REPORT

on

SITES ANTICLINE

for Consolidated Royalty oil Company

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GLENN AND COLUSA COUNTIES

CALIFORNIA

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BY

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1923

Peterson Salt Lake

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no maps were attached to the original in the file

THE SITES ANTICLINE

INTRODUCTION

The Sites Anticline is located in Colusa and Glenn Counties, North-Central California. It is one of possibly several folds adjacent to the Coast Range Mountains on the west side of the Sacramento Valley. The Anticlinal axis passes just west of the Town of Sites, from which the name was adopted.

The Structure is about nine miles due west of the town of Maxwell, a station on the Southern Pacific railroad. From Maxwell a good graveled road leads to Sites and thence westward directly across the anticline. Roads both north and south of Sites parallel the anticline and render access to the fold possible by automobile. Other roads leading west from Delevan and Willows likewise cross the anticline so that it is possible to visit any particular area with ease.

The region was chosen for investigation for oil and gas possibilities due to the known presence of oil and gas seeps in the district and to the reported occurrence of oil in several wildcat wells.

The district is mentioned in the publication of the California State Mining Bureau, Bulletin 69 and 89. In both reports the oil and gas possibilities are mentioned and the anticline roughly outlined. The structural conditions are not however sufficiently well developed to be of benefit to prospectors and the conclusions reached are not justified by the reconnaissance character of the work.

The present report with the accompanying maps contains data obtained by the writer and field party during the summer of 1923.

TOPOGRAPHY

The Sites anticline is outlined on the east and west by high ridges of sandstone, members of the Chico formation. The escarping ridges are more resistant to erosion than the softer shales on the anticlinal axis, as a result of which the anticline is marked by a more or less smooth valley bounded by relatively high hills. Within the valley proper are many low undulating ridges and topographic domes. From both the east and the west the valley floor rises toward the axis of the anticline, which causes at least one of the streams on the west flank to flow southward around the southern closure of the anticline; then northward and finally eastward toward the Sacramento Valley. This character of drainage is seen on the map in Section 30, Township 17 North, Range 4 West.

The anticlinal axis on the surface is marked by a line of low ridges which at places may attain an elevation of two hundred feet or more above the valley proper.

The valley floor is largely filled with alluvium but in nearly all of the stream beds the underlying rock is exposed. There are also several resistant sandstone members which outcrop through the alluvium as on the flanks of the dome-shaped hills.

Although the escarpments are extremely rough and rise sharply from the valley, the drillable area is generally smooth and given to the cultivation of grain crops. It so happened that the grain was standing ready for harvest at the time the structure was mapped and it is possible that some significant outcrops were thereby concealed.

STRATIGRAPHY

The surface rock involved on the Sites Anticline, as well as that which would be encountered in drilling, belongs entirely (?) to the Cretaceous system, although it is divisible into the upper and lower series. It seems probable that on paleontological evidence the upper series may be again subdivided into two formations and the lower into possibly three. The division and subdivisions may be best shown in tabulated form.

System	Series	Formation
CRETACEOUS	Upper Cretaceous	Upper Chico Formation
		Lower Chico Formation
	Lower Cretaceous	Horsetown Formation
		Knoxville Formation
?	?	Sub-Knoxville Formation

There are represented in the above formations a total thickness of some 30,000 feet of rock, but only the Lower Chico and possibly the uppermost Horsetown would be penetrated by a well. This rather exceptional thickness, for rocks deposited in a more or less closely confined area, was not measured entirely in the vicinity of this anticline. The measurement is that of Mr. Diller, who examined the series that seventy-five miles north of Sites, and who reports thickness as follows:

Section on Elder Creek, Tehama County, California.

Upper Cretaceous

Chico Group . . . . . 3,897 feet

Lower Cretaceous

Shasta - Horsetown	6,109 feet
Knoxville	19,974 feet
	29,980 feet

Still further north in Shasta County, Mr. Diller reports the Chico and Horsetown formation to be in thickness:

Chico	3,625 feet
Horsetown	5,218 feet

The Chico Knoxville series has been the object of much discussion among geologists, but little detailed work has been done, so that when we refer to a particular formation it is necessary to closely define our terms. On the basis of lithology we might perhaps include in the Chico, rocks, which on faunal evidence belong to the Horsetown.

But whatever may be the true divisions of the strata, it certainly appears that the entire series was deposited without any significant breaks, so that there is a gradation from the Knoxville shales, at the base of the section, to the massive sandstones of the Chico formation at the top, the intermediate Horsetown partaking somewhat of the characteristics of both.

Considering the series, therefore, in its general and type occurrence, we find the Knoxville formation to be composed essentially of black and blue shale with many, but thin, beds of sandstone. These sandstones are not suitable as oil reservoirs. The Knoxville therefore is that formation at the base of the series including an unusual thickness of shale. It can be easily identified in the section by its thickness. It may also be identified by its typical fauna, being especially notable for the occurrence of Aucella therein.

The typical Knoxville has a rather wide distribution extending from San Luis Obispo County in Southern California to near Seattle in the State of Washington.

Above the Knoxville, the Horsetown formation is noticeably more sandy, but still contains great thickness of shale. There is no distinct stratigraphic or lithological break although there is a change in the fossil forms. The Aucella, so prevalent in the Knoxville apparently does not extend upward past the lowermost part of the Horsetown, at which position there is an intermingling of true Knoxville and true Horsetown species.

The Horsetown contains a rather distinctive fauna, rich in ammonites and cephalopod forms, especially of the genera Desmoceras, Lytoceras and Phylloceras. It is only by determination of such forms that the formation can be distinguished from the Chico above, or the true Knoxville below, for the Upper Horsetown quite resembles the Chico Lithologically and the lower Horsetown could well be mistaken for the Knoxville.

The Horsetown has a somewhat limited occurrence and appears to be restricted to the Sacramento Valley. It is not found in Southern California.

Above the Horsetown and apparently conformable therewith is a formation composed essentially of thick massive sandstones. This formation is known as the Chico. However the Chico contains many shale members which may reach a maximum of 1,000 feet in thickness. The upper Chico in Southern California contains a thick member of diatomaceous shale, known as the Moreno shale, but this member has not been identified in Northern California. The fauna of the Chico is rich in gastropod forms but contains many cephalopods closely related to those of the Horsetown. It is

probable that even the Horsetown ammonites may extend more than half way up into the Chico.

Having some idea of the general characteristics of the formations, there is here included the section measured by Diller and Stanton and recorded in the Bulletin of the Geological Society of America, Volume 5, 1894. These sections are included for comparative purposes only and later we shall see the similarity with the actual strata exposed on the Sites Anticline.

In this report, it must be remembered that we are dealing with rocks concerning which very little is known and all the evidence leading to the conclusions is submitted. There are no known methods for quick determination of these formations and yet it is essential that we be as positive as is possible when discussing the rocks in which the oil may, or may not exist.

THE SHASTA-CHICO SERIES
By Diller & Stanton
Bull. Geol. Sec. Am. V. 5, 1894

Sections of the Series

Elder Creek Section, Tehama County, California

Feet	Rocks	Fossils
500	Shales with some thin sandstones	(Inoceramus (Pecten, sp. a. (Pectin operculiformis (Exogyra parasitica.
1000	Sandstones	(Amm. (Pachydiscus) (Cucullaea truncata. (newberranus (Trigonia leana
1500	Shales containing one 25 foot bed of ss.	(Inoceramus witneyi. (Grigonia evansana. (Meekia sella. (Coralliochama orcutt.
2000	Massive Sandstone	(Thetis annulata. (Chione varians. (Chione varians (Caryatis Nitida. (Tellina ashburneri (Thetis annulate.
2500	Conglomerate ..	(Tellina parilis (Dentalium stramineum, (Gyrodes expansa. (Lunatia avellana. (Ancurra californica (Gyrodes expansa. (Anchura californica. (Anchura falciformis.
	Massive sandstone with thin conglomerate	.....(Cinulia matthewsoni. (Actaeon inornatus.

Elder Creek Section, Tehama County, California (Cont'd)

Feet	Rocks	Fossils
		(Pecten operculiformis
3000	Shales	(Cucullaea truncata.
		(Nemodon vancouverensis
	Conglomerate with limestone pebbles.	(Trigonia evansana
		(Trigonia leana
		(Trigonia aequicostata (?)
3500	Sandstone, shale and conglomerate.	(Pectunculus veatchi.
		(Meekia sella.
4000	Chiefly conglomerate	(Chione varians.
		(Carvatis nitida.
		(Coralliochama orcutti.
4500	Shales with thin ss.	(Dentalium stramineum.
		(Lunatia avellana.
		(Anchura californica.
5000	Shales	(Amm. (Desmoceras), sp.a.
	Sandstone	
6000	Shales	
		(Pecten operculiformis.
6500	Shales	(Nemodon vancourverensis.
7000	Shales	
7500	Shales and thin ss.	
8000		
8500		
9000	Shales	
9500	Shales and sandstone	(Inoceramus sp.
10000		(Amm. (Desmoceras), sp. c.
10,500	Shales twisted and veined	
11,000		
11,500		
12,000	)	(Belemites impressus.
12,500	) Shales with	(Amm. (Desmoceras) sp.
13,000		
13,500	) calcareous layers	(Belemnites impressus.
14,000	)	(Amm. (Lytoceras) batesi.
14,500		
15,000		
15,500		
16,000		
16,500		
17,000		(Ferns and other plants.
17,500		(Locality d.)
18,000	Shales, with calcareous	
18,500		
19,000	layers, in places much	
19,500		
20,000	folded.	
20,500		
21,000		
21,500		
22,000		

Elder Creek Section, Tehama County, California (Cont'd)

Feet	Rocks	Fossils
22,500		
23,000	Shales and shaly sandstones	
23,500		
24,000	with calcareous layers.	
24,500		
25,000		
25,500	Shales and shaly	
26,000		
26,500	Sandstone with small sand (Aucella Piochi	
27,000		
27,500	stones increasing.	
28,000		
28,500		
29,000		
29,500		
30,000		
	Serpentine (Periodite).	

Section on North Fork of Cottonwood Creek

Feet	Rocks	Fossils
500	Shales	(Nucula truncata
1000	Sandstones and shales	(Nucula truncata (Amm. (Scholoenbachia) chicoensis. (Inoceramus whitneyi.
1,500	Shales, with occasional thin beds of sandstone..	(Pecten, sp. a. (Potamides tenuis (?) (Lunatia, sp. (Trochosmilia, sp.
2,500	Conglomerate and Sandstone ..	(Pecten operculiformis. (Cucullaea truncata. (Trigonia evansanta. (Meekia sella. (Chione varians. (Caryatis nitida. (gyrodes expansa. (Anchura californica (Cinulia obliqua (Amm. (Acanthoceras), sp. (Amm. (Desmoceras), sp. a.
3,000	Shale	(Pecten operculiformis. (Exogyra parasitica. (Nemodon vancourverensis.
	Conglomerate and sandstone	(Cucullaea truncata. (Trigonia evansana. (Trigonia leana.
3,500	Shale	(Coralliochama orcutti. (Anchura falciformis.

Section on North Fork of Cottonwood Creek (Cont'd)

Feet	Rocks	Fossils
	Sandstone and shale ..	(Amm.(Desmoceras) Hoffmanni ? (Amm.(Desmoceras), sp.a. (Amm.(Desmoceras), sp.b.
45,000?	(continued in Horsetown beds, Page 15)	
4,000	Shales, considerably dis-	(Exogyra parasitica. (Cucullaea truncata.
4,500	turbed, without prominent bed of sandstone	(Lunatia Avellana. (Amm. (Schloenbachia) inflata
		(Crioceras percostatus. (Ancyloceras lineatus.
5,000		(Turnus plenus
5,500		(Amm.(Desmoceras) hoffmanni
		(Crioceras percostatus.
6,000		
6,500	Sandstone	(Pecten operculiformus (Nemodon vancouverensis (Trigonia leana (Trigonia aequicostata. (Diptychoceras laevis.
7,000	Shales, with thin beds of sandstone near base.	(Amm.(Lytoceras) batesi. (Amm.(Desmoceras) hoffmanni (Amm. (Phylloceras?) ramosus. (Amm.(Hoplites) remondi. (ancyloceras remondi.
7,500		(Pecten operculiformis (oyytoma mucronata. (Plicatula variata. (Nemondon vancouverensis. Trigonia aequicostata.
8,000		(Pleuromya laevigata. (Lunatia avellana, (Helicaulax bicarinata. (Potamides diadema. (Belemnites impressus.
	Sandstone	(Pecten operculiformis. (Plicatula variata. (Nemodon vancouverensis. (Trigonia aequicostata. (Pleuromya laovigata. (Lunatia avellana. (Potamides diadema. (Amm. (Lytoceras) batesi. (Diptychoceras laevis.
8,500		(Belemnites impressus
	Shales	
9,000	Conglomerate	
	Diorite	

Both of the above sections were measured many miles to the north of the Sites Anticline, but as the formations are quite persistant, it may be assumed that the same general characteristics prevail at Sites.

Before we discuss the rocks exposed on the anticline, it is well to understand the general structure of the district. The Sites anticline is a comparatively minor fold situated on the east flank of a great uplift, the Coast Range Mountains. From the evidence now at hand, it would seem that the Coast Range was first upheaved at, or near, the close of the Jurassic Age. Further movement occurred at the close of the Knoxville epoch, at which time a portion of California was withdrawn from oceanic submergence, for we find in Southern California that the Chico rests directly on the tilted edge of the Knoxville, the Horsetown being entirely absent. In northern California, however, the Mountain range failed to act as barrier to the sea, and rapid sedimentation was in progress throughout the Sacramento Valley during the Horsetown epoch.

Knoxville time was also marked by great intrusions of peridotite in the Coast Range. These intrusions had ceased before the Chico was deposited, for on the west side of the mountains, the coast side, it is reported that the Chico rests upon the metamorphosed peridotites.

Therefore such intrusions could only have effected the Jurassic and earliest Cretaceous strata and, together with a metamorphosed sedimentary series, the Franciscan formation, furnished the basement upon which the Younger, Cretaceous rocks were deposited.

The movement at the close of the Jurassic was not confined however to the Coast Range province but effected likewise, and gave the final folding to, the older Sierra Nevada Mountains on the East

side of the Sacramento Valley. We cannot positively say that the Great Valley of California, including both the Sacramento and the San Joaquin, was formed at the close of the Jurassic, for its inception may have been much earlier. Nevertheless after the inception, the movements were recurrent until after the Eocene period, possibly in late Miocene time the valley was finally lifted above sea level and began to assume its present configuration.

The Great Valley is bounded on the east by the Sierra Nevada Mountains and on the west by the Coast Range. The sedimentary Cretaceous strata is concealed in the central portion of the valley by overlying Tertiary and Quaternary deposits, but reappear on the flanks of both mountain ranges. The general structure is therefore seen to be synclinal; the Great Valley forming a geosyncline between the ranges, with the Sites Anticline forming a minor fold on the west flank of the geosyncline.

The rocks effected by folding at Sites have a time range from Jurrasic to possibly Eocene and therefore we may say that the fold was formed possibly in Miocene time, occasioned by the final movement in the Coast Range province.

It is also clearly evident that the Cretaceous sediments were laid down under conditions of continued subsidence without serious interruption. The sea during this age was transgressing eastward.

The fossils collection indicate a decided change from boreal conditions in the lower Cretaceous to tropical conditions during the Horsetown and Chico time. Such climatic changes must have had a great influence upon the character of the organisms which inhabited the waters and consequently a direct effect upon the source material from which the oil or gas would be derived.

ROCKS EXPOSED ON THE SURFACE

There are roughly about 11,000 feet of rocks exposed on the east flank of the Sites anticline. This includes all the rocks from the axis of the structure to the uppermost beds which disappear beneath the alluvium of the valley. As we approach the anticline from the east the first rocks encountered are dipping eastward at an angle of 15° to 30°. These rocks comprise a series of blue shales and chalk grading downward into sandy shale and shale, intercalated with thin sandstones. Occasionally rather thick massive sandstones appear, which become fairly numerous from about 4500 to 5500 feet stratigraphically below the uppermost shale and chalk beds.

This upper series, comprising 5500 feet of rocks, is considered as a unit, and although no fossils could be found, it is tentatively assigned as belonging in the Tertiary system and probably of Eocene age. That it can be considered at least as a mapable unit is evident even from the topography of the area underlain by the series. The area is gently rolling with a gradual rise in elevation and rougher topography near the base of the section, which is a result of the numerous and resistant sandstone beds.

Below the strata considered above, there is a second series of rocks which are at least 5400 feet thick and which include groups of shales, sandstones and conglomerates. The upper group of this series is 1200 feet and is composed of massive, light greenish, hard sandstones, which we will designate as the Quarry Group. In the past these sandstones have been rather extensively quarred for building stone. The uppermost member of this group dips eastward at an angle of 45° which is considerably steeper than the overlying Tertiary (?) strata. The presence of an unconformity is therefore suggested as can be seen in the cross section along "Stone Corral

Creek from Foot Hills to Valley." We cannot say definitely that an unconformity exists although the suggestion is quite evident.

There were no fissils found in the quarry sandstones and until further evidence is produced they will be considered as marking the top of the Chico (Cretaceous) formation. The quarry group upholds an area of steep hills which rise suddenly to an elevation of at least a thousand feet above Stone Corral Creek. The character of the formation and of the topography is seen in the following photographs.

Below the Quarry sandstone and apparently conformable therewith are 1450 feet of interbedded shales and sandstones, with the shale representing about seventy-five percent of the entire thickness. It is this shale member, assisted by the overlying Quarry sandstones which forms the east escarpment of the Anticline.

The shale member rests upon an interesting group composed of sandstones, shales and conglomerates. The conspicuous portion is the conglomerates which, for descriptive purpose, is referred to as the Conglomerate Group. This group is 1950 feet thick, containing in all four very distinct conglomerate beds.

The uppermost conglomerate is about 75 feet thick, but apparently quite lenticular. The two next lower conglomerates are somewhat thinner, ranging from 25 to 50 feet. The lowermost conglomerate, which on the maps and sections is numbered 4, at places reaches a maximum thickness of 100 feet.

The conglomerate members are separated by shales and sandstones. The sandstones are often quite thick and massive and distinct from the quarry sandstones, both in color and texture. The quarry sandstones are light green in color and silicified; the

the sandstones associated with the conglomerates are buff in color, coarse grained, and fairly soft.

The intervals between the conglomerates from the top downward are:

Conglomerate No. 1	
Sandstone and shale	500 feet
Conglomerate No. 2	
Sandstone and shale	312 feet
Conglomerate No. 3	
Sandstone and shale	390 feet
Conglomerate No. 4	

The conglomerate members are composed of poorly assorted pebbles of porphyry, chert, limestone, sandstone and shale. The pebbles are firmly imbedded in a sandy matrix. The majority of the pebbles range in size from about one-half inch in diameter to as much as four inches. The porphyry and chert pebbles, which compose perhaps seventy per cent of the mass, are well rounded, but the limestone and sandstone pebbles are sub-angular to angular and thereby indicate that they were picked up not far from where the conglomerate was forming.

Immediately above the uppermost conglomerate a fossiliferous horizon was found and although many of the forms remain undetermined, yet several very significant species were identified. The identified forms include:

1. Trigonia evansana.
2. Turritella chiocoensis.
3. Meretrix varians.
4. Fusus sp.
5. Basina sp.
6. Tellina sp.

This certainly proves that the rock is of Cretaceous age and belongs to the Chico formation. There is no apparent stratigraphic break above the fossil horizon to and including the Quarry Group, and, as the strata is lithologically similar, it is concluded that the rocks so far considered below the top of the Quarry sandstone all belong to the Chico formation.

Geologists of the California State Mining Bureau, working in what is known as the Mountain House area, about seven miles south of Sites, have shown the Chico-Knoxville contact to pass just east of the Mountain House. They have shown by cross section and in their reports that the Chico is marked at the base by conglomerates. The conglomerate group was therefore traced south from Sites to see if it connected with the conglomerates reported by the State Bureau. It was found that apparently the outcrops were continuous, although thinning southward, and did pass just east of the Mountain House. It might be concluded therefore that these conglomerates mark the basal Chico.

It is thought, however, that the State geologists have erred in their correlations, for the fossil collections obtained just above the conglomerates show one form, "Turritella Chicoensis", which is considered determinative of the Upper Chico, at least this form has never been reported from the Lower Chico. You will also note in the sections of Diller and Stanton that conglomerates are very numerous in the mid-section of the Chico, as well as near the base. We must therefore conclude that either the former State investigators were mistaken, or that the Turritella chicoensis is common to both upper and lower Chico. There are however other reasons which convince the writer that the conglomerates in this case mark the base of the Upper Chico formation.

Below the conglomerate group, and exposed on the immediate flank of the anticline is a series composed essentially in the upper half of shale and containing in the lower half several sandstones from five to fifteen feet thick. The sandstones are numerous and underlain by a chalk-shale member. This latter member is approximately on the axis of the anticline and marks the base of the group.

At the top of this lowest group and first below the conglomerates, several large ammonites were found. Two of these were at least two feet in diameter and six inches thick. The size suggests the general Phylloceras, or Lytaceras, commonly found in the Horsetown formation, but here apparently in the Lower(?) Chico.

The group is 1900 feet thick, as measured from the axis of the anticline to the base of the conglomerates.

We may therefore conclude that the strata exposed on the anticlinal axis is at least 5600 feet below the top of the Chico formation and probably belongs to the Lower Chico division.

ROCKS BELOW THE SURFACE ON THE ANTICLINE

It is evident in the field that just west of the Sites syncline there occurs a great strike fault which, as seen on Cross-section Plate II, has duplicated at least all of the conglomerate group. Measuring downward below this group on the west side of the syncline we were able to approximate the position of the strata which outcropped on the anticlinal axis. Such however, is the nature of the terrain and the outcrops at the point where the section was started that no definite horizon could be identified. It is believed, however, that the actual position of the apex rock

was closely approximated.

The section was measured up a small narrow ravine exhibiting few good exposures save of the sandstone members. The shale members were mostly covered so that the section appeared possibly more sandy than is actually the case.

The section, as measured stratigraphically downward is given in detail below.

Measured Section West of Sites Anticline:

	From	to	Thickness
Thin sandstone 2-10' thick at top and bottom, separated by shale and thin sandstones mostly shale	0'	580'	580'
Thin sandstones and shale	580	809	229
Largely concealed. Possibly thicker sandstones - 1 bed of conglomerate but mostly shale	809	1149	340
At base thick massive sandstone, above which are sandstones 15-20' thick separated by shales of like thickness	1149	1309	160
Sand - Soft, massive, light green very thin shale breaks	1309	1423	114
Sandstone	1423	1473	50
Shale	1473	1498	25
Sandstone	1498	1585	87
1b - 2 Thick sandstones and thin shales - mostly sand	1585'	1830'	245'
2 - 2a Thick sandstone and thin shales occasional sandy shale beds	1830	1897	67
2a -2b Thin brown shale just below 1897', then thin laminated grayish green sandstone and shale	1897	2053	156

	From	to	Thickness
2b - 3 Shale in thickness 30-40' separated by sandstones - a shale horizon - at least two sandstones	2053	2313	260
3 - 3b Shale with thin sandstones	2313	2685	372
3b - 4 Shale and occasional thin greenish sandstones	2685	2974	289
4 - 4a Shale grading downward into coarse sandstone to massive sandstone	2974	3219	245
4a - 5a Shale	3219	3358	139
Conglomerate Base of Chico			
Massive sandstone	3433	3855	422
Shale and thin sandstones	3855	4500	645

You will note in the measured section and near the base thereof, a conspicuous conglomerate seventy-five feet thick. This member outcrops prominently on the mountain side. It is composed of well rounded pebbles of porphyry and quartzite, imbedded in a sandy matrix. No pebbles of sandstone or limestone could be found, which is in contrast to the conglomerate noted as marking the base of the Upper Chico. Beneath the conglomerate is a thick massive sandstone underlain by shale and thin sandstones with the proportion of shale increasing downward. The general section, although apparently much thicker, somewhat resembles that which Diller and Stanton measured on Elder Creek in Tehama County.

POSSIBILITIES OF OIL AS SEEN IN THE GEOLOGIC SECTION

The rocks measured in the above section seem to be divisable into two groups, the upper group, from 0 to 1897 feet is

largely composed of sandstones.

These sandstones are for the most part thick and massive, light green to buff in color and are separated by thin bedded light green shales. The outcrop where measured exhibited no evidence that the rocks contained petroleum, or ever had. The shales do not impress one as being a favorable source for oil. We are lead to believe that a shale capable of originating oil should be more or less black in color, or at least considerably organic. The shales seen in the outcrop are certainly not of this character. One shale mass, which in outcrop appeared to be a blue-black color was sampled and analysed under the microscope. The color was found to be due to carbon dust and fragments of carbonized wood, representative of the cellular tissue of plant fragments. These appeared to be abundant in the sample and there was also a slight suggestion of a previous organic content oblivated by weathering and other processes to which the shale had been exposed. A distillation and chloroform extraction test on the same sample furnished no evidence of an oil content.

In the same shale mass several forms of marine gastrapods were found so that it appears the rock is truly marine and therefore we assume the plant fragments are of the same character. There are many geologists who hold exclusively to the plant origin of oil theory and by these this shale mass might be held as a possible origin. The writer feels, however, that much is to be learned regarding origin rocks and that the information regarding the sample discerned is too indefinite to be determinative.

The lower group of rocks, as measured in the section from 1897 feet to the conglomerate at the base of the Chico formation, is largely composed of shale. For the most part this shale is light

green in color. A sample was taken at a point stratigraphically about 200 feet above the basal conglomerate. This sample, under the microscope, contained an abundance of carbonized plant fragments and was quite similar to the sample previously measured. It might, or might not, afford an origin, we simply have not the information to tell.

Below the basal Chico conglomerate, and save for the massive 422 foot sandstone at the base of the measured section, is an exceptional thickness of shale comprising the Horsetown (?) and Knoxville formations. This shale differs in character from the Chico shale. It is gray in color grading downward into typical blue or black. Of four samples collected, all were organic regarding plants although the single cell animal organisms were conspicuously absent.

The Horsetown and Knoxville formations are together about 25,000 feet thick. Of this thickness, it is estimated ninety per cent is shale, which is lean regarding organic content, but which in the aggregate must contain sufficient organic material to have originated a considerable quantity of oil or gas if the distillation was complete and directed to that end. As to these latter factors we can only surmise and we know still less concerning the factors of migration even if oil was originated in the shales.

From the foregoing, we may assume that so far as the actual examination of the section is concerned no definite origin rock was identified but this does by no means determine that an origin is not present. We have certain other evidence which indicates that exactly the opposite may be true. This evidence we will now discuss.

SURFACE EVIDENCE OF OIL AND GAS

On the axis of the Sites Anticline and generally associated with the faults which cross the structure are several very conspicuous gas seeps. Such seeps are known at several localities on the Peterson ranch and can be found northward therefrom for several miles. The quantity of gas escaping is not great and is always associated with springs of salt water. In several cases the brine flows slowly from the springs but in an equal number of cases the springs are mere puddles, the water agitated only the escaping gas. The gas is easily ignited and will burn above the water when protected from the wind.

We know from certain other water springs on the Peterson ranch that the so-called "ground water" is both soft and fresh. None of the fresh water spring exhibit any gas at all and from this we reason that the bas and brine come from a depth below the ground water issuing to the surface along the faults which cut the rocks. The brine shows no dilution and indicates that the pressure below, either because of the gas or the hydrostatic head, is greater than the down pressure exerted by terrestrial waters which normally would seep down the fault plane.

In as much as the gas seeps are located on faults it is possible that these faults in depth have cut sandstones saturated with gas as well as sandstones saturated with connate salt water - both the water and gas escaping along the fault to the surface.

Far removed from the anticline to the east and at the outcrop of certain Chico sandstones, where these members are submerged below surface streams, the same phenomena occurs. Gas can be seen bubbling through the water. One such seep is on the George Ellis ranch west of Willows. The gas seeps from the Chico sandstones

both at the outcrop and along faults are very numerous in Glenn County, so numerous in fact that the writer is prone to attach considerable significance thereto - not that the seeps indicate an accumulation but rather that some parts, or a part, of the shales must be capable of originating the product.

To the south of the anticline, beginning at a point approximately four miles south of the town of Sites and continuing southward are a number of oil seeps. These seeps are distributed along a rather definite line which follows the outcrop of a particular horizon in the Chico formation. So persistent are the seeps along this line that we may have here direct evidence of an oil source somewhere within the Chico formation. The sandstone members at this horizon are saturated with oil and slowly exude a highly filtered petroleum. In the vicinity of the Mountain House, in Colusa County, wells have been drilled down the dip from the oil springs and on the Campbell ranch a well capable of pumping five barrels of oil per day was completed. Oil was found at depths of 700 and 900 feet. The oil is light brown in color and quite apparently gained its position by migration and its gravity by evaporation of the lighter fractions which escaped from the nearby outcrop. The oil is paraffine base and that it did not all escape but that some was retained as far as 900 feet down the dip is exceptional. Had this sandstone, in which the oil is found been folded into an anticline an accumulation would have resulted.

Another oil well was completed about a mile northeast of the Mountain House. Apparently this completion was in the same sandstone and with the same character of product as that above mentioned.

At the Mountain House a well 700 feet penetrated a gas stratum which is reported to have had 240 pounds rock pressure. From the size of the fittings and central gate on the well, the report appears authentic. This well was completed many years ago and now is full of water through which enough gas escapes to furnish the Mountain House with heat. The record of the well indicates that the hole was drilled "wet" and at no time was casing set to protect the gas.

East from the Mountain House, perhaps five miles and adjacent to the road leading to the town of Williams a well was completed sometime in the "80's". A newspaper report states this well struck gas which ignited and burned with a forty foot flame. The flame illuminated the sky brightly enough to have been reported sixty miles away, across the Sacramento Valley at Marysville. It was a Marysville paper which contained the report.

It may be added here that a possible total of ten wells drilled along the base of the Coast Range Mountains, all have found significant evidence of either oil or gas. All of these wells, including the ones mentioned above, were drilled at locations where there was absolutely no favorable rock structure. The wells are on monoclines and such favorable evidence of oil as was obtained was due to slight accumulations against faults or the product only of a residual nature.

Therefore, although we cannot find a source rock in the outcrop, yet the actual evidence of the hydrocarbon products derived from the rocks is abundant and this as <u>positive</u> is considered much more trustworthy than the negative.

STRUCTURE

We have seen that the Sites Anticline is located on the east flank of the Coast Range Mountains. Were the anticline not present the strata which is exposed on the mountains would dip constantly in the one direction, namely, eastward toward the base of the Sacramento Valley Syncline. In the vicinity of the town of Sites however, the regularity in the east dips is suddenly broken. The strata involved, instead of dipping downward to the east, starts rising to the east, or dips downward to the west. This we call the reverse dip and introduces in this region an anticline; a structure wherein the rocks dip away in opposite directions from a certain line called the anticlinal axis.

The anticlinal axis trends, for the most part, about north 10° east, although at certain points it curves gently to assume a north and south direction, or even swings to the west trending north 10° west. The axis is therefore not a straight line which can be projected into any given locality. The position of the axis must be located in the field. The axis is shown on the map through a distance of six miles, but extends northward beyond the confines of the map for perhaps another ten miles.

To the east of the axial line, the strata dips to the east constantly but at an ever changing angle. Far removed from the axis to the east, the uppermost strata dips beneath the alluvium of the valley at an angle of twelve to ten degrees. From this, the flattest dip encountered, as you progress westward toward the axis, the dips become progressively steeper even to as high as seventy degrees near the anticlinal axis. But from the maximum east dip, whatever it may be, the strata suddenly flattens on the axis, creating an arch, and starts plunging to the west.

The space separating a definite east dip from a definite west dip is often very small, perhaps not more than three hundred to four hundred feet. The arch effect must be accomplished within the same limit and as the dips adjacent to the axis may approximate forty-five degrees, we see that there is created a knife-edged anticline.

To the west of the axial line, the strata dips westward, usually less steeply than does the strata at the same distance to the east of the axis. The anticline is therefore somewhat assymetrical but not sufficiently so to cause the axial plane to fall far out of the vertical. At some places the reverse is true, namely, the west dips are steeper than the east dips.

The maximum west dip, observed by the writer, was fifty-two degrees and this within one-eighth mile of the axis. From this point, as you travel to the west, the dips become less intense until near the axis of the syncline, where the strata dips westward five degrees. Beyond the syncline, still continuing westward, the strata again dips to the east at low angles while within the effects of the syncline, but become progressively steeper to the west until an average of thirty-five degrees is attained adjacent to a severe fault, which entirely disrupts the normal sequence of the strata.

The accompanying map shows the character of the anticline and the intensity of the folding, much more clearly than it is possible to describe it. For general characteristics your attention is also called to the cross sections included. These sections illustrate the character of the fold very well. There are however some rather unusual features of structure which need mention and which are not shown on the map.

The anticline continues northward far beyond the limit mapped, but to the north, the east and west dips become even more accentuated, approaching eighty-five degrees. The anticline tends to overturn and for several miles the arch is obliterated by perpendicular strata immediately on the axis. This effect is shown in the accompanying sketch. It was thought at first that the perpendicular attitude of the rocks indicated faulting along the axis, but after considerable study it was decided such was not the case for between the area mapped and the outcrop of the vertical rocks, the strata can be seen actually crossing the axis without being disrupted. Of course the area within which the strata is vertical is eliminated as being favorable for oil. The favorable area is that which has not been so severely folded and where the strata is flexed smoothly across the axis.

The main anticline plunges continually to the north as is evidenced by the fact that as you proceed northward from the town of Sites the rock encountered on the axis is higher in the geological section, which is of younger age than the rocks on the axis to the south. The same is evident in the strike of the rocks on the flanks of the anticline. The rocks exposed east of the axis all strike toward the axis; this is likewise true on the west flank. By following a particular stratum, such as a sandstone, you will find that as you work northward along the outcrop you are ever and ever coming closer to the axis until finally the sandstone crosses the axis and to continue following it you would have to walk southward.

The north plunge of the anticline is however accomplished slowly. The strata exposed at Sites a half mile east of the axis does not cross the axis until it reaches a point seven or eight miles

north of Sites. In the vicinity of the railroad station of Millsholm, in Glenn County, and at a point approximately fifteen miles north of Sites the writer considered that the strata on the axis is at least 2000 feet stratigraphically above the rocks exposed on on the anticlinal axis at Sites. It is well to call attention to the fact that the east escarpment of the structure, while it appears quite regular and is upheld by the same resistant rock members, is not parallel to the strike of the strata.

We again find that over its entire distance the axis tends to encroach northward upon the valley, leaving the mountains ever further to the west. That is, the anticline is not parallel to the front range of the mountains. Near Sites the south end of the structure is west of the first line of foothills but on the north end, beyond Athena in Glenn County, the anticline is slightly east of the frontal foothills.

All of these things indicate the north plunge of the structure and we are therefore assured a considerable north closure on the main anticline. But it is different regarding the southern closure.

Considering the regional features of the anticline, it may be said that it has no normal closure to the south. This does not mean there is no southern closure on certain domes which are superimposed on the anticline and we must bear in mind the differentiation between the regional and the local structure. The local structure may be closed and yet the regional anticline open. The main anticline therefore does not plunge to the south but is terminated about a mile south of Sites by faulting which displaces the strata some 2,000 feet. This fault is a conspicuous feature

of the areal geology of the district and has a very interesting relationship to the Sites Anticline.

Strike faulting is exceedingly common in the Coast Range Mountains. The fault rifts can often be traced for a hundred miles, or more. The fault herein mentioned can be identified over a distance of forty miles and is probably much longer. Seldom, however, can the actual fault be seen, but the topographic effect produced by faulting marks the position. The writer actually saw the displacement of the rocks along the fault to the northwest of the anticline some twenty miles, on the Prentice Ranch in Glenn County.

At a point about seven miles south of the Town of Sites the fault trends almost north and south therefrom. Northward some distance the bearing of the fault gradually swings to a few degrees east of north approximating perhaps north 8° east. It continues on this trend to a point near the south line of Section 31, Township 17 North, Range 4 West, thence swinging westward assuming a direction about north 15° west. This can be seen on the map.

At the point where the fault changes its direction, the anticlinal folding begins; the axis of the anticline being more or less a projection of the fault line if the fault had not swung westward. It appears therefore that the anticline is a reflection of the strain which caused the fault but when the course of the fault changed, the force applied, perpendicular to the former fault line, was insufficient to cause fracturing and the Sites Anticline was the result. But whatever the cause, the anticline is present plunging to the north and abutting against the fault on the south.

The severity of the fault caused the rocks to be so displaced that there is no doubt, in the writer's mind, but that many of the sandstones northeast of the fault are sealed against shales to the southwest and west of the fault and this may or may not effect a south seal on the main anticline. We do not expect that the main anticline will be oil or gas bearing but that the accumulation is governed by features which are more or less local in certain areas. These features we will now consider.

DOMES ON THE ANTICLINE.

In certain areas the field evidence indicates that as the axis plunges to the north there are interruptions in the normal rate of plunge and in fact certain reversals which introduce southern closure and thereby create domes on the main anticline. These domes are not well marked on the surface, being indicated by changes in the normal strike of the strata.

In Sections 19 and 30, Township 17 North, R. 4 W., you may note evidence of doming. The northern closure here is very definite. The strata west of the axis strike north 60° east dipping 40° northwest. Immediately east of the axis the strata strike north 15° west and dips 56° east. These altitudes can be seen on the map on the south line of the northeast quarter of Section 19, and were taken on thin shales and hard sandy layers, exposed in the bed of a dry creek. The rock surface was removed by digging until a definite member was exposed.

Following south on Antelope Creek, still east of the axis, the strike swings from north 15° west to north 23° east and finally to north 80° east in the Northwest quarter of Section 30. The strike has therefore swung through an arc of 95° on the east side of the axis. On the west side starting at the strike of north

60° west on the north end of the dome and going southward we find a prominent ledge of conglomerate in the Southwest quarter of Section 19, which strikes north 16° east and dips 35° west. As the anticlinal axis in this area trends almost north 45° east, the above attitude if continued would swing the conglomerate across the axis affecting southern closure. This is exactly what it seems to do, for the conglomerate in the Northwest Quarter of Section 30, while flat lying, is eighty feet lower than the outcrop in the Southwest Quarter of Section 19.

From such evidence it seems probable that a small dome exists on parts of Sections 19 and 30. This dome is outlined by Antelope Creek which, as mentioned, partially encircles the dome.

A much larger dome with the "structural high" at the Peterson Salt Lake covers portions of Sections 31 and 32, Township 18 North, Range 4 West and Sections 5 and 6, Township 17 north, Range 4 West. This dome which we may call the "Salt Lake Dome" is closed on the north by the general north plunge of the main anticline and somewhat accentuated by certain converging strikes immediately north of the lake. The south closure is evidence only by converging strikes, which however are so near each other that closure must be effected. You may note these converging strikes, on the map, in Section 32, Township 18 North, Range 4 West immediately at the lake. Indications of the same effect can be found in the Southwest Quarter of Section 5, Township 17 North, Range 4 West, although at this latter locality the rocks were not satisfactorily exposed.

Faults

Faulting of the normal type is exceedingly prevalent on the structure. The faults parallel to the dip of the strata have

not great displacements and are apparently not arranged according to any system. More work on this problem might show two or more rectangular systems, of faults but there was no attempt made in the field to establish the relationship.

No definite evidence of strike faulting was found but there are undoubtedly many more dip faults (faults parallel to the dip, or nearly so) than are shown on the map. The dip faults trend in all directions, some running northwest, others northeast, southeast, or southwest as the case may be. The fault traces seen on the map were established by projection along the straight line joining two definite points on the same fault. This could be done only on the heavier rocks such as occur in the escarpment and we were unable to trace any of the faults entirely across the anticline.

The most conspicuous fault as well as the one with the greatest observed displacement occurs crossing Sections 8,9, T. 17 N., R. 4 W. This fault trends approximately northeast - southwest with a downthrow to the south of 150 feet. It also hades to the south about sixty degrees. In the south half of Section 7, T. 17 N., R. 4 W., are two small faults one of which may be a continuation of the fault observed in Section 8. If so, however, the displacement is much less and the fault would be dying out westward.

The fault shown in the Northeast Quarter of Section 20, T. 17 N., R. 4 W. trends northwest-southeast and with the fault in Section 8 creates a triangular fault block with the apex of the triangle on the axis of the anticline. The writer believes that this triangular fault block is only one of many such blocks and that in fact the anticline is "chopped" into such, which in general resemble the blocks on the Elk Basin Anticline in Wyoming.

There are many small faults which cut the rocks exposed at the Peterson Salt Lake. These faults have not displaced the rocks which they cut. Along the fault planes calcite has been deposited in some cases to a thickness of six inches, while the surface trace of the fault can easily be located by following either the detrital calcite strewn along the ground, or the actual fault with the calcite between the walls can often be seen.

If you follow the calcite filled faults long enough eventually you will find either gas or salt water seeps thereon. It has been mentioned previously that gas and water escapes from the faults and that it seemingly comes from horizons saturated with these products and exerting pressure within the anticline. It is expected that the well, which tops the horizon from which the gas originally escaped into the faults, will find sufficient gas to afford a commercial gas well. This is one of the main reasons for testing the structure.

Drainage.

The Sites anticline represents, so far as we know, the only favorable structure situated on the east slope of the Coast Range Mountains in the district. East of this locality the strata dips into the Sacramento Valley Syncline. The Cretaceous rocks involved in the synclinal structure are overlain by Tertiary rocks and by recent accumulations of alluvium so that the exact position of the base of the trough is in doubt. We know, however, that it is many miles to the east of the Sites Anticline and it is not unreasonable to assume that the valleyward flank of the anticline is unbroken by reverse dips even to the base of the geosyncline.

It is in distance about seventy-five miles across the valley east from Sites and apparently the base of the geosyncline lies approximately midway between the two mountain ranges. This would create a thirty-five miles. The anticline, considering its entire length, is sixteen miles long, so we see a very ample drainage of five hundred square miles, within which oil or gas, if originally present in the rocks, would drain toward the anticline and tend to accumulate therein.

The extremely large drainage area may overcome to some extent the apparent lack of a satisfactory source bed. If the rock is lean in organic material capable of originating only a limited amount of either oil or gas and yet as we know some quantity has been created, then perhaps over such a large area, if the products all collect at one place, there should be sufficient to saturate the comparatively limited voids in the sandstones immediately on the anticline.

That there is a migration of the hydrocarbons from the valley toward the mountains seems certain, for at the outcrop of the rocks exposed on the monocline gas is actually escaping.

POSSIBILITIES OF PRODUCTION AS REFLECTED IN THE STRUCTURE

The relationship of the local structure at Sites to the regional structure of the district is the same as is generally found in the productive fields of California.

The rocks on the anticline are, however, somewhat more sharply folded than in the Southern California fields. This, while it limits the drillable area on the anticline, does not adversely effect the retentive character of the anticline.

The domes situated on the main anticline are so formed as

to indicate that they will retain any product either oil, or gas, which gathers therein.

It is thought that the cross faults cutting the anticline may help materially in effecting a seal through which the oil or gas will not migrate.

Location of Test Oil

After a thorough review of the field conditions, it was decided that the most favorable location for a test well is near the southeast corner of Section 31, Township 18 North, Range 4 West. This location was chosen for several reasons. It is near the apex of a minor dome and on the axis of the major anticline. A cross section east and west at this point shows the structure to be nearly symmetrical and the surface axis here is thought to more nearly coincide with the subsurface axis than in other parts of the field.

The well is spotted about one-half mile south of the Peterson Salt Lake, where the gas seepages are so prominent. The well should therefore cut, at some depth below the surface, the sandstone from which gas originally came and yet it is removed from the severe effect of the faulting at the lake.

Drilling Depths.

It is impossible for the geologist to even attempt to definitely determine the depth to which a well should be drilled on this structure. We know that even a shallow well will penetrate many sandstones, but we do not know which, if any, of these sandstones will contain the products. A deeper well will find many more sandstones, any of which may prove, but none of which will necessarily disprove the structure. Therefore we must search for this particular member and if possible drill the test well to a depth beyond which even if oil were found it could not be produced

at a profit.

The writer makes no claims as to any definite knowledge as to where production will be found but has some idea as to where the sandstones will be encountered. If you will note the measured section you will see that a 4,000 foot well will cut a great number of sandstones, some of which certainly have better chances than have others for producing. The sandstones which, to the south of the town of Sites, show oil seeps should be found at a depth of from 1,000 to 1,500 feet. If this is really a more or less definite oil horizon, then we may expect to find certain showings in the well at, or between these depths.

From a depth of 1,500 feet to 3,900 feet many sandstones will be encountered but the 422 foot sandstones shown in the section from 3433 to 3855 feet appears to have good prospects for containing either oil or gas. This is true because the member is at the contact with a thick mass of shale immediately below. This seals, the writer considers may furnish the product which would normally accumulate the sandstone mentioned. It is well to state, however, that while the measured section shows the sandstone at a depth of 3433 feet, yet actually it may either be found at this depth or deeper. After the well itself has been drilled 1,000 feet, certain key beds will have been found, which can be identified in the section and then the interval between the key bed and the sandstone at the base of the measured section can be established, but not before.

The well will penetrate a series of rocks belonging to the Lower Chico formation. This formation contains among other fossil forms, Inoceramus labiatus and Ostrea congesta and is the time equivalent of the Colorado Group in which the bulk of the Rocky

Mountain light oils are found.

CONCLUSIONS

The writer considers that the geological conditions present in the vicinity of Sites are sufficiently favorable to recommend a test well be drilled on the anticline. There is no intention to minimize the risk involved, for we are here dealing with a series of rocks not known to be petroliferous in the State of California. Many of the factors analysed are unfavorable but many also are favorable and to which may be added certain economic conditions of the districts which must be considered in making such a test.

There is no oil or gas produced in Northern California save only in very limited quantity and yet the region is thickly settled, furnishing almost an ideal area for the marketing of either product. It appears that the possibilities of finding gas on the structure are much better than the possibilities of finding oil. If gas can be developed, there certainly is an almost unlimited market immediately at hand.

In view of all the conditions, both geologic and economic, I think the Consolidated Royalty Oil Company would be justified in taking leases on the anticline with the ultimate view of test for oil and gas.

Respectfully submitted,

W. H. GEIS

August 1923.