

OIL & GAS CONSERVATION COMMISSION
Meeting: May 17, 1967
Mr. John Bannister, Executive Secy

JACK WILLIAMS
GOVERNOR
LYNN LOCKHART
CHAIRMAN
LUCIEN B. OWENS
VICE CHAIRMAN
HIRAM S. CORBETT
MEMBER
GEORGE T. SILER
MEMBER
KENNETH G. BENTSON
MEMBER

Oil and Gas Conservation Commission

OFFICE OF
STATE OF ARIZONA
ROOM 202
1624 WEST ADAMS
Phoenix, Arizona 85007
PHONE: 271-5161

JOHN BANNISTER
EXECUTIVE SECRETARY
J. R. SCURLOCK
PETROLEUM GEOLOGIST

A G E N D A

Meeting
May 17, 1967

9:30 a.m. Call to order

- ✓1. Approval of minutes of meeting of April 19, 1967.
- ✓2. Executive Secretary's Report
- ✓3. Geologist's Report
- ✓4. Old business
 - ✓1. June IOCC meeting *June 12*
- ✓5. New business
 - ✓1. Discuss time and method of arriving at decisions

OIL AND GAS CONSERVATION COMMISSION
1624 West Adams - Suite 202
Phoenix, Arizona

Minutes of Meeting
April 19, 1967

Present:

Mr. Lynn Lockhart, Chairman
Mr. Lucien B. Owens, Vice Chairman
Mr. George T. Siler, Member
Mr. Kenneth G. Bentson, Member
Mr. John Bannister, Executive Secretary
Mr. J.R. Scurlock, Geologist

Absent:

Mr. Hiram S. Corbett, Member

Others Present:

Mr. James J. Fulton
Mr. Darby Hand
Mr. Ray B. Jones, ArkLa Exploration Company
Mr. William S. Livingston, Humble Oil & Refining Co.
Mr. Brian Kirby, Arkla Exploration Company
Mr. Francis S. Irvine, Kerr-McGee Corporation
Mr. C.F. Miller, Kerr-McGee Corporation
Mr. Henry F. Pohlmann, Navajo Tribe
Mr. James R. Pickett
Mr. P.T. McGrath, U.S. Geological Survey
Mr. John A. Anderson, U.S. Geological Survey
Mr. J. Val Connell, Kerr-McGee Corporation
Dr. Willard Pye, University of Arizona

Meeting was called to order at 9:30 a.m.

Minutes of meeting of March 15, 1967 were approved.

The Executive Secretary's Report and Geologist's Report were accepted for filing.

It was agreed that arrangements be made for three persons to attend the June, 1967 IOCC meeting in Denver, and at the next regular Commission meeting it would be decided who from the Commission would attend.

Meeting adjourned at 10:00 a.m. and the Commission immediately entered into Hearing, Case 24, to amend Rule 102.

APPROVED: May 17, 1967



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JOHN BANNISTER
EXECUTIVE SECRETARY
J. R. SCURLOCK
PETROLEUM GEOLOGIST

May 10, 1967

Memo to: Commissioners
From: John Bannister, Executive Secretary
Re: Report of Activity

Since our last meeting conference calls have been set up wherein decisions were reached in Case 24 and Case 25.

I would like to take this opportunity to explain to the Commissioners that it is necessary following a hearing that the Commissioners reach a decision within a "reasonable time." The Attorney General has indicated that a reasonable time is ten days to two weeks in most instances.

In the two cases above referred to, a considerable amount of interest and action of many of the companies were pending, awaiting our decision. It was felt that in order to expedite matters it was necessary to contact the Commissioners by telephone. As you are aware, this practice of conference call communication had been established and followed in the past on hearings.

It has been noted that concern has been expressed by some of our commissioners as to this method of reaching a decision, and it is felt that the commissioners should establish among themselves a procedure for concluding a case once it is heard. It is my feeling that should the commissioners so desire, that no decision be made until the following regular meeting, this would be acceptable if it were pointed out to the participants of the hearing that this would be the case.

I visited the Dineh bi Keyah Field on April 20 and 21. Copies of my notes are enclosed.

As you may be aware, Kerr-McGee would like to take the Governor and the Commission to the Field to view first hand the activities in this area. It is presently contemplated that on June 2nd, at approximately 7:00 a.m., Kerr-McGee will pick

up the Governor's party and those commissioners in Phoenix, proceed to Flagstaff or Holbrook to pick up commissioners in this area. Kerr-McGee then contemplates flying to the Field for both an aerial and ground inspection, have lunch somewhere, and tentatively return by 5:00 - 6:00 p.m. to Phoenix. Time and date will depend upon availability of the governor.

New Permits:

- 397: Kerr-McGee #C-1 Navajo, SE SW 33-36N-30E, Apache County
- 398: Kerr-McGee #E-1 Navajo, SE SE 20-36N-30E, Apache County
- 399: Kerr-McGee #12 Navajo, SE NE 29-36N-30E, Apache County
- 400: Humble #2 Navajo 138, SE SE 6-35N-30E, Apache County
- 401: Humble #1 Navajo 87, SE NE 23-36N-29E, Apache County
- 402: Kerr-McGee #1 Santa Fe, SW NW 14-19N-27E, Apache County
- 403: Kerr-McGee #2 Santa Fe, NW SE 19-19N-28E, Apache County
- 404: Kerr-McGee #3 Santa Fe, SE NW 34-19N-28E, Apache County
- 405: Kerr-McGee #10 Santa Fe, NW SW 23-20N-27E, Apache County
- 407: Kerr-McGee #5 Santa Fe, NW NE 23-20N-28E, Apache County
- 408: Kerr-McGee #6 Santa Fe, NW NW 9-19N-29E, Apache County
- 409: Kerr-McGee #7 Santa Fe, NE NE 2-18N-29E, Apache County
- 411: Kerr-McGee #9 Santa Fe, NE NE 27-17N-29E, Apache County

It will be noted from the above permits that Kerr-McGee has begun strat test exploration program (Permits 402 through 411) in the area south and east of Pinta Dome. These holes will not be drilled with the intention to produce, but merely gain information. It is Kerr-McGee's intention at the present time

to plug each hole upon completion. At this writing two (#1 and #10) of the ten tests have been completed and plugged.

The Dineh bi Keyah has created much additional work and expense upon the Commission. As you have long been aware, toward the end of each quarter is a very critical period concerning money for commissioner's salaries. At our last two meetings the Commission, in addition to the regular meeting, heard two cases. It is felt that the burden imposed upon the commissioners in trying to assimilate this much technical information is unfair and it would be far preferable to space our hearings. However, in order to do this it would be necessary that additional money be available for payment of the commissioners.

You have long been aware too of the critical staffing problem in this office. Our secretary, Mrs. Rushton, is bearing an unfair burden as are both Mr. Scurlock and I. The administrative work of this office now prevents Mr. Scurlock or me from being in the field at times when we should.

In addition to this, travel money, both in-state and out-of-state, will soon have reached a critical point. Looking forward to our next fiscal year, which begins July 1, it is contemplated that lack of sufficient funds will greatly hamper the activities of the Commission.

Consequently it is suggested that representatives of the Commission should approach Governor Williams to request an amendment to our budget to allow sufficient funds for the Commission to effectively function. Inasmuch as it is contemplated that a special session of the Legislature will be called, the Governor could include a supplemental appropriation for the Commission in this call.

It is also my suggestion that should the commissioners so approve, a delegation be appointed to seek audience with the Governor at the first available opportunity for the purposes of the following:

(a) secure a substantial salary increase for the current staff.

(b) secure sufficient additional money for salaries of the commissioners so that a minimum of 10 additional days per year may be available for commissioner's purposes.

(c) secure an increase in out-of-state travel from \$2,500 to \$3,500, and combine both in-state and out-of-state travel into one fund instead of two separate funds

(d) secure the necessary money to hire an administrative assistant, and if possible, one additional steno to hopefully alleviate the burden now upon Mrs. Rushton.

(e) With the hearing burden that will now be thrown on the Commission due to Dineh bi Keyah Field, an available petroleum engineer will become a necessity. In order to avoid undue expenditure it is suggested that funds be secured, perhaps in the neighborhood of \$200 per month to maintain Mr. Walsh as a petroleum engineer consultant. This would permit Mr. Walsh to remain in position to avoid conflicts of interest and in this amount it would include one trip to Phoenix to attend our meetings or hearings. If more were to be demanded it would be necessary to pay him his customary fee. In this manner for an expenditure of \$2,400 to \$3,000 we would have a consultant permanently available.

It is suggested that the entire budget be reviewed prior to going to the Governor should the commissioners decide to take this approach.

In the Harless matter, the Attorney General has advised that the formal written decision of the court has been rendered. Some of the interested parties have requested a meeting with the Attorney General prior to any hearing or further action on our part. Mr. Green intends to give the Commission a letter indicating the full steps to be taken in this matter.

I anticipate that it is his desire that a hearing be scheduled, perhaps June 21, and that the Attorney General will change his mind and request that we publish new notices. Undoubtedly the Attorney General will desire at least 30 days to take dispositions from Mr. Harless.

As a result of the current Arizona discovery and the wide publicity it has been receiving, both locally and nationally, the State Land Department has enjoyed a great increase in leasing activities. I have been informed that the federal leasing in the Bureau of Land Management are likewise having greatly increased activity.

The Water Quality Control Council has scheduled hearings in Yuma and in Kingman on May 23 and May 25. A later meeting is scheduled for Phoenix. It will be necessary that I be out of the office on these days.

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JOHN BANNISTER
EXECUTIVE SECRETARY
J. R. SCURLOCK
PETROLEUM GEOLOGIST

May 11, 1967

Memo to: Commissioners
From: J.R. Scurlock, Geologist
Re: Report of Activities

April 4, Sedona: checked Harless rig. No activity. No change.

April 5: Checked J.C. Mann Drilling Co. well (located 10 miles south Mexican Water). Total depth 6031' in pre-Cambrian. No show encountered.

April 25-26-27, Dineh Bi Keyah Field. Accompanied Commissioner Siler to see the new oil field which was alive with activity. Saw trucks (capacity 275 barrels) loading oil from the tank battery at Kerr-McGee #1 Navajo. (Tank battery represents 7,000 barrels storage.) Small amount of gas being flared.

Saw Humble building tank battery. Visited Humble #1 Navajo 138 (a completed well).

Visited Kerr-McGee #3X well (a prolific producer), Kerr-McGee #1B (completed well), Kerr-McGee #2B (drilling).

May 1-3, Anadarko well: Dry hole. Total depth 4242' in granite. The syenite sill (igneous intrusive) pay zone was not present in this well, which ran 170' structurally high to the Kerr-McGee discovery well. No show of oil in this well. Inert gas recovered from drill stem test of Devonian being tested for helium. Only dry hole in the field thus far.

Current Well Status

Kerr-McGee #1 Navajo (discovery well) Tested on April 26: pumped 755 bbls. oil/24 hrs.

Kerr-McGee #2 Navajo Tested April 26: pumped 2907 bbls. oil/24 hrs; made 259 MCF gas. (Note: this well pumped 46,372 bbls. oil in March--doubling Arizona's production.)

Kerr-McGee #3X Navajo. Tested April 26: pumped 2938 bbls. oil/24 hrs; made 242 MCF gas. (Piping this oil to tanks on #1 Navajo location.)

Kerr-McGee #7 Navajo. Tested April 27: pumped 2,578 bbls oil/24 hrs.

Kerr-McGee #9 Navajo. Tested May 8: pumped 2,622 bbls oil/24 hrs. Made 366 MCF gas.

Kerr-McGee #1B Navajo. Well originally drilled to a depth of 3800 ft. Have now moved drilling rig (Pico) back on location. Drilling deeper to Cambrian.

Kerr-McGee #-1 Navajo. Drilling.

Kerr-McGee #2B Navajo. Have run 5½" to total depth of 4,565'. No igneous sill pay zone in this well. Currently testing.

Kerr-McGee #10 Santa Fe (mineral strat test) NW SW 23-20N-27E Apache County (South Pinta Dome Area) Total depth 1,330' in Coconino. Plugged.

Kerr-McGee #1 Santa Fe (Mineral strat test) SW NW 14-19N-27E Apache County (South Pinta Dome Area) Total depth 1,417' in Coconino. Plugged.

Humble 138-1 Navajo. Installing Reda pump.

Humble 138-2 Navajo. Moving in rig (Loffland Drl. Co.)

Humble 140-1 Navajo. Drilling 2,942'.

Humble 87-1 Navajo. Drilling.

Note: Kerr-McGee still reports bottleneck situation in trucking out oil. They have surveyed a route for pipeline and have taken bids for such a line.

4-24-67

John Fisher - Kerr-McGee - Area Production Super.
meet Dr. Pye and me at 7:00 AM - Glencliff Motel.

Kerr is setting up a tank farm in NE of 29. Will put in one 30,000 Bl tank & several 5,000 Bl tanks. If field comes up to expectations will install automatic lease control equipment. Many locations are high & hilly & trucking in winter weather will be difficult. Ultimately a pipeline from tank farm to 4 corners pipeline is planned - approx 35 miles long. If this is done Kerr will take all pumping controls into Farmington office and each well-pump-flow lines can be controlled from there independent of weather.

Currently 3x is being produced into tanks at No 1 location, eventually production from B lease will be flowed (gravity) to #1 location too. The #7 is now (as of midnight the 24th) flowed (gravity) to #2 location.

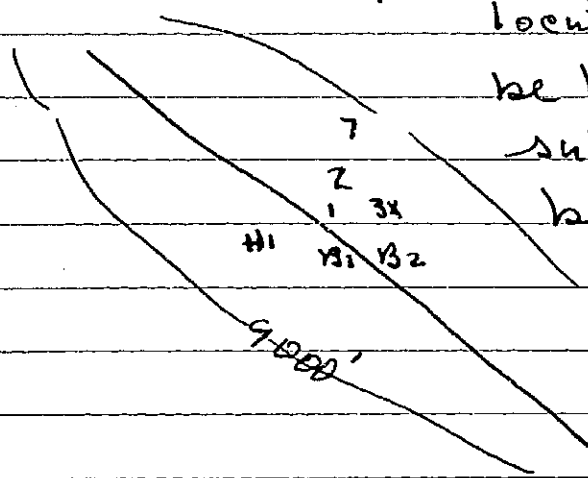
Kerr has ordered the F-1 and E-1 completed prior to May 25th, the next Indian lease sale. Kerr will undoubtedly go tight on all wells until then.

Approx 12 dozers working 24 hrs. a day on roads, locations, pipeline Always. Orders are to bring in any and all equipment needed to proceed at fast pace. Dozers are critical and

Fisher has been given OK to bring dozers in from Okla. City if necessary.

All personnel met were cautious but reluctant to give info. Due to amount of money being spent and amount of equipment being used Kerr is obviously optimistic as to size and extent, capacity and life of field. Many expressions of delight that discovery in Arizona (NO pronouncing) rather than in N. Mex (approx 75 BOPDP/Well).

If picture of anticline shown in hearing is correct locations N & W of No 1 (discovery) should be best locations according to Pye. Pye said Humble's locations all 3 - could be too far S - the B1 a marginal well and the B2 OK. Kerr cannot at this time explain B1's gas & almost total lack of oil, though Pye says that he suspects it could be a purely mechanical problem.



Speculation in field and in Farmington is that Humble will make good well - especially since the three tanks are being installed. Kerr feels that No. 7 & 3X will be better wells than #2. Still talking of reworking #1 but somewhat fearful that a new fracture might enter the Coconino rather than Hermosa.

Oil brought back from separator on #7

Kerr has locations ready for # 4, 6, 12, C-1, E-1 & F-1.
(or will be ready by 4-27 or 4-28)

It takes approx 2 hr. to go to field from Farmington.

Many large pine trees being cut down for location work. So far Navajos are not charging for location damage or trees cut - although trees must be sawed into specified lengths (depending on dia.) and stacked by roads. A 1 acre potatoe field in vicinity of Kerr #1 is only source of location trouble and this apparently can be satisfied by clearing a 1 acre plot for the Indian involved.

Kerr-McGee keeping roads in good shape - especially for trucks. Are naturally anxious for Indians to pave the main roads - some discussion has already been done with Nav. tribe. Nav. receiving $16\frac{2}{3}\%$ royalty.

JB

No Kerr-McGee core in area. Fisher will send 1 foot or so of core from #2. Says core will almost powder when hit by hammer.

Visited all drilling or finished locations.

4-24-67

Permian Corp. is running 13 tank trucks - each carrying 1 trailer. Each truck makes approx 2 round trips ea. 12 hrs - ave. load 200 Bls per trip.

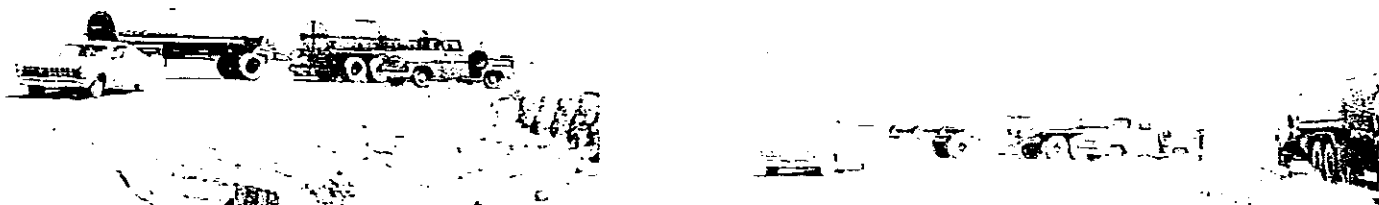
Oil is delivered into 2 Permian tanks (3000 Bls ^{total}), loaded from 3 sides (S, W, E) and pumped by HACT, where it is metered into 4 corners pipeline - destination Compton, Calif. Pipeline under present pumping setup may receive up to 400 Bls per hr.

Loading point - 4 1/2 miles S. of Shiprock, N. Mex on Hwy 666 (Shiprock to Gallup) on W. side of road - approx 100 yards off of hwy.

Posted Field Price - \$2.80 per Bl. - trucking charge 35¢ per Bl. Kerr-McGee then receives \$2.45 per Bl.

IF 4 corners is unable to accept all of Dineh bi Kayeh oil it is likely that the line going into Texas will also be used.

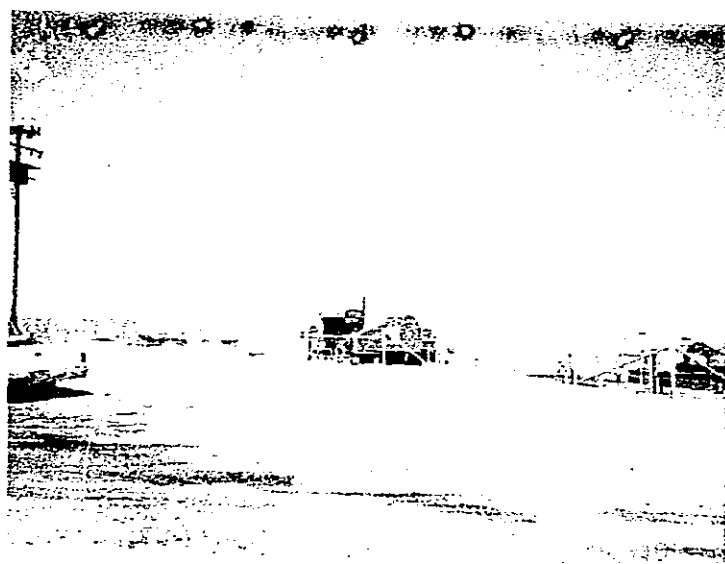
(See pictures attached)



Tanks Trucks leaving for Deneh bi Keyeh field.



Unloading into Permian Corp. Tanks



Pumps taking from Permian Corp. tanks & pumping into 4-Corners pipeline.

Arizona's spectacular oil strike tops Rocky Mountain field interest

Joseph A. Kornfeld, President, and
Maury M. Travis, Vice President,
Kornfeld International, Tulsa

NORTHEAST ARIZONA created nation-wide attention during April, after the Dinah Bi Keyah oil field gained its fourth producer from a 3,000-foot Pennsylvanian high gravity reservoir.

Fifteen operations currently are active in the area. Strong lease participation is underway by a blue ribbon group of major oil companies, paralleling similar participation in the Uintah basin development in Utah during recent years. Also, there is active leasing by a representative group

of independents from the Rocky Mountain region.

The new field, located on the major Lukachukai anticline on the Chuska Mountain range 50 miles southwest of Farmington, New Mexico, has apparently broken the oil drought for Arizona. The strike lies on the southwestern rim of the San Juan basin of northeast Arizona, northwest New Mexico and southwest Colorado.

Fast payout. Because of the discovery, the northeast corner of Arizona stands an excellent chance to spark a major exploration program. Economic factors in the new field certainly point to such a development:

- Kerr-McGee Oil Corporation has proven an oil field with high initial

productivities, ranging up to 2,860 bpd per well.

- Exceptionally rapid payout, due to the excellent shallow well productivity and the lack of market restrictions on output.

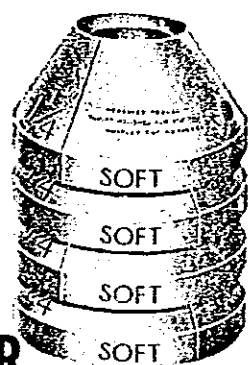
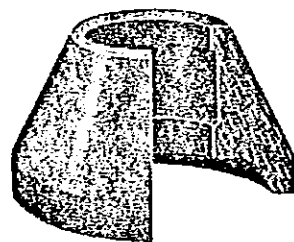
- Fast, easy drilling to shallow producing depths in the order of 3,000 feet.

- Excellent refining quality of high gravity crude from the four wells completed to date, i.e., 42-44° API.

- Proximity to major crude oil gathering systems in northeast Arizona and northwest New Mexico.

If production holds up, the new field will sharply increase Arizona's

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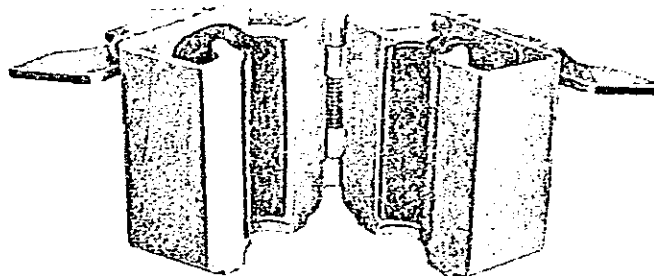
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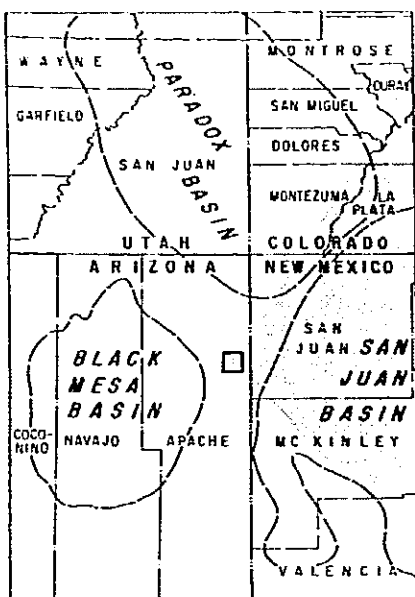
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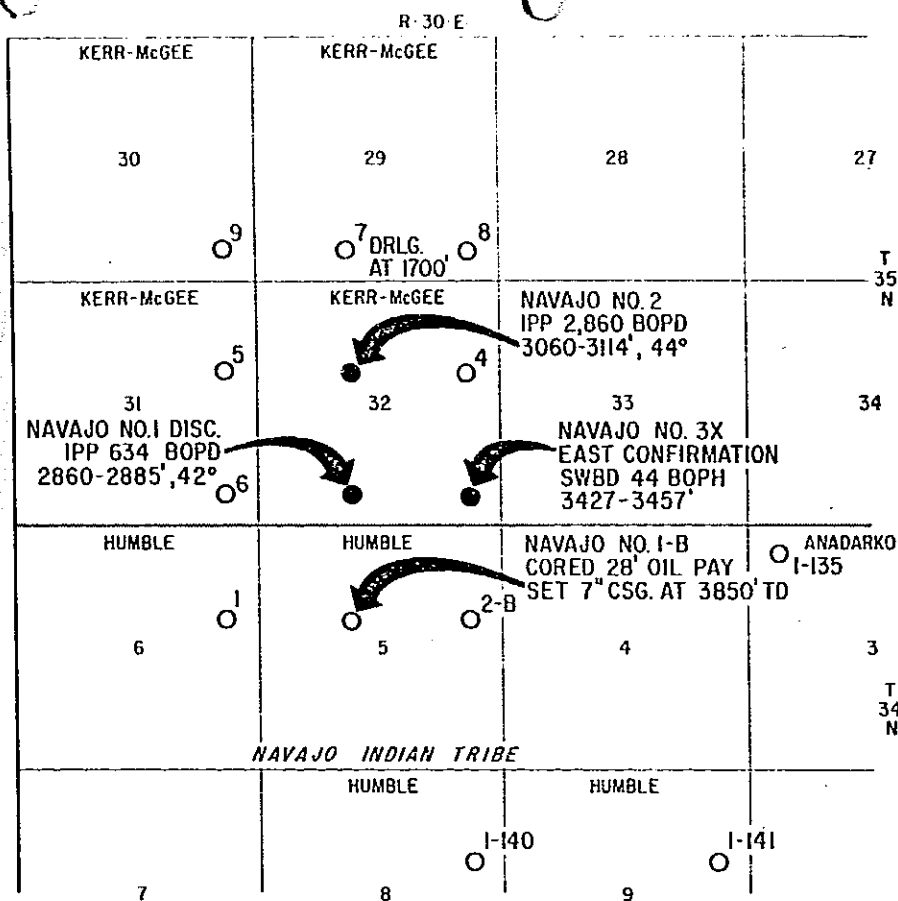
Kerr-McGee Corporation's first three Pennsylvania shallow wells in the prolific new Dineh Bi Keyah oil field. Field lies in the Chuska Mountains on the Toadlena Anticline in eastern Apache County between the Black Mesa basin of northern Arizona and the San Juan basin. The field, regarded as the most significant development in the Rocky Mountains this year, has sparked a 15-well drilling boom on the Navajo Indian Tribe reservation.

contribution to the nation's crude supply. The State's first commercial oil production was discovered during 1954 from Devonian, Mississippian and Pennsylvanian reservoirs lying on a platform between the San Juan, Paradox and Black Mesa basins.

Arizona's average crude output prior to the strike was 400 bpd, all in Apache County about 50 miles north of the discovery well (See *WORLD OIL*, July 1963, Page 109). In mid-April, the new field's first three wells were producing more than 6,000 bpd—and indications were that production was holding up. This is remarkable because of the low permeability in the matrix of the reservoir's igneous rock, ranging from 25 md and below despite the high porosity ranging from 10-15%.

Navajos helped. The discovery also shows promise of providing the Navajo Indians with much-needed income.

As a starter the March 16, 1967 lease sale of 45,241.60 acres of Navajo Indian lands, which brought \$400,166.79, marked a major new stimulus to the 16 million-acre area owned in fee by the Navajo Tribe. Another sale will be held in late May or early June.



Until recent years, large portions of the region were never explored by conventional methods due to title litigation that tied up the predominantly Indian land.

Major Pennsylvanian strike. The new oil field, Kerr-McGee Oil Corporation Navajo 1, was completed last February pumping 634 bpd from Pennsylvanian perforations at 2,860-85 ft. The Pennsylvanian formation was encountered at 1,305 ft.

The discovery well originally was completed by Kerr-McGee as a dry hole during 1965 at a total depth of 3,864 ft. However, the operator re-entered the hole January 31, 1967, set casing at 3,159 ft., and plugged the well back to 3,056 ft. before perforating for production.

Major impetus to the new field was given by Kerr-McGee's Navajo 2, north confirmation producer one-half mile north of the discovery well. It was completed pumping 2,860 bpd of 44° gravity crude from Pennsylvanian perforations at 3,060-3,114 ft. Actual crude oil gage during the first 24-hour test last March was 2,856.5 barrels.

The third and largest producer, one-half mile east of the discovery

well, was completed in mid-April when Kerr-McGee's Navajo 3-X flowed 2,864 barrels of oil and 367,000 cubic feet of gas daily. Initial gas-oil ratio is very low at 128 cubic feet per barrel of oil. Producing Pennsylvanian perforations were made at 3,427-57 ft.

The fourth well, Kerr-McGee's south offset Navajo 1-B, was producing at commercial rates in mid-April. Operators set 7-inch pipe at 3,850 ft. total depth after coring 28 ft. of oil pay.

Meanwhile, Kerr-McGee has announced four new locations for the field, all on 160-acre spacing. Humble Oil and Refining Company has five locations staked around the discovery well. Anadarko Production Company marks the first gas firm to enter the play.

Unusual oil reservoir. The producing oil reservoir in the new Pennsylvanian field is unusual in that it produces from an igneous syenite sill. This geologic condition has been confirmed by the Oil and Gas Conservation Commission of the State of Arizona and Kerr-McGee Oil Corporation geologists.

It is reported that this may be the only producing oil reservoir in the

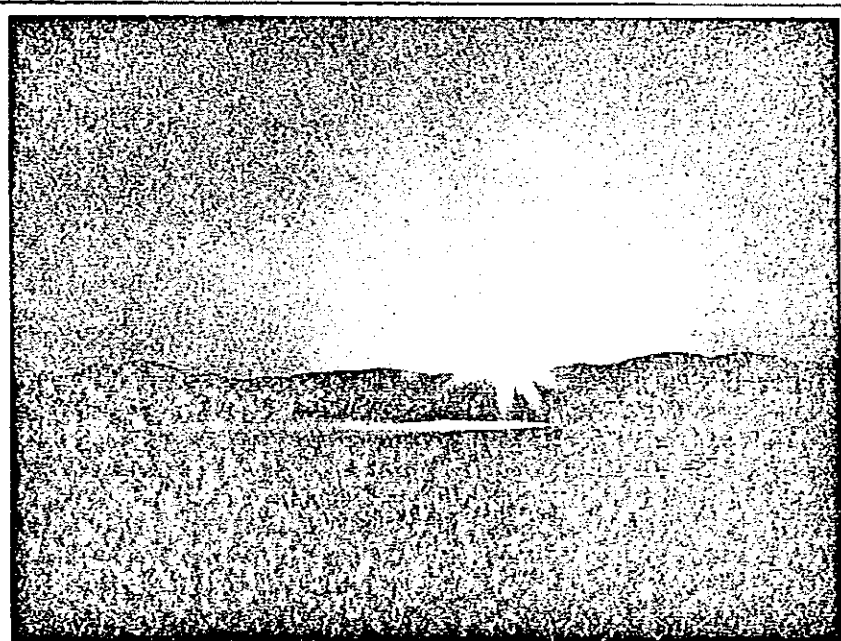
United States which produces from this type of igneous sill.

Core analysis results. Kerr-McGee geologists report the sill has the following lithologic composition from a zone at 3,060-3,152 ft. at its Navajo 2 north confirmation producer to the discovery oil well:

Mineral	Percent
Nepheline	30
Diopside	30
Phlogopite	30
Sanidine	10
Total	100

The producing oil reservoir is intercalated between a limestone and shale stratigraphic series in the Pennsylvanian system.

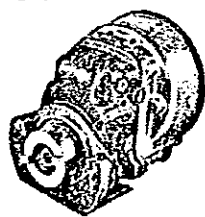
Electric logging surveys. Electric well logging surveys conducted to date on the Kerr-McGee wells in the Dineh bi Keyah field include the induction electric bore-hole compensated sonic log and compensated formation density log. This combination of electric logs is designed to determine effective porosity, and secondary porosity index.



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Discovery Well Summary (Electric Log Determinations)

Kerr-McGee Oil Corporation, Amarillo, Texas, Navajo 1, SE/4 SW/4 32-36N-30E, discovery oil well of new Dineh bi Keyah (Pennsylvanian) oil field, Apache County, Arizona. Old well plugged back. O.T.D. 3,864 ft. Originally completed during 1965 as a dry hole. Re-enter hole on January 31, 1967. Set casing at 3,159 ft. Plug-back depth 3,036 ft. Perforations 2,860 = 2,865 ft. w/4 shots per ft. Initial pumping potential 634 bopd. Elevation: 7,564 ft., ground level.

Formation Marker	Depth	Datum
Permian.....	573'	(+6,991')
Pennsylvanian...	1,305'	(+6,259')
Mississippian....	3,127'	(+4,437')
Devonian.....	3,324'	(+4,240')
Cambrian.....	3,690'	(+3,874')
Pre-Cambrian...	3,830'	(+3,734')

New lease sale. The lease terms under which the next gas and oil lease sale will be held in late May or early June 1967 include the following provisions approved at a meeting of the Navajo Tribal Council, Window Rock, Ariz. on March 29:

1. Basic royalty rate: 16 $\frac{2}{3}$ percent.
2. Minimum bonus: \$2.50 per acre.
3. Primary lease term: 5 years unless extended by production, with no minimum drilling period required.
4. Lessee shall furnish the Navajo Tribe copies of all reports required to be made to the Supervisor, United States Geological Survey by 30 CFR 221.58 and 30 CFR 221.59.
5. The Chairman of the Navajo Council is authorized to do any and all things necessary to carry out the purposes of this resolution.

Who's leasing. The list of successful bidders at the March 16, 1967 sale held at Window Rock, Ariz., include the following companies:

Major companies: Pan American Petroleum, Mobil Oil, Humble Oil and Refining, Gulf Oil, Cities Service, Texaco, AtlanticRichfield, Champlin Petroleum, Union Oil of California, Skelly Oil and others.

Independents: Jack J. Grynberg, Texac Pacific Oil Co., Kimbark Exploration, Texas Pacific Oil Co., Monsanto, W. T. Blackburn, Depeco, Pubco Petroleum, E. R. Richardson, Colo-

radio Oil and Gas Corp., Thomas Connelly, and others.

Navajos need income. The Navajo tribe's Minerals Supervisor Henry F. Pohlman reports the new discovery and recent sale were badly needed, because the tribe's crude revenues from the Aneth field have declined and the economic pinch is being felt.

DRILLING, COMPLETION

Drilling contractors. Active in the new Dineh bi Keyah development

are: Carmack Drilling Co., Grand Junction, Colo., which drilled the first three producers; Barker Well Service Co., Grand Junction, Colo.; Pico Drilling Co., Breckenridge, Tex.; and Mesa Drillers, Lubbock, Tex.

Drilling practices. Kerr-McGee drilling engineers set 10 $\frac{3}{4}$ -inch surface casing at 400 ft. and cement with 500 sacks; set 7-inch production string through Lower Hermosa (Pennsylvanian) oil pay and cement with 150 sacks.

Humble drilling engineers set 10 $\frac{3}{4}$ -inch surface casing at 537 ft., cement with 525 sacks; drill long hole through the oil pay and set 7-inch to oil pay base and cement with 150 sacks.

Completion practices. Well completion practices to date have followed set through and selective perforating using a shot density of 1 jet per foot of pay.

Wells are swabbed natural then given a bore-hole acid treatment prior to sandoil fracturing for completion. Load is then swabbed back, the hole tubed and well placed either on the pump or completed as a flowing well.

Well spacing. To date, development has been conducted uniformly on a pattern of one well to 160 acres, and this present spacing practice has been followed voluntarily by Kerr-McGee, Humble, Anadarko.

Exploration reaches high levels in Western Canada

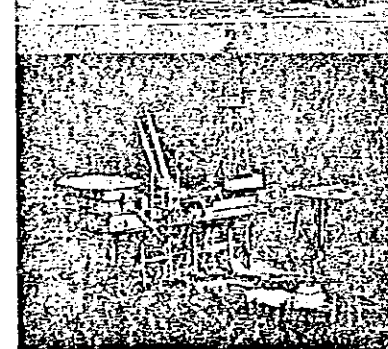
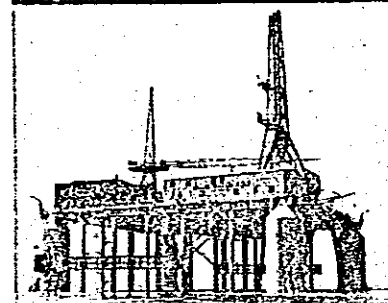
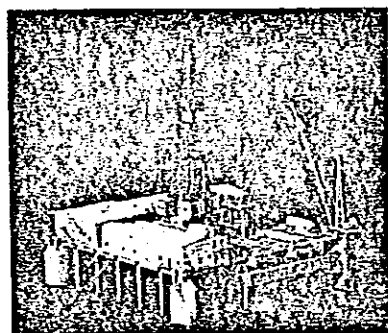
PETROLEUM EXPLORATION in Western Canada continues to boom as a result of the finding of huge reserves of oil and gas in the Rainbow-Zama Lake area of northwestern Alberta.

The number of geophysical crews at work in Western Canada in recent months has exceeded 100 for the first time in eight years. During February 1967, the number of crews in operation may have reached 137, according to a recent estimate. That would be the highest level since the winter of 1957, when the Swan Hills field was discovered during the Suez crisis.

Nearly two-thirds of the presently active crews are at work on the Keg River-Muskeg formations of the Rainbow-Zama area. Seismic techniques are proving invaluable for locating the narrow pinnacle reefs typical of the area.

Wells. Since the original Rainbow discovery two years ago, approximately 210 wells, most of them exploratory, have been drilled in the region, with a remarkable wildcat success ratio of close to 50 percent. It is estimated that the industry will drill an additional 65 wells in the area before the spring thaw and break-up of operations.

Pipe line. Also scheduled before the spring thaw is the completion of an



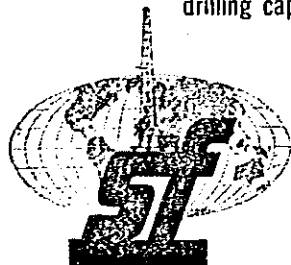
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Arizona: a new exploration

MOST of Arizona is relatively unexplored for oil and gas and large areas have not been tested by drill. The northeastern, northwestern, and southeastern portions of Arizona are favorable both structurally and stratigraphically for oil and gas. Shows, seeps, and actual production of oil, gas, and helium are found in these areas. The southwestern portion of Arizona is an unknown quantity which will need considerable exploration to evaluate but at the present does not appear to have the potential of the rest of the state.

The earliest officially recorded well drilled for oil and gas was completed in 1903. To date the Oil & Gas Conservation Commission records 548 wells which have been drilled for oil, gas, or helium in the state. The above figure includes records of potash tests drilled in the Four Corners area which drilled through the Coconino sandstone to test it for helium.

Of the total number of wells, 384 are located in Apache and Navajo counties of northeastern Arizona and 41 are in Cochise County in southeastern Arizona. The first official commercial production of oil and gas was in 1958; the first commercial production of helium was in 1961.

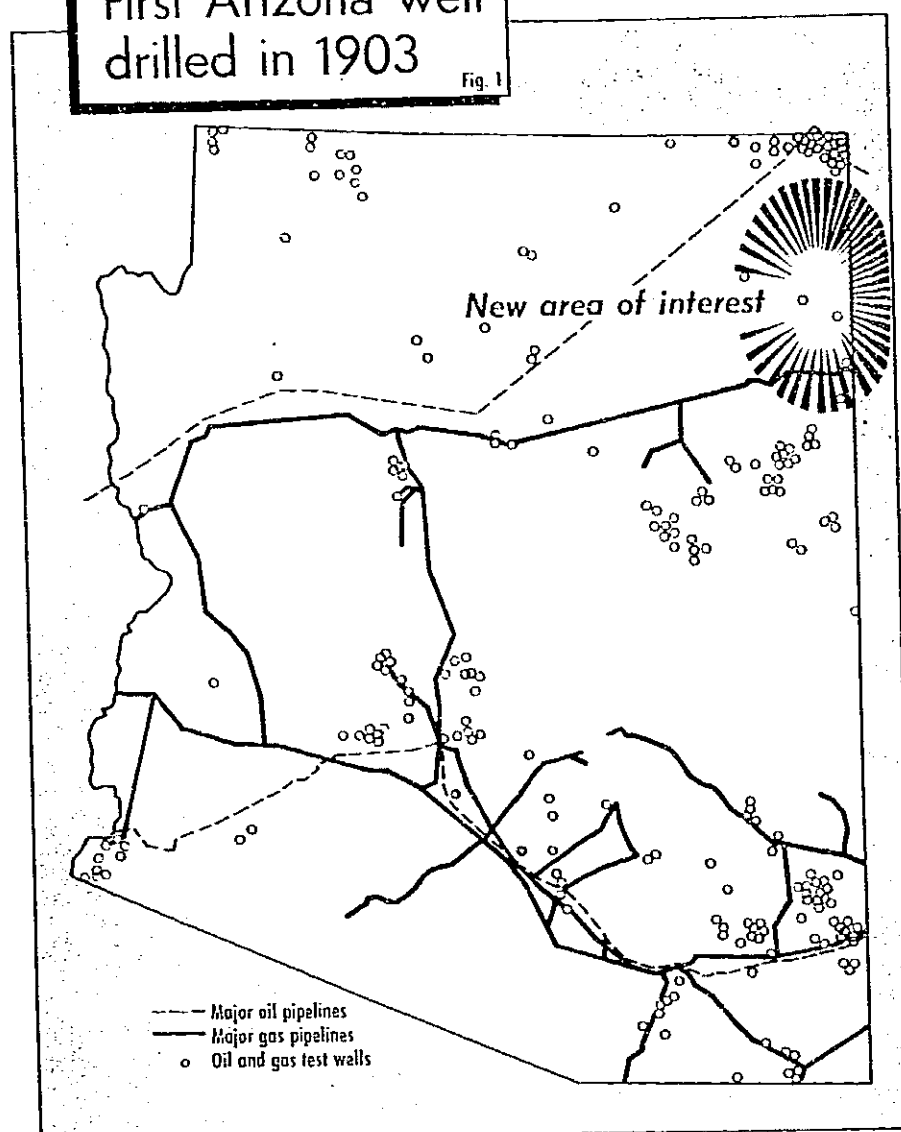
The official 1965 cumulative production for Arizona is 482,000 bbl of oil, 4,819,000 Mcf of petroleum gas, and 2,094,000 Mcf of raw helium gas. This production is from five named and one unnamed oil and gas fields and from two helium gas fields all located in the Four Corners area.

Of the approximately 73,000,000 acres in Arizona, about 5,000,000 acres or 7% of the state is under lease with 2,500 acres proved productive. Two deep wells have been drilled to date. One well is 7,568 ft deep in Navajo County in northeastern Arizona; the second one is 7,579 ft deep in Cochise County in southeastern Arizona. The average well is about 4,500 ft deep. In 1964 lease bonuses paid to the Hopi and

This is an abridged version of a paper prepared by Dr. Willard D. Pye, Department of Geology, University of Arizona, and delivered at the Interstate Oil Compact Commission meeting in Phoenix.

First Arizona well drilled in 1903

Fig. 1



Dr. Willard D. Pye
University of Arizona

Navajo Indian tribes were over \$20 million.

Helium ranges from 8 to 9% with the balance of the gas being largely nitrogen. The present price for raw helium gas is \$1.76/Mcf and for refined helium gas \$35/Mcf.

Natural gas and oil transmission and distribution lines network the state.

Arizona geology

Two areas. Arizona is sharply divided into two contrasting areas: the Colorado Plateau and the Basin

and Range geologic provinces.

The boundary between them can be considered to enter the eastern edge of Arizona approximately one-third of the distance northward from Arizona-Mexican boundary. The line separating the provinces diagonals northwestward and passes into Utah a short distance east of the Arizona-Nevada boundary. The boundary between the two provinces is often marked by an abrupt cliff sometimes 1,500 ft in height and locally known as the Mogollon Rim.

Between the two provinces there is a transition zone which bears structural and sedimentational characteristics of both of them. Despite

frontier

this transition, the two provinces are marked by a rather abrupt change in structural characteristics and to a lesser degree by difference in sedimentational features, the latter being more apparent because of the influence structure has had upon the distribution and outcrops of the sediments.

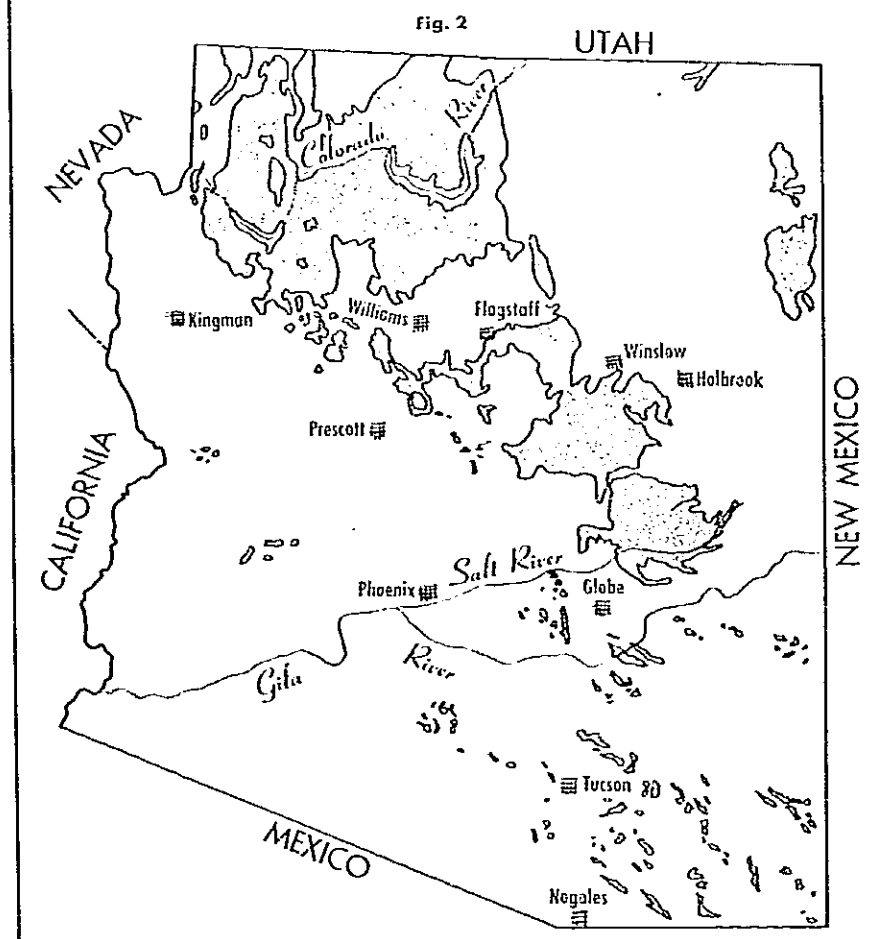
In the Plateau area the surface rocks are almost exclusively Permian and Mesozoic red beds and sandstones; each formation has broad outcrops. South of the rim, formations usually outcrop as either crystalline cores of mountains or as long narrow bands of Paleozoic limestones which form part of the ranges. These outcrop bands are separated by broad, flat areas of Tertiary and Quaternary alluvium.

Sedimentation. Sedimentation in Arizona throughout Paleozoic time was essentially that of a shelf receiving primarily sand, lime, and some silt and mud. From Cambrian to Devonian time Mazatzal land and the Defiance uplift formed a broad, low-lying positive area diagonaling southwestward from the Four Corners to possibly as far as southern California. Although by Mississippian time the western part of the uplift had probably vanished, the northeastern Defiance portion remained positive throughout Paleozoic time.

South of this positive area was the Sonoran embayment which entered Arizona near the southeastern corner of the state and extended from Mexico northwestward into Southeast Central Arizona. This embayment controlled marine sedimentation throughout the Paleozoic era and again in early Cretaceous time.

Along the western edge of the state was the eastern margin of the Cordilleran geosyncline which controlled sedimentation throughout the Paleozoic and most of the Mesozoic eras. Its presence in the northwest corner of the state as well as some 40 miles south of the southwest corner of the state are clear; between these points its history and boundaries in Arizona are obscure.

The promising Paleozoics of Arizona



Local basins such as the Paradox basin in the Four Corners area and local uplifts modified the overall pattern of deposition.

Pre-Pennsylvanian sedimentation was predominantly limestone and dolomite with basal sandstone and some shale. In general, the sections are lithologically somewhat similar over much of Arizona and tend to follow the pattern of thickening off of the Mazatzal-Defiance positive area. Their thinning along its flanks is partly due to nondeposition but also to a considerable extent to several periods of post-depositional erosion.

In Pennsylvanian time red beds began to be deposited in northeastern Arizona. Deposition of the red beds and evaporites spread south and westward until by Permian time they covered about half of the state. With the exception of the time when the marine Kaibab limestone was

being deposited, northeastern Arizona continued to receive red beds, nonmarine sandstones, and other continental and near continental sediments from Pennsylvanian to Cretaceous time. A final marine sequence was deposited in the Four Corners during Upper Cretaceous and early Tertiary time.

Marine sediments. In contrast, the Cordilleran geosyncline continued to receive marine sediments throughout most of the Mesozoic era, but southeastern Arizona received no marine sediments after Permian time except for a short period in Lower Cretaceous time when seas again occupied the Sonoran embayment. Some red beds may have been deposited in the Triassic-Jurassic interval in southeastern Arizona. Red beds and volcanics in great thicknesses were deposited in southeastern Arizona during Upper Cretaceous

ous and early Tertiary time.

Throughout Arizona Tertiary and Quaternary were times of erosion of highlands and continental deposition in basins.

Structurally, the Plateau province, which is generally over 5,000 ft and may exceed 9,000 ft elevation, is underlain by sedimentary beds which are nearly horizontal but may dip gently northward. Locally the beds are deformed by broad warps and sharp monoclinical folds which may be broken by steep angle faults.

Structurally and topographically

the highest area is the Kaibab plateau through which the Colorado River has cut the Grand Canyon. Both to the east and to the west both structure and topography are "stepped down" by a series of successively lower blocks formed by north-south trending monoclines and faults separated by broad subplateaus.

The Basin and Range province is characterized by numerous linear mountain ranges which trend in a general north-northwest and south-southeast direction and which are

separated by broad, flat basins. These mountain masses reach elevations of between 8,000 and 10,000 ft above sea level and range from a few miles to some 25 miles across and from a few miles to over 100 miles in length.

Although the ranges are generally subparallel to each other, there are some transverse and arcuate ranges. The structure within the ranges is usually complex, consisting of crystalline and sedimentary rocks often intricately folded, thrust, and block faulted. The basins are of similar dimensions and shape as the mountains or may be larger. They are filled with Tertiary and Quaternary alluvial sediments which generally conceal the underlying structure.

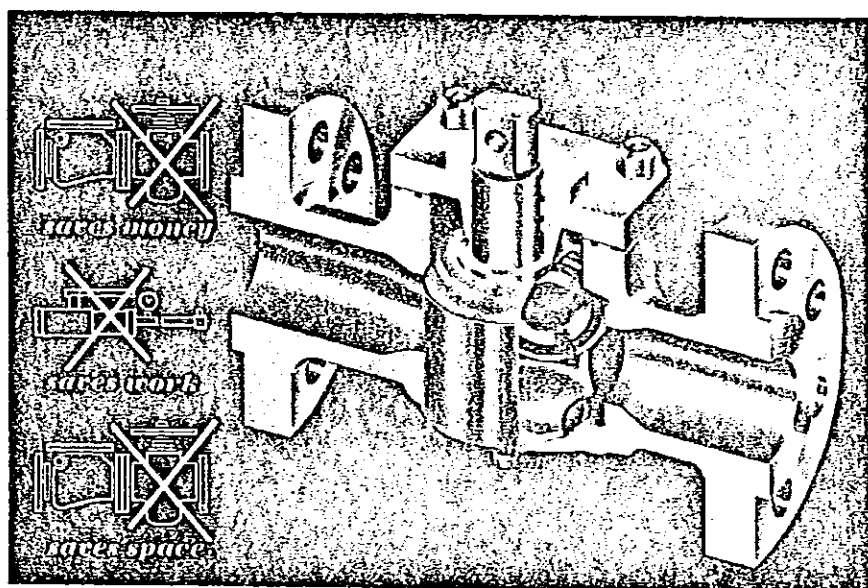
Petroleum possibilities

Five regions. For the purpose of this discussion, Arizona may be divided into northwestern, northeastern, southeastern and southwestern regions. The northwestern and northeastern regions comprise, in general, the plateau portions of Arizona. The southeastern region includes that part of Arizona east of Tucson and south of the plateau, and the southwestern region comprises that portion of Arizona west of Tucson and south of the plateau.

The separation into northeastern and northwestern portions is based upon the distinction between the geosynclinal province of northwestern Arizona and the shelf and local basin province of northeastern Arizona. The separation between the southeastern and southwestern provinces is based upon a possible northwest-southeast trending area of thin sedimentation lying between the Sonoran and Cordilleran sedimentational basins and the fact that the geology of the southwestern part of the state is largely concealed.

A fifth region corresponding with the transitional area between the plateau and Basin and Range provinces and trending northwest-southeast through the central portion of the state would be composed of the northern portions of the southeast and southwest regions of Arizona herein discussed.

This fifth region is largely composed of crystalline rocks and is considerably mineralized and locally has numerous volcanic flows. However, this transition zone is included



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in the other regions in this discussion. Its oil potential is very limited.

Northwestern Arizona. In northwestern Arizona a thick marine section of rocks occur. All Paleozoic systems are represented with the possible exception of the Silurian and Ordovician systems.

Overlying this marine section is a Mesozoic section composed primarily of red beds and sandstone units. Erosion has removed most of the Mesozoic units and in places has beveled the section well down into the Paleozoic formations.

Locally, deep canyons have cut entirely through the sedimentary rocks and into the underlying Precambrian crystalline rocks. Oil and gas which might have been present in the sedimentary beds may have escaped through drainage into the canyons. The Paleozoic section thins rapidly eastward, and in some cases entire units may pinch out.

Structurally, the northern part of the area consists of a series of gently tilted beds which at various points have been broken by major vertical faults or monoclinical folds. South and west into the transition area the structure is more complex and consists of large scale faulting and in some areas close folding.

Volcanic rocks between Flagstaff and Seligman cover much of the area, but presumably the underlying sedimentary rocks are similar to those exposed farther north, east, and west. The intrusives which fed the volcanoes in the area locally may have destroyed any oil present. In this area determination of structural traps is difficult because volcanic flows mask all underlying beds.

Oil shows have been reported from a number of formations where their edges have been exposed in the canyon walls or where they have been penetrated by wells. Some production has been secured adjacent to the area in Utah.

The area contains rock units which could serve both as source and reservoir beds. Gently folded and simply faulted structures are present which could serve as traps; stratigraphic traps may be present also. The possibility that the oil and gas may have escaped by flushing or natural drainage is the main problem in evaluating the petroleum potential of the area.

Northeastern Arizona. In northeastern Arizona, Paleozoic rocks are overlain by Triassic and Jurassic nonmarine red beds and sandstones. These in turn are overlain in the Black Mesa basin by Cretaceous marine beds and elsewhere locally by Tertiary and Quaternary sediments. The Paleozoic section may be thin or almost absent, as on the Defiance uplift. In other areas the section may be relatively thick as adjacent to the Paradox basin.

Rocks of Cretaceous age in the Black Mesa basin are relatively thin because of erosion. Some of the extensive Cretaceous sandstones which produce oil and gas in New Mexico are present in the basin, but because of thin cover or exposure of their edges may have lost any oil or gas they may have contained. The predominantly nonmarine Permian, Triassic, and Jurassic sandstone beds serve as reservoirs for gas which may carry appreciable amounts of helium.

The Apache limestone, which occurs within the Supai red bed Permian sequence is a fossiliferous, marine unit which frequently carries

shows of gas and oil in wells and at the outcrop. At the outcrop it may be porous, but in the subsurface this porosity may be missing and this may restrict its petroleum potential.

The Hermosa-Paradox formations occur in the extreme northeastern corner of the state. These interfingering Permo-Pennsylvanian limestone, red bed, evaporite, and shale facies have yielded oil and gas in Arizona and elsewhere in the Four Corners.

The pre-Pennsylvanian beds are largely of marine origin. Production of oil has been secured from the Mississippian and Devonian. These formations are widespread over the state and in many places the Devonian section yields at the outcrop a petroliferous odor. There is at least one oil seep from the Devonian.

Numerous anticlines, synclines, and normal faults are present in the area. In the Holbrook basin, which lies north of the rim and south of Black Mesa basin, a number of surficial anticlinal trends are evident. This area is underlain by a salt section which has locally been dis-

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solved by ground water with a resulting collapse of the overlying beds and the formation of apparent anticlinal structures. In places these collapse basins and troughs are filled with water and form lakes.

The Hope Buttes and other volcanic fields present in northeastern Arizona may have done no vital damage to the oil potential, but dikes, sills, and subsurface alteration may be found. The extensive volcanic fields in Greenlee and Apache counties mask all clues as to subsurface structure and rock composition; it can be assumed that the stratigraphic section and structure are similar to that further north where no volcanics overlie the sediments.

Alteration around the volcanic throats and dikes is very limited. The main problem may be the loss of reservoir pressure since the formations have been pierced by the vents through which reservoir gas may have escaped.

In summary, the northeastern part of Arizona contains both source and reservoir beds. Good structural traps are present. In addition, the pinch-out of the pre-Pennsylvanian marine section against the Defiance uplift, reefing against it and other facies changes may give rise to good stratigraphic traps in the area.

This northeastern Arizona region is potentially one of the more prospective areas of Arizona, but oil and natural gas production will come primarily from the Paleozoic marine limestone section.

The Holbrook basin is the center of helium production in Arizona. Pinta and Navajo Springs domes are the main producing structures although good shows have been found in some wells outside of these areas. To date, all of the production is coming from the Coconino sandstone of Permian age, but the Shinarump conglomerate of Triassic age has reportedly commercial potential (wells are presently shut in pending completion of processing facilities).

Helium shows also have been found in other porous reservoirs ranging from Devonian to Mesozoic in age.

Southeastern Arizona. East of Tucson and south of the plateau occurs a thick section of Paleozoic marine limestone, sandstone, and shale beds. This section contains

representatives of all the Paleozoic systems with the possible exception of the Silurian system which has not been positively identified in the area.

Rocks of Ordovician age are limited to a limestone tongue in extreme eastern Arizona. The most favorable rocks for the occurrence of oil or gas in southeastern Arizona are the Devonian, Mississippian, Pennsylvanian, and Permian marine beds. These are predominantly limestone with some sandstone units. Reefs are probably present in these formations around some of the Paleozoic high areas.

The exposed post-Paleozoic rocks are largely continental red beds of Upper Cretaceous age. These may be overlain by Tertiary rocks which in many places include extensive volcanics. Quaternary alluvium is found in most of the basins. In the southeastern portion of southeastern Arizona, the Lower Cretaceous rocks become marine in character with several well developed limestone horizons. Under proper conditions, these marine Cretaceous beds might carry oil.

Structurally, the rocks show considerable faulting and folding. In places their deformation may become very complex. Also, the section locally may be extensively intruded and mineralized. The entire area is broken into narrow, somewhat west of north trending, uplifted mountain blocks separated by down-dropped basins.

Within the basins the same Paleozoic section may be present as is found in the mountains; however, thick accumulation of sand, gravel, and other valley fill has masked the character of the older rocks and concealed their structure. Therefore, within the basins it is difficult to predict how much section may be present, the structural relationships, and whether there has been any mineralization or metamorphism of the sediments.

The depth of the basin fill may be substantial, since a well drilled in one of the basins near San Simon penetrated more than 7,500 ft of alluvium without passing into the underlying bedrock. Elsewhere, the cover may be only a few feet thick.

Southeastern Arizona has an excellent stratigraphic section consisting of a marine section over 10,000 ft thick, containing source beds,

reservoir beds, and facies changes which may produce stratigraphic traps. But structural complexities and concealed subsurface relationships make it difficult to evaluate and pinpoint traps.

Southwestern Arizona. Southwestern Arizona consists essentially of mountain blocks composed of volcanic and crystalline rocks and some metamorphosed sediments. These are separated by broad basins which are filled with Tertiary and Quaternary alluvium and volcanics.

In the few areas of exposure of Paleozoic rocks, the structure is complex and the rocks have been metamorphosed and mineralized to varying degrees. However, some 40 miles southward in Mexico are found some 10,000 ft of Paleozoic and Mesozoic marine strata which are predominantly limestone.

The section is structurally simple and the rocks are unmetamorphosed. It is possible that this section or equivalents extends northward and is present in part of southwestern Arizona under the alluvial cover. Water wells have found over 3,000 ft of alluvium but the prealluvial section has not been explored.

Tertiary marine beds occur along the Colorado River and are extensions of marine sediments from the Gulf of California. Their outcrop is limited.

In southwestern Arizona the oil potential is essentially unknown. However, based upon meager information it is not considered to be too great unless under some of the basins unmetamorphosed Cordilleran geosyncline sediments occur.

Barber Co., Kan.

Magic Circle Oil Co. has two discoveries under way in Barber County, Kan.

Indicated gas discovery is 1 T. Knackstedt, C NW NE 18-30s-13w. Spotted 15 miles northwest of Medicine Lodge, it is 2 miles northwest of the Skinner multipay field. Drill-stem test over interval 4,517-52 ft, Viola Ordovician, stabilized with a flow of 6,000 Mcfd after 6 min. Bottom-hole pressures measured 1,615 and 1,593 psi. Proposed depth is 4,800 ft. Additional testing of lower zones is planned.

To the east, Magic Circle 1 National Gypsum is an apparent oil