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Oil and Gas Possibilities in Southern Nevada

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ABSTRACT.—Before the end of 1972 approximately 40 holes had been drilled in southern Nevada by various companies in search of oil and gas. Although shows were encountered in different formations of Paleozoic age, one in the Triassic, and one in Cenozoic rocks, no commercial production of petroleum has resulted. Most of these tests were made in Clark County, and few of them were made on favorable geologic structures; however, many were located by nongeologic techniques. It is herein interpreted that favorable Paleozoic and Early Mesozoic sedimentary rocks of basinal facies west of the Las Vegas Hinge Line, as well as thinner strata of comparable age adjacent to this line as well as on the shelf east of it have strong possibilities for petroleum production. There are favorable anticlinal structures, fault traps, and facies pinch-outs in various places in southern Nevada that invite adequate testing with the drill bit.

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INTRODUCTION

Almost twenty years ago (February 1954), Shell Oil Company discovered crude oil in commercial quantities in the Eagle Spring Unit, Railroad Valley, Nye County, Nevada, thereby opening up exploration for petroleum in Nevada. Of a total of 125 wells drilled for oil and gas in Nevada between 1953 and 1972, fourteen, all in the Eagle Spring field, were completed as producing oil wells. Prior to 1954, exploration drilling in the state was concentrated in three areas: southern Nevada (Clark County), northeastern Nevada (Elko and White Pine Counties), and west-central Nevada (Churchill County). Between 1965 and 1972 four tests were made in Lincoln County.

Up to the year 1953, approximately 20 holes had been drilled in southern Nevada; and between 1953 and 1972 an additional 20 tests were made, 19 in Clark County and 1 in southern Lincoln County. Two tests were made in northern Lincoln County, both in Cave Valley: the Willard Pease Drilling Company

Federal No. 1 (1965, in Sec. 22, T. 9 N., R. 63 E.) and Gulf Oil Corporation Cave Valley Unit No. 1 (1966, in Sec. 19, T. 7 N., R. 64 E.). Both were plugged and abandoned. In 1966 Gulf Oil Corporation drilled its Nevada-Federal No. 1 in Coal Valley (Sec. 17, T. 1 S., R. 60 E.) but plugged and abandoned it at a depth of 2,434 feet. In 1972 Texaco drilled the Meadow Valley Mountain anticline in Sec. 18, T. 12 S., R. 65 E., in southern Lincoln County but plugged and abandoned it at a depth of 7,030 feet. To date, information such as depths to tops of formations has not been released.

In this brief paper the writer will call attention to what he interprets as favorable potential geologic structures for oil and gas generation and pooling in southern Nevada, focusing largely on areas in Clark County, Nevada, near Las Vegas. A total of 22 tests selected from a larger number of holes drilled

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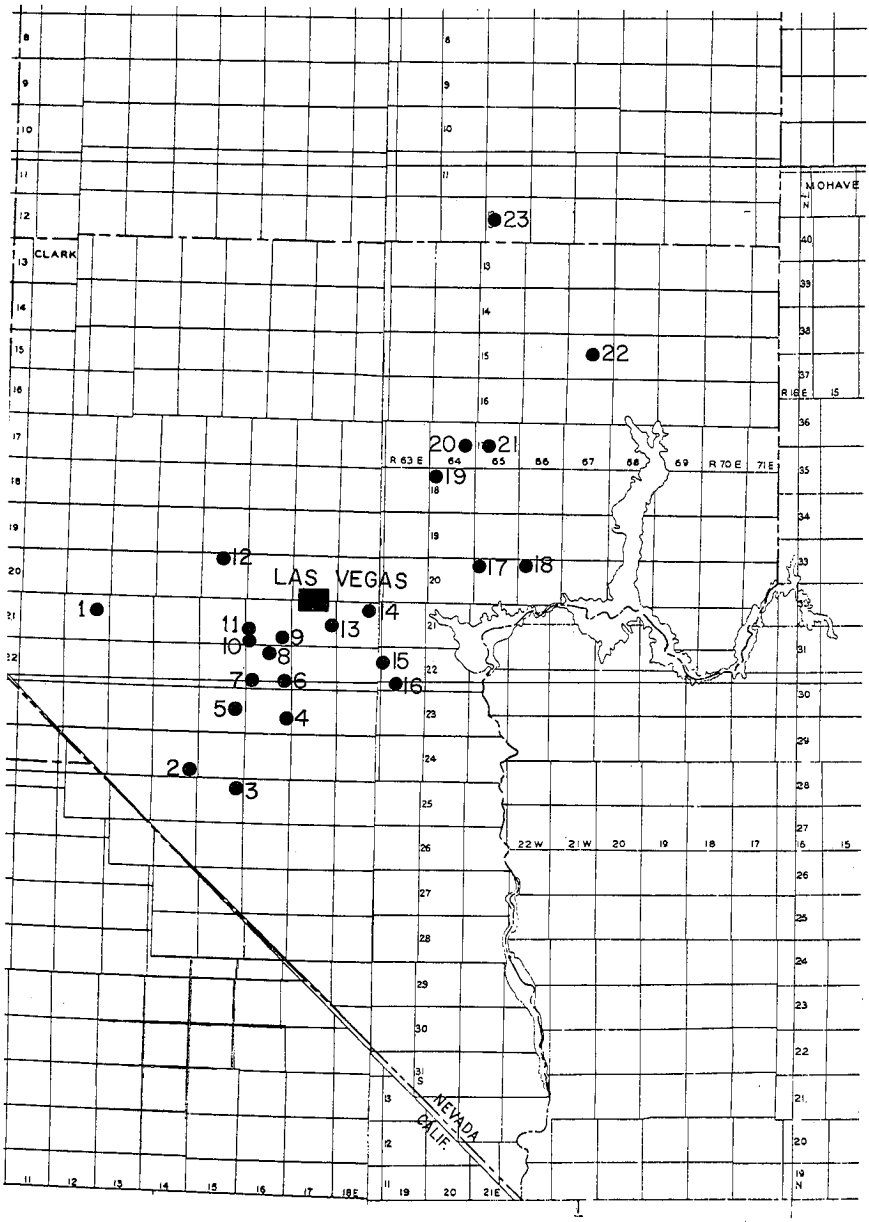
TEXT-FIGURE 1.—Map of Clark County, Nevada, showing locations of 22 holes drilled for oil and gas and of Texaco's test in southern Lincoln County.

1. Tri-State Exploration Co. Miskell-Government No. 1. Sec. 22, T. 21 S., R. 56 E.; T. D.: 2,602 feet.
2. New Haven Oil Company No. 1, Sec. 26, T. 24 S., R. 58 E.; T. D.: 716 feet.
3. Intermountain Associates, Inc. (Jean) No. 2, Sec. 1, T. 25 S., R. 59 E.; T. D.: 2,273 feet.
4. Nevada Exploration Company, No. 1 Sloan, Sec. 13, T. 23 S., R. 60 E.; T. D.: 2,002 feet.
5. Intermountain Associates, Inc., Arden Dome No. 1 (No. IX), Sec. 23, T. 23 S., R. 59 E.; T. D.: 3,293 feet.
6. Kamarden Oil Co. Federal (drilled in 1969), Sec. 22, T. 22 S., R. 60 E.; T. D.: 6,760 feet.
7. Red Star Oil Company—J. B. Nelson No. 2, Sec. 20, T. 22 S., R. 60 E.; T. D.: 3,767 feet.
8. Jack F. Grimm Wilson No. 1 (Minerals Drilling Inc.), Sec. 9, T. 22 S., R. 60 E.; T. D.: 5,686 feet.
9. E. W. Bannister No. 1, Sec. 34, T. 21 S., R. 60 E.; T. D.: 522 feet.
10. Commonwealth Oil Company No. 1, Sec. 31, T. 21 S., R. 60 E.; T. D.: 1,897 feet.
11. Bonanza Oil Corp. Arden Dome No. 1, Sec. 31, T. 21 S., R. 60 E.; T. D.: 3,260 feet.
12. C. J. Lichtenwalter and C. M. Turpin, Turpin No. 1, Sec. 4, T. 20 S., R. 59 E.; T. D.: 777 feet.
13. Joe E. Brown Wilson-Government No. 1, Sec. 24, T. 21 S., R. 61 E.; T. D.: 8,508 feet.
14. McAuley Associates No. 2, Sec. 2, T. 21 S., R. 62 E.; T. D.: 2,268 feet.
15. Trans-World Oil Co. (Leonard Wilson), Houssels-Wilson-Milka No. 1 (USA No. 1), Sec. 30, T. 22 S., R. 63 E.; T. D.: 2,300 feet.
16. Leonard R. Wilson No. 1a Government, Sec. 32, T. 22 S., R. 63 E.; T. D.: 1,465 feet.
17. Rosen Oil Co., Muddy Dome (Fed.) No. 1, Sec. 7, T. 20 S., R. 65 E.; T. D.: 5,666 feet.
18. Shell Oil Co. Bowl of Fire Unit No. 1, Sec. 5, T. 20 S., R. 66 E.; T. D.: 5,919 feet.
19. United Petroleum Corporation No. 1 Apex, Sec. 6, T. 18 S., R. 64 E.; T. D.: 1,247 feet.
20. Last Chance Oil Company No. 1 Crystal, Sec. 11, T. 17 S., R. 64 E.; T. D.: 1,002 feet.
21. Southern Great Basin Oil and Gas Inc., Government No. 1, Sec. 18, T. 17 S., R. 65 E.; T. D.: 5,085 feet.
22. Moapa Nevada Oil and Gas. Co., Logandale No. 1, Sec. 21, T. 15 S., R. 67 E.; T. D.: 575 feet.
23. Texaco's test on the Meadow Valley Mountain anticline, Sec. 18, T. 12 S., R., R. 65 E., Lincoln County; T. D.: 7,030 feet.


CLARK
MOHAVE
LAS VEGAS
1
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16
17
18
19
20
21
22
23
NEVADA
CALIF.
R 63 E
R 70 E
R 18 E
22 W
21 W
21 E

in Clark County shows that 6 are northeast of Las Vegas, 6 are to the east, and the remaining 10 are west of the city (Text-fig. 1).

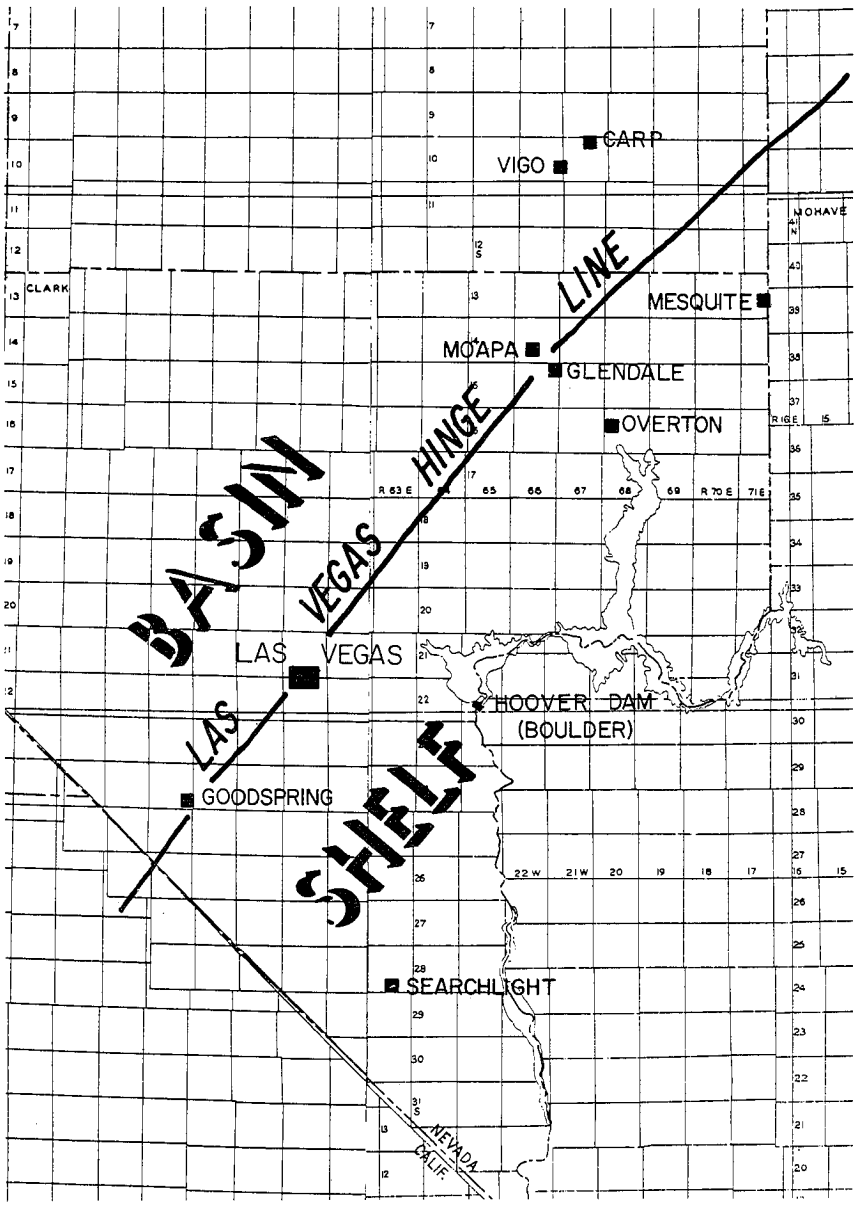
GENERAL GEOLOGY

Recently published geologic reports and colored geologic maps of Clark and Lincoln counties in southern Nevada are of great value in appraising the general stratigraphic and structural geology (*see* Longwell et al., 1965; Tschanz and Pampeyan, 1970). Plate 1 is a copy of Plate 5, a tectonic map of Clark County (Longwell, et al., 1965) with certain data plotted for ready reference. With this map the reader can locate the principal geologic units and the major structures. Southern Nevada (southern Lincoln County and most of Clark County) contains a thick sedimentary section of Paleozoic, Mesozoic, and Cenozoic marine and nonmarine rocks. For this reason oil companies have drilled into these sedimentary rocks for oil and gas. There are present some interesting anticlines and fault blocks, but these apparently have not been conclusively tested. Clark County, however, is also characterized by rather complex fault patterns; for example, there are overthrust faults (such as the Keystone Thrust west of Las Vegas), shear faults, and reverse and normal faults. These faults have been active, some in the Mesozoic, and others at various times from the Cenozoic to the present. The reader interested in the oil and gas potential of this relatively unexplored geologic province is referred to the references at the end of this paper for details of its stratigraphy and structure.

Eastern Nevada and western Utah were part of the vast Cordilleran Miogeosyncline (now shortened to *miogeocline*) during Late Precambrian, Paleozoic, and Early Mesozoic times. The eastern part of this miogeocline was separated from the shelf to the east of it by the Las Vegas—Wasatch Hinge Line. Text-figure 2 shows the Las Vegas segment of this tectonic hinge as it extends from southwestern Utah in a southwesterly direction across southern Nevada. The basin lay to the west of this line, whereas the shelf was east of it.

Text-figure 2 should be compared with Text-figure 1 for locating some of the significant subsurface tests in southern Nevada. Most of the holes drilled in search of oil and gas tested but a small part of the shelf facies; only about six tests were in basinal sediments, and all these are inconclusive. In other words, the Rosen test penetrated Upper Paleozoic strata, and Shell's Bowl of Fire test penetrated to the Cambrian. In both holes, however, the stratigraphic sections are thinner than those tested near or west of the Las Vegas Hinge Line, and they also lacked certain units, namely, all or part of the Ordovician, the Silurian, and a thick Devonian section. Texaco's test in southern Lincoln County (No. 23 of Text-fig. 1) was spudded in the Pennsylvanian-Permian Bird Spring Group, but tops to other formations have not been announced.

As herein interpreted, the sedimentary rocks of the basin (*see* Pl. 1 and Text-fig. 2) have not been adequately tested; most holes drilled to date are mostly off-structure and they are therefore inconclusive tests of the Paleozoic stratigraphic section. For these reasons, the writer believes that the petroleum potential of southern Nevada has not been adequately appraised with subsurface tests that have been made to date. There are gentle anticlines in which a thick and significant basinal succession is present, and there are high-angle normal faults that could serve as traps for petroleum pools. Some structures on the shelf have Mesozoic sedimentary rocks at the surface, and some structures have Cenozoic nonmarine sedimentary rocks at the outcrop over favorable structures.



TEXT-FIGURE 2.—Map of Clark County, Nevada, with portions of adjacent counties, showing approximate position of the Paleozoic-Early Mesozoic Las Vegas Hinge Line that separated the shelf on the east from the basin (i.e., the miogeocline) on the west.

OIL AND GAS POSSIBILITIES

The Shelf.—Most of the test holes drilled in search of petroleum in southern Nevada were in sediments of the shelf or were in close proximity to it; these are, in the writer's opinion, inconclusive. Test No. 13 of Text-figure 1, the Joe W. Brown Wilson—Government No. 1 (taken to a depth of 8,508 feet), was drilled literally in the outskirts of Las Vegas. Apparently it penetrated some Cenozoic lake and stream sediments, encountered the Tertiary or Cretaceous Overton Fanglomerate and the Cretaceous Baseline Sandstone, and topped the Bird Spring Group at about 6,150 feet. Some oil shows were reported in the Permian (possibly the Toroweap or Kaibab). There is no surface structure, and evidently there was no geophysical basis upon which this test was located. Other tests obtained in this vicinity (*see* Nos. 14, 15, and 16 of Text-fig. 1), being shallow, are of little value in appraising the oil and gas potential of this part of the shelf.

Shell Oil Company drilled its Bowl of Fire Unit No. 1 (Sec. 5, T. 20 S., R. 66 E.) in 1959 to 5,830 feet, stopping in Cambrian sedimentary rocks; evidently, the hole was drilled on the structure and encountered no overthrust or other faults. Tops are reported as follows (Schilling and Garside, 1968, p. 8):

Surface	Moenkopi Formation (Lower Triassic)
1,090 ft.	Kaibab Formation
1,430 ft.	Toroweap Formation
1,875 ft.	Coconino Sandstone
1,975 ft.	Hermit Formation
2,920 ft.	Pakoon Formation
	Permian
3,720 ft.	Callville Limestone (Pennsylvanian)
4,435 ft.	Chainman Formation
4,571 ft.	Monte Cristo Limestone
	Mississippian
5,175 ft.	Sultan Limestone (Devonian)
5,700 ft.	Pogonip Limestone (Ordovician)
5,830 ft.	Cambrian

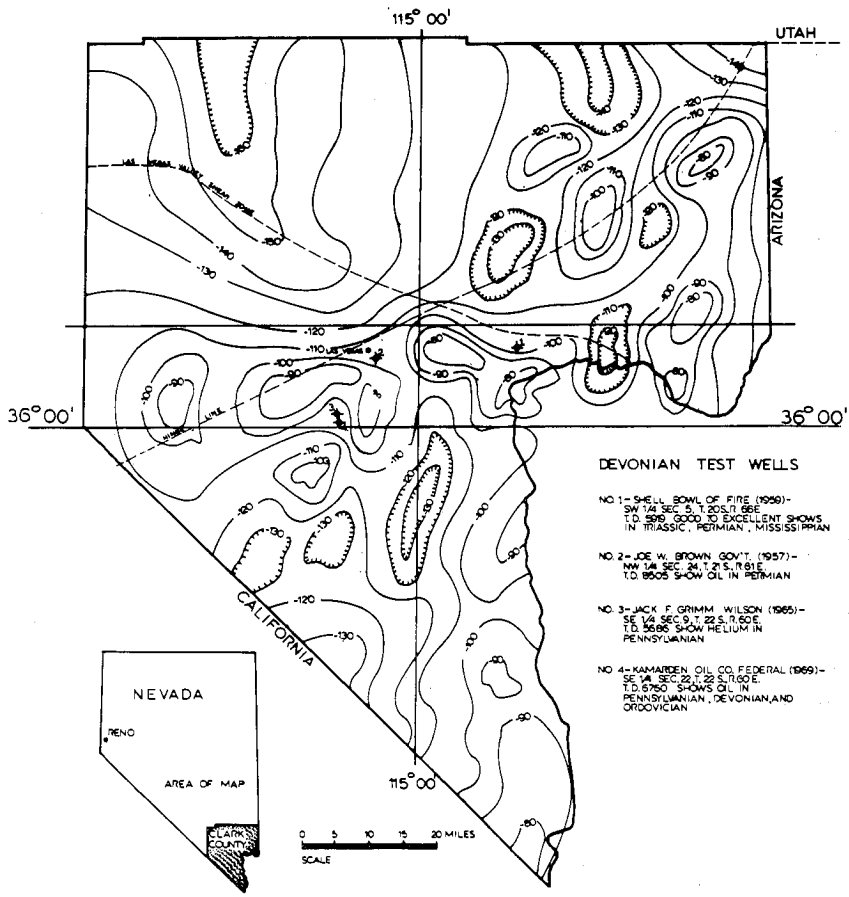
Published reports (Wiese, 1960, p. 232-33) suggest that better than fair shows of oil were noted in the Triassic, Permian, and Mississippian.

Test No. 17 of Text-figure 1 is the Rosen Oil Company Muddy Dome (Federal) No. 1 in Sec. 7, T. 20 S., R. 65 E., drilled in 1965. At 5,666 feet this hole was abandoned in a fault. However, it was spudded in the Jurassic Aztec Sandstone and a thickness of 1,648 feet of this formation was penetrated. Below the Aztec, 1,082 feet of the Triassic Chinle Formation, 107 feet of the Triassic Shinarump, 1,796 feet of the Triassic Moenkopi, 197 feet of the Permian Kaibab, 383 feet of the Permian Toroweap, and the upper 254 feet of what was formerly termed *Supai* (now Coconino and Supai) were penetrated before a fault was encountered at a depth of 5,450 feet in the hole. No reports were published relating to oil and/or gas shows in the Rosen test, so it must be regarded as inconclusive for this structure. Although it was termed the *Muddy Dome* (Schilling and Garside, 1968, p. 7), it is identified as the *Gale Anticline* on other maps of Clark County (*see* Pl. 1).

Depths to the tops of formations in the Southern Great Basin Oil and Gas Inc., Government No. 1, in Sec. 18, T. 17 S., R. 65 E., have not been published,

but this test was plugged and abandoned, supposedly at 5,085 feet, in 1954 (Schilling and Garside, 1968, p. 8). Rice-Haeber Company attempted to re-enter this hole in 1972, encouraged by reports of alleged gas shows at a depth below 3,000 feet. It became necessary to offset, and a core taken at about 3,400 feet suggested, in its lithology, that this hole was plugged and abandoned possibly in the Cenozoic nonmarine Horse Spring Formation.

Some untested structures on the shelf that deserve mention are mapped on Plate 1, Nevada Bureau of Mines Bulletin 62, the colored geologic map of Clark County, Nevada on a scale of 1:250,000 (*see* Longwell, et al., 1965). This map was preceded, in 1958, by a geologic map of Clark County on a scale of 1:200,000, not in color (Bowyer, et al., 1958). The reader should consult both maps in appraising the geology of Clark County. So that these structures can be related to gravity anomalies, a copy of the generalized Bouguer Gravity Anomaly Map of Clark County, Nevada is provided as Text-figure 3. Although



TEXT-FIGURE 3.—Copy of the Generalized Bouguer Gravity Anomaly Map of Clark County, Nevada (cf. Text-fig. 2).

the geographic position of the Las Vegas Hinge Line differs somewhat from the one shown on Plate 1 and Text-figure 2 of this report (particularly for the area west of Las Vegas), certain relationships are obvious. For example, positive anomalies are shown for parts of the Muddy Mountains, particularly the Buffington Pockets and other structures that lie northwest of the Valley of Fire (cf. Pl. 1). As herein interpreted, an interesting Paleozoic section of sedimentary rocks should be present in subcrop beneath the Jurassic Aztec Sandstone in some of those structures. One such interesting structure is the Buffington Window (shown on topographic maps as "Buffington Pockets"), located in T. 18 S. and T. 19 S., R. 65 E., in the western part of the Muddy Mountains (*see* Pl. 1). It is a classic fenster, in that an upper overthrust plate of Paleozoic sedimentary rocks was displaced easterly over Mesozoic sedimentary rocks; undivided Cambrian-Devonian strata here and there are in overthrust contact upon the Jurassic Aztec Sandstone. After the overthrusting, this area was gently folded, and a southwest-northeast-trending anticline was formed in the Aztec, arching the region. And then the structure was breached by erosion, forming the window (fenster). It is because a normal shelf sequence lies in the Buffington Pockets and because it is just south of the Las Vegas Hinge Line that this "hinge-line play" could have a significant oil and/or gas potential. As herein interpreted, a test of subsurface conditions in the NE¼ T. 18 S., R. 65 E. of the Buffington Pockets, which would spud in the Jurassic Aztec Sandstone, could test the Triassic Moenkopi Formation before reaching 3,000 feet. The Kaibab, Toroweap, Coconino, and other Permian formations could be tested between about 4,500 and 9,000 feet.

The scales of Plate 1 and Text-figure 3 being identical, a comparison of the figures points up the location of the Virgin Mountain Anticline in the northeastern part of Clark County, Nevada. This anticline was named by Seager (1966) who mapped this area in detail; he also discussed the significance of the low-angle gravity-glide structures in this region (Seager, 1970). In addition, Beale (1965) studied and mapped the nearby Bunkerville district. On the tectonic map of Clark County (*see* Pl. 1), Seager's Virgin Mountain Anticline is so drafted that it plunges southwesterly into Quaternary alluvium on the southeast side of outcropping Precambrian crystalline rocks. In reality, however, the axis of this anticline extends southwesterly through the Precambrian rocks, and a high-angle normal fault (the Virgin Mountain Fault of Seager, 1966) drops the Precambrian into a graben-like structure on the southeast. Understandably, this anticline is disregarded from a petroleum potential. However, a southwesterly-plunging anticline to the southeast of it merits brief mention; it lies in sections 11, 15, 21, and 22, T.16 S., R. 70 E. Its significance lies in the fact that part of the Triassic Moenkopi Formation forms surface outcrops in sections 5 and 22, and a shelf section of Paleozoic carbonates and clastics not involved in overthrust faulting should be present in subcrop there. As herein interpreted, the Moenkopi Formation is thin here because the upper beds have been removed by erosion; therefore, it would be realistic to think that the entire Permian stratigraphic section could be tested by the drill stem before a depth of 4,000 feet is reached. In addition, the Pennsylvanian Callville Limestone, the Mississippian Monte Cristo Limestone, and the Devonian Muddy Peak Limestone should prove interesting targets. The top of the Cambrian should be reached before a depth of 7,000 feet. This would be a "hinge-line play," in that the Las Vegas Hinge Line was situated a few miles to the north of this anticline during the Paleozoic into Early Triassic times.

Reference to Text-figure 3 will reveal that another gravity anomaly is present in the Frenchman Mountain area, directly east of Las Vegas, an area which lies in close proximity to, and east of, the Las Vegas Hinge Line (*see* Pl. 1). Should a structural terrace exist in subcrop beneath the Mesozoic sedimentary rocks in that area, particularly in the central part of T. 20 S., R. 63 E., oil and gas possibilities would be a likelihood. A similar geologic setting typifies the Virgin oil field of southwestern Utah, west of Zion National Park: production there comes from the basal Moenkopi (the Timpoweap Member) in a structural terrace.

The Sloan Anticline is situated along the proximal part of the shelf adjacent on the east to the Las Vegas Hinge Line (*see* Pl. 1); therefore the Paleozoic rocks that occur in subcrop there are essentially transitional from the shelf to the basinal sedimentary rocks farther west (Bissell, 1969; Bissell and Chilingar, 1968). This anticline, in the writer's opinion, has not been given a test that can justify writing off its petroleum potential. On the colored geologic map of Clark County, Nevada (Longwell et al., 1965, Plate 1), the area of main interest of this anticline lies in the SE ¼ T. 23 S., R. 60 E. In 1947 the Nevada Exploration Company put down its No. 1 test in Sec. 13, T. 23 S., R. 60 E. to a total depth of 2,002 feet and, according to Lintz (1957a, p. 25-26), topped dolomites of Mississippian-Devonian age at a depth of 350 feet in the hole, which would indicate (1) that the hole was drilled through the Mississippian Monte Cristo carbonates and, seemingly, through the Devonian Sultan Limestone, and (2) that it must have bottomed in older carbonates. In 1964 Intermountain Associates Inc., drilled their Arden Dome No. 1 (No. IX) in Sec. 23, T. 23 S., R. 59 E. to a total depth of 3,293 feet. Valley fill is at the surface, and, according to Schilling and Garside (1968, p. 7), the top of the Mississippian (evidently the Monte Cristo) was encountered at a depth of 1,100 feet in this test. Mississippian, Devonian, and some older rocks evidently were not given drill-stem tests, although they were penetrated. However, adequate lithologic logs and reliable reports of oil and/or gas shows are not available, so these two tests should not be considered final for the Sloan Anticline. The Big Basin Oil Company No. 1 test, located in Sec. 17, T. 23 S., R. 61 E. (more on the basis of topography than on sound geologic advice), was drilled to a total depth of 1,180 feet, but no lithologic log or other information is available.

In essence, therefore, the few tests on the Sloan Anticline have neither been on structure nor are they conclusive. The Bird Spring Group of Pennsylvanian and Permian ages forms the surface outcrops, and so the prime targets in a subsurface test that is correctly located on structure would be the Mississippian Monte Cristo limestones and dolostones, similar carbonates of the Devonian Sultan, and possibly thin Silurian and Ordovician carbonates and clastics in tongues that wedge out to the east.

Paleozoic and Mesozoic sedimentary rocks of the shelf are represented in a wide spectrum of carbonates and clastics. The Virgin Limestone Member of the Moenkopi Formation (Lower Triassic) is of significance because it represents shoal-water environments (Belnap, 1971) of sedimentation, many of its enclosed bioherms containing tarry hydrocarbons. Shelf accumulations of the Permian Kaibab and Toroweap Formations—which produce commercial oil in the Upper Valley Field of Utah—have yet to be adequately tested in subsurface in southern Nevada. They consist of porous and permeable limestones and dolostones, and dolomitized units within them emit strong "sweet" hydrocarbon odors when the rock is fractured with a geology pick. Beneath the Toroweap Formation are

porous and permeable sandstones in the Coconino, Hermit, and Queantoweap formations. Dolostones of the Lower Permian Pakoon Formation are vuggy, porous, and permeable. Similar optimism can be expressed for the Callville carbonates and for dolostones and limestones of the Monte Cristo, Sultan, and older Paleozoic rocks.

The Basin.—Of the various holes that have been drilled west and southwest of Las Vegas (and thus in basinal sediments west of the Las Vegas Hinge Line), none adequately tested the Paleozoic section for petroleum potential. The Arden Dome west of Las Vegas was a structure of interest to petroleum geologists even before the U. S. Geological Survey unpublished report on it by Miller (1944). Several subsurface tests have a significant bearing upon this present discussion. They will be discussed geographically rather than in the sequence in which each test was made. A test of possible significance is the Kamarden Oil Company Federal, drilled in 1969 in Sec. 22, T. 22 S., R. 60 E.; total drilling was 6,760 feet. The Kamarden hole is No. 6 of Text-figure 1; it is interpreted that this test was made about three miles east of the axis of the Arden Dome and approximately six miles northwest of the center of a gravity closure (*see* Text-fig. 3). The lithologic log of this hole is significant: from 330 to about 1,000 feet in the hole, limestones, cherty limestones, minor shale, and sandstones were penetrated. Seemingly, this is the Kaibab-Toroweap couplet. Strong odors of oil and gas were reported at about 1,200 feet. Possibly the Hermit and Queantoweap Formations extend to a depth of about 2,200 feet; oil and gas shows were reported at depths of about 1,750 and 1,950 feet. It is interpreted that the top of the Bird Spring Group was encountered at about 2,225 feet and continued to a depth of about 3,200 feet, beneath which are the Mississippian Monte Cristo carbonates, Devonian Sultan carbonates, and questionable Ordovician Pogonip. Shows of oil and gas were reported at various horizons. It was suggested that the top of the Middle Cambrian Chisholm Shale was hit at a depth of about 6,300 feet, and rocks of Cambrian age continued to the bottom of the hole. It is unfortunate that no drill-stem or other tests were run on this deep hole.

Red Star Oil Company's J. B. Nelson No. 20 is a 20-foot offset from the J. B. Nelson No. 1 (T. D.: 2,210 feet) and was drilled to 3,767 feet; both are located in Sec. 20, T. 22 S., R. 60 E., about two miles west of Kamarden's deep hole, and are herein interpreted to have been on or near the anticlinal axis of the Arden structure but south and downstructure from the crest of this flexure. Shows of hydrocarbons at about 3,200 feet deep were recorded by Lintz (1957a, p. 23) and on a Halliburton electric log of the J. B. Nelson No. 1 test. Unconfirmed reports suggest that swab tests run on the No. 2 hole between about 3,300 and 3,340 feet obtained good shows of oil. A core taken about 3,205 feet is reported to have yielded hydrocarbons when cut with CCl_4.

The E. W. Bannister No. 1 hole, drilled in Sec. 34, T. 21 S., R. 60 E. to 522 feet is off-structure from the anticlinal axis of the Arden Dome and is inconclusive. The Commonwealth Oil Company No. 1, west of it, in Sec. 31, T. 21 S., R. 60 E. (*see* Text-fig. 1), is significant because, even though it was located more on-structure, it was drilled to only 1,897 feet. Lintz (1957a, p. 18-21) reported shows of gas at 800-805 and at 1560-1575 feet in this hole. The Jack F. Grimm Wilson No. 1 (Minerals Drilling Inc.) test (No. 8 in Text-fig. 1), in Sec. 9, T. 22 S., R. 60 E., was drilled to a total depth of 5,686 feet in 1965. Helium was encountered between 1,870 and 1,900 feet. Schilling and Garside

(1968, p. 7) report that the top of the Pennsylvanian-Permian Bird Spring Group was hit at a depth of 2,380 feet, the top of the Mississippian at 3,950 feet, and the top of the Devonian at 4,600 feet. Possibly the hole bottomed in the Cambrian, but it is not known if the Ordovician Pogonip is present, even in a thin wedge-edge pinch-out.

Bonanza Oil Corporation drilled its Arden Dome No. 1 (Consolidated Government No. 1) in the SW¼ Sec. 31, T. 21 S., R. 60 E., not far from Commonwealth Oil Company's test. The Bonanza hole, drilled to 3,260 feet, possibly bottomed in the Pennsylvanian segment of the Bird Spring Group. The hole was drilled in 1957 to the immediate east of the axis of the Arden Dome on a gravity anticlinal closure. Oil and gas shows were reported at 1,500 and 1,700 feet (in what was then termed the *Supai Formation*); gas shows, at 3,056 to 3,072 feet (in the Bird Springs); and oil shows, from 3,239 to 3,260 feet. The latter two were cored, and drill-stem tests were made. This hole was reentered in 1970 and was redrilled and washed to the old depth, and a battery of logs was run by Birdwell Division of Seismograph Service Corporation to evaluate the hole. Good porosity zones, and gas and oil shows were reported, all of which suggest that the tests of the Arden Dome directly west of the city of Las Vegas are not conclusive. On the contrary, they prove that oil and gas *are* present in the Paleozoic carbonates; what has yet to be established is their commercial value. It is herein strongly recommended that the Arden Dome be given an adequate test, namely, in a hole drilled from 5,500 to about 6,000 feet deep, on-structure, and near Bonanza's test.

Reference to Plate 1 will show the presence of a small flexure west of the Arden Dome in the Blue Diamond Hill area; outcropping sedimentary rocks involve the Virgin Limestone Member of the Moenkopi Formation and the Harrisburg Member of the Kaibab Formation. This fold is not shown on the Tectonic Map of Clark County, but it merits mention here because of its petroleum potential. The axis of this fold (essentially a structural terrace) extends from the SE¼ T. 21 S., R. 59 E., and is reflected in the outcropping Lower Triassic strata just west of Blue Diamond Village in Sec. 7, T. 22 S., R. 59 E. Petroleum potential may be in subsurface here in sandstones of the Queantoweap Formation, vuggy and porous carbonates of the Pakoon Formation (both of which are Permian), various clastics and carbonates of the Bird Spring Group (Pennsylvanian-Permian), the Mississippian Monte Cristo limestones and dolostones, and carbonates of the Devonian Sultan Formation. Gentle anticlinal flexures in the Blue Diamond Hill area lie east of the leading edge of the Keystone overthrust fault; the Paleozoic rocks here must therefore be in the lower-plate, or autochthonous, succession. Permian and Triassic sedimentary rocks here are west of the Las Vegas Hinge Line and show a shelf-to-basin transition (Bissell, 1969; Bissell and Chilingar, 1968).

Two structures west of the leading edge of the Keystone overthrust fault and, accordingly, in the upper plate that was translated to the east, are the Lost Cabin Anticline and the Mule Spring Anticline (*see* Pl. 1). Because the Lost Cabin structure was given a shallow test by an oil company, it will be discussed first. This anticline is shown but not labeled on the Tectonic Map and the Geologic Map of Clark County, Nevada. A comparison of Plate 1 with Text-figure 3 indicates that a large gravity anomaly is present in this area. The name, *Lost Cabin Anticline,* is new, being proposed herein; the name is taken from Lost Cabin Spring in the southwestern part of the Spring Mountains in Sec. 36, T. 21 S., R. 56 E., Clark County, Nevada. As will be noted in Plate 1 this is a

southerly-plunging anticline, sometimes loosely referred to by oil geologists (not in print, however) as the "Lovell Nose." Lovell Wash lies just to the east of this structure. Surface rocks in the anticline are the Lower Triassic Virgin Member of the Moenkopi Formation, with unnamed Permian redbeds (marine sandstones) in the core in the northerly part of this structure. This is the thickest section of the Virgin Member, in that its thickness expanded at the expense of the nonmarine members of the Moenkopi Formation as this Lower Triassic succession is traced from the shelf farther east to the miogeocline (*see* Bissell, 1969, 1970). A shallow test was made in the northern part of this anticline in 1959 when the Tri-State Oil Exploration Company drilled its J. H. Miskell-Government No. 1, spudding low in the section of the Permian redbeds. The 2,602-foot-deep hole is in the NE¼ Sec. 22, T. 21 S., R. 56 E. Only the Permian part of the Bird Spring Group was tested. A detailed lithologic log made available to the writer reveals slight oil shows and a thick sandstone section in the Bird Spring Group. It was plugged and abandoned, and because of its shallow depth is certainly an inconclusive test of this structure. More realistic tests of this anticline could be made about three to four miles north of the J. H. Miskell test: one could be located on the structure south of the C C Spring Fault in Sec. 11, T. 21 S., R. 56 E., or locations could be made adjacent to the C C Springs Fault where it offsets the Lost Cabin Anticline in Sec. 35 or Sec. 36, T. 20 S., R. 56 E. In any of these, surface exposures are the Pennsylvanian-Permian Bird Spring Group, and it would be anticipated that the top of the Mississippian Monte Cristo Formation would be about 3,000 feet deep, the Devonian Sultan Limestone about 4,500 feet, the Silurian Lone Mountain Dolomite about 6,000 feet, and the top of the Ordovician about 6,500 feet. Any test of the Lost Cabin Anticline farther south, particularly in the vicinity in which this structure plunges beneath Quaternary alluvium of Pahrump Valley, would obviously have to be a deep test.

The name *Mule Spring Anticline* is new, being proposed herein to identify a southerly-plunging structure that lies east of the Lost Cabin Anticline. The name is taken from Mule Spring, which is in Sec. 15, T. 22 S., R. 57 E., about 1½ miles north of the Pahrump Road. This anticline is not shown on the Tectonic Map of Clark County, so I have labeled it as well as the Lost Cabin Anticline on Plate 1. At Mule Spring the Toroweap and Kaibab Formations form the surface outcrops, whereas unnamed Permian redbeds (marine sandstones and orthoquartzites with minor limestones) crop out to the north adjacent to Lovell Wash. Postulated relations of these unnamed Permian redbeds were shown on a restored section of these strata as they are traced westerly from outcropping Queantoweap and Hermit Formations west of Las Vegas (Bissell, 1969). The Mule Spring Anticline is an unfaulted, gentle flexure and lies within, or on the flank of, a gravity anomaly. A somewhat similar stratigraphic section could be anticipated in subcrop here as with the Lost Cabin Anticline, although the full thickness (about 2,400 feet) of the unnamed Permian redbeds would of necessity have to be penetrated before the Bird Spring Group could be tested.

Interest in both the Lost Cabin and Mule Spring structures stems from the fact that these are gently-plunging anticlines with relatively low-angle dips on the flanks. East dips on the Lost Cabin Anticline at its extreme north are steep, however, becoming overturned in places. By contrast, the Mule Spring anticline has gentle flank dips. The stratigraphic section is of basinal sedimentary rocks and as such should contain shales and limestones capable of generating hydrocarbons.

Few publications carry overly optimistic statements concerning the oil and gas possibilities in southern Nevada (*see* Lintz, 1957b; Smith, 1956). Perhaps those geologists who have studied at least two of Longwell's papers pertaining to the structure of this part of Nevada have come to believe that the region is structurally too complex (*see* Longwell, 1949; 1950). The present writer still expresses optimism concerning southern Nevada's potential as a petroleum producer. Although the results of the tests of Texaco's hole in the Meadow Valley Mountain structure are not released, this area and those to the east (*see* Olmore, 1969) may yet prove to be productive in the Paleozoic rocks.

REFERENCES CITED

Beale, L. H., 1965, Geology and mineral deposits of the Bunkerville mining district, Clark County, Nevada: Univ. of Nevada, Nevada Bur. Mines Bull. 63, 96 p., colored geologic map.

Belnap, D. W., 1971, Petrology and geochemistry of shoal-water carbonates of the Virgin Limestone Member, Triassic Moenkopi Formation, Clark County, Nevada: Brigham Young Univ. Geol. Studies, v. 18, pt. 1, p. 147-84.

Bissell, H. J., 1969, Permian and Lower Triassic transition from the shelf to basin (Grand Canyon, Arizona to Spring Mountains, Nevada), *in* Geology and Natural History of the Grand Canyon Region: Four Corners Geol. Society Guidebook, p. 135-69.

———, 1970, Petrology and petrography of Lower Triassic marine carbonates of southern Nevada, U.S.A.: International Sedimentary Petrographical Series, v. 14, the Netherlands. 150 photomicrographs, 13 figs., 95 p.

———, and Chilingar, G. V., 1968, Shelf-to-Basin Permian sediments of southern Nevada, U.S.A.: XXIII International Geol. Congress, 23rd Session, Czechoslovakia, Proc. Sec. 8, p. 155-67.

Bowyer, B., and others, 1958, Geologic Map of Clark County, Nevada: U.S. Geol. Survey Mineral Inves. Field Studies Map MF-138 (scale 1:200,000) (not colored).

Lintz, J., Jr., 1957a, Nevada oil and gas drilling data, 1906-1953: Nevada Bur. Mines Bull. 52, Univ. of Nevada. 85 p.

———,1957b, What does Nevada's oil promise for the future?: The Oil and Gas Jour., April 1, 1957, p. 243-51.

Longwell, C. R., 1949, Structure of the Northern Muddy Mountain area, Nevada: Geol. Soc. Amer. Bull., v. 60, p. 923-68.

———, 1950, Tectonic theory viewed from the Basin Ranges: Geol. Soc. Amer. Bull., v. 61, p. 413-34.

———, and others, 1965, Geology and mineral deposits of Clark County, Nevada: Nev. Bur. Mines Bull. 62, Univ. of Nevada, 218 p., colored geologic map (scale 1:250,000).

Miller, J. C., 1944, Geologic reconnaissance of Arden Area, Clark County, Nevada: U.S. Geol. Survey unpublished report.

Olmore, S. D., Structure and stratigraphy of East Mormon Range and Vicinity, southern Nevada: unpublished M.S. thesis, Univ. of Utah, 98 p.

Schilling, J. H., and Garside, L. J., 1968, Oil and gas developments in Nevada, 1953-1967: Nev. Bur. Mines Report 18, Univ. of Nevada, 43 p.

Seager, W. R., 1966, Geology of the Bunkerville Section of the Virgin Mountains, Nevada and Arizona: unpublished Ph.D. thesis, Univ. of Arizona, 124 p.

———, 1970, Low-angle gravity glide structures in the Northern Virgin Mountains, Nevada and Arizona: Geol. Soc. Amer. Bull., v. 81, p. 1517-38.

Smith, W. T., 1956, Nevada still promising—but unproved: The Oil and Gas Jour., April 2, 1956, p. 181-83.

Tschanz, C. M., and Pampeyan, E. H., 1970, Geology and mineral deposits of Lincoln, County, Nevada: Nev. Bur. Mines Bull. 73, Univ. of Nevada, 188 p., colored geologic map (scale 1:250,000).

Wiese, J. H., 1960, The penetration chart of significant Nevada wildcats, p. 232 and chart *in* Geology of east-central Nevada: Intermount. Assoc. Petrol. Geol. 11th Ann. Field Conf. Guidebook, 278 p.