AREAS RECOMMENDED FOR TIGHT FORMATIONS IN CLAY AND BRAXTON COUNTIES, WEST VIRGINIA

West Virginia

Tight Formation Committee's Report

January 1983

(Tight Formation Committee, 1983)

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INTRODUCTION

This report of the West Virginia Tight Formation Committee covers Clay and Braxton Counties, West Virginia. These two counties are situated in the geographical center of the State. The total area of both is about 867 square miles (Clay County, 347 square miles and Braxton County, 520 square miles).

Both counties are located in the physiographic province known as the Appalachian Plateau which is characterized structurally by broad anticlinal and synclinal folds. Both counties lie within a gently northwest-dipping regional monocline upon which a series of low-amplitude, predominantly northeast-striking folds are superimposed. Exposed beds in both counties are of the Pennsylvanian System, extending from the uppermost Pottsville Group up to Dunkard (Permian?) beds exposed in the northwestern part of Braxton County.

Gas-producing intervals, all of which are in the Mississippian and Devonian Systems, recommended by the Committee as qualifying to be designated as tight are described in the first section of this report. In the second section the various types of geological and engineering data used in making these recomendations are described. In the third section each recommended gas-producing interval is discussed in terms of map description and interpretation.

The Committee's recommendations are based on calculations of expected in situ permeabilities, natural production rates and oil production rates, as outlined in the Federal Energy Regulatory Commission's (FERC) Order No. 99 for tight-formation determination. The Committee also addresses the requirement of protecting fresh-water aquifers before setting forth their final recommendations in a concluding section.

The "Squaw" sandstone is of Early Mississippian age and of the Pocono Group (see Plates X and XI). The Pocono Group reflects a marine transgression with deposition being in near-shore shallow environments. The "Squaw" sandstone is found below the "Big Injun" sandstone, and is separated from it by a thin erosional shale. The "Squaw" sandstone may be completely removed by erosion and when present has only limited areal extent (see Plates X and XI).

5. "Weir" sandstone: The "Weir" sandstone (drillers' term) lies below the "Squaw" sandstone when present (see Plates X and XI). This sandstone lies near the middle of the Pocono Group (see Figure 2 and Table 2). The sandstone is greenish gray-to-white, medium-grained, well-sorted and argillaceous. The "Weir" sandstone ranges in thickness from 20 feet in northern Clay County to 100 feet in northern Braxton County. The sandstone, due to erosion, is not present in eastern Braxton County.

6. "Gantz" to "Gordon" sandstones: The "Gantz" to "Gordon" interval includes "Gantz", "Gantz A", "Fifty Foot", "Thirty Foot", Gordon Stray" and "Gordon" sandstones (drillers' terms; see Figure 2 and Table 2). These potentially-productive sandstones are Late Devonian in age (upper Hampshire Group) and were deposited in a delta-plain environment. Depositional environments range from shallow subaqueous to subareal. Delta-plain sediments of this interval are coarser and less shaley than the overlying near-shore marine, shallow transgressive sediments of the Pocono Group.

The "Gantz" sandstone is considered to mark the top of the Devonian section. This sandstone (including "Gantz A") and the Berea Sandstone, which, when present, marks the time of maximum regression, are often confused in drillers' reports. The "Gantz" sandstone is located 50 to 300 feet below the base of the Greenbrier in Braxton County (see Plates X and XI). In Clay County no gamma-ray logs of Devonian strata were available; however, drillers' logs

reveal that Upper Devonian sandstones are present in Braxton County, but generally absent in Clay County.

The "Fifty Foot" and "Thirty Foot" sandstones, when present, are found below the "Gantz" sandstone. Only the "Fifty Foot" sandstone is present in the area, in extreme eastern Braxton County (see Plate XI). Statewide these sandstones are extremely variable, both in areal extent and in thickness.

The "Gordon Stray" and "Gordon" sandstones range in color from light gray-to-grayish yellow and are fine-to-very-fine grained with conglomeratic zones. The "Gordon Stray" sandstone, when present, is located about 50 feet above the "Gordon" sandstone, which is located 300 to 400 feet below the base of the Greenbrier. The "Gordon Stray" and "Gordon" sandstones are found in northern Braxton County, but are best-developed in eastern Braxton County (see Plates X and XI). The "Gordon" sandstone thins westward in Braxton County, from 100 to 25 feet.

7. "Fourth" to "Bayard" sandstones: The "Fourth" to "Bayard" interval includes "Fourth", "Fourth A", "Fifth", "Lower Fifth", "Bayard" and "Lower Bayard" sandstones (drillers' terms; see Figure 2 and Table 2). These potentially-productive sandstones are Late Devonian in age and are of the lower Hampshire Group. These sandstones, like the "Gantz" to "Gordon" sandstones, were deposited in a delta-plain environment, but further seaward than those of the "Gantz" to "Gordon" sandstones.

The "Fourth" sandstone (including "Fourth A") ranges in color from white-to-grayish green and are very-fine-to-fine-grained with lenses of coarse-grained sandstone being present. The "Fourth" sandstone is present in northern Braxton County where its thickness does not exceed 20 feet (see Plates X and XI).

The "Fifth" sandstone (including "Lower Fifth") ranges in color from light gray-to-grayish yellow and is very-fine-to-fine-grained. The "Fifth"

sandstone is located 500 to 700 feet below the base of the Greenbrier, and is best-developed in northeastern Braxton County where it reaches a thickness of 30 feet (see Plate X).

The "Bayard" sandstone (including "Lower Bayard") is fine-grained and located 50 to 100 feet below the "Fifth" sandstone. The "Bayard" is the basal sandstone of the Hampshire Group.

8. "Elizabeth" to "Bradford" sandstones: The "Elizabeth" to "Bradford" interval includes "Elizabeth", "Warren", "Upper Speechley", "Speechley", "Balltown" and "Bradford" sandstones (drillers' terms; see Figure 2 and Table 2). These potentially-productive sandstones are Late Devonian in age (upper Chemung Group) and were deposited in a delta-front environment, further seaward and thus further from the source of sediments than those overlying sandstones of the delta-plain environment.

"Elizabeth", "Warren", "Upper Speechley", "Speechley", "Balltown", and "Bradford" sandstones are all present in Braxton County (see Plates X and XI). This interval is characterized by a higher percentage of shale and a lower percentage of sandstones and siltstones than the overlying "Fourth" to "Bayard" interval. These sandstones and siltstones are also generally thinner and more argillaceous than the "Fourth" to "Bayard" sandstones. Color of these sandstones is predominantly light gray. Also, sandstones and siltstones become less numerous downward in this interval as the percentage of shale increases.

9. "Riley" and "Benson" siltstones: "Riley" and "Benson" siltstones (drillers' terms; see Figure 2 and Table 2) are Late Devonian in age and are of the lower Chemung Group. These siltstones, like the "Elizabeth" to "Bradford" sandstones and siltstones, were deposited within a delta-front environment.

The "Riley" and "Benson" siltstones range from coarse silt to very-fine-grained sandstones. Color in the "Riley" and "Benson" siltstones ranges from

light gray to brown, where the brown coloration is due to high organic content. The "Benson" siltstone is present in Braxton County and is better-developed than the "Riley" siltstone (see Plates X and XI). The average thickness of the "Benson" in Braxton County is 20 feet.

(Tight Formation Committee, 1983)

GEOLOGICAL AND ENGINEERING DATA

Criteria and Method of Designating Tight-Formation Areas

Tight-formation areas in Clay and Braxton Counties were designated on the basis of expected in situ permeability and natural open flows versus depth. These criteria were investigated completely to the extent that available information would allow. In situ permeability, natural open flows, and oil production data were used to disqualify other areas.

Permeability Data

The Federal Energy Regulatory Commission's (FERC) guidelines for tight-formation designation as set out in 18 C.F.R. 271, Subpart G (as set out in order 99, issued by FERC August 15, 1981, Docket No. RM 79-76) states that the average permeability throughout the "pay" or gas-producing section of the recommended formation may not exceed 0.1 millidarcy (md). Cored wells were used to provide permeability information for this project. Due to limited availability of cores, wells with porosity data calculated from logs were used in addition to cored wells to determine whether the "pay sand" under consideration was below 0.1 md and thus a tight sand. The method employed was utilized in the Fayette and Raleigh Counties Tight Formation Report (January 1981), Mercer, McDowell, and Wyoming Counties Tight Formation Report (November 1981) and the Boone, Cabell, Kanawha, Lincoln, Logan, Mingo, Putnam, and Wayne Counties Tight Formation Report (March 1982).

The method of determining permeability for non-cored wells involves the relationship between measured core porosities and permeabilities from existing core data (see Core Location Map, Plate XII). Plotting core-derived permeability versus porosity through the pay section of the interval under consid-

eration determines what cut-off porosity is associated with a permeability of 0.1 md. Where cores do not exist, log-derived porosities below this cut-off porosity can be used to state that permeabilities are expected to be less than 0.1 md for these wells.

Natural Open Flows

Federal Energy Regulatory Commission (FERC) guidelines stipulate that non-stimulated, stabilized production rates, against atmospheric pressure, for formations under tight-formation consideration must not exceed the specified maximum-allowable natural open flow versus depth (see Table 1). Natural flow information when recorded in drillers' logs can be recorded for an individual gas-bearing formation or for comingled natural flows in multiple pay wells. Natural flows as recorded in drillers' logs are unstabilized against atmospheric pressure. The absence of stabilized natural open flow rates is due to the fact that, for gas flow to stabilize, it would be necessary to shut down the well for extended periods of time, a practice which is economically unfeasible. However, the natural flow as recorded in a drillers' report is higher than stabilized natural flows to the atmosphere would be.

Oil Production Rates

Federal Energy Regulatory Commission guidelines for tight-formation designation exclude all wells expected to produce, without stimulation, more than 5 barrels of oil per day.

Tight Formation Map Construction

Information contained on Clay and Braxton Counties computer-generated tight-formation maps (Plates I-IV) includes: location of producing wells

(single, multiple, and combination); dry holes, oil, and storage wells (undifferentiated); and dry penetrations. Due to a computer-programming change a second series of computer-generated maps was produced (Plates V-IX). These maps display locations of producing gas wells and dry holes. It should be noted that well symbols do differ between the first and second series of computer-generated maps. Core locations, nonqualifying wells, and geographic areas designated as not being tight specific to the stratigraphic interval mapped, have been added to all maps.

Tight-formation geographic areas of stratigraphic intervals mapped are expected to have an in situ permeability less than 0.1 md and/or natural flow rates which do not exceed criteria as established by the Federal Energy Regulatory Commission. Approximately 2500 drilling records were examined and the reported natural open flows were used to determine whether any geographic area of a stratigraphic interval mapped did not qualify as a tight formation. Where a significant number of non-qualifying wells, based on natural flows, permeability or oil production, are present in a clearly-defined gas field, this field has been excluded from tight-formation consideration. Boundaries of these nonqualifying fields were determined by the extent of productive wells and the presence of dry penetrations. In other areas where non-qualifying wells are isolated individually or are surrounded by dry penetrations, the area was not excluded from tight-formation consideration. It is shown in this report that there is a statistically significant difference in the percentage of nonqualifying wells in excluded-versus-recommended areas.

Also eliminated from tight-formation consideration for a given stratigraphic interval in Clay and Braxton Counties are existing oil fields where production rates of oil have exceeded 5 BOPD or may potentially exceed 5 BOPD.

"Weir" sandstone

Plate V shows all penetrations, producing wells and nonqualifying wells in the "Weir" sandstone. Tight-formation designation was based on natural open flows.

In those areas recommended for tight-formation consideration (see Table 5) of 413 total penetrations, only 1 (or 0.2%) exceeded natural open flow versus depth guidelines.

The West Virginia Tight Formation Committee recommends that the "Weir" sandstone (see Plate V) be designated as tight.

"Gantz" to "Gordon" sandstones

Plate VI shows all penetrations, producing wells, and nonqualifying wells in the "Gantz" to "Gordon" interval. Tight-formation designation was based on natural open flows.

In those areas recommended for tight-formation consideration (see Table 5), of 336 total penetrations, only 1 (or 0.3%) exceeded natural open flow versus depth guidelines.

The West Virginia Tight Formation Committee recommends that all sandstones in the "Gantz" to "Gordon" interval (see Plate V and Table 2) be designated as tight.

"Fourth" to "Bayard" sandstones

Plate VII shows all penetrations, producing wells and nonqualifying wells in the "Fourth" to "Bayard" interval. Tight-formation designation was based on natural open flows.

In these areas recommended for tight-formation consideration (see Table 6), of 162 total penetrations, only 1 (or 0.6%) exceeded natural open flow versus depth guidelines.

The West Virginia Tight Formation Committee recommends that all sandstones in the "Fourth" to "Bayard" interval (see Plate VII and Table 2) be designated as tight.

"Elizabeth" to "Bradford" sandstones

Plate VIII shows all penetrations, producing wells and nonqualifying wells in the "Elizabeth" to "Bradford" interval. Tight-formation designation was based on natural open flows.

In these areas recommended for tight-formation consideration (see Table 6), of 147 total penetrations, only 1 (or 0.7%) exceeded natural open flow versus depth guidelines.

The West Virginia Tight Formation Committee recommends that all sandstones in the "Elizabeth" to "Bradford" interval (see Plate VIII and Table 2) be designated as tight.

"Riley" and "Benson" siltstones

Plate IX shows all penetrations, producing wells and nonqualifying wells in the "Riley" and "Benson" siltstones. Tight-formation designation was based on in situ permeability and natural open flow information.

One core was available for analysis (Braxton 1121; see Plates IX and XII). Permeability values, all from this "Benson" core, were all below 0.1 md (see Figure 33).

In those areas recommended for tight-formation consideration (see Table 7), of 108 total penetrations, only 2 (or 1.9%) exceeded natural open flow versus depth guidelines.

The West Virginia Tight Formation Committee recommends that the "Riley" and "Benson" siltstones (see Plate IX) be designated as tight.

(Tight Formation Committee, 1983)

PROTECTION OF FRESH WATER

Existing State and Federal Regulations will assure that development of the gas-producing "sands" studied in this report will not adversely affect any fresh-water aquifers that are, or are expected to be, used as a domestic or agricultural water supply. In West Virginia, the Oil and Gas Division of the State Department of Mines has the statutory responsibility for protecting surface and subsurface water from oil and gas production-associated activities. West Virginia Administrative Regulations (1979 Edition) Chapter 22-4, Section 15.01, 15.02, and 15.03 state as follows:

> 15. Regulations Related to Code 22-4-5, 22-4-6, 22-4-7, 22-4-8, and 22-4-8a.
>
> 15.01 Casing Not Exclusive. In addition to the casing required by Code 22-4-5, 22-4-6, 22-4-7, 22-4-8, and 22-4-8a, there shall be used in each well such material and equipment and there shall be employed such additional procedures as are necessary for the purpose of separating high pressure zones from low pressure zones, the producing horizons, the water-bearing strata, and mineable coal zones for the life of the well.
>
> 15.02 Multiple Casing Through Coal Seams (a) The coal protection string of casing required by Code 22-4-5 through 22-4-8 to be installed through the workable coal seam or seams shall be in addition to the production string of casing.
>
> (b) The coal protection string of casing required by Code 22-4-5 shall have cement circulated in the annular space outside said casing. The volume of cement needed shall be calculated by using approved engineering methods to assure the return of the cement to the surface. In the event cement does not return to the surface, every reasonable attempt will be made to fill the annular space by introducing cement from the surface.
>
> 15.03 Fresh Water Casing. The fresh water protective string of casing required by Code 22-4-8a shall extend 30 feet below the deepest fresh water horizon (being the deepest horizon which will replenish itself and from which fresh water or usable water for household, domestic, industrial, agricultural, or public use, may be economically or feasibly recovered), and shall have cement circulated in the annular space outside said casing. The

> volume of cement needed shall be calculated using approved engineering methods to assure the return of the cement to the surface. In the event cement does not return to the surface, every reasonable attempt will be made to fill the annular space by introducing cement from the surface. If the coal protection string of casing is cemented to the surface in accordance with prescribed procedure, this may also be considered a fresh water string for water strata above the coal.

The Oil and Gas Division is required by statute to enforce proper casing and plugging practices which will protect subsurface fresh-water aquifers. Lesiglation also allows the West Virginia Oil and Gas Conservation Commission to adopt and enforce rules and orders which relate to the prevention of pollution in regard to drilling, producing and operating deep gas wells, and oil wells in secondary recovery projects.

(Tight Formation Committee, 1983)

CONCLUSIONS

The Tight Formation Committee of West Virginia hereby recommends that those areas in Clay and Braxton Counties, not otherwise excluded on Plates I through X, meet those guidelines as set out in 18 C.F.R. 271, Subpart G (as set out in order 99, issued by FERC August 15, 1981, Docket No. RM-79-76), as it relates to Section 107(b) of the Natural Gas Policy Act of 1978.

The recommended "sandstones" are known by drillers' terminology (see Table 2) as the "Maxon" ("Maxton"), "Upper Maxon" ("Upper Maxton"), "Lower Maxon" ("Lower Maxton"), "Second Maxon" ("Second Maxton"), "Third Maxon" ("Third Maxton"), "Little Lime", "Blue Monday", "Big Lime", "Keener", "Big Injun", "Squaw", "Weir", "Gantz", "Gantz A", "Fifty Foot", "Thirty Foot", "Gordon Stray", "Gordon", "Fourth", "Fourth A", "Fifth", "Lower Fifth", "Bayard", "Lower Bayard", "Elizabeth", "Warren", "Upper Speechley", "Speechley", "Balltown", "Bradford", "Riley", and "Benson". These sandstones are in the Mississippian and Devonian Systems.

In recommending the above sandstones for tight classification, the Committee has concluded that all areas on the enclosed maps, except those excluded by outlines, meet each of the Federal Energy Regulatory Commission's guidelines for tight-formation designation.

The Committee has prepared the necessary information for the recommendation (see attached Figures, Plates, Tables, and Appendices).

The estimated average in situ permeabilities through the pay section in areas not outlined on Plates I through IX are expected to be less than 0.1 millidarcy.

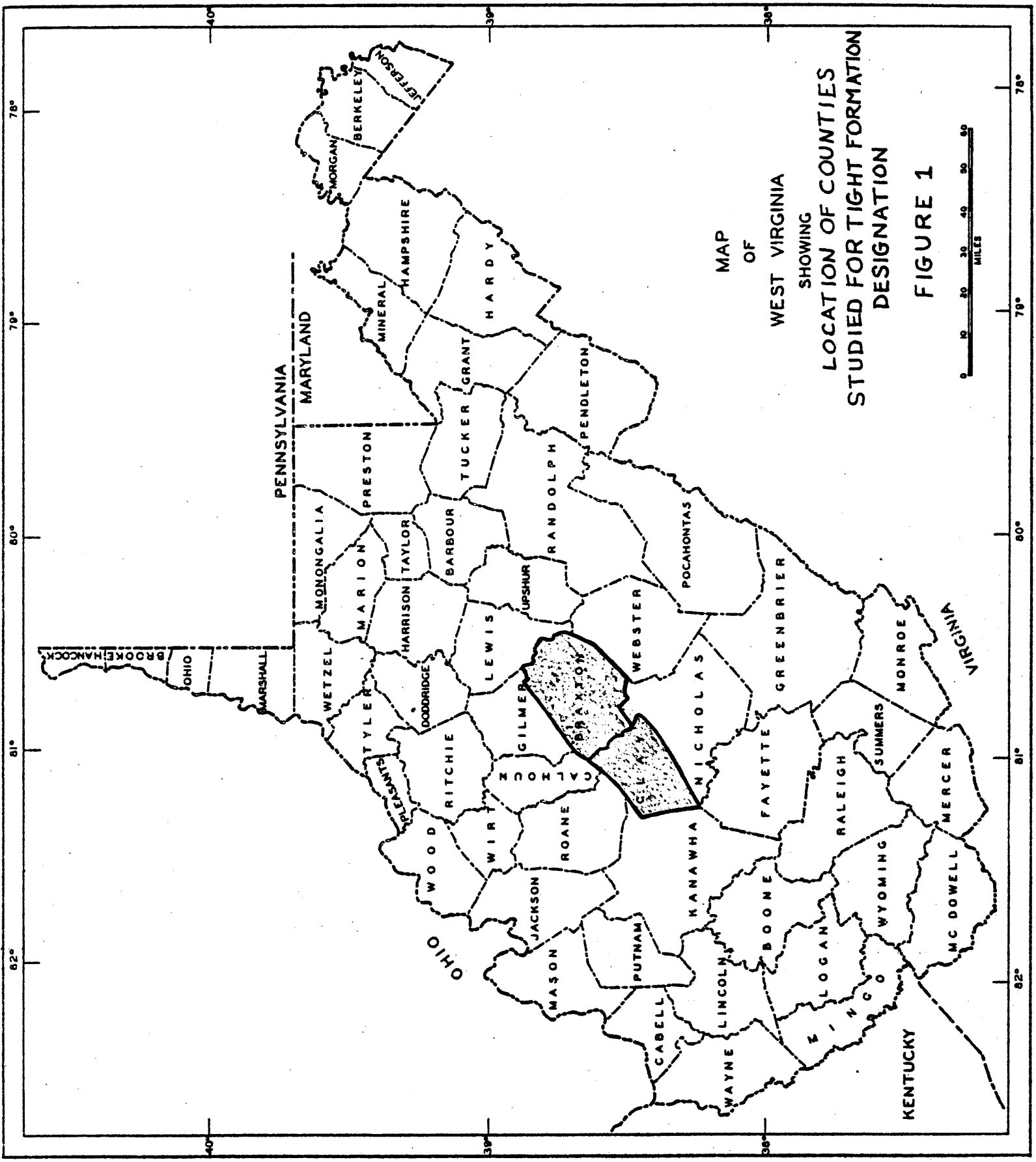
The stabilized production rate, against atmospheric pressure, of wells completed for production without stimulation in these recommended sandstones in this two-county area is not expected to exceed the production rate

determined in accordance with the table in 18 C.F.R. 271.703(c)(2)(i)(b) (see Table 1).

No well drilled into these sandstones in the designated areas would be expected to produce, without stimulation, more than five barrels of oil per day.

Existing State and Federal regulations assure that development of these sandstones will not adversely affect any fresh-water aquifers that are used or expected to be used as a domestic or agricultural water supply.

(Tight Formation Committee, 1983)



(Tight Formation Committee, 1983)

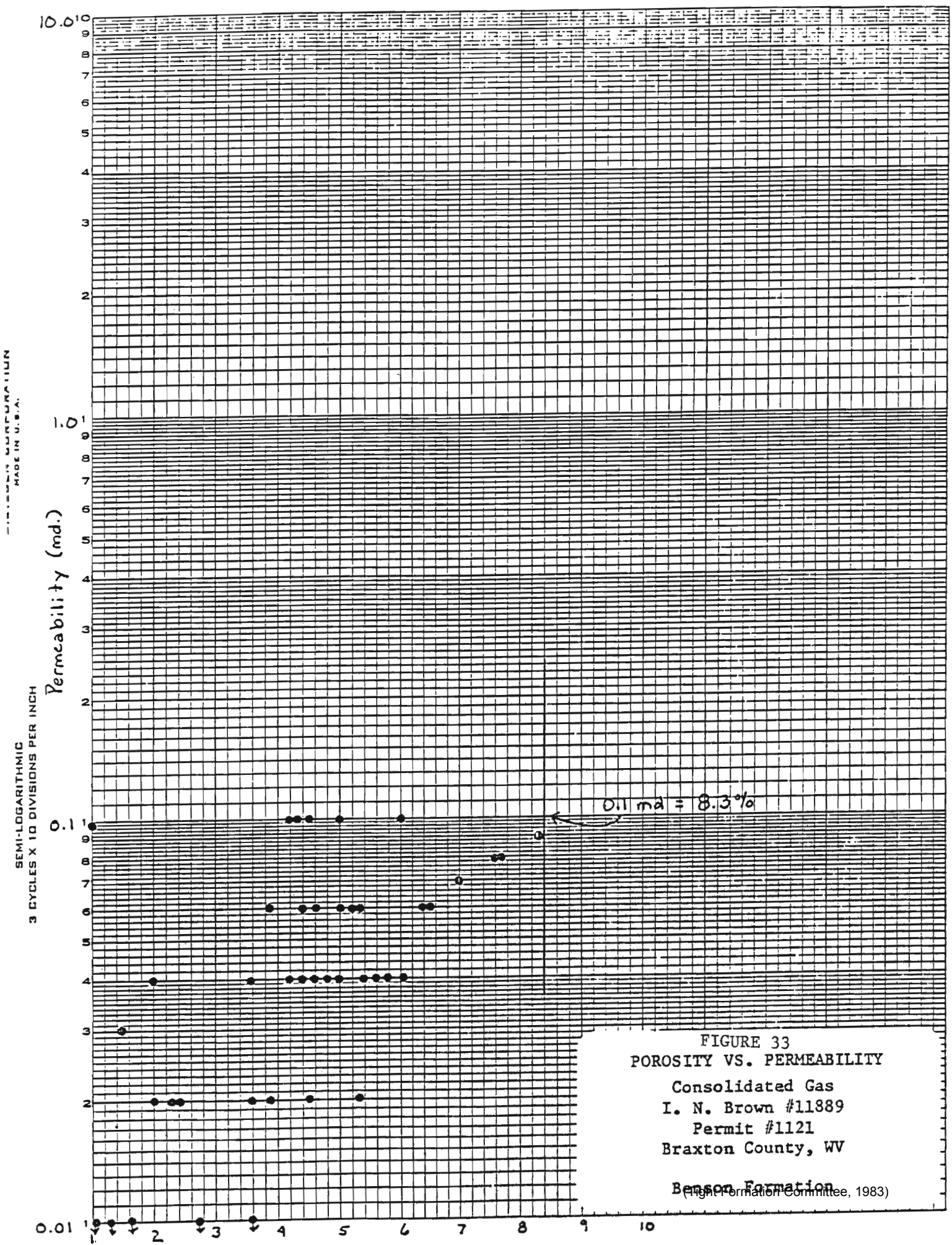


FIGURE 33
POROSITY VS. PERMEABILITY
Consolidated Gas
I. N. Brown #11889
Permit #1121
Braxton County, WV

Benson Formation

(High Formation Committee, 1983)

"Weir"

RECOMMENDED 'TIGHT FORMATION' AREA

	TOTAL PENETRATIONS	WELLS EXCEEDING NATURAL OPEN FLOW/DEPTH CRITERION	PERCENT
CLAY	68	0	0.00%
BRAXTON	345	1	0.29%
TOTAL	413	1	0.24%

NO RECOMMENDED EXCLUDED AREAS

"Gantz" to "Gordon"

RECOMMENDED 'TIGHT FORMATION' AREA

	TOTAL PENETRATIONS	WELLS EXCEEDING NATURAL OPEN FLOW/DEPTH CRITERION	PERCENT
CLAY	14	0	0.00%
BRAXTON	322	1	0.31%
TOTAL	336	1	0.30%

NO RECOMMENDED EXCLUDED AREAS

(Tight Formation Committee, 1983)

Table 5

"Fourth" to "Bayard"

RECOMMENDED 'TIGHT FORMATION' AREA			
	TOTAL PENETRATIONS	WELLS EXCEEDING NATURAL OPEN FLOW/DEPTH CRITERION	PERCENT
CLAY	1	0	0.00%
BRAXTON	161	1	0.68%
TOTAL	147	1	0.68%
NO RECOMMENDED EXCLUDED AREAS			

"Elizabeth" to "Bradford"

RECOMMENDED 'TIGHT FORMATION' AREA			
	TOTAL PENETRATIONS	WELLS EXCEEDING NATURAL OPEN FLOW/DEPTH CRITERION	PERCENT
CLAY	0	--	--
BRAXTON	147	1	0.68%
TOTAL	147	1	0.68%
NO RECOMMENDED EXCLUDED AREAS			

(Tight Formation Committee, 1983)

Table 6

RECOMMENDED 'TIGHT FORMATION' AREA

	TOTAL PENETRATIONS	WELLS EXCEEDING NATURAL OPEN FLOW/DEPTH CRITERION	PERCENT
CLAY	20	0	0.00%
BRAXTON	322	2	0.62%
TOTAL	342	2	0.58%

NO RECOMMENDED EXCLUDED AREAS

(Tight Formation Committee, 1983)

Table 7