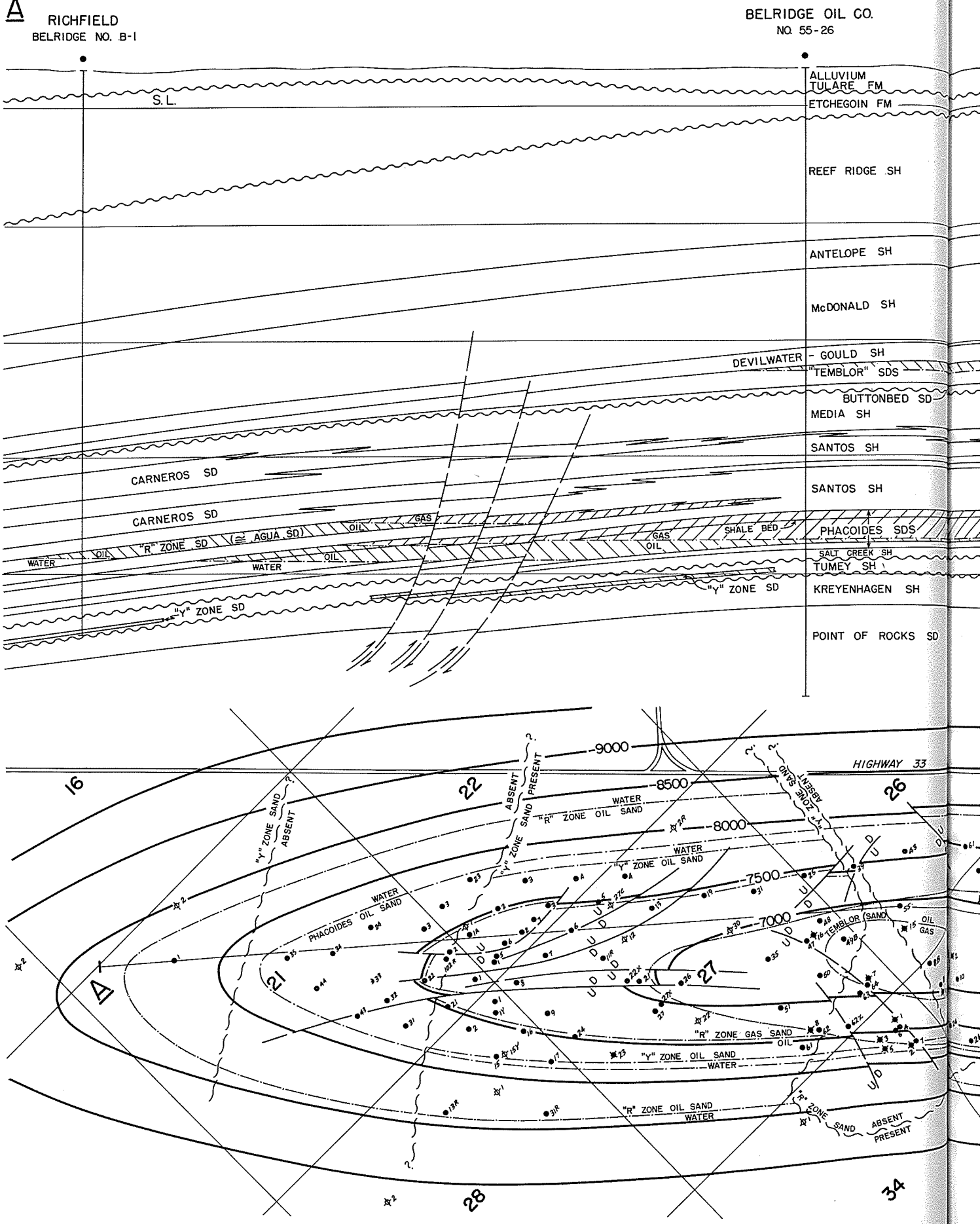


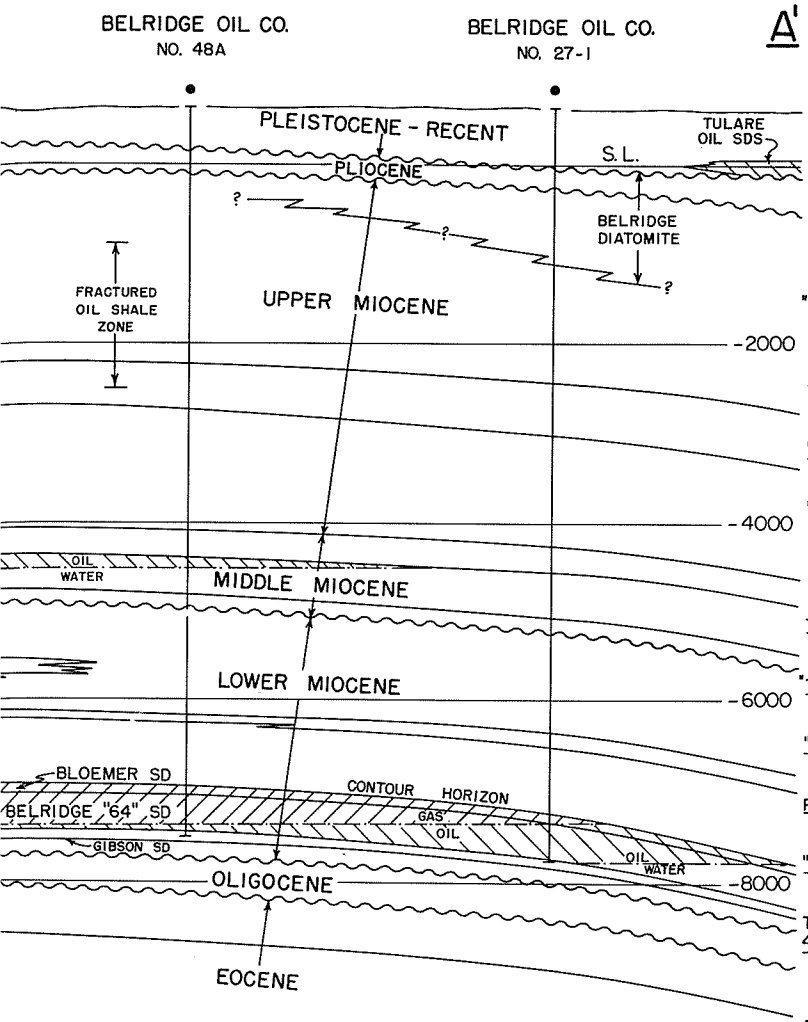


DISCOVERY DATE - 1945
DISCOVERY WELL - WILLIAMS BROS. LAYMAN #1
Location - SE corner section 12-28-19

MAJOR POOL DISCOVERY - 1950
FERGUSON & BOSWORTH - LAYMAN #2
Location - 1540' South and 1100' east from center of sec. 18-28-20
Type Accumulation - Fault trap - Anticlinal nose.
Present Cumulative Production, January, 1968 - 9,500,000 bbls.
Gravity of oil - 15° to 44° - green in color.
Average depth of wells - Range from 800' to 3700' with 13 distinctive producing zones - totalling in excess of 750' of pay zone.
Total wells drilled, Layman area - 90
Total wells drilled delineating McDonald Anticline exceed 200.




A
RICHFIELD
BELRIDGE NO. B-1
BELRIDGE OIL CO.
NO. 55-26
S. L.
ALLUVIUM
TULARE FM
ETCHEGOIN FM
REEF RIDGE SH
ANTELOPE SH
McDONALD SH
DEVILWATER - GOULD SH
"TEMBLOR" SDS
BUTTONBED SD
MEDIA SH
SANTOS SH
SANTOS SH
CARNEROS SD
CARNEROS SD
"R" ZONE SD (≅ AGUA SD)
OIL
GAS
WATER
SHALE BED
PHACOIDES SDS
SALT CREEK SH
TUMEY SH
KREYENHAGEN SH
POINT OF ROCKS SD
"Y" ZONE SD
HIGHWAY 33
-9000
-8500
-8000
-7500
-7000
WATER
"R" ZONE OIL SAND
"Y" ZONE OIL SAND
PHACOIDES OIL SAND
"Y" ZONE SAND ABSENT
"Y" ZONE SAND PRESENT
"Y" ZONE SAND ABSENT
TEMBLOR SAND
OIL
GAS
"R" ZONE GAS SAND
"R" ZONE SAND ABSENT PRESENT
16
22
26
21
27
28
34



NORTH BELRIDGE OIL FIELD

DISCOVERY DATA

MIOCENE FRACTURED SHALE

Mannel - Minor Oil Co., M&M No. 1
Sec. 35-27S-20E June 1912
I.P. 18 B/D, 31°

TULARE POOL

Union Oil Co., Gibson No. 1
Sec. 36-27S-20E Sept. 1917
I.P. 10 B/D, 14°

"TEMBLOR" POOL

Belridge Oil Co., Well No. 15
Sec. 26-27S-20E Oct. 1930
I.P. 3014 B/D, 44°, 50,000 MCF

PHACOIDES POOL

Belridge Oil Co., Well No. 64-27
Sec. 27-27S-20E June 1932
I.P. 2040 B/D, 50°, 75,000 MCF

"R" ZONE POOL

Discovered Sept. 1939
Other Data Not Available

"Y" ZONE POOL

Belridge Oil Co., Well No. 47-27
Sec. 27-27S-20E May 1942
I.P. 1061 B/D 50°

PRODUCTION DATA

TULARE & FRACTURED SHALE

Cumulative to 1/1/67 6,096,000 Bbls
1966 148,000 Bbls

"TEMBLOR" POOL

Cumulative to 1/1/67 19,310,000 Bbls
1966 82,000 Bbls

"R" ZONE POOL

Cumulative to 1/1/67 1,771,000 Bbls
1966 43,000 Bbls

PHACOIDES POOL

Cumulative to 1/1/67 38,281,000 Bbls
1966 143,000 Bbls

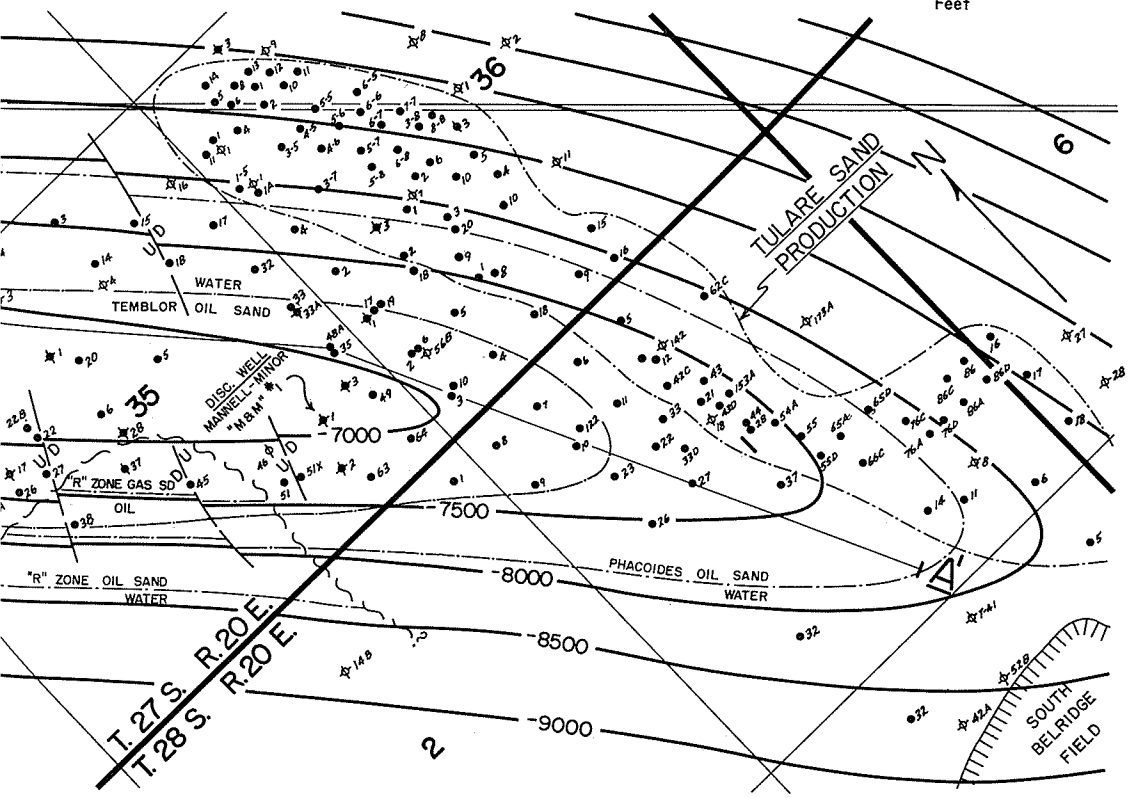
"Y" ZONE POOL

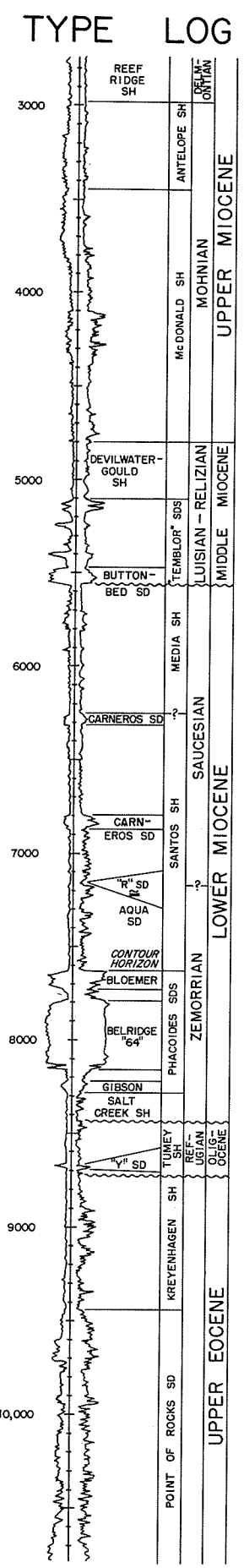
Cumulative to 1/1/67 2,698,000 Bbls
1966 19,000 Bbls

TOTAL TO 1/1/67: 68,156,000 Bbls; 465,000 MCF GAS; 1966, 435,000 Bbls.

CONTOURED ON TOP PHACOIDES SD
C. I. = 500'

SCALE
0 1000 2000
Feet

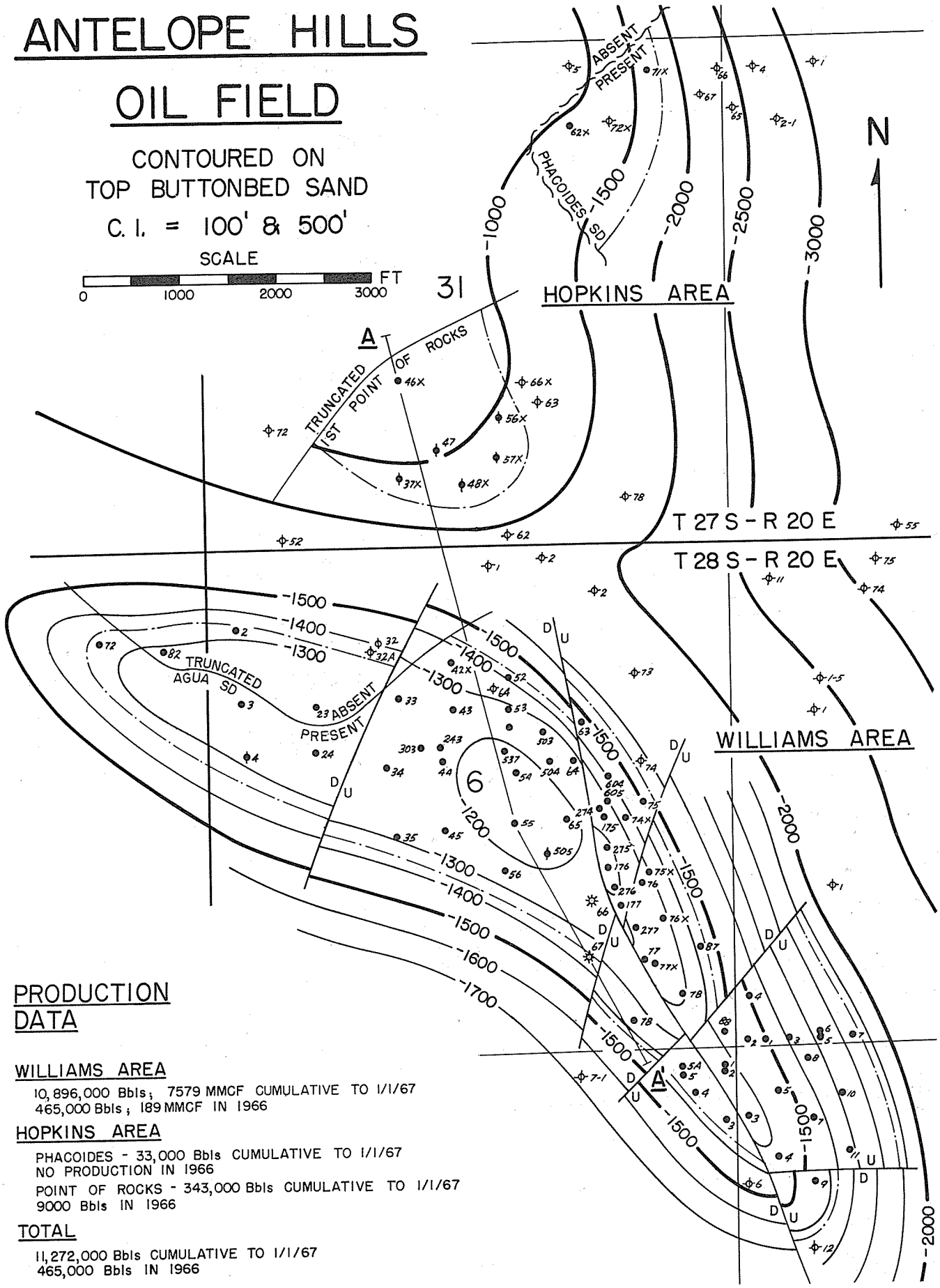




ANTELOPE HILLS OIL FIELD

CONTOURED ON
TOP BUTTONBED SAND
C. I. = 100' & 500'

SCALE
0 1000 2000 3000 FT



PRODUCTION DATA

WILLIAMS AREA

10,896,000 Bbls; 7579 MMCF CUMULATIVE TO 1/1/67
465,000 Bbls; 189 MMCF IN 1966

HOPKINS AREA

PHACOIDES - 33,000 Bbls CUMULATIVE TO 1/1/67
NO PRODUCTION IN 1966

POINT OF ROCKS - 343,000 Bbls CUMULATIVE TO 1/1/67
9000 Bbls IN 1966

TOTAL

11,272,000 Bbls CUMULATIVE TO 1/1/67
465,000 Bbls IN 1966

DISCOVERY DATA

WILLIAMS AREA

AGUA ZONE - SHELL OIL CO
WILLIAMS No. 45-6 6-28S-20E
MAY 1942 718 B/D, 17°

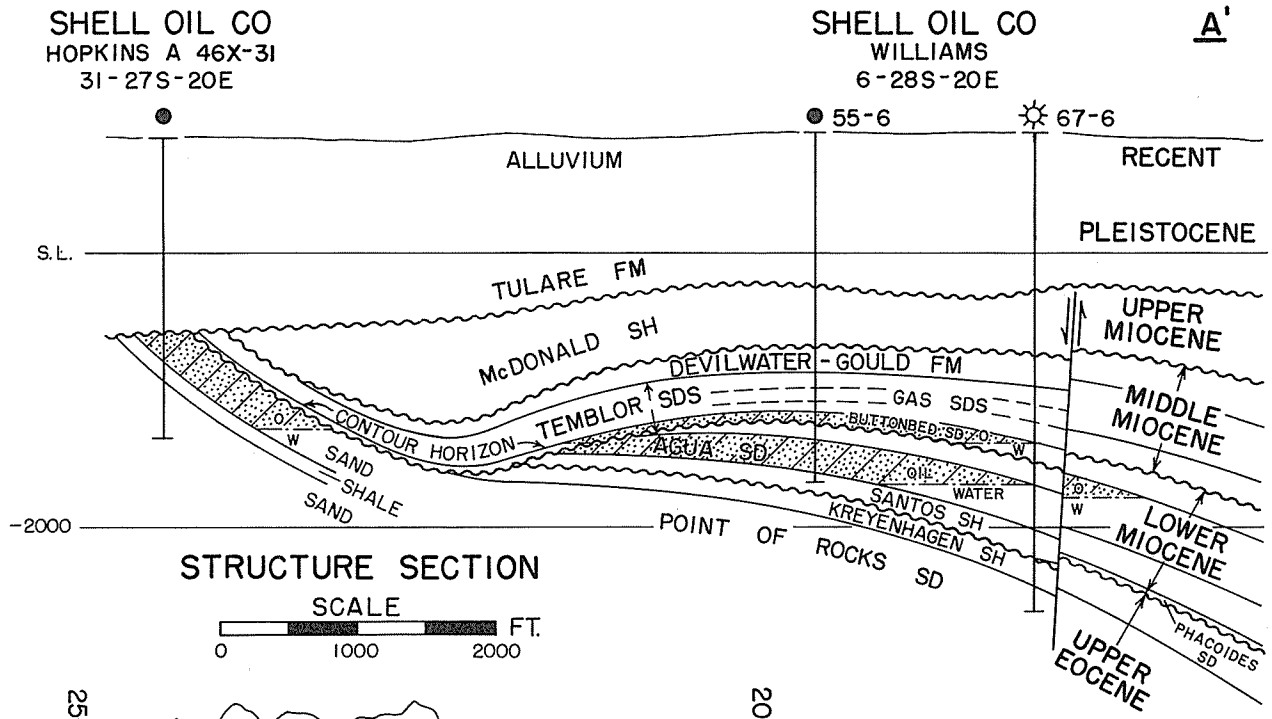
TEMBLOR GAS ZONE - SHELL OIL CO
WILLIAMS No. 67-6 6-28S-20E
JUNE 1942 300 MCF/D

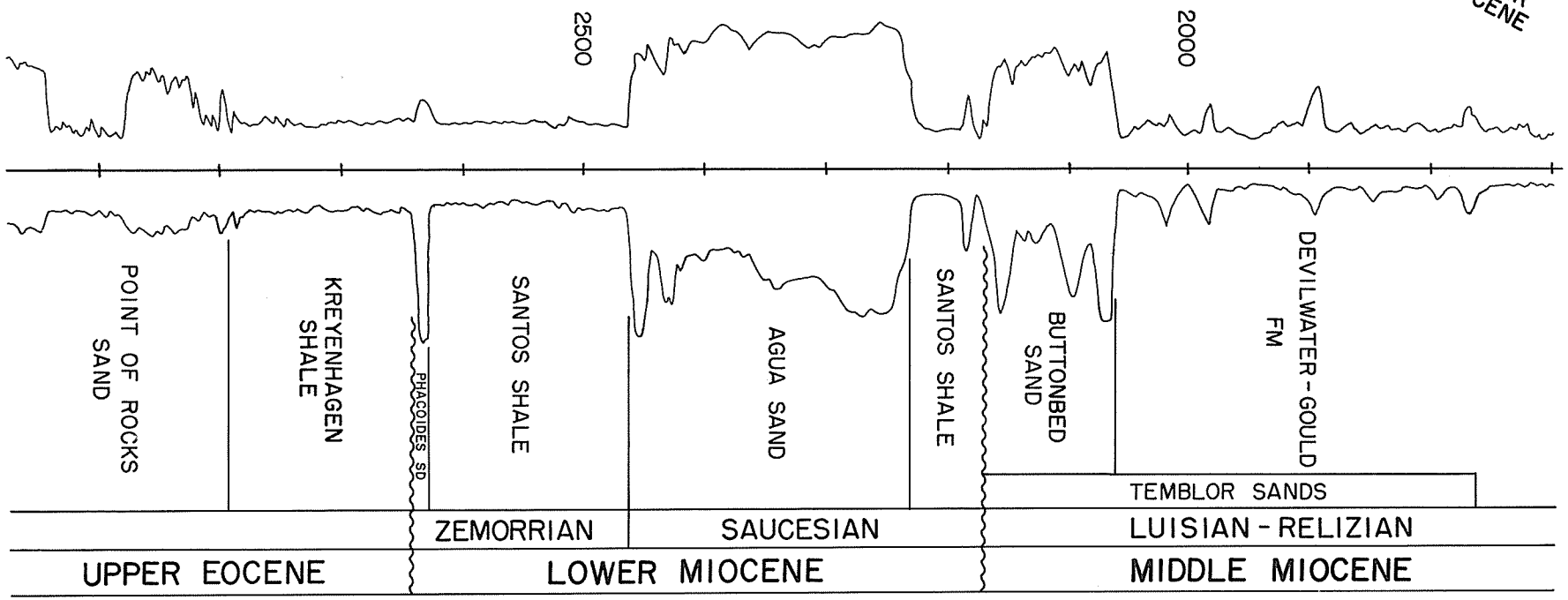
BUTTONBED ZONE - SHELL OIL CO
WILLIAMS No. 23-6 6-28S-20E
SEPT. 1942 54 B/D, 17°

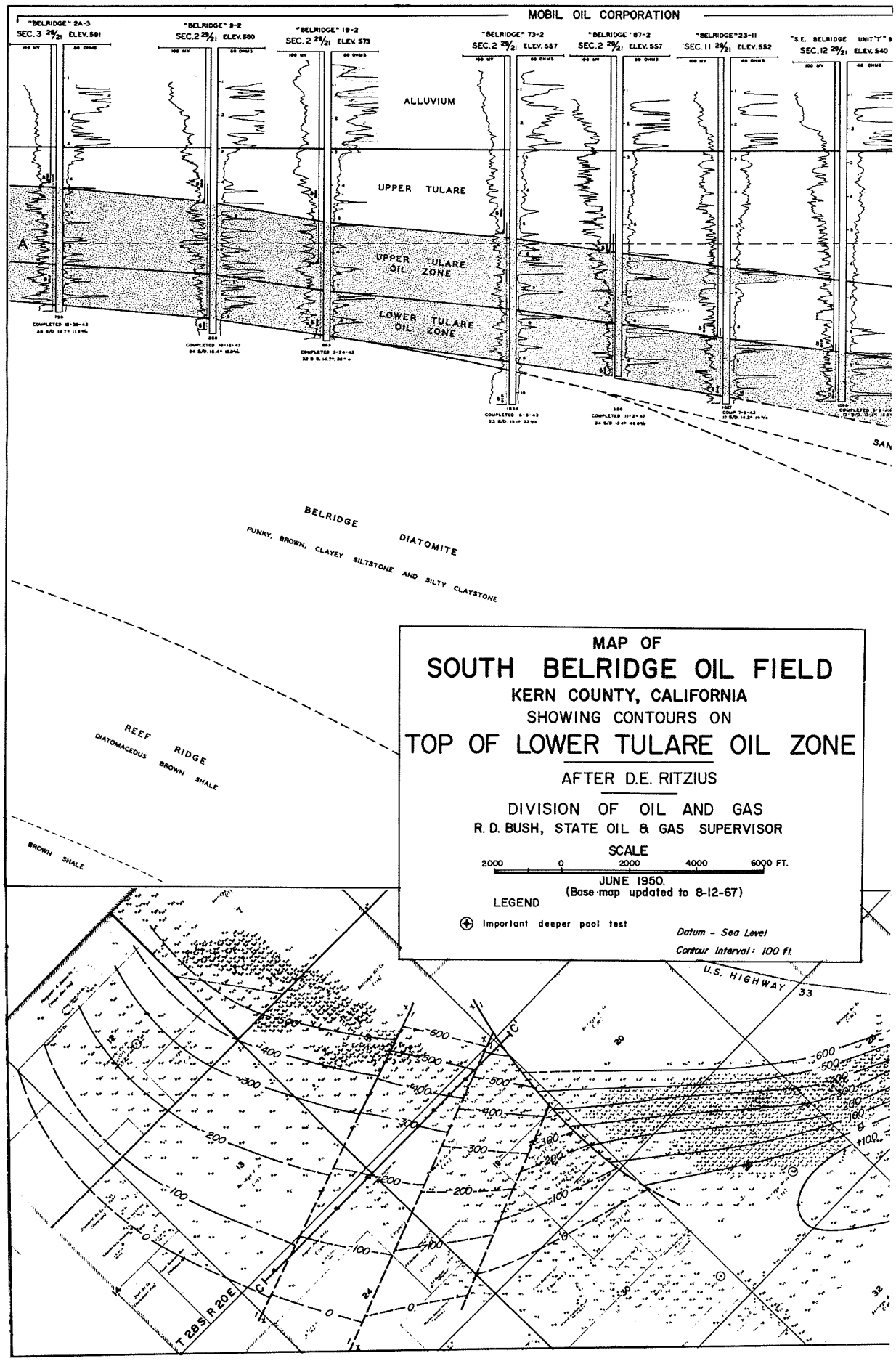
HOPKINS AREA

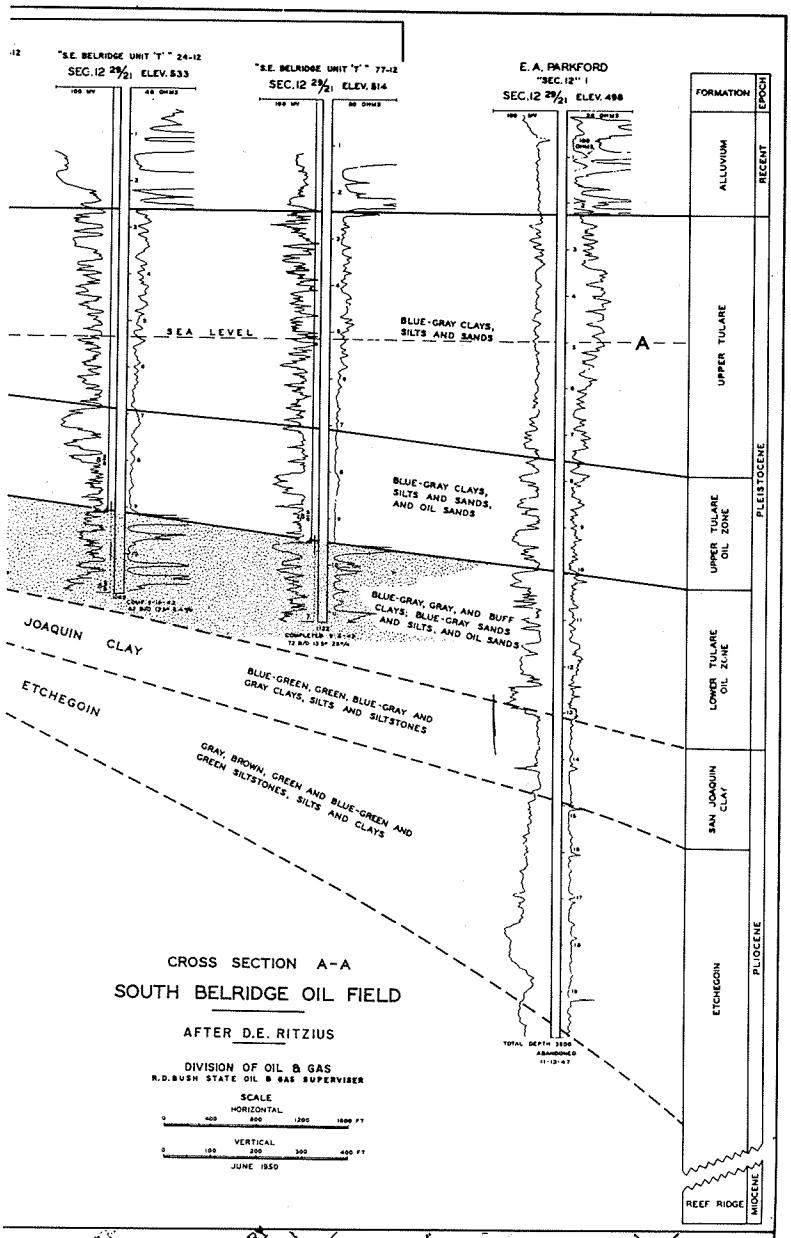
POINT OF ROCKS ZONE - SHELL OIL CO
HOPKINS FEE No. 57X-31 31-27S-20E
JUNE 1944 34 B/D, 16°

PHACOIDES ZONE - SHELL OIL CO
HOPKINS A No. 62X-31 31-27S-20E
JAN. 1952 14 B/D, 33°






MOBIL OIL CORPORATION
"BELRIDGE" 2A-3
SEC. 3 29/21 ELEV. 591
"BELRIDGE" 9-2
SEC. 2 29/21 ELEV. 580
"BELRIDGE" 19-2
SEC. 2 29/21 ELEV. 573
"BELRIDGE" 73-2
SEC. 2 29/21 ELEV. 557
"BELRIDGE" 87-2
SEC. 2 29/21 ELEV. 557
"BELRIDGE" 23-11
SEC. 11 29/21 ELEV. 552
"S.E. BELRIDGE UNIT 'Y'"
SEC. 12 29/21 ELEV. 540
ALLUVIUM
UPPER TULARE
UPPER TULARE OIL ZONE
LOWER TULARE OIL ZONE
BELRIDGE DIATOMITE
PUNKY, BROWN, CLAYEY SILTSTONE AND SILTY CLAYSTONE
REEF RIDGE
DIATOMACEOUS BROWN SHALE
BROWN SHALE
MAP OF
SOUTH BELRIDGE OIL FIELD
KERN COUNTY, CALIFORNIA
SHOWING CONTOURS ON
TOP OF LOWER TULARE OIL ZONE
AFTER D.E. RITZIUS
DIVISION OF OIL AND GAS
R. D. BUSH, STATE OIL & GAS SUPERVISOR
SCALE
2000 0 2000 4000 6000 FT.
JUNE 1950.
(Base map updated to 8-12-67)
LEGEND
Important deeper pool test
Datum - Sea Level
Contour Interval: 100 ft.
U.S. HIGHWAY 33
T 28 S R 20 E



SOUTH BELRIDGE OIL FIELD

Discovery of the South Belridge Oil Field was made on April 21, 1911, by the Belridge Oil Company with the completion of Well No. 101 at a depth of 782'. Initial production was 100 BOPD of 25.3° gravity oil from the Tulare (Pleistocene) and Belridge Diatomite (Pliocene-U. Miocene) zones. The well was located a short distance from an outcrop of dry oil sand in Section 33, T28S, R21E., MDB&M.

Oil entrapment at South Belridge is primarily localized within a broad northwest-southeast trending anticline, augmented by the stratigraphic changes in Pleistocene sediments that become less sandy from East to West. Productive horizons are presently confined to shallow depths and include lenticular sands of the Tulare (Pleistocene), local occurrence of lenticular sands in the Etchegoin (Pliocene) on the West flank, and fractured shales of the Belridge Diatomite (Upper Miocene) along the crest of the structure.

Historically, the development has been slow and sporadic. Active drilling periods occurred from 1911 to 1914, 1916 to 1918, 1927 to 1929, 1942 to 1949, and 1961 to the present. These periods of drilling have been dictated by the vascillating market demand for heavy asphaltic type crude oil. The later and most recent period of drilling has been stimulated by the successful application of down-hole heat, utilizing steam "huff and puff" and fire flood recovery methods. On a 2.75 acre plot in the northeast corner of Section 10, T29S, R21E, the first field test of an underground burn was initiated in October, 1955, with air injection started on March 1, 1956. Twelve companies participated, with General Petroleum Corporation (now Mobil Oil Corporation) as operator. The experiment demonstrated that viscous oil could be readily moved over limited distances. The percentage of oil recovery has been estimated at 40-60% compared to the primary factor of 10-15%. Special high temperature stainless steel liners are required in the completion of fire flood wells; several thermal patterns are now in operation.

Heat resistant cements and gravel-flow pack liners are a common practice of completion to withstand the excessive heat and to control sand entry. Gathering systems utilize open ground sumps rather than conventional tank farms.

Production for September, 1967 was 686,794 barrels of oil, 2,422,570 barrels of water, and 24,476 MCF of gas, or an average of 22,893 BOPD from active wells. Cumulative oil production for the field is estimated at 132,504,000 barrels to January 1, 1968. There have been approximately 3200 wells drilled within the 9450 proven acres of field area. The average well depth is 1013 feet and oil gravities range from 12 to 31° API. It is estimated the ultimate recovery will exceed 200MM barrels.

Selected References:

Wharton, J.B. (1943) California Division of Mines, Bulletin No. 118, pp. 502-504.

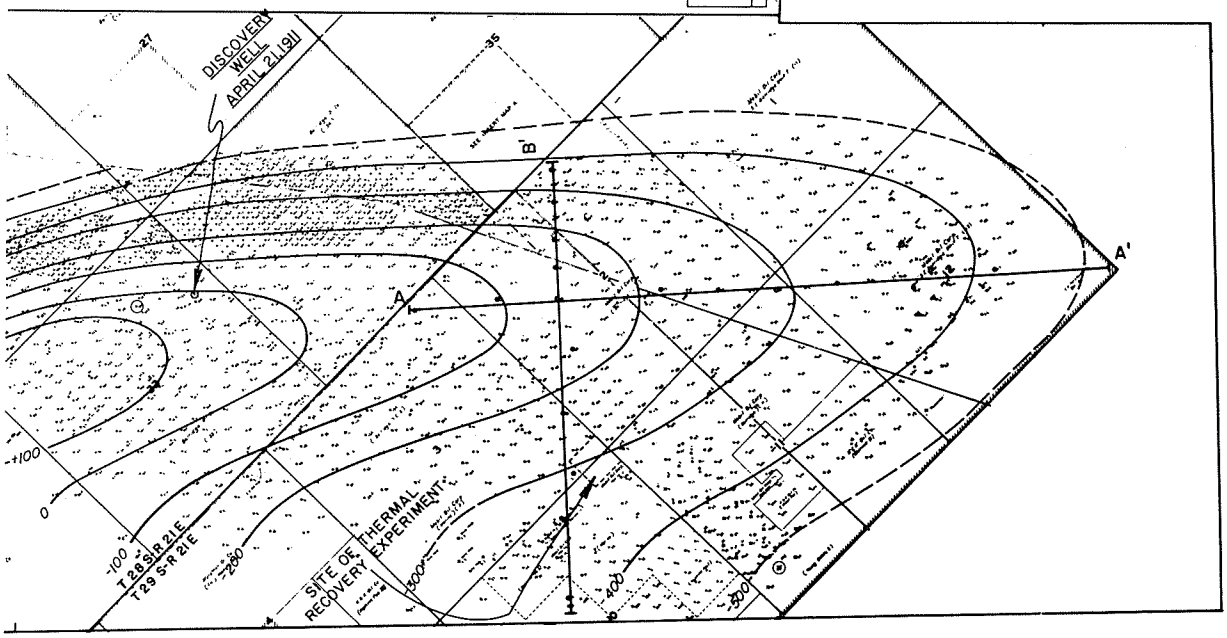
Ritzius, D. E. (1950) California Division of Oil and Gas, Summary of Operations, Vol. 36, No. 1, pp. 18-24; condensed in AAPG-SEPM-SEG Guidebook, pp. 218-223, March, 1952.

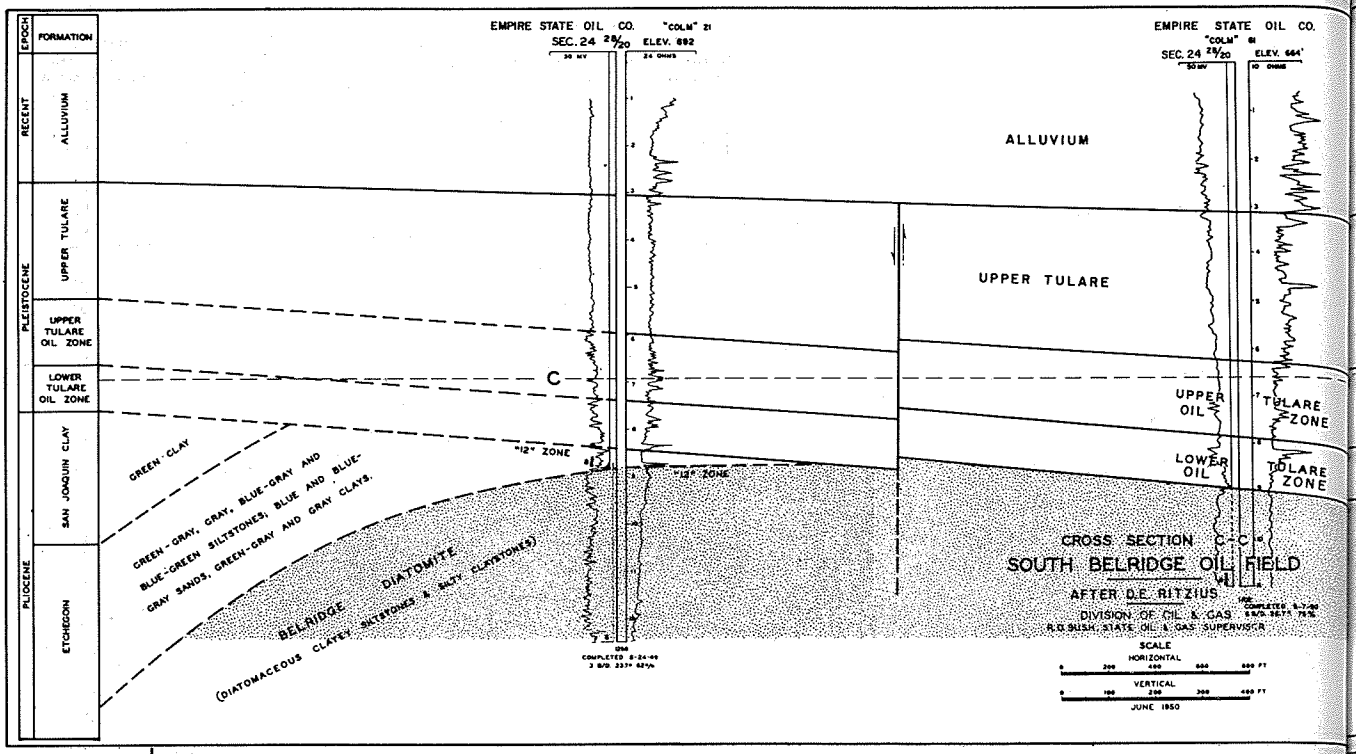
Barger, R. M. (1958) California Division of Oil and Gas, Summary of Operations, Vol. 42, No. 2, pp. 21-36.

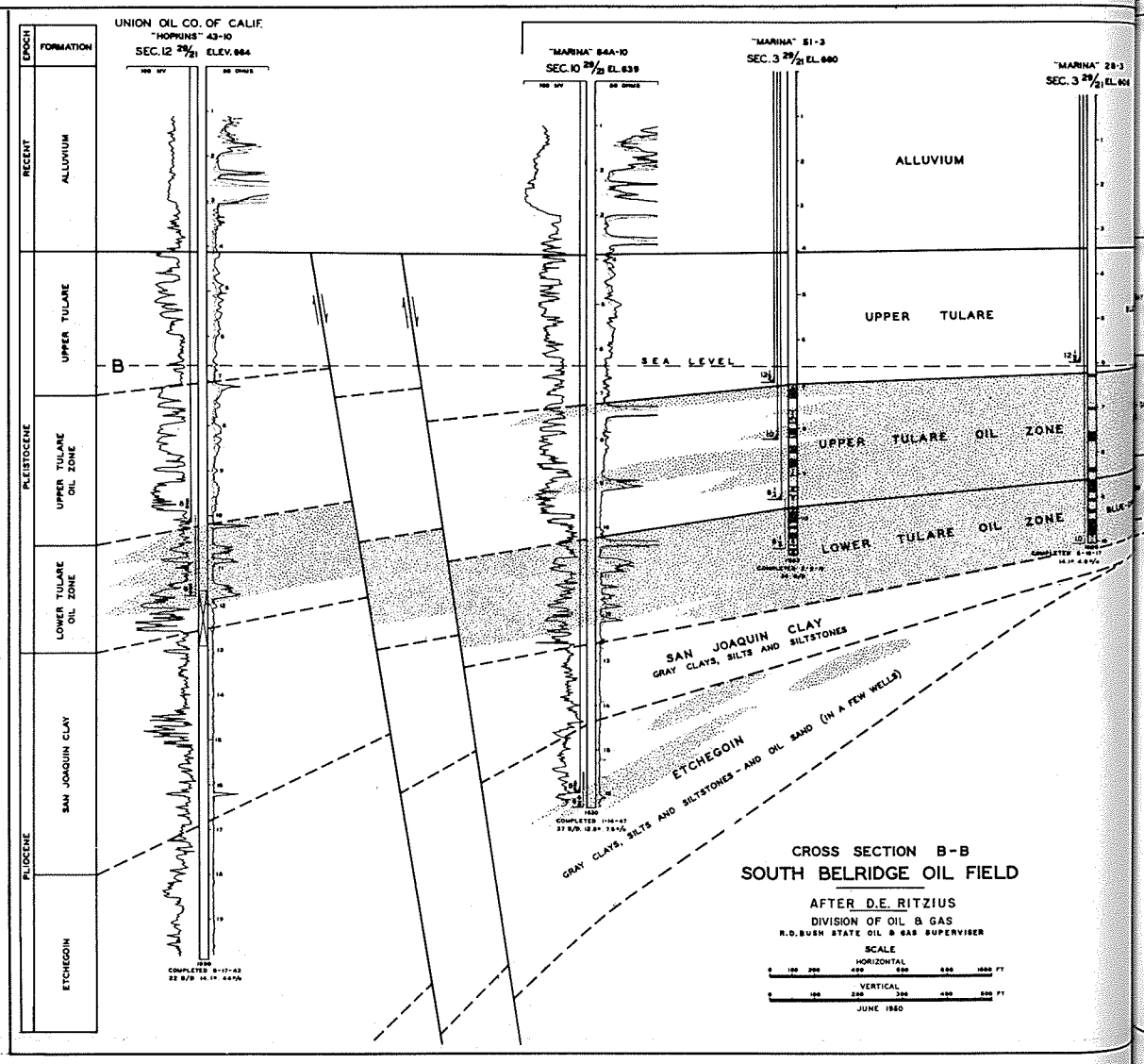
Gates, C. F. and Ramey, Jr., H. J. (October, 1958) Journal of Petroleum Technology, pp. 236-244.

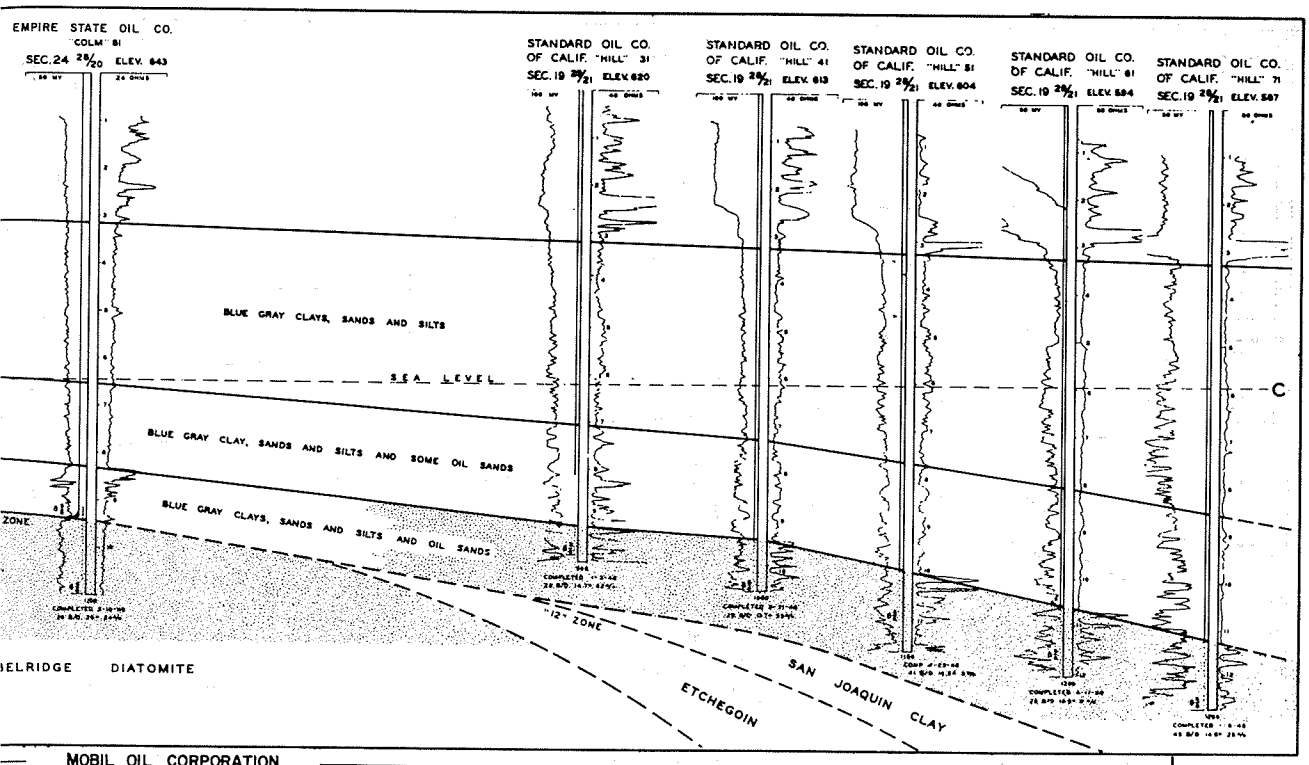
California Division of Mines, California Oil and Gas Fields, Part I, pp. 32-33, October, 1960.

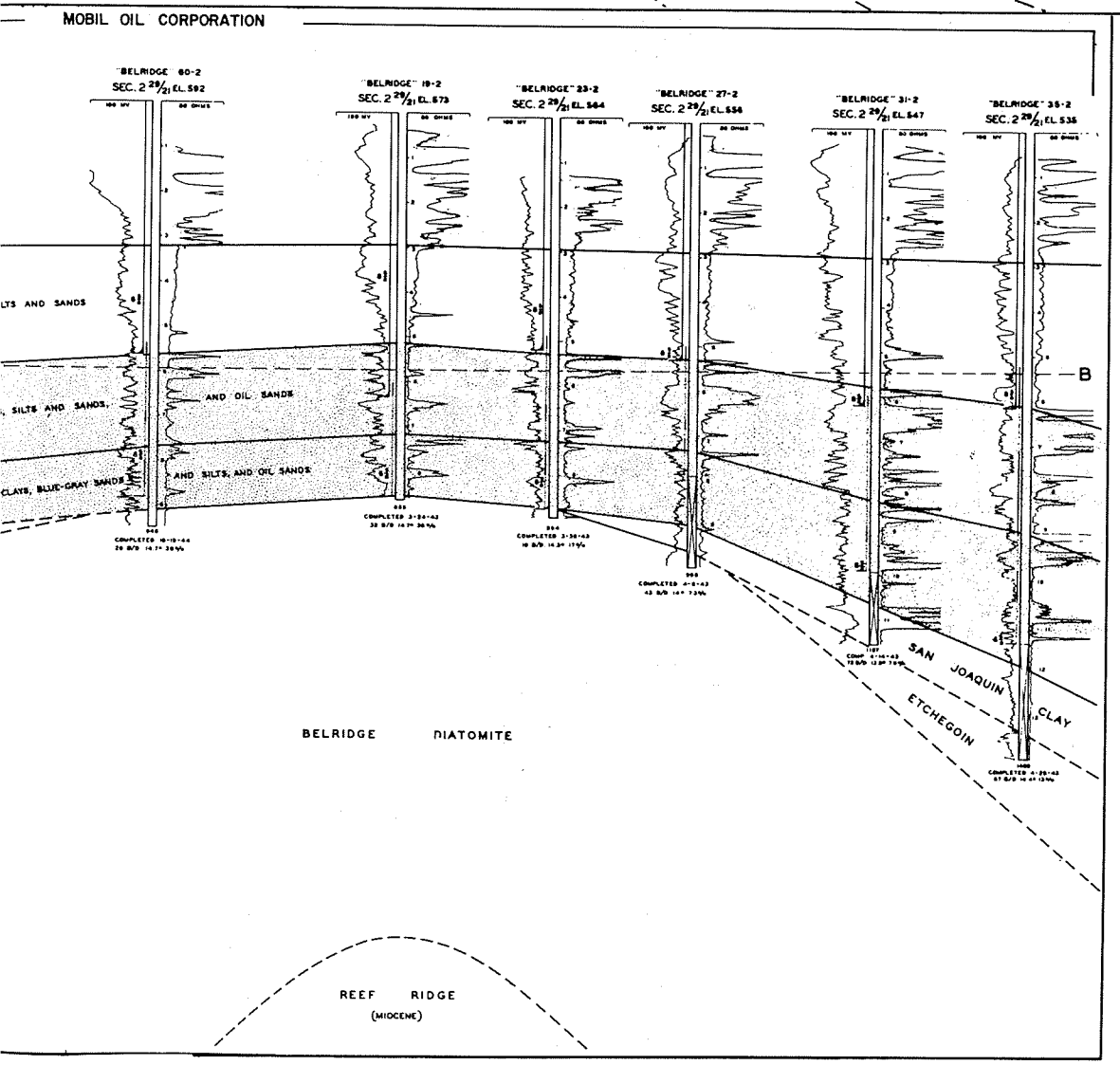
R. G. Colvin
January 25, 1968

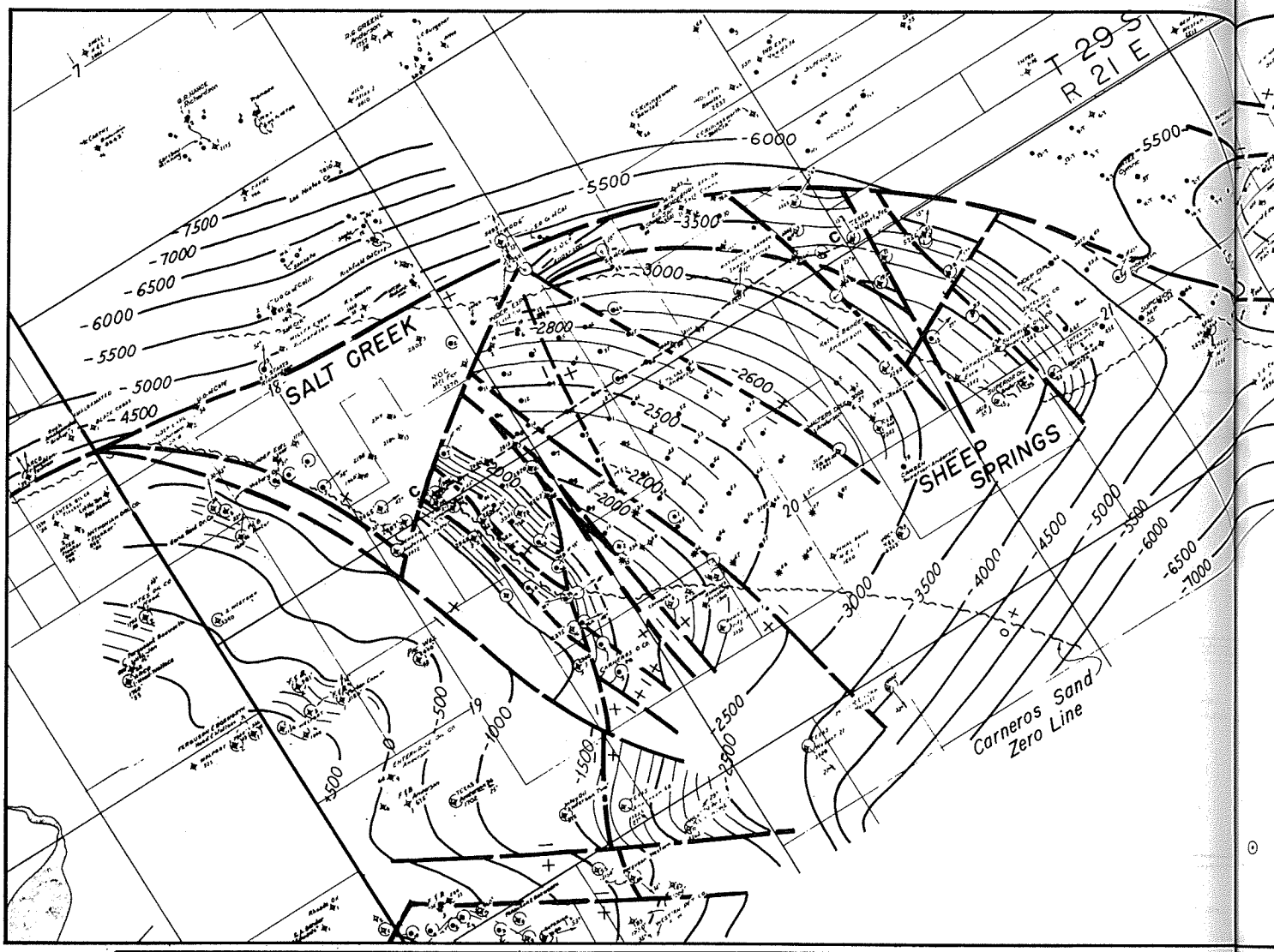


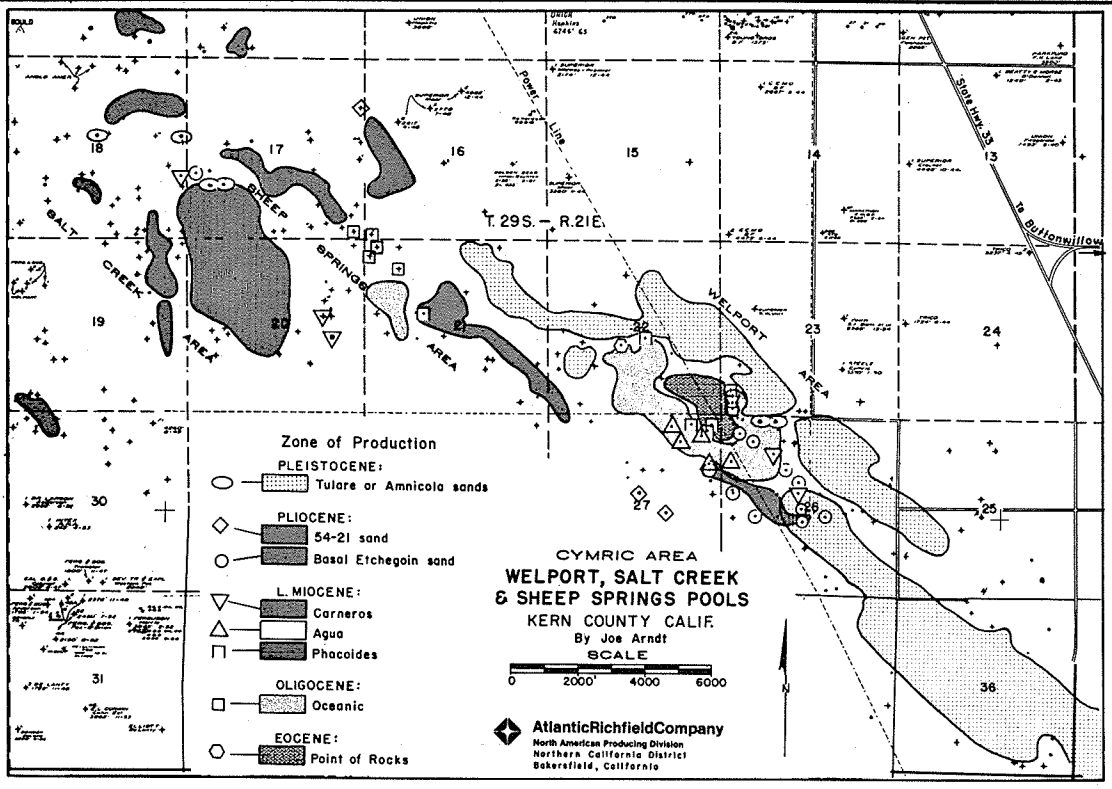

EPOCH
FORMATION
RECENT
ALLUVIUM
PLEISTOCENE
UPPER TULARE
UPPER TULARE OIL ZONE
LOWER TULARE OIL ZONE
SAN JOAQUIN CLAY
PLIOCENE
ETCHEGOIN
EMPIRE STATE OIL CO. "COLM" 21
SEC. 24 29/20 ELEV. 692
EMPIRE STATE OIL CO.
SEC. 24 29/20 ELEV. 664'
ALLUVIUM
UPPER TULARE
C
"12" ZONE
"13" ZONE
UPPER OIL
LOWER OIL
TULARE ZONE
GREEN-CLAY
GREEN-GRAY, GRAY, BLUE-GRAY AND BLUE-GREEN SILTSTONES, BLUE AND BLUE-GRAY SANDS, GREEN-GRAY AND GRAY CLAYS.
BELRIDGE DIATOMITE
(DIATOMACEOUS CLAYEY SILTSTONES & SILTY CLAYSTONES)
CROSS SECTION C-C
SOUTH BELRIDGE OIL FIELD
AFTER D.E. RITZIUS
DIVISION OF OIL & GAS
R.D. BUSH, STATE OIL & GAS SUPERVISOR
SCALE
HORIZONTAL
VERTICAL
JUNE 1950

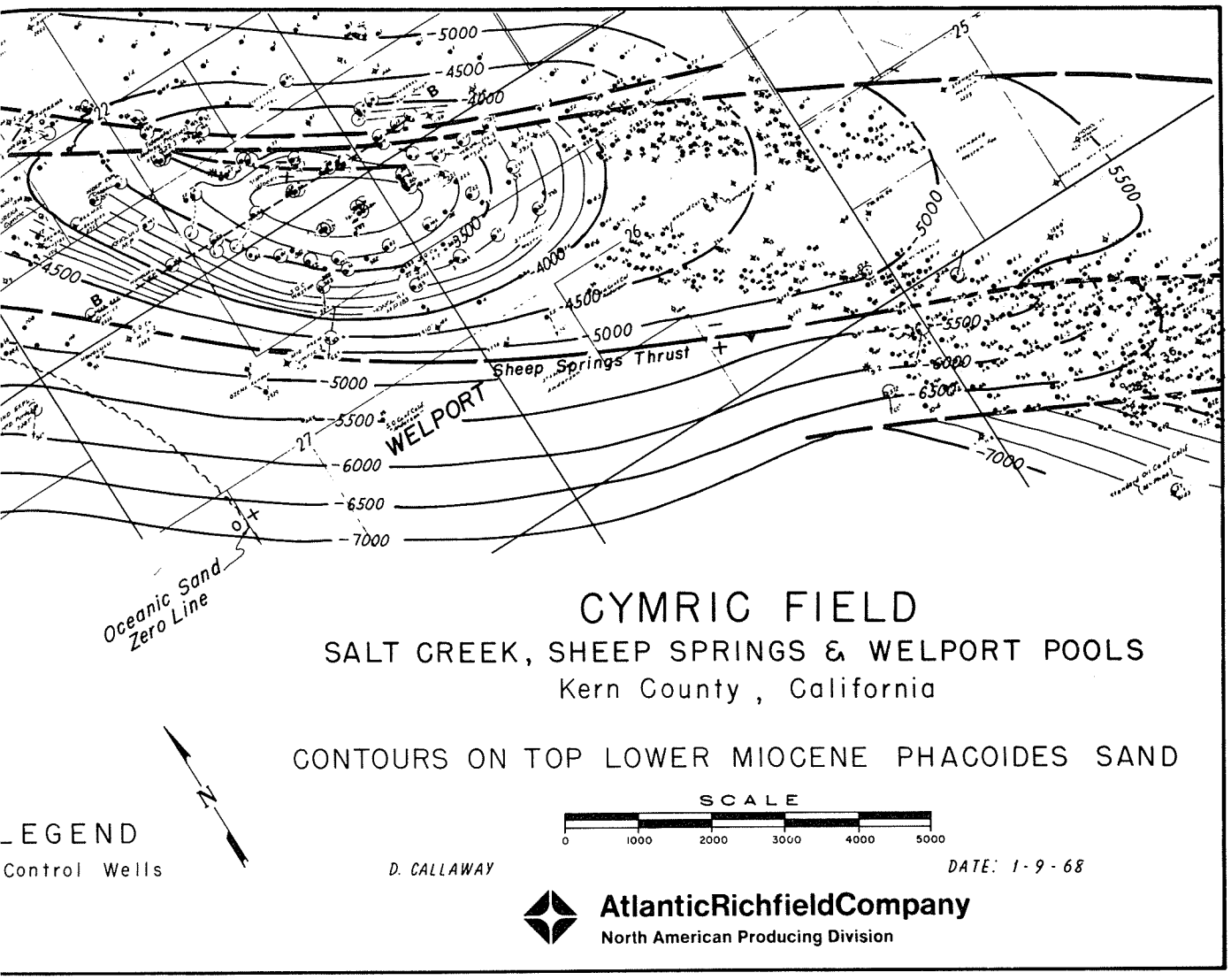

EPOCH
FORMATION
RECENT
ALLUVIUM
PLEISTOCENE
UPPER TULARE
UPPER TULARE OIL ZONE
LOWER TULARE OIL ZONE
SAN JOAQUIN CLAY
PLIOCENE
ETCHEGOIN
UNION OIL CO. OF CALIF.
"HOPKINS" 43-10
SEC. 12 29/21 ELEV. 664
"MARINA" 84A-10
SEC. 10 29/22 EL. 639
"MARINA" 51-3
SEC. 3 29/21 EL. 680
"MARINA" 28-3
SEC. 3 29/21 EL. 661
ALLUVIUM
UPPER TULARE
B
SEA LEVEL
UPPER TULARE OIL ZONE
LOWER TULARE OIL ZONE
SAN JOAQUIN CLAY
GRAY CLAYS, SILTS AND SILTSTONES
ETCHEGOIN
GRAY CLAYS, SILTS AND SILTSTONES - AND OIL SAND (IN A FEW WELLS)
CROSS SECTION B-B
SOUTH BELRIDGE OIL FIELD
AFTER D.E. RITZIUS
DIVISION OF OIL & GAS
R.D. BUSH STATE OIL & GAS SUPERVISER
SCALE
HORIZONTAL
VERTICAL
JUNE 1950


EMPIRE STATE OIL CO.
"COLM" 81
SEC. 24 28/20 ELEV. 643
STANDARD OIL CO. OF CALIF. "HILL" 31
SEC. 19 29/21 ELEV. 620
STANDARD OIL CO. OF CALIF. "HILL" 41
SEC. 19 29/21 ELEV. 613
STANDARD OIL CO. OF CALIF. "HILL" 51
SEC. 19 29/21 ELEV. 604
STANDARD OIL CO. OF CALIF. "HILL" 61
SEC. 19 29/21 ELEV. 594
STANDARD OIL CO. OF CALIF. "HILL" 71
SEC. 19 29/21 ELEV. 587
BLUE GRAY CLAYS, SANDS AND SILTS
SEA LEVEL
C
BLUE GRAY CLAY, SANDS AND SILTS AND SOME OIL SANDS
BLUE GRAY CLAYS, SANDS AND SILTS AND OIL SANDS
ZONE
"12" ZONE
ETCHEGOIN
SAN JOAQUIN CLAY
BELRIDGE DIATOMITE


MOBIL OIL CORPORATION
"BELRIDGE" 60-2
SEC. 2 28/21 EL. 592
"BELRIDGE" 19-2
SEC. 2 29/21 EL. 573
"BELRIDGE" 23-2
SEC. 2 29/21 EL. 564
"BELRIDGE" 27-2
SEC. 2 29/21 EL. 558
"BELRIDGE" 31-2
SEC. 2 29/21 EL. 547
"BELRIDGE" 35-2
SEC. 2 29/21 EL. 535
LTS AND SANDS
B
AND OIL SANDS
SILTS AND SANDS
AND SILTS, AND OIL SANDS
CLAYS, BLUE-GRAY SANDS
SAN JOAQUIN CLAY
ETCHEGOIN
BELRIDGE DIATOMITE
REEF RIDGE
(MIOCENE)

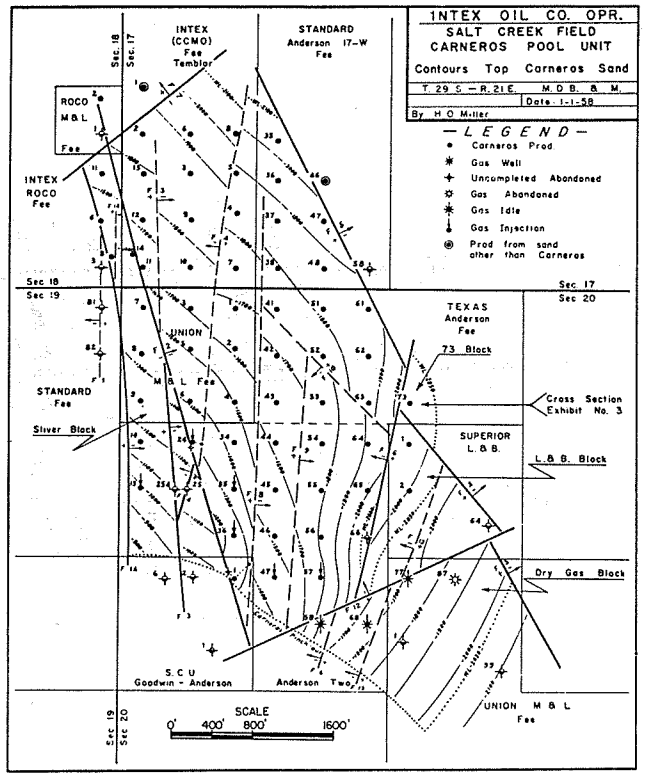

T 29 S
R 21 E
SALT CREEK
SHEEP SPRINGS
Carneros Sand Zero Line
-6000
-5500
-7500
-7000
-6500
-5000
-4500
-3500
-3000
-2800
-2600
-2500
-2000
-1500
-1000
-500
0
-4000

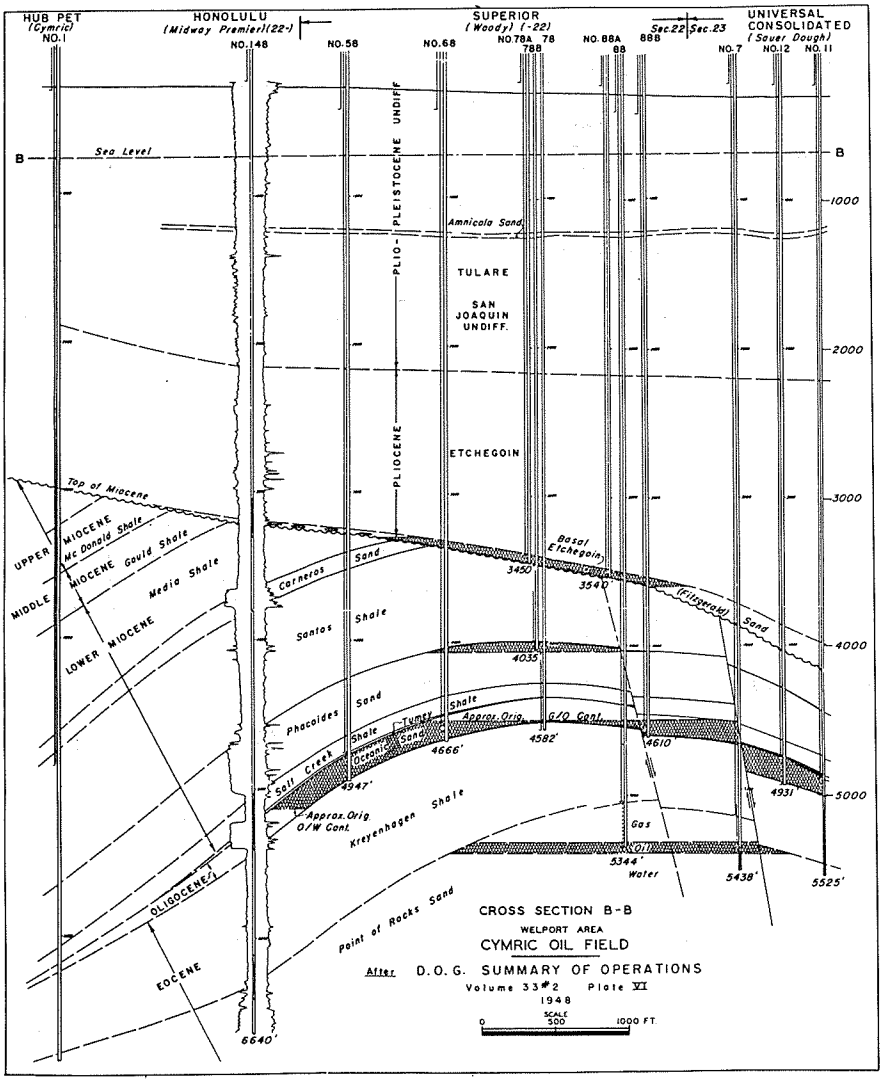

T. 29S. – R.21E.
SALT CREEK AREA
SHEEP SPRINGS AREA
WELPORT AREA
Power Line
State Hwy. 33
To Bullonwillow
Zone of Production
PLEISTOCENE:
Tulare or Amnicola sands
PLIOCENE:
54-21 sand
Basal Etchegoin sand
L. MIOCENE:
Carneros
Agua
Phacoides
OLIGOCENE:
Oceanic
EOCENE:
Point of Rocks
CYMRIC AREA
WELPORT, SALT CREEK
& SHEEP SPRINGS POOLS
KERN COUNTY CALIF.
By Joe Arndt
SCALE
0 2000' 4000 6000
AtlanticRichfieldCompany
North American Producing Division
Northern California District
Bakersfield, California

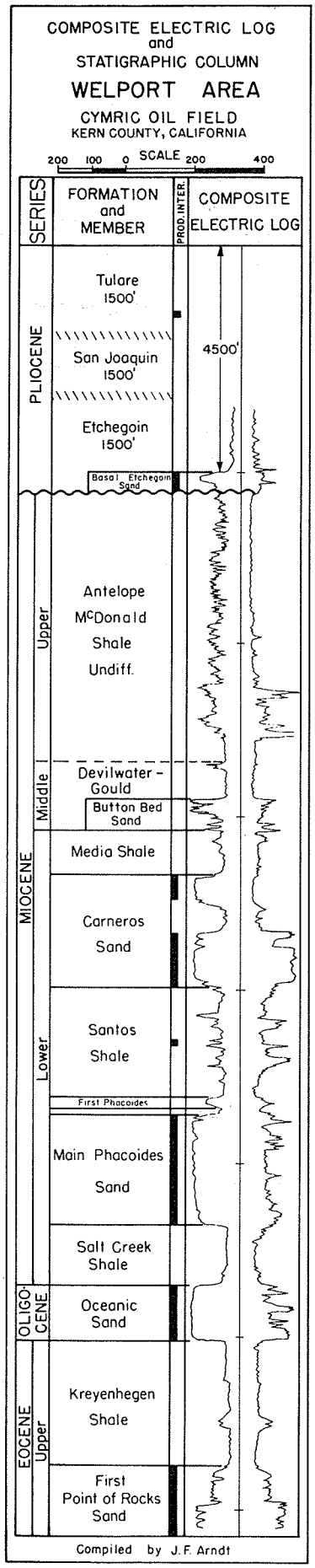


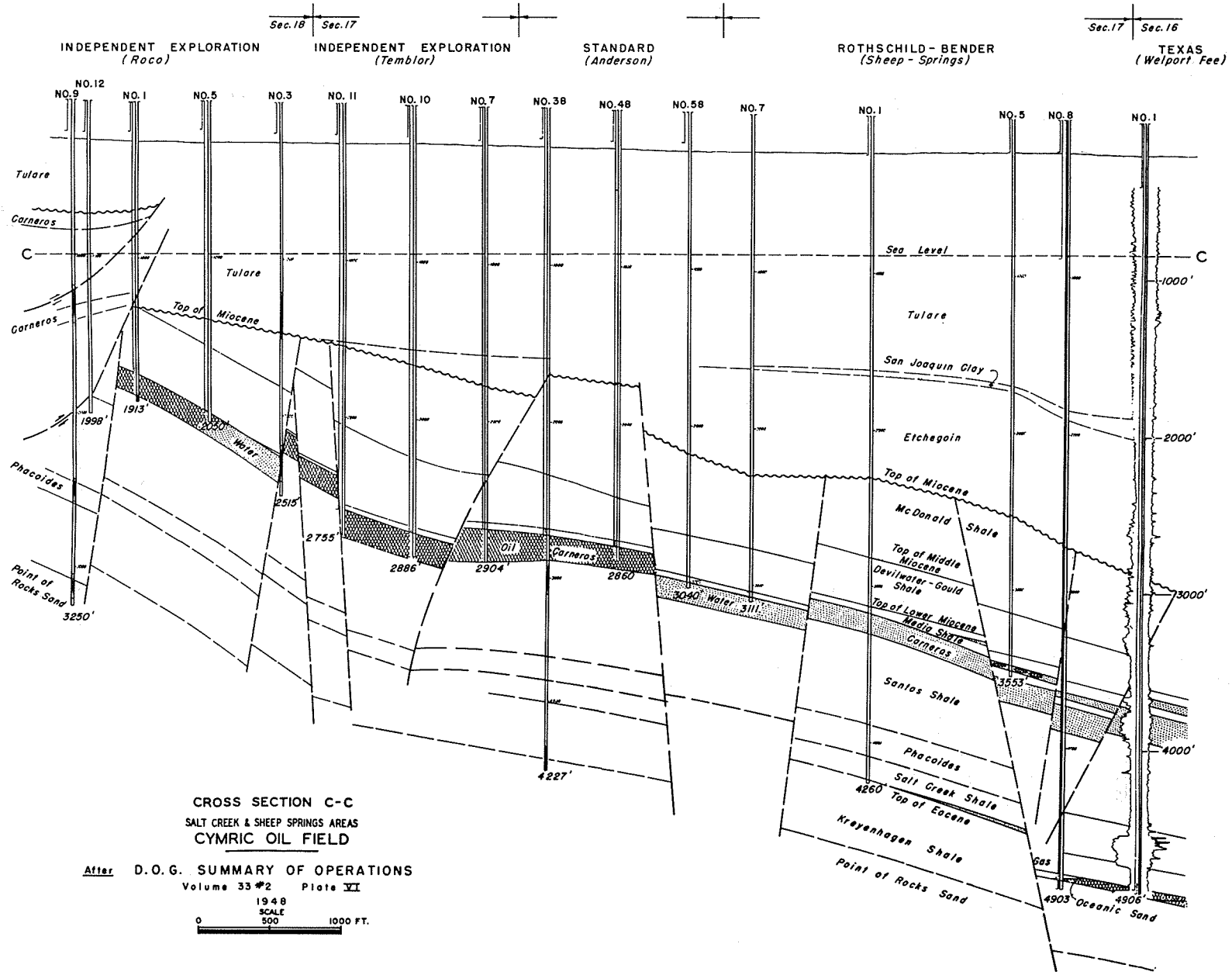
CYMRIC OIL FIELD

Area	Disc. Date	Disc. Well	Reason Drld.	Cum. prod. to 1/67 (Millions	Gravity API	Avg. Depth	Total Wells
Salt Creek*	1946	Indep. Expl. Co. Temblor #1, Sec. 17, 29S-21E	Surface Geology	20.2 bbls oil 21 cu. ft. gas	18°	2700'	62 drld. 40 prod.
		(*Carneros sand, 33.6% porosity, 1300 md permeability)					
Sheep Springs	1944	Rothschild Bender Oil Opr. Well #2 Sec. 17-29S-21E	Surface Geology	1.2 bbls oil 221 cu. ft. gas	22°	3400'	8 drld. 8 prod.
Welport (shallow)	1916	H.S.Williams Oil Co. Well #20 Sec. 26-29S-21E	Surface Geology	22.1 bbls oil 2 Mcf gas	12.5°	1200'	367 drld. 275 prod.
("Oceanic")	1945	Indep. Explo. Co. Sec. 22-29S-21E	subsurface geology	22.1 bbls oil 34.2 Mcf gas	33.5°	4900'	38 drld. 24 prod.


INTEX OIL CO. OPR.
SALT CREEK FIELD
CARNEROS POOL UNIT
Contours Top Carneros Sand
T. 29 S. — R. 21 E. M. D. B. & M.
Date 1-1-58
By H. O. Miller
— LEGEND —
Carneros Prod
Gas Well
Uncompleted Abandoned
Gas Abandoned
Gas Idle
Gas Injection
Prod from sand other than Carneros
INTEX (CCMO) Fee Temblor
STANDARD Anderson 17-W Fee
ROCO M&L Fee
INTEX ROCO Fee
Sec 18
Sec 17
Sec 19
Sec 20
UNION
M & L Fee
STANDARD Fee
Silver Block
TEXAS Anderson Fee
73 Block
Cross Section Exhibit No. 3
SUPERIOR L. & B.
L. & B. Block
Dry Gas Block
S. C. U. Goodwin - Anderson
Anderson Two
UNION M & L Fee
SCALE
0' 400' 800' 1600'


HUB PET (Cymric) NO. 1
HONOLULU (Midway Premier) (22-) NO. 148
NO. 58
NO. 68
SUPERIOR (Woody) (-22) NO. 78A 78 78B
NO. 88A 88 88B
Sec. 22 Sec. 23
UNIVERSAL CONSOLIDATED (Sauer Dough) NO. 7 NO. 12 NO. 11
B
Sea Level
1000
2000
3000
4000
5000
PLIO-PLEISTOCENE UNDIFF
Amnicola Sand
TULARE
SAN JOAQUIN UNDIFF.
PLIOCENE
ETCHEGOIN
Top of Miocene
UPPER MIOCENE
Mc Donald Shale
MIDDLE MIOCENE
Gould Shale
Media Shale
LOWER MIOCENE
Carneros Sand
Santos Shale
Phacoides Sand
Salt Creek Shale
Oceanic Sand
Tumey Shale
Approx. Orig. O/O Cont.
Approx. Orig. O/W Cont.
Kreyenhagen Shale
Point of Rocks Sand
OLIGOCENE
EOCENE
Basal Etchegoin
Gas
Oil
Water
3450
3540
4035
4582'
4610
4666'
4947'
4931
5344'
5438'
5525'
6640'
CROSS SECTION B-B
WELPORT AREA
CYMRIC OIL FIELD
After D.O.G. SUMMARY OF OPERATIONS
Volume 33 #2 Plate VI
1948
SCALE
0 500 1000 FT.


COMPOSITE ELECTRIC LOG
and
STATIGRAPHIC COLUMN
WELPORT AREA
CYMRIC OIL FIELD
KERN COUNTY, CALIFORNIA
200 100 0 SCALE 200 400
SERIES
FORMATION and MEMBER
PROD. INTER.
COMPOSITE ELECTRIC LOG
PLIOCENE
Tulare 1500'
San Joaquin 1500'
Etchegoin 1500'
4500'
Basal Etchegoin Sand
MIOCENE
Upper
Antelope McDonald Shale Undiff.
Middle
Devilwater - Gould
Button Bed Sand
Media Shale
Lower
Carneros Sand
Santos Shale
First Phacoides
Main Phacoides Sand
Salt Creek Shale
OLIGOCENE
Oceanic Sand
EOCENE
Upper
Kreyenhegen Shale
First Point of Rocks Sand
Compiled by J. F. Arndt



CROSS SECTION C-C

SALT CREEK & SHEEP SPRINGS AREAS

CYMRIC OIL FIELD

After D.O.G. SUMMARY OF OPERATIONS

Volume 33 #2 Plate VI

1948

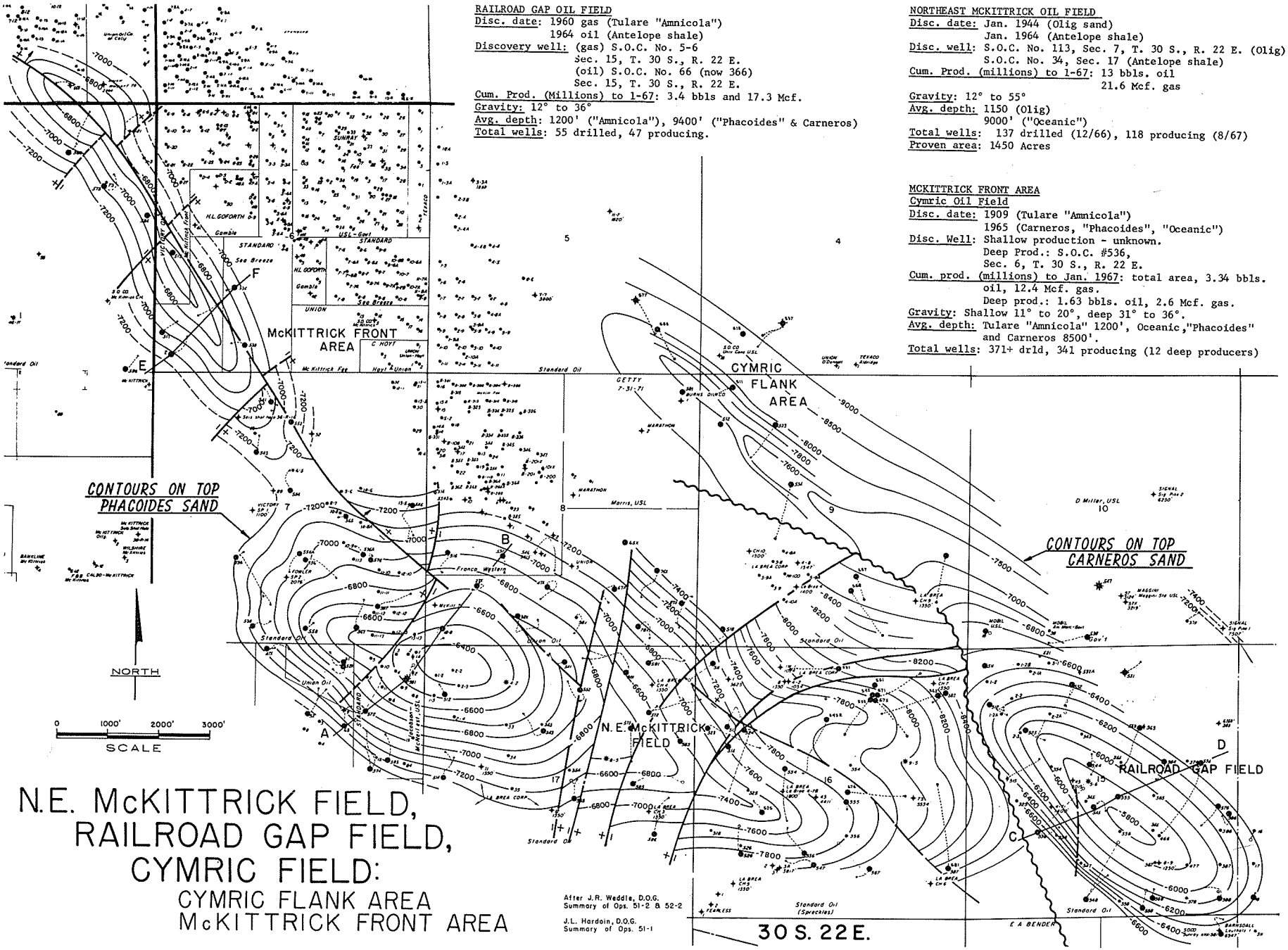
SCALE

0 500 1000 FT.

RAILROAD GAP OIL FIELD
Disc. date: 1960 gas (Tulare "Amnicola")
1964 oil (Antelope shale)
Discovery well: (gas) S.O.C. No. 5-6
Sec. 15, T. 30 S., R. 22 E.
(oil) S.O.C. No. 66 (now 366)
Sec. 15, T. 30 S., R. 22 E.
Cum. Prod. (Millions) to 1-67: 3.4 bbls and 17.3 Mcf.
Gravity: 12° to 36°
Avg. depth: 1200' ("Amnicola"), 9400' ("Phacoides" & Carneros)
Total wells: 55 drilled, 47 producing.

NORTHEAST MCKITTRICK OIL FIELD
Disc. date: Jan. 1944 (Olig sand)
Jan. 1964 (Antelope shale)
Disc. well: S.O.C. No. 113, Sec. 7, T. 30 S., R. 22 E. (Olig)
S.O.C. No. 34, Sec. 17 (Antelope shale)
Cum. Prod. (millions) to 1-67: 13 bbls. oil
21.6 Mcf. gas
Gravity: 12° to 55°
Avg. depth: 1150 (Olig)
9000' ("Oceanic")
Total wells: 137 drilled (12/66), 118 producing (8/67)
Proven area: 1450 Acres

MCKITTRICK FRONT AREA
Cymric Oil Field
Disc. date: 1909 (Tulare "Amnicola")
1965 (Carneros, "Phacoides", "Oceanic")
Disc. Well: Shallow production - unknown.
Deep Prod.: S.O.C. #536,
Sec. 6, T. 30 S., R. 22 E.
Cum. prod. (millions) to Jan. 1967: total area, 3.34 bbls. oil, 12.4 Mcf. gas.
Deep prod.: 1.63 bbls. oil, 2.6 Mcf. gas.
Gravity: Shallow 11° to 20°, deep 31° to 36°.
Avg. depth: Tulare "Amnicola" 1200', Oceanic, "Phacoides" and Carneros 8500'.
Total wells: 371+ drld, 341 producing (12 deep producers)

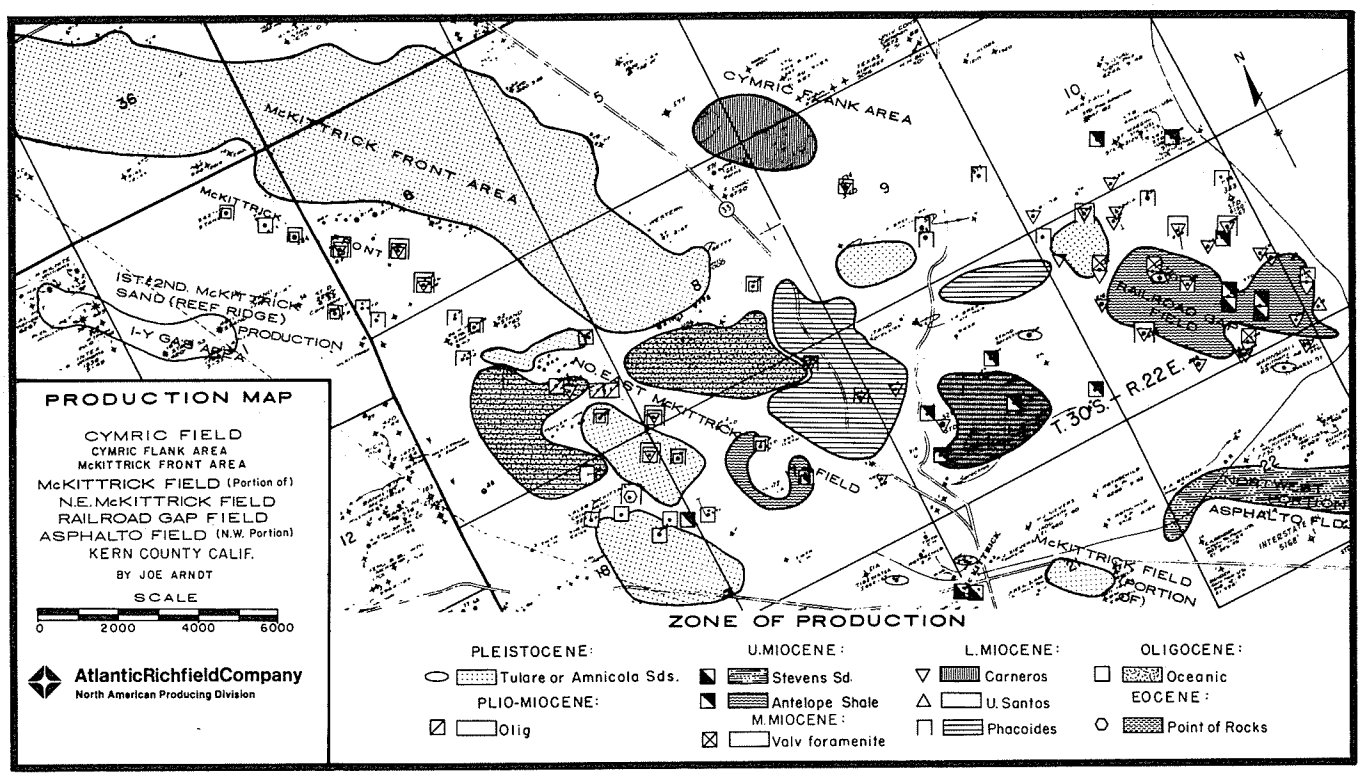


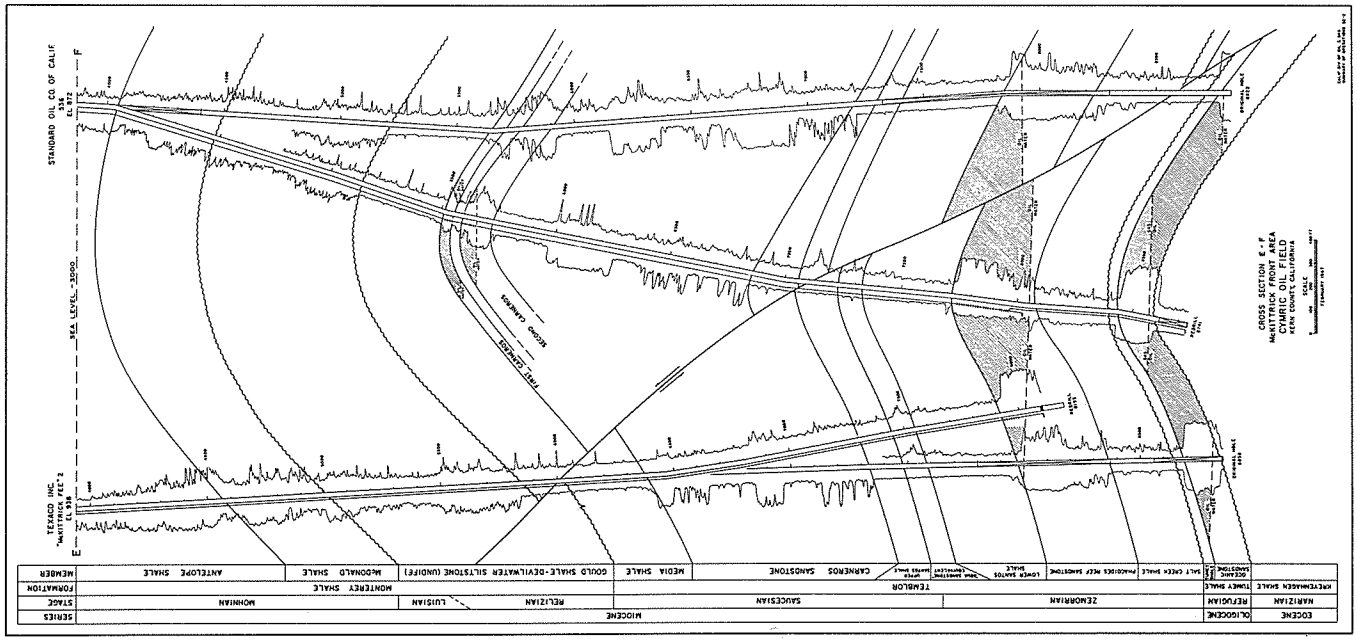
N.E. McKITTRICK FIELD, RAILROAD GAP FIELD, CYMRIC FIELD:

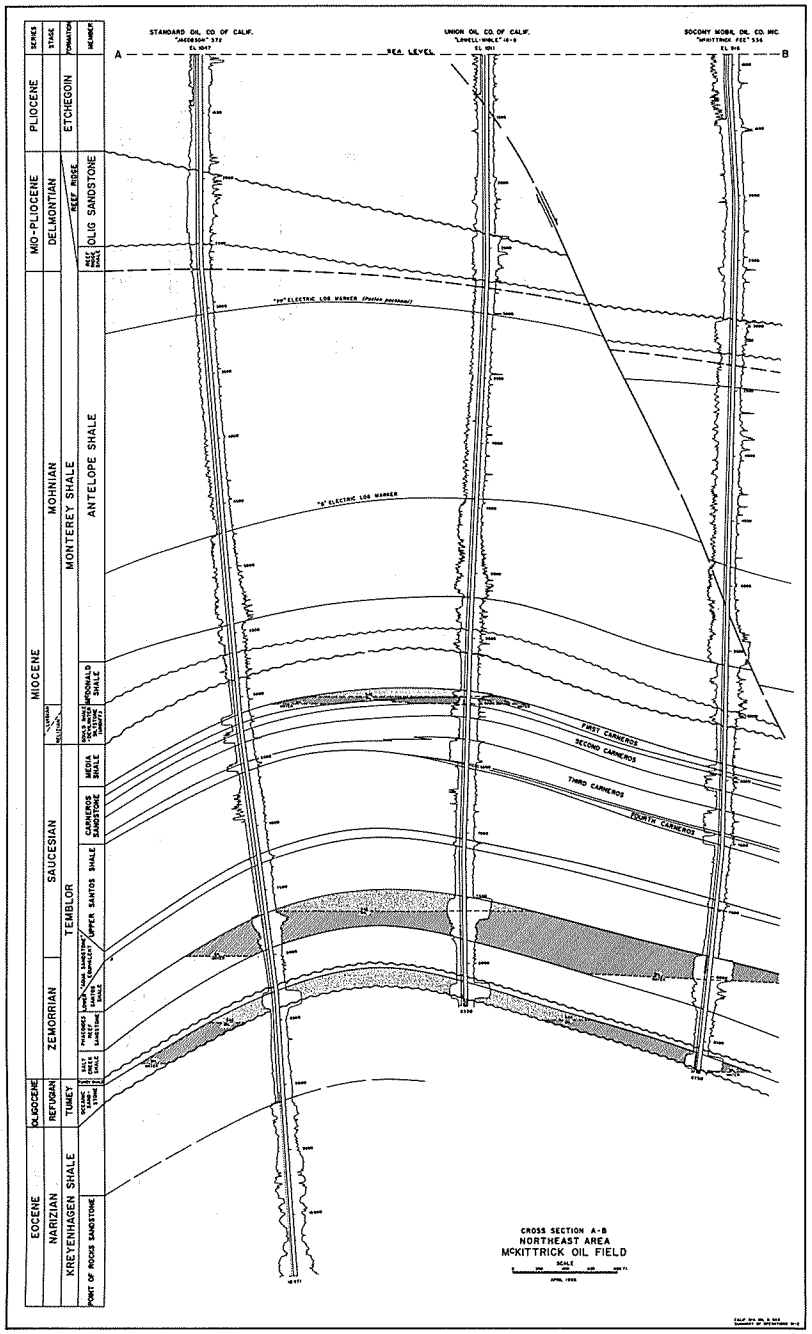
CYMRIC FLANK AREA
McKITTRICK FRONT AREA

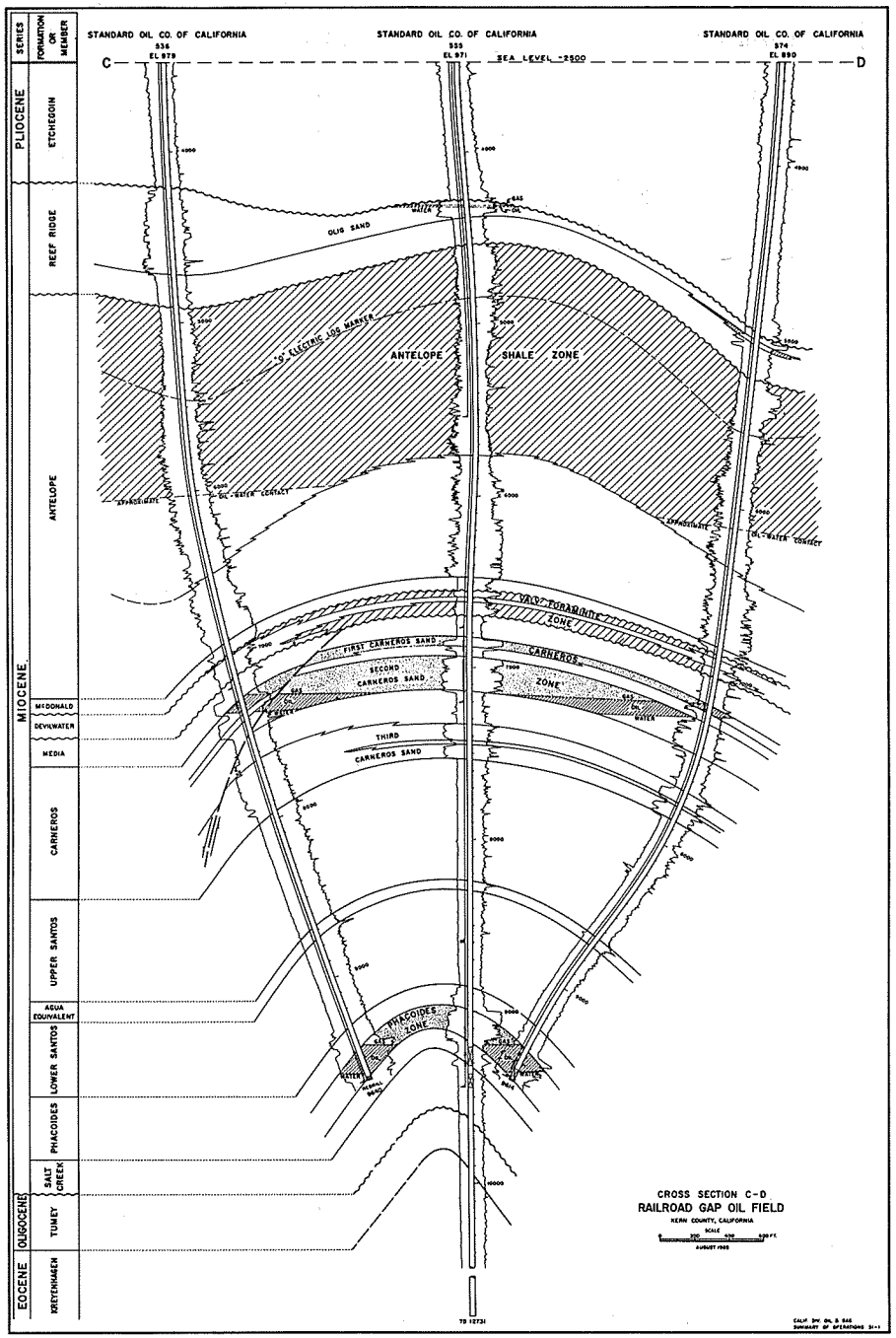
After J.R. Weddle, D.O.G. Summary of Ops. 51-2 & 52-2

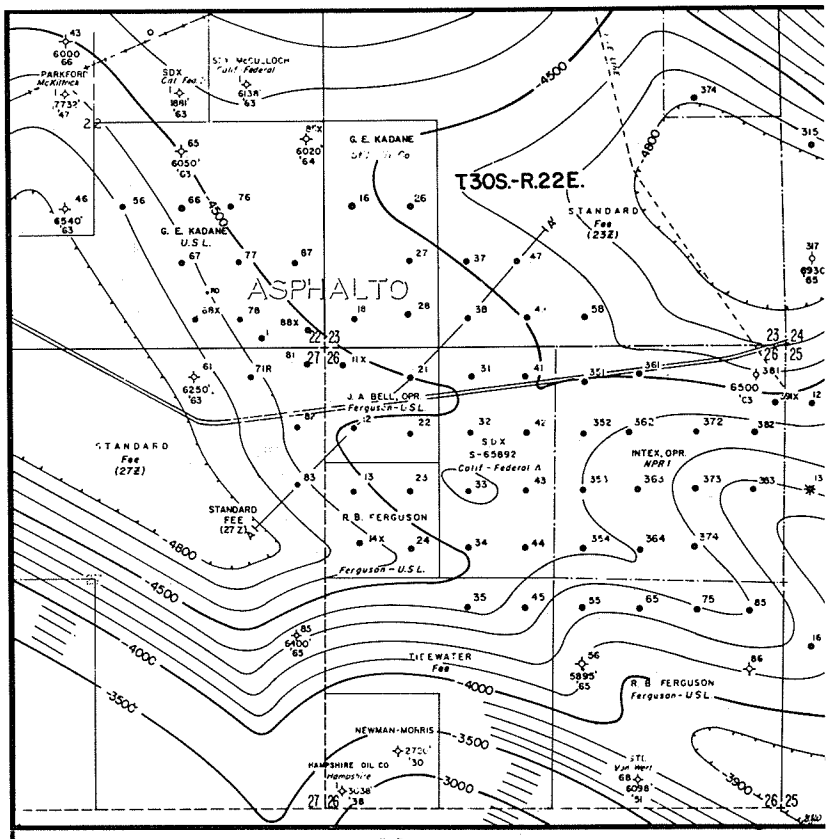
J.L. Hardoin, D.O.G. Summary of Ops. 51-1


PRODUCTION MAP
CYMRIC FIELD
CYMRIC FLANK AREA
McKITTRICK FRONT AREA
McKITTRICK FIELD (Portion of)
N.E. McKITTRICK FIELD
RAILROAD GAP FIELD
ASPHALTO FIELD (N.W. Portion)
KERN COUNTY CALIF.
BY JOE ARNDT
SCALE
0 2000 4000 6000
AtlanticRichfieldCompany
North American Producing Division
CYMRIC FLANK AREA
McKITTRICK FRONT AREA
1ST & 2ND McKITTRICK SAND (REEF RIDGE) PRODUCTION
I-Y GAS AREA
NO. EAST McKITTRICK FIELD
RAILROAD GAP FIELD
T. 30 S. - R. 22 E.
ASPHALTO FIELD
McKITTRICK FIELD (PORTION OF)
ZONE OF PRODUCTION
PLEISTOCENE:
Tulare or Amnicola Sds.
PLIO-MIOCENE:
Olig
U.MIOCENE:
Stevens Sd.
Antelope Shale
M.MIOCENE:
Valv foramenite
L.MIOCENE:
Carneros
U. Santos
Phacoides
OLIGOCENE:
Oceanic
EOCENE:
Point of Rocks

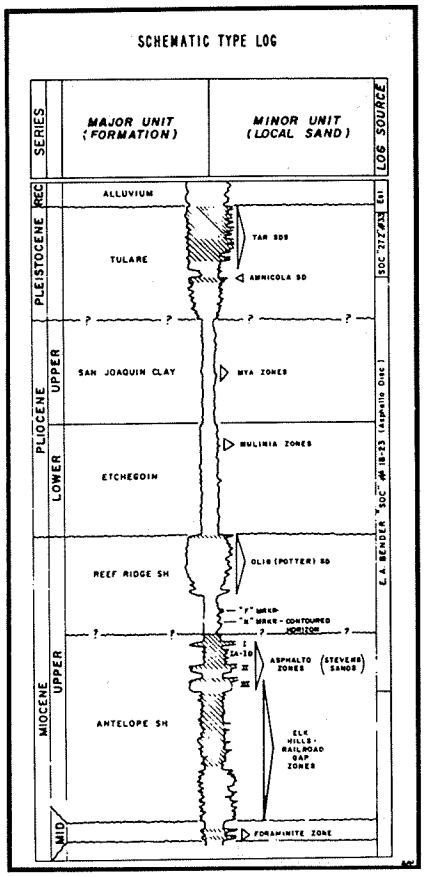

STANDARD OIL CO. OF CALIF.
TEXACO INC.
SEA LEVEL -2000
CROSS SECTION E-F
McKITTRICK FRONT AREA
CYMRIC OIL FIELD
KERN COUNTY, CALIFORNIA
SERIES
STAGE
FORMATION
MEMBER
MIOCENE
MOHNIAN
LUISIAN
RELIZIAN
SAUCESIAN
ZEMORRIAN
NARIZIAN
RUPELIAN
OLIGOCENE
EOCENE
MONTEREY SHALE
MCDONALD SHALE
ANTELOPE SHALE
GOULD SHALE-DEVILWATER SILTSTONE (UNDIFF)
MEDIA SHALE
CARNEROS SANDSTONE
TEMBLOR
LOWER SANTOS SHALE
PHACOIDES REEF SANDSTONE
SALT CREEK SHALE
TUMEY SHALE
HRETZMANN SHALE

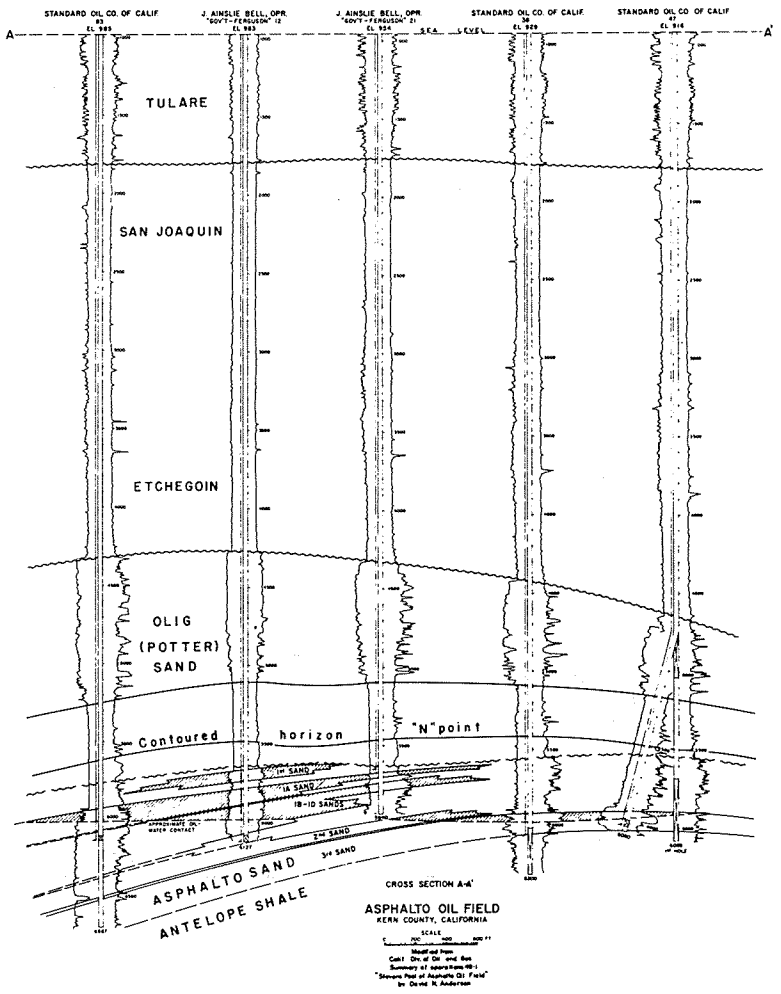

SERIES
STAGE
FORMATION
MEMBER
PLIOCENE
MIO-PLIOCENE
MIOCENE
OLIGOCENE
EOCENE
ETCHEGOIN
DELMONTIAN
MOHNIAN
SAUCESIAN
ZEMORRIAN
REFUGIAN
TUMEY
NARIZIAN
KREYENHAGEN SHALE
POINT OF ROCKS SANDSTONE
REEF RIDGE
OLIG SANDSTONE
MONTEREY SHALE
ANTELOPE SHALE
TEMBLOR
UPPER SANTOS SHALE
CARNEROS SANDSTONE
MEDIA SHALE
MCDONALD SHALE
FIRST CARNEROS
SECOND CARNEROS
THIRD CARNEROS
FOURTH CARNEROS
STANDARD OIL CO. OF CALIF.
UNION OIL CO. OF CALIF.
SOCONY MOBIL OIL CO. INC
SEA LEVEL
A
B
CROSS SECTION A-B
NORTHEAST AREA
McKITTRICK OIL FIELD
SCALE
APRIL 1955


SERIES
FORMATION OR MEMBER
PLIOCENE
MIOCENE
OLIGOCENE
EOCENE
ETCHEGOIN
REEF RIDGE
ANTELOPE
MCDONALD
DEVILWATER
MEDIA
CARNEROS
UPPER SANTOS
AGUA EQUIVALENT
LOWER SANTOS
PHACOIDES
SALT CREEK
TUMEY
KREYENHAGEN
STANDARD OIL CO. OF CALIFORNIA
C
D
SEA LEVEL -2500
OLIG SAND
"S" ELECTRIC LOG MARKER
ANTELOPE
SHALE ZONE
OIL-WATER CONTACT
VALV. FORAMINIFERA ZONE
FIRST CARNEROS SAND
SECOND CARNEROS SAND
CARNEROS ZONE
THIRD CARNEROS SAND
PHACOIDES ZONE
CROSS SECTION C-D
RAILROAD GAP OIL FIELD
KERN COUNTY, CALIFORNIA
SCALE
AUGUST 1955



Contours on "N"-Point E-Log Marker
ASPHALTO FIELD SCALE
Kern Co, California
By G.J. Welsh 1-10-68
Feet 0 500 1000





ASPHALTO OIL FIELD

Discovered Dec. 1962

Disc. by Bender "S.O.C." #18

Section 23-T30S, R22E

Reason: Subsurface geology

Cum. Prod. to 1-67 (Millions):

15.5 Bbls oil

17.5 MCF Gas

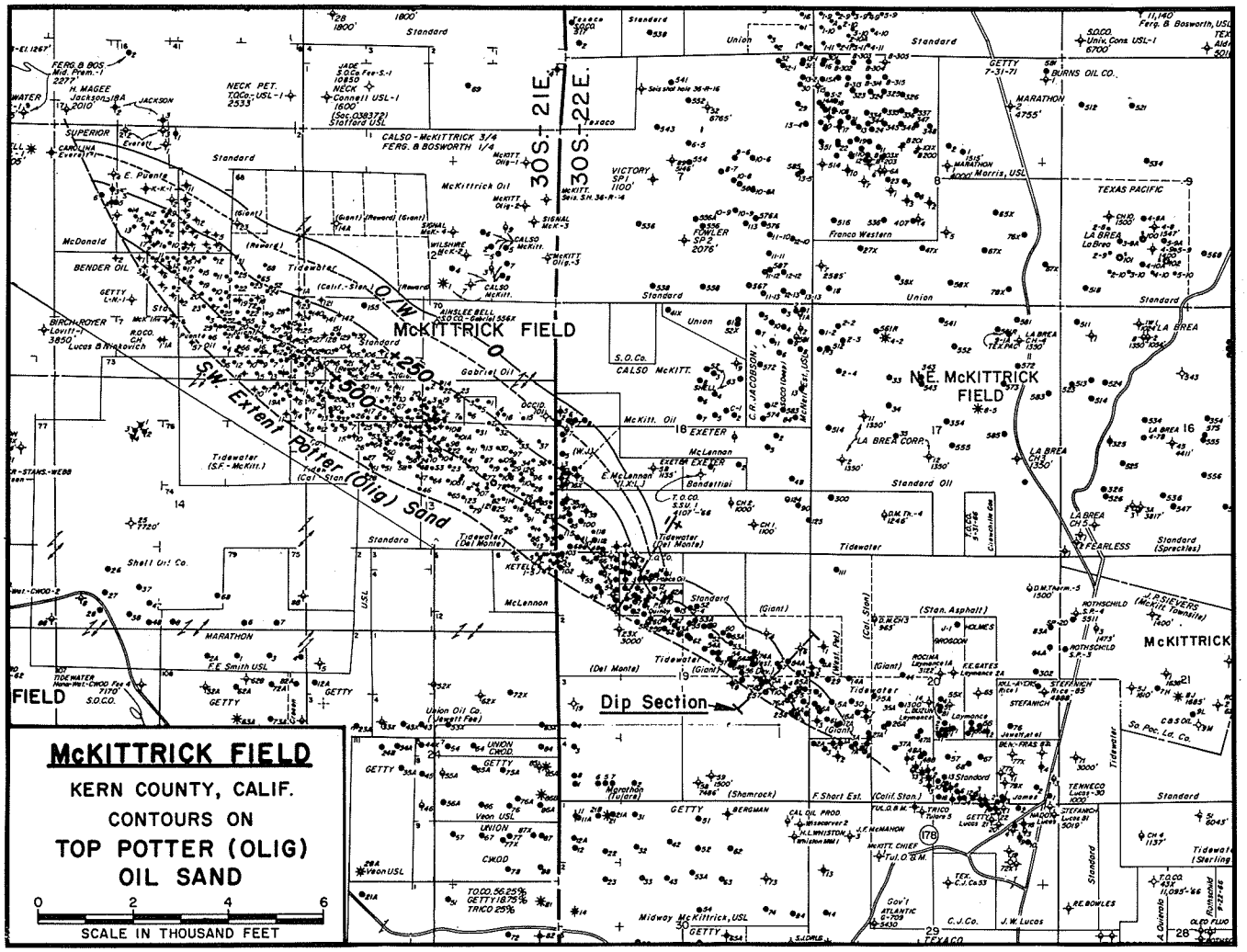
Gravity: 31° to 34°

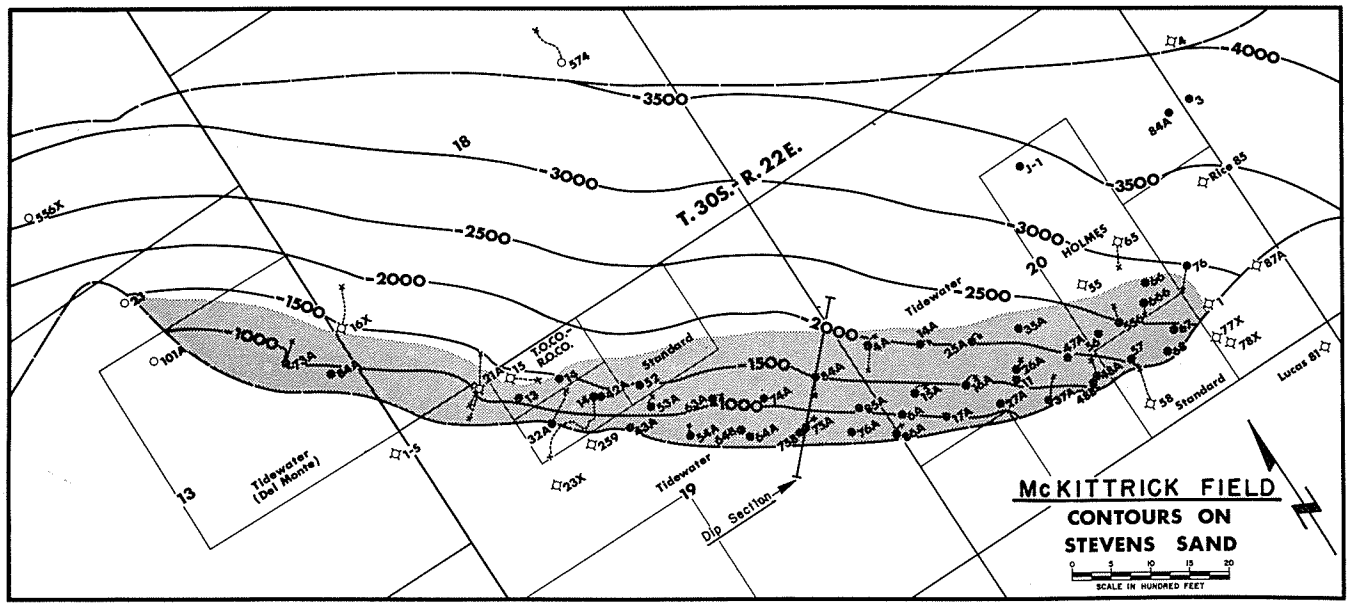
Average Depth: 5800'

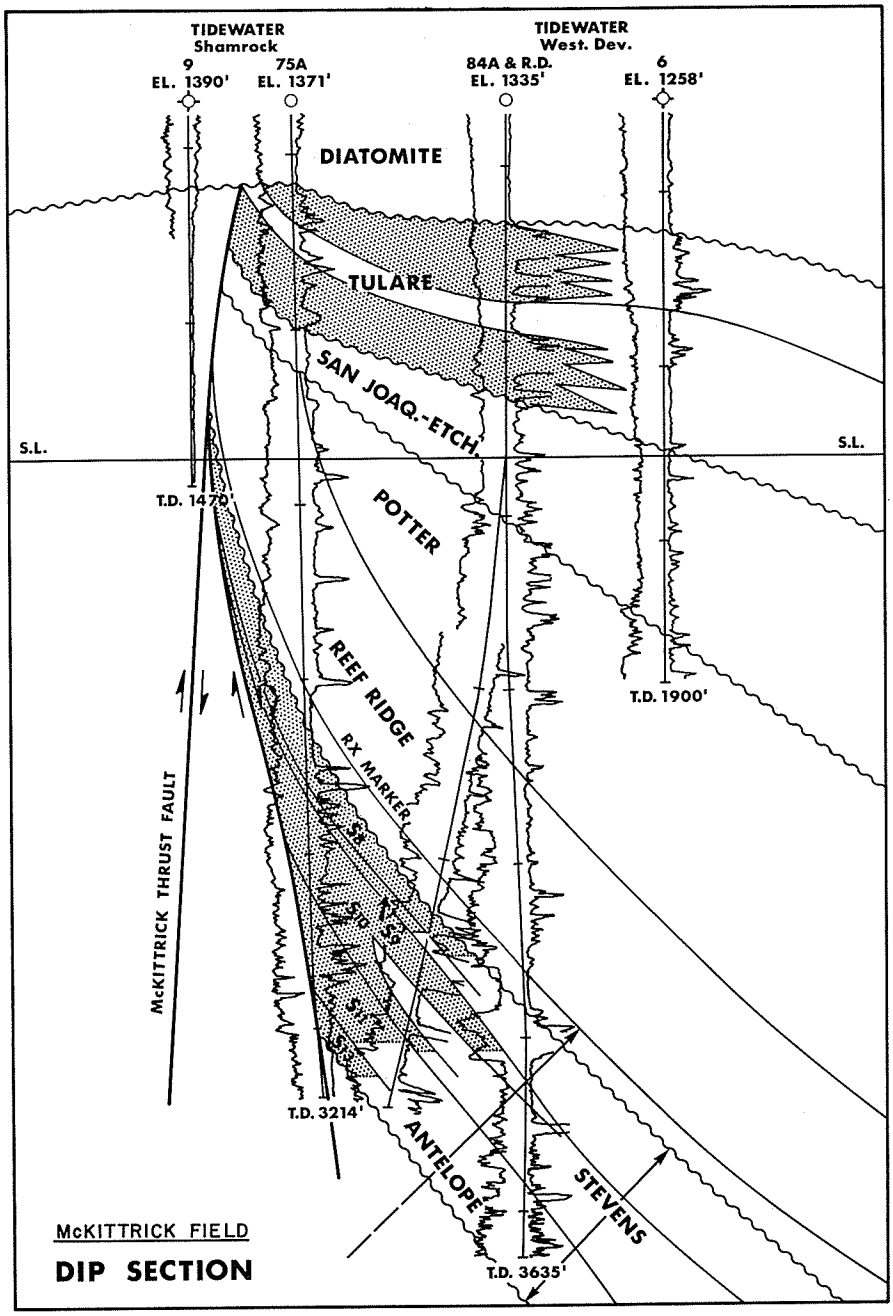
Total Wells Drilled: 72

Wells producing (1-67): 51

Proven Area: 590 Acres


McKITTRICK FIELD
KERN COUNTY, CALIF.
CONTOURS ON
TOP POTTER (OLIG)
OIL SAND
0 2 4 6
SCALE IN THOUSAND FEET
30S-21E
30S-22E
S.W. Extent Potter (Olig) Sand
McKITTRICK FIELD
N.E. McKITTRICK FIELD
McKITTRICK
Dip Section
Tidewater
Standard
Union
Texas Pacific
Franco Western
Standard Oil
Tidewater (Del Monte)
Tidewater (Giant)
Tidewater (Calif. Stan.)
Tidewater (Sterling)
McLennon
McKitt. Oil
Gabriel Oil
Shell Oil Co.
Marathon
Getty
Union Oil Co.
Texaco
Midway McKittrick, USL
Gov't Atlantic
Lucas 81


McKITTRICK FIELD
CONTOURS ON
STEVENS SAND
SCALE IN HUNDRED FEET
T. 30S.-R. 22E.
Tidewater
Standard
T.O.CO.-R.O.CO.
Tidewater (Del Monte)
Dip Section
Holmes
Lucas 81



MCKITTRICK OIL FIELD

UPPER OIL ZONE: Tulare and Potter (Olig)

Discovery Well: Klondike Oil Co. "Shamrock" Reported to have flowed 1300 B/D Location unknown.

Discovery date: 1896 (Pits and shafts were dug near oil seeps as early as 1863.)
1966 Production: 1,735,742 bbls.
Peak Production: 1909 5,807,360 bbls.
Cumulative Production: to 1/1/67 114,861,000
Gravity: 11-16° API
Permeability: Variable, up to 3000 millidarcys
Wells Drilled: 471
Wells Producing: 355

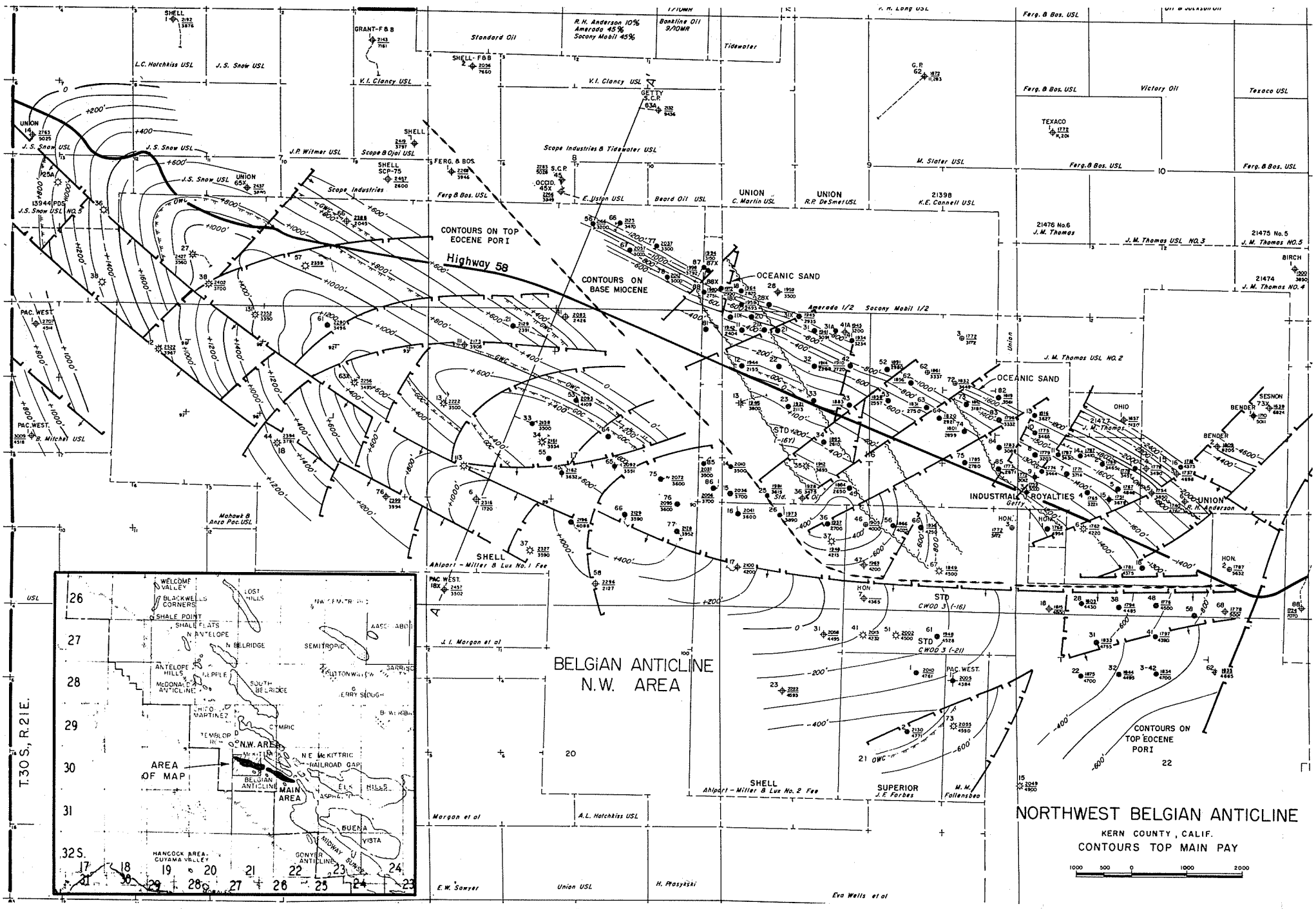
REEF RIDGE SAND:

Discovery Well: Getty Oil Co. "Giant" #253, Sec. 19, 30S-22E

Discovery Date: April 23, 1966
1966 Production: 121,929 barrels
Gravity: 15-19°
Permeability: Variable, up to 2500 millidarcys.
Wells Drilled: 49
Wells Producing: 42

STEVENS SAND

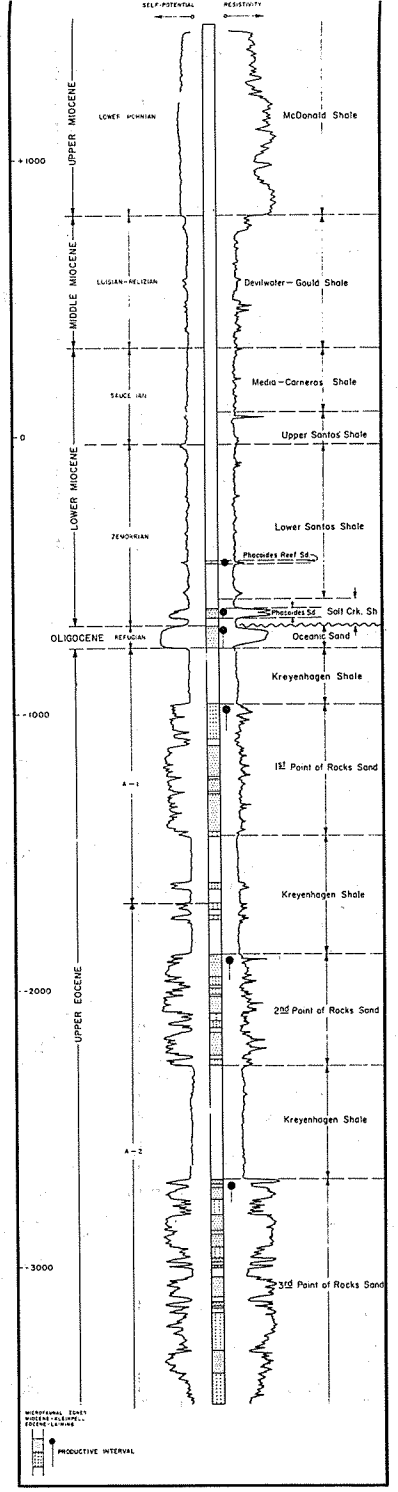
Discovery Well: W. W. Holmes "Laymance" #66-20Z Sec. 20, 30S-22E.
Discovery Date: July 4, 1964
1966 Production: 2,200,405 barrels
Cum. Production: 4,281,000 to 1/1/67
Gravity: 21-32° API
Permeability: Variable, up to 3,000 millidarcys
Wells Drilled: 6
Wells Producing: 6

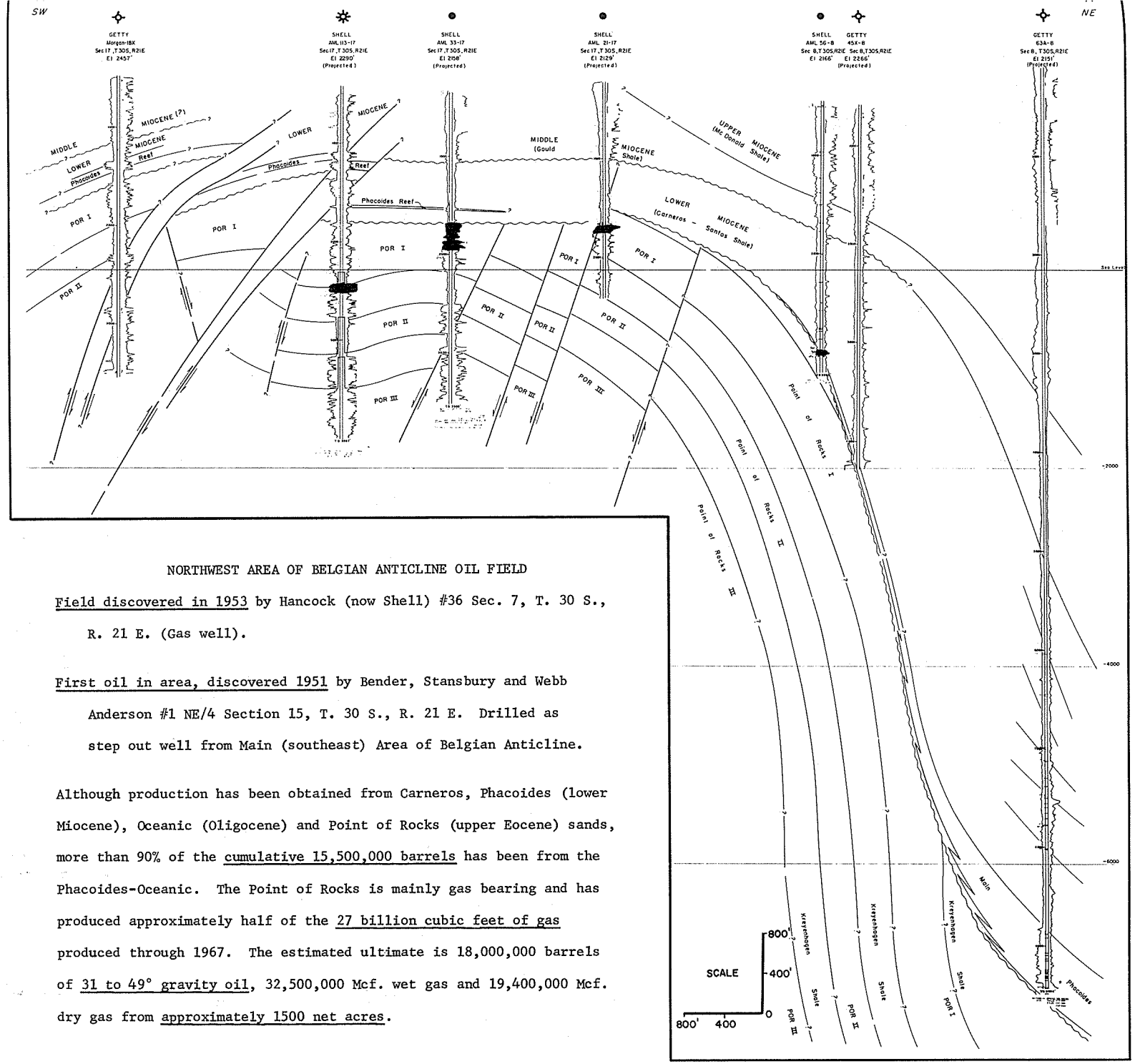

NORTHWEST BELGIAN ANTICLINE
KERN COUNTY, CALIF.
CONTOURS TOP MAIN PAY
BELGIAN ANTICLINE
N.W. AREA
CONTOURS ON TOP EOCENE PORI
CONTOURS ON BASE MIOCENE
Highway 58
OCEANIC SAND
INDUSTRIAL ROYALTIES
T.30S., R.21E.
AREA OF MAP
N.W. AREA
MAIN AREA
BELGIAN ANTICLINE
SHELL
Ahlport - Miller & Lux No. 1 Fee
Ahlport - Miller & Lux No. 2 Fee
SUPERIOR
J.E. Forbes
M.M. Fallensbee
PAC. WEST
Amerada 1/2 Socony Mobil 1/2
J.M. Thomas USL NO. 2
J.M. Thomas USL NO. 3
J.M. Thomas NO. 4
J.M. Thomas NO. 5
Victory Oil
Texaco USL
Ferg. & Bos. USL
Standard Oil
Tidewater
Scope Industries & Tidewater USL
Scope Industries
Beard Oil USL
E. Uston USL
C. Martin USL
R.R. DeSmet USL
K.E. Connell USL
M. Slater USL
J.S. Snow USL
L.C. Hatchkiss USL
J.P. Wilmer USL
V.I. Clancy USL
Mohawk & Anta Pac. USL
A.L. Hatchkiss USL
J.I. Morgan et al
E.W. Sawyer
Union USL
H. Plasyzki
Eva Wells et al
Bankline Oil
R.H. Anderson 10%
Amerada 45%
Socony Mobil 45%
WELCOME VALLEY
BLACKWELLS CORNERS
SHALE POINT
SHALE FLATS
N. ANTELOPE
N. BELRIDGE
SEMITROPIC
ANTELOPE HILLS
McDONALD ANTICLINE
SOUTH BELRIDGE
CYMRIC
TEMBLOR HILLS
NE McKITTRICK
RAILROAD GAP
ELK HILLS
BUENA VISTA
MIDWAY SUNSET
GONYER ANTICLINE
HANCOCK AREA
CUYAMA VALLEY
LOST HILLS
SEMITROPIC
BERRY SLOUGH
CONTOURS ON TOP EOCENE PORI
1000 500 0 1000 2000

TYPE LOG

A

A'



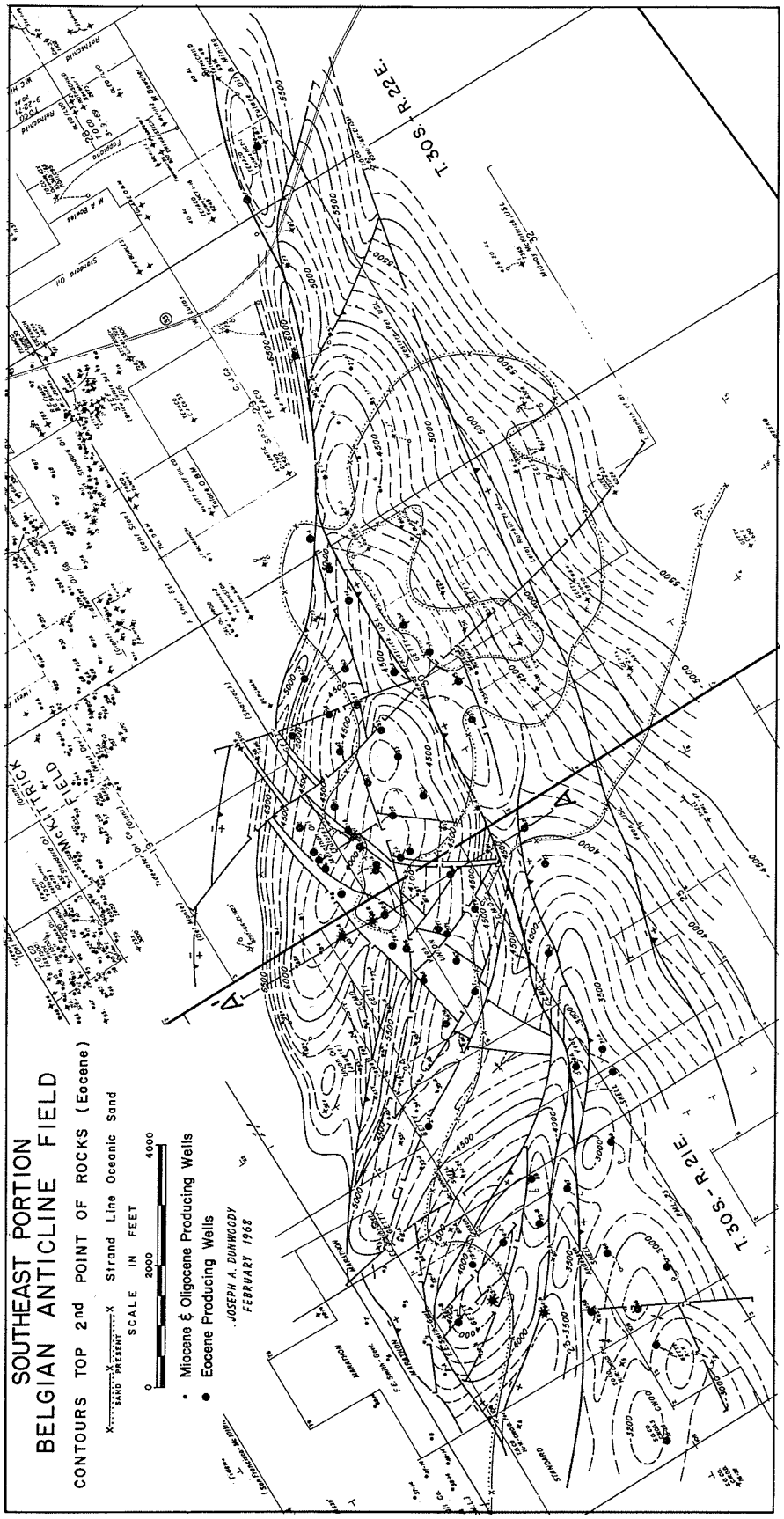


NORTHWEST AREA OF BELGIAN ANTICLINE OIL FIELD

Field discovered in 1953 by Hancock (now Shell) #36 Sec. 7, T. 30 S., R. 21 E. (Gas well).

First oil in area, discovered 1951 by Bender, Stansbury and Webb Anderson #1 NE/4 Section 15, T. 30 S., R. 21 E. Drilled as step out well from Main (southeast) Area of Belgian Anticline.

Although production has been obtained from Carneros, Phacoides (lower Miocene), Oceanic (Oligocene) and Point of Rocks (upper Eocene) sands, more than 90% of the cumulative 15,500,000 barrels has been from the Phacoides-Oceanic. The Point of Rocks is mainly gas bearing and has produced approximately half of the 27 billion cubic feet of gas produced through 1967. The estimated ultimate is 18,000,000 barrels of 31 to 49° gravity oil, 32,500,000 Mcf. wet gas and 19,400,000 Mcf. dry gas from approximately 1500 net acres.



BELGIAN ANTICLINE OIL FIELD
SOUTHEAST PORTION
(MAIN AREA)

Discovery Well:

The Texas Co.(Now Texaco Inc.) Westpet NCT-One #77-29, Section 29, T30S, R22E. Discovery was from the Oligocene Oceanic sand at a depth of 5140 feet. Initial production was at a rate of 140 B/D of 72° gravity condensate and 2230 MCF/D gas in October 1946.

Producing Zones:

Lower Miocene Phacoides Sd.
Produces 38° gravity oil from lenticular sand on southeast end of field.

1966 Production

35,000 bbls. 64,000 MCF.

Cumulative to 1/1/67

1,068,000 bbls. 2,344,000 MCF.

Oligocene Oceanic Sd.
Porosities of 27% and permeabilities of 500-6000 millidarcies result in recoverable oil estimated as high as 1000 bbls. per acre foot. Rapid variation in thickness and lateral extent is due to deposition on Eocene erosional surface and truncation by unconformity at the beginning of Miocene time.

1966 Production

378,000 bbls. 875,000 MCF.

Cumulative to 1/1/67

13,775,000 bbls. 26,374,000 MCF.
(includes 243,000 bbls., 387,000 MCF from Telephone Hills Area).

Point of Rocks Sds.
Approximately 5600 feet of Eocene section was penetrated in the Pacific Western (now Getty Oil Co.) M&M #22, Section 30, T30S, R22E, of which approximately 1300 feet is Eocene Kreyenhagen shale and the remaining 4300 feet is Point of Rocks sands divided into three main sand bodies. Rapid changes in permeability and porosity accounts for lateral variations in productivity. The Second Point of Rocks is the most prolific horizon within the Eocene.

1966 Production

300,000 bbls. 1,567,000 MCF.

Cumulative to 1/1/67

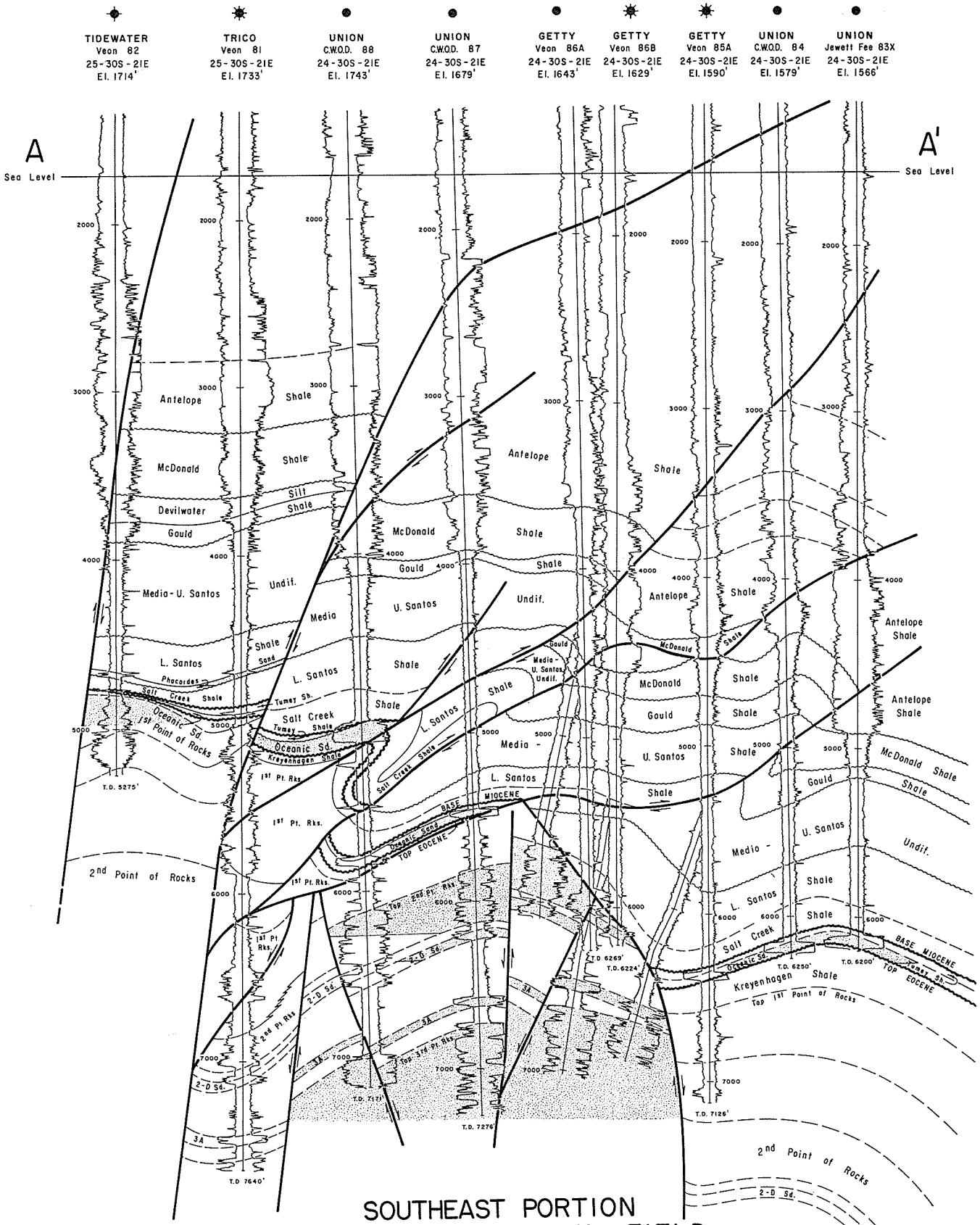
8,777,000 bbls. 67,236,000 MCF.

Total Production (Main Area)
1966

613,000 bbls. 2,506,000 MCF.

Cumulative to 1/1/67

23,620,000 95,854,000 MCF.



SOUTHEAST PORTION BELGIAN ANTICLINE FIELD

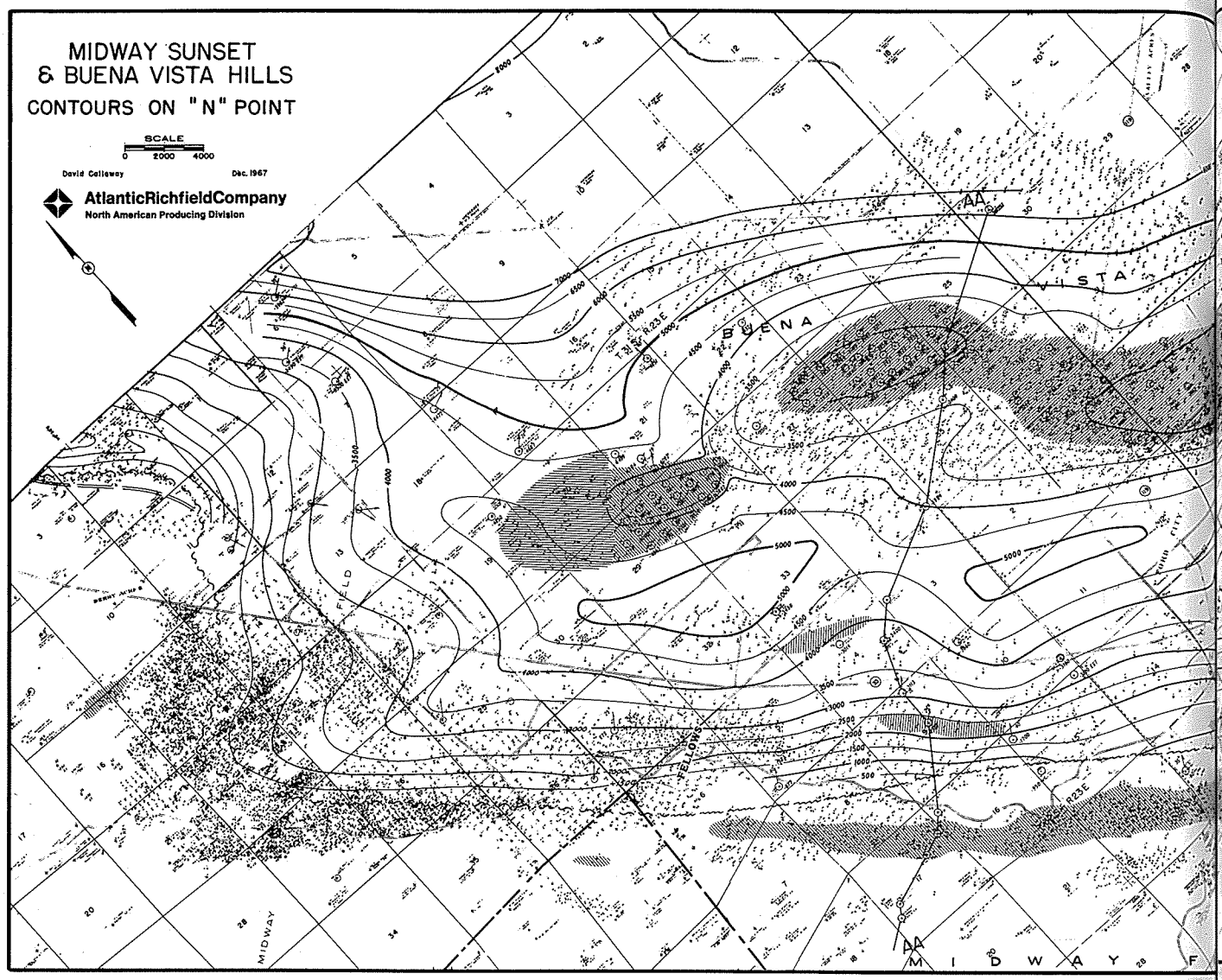
CROSS SECTION A-A'

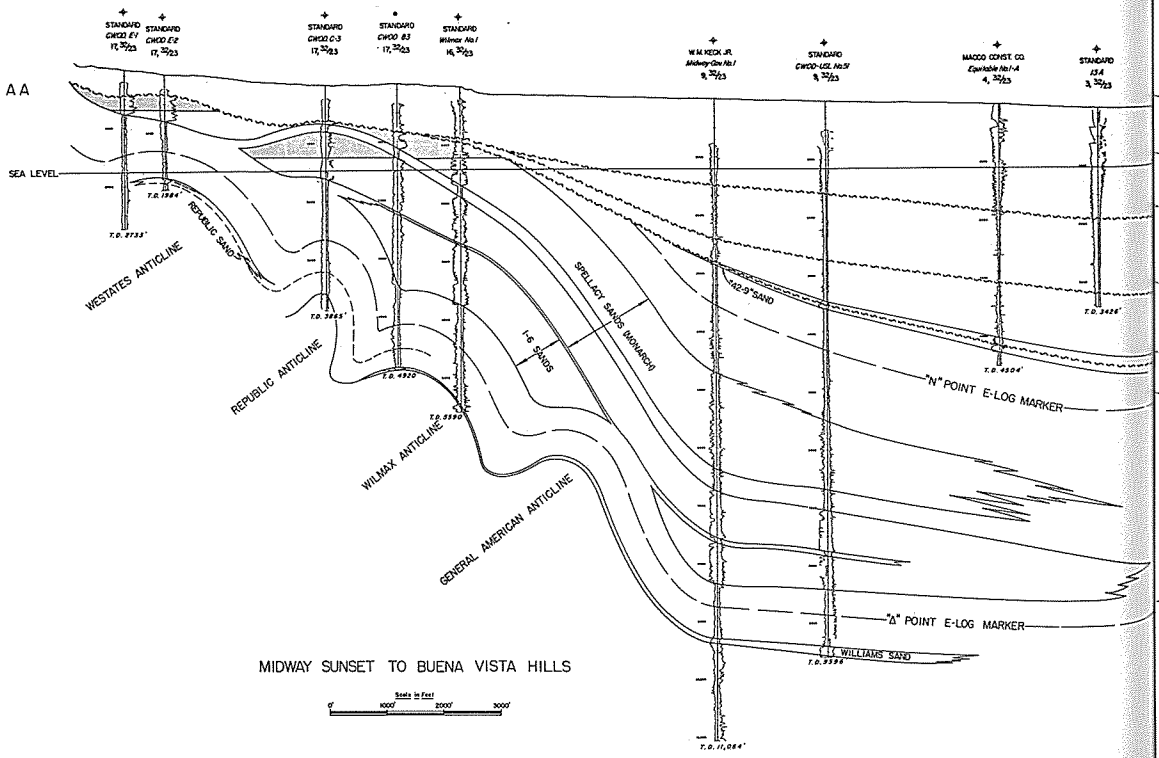
SCALE IN FEET

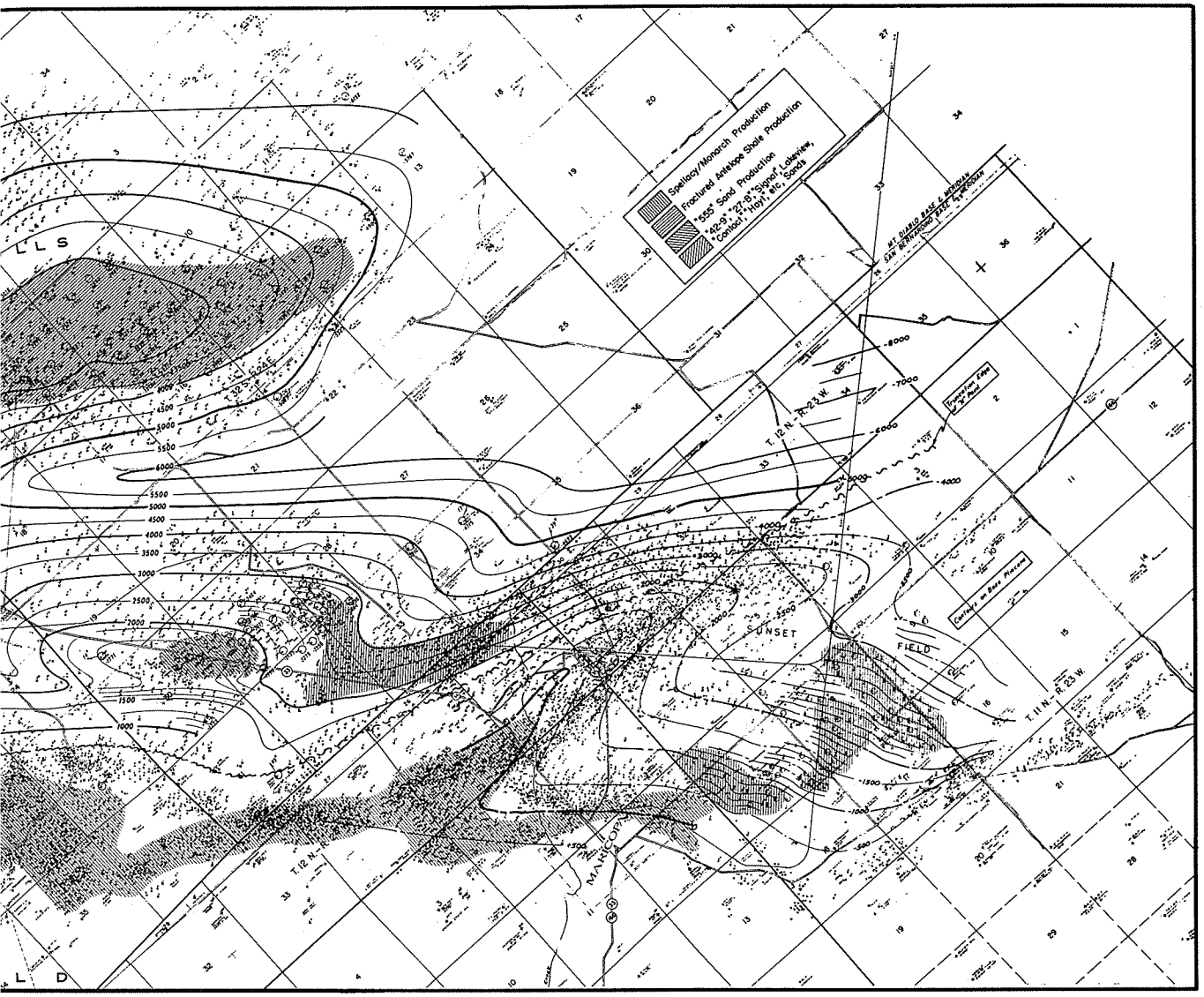
0' 1000'

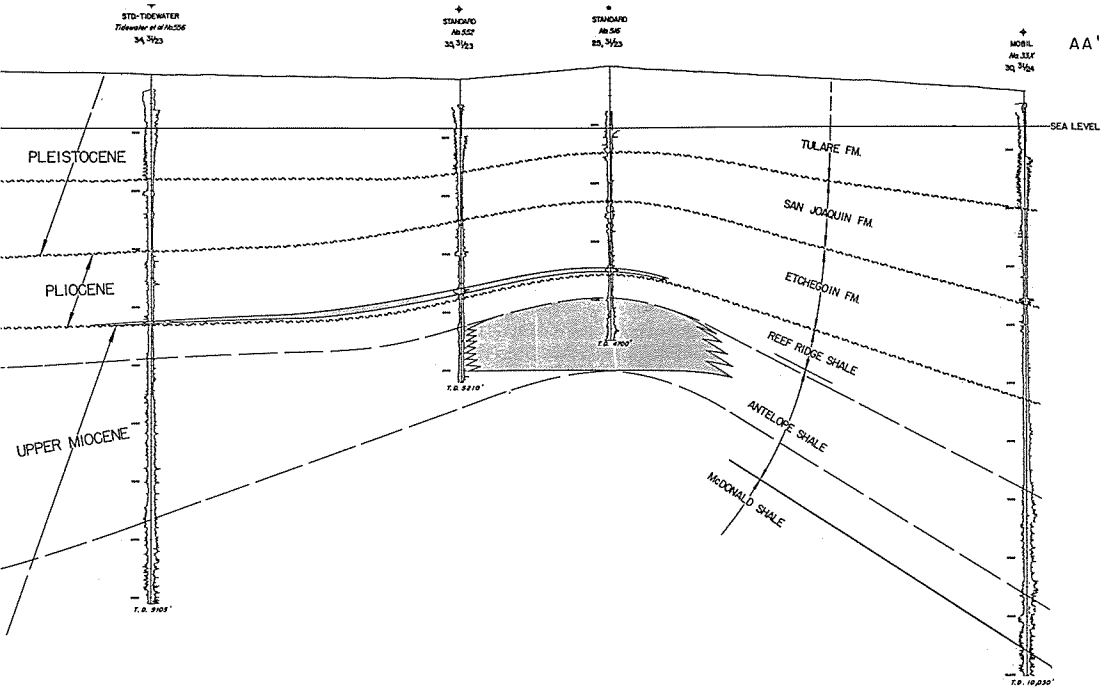
JOSEPH A. DUNWOODY

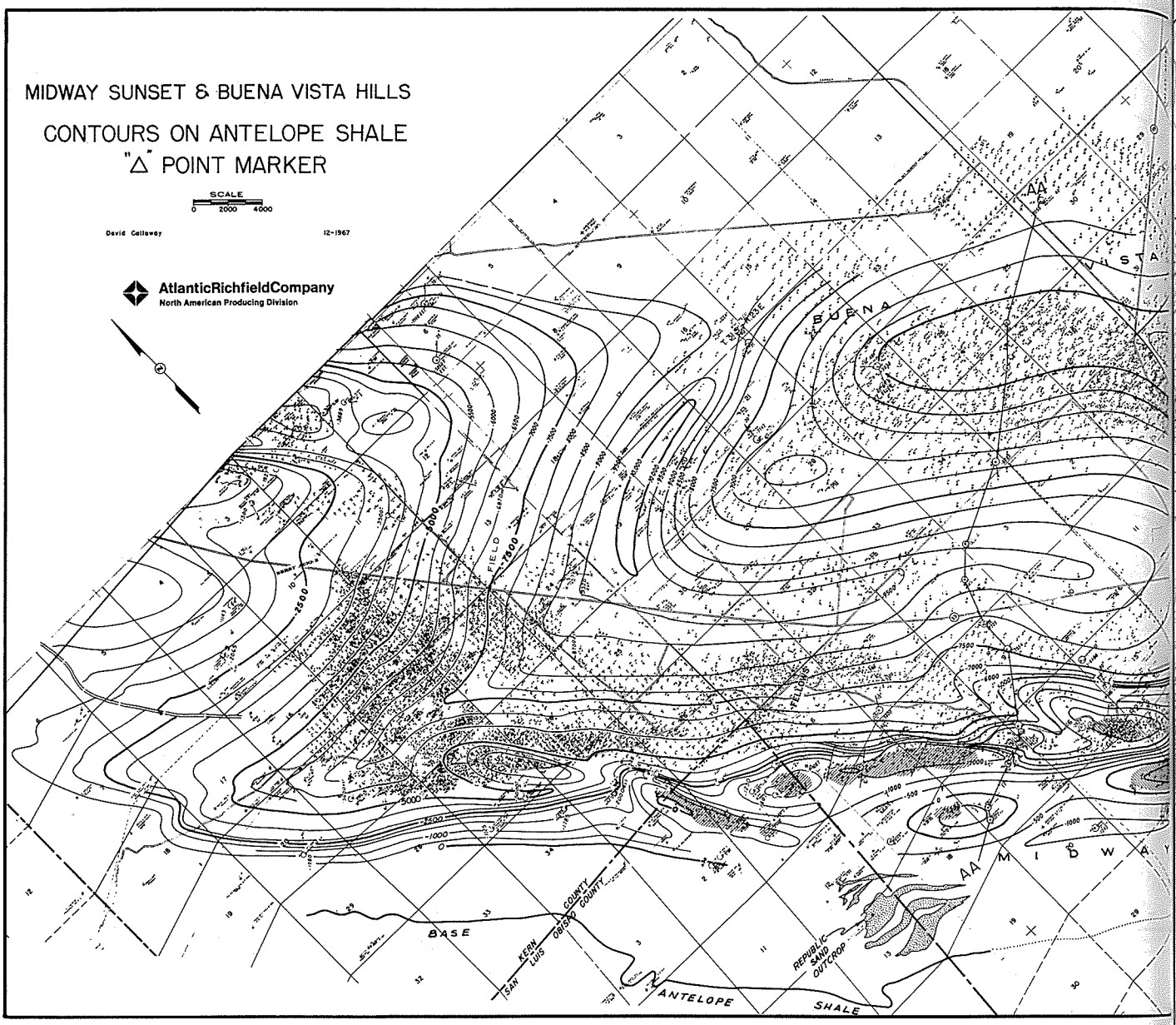
FEBRUARY 1968

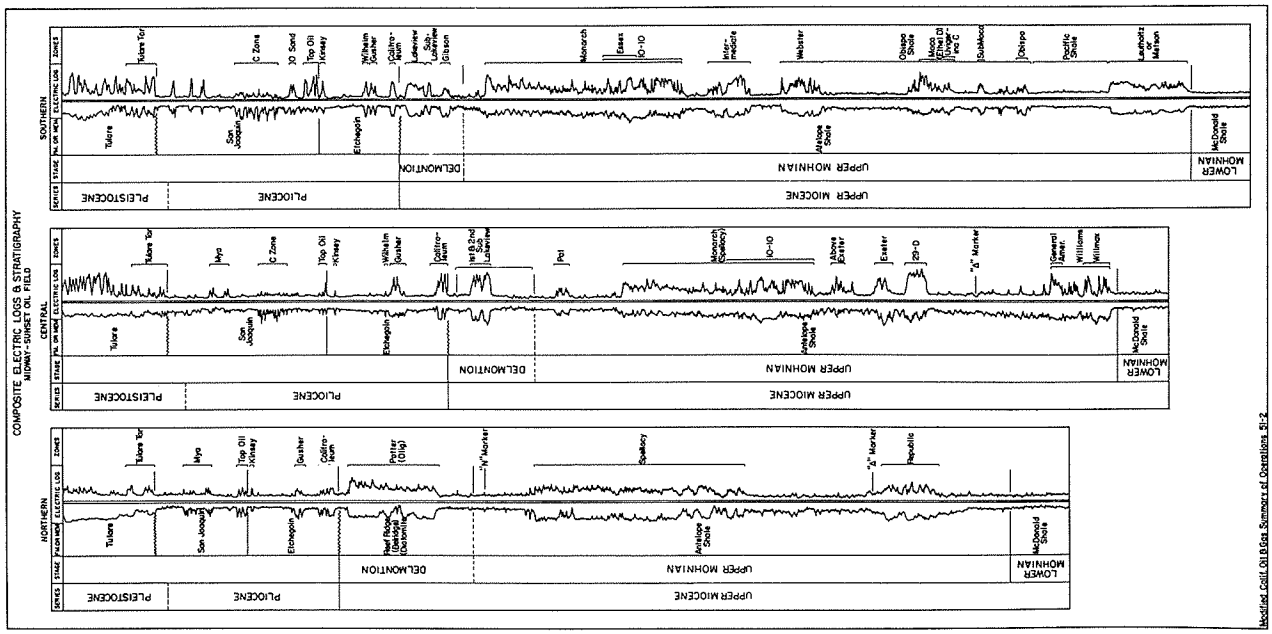

MIDWAY SUNSET
& BUENA VISTA HILLS
CONTOURS ON "N" POINT
SCALE
0 2000 4000
David Calloway
Dec. 1967
AtlanticRichfieldCompany
North American Producing Division
BUENA
VISTA
MIDWAY
FIELD
YELLOW
AA
T. 32 S. R. 23 E.
R. 23 E.

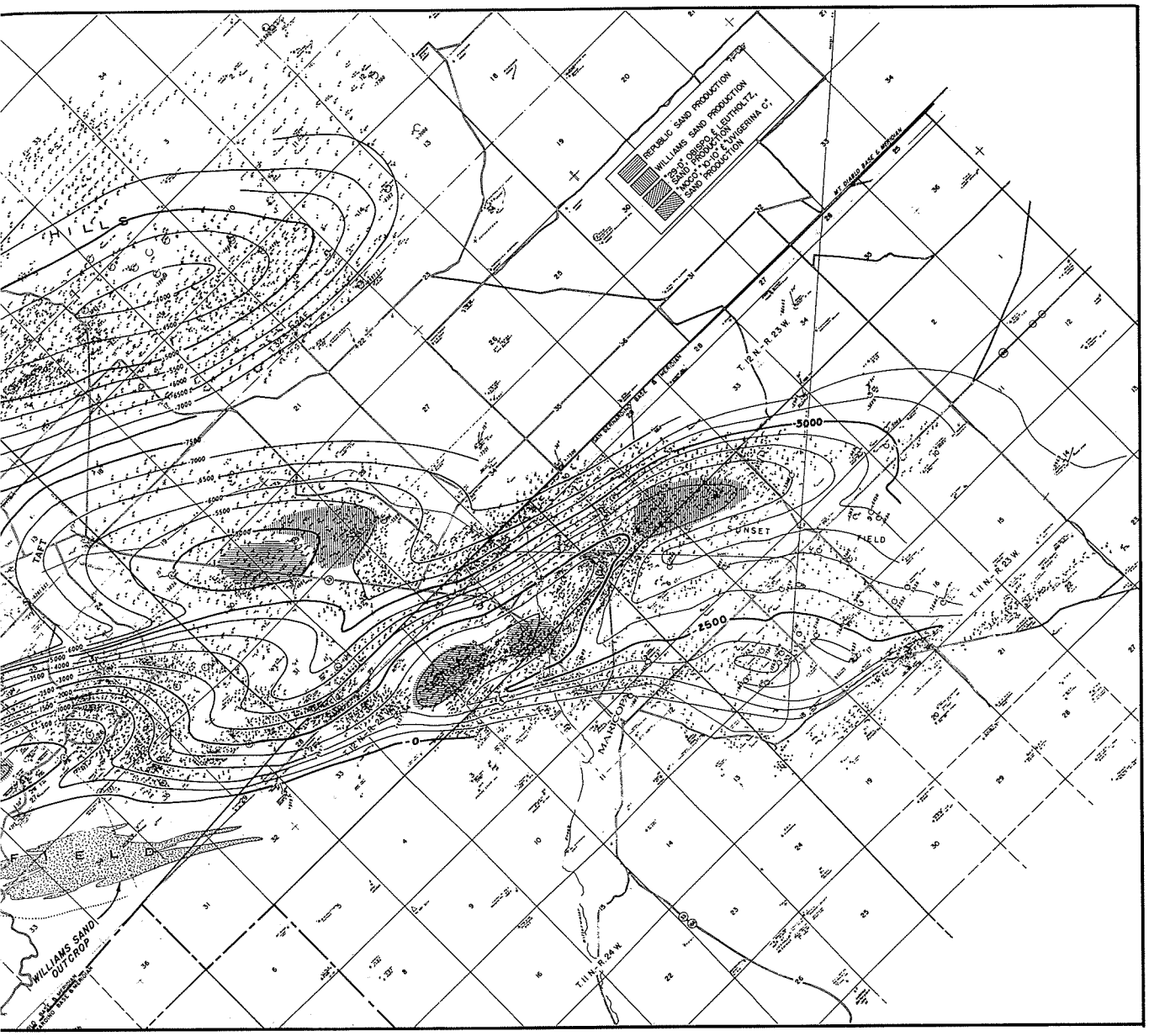

AA
SEA LEVEL
STANDARD CWOD E-1
STANDARD CWOD E-2
STANDARD CWOD C-3
STANDARD CWOD B3
STANDARD Wilmax No.1
W.M. KECK JR. Midway-Gas No.1
STANDARD CWOD-USL No.51
MACCO CONST. CO. Equitable No.1-A
STANDARD 134
T.D. 8733'
T.D. 7584'
T.D. 3865'
T.D. 4920'
T.D. 5590'
T.D. 11,064'
T.D. 9598'
T.D. 4504'
T.D. 3426'
WESTATES ANTICLINE
REPUBLIC SAND
REPUBLIC ANTICLINE
WILMAX ANTICLINE
GENERAL AMERICAN ANTICLINE
SPELLACY SANDS (MONARCH)
I-5 SANDS
"N" POINT E-LOG MARKER
"Δ" POINT E-LOG MARKER
WILLIAMS SAND
MIDWAY SUNSET TO BUENA VISTA HILLS
Scale in Feet
0' 1000' 2000' 3000'


Spellacy/Monarch Production
Fractured Antelope Shale Production
"555" Sand Production
"42-9" "27-8" "Signal" Lakeview, Cantlon, "Hoyt" etc. Sands
T. 12 N. - R. 22 W.
T. 11 N. - R. 23 W.
T. 12 N.
SUNSET
FIELD
MANICOPA
Carrizo or Bear Mountain
Temporary Edge of Field


STD-TIDEWATER
Tidewater et al No.1206
34, 31/23
STANDARD
No.552
33, 31/23
STANDARD
No.546
25, 31/23
MOBIL
No.331
30, 31/24
AA'
SEA LEVEL
PLEISTOCENE
PLIOCENE
UPPER MIOCENE
TULARE FM.
SAN JOAQUIN FM.
ETCHEGOIN FM.
REEF RIDGE SHALE
ANTELOPE SHALE
McDONALD SHALE
T.D. 5210'
T.D. 9105'
T.D. 10,030'


MIDWAY SUNSET & BUENA VISTA HILLS
CONTOURS ON ANTELOPE SHALE
"Δ" POINT MARKER
SCALE
0 2000 4000
David Calloway
12-1967
AtlanticRichfieldCompany
North American Producing Division
BUENA
VISTA
MIDWAY
FIELD
BASE
KERN COUNTY
SAN LUIS OBISPO COUNTY
REPUBLIC SAND OUTCROP
ANTELOPE SHALE
-2500
-5000
-7500
-1000
0


COMPOSITE ELECTRIC LOGS & STRATIGRAPHY
MIDWAY-SUNSET OIL FIELD
SOUTHERN
CENTRAL
NORTHERN
SERIES
STAGE
PLEISTOCENE
PLIOCENE
UPPER MIOCENE
DELMONTIAN
UPPER MOHNIAN
LOWER MOHNIAN
Tulare
San Joaquin
Etchegoin
Antelope Shale
McDonald Shale
Modified Calif. Oil & Gas Summary of Operations, 51-2



Field/Pool	Discovery Date	Discovery Well Name	Discovery Well Sec. T & R	Discovery Well Reason	Cumulative Prod. to 1-67 (X one million)	Gravity	Average Depth	Total Wells Drilled	Proven Acreage (Acres)
IDWAY SUNSET OIL FIELD	1894	Jewett & Blodgett #1	2-11N-23W	Oil Seep	962 Bbls 466 Mcf			6084	31,500
Olig Pool	1963	Standard Oil "35Z"(67) 9-10	35-30S-22E	Subsurface Geol.	1.5 Bbls 4.4 Mcf	15°	2300'	77	360
Republic Pools*	1928	Republic Pet. #25	8-32S-23E	Deeper Pool Test	25.2 Bbls 10.0 Mcf	12-25°	2300-4400'	92	370
Quality Pool	1936	Union "Williams" 1	22-32S-23E	Deeper Pool Test	12.6 Bbls	15°	2100'	60	225
Monarch/ "10-10" Pool	1963	Standard Oil #524	29-32S-24E	Subsurface Geology	4.6 Bbls 6 Mcf	28-36°	4400'	32	225
Exeter/"29D" Pool	1954	Exeter Oil "Murphy Fee"-11	28-32S-24E	Subsurface Geology	10.4 Bbls 11.5 Mcf	31°	5300'	32	270
Lakeview Pool	1910	Unknown	32-32S-24E	?	49.2 Bbls	22°	3100'	109	520
Leutholtz Pool	1945	Gulf "Woodward-USL"-1	21-11N-23W	Surface & Subsurface Geol.	16.8 Bbls 9 Mcf	15-28°	3100'	41	220
BUENA VISTA HILLS OIL FIELD	1909	(Honolulu Consol) Tidewater #1	10-32S-24E	Surface Geology	575 Bbls 774 Mcf			2005	18,400
Buena Vista Front Pool	1912	(Boston Pacific) Mobil "Boston" 1-C	32-31S-24E	Subsurface Geology	120.5 Bbls 57 Mcf	14-18°	4000'	368	7,040
Antelope Shale Pool	1952	(Standard Oil) Tidewater #502	9-32S-24E	Deeper Pool Test	25.5 Bbls 101 Mcf	28-35°	4800'	153	7,300
"555" Pool	1957	Tidewater, Tidewater-Richfield 555	20-31S-23E	Deeper Pool & Subsurface Geology	27.7 Bbls 5 Mcf	25-32°	5550'	52	1,025
"27-B" Pool	1944	Standard Oil 358	27-31S-23E	Deeper Pool Test	97.6 Bbls 62.6 Mcf	24-34°	3800'	203	4,400

*Includes Westates, Willmax, General American, Bee and Republic Pools

PALEONTOLOGY PAPERS

THE McKITTRICK TAR SEEPS[1]

C. C. CHURCH[2]

INTRODUCTION AND ACKNOWLEDGMENTS

The McKittrick tar seeps comprise one of the most extensive deposits of asphalt in the state. They are situated on a terrace in the foothills of the Temblor Range west of McKittrick, in western Kern County. The extensive seeps follow the trend of the old McKittrick oil field in a northwesterly to southeasterly direction. The asphalt deposits attracted the attention of prospectors and the early exploitation of the asphalt led to the discovery of oil below the seeps and to the fossilized remains of birds and mammals in the asphalt itself.

In the compilation of data on the McKittrick tar seeps, I am indebted to Mr. Richard C. Bailey, Director of the Kern County Museum and his staff for pictures of the 1949 excavation and for pertinent information on the early history of the tar pit exploration and to Mrs. Imogene Gervais, secretary in the Kern County schools office of Educational Services, for pictures of tar seep fossils.

I also wish to express my thanks to Dr. J. R. MacDonald, Senior Curator of Vertebrate Paleontology of the Los Angeles County Museum of Natural History for certain facts about the McKittrick tar seep fossils and Dr. Donald E. Savage, Professor of Vertebrate Paleontology, University of California, Berkeley, for information on the University of California excavations at McKittrick.

GEOLOGIC SETTING

The McKittrick oil field was developed along a narrow structure for a length of about four and one-half miles and a width of one-half mile. The tar seeps follow the crest of the field, finding their way to the surface through crumpled and faulted Miocene cherty and diatomaceous shale. These shales have been thrust over the younger Tulare beds at a low angle, much in the nature of a gigantic land slide. At present, however, there is no general agreement as to the process or processes by which the Miocene shale arrived at its present position. One of the more recent opinions suggests that both faulting and landsliding may be involved. This opinion, by the late Dr. R. L. Hewitt (1952), was based on a detailed study of the field and the deep wells of the Belgian Anticline field.

Extensive seeps occur in the Tulare Formation to the southeast of the field, a short distance northwest of Highway 33. The Miocene overlap ends about a half mile northwest of the highway. The more continuous and extensive of these seeps are situated along a trend which subparallels the northeasterly downslope edge of the older Miocene and Pliocene Formations where it abuts against the younger beds. This is a zone of complex shearing which, in the opinion of Ben M. Page and coauthors of Preliminary Map 35, U.S.G.S., cannot be accounted for by faulting alone. Much of the structural complexity appears to be due to clastic intrusions of one type of sedimentary material into another. Many of the rocks in anomolous positions appear to have been injected by a process of solid flow. At the contact of the older beds with the Tulare Formation, the dip of the beds is very steep, the Tulare Formation having dips of 12 to 89 degrees and some even overturned with consequent reverse dips.

About a quarter mile west of the center of sec. 20, T. 30 S., R. 22 E., the younger Tulare Formation disappears under the overriding Monterey shale. From this point the Miocene thrust sheet extends progressively farther out into the McKittrick Valley almost to the northwest corner of Sec. 20 and thence northwesterly roughly in alignment with the foothills for about three miles.

The present Highway 33 intersepts the outer edge of the asphalt about a quarter mile southwest of McKittrick, cutting through the brea for a distance of over 1,200 feet and to a depth of about ten feet in the deepest part. Surprisingly, nothing in the way of large mammal bones were exposed. There are many small mamal and bird bones and many beatles in pockets of soft brea near the surface but little else.

Southwest of the asphalt deposit the roadway is cut between two hills composed of well cemented to friable sandstone for the first 125 feet. This sand is considered to be the Etchegoin Formation by the authors of U.S.G.S. Preliminary Map 35 on the basis of lithology. The Etchegoin Formation is in discordant contact with diatomaceous siltstone along a fault plane that dips 46 degrees northeast. The adjacent rock south of the fault is of Miocene age, bleached white at the surface but oil-stained below. About a quarter mile southwest of the first cut, the road cuts through another hill of diatomaceous siltstone like that just described. On the south slope of this hill, near its base, the basal San Joaquin, Pliocene, *Pecten eldridgei* zone, called *Aequipecten circularis eldridgei* (Woodring et al., 1940), lies unconformably upon the Miocene beds which are practically vertical at this point. These older beds consist of about twenty-five feet of sand, silt and pebbly sand. The two to three-foot thick *Pecten eldridgei* zone is composed of about 95 per cent of the small *Pectens* with a few small oysters. This bed is loosely cemented and the small bivales are well preserved. Northwest of where the highway cut through the broad deposit of asphalt, the brea is exposed at the surface for at least a half mile. This exposure was examined for fossils but none were found. There are

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[1]Manuscript submitted Jan. 1968.

[2]Consulting Micropaleontologist, Bakersfield, California.

other, smaller exposures of tar and seeps to the northwest along the crest of the field but the thick, more continuous deposit appears to be about two to two and one-half miles long, about a mile and a half of which extends southeast of Highway 33.

ASPHALT PRODUCTION

Besides the more extensive asphalt-soaked alluvium and sand, there are numerous asphalt veins, largely confined to the Tulare Formation in the southeastern part of the district. These veins may be up to one hundred feet long and from a few inches to eight feet in width but most of them are of the smaller type. The vein material is a mixture of sand and asphalt with the asphalt making up as much as 70 per cent in some cases but this is an exception rather than the rule. These deposits were mined by the early workers and tunnels and shafts are still in evidence in the southwest quarter of section 27, about one and one-half mile southeast of McKittrick. Brick used in the foundation and construction of the refinery are still to be seen at the mouth of a gulley in section 28. Anyone visiting the area should proceed with caution as there are still deep, open shafts and tunnels, unmarked and partially concealed, a possible death trap for the unwary.

The earliest recorded attempt at exploiting the asphalt deposits was in 1861. J. S. Hambleton and O. J. Lovejoy visited the deposits and dug the first pit with a pick and shovel to a depth of ten feet. Mr. J. L. Zulberti (1965), in reviewing the early history of the field states, "In February, 1864, J. O. Lovejoy organized the Buena Vista Petroleum Co. under the guidance of J. S. Hambleton. The first Buena Vista oil works erected by the company was about one mile southeast of the Temblor Ranch house, and the second refinery was erected on the northwest quarter of section 13 near the town of Reward. Asphalt mined from tunnels up to 180 feet long and brea bailed with buckets from open pits near McKittrick was distilled to produce kerosene and lubricating oil." In a later account Mr. Latta (1949) wrote that, "The late Mr. John L. Sullivan of Grangeville, Kings County, and who helped operate the still, stated that the thick, crude petroleum was full of the bones of birds and animals. When the still became partly filled with the bones they were shoveled out." This early refining operation was successful but because of the cost of transportation they were not able to compete with eastern oil and were forced to suspend operations in May, 1867.

The next attempt to make commercial use of the asphalt was begun in 1870 by the Buena Vista Petroleum Works, which was located near the town of Asphalto or present day McKittrick. As in the earlier operation, tunnels were dug into the asphalt beds. Of this operation Mr. Latta wrote, "Attention was again called to the McKittrick remains during the 1870's when asphaltum was mined and refined in that locality. The fluxing kettles soon became clogged with bones of many descriptions. These were also shoveled out of the kettles and used for fuel to fire the kettles." Some of the bones from these early discoveries found their way to museums and in 1865 Joseph Leidy listed "*Equus occidentalis* from Santa Maria oil springs, locality approximately two miles to the southwest of McKittrick."

EARLY DRILLING AND PRODUCTION

Although the exploitation of the asphalt and heavy oil began as early at 1864, and it is difficult to determine what might be considered as the discovery well for petroleum. Some of the early attempts at drilling failed from mechanical or other difficulties. As an example, one of the unusual hazards described by Mr. Zulberti (1956) as "The Pacific Development Company drilled a well in this area in 1876 and obtained oil, but the location was deserted and the equipment abandoned after the drilling crew was murdered by members of the Vasquez gang." Later, in 1898, the Columbia Oil Company was organized and made an unsuccessful attempt to drill a well with a hand auger. "A 40-foot Pennsylvania-type rig was then set up in Section 24, T. 30 S., R 21 E., the first permanent rig in this part of California" (Zulberti). In this drilling attempt the tools became stuck and the company lost interest in further drilling.

The first real production from wells was obtained when the Standard Asphalt Company took over the Columbia Oil Company property and began mining asphalt. "A number of wells were drilled by E. Rowe of Stockton, in 1892. One was 410 feet deep and produed 22 barrels per day, another was 92 feet deep and produced 3 barrels per day. This was heavy oil under 16 degrees Baume' and was considered as asphalt" (Zulberti).

The first oil gusher was drilled by Milton McWhorter who organized the Klondike Oil Company and brought in the "Shamrock" well for 1300 barrels per day. This may have been the first well drilled into the Olig Sand but its exact location cannot now be determined. Soon after, the railroad company "made a determined effort to depress the price of crude petroleum. With no other outlet Milton McWhorter was forced to abandon development work in the McKittrick field."

Two years later, 1898, real production from the field began. The statistical record shows that 10,000 barrels were produced that year and production climbed steadily after that. This was all from the old field. The recent production in and around the old field is a result of a better understanding of the subsurface geology and advanced drilling equipment and techniques, making the drilling of deep wells a normal, routine procedure.

EARLY EXCAVATIONS

In 1903 J. C. Merriam described *Canis Indianensis* from a locality given as Oil Springs in Tulare County. Doubt was expressed as to the locality since in the same paper *Hyaenognathus pachyodon* was described from late Pliocene or Quaternary near Asphalto.

F. M. Anderson (1908) described a series of terraces in the McKittrick area and mentioned extensive beds of asphalt in which were found remains of elephants, horses and an extent species of wolf. The age of the beds he considered as Pleistocene.

For a number of years after Anderson's report there was no published scientific information on the fossils from the tar seep area until 1921. When the new highway between McKittrick and Taft cut through the asphalt deposit about three quarters of a mile southwest of McKittrick live asphalt seepages caused some concern for highway engineers. This attracted the attention of J. B. Stevens, a Petroleum Engineer with the Associated Oil Co., at Fellows, who had a special interest in fossils. On one of his visits to the seep area he noticed some bones projecting from the asphalt. Knowing that they would be of considerable interest to the vertebrate

paleontologists, he made a collection of the bones and sent them to Professors J. C. Merriam and Chester Stock at the University of California. Soon after receiving the fossils these men sent a team of graduate students to the site and the first University of California excavation was opened southeast of the road. More animal and bird bones were found and from this first collection eleven mammalian forms were reported, as follows: *Aenocyon dirus,* the dire wolf; *Canis* near *ochropus; Felis atrox,* a large lion-like cat; *Felis* near *daggetti; Arctotherium simum,* a short-faced bear; *Mylodon* sp., a large extinct ground sloth; *Equus occidentalis,* the western horse; *Antilocapra ? sp.,* the pronghorn antelope; *Bison* sp.; a slender-limbed camel, later named *Llama stevensi; Mastodon* sp.

This locality is about 550 feet southwest of the historical marker which commemorates the discovery of the fossils. The monument is located just off Highway 33 where the old road from McKittrick turns off. This road is now Highway 58 and locally known as the Santa Maria or Santa Margarita road. The plaque is in error in the statement that the site was first explored by the University of California in 1928. Actually the discovery was made in the summer of 1921 (as personally related to Mr. Richard C. Bailey, Director of Kern County Museum, by Mr. Stevens), and the exploration began shortly thereafter. The above location as given by the University of California is as follows: The Pleistocene deposit is situated in the NE ¼ of NE ¼, Sec. 29, T. 30 S., R. 22 E. M.D.B.M., Loc. on the NE side of road, U.C. Loc. 4096; that to the SW is U.C. Loc. 7139, Loc. 138, Calif. Inst. Technology, same as U.C. Loc. 7139.

Charles H. Sternberg (1932), famous for his great dinosaur discoveries, obtained from Dr. Chester Stock of the University of California, a commission to make a further search for fossils at the McKittrick tar pits. He began work August 28, 1925, and continued until October, 1927. He worked first in the old University of California quarry but because of a twelve-foot wall of rock over the excavation and its danger of caving, he moved to the northwest side of the highway. Of this new area he wrote, "Here I was so fortunate as to discover a great drift of bones fifty by sixty feet in area, and about two feet thick. These bones were filled with asphaltum, from a flow of quite recent time." Sternberg had expected the McKittrick deposit to be like the Rancho La Brea deposit where the bones were indiscriminately mixed together but said, in his account, "In my quarry, however, I found this pile of bones to have been carried in by water. Many articulated skeletons of carnivores and herbivores lay mixed together, besides countless thousands of scattered bones of birds and mammals." Here he found the "Great Bison, much larger than the recent buffalo, the horn cores measuring forty-four inches from tip to tip. It was eleven feet from the tip if the chin to the base of the tail." Here he also found the skeleton of a *Mastodon,* nearly complete but without the skull; also twelve skulls of the western horse; a large camel; two llama skulls; a musk ox; two pronghorn antelopes; six dire wolves; ten skulls of the grey wolf; sixteen coyotes; one small and one large lion; one brown bear; one short-faced bear skull and skeleton; one saber-tooth cat, the first found here. Also badgers, a skunk, fox, jack rabbits, rats, mice and many birds among them the great extinct vulture. The bones were cleaned with distillate in his workshop nearby and then treated with dilute shellac to preserve them. The collection was sent to Dr. Stock at the California Institute of Technology where he was then teaching.

The author was fortunate in being able to accompany Dr. Hanna of the California Academy of Science on a visit to Sternberg's site in 1927. When we arrived he was digging in a pit about five or six feet deep and had just removed the nearly perfect skull of a horse, just one of several which he found here. He later showed us more of his finds and described his method of cleaning and preserving the bones. As a result of Sternberg's work, Stock and Furlong (1927), announced the discovery of a musk ox-like animal which they tentatively referred to as *Preptoceras sinclari* and in 1928 Stock described some peccary remains, referring them to *Platygonus* near *compressus.* At this same time *Llama stevensi* was designated the type of a new genus, *Tanupolama.* Furlong (1930) listed *Capromeryx minor,* a small extinct antelope, and Merriam and Stock (1932) listed *Smilodon californicus* from McKittrick for the first time. A puma from the same collection was compared to *Felis bituminosa.*

RECENT EXCAVATION

The most recent professional search for fossils at the old University of California site was in 1949 in a joint sponsorship of the Kern County Museum, the Los Angeles County Museum and California Institute of Technology. The work was under the supervision of Mr. F. F. Latta, Director of the Kern County Museum, and Dr. Chester Stock, Curator of Science at the Los Angeles Museum and Chairman of the Division of Geological Sciences, California Institute of Technology. Mr. George P. Kanakoff and Mr. Leonard C. Bessom of the Los Angeles County Museum, directed the work at the site. (See photo)

Fig. 1. McKittrick Tar Pits 1949 Excavation.

Work began in the later part of June and was completed by October 10, 1949. Cleaning and preparation of the fossils was carried on at the Los Angeles County Museum but a considerable amount of unprocessed material is at present stored at the Kern County Museum. On display at the Museum are a few of the fossils obtained at the McKittrick tar pit in 1949, these include the skull of the great bison, the dire wolf, part of the lower jaw of the western horse and part of a camel skull.

Of the 43 animals identified from the McKittrick site, 20 are now extinct and of the 58 species of birds, 9 are now extinct. One of the puz-

zling features of the tar seep is the presence of numerous, roughly circular pipes filled with sand and brea. They range from two inches to several feet in diameter and extend from near the surface down to the underlying sediment, usually becoming smaller near the bottom. Mr. Sternberg found them filled with the bones of rodents, birds, insects and plant debris suggesting an origin more recent than the asphalt layer. One of these was seventeen feet deep, extending through the asphalt to the clay bed below it. There has been no satisfactory explanation for the origin of these pipes.

At the present time there is little evidence of the deep pits dug by the early University of California excavators or of the 1949 exploration. In the articles which have been written about the deposit and its fossils, the statement had been made that the deposit was worked out. In all likelihood this is not true, in fact, if one considers what a very small part of the deposit has been worked in the past, it seems reasonable to suppose that there are as many or more fossils remaining in the deposit than have been removed in all of the previous digging.

MAMMAL ASSEMBLAGE

Of the numerous papers written about the McKittrick tar seep fossils, the most comprehensive is that written by John R. Schultz (1938). This paper gives a complete list of the animals and birds identified, papers published and other information about the deposit. He describes the seeps as being from ten to twelve feet thick and forming a definite stratified layer which rests with unconformity upon folded Tertiary and Pleistocene sediments. He also points out that the deposit is now 700 feet above the level of Buena Vista Lake and that there is no evidence of lake beds in the tar seeps. As a matter of fact, the rocks exposed on the uphill side of the road between the monument and the fossil site are apparently typical Tulare Formation and have been mapped as such.

The above list does not include the numerous smaller animals, such as the rats, mice, ground squirrels, etc., which have been found in the tar pits, nor the amphibians, land snails or insects as many of these are of later origin.

In compiling the list of fossil mammals found at McKittrick, those found or reported from Asphalto were not segregated from those found at the more recent site southwest of McKittrick. Of special interest in this respect, is the fast that J. R. Schultz (1938) regarded the Asphalto fauna as separate and older than that found at the U.C. site near McKittrick. Schultz believed that, "The Asphalto fauna served to revive paleontological interest in the region but the assamblage is not closely related to that of McKittrick." This is an interesting and possibly significant observation as the two localities are over a mile distant from each other. Both localities are in tar seeps of the Tulare formation and are stratigraphically and structurally contemporaneous in origin. The animal remains reported from the tar seeps prior to the discovery in 1921 by J. B Stevens were, *Equus occidentalis, Canis indianensis, Hyaenognathus pachyodon* and an elephant. Of these, *Equus occidentalis* was abundant at McKittrick and the citation of the elephant is somewhat doubtful as I have found it reported only in Anderson's paper of 1908. The two species of Canidae however, were not found at the McKittrick site and may indicate a difference in age not accounted for in the present state of our knowledge.

Some of the larger and better known species of animals found in the McKittrick tar pits are as follows:

Parelephas columbi (Falconer)	Elephant, extinct.
Mastodon raki Frick	*Mastodon*, extinct.
Platygonus near *compressus* LeConte	Peccary.
Smilodon californicus Bovard	Saber-tooth cat, extinct.
Felis atrox Leidy	Large lion, the Great Cat, nearly one fourth larger than present-day lion or tiger.
Felis daggetti Meriam	Similar to but larger than mountain lion
Lynx rufa fischeri Merriam	Bob cat, variety of living species.
Canis latrans orcutti (Merriam)	Coyote, variety of living species.
Aenocyon dirus (Leidy)	The dire wolf, extinct.
Aenocyon near *milleri* (Merriam)	Wolf, similar to dire wolf, extinct.
Cervus nannodes	Tule Elk.
Bison antiquus Leidy	Large, antique bison, extinct.
Preptoceras ? cf. sinclari Furlong	Musk ox-like bovine.
Camelops hesternus (Leidy)	Large, extinct camel.
Tanupolama stevensi (Merriam and Stock)	Slender-legged camel, extinct.
Equus occidentalis Leidy	Western horse, extinct.
Cervus sp.	Deer.
Odocoileus sp.	Mule deer.
Capromeryx minor Taylor	Small antelope, extinct.
Antilocapra americana (Ord)	Pronghorn antelope.
Tremarctotherium simum (Cope)	Short-faced bear, very large, extinct.
Ursus optimus Schultz	Black bear.
Megalonyx ?	Ground sloth, extinct.
Paramylodon harlani (Owen)	Ground sloth, extinct.
Taxidea taxus cf. neglecta Mearns	Badger.
Spilogale phenax phenax Merriam	Spotted skunk.
Mephitis mephitis holzneri Mearns	Striped skunk.
Mustela frenata nigriauris Hall	Weasel.
Lepus californicus orthognathus Dice	California jack rabbit.
Sylvilagus audobonii pix Dice	Cotton tail rabbit.
Sylvilagus bachmani cinerascens (Allen)	Brush rabbit.
Hyaenognathus pachyodon Merriam	Canidae, dog family, extinct.
Vulpes macrotis cf. mulica C. H. Merriam	Fox.

BIRD ASSEMBLAGE

Along with the mammal bones found in the asphalt, there were also many bird bones. These were reported by L. W. Miller (1925). Of the one thousand specimens ex-

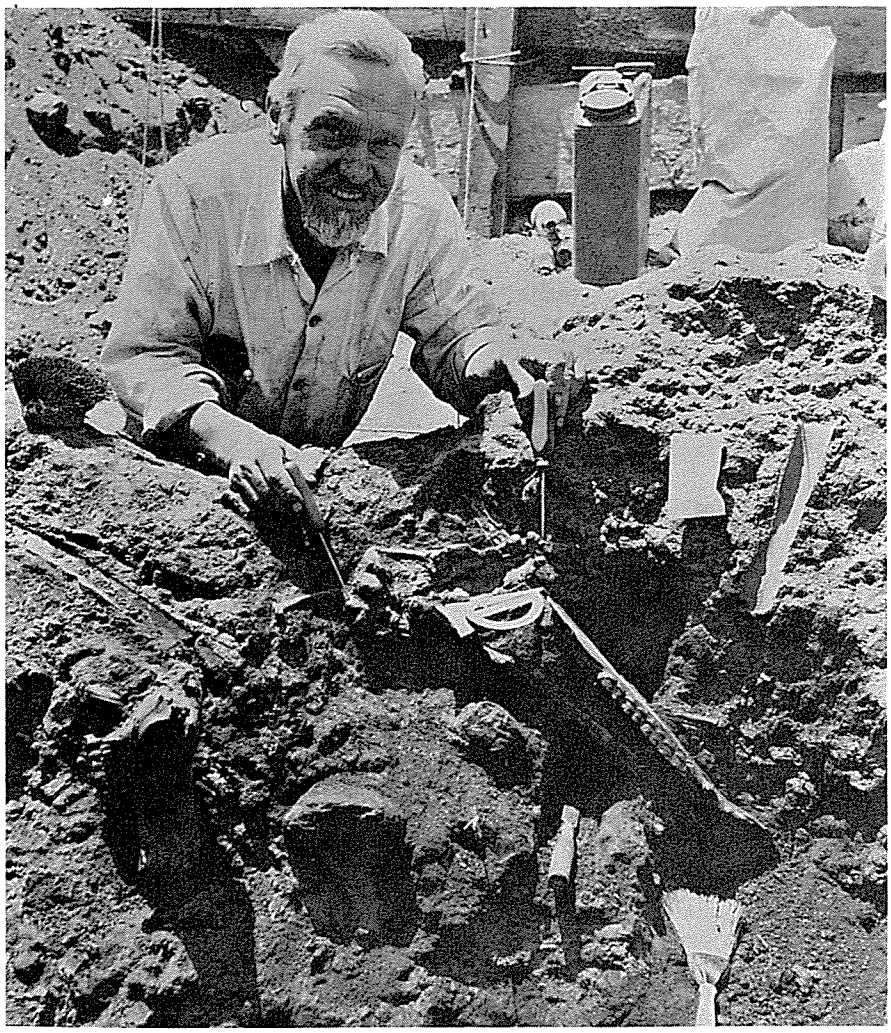

Fig. 2. Dr. Geo. Kanakoff during 1949 excavation. Skull of dire wolf in center of picture between picks. Lower mandible of **Equus occidentalis** Leidy at lower right.

amined, he recorded eighteen living species, four extinct and seven species not specifically identified. The water birds outnumbered the others two to one with ducks and shore birds predominating. As a single species, the golden eagle was most abundant. In considering the possible environmental conditions of the McKittrick area in the Pleistocene, he wrote as follows, "The great mass of material from these beds is composed of ducks, herons, storks and shore birds. Their extreme abundance, coupled with the scarcity or absence of gulls, divers, pelicans and land birds, suggests to the imagination practically the only possible restoration: a landscape made up of shallow, open, muddy-margined ponds interspersed with grasses or sedge—the ponds too shallow for gulls and other fish-eating birds, the mud and grass attracting shore birds, cranes, herons, ducks and storks . . ."

The above general statement about the bird fossils does not attempt to include a full list of the species but a few further details about the avian fauna which seem especially noteworthy should be mentioned. The large, condor-like vulture, *Teratornis merriami* Miller, is present at McKittrick but very rare, possibly not so much because of its actual scarcity at the time but because of the physical nature of the McKittrick seeps. This huge bird stood about two and one-half feet tall, had a probable wing spread of at least twelve feet and possessed a skelton with a curious combination of eagle and condor-like characters. It is one of the extinct species and was a very common element in the Rancho La Brea fauna. Also present but quite rare was the California condor, *Gymnogyps californicus* (Shaw), the largest living vulture in California, now approaching extinction because of the restriction of its range and its very limited reproductive ability. Another of the large species of fossil birds found at McKittrick was the stork, *Jabiru mycteria* (Lichtenstein). It is no longer living in the western United States but does survive in other parts of the world. Other stork-like birds, such as the little brown crane, *Grus canadensis* (Linnaeus); the great blue heron, *Ardes herodias* Linnaeus, were quite common in the area along with other shore birds still living at the present time.

EXTINCTON OF FAUNA

One question of interest to many is, what kind of climate is suggested by this array of Pleistocene animals and birds? The general conclusion is that there was a somewhat moister climate than at present and hence more favorable conditions for grazing and browsing animals but otherwise not greatly different from that of today. If this is true, we are faced with the perplexing question of why many of these animals became extinct when others of similar habits lived on into the present. One writer recently attributed the disappearance of certain species of animals to the coming of man but very few facts have been set forth to support this theory. There is ample evidence that there was an abundance of game in the Americas when the first European explorers arrived. While it is true that many of the Indian tribes were largely dependent on wild life for

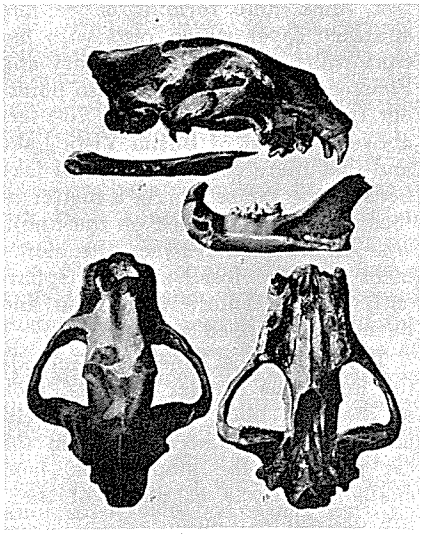

Fig. 3. Skull of **Felis Atrox** Leidy. Late Pleistocene, McKittrick, Calif. (**From** Carnegie Inst. Washington Pub. 478.)

their food, particularly the plains Indians, they were not a serious threat to the existence of any single species. It is a generally accepted belief among paleontologists that a number of the larger animals, now extinct, were living during the early human occupation in America as human relics and weapons have been found associated with the bones of the great bison, the mammoth, camel, horse, tapir and *Mastodon*. This mere association, however, does not tell us to what extent these early, Ice-age men contributed to their extinction. No artifacts or tools of contemporaneous origin have been found in the tar pits even though there is a strong possibility that man occupied the region at the time.

Dr. Alfred S. Romer (1945), in discussing the extinction of the great ground sloth wrote, "The factors causing their extinction were as mysterious as those which destroyed most of the other large mammals of the western world." However, Dr. Romer advances a more positive theory for the extinction of the saber-tooth cat, that their demise "may very possibly have been due to the practical extinction of the large, thick-skinned animals which may have formed their prey." and concluded by adding, "In the Pleistocene, for example, there were four large and common proboscideans in North America, as well as numerous ground sloths. Today all are extinct." In part this view supports a theory of some standing among paleontologists, that the more highly specialized types of animals, as exemplified by the horse, the camel and the saber-tooth cat, reach a stage of racial old age in which they lose their adaptability to changing conditions. Thus, in the face of a change of climate, of food or natural enemies, they cannot survive. Dr. H. F. Osborn (1936) reasoned that the increased moisture and cold brought on by an advancing glacier may have indirectly affected the horse population through its effect on the food supply, the increase in insect pests and upon fertility and reproduction. Another factor which has been considered but perhaps not sufficiently stressed is the devastating effect of a disease epidemic among animals. Animal diseases such as the deadly anthrax are certainly not new and could wipe out vast herds of ungulates. This, of course, again brings up the question of why disease or any other factor should be so selective. If it did, indeed, wipe out the great bison, the horses and the camels, why not the buffalo and the deer? If we could know the truth of the matter, we would probably find it was a combination of many interacting forces.

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Pullenia Moorei-Rotalia Becki

(PSEUDOSAUCESIAN)

BIOFACIES OF THE LOWER MOHNIAN[1]

C. H. RUDEL[2]

An interval of sediments has been recognized by its contained fauna in the Upper Miocene. These sediments are found on the West Side of the San Joaquin Valley. The faunal facies has been called the "Pseudosaucesian" facies because the faunas contain several deep water foraminifers generally typical of the Saucesian Stage, Lower Miocene. A few short-ranging species, notably *Pullenia moorei* and *Rotalia becki*, restricted to the basal Lower Mohnian Stage; aid in placing these sediments in their proper stratigraphic sequence.

The designation of "Pseudosaucesian" facies was first presented by R. S. Beck in 1950 (compilation chart in AAPG Guidebook, 1952). He included all of the Middle Miocene and the basal Lower Mohnian sediments of the West Side of the Southern San Joaquin Valley in this facies. Many species of foraminifera, normally associated with Saucesian sediments range through the Middle Miocene-basal Lower Mohnian, Upper Miocene in the Maricopa area. Kleinpell noted a repetition of a biofacies in his biostratigraphic studies (Miocene Stratigraphy of California, 1938, p. 83) as ". . . a recurrent expression of a migrating or oscillating ecologic niche within a province."

An excellent outcrop section of sediments representing the "Pseudosaucesian" facies is located south of Maricopa in the Hazelton Junction area, Sec. 14-23, 11 N., 24 W., SBB&M. Evidently continued deep water sedimentation allowed deeper water faunal elements usually associated with the Lower Miocene, Saucesian Stage, to range through the entire Middle Miocene - basal Mohnian Stages in this area (Bandy and Arnal, AAPG Bull. Vol. 44 #12; Dec. 1960; pp 1921-31).

This "Pseudosaucesian" facies fauna is found in the Lower Mohnian, Upper Miocene sediments over slightly shallower water deposits containing normal restricted Middle Miocene faunas in the area of Belgian Anticline. A well typical of this faunal sequence is the Getty "M & M" #1 (formerly Marathon "M & M" #1) Sec. 32-30 S., 22 E., MDB&M. The basal Mohnian "Pseudosaucesian" facies is present in this well in a cored interval from 4250′ to 4520′.

Species restricted to the basal Lower Mohnian are *Pullenia moorei, Rotalia becki* and a type of *Sigmoilina sp.* Long ranging deeper water forms generally present with those listed above are *Pletofrondicularia californica, Sphaeroidina variabilis, Cibicides cf. floridanus, Nonion pompilioides, Bulimina inflata alligata, Eponides healdi* and *Cassidulina laevigata carinata.* Rare occurrences of *Bolivina advena striatella, Baggina californica,* and a few other Middle Miocene forms are considered to be reworked or redistributed in these sediments.

The *Uvigerina hootsi* and *Pulvinulinella gyroidinaformis* faunules of Lower Mohnian age overlie the *Pullenia moorei-Rotalia becki* biofacies nearly everywhere. Good Middle Miocene, Luisian faunas consisting of *Pullenia miocenica, Anomalina salinasensis, Baggina californica* and *Siphogenerina spp.* are found directly beneath the *Pullenia moorei-Rotalia becki* biofacies. Thus, the biofacies serves as an excellent faunal group for correlation.

The deeper water faunas characteristic of the "Pseudosaucesian" facies show similarities to the deep water Pliocene, Repetto faunas of the Los Angeles and Ventura Basins.

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NON-PETROLEUM PAPERS

SANDSTONE DIKES IN THE McDONALD SHALE ALONG CHICO MARTINEZ CREEK, KERN COUNTY, CALIFORNIA[1]

GARY L. PETERSON[2]

INTRODUCTION

Sandstone dikes (often referred to as clastic dikes) are tabular intrusive bodies of sedimentary rocks; in general appearance and field relations, they closely resemble igneous dikes. However, unlike the igneous variety which crystallize from an injected melt, sandstone dikes are the result of injection or gradual infilling of sediment in a mobile state into an opening or already open fracture. Also, unlike igneous dikes which are almost invariably injected from below, sandstone dikes may be the result of intrusion from either below or above; it is often difficult to demonstrate from which direction a particular set of sandstone dikes originated.

Sandstone dikes are characteristically found in thick successions of clastic sedimentary rocks, but not exclusively; some have been reported which intrude granitic rocks (Harms, 1965) and other sets are known to intrude volcanic rocks (Lupher, 1944; Flackler, 1941; Walton and O'Sullivan, 1950). The dikes range in texture from clay to conglomerate, but most commonly are within the sandstone size range. Structures described as clastic dikes range in size from minor crevice fillings to 20 feet or more in width and up to several miles or more in length. Sandstone dikes are generally best developed in thick successions dominated by shale; they characteristically are more resistant to erosion than the shale host rock, and as such, locally stand up as bold ridges. Single dikes are rare; usually clastic dikes occur as swarms cropping out over fairly large areas. In a number of cases, the fracture system filled by the dikes has been related to the local or regional structure (Duncan, 1964; Harms, 1965; Peterson, 1966b; Smith, 1952; Chuber, 1961; Kelsey and Denton, 1932).

SANDSTONE DIKES IN CALIFORNIA

Although sandstone dikes and related phenomena are minor geologic features and would probably be classified as "curiosities" by most geologists, they are actually fairly common and have been reported from a wide geographic and stratigraphic range (*see* Potter and Pettijohn, 1963, p. 162-165; Schrock, 1948, p. 212-221). Of the various swarms of dikes reported in the United States, one area stands out both for quantity and quality—California. Two of the earliest and now classic references on clastic dikes are concerned with California examples (Diller, 1889; Newsom, 1903).

In California, sandstone dikes crop out at scattered localities occurring in a slightly westward-curved line from the Ono area at the northern end of Sacramento Valley (Diller, 1889; Peterson, 1966b) southeast to the southern part of the Los Angeles Basin (Meek, 1928), and have been noted west of this line to the Pacific Coast (Newsom, 1903). No dikes are known by the writer to occur north of the Ono area or to the east of the aforementioned line; however, this region is largely dominated by igneous and metamorphic rocks, and although clastic dikes are known from such terrains, they are far more common in sedimentary successions.

Within the outlined area in California, clastic dikes seem to be concentrating along the western edge of the Great Valley Province or the eastern foothills of the Coast Ranges. Within this narrow belt, the dikes seem to be located predominantly in Upper Cretaceous shales (including the Moreno Shale), in the Eocene Kreyenhagen Shale, and in the Miocene Monterey Shale. In addition to the dikes of the Ono area at the northern end of the valley, sandstone dikes have also been reported from the Fruto area (Chuber, 1961), the Crows Landing area (Anderson and Pack, 1915), the Moreno Gulch area in the eastern portion of the Panoche Hills (Anderson and Pack, 1915), the Coalinga area (Jenkins, 1930), and at several localities, one of which is the topic of this paper, in the Temblor Range (English, 1921). Undoubtedly, dikes also occur at localities other than those listed above, but they do not seem to be recorded in the literature.

SANDSTONE DIKES OF CHICO MARTINEZ CREEK

The southernmost group of dikes reported in the Great Valley is a small swarm cutting the McDonald Shale (Miocene) near where this rock unit crosses Chico Martinez Creek northwest of McKittrick in the foothills of the Temblor Range. The dikes were originally noted briefly by English (1921, p. 25) in his description of the general geology of the region. William J. Elliott of Standard Oil Company of California called the writer's attention to the dikes.

[1]Manuscript received Jan. 1968

[2]Department of Geology, San Diego State College

The swarm of dikes exposed at Chico Martinez Creek is very small when compared with some of the other Great Valley clastic dike swarms such as the dikes near Ono or those in the Moreno Shale in the eastern Panoche Hills. Altogether, there are about 15 to 20 small dikes in the Chico Martinez swarm; they are exposed in a narrow belt about 400 feet wide at the maximum. The belt trends north to northeast across the crests of two hills for a total distance of about a half mile. In about the middle portion of the swarm there is an abrupt offset of the dikes; although the exposures are poor at this point, it seems most likely that the swarm has been truncated and offset by a small northwest - trending left lateral - slip fault (Figure 1). For the purpose of description, this conveniently divides the dikes into a northern and southern group.

The dikes of the Chico Martinez Creek area are intruded into a rock unit designated "Maricopa Shale" by English (1921), since changed to Monterey Formation (Bramlette, 1946). Local mappable members of the Monterey are recognized in the Chico Martinez Creek area and elsewhere in the Temblor Range (Heikkila and MacLeod, 1951). The dikes intrdue the McDonald Shale Member and contrast markedly with the lithology of the host unit. The McDonald Shale consists of light-colored splintery shale with thin beds of tan to brown limey shales. Some of the limey beds crop out as small ridges and indicate the attitude of the unit. The remainder of the shale unit crops out poorly in the vicinity of the dikes but can be easily recognized by abundant small light-colored shale chips in the soil.

The Chico Martinez dikes crop out as raised ridges of sandstone near the crest of the hill in the southern group of dikes. The ridges are very irregular and stand a few feet to about ten feet high. Throughout most of the remainder of the area, the dikes more characteristically crop out as strings of sandstone boulders lying in the soil, but they may be readily traced and there is little question that they represent sandstone dikes. Exposures of the contact between the dikes and the McDonald Shale are evident only near the crest of the southern hill.

The dike rock is light tan, grey- to brown-weathering medium-grained sandstone very well indurated with calcite cement. The cement weathers faster than the clastic grains giving the dikes a very rough surface texture. The dikes also have a peculiar weathering characteristic in that locally they have a very pitted or cavernous appearance. In some dikes local irregular mottlings of lighter colored sandstone appear to be concretionary portions within the dike.

In almost all dikes, at least locally, the dike rock contains numerous small chips of tan to brown shale. The shale chips are nearly identical to the shales of the host formation and were undoubtedly derived from the walls of the fractures. Characteristically, the shale chips are sharp and angular; they seem to weather slightly faster than the enclosing sandstone and, as such, make small angular indentations in the dike surface. Most of the shale fragments are small, but some can easily be found ranging up to about two inches in maximum dimension and locally a few even larger examples are present. Shale fragments have been noted in other sandstone dikes, particularly those of the Ono area where many are oriented with their long dimensions parallel to the walls of the dikes (Diller, 1889). The shale fragments in the Chico Martinez dikes appear random in orientation.

Another characteristic feature of the Chico Martinez dikes is that they are highly fractured. The fractures have mostly been recemented so that the dike rock is quite hard and durable, but a pronounced fracture pattern is evident in the dikes at most outcrops. In some dikes the fracture system has been cemented to a greater degree than the intervening portions of the rock, leaving a raised fracture pattern. Typically, however, the fractures are cemented to a lesser degree and thus tend to weather faster, leaving a system of deeply etched grooves in the dikes. In some dikes the fracturing seems random and pervasive; in other dikes, however, the fracture system is very regular; three or four distinct sets of intersecting fractures can be discerned. In a few dikes some of the fractures run parallel or nearly so to the dike walls and are useful indicators of dike attitude. Locally the dikes appear to have a faint banding parallel to the walls, but this internal structure is nowhere nearly as distinct as somewhat similar features noted in the dikes of the Ono area (Peterson, 1966a).

Precise attitudes are difficult to obtain directly from the dikes because of the highly fractured character of the dike rock, because the dikes tend to crop out as strings of boulders across a hillside, and because the attitudes of a given dike appear to be somewhat variable from place to place. Attitudes obtained from the dikes, however, seem to be fairly consistent; most strike N. 10°-15° E. and dip 75° to 85° W. Plotting of the dikes on the topographic map (Figure 1) agrees fairly closely with these attitudes, but suggests that the dikes may strike slightly more easterly and perhaps have a slightly greater inclination. Attitudes of the host rock are indicated on the accompanying map; the strike is uniformly northwest, at about 60°-90° to that of the dikes, and the shales dip 45°-80° northeast.

Lengths of dikes vary considerably from some very small exposures about ten feet in length to the largest dike which crops out continuously for almost 1200 feet. Some of the other larger dikes, located almost entirely in the southern group, range between 500 to 700 feet in length. Most of the dikes in the northern grouping range only up to about 500 feet long.

Widths of dikes vary considerably both from dike to dike and from different places on the same dike. Most of the dikes fall within the range of about three to six feet wide throughout their extent. Some local swellings approach about ten feet wide and one dike locally has a maximum width of 15 feet. The largest dikes are exposed in the southern group.

Several thin sections were prepared from specimens obtained near the southern extremities of the dikes. Mineralogically, the sections were very similar. Principal clastic grains and their percentages are as follows: quartz (54%); K-feldspar, including sanidine, orthoclase, microcline and perthitic grains (28%); plagioclase (8%); rock fragments, including quartzite, chert and a variety of very fine-grained fragments many of which appeared to be rhyolitic volcanic rocks, but excluding shale fragments derived from the host formation (7%); and miscellaneous unidentified minerals and opaque grains (3%).

The grains are predominantly sharp and angular. Only about 10 percent have rounded corners. Very few grains could be termed well-rounded and those were generally the larger grains. Most grains are triangular, lath-shaped, or irregu-

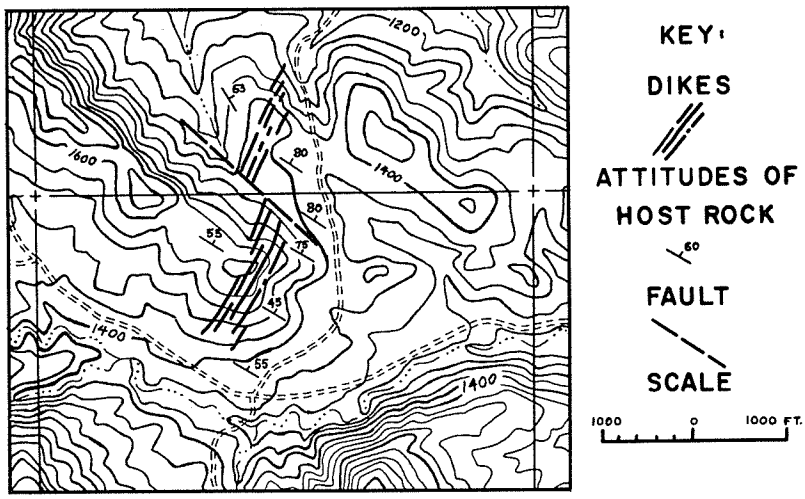

FIGURE 1. Topographic map showing position of sandstone dikes and attitudes of stratification in the host formation. Line through center of map is boundary between sections 3 and 10, T. 29 S., R. 20 E., Carneros Rocks 7.5 minute quadrangle. Chico Martinez Creek flows west to east through southern part of map.

larly polygonal. Some are long and splintery resembling glass shards, but are quartz. A few of the quartz grains appear to be subhedral. Grains are fairly well sorted with most in the fine to medium sand size range; included with these grains are some randomly distributed coarser grains and some considerably larger shale fragments. There is a minor amount of fine clastic matrix.

The grains are set in calcite cement which constitutes about 39 percent of the rock. Two markedly different arrangements of the grains and cement were observed. In one, the calcite grains ranged from about the same size as the clastic grains down to extremely fine-grained size and appeared to be randomly oriented. In this arrangement, the cement appeared almost like a matrix in graywacke-type sandstones. In the second arrangement, the cement consisted of large crystals of calcite showing twin lamellae and cleavage over areas up to about one-quarter square inch; these grains abutted against similar grains, in some instances along clearly defined crystal faces. In this arrangement, the clastic grains were suspended within the larger crystals of calcite; only about a quarter of the clastic grains touched one another. Some of the large calcite grains had been deformed as evidenced by bent cleavage, bent twin lamellae, and undulatory extinction. This second arrangement certainly qualifies as one of the most peculiar clastic sedimentary rocks ever viewed by the writer and is difficult to explain unless an originally fine-grained calcite matrix, perhaps somewhat like that described in the first arrangement, was extensively recrystallized following intrusion of the sediment.

The constituents and their proportions in the dike rock raise some question about the nature of the sediment source. The clastic grains seem to indicate that the dikes were derived from a mobilized sand bed; the original source of sand in the bed would have to be at least in part from a rhyolitic volcanic terrane and in part from a granitic terrane as indicated by the mineralogy. The high percentage of calcite is almost impossible to explain as an intergranular filling as in the case of a true cement. More probably, the calcite was intruded along with the clastic debris, perhaps as a very fine-grained lime mud which later recrystallized to varying degrees. The question remains as to whether both constituents were derived from the same mobilized bed, or whether they represent separate sources mixed during intrusion.

The origin of the sediment is in question, as is the direction from which these dikes were intruded. One possible line of evidence includes the shape and trends of the dikes. For example, with the southernmost group, the greatest widths were measured across the crest of the hill; the dikes become thinner and tend to die out going down the hill especially to the south, but also to the north. Likewise, north of the small fault, the thickest portion of the dikes is near the crest of the hill and this set of dikes thins and dies out going down the hill to the north. This geometry suggests that the dikes are wedge-shaped in a downward direction; if so, this suggests that the dikes may have been intruded from above.

One possible way to determine direction of intrusion with this particular set of dikes would be to collect many of the small shale fragments from within the dikes and check them for age should they contain microfossils. This might be a positive way of determining intrusion direction, but has not been checked yet by the writer. Another possible solution which has proven of use with another example of California dikes (Meek, 1928), would be to compare the heavy minerals in the dike rock with those in sandstones in the section; possibly the origin of the sand could be determined, but it would require extensive knowledge of the mineral succession.

Sandstone dikes are in many cases developed as fillings of fracture systems related to the local structure; the Chico Martinez dikes appear to hear such a relationship to the structure of the Temblor Range. Although the structure of the range is quite complex, in general, in that portion near Chico Martinez Creek it seems to be a broad anticlinorium with the San Andreas Fault along the southwestern side and running at a slight angle to the anticlinorium axis. Upper Cretaceous rocks are exposed in the center of the structure and this core is flanked on both sides by Eocene and Miocene strata. The trace of the axial plane trends about N. 50° W., and the structure plunges gently to the southeast, as the Cretaceous rocks pass beneath the Cenozoic strata in that direction.

The sandstone dikes trend slightly to the east of north and dip steeply west. Thus there is a little greater than 60 degree angle between the trends of the dikes and the axial trace of the anticlinorium. The intersection of a hypothetical axial line, which would plunge to the southeast, with a vertical line on a plane representing the average position of the sandstone dikes would be nearly at right angles. This attitude and position of the sandstone dikes with

respect to the main structure of the range suggests that the dikes possibly originated as fillings of shear fractures or shear joints (Billings, 1954) associated with post-Miocene folding of the Temblor Range. In such folding, the least stress axis was parallel to the axial line. Possibly the intrusive sediment was derived from a bed (or beds) which was unconsolidated at the time of deformation and, responding to the pressure involved, readily flowed into the shear fractures simultaneous with their formation. The structural history is more complex than this, however, for the dikes are cut by a later fault and their highly fractured character likewise indicates deformation subsequent to their lithification. In this later deformation, they may have been rotated and reoriented slightly from their original position of intrusion.

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SOIL-CHEMICAL ANALYSIS AND APPRAISAL OF THE LOST HILLS AREA[1]

E. A. Laskowski[2]

INTRODUCTION

The Lost Hills soils area, examined in this report, is located in the northwestern part of Kern County which occupies the extreme south end of the great agricultural San Joaquin Valley. Kern County ranks as No. 1 oil and mineral producing county in California and is the third largest agricultural producing county in the United States of America.

LOCATION

The town of Lost Hills (Section 35, T. 26 S., R. 21 E.) with its surrounding land areas (a potential growth area for agriculture, commerce and industry) is located close to the intersection of Highway No. 46 (to Paso Robles and Morro Bay), California Aqueduct (Feather River Water Project) and the new Interstate Freeway No. 5 which will eventually connect Kern County with Canada. The town of Lost Hills is about 60 miles from Bakersfield, 38 miles from Wasco and 81 miles from the coastal town of Morro Bay.

PHYSIOGRAPHY

The land near Lost Hills is situated on very low rolling hills with gentle slopes (average gradient 25 feet per mile, good for machine agriculture). The low rolling hills are part of the alluvial fan which has an areal slope to the northeast and east. (Sloping areas have usually good soil water drainage.) The greater percentage of the alluvial sediments have been derived from rocks of the Temblor Mountains to the west of Lost Hills. The elevation in this area ranges from 400 feet at Lost Hills to 235 feet at the Kern River channel to the east of the town. The drainage follows more or less the same areal slope. To the east of this well drained area, but far enough removed, several alkali or saline soil spots have been noticed especially where the drainage is poor due to flat lying areas.

[1]Manuscript received Feb. 1968.

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CLIMATE

The Lost Hills area can be classified according to the *Koppen* climatic system as semi-arid. This means, that the area experiences hot, dry summers and mild somewhat moist winters. Based on *Koppen's* world climates, the area lies at the boundary between steppe and desert climatic zones. According to the U.S. Weather Bureau data the lowest annual average temperature is 17° F; the highest annual average temperature is 115° F. The average monthly and seasonal precipitation (in inches) for Lost Hills is as follows: July - trace, August - trace, September - .06, October - .17, November - .49, December - .78, January - .98, February - 1.06, March - .83, April - .55, May - .21, June - .02, and the average total seasonal precipitation is 5.15.

SOILS

There is unanimous agreement among planners and developers that this area has the advantage over other underdeveloped areas because it is located at the crossroad of a highway, a freeway and the California Aqueduct. Therefore, the soils of this area have been analyzed by the writer in greater detail then the soils of other undeveloped areas. The average chemical analysis of the soils located close to the California Aqueduct and paved access roads is reported below. It has been predicted that much of this area will be a part of the green belt of California.

The alluvial fan or fans on which the Lost Hills area and the Blackwells Corner area are located are generally sands and sandy loam soils. These soils have been derived from calcareous sedimentary rocks of the Temblor Mountains. The rocks consist chiefly of sandstones and shales. The sandstone grains contain quartz, orthoclase/plagioclase feldspars and biotite which indicates that the sediments were probably derived from granitic parent materials. The soils of this alluvial fan have been classified by the United States Department of Agriculture (1942) as soils of the *Panoche* Series. These soils are, with very few exceptions, well drained and compartively free of alkali or saline constituents. The Panoche soils can be recognized by their light yellow or grayish brown color. Presently little of the Panoche soils are farmed in Kern County. Lack of irrigation water has been the major factor for leaving this area undeveloped. With sufficient irrigation water available many high yield crops can be grown here. The average quantitative soil chemical analysis within this area indicates the following:

CHEMICAL ANALYSIS OF SOILS IN THE LOST HILLS AREA

	RANGE
pH, almost all samples	7.6
Saturation percentage	29 to 41
Electric conductivity-Millimhos/cm (E.C.)	.80 to 2.10
Soluble calcium percentage	40 to 60
Soluble Magnesium percentage	8 to 15
Sulfate (high values usually due to gypsum deposits nearby) ppm	62.5 to 800
Chloride - ppm	28.3 to60
Boron - ppm	0.50 to .65
Calcium, percent exchange capacity	75 to 82
Magnesium	4.0 to 11.5
Potassium	1.2 to 4.5
Sodium	0.44 to 1.09
Exchange capacity me./100 grams	27.7 to 60.8
Exchangeable sodium percentage (ESP)	0.1 to 1.5
Sand percent (average)	53.2
Silt percent (average)	20.0
Clay percent (average)	26.8
Soil type—sandy clay loam	
Deviation from average where applicable	12 percent

REMARKS

Soils with pH 5.5 to 8.4—growth of most crops.

Soils with electrical conductivity (E.C.) below 2.0—no salinity problem.

Soils with ESP below 10—generally no permeability problem.

Soils with an E.C. of 2.00 would reduce the crop yield of beans, carrots, onions, bell peppers, lettuce, clover and meadow foxtail by 15%.

To the east of this area, but far enough removed, several alkali or saline soil spots have been noticed especially where the drainage is poor due to the flat lying topography. Alkali soils are soils high in sodium carbonates; saline soils are soils high in sodium sulfate, sodium chloride, calcium chloride, etc. The more extensive alkali and saline soil area, however, is located further to the east of Lost Hills, that is, just west of Wasco. The alkali and saline soils area extends over Township 25 and 26 South, Ranges 22. 23 and 24 East. Therefore, the soils in the area near Lost Hills (according to soil-chemical analysis) cannot be classified as saline or alkali soils as has been rumored by some agricultural "experts."

WATER

Although in many areas of the county the water level has dropped considerably due to overdraft, in the Lost Hills area an overdraft of water was never experienced. The reasons for the low water consumption in the Lost Hills area are: (1) As mentioned above, little of the Panoche soil was farmed because of the distance from Wasco around which much of the agricultural lands were developed, that is, Wasco served as a point of attraction and agricultural center. (2) The subsurface water (100-175 feet deep) in the Lost Hills area is saline. Besides the salinity of the water, the water contains several toxic ions (lithium, boron and others) which have been released from the sandstone and shales that are comprising the Coast Ranges. The percolating water coming from the Coast Ranges carry the unwanted ions *and cations* through permeable sedimentary layers to the east. Perhaps this is one of the reasons why some of the lowest areas of the county (especially northwest of Wasco) have alkali, saline and toxic soils which have formed due to capillary action of these chemically concentrated waters during periods of drought. A similar study made by the writer in the Lebec area points to such concentrations of salts at the sub-surface due to capillary action during periods of high desication of the soils. Fortunately, the Lost Hills area is located on the middle to lower slopes of the Temblor-alluvial fan where concentration of salts does not occur. And even if the chemicals would concentrate in the soils, the middle and lower slopes of the alluvial fan with an average gradient of 25 feet per mile would permit leaching (sandy loams) of the soil and drainage of the soil water to the east. Irrigation of the soils in the Lost Hills area and the leaching of alkali and saline soils in the distant areas of Lost Hills (those areas with very low gradient) will most probably be accomplished with the fresh water which will be delivered fairly soon by the California Aqueduct system.

CROPS

On sandy loams, when properly irrigated, a wide range of crops can be grown. Sandy loams are

presently used more and more by orchardists. Tree crops grown on such soils reflect sufficient yield per acre. In the Lost Hills area similar crops can be grown as in the Wasco-Shafter area. The following crops will probably give the best per acre yield: potatoes, alfalfa, cotton, barley, cowpeas, carrots, cantaloupes, watermelons, almonds, grapes, peaches, apricots, dry onions and sugar beets. With the California Aqueduct water available for irrigation, many specialized crops can be grown in this area. Experimental crops grown on the Panoche sandy loams will increase the food crop variety. With the low boron content of the Panoche soils, some agronomists claim that certain species of oranges will do especially well in areas where calcareous soils are available.

LANDS

With the combination of good soil, California Aqueduct water, closeness to access roads, freeways and the airport (at Lost Hills which could be developed into a cargo airport for air shipment of fruits and vegetables to the east), the following prediction for land-use can be summarized:

A—The soils are suitable for farming, ranching and orcharding.

B—Some of the land can be used for light industrial parks or for light industrial development.

C—Some of the land can be used for recreational developments.

D—Other business developments.

To complete the land use prediction it would be appropriate to mention the urban geographer's motto: "When employment grows—housing development grows."

CONCLUSIONS

The Economic Research Associates (1964) predict that the production of crops in Kern County is expected to *decline* from the present level without the importation of water. Much of the prediction is not based on poor farming practices or poor soil conservation, but rather on the increasing annual overdraft of underground water. If this overdraft continues, the economic pumping of the water for agricultural purposes alone will bring about a critical situation. If agricultural growth declines, other industries will follow suit and employment will decrease also. With the importation of water not only underdeveloped soil areas can be cultivated and a greater variety of food products can be grown but at the same time alkali or saline soil areas with fair drainage can be leached and put into production. With the increase of agricultural products "other manufacturing" as well as other services will increase. Consequently, employment and housing developments will rise, especially in the presently agricultural underdeveloped areas. The Lost Hills area is one area among the many undeveloped but potentially good soils areas which will add to the economic growth of Kern County. The Panoche soil is unquestionably one of the better soils.

NOTE

Over the past years many people have invested in agricultural land in order to lease or cultivate the land. Other people have bought land for speculative purposes. Whatever the purpose is land buyers often do not take into account soil properties and the underlying geology of the area. Experience has shown that land which was bought for future agricultural purposes turn out to have saline, alkali or toxic soil constituents. Recent experience, recent studies show that flat land overlying active fractures and/or faults may with time be contaminated by undesirable chemicals which are emitted along fractures or faults to the soil's surface. These emitted chemicals concentrate not only in the soil but in ground waters as well. If such water is used for irrigation or crops are grown on soils which are receiving these emenations of chemicals, agricultural "blind spots" in the soil or crop may occur. This in time will reduce the per acre yield of almost any crop. In fact the area may become toxic and infertile. There are several such areas which have developed a chemically concentrated condition in this soil over the past years due to slight fault or fracture movements. It is therefore advisable to consult a geologist and a soil chemist who are familiar with the geology or soil conditions of the area before purchases of land are made.

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TWO LATE PLEISTOCENE RADIOCARBON DATES NEAR BUTTONWILLOW, CALIFORNIA[1]

JOHN C. MANNING[2]

During the autumn of 1964, HydroDevelopment was engaged in a shallow drilling program along the Kern River Flood Channel (Buena Vista Slough) west of Buttonwillow. The purpose of the drilling was to explore the channel bottom for sites that could be used as ground water recharge ponds. The work was done for the Buena Vista Soil Conservation District, and results of drilling were published privately in a report entitled "Ground Water Recharge Potential of the Kern River Flood Channel—Part II."

[1]Manuscript received Jan. 1968.

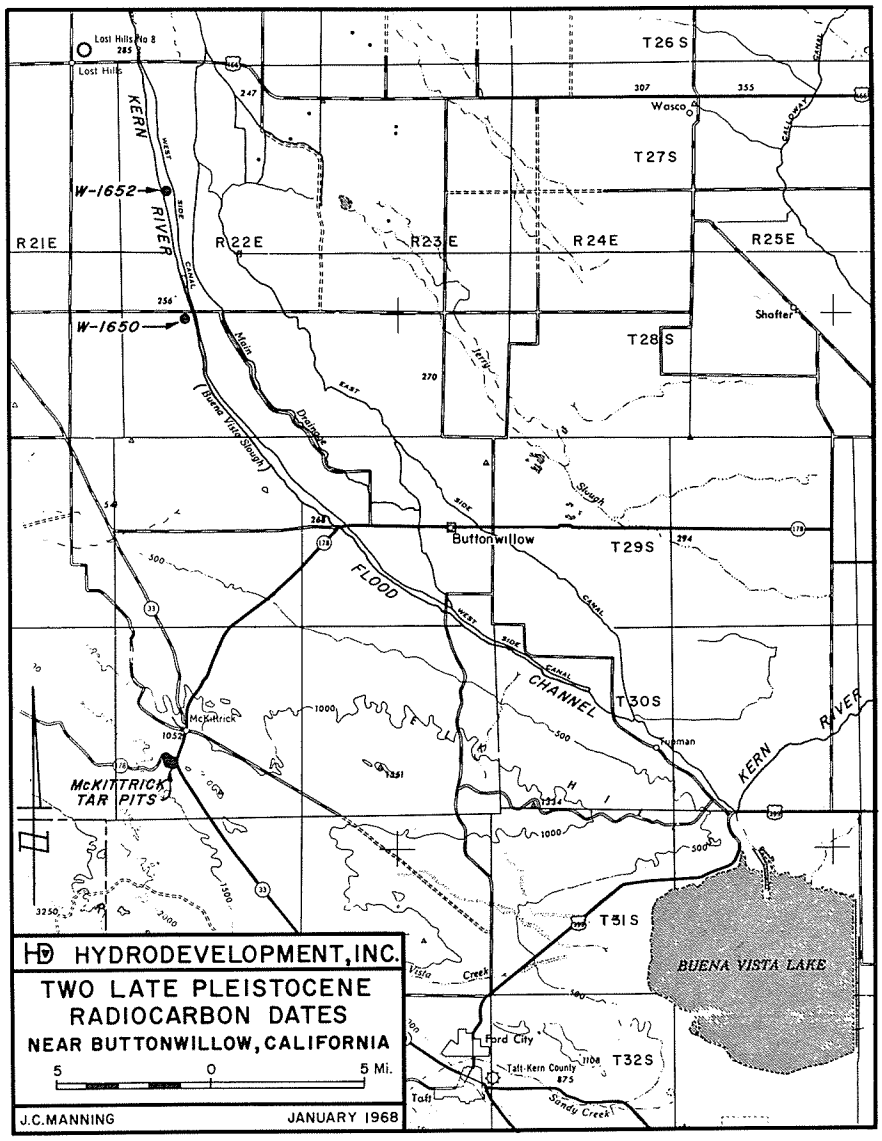
[2]HydroDevelopment, Inc., Bakersfield, California.

Drilling was done by a reverse-rotary method, using a modified seismic shot-hole with 1½″ drill pipe and with water as the drilling fluid. This method of drilling provides very good formation samples, even in unconsolidated sand and silt; and any foreign material in the formation such as shells, wood, etc., is sampled right along with the enclosing sediments. A number of wood samples were obtained from the subsurface in this way, and two of these were submitted to the U.S. Geological Survey isotope laboratory for analysis. The U.S.G.S. reports are given below exactly as they were reported, and locations are shown on the accompanying map.

These dates, along with some others in the general area, were reported on recently by P. C. Ives and others in the journal, RADIOCARBON, Vol. 9, pp. 514-15, 1967.

RADIOCARBON AGE DETERMINATION

LAB. NO.	FIELD NO.	DESCRIPTION	AGE (Yrs. B.P.)
W-1650	Test hole 28S/22E-16D	Bluish-grey sand with wood fragments from a depth of 35 feet. Located about 9 miles southeast of Lost Hills, California, Lokern Quad., Kern County, California, in NW ¼, NW ¼, sec. 16, T. 28 S., R. 22 E., approx. 35°30′N. lat., 119°37′ W. long. Collected by M. G. Croft, October, 1964.	14,060 ± 450
W-1652	Test hole 27S/22E-20L	Bluish-grey sand with wood fragments, collected from a depth of 20 feet. Located about 5 miles SE of Lost Hills, California, Lost Hills Quad., Kern County, California, NE ¼, SW ¼, sec. 20, T. 27 S., R. 22 E., approx. 35°33′45″ N. lat., 119°38′ W. long. Collected by M. G. Croft, October, 1964.	13,350 ± 500



One should not infer too much geologic history from a few dated samples. But these dates do give us important time benchmarks at the uppermost end of the geologic column. It would be interesting to know the radiocarbon date of the Pleistocene fossil fauna of the McKittrick tar pits, as these fossils apparently represent latest Pleistocene time in this general region. If the McKittrick fauna should turn out to be around 10,000 to 15,000 years old, then the wood samples reported on here could be assumed to represent uppermost Pleistocene deposits in the trough of the valley.

If we accept the time of the beginning of the Recent Epoch as being about 10,000 to 12,000 years Before Present (B.P.), then these samples would represent latest Pleistocene time in this part of the San Joaquin Valley. Also the depth of 20 to 35 feet would give at least an approximate figure for thickness of alluvial deposition in the lowest part of the Southern San Joaquin Valley during the Recent Epoch. Furthermore, if these samples are representative in age and depth, much of what we have been calling Recent alluvium in the valley is really late Pleistocene alluvium.

SLIPPAGE ON THE BUENA VISTA THRUST FAULT[1]

ROBERT D. NASON, ALAN K. COOPER AND DON TOCHER[2]

Active fault movement on the Buena Vista thrust fault, north of Taft, California, was recognized in 1932 and ably described by Thomas W. Koch (1933). Pipelines crossing the fault were buckled by being shortened and oil wells penetrating the fault plane were bent and offset. Figure 1 shows a map of the affected wells. Oil wells in section 7, near the center of the surface fault trace, were offset about 15 inches in ten years, indicating fault movement of about 1.5 inches/year (38 mm/year). Wells in section 6, which penetrate the fault at a deeper level, indicated fault movement of about 1.1 inches/year (28 mm/year). Wells in section 8, east of section 7, indicate fault movement of about 0.9 inches/year (23 mm/year). The rate of fault movement was apparently different on different parts of the fault in the years preceeding 1933.

Monuments were established on opposite sides of the fault by James Wilt and J. H. Masters in 1933 and have been measured periodically since then (Wilt, 1958). The monuments are in section 8. Figure 2 shows the results of the measurements (line 1A-1B), continued by us. The average slippage rate was about 1.3 inches/year (35 mm/year) from 1933 to 1939, 0.7 inches/year (18 mm/year) from 1939 to 1950, 0.45 inches/year (11 mm/year) from 1950 to 1956, and 0.95 inches/year (24 mm/year) from 1956 to 1967.

Because of its interest in the phenomenon of fault creep the Earthquake Mechanism Laboratory of the U.S. Environmental Science Services Administration (ESSA) installed a creep recorder to continuously measure fault slippage on the Buena Vista thrust fault. The creep recorder is situated near the surface fault trace at the boundary of section 7 and section 8, near monument line 1 of Wilt (1958); a 20-inch hole was drilled down to the thrust fault and cased. A second hole was drilled into the rocks below the thrust fault and a 4-inch pipe extending to the ground surface cemented into it. The 4-inch pipe indicates the position of the rock below the thrust fault and the casing indicates the position of the block above the thrust fault; movement of the casing relative to the 4-inch pipe indicates slippage on the fault plane. The movement is recorded on a modified clock-drive barograph recorder (figure 3) similar to the creep recorder at Cienega Winery (Tocher, 1960).

The creep recorder has run continuously since installation in August 1967 and has shown that both gradual fault creep and distinct creep events occur on the Buena Vista thrust fault. From August 28, 1967 to December 25, 1967, gradual fault creep of 2.9 mm (corrected for fault dip) occurred; and on December 25, 1967 a creep event began and lasted for approximately five days (figure 4). In the five days of the creep event, the movement was 7.0 mm (corrected). The creep event is similar to creep events at Cienega Winery south of Hollister (Tocher, 1960). The total movement in the five months from August 1967 to January 1968 was 10.1 mm (approximately 24 mm/year), which agrees well with the movement rate determined by measurement of monuments from 1956 to 1967.

The slippage on the Buena Vista thrust fault may be due to tectonic forces, as thought by Koch (1933), to local influences such as ground subsidence following the withdrawal of petroleum, or to a combination of influences. The occurrence of different movement rates on different parts

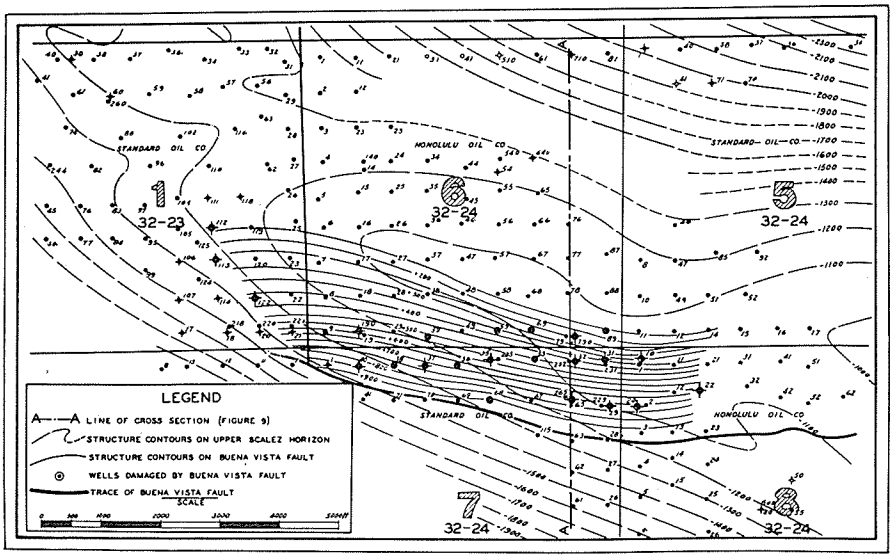


Fig. 1 Map of wells at Buena Vista Thrust fault, from Thomas W. Koch 1933).

[1]Manuscript received Feb. 1968.

[2]ESSA Earthquake Mechanism Laboratory, San Francisco, Calif.

of the fault with apparently less movement at depth than at the surface, as shown by the well data grathered by Koch (1933), may be interpreted as favoring non-tectonic stresses. As regards earthquakes, Wilt (1958) thought that movement in 1952 might be related to the 1952 Kern County earthquake. However, the average rate of movement from 1950 to 1956 did not change in 1952, so the relation to earthquakes is ambiguous. The comparison of creep events on the Buena Vista thrust fault with creep events occurring on the San Andreas fault is important to an understanding of the mechanism of fault creep.

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Tocher, Don, 1960, Creep on the San Andreas Fault: Seism. Soc. Amer. Bull., vol. 50, pp. 396-404.

Wilt, James W., 1958, Measured Movement Along the Surface Trace of an Active Thrust Fault in the Buena Vista Hills, Kern County, California: Seism. Soc. Amer. Bull., vol. 48, pp. 169-176.

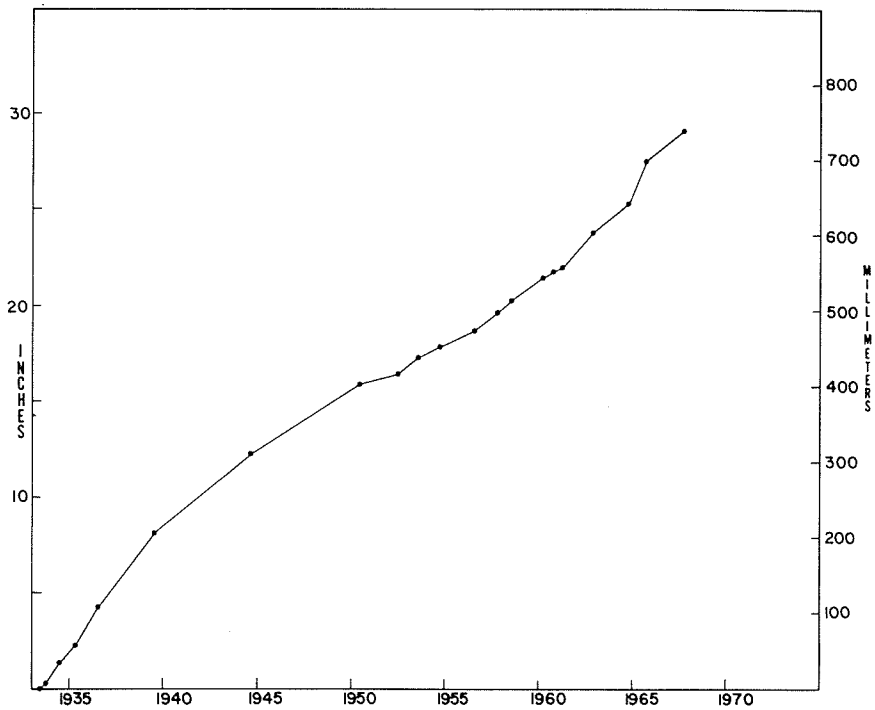


Fig. 2 Cumulative offset of Buena Vista thrust fault at monument line 1A-1B. Data to 1957 from James Wilt (1958).

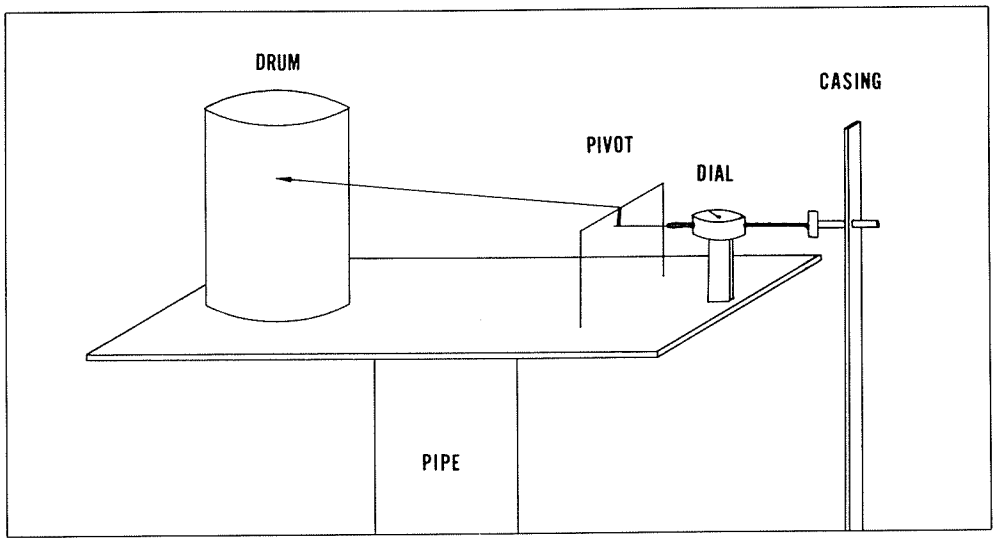


Fig. 3. Diagram of creep recorder at Buena Vista Thrust Fault.

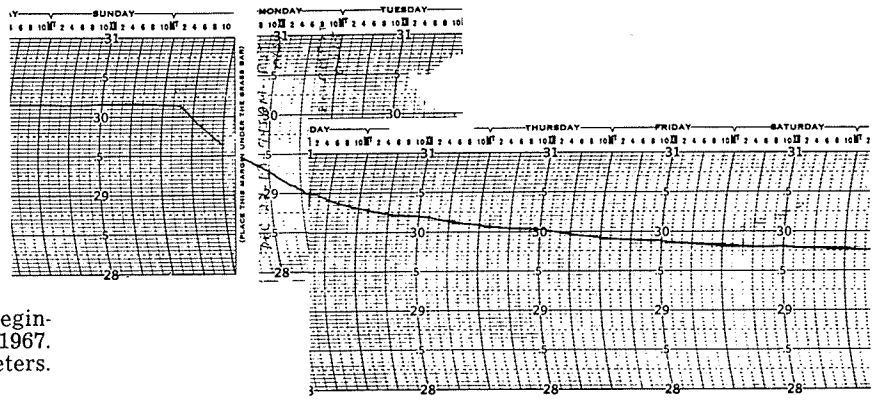
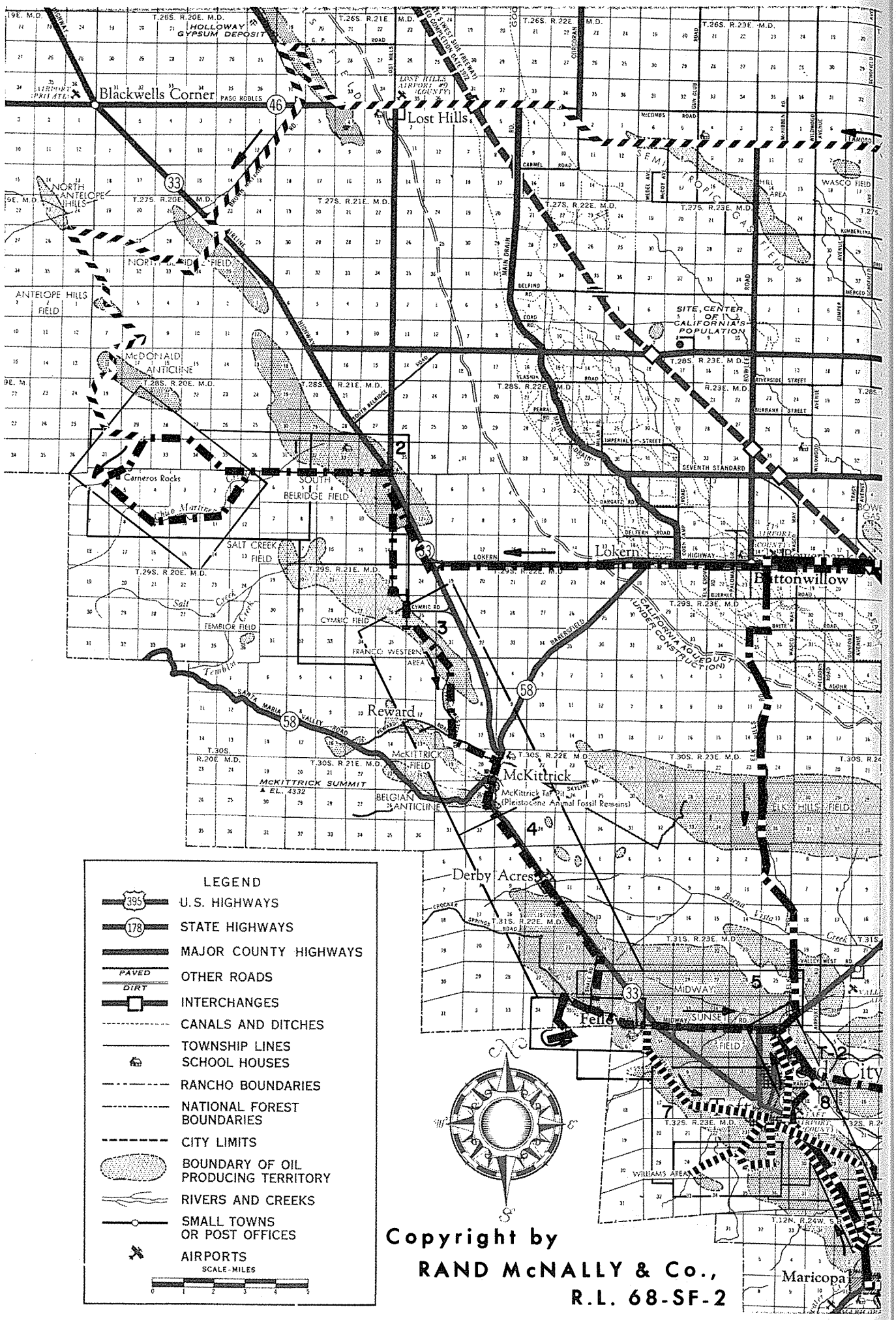


Fig. 4. Creep event beginning December 25, 1967. Total offset is 7 millimeters.


Blackwells Corner
Lost Hills
HOLLOWAY GYPSUM DEPOSIT
NORTH ANTELOPE HILLS
ANTELOPE HILLS FIELD
McDONALD ANTICLINE
Carneros Rocks
SOUTH BELRIDGE FIELD
SALT CREEK FIELD
FEMBLOR FIELD
CYMRIC FIELD
FRANCO WESTERN AREA
Reward
McKITTRICK FIELD
McKITTRICK SUMMIT
BELGIAN ANTICLINE
McKittrick
McKittrick Tar Pit (Pleistocene Animal Fossil Remains)
Lokern
Buttonwillow
SITE, CENTER OF CALIFORNIA'S POPULATION
WASCO FIELD
SEMI-TROPIC GAS FIELD
CALIFORNIA AQUEDUCT (UNDER CONSTRUCTION)
Derby Acres
ELK HILLS FIELD
MIDWAY
Fellows
WILLIAMS AREA
Maricopa
LEGEND
U.S. HIGHWAYS
STATE HIGHWAYS
MAJOR COUNTY HIGHWAYS
PAVED
DIRT
OTHER ROADS
INTERCHANGES
CANALS AND DITCHES
TOWNSHIP LINES
SCHOOL HOUSES
RANCHO BOUNDARIES
NATIONAL FOREST BOUNDARIES
CITY LIMITS
BOUNDARY OF OIL PRODUCING TERRITORY
RIVERS AND CREEKS
SMALL TOWNS OR POST OFFICES
AIRPORTS
SCALE-MILES
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KERN COUNTY, CALIFORNIA
FIELD TRIP ROUTES LOCATION MAP

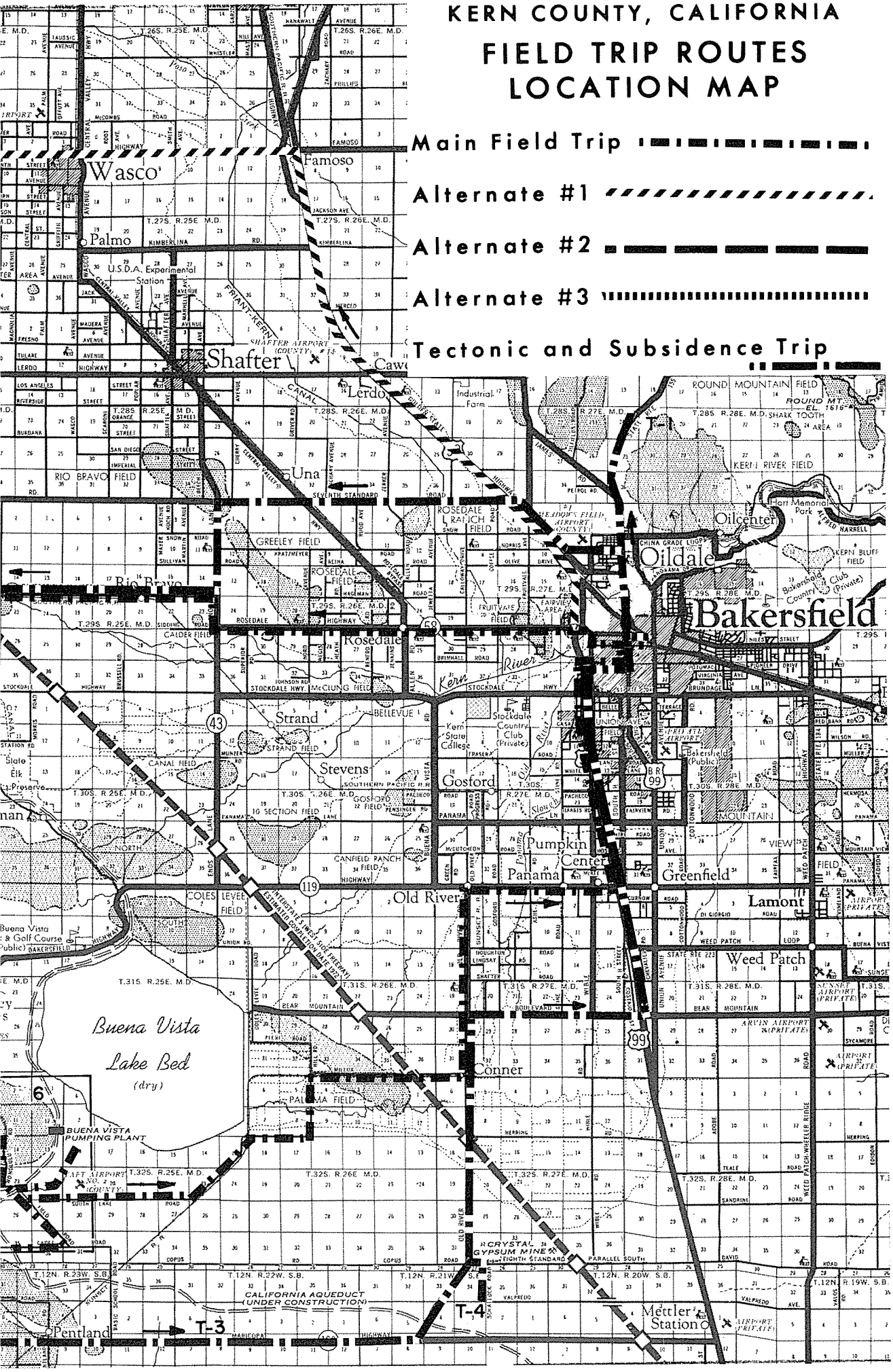
Main Field Trip

Alternate #1

Alternate #2

Alternate #3

Tectonic and Subsidence Trip



ROAD GUIDES

WEST SIDE OIL FIELDS AND TEMBLOR RANGE OUTCROP AREA

Road Guide prepared by: WILLIAM J. ELLIOTT, *Standard Oil Company of Calif.*

EUGENE TRIPP, *Texaco, Inc.*

STANLEY E. KARP, *Bakersfield College*

INTRODUCTION

Several West Side oil fields will be observed along the main field trip route. Some of them are: South Belridge, Cymric, McKittrick, Belgian Anticline, Midway - Sunset, Buena Vista Hills, and Elk Hills. Stops in the Carneros Creek, Chico Martinez Creek area will provide an excellent opportunity to view exposures of source and reservoir rocks that produce oil and gas in these West Side fields. Afternoon stops include the active Buena Vista thrust fault, California Aqueduct Buena Vista Pumping Plant, and a subsidence area along the Aqueduct canal.

NOTE: Portions of the main field trip and side trips are on dirt roads which are impassable during wet weather, even in 4-wheel drive vehicles. The portion of the main field trip in the outcrop area is on private land with locked gates. Permission to pass must be requested at the Temblor Ranch prior to the trip. A full tank of gas and a reliable passenger car will help make a successful trip.

Speakers and contributors to the road log are listed at the end of the Guide. Without their help this road log would not have been possible.

Buses will load in the west parking lot of Bakersfield Civic Auditorium; the trip will begin at 7:00 A.M. and return to Bakersfield about 6:00 P.M. Leave the parking lot and turn right onto N Street and proceed one-half block north to Truxtun Avenue. Turn left (west) and begin mile 0.0.

CUMULATIVE MILEAGE	MILEAGE TO NEXT COMMENT
0.0	1.4

Proceed west on Truxtun Ave.

1.4	0.5

Oak Street. TURN RIGHT (north).

1.9	0.1

24th Street (Highway 58). TURN LEFT (west).

2.0	0.2

Kern River Bridge. The Kern River was named for Edward M. Kern, topographer on the third Fremont Expedition. It was harnessed in 1953 with the completion of the dams forming Isabella Lake in the southern Sierra Nevadas east of Bakersfield. In wet years excess water is released from Isabella Lake and flows down the Kern River to Buena Lake. Normally dry, Buena Vista Lake is now full due to heavy rain and snow pack in the winter 1966-67. In the early years of California it is said that a person could travel from Bakersfield to San Francisco via the Kern River and connecting sloughs.

2.2	0.5

Intersection of Highway 58 and Freeway 99 overpass. At this point the main field trip will CONTINUE STRAIGHT AHEAD (west) under Freeway 99 along Highway 58 (Rosedale Highway).

Alternate Route 1 to the West Side via Wasco and Lost Hills, begins at this intersection.

2.7	0.8

Fruitvale Oil Field. For the next two and one-half miles, Highway 58 crosses the Fruitvale Oil Field discovered in 1928 by Western Gulf Oil Co. About 410 wells produce 17° to 23° oil from Mio-Pliocene age sands. The southwest dipping faulted homocline is at a depth of 3,000 to 3,600 feet. Cumulative production to 1/1/'67 is 92,181,000 bbl; daily average, 4,892 bbl.

3.5	0.3

Mohawk Road. The Signal Oil and Gas Company, Bakersfield Refinery (ahead at 10 o'clock), is located about one mile south. Pastel colored storage tanks and the large 285′ catalytic cracker can be seen from the highway. This refinery has a capacity of about 20,000 b/d and is the largest in Kern County. (Kern County refineries and cracking plants have a combined 72,650 b/d capacity.) Signal's hydrocracker, the third of its kind in the world and only one in Kern County, allows the refinery to convert more than 80% of crude input into gasoline. Other products include diesel, propane, butane, and about 10% coke (160 tons/day of 99+% pure carbon).

3.8	1.2

Mohawk gas station and refinery to the left (south). The Mohawk Petroleum Corp. refinery is located one-half mile south, next to the Signal Refinery. The Mohawk Refinery skims gasoline and jet fuel stock, and pipes the remainder out of the county for cracking and further processing. Daily capacity is 16,000 bbl.

5.0	1.5

Friant-Kern Canal, completed in 1951. Sunland Oil Refinery is one-half mile south (group of silver tanks at 9 o'clock). The refinery has a capacity of about 4,500 b/d and

produces mostly gasoline and diesel fuel. Pacific Gas and Electric Company, Kern Steam Plant, is located just south of the highway; it is the large structure with four large black stacks. Leaving Fruitvale Oil Field.

6.5 1.5
Greenacres Oil Field is located one-third mile to the right (north). It was discovered by an independent operator in 1953. Two wells produce 19° oil from Mio-Pliocene sands. Average depth of the southwest dipping faulted homocline is 4,300 to 4,400 feet.

When the Kern County Land Company was incorporated in 1890, colonization of Rosedale began. The palm trees at Green Acres, Fruitvale and Rosedale were planted by the English colonists to give the area a tropical look befitting the climate of Kern County.

8.0 0.7
Allen road, community of Rosedale. CONTINUE AHEAD.

8.7 1.2
Rosedale Oil Field was discovered by Humble Oil and Refining Company in 1951. Thirteen wells produce 26° to 35° oil from Upper Miocene Stevens sands. Production is from a faulted gently west plunging nose at 5,600 to 5,800 feet. Cumulative production to 1/1/'67 is 4,067,000 bbl; daily average, 177 bbl.

9.9 1.1
English Colony Oil Field. Note the pumping well in the church yard on the east side of the church. Royalty derived from this well helped finance the newly completed Mennonite Church. The field was discovered by Standard Oil Co. of California in 1963. Five wells produce 32° oil from Upper Miocene sands. Average depth of the faulted southwest dipping homocline is 6,300 to 6,800 feet. Cumulative production to 1/1/'67 is 790,367 bbl; daily average 378 bbl.

11.0 3.0
Nord Avenue, CONTINUE AHEAD. Greely Elementary School is ahead on the right and the Greeley Oil Field continues for four miles to the northwest. Standard Oil Company of California discovered the field in 1936. About 35 wells produce 34° to 36° oil from Upper and Lower Miocene sands. Producing depths in the northwest trending anticlinal fold range from 7,300 to 11,300 feet. Cumulative production to 1/1/'67 is 100,000,000 bbl; daily average, 7,133 bbl.

14.0 1.0
Calders Corner. Highway 43, TURN RIGHT (north). One-half mile west is the Calders Corner Oil Field discovered by Socony Mobil Oil Corp. in 1949. This two well field produces 35° oil from Upper Miocene Stevens sands. The southwest plunging faulted anticlinal nose is at a depth of 8,500 feet. Cumulative production to 1/1/'67 is 420,796 bbl; daily average, 13 bbl.

15.0 3.7
Junction of Highway 43 and Highway 58. TURN LEFT on Highway 58.

18.7 3.2
Goosloo Oil Field (Abd.). One-fourth mile left (south), Texaco, Inc., discovered the pool in 1952. This one well field produced 2,131 bbl of 36.6° oil from Upper Miocene Stevens sands. Production was from a stratigraphic trap at 10,000 feet.

21.9 5.3
Bowerbank Gas Field. Discovered by Texaco, Inc., in 1942 extends along the route for a mile. Gas production was from a northwest trending faulted anticline (Pliocene) at a depth of 4,000 to 4,700 feet. Cumulative production to 1/1/'67 was 10,027,000 Mcf.

27.2 3.8
Buttonwillow. Elevation 283 feet. This agricultural community was first established about 1885 as a headquarters ranch for Miller and Lux. The 275,000 acre ranch and farm enterprise remained intact until 1941 when hundreds of acres were divided and sold. A Buttonwillow tree planted in 1939 can be seen in front of the post office on the right side of the road. The original Buttonwillow tree, believed to have been planted by the Yokuts Indians is located about a half mile northwest of the post office.

31.0 1.6
Road forks. CONTINUE AHEAD ON RIGHT FORK Lokern Road, toward North Belridge field.

32.6 5.4
CALIFORNIA AQUEDUCT. Canal construction of the California Aqueduct, South San Joaquin Division, started in late summer of 1965. At this time approximately 45 miles of canal is complete from Kettleman City to 7th Standard Road. Initial water deliveries were received in January of this year at Kettleman City from the San Luis Division canal, which was constructed by the United States Bureau of Reclamation. The annual entitlement of water for the San Joaquin Valley service area


Survey crew in bottow of California Aqueduct canal prior to cement lining operations.

is 1,345,000 acre feet which is approximately 30 percent of the minimum project yield of 4,230,000 acre feet. The canal capacity at Kettleman City is 8,100 cubic feet per second decreasing at 4,410 cubic feet per second at the Tehachapi Mountains.

At this road crossing the trapezoidal shaped canal, when completed, will be 28 feet deep with a bottom width of 32 feet and a top width of 145 feet. Side slopes are a 2 foot horizonal cut per each foot of vertical cut. The entire canal will be lined with 4 inches of unreinforced concrete. Construction of this reach of canal was started in the spring of 1967 and is scheduled to be finished by September of 1969.

38.0 1.4
Highway 33. TURN RIGHT (north) AT Y IN ROAD. Eight miles to the west, the Buena Vista Oil Refinery, one of the first in California, operated in the Temblor area from 1864 to 1867.

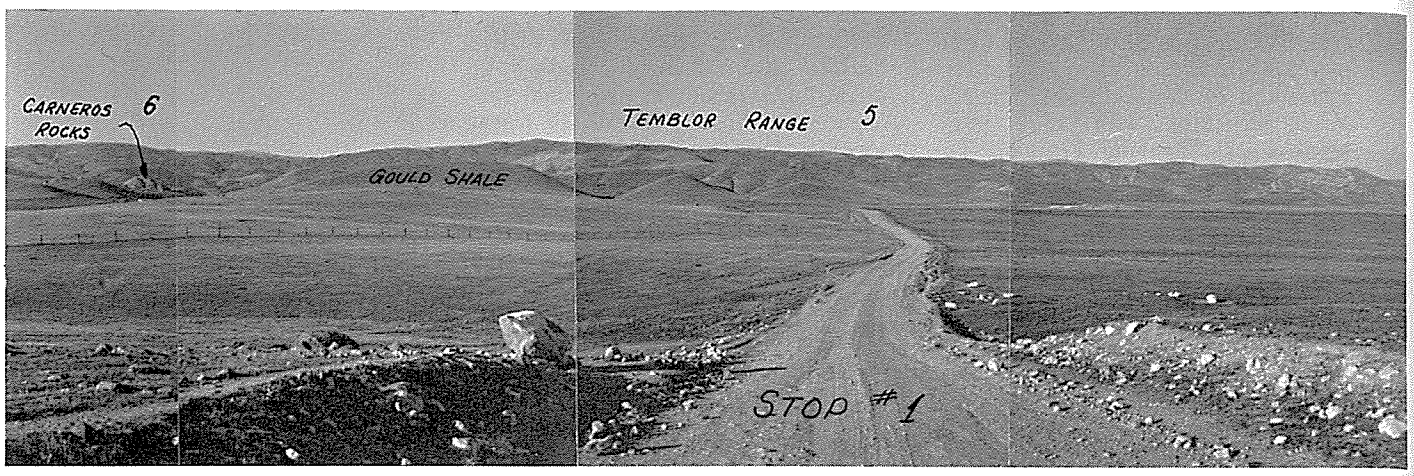
39.4 1.7
Delfern Road, CONTINUE AHEAD. Southern end of South Belridge Oil field. See page 64. Cumulative production to 1/1/'67 is 124,600,000 bbl; daily average, 20,742 bbl.

41.1 0.6
Franco Western Road enters at an acute angle from the left (south). CONTINUE AHEAD.

41.7 0.7
Seventh Standard Road. TURN LEFT (west).

42.4 1.2
Note jack line units and plant on left. Twelve or more wells are pumped by a single 50 h.p. gasoline engine by the use of a central eccentric. Wells in this unit are about 800 feet deep.

43.6 2.8
Leaving South Belridge Oil Field. CONTINUE AHEAD on Seventh Standard Road.



46.4 0.7
Chico Martinez Oil Field on the left (south). Note the large yellow iron-pipe gate (locked) on the left. The trip will exit through this gate (at mile 60.0) after making the circle through Carneros Creek and Chico Martinez Creek. CONTINUE AHEAD. The Chico Martinez Oil Field was discovered by an independent operator in 1927. About 12 wells produce 12° oil from Pliocene Etchegoin sands. The northeast dipping truncated homocline produces from an average depth of 900 feet. Cumulative production to 1/1/'67 is 126,000 bbl; daily average, 12 bbl.

47.1 0.3
Chico Martinez Field extension on the right (north) was discovered in 1967. The low hill immediately ahead is composed of Pleistocene Tulare Formation.

47.4 0.9
Road bends to right and immediately crosses a creek. CONTINUE AHEAD TOWARD THE NORTHWEST. Gypsite strip mines are seen for the next mile and one-half. Strip mining methods are used to recover the gypsite which is usually a foot or two beneath the surface. The deposits range in thickness from three to fifteen feet, and occur in the Pleistocene Tulare Formation. Gypsite is used as a soil conditioner.

48.3 0.4
Side road enters from left. CONTINUE AHEAD to northwest.

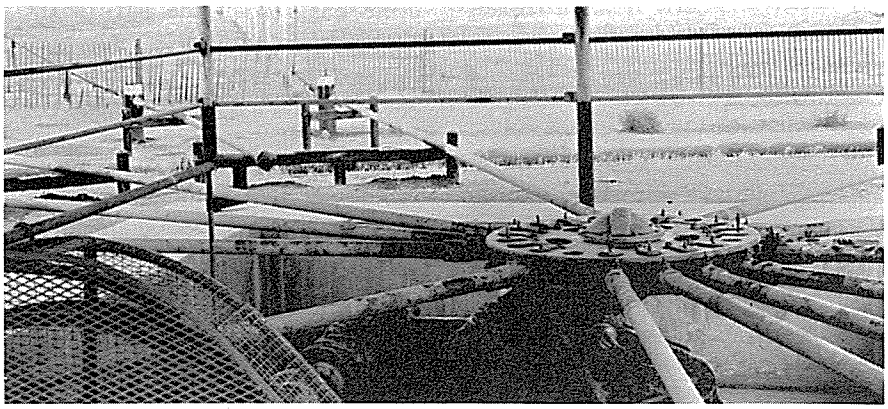
48.7 1.4
Road forks, TURN LEFT (west). End of pavement. CAUTION—DO NOT GO BEYOND THIS POINT DURING WET WEATHER. Roads are impassable even to 4-wheel drive vehicles. Return to Highway 33 and continue trip at mileage 64.8.

The low northwest trending Bacon Hills are immediately to the right (northeast). Pliocene Etchegoin Formation is exposed at the crest and dips 35° northeast. Pleistocene Tulare Formation lies with angular unconformity on the Etchegoin. The Bacon Hills area of McDonald Anticline Oil Field is at the northwest end of Bacon Hills, about two and one-half miles northwest. The original production in this area was from Oligocene Oceanic sand in Section 21 at a depth of 7850′-8120′. Three wells produced 38° clean oil but all are abandoned at the present time. A mile to the northwest in Section 20, six wells are currently producing 32 b/d of 20° oil from Middle Miocene sands at an average depth of 2,000 feet. Cumulative production to 1/1/'67 is 11,700 bbl.

50.1 0.6
STOP 1. This stop offers an excellent opportunity to review the regional relationship of the more than fifty mile long en echelon string of northwest trending oil fields to the source and reservoir rocks exposed immediately to the west in the east flank of the Temblor Range.

At this point the trip has passed through South Belridge Oil Field and several other West Side oil fields that are visible to the northwest. These fields produce oil and gas from sand and fractured shale reservoir rocks which are exposed in the Temblor Range ahead. The majority of the reservoirs are in Miocene and Pliocene rocks; other reservoirs are in Pleistocene, Oligocene, and Eocene rocks.

Regionally, the Temblor Range is a southeasterly plunging anticlinorium with a steep and complex west flank adjacent to the San Andreas fault and a complex homoclinal east flank dipping northeasterly under the San Joaquin Valley. Cretaceous sedimentary rocks are exposed along the crest near the northwest end of the range and in the Orchard Peak area at the southern end of the Diablo Range. Paleocene, Eocene, Miocene, Pliocene, and Pleistocene sedimentary rocks surround the Cretaceous core and only Miocene and younger rocks are exposed in the southern end of the Range. The West Side oil and gas fields are located along the buried complex east flank of the Temblor Range. Anticlines, faults, and stratigraphic changes form closures that trap most of the oil in these fields.


Central eccentric of jack line unit. Twelve wells are simultaneously pumped from this central unit.

Note the angular unconformity at the base of the Tulare Formation southeast of Stop 1, as indicated on the 1″=2,000′ detailed Geologic Map of Carneros Creek-Chico Martinez Creek Area.

Refer to the panoramic photo on this page. From right to left the following features are visible, especially on a clear day. 1) Silver tank about one and one-half miles to the north-northwest is on the north end of Bacon Hills and is in the Bacon Hills Oil Field. 2) To the north-northeast, about five miles beyond Bacon Hills, North Belridge Oil Field can be seen on a clear day. 3) There are two oil fields visible to the northwest, McDonald Anticline Field, about two and one-half miles, and Antelope Hills Field, at the base of the low relief Antelope Hills on the horizon. 4) On a clear day, Orchard Peak (Cretaceous) is visible twenty-six miles northwest in the southern end of the Diablo Range. Antelope Valley, crossed by Highway 46, is the generally accepted boundary between the Diablo Range to the north and the Temblor Range to the south. 5) Ahead (west) is the east flank of the north end of the Temblor Range. Dark brushy vegetation along the crest of the high range marks the Cretaceous, Paleocene, and Eocene Formations. Light colored grassy vegetation covers Miocene outcrops in the foreground. The first prominent low ridges in the foreground are underlain by resistant limy and siliceous shales in the Middle Miocene Gould Shale. These beds dip about 60° northeast. 6) Immediately beyond the first low ridges of Gould shale to the southwest are massive bold outcrops of Eocene Point of Rocks Sandstone. These faulted exposures occur in Carneros Canyon and are called Carneros Rocks, a misleading name. The geographic Carneros Rocks are Eocene age and the Carneros sandstone is Lower Miocene age.

Looking south, the rubble strewn hill in the foreground is mapped as Antelope shale. Further south, the Tulare crops out along the crest of the hill. (Refer to Geologic Map.)

From here the trip will enter private land and proceed up Carneros Canyon to the basal Miocene formations and then turn southeast along strike two miles to Chico Martinez Creek and Zemorra Creek. Along Zemorra and Chico Martinez Creeks the trip will pass through a nearly complete and unfaulted section of northeast dipping Miocene strata ranging in age from Zemorrian through Delmontian Stages.

CONTINUE AHEAD. Alternate Route #1 ends and joins the main road log here.

50.7 0.5

Locked gates. This is private land. Lock combinations can be requested at the Temblor Ranch. Please be careful with fire and trash, help us keep our good relationship with these cooperative land owners. Temblor Ranch was acquired by Carl Twisselman and his father during the 1930's and 1940's through purchase of old homestead land. About 3,000 head of cattle are run on the 27,000 acre ranch which lies in the central Temblor Range. PROCEED THROUGH LEFT (southeast) GATE, AND KEEP RIGHT ALONG FENCE LINE TOWARD RANCH HOUSE. At least a dozen wells have been drilled within a mile of this location searching for fault or stratigraphic closures in Miocene and Eocene sands which crop out ahead. One of these wells was abandoned in 1954 by the Drilling and Producing Co. "Trico" 71-32 which drilled to a total depth of 4,182 feet. It is located approximately 1,500 feet east of the gate on the west side of the low hill.

51.2 0.2

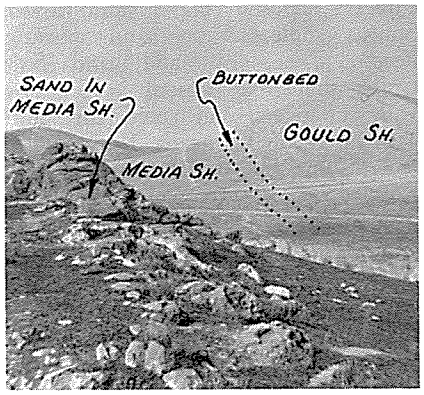
Entering corrals. PLEASE CLOSE EVERY GATE YOU OPEN. Approximate contact between older alluvium and Devilwater-Gould shale is at corral.

51.4 0.1

Ranch house. PASS TO THE LEFT OF THE RANCH HOUSE.

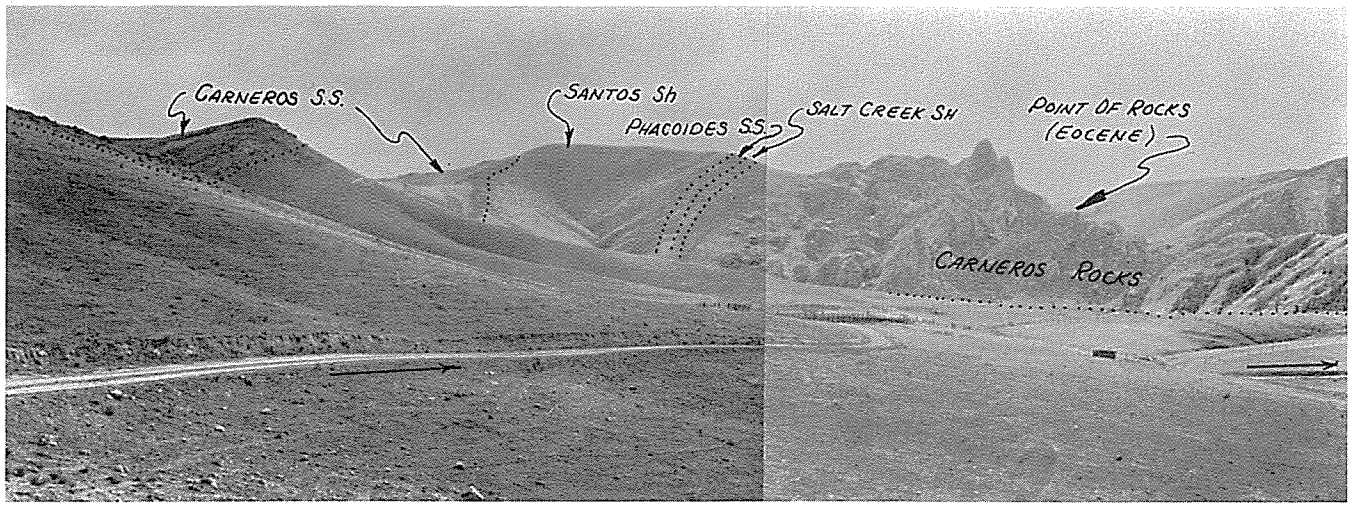
51.5 0.1

Buttonbed sandstone. This resistant shallow water sandstone, with locally abundant *Scuttella merriami*, is exposed at the break in slope on the west side of the hogback across Carneros Creek to the north.



Looking north at mile 51.5.

Buttonbed is the upper sand of Anderson (1905 p. 168-173) Temblor Formation which includes the Relizian Buttonbed and all of the Lower Miocene section below. It lies unconformably on Media shale and is variable in thickness, from 0 to 70+ feet. This sand produces at North Antelope Hills, Antelope Hills, North Belridge, and McDonald Anticline fields. For the next 0.1 miles the road crosses buff to brown silty and clayey Media shale. Refer to stratigraphic column. CONTINUE AHEAD.



Looking south at Carneros Spring—mile 51.65.

51.6 0.05
Carneros sand (middle Temblor sand) is exposed in the road cut on the left (south). It underlies the hill immediately left of the road and is visible along strike to the northwest across Carneros Creek. It is fine to medium grained and locally almost a coquina. This sand is a prolific producer in many of the West Side oil fields.

51.65 0.25
Near the base of the Carneros sand, road turns left, CONTINUE AHEAD (south) TOWARD CORRALS. Poorly exposed upper and lower Santos shale (Agua sand missing here), Phacoides sand, and Salt Creek shale are present in the low valley between here and the bold exposures of Carneros Rocks (Eocene) on the right (southwest). Refer to stratigraphic column.

51.9 0.3
HAIRPIN RIGHT TURN ON NORTH SIDE OF CORRALS. The small creek ahead originates at Carneros Spring at the base of Carneros Rocks (Eocene) to the left (south). El Arroyo de los Carneros (slaughter pens) was considered to be one of the most spectacular stops along El Camino Viejo a' Los Angeles. The spring and natural caves for shelter were used by travelers along the early California trail from San Pedro to East Oakland. Indians, sheepmen, cattlemen, wild horses and such famous outlaws as Dalton and Jessie James used this old watering hole. An interesting account of this old trail by F. F. Latta was published by the Kern County Historical Society in 1936.

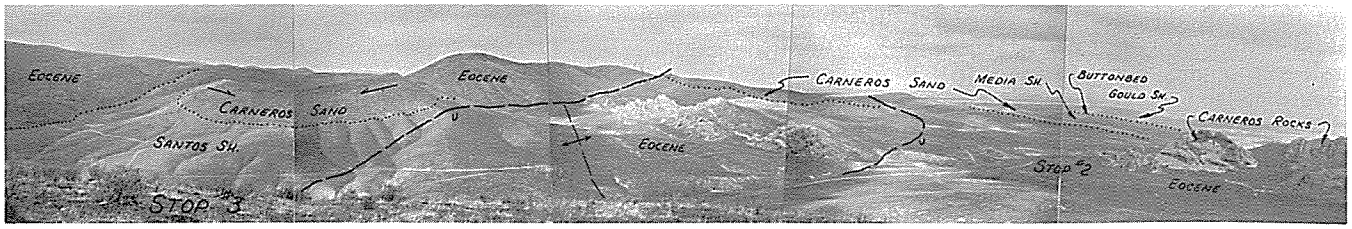
52.2 0.1
Zemorrian Phacoides sand rubble on road and on low hill to left (south) (lower Temblor sand). This sand is a prolific deep objective in many West Side fields. The poorly exposed Salt Creek shale lies between the Phacoides sand and the Eocene Point of Rocks Sandstone (Carneros Rocks). The Zemorrian Salt Creek shale is variable in thickness and lies unconformably on the Eocene Point of Rocks sandstone. The Eocene Kreyenhagen shale which overlies the Point of Rocks in the subsurface along the West Side is absent here in outcrop, probably due to truncation by the unconformity between the Eocene and the Miocene. Also missing is the Oligocene Tumey shale and Oceanic sand. This West Side objective sand is present only in the subsurface. Oligocene rocks are usually missing at the surface throughout California.

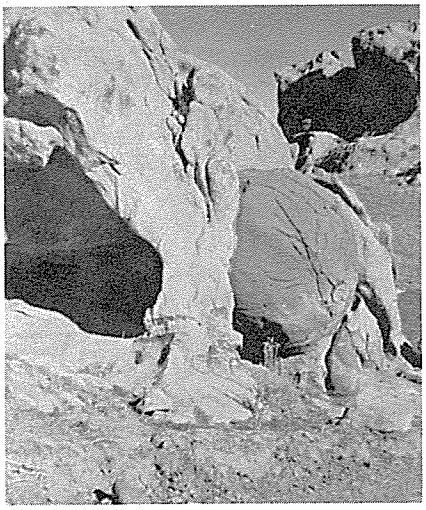
52.3 0.1
Gate in barbed wire fence. CONTINUE AHEAD.

52.4 0.2
STOP 2. Carneros Rocks, Eocene Point of Rocks Sandstone. Note the large dark colored concretions and the cavernous weathering in this medium grained massive buff sandstone. Locally abundant eight to ten inch concretions have prompted the term cannonball weathering. Tests of the Point of Rocks in the subsurface have been generally disappointing. However, in 1967, Standard Oil Company discovered gas and condensate in Eocene sand on the north flank of the San Emigido Range at the south end of the San Joaquin Valley. Refer to the penetration chart for West Side fields that produce from this reservoir. CONTINUE AHEAD. STAY ON THE SOUTH SIDE OF CARNEROS CREEK.

52.6 0.2
Nearly vertical dipping Point of Rocks sandstone on the right (north) across Carneros Creek.

52.8 0.1
CONTINUE AHEAD ACROSS SMALL TRIBUTARY TO CARNEROS CREEK. Point of Rocks sandstone is exposed in the road and stream cuts on the left (south).

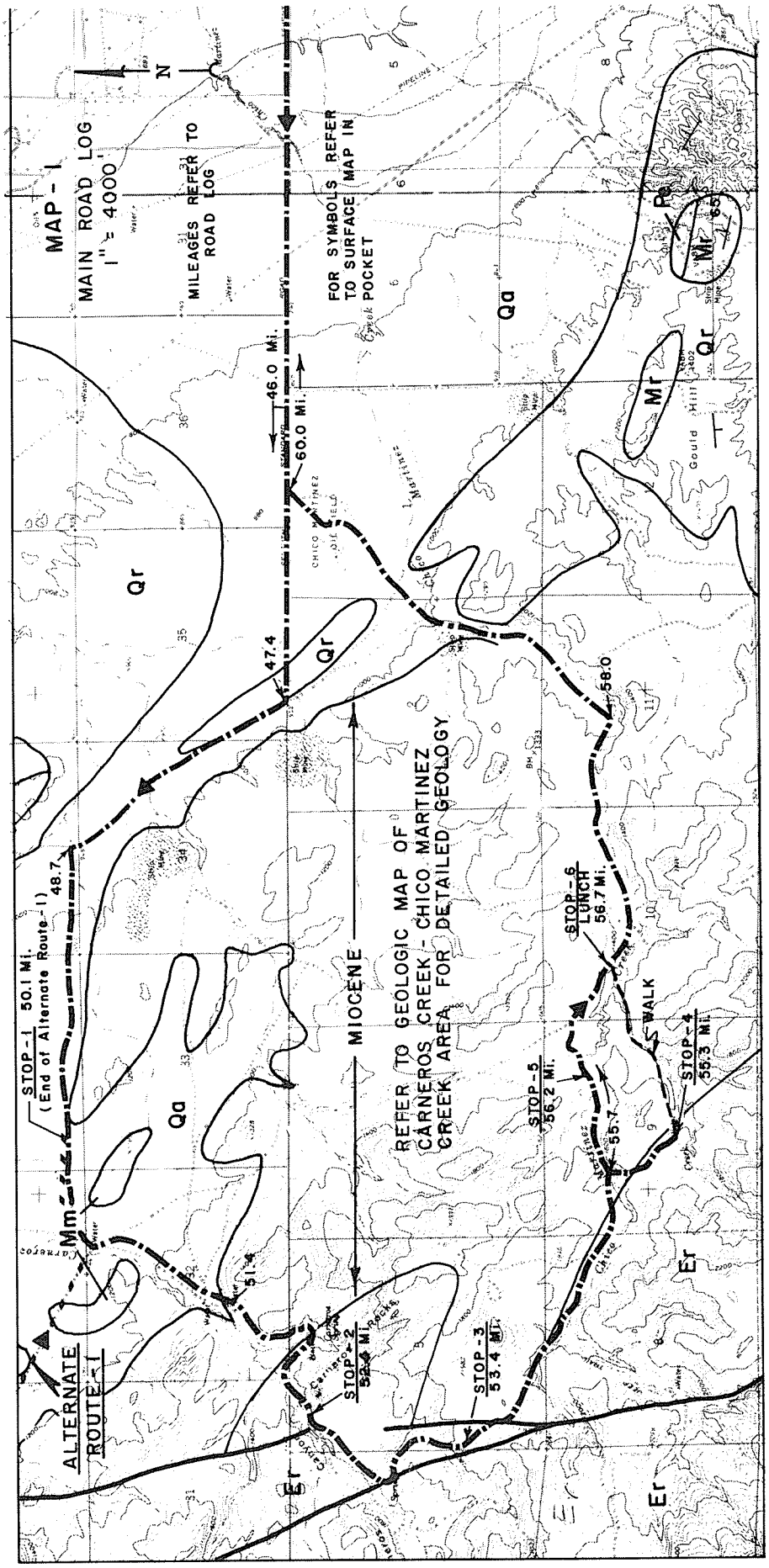


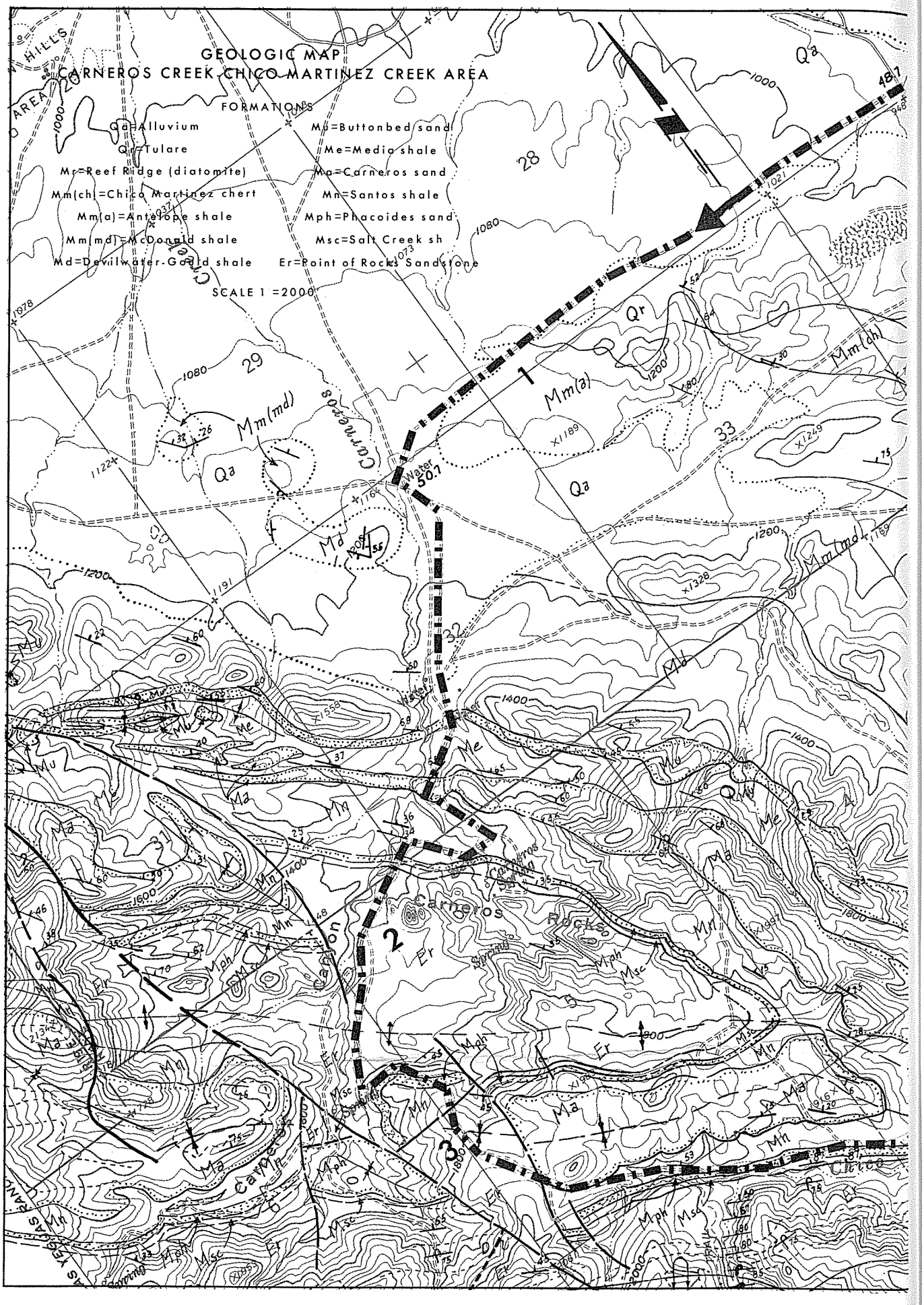


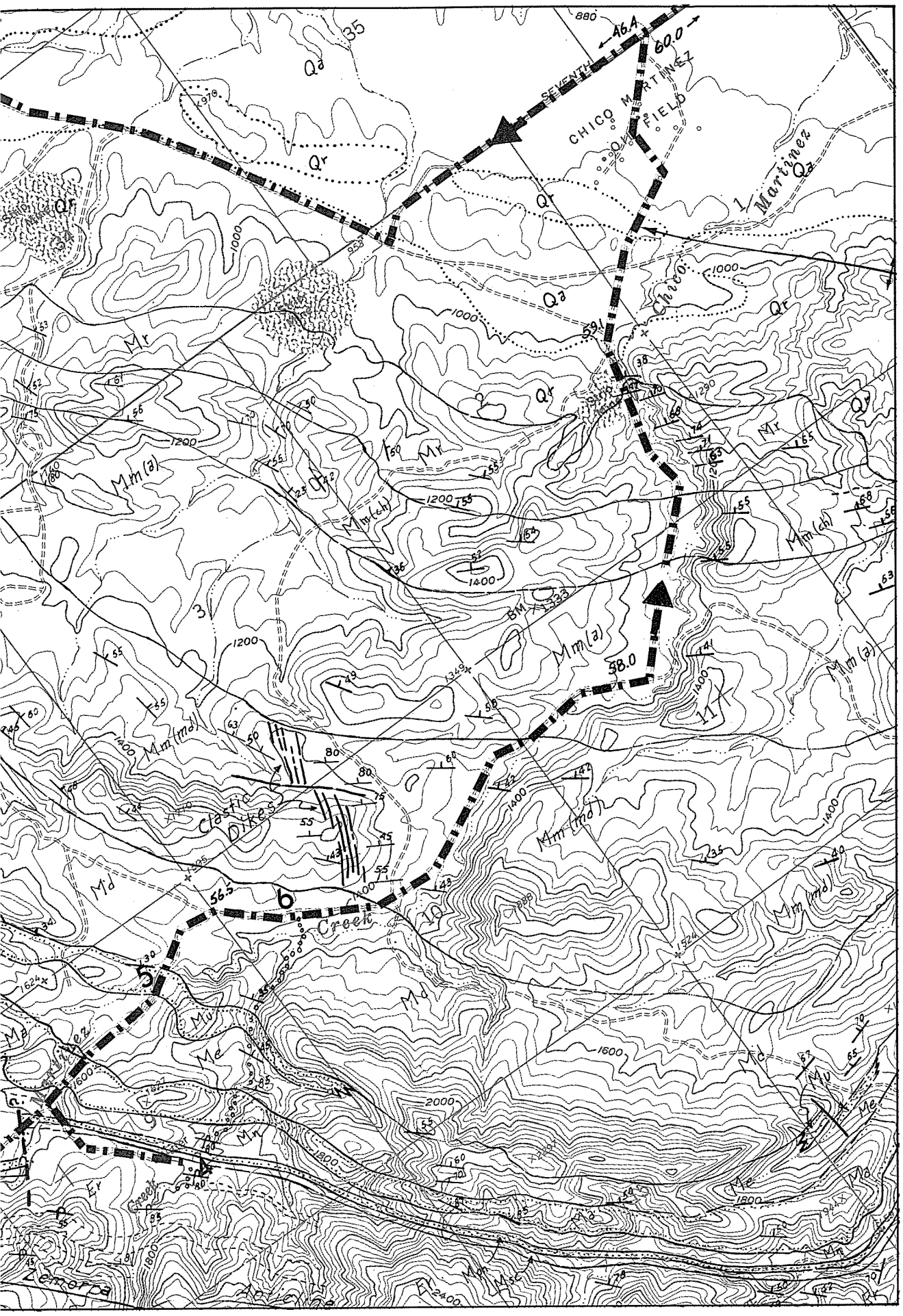
Point of Rocks concretions.

52.9 0.5
Road bends sharply left and begins ascent on east side of hill. The roadcuts on this hillside are in Phacoides sand and Salt Creek shale. Phacoides sand derives its name from the presence of *Lucina* (Phacoides) *acutilineatus*. CONTINUE AHEAD UP THE HILL.

53.4 0.2
STOP 3. View of Carneros Rocks and Carneros Canyon. LEAVE VEHICLE AND WALK BACK (north) ABOUT 500 FEET to the crest of the knoll on the west side of the road. Note the Point of Rocks cannonball concretions littering the ground along the way. Refer to photo. From left to right the following features are visible: 1) To the west and southwest (west of Carneros Creek) dark trees and brush cover bold outcrops and prominent dip slopes of Eocene Point of Rocks Sandstone. 2) Salt Creek shale, Phacoides sand, and Santos shale underlie the low grassy west-facing slope immediately east of Point of Rocks sandstone and the strike valley along Carneros Creek. 3) To the northwest Carneros sand forms the rim of the shallow syncline and lies on the deeper gullied Santos shale which forms the grassy low slopes below. 4) Along the east side of the syncline a fault separates the Miocene rocks on the west from the nearly vertical Eocene rocks on the east. 5) To the north, the small syncline rimmed with Carneros sandstone is in a normal stratigraphic relationship with the underlying Santos, Phacoides, and Salt Creek below and the nearly vertical Eocene in the foregound. 6) Minor fault on the east side of the syncline. 7) Carneros sandstone on ridge to the




GEOLOGIC MAP
CARNEROS CREEK-CHICO MARTINEZ CREEK AREA
FORMATIONS
Qa=Alluvium
Qr=Tulare
Mr=Reef Ridge (diatomite)
Mm(ch)=Chico Martinez chert
Mm(a)=Antelope shale
Mm(md)=McDonald shale
Md=Devilwater-Gould shale
Mu=Buttonbed sand
Me=Media shale
Ma=Carneros sand
Mn=Santos shale
Mph=Phacoides sand
Msc=Salt Creek sh
Er=Point of Rocks Sandstone
SCALE 1 =2000'
Carneros
Rocks
Chico


SEVENTH
CHICO MARTINEZ
OIL FIELD
Martinez
Creek
Clastic Dikes
Zemora
Qa
Qr
Mr
Mm(a)
Mm(ch)
Mm(md)
Md
Me
Mu
Ey
46.4
60.0
58.0
56.5
35
3
6
5
9
10
11

GENERALIZED STRATIGRAPHIC COLUMN
FOR THE CARNEROS CREEK-CHICO MARTINEZ CREEK AREA

Era	Period	Epoch	Stage	Formation	Member		Approx. Thickness in Feet	Generalized Lithology and Microfossils
CENOZOIC	QUAT.	PLEIS.		TULARE			300'-400' Exposed	Non-marine silty clays and gravels with coarse unsorted sand at base. Weathers to a slight pink color.
TERTIARY		MIO-PLIO.	DEL-MONTIAN	ETCHEGOIN / MONTEREY	CHICO-MART. (BELRIDGE) DIATOMITE		755'±	Punky, diatomaceous, silty shale, laminated and contains some chert. Barren in outcrop. Elphidium hughesi and Bolivina obliqua in subsurface.
		MIOCENE	MOHNIAN		McLURE SHALE	CHICO-MART. CHERT & ANTELOPE SHALE	700'±	Interbedded, laminated, punky diatomaceous, siliceous shale. Brittle and blocky fracturing. Reddish to buff siliceous shale and opaline chert prominent at base. Rare arenaceous forams as compressed Trochammina and Cyclammina.
						McDONALD SHALE	2750'±	Hard light brown to buff, blocky, brittle laminated shales and siltstones. Nine hard, resistant limestones prominent in upper part of unit. Uvig. subperegrina, Buliminella elegantissima, Nonionella miocenica, Pecten peckhami.
			LUISIAN		DEVILWATER SILT		1180'±	Silty shale and siltstone, massive, nodular and clayey. Locally siliceous and calcareous. Color ranges from gray to buff to brown. Valvulineria californica, Siphogenerina collomi, Pullenia miocenica, Siphogenerina nuciformis, Siphogenerina reedi.
			RELIZIAN		GOULD SHALE		550'±	Hard light brown, brittle, laminated shale, siliceous with calcareous intervals. Siphogenerina branneri, Baggina robusta. Nonion costiferum.
			SAUCESIAN	TEMBLOR	BUTTONBED SAND		0-70'±	Hard, fine to coarse gray sandstone with abundant fossils. Upper Temblor Sand. Abundant echinoids as Scuttella merriami. Pecten andersoni, Nonion costiferum, Nonionella miocenica. Sporbo.
					MEDIA SHALE		400'±	Buff brownish siltstones and shales. Sandy and clayey in places. Scattered calcareous intervals. Upper Temblor Shale. Some Relizian forams in upper part. Lower shale contains Robulus simplex, Bulimina inflata var., Uvigerinella obesa.
					CARNEROS SAND		350'±	Tan, silty, fine to medium well sorted sand with hard calcareous sandstone "reef" at top. Middle Temblor Sand. Few fragments Saucesian forams. Pecten migulensis, Pecten estrellanus.
					UPPER SANTOS SHALE		100'±	Light brown nodular shale, occasionally laminated. Silty and sandy in places. Some calcareous intervals. Common "sporbo", abundant near base. Glauconite, Middle Temblor Shale. Sipho. transversa, Cibicides americanus, Sipho. tenua, Sipho. mayi.
			ZEMORRIAN		"AGUA SAND" INTERVAL		70'±	Light gray-buff sandstone with hard, calcareous resistant intervals. Sand is interbedded with sporbitic-glauconitic silts in interval. Ab. Buliminella subfusiformis, Bulimina carnerosensis, Siphogenerina mayi, Uvigerinella sparsicostata.
					LOWER SANTOS SHALE		200'±	Dark brown-buff argillaceous shale with common sporbo and glauconite. Glauconite abundant at base. Some glauconitic sandy intervals. Siphogenerina nodifera, Uvigerina gesteri, Anomalina californiensis, Nonion incisum var. kernensis, Uvig. gallowayi.
					PHACOIDES SAND		40'±	Massive, medium grained, light buff sandstone. Glauconitic and contains beds of sporbo in upper part. Fosilliferous, hard, "reef bed" at base. Cibicides floridanus., Uvig. obesa impolita, Elphidium sp., Lucina (Phacoides) acutilineatus, ab. other mollusca.
					SALT CREEK SHALE		35'±	Hard, fractured, gray to purplish brown silty shale. Cyclammina clarki, Cyclammina incisa, Haplophragmoides translucens, Trochammina Plectofrondicularia vaughani.
		EOC.	NARIZIAN	POINT OF ROCKS SAND-SHALE				Massive, somewhat friable, medium grained buff sandstone with greenish cast. Common small pebbles near top. Shale interbeds are gray and silty to sandy with abundant forams. Uvigerina churchi, Bulimina corrugata, Cibicides pygmaea, etc. in upper shales.

left of and beyond Carneros Rocks which are dipping eastward. The Buttonbed is on the break in slope of the hogback beyond the Carneros sand ridge. Note the color change at buttonbed from dark Media shale below to light buff Gould shale above. North Belridge Field on horizon. 8) Stop 2, the prominent honeycomb ridge in the foreground (east) is the Eocene Carneros Rocks. 9) South Belridge Oil Field is visible beyond Carneros Rocks, about nine miles to the east. 10) To the southeast, looking along strike, the high ridge is a syncline rimmed with Carneros sandstone. The trip will proceed from here southeast along the southwest limb of this syncline. RETURN TO VEHICLE AND CONTINUE AHEAD.

53.6 0.4

Road forks at crest of hill (saddle), TURN LEFT (southeast) AND PROCEED DOWN THE STRIKE VALLEY. A small cross fault here separates Point of Rocks sandstone on the west from the lower Miocene syncline to the east. For the next mile the road follows the strike and wanders through the Santos shale, Phacoides sand, Salt Creek shale, and Eocene Point of Rocks sandstone. Bold exposures on the right are Point of Rocks sandstone and the sands high on the ridge to the left are Carneros sandstones. The Phacoides sand is poorly exposed along this strike valley. It should be recalled again that these sands and shales exposed here in outcrop are the reservoir and source rocks in the West Side oil fields a few miles to the east, along the east flank of the Temblor Range.

54.0 0.3

CROSS SMALL CREEK. Good exposures of Salt Creek shale to the right in the stream cut.

54.3 0.2

Gate in barbed wire fence. CONTINUE AHEAD. Point of Rocks at right.

54.5 0.3

Dirt road enters from left, CONTINUE AHEAD.

54.8 0.1

Carneros sand forms the east flank along the ridge at about 10 o'clock. The resistant buttonbed forms the ridge on the skyline beyond the Carneros sand. Note that the Buttonbed is considerably thicker here than it is in Carneros Canyon near Stop 2.

54.9 0.4

Chico Martinez Creek, road forks, TURN RIGHT ACROSS CHICO

Upper Santos shale overlain unconformably by Recent stream gravels at Chico Martinez Creek.

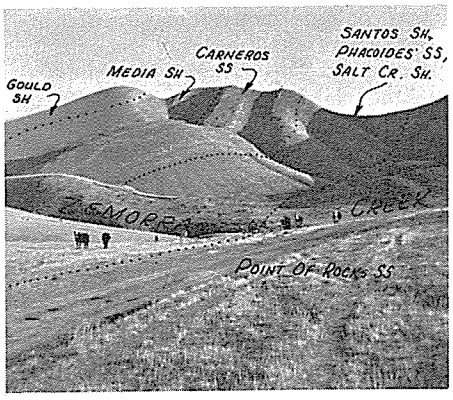
MARTINEZ CREEK AND PROCEED UP THE HILL AHEAD. Note recent gravels lying unconformably on Santos shale and Agua sand in the stream cut to the left.

55.3 0.4

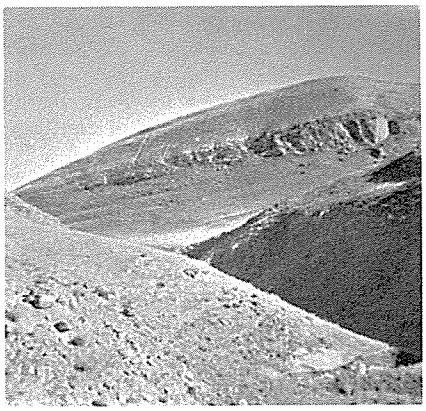
STOP 4. CONTINUE AHEAD PAST THE TREE AND WATER TANK AND STOP NEAR THE NORTH SIDE OF ZEMORRA CREEK. The view ahead to the southeast is a normal northeast dipping section (see photo). Beginning on the right (west) off the picture is the dark brush covered Eocene Point of Rocks sandstone. In the saddle on the skyline are poor exposures of Salt Creek shale, Phacoides sand, and Santos shale. These Lower Miocene formations lie unconformably on the Eocene. The Oligocene Tumey shale, Oceanic sand and Eocene Kreyenhagen shale are all missing here in outcrop. Nearly vertically dipping Carneros sand forms the double ridged hill left of the saddle.

A trench dug in the Media shale for paleo samples is visible on the skyline just east of the Carneros sand. On the east side of the low saddle at the east end of the trench is where Buttonbed should be. The prominent bold Buttonbed outcrop in Zemorra Creek to the east can be traced along strike to the southeast and seen to pinch out before it gets to the top of the hill. Gould shale forms the crest of the ridge above Buttonbed. The trench in the immediate foreground across Zemorra Creek extends from Point of Rocks on the right (west) to Carneros sand on the left. R. S. Beck will present a short talk on the micropaleontology of the section.

WALK APPROXIMATELY ONE MILE DOWN ZEMORRA CREEK to the lunch stop at the confluence of Zemorra and Chico Martinez Creeks. The members not walking along the creek will return by bus to Chico Martinez Creek and follow the road to the lunch stop. The buses will make a short stop (5) at Buttonbed along the way. The walk down Zemorra Creek will cross in this order: Eocene Point of Rocks sandstone; Eocene - Miocene unconformity; Zemorrian Salt Creek shale, Phacoides sand, lower Santos shale, and Agua sand; Saucesian upper Santos shale, Carneros sand, and Media shale (upper part is lower Relizian); the unconformity at base of Buttonbed; Relizian Buttonbed, and Gould shale; and Luisian Devilwater silt. Zemorra Creek is the type locality of Kleinpell's (1938, p. 108) Zemorrian Stage defined as "the 380 feet of partially foraminiferal, phosphatic. and glauconitic shale and intercalated thin sandstone beds on Zemorra Creek which overlie the sandstone mapped by Arnold and Johnson (1910) as the uppermost member of the Tejon Formation"



View southwest. Lower Miocene outcrop along Zemorra Creek.



Bold Buttonbed sand outcrop underlying Gould Shale at Zemorra Creek. Clastic dikes in McDonald shale.

(Point of Rocks Sandstone). He placed the top of the Zamorrian at the top of the 30-foot sand which is now called Agua sand. This walk will afford an excellent opportunity to view and collect from the Lower Miocene section. Signs have been placed along the creek at the formation boundaries. Buses will turn around and return to Chico Martinez Creek.

55.7 0.5

TURN RIGHT (east) AND PROCEED DOWN CHICO MARTINEZ CREEK. Immediately ahead on both sides of the road are good exposures of Carneros sand. Arroyo de Chico Martinez was named after a noted Mexican pioneer and mustang runner.

56.2 0.3

STOP 5. Buttonbed sandstone. This stop offers an opportunity to collect the small sand dollar, *Scuttella merriami*, and observe the variable thickness of sand along the strike. Buttonbed is overlain conformably by Relizian Gould shale and lies unconformably on the Saucesian-Relizian Media shale.

56.5 0.2

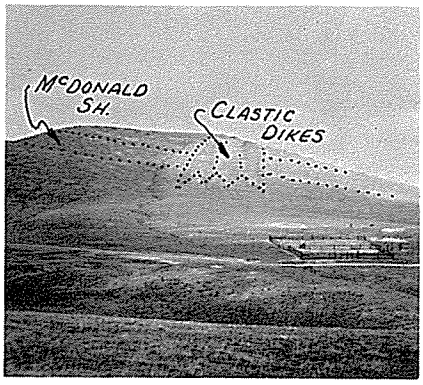
Dirt road enters from left, TURN RIGHT (southeast). Between here and the lunch stop the road is subparallel to the regional strike and is in the valley-forming Devilwater silt. Ridges on the right (southwest) are underlain by the resistant Gould siliceous and limy shale and the ridges on the left (northeast) are underlain by the lower Mohnian lime and siliceous McDonald shale.

56.7 0.3

STOP 6. LUNCH STOP. Walkers and bus riders will join here at the confluence of Chico Martinez and Zemorra Creeks for lunch. During or after lunch you may walk approximately 0.2 mile due east to the nose of the hill just north of the corral and view the sandstone or clastic dikes. These en echelon dikes are in the lower Mohnian McDonald shale and cut across the bedding at about 50°. See paper by G. L. Peterson. After lunch, buses will continue ahead to the southwest.

57.0 0.6

Corral on left (north). Clastic dikes can be seen at the crest of the hill to the north beyond the corral. This is approximately the contact between the Middle Miocene Devilwater-Gould formation and the overlying lower Mohnian McDonald shale. The Miocene rocks above buttonbed and below Pliocene are collectively mapped as Monterey Formation. However most workers in the San



Clastic dikes in McDonald Shale.

Joaquin Valley use the members of the Monterey as convenient paleo and subsurface mappable units.

57.6 0.4

Approximate contact of lower Mohnian McDonald shale with the overlying upper Mohnian Antelope shale. The ridge to the left is near the base of the Antelope shale. Although not present here, the upper Miocene Spellacy sand (Alternate Route 2) and Williams sand (Alternate Route 3) occur within the Antelope interval. These and other sands and the broad category of Stevens sands produce at Midway-Sunset and many of the east side fields.

58.0 0.4

TURN LEFT (northeast) AND STAY ON THE NORTHEAST SIDE OF CHICO MARTINEZ CREEK. Note the apparent syncline in the steeply dipping Antelope shale in the stream cut bank to the right.

58.4 0.2

Change in vegetation on hillside to right marks the contact of grass covered Antelope shale with overlying Mohnian - Delmontian Chico Martinez white chert. Oil is produced from fractured chert and fractured Antelope shale reservoirs in the South Belridge Oil Field. Refer to Penetration Chart.

58.6 0.2

Approximate contact of Chico Martinez chert with overlying Delmontian diatomite. The contact can be seen to the right in the stream cut bank where the resistant white chunky weathering chert ends and the gentle rounded saddle in the diatomite begins. This contact is near the electric log correlation marker known as "N" point. The Belridge diatomite also produces in South Belridge Oil Field. The contact between the buff brown Pleistocene Tulare Formation and the white Belridge diatomite is visible at the break in slope of hill on the right at about 1 o'clock.

58.8 0.3

Approximate contact of the Tulare Formation lying unconformably on the Belridge diatomite. This rubbly poorly consolidated Pleistocene formation produces in many of the West Side fields. It has produced 125 million bbl. of low gravity oil at South Belridge. Refer to Penetration Chart.

59.1 0.4

Locked gate in barbed wire fence. Approximate contact of Tulare Formation with overlying older alluvium. GO THROUGH THE GATE AND TAKE THE RIGHT FORK, PROCEED NORTHEAST TOWARD CHICO MARTINEZ FIELD.

59.5 0.5

First well on south side of Chico Martinez Field, TURN LEFT THROUGH THE FIELD. KEEP TO THE LEFT OF THE TANKS THEN BEAR RIGHT PAST THE TANKS TOWARD THE NORTHEAST AND THE YELLOW PIPE GATE. The trip now leaves the Temblor Range outcrop area. For the next forty miles the route will pass through several of the West Side fields that produce from Tertiary sandstone and fractured shale reservoirs that have just been observed in the Temblor Range.

60.0 2.8

Locked yellow pipe gate. PROCEED THROUGH THE GATE AND TURN RIGHT (east) ON SEVENTH STANDARD ROAD.

62.8 2.0

West edge of South Belridge Oil Field, CONTINUE AHEAD TO HIGHWAY 33.

64.8 0.2

Highway 33. TURN RIGHT.

65.0 0.4

Missouri Triangle, store and gas on the left.

65.4 0.7

Franco Western Road enters at an acute angle from the right. TURN RIGHT ONTO FRANCO WESTERN ROAD AND CONTINUE DUE SOUTH THROUGH SOUTH BELRIDGE FIELD.

66.1 1.7

Note the steam generator on the right (west). Steam is used to heat low gravity oil to lower the viscosity. A greater amount of oil can be recovered from the reservoir by this technique.

66.8 1.0

Delfern Road—Leaving South Belridge Field.

67.8 1.0

Lokern Road. Salt Creek area of the Cymric Field is at the base of the

low hills three miles to the right (west). Refer to maps in this guidebook.

68.8 1.5
Franco Western Road turns left (east). TURN LEFT. Entering Wellport area of Cymric Field. See page 68.

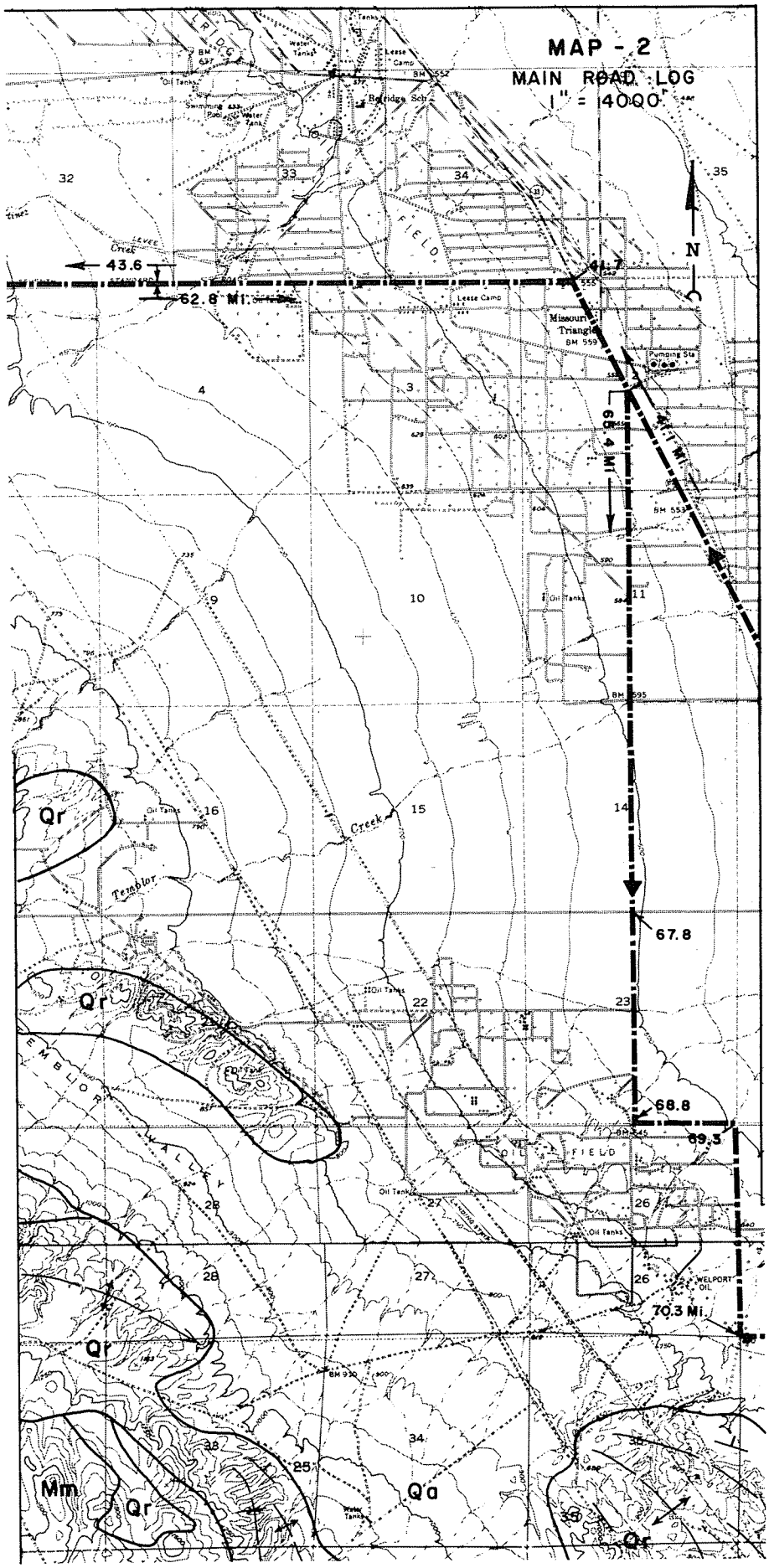
70.3 1.7
FRANCO WESTERN ROAD TURNS LEFT (east). TURN LEFT. For the next five miles follow the main paved road through Cymric Field. Wells along the way billowing steam clouds are shallow low gravity wells being steamed.

72.0 0.8
Production to the right (west) is from the Pleistocene Tulare Formation. For the next two miles the Tulare Formation is folded into an anticlinorium forming the low hills.

72.8 1.4
Facilities on the right (west) are for the deeper pool discovery within the McKittrick Front area of the Cymric Field. It was discovered in 1966 by Standard Oil Company of California #536-6Z well, producing from Carneros, Phacoides, and Oceanic sands. Refer to penetration chart.

74.2 0.8
Union Oil Company pumping station is on the right. Northeast McKittrick area. Production is from fractured Antelope shale, Carneros, Phacoides, and Oceanic sands. Refer to page 72 and penetration chart in this guidebook. Good oil shows have been reported in Eocene Point of Rocks sandstone. However, tests have shown that it is sub-commercial in this area, probably due to impermeability. Eocene production has been established two miles southwest at Belgian Anticline.

75.0 1.7
Reward Road, TURN LEFT (southeast). The hills on the right (southwest) side of Reward Road are composed of contorted Monterey shales. The break in slope near the base of the hills mark the approximate position of the McKittrick landslide which has superimposed Monterey shale on younger Pliocene and Pleistocene rocks. The landslide serves in part as a trapping mechanism for heavy oil found in these younger formations in the McKittrick Field located on top of the hills. The field has produced approximately 120 million bbl of oil from the Plio-Pleistocene and more recently from upper Miocene Stevens sand.



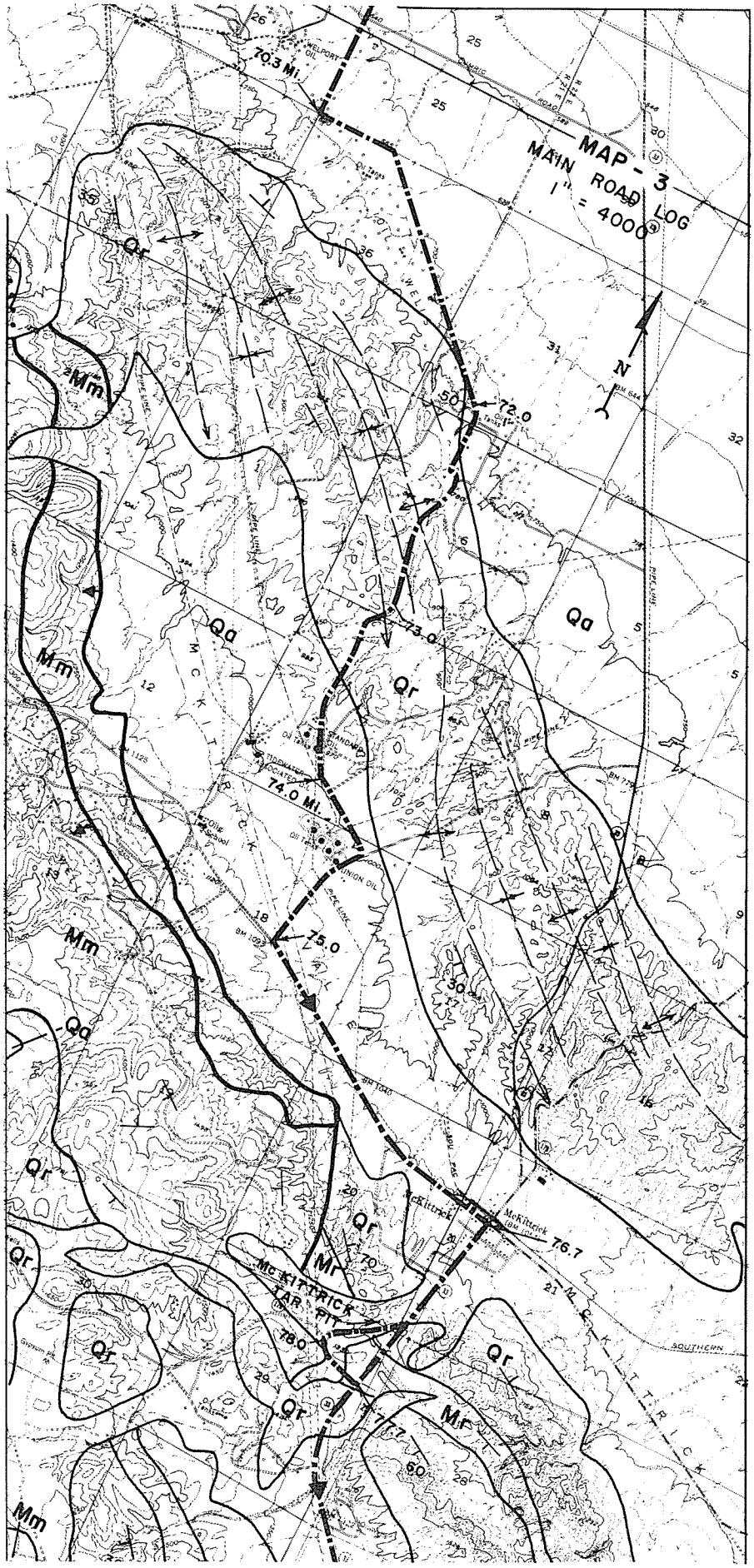
Asphalt was discovered near the town of Reward in 1854, and the town of Reward was founded in 1907, about two miles west of here in the low hills.

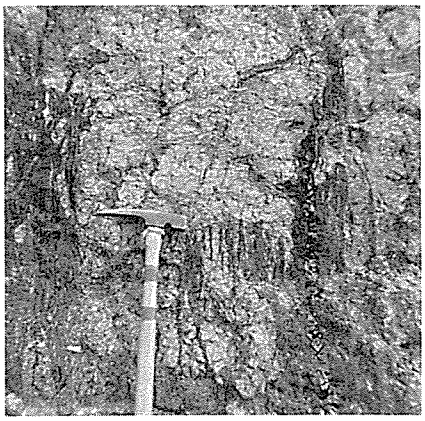
76.7 0.6
Town of McKittrick and Highway 33. TURN RIGHT (south). Note old Southern Pacific Railroad station on northeast corner. The Railroad Gap Field discovered in 1964 by Standard Oil Company of California was named after the railroad gap in the low hills about two miles to the northeast. See page 72. Two miles due east of McKittrick is the Asphalto Field discovered in 1962. This field has produced about 16 million bbl. of oil from a stratigraphic trap within the Asphalto sand (Stevens equivalent). See page 75. The first oil wells drilled in the county were in the McKittrick area in 1877. Miners working the asphalt deposits at the tar seeps established the Camp of Asphalto (a few miles east) about 1891. The settlement moved several times and by 1893 Asphalto #3 was established at present day McKittrick. The name was changed at the turn of the century in honor of Captain William E. McKittrick who was aide-de-camp to General Shafter, commander of American troops in Cuba during the Spanish-American War. Southern Pacific Railroad built a branch line in 1893 to connect McKittrick to Bakersfield and began refining the asphalt. See paper by C. C. Church for early history of McKittrick area and tar seeps.

77.3 0.4
Junction of Highway 33 and Highway 58, CONTINUE AHEAD on Highway 33. The trip will make a one mile loop to view the tar seeps and return to this point. Note the oil and tar seeps in the Tulare Formation in the road cuts on both sides of highway for the next 0.4 miles.

77.7 0.3
TURN RIGHT (west) off of Highway 33 onto a paved road. Upper Monterey shales are exposed in hills ahead (west).

78.0 0.4
ROAD FORKS, TURN RIGHT. Note the oil seeping out of the road cut in the Tulare Formation on the right (east) at the junction. In the canyons along the left (northwest) side of the road for the next 0.4 miles are the McKittrick Tar Pits. The producing wells in the canyons and hills immediately beyond to the northwest are part of the McKittrick Field. See page 76.





Oil Seeps near McKittrick Tar Pits.

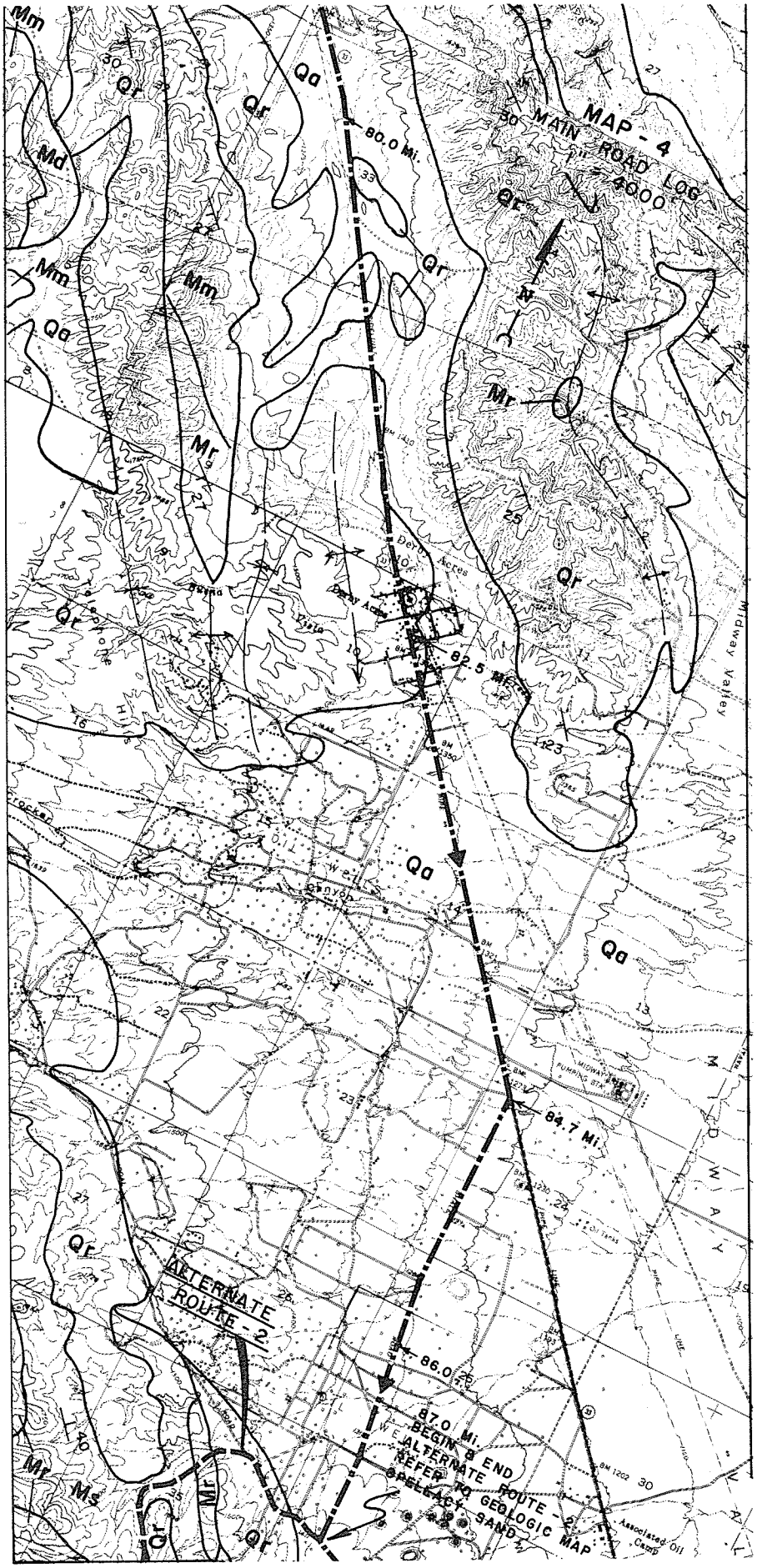
78.4 0.7
Highway 33, TURN RIGHT (south) on Highway 33. McKittrick Brea Pit Historical Monument on right just before turn. Again note the oil and tar seeps in the road cuts on both sides of highway.

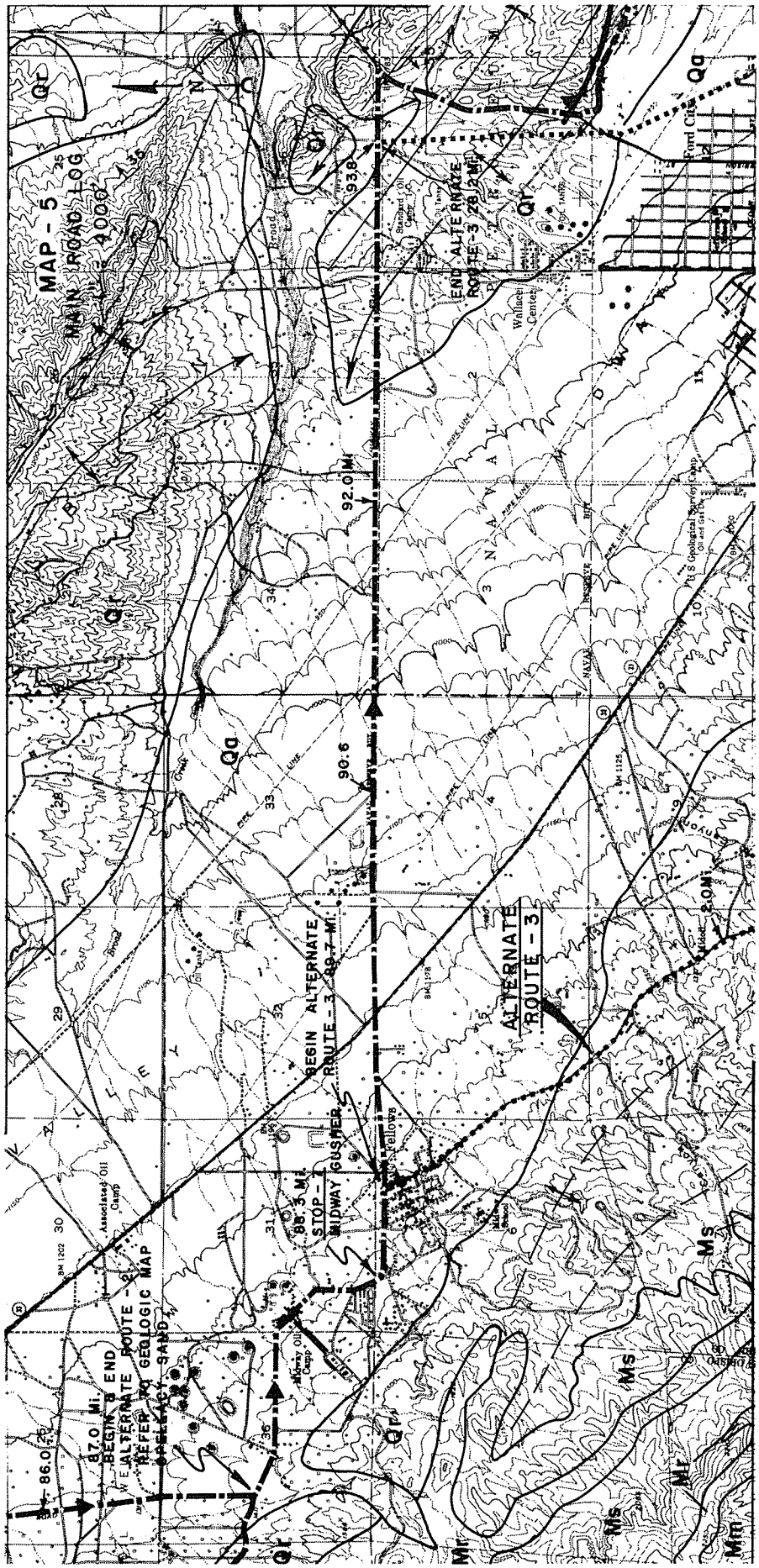
79.1 3.4
Crossing southeast end of northwest trending Belgian Anticline Oil Field. The Pleistocene Tulare Formation crops out on both sides of the road. The well location on the right (west) side of the road is the discovery well, Texaco "Westpet" #77-29, drilled in 1948. It produced gas from the Oligocene Oceanic sand. The field has produced about 39 million bbl of oil from the Oceanic, Phacoides and Point of Rocks sands. Refer to pages 78 and 80.

82.5 0.6
Derby Acres. North end of Midway-Sunset Oil Field. This field has produced a billion bbl of oil since its discovery in 1889, from Pleistocene, Pliocene, and upper Miocene sands. See page 82.

83.1 1.4
Old wood derricks on the left (northeast) are some of the last remaining wood derricks from the oil boom around the turn of the century.

84.5 0.2
Wood bull wheel and walking beam pumping on the right (west). This well, #23A-16, was drilled by Standard Oil Company of California in 1914. It is still (1968) producing 2 b/d of 20.2° oil and 4 Mcf/day gas. The Buena Vista Hills and Oil Field is visible at about six miles southeast. Five miles to the east the mammoth Elk Hills Oil Field is located on the east-west trending Elk Hills. Both fields are anticlinal features within the Tulare Formation and can be recognized by their topographic expression. Buena Vista





Field has produced about 575 million bbls and Elk Hills about 276 million bbls from Pliocene and Miocene formations. Elk Hills is within the U.S. Naval Petroleum Reserve #1 and production is currently restricted. See paper by R. J. Lantz.

84.7 2.3

Shale Road. TURN RIGHT (south) ONTO SHALE ROAD.

87.0 0.2

Mocal Road. TURN LEFT (east). A Texaco steam plant is located just northeast of this intersection. Note several tanks and expansion loops in steam pipes leading away from this plant. Alternate Route 2 to Spellacy sand outcrop west of Fellows begins and ends and this intersection.

87.2 0.6

Texaco Fellows Area Headquarters on the left (north).

87.8 0.5

Chancelor Western Oil and Development Company, Midway Oil Camp.

88.3 0.4

STOP 7. Kern County Fellows Park. First Midway Gusher historical monument and rest stop. The historical marker is across the road to the northeast and some old wood bull wheel and walking beam rigs are beyond for those wishing to take pictures. Restrooms are in the Fellows Park to the east across from the fire station. Buses will load in the park. The first Midway Gusher, well #2-6, made the Midway Oil Field famous. It was located within an area of small 40 to 50 b/d wells as a deeper pool wildcat on June 1, 1909. Well #2-6 blew in over the derrick top on November 27th, 1909, with an initial production rate of 2,000 b/d; this started one of the greatest oil booms California has ever experienced. CONTINUE AHEAD ON MOCAL ROAD (Broadway).

88.7 1.0

Fellows. Intersection of Broadway and Midway Street. CONTINUE AHEAD (east). Alternate Route 3 begins at this intersection. This side trip goes to Williams sand outcrop, Taft, and the Lake View Gusher. In 1908 a diminishing pile of lumber and oil well supplies occupied what is now Fellows. When drilling activity increased the following year, Santa Fe established headquarters for their operations at North Midway as Chanslor-Canfield Oil Company. Within two years, the town boasted three stores, a drug store, hospital, pool hall and a liberal supply of saloons. A Kern County Board of

Trade publication of 1912 described Fellows as "the Gem of the Foothills" and a town that "has the go-ahead spirit of the West and will always make good."

89.7 0.9
Highway 33. CONTINUE AHEAD (east).

90.6 1.4
Leaving Midway-Sunset Oil Field.

92.0 1.2
Entering Buena Vista Hills Oil Field. Refer to page 82.

93.2 0.6
Standard Oil Company of California Buena Vista Producing Office on left (north) and 1-C Gas Plant on right (south). This gas plant has an intake of 40 million cubic feet/day of wet gas. From this, the following products are separated: 70,000 gal./day of 36 lb. vapor pressure gasoline (not for automobiles), 55,000 gal./day propane, 5,000 gal./day liquid carbon dioxide, and 33 million cubic feet/day dry gas.

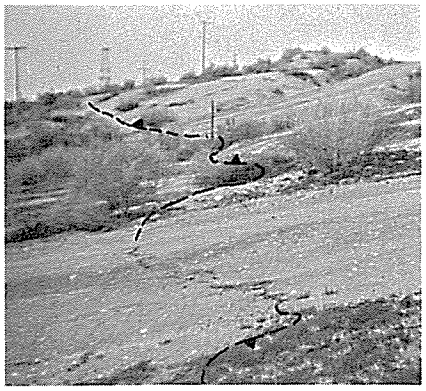
93.8 0.3
Highway 119, CONTINUE AHEAD. Alternate route #3 ends here.

94.1 1.0
TURN HARD RIGHT ONTO HARRISON STREET.

95.1 1.4
TURN LEFT ONTO SIDE ROAD and follow sign to Standard's 7-D Plant. Stay on main paved oil field road. The trace of the Buena Vista Thrust fault sub-parallels the road for the next two miles on the left (north) at about the break in slope of the hills.

96.5 0.2
TURN LEFT (north) AND PROCEED UP HILL toward the small white box near the break in slope.

96.7 0.2
STOP 8. Buena Vista thrust fault. Pull off the oiled road to the left and park in front of the 4 foot square white box. Note three pairs of yellow pipes, one to the right (north) and two to the left (south). The white box and the yellow pipes to the north are on the hanging wall of the Buena Vista thrust and the two sets of yellow pipes to the south are on the footwall of the thrust. A creep meter is housed in the white box and will be explained by Robert Nason of ESSA/Earthquake Mechanism Laboratory. Refer to paper by R. D. Nason, A. K. Cooper, and D. Tocher. The yellow pipes mark the locations of reference stakes 1, 1A, and 1B from south to north. These, and three other sets of reference stakes east of here in Section 8 have been used



Surface trace of Buena Vista Thrust Fault.

by James W. Wilt (1958) *et al.* to record movement on the fault since 1933. Refer to paper by John Manning in this guidebook. The average rate of movement parallel to the dip is 0.068 feet per year.

Prior to 1933 oil field operators discovered that wells in this area were experiencing well-casing failure. Correlation of failure points and topographic surface expression lead to discovery of the active shallow thrust fault dipping about 22° to 25° north. The surface trace extends for about 2 miles across Sections 7 and 8. In 1932 Thomas W. Koch published a map, cross sections and photographs of bent pipes across the thrust. Oiled roads to the east of the white box show cracks and buckling along the trace of the thrust. A line of nails driven in the pavement across the fault trace by members of ESSA is intended to give further data on the Buena Vista thrust movement. If time permits, a walk to the east along the fault trace will offer a chance to view closeup the remarkable break in slope, and the sinusoidal nature of the low angle thrust trace. Note also that immediately north of the fault trace there are no operating wells. However, immediately south of the thrust wells not effected by the fault are still in operation.

The view to the southwest is of Ford City, Taft, and the southern Temblor Range. The town of Ford City, named after the Model T Ford automobile, was founded in 1921. Taft was first established as the town of Moron in 1908; it was destroyed by fire the following year and renamed Taft after President William H. Taft. On a clear day, the San Emigdio Range is visible to the southeast. RETURN TO MAIN E-W OIL FIELD ROAD, 0.2 miles south of the white box on the Buena Vista thrust trace.

96.9 0.3
TURN LEFT (east) on main oil field road.

97.2 0.3
Airport Road, CONTINUE AHEAD on east-west road.

97.5 0.4
Getty Oil Company Buena Vista Hills A.P.-2 gas plant on the left (north). This plant, which is being expanded this year, processes 10,800 Mcf/day of wet gas. Products are: 15,200 gal./day gasoline, 5,200 gal./day propane, 15 tons/day liquid carbon dioxide and 9,200 Mcf/day dry gas.

97.9 0.6
Road forks, KEEP LEFT. Right fork and dashed white center line lead to Standard Oil Co 9-D Camp.

98.5 0.6
Cross roads, CONTINUE STRAIGHT AHEAD on right hand paved road. On the hill to the right Standard Oil Co injected carbon dioxide into lower Etchegoin sand from 1959 to 1962. This procedure designed to lower oil viscosity and increase formation pressure, has been successful only from the engineering standpoint. However, since 1962, remarkable economic success has been achieved with water injection into these shallow sands.

For the next two miles the road follows the crest of Buena Vista Hills. Elk Hills Naval Petroleum Reserve No. 1 can be seen at several points along this road six miles to the north. Buena Vista Lake is below to the north.

99.1 0.3
Road forks, KEEP RIGHT ALONG CREST OF HILLS.

99.4 1.0
Road forks, KEEP LEFT ON MAIN ROAD.

100.4 0.2
Road forks, CONTINUE STRAIGHT AHEAD.

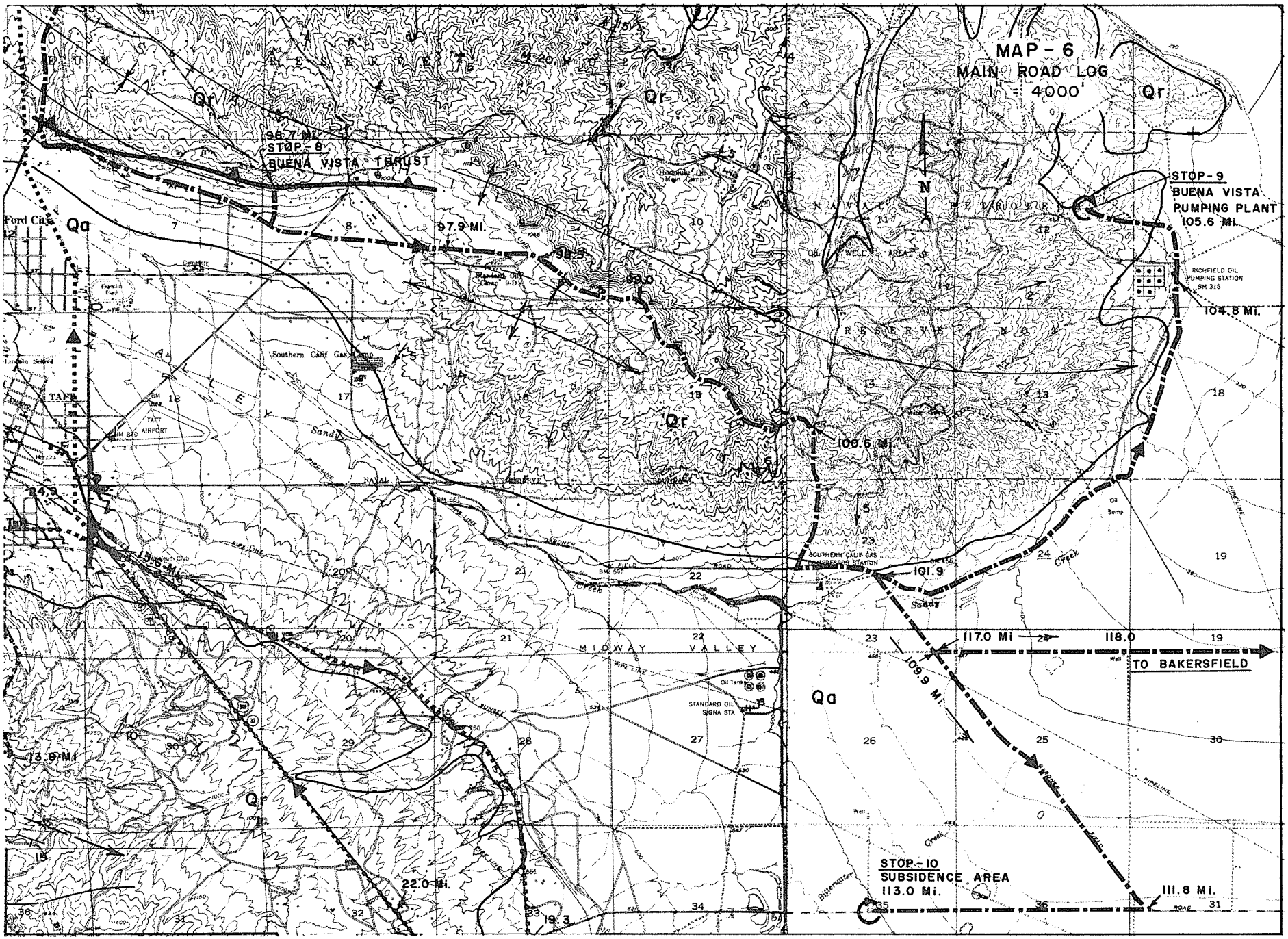
100.6 0.8
TURN RIGHT (south) ON HONOLULU ROAD.

101.4 0.4
Gardner Field Road, TURN LEFT (east).

101.8 0.1
Note subsidence basins along California Aqueduct on both sides of the road. Aqueduct follows 500′ contour at this location.

101.9 2.9
TURN LEFT on paved road leading to Buena Vista Pumping Plant and Atlantic Richfield Oil Company pumping station.

104.8 0.6
Atlantic Richfield Oil Company


MAP - 6
MAIN ROAD LOG
1" = 4000'
96.7 Mi.
STOP - 8
BUENA VISTA THRUST
97.9 Mi.
98.5
99.0
100.6 Mi.
101.9
104.8 Mi.
STOP - 9
BUENA VISTA
PUMPING PLANT
105.6 Mi.
RICHFIELD OIL
PUMPING STATION
117.0 Mi
118.0
TO BAKERSFIELD
109.9 Mi.
111.8 Mi.
STOP - 10
SUBSIDENCE AREA
113.0 Mi.
19.3
22.0 Mi.
13.9 Mi
15.5 Mi
24.9
Ford City
TAFT
Southern Calif Gas
MIDWAY VALLEY
STANDARD OIL
SIGNA STA
SOUTHERN CALIF GAS
COMPRESSOR STATION
Qa
Qr
N

pumping station on left. Richfield's Lake Station pumping plant was built in 1924 to gather and transfer Elk Hills crude oil to Southern California. Presently the facility collects San Joaquin Valley and Cuyama Valley crude oil and annually pumps 25,000,000 bbl of oil to their Watson Refinery in Long Beach. Storage capacity at this terminal station is 404,000 bbl.

105.4 0.1

Road forks, TURN RIGHT.

105.5 0.1

Road forks, TURN LEFT.

105.6 3.7

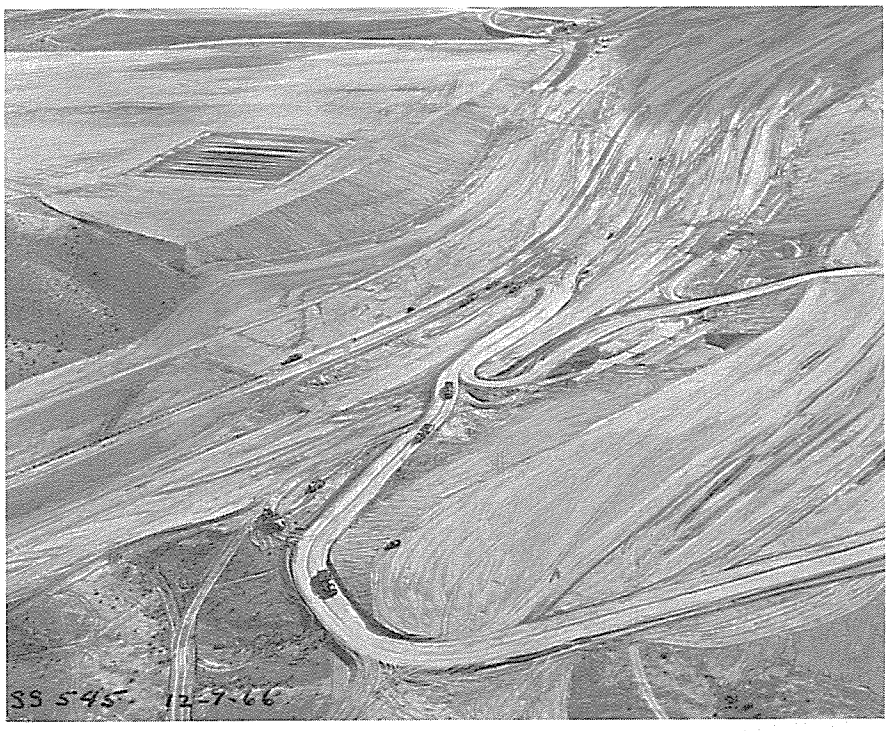
STOP 9. Parking lot overlooking Buena Vista Pumping Plant. This is the third lift along the 444 mile long California Aqueduct. At the sixth and last Tehachapi Pumping Plant more than 800 billion gallons annually will be lifted nearly 2,000 feet, the highest single pump lift in the United States.

The Buena Vista Pumping Plant site is located on the northeast flank of the Buena Vista Hills. When completed, the eleven units, with a combined capacity of about 4,500 cubic feet per second, will lift water 205 feet. The water after leaving the outlet structure at the top of the discharge lines will flow across the southern end of the San Joaquin Valley to Wheeler Ridge.

Extensive subsurface investigations were conducted to determine the foundation and geologic conditions at this site. Subsurface exploration employed auger and rotary borings, resistivity and seismic surveys, E-logging, and trenching. The most unique program was a visual inspection of the material in place utilizing 36-48″ diameter bucket auger holes into which a man cage was lowered; from this cage the holes were inspected, logged, sampled, and in-situ tested.

Work was started on the first stage excavation in October 1965 and essentially completed in March 1967. The total excavation for the intake channel and pumping plant area is approximately 9,800,000 cubic yards, almost entirely within the continental deposits of the Tulare Formation. In the plant area the general attitude of the beds strike N 15-20° W and dip 4-5° NE. The very first stage of the pumping plant construction is now in progress.

Aerial view looking south at site of Buena Vista Pumping Plant. Date Nov. 9, 1966.



Intake channel and waste pile. Overturned fold in Tulare Formation are exposed along left bank of channel.

About one-half mile to the north the Smithsonian Institution in 1933 excavated several Tulamni Indian burial sites. Approximately one-fourth million cubic feet of debris was excavated consisting primarily of molluscan remains, *Anodanta nuttalliana.* The abundance of this freshwater mollusc in the refuse dumps indicates that it was undoubtedly an important dietary item of the Indians. Also, birds, jackrabbits, turtle, and elk remains were commonly found. More than 400 Indian burials were uncovered as well as numerous artifacts. The early Indians used asphaltum (probably from Maricopa) to waterproof baskets, create decorative shell inlays, and for cementing scraper and cutting tool mountings. The village was estimated to have been occupied from about 1300 to 1600 years ago. More recent burial sites, at the north end of Buena Vista Lake were excavated in 1935 by the Southwest Museum of Los Angeles. Forty-six Indian burials were uncovered; occupancy was estimated to be as late as 1860.

RETURN TO GARDNER FIELD ROAD.

109.3 1.4
TURN LEFT (southeast) on Gardner Field Road.

110.7 1.1
Note low level of irrigated land due to shallow land subsidence to the left (east) as compared to unirrigated higher ground on the right. Poor condition of highway is due to subsidence of land.

111.8 0.2
Cadet Road, TURN HARD RIGHT (through barricades).

112.0 0.8
Caution: Road is in poor condition. Cracked pavement and low ground on the right (north) is due to irrigation. The higher ground on the left has not been irrigated.

112.8 0.6
Ground here has not been irrigated and is near the level as the road.

113.4 1.6
STOP 10, if time permits. Turn around and stop at barricades. Presubsidence basins along California Aqueduct here have cracked and lowered Cadet Road about 10 feet.

The Cadet Road area exhibits dramatically the phenomenon of shallow land subsidence. Shallow land subsidence is defined as the downward displacement of the natural ground surface resulting from the compaction of low density soils by the application of sufficient quantities of water. Shallow subsidence has long been recognized along the western and southern parts of the San Joaquin Valley by ranchers, road maintenance crews, and oil companies. When planning the California Aqueduct along the West Side, it was recognized that unless properly treated, soils that exhibit subsidence would result in damaging differential settlement of the canal and canal structures. The Department of Water Resources, in cooperation with many other interested groups and governmental agencies, conducted an extensive test program to delimit areas of shallow subsidence and to determine the most effective means of treating the unstable soils. These studies indicated that it would be necessary to preconsolidate the subsidence areas; 56 miles of the aqueduct alignment, where soils indicated a subsidence potential, have been preconsolidated between Lerdo Highway and Highway 99. Preconsolidation is accomplished by applying sufficient quantities of water. Dikes are built to pond the water, and deep gravel packed wells are constructed in the ponds to increase the infiltration of the applied water.

Cadet Road. Road damage due to compaction of soils causing subsidence.

The physical evidence of subsidence is well defined at Cadet Road. The road is badly damaged by the application of irrigation waters. The magnitude of the subsidence can be judged by the marked difference in ground elevation between the north and south sides of the road. At the aqueduct crossing the roadway was once approximately the same elevation. To the north, worthy of note, is the typical concentric stair-stepped cracking which has developed as subsidence progressed.

RETURN TO GARDNER FIELD ROAD.

115.0 2.0
TURN LEFT (northwest) ON GARDNER FIELD ROAD.

117.0 12.1
South Lake Road, TURN RIGHT.

129.1 2.0
Millux Road, TURN RIGHT (east). The trip crosses the northwest trending Paloma Oil Field for the next three miles. It was discovered in 1934 by the Ohio Oil Company (now Marathon). About 29 wells produce 35° to 55° oil from upper Miocene sands and 978 to 1015 B.T.U. gas from Pliocene sands. The structure is an elongated dome. Upper Miocene oil production is from 11,400 to 11,800 feet and Pliocene gas production is from 4,180 to 5,520 feet. Paloma is one of Kern County's deepest producing fields, and in 1953 the Ohio Oil Company completed what was then the deepest oil well in the world at 20,521 feet. Cumulative production to 1/1/'67 is 37,781,000 bbl; daily average, 332 bbl.

131.1 1.8
Gulf Oil Corp. Paloma Cycling Plant on the right (south). At 5 A.M. July 21, 1952, several large butane tanks toppled at the plant due to the Tehachapi-Arvin earthquake. The resulting fire lasted 12 hours destroying half the plant and burning 2,500 bbl of butane. Damage to the facilities amounted to about $1,000,000.

132.9 1.2
Interstate Highway 5, overpass.

134.1 6.0
River Road, TURN LEFT (north).

140.1 3.9
Taft Highway (State 119), TURN RIGHT (east). Settlement of Old River.

144.0 1.0
Pumpkin Center, CONTINUE AHEAD.

145.0 7.2
Freeway 99, TURN RIGHT ONTO ON-RAMP AND PROCEED NORTH ON 99 TOWARD BAKERSFIELD.

152.2 1.2
California Avenue. TURN RIGHT ON OFF-RAMP AND PROCEED EAST ON CALIFORNIA AVENUE TOWARD CENTRAL BAKERSFIELD.

153.4 0.4
Chester Avenue, TURN LEFT (north). STAY IN RIGHT HAND LANE ON CHESTER FOR NEXT TURN.

153.8 0.2
Truxtun Avenue, TURN RIGHT (east).

154.0
N Street, TURN RIGHT (south), AND THEN IMMEDIATELY LEFT INTO THE WEST PARKING LOT OF BAKERSFIELD CIVIC AUDITORIUM. END OF MAIN FIELD TRIP—FINI.

Alternate Route #1

Alternate Route to the West Side via Wasco and Lost Hills

This trip passes through or near the following fields: Rosedale Ranch, Pozo Creek, Wasco, Semitropic, Lost Hills, North Belridge, North Antelope Hills, Antelope Hills, and McDonald Anticline. The trip will also pass through the Lost Hills gypsite quaries.

CUMULATIVE MILEAGE — MILEAGE TO NEXT COMMENT

0.0 4.0
Begin at intersection of Highway 58 and Freeway 99. Proceed north on Freeway 99. (See mile 2.2 of Main Field Trip Road Log.)

4.0 1.0
Highway 65 to Sequoia and Kings Canyon National Parks, CONTINUE AHEAD (northwest) on Freeway 99. Three and one-half miles due west is the Rosedale Ranch Field discovered in 1945 by Socony Mobil Oil Co. About 50 wells produce 17° to 24° oil from Pliocene and Miocene sands. Production from the west plunging faulted nose is at a depth of about 4,200 to 4,800 feet. Cumulative production to 1/1/'67 is 8,548,900 bbl.; daily average, 1,600 bbl.

5.0 13.3
Oil derricks in the Poso Creek and Kern Front Fields are visible to the right, approximately two miles northeast of the Freeway. The Poso Creek Oil Field was discovered by Standard Oil Company of California in 1919. Approximately 530 wells produce 11° to 15° oil and some dry gas from Upper Miocene and Pliocene sands. Production from the southwest dipping faulted homocline is at a depth of 1,150 to 3,100 feet. Cumulative production to 1/1/'67 is 43 million bbl.; daily average, 6,520 bbl.

The Kern Front Oil Field was discovered by Standard Oil Co of California in 1915. About 800 wells produce 14° to 15° oil from Mio-Pliocene sands at a depth of 1,700 to 1,900 feet. Production is from a southwest dipping faulted homocline. Cumulative production to 1/1/'67 is 111 million bbl.; daily average, 6,980 bbl.

18.3 7.3
Famoso Junction. EXIT HERE TO THE RIGHT AND SWING LEFT OVER FREEWAY 99. PROCEED WEST ON HIGHWAY 46 TOWARD WASCO.

25.6 5.0
Wasco. CONTINUE AHEAD (west) on Highway 46. Wasco (originally named Dewey) had its beginning in February, 1907, when nine sections of Kern County Land Company property were auctioned off to about 200 homeseekers from all parts of the United States. Ample ground water was readily available and the city soon became the agriculture center of the district. With the discovery of oil at Lost Hills in 1910, Wasco became the transfer point for derrick timber and oil field supplies unloaded from the Santa Fe Railroad.

30.6 4.8
Wasco Oil Field (highway marker, Eucalyptus trees and San Joaquin Quarter Horse Ranch sign on left of highway). The 250 acre Wasco Oil Field (abandoned 1960) was discovered by Continental Oil Co. April 11, 1938. The northwest trending closed anticline was located by reflection seismograph. Production from Lower Miocene sands at an average depth of 13,135 feet was the deepest in the world for some time. Deepest production in the world was again achieved in 1949 with the completion of Standard's Mushrush No. 5 at a depth of 15,530 feet. Pliocene fractured shale produced 20° oil from 7,200 feet, Lower Miocene Vedder sand produced 32° to 39° oil from 13,000 feet, and Eocene sand produced 40° oil from 15,000 feet. Cumulative production was 5,071,061 bbl.

35.4 2.5
Semitropic School on right and approximate east side of north end of Semitropic Oil Field. Semitropic Oil Field (formerly Semitropic Gas Field) was discovered by Standard Oil Co. of California in 1935. Twenty-two gas wells were completed and produced 990 B.T.U. gas from Pliocene sands at a depth of 2,200 to 4,400 feet. Seven oil wells produce 28° oil from 7,400 feet deep Pliocene sands. The trap is an elongated northwest trending dome. Cumulative gas production to 1/1/'67 is 15,100 M.c.f.; cumulative oil production to 1/1/'67 is 217,600 bbl.; daily average, 105 bbl.

37.9 5.9
Green house on the right side of highway is approximate western edge of the northern end of Semitropic Oil Field.

43.8 2.1
West Side Freeway, Interstate 5. Estimated completion date, 1972.

45.9 0.5
Lost Hills. Like many towns of the southern San Joaquin Valley, Lost Hills had its beginning as a railroad unloading point for oil field supplies. With the discovery of oil in the Lost Hills Field in 1910, the community was founded to meet the needs of the workers. Lost Hills is said to

have gotten its name from its very low relief. When viewed from a distance, the "hills" are quite apparent but seem to become "lost" when the traveler is on the topographic high.

46.4 0.9
California Aqueduct. See Main Road Guide for comments on Aqueduct.

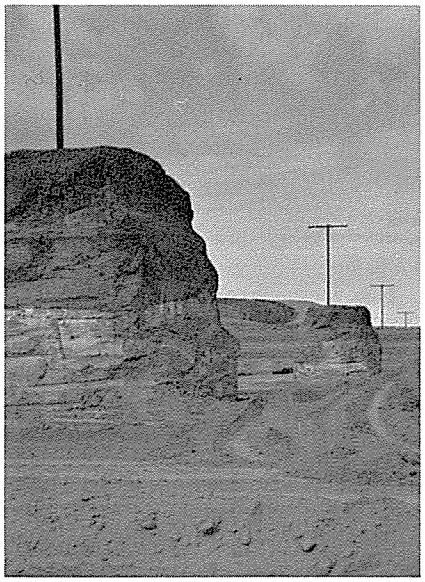
47.3 0.6
East edge of southern end of Lost Hills Oil Field. Note small pumping units and older jack lines. The Lost Hills Oil Field was discovered in 1910 by Martin and Dudley when their intended water well encountered 15° oil at 472 feet. Most of present production is from Pliocene Etchegoin sands and Miocene cherts along the southeasterly plunging anticline. 1,063 wells produce from the asymetric anticline. Pleistocene Tulare sands produce 12° to 20° oil from 200 feet; Pliocene Etchegoin sands produce 14° to 40° oil from 1,000 feet; Upper Miocene fractured shale produce 25° to 35° oil from 4,900 feet; and Lower Miocene Carneros sand produced (now abd) 32° oil from 6,020 feet. Cumulative production to 1/1/'67 is 100 million bbl.; daily average, 7,540 bbl.

Jack line pump unit at Lost Hills.

47.9 2.8
Paved road enters from right. TURN RIGHT (north) into Lost Hills Field (highway marker is an orange circular GULF sign). Stay on main paved road that goes northwest subparallel to the field. (Alternate: those not wishing to pit their skill against oil field roads continue west on Highway 46 to Brown Material Road [mile 53.9] and rejoin the Main Road Log.)

50.7 0.5
G.P. Road. TURN LEFT (west), a main straight E-W road, and proceed out of Lost Hills Oil Field and into the gypsite quaries.

51.2 0.3
Brown Material Road. TURN RIGHT (north). Note the shallow strip mining operation. Agricultural gypsite is mined here as well as numerous other areas in the San Joaquin Valley.


Gypsite excavation at Lost Hills.

51.5 2.5
U TURN AT HOLLOWAY'S GYPSUM YARD AND PROCEED SOUTHWEST ON BROWN MATERIAL ROAD.

54.0 5.0
Highway 46. CONTINUE AHEAD (southwest) ON BROWN MATERIAL ROAD. The view ahead is of North Belridge Oil Field and the Temblor Range.

59.0 0.4
Highway 33. TURN LEFT (southwest) AT Y IN BROWN MATERIAL ROAD AND PROCEED SOUTHWEST ON HIGHWAY 33. North Belridge Oil Field on right. Refer to maps in Guidebook.

59.4 0.1
North Belridge Oil Field Road. TURN RIGHT. (Highway marker: "Tidewater Oil Co., Carneros Station 1.7 miles," sign at turnoff on west side of highway.)

59.5 1.7
North Belridge gas plant on the left.

61.2 0.1
Tidewater Carneros Pump Station is ahead. TURN HARD RIGHT ONTO DIRT ROAD APPROXIMATELY 220 FEET FROM MAIN BUILDING. This station is one of several pump stations that gathers crude oil from the West Side fields and pumps it to their Avon Refinery in the San Francisco area. Daily thru put of the station is 31,000 bbl. Storage capacity is 250,000 bbl.

Note: Most dirt roads are impassable during wet weather. The portion of the road log from Tidewater Carneros Pump Station, mile 61.2 to the south end of North Antelope Hills Oil Field, is dirt. If there is any doubt about the condition of this road, the following alternate may be followed and rejoin the log at mile 66.0 at the south end of North Antelope Hills Field. Return to Highway 33 and turn north. At Blackwells Corner, turn west onto Highway 46 and proceed 1.9 miles to an unmarked road leading south (a small sign, "Tidewater Oil Co., Antelope Hills Sec. 14/27-19" is the only marking). Turn left (south) on this paved road and follow it to and through North Antelope Hills Oil Field. Join the road log at the southernmost well in the field at mile 66.0.

61.3 0.3
Gate through barbed wire fence. KEEP RIGHT after gate and continue ahead to the northwest.

61.6 0.6
Road forks, CONTINUE STRAIGHT ON RIGHT FORK (white and green 3″ iron pipes protect valves on each side of the road at this fork).

62.2 0.7
Open gate in barbed wire fence, GO THROUGH THE GATE AND TURN LEFT (west) paralleling the fence.

62.9 2.0
Road forks, TURN RIGHT and follow road parallel to 2-wire telephone line.

64.9 0.4
Cross roads, CONTINUE STRAIGHT AHEAD (west).

65.3 0.7
Open gate in barbed wire fence, CONTINUE STRAIGHT AHEAD.

66.0 2.3
Paved road. (A ten foot diameter water tank is on the west side of the road at this intersection.) This is the south end of North Antelope Hills Oil Field. It is a narrow field two to three wells wide and continues north along this paved road for two miles. Refer to map in Guide Book. TURN LEFT (south) on the paved road and proceed with caution; there are many chuckholes.

68.3 0.6
Road bends to the right. This is the

north end of the Antelope Hills Oil Field. Follow the main paved road through the field.

68.9 1.3
Road bends left. Sheds and tanks on right.

70.2 0.9
TURN RIGHT (west) on paved road. (A sign "Laymac Corp. Opr., Ferguson and Bosworth Layman Area Pool" marks this junction.)

71.1 0.1
TURN LEFT (south) ON MAIN PAVED ROAD.

71.2 0.4
Beginning of north end of McDonald Anticline Oil Field. Refer to map in Guide Book.

71.6 0.4
The small refinery on the left (east) is operated by Ferguson and Bosworth and has a capacity of about 1,900 b/d.

72.0 0.2
TURN RIGHT ON PAVED ROAD.

72.2 0.5
Go past the three houses and TURN LEFT (south) between the last house and a large gray steel tank onto a dirt road. Follow this dirt road as it bends to the right toward the Temblor Range.

72.7 0.8
Intersection of dirt roads, TURN LEFT (south) and continue south, subparallel to the east flank of the Temblor Range.

73.5 0.5
Cross Santos Creek, CONTINUE STRAIGHT AHEAD.

74.0 0.8
Intersection with road leading west into Santos Creek through a locked gate, CONTINUE STRAIGHT AHEAD.

74.8 0.4
Low hill on the left is Upper Miocene McDonald shale.

75.2 0.6
Two locked gates leading into Carneros Creek. Mile 50.7 of Main Road Guide. TURN LEFT (east) for 0.6 miles to join the Main Field Trip Road Log at STOP 1.

75.8
STOP, make a U turn on this low rise in the road and begin STOP 1 (mile 50.1) of the Main Field Trip Road Log. END OF ALTERNATE ROUTE #1.

ALTERNATE ROUTE #2

Spellacy Sand Outcrop West of Fellows

This short side trip visits outcrops of Upper Miocene Spellacy sand and provides excellent views of nearby oil fields.

CUMULATIVE MILEAGE — MILEAGE TO NEXT COMMENT

0.0 0.6
This trip begins at the intersection of Shale Road and Mocal Road and returns to the same point to rejoin the Main Field Trip Road Log at mile 87.0. PROCEED WEST ON MOCAL ROAD; refer to Alternate Route #2 Geologic Map of Spellacy Sand.

0.6 0.4
TURN LEFT OFF MOCAL ROAD ONTO A SHORT PAVED ROAD LEADING TO A PUMPING UNIT. KEEP LEFT (east) OF THE PUMP AND CONTINUE SOUTH UP THE HILL ON A DIRT ROAD ON THE WEST SIDE OF THE CANYON. Note: Dirt roads are impassable during wet weather.

1.0 0.8
Cattle guard in barbed wire fence, CONTINUE STRAIGHT AHEAD. Road cuts for the next 0.8 mile are in Pleistocene Tulare Formation.

1.8 0.5
STOP 1. Pull off to the right and park near the six foot diameter concrete water tank and nine inch diameter well head casing, McKee #1. The Tulare Formation-Antelope shale contact is approximately 100 feet west of the water tank and dips

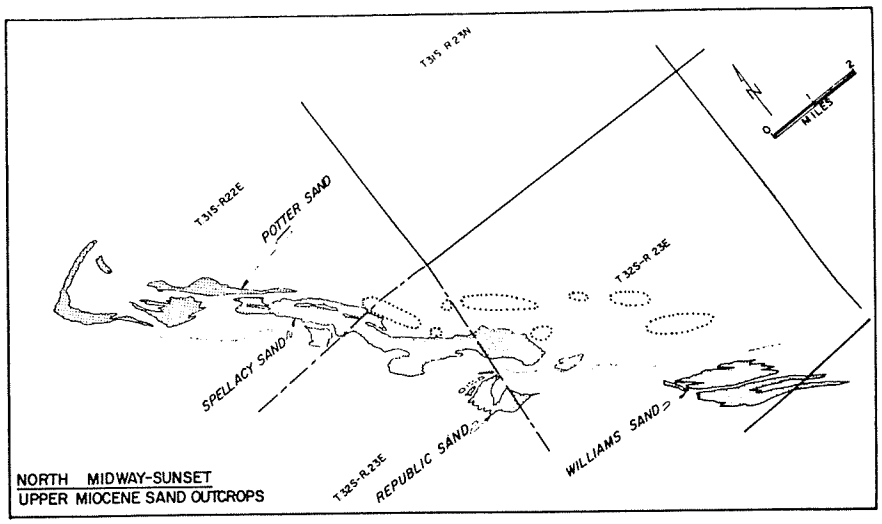


Fig. 1. Outcrop pattern of Upper Miocene sands.

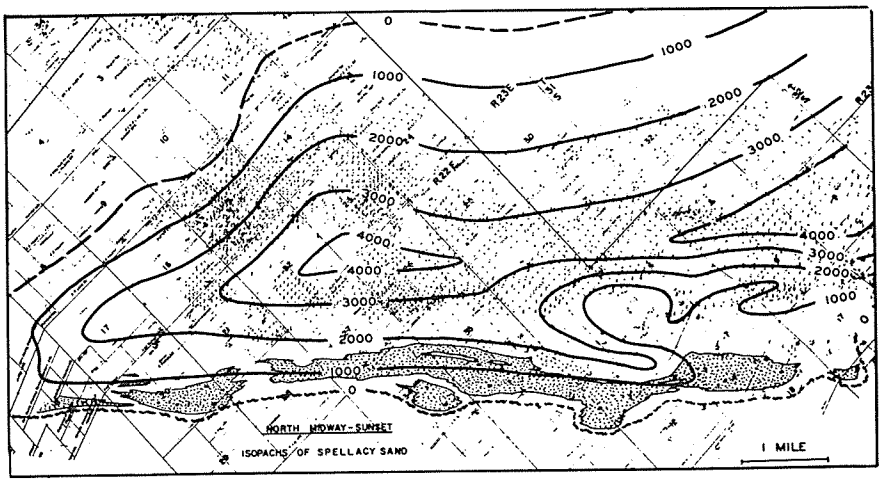


Fig. 2. Isopachs of Spellacy sand (Callaway, 1962).

eastward. Spellacy sands are ahead to the northwest down the slope on the west side of the low ridge. Here, and for the half mile up the road, are scattered exposures of Spellacy sand.

"*The Spellacy* is a series of lensing, lenticular, and discontinuous (Fig. 1) bodies of sand. Lithologically the Spellacy ranges from fine grained to boulder conglomeratic. It is arkosic, kaolinitic. biotitic and has beds of angular to round quartz, feldspar, chert grits and pebbles. Massive granitic boulders are common and silt beds are rare near the outcrop. Further from the outcrop this relation reverses, the boulders becomeing rare and siltiness increasing.

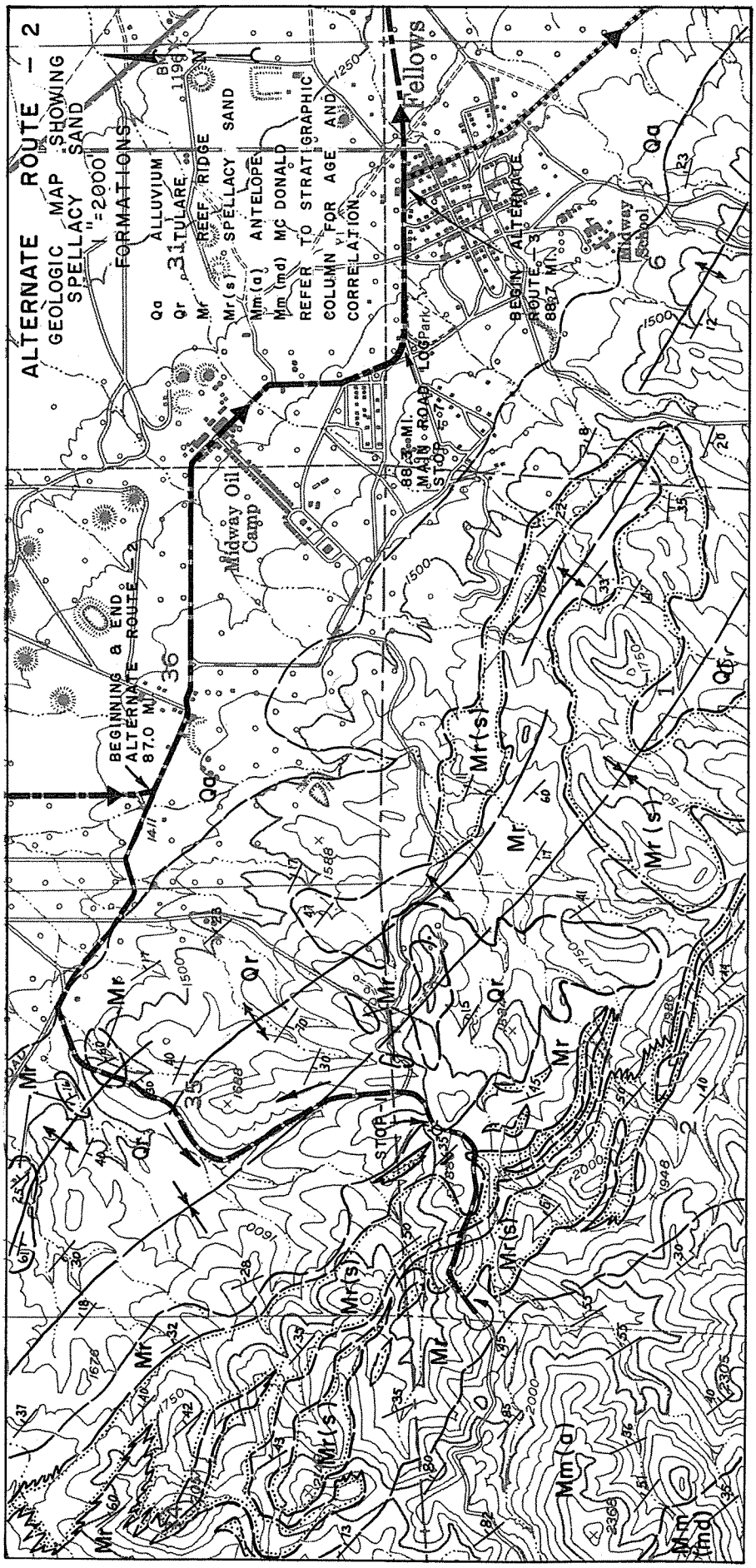
"The Spellacy is equivalent to Simonson and Kreuger's Santa Margarita of the Crocker Landslide Area. The source of the sand is from an uplifted granitic high area immediately southwest of the San Andreas Fault. Isopachs (Fig. 2) indicate the Spellacy to be confined to the southwest of the Buena Vista Hills, the pinchout of the sand probably occurring low on the flank of Buena Vista. The areal distribution and lithologic character of the Spellacy suggests a "dump" type of deposit filling the low area between the San Andreas granitic high and the growing submarine high of Buena Vista Hills." (Calloway, 1962, p. 49)

CONTINUE AHEAD up the road by car to view more exposures of Spellacy sand.

2.3 1.7
U TURN AND RETURN TO MOCAL ROAD. (Note: This road ends at 3,662 foot high Midway Peak, and crosses Upper Miocene; lower Antelope shale and McDonald shale; and Middle Miocene Devilwater-Gould shale. Refer to stratigraphic column.)

4.0 0.6
MOCAL ROAD, TURN RIGHT (east).

4.6
Intersection of Mocal Road and Shale Road. End of Alternate Route #2, rejoin Main Field Trip Guide at mile 87.0.



Alternate Route #3

Williams Sand Outcrop Southwest of Taft and Lakeview #1 Gusher Southeast of Taft

This 28 mile side trip goes through the Midway-Sunset field to Taft and turns southwest to Upper Miocene Williams sand outcrops; there are excellent panoramic views of the southern San Joaquin Valley from Hill Road. The trip returns to Taft and then southeast on Division Road to the Lakeview #1 gusher. The trip ends and joins the Main Field Road Log at Highway 119 and Midway Road, three miles north of Taft.

CUMULATIVE MILEAGE	MILEAGE TO NEXT COMMENT
0.0	0.2

This trip begins at the intersection of Broadway and Midway Street on the north side of Fellows. (Refer to mile 88.7 of Main Field Trip Road Guide.) Leave the Main Field Trip Road Guide here and go south on Midway Street. Fellows, a one-time railroad terminal of the Sunset Western Railroad from Maricopa, was named after a Santa Fe Railroad construction engineer about 1909.

0.2 3.5
Road forks, junction of Midway Street and Midoil Road. CONTINUE STRAIGHT AHEAD ON RIGHT FORK, Midoil Road. For the next five miles the route will pass through the Midway-Sunset Oil Field; stay on the main paved road. See maps on Midway-Sunset Field in this Guide Book.

3.7 1.5
Road bends to left down Twenty-one Canyon for 0.3 miles.

5.2 0.8
Road bends slightly to left and becomes "A" Street, CONTINUE STRAIGHT AHEAD ON "A" STREET.

6.0 0.4
10th Street (Lincoln Street), TURN RIGHT.

6.4 1.4
Road turns left, leaves the city of Taft, and becomes Hill Road; PROCEED AHEAD ON HILL ROAD TO THE CREST OF 25 HILL.

7.8 0.6
Crest of 25 Hill, main paved road turns left (south). TURN RIGHT (west) down the hill on a paved oil field road.

8.4 0.6
Road intersection, TURN LEFT (south) AND PROCEED UP THE CREEK AND THEN FOLLOW RIGHT UP A SIDE CANYON.

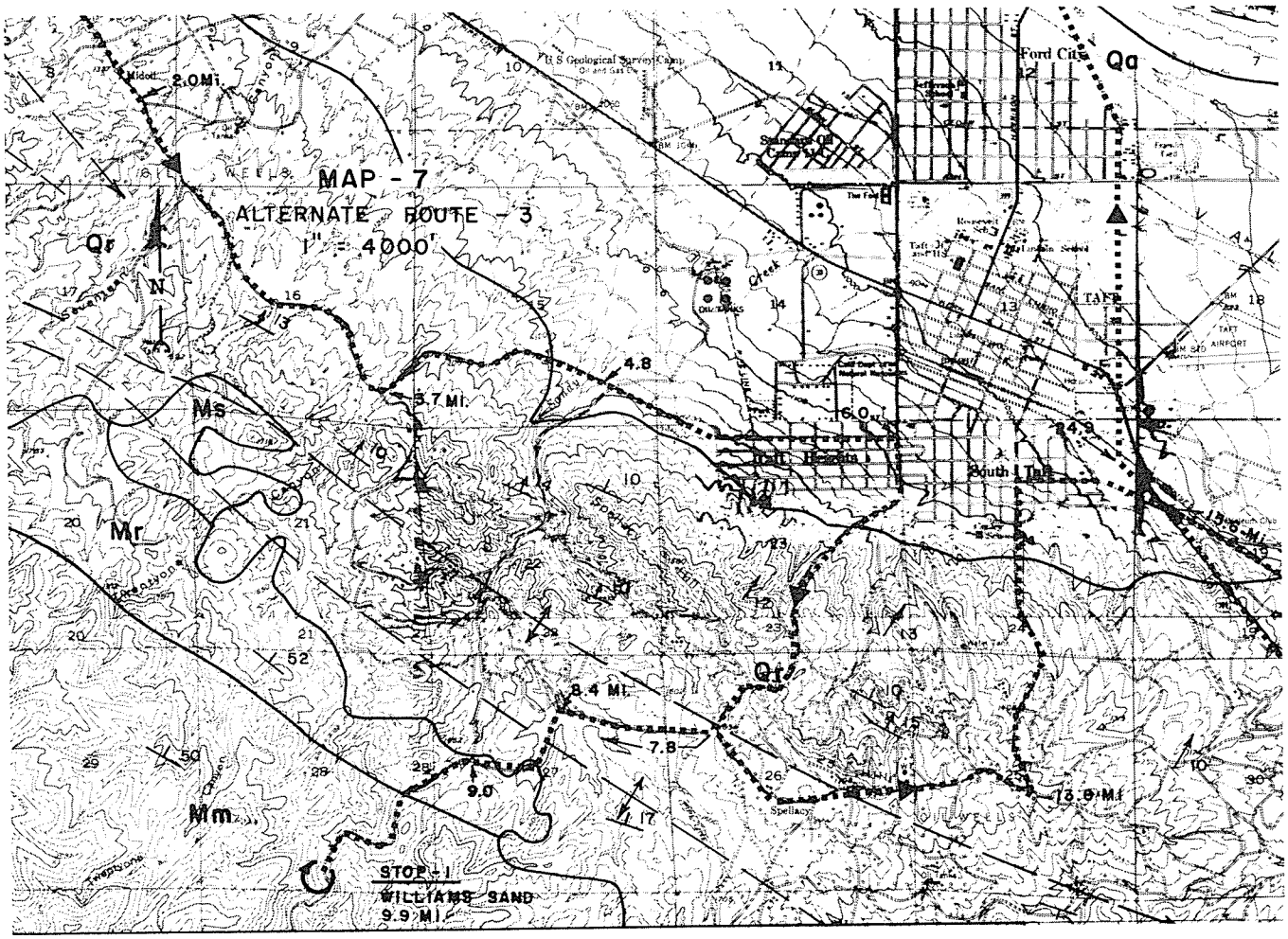
9.0 0.5
Road forks, TURN LEFT (west) THROUGH CATTLE GUARD ONTO DIRT ROAD AND PROCEED WEST UP CANYON. (Caution: Dirt roads are impassable during wet weather. If in doubt, return to Hill Road and continue the trip at mile 12.1.)

9.5 0.3
Road bends right. Outcrops of Upper Miocene Williams sand are on the left (east) on the knoll. The Williams Area of the Midway-Sunset Field is beyond the knoll to the southeast.

9.8 0.1
Exposures of Williams sand on each side of the road.

9.9 2.2
STOP 1. Outcrops of Upper Miocene Williams sand on the left (east) side of the road.

"*The Williams Sand* crops out in Section 28, 33, 34 and 35, T. 32 S., R. 23 E., as a locally confined body



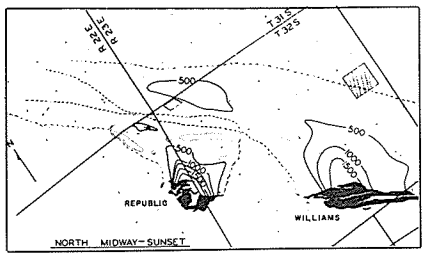


Fig. 1. Aerial distribution and Isopachs of Republic and williams sands.

of lensing sand beds. The areal distribution (Fig. 1) of this sand shows a fan shape which streams off to the northwest. In the outcrop area the Williams is quartzose, fine grained to pebbly conglomeratic, but mainly fine to coarse with local occasional beds of subrounded quartz and shale pebbles. Siltstone streaks are rare. As the distance from the outcrop increases the grain size decreases. Well cores in the area of the Midway Syncline find the sand to be silty to fine grained with occasional medium grains. Silt streaks are abundant. Further from the outcrop the sand silts out completely." (Callaway, 1962, p. 49)

RETURN TO HILL ROAD (mile 7.8 of the log).

12.1 1.5

Hill Road, TURN RIGHT (south). Hill Road follows the crest of 25 Hill for 1.5 miles.

13.6 1.2

Hill Road bends sharply to the left and begins its descent to Taft. The Sunset Western Railroad extended its line in December 1908 from Maricopa to the rapidly developing Midway Oil Field. Within six months the community of Moron had grown to some 200 people, all living on railroad land south of the tracks. On October 22, 1909, a disastrous early morning fire destroyed the entire business district at an estimated loss of $50,000. Rebuilding began immediately, only now it was the north side that grew. On November 8, 1910, "Moron" was incorporated and changed its name to "Taft" in honor of President William H. Taft.

14.8 0.2

South side of Taft. Hill Road becomes Olive Street, CONTINUE STRAIGHT AHEAD on Olive Street.

15.0 0.3

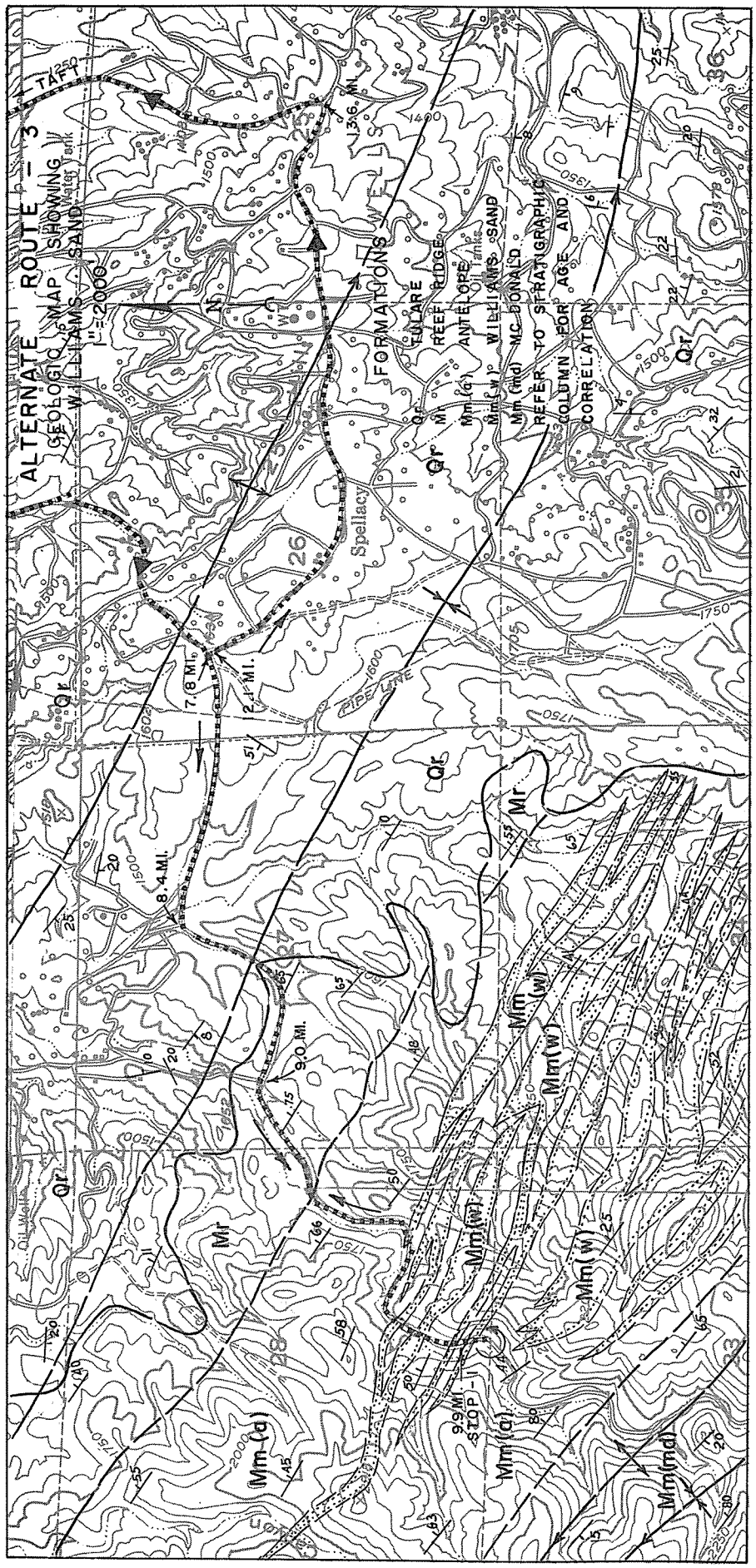
Wood Street, TURN RIGHT.

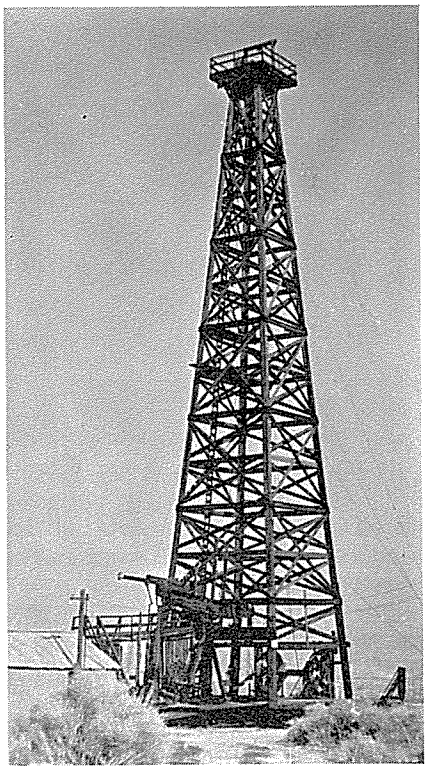
15.3 0.1

Road bends slightly to the right and leaves the city of Taft.

15.4 0.2

Old Wood oil derrick on the left, Jameson Oil Co. #17-24C, Sec. 24,





Wood derrick of well drilled in 1917.

T. 32 S., R. 23 E. It was drilled in 1917-1918 with cable tools to a total depth of 2,495 feet. The initial production was 958 b/d of 26° oil. The well was later deepened to a total depth of 2,965 feet. It presently produces 5 b/d oil and 3 b/d water. Most of the original equipment is still intact at this location, and the well is still producing at this time.

15.6 4.2
Intersection of Wood Street (Division Road) and Highway 33. CONTINUE AHEAD (southeast) on Division Road.

19.8 0.5
STOP 2. Lakeview #1.

Civic pride was running high in the growing community of Taft in early 1910, with Mrs. J. W. Jameson undertaking the job of naming new streets in the boom town and a move afoot to incorporate scattered residential sectors known variously as Moron and Taft.

Enterprising citizens opened several new tent hotels on Center Street, prompting one wit to remark there was more apt to be an over-production of lodging houses than of oil on the West Side. The price of a night's lodging was 35 cents; of a good meal, 25 cents.

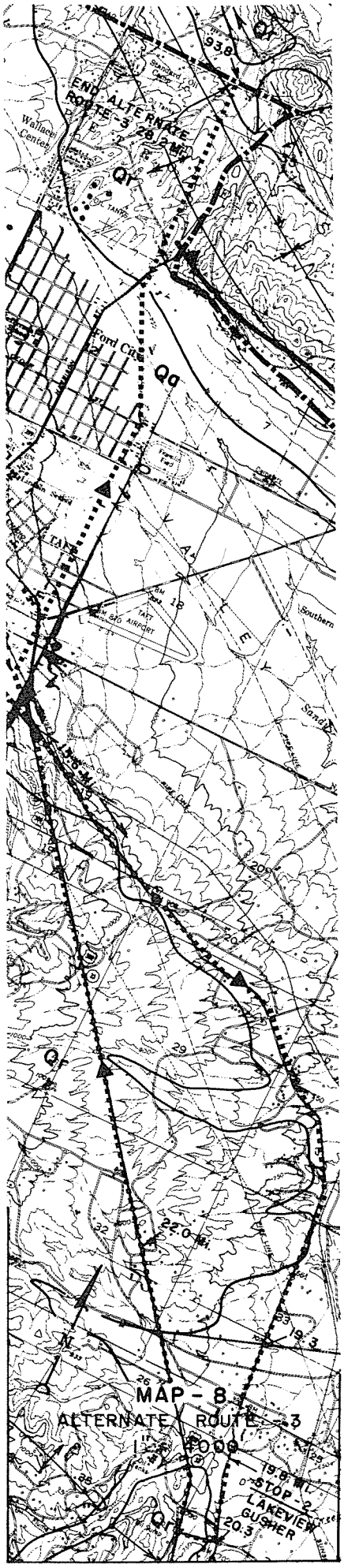
In the oil fields, a 20-acre lease on 25 Hill sold for $50,000 and gushers were not an infrequent sight. The fields teemed with interesting characters, including a former mayor of San Francisco who claimed to have a drilling device that would enable an operator to drill to 3,000 feet in three weeks.

On the Lakeview lease between Taft and Maricopa, a cable tool rig was making slow progress at Lakeview No. 1, a wildcat which had been spudded on January 1, 1909. It had taken 14 months to pass the 2,000-foot mark. The well was on land leased from Barrett & Dunn, Julius Fried and F. P. Wells, a Buffalo, N.Y., industrialist who reportedly manufactured oars for the British Navy. Union Oil Co. of California was the operator, having bought controlling interest from Lakeview Oil Co.

On the morning of March 14th or 15th (the bronze plaque marking the site lists the date as the 14th; the Union Oil well log and history lists it as the 15th; newspapers of the day did not start covering the story for several days and are not clear on the date the blowout began) Walter Barnhart, Union Oil Co. of California's drilling superintendent, tethered his horse near the rig and learned from the driller that the bailer was stuck. Barnhart instructed the driller to limber up the bailer by yanking the cable up and down. When he put a strain on the sand line, gas pressure blew the bailer into the crown block. Men scattered as oil spurted from the well. There was no stopping the column of dark brown oil. The gushing column was visible from as far away as Conner's Station 30 miles from the well, and the roar could be heard for miles around. Sand buried the engine house, bunk houses and coal shack. Particles of spray drifted for miles, bringing down the wrath of housewives who'd hung up laundry. In a matter of hours, the flow of oil began to demolish the derrick over Lakeview No. 1.

Frank Hill, director of production for Union Oil, was in Santa Maria when word of the blowout reached him. He lost no time heading for the wild well, traveling by car through Cuyama Valley.

An oil stream the size of a trout stream — and quickly dubbed just that — was flowing away from the Lakeview gusher when Frank Hill took charge. Work began immediately on the building of earthen reservoirs in what was soon known as the "cornfield," sloping land between the well and Buena Vista Lake. All the teams and scrapers



that could be hired in the field were thrown into service. Upwards of 400 men worked to build a barricade around the well. Sand bags and sagebrush were laced into a levee to hold back the flow of oil. Three pumps—two 4-inch pumps and one 6-inch pump—worked to full capacity pumping oil to a pair of 55,000 bbl. tanks on Producers Transportation Co.'s property at Maricopa.

Sandbag dike at Lakeview No. 1. Original bags still visible after 58 years.

Every precaution was taken to keep from turning the well into a firey holocaust. Activity at other wells in the area was halted, and guards were posted to keep people away from the well. Food for men working on the well was prepared in Maricopa since fires were strictly forbidden in cookhouses on leases near the gusher.

Men toiled in the oily spray for 10 hours at a stretch. The only casualties, and there were plenty of them, were the men whose skins could not stand the distillate baths that were necessary after working a 10-hour shift at the wild well.

In newspapers of the day, stockbrokers took half page ads advising their readers to jump on the stock bandwagon. Brokers fought for stock in Monte Cristo Oil Co., which had 800 acres near the gusher, and Monte Cristo stock skyrocketed to a record $3.50 per share. There was serious talk of forming a stock exchange in Bakersfield.

Thirty-nine new oil companies were formed in two weeks, and the price of real estate spiraled upward in Taft until two lots on Center Street sold for $250.

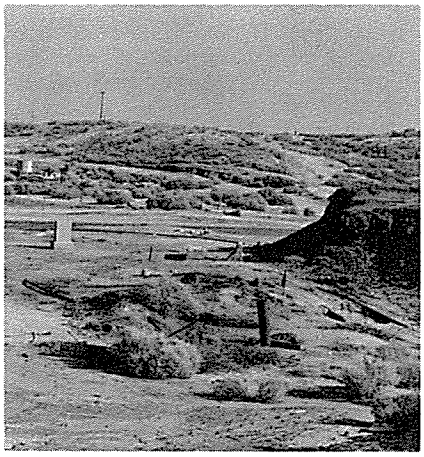
As if visitors couldn't see enough of the gusher in the day light, they could soon see it at night too. A well known as Tight Wad No. 3 caught fire on 25 Hill and lit up the countryside for miles around.

A month after the well blew in, it was still flowing at an estimated 40,000 b/d rate. As oil flowed from the gusher, the price of crude dropped from one dollar a barrel to less than 30 cents a barrel. One enterprising company, now one of the biggest producers in the state, sized up the situation, built earthen reservoirs near Bakersfield, and bought all the cheap oil it could get, storing it for the day the price would rise again.

Finally on September 9, 1911—544 days after the well blew in—the Lakeview gusher caved at the bottom and died. It had produced an estimated nine million barrels of oil. More than four million barrels had been saved; the remainder was lost through evaporation and seepage in cracks in the earth.

Union dug a 100-foot shaft to find the top of the well's six and five-eighths inch casing and proceeded to redrill the well, putting it on the pump in January, 1913. The well made about 30 barrels a day for awhile and finally died. Eventually in the 1930's another operator—General Petroleum Corp., now Mobil Oil Corp.—redrilled the well, and, failing to get production, abandoned it.

Until February, 1952, the Lakeview gusher was all but forgotten—an abandoned symbol of early days in the Kern County oil fields. Then the location was marked with a bronze plaque, dedicated in ceremonies sponsored by Miocene Parlor No. 228, Native Daughters of the Golden West; Kern County Historical Society; and Kern County Museum. Among the speakers at the dedicatory ceremony was the late Frank Hill,



Site of Lakeview No. 1 as it looks today.

who had fought the Lakeview gusher some 42 years before.

PROCEED SOUTH ON DIVISION ROAD.

20.3 0.2
Kerto Road, TURN RIGHT (west).

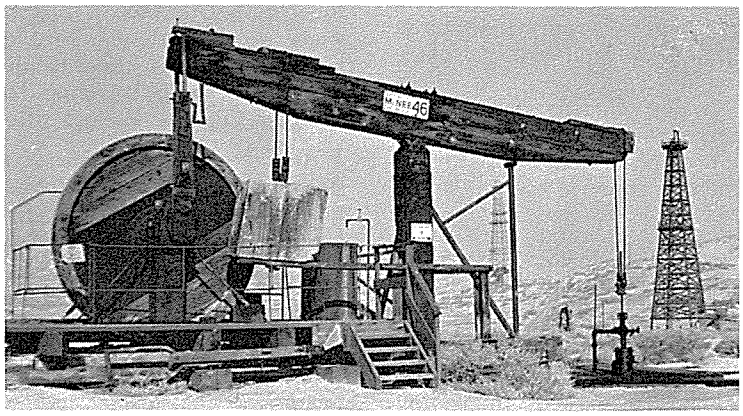
20.5 4.4
Highway 33. TURN RIGHT (north) AND RETURN TO TAFT.

24.9 3.3
Road forks. Leave Highway 33 and KEEP RIGHT ON HIGHWAY 119 (north).

28.2
Midway Road. TURN RIGHT (east) AND REJOIN THE MAIN FIELD TRIP ROAD GUIDE AT MILE 93.8. END OF ALTERNATE ROUTE 3.

(Lakeview Story by William Rintoul)

Wooden bull wheel and walking beam.



FIELD TRIP TO AREAS OF ACTIVE TECTONISM AND SHALLOW SUBSIDENCE IN THE SOUTHERN SAN JOAQUIN VALLEY[1]

JOHN C. MANNING[2]

INTRODUCTION

The Southern San Joaquin Valley, a tectonic basin formed during late Cenozoic time, is still undergoing deformation by large-scale forces acting within the upper part of the earth's crust. Active faults together with broad uplift and subsidence are evidence that tectonic forces are still active today.

Although this region probably has been subjected to almost continuous orogenic movements throughout late Mesozoic and all of Cenozoic time, the latest "pulse" of mountain building apparently began in middle or late Pleistocene time, about 500,000 years ago. It was this orogeny (or orogenic "pluse") that formed much of the present topography. The Sierras began rising more rapidly and much of the West Side topography was formed or accentuated. The Elk Hills, Buena Vista Hills, Buttonwillow and Semitropic Ridges and numerous other anticlinal folds were formed or greatly accentuated at this time.

Regional stresses in the upper part of the crust in this region have caused an interesting pattern of deformation in the southern San Joaquin Valley. The east side of the valley has been deformed mainly by uplift and normal faulting, suggesting a region of tensional stress along the East Side at the base of the Sierra Nevada. The west side of the valley, on the other hand, has apparently been subjected mainly to compressional stresses, and these have resulted in anticlinal folds and reverse (or thrust) faulting.

It is not unusual to find evidence for a stress system that acted in the past and produced a pattern of rock deformation now recognizable as old fault traces and fold axes. What makes the southern San Joaquin Valley unique is the fact that, not only is the orogenic stress still active, but that the evidence of activity can be observed today in the movement of active faults. Further, the long-established regional tectonic pattern is represented faithfully in detail. The active (Kern Front) normal fault of the East Side and the (Buena Vista) thrust fault of the West Side demonstrate conclusively that tectonic patterns of the recent past still prevail.

Further evidence of tectonic movements on a regional scale is found in the results of U. S. Coast and Geodetic Survey precise leveling. Lofgren (1966) has analyzed results of the leveling and has reported tectonic uplift of the Grapevine area of the San Emidio Mountains at the south end of the San Joaquin Valley. This mountain mass has risen approximately 2 feet, with respect to sea level, since 1952. Lofgren (1966) also suggests that the San Joaquin Valley may be subsiding as the surrounding mountains continue to rise, but the amount of tectonic subsidence is masked by extensive shallow subsidence caused by compaction of young sediments underlying the valley floor.

Two kinds of shallow subsidence have been observed in the southern San Joaquin Valley. One type of subsidence occurs at the land surface in localized areas and is due to compaction of low-density soils when they become saturated with water. The other type of subsidence is regional in extent and is due to compaction of fine-grained, near-surface sediments as a result of withdrawal of fluids from the underground. Both types of subsidence will be discussed on the field trip, and examples of soil consolidation due to application of water will be observed. Regional subsidence cannot be observed directly, but a visit to a U. S. Geological Survey recording station will demonstrate one way in which this kind of subsidence is measured.

ACKNOWLEDGEMENTS

The press of time prevented joint authorship of these pages with several people who contributed data and drawings, and I would like to acknowledge the considerable contribution made by William Edmondson, Ben Lofgren, Gardner Pittman, Charles Richter, and James Wilt. I would also like to thank the Valley Waste Disposal Company for permission to visit their Maricopa wastewater sump and injection well field. Mr. Charles Burdick, manager of Valley Waste, was most helpful in making this visit possible and in providing information on the wastewater operations.

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[1]Manuscript received Feb. 1968

[2]HydroDevelopment, Inc.
Bakersfield, California

THE KERN FRONT FAULT

The Kern Front fault has been described by Park (1965) as the fault that provides eastern closure for the Kern Front oil field. As noted by Park, the surface trace of this normal fault is marked by a low scarp (6″ to 12″ high) that makes it easy to map in the field. Continuous movement along the fault has required frequent repairs in the roads that it crosses, and where the movement is most pronounced, a sharp bump is felt as one drives over the fault scarp. The accompanying map (Figure 1) shows the surface trace of the fault in the field trip area. It has not been traced to its extremities and may extend for some distance beyond the area mapped.

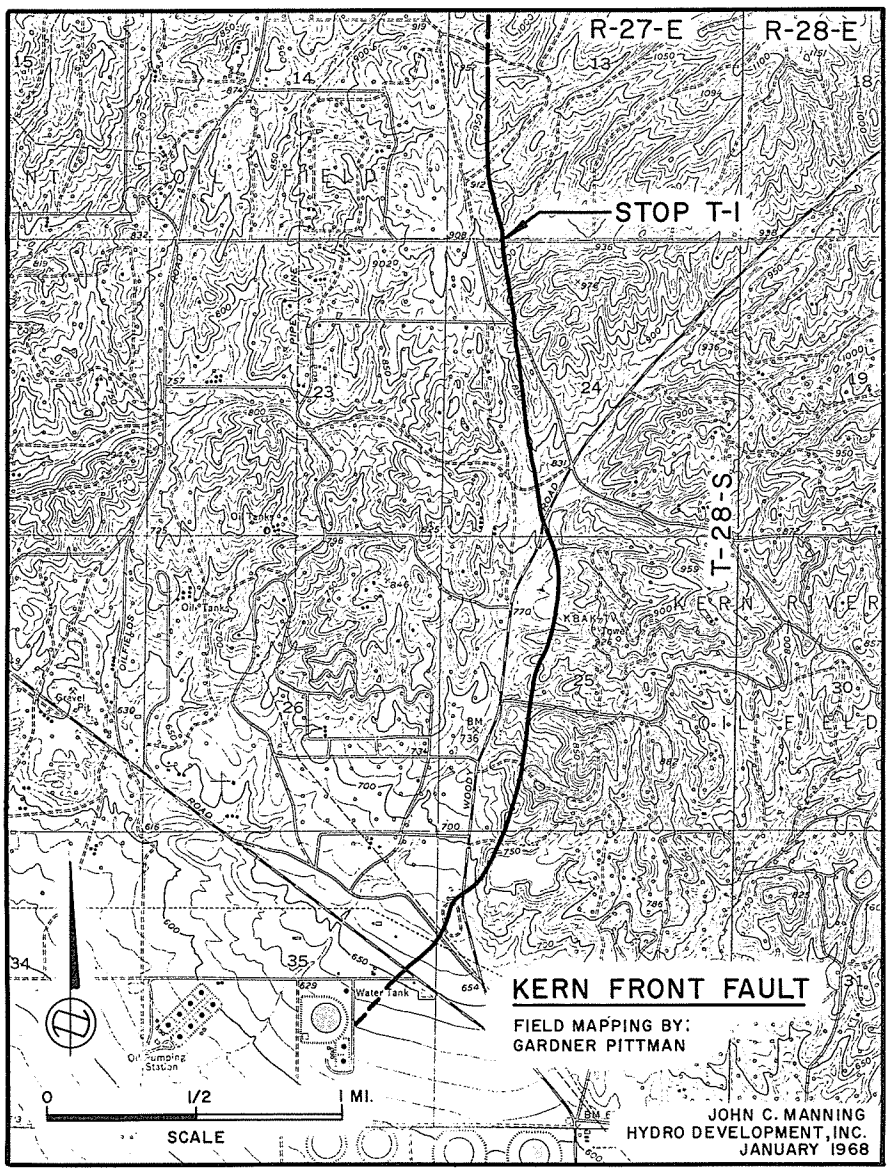


Fig. 1. Surface trace of Kern Front Fault.

This fault is an interesting geological phenomenon and is worthy of further study for several reasons. It would be interesting to know its relationship to seismic events occurring on the east side of the San Joaquin Valley and whether or not movement is a slow creep or is characterized by periodic pulses that cause seismic disturbances. Seismic instrumentation in this region is now much more intensive than it was before the 1952 earthquake, and interpretation of recorded events, with a view toward studying movements on this fault, would appear to be worthwhile. Also, there are probably not many normal faults anywhere in the world that are moving at the current rate of the Kern Front fault. Ready access makes this fault easy to study, and creep meters or other devices to measure movements would be easy to install. In fact, the main purpose of this field trip is to call attention to this active normal fault in the hope that other workers with the requisite knowledge and equipment will become interested in studying the fault's movement.

REFERENCE

Park, W. H., 1965, Kern Front Oil Field: California Division of Oil and Gas, Summary of Operations—California Oil and Gas Fields, V. 45, pp. 13-22.

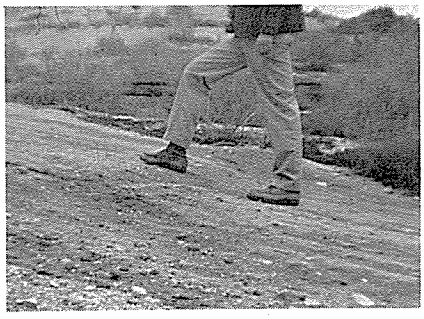
Oil field road crosses Kern Front fault.

THE BUENA VISTA THRUST FAULT

Although this active fault is marked by a low scarp at the ground surface, it was not discovered until fault movement began causing dislocations in oil well castings and surface pipe lines. T. W. Koch (1933) described the fault and determined its strike (N 75° W) and dip (25° N) by plotting the surface trace and by contouring the fault plane from casing-failure data. Koch also estimated the average movement along the fault plane to be about 1½ inches per year, with the overriding block moving southward. At about the time that Koch's paper appeared, J. W. Wilt established 4 sets of measuring points along the surface trace of the fault (Figure 2) and began making taped measurements of fault movements. Wilt (1958) reported after 24 years of measurements that the fault had moved during this period a maximum of 1.637 feet, or an average of 0.068 feet per year (about 0.82 inches per year). Thus from Koch's estimate of movement prior to 1933 and Wilt's measurements during the subsequent 24 years it would appear that the fault has probably been moving about one inch per year during recent geologic time. Although the rate of movement, as measured by Wilt, increased slightly right after the 1952 earthquakes in the southern San Joaquin Valley, there do not appear to be any seismic events connected specifically with this fault movement.

Figures 3 and 4 (reproduced from Koch's paper) show the mapped trace of the fault and its inclination in the subsurface; and the accompanying photographs show the surface appearance of the fault. The pictures copied from Koch's paper also show the way that pipe lines were bent and shortened by the fault movement. After the oil companies operating in the area learned what was making the lines buckle, all pipe lines crossing the fault were fitted with swing joints or other flexible attachments to prevent buckling across the fault zone. Deep cellars (some more than 100 feet deep) were also installed on several of the oil wells to make them last longer in the zone of active fault movement. The best place to see evidence of active movement today is in the cracked and deformed pavement of roads crossing the fault. If one examines the pavement carefully where the road crosses the fault scarp just west of Wilt's 2A-2B measuring points (Figure 2), the recent cracking and crumbling of the asphalt road pavement is quite apparent (see photo showing man standing on fault trace in road).

In addition to Wilt's measurements, the U. S. Coast and Geodetic Survey has been measuring the fault movement by periodic traverses since 1932. These data for the period 1932-1959 have been analyzed by J. H. Howard (1967) to determine strains developed in the horizontal plane. Howard concluded that both overthrusting and underthrusting have occurred at the eastern end of the fault trace, but that near its western end both blocks of the fault have been moving north (toward the dip of the fault), with the lower block moving more than the upper. Thus, according to Howard's analysis, the major part of the fault movement appears to be an underthrust rather than an overthrust.



Buena Vista Thrust scarp as it crosses oil field road.

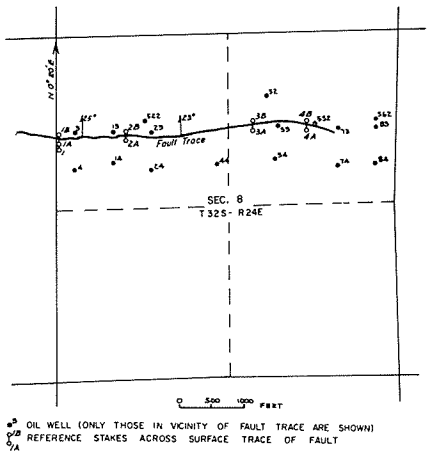


Fig. 2. Surface trace of fault and location of reference stakes from James Wilt (1958).

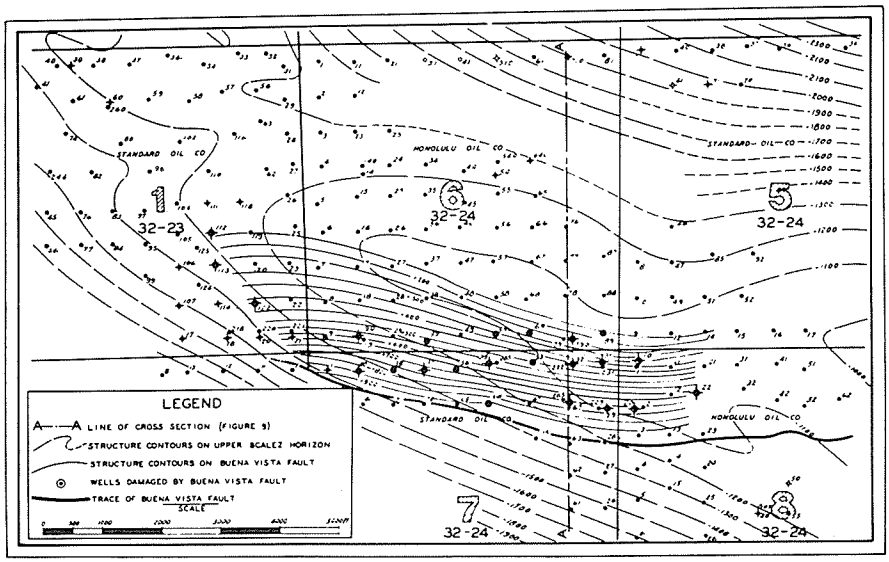


Fig. 3. Map of wells at Buena Vista Thrust Fault (from Thomas W. Koch 1933).

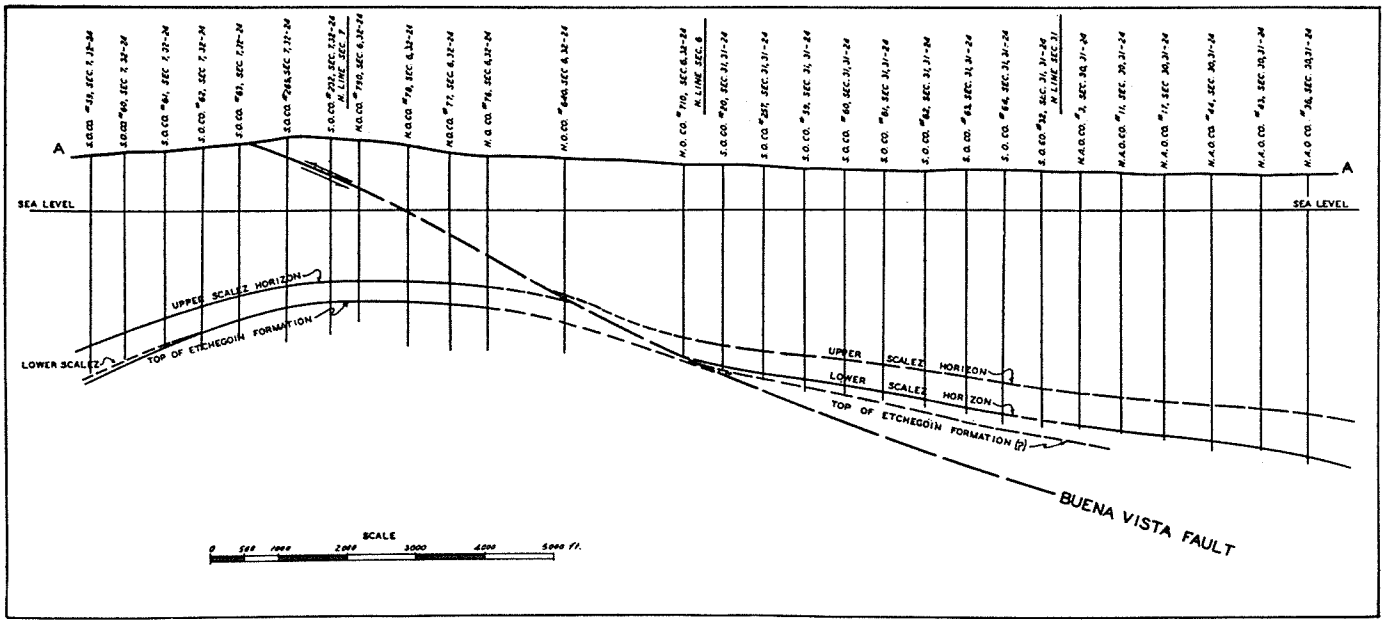


Fig. 4. North-south section through Buena Vista anticline near east line of Section 7, T. 32 S., R. 24 E. Buena Vista thrust is an active fault moving at present. (From Thomas W. Koch 1933)

Koch postulated that the origin of the fault was in a bedding-plane slip on the north flank of the Buena Vista anticline and that fault movement was simply accommodation in the bedding to continuous compressive forces acting on this still-growing fold. He concluded from structural and stratigraphic studies that the Buena Vista fold and other surface anticlines in this general area began to form not later than the beginning of the Pliocene epoch. The rate of folding (and consequent uplift) probably has not been constant during all this time. The strong orogenic pulse that occurred in middle or late Pleistocene time (about 500,000 years ago) may have produced a rate of uplift or folding much more rapid than the rate prior to that time, and it is conceivable that the present rate of movement on the Buena Vista thrust fault is comparable to movement during the most intense period of orogeny in the past.

The active faults and frequent earthquakes in the southern San Joaquin Valley suggest that the mid-Pleistocene orogeny is still in progress. It would be interesting to see an analysis of Coast and Geodetic leveling data for this area to see if the Buena Vista hills are rising with respect to the valley floor. Evidence presented by the investigators of this fault movement would seem to suggest that the fold is growing and that the elevation of the Buena Vista Hills may indeed be increasing.

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Wilt, J. W., 1958, Measured movement along the surface trace of an active thrust fault in the Buena Vista Hills, Kern County, California, Seismological Soc. America Bull., V. 48, pp. 169-176.

Abandoned 2-inch fuel line in north half of section 1, T. 32 S., R. 24 E., showing character of buckling it suffered at trace of Buena Vista fault. (From Thomas W. Koch, 1933)

Although tectonic subsidence no doubt has occurred, and may still be occurring, it is extremely difficult to measure because of the more obvious shallow subsidence in the southern San Joaquin Valley. The shallow subsidence is of two kinds. One type of subsidence is due to application of water to the surface soil and is localized in areas of low-density soils that have become saturated. The other type of subsidence is regional in extent and is caused by compaction of fine-grained sediments due to withdrawal of fluids from the subsurface.

Subsidence due to saturation of surface soils is widespread on the west side of the San Joaquin Valley and occurs wherever low-density soils become saturated with water, mainly from irrigation and from waste water disposal. The low-density soils were deposited mostly as debris flows (or mud flows) during torrential storms in the past and have never been wet to the point of saturation since their deposition. When they are saturated for the first time, the grains are rearranged into a more compact and dense type of packing and the resulting volume decrease causes the land surface to subside. Subsidence areas, with their surrounding zones of peripheral cracking, sometimes form spectacular depressions. The area of waste water disposal sumps east of Maricopa is one of the most interesting to visit in the field.

The Valley Waste Disposal Company's open sump and injection well field provide good examples of subsidence due to saturation of surface soil. The open sump, in Section 7, T 11 N, R 23 W, SBBM, has been receiving oil field waste waters for 6½ years, and during that time approximately 31,000,000 barrels (1,302,000,000 gallons) of water have been applied to the soil in this sump. The land surface here was level before water was applied, and the subsidence appears to have been about 13 feet in the oldest (wettest) part of the sump.

Another interesting case of subsidence can be seen at well No. 8 in the Valley Waste injection well field just east of the open sump area (Section 5, T 11 N, R 23 W, SBBM). Here a shallow casing failure allowed about 265,000 barrels (11,130,000 gallons) to leak out into the near-surface soil within a period of about 3 weeks. The resulting subsidence area is about 250 feet in diameter and about 5 or 6 feet deep. It is perfectly symmetrical around the well, and large concentric cracks in the ground are conspicious all around the depression. Subsidence stopped when the well was abandoned in August of 1964.

SUBSIDENCE IN THE SOUTHERN SAN JOAQUIN VALLEY

The California Aqueduct passes through many miles of low-density soils along the west and south sides of the San Joaquin Valley, and extensive reaches of the aqueduct alignment have been treated to preconsolidate the soils prior to aqueduct construction. This has been done by ponding water for periods up to 18 months in large ponds along the alignment and allowing the soil to become saturated so that maximum subsidence will occur before construction begins. It is hoped that by this method of preconsolidation the completed aqueduct will be protected from the effects of near-surface soil subsidence. The Main Road Guide will visit some of these preconsolidation pond areas, and the interested reader is referred to the road log of that trip for sites where this type of preconsolidation treatment may be seen in the field.

Regional subsidence, caused by a decline in ground water levels, has been a subject of study by the U. S. Geological Survey for a number of years. Poland and Davis (1956) have described areas of subsidence in the central and northern part of the San Joaquin Valley, and Lofgren (1963) has reported on this type of subsidence at the southern end of the valley. The total area affected is about 3,000 square miles, with about 400 square miles being in the southern San Joaquin Valley in the area covered by this field trip.

The accompanying map in Figure 5 shows the area of subsidence in the southern San Joaquin Valley. Although the contours on the map show a subsidence for the period 1957-65 of about 4 feet in the lowest part of the area, the long-time maximum subsidence here is almost 8 feet. This type of regional subsidence is being measured in two ways: by periodic leveling by the U. S. Coast and Geodetic Survey; and by stationary deep recorders installed and maintained by the U. S. Geological Survey.

At the compaction-recorder station shown on the map there are three specially designed compaction recorders that have been maintained by the U. S. Geological Survey since 1960. Lofgren (1961) has described the method of installation and operation of these recorders in the San Joaquin Valley. Each recorder assembly consists of a heavy weight emplaced in the formation below the bottom of a well casing, with an attached cable stretched upward in the casing and counterweighted at the land surface to maintain constant tension. A monthly recorder mounted over the open casing measures directly the amount of cable that appears above the casing as subsidence occurs. About 30 of these compaction recorders are now operating throughout the subsidence areas of California.

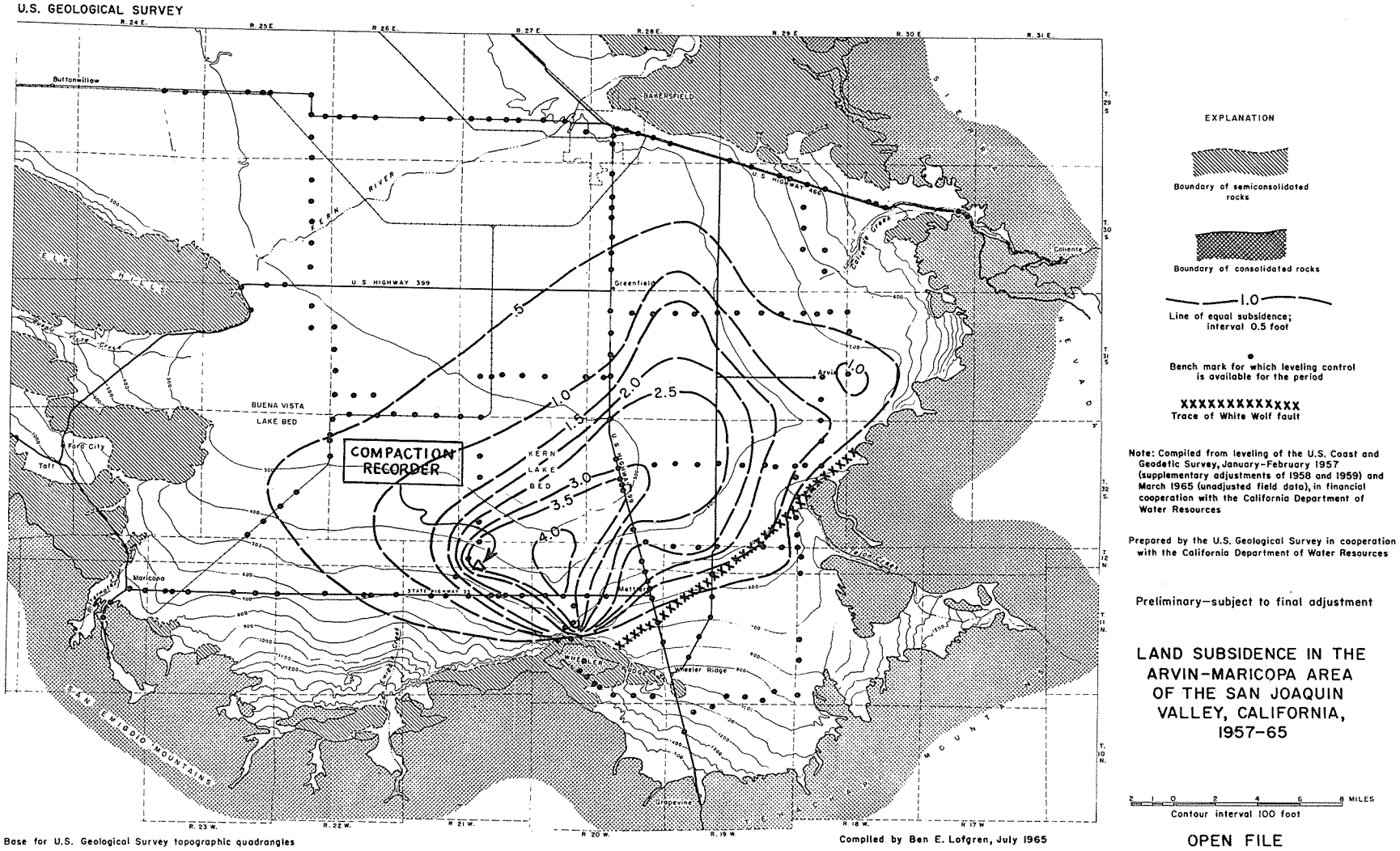


Fig. 5. Land subsidence in the Arvin-Maricopa Area.

The three compaction recorders at this location are anchored at depths of 105, 810, and 1,500 feet, respectively. By comparing the compaction records from these three recorders, the amount of compaction occurring in each depth interval can be computed. The total subsidence at this location is determined by periodic releveling of surface bench marks referenced to distant stable bench marks. Water-level recorders are also maintained in these shelters to keep track of the trend of the water-level fluctuations in the area.

Figure 6 is a digram of the compaction-recorder installation.

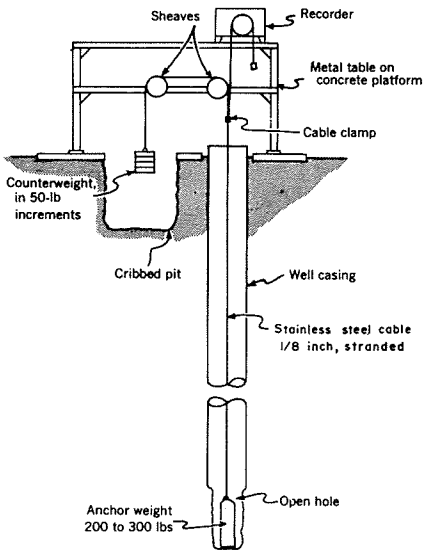


Fig. 6. Diagram of compaction-recorder installation.

Figure 7 shows the measured compaction in the three depth intervals, and the subsidence of bench mark W1156 since 1960. As shown, compaction to 1,500 feet roughly equals the surface subsidence. Compaction is directly related to changes in effective stress, which in turn is related to changes in water level in deep, confined aquifer systems and in shallow, unconfined aquifers.

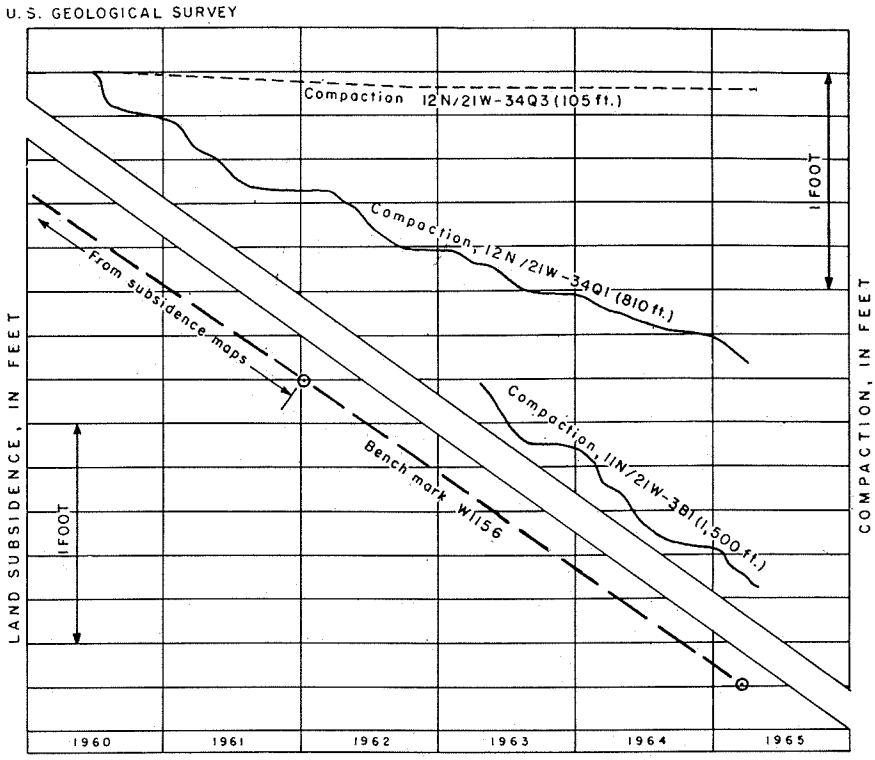
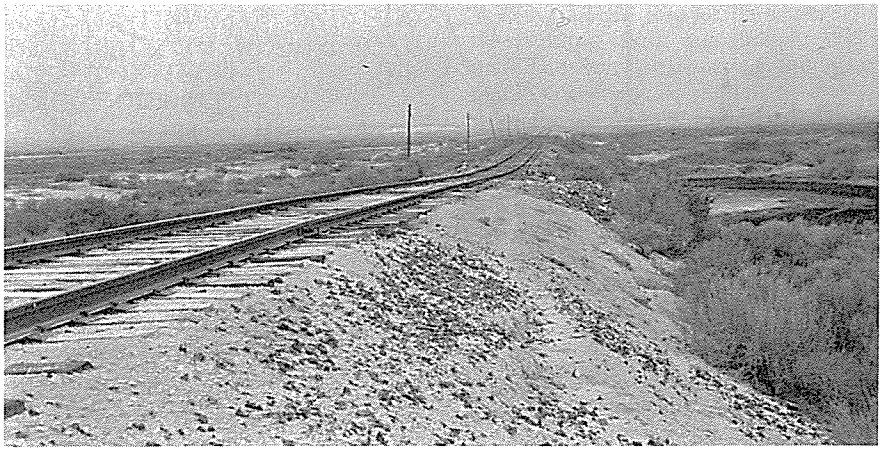


Fig. 7. Land subsidence and measured compaction near Lakeview, California, 1960-65.

Subsidence at waste water injection well No. 8 in Section 5, T. 11 N., R. 23 W. Man is standing on capped well head.



Subsidence along Sunset Railroad bed at waste water sump.

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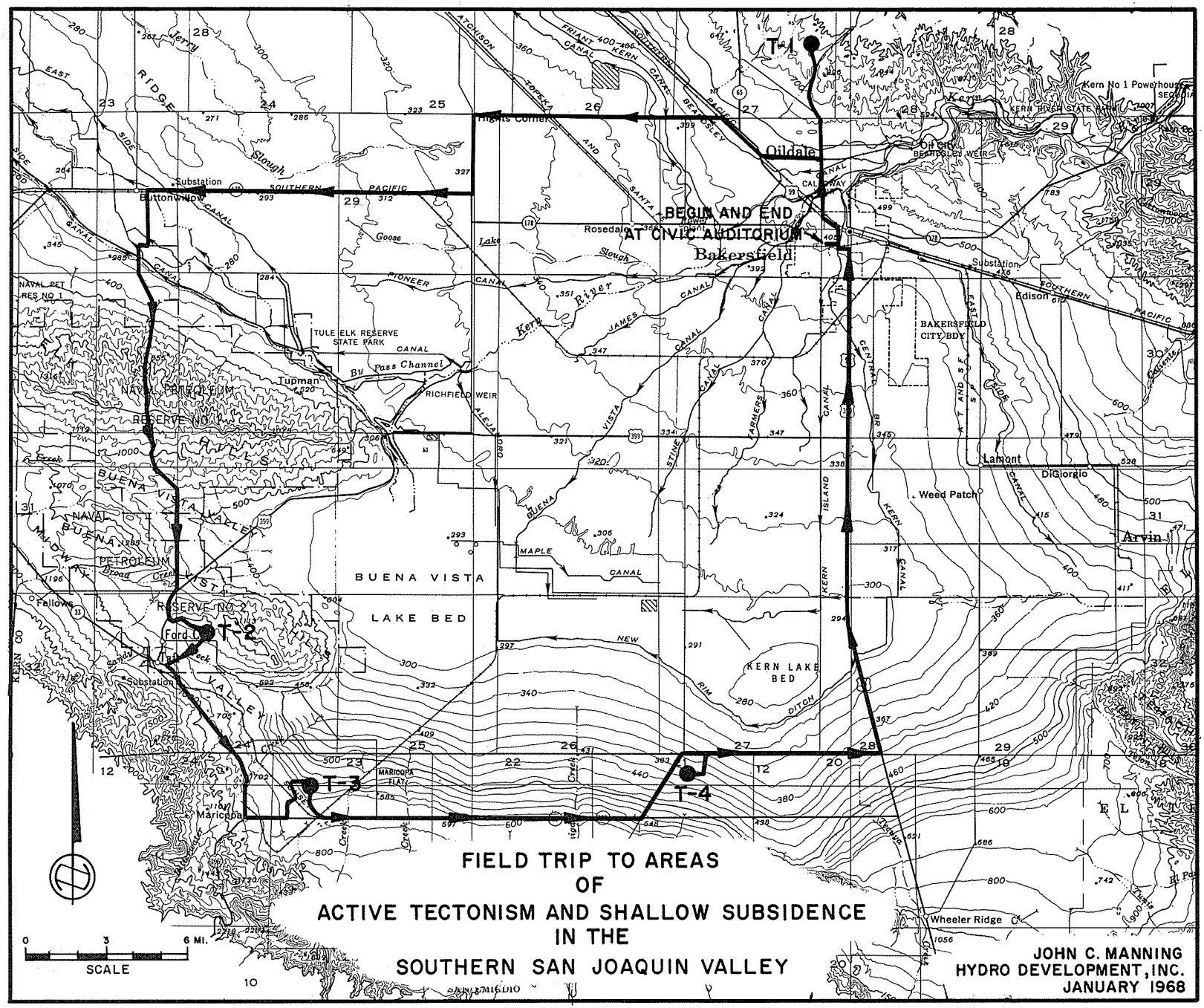

T-1
T-2
T-3
T-4
BEGIN AND END
AT CIVIC AUDITORIUM
Oildale
Bakersfield
Rosedale
Buttonwillow
Tupman
Lamont
Arvin
DiGiorgio
Weed Patch
Maricopa
Wheeler Ridge
Edison
Fellows
Ford City
Kern No 1 Powerhouse
BUENA VISTA
LAKE BED
KERN LAKE BED
NAVAL PETROLEUM RESERVE NO 1
NAVAL PETROLEUM RESERVE NO 2
TULE ELK RESERVE STATE PARK
BAKERSFIELD CITY BDY
MARICOPA FLAT
RICHFIELD WEIR
BEARDSLEY WEIR
Kern River
Goose Lake Slough
Buena Vista Slough
Pioneer Canal
James Canal
Stine Canal
Farmers Canal
Maple Canal
New Rim Ditch
Kern Island Canal
Friant Kern Canal
Southern Pacific
Atchison Topeka and Santa Fe
Highway 58
Highway 178
Highway 99
Highway 65
Highway 33
Highway 399
Highway 119
Highway 166
Substation
SCALE
0
3
6 MI.
FIELD TRIP TO AREAS
OF
ACTIVE TECTONISM AND SHALLOW SUBSIDENCE
IN THE
SOUTHERN SAN JOAQUIN VALLEY
JOHN C. MANNING
HYDRO DEVELOPMENT, INC.
JANUARY 1968

The map on the opposite page shows the main route of the field trip, and the log below supplies details for the route. On the map each area of stops is marked T-1, T-2, T-3, and T-4, but there are several locations for observation and study at each T stop. The reader is referred to the descriptive material preceding this road log for detailed information on the various features to be observed at the main stops.

CUMULATIVE MILEAGE	MILEAGE TO NEXT COMMENT

0.0 .05
Leave Bakersfield Civic Auditorium heading east on Truxtun Avenue.

.05 .65
TURN LEFT (north) on Q Street at traffic signal.

.7 .3
TURN LEFT on Golden State Highway.

1.0 4.3
Take Oildale turnoff to right at traffic circle and proceed north on Chester Avenue.

5.3 .9
Bear right on Woody Road (towards Glenville).

6.2 1.2
Note slight fault scarp on hills to the right. Scarp is readily visible when light conditions and vegetative cover on hills combine to highlight it. At other times it may be necessary to have someone point it out in order to see what you are supposed to be looking at. You just went over fault trace in the road, but it will be more apparent on the return trip after you have learned what to look for.

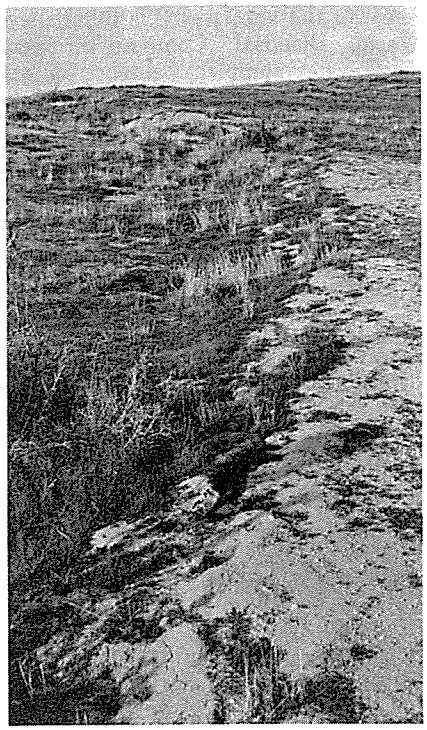
7.4 .1
STOP T-1a. Kern Front Fault. Woody Road crosses Kern Front Fault for second time. Note transverse cracks in pavement paralleling trend of fault. A small scarp is visible in the field on the left side of the road.

7.5 .28
TURN LEFT ONTO PAVED OIL FIELD ROAD.

7.78 .57
Road again crosses fault. Note six inch drop in road where crossed by the fault. Road must be repaired frequently at this crossing.

8.35 .1
TURN RIGHT AND DRIVE UP HILL.

8.45 .95
STOP T-1b. Kern Front Fault. Road crosses Kern Front Fault and there is a noticeable scarp in pavement where fault offsets road surface. The fault scarp is very well developed



Kern Front Fault scarp.

north of the road, and movement is obviously faster than erosion along this reach of fault. Fault zone is softer than surrounding ground and is favored by gophers as a place to burrow. You can trace fault by line of burrows as well as by scarp. TURN AROUND and retrace route back to Woody Road.

9.4 1.5
TURN RIGHT AND HEAD SOUTH ON WOODY ROAD.

10.9 .2
Road crosses fault at this point. TURN TO THE RIGHT AND CIRCLE AROUND THE STADIUM.

11.1 2.3
At southwest corner of stadium note crack in stadium embankment to the left which lines up with offset and cracks in paved road to the right. CONTINUE AROUND STADIUM BACK TO WOODY ROAD AND CONTINUE SOUTH TOWARDS OILDALE.

13.4 2.25
TURN RIGHT ON NORRIS ROAD (traffic signal). Norris Road runs along north side of railroad tracks.

15.65 1.75
TURN RIGHT ONTO HIGHWAY 99.

17.4 .15
TURN OFF AT 7th STANDARD ROAD.

17.55 .8
TURN LEFT AND HEAD WEST ON 7th STANDARD ROAD.

18.35 1.55
Lerdo Canal.

19.9 .4
Friant-Kern Canal.

20.3 6.9
Calloway Canal.

27.2 3.0
TURN LEFT (south) ON ENOS LANE.

30.2 12.2
TURN RIGHT (west) ON HIGHWAY 58.

42.4 3.05
TURN LEFT (south) ON MIRASOL AVENUE (Taft Highway) in middle of downtown Buttonwillow.

45.45 .95
Kern River Flood Channel.

46.4 12.1
California Aqueduct.

58.5 1.7
TURN RIGHT ONTO HIGHWAY 119.

60.2 .1
TURN LEFT ONTO HARRISON STREET (just beyond Ford City turnoff).

60.3 1.45
TURN RIGHT TOWARD 7D PLANT.

61.75 .15
TURN LEFT AND HEAD FOR WHITE BOX ON HILL.

61.9 .05
STOP T-2a. Buena Vista Thrust Fault The 4-foot-square white box, which is sitting right on top of the fault scarp, houses a creep meter for measuring fault movement. This instrument was installed by the U.S. Environmental Sciences Services Administration (ESSA), and a description of its function is contained in a paper by Nason and others to be found in an earlier section of this guidebook. Just to the west of the white box are two yellow stakes and a survey hub low on the ground between them. This is part of J. W. Wilt's 1-1A-1B measuring course for determining fault movement. Wilt's map showing locations of the measuring traverses is shown in Figure 2 in the section preceding this road log. The 1A hub (nearest you at this point) is on the footwall block just south of the surface trace of the fault. If you look westerly and easterly from this point (station 1A or the white box) you can see the low scarp of the thrust fault where it makes a distinct break in slope on the hillside surface.

NOW GO EASTERLY ALONG OILED ROAD JUST ABOVE FAULT SCARP AND PASS WELLS TOC-8-3 AND TOC-13.

61.95 .15
Well TOC 8-3.

62.1 .05
Well TOC 13. The cellars in these wells were excavated below the fault plane in an effort to prolong the life of the wells. In spite of this, fault movement has so deformed the well casings that the wells have had to be taken out of service.

HEAD DOWN THE HILL JUST PAST WELL TOC-13. Notice bump in road where road crosses fault scarp.

62.15 .25
STOP T-2b. Buena Vista Thrust Fault. Just east of road is Wilt's 2A measurement hub. If you look at asphalt pavement where road crosses fault trace, you can see where movement is disturbing and crumbling asphalt paving along trace of moving thrust fault.

FROM HERE PROCEED EASTERLY DOWN THE HILL TO A MAIN PAVED ROAD.

62.4 2.1
TURN RIGHT ON MAIN PAVED ROAD AND HEAD TOWARD TAFT.

64.5 6.6
TURN LEFT ON HIGHWAY TOWARD MARICOPA.

71.1 1.45
TURN LEFT ONTO HIGHWAY 166.

72.55 .25
TURN LEFT ONTO PAVED ROAD.

72.80 .2
Fence at east end of waste-water sump area. The area beyond the fence to the left (west) is the Valley Waste Disposal Company's open waste-water sump. Subsidence of up to 13 feet has occurred here through settlement of the surface soil due to saturation with water (see descriptive material preceding this road log for more details).

73.0 .5
BEAR RIGHT ON MAIN GRAVEL ROAD THROUGH OIL FIELD.

73.5 .15
TAKE LEFT FORK IN ROAD, PROCEED 100 FEET AND TURN LEFT.

73.65 .6
STOP AT RAILROAD TRACK, look both directions, and note the subsidence of what were once level tracks.

BEAR TO LEFT ON MAIN ASPHALT ROAD.

74.25 .45
TURN RIGHT ON PAVED ROAD.

74.7 .45
TURN RIGHT (just past green tanks and separators).

75.15 .35
TURN RIGHT.

75.5 .1
TURN RIGHT AND DRIVE ALONG PIPE LINE. Be careful not to drive too far into subsidence area.

75.6 .05
STOP T-3. Collapse and subsidence due to break in well casing at well No. 8. Note arcuate step faults around subsided area. (Again, see descriptive material preceding road log for details.)

TURN AROUND AND HEAD BACK.

75.65 .05
TURN LEFT ON DIRT ROAD TOWARD RAILROAD TRACKS.

75.7 .5
TURN LEFT AND CONTINUE PARALLEL TO RAILROAD.

76.2 .15
PASS THROUGH YARD AT SILICA PLANT AND CROSS RAILROAD TRACKS.

76.35 12.35
TURN LEFT (east) ONTO HIGHWAY 166.

88.7 .6
TURN LEFT ON OLD RIVER ROAD.

89.3 2.4
California Aqueduct.

91.7 .5
TURN RIGHT ON COPUS ROAD.

92.2 1.2
TURN RIGHT ON SCHALLOCK ROAD.

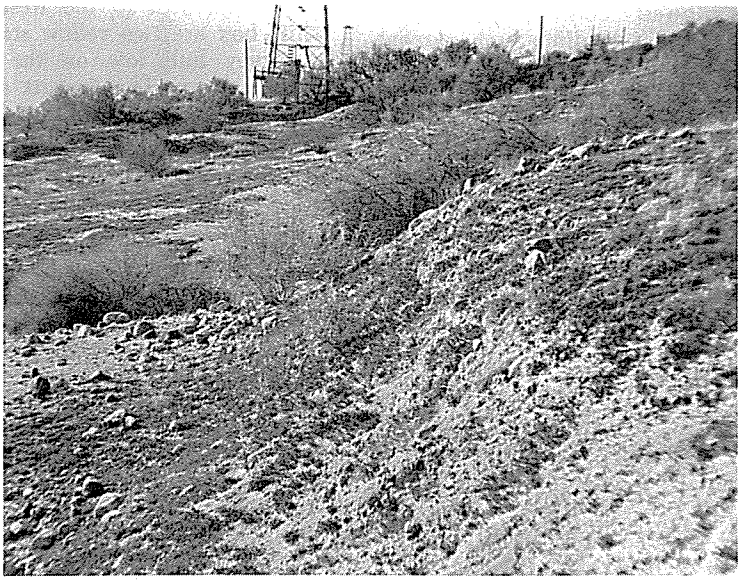
93.4 .35
TURN RIGHT ON DIRT ROAD (extension of Valpredo Avenue).

93.75 1.55
STOP T-4. Deep subsidence recorder in locked shelter. (See descriptive material preceding road log for details and description of recorder.)

TURN RIGHT AND RETURN TO COPUS ROAD.

95.3 7.0
TURN RIGHT (east) ON COPUS ROAD.

102.3
TURN RIGHT ONTO HIGHWAY 99 NORTH AND CONTINUE NORTH TO BAKERSFIELD.



Fault scarp of Buena Vista Thrust.

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GEOLOGIC MAP OF
TEMBLOR RANGE
SAN LUIS OBISPO AND KERN COUNTIES, CALIFORNIA

TO ACCOMPANY
1968 FIELD TRIP GUIDEBOOK

FORMATIONS

QUATERNARY

- **Recent**
  - Qa — **ALLUVIUM**
  - Ql — **LANDSLIDE RUBBLE**
- **Pleistocene**
  - Qt — **TERRACE GRAVEL**
  - Qr — **TULARE** gravel, sand, in San Joaquin Valley
  - Qp — **PASO ROBLES** gravel, sand, & silt

TERTIARY

- **Pliocene**
  - Pe — **SAN JOAQUIN** clay and **ETCHEGOIN** marine sand not in contact
  - Pp — **PANORAMA HILLS** gravel, sand, clay (nonmarine)
  - Pb — **BITTERWATER CREEK** shale, sandstone (marine)

unconformity ?

- **Miocene**
  - Ms — **SANTA MARGARITA** granitic conglomerate and sandstone
  - g s — g, granite landslide; s, schist landslide
  - Mr — **REEF RIDGE** diatomaceous shale
  - Mm — **UPPER MARICOPA or MONTEREY** (Antelope, Mc Donald; or Mc Lure) siliceous shale
  - Md — **LOWER MARICOPA or MONTEREY** (Devilwater, Gould) siliceous and clay shale
  - Mu — **BUTTON BED** sandstone
  - Mt — **"TEMBLOR"** shale, sandstone
  - Me — **MEDIA** shale
  - Mv — **TEMBLOR or VAQUEROS**
  - Ma — **CARNEROS** sandstone
  - Mi — **PLEITO** sandstone, shale
  - Mn — **SANTOS** shale

unconformity

- **Eocene**
  - Er — **POINT OF ROCKS** sandstone
  - Ec — **CANOAS or GREDAL** shale
  - Em — **MABURY** sandstone
  - Ea — **AVENAL** sandstone

unconformity

CRETACEOUS

- Kp — **PANOCHE** sandstone, shale
- Kk — **"KNOXVILLE"** shale, thin sandstones
- f — **FRANCISCAN** graywacke, shale, chert, greenstone
- Sp — **SERPENTINE** (intrusive into Franciscan and "Knoxville")
- hd — **HORNBLENDE DIORITE** ?

SYMBOLS

- marine sandstone
- marine ? conglomerate
- basalt
- crystalline basement complex

Contact — Fault (dashed where uncertain; dotted where concealed)

Strike and dip of beds

Strike and dip of overturned beds

Strike of vertical beds

Anticline / Syncline — Axes of folds showing direction of plunge

Abandoned test hole drilled for oil or gas

Field Trip Route

Compiled by T.W. Dibblee Jr. 1962

Cross sections revised by S.A. Carlson 1968
Drafted by M.B. Norman 1962 & D.H.H. 1968.

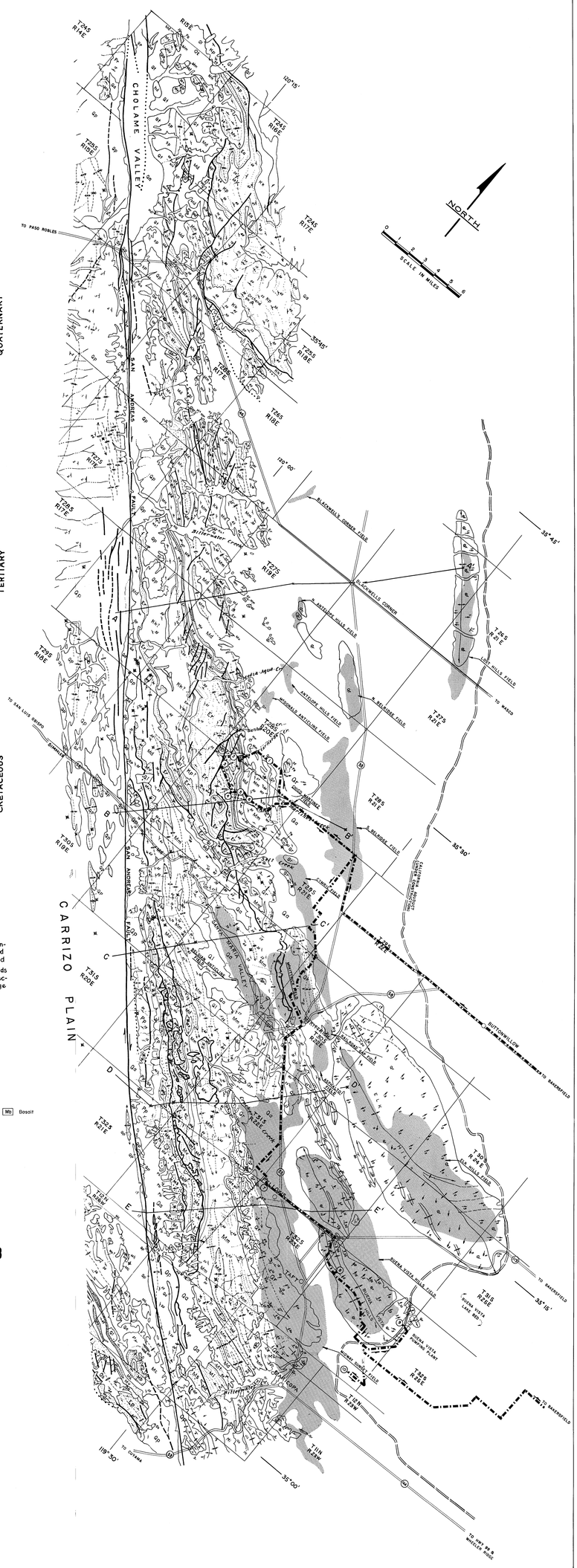
NOTE: For area southwest of San Andreas Fault see Geologic map by T. Dibblee in Guidebook "Geology of Carrizo Plains - San Andreas Fault," 1962, published by San Joaquin Geological Society - Pacific Section AAPG-SEPM.

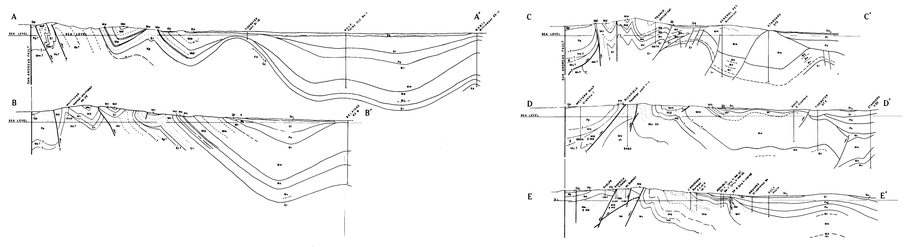
SUMMARY OF FORMATIONS WEST OF SAN ANDREAS FAULT

PLIOCENE —	Pm	Morales gravel, sand, silt
	Pq	Quatal clay
	Pr	Pancho Rico shale
MIOCENE —	Mc	Caliente non-marine beds, Mh Branch Canyon ss, Mb Basalt
	Ml	Soda Lake shale
MIO - OLIG —	Os	Simmler non-marine beds
PALEOCENE —	Ep	Pattiway ss, sh

PACIFIC SECTION
AAPG · SEG · SEPM
43RD ANNUAL MEETING

BAKERSFIELD, CALIF. MARCH 28, 29 & 30, 1968





SCALE — 0 1 2 3 4 MILES — 5000 feet — 10000 feet

CROSS-SECTIONS OF THE
TEMBLOR RANGE AREA, CALIFORNIA