AREAS RECOMMENDED FOR

TIGHT FORMATIONS

IN

BARBOUR, DODDRIDGE, GILMER,

HARRISON, LEWIS, UPSHUR

AND RANDOLPH COUNTIES

WEST VIRGINIA

TIGHT FORMATION COMMITTEE'S REPORT

JUNE 1982

(WV Tight Formations Committee, 1982-BDGHLUR)

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INTRODUCTION

The area covered by this report is in north central West Virginia and includes the following counties: Doddridge, Gilmer, Lewis, Harrison, Barbour, Upshur and the western part of Randolph (Fig. 1). These counties are located in the physiographic province known as the Appalachian Plateau which is characterized structurally by broad anticlinal and synclinal folds. The geologic age of rocks exposed on the surface in these counties is primarily Pennsylvanian.

The complete sedimentary interval in this area is represented by formations of the Paleozoic period ranging from Cambrian through Pennsylvanian, some 27,000± feet of sedimentary rocks. The producing intervals to which this report is addressed occupy only the upper part of the Devonian System, and the lower and middle part of the Mississippian System and represent on the average only 4,000 feet of the total stratigraphic column.

Data from approximately 9,500 wells were reviewed in the compilation of this report. The Committee's recommendations are based on expected permeabilities, natural open flows versus depth, and oil production rates, as outlined in the Federal Energy Regulatory Commission's guidelines for tight formations. The Committee also addresses the requirement of protecting fresh water aquifers.

GEOLOGIC DESCRIPTION

The formations recommended for tight classification were deposited during Late Devonian and Early to Middle Mississippian time. Therefore, they occur in the interval from the base of the Devonian Brallier formation to the lower part of the Mississippian Greenbrier Limestone as shown on the stratigraphic column (Fig. 3).

This stratigraphic interval can be divided on the basis of gamma-ray log and lithologic character into major sediment bundles or zones related to gross deltaic and marine facies. Because of the similarity of individual sandstones that occur in the same deltaic facies, it was determined that the best way to present their geological description was by these zones rather than individually. Four major environments of deposition were grouped into four zones for this study. Three deltaic environments associated with marine regression were identified as the pro-delta (Zone 4), delta front (Zone 3), and delta plain (Zone 2). The marine transgression which followed resulted in Pocono sandstone deposits and eventually Greenbrier Limestone deposits. These two accumulations are grouped into a single zone, Mississippian marine environment (Zone 1), for purposes of mapping and data interpretation. The relationship of these depositional sequences can be understood by referring to Figure 4 (Schematic Diagram of Depositional Environments) and Plate I and II (Stratigraphic Cross-Sections).

The pro-delta is the most seaward part of a delta and therefore, it represents the deepest water type of deposition in a delta complex. It could be thought of as the basal part of a delta. Because this part of the delta is the most distant from the source of sediments, i.e. the rivers, the sediments that accumulate there have characteristics different from those in the other deltaic environments.

Because only the smallest particles, mostly clay sized, are transported to this environment the resulting rocks are predominately shales. Occasionally, thin siltstones and very fine-grained sandstones are found interbedded with the shales in this environment. The most logical explanation for their presence is that they were transported into the deeper water by turbidity flows (Fig. 4). These flows are believed to originate in the upper, shallower parts of the delta where sediments are deposited at faster rates. When these shallow sediments build up beyond a critical slope, they may slump and slide as a density flow into the deeper water where they spread out as a layer of coarser-grained material on top of the clays. This is the likely origin of the sands and silts that are today potential pays in this zone.

The potentially productive sandstones that were deposited in this environment are known by the drillers as the Sycamore, Fox, Haverty, Elk(s), Alexander, Cedar Creek (Bluestone Creek) and Leopold. These are all very fine-grained sandstones to siltstones that contain high percentages of clay. The brown color that is characteristic of these sandstones or siltstones as they are being drilled is due to their relatively high organic content.

2. Delta front environment and sediments, Zone 3

Rocks deposited in this environment are stratigraphically above the pro-delta deposits and consist of sediments deposited in water shallower and closer to the source of sediment supply. Overall, these rocks contain a smaller percentage of shale and a higher percentage of sandstones and siltstones than the underlying pro-delta lithologies. Also, sandstones and siltstones become more numerous upward in this interval. The sandstones and siltstones also are generally thicker and cleaner, i.e. contain less clay, than those deposited in the pro-delta environment. Color ranges from brown in the lower part to light gray in the upper part.

The sands and silts in the delta front are basically from two sources. Some are probably from turbidity flows similar to those in the pro-delta environment. However, some of those in the upper part of the delta front probably represent deposition in submerged bars that built up at the mouths of river channels. In general, these deposits would be coarser grained than those found in the turbidity flows.

The potentially productive sandstones that were deposited in this environment are known as the Benson, Riley, Bradford, Balltown, Speechley, Upper Speechley, Warren and Elizabeth.

3. Delta Plain environment and sediments, Zone 2

This is the most complex environment in the deltaic system and represents the top of the deltaic sequence. Sediments accumulate in environments which range from very shallow subaqueous to subaerial.

Sandstone and siltstone reservoirs can be deposited in a variety of depositional systems as illustrated in Figure 4. These can be in the river channels themselves, in crevasse systems, or as sands concentrated around the margin of the delta in beach ridges, spits and nearshore bars.

The coarsest sediments of the delta are found in this environment because of the proximity to the source. The total shale content is less in this interval than in the pro-delta or delta front intervals. Some of the sandstones are reddish to maroon in color, unlike the dominant gray and brown colors in the pro-delta and delta front sandstones and siltstones The red colors are probably a result of oxidation.

The potentially productive sandstones that were deposited in this environment are the Lower Bayard, Bayard, Lower Fifth, Fifth, Fourth A, Fourth, Gordon, Gordon Stray, Thirty-Foot, Fifty-Foot, Gantz A, Gantz and Berea.

4. Mississippian marine environment, Zone 1

The uppermost interval in the stratigraphic sequence being evaluated by the West Virginia Tight Formation Committee is represented by Mississippian carbonates (Greenbrier Limestone) along with the underlying clastics of the Pocono Group. The Pocono Group reflects a marine transgression following maximum regression during Berea deposition and is represented in the study area by the Squaw and Weir sandstones and intervening shales. These clastics represent nearshore shallow marine deposition. Squaw and Weir are essentially silt and sand size with minor amounts of clay and are light gray to greenish gray. The Greenbrier Limestone lies unconformably above the Pocono Group and is of Middle Mississippian age. The beds are of marine origin and are predominately limestones. However, the lower section may be a sandy zone ranging from quartz sand to calcareous sandstone to sandy dolomite. It is commonly white in color. This sandy portion of the Greenbrier is the well-known "Big Injun" sand and has been an important reservoir throughout the history of oil and gas development in central West Virginia.

Therefore, to properly evaluate the data available, six productive interval groups were established with respect to original depositional environment and balance of units for mapping purposes. In the final analysis the intervals established and the individual units within those intervals are as follows:

1. <u>Injun-Weir</u> (Zone 1)

   Big Injun

   Squaw

   Weir

2. <u>Berea-Gordon</u> (Zone 2)

   Berea

   Gantz

   Gantz A

   Fifty Foot

   Thirty Foot

   Gordon Stray

   Gordon

3. <u>Fourth-Bayard</u> (Zone 2)

   Fourth

   Fourth A

   Fifth

   Lower Fifth

   Bayard

   Lower Bayard

4. <u>Elizabeth-Bradford</u> (Zone 3)

   Elizabeth

   Warren

   Upper Speechley

   Speechley

   Balltown

   Bradford

5. <u>Riley-Benson</u> (Zone 3)

   Riley

Benson

6. Elk-Brallier (Zone 4)

Leopold

Cedar Creek (Bluestone Creek)

Alexander

Elks

Haverty

Fox

Sycamore

Application for the tight formation recommended areas is by the above designated intervals rather than individual units. The remainder of this study concerns data evaluation and recommended tight formation areas as developed by the West Virginia Tight Formation Committee.

GEOLOGICAL AND ENGINEERING DATA

Permeability, natural open flow versus depth, oil production and protection of fresh water aquifers were individually studied and subsequently incorporated into a data base for designation of tight formation areas in the counties of Barbour, Doddridge, Gilmer, Harrison, Lewis, Randolph, and Upshur. All criteria were investigated completely to the extent that available information would allow.

Because detailed core analyses are sparse compared to the density of drilling, it was determined that analysis of natural open flow versus depth for all wells in the prescribed counties was appropriate. Table 1 is the depth versus maximum allowable natural open flow chart as specified in the Federal Energy Regulatory Commission guidelines and utilized for this report. Approximately 9,500 well records were examined and the reported natural open flows were mapped to determine all geographic areas where these sandstones qualify as tight formations based on this criterion. If the natural open flow reported at total depth was below that allowable for even the shallowest identified sandstones, then all sandstones were determined to qualify as tight in that specific well. If the natural open flow rate reported at total depth exceeds that allowable for the shallowest zone, the well record was examined to determine which sandstone (or sandstones) was responsible for the excessively high gas flow. The responsible sandstone (or sandstones) was then disqualified for tight formation consideration, but all others were qualified in that specific well. For example, a well in Harrison County, (permit number 1076) drilled through the Upper Devonian Benson sand (4382'-4411') recorded a significant natural flow of gas from the Upper Devonian Fourth sand at 2257', but recorded no other significant natural flows in the well. This Fourth sand natural flow of 133 MCFGPD far exceeds that allowable for the recorded depth. Thus, this well is designated as a nonqualifier for tight formation consideration in the Fourth to Bayard interval. All other Upper Devonian siltstone and sandstone intervals qualify as tight in this well, because no additional significant natural flows were recorded.

The normal drilling procedure employed throughout the study area was formerly by cable tool and more recently by the air-rotary method. Both of these types of drilling operations permit continual monitoring of gas shows as a hole is drilled. The normal procedure during drilling is that at any time a significant show of gas is encountered, the rig is shut down for a short period of time so that a gas check can be made to measure the flow encountered. The listings of drillers records in the Appendices reflect the way in which these tests are recorded. For example: the well record for Upshur-286 reveals that six gas checks were made during the drilling operations. These tests were as follows: Gas sand at 597 feet had a show of gas too small to gauge; Big Lime at 1587 feet had a flow of 13,845 cubic feet, Gordon Stray at 2224 feet tested 47,000 cubic feet, a test at 4097 feet yielded 7,530 cubic feet and there was a show at 4155 feet in the Benson of 3,765 cubic feet. None of these shows exceeded the amount which would disqualify any of the sandstones as tight formations in this well.

It should be emphasized that these reported natural open flows do not represent stabilized natural production against atmospheric pressure. The absence of stabilized natural open flow rates is due to the fact that tests were conducted during drilling, or shortly after drilling was completed. In order to obtain a stabilized flow to the atmosphere from these sandstones, it would be necessary to shut the drilling rig down for extended periods of time, a practice which is economically unfeasible. In addition, large volumes of gas would be vented to the atmosphere and wasted. Therefore, natural flows as shown (see Appendices) are unstabilized and are higher than stabilized natural flows to the atmosphere would be.

Natural flows after perforations, but before stimulation, are not recorded by operators in West Virginia because these flows are generally too small to measure.

This procedure was applied to all wells examined in the seven county area. Six area maps were computer-generated showing all penetrations and producers (pay sand maps) for a given stratigraphic interval. Wells designated as nonqualifers were then appropriately mapped. For any given stratigraphic interval map where nonqualifying wells were clustered, that area was circled and thus identified as not available for tight formation consideration. The remaining areas for any given stratigraphic interval map are recommended as tight based on natural open flow data interpretation. Tables 2-7 indicate the number of total penetrations and total non-qualifying wells for those areas recommended as tight formations for each mapped stratigraphic interval. In each case the percentage of wells not qualifying for tight formation recommendation is extremely small.

Each map was further refined by applying permeability, oil production and exclusion of gas storage areas criteria to the individual pay sand maps. Because the geographic area covered by this report is large and the total stratigraphic section addressed contains many producing sandstones, permeability data derived from available cores were not considered conclusive. For this reason, natural open flow data form the foundation for this report and core-derived permeability helps to refine the tight formation designations. The locations of all available cores are shown on the core location map (Plate III). Key permeability parameters are identified with each core. Where average permeability exceeds 0.1 md, the stratigraphic interval from which the core was taken does not qualify for tight formation designation in this well. Cores exhibiting average permeabilities of less than 0.1 md over the interval cored can be located in recommended tight formation areas for the stratigraphic interval specified. Therefore, in the recommended tight formation areas the committee expects the average in-situ permeability to be less than 0.1 md.

Also eliminated from tight formation consideration for a given stratigraphic interval are areas of gas storage and exisitng oil fields where production rates of oil have exceeded 5 BOPD or may potentially exceed 5 BOPD.

MAP DESCRIPTION AND INTERPRETATION

This tight formation committee report contains twelve production/penetration maps (Plates IV-XV). Six maps illustrate tight formation recommended areas in Doddridge, Gilmer, Harrison and Lewis Counties and six maps illustrate tight formation recommended areas in Barbour, Randolph and Upshur Counties. The following is a description of each map and an interpretation of the data presented with that map. In all cases, it is a stratigraphic interval including several reservoirs that is being recommended for tight formation designation and not an individual productive sandstone. For example, if an area on the Elizabeth-Bradford Map is recommended for exclusion from tight formation consideration, whether it is a storage field, oil-producing area, or an area with high natural open flows, then all sandstones represented by that map (Elizabeth, Warren, Speechley, Balltown and Bradford) are excluded in that specific area.

Doddridge-Gilmer-Harrison-Lewis Counties

Greenbrier and Pocono Reservoirs
(Big Injun to Weir)

Plate V is a map showing all penetrations and producing wells in the Big Injun and uppermost Pocono sandstones. The West Virginia Tight Formation Committee recommends that these sandstones (Big Injun, Squaw and Weir) be designated tight except in those areas otherwise designated as oil-producing areas or areas excluded on the basis of high natural open flow. In those areas recommended for tight formation consideration, of 6500 total penetrations, only 261 (or 4.0%) exceeded natural open flow versus depth guidelines. However, in those areas excluded from tight formation consideration on the basis of high natural open flow, 204 of 511 penetrations (or 39.9%) exceeded those guidelines established by FERC.

Lower Pocono and Upper Hampshire Reservoirs (Berea to Gordon)

Plate V is a map showing all penetrations and producing wells in the subject stratigraphic interval. The West Virginia Tight Formation Committee recommends that this interval (to include Berea, Gantz, Gantz A, Fifty Foot, Thirty Foot, Gordon Stray, and Gordon) be designated tight except in those areas designated as gas storage fields, oil-producing areas, or areas excluded on the basis of high natural open flow. In those areas recommended for tight formation designation, 3193 total penetrations are mapped. Of those wells, only 66 (or 2.1%) exceeded natural open flow versus depth guidelines. However, in those areas excluded from tight formation designation on the basis of high natural open flow, 28 of 46 penetrations (or 60.8%) exceeded the prescribed guidelines.

Lower Hampshire Reservoirs (Fourth to Bayard)

Plate VI is a map showing all penetrations and producing wells in the subject stratigraphic interval. The West Virginia Tight Formation Commitee recommends that this interval (to include the Fourth, Fourth A, Fifth, Lower Fifth, Bayard and Lower Bayard) be designated tight except in those areas otherwise designated as oil-producing areas or areas excluded on the basis of high natural open flow. In those areas recommended for tight formation designation, only 32 wells exceed the open flow versus depth criteria among 2364 total penetrations (1.4%). However, in those areas excluded from tight formation designation on the basis of high natural open flow versus depth, 23 of 39 total penetrations (or 58.9%) exceed the allowable flow.

Upper Chemung Reservoirs
(Elizabeth to Bradford)

Plate VII is a map showing all penetrations and producing wells in the subject stratigraphic interval. The West Virginia Tight Formation Committee recommends that this interval, (to include Elizabeth, Warren, Upper Speechley, Speechley, Balltown and Bradford) be designated tight except in those areas excluded on the basis of high natural open flow or available permeability data. In those areas recommended for tight formation consideration, only 40 of 1989 total penetrations (or 2.0%) exceeded the guidelines for natural open flow versus depth evaluations. However, in those areas excluded from tight formation consideration, 62 of 93 total penetrations (or 66.7%) exceeded those guidelines.

Lower Chemung Reservoirs
(Riley and Benson)

Plate VIII is a map showing all penetrations and producing wells in the Riley and Benson sandstones. The West Virginia Tight Formation Committee recommends that these sandstones be designated tight except in those areas excluded on the basis of high natural open flow or available permeability data. In those areas recommended for tight formation consideration, only 51 of 1972 total penetrations (or 2.6%) exceeded the guidelines established for natural open flow versus depth evaluations. However, in those areas excluded from tight formation consideration, 12 of 31 total penetrations (or 38.7%) exceed those guidelines.

Basal Chemung and Brallier Reservoirs (Leopold to Sycamore)

Plate IX is a map showing all penetrations and producing wells in the subject stratigraphic interval. The West Virginia Tight Formation Committee recommends that this interval (to include the Leopold, Cedar Creek (Bluestone Creek), Alexander, Elk(s), Haverty, Fox and Sycamore) be designated tight except in those areas excluded on the basis of high natural open flow or available permeability data. In those areas recommended for tight formation consideration, only 20 of 465 total penetrations (or 4.3%) exceeded the guidelines established for natural open flow versus depth evaluations. However, in those areas excluded from tight formation consideration, 12 of 31 total penetrations (or 38.7%) exceed those guidelines.

Barbour-Randolph-Upshur Counties

Greenbrier and Pocono Reservoirs (Big Injun to Weir)

Plate X is a map showing all penetrations and producing wells in the subject stratigraphic interval. The West Virginia Tight Formation Committee recommends that this interval (to include the Big Injun, Squaw and Weir) be designated tight except in those areas otherwise excluded on the basis of high natural open flow, or areas excluded as gas storage fields. In those areas recommended as tight there are 2976 total penetrations mapped. Of these, only 15 wells (0.5%) had natural flows in excess of the depth versus flow guidelines. However, in the areas excluded from tight formation consideration, 7 of 17 wells (or 41%) had natural open flows exceeding the FERC guidelines.

Lower Pocono and Upper Hampshire Reservoirs (Berea to Gordon)

Plate XI is a map showing all penetrations and producing wells in the subject stratigraphic interval. The West Virginia Tight Formation Committee recommends that this interval (to include the Berea, Gantz, Gantz A, Fifty-Foot, Thirty-Foot, Gordon Stray and Gordon) be designated as tight except in these areas excluded on the basis of high natural open flow. In the areas recommended for tight formation designation, 2974 wells penetrated this interval with only 14 (0.47%) having natural flows above the flow-depth guidelines. In the non-qualifying area, however, 6 of 14 wells (or 43%) of the penetrations had excessive flows.

Lower Hampshire Reservoirs (Fourth to Bayard)

Plate XII is a map showing all penetrations and producing wells in the subject stratigraphic interval. The West Virginia Tight Formation Committee recommends that this interval (to include the Fourth, Fourth A, Fifth, Lower Fifth, Bayard and Lower Bayard) be designated as tight except in those areas excluded on the basis of natural open flows in excess of the FERC guidelines. As indicated on Plate XII there are 2955 total penetrations in the area recommended for qualification as tight. Only 27 (0.9%) of these wells would not meet these tight formation standards. On the other hand, 9 of 17 wells (or 53%) in the non-qualifying areas had volumes in excess of these standards.

Upper Chemung Reservoirs (Elizabeth to Bradford)

Plate XIII is a map showing all penetrations and producing wells in the subject stratigraphic interval. The West Virginia Tight Formation Committee recommends that this interval (to include Elizabeth, Warren, Upper Speechley, Speechley, Balltown and Bradford) be designated tight throughout the entire three county area. Only 4 of the 2776 total penetrations (0.14%) had open flow volumes in excess of the open flow versus depth relationship as outlined by FERC.

Lower Chemung Reservoirs (Riley and Benson)

Plate XIV is a map showing all penetrations and producing wells in the Riley and Benson sandstones. The West Virginia Tight Formation Committee recommends that these sandstones (Riley and Benson) be designated as tight except for those areas excluded on the basis of natural open flows in excess of volumes set forth in Table 1, or permeability data based on core analysis. As indicated on the accompanying map, in the area recommended for tight formation consideration there are 2621 total penetrations of which only 52 (or 1.98%) will not qualify as tight. However, within the non-qualifying areas 68%, or 45 of the 66 total penetrations, exceed the flow depth guidelines.

Basal Chemung and Brallier Reservoirs (Leopold to Sycamore)

Plate XV is a map showing all penetrations and producing wells in the subject stratigraphic interval. The West Virginia Tight Formation Committee recommends that this interval (to include the Leopold, Cedar Creek (Bluestone Creek), Alexander, Elk(s), Haverty, Fox and Sycamore) be designated tight except in those areas excluded on the basis of high natural open flow and permeability data.

In the three county area, there were 608 penetrations of the basal Chemung and Brallier interval. Of these 608, only two wells had flows in excess of the FERC guidelines. Therefore, the committee recommends that the entire three county area be designated for tight formation status for this interval, with the exception of the areas around the two adjacent non-qualifying wells.

PROTECTION OF FRESH WATER AQUIFERS

Existing State and Federal Regulations will assure that development of the sandstones 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. (1) 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. Legislation 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.

CONCLUSIONS

The Tight Formation Committee of West Virginia hereby recommends that those areas in Barbour, Doddridge, Gilmer, Harrison, Lewis, Upshur and the western part of Randolph Counties, not otherwise eliminated on Plates IV through XV, 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 as the Sycamore, Fox, Haverty, Elk(s), Alexander, Cedar Creek, (Bluestone Creek), Leopold, Benson, Riley, Bradford, Balltown, Speechley, Upper Speechley, Warren, Elizabeth, Lower Bayard, Bayard, Lower Fifth, Fifth, Fourth A, Fourth, Gordon, Gordon Stray, Thirty-Foot, Fifty-Foot, Berea, Gantz A, Gantz, Weir, Squaw and Big Injun. 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 eliminated 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 throughout the pay section in areas not outlined on Plates IV through XV are expected to be less than 0.1 millidarcy.

The stabilized production rate, against atmospheric pressure of wells completed for production in these recommended sandstones in this seven county area without stimulation, 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.

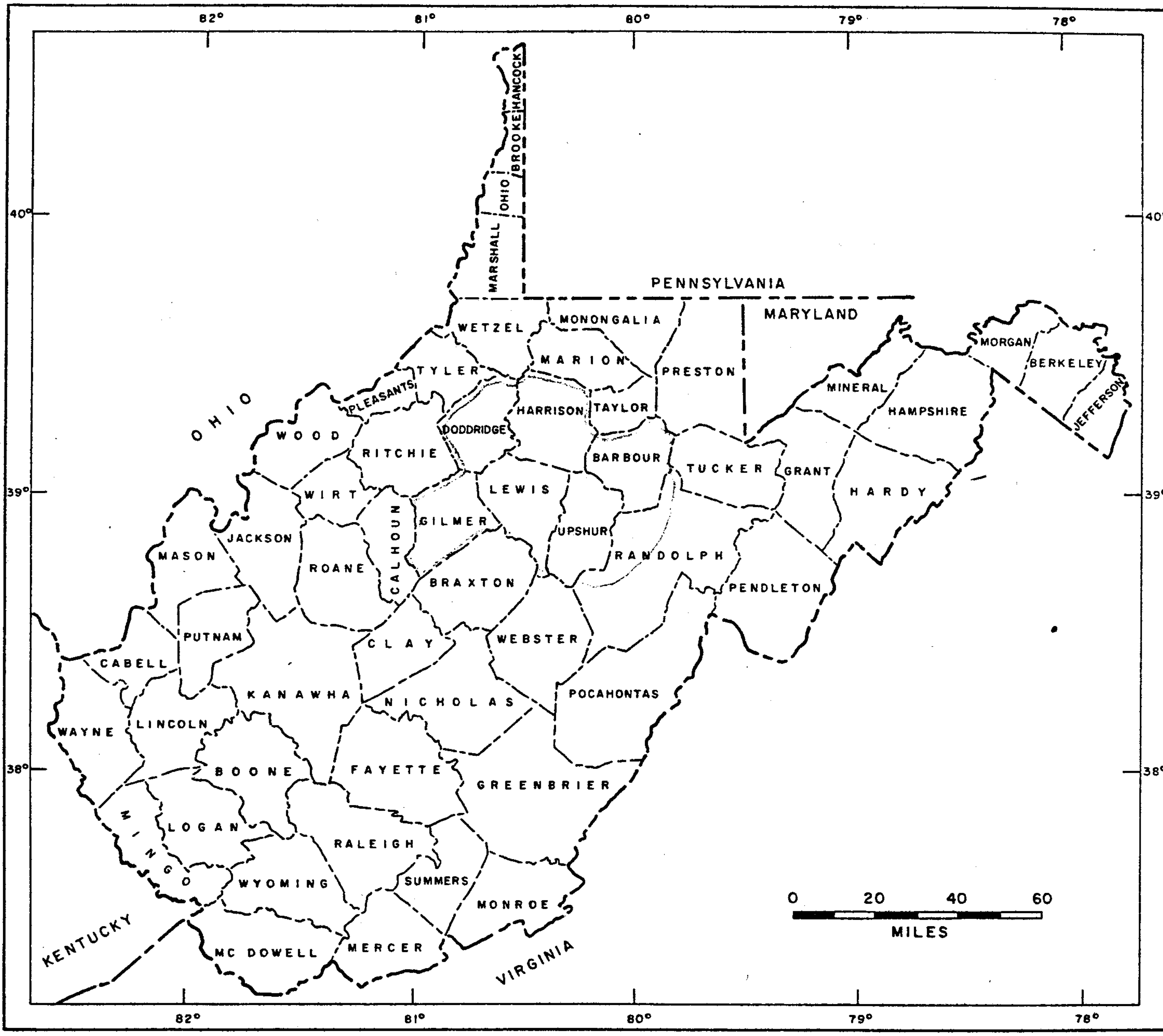


Figure 1

(WV Tight Formations Committee, 1982-BDGHLUR)

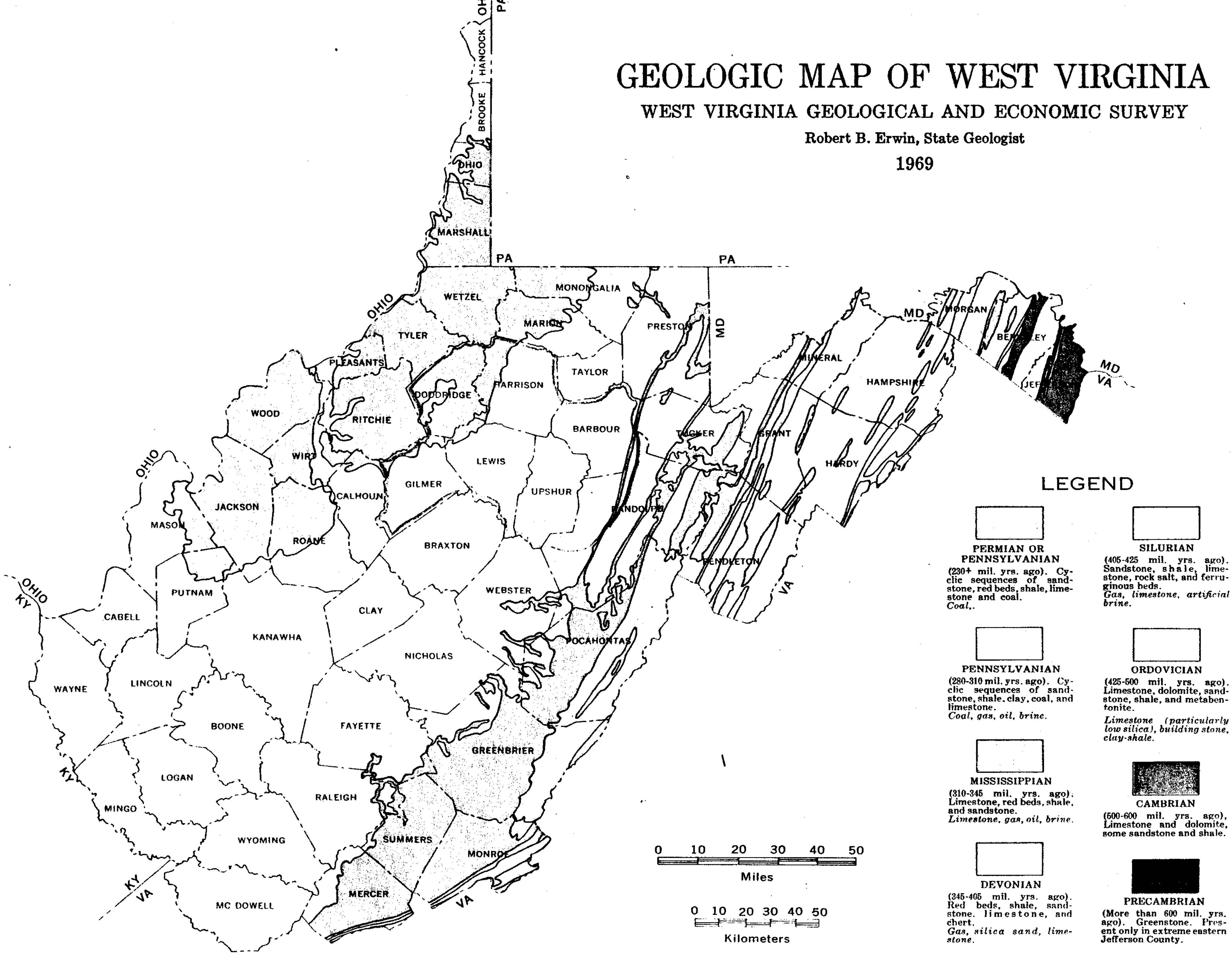
Figure 2

GEOLOGIC MAP OF WEST VIRGINIA

WEST VIRGINIA GEOLOGICAL AND ECONOMIC SURVEY

Robert B. Erwin, State Geologist

1969



(WV Tight Formations Committee, 1982-BDGHLUR)

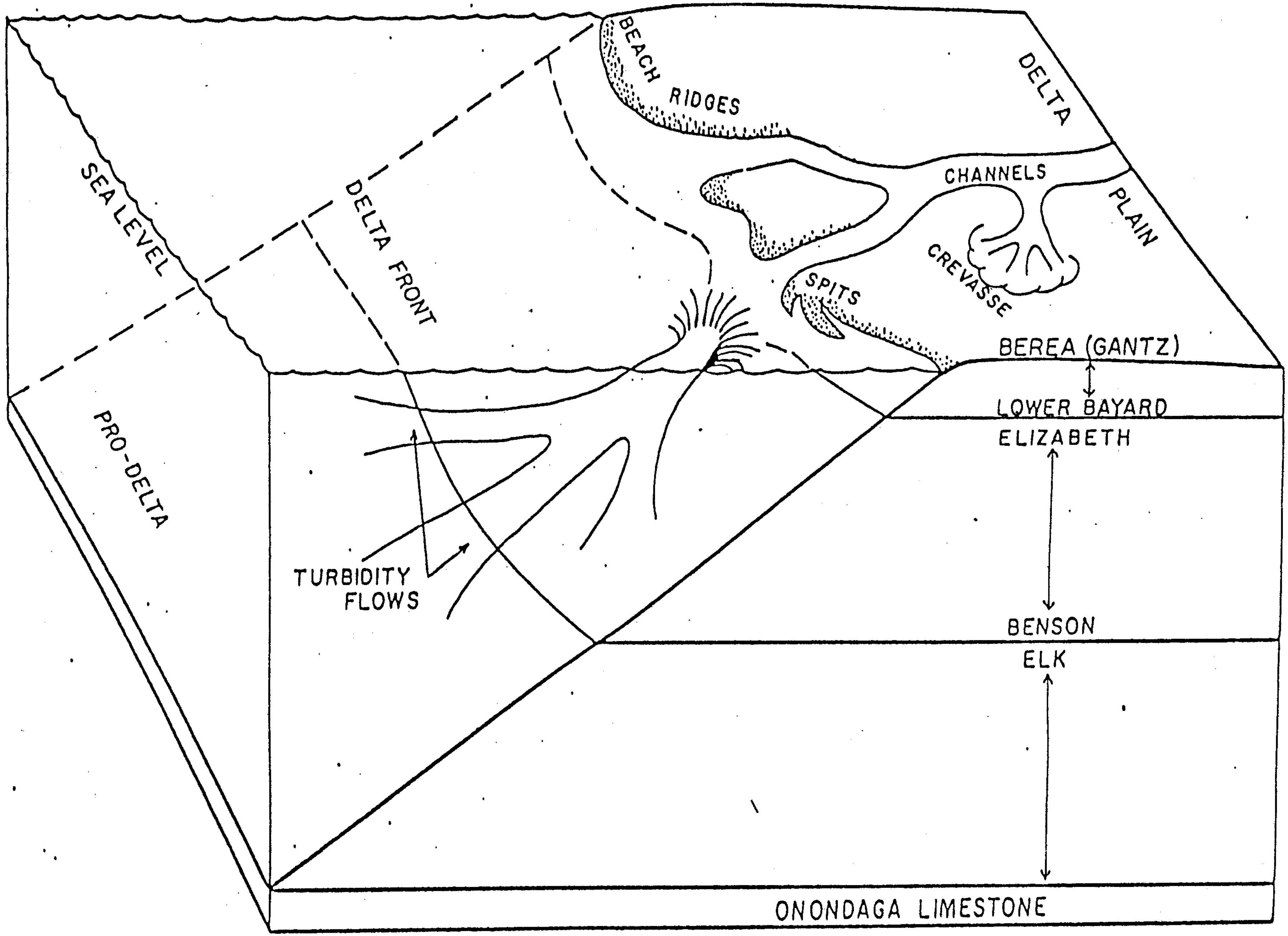
GENERALIZED STRATIGRAPHIC COLUMN

SYSTEM	SERIES	STRATIGRAPHIC NOMENCLATURE	DRILLERS TERMINOLOGY	INTERVAL MAP	ZONE
MISSISSIPPIAN	MIDDLE	GREENBRIER LIMESTONE	BIG INJUN	INJUN-WEIR	1
MISSISSIPPIAN	LOWER	POCONO GROUP	SQUAW WEIR	INJUN-WEIR	1
MISSISSIPPIAN	LOWER	POCONO GROUP	BEREA	BEREA-GORDON	2
DEVONIAN	UPPER	HAMPSHIRE GROUP	GANTZ GANTZ A FIFTY-FOOT THIRTY-FOOT GORDON STRAY GORDON	BEREA-GORDON	2
DEVONIAN	UPPER	HAMPSHIRE GROUP	FOURTH FOURTH A FIFTH LOWER FIFTH BAYARD LOWER BAYARD	FOURTH-BAYARD	2
DEVONIAN	UPPER	CHEMUNG GROUP	ELIZABETH WARREN UPPER SPEECHLEY SPEECHLEY BALLTOWN BRADFORD	ELIZABETH-BRADFORD	3
DEVONIAN	UPPER	CHEMUNG GROUP	RILEY BENSON	RILEY-BENSON	3
DEVONIAN	UPPER	CHEMUNG GROUP	LEOPOLD CEDAR CREEK (BLUESTONE CREEK) ALEXANDER	ELK-BRALLIER	4
DEVONIAN	UPPER	BRALLIER FORMATION	ELK(S) HAVERTY FOX SYCAMORE	ELK-BRALLIER	4

FIGURE 3

(WV Tight Formations Committee, 1982-BDGHLUR)

Schematic Diagram of Depositional Environments



(WV Tight Formations Committee, 1982-BDGHLUR)

Figure 4

Maximum allowable production rate for

average depth to proposed tight formation.

If the average depth to the top of the formation (in feet)		The maximum allowable production rate (in Mcfpd) may not exceed:
exceeds:	but does not exceed:	
0000	1000	44
1000	1500	51
1500	2000	59
2000	2500	68
2500	3000	79
3000	3500	91
3500	4000	105
4000	4500	122
4500	5000	141
5000	5500	163
5500	6000	188
6000	6500	217
6500	7000	251
7000	7500	290
7500	8000	336
8000	8500	388
8500	9000	449
9000	9500	519
9500	10000	600
10000	10500	693
10500	11000	802
11000	11500	927
11500	12000	1071
12000	12500	1238
12500	13000	1432
13000	13500	1655
13500	14000	1913
14000	14500	2212
14500	15000	2557

From 18 C.F.R. 271.703 (c) (2) (i) (b)

Table 1

(WV Tight Formations Committee, 1982-BDGHLUR)

RECOMMENDED 'TIGHT FORMATION' AREA			
	TOTAL PENETRATIONS	WELLS EXCEEDING NATURAL OPEN FLOW/DEPTH CRITERION	PERCENT
BARBOUR	1101	4	0.36%
DODDRIDGE	1583	79	4.99%
GILMER	1996	99	4.96%
HARRISON	1248	18	1.44%
LEWIS	1673	65	3.89%
RANDOLPH	211	0	0.0%
UPSHUR	1664	11	0.66%
TOTAL	9476	276	2.91%
RECOMMENDED EXCLUDED AREAS			
TOTAL	528	211	39.96%

Table 2

(WV Tight Formations Committee, 1982-BDGHLUR)

RECOMMENDED 'TIGHT FORMATION' AREA

	TOTAL PENETRATIONS	WELLS EXCEEDING NATURAL OPEN FLOW/DEPTH CRITERION	PERCENT
BARBOUR	1089	6	0.55%
DODDRIDGE	458	9	1.97%
GILMER	464	8	1.72%
HARRISON	1016	17	1.67%
LEWIS	1255	32	2.55%
RANDOLPH	201	0	0.0%
UPSHUR	1684	8	0.47%
TOTAL	6167	80	1.29%

RECOMMENDED EXCLUDED AREAS

TOTAL	60	34	56.67%

Table 3

(WV Tight Formations Committee, 1982-BDGHLUR)

Fourth-Bayard

RECOMMENDED 'TIGHT FORMATION' AREA

	TOTAL PENETRATIONS	WELLS EXCEEDING NATURAL OPEN FLOW/DEPTH CRITERION	PERCENT
BARBOUR	1089	8	0.73%
DODDRIDGE	358	1	0.28%
GILMER	293	1	0.34%
HARRISON	895	17	1.90%
LEWIS	818	13	1.59%
RANDOLPH	205	4	1.95%
UPSHUR	1661	15	0.90%
TOTAL	5319	59	1.11%

RECOMMENDED EXCLUDED AREAS

TOTAL	56	32	57.14%

Table 4 (WV Tight Formations Committee, 1982-BDGHLUR)

RECOMMENDED 'TIGHT FORMATION' AREA			
	TOTAL PENETRATIONS	WELLS EXCEEDING NATURAL OPEN FLOW/DEPTH CRITERION	PERCENT
BARBOUR	922	3	0.32%
DODDRIDGE	339	2	0.59%
GILMER	183	0	0.0%
HARRISON	764	23	3.01%
LEWIS	703	15	2.13%
RANDOLPH	166	0	0.0%
UPSHUR	1545	1	0.06%
TOTAL	4622	44	0.95%
RECOMMENDED EXCLUDED AREAS			
TOTAL	93	62	66.67%

Table 5 (WV Tight Formations Committee, 1982-BDGHLUR)

RECOMMENDED 'TIGHT FORMATION' AREA			
	TOTAL PENETRATIONS	WELLS EXCEEDING NATURAL OPEN FLOW/DEPTH CRITERION	PERCENT
BARBOUR	994	18	1.81%
DODDRIDGE	328	8	2.44%
GILMER	169	10	5.91%
HARRISON	578	20	3.46%
LEWIS	569	13	2.28%
RANDOLPH	263	1	0.38%
UPSHUR	1364	13	0.95%
TOTAL	4265	83	1.95%
RECOMMENDED EXCLUDED AREAS			
TOTAL	97	57	58.76

Table 6 (WV Tight Formations Committee, 1982-BDGHLUR)

RECOMMENDED 'TIGHT FORMATION' AREA

	TOTAL PENETRATIONS	WELLS EXCEEDING NATURAL OPEN FLOW/DEPTH CRITERION	PERCENT
BARBOUR	210	0	0.0%
DODDRIDGE	286	12	4.20%
GILMER	89	6	6.74%
HARRISON	49	2	4.08%
LEWIS	41	0	0.0%
RANDOLPH	101	0	0.0%
UPSHUR	295	0	0.0%
TOTAL	1071	20	1.87%

RECOMMENDED EXCLUDED AREAS

TOTAL	44	14	31.82%

Table 7

(WV Tight Formations Committee, 1982-BDGHLUR)

Respectfully Submitted,

TIGHT FORMATION COMMITTEE

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Floyd B. Wilcox, Chairman, Peake Operating

Members:

James Alkire-Allegheny Land & Mineral Co.

Katharine L. Avary-WV Geological & Economic Survey

Mary C. Behling-WV Geological & Economic Survey

Porter J. Brown-Columbia Gas Transmission Corp.

Denise Carney-Kem Gas Corp.

David Cox-Kem Gas Corp.

Janet E. Eldridge-West Virginia Tight Formation Committee

Paul L. Gebhard-Cabot Oil &   Corp.

James Gehr-Allegheny Land & Mineral Co.

Michael E. Hohn-WV Geological & Economic Survey

Richard H. Martin-Tom Marsh Inc.

Chris McGill-Tom Marsh Inc.

David Meghreblian-Cabot Oil & Gas Corp.

Douglas Patchen-WV Geological & Economic Survey

Robert Pryce-Kem Gas Corp.

Edward Rothman-Columbia Gas Transmission Corp.

William Ryan-Spartan Gas Company