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CONTENTS

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Contents

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Petrography of the Kaibab and Plympton Formations (Permian), Near Ferguson Mountain, Elko County, Nevada*

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ABSTRACT.—The northernmost complete surface section of the Medial Permian upper Loray, Kaibab, Plympton and Indian Canyon formations is near the northeastern part of Ferguson Mountain, about 20 miles south of Wendover, Utah-Nevada. These marine sedimentary rocks consist mostly of limestone and dolostone, with minor sandstone and claystone and measure about 450 feet.

A total of 180 thin sections was prepared from samples taken from the measured section. The sedimentary carbonate rocks consist of a spectrum of micrite, algal-micrite, bryalgal limestone, crystalline limestone, and diagenetically dolomitized limestones, now in anhedral to euhedral crystalline forms. Sandstones, by contrast, were not markedly changed during diagenesis. Diagenetic dolomitization created highest permeability and porosity in the carbonates. The result was formation of shrinkage cracks, pin-point to vuggy porosity, along which later migration of hydrocarbons was effected. Residual or dead oil is present in moderate to substantial amounts along channels and within pore spaces.

Contiguous regions to the north and northeast of the study area have not been tested in subsurface for oil and gas potential; if the shallow marine seaway in which these sediments accumulated was near a northern shoreline, then reasons can be advanced to encourage exploratory subsurface tests.

CONTENTS

INTRODUCTION

Ferguson Mountain lies in northeastern Nevada about 280 miles slightly southwest of Wendover, Utah-Nevada. Alternate U.S. Highway 50 joins Ely, Nevada with Wendover and passes within 100 yards of the study area (see Text-fig. 1). The Elko sheet, (U.S. Army map service) is the only topographic base map of this part of Nevada and has a scale of 1:250,000. The area of investigation lies within Sections 14 and 15, T. 30 N., R. 70 E., Elko County, Nevada. This investigation relates mostly to petrographic study of one measured section of outcropping mid-Permian sedimentary rocks on part of northeastern Ferguson Mountain. Ferguson Mountain is an easterly bulge on the north-south

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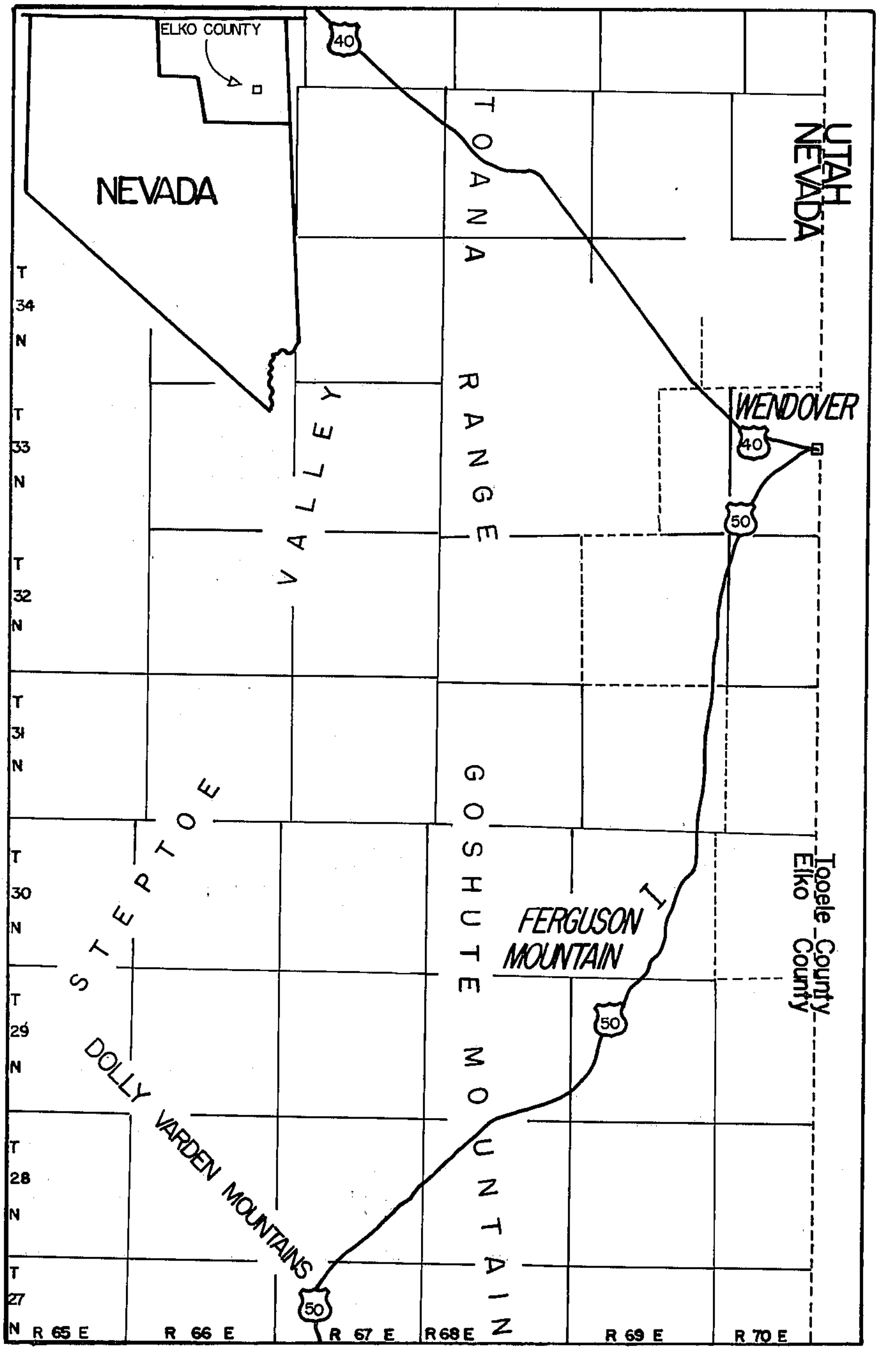
ELKO COUNTY
NEVADA
40
TOANA RANGE
UTAH
NEVADA
WENDOVER
40
50
VALLEY
STEPTOE
GOSHUTE MOUNTAIN
FERGUSON MOUNTAIN
Tooele County
Elko County
50
DOLLY VARDEN MOUNTAINS
50
T 34 N
T 33 N
T 32 N
T 31 N
T 30 N
T 29 N
T 28 N
T 27 N
R 65 E
R 66 E
R 67 E
R 68 E
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R 70 E

trending Toana Range-Goshute Mountains, a fault block within part of the Great Basin.

Berge (1960, Pl. 1) mapped most of the Ferguson Mountain area; the surface section studied for the present paper lies near the northeastern part of his map. Hodgkinson (1961, p. 176-183) studied Permian strata in parts of northwestern Utah and northeastern Nevada, but did relatively little work in the Ferguson Mountain area. Bissell (1961, p. 1096-1099) called attention to the Permian stratigraphy in this part of the Great Basin.

Acknowledgments

Dr. H.J. Bissell suggested a petrographic study of some Medial Permian carbonate sedimentary rocks as a thesis problem, and also served as chairman. Dr. W.K. Hamblin and Dr. G.H. Hansen served as committee members, and gave valuable advice. The writer received financial assistance through a research grant to Dr. Bissell from the Research Division of Brigham Young University. The writer extends grateful appreciation to these professors for valuable guidance and assistance.

The writer also appreciates the facilities made available by the Geology Department of Brigham Young University for office and laboratory studies.

STRATIGRAPHY

Permian sedimentary rocks in the study area are of Wolfcampian, Leonardian and Guadalupian ages (Bissell, 1962, Table 1, p. 196). Those considered herein are included within the lower Guadalupian, consist mostly of limestones and dolostones, and include (in ascending order) upper Loray, Kaibab, Plympton, and lower Indian Canyon formations. Other than the Loray, these formations comprise most of the Park City Group (see Hodgkinson, 1961, p. 189; Bissell, 1962, p. 1096-1100; 1964, p. 574). They are considered to have accumulated within the Cordilleran Miogeosyncline (see Bissell, 1962, 1964, 1967; Armstrong, 1968).

The section of outcropping Permian sedimentary carbonate rocks chosen for this research is apparently the most complete one in surface sections in this area. It is the northernmost known complete succession of the formations under consideration, and represents essentially the northernmost advance of the Kaibab sea (see Hodgkinson, 1961, Text-fig. 21, p. 177). This is of particular significance to the present paper, because this research is directed towards determining reasons for oil and gas migration and entrapment in marine limestones and dolostones within shallow water realms. The study area, therefore, may have been near shorelines of mid-Permian seas.

PERMIAN SYSTEM

Loray Formation

Steele (1960, p. 106-107) proposed the name Loray Formation for a succession of tan and yellow-tan, gypsiferous siltstones and thin bioclastic limestones exposed at the head of Loray Wash in Section 28, T. 38 N., R. 68 E., Elko County, Nevada. Bissell (1964, p. 616-617) pointed out that its age (in large measure, at least) is Wordian, as shown by diagnostic ammonoids. Only the uppermost few scores of feet of the formation are considered in this study in order to effect a stratigraphic continuum with the overlying Kaibab Formation. At the locality of the measured section of rocks for this study, approximately 35 feet of dolostone, limestone and claystone crop out. Some additional beds, lower stratigraphically, are alluvium-covered, but the lower remainder is faulted out. A few miles farther south, however, the formation is again exposed and is at least 1,000 feet thick, and consists of interbedded sandstone, dolostone, and minor limestone. Directly south of the Ferguson Springs highway maintenance station, and adjacent on the west to alternate Highway 50, gypsum, dolomicrite (with dead oil) and claystone occur within the upper 210 feet of the Loray Formation.

Kaibab Formation

Hodgkinson (1961) and Bissell (1962; 1964) have discussed the regional stratigraphy and lithology of the Park City Group in this part of the eastern Great Basin, and so these aspects will not be repeated here. The Kaibab Formation forms continuous to discontinuous outcrops east and northeast of Ferguson Mountain; many are near the highway. Along the traverse up the measured section, the Kaibab Formation is 115 feet thick and consists of massive, cherty, encrinal limestone. The complete measured section of the Kaibab and related formations is given below.

Measured Section

Measured section of Kaibab and Plympton formations (with part of underlying and part of overlying formations) northeast part of Ferguson Mountain, Sections 14, 15, T. 30 N., R. 70 E., Elko County, Nevada.

	Thickness in Feet
PERMIAN SYSTEM	
INDIAN CANYON FORMATION	
Sandstone, dolostone, and limestone, with intergradation of each, in an interbedded sequence. Colors vary from tan to pink, to medium gray and light red-brown. Textures are medium to very fine grained and/or crystalline. Thin to medium bedded. Some carbonates contain pink chert (only basal part measured)	100
..........conformable (?)..........	
PLYMPTON FORMATION	
Unit 2—Dolostone, calcareous dolostone, and dolomitized limestone in an interbedded succession, micritic and finely crystalline to sucrosic and coarsely crystalline; pink, light tan-gray to medium light-gray; thick to massive; in part cherty	57
Unit 1—Dolostone and dolomitic limestone, with minor calcareous dolostone. Fine to coarse crystalline, dense to very porous. Light gray, light orange-gray to tan-gray; thick to massive; variable in chert content; many rocks emit strong hydrocarbon odor when fractured. Total Plympton	103
..........conformable (?)..........	
KAIBAB FORMATION	
Unit 2—Limestone, encrinal to coarsely crystalline (diagenetic); medium light pink to tan-gray and very light gray-tan. Variable amount of pink chert, thick to massive	63
Unit 1—Limestone, coarsely crystalline encrinal limestone, and bioclastic limestone. Light pink-gray, light gray-tan, to tan-gray. Mostly thick to massive. Has prominent brown to dark tan chert layers and irregular masses. Within lower one-half, bryalgal material sur-	

	rounds poorly preserved specimens of the sponge *Actinocoelia* sp. One brown-gray limestone bed contains dead oil	52
	Total Kaibab	115
	....conformable (?)	
LORAY	FORMATION	
	Interbedded dolostone, claystone, and dolomitic siltstone. Tan, brown, and orange-tan to brown-gray. Thin to medium bedded (only upper part measured	35

Plympton Formation

Hose and Repenning (1959, p. 2181) named the Plympton Formation for a succession of dolomite rocks in the Confusion Range of west-central Utah. Bissell (1962, p. 1098-1099) indicated that it is 375 feet thick on the southwest part of Ferguson Mountain. It measures 103 feet of mostly crystalline medium light-gray dolostone on the northeastern part of Ferguson Mountain in the study area. Numerous strata in this formation in and adjacent to the study area contain dead oil where porosity has been developed, and most rocks emit hydrocarbon odors when fractured. Hodgkinson (1961, Text-fig. 3, p. 183) shows the distribution of this and younger Permian sediments.

Indian Canyon Formation

Hodgkinson (1961, p. 181-182) named the Indian Canyon Formation for a sequence of cherty, sandy and silty dolostones, dolomitic orthoquartzites and dolomitic siltstones in the Pequop Mountains, (Section 21, T 31. N., R. 65 E., Elko County, Nevada). This area is a few miles southwest of Ferguson Mountain. Bissell (1962, p. 1099) indicates this formation is 500 feet thick on the southwestern part of Ferguson Mountain, so conceivably it is also this thick in the study area, but only the basal 100 feet was measured and sampled in order to establish stratigraphic relationship with the underlying Plympton Formation.

PETROGRAPHY

General Statement

Aggregate thickness of the measured section of upper Loray, Kaibab, Plympton, and lower Indian Canyon formations does not exceed 450 feet. A total of 180 thin sections was prepared for petrographic study; which, in essence, provides an average control point for each two and one-half feet of the surface stratigraphic section. Actually, each rock slice does not represent each stratigraphic increment of two and one-half feet; samples were taken of each significant lithologic change. However, these lithologic breaks are within a two- to five-foot spacing.

Of the total of 180 thin sections, 130 are 1" x 2" size, and the remaining 50 are 2" x 3" dimension. The 1" x 2" sections were ground to a standard thickness of 0.03 mm; the larger ones were purposely ground thicker to preserve features not possible in thinner slices. Because this petrographic investigation relates mostly to the Kaibab and Plympton formations, most thin sections (and detailed microscopic study) relate to these carbonate rocks. Brief discussion, however, will be directed towards the petrography of the upper Loray Formation (subjacent to the Kaibab) and also to the lower Indian Canyon Formation (superjacent to the Plympton).

Photomicrographs were obtained of most thin sections, using a Zeiss photomicroscope and a Spencer polarizing binocular microscope. Various light sources and filters were utilized to effect certain contrasts. The photographs were enlarged to appropriate scale for study but only a few are included in Plates 1 to 4.

Loray Formation

Within the uppermost 35 feet of exposed strata, the rock types are predominantly calcareous to dolomitic quartz sandstone, siltstone and very fine-grained angular quartz sandstone, with interbedded micritic to algal limestone and dolostone.

Calcarenites in this sequence are quartzose, and consist of limeclasts, algal material, dolomite and quartz clasts embedded in fine-grained calcareous cement and matrix. Grains range in size from 0.001 mm to 1.2 mm. Calcite and quartz crystals are anhedral; calcite is replaced locally by dolomite as indicated by sutured outlines of dolomite into calcite (Plate 1, fig. 1). Dolomite crystals are mostly subhedral, and are medium to coarsely textured. Vuggy porosity is developed, and dead oil occurs within these openings.

Micritic limestone to calcilutite in the upper Loray Formation is fine to medium crystalline calcite embedded in limemud. Few crystals are subhedral, very few are euhedral, but most are anhedral. Solution and shrinkage vuggy porosity have been developed, with concomitant to subsequent migration of oil into porous zones—this oil, however, is now a black residue. The presence of minor euhedra and subhedra of calcite seemingly is the result of recrystallization of what formerly was a micritic limestone—a limemud (Plate 1, fig. 2).

Kaibab Formation

Most thin sections prepared from sampled units in this formation consist of encrinal limestone (biocalcarenite), micritic limestone, and coarsely crystalline skeletal limestone. Most of the crystalline limestone is the result of diagenetic recrystallization of the biocalcarenite, whereas some is recrystallized micrite and algal micrite. It is noteworthy that in some thin sections of micritic limestone

Explanation of Plate 1

PHOTOMICROGRAPHS

All X 8.5, except where noted. Plain Light

FIG. 1.—Recrystallized limestone, near top of Loray Formation. Shrinkage crack has been formed.

FIG. 2.—Calcarenite, near top of Loray Formation. Dark layers contain hydrocarbon residue.

FIG. 3.—Lumps of unaltered micritic limestone surrounded by sparite; lower part of Kaibab Formation.

FIG. 4.—Vugs and channels developed during diagenesis of a micrite—residual oil is dark area; middle Kaibab Formation. X 4.5.

FIG. 5.—Channels developed during diagenesis of a micritic limestone—residual oil (dark) remains in shrinkage cracks; upper part of Kaibab Formation.

FIG. 6.—Coarsely crystalline limestone formed during diagenesis of an encrinal limestone, with development of pin-point porosity and connecting channels. upper Kaibab Formation.

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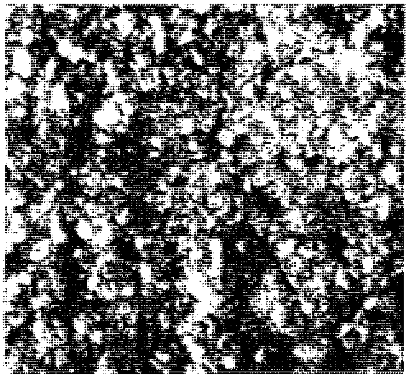

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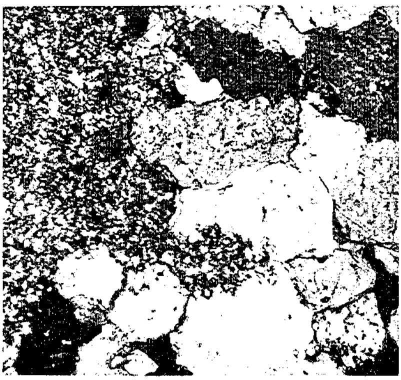

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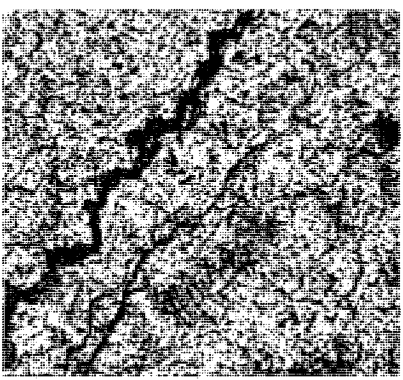

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PLATE 1

and algal micrite, there are lumps and aggregates of unaffected micrite and/or algal masses surrounded by a matrix of medium to coarsely crystalline sparite (Plate 1, fig. 3).

In some cases there is little or practically no change, i.e., diagenetic recrystallization. However, scattered small patches of hydrocarbon and iron pyrite are found in such sections and, significantly, pseudomorphs of limonite after pyrite are found. Evidently the presence of permeability channels aided in transferring solutions to other parts of a rock body, thereby effecting a sedimentary bypassing (Plate 1, fig. 4). The channels, possibly shrinkage cracks, were the routes of migration of oil postdating other diagenetic changes, as can be determined by the presence of oil residue in vugs and along shrinkage cracks.

Also in a few of the sections, limemud has been replaced by dolomite, forming dolorhombs, thereby affecting the original mass to some extent. In such cases the channels also seemingly were the migration routes of solutions (Plate 1, fig. 5).

Wherever, recrystallization processes have affected the rock type, the resulting calcite grains are coarse-textured and crystallinity varies from anhedral to euhedral. This recrystallization has developed excellent pin-point porosity with connecting channels (Plate 1, fig. 6).

There is almost complete recrystallization of limemud to calcite in some units. The microvuggy porosity and relatively small amount of dead oil in some samples are characteristic of the Kaibab Formation. Most of the fossiliferous limestones have been recrystallized resulting in coarsely crystalline limestone; furthermore nearly complete recrystallization of skeletal limestones has taken place. In most instances, however, algae resisted diagenesis, whereas crinoid stems have been largely destroyed. (Plate 2, fig. 1). Even minor channels have been routes of solution migration.

In the case of algal limestone, these organisms have been only partially affected whereas the surrounding matrix has been recrystallized (Plate 2, fig. 2). Most algal calcilutities have been partially recrystallized to coarse crystalline limestone; the centers of some algae were replaced by calcite. Recrystallization has occurred in some skeletal limestones and locally, chalcedony has replaced

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EXPLANATION OF PLATE 2

PHOTOMICROGRAPHS

All X 8.5, Plain Light except where noted.

FIG. 1.—Algal oncolite, unaltered during diagenesis, whereas surrounding matrix has been crystallized; upper part of Kaibab Formation.

FIG. 2.—Diagenetic dolomitization of a limestone resulting in sutured dolorhombs, moderate porosity (containing dead oil), and connecting channels; upper Plympton Formation. Crossed nicols.

FIG. 3.—Diagenetic dolomitization—subhedra of dolomite surrounded by partially recrystallized dolomite, and with dead oil flecks; middle part of Plympton Formation.

FIG. 4.—Dolorhombs impinging into limemud; middle Plympton Formation. Crossed nicols.

FIG. 5.—Diagenetic dolomitization of an algal limestone; vugs contain dolorhombs and dead oil, whereas algae are relatively unaltered. lower Plympton Formation.

FIG. 6.—Algal limestone affected by recrystallization—the dark areas are slightly altered algal lumps, with minor amount of dead oil; lower Indian Canyon Formation.

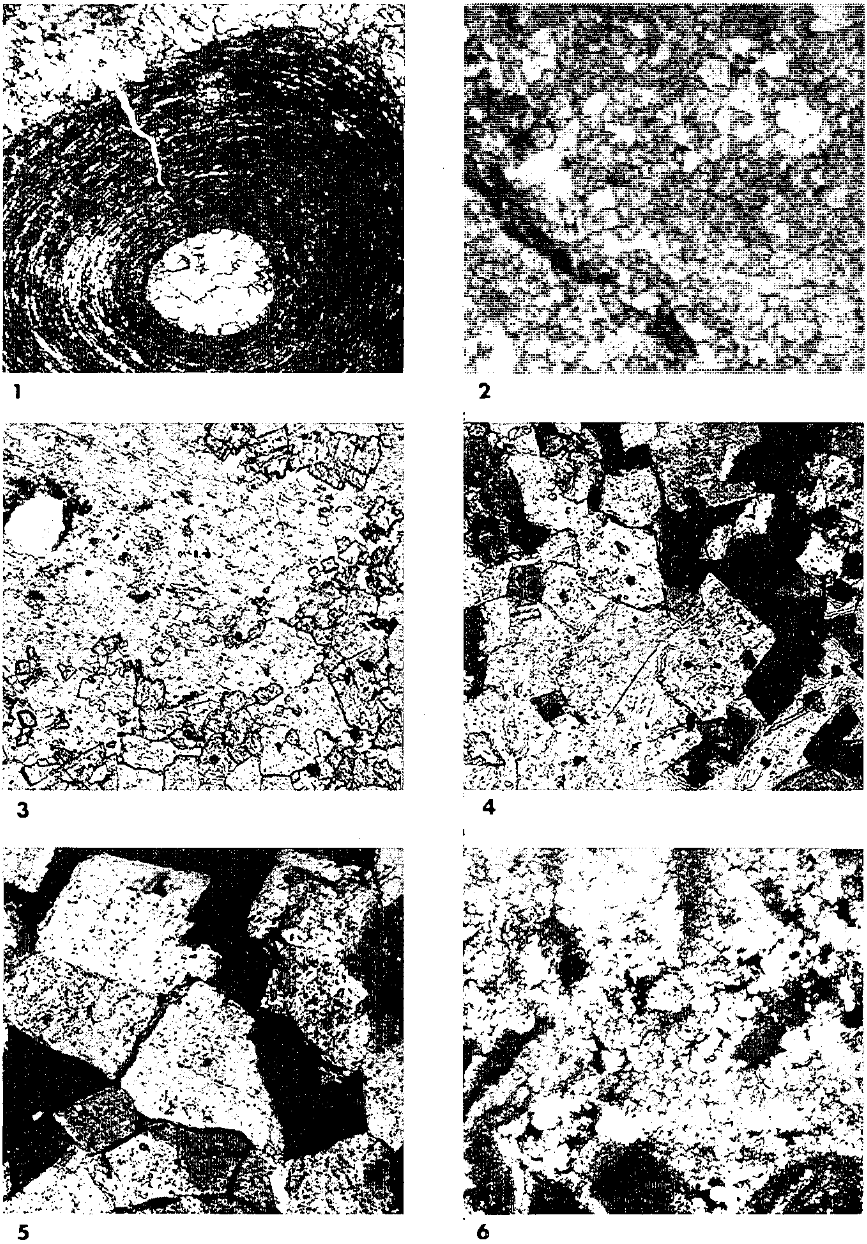

PLATE 2

bryozoans and algae. Dolomitizing solutions formed subhedral and euhedral crystals, replacing fossils in some places. In bryalgal limestones, bryozoans and algae are the most resistant to recrystallization

In a few rock-types, diagenetic dolomitization of what was primarily recrystallized limestone has taken place. This demonstrates a paragenetic sequence which proceeded first as crystallization of a skeletal limestone with calcite forming the sparite. Later, during diagenesis, dolomitizing solutions replaced calcspar with dolorhombs.

The detailed petrographic studies of the carbonates in the Kaibab Formation indicate that notable porosity was developed during diagenesis, and permeability channels were developed. However, this percentage porosity is greater than remnant dead oil, which now is a residue in the voids and channels. Evidently oil and gas which originated in these rocks migrated to other units, leaving only a little dead oil.

Plympton Formation

Carbonate rocks of the Plympton Formation contrast in significant manner with those of the underlying Kaibab Formation; the latter are mostly limestones, whereas Plympton rocks are dominantly dolostones, calcareous dolostones, and dolomitized limestone. Micrite and fine to coarsely crystalline limestones are of minor importance.

Lowermost units of the Plympton contrast sharply with subjacent uppermost Kaibab, and display dolomitized limestone, but some similarities are also noted in that recrystallization only of limestones has occurred. Some samples reveal that micritic limestones have been only partly dolomitized; commonly, lumps of unreplaced micrite are surrounded by a matrix of coarsely crystalline, dolomitized limestone. Locally, cores of the lumps of micritic material have been crystallized as well as the interstitial matrix material. Progressively higher in the Plympton section, most units display essentially complete diagenetic dolomitization, with concomitant development of pin-point to vuggy porosity. Interestingly enough, numerous connecting channels ramify the rock, resulting in effective permeability routes. Some of the porous zones and channels as well are partially filled with dead oil flakes and patches, indicating a post-diagenetic migration of hydrocarbons. (Plate 2, fig. 3).

During diagenetic dolomitization of what were crystalline limestones of the Plympton, most of the sparite was replaced, and dolorhombs resulted. However, in some units the replacement was not complete, and relicts of sparite are surrounded by euhedral dolorhombs. Presence of well-developed dolorhombs suggests crystal growth from a super-saturated magnesium-rich brine. Seemingly crystal-to-crystal diagenetic replacement occurred, impingement took place, and calcite reverted to dolomite (Plate 2, fig. 4). Excellent high-percentage porosity and permeability resulted during this diagenetic change.

In some recrystallized encrinal limestones, dolomitization is incomplete, as though the process had been arrested. This is true in certain instances, even though euhedra of dolorhombs are characteristic. Furthermore, not only has diagenetic dolomitization affected crystalline limestones which were formerly encrinal limestones (see also Lucia, 1965, p. 848-865), but this alteration also permitted almost complete dolomitization of micritic limestones, with resultant vuggy porosity as an end result. Where algal limestones were involved by dolomitizing solutions, the interstitial or matrix material was changed to subhedral to euhedral dolorhombs, whereas the algal masses were left relatively unchanged (Plate 2, fig. 5).

When samples were obtained from the surface section of the Plympton Formation in the study area, it was noted that moderate to strong hydrocarbon odors were released from broken dolostones. Essentially all thin sections cut from these samples reveal significant increase in porosity, permeability, and dead oil content over rocks of the Kaibab Formation. It is thus suggested that the sedimentary carbonate rocks of the Kaibab Limestone were only partially and locally diagenetically dolomitized, whereas those of the overlying Plympton Formation (by contrast) were completely to nearly-completely, dolomitized during proccesses of diagenesis. Carbonates of the Plympton Formation, it would seem, were at one time more calcareous, but magnesium-rich solutions permeating these limestones and skeletal limestones effectively replaced calcite with dolomite, thereby creating an effective high porosity and permeability. Hydrocarbon products generated in carbonates of the Plympton Formation (and likely those of the subadjacent Kaibab Limestone as well) migrated through various channels, particularly upward from the Kaibab Limestone. Dead oil in Plympton dolomitized limestones is shown as flecks, flakes, near filling of vugs and channels, and as coatings on dolorhombs. Where chert was deposited in channels and vugs before oil migration, it formed an effective dam to further movement.

Indian Canyon Formation

In the study section the rock types of the Indian Canyon Formation are detrital to fine-grained limestones, dolosiltites, and sandy to dolomitic limestones. These are composed of fine to sand-sized particles of limestone, pelletal material and quartz grains in a fine-grained matrix. Calcite grains are anhedral to subhedral and quartz grains are anhedral. A few small patches of dead oil are found locally. Porosity is distinct and interstitial. Algal material is present as lumps in some carbonates. Larger fossils are not present, at least in the few samples studied. In some sections replacement of calcite by dolomite has occurred. Dolomitization has affected the texture of the rock, producing porosity, which in turn has become the route of oil migration through rocks, as can be inferred from the remnant oil (Plate 2, fig. 6).

CONCLUSIONS

Field investigations in the study area near northeastern Ferguson Mountain indicated that some, not all, sedimentary carbonate rocks of the Medial Permian upper Loray, Kaibab, Plympton, and lower Indian Canyon formations contain variable quantities of hydrocarbon residue in porous zones. In addition, numerous of these rocks emit moderate to strong hydrocarbon odors when fractured. The problem, therefore, resolved itself to detailed petrographic study of numerous samples obtained from a measured stratigraphic section in an attempt to discover reasons for variations in porosity, permeability, dead oil content, and relation of hydrocarbon content to lithology and porosity type.

Results of the petrographic investigations conclusively prove the following:

1. Upper units of the Loray Formation have been relatively unaltered during diagenesis, and low porosity only was developed. Dead oil is limited mostly to micritic limestone and dolostones.
2. Most limestones of the Kaibab Formation are diagenetically altered to sparite or

sparite-bearing limestones. Dolomitization is of minor significance. Where diagenesis occurred, however, porosity and permeability developed, and oil was able to migrate to areas of higher porosity. Hydrocarbon residues, though of significantly greater amount than the underlying Loray, are not of unusually high quantity or universal distribution within the formation. Where diagenetic dolomitization took place, however, a substantial increase in porosity and development of migration channels resulted, and a concomitant increase in hydrocarbon residue is evidenced.

3. The carbonates of the Plympton Formation in the study area are predominantly diagenetic; i.e., they formed after dolomitizing solutions changed limestone to crystalline dolostone. During diagenesis, porosity increased substantially, and various types ranging from pin-point to vuggy porosity developed. Subsequent to development of permeability channels (shrinkage cracks, etc.) and porous zones, hydrocarbons migrated much more freely through the rocks. Dead oil now remains as coatings upon dolorhombs, and as flecks, patches, and near-fillings within pin-point openings, along channels, and within vugs. It was necessary, therefore, for diagenetic dolomitization to precede (and become essentially complete) before oil and gas could move through the carbonates.
4. Of the few samples of the lower Indian Canyon Formation tested in this study, only a few show evidence of having been diagenetically altered. Hydrocarbon residues are relatively sparse.
5. Detailed petrographic studies of numerous thin sections indicate that shrinkage

EXPLANATION OF PLATE 3

PHOTOMICROGRAPHS

All X 8.5, Plain Light except where noted.

FIG. 1.—Recrystallized limestone—sparite crystals with limemud, near top of the Loray Formation. Plain light with red filter.

FIG. 2.—Crystalline limestone with lumps of micrite, lower part of Kaibab. Vugs filled with dead-oil.

FIG. 3.—Coarsely crystalline limestone, development of pin-point porosity and connecting channels—indicated by residual oil as dark areas; lower part of Kaibab Formation. Crossed nicols.

FIG. 4.—Recrystallized limestone—sparite surrounded by limemud, with development of vugs. Residual oil is dark area. Middle Kaibab Formation. Crossed nicols.

FIG. 5.—Biocalcarenite—Middle Kaibab Formation. Residual oil indicated by dark area.

FIG. 6.—Recrystallized limestone with dolorhombs—partly diagenetically dolomitized. Lower part of Plympton Formation.

EXPLANATION OF PLATE 4

PHOTOMICROGRAPHS

All X 8.5, Plain Light except where cited.

FIG. 1.—Recrystallized limestone. Sparite and dolorhombs surrounded by lumps of micrite. Dark patches represent dead oil. Lower part of Plympton Formation.

FIG. 2.—Unaltered algae surrounded by recrystallized matrix during diagenesis; lower Plympton Formation.

FIG. 3.—Diagenetic dolomitization of recrystallized limestone—well developed dolorhombs surrounded by sparite. Middle part of Plympton Formation. Plain light with red filter.

FIG. 4.—Diagenetic dolomitization—subhedra and euhedra of dolorhombs impinging into limemud and sparite. Middle part of Plympton Formation.

FIG. 5.—Calcarenite with vugs represented by dark areas as residual oil. Upper part of Plympton Formation. Crossed nicols.

FIG. 6.—Bryalgal limestone, bryozoans affected by diagenesis developing vugs. Dark area is residual oil. Upper part of Plympton Formation. Crossed nicols.

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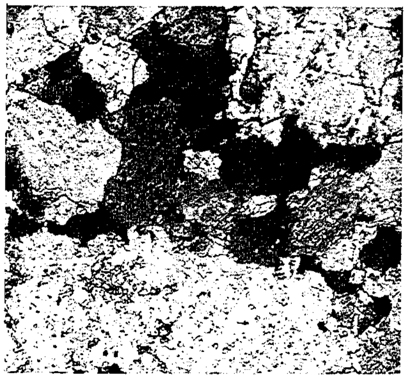

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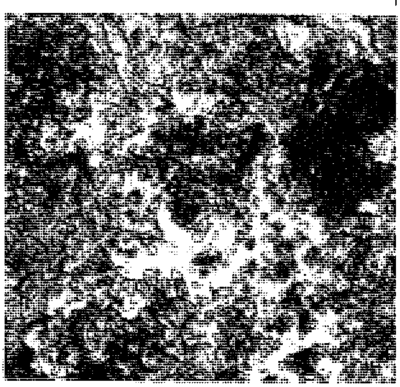

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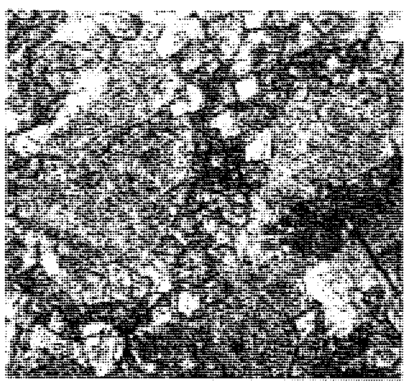

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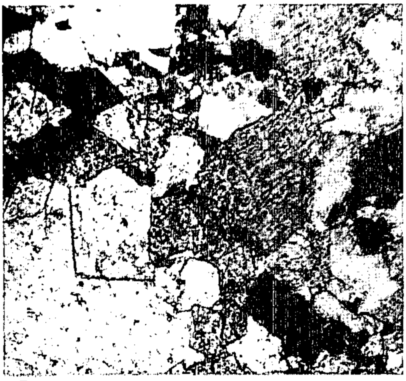
PLATE 3



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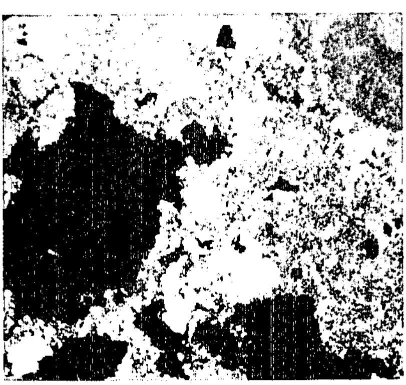

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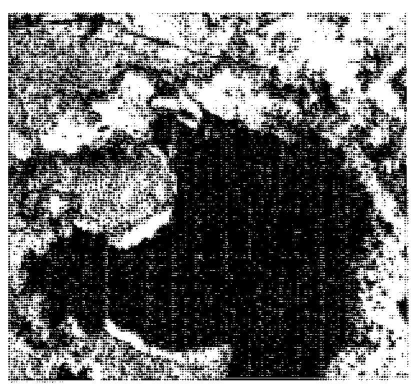

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PLATE 4

cracks and other permeability channels developed during late diagenetic dolomitization of many units. Subsequently, oil migrated through these channels, and some dead oil still remains on the walls of these openings.

6. It is suggested that hydrocarbons were generated in various rocks of the Loray and younger Permian formations. Algae, foraminifera, and possibly other organisms likely were the sources. What is not known, of course, are the lateral and vertical distances of migration, nor the amounts.

In addition to accumulation of the above factual data concerning these marine Permian rocks in this part of the Cordilleran Miogeosyncline, the following inference is advanced; this succession of carbonates accumulated in a shallow marine realm not far south and southwest of a shoreline. Therefore, if these units pinch out towards the shoreline, they seemingly could provide stratigraphic traps for oil and gas accumulations. The area to the north, northeast, and east of the northernmost surface expressions of these marine rocks is now relatively monotonous, nearly-horizontal salt flats. The Paradox Salt Basin of the Four-corners area, and numerous other salt basins of the world contain oil and gas. The Loray Formation of eastern Nevada and western Utah, for example, contains thick salt accumulations. It is therefore possible that subsurface occurrences of Loray and younger Permian strata east and northeast of Ferguson Mountain, beneath the Salt Flats, could contain commercial hydrocarbons. This area, however, has not been tested by exploration.

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