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THE NAVAJO INDIAN NATION AND DINEH BI KEYAH

By

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INTRODUCTION

The Navajo Indian Tribe has been described as "a nation within a nation." It has been defined also as "a sovereign dependent nation." Both descriptions have merit. Approximately 110,000 Navajo people own 16,000,000 acres of land. Most of the land is barren, some is covered with lush vegetation, and all of it has beauty.

The Navajo Reservation's new oil development—Dineh bi Keyah, "The Peoples Field"—continues to expand. It is obviously a big strike and will get bigger. Present production is 15,000 barrels per day. The productive syenite sill is not the only economic target. The deeper Pennsylvanian and Devonian intervals contain commercial quantities of helium gas.

Good pressure information still is being obtained, and exploration continues; available figures indicate that large oil reserves in igneous rock probably are present and that increasing attention will be paid to the development of helium resources.

The People

The Navajo Indians,—"The People"—number about 110,000. Some recent estimates have reached 120,000. One hundred years ago the number was approximately 10,000 and times were much more difficult. However, survival today in the remote areas of the Reservation still is not an easy matter.

The United States in 1846 took possession of the Southwest territories from Mexico. Treaties with the Navajos were quickly and easily made, and rapidly broken. Military forces came and went. The Navajos held their ground until Colonel Kit Carson arrived in 1863. Carson's campaign under Brig. Gen. J. H. Carleton's scorched earth policy brought the majority of the people to their knees. Some of the strongest never capitulated.

Approximately 9,000 of the people subdued by Carson's forces eventually made the "Long Walk." The walk started at Fort Defiance, Arizona and ended at Fort Sumner, New Mexico, a distance of 300 miles. After four years of misery, the treaty of 1868 was signed and The People returned home. *Editor's Note*: See James' "The History of Fort Wingate," this guidebook.

Today the people are strong and they get stronger. Many problems remain but solutions are forthcoming.

Government

The People are governed by a 74-member Council elected by popular vote from 18 districts, a Chairman, and a Vice Chairman. An election takes place every four years and all political positions are placed on the block—it may be said the "infighting" gets rough. Although more than 50 percent of The People are fluent both in Navajo and English, some Navajos lack the ability to understand or read English therefore the ballots feature many photographs. The present Chairman, Raymond Nakai, has just started his second term.

All major business is done on the Council floor at Window Rock, Arizona, where the Council Members sit at individual desks facing the rostrum. If an oil and gas lease sale is being proposed, the majority of the Council must be convinced that such a sale has merit. The question is presented after the matter at hand has been discussed, (usually in Navajo), a vote is taken, and the majority rules.

The People recently have begun to assume their rightful place in the operation of state governments. Wilbert Begay, a member of the Minerals Department staff, is a New Mexico State Representative. Three other Navajo people hold similar positions in New Mexico and Arizona ruling bodies. Herbert Tsosie, another key member of the Minerals Department, also contributes much to his Navajo people.

Land

The Navajo Reservation covers at least 16,000,000 acres and is approximately the size of the State of West Virginia. Most of the land is rocky, windblown, eroded, cruel, and over-grazed. Still, there is a majesty and beauty over all. Some of the land is covered with tall timber and fern thickets, and dotted with lakes. The Chuska Mountains area is one of tall timber and the Dinch bi Keyah is in one of the more heavily wooded portions of the mountains.

Most of the Navajo Reservation is in Arizona but large areas also are in New Mexico and Utah. The Ute Indian Tribe occupies the extreme southwest corner—"the arrowhead"—of Colorado that juts into the side of the Navajo Reservation from the northeast.

The Hopi Indians occupy a reservation of approximately 631,000 acres that is surrounded by the Navajo Reservation but separated from it by what is commonly referred to as "the disputed area," the "50-50" area, or the "Navajo-Hopi Reservation."

The disputed area consists of 1,800,000 acres and is located in the center of the Arizona portion of the Navajo Reservation. The rectangularly shaped area was deemed to be 50 percent Navajo and 50 percent Hopi by a recent Supreme Court ruling. A big problem is present here. The Supreme Court apparently lost sight of the fact that almost 100 percent of the disputed area is occupied by Navajo people.

There is no relationship between the Navajo and Hopi languages.

Only part of the Navajo Reservation has been prospected for exploitable resources and the significant dis-

coveries to date have been petroleum deposits (mostly in New Mexico), natural gas, (some of which contains helium), widespread and important coal deposits, and uranium. The oil and gas deposits constitute by far the most important mineral resources of the Navajo Nation but 7,500 tons per day of Navajo coal are being used by the Arizona Public Service power generating plant near Kirtland, New Mexico.

The area of Navajo land under oil and gas lease (as of 6/30/67) is as follows:

State	*Area (acres)*
Arizona	341,259
New Mexico	447,484
Utah	192,042
Total	980,785

DINEH BI KEYAH

Dineh bi Keyah, "The People's Field" (or pasture) was discovered by the Kerr-McGee Corporation on top of the Toadlena anticline in the Chuska Mountains of Apache County, Arizona. The center of Dineh bi Keyah is approximately 5 miles due east of the Arizona–New Mexico boundary, and about 52 miles southwest of Farmington, New Mexico. Shiprock, New Mexico, lies 33 miles northeast from the discovery.

This is high country. Kerr-McGee's discovery well is 7,560 feet above sea level and their Navajo No. 14 is at 8,555 feet.

The climate is what might be expected at the indicated elevations. It is wonderful for three months, livable for an additional four months, and insufferable for the remaining five.

The Discovery Well

Kerr-McGee's Navajo No. 1 (Fig. 1, Map, SW¼, Sec. 32, T.36N., R. 30E., and Fig. 2, Photograph) was spudded in at 6:30 A.M. on January 22, 1965. Seven-inch casing was cemented at 3,159 feet on February 13, 1965. After placement of the casing, operations were suspended pending moderation of weather and availability of a company workover unit.

During early June of 1965 the shallow Coconino interval (starting at 590 feet) was thoroughly tested. Gas containing helium was found, but pressure and volume remained too low for commercial interest. The presently-producing igneous interval was not tested at this time. Kerr-McGee formally abandoned the well on June 22, 1965.

The first notice of new interest came via a U. S. Geological Survey notice dated January 17, 1967. The notice stated that Kerr-McGee wanted to re-enter No. 1, clean out the cement plugs, perforate from 2,860 feet to 2,885 feet and test that interval.

The following account of subsequent operations will be of interest:

1-26-67 Spotted 1,000 gallons of 10 percent acetic acid at 3,020′ Perforated from 2,860′-2,885′ with 4 jets per foot. Swabbed well dry. No fill up.

1-27-67 Acidized with 358 gallons of 10 percent acetic acid. Recovered 4 barrels of new oil in 5 hours of swabbing.

1-28-67 Swabbed 6.75 barrels of new oil in 8 hours.

1-29-67 Fractured well with 10,000 gallons of crude oil and 10,000 pounds of 20-40 sand.

1-30 and 31-67 Swabbed back all of frac oil and 137 barrels of new oil.

2- 1-67 Tested well at rate of 611 B/D (barrels per day).

The discovery well ultimately settled at 1,400 B/D until July 19, 1967 when an additional interval was opened. After the additional zone (2,885′-2,942′) was introduced, production climbed. The production on July 23, 1967 was 1,851 B/D of 43.3° oil, 135 MCF/D (thousand cubic feet per day) gas, and 0 B/D water. The GOR (gas-oil ratio) was 73 cu. ft./barrel (see Fgure 3 for electric log cross section).

Several very important and now obvious points were demonstrated by the action that took place in the discovery well. First, we can no longer ignore any igneous rock when some oil or gas saturation is indicated. Second, a negative drill stem test (or swab test) of untreated but potentially productive igneous rock means nothing. The same kind of rock can be acidized and results may still remain poor. A frac job in Dineh bi Keyah was obviously the difference between the kind of production we all desire and complete failure. We wonder how close Kerr-McGee came to missing the Dineh bi Keyah? How many other Dineh bi Keyahs have been passed up?

Bid patterns on recent Navajo oil and gas lease sales indicate that some people believe other fields of this type may be sleeping under the surface cover of Navajoland. Areas that have already sold two or three times are being purchased again.

Rocks

The Chuska Sandstone underlies most of the surface of the Chuska and Lukachukai Mountains. The standard northeastern Arizona geologic section lies beneath the Chuska, and all of the common rock units are present (see correlation chart at front of this guide book).

Our main interest centers on the syenite sill—the formation giving up the "money." The writer would be happy to think of and call this rock a quartz-free granite containing many recognizable minerals, but those geologists petrologically oriented might be offended. The following lithologic description is quoted from a memorandum letter by F. Peterson and G. A. Izett, Branch of Mineral Classification, Conservation Division, U. S. Geological Survey, Denver, Colorado.

"The interesting green rock is a biotite-rich vogesite and thus belongs to the syenite lamprophyre group of igneous rocks. The rock has undergone surprisingly little alteration. Lamprophyres are usually altered considerable but only a small part of some of the grains in your sample have been changed to chlorite, calcite, and ores.

The rock consists of euhedral grains of diopside, biotite, apatite, rutile (?), and ores enclosed in large anhedral

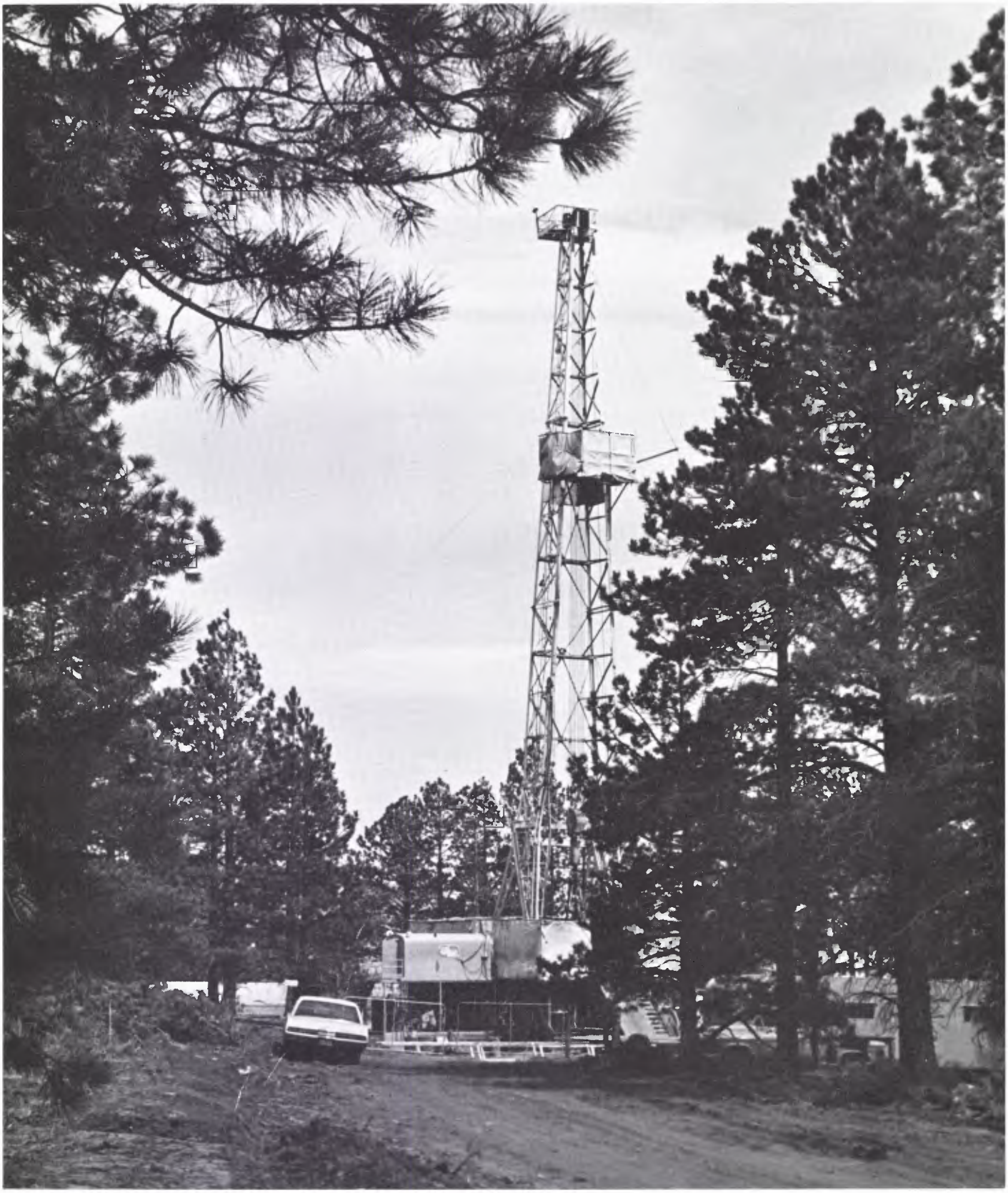


FIGURE 2.
Humble Oil and Refining Co.—Navajo No. 1—87

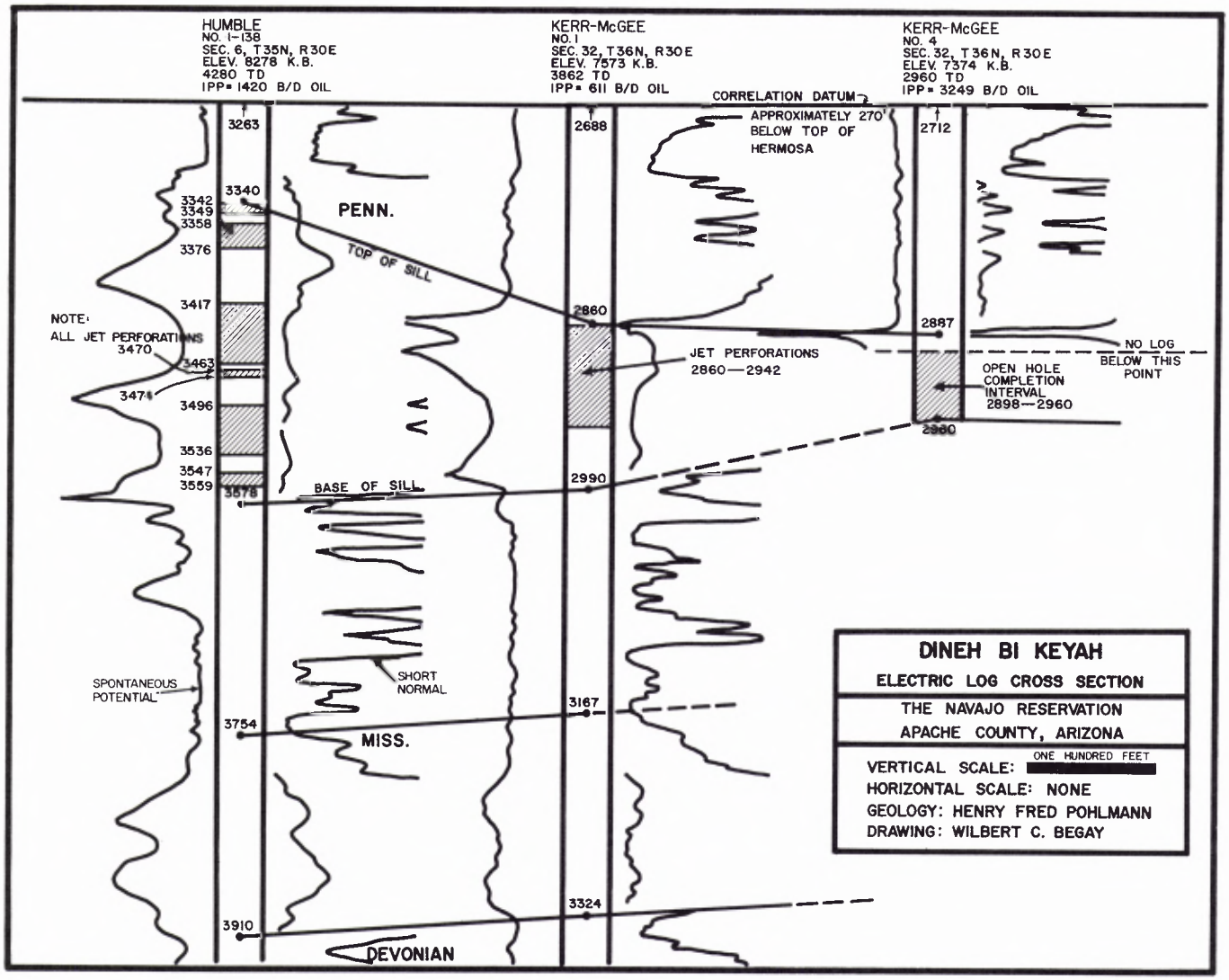


FIGURE 3
Position of seyenite sill in three wells in Dineh bi Keyah.

grains of sanidine (poikilitic texture). Chlorite, calcite, and some of the ores are alteration products. Diopside imparts the green color to the rock and there is evidence of zoning of this pyroxene. The biotite is about medium brown with dark brown rims and is slightly altered to chlorite; diopside is a little more altered to chlorite, calcite, and ores. Small prisms of apatite and needles of rutile (?) are scattered throughout the sanidine. The opaque "ores" are silver in reflected light and probably are magnetite or ilmenite. The following modal analysis is based on a count of 100 points.

	Percent of all constituents	Percent of rock forming minerals[1]
Sanidine	43	47
Diopside	22	27
Biotite	21	22
Chlorite	3	—
Ores	2	2
Apatite	1	2
Rutile	<1	<1
Calcite	<1	—
Cavities	8	—

1 Excludes alteration products (chlorite, calcite) and cavities.

The following list is the general sequence of crystallization of the rock.

Diopside (first)
Diotite
Apetite, rutile(?), ores
Sanidine
(cavaties)
Calcite, ores
Chlorite

Pore space amounts to 8 percent or less if the thin section is representative of the rock body in its entirety. Plucking of grains during the thin section grinding process

TABLE 1
Dineh Bi Keyah Production Results

Company	Well No.	Completion Date	Initial Production Oil (B/D)	Gas (MCF/D)	June 1967 Production Oil (Barrels)	Gas (MCF)	Cum. Oil Prod.[1] to 7/1/67	Pumping (P)[2] Flowing (F)
Kerr-McGee Corporation	1	2-1-67[3]	611	—	18,061	1,230	70,552	P
	2	3-12-67	2,857	—	79,537	6,463	284,761	P
	3X	4-7-67	2,865	367	81,706	5,256	206,284	P
	4	7-18-67	3,249	189	—	—	—	P
	6	7-8-67	163	22	—	—	—	P*
	7	4-22-67	2,578	276	32,590	3,263	91,087	P
	9	5-5-67	2,622	36	44,997	4,506	99,862	P
	14	7-9-67	301	390	—	—	—	F
	15	7-16-67	250	25	—	—	—	P
Humble Oil and Refining Co.	1-138	5-16-67	1,420	300	22,148	9,191	34,370	P*
			16,916	1,605	279,039	29,909	786,916	

1 The 1,000,000th barrel of Dineh bi Keyah oil was produced on July 27, 1967.
2 P* indicates standard pumping unit. All others are Reda submersible pumps.
3 An additional interval was opened in Kerr-McGee No. 1 on 7/19/67. Production on 7/23/67 was 1,851 B/D of 43.3° oil, 135 MCF/D gas and 0 B/D water.

may be responsible for some of the porosity and the figure should perhaps be considered maximum and not very reliable. There is no significant alteration of minerals surrounding the cavities and this suggests the cavities formed during cooling of the magna and not by subsequent leaching."

This rock has obvious primary porosity, but the degree and type of fracture system also must play an important role. Section 32 of T. 36 N., R. 30 E., probably is underlain by a highly complex fracture system. All wells in this section are outstanding producers.

The thickness of the producing igneous rock varies. In HORC (Humble Oil and Refining Company) No. 1-87 only a single 18 foot bed is present, but in HORC No. 1-138 a multi-bed thickness of 160 to 170 feet is present. No. 1-138 is the only multi-zone well in this field to date and the multi-layered and thicker intrusive zone is much different from the single zone intrusive found in all other Dineh bi Keyah wells.

Although the presently-known syenite sill is confined to the Pennsylvanian interval, it does not precisely conform to any particular horizon in the Pennsylvanian. In well No. 1-87 the base of the 18 feet of intrusive rock is 66 feet above the Pennsylvanian–Mississippian contact. In the Kerr-McGee No. 1 discovery well the base of the 82 feet of perforations is 225 above the Pennsylvanian–Mississippian contact. The top of the multi-layered intrusive in No. 1-138 is 414 feet above the contact.

The intrusive rock has been determined to be about 31,000,000 years old which indiciates probably emplacement during the Oligocene. The host rock is approximately 300,000,000 years old and thus was deposited during Pennsylvanian time.

Extent Of Field

Although the writer was unable to define an obvious barrier between HORC No. 1-138 and the remainder of the field, he believes that No. 1-138 is in a separate pool or compartment. No. 1-138 is structurally the highest well in Dineh bi Keyah (top of sill at +4938), but Kerr-McGee No. 14 has a higher GOR. It will be interesting to note the GOR in Kerr-McGee No. 13 after it is placed on production. No. 13 is midway between No. 1-138 and No. 14. The present known extent of the field is delineated on Figure 1 by the distribution of the producing wells.

The performance history of Dineh bi Keyah (table 3) gives a better clue to the probable separation of the source rocks for 1-138 and the rest of the known field. Note the original field or pool pressure was 729 psia (pounds per square inch, absolute) as determined in the discovery well on February 4, 1967. Three months later the approximate pool pressure was 590 psia, but the pressure measured in No. 1-138 was 732 psia on May 10, 1967. These pressures support the belief that the wells tap separate pools, and hint that still other pools may be present.

Helium

A secondary target in Dineh bi Keyah is helium. Helium has been found in commercial quantities in the deeper horizons and could be of great commercial value in the near future. Table 2, showing drill-stem test results in the Devonian (McCracken and Aneth intervals), lends weight to this supposition—note the high helium content (5.18 to 6.23 percent).

Flow rates of 605 to 1,599 MCF/D may not seem to be world beaters, but other factors must be considered. After acid treatment and frac, a 1,000 MCF/D well probably will be capable of 4,000 MCF/D. If the intervals between known helium wells also yield production; large reserves are assured.

The Federal Government pays 20¢ at the well head for one MCF of 5 percent helium gas. The well-head value of one MCF of 5 percent helium gas would be closer to 50¢ if sold to a privately owned plant. Pure helium gas is now sold under competitive conditions and the current value of one MCF is $28.00. We believe much profit would be made by the plant owner if the total cost of raw gas needed to produce one MCF of pure helium

TABLE 2
Formation Test Results and Analysis of Production Gases

Company	HORC[1]	HORC	HORC	ANADARKO	Kerr-McGee[2]
Well Number	1-140	1-140	1-87	1-135	1
Location (T-R-S)	35-30-8	35-30-8	36-29-23	35-30-3	36-30-32
Test Interval (Feet)	4532-4633	4663-4806	5231-5505	4014-4242	590-617
Formation	McCracken	Aneth	McCracken to Pre-Cambrian	Aneth	Coconino
Test Date	5-23-67	5-25-67	5-26-67	—	—
Flow Rate (MCF/D)[3]	1500	60	605	30	Very low
I.S.I.B.H.P. (PSIG)[4]	897	869	1597	975	13.1
Methane	2.2%	3.4%	3.1%	0.14%	4.0%
Ethane	0.2	0.5	0.4	0.01	—
Propane	0.1	0.2	0.2	0.01	—
Normal Butane	0.2	0.2	0.1	Trace	—
Isobutane	0.0	0.0	0.0	Trace	—
Normal Pentane	0.0	0.0	0.0	0.0	—
Isopentane	0.0	0.0	0.0	0.0	—
Cyclopentane	0.0	0.0	0.0	0.0	—
Hexanes plus	0.0	0.0	0.0	0.0	—
Nitrogen	83.4	78.7	78.8	92.18	—
Oxygen	0.0	0.0	0.3	0.0	—
Argon	0.8	0.8	0.8	0.0	—
Hydrogen	Trace	Trace	Trace	Trace	—
H_2S	0.0	0.0	0.0	0.0	—
CO_2	7.8	11.1	10.6	1.43	—
Helium	5.18	5.23	5.58	6.23	5.73
Gross BTU/cu.ft.	35.0	55.0	47.0	—	—
Specific Gravity	0.964	0.980	0.973	0.923	—

1 Humble Oil and Refining Company.
2 Only one Kerr-McGee shallow drill stem test result is shown here. This company conducted three additional tests in the No. 1 well at 683'-695', 683'-700', and 683'-700' (again) with the same basic result as illustrated here. The 683'-700' interval yielded a better I.S.I.B.H.P. of 190 PSIG.
3 Thousand cubic feet per day.
4 Initial shut-in bottom hole pressure (pounds per square inch gage).

was only $10.00. In short, don't get careless with an untreated Devonian well capable of producing 1,000 MCF/D of 5 percent helium gas. This kind of well could produce $1,000.00 to $2,000.00 worth of helium gas per day. What is the daily income from your average gas well?

Production And Pressure

The subject matter is best explained by Tables 1 and 3. Kerr-McGee's No. 4 currently is the best well in the field. It is difficult to top 3,249 B/D in the U.S.A. today. No. 4 probably would be capable of yielding 10,000 B/D if additional pump capacity were added.

Some pressure decline has taken place; a plot of pressure vs. time, or pressure vs. cumulative production quickly proves the decline. Pressure decline is becoming less severe and will continue to decline for some time. A gas cap is expected to start forming in the near future. Bubble point pressure of the Dineh bi Keyah oil is approximately 660 psia.

It is probable that expansion, solution gas, and gravity each contribute part of the energy needed to produce oil from this field. Help from water is not expected although some water is present in Kerr-McGee No. 7.

Economics

Big wells, no production restrictions, shallow, easy drilling, quality crude oil, a firm market, and nearness to a half-empty major pipeline make Dineh bi Keyah one of the most attractive economic ventures in the U.S.A. today.

Dineh bi Keyah oil sells for $2.80 per barrel at Four Corners. Kerr-McGee recently completely a 33-mile, 8 inch, Dineh bi Keyah-to-Four Corners pipeline having a gravity flow capability of 20,000 B/D. If pumps are added the capacity could be doubled. The pipeline charge for transporting Dineh bi Keyah crude oil to the Four Corners probably will be 25¢ per barrel. Royalty will amount to about 43¢ per barrel and another 8¢ will go to the State of Arizona. And estimated operator-value of $2.00 per barrel means the average Dineh bi Keyah well is producing approximately $3,200.00 per day.

TABLE 3
Dineh bi Keyah Performance History (1)

Operator	Well No.	Date	Shut-In Pressure (psia)	Source of Pressure Measurement	Shut-In Time (hours)	Cumulative Total Reservoir Oil Production[3] (Stock Tank Barrels)
Kerr-McGee	1	2-4-67	729	Liquid Level	—	539
Corporation		7-6-67	517	Sensor	64	811,308
	2	3-10-67	665	Bomb	—	17,099
	3X	4-7-67	612	Sensor	—	92,658
		7-6-67	484	Sensor	64	811,308
	4	7-17-67	470	Bomb	—	889,621
	6	6-30-67	546	Liquid Level	—	772,645
	7	4-18-67	594	Bomb	—	151,457
		7-10-67	462	Sensor	96	832,985
	9	5-4-67	597	Bomb	—	262,901
		7-9-67	439	Sensor	72	827,769
	14	7-8-67	551	Bomb	—	822,049
	15	7-14-67	471	Bomb	—	865,024
Humble Oil and Refining. Co	1-138	5-10-67	732	—	—	322,951

1 This information compiled by H. J. Gruy and Associates and used by Kerr-McGee at Arizona Oil and Gas Conservation Commission hearing on 8/16/67.
2 Measured pressure converted to 4500′ datum.
3 Relate to date column.

CONCLUSIONS

No detailed conclusions concerning The People, their government, or this land will be made. Work, education and time will solve most of their problems. Income from mineral reserves will continue for a long time to furnish the fuel needed to keep the wheels of progress turning.

The Dineh bi Keyah story is just starting. Due to the unique nature of the discovery and the inability at this time to predict the presence of subsurface intrusives, it seems reasonable to assume that many wells will be drilled. Drilling contractors should enjoy the prospects.

The limits of Dineh bi Keyah will continue to expand, probably to the west and southwest, but other syenite production will be found also on this vast structure. The next remote drilling action probably will take place on the Arizona–New Mexico boundary and in New Mexico. Close-to-production drilling in and around Dineh bi Keyah obviously will continue.

A superb economic and operations environment makes Dineh bi Keyah one of the most attractive current oil ventures in the U.S.A.

The Navajo Tribe and particularly the Navajo Minerals Department enjoys the action. It's been a long dry season in Arizona.