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Oil and gas potentialities of northern Arizona

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OIL AND GAS POTENTIALITIES OF NORTHERN ARIZONA

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Geological Consultants
Durango, Colorado

Early exploratory wells drilled in Arizona prior to 1948 recorded limited, and in many cases, misleading data. The later wildcatting phase, starting about 1948, has produced much reliable data, but these exploratory tests are thinly scattered over a very large area. Present exploration in Arizona is on a regional basis with local areas of interest being detailed.

This paper, with the accompanying exhibits, is intended to point out some of the stratigraphic and structural problems. Data for this study are based upon an evaluation of lithological, electrical and radioactivity logs, and surface studies on a regional basis, although writers have had occasion to detail many local areas throughout northern Arizona.

Northern Arizona contains two distinct geological basins, namely, the Paradox basin on the north and the Black Mesa basin on the south. Only relatively small portion of the Paradox basin extends into Arizona (Exhibits I, II & III), where to date all oil and gas production is confined.

The widely scattered tests in northern Arizona outside of the Paradox basin have not developed commercial production, but good oil and gas shows indicate commercial potentials under proper conditions.

STRUCTURE

The Black Mesa is a structural depression which lies near the center of the Navajo Reservation. It is bounded on the east by the Defiance uplift, on the west by the Kaibab Plateau, on the north by the Monument upwarp, and on the south by the Mogollon Rim. The various divisions of the Black Mesa basin proper, such as the Mogollon slope, Tyende saddle, etc., will not be used in this report except in a limited sense on the cross-sections. (Exhibits II & III).

There are several lines of folding in the Black Mesa basin. The major folding, of Paleozoic age, has a northwest alignment. Secondary alignments have a northeast trend, a north-south trend and a still weaker trend which parallels the edge of the basin. These secondary alignments are post-Paleozoic in age. The Paleozoic trends are considered the most favorable for commercial production. Test wells drilled on the younger structures have recorded numerous oil and gas shows, none of which were commercial. These shows are probably the result of leakage of the more volatile hydrocarbons from the older structures.

The Defiance uplift was a positive area during Pennsylvanian and probably into lower Permian time, while the

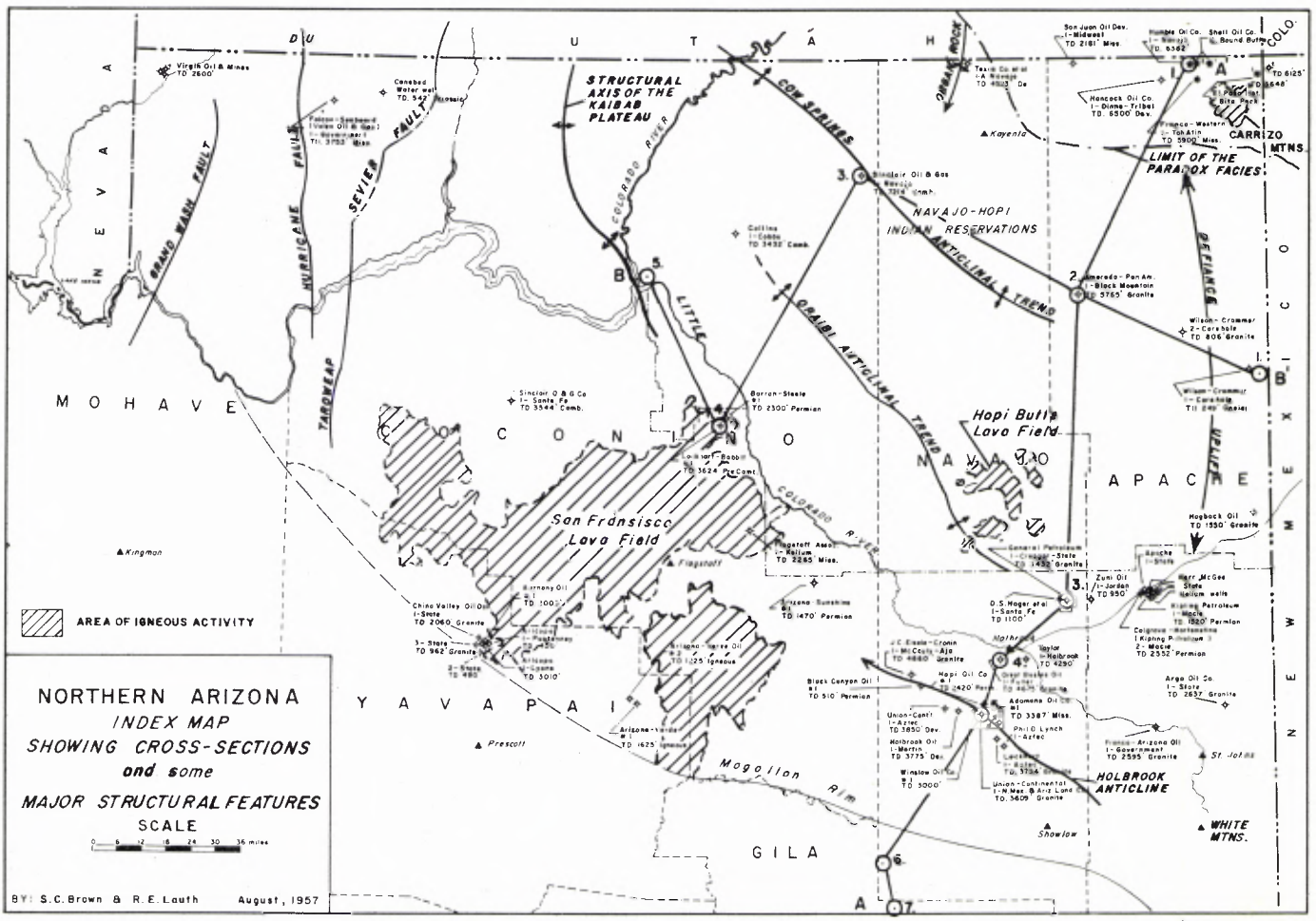


EXHIBIT I.

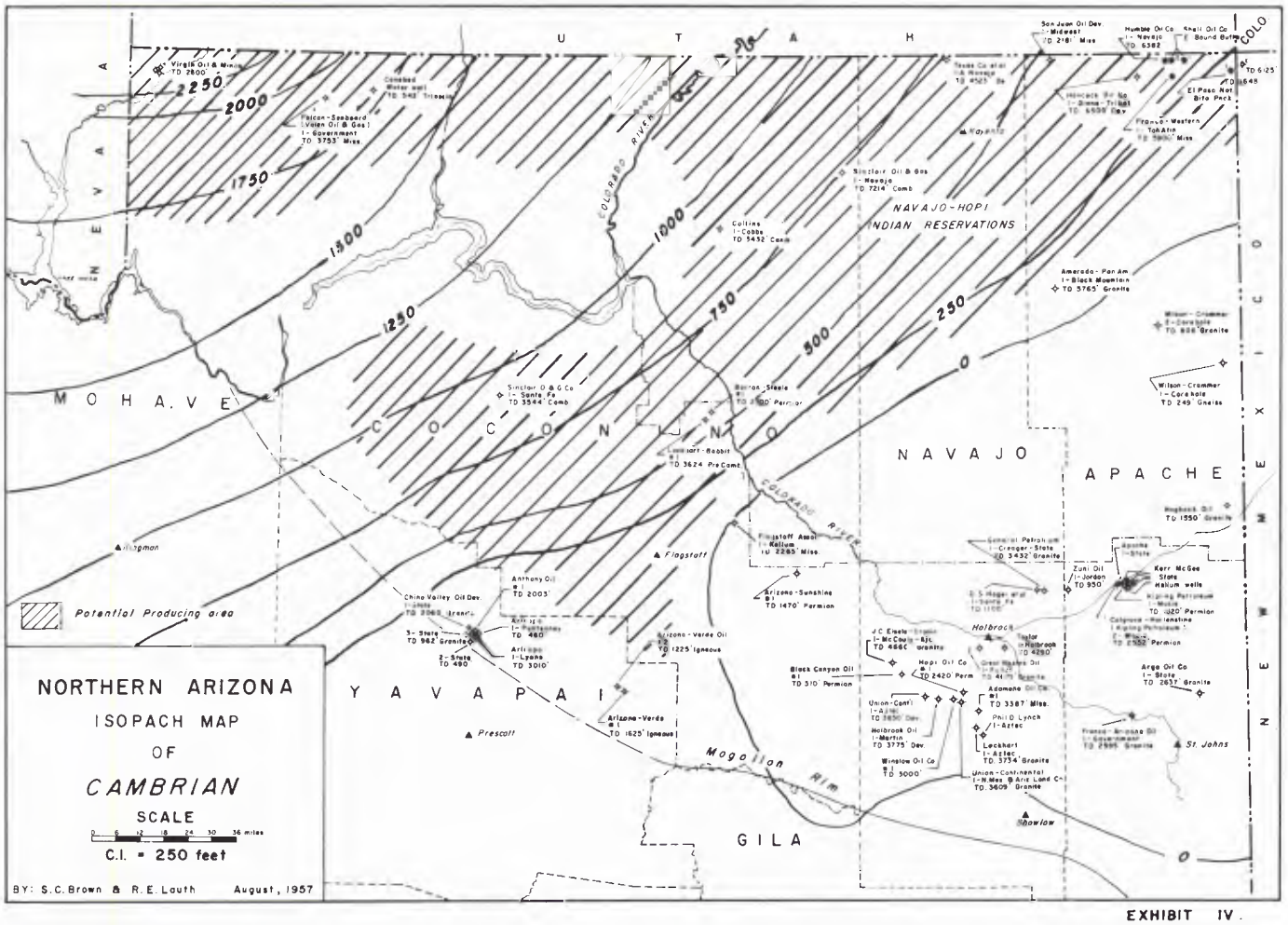


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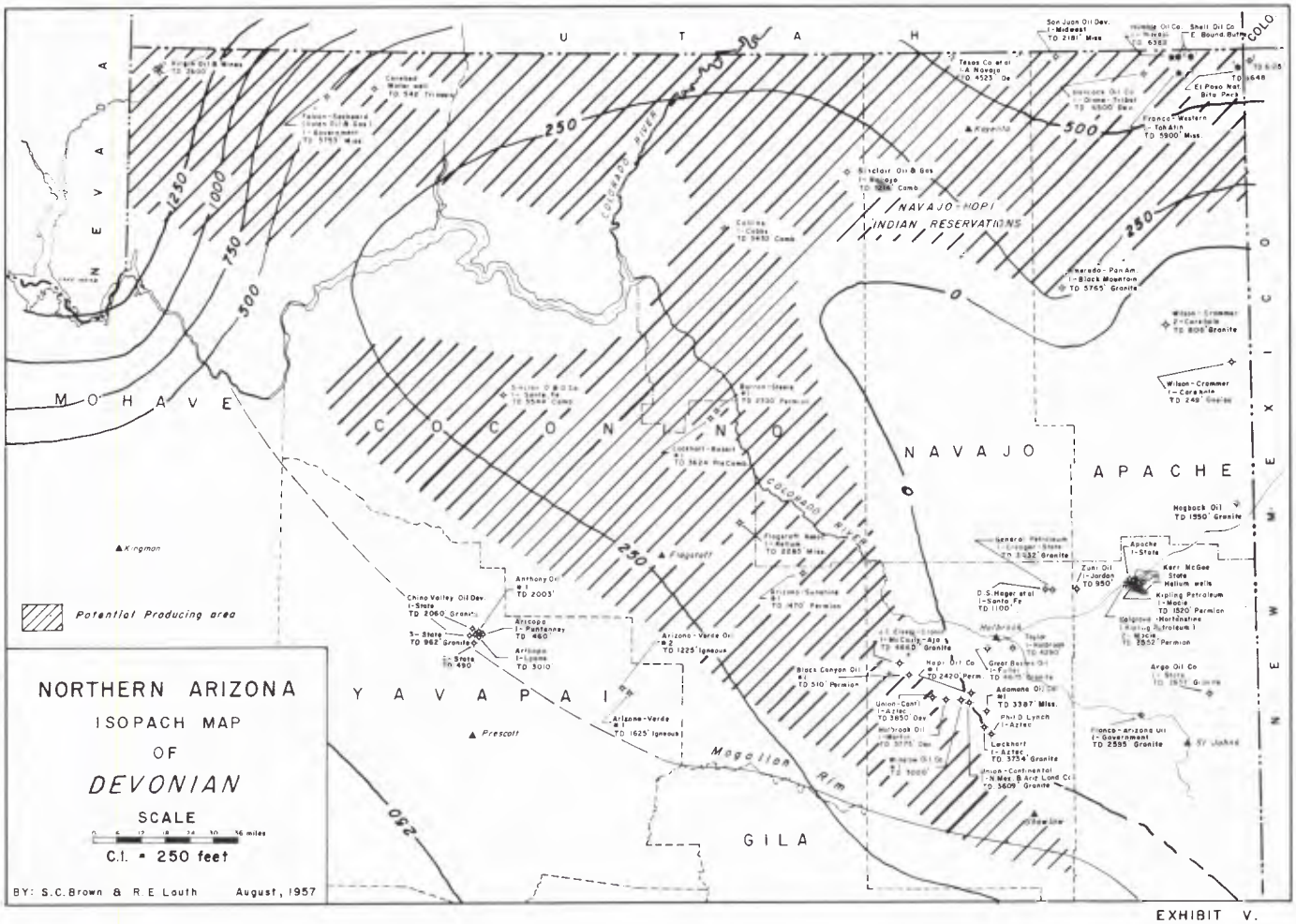


EXHIBIT V.

other uplifts surrounding the Black Mesa basin are much younger (Laramide). All periods of uplift have influenced present-day structural trends.

Most of northern Arizona is relatively free of major faults except in the vicinity of the Colorado River and in the "Strip" country in northwestern Arizona between the Colorado River and the Utah state line. The few small faults present in the Black Mesa basin proper would appear to have little or no effect upon the migration or accumulation of oil and gas. More detailed geological work may indicate fault-trap possibilities, but these are expected to be limited in size and number.

STRATIGRAPHY

Each major period of deposition during the Paleozoic Era, with the exception of the Permian System, shows a general thickening from east toward the west and northwest. Stratigraphic traps formed as pinch-out zones on anticlinal trends, and localized areas showing good permeability and porosity, are possible in various formations. Pinch-out or overlap type of stratigraphic traps are possible throughout most of the Black Mesa basin area. The best possibilities for this type of trap are expected along the west flank of the Defiance uplift and on the flanks of a buried granite ridge in the vicinty of Holbrook, Arizona.

The two cross-sections (Exhibits II & III) show the generalized thickness of the formations, projected correlations, outcrops, topography and the general structural features.

Some stratigraphic units are not favorable petroleum prospects, therefore, only those systems which are considered to have oil and gas potential are discussed.

CAMBRIAN

The Cambrian sediments range in thickness from zero feet on the flanks of the Defiance uplift to about 2500 feet in the extreme northwestern corner of Arizona (Exhibit IV). These rocks transgress time lines and become progressively younger to the east. Small shows of oil have been reported in wells drilled in the northwestern part of the State while no shows have been reported near the center of the Black Mesa basin. Because of the thick section of dolomites, limestones, shales and sandstones present in the northwestern part of th estate. the Cambrian rocks ae considered an objective in that area.

The Lynch formation previously classified as upper Cambrian may be partly of Ordovician age. An ostracod found in Cambrian lithology at Boundary Butte on the Arizona-Utah state line has been identified as probable Ordovician.

DEVONIAN

The Devonian section ranges in thickness from zero feet on the flanks of the Defiance uplift to about 1500 feet in the northwest corner of the state (Exhibit V). The section consists of medium to dark gray limestones and dolomites, green, red and gray shales and minor sandstone beds. Outcrops of limestone and dolomite along the Mogollon Rim from the Salt River Canyon south of Showlow, to Chino valley north of Prescott, give a petroliferous odor on fresh fracture. Oil shows in the Devonian were recorded in wells drilled on the Boundary Butte anticline immediately north of the Arizona-Utah state line. Most of the wells drilled in the Black Mesa basin, many of which were drilled on the younger structural trends, recorded no shows of oil or gas in the Devonian.

The Devonian rocks are considered a good objective horizon for oil and gas in northern Arizona where the proper structural and stratigraphic conditions exsist (Exhibit V).

MISSISSIPPIAN

The Mississippian section ranges in thickness from zero feet along the flanks of the Defiance uplift to about 1600 feet in the northwest corner of the state (Exhibit VI). These rocks consist of white to buff, chalky to crystalline limestone with chert nodules; thin beds of gray to tan, crystalline dolomite, and gray to red-brown shale. Good to excellent porosity has been recorded almost everywhere in the Paradox basin and in many parts of the Black Mesa basin.

Some low B. T. U. gas has been found in the Mississippian at East Boundary Butte. Oil, helium and carbon dioxide gas has been found in this section in southeastern Utah and in northwestern New Mexico. Because of the good porosity and numerous oil and gas shows, the Mississippian formations are considered good objectives.

PENNSYLVANIAN

The Hermosa formation, which includes the Paradox member, ranges in thickness from zero feet on the flanks of the Defiance uplift to about 1800 feet in the northeastern corner of the state (Exhibit VII). At the extreme northwestern part of Arizona, the Hermosa reaches a maximum thickness of about 1600 feet.

The Paradox member of the Hermosa formation is the only commercial oil and gas producing horizon in the state. The Paadox facies extends only a short distance into Arizona from the north (see Exhibits I & II). The Paradox member consists of black shales; medium to dark gray, dense to crystalline limestones and dolomites; white to light gray anhydrite and salt.

The upper and lower Hermosa are predominantly gray, dense to crystalline limestones with minor dolomite, sandstone and shale beds. The upper Hermosa has had many good shows and is considered an objctive. The "B" and "C" zones of the Paradox (Exhibit X), which are productive at Aneth, Boundary Butte and other fields, are classified by the writers as part of the Paradox facies. Many geologists put the "B" zone in the upper Hermosa, however, this separates the zones in the middle of a facies.

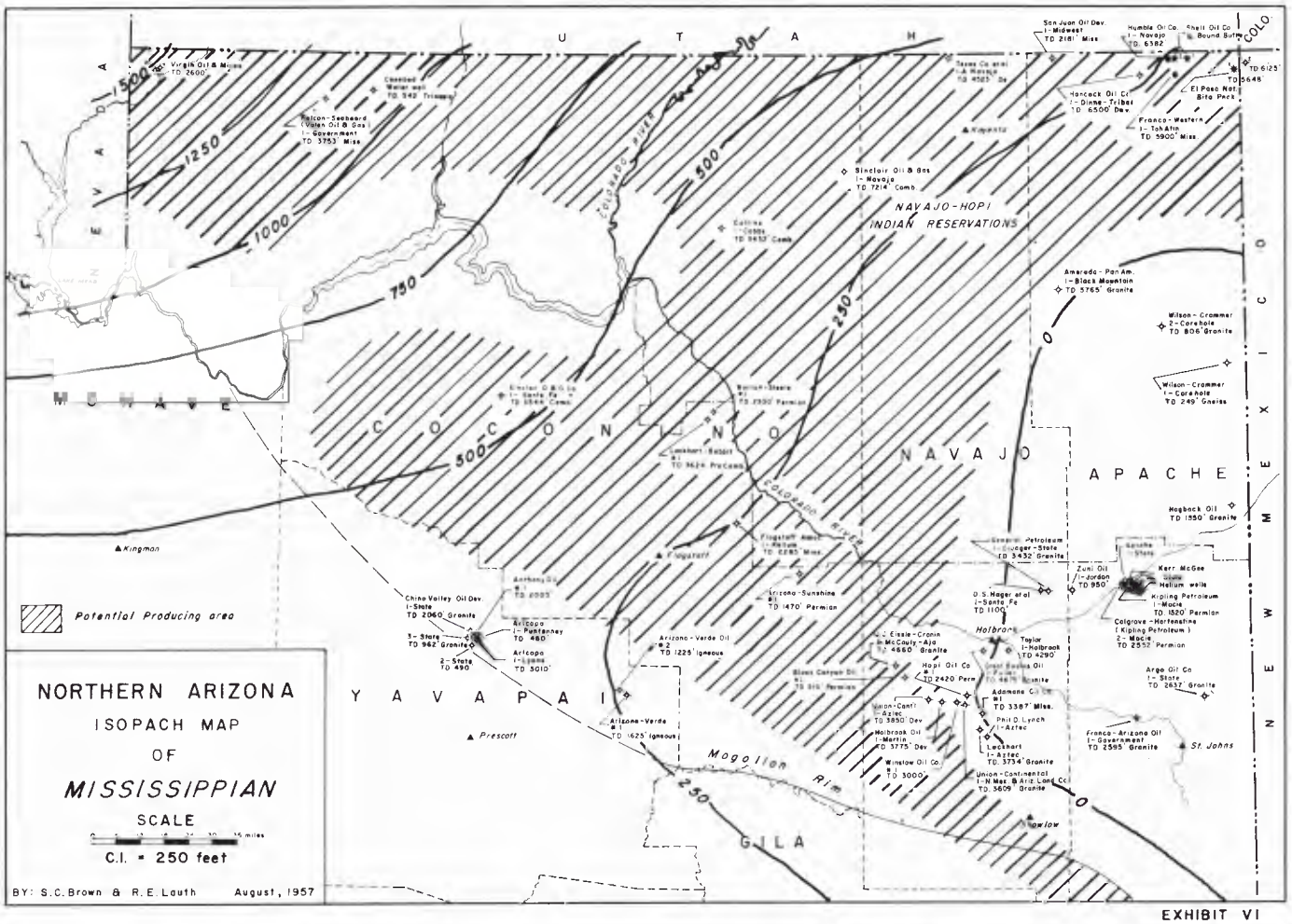
Many good shows have been recorded in wells drilled on the Holbrook Anticline along the southern edge of the Black Mesa basin. The isopach map (Exhibit VII) shows a rather rapid thickening of the Hermosa southwest of Holbrook. The Naco fomation from the south may interfinger with the Hermosa giving rise to possible facies-change type of reservoirs in that area.

The Pennsylvanian formations are considered very good objectives for commercial oil and gas production (Exhibit VII).

PERMIAN

The Permian rocks range in thickness from less than 250 feet on the Defiance uplift to more than 3500 feet in the Holbrook area (see Exhibit VIII). In the southern part of the Black Mesa basin, the Permian strata include in descending order: the Kaibab, Coconino and Supai formations, while in the northern part of the Basin, the Permian is represented by the Cutler formation or group.

The Kaibab is predominantly a buff, gray to bluish-gray, cherty and fossiliferous, crystalline limestone. Minor sandstones and shale beds are present throughout the section. The Kaibab ranges fom zero feet in the Holbrook area to about 800 feet in thickness in the Kaibab Plateau area in the nothwestern part of the state. Since the Kaibab crops out or is near the surface throughout its depositional limits, it is considered a very limited objective for oil and gas. Oil is present in geodes found in a Kaibab outcrop on the east flank of the San Rafael swell in Utah.


NORTHERN ARIZONA
ISOPACH MAP
OF
MISSISSIPPIAN
SCALE
C.I. = 250 feet
BY: S.C. Brown & R.E. Lauth August, 1957
Potential Producing area
U T A H
COLO
NAVAJO-HOPI
INDIAN RESERVATIONS
M O H A V E
C O C O N I N O
N A V A J O
A P A C H E
Y A V A P A I
G I L A
Kingman
Flagstaff
Prescott
Holbrook
St. Johns
Show Low
Mogollon Rim
Colorado River
Limit of Paradox facies
Virgin Oil & Mines TD 2600'
Canebed Water well TD 542' Triassic
Falcon-Seaboard (Valen Oil & Gas) 1- Government TD 3753' Miss
San Juan Oil Dev. 1- Midwest TD 2181' Miss
Humble Oil Co. 1- Navajo TD 6582'
Shell Oil Co. Bound Butte TD 6125'
El Paso Nat. Gas Bita Peck TD 6648'
Hancock Oil Co. 2- Dinne-Tribal TD 6500' Dev.
Franco-Western 1- Toh Atin TD 5900' Miss
Sinclair Oil & Gas 1- Navajo TD 7214' Comb
Collins 1- Cobbs TD 3432' Comb
Amerada-Pan Am. 1- Black Mountain TD 5765' Granite
Wilson-Crammer 2- Corehole TD 806' Granite
Wilson-Crammer 1- Corehole TD 249' Gneiss
Hogback Oil TD 1550' Granite
Zuni Oil 1- Jordon TD 950'
Kerr McGee State Helium wells
Kipling Petroleum 1- Macie TD 1520' Permian
Colgrove-Hortenshine (Kipling Petroleum) 2- Macie TD 2552' Permian
Argo Oil Co 1- State TD 2637' Granite
Franco-Arizona Oil 1- Government TD 2595' Granite
Sinclair O & G Co 1- Santa Fe TD 3544' Comb
Barron-Steele TD 2300' Permian
Lockhart-Babbit TD 3624' Pre Camb
Flagstaff Assoc. 1- Kellum TD 3265' Miss
Anthony Oil TD 2003'
Chino Valley Oil Dev 1- State TD 2060' Granite
Aricopa 1- Puntenney TD 480'
3- State TD 962' Granite
Aricopa 1- Lyons TD 3010'
2- State TD 490'
Arizona-Verde TD 1225' Igneous
Arizona-Sunshine TD 1470' Permian
D.S. Hager et al 1- Santa Fe TD 1100'
J.C. Eisele-Cronin 1- McCoy-Ajo TD 4680' Granite
Taylor 1- Holbrook TD 4290'
Hopi Oil Co TD 2420' Perm
Great Basins Oil 1- Fuller TD 4675' Granite
Adamana Oil et al TD 3387' Miss.
Phil D. Lynch 1- Aztec
Union-Cont'l-Aztec TD 3850' Dev
Holbrook Oil 1- Martin TD 3775' Dev
Lockhart 1- Aztec TD 3734' Granite
Winslow Oil Co TD 3000'
Union-Continental 1- N Mex & Ariz Land Co. TD 3609' Granite
Blues Canyon Oil TD 510' Permian
Arizona-Verde TD 1625' Igneous
EXHIBIT VI
NORTHERN ARIZONA
ISOPACH MAP
OF
PENNSYLVANIAN
SCALE
C.I. = 250 feet
BY: S.C. Brown & R.E. Lauth August, 1957
EXHIBIT VII

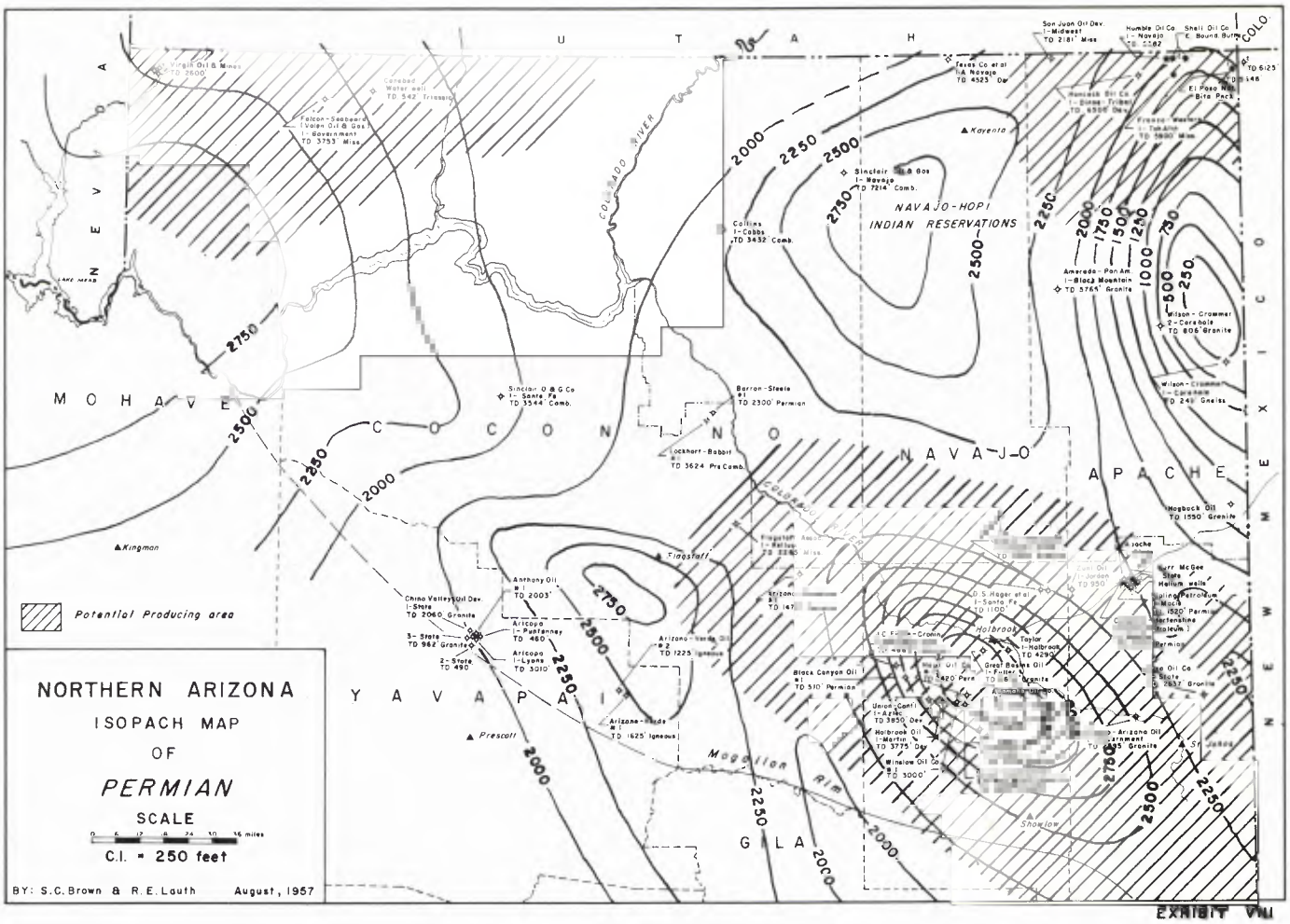


EXHIBIT VIII

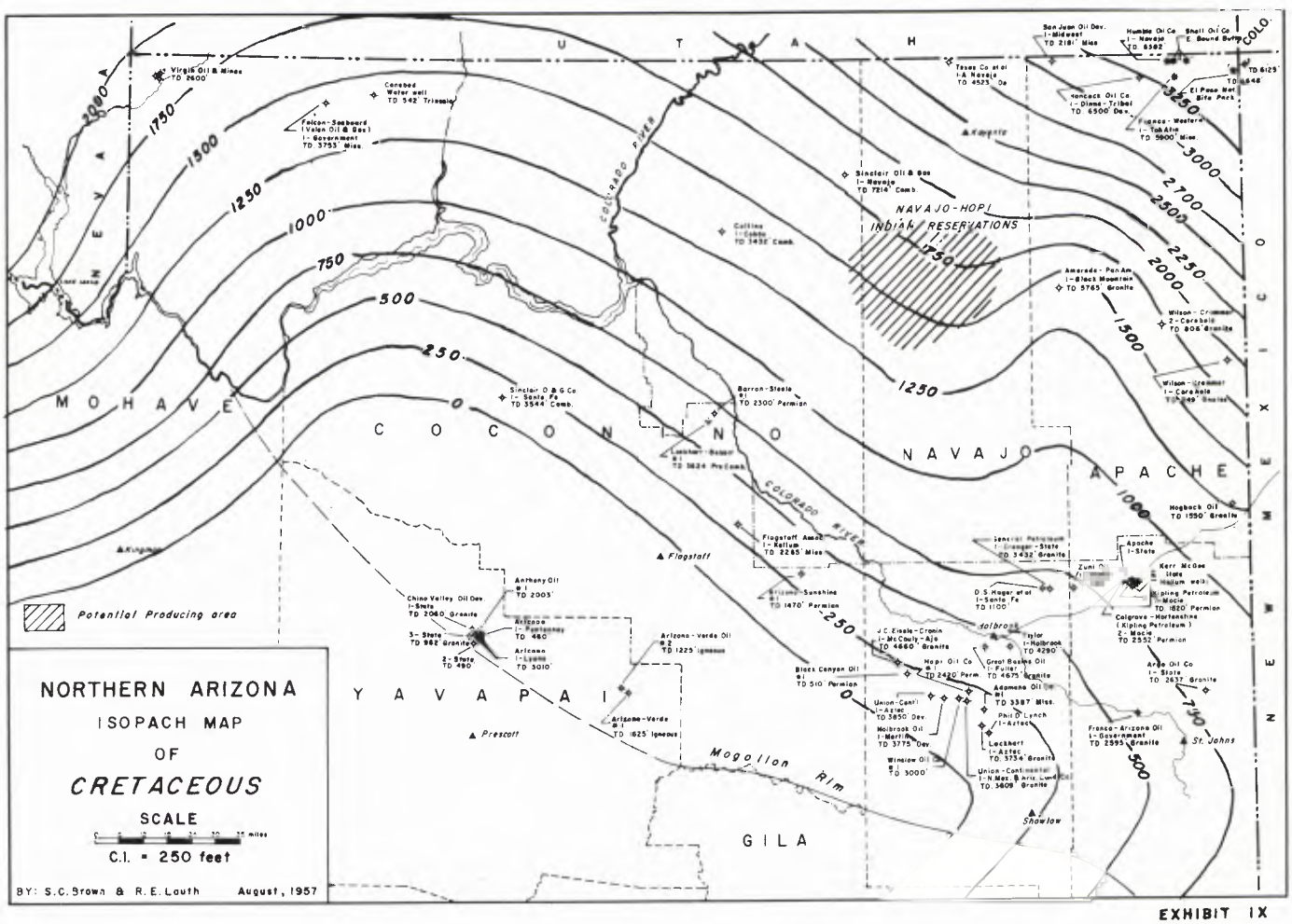
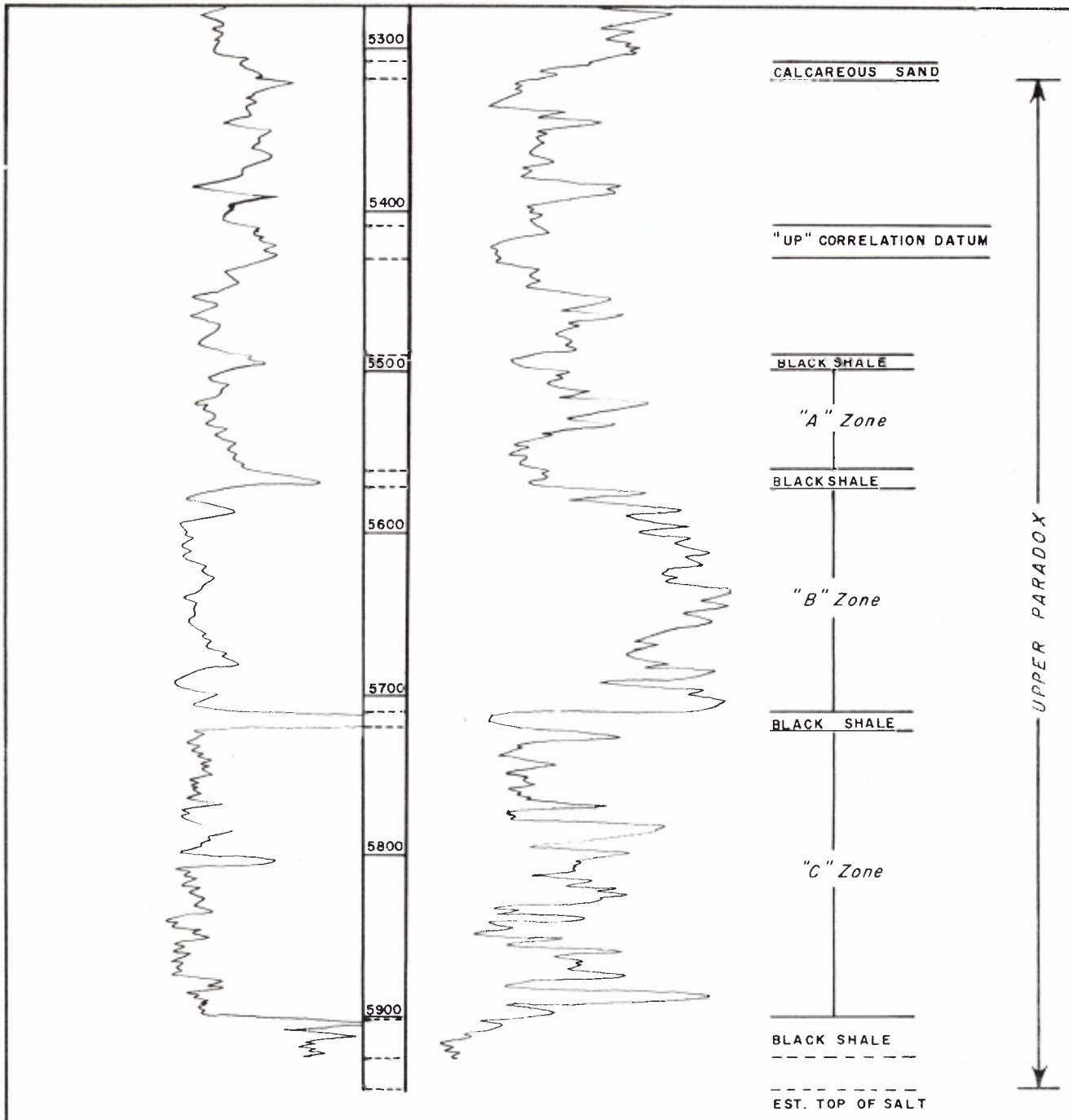


EXHIBIT IX



Gamma - Neutron Log

The Texas Company
Navajo Aneth C-1
Sec. 23 - 40S - 24E
San Juan County, Utah
Elev. 4922 DF

RADIOACTIVITY LOG PARADOX BASIN

showing the various zones of the Upper Paradox member of the Hermosa Formation

BY: S.C. Brown & R.E. Lauth

August, 1957

EXHIBIT X

The Coconino sandstone varies in thickness from about 80 feet to over 750 feet. It is a white to buff, highly cross-bedded, fine to medium-grained sandstone. Core analyses of the Coconino sandstone show 19 to 21 percent porosity in its upper part. Sample studies indicate excellent porosity throughout its entire section. Minor dead oil stain was noted in the General Petroleum well near Holbrook. Helium was found in the Coconino on the Pinta structure near Navajo, Arizona. Where the Coconino has proper cover, helium, low B. T. U. gas and limited oil reserves may be found.

The Supai formation ranges in thickness from less than 1500 feet to approximately 3000 feet in the Holbrook area. It consists predominantly of alternating red sandstones and shales, abundant salt locally and minor limestone beds. The most prominent limestone horizon is the Fort Apache member. The Fort Apache, which is nearly 200 feet thick at its type section near the Fort Apache Indian Agency south of Showlow, thins westward to zero feet at Sycamore Canyon southwest of Flagstaff. The northern limit is unknown due to lack of subsurface data.

Many wells along the Holbook Anticline recorded good shows in the Fort Apache horizon. The Lockhart No. 1 Aztec test might have made a small producer with proper treatment. The limestones and dolomites of the outcrop areas along the Mogollon Rim have a good petroliferous odor. Where the Fort Apache member attains a reasonable thickness, it is considered a good objective horizon for commercial oil and gas production.

The Colgrove No. 1 Hortenstein well on the Pinta structure reported a show of inflammable gas in sandstone at about 2530 feet. This show is about 1000 feet below the top of the Fort Apache member.

A thick section of salt is present in the Supai formation. The Colgrove well on the Pinta structure recorded approximately 1000 feet of salt. Geologic evidence suggests the evaporitic sequence in the Zuni embayment (St. John sag of Kelley) to be connected with the evaporitic Permian seas of west Texas and southeast New Mexico.

Continued uplift of the Defiance and the White Mountain positives retarded movement of waters in the westward extension of the Permian seas which resulted in relatively thick salt deposition in a small area.

Reefing conditions have not been observed in the limited number of wells drilled to date; however, reefs should be kept in mind as a possible reservoir for oil and gas along the edges of the salt basin.

Although the Supai has been assigned to the Permian period, the lower marine Supai may be partially Pennsylvanian in age.

The Permian section in the northern part of the Black Mesa basin is represented by the Cutler formation. The Cutler formation is composed of the following members from top to bottom: Hoskininni Tongue, De Chelly sandstone, Organ Rock Tongue, Cedar Mesa sandstone and the Halgaito Tongue. The Cutler sediments consists of red shales and red to white sandstones of continental origin.

Some geologists have elevated the Cutler formation to a group status and, although it has considerable merit this classification has not been fully accepted by everyone in the profession

Although there is no commercial production from the Cutler to date in Arizona, immediately north of the Arizona -Utah state line at Boundary Butte, oil is produced from the De Chelly sandstone. Certain other structures in northern Arizona are expected to be productive from this horizon, which has previously been assigned to the Coconino.

CRETACEOUS

The Cretaceous section includes the Dakota, Mancos and Mesaverde formations. The Dakota sandstone and the Mancos shale crop out around the margin of Black Mesa, thus limiting their potential producing area to the central part of the Mesa (see Exhibit IX). The Mesaverde Group caps the higher ridges of Black Mesa and is dissected by cross-canyons, which eliminates it as an objective for petroleum.

Water wells have been drilled near the outcrop belt of the Dakota sandstone indicating the possibility, but not the probability, that the Dakota has been flushed by fesh water throughout the basin area. It is quite possible that structural traps do exsist in the central part of the basin favorable for the accumulation of oil and gas in commercial quantities.

The Mancos shales have some sandy zones along their outcrop area but none of large magnitude. The Mancos shales are excellent source beds and the sandstone beds generally carry oil and gas in varying amounts. If the sand lenses are well developed as to thickness and areal extent, commercial production can be expected.

CONCLUSIONS

The largest oil and gas wells have been and shall probably continue to be found along the southern edge of the Paradox basin in its foreland facies zone (see Exhibit VII). The Pennsylvanian formations have good potentials along the southern edge of the Black Mesa basin. Based upon shows in wells, petroliferous indications along the outcrop areas and the regional thickening of the Mississippian, Devonian and Cambrian, potential producing reservoirs may be developed in rocks of these systems.

The Fort Apache member of the Supai, the De Chelly member of the Cutler, and the Coconino sandstone have excellent potentials for shallow production.

A furthur outlining of the potential areas for production is shown on the isopach maps (Exhibits IV to IX). The maps show the approximate thickness of the various systems as well as possible producing areas. The potential aeas were outlined, disregarding dry holes within their limits. The dry holes do not condemn large areas, for various reasons, such as being off structure, or on young trends. Favorable anticlinal structure and stratigraphic traps are expected within portions of the shaded potential areas.

Approximately 4,000,000 acres of fee land in the State of Arizona is held by large Land Holding companies. This constitutes about one-third of all of the fee land in the State, which totals slightly over 12,000,000 acres. A major portion of the above acreage is held by the Aztec Land and Cattle Company, the New Mexico-Arizona Land Company and the Santa Fe Railroad. These companies have leasing terms which are considered unreasonable by the authors, particularly in a rank wildcat area. Their terms have hindered wildcat exploration and drilling in northern Arizona in past years.

Negotiations are presently (June, 1958) being made by a major company to drill four wells in Navajo and Coconino counties in an area south of, and parallel to, the Holbrook anticline.

Since this report was originally written (1957) several wells have been drilled in the Arizona portion of the Paradox basin. These wells did not materially change our interpretations so they have not been added to the base maps.

The Black Mesa basin has many possibilities for commercial oil and gas production. More detailed surface and subsurface studies are expected to outline local areas that will prove commercially productive.

The writers are indebted to Mr. A. Vitali, Jr., Consulting Geologist, for his valuable suggestions and criticism, and to many individuals and companies who furnished much of the data used herein.

Data were freely used from the references cited; however, inasmuch as the writers exercised their own judgment and interpretation in controversial cases, they accept full responsibility for the final form of the material.

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HELIUM IN SOUTHERN BLACK MESA BASIN

By EDWARD C. BEAUMONT
Consulting Geologist
Albuquerque, New Mexico

Helium, the wonder gas with a rapidly growing list of industrial uses, is known to occur in this region. The first recorded report of helium-bearing gas was from the Great Basins Oil Company's Taylor-Fuller No. 1 well, a non-productive oil test drilled a few miles south of Holbrook in 1927. The amount of helium is reported by Anderson and Hinson (1951) to be only a little more than one per cent with an open-flow potential of 100 MCFPD. In 1950 the Macie No. 1 test was drilled to the southwest of Navajo by the Kipling Petroleum Company. This test encountered some helium-bearing noninflammable gas in the Chinle formation, and a relatively large flow in the uppermost part of the Coconino sandstone at a depth of 1032 feet (Heindl, 1952). Heindl also reports that the gas, principally nitrogen (89%), contained about 8% helium and about one per cent each of carbon dioxide and hydrocarbons. The eight per cent helium content ranks favorably with known occurrences of helium in the world. Natural gasses bearing about two per cent helium are processed in Kansas and Texas. The high nitrogen content is characteristic of relatively high helium-bearing natural gasses. This well is reported to havehad a 24,000 MCFPD potential four weeks after completion with a casing head pressure of 98 psi. It is said to have flowed unrestricted for an eight-month period.

The Macie Nos. 1 and 2 wells were acquired by Kerr-McGee Oil Industries who in the past several years have drilled five more wells in the same area. Detailed information regarding these later wells is not available although it is known that the Coconino sandstone was encountered from between 800 and 1100 feet. To date the refining and marketing of helium is completely controlled by the federal government. There are signs, however, that the U. S. Bureau of Mines, the agency within which this authority rests, may relinquish all or part of this operation to private industry. Facilities for the refining of helium are not available in this region, but presumably adequate reserves will eventually lead to the building of a helium plant. The Bureau of Mines officials foresee the need for at least a dozen new plants in the near future to handle the industrial demands for helium.

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