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HYDROCARBONS IN THE NORTHERN BASIN AND RANGE, NEVADA AND UTAH

Louis C. Bortz

Amoco Production Company
Denver, Colorado

ABSTRACT

Occurrences of surface and subsurface hydrocarbons in the northern Basin and Range suggest that oil and gas have been generated in several areas in this province. Documented surface occurrences include: 1) oil in ammonites found in Triassic shales in the Augusta Mountains northeast of Dixie Valley, 2) the Bruffey oil and gas seeps and asphaltite dikes in Pine Valley, 3) Diana's Punch Bowl (probable gas seep) in Monitor Valley, 4) in the ranges surrounding Railroad and White River valleys, droplets of oil are found in goniatites (Mississippian Chainman shale) and part of the Sheep Pass formation is oil stained at one locality, 5) oil shale occurs in the Tertiary Elko formation near Elko and the Ordovician Vinini formation in the Roberts Mountains, 6) numerous outcrops have a petroliferous odor and a few are oil stained.

Subsurface oil and gas shows are more widespread, but most have been found in the same general area as the surface shows. However, there are some important exceptions.

To date all commercial and noncommercial oil and gas fields in the northern Basin and Range are located near the sites of the surface hydrocarbons. This relationship emphasizes the importance of source rock studies to exploration in this province. Prospective areas that lack surface hydrocarbons might be delineated by source rock studies.

A total of eleven oil and gas fields have been discovered in this province of which only three or four can be classed as commercial fields. All of these fields are located in Neogene basins--no fields have been found in an exposed mountain range. The significant fields have some additional common characteristics: 1) the traps are associated with a Tertiary unconformity, 2) the reservoirs have a relatively thick oil column, 3) fractures usually enhance the reservoir quality. Fields in Railroad Valley and the Great Salt Lake are used to illustrate these and other characteristics.

INTRODUCTION

Numerous occurrences of hydrocarbons in the Northern Basin and Range province are direct evidence that oil and gas have been generated in many places within the province. Because of the great diversity of the geology and geologic history associated with these oil and gas "shows", it can be concluded that oil and gas have been generated from a variety of source beds within the northern Basin and Range province.

The scope of this paper is to briefly discuss the oil and gas fields, describe the important surface and subsurface hydrocarbon occurrences, suggest possible hydrocarbon source rocks for some of the areas, and summarize the characteristics common to the significant fields.

NORTHERN BASIN AND RANGE PROVINCE

This province as defined in this paper includes the area from Reno, Nevada, east to Salt Lake City. From north to south it extends from the northern Utah and Nevada state boundaries to a few miles south of the south end of Railroad Valley. (The province extends south to at least the Las Vegas shear zone, but this area was excluded because of "figure" format.) Figure 1 is a regional map of this area generalized from the Nevada (Stewart and Carlson, 1978) and Utah (Hintze, 1980) state geologic maps. This map shows the major Neogene-Quaternary basins. The intervening areas are the ranges, and in some places, late Tertiary volcanic rocks. The Tertiary volcanic rocks in northern Nevada are basalts that range in age from 6-17 m.y. (Stewart and Carlson, 1978). The approximate east edge of the province is shown by the hatchured line that extends north and south from Salt Lake City.

OIL AND GAS FIELDS

There are eleven oil and gas fields in this province; however, only four of these fields are currently producing. These fields are shown on Figure 1 and pertinent data for each field (or producing well) are shown on Table I. The two best fields are both in Railroad Valley. Eagle Springs, discovered in 1954 by Shell, has produced 3,570,206 BO

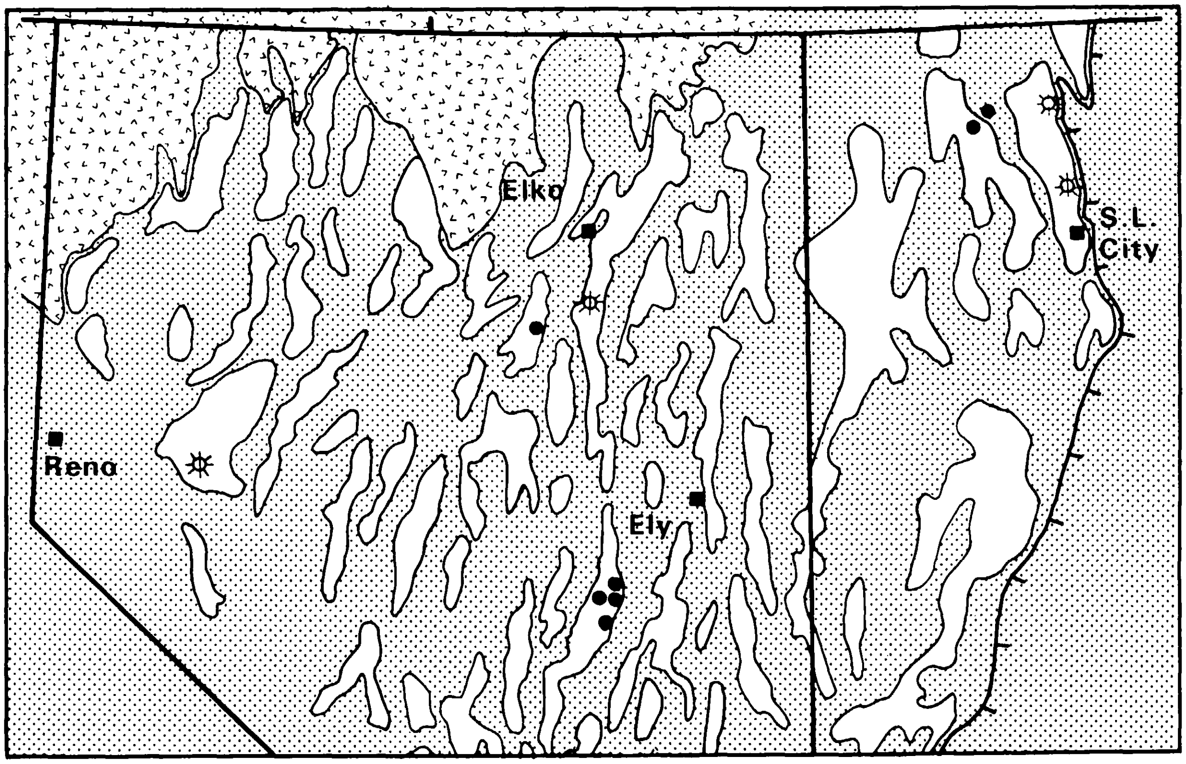

Figure 1. Northern Basin and Range province. ☐ - Major Neogene and Quaternary basins; ⊡ - Mostly pre-Neogene rocks; ⊡ - Upper Tertiary volcanic rocks (6-17 m.y.); - East edge of Basin and Range province; ● - Oil field; ☼ - Gas field.

TABLE I

Oil and Gas Fields

Field	Location	Disc. Date & Co.	Producing Fms.	Prod. Depth	Cumulative BO thru 1982	Remarks
NEVADA						
Fallon Area	T17-18N, R28-30E	1920's - ?	Quaternary	160'±	Unknown	97-98% CH_4 Tr C_2 H_6+
Eagle Springs	T9N-R57E	1954 - Shell	Oligo. Volcanics Eocene Sheep Pass Paleozoics	5780'-7256'	3,570,206	26-29° API 65-80°F Pour point
Trap Spring	T9N-R56E	1976 - NW Expl.	Olgio. Volcanics	3330'-4865'	4,602,874	21-25° API 0-5° F Pour point
Currant	T10N-R57E	1979 - NW Expl.	Eocene Sheep Pass	6856'-7080'	635 - SI	95°F Pour point 15° API
Bacon Flat	T7N-R57E	1981 - NW Expl.	Paleozoics	5316'-5354'	60,127	28° API 10° F Pour point
Jiggs	T29N-R55E	1980 - Wexpro	Tert. Elko	9096'-9420'	None - SI	IP 93 MCFD 558' Oil on DST
Blackburn	T27N-R52E	1982 - Amoco-Getty-North Central	"Tite Hole"	?	12,434	27° API
UTAH - BASIN AND RANGE						
Farmington	T3N, R1W	1892 - ?	Quaternary	500'±	150,000 MCF (Abn)	BTU 833
Rozel Point	T8N, R8W	Early 1900's - ?	Pliocene Basalt	125'-300'	3000+ BO Since 1956	9° API
Brigham City	T9N, R3W	1920's - ?	Quaternary	400'-700'	Unknown	
West Rozel	T8N, R8W	1978 - Amoco	Pliocene Basalt	2100'-2400'	28,000 BO (Abn)	4-6° API

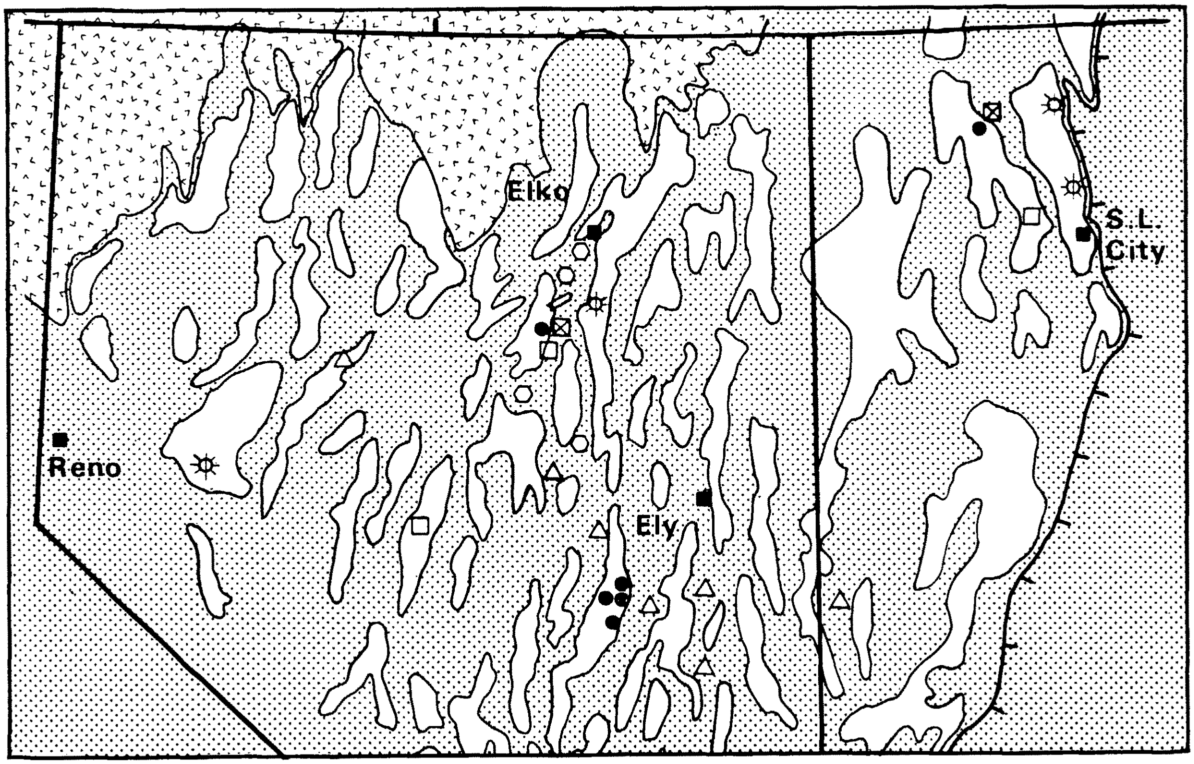

Figure 2. Documented surface oil, gas and other hydrocarbon occurences. ⊠ - Oil seep; □ - Gas seep; △ - Oil stain or droplets; // - Asphaltite dike; ⬡ - Oil shale locality.

TABLE II

Surface Hydrocarbons

	Area	Location	Reference
NEVADA			
Bruffey oil seep	Pine Valley - Sulphur Spring Range	T27N, R52E	Foster, et al., (1979)
Bruffey gas seep	Pine Valley - Sulphur Spring Range	T27N, R52E	Foster, et a., (1979)
Asphaltite Dikes	Pinon Range	T29N, R52E	Smith & Ketner (1975)
Gas Seep - Diana's Punch Bowl	Monitor Valley	T14N, R47E	Garside & Schilling (1979)
Bitumen and liquid oil in voids- Dev. Woodruff Fm.	Southern Fish Creek Range	T15-16N, R52E	Desborough, et al., (1979)
Oil in ammonites	Augusta Mtns. - Dixie Valley	T25-27N, R39E	Nichols & Silbering (1977)
Oil in goniatites	Railroad - White River Valleys	T13N, R56E T6N, R63E	Youngquist (1959)
Oil stain in Sheep Pass Fm.	Egan & Grant Ranges	T10N, R62-63E T9N, R58E	Winfrey (1959)
Oil Shale - Vinini Fm.	Roberts Mtns.	T23N, R51E	Merrian & Anderson (1942)
Oil Shale - Newark Canyon Fm.	S. Diamond Range	T20N, R54E	Foster, et al., (1979)
Oil Shale - Elko Fm.	Near Elko	T23N, R55E	Winchester (1923)
Oil Shale - Dev. Woodruff Fm.	Pinon Range	T32N, R52E	Desborough, et al., (1981)
UTAH			
Rozel Point oil seeps	Great Salt Lake	T8N, R8W	Eardley (1963)
Oil in fossils; Dead oil stain	Northern Needle Range	T25-26S, R19W	Gould (1959)
Gas Seeps	Great Salt Lake - So. Arm	Unknown	---

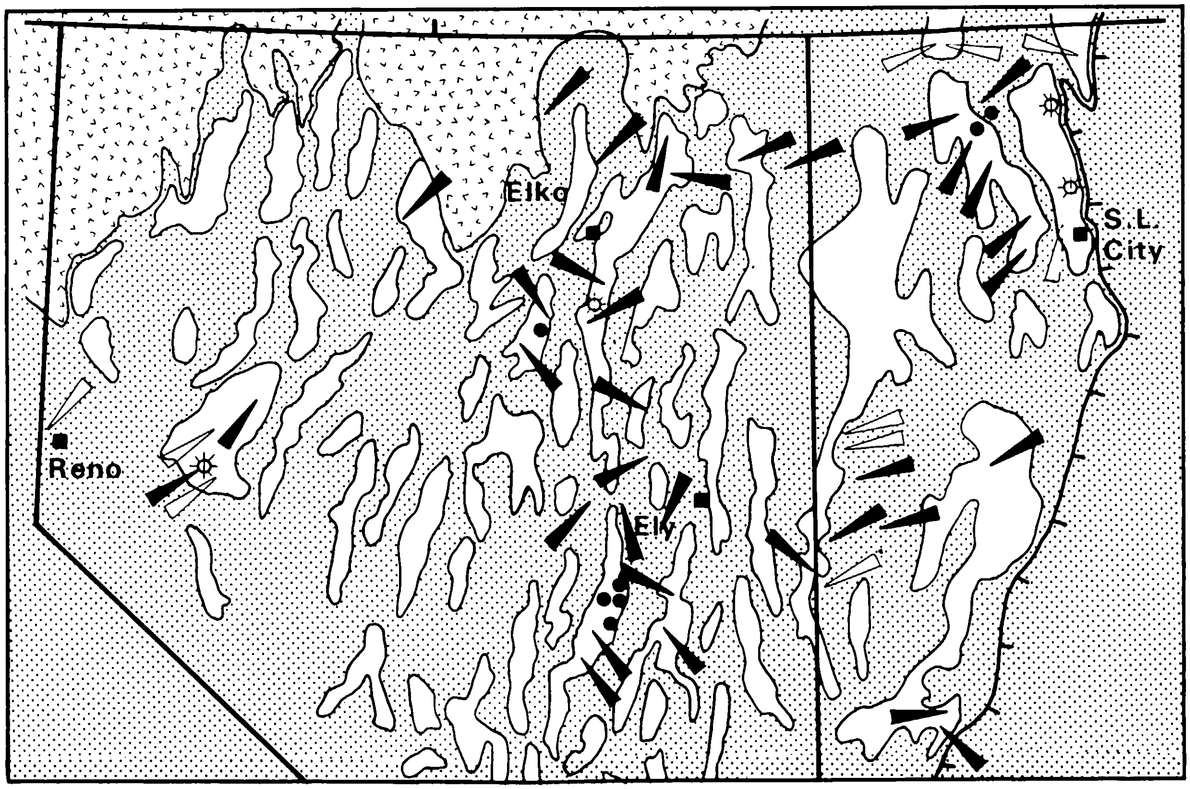

Figure 3. Subsurface shows of hydrocarbons. — Oil and gas shows; — gas shows only.

through October, 1982. Trap Spring was found in 1976 by Northwest Exploration and their partners and has produced 4,602,804 BO through October, 1982.

All of the fields produce from Tertiary or Quaternary sedimentary or volcanic rocks except for the Bacon Flat field which produces only from Paleozoic carbonates. Eagle Springs has one well that produced a small amount of oil from fractured Paleozoic carbonates (Bortz and Murray, 1979) and some of the wells in the eastern part of the field may also produce from Paleozoic rocks. The producing formation(s) in the Blackburn oil discovery has not been released.

All of these fields are located within a Neogene-Quaternary basin. Several wells have been drilled in the ranges or areas of pre-Miocene outcrop but only minor oil and gas shows have been encountered (Lintz, 1957; Shilling and Garside, 1968). Neogene and younger lacustrine and playa sediments apparently form effective reservoir seals in many of these late Tertiary basins. It is certainly possible for traps not associated with the Neogene basins to have economic reserves of oil and gas, but the chance of trap preservation is reduced because of tectonic activity prior to mid-Miocene time.

SURFACE HYDROCARBON OCCURRENCES

Documented surface oil, gas and other hydrocarbon occurrences are shown on Figure 2 and listed with references on Table II. Many outcrops within this province have sedimentary rocks that have a fetid or petroleum smell when freshly broken. These occurrences have not been included in Table II. No doubt there are other surface shows in this area that should be included in this list.

Surface shows of oil and/or gas are found in the vicinity of most of the producing areas. For example, the Bruffey oil and gas seeps are about four miles east of the Blackburn oil discovery in Pine Valley; the West Rozel oil field in the Great Salt Lake is 4 miles southwest of the Rozel Point oil seep; near the Railroad Valley oil fields, where surface shows are less obvious, droplets of oil are present in goniatites in a few local areas and oil stain is found in parts of the Eocene Sheep Pass formation in a few localities.

Oil shale is found in four different formations (Ordovician Vinini, Devonian Woodruff, Cretaceous Newark Canyon and Tertiary Elko) in an area from Elko to Eureka, Nevada. These organic-rich sediments and associated sediments may be possible oil and gas source rocks for this area.

Additional discussion of the surface hydrocarbons listed on Table II may be found in the section "Specific Areas for Discussion."

SUBSURFACE SHOWS OF OIL AND GAS

Subsurface shows of oil and gas in this province are shown on Figure 3 and are more widespread than surface shows. Data for this figure is from Lintz (1957), Schilling and Garside (1968), Garside, et al., (1977), commercial well reports and some Amoco data. It is very difficult to obtain complete and accurate data for all wells drilled in this province; some of these shows may not be legitimate in wells that were drilled on "promotional highs." Another problem is that many of these wells were drilled as "tite holes," and much of this valuable information has been lost or buried in company files. No list of subsurface shows is included in this paper.

Most of the subsurface shows will be discussed as part of the "Specific Areas for Discussion." Three areas which have had significant subsurface shows outside of these detailed areas will be discussed briefly in this section:

1) In the Fallon area there are several minor gas shows that are associated with the shallow gas field. The gas is probably biogenic, but several wells have reported minor "asphalt" or oil shows associated with the gas shows. An analysis by the U.S.G.S. (Casper Wyo. No. 47-G-8) of gas from a water well (Sec. 1, T19N, R30E) has a surprising amount of heavy hydrocarbons:

	Percent	
Carbon Dioxide	- 1.65	
Oxygen	- 0.0	
Methane	- 40.21	BTU - 689
Ethane+	- 15.88	
Nitrogen	- 42.26	

Possibly, there could be oil source rock in some of the western Nevada Neogene-Quaternary basins. Alternatively these oil shows may be the result of local oil generation near igneous activity centers.

2) North and northeast of Elko in the "Humboldt Basin" there is a concentration of documented oil shows in the Lower Tertiary Elko formation. Possible source rocks for this area include the Elko formation, Mississippian Chainman shale and Ordovician Vinini formation.

3) In west-central Utah, from the Confusion Range south to the Needles Range, several shows of oil and gas have been found in lower Paleozoic formations. Parts of the lower Paleozoic section, the Devonian Pilot shale and the Chainman shale could be the source for these shows.

FREE OIL AND GAS SHOWS

There are surprisingly few free oil and gas shows in this province that can documented. The ones that I feel are legitimate are shown on Figure 4 and listed with pertinent information in Table III. There may be additional wells that have had shows of free oil or gas.

Somewhat surprising is the fact that in Railroad Valley, outside the limits of the oil fields, there is not one well that has recovered free oil on DST, production tests or on the pits while drilling.

Most of the free oil shows have been found close to the known fields and will be described in the "Specific Areas for Discussion" portion of this paper. Two exceptions to this are two wells NE of Elko and a well in the Snake Valley SE of Ely.

NE of ELko the Gulf No. 1 Wilkins Ranch (Sec. 21, T38N, R61E) had a show of oil on the pits while drilling at 7700 feet in the Elko formation. Several zones in this well had live oil staining but no free oil was recovered on DST. In the same township, Shell Oil at the 1 Mary's River Federal (Sec. 30, T38N, R61E) recovered 275 feet of GCM and 25 to 35 MCFD on a DST of the Tertiary from 3515 to 3545 feet. The sample chamber of this DST had 2100 cc mud/oil emulsion and about 50 cc of 39° API oil. A well that was recently abandoned, Sun No. 3-13 S.P. (Sec. 13, T39N, R65E) is rumored to have recovered free oil on at least 2 DSTs. The formation is unknown but it is probably the Elko formation.

In Snake Valley, Commodore No. 1 Outlaw-Federal (Sec. 1, T10N, R70E) recovered three feet of heavy viscous oil during a swab test of perforations from 12,081 to 12,090 feet in the Ordovician Pogonip.

There have been very few free gas recoveries outside of the gas fields. The oil fields in Railroad Valley produce virtually no gas. Gas shows near the Fallon, Brigham City and Farmington fields were not included in the map or list because very little reliable data is available. For additional information on the Fallon area see Lintz (1957) and Schilling and Garside (1968).

The only free gas shows on the map and list (Figure 4 and Table III) were reported from the Shell Oil 1 Mary's River Federal (previously mentioned) and the Amoco No. 1 Jiggs (Sec. 19, T29N, R56E) that had GTS, TSTM on a DST of 4685 to 4807 feet in Tertiary sediments. This dry hole is three miles east-southeast of the Wexpro Jiggs gas well.

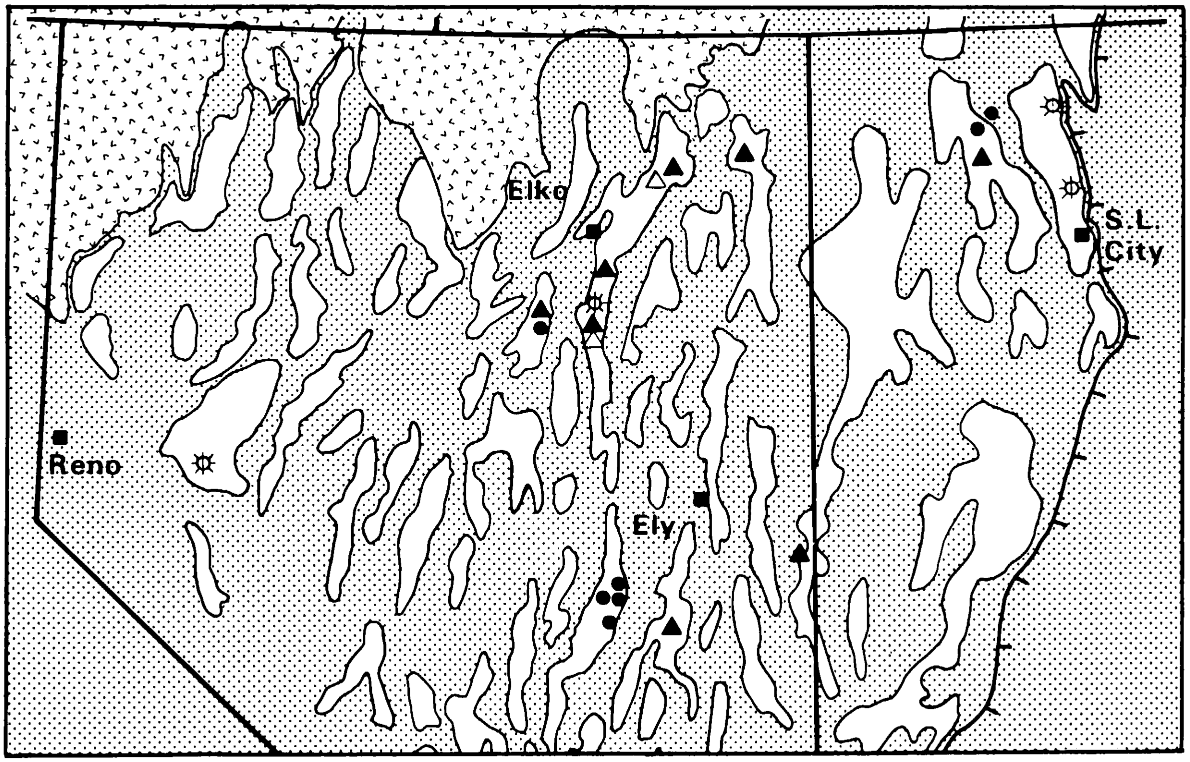

Figure 4. Documented free oil and gas shows. ▲ - Oil; △ - Gas

TABLE III

Free Oil and Gas Shows

Well	Location	Area	Formation	Show	Depth	Remarks
NEVADA						
NW Expl. 6 WRV	7N-61E	White River Valley	Tov	1 cu. in - DST	2190'-2225'	Pour point 115°F; BHT 95° F
Commodore 1 Outlaw-Fed.	10N-70E	Snake Valley	Pogonip Gp.	3 feet in tubing	12,081'-12,090'	High pour point
Beyerbach 1 Fee	27N-52E	Pine Valley	Qal	F 5 BO in 1 day	112'-242'	Near Bruffey seep
Amoco 1 Jiggs	29N-56E	Huntington Valley	Elko Formation	Oil on pits DST-Rec 587' OCM&W	6550'-6652'	GTS TSTM @ 4685'-4807'
Amoco 1 Huntington	31N-56E	Huntington Valley	Elko Formation	Swbd 8 BO + wtr in 8 days	5760'-5830'	Sli S/G
Gulf 1 Wilkins Ranch	38N-61E	Wells	Elko Formation	Show oil on pits	7705'-7772'	DST Rec 90' mud with oil spots
Shell 1 Mary's River	38N-61E	Wells	Tert.	50 cc oil, 39° API	3515'-3545'	GTS 26 to 39 MCFD
Sun 3-13 SP	39N-65E	Pequop	Tert. (?)	Rumored--2 DSTs rec. free oil	?	
UTAH						
Amoco 1 State "P"	8N-8W	Great Salt Lake "E. Gunnison"	Pliocene Sediments	DST 2 - Rec. 19' oil DST 3 - Rec. 1 gal., oil	4880'-5004'	High pour point oil

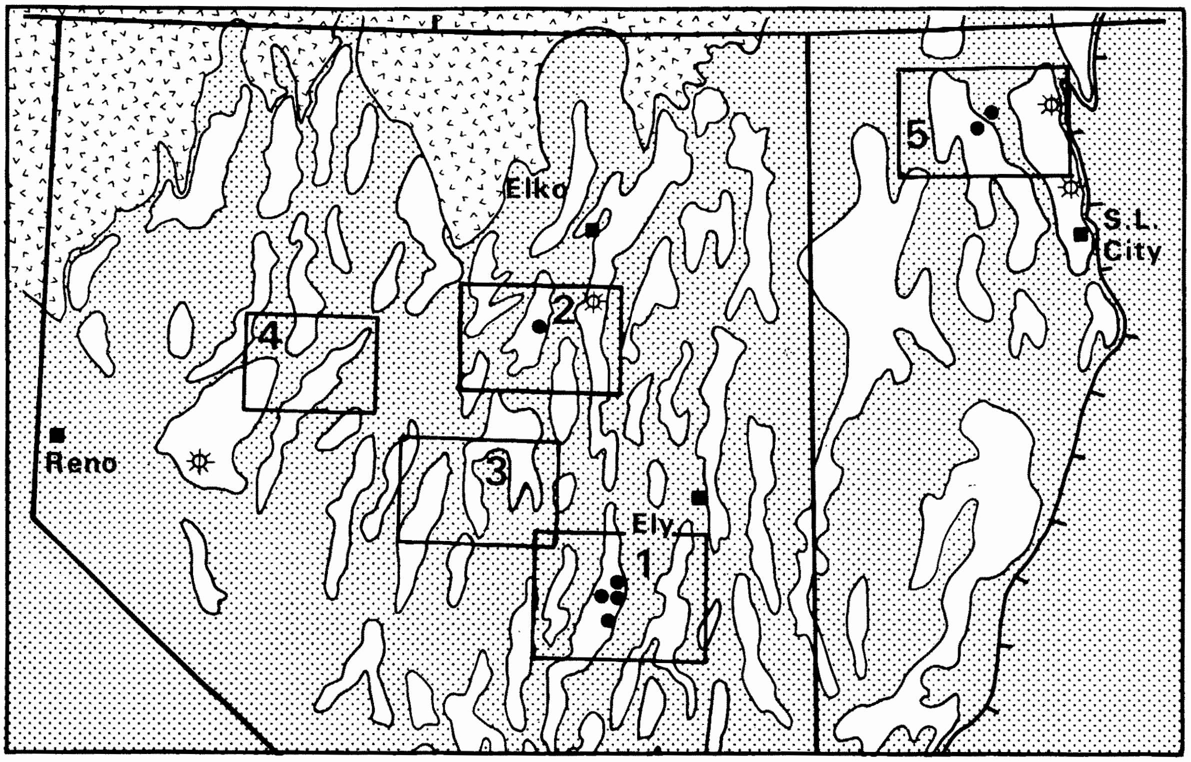

Figure 5. Map showing specific areas for discussion. 1 - Sheep Pass Basin; 2 - Pine Valley; 3 - Monitor Valley (Diana's Punch Bowl); 4 - Dixie Valley; 5 - North Great Salt Lake.

SPECIFIC AREAS FOR DISCUSSION

Figure 5 shows five areas that will be described in some detail to show the relationship between hydrocarbon occurrences and the geology. The five areas are:

1) Sheep Pass Basin (Railroad and White River Valleys)
2) Pine Valley
3) Monitor Valley (Diana's Punch Bowl)
4) Dixie Valley
5) North Great Salt Lake

SHEEP PASS BASIN (RAILROAD AND WHITE RIVER VALLEYS)

Railroad Valley, located within the Sheep Pass Basin (Winfrey, 1960), has been the center of oil exploration in the Basin and Range province since Shell Oil discovered the Eagle Springs field in 1954. Eagle Springs and the Trap Spring fields have produced virtually all of Nevada's cumulative total of 8,246,278 BO through October, 1982. The petroleum geology of Railroad Valley is discussed by Duey in this volume.

Figure 6 is a generalized geologic map of the Sheep Pass basin modified after Stewart and Carlson, 1978. The valley areas shown by the QT outcrops form the Neogene Basins which were initiated during the Miocene. Beneath the Miocene sediments the older Tertiary and Paleozoic outcrop pattern is approximately the same as can be seen in the adjacent ranges (Bortz and Murray, 1979). (This principle may apply to all five of the detailed areas.)

Tertiary intrusives are present in the Grant and White Pine Ranges east of the producing fields. The deepest well in the Eagle Springs field TD'd in an intrusive below Paleozoic rocks (Bortz and Murray, 1979). Obviously, the presence of intrusive rocks in this and other areas within this province does not destroy its petroleum potential.

Surface occurrences of oil in this area include oil in fossils and oil stain in the Sheep Pass formation. Free oil occurs in late Mississippian goniatites in black limestone lenses in the upper part of the Chainman formation (Youngquist, 1949). Two documented localities shown on Figure 6 are: 1) northern Railroad Valley in Section 17, T13N, R56E, and 2) southern Egan Range, Section 7, T6N, R63E. Only a small percentage of these fossils have free oil when cracked open.

The Sheep Pass formation is oil stained in an 800-foot interval in the type section in the Egan Range. Figure 7 is the type section as described by Winfrey (1960) that has oil

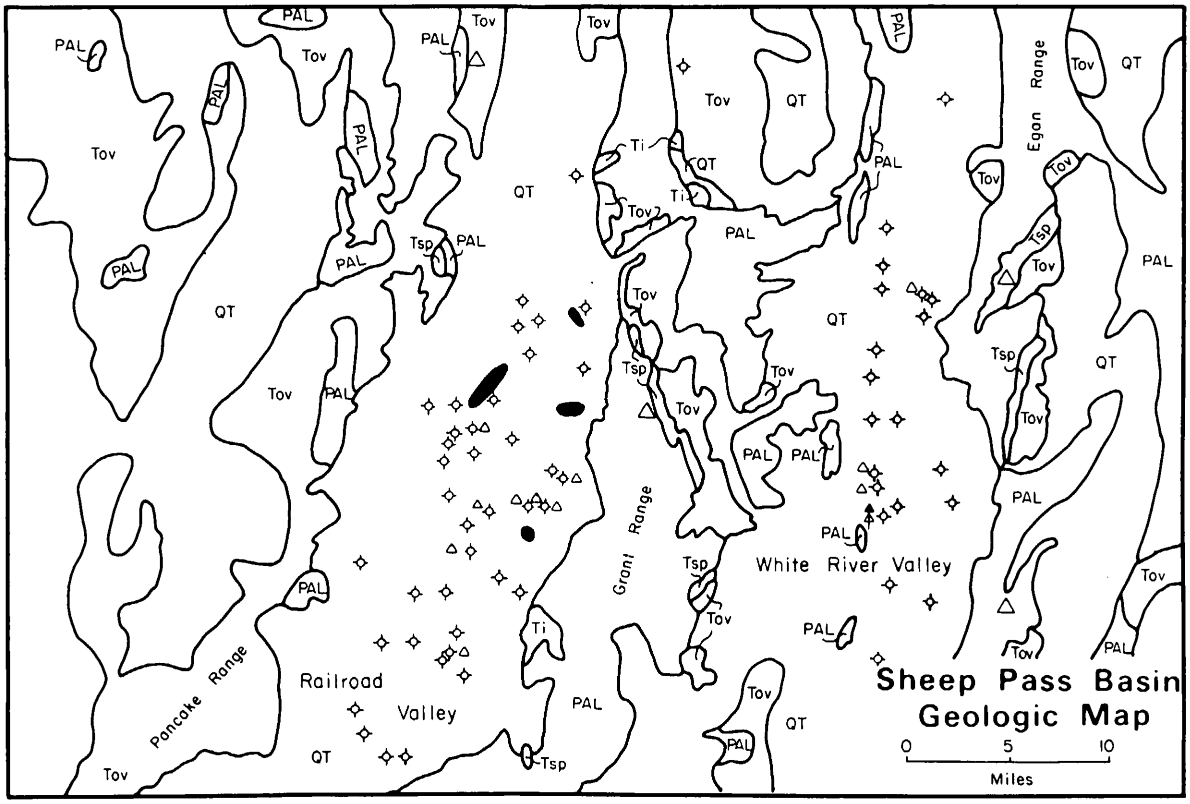

Figure 6. Sheep Pass basin. QT - Miocene to Recent volcanic and sedimentary rocks; Tov - Oligocene volcanic rocks; Tsp - Cretaceous - Eocene Sheep Pass Formation; PAL - Paleozoics undifferentiated; Ti - Tertiary intrusive; - Oil field; ▲ - Free oil show; △ - Minor oil show; - Minor gas show; △ - Surface oil show.

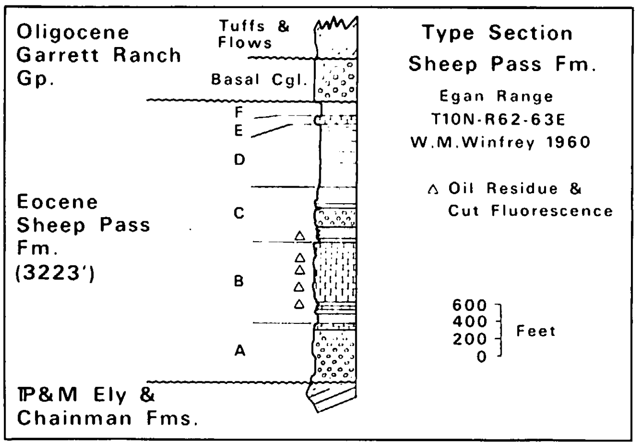

Figure 7. Type section, Sheep Pass formation.

stain, residue and cut fluorescence in the "B" and "C" members. The "B" member is probably equivalent to the Sheep Pass reservoir in the Eagle Springs field. Minor oil staining in Sheep Pass limestones has been observed in the Grant Range due east of the Eagle Springs field.

Possible source rocks for the Sheep Pass basin area are the Mississippian Chainman shale, Devonian Pilot shale and the Eocene Sheep Pass formation (Poole, et al., this volume).

Subsurface shows of oil and gas are shown on Figure 6 for all wells completed through 1982. Some of the dry holes near the producing fields have been omitted from the map; however, many of these wells did not have any significant shows of oil or gas. Only a small percentage of the wells drilled in these two valleys had oil and gas shows. Most of the shows were found in the Sheep Pass formation and the Oligocene volcanic rocks. A few shows have been reported from Paleozoic formations and the Miocene to Recent sediments. Typical shows are scattered oil stain and minor amounts of gas detected by mudlogging units.

No free oil recoveries have been reported outside of the field areas in Railroad Valley. In White River Valley, one cubic inch of heavy oil was recovered on a DST (2190-2225 feet) of Oligocene volcanic rocks in the Northwest Exploration No. 6 White River Valley (Sec. 10, T7N, R61E). The small amount of oil recovery can be attributed to the pour point of the oil (115°F) being higher that the temperature of the DST interval (95°F).

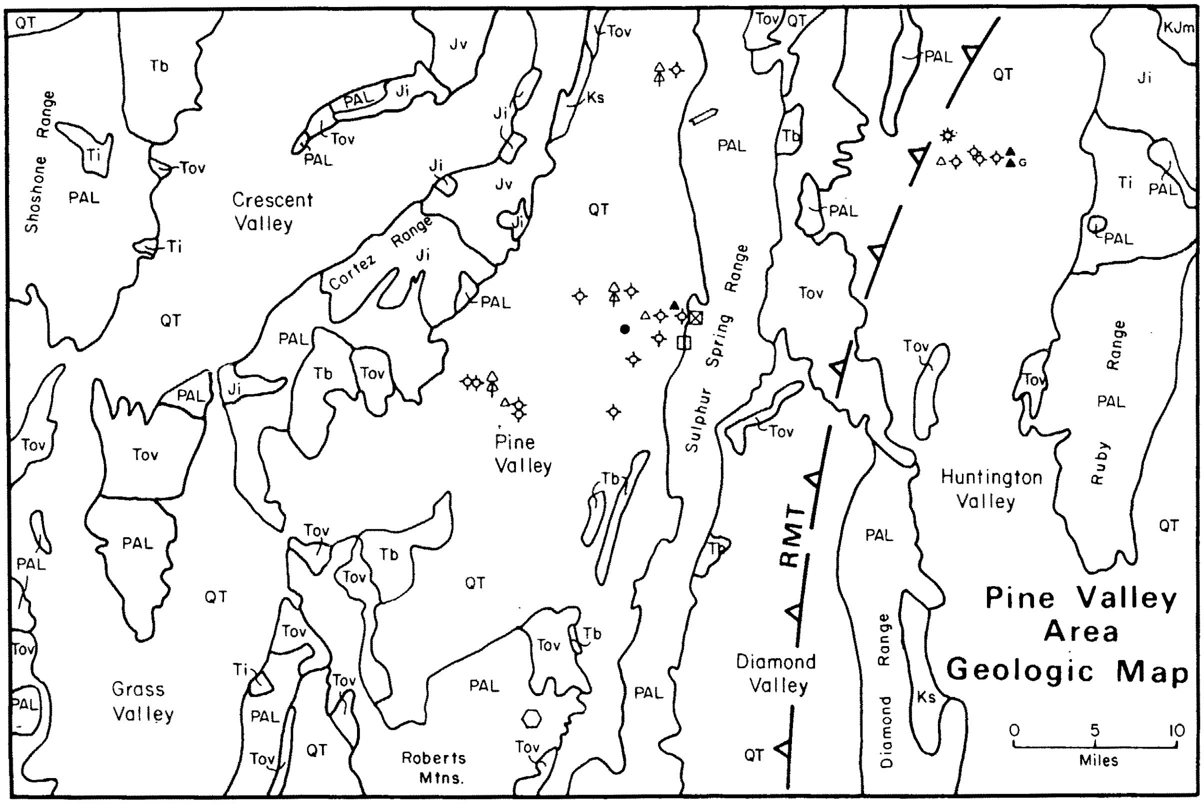

Figure 8. Pine Valley area. QT - Miocene to Recent volcanic and sedimentary rocks; Tb - Basalt; Tov - Oligocene volcanic rocks; Ks - Lacustrine and fluvial rocks; Jv - Volcanic sandstone, tuffs, rholite and rhyodacite; PAL - Paleozoics undifferentiated; T, Ji - Intusives; KJm - Metamorphic rocks; - Approximate leading edge of Robert's Mtns. thrust; ● - Oil discovery (Amoco No. 3 Blackburn); - Gas discovery (Wexpro No. 10-1 Jiggs); ⊠ - Oil seep; □ - Gas seep; - Asphatite dike; ⬡ - Oil shale locality; ▲ - Free oil show; △ - Minor oil show; ▲G - Free gas show; - Minor gas show.

Figure 9. Bitumen-impregnated conglomerate at Bruffey oil seep.

Figure 10. Bruffey Gas seep.

PINE VALLEY AREA

The generalized geologic map (Figure 8) of the Pine Valley area has been modified after Stewart and Carlson (1978). This area was active during the Antler orogeny in which the Ordovician Vinini shales and siliceous rocks were thrust eastward over Devonian and older miogeosynclinal carbonates (Roberts, et al., 1958). The eastern edge of the Roberts Mountains thrust is somewhere between the Sulphur Springs Range and the Diamond Range. Thus, in Pine Valley and the western part of Huntington Valley, the Vinini formation may be present beneath the Neogene and younger sediments and is potentially an additional source rock.

Pine Valley has Nevada's best known oil and gas seeps, the Bruffey Ranch seeps, that have been described in detail by Foster, et al., (1979). The seeps are located in Quaternary sediments and Ordovician Vinini shales and cherts in Sections 11 and 14, T27N, R52E. The seeps are associated with the main boundary fault zone that separates the east flank of Pine Valley from the Sulphur Springs Range. Foster, et al., state that "the seep consists of black tar- or bitumen-impregnated conglomerate composed of limestone and dolomite pebbles in the clay and sandstone matrix." Figure 9 is a photograph of the bituminous seep. About 100 feet west of this seep is another oil seep in an outcrop of Vinini shale that has been observed by Charles H. Thorman (personal communication, 1983). This seep is also within the boundary fault zone. The original seep was discovered over 50 years ago when Mr. R. V. Bruffey enlarged a hot spring for an irrigation development and oil began to ooze out upon the surface in black tarry masses. Foster, et al., submitted a sample of the bituminous material to a major company (unnamed) for analysis. The subsequent report stated that the material is strongly degraded oil, possibly of parafinic base.

A mile south of the oil seeps is a thermal spring from which a large number of gas bubbles rise from mud on bottom and break to the surface (Figure 10). Foster, et al., collected a gas sample which was analyzed by Hager Laboratories, Inc., of Denver, Colorado. The following is a summary of the quantitative analysis:

	ppm by volume
Methane	8300
Ethane	1.5
Propane	0.3
n-Butane	0.2
n-Pentane	0.8
n-Hexane	0.2
z-Methyl-Heptane	0.1

This analysis containing fractions of C_1 through C_7 hydrocarbon compounds suggests that origin of gas was thermogenic rather than biogenic.

Two other surface hydrocarbon occurrences shown on Figure 8 are: the oil shales of the Vinini formation exposed along Vinini Creek in the Roberts Mountains and reported by Merrian and Anderson (1942) to give assay yields in excess of 25 gallons per ton, and the asphaltite dike in the Pinon Range (NE/4 Sec. 1, T29N, R52E) where solid bituminous material occurs as a narrow vein-like body and as fracture fillings in Chainman shale (Smith and Ketner, 1975). Exposures of this dike are very poor.

Possible source rocks capable of generating oil and gas in the Pine Valley area are:

- Ordovician Vinini shales and cherts
- Devonian Woodruff formation
- Mississippian Chainman shale
- Cretaceous-Paleocene Newark Canyon formation

Foster, et al., (1979) discuss the source rock potential of the Vinini and Newark Canyon formations.

On January 3, 1983, Amoco Production Company announced the completion of an oil discovery in Pine Valley. The Amoco-Getty-North Central Blackburn Unit No. 3 (SW SE 8-T27N-R52E) was completed pumping 346 BO and 767 BWPD. The oil has an API gravity of 27° and is being trucked to a refinery in Tonopah, Nevada. Through October, 1982, the Blackburn discovery has produced 12,434 BO. The producing formation(s) and perforated intervals (two zones) have not been released by Amoco.

The Blackburn discovery is 3 1/2 miles west of the Bruffey oil and gas seeps. Two offset wells, 1/2 mile west and 1/2 mile south, have been completed as dry holes.

Several wells have been drilled near the Bruffey seeps in Pine Valley, the boundary fault zone and in the Sulphur Spring Range (Foster, et al., 1979). The best show of oil was found in the Beyerbach and Black well (NE NW SE 11-T27N-R52E) which was drilled in the fault zone to a depth of 1205 feet in Quaternary sediments. Oil shows were encountered at 112 and 242 feet and reportedly the well flowed 5 BO for one day in 1960.

Shows of oil and gas have been found in other parts of Pine Valley. The Getty No. 1 NOST (NW NE 32-T28N-R52E) drilled in 1977 to a TD of 10,505 feet in Tertiary or Cretaceous volcaniclastics encountered only minor shows of oil (oil stain) and gas. Aminoil No. 1-23 SP (Sec. 23, T30N, R52E) drilled in 1979 to a TD of 7145 feet in the Paleozoics also found only minor increases of methane on the mud log and at 5430 feet asphaltic material had a yellow cut fluorescence. Four wells have been drilled about 8 miles southwest of the Blackburn discovery, and two of these wells reported oil and gas shows, but no description of the type of shows is available.

In Huntington Valley, Wexpro completed the No. 10-1 Jiggs (Sec. 10, T29N, R55E) flowing 93 MCFPD from perforations between 9096 and 9420 feet in the Teritary Elko formation. A DST of 9391 to 9440 feet recovered 558 feet of heavy oil and some natural gas, TSTM. The Wexpro well is probably not commercial; however, this well proves that hydrocarbons have been trapped in this area. Four other wells have been drilled nearby and shows of oil and gas were reported from two of them. The best show was in the Amoco No. 1 Jiggs (NE NE 19-T29N-R56E) which had a show of oil on the pits while drilling between 6550 and 6652 feet in the Tertiary Elko formation. A DST of this interval recovered 587 feet of oil cut mud and water. GTS TSTM was recovered on a DST at 4685-4807 feet.

MONITOR VALLEY AREA (DIANA'S PUNCH BOWL)

As can be seen on the generalized geologic map (Figure 11) modified after Stewart and Carlson (1978), this area is similar to Pine Valley in that the leading edge of the Roberts Mountain thrust is in eastern portion of the area. East of the thrust only pre-Antler eastern assemblage rocks are present, but to the west, both western and eastern assemblage rocks are present. Thus, the Paleozoic source rocks for the two areas are similar.

Diana's Punch Bowl is the only dramatic occurrence of surface hydrocarbons in this area. The best reference to Diana's Punch Bowl, located in Section 22, T14N, R47E, is Garside and Schilling (1979). They describe the bowl "...as a cup-shaped depression approximately 50 feet in diameter at the top of a domelike hill of travertine approximately 600 feet in diameter. Warm water in the pool of the bowl is 30 feet below the top of the rim while the top of the hill is about 75 feet above the level of Monitor Valley." Figure 12 is a photograph of Diana's Punch Bowl from the road. The hot spring was originally called the Devil's Punch Bowl in the early 1900's because occasional flames were seen and more gas than at present was emitted. This was described by J. J. Butler in Spurr (1905).

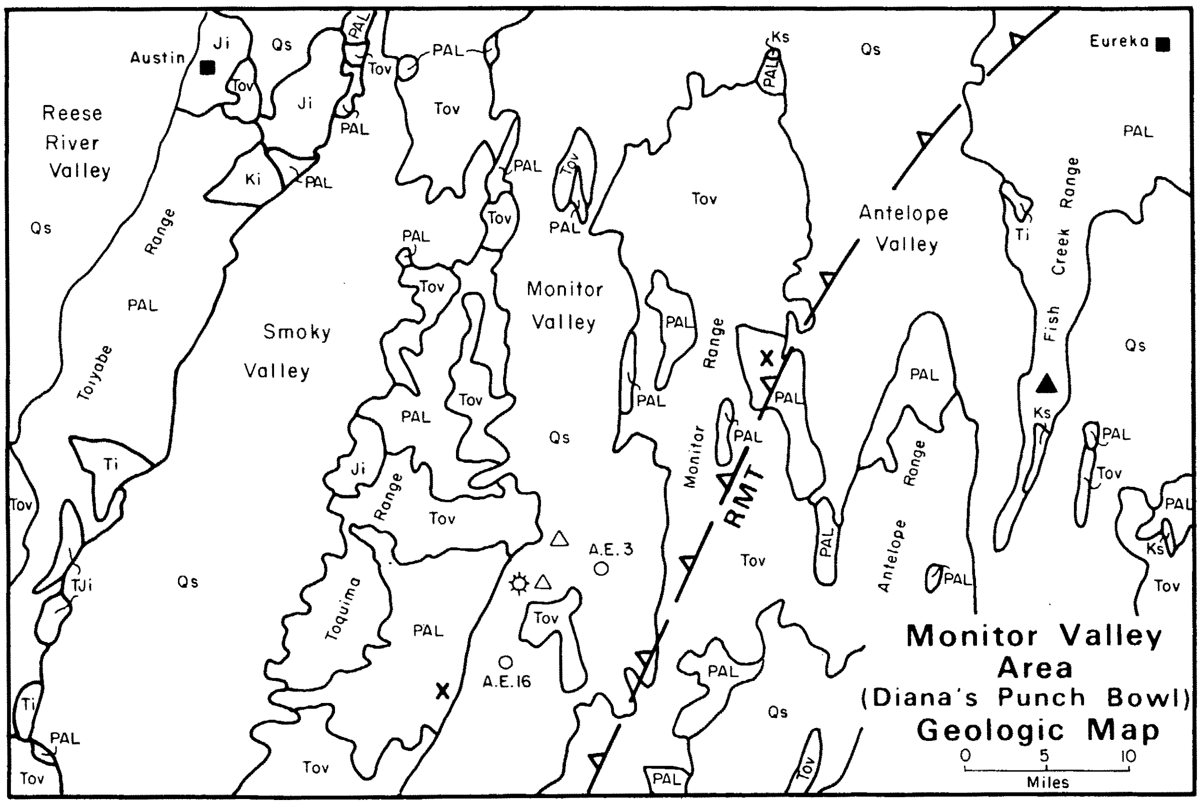

Figure 11. Monitor Valley area. Qs - Quaternary alluvial and playa deposits; Tov - Oligocene volcanic rocks; Ks - Cretaceous to Eocene lacustrine and fluvial rocks; PAL - Paleozoics undifferentiated; Ti, Tji, Ki, Ji - Intrusives; - Approximate edge of Robert's Mtns. thrust; - Diana's Punch Bowl; △ - Gas seep; ▲ - surface oil show; ○A.E. - A.E.C. well; X - Petroliferous odor in rocks.

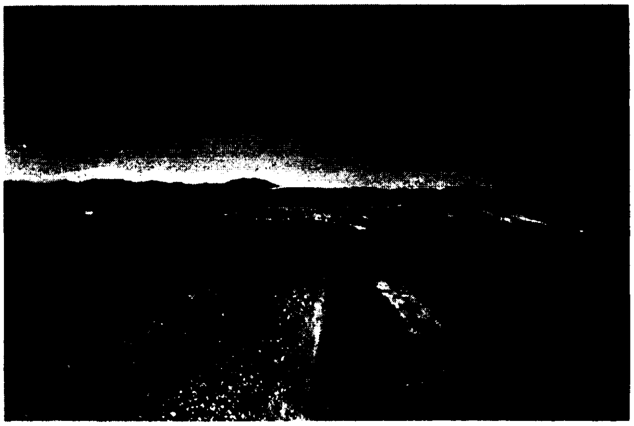

Figure 12. Diana's Punch Bowl.

No analysis of the gas from Diana's Punch Bowl is available to the writer. The gas could be biogenic and insignificant to oil and gas exploration. However with the presence of C_1 through C_7 in the Bruffey gas seep, there is a possibility that the gas in Diana's Punch Bowl is similar and that there may be significant source rocks for oil and gas in this area.

At Potts' Ranch four miles north of Diana's Punch Bowl there are several hot springs (Sec. 2, T14N, R47E) including one that emits some gas (Garside and Schilling, 1979). Mariner, et al., (1975) report an analysis of this gas in volume percent: $O_2 + A_r = 4$, $N_2 = 93$, $CH_4 < 1$, $CO_2 = 3$. This gas may be biogenic since methane is the only hydrocarbon present; however, the composition of this gas is probably different than the gas at Diana's Punch Bowl because this mixture with less than 1 percent methane probably would not ignite.

In an unnamed Devonian limestone about 7 miles southwest of Diana's Punch Bowl (X on Figure 15), McKee (1976) has described 100 feet or more of thin-bedded dark petroliferous-smelling limestone and black shale. In the Monitor Range (X on Figure 11), Bortz (1959) reported strong petroliferous odor in brown-black calcareous mudstone at the base of the Ordovician Hanson Creek formation. Many of the Paleozoic formations in the Basin and Range province contain limestones and shales that have a fetid or petroliferous odor. These occurrences have not been mentioned in other areas because they are so common. If there were no units in the Monitor Valley area with petroleum odor, its potential for significant source rocks would be reduced.

In the southern Fish Creek Range (T15-16N, R52E) Desborough, et al., (1979) have described oil shows in the Devonian Woodruff formation. They state, "In fresh rock solid bitumen and liquid oil fill voids and microfractures." The Woodruff formation is a possible source rock in the eastern part of the Monitor Valley area.

No wells have been drilled for oil and gas in the Monitor Valley area (Figure 15). Two wells were drilled in Monitor Valley by the A.E.C. as test holes for nuclear devices (Hoover, et al., 1969). One well (UCe 3) 5 miles east of Diana's Punch Bowl encountered only welded tuffs from surface to a TD of 2000 feet. The other well (UCe 16) 5 miles south of Diana's Punch Bowl penetrated 1100 feet of alluvium, then drilled volcanic tuffs and flows to a TD of 4353 feet. No oil or gas shows were reported in either well.

DIXIE VALLEY AREA

This area is the only detailed area in western Nevada and the generalized geologic map (Figure 13) shows that the geology is quite different from the other detailed Nevada areas. (This map is also modified after Steward and Carlson, 1978.) There are no Paleozoic rocks in the Dixie Valley area; the oldest rocks are Triassic sediments and intrusives. The valley areas are also Neogene to Recent depositional basins.

Since 1978 at least 12 geothermal wells have been drilled in Dixie Valley ranging in depth from 3010 to 12,500 feet. Some of these wells are geothermal producing wells and others are temperature gradient and observation wells. These wells are in the general area of the three wells shown on Figure 13 and are in T24N, R36 and 37E. See Edmiston (1982) for a review of geothermal activity in the northern Basin and Range from 1974 through 1981.

The petroleum industry is attracted to this area because of possible Triassic source rocks in the ranges flanking the northern part of Dixie Valley. Nichols and Siberling (1977) describe the Fossil Hill member of the Middle Triassic Favret formation as a 200-meter sequence of dark-gray calcareous shale with interbeds of fossiliferous lime mudstones in the Augusta Mountains (T25N, R39E). When broken, chambers of ammonoids from concretions commonly yield liquid hydrocarbons (Figure 14). Figure 15 shows an outcrop of dark-gray calcareous shale within the Fossil Hill member in the Augusta Mountains. This is part of the "Triassic "C" outcrop shown on Figure 13.

In the Tobin Range at the north end of Dixie Valley between the Augusta Mountains and the Stillwater Range, Burke (1973) found similar hydrocarbon-bearing cephalopods within the higher part of the Favret-Prida section (T26 and 27N, R39E). This section consists of 300 feet of poorly exposed dark mudstone, fine-grained limestone and fine-grained calcarenite. All of these rocks have a strong petroliferous odor when broken and liquid hydrocarbon was found in the hollow chambers of some cephalopod shells.

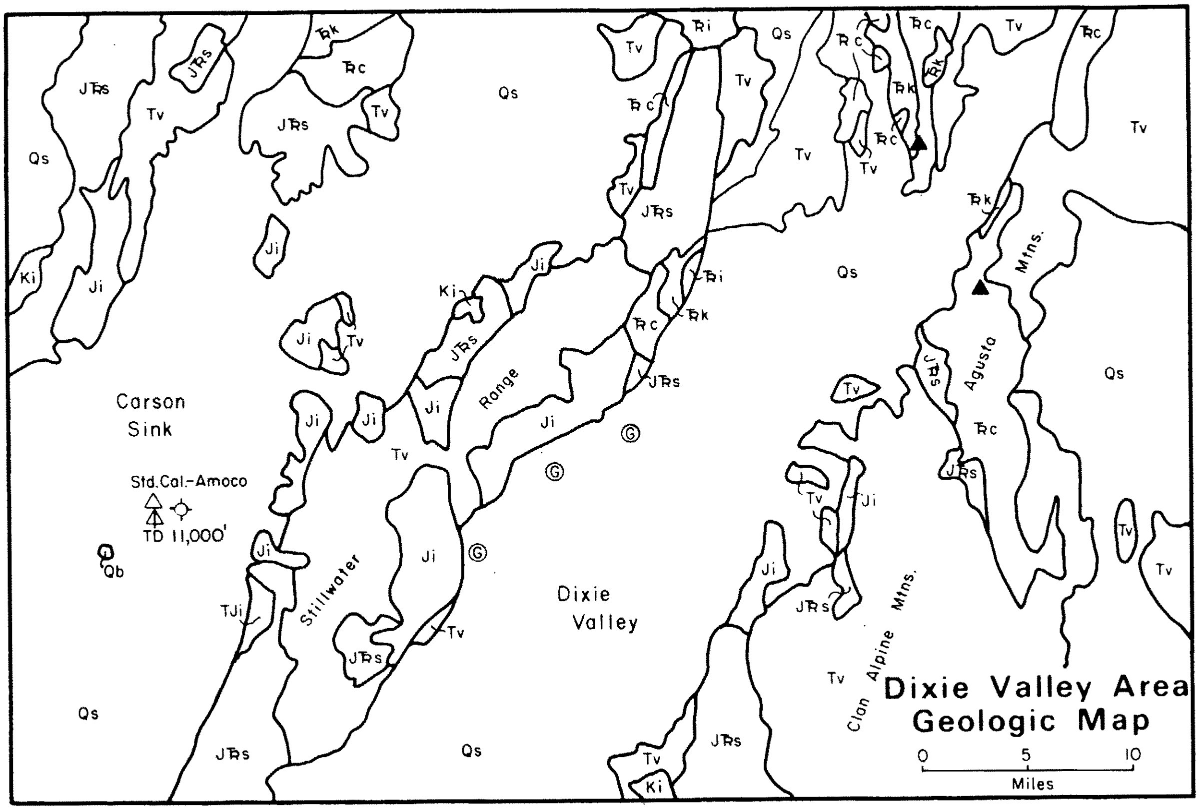

Figure 13. Dixie Valley area. Qs - Quaternary alluvial and playa deposits; Qb - Quaternary basalts; Tv - Tertiary volcanics; JTRs - Upper Triassic and Lower Jurassic sediments and volcanic rocks; TRc - Lower, Middle, and Upper Triassic (Tobin, Dixie Valley, Favret and Augusta Mtns. fms.); TRk - Lower Triassic Koipato volcanic and clastic rocks; Tji, Ki, Ji, TRi - Intrusives; Ⓖ - Geothermal well or test; △ - Minor oil show; ⯅ - Minor gas show; ▲ - Surface oil show.

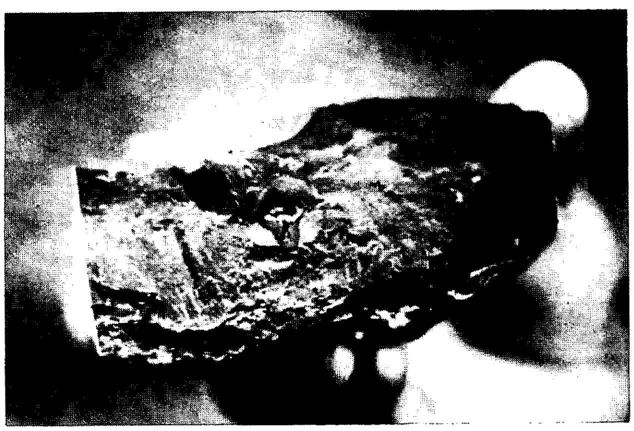

Figure 14. Concretion of calcareous mudstone from Triassic Favret formation in the August Mountains - chambers of this ammonite contained liquid hydrocarbons.

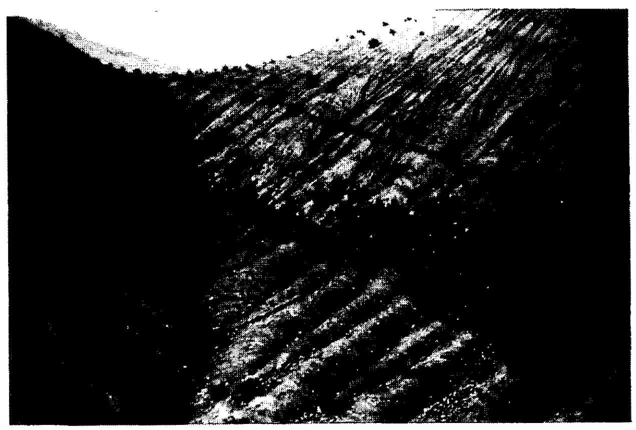

Figure 15. Outcrop of the Fossil Hill member of the Favret formation in the Augusta Mountains.

Oil-bearing ammonoids have only been reported from the Favret and Prida formations in the ranges north and east of the geothermal wells in Dixie Valley. The Favret and Prida formations are included in the Triassic "C" outcrop shown on Figure 13. Thus, if the Favret and Prida are significant source rocks for oil and gas, they may be present beneath the Neogene sediments in Dixie Valley northeast of the geothermal wells. If traps are present, this part of Dixie Valley is an attractive prospective area for oil and gas.

The only well on Figure 13 that was drilled as an oil and gas exploratory well is the Standard-Amoco No. 1 S.P. Land Co. (Sec. 33, T24N, R33E) located in the northeastern part of the Carson Sink. Hastings (1979) states that this well penetrated 11,000 feet of Tertiary sediments and volcanic rocks. Oil and gas shows were reported by Hastings:

"Free oil was present in vugs at the top of a core of calcite cemented basalt breccias taken in the interval 8,168-8,198 feet. A laboratory analysis described the oil as moderately mature and paraffinic. The only other hydrocarbon shows of significance consisted of weak cut fluorescence from sidewall samples taken in an interval above an igneous sill at 5,130 feet and strong methane shows in the drilling mud in the interval between 1000 and 4200 feet."

Hastings also summarizes the Tertiary source rock potential for this well. From the surface to 6,900 feet, the lacustrine-playa sediments are high in organic content (up to 5 1/2%) but immature. He concludes that rocks in the lower part of the section are too low in organic content to be good source rocks.

NORTH GREAT SALT LAKE

The Great Salt Lake is one of the remnant Pleistocene lakes in the Basin and Range province. Aside from the lake, this area is similar to the other areas that have been previously discussed. The Great Salt Lake covers several major Neogene depositional basins; one of these basins is essentially the area that includes the wells within the lake shown on Figure 16. Smaller subsidiary basins flank most of the major basin areas; an example of a smaller basin is the "Rozel graben" north and

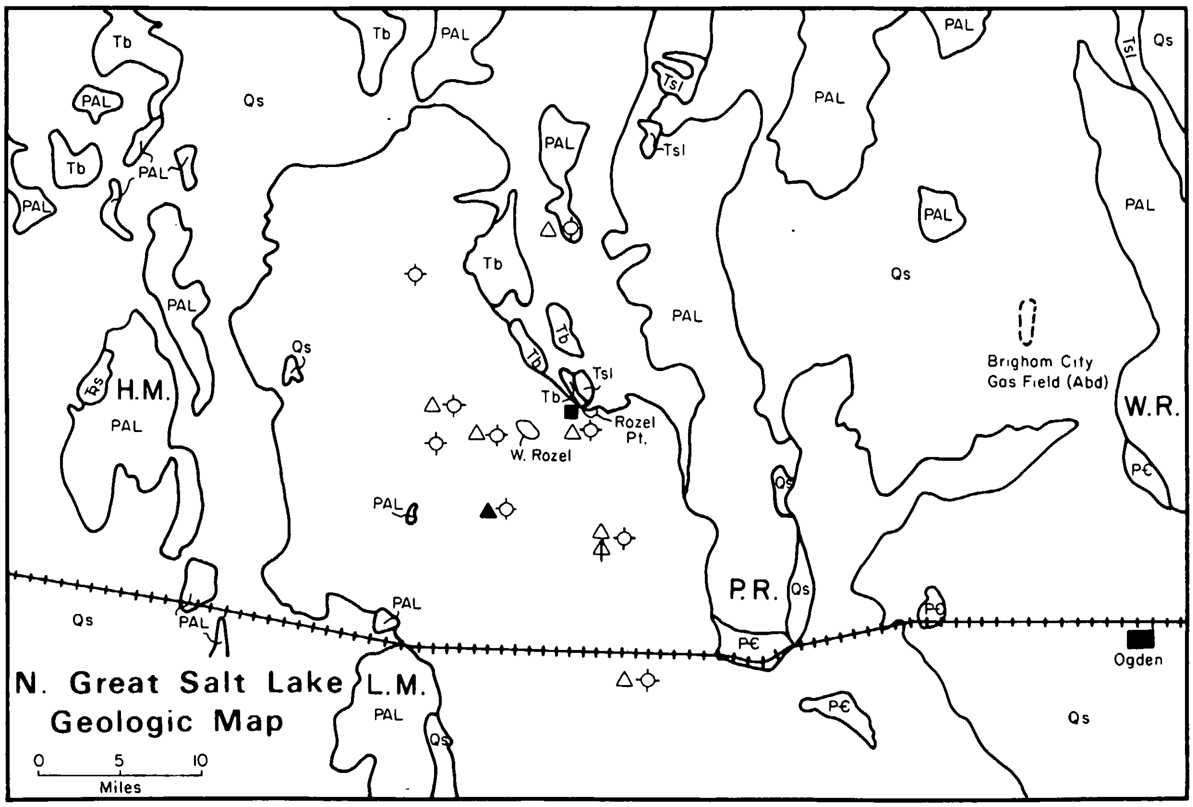

Figure 16. North Great Salt Lake. Qs - Quaternary lacustrine and fluvial sediments; Tsl - Miocene - Pliocene Salt Lake Group; Tb - Tertiary basalts; ₮s - Triassic sediments; PAL - Paleozoics undifferentiated; PЄ - Precambrian; ▲ - Free oil show; △ - Minor oil show; ⏃ - Minor gas show.

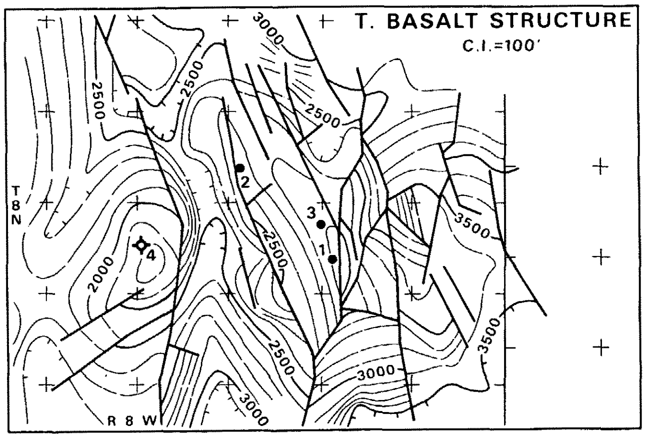

Figure 17. Top of basalt structure map in the West Rozel Field area - datum is the surface of the Great Salt Lake.

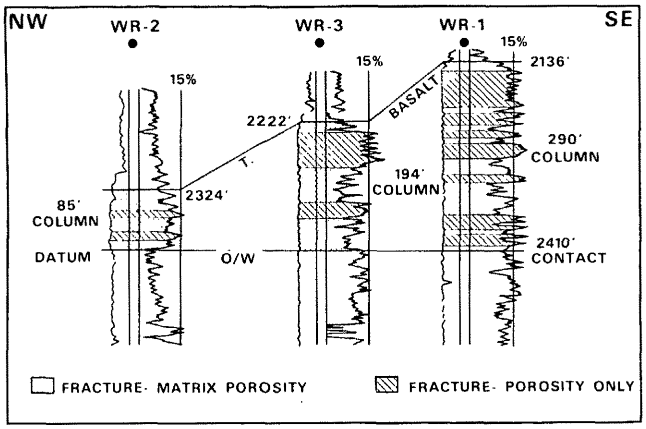

Figure 18. Structure section at West Rozel showing basalt reservoir. Closures are shown by stippled line. See figure 17 for well locations.

east of Rozel Point. Figure 16 is a generalized geologic map of the area modified after Hintze (1980).

The Rozel Point oil seeps flow heavy, viscous oil at the south end of Rozel Point (Sections 8, 9 and 16, T8N, R7W) along a probable fault zone which has uplifted the Rozel Hills relative to the lake to the southwest (Eardley, 1963). Some of the oil seeps are associated with springs that emit oil and water and build small circular mounds of travertine; these can be observed only during periods when the lake level is low.

Since the early 1900's there have been many attempts to produce oil from shallow wells drilled near the seeps and from surface pools of oil at the seeps. The area is currently leased and intermittently produced. Wells encounter the oil in a Pliocene basalt reservoir from 150 to 300 feet. A high percentage of water is produced with the oil. Twenty or thirty shallow wells have been drilled in and around the seeps and also four or five holes 1500 to 2800 feet deep have been drilled. (These wells are not shown on Figure 16).

An offshore Great Salt Lake exploration program by Amoco commenced in June, 1978, and drilled a total of 15 wells before the program was completed in January, 1981. The oil discovery at West Rozel (Sec. 23, T5N, R8W), 4 1/2 miles southwest of Rozel Point, was completed in Pliocene basalts from perforations at 2270 to 2410 feet flowing intermittantly 1 to 5 BOPH using a nitrogen lift. API gravity is 4-6 degrees with 13% sulphur. The second well drilled at West Rozel was equipped with a submersible hydraulic pump and produced at rates up to 90 BOPH for short periods from open hole at 2340 to 2384 in the same Pliocene basalt reservoir. A third well was drilled and produced from the basalt (2305 to 2348 feet) continuously for 64 days. During the last five days of the test, the well averaged 311 BO and 675 BW. Total field production was 28,000 BO. Economics for developing the field were not favorable at that time and the three wells were plugged and abandoned.

The West Rozel structure is a faulted, closed anticline with approximately 300 feet of vertical closure covering 2300 acres (Figure 17). Figure 18 is a structure section that shows the basalt reservoirs of the three producing wells.

Of the twelve exploratory wells drilled in this program all but four encountered some shows of oil and gas. Commonly oil shows were stain and globules of heavy oil in the Neogene sediments and volcanic rocks. Gas shows were usually small increases in the mud in Tertiary rocks; however, one well near the south end of the lake (Sec. 4, T1S, R4W) had a minor gas blowout at 435 feet.

In the Amoco No. 1 East Gunnison (Sec. 10, T7N, R8W) high pour point oil was recovered on 2 DSTS (19' oil and 1 gallon oil) of Pliocene limestones and tuffaceous shales from 4880 to 5004 feet.

Source rock studies by Amoco on Paleozoic and Mesozoic surface and subsurface samples found no significant oil source rocks in these units. Their potential as a gas source was poor. Since no pre-Neogene Tertiary rocks were penetrated in the Great Salt Lake, the Neogene fluvial and marginal lacustrine rocks may be the source for the oil at Rozel Point and West Rozel. Neogene to Recent sediments and volcanic rocks are about 15,000 feet thick in the basin west of the south end of the Promontory Range. If high heat flow existed in the northern Great Salt Lake during and after the extrusion of the Pliocene basalts at West Rozel and Rozel Point, then some of the organic-rich Neogene sediments could be the source of this heavy, viscous oil.

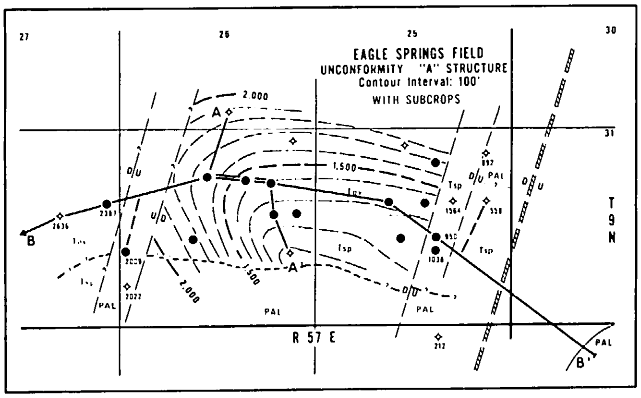

Figure 19. Eagle Springs field structure map. Discovery well in shown by circle around well symbol. Symbols the same as Figures 20 and 21.

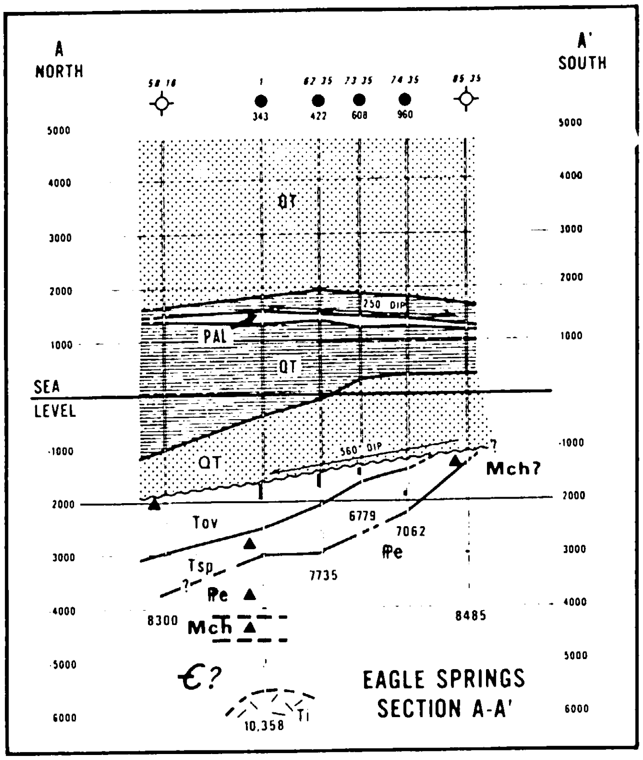

Figure 20. North-south 1:1 structural-stratigraphic section. Solid bars - perforated intervals; solid triangles - oil shows; € ? - Cambrian; Mch - Chainman Shale; Pe - Ely Group; Tsp - Eocene Sheep Pass Formation; Tov - Oligocene volcanic rock; Ti - Tertiary Intrusion; QT - Miocene to Recent sediments. Within the QT, stippled area shows coarse clastic facies and dashed lined area shows fine clastic facies. Well number, initial production, and total depth of each well are show. See Figure 19 for location of section.

COMMON CHARACTERISTICS OF BASIN AND RANGE OIL FIELDS

Three fields--Eagle Springs, Trap Spring and West Rozel--will be used to discuss the following common characteristics of Basin and Range oil fields:

- -Most traps are associated with a Tertiary unconformity
- -Oil columns are relatively thick
- -Fractures usually enhance reservoir quality
- -Most fields have volcanic rocks as reservoirs
- -Faults form part of the trap

Eagle Springs Oil Field. The unconformity "A" structure is shown on Figure 19, and two true-scale structure sections are shown on Figures 20 and 21. (For detailed information on the Eagle Springs field see Duey, this volume, and Bortz and Murray, 1979.) Unconformity "A" is the base of the "valley fill" sediments probably mid-Miocene or younger in age at Eagle Springs. At the base of the valley fill claystones and siltstones provide the seal for the three oil reservoirs--Oligocene volcanics, Eocene Sheep Pass formation and Paleozoics. The gross oil column is over 1500 feet and can best be seen on Section B-B' (Figure 21). The top of the pay in the easternmost producing well is at a datum of -959 feet and the base of the producing interval in the westernmost well is -2498 feet for total column along Section B-B' of 1539 feet. Bortz and Murray (1979) have evaluated the reservoir characteristics of the

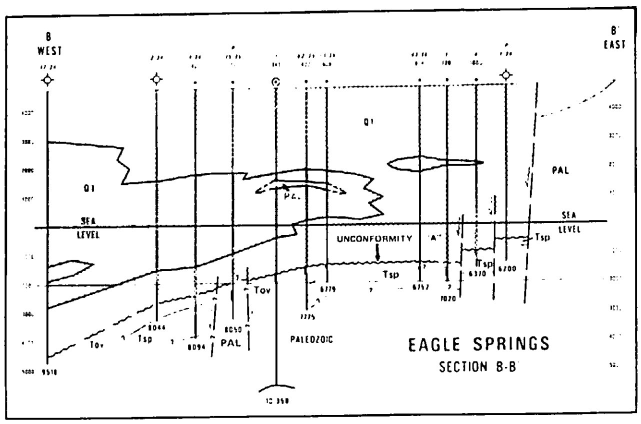

Figure 21. West-east 1:1 structural-stratigraphic section. Symbols used are same for Figure 20, plus PAL for Paleozoics undifferentiated. Section illustrates proximity of field to Grant Range on east. Fault separating Grant Range from field is diagrammatic. See Figure 19 for location of section.

three producing formations and conclude that porosity and permeability in the Oligocene volcanic rocks is attributed primarily to fractures. The best producing zones in the Sheep Pass limestones have matrix porosity and permeability; however, some zones are fractured. The Pennsylvanian Ely limestone in the Shell No. 15-35 produced oil from a fractured and brecciated zone. Figure 21 shows that the east side of the trap is formed by down-to-the-basin normal faults.

Trap Spring Oil Field. Figure 22 is a current plat of the field showing the producing oil wells, dry holes, and the line of Section A-A' (Figure 23). See Duey (this volume and 1979) for a more complete discussion of this field. Unconformity "A" is at the top of the Oligocene volcanics in the Trap Spring field area. At the base of the "valley fill", thin beds of fine clastic sediments provide a top seal for the volcanic reservoir. An additional seal is formed by the "ash zone" at the top of the volcanic rocks. The oil column is about 1700 feet thick along Section A-A' which is probably the maximum column. There is very little effective matrix porosity in the volcanic rocks at Trap Spring which is an ignimbrite sequence. Duey (1979) states that the fractures resulted from ignimbrite cooling and subsequent faulting. The fault between TS 2 and TS 3 on Section A-A' is evidence that faulting forms part of the trap. The water recovery below the perforations in TS 2 suggests that this well is in a separate fault

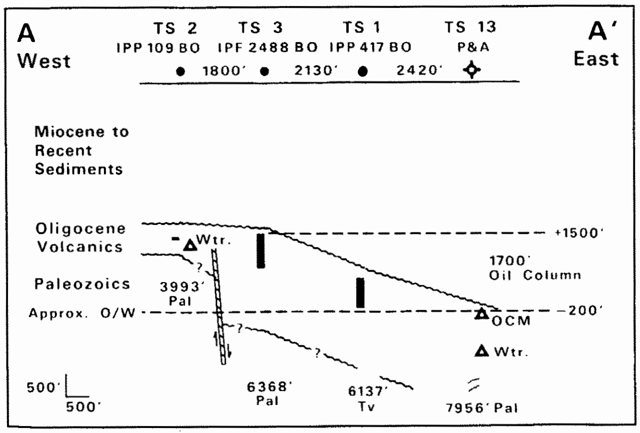

Figure 23. Trap Spring field true-scale cross section A-A'. See Figure 22 for line of section.

block west of the main producing area. West of Section A-A', Duey (1979) has mapped a major fault which probably forms part of the west side of the Trap Spring trap.

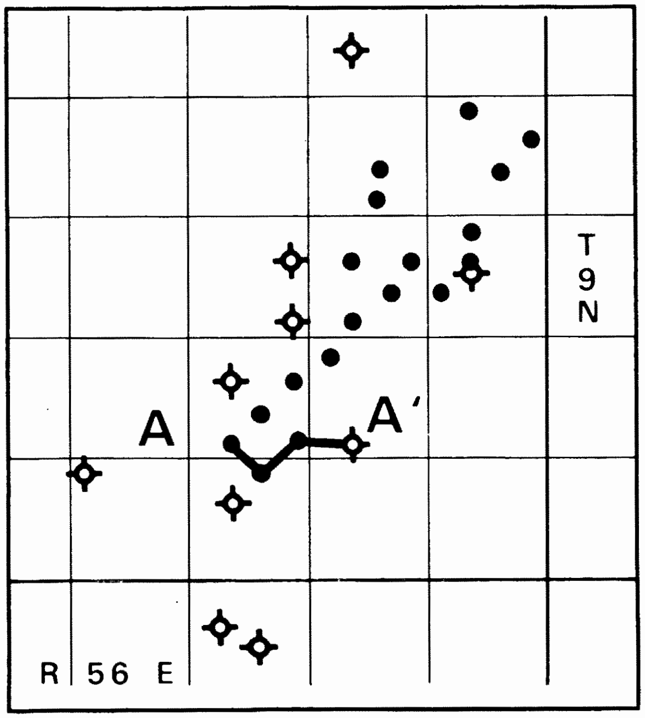

Figure 22. Trap Spring field plat

West Rozel Oil Field. The Tertiary unconformity associated with the trap at West Rozel is the top of the basalt on Figure 18. The unconsolidated Upper Pliocene claystones and siltstones immediately above the unconformity form the top seal for trap. The maximum oil column shown on this section is 290 feet in the West Rozel No. 1. The maximum column is estimated to be a little over 300 feet. As can be seen on Figure 18, much of the basalt has high porosity (greater than 15% density log porosity); however, most of this is not effective porosity since the basalt contains a high percentage of vugs and vesicules. Numerous fractures are present in cores of the basalt reservoir and in surface exposures of the basalt in the Rozel Hills. Also, high formation permeabilities determined from DST and production pressure data suggest that this reservoir has an extensive fracture system. Shown on Figure 18 is my interpretation of those zones in the basalt that have only fracture porosity and those zones with both fracture and matrix porosity. The only faults in Figure 17 which form part of the trap are those faults east of WR No. 3 that are down to the east. These faults form a side seal in that they place impermeable clays and silts against the basalt reservoir.

CONCLUSIONS

Oil and gas production in the northern Basin and Range province is closely related to surface and subsurface hydrocarbons shows. Some of these shows are quite obvious as in the Pine Valley area with the Bruffey oil and gas seeps and in the Great Salt Lake with the Rozel Point oil seep. The Railroad Valley-

Sheep Pass basin may be more typical with less dramatic surface and relatively few subsurface shows. Monitor Valley (Diana's Punch Bowl) and Dixie Valley are two examples of areas that are prospective for oil and gas reserves because of surface shows of oil and gas.

Surface and subsurface shows are only a reflection of the source rocks present in a given area. Source rock studies must be an integral part of any exploration program in this province. Certain areas with favorable source rocks that lack surface and subsurface oil and gas shows may be prime prospective areas.

The most important common characteristic of the significant producing fields is the thick oil column. This province has giant oil field potential if good reservoir rocks can be found within a thick oil column.

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