UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

RECOMMENDATION OF THE RAILROAD COMMISSION OF TEXAS THAT THE TRAVIS PEAK FORMATION BE DESIGNATED AS A TIGHT FORMATION IN TEXAS	§ § § § §	DOCKET NUMBER 5-76,659

TO THE HONORABLE FEDERAL ENERGY REGULATORY COMMISSION:

NOW COMES THE RAILROAD COMMISSION OF TEXAS (hereinafter referred to as "Commission") and hereby files this recommendation that the FEDERAL ENERGY REGULATORY COMMISSION (hereinafter referred to as "FERC") designate the TRAVIS PEAK FORMATION (hereinafter referred to as the "TRAVIS PEAK") as a tight formation in Texas. Authority for designation of a tight formation is under Section 107(b) of the Natural Gas Policy Act of 1978. 15 U.S.C. §3317(b) (1980). Procedure for this recommendation is pursuant to regulations promulgated to implement Section 107(b) and set out in 18 C.F.R. §271.703(c) (Final Rule originally issued in FERC Docket No. RM79-76 on August 15, 1980).

The Railroad Commission of Texas held a public hearing on May 29, 1981, for the purpose of obtaining information on the Travis Peak as a proposed tight formation in Texas. Pre-filed testimony was entered into evidence at the hearing. Participants in the hearing were subject to examination by the presiding Commission examiners. See Transcript of Testimony, Docket No. 5-76,659. These legal and technical examiners subsequently analyzed and verified the data, and prepared the Railroad Commission exhibits upon which this recommendation is based.

Initially, a geographical and geological description of the Travis Peak is presented. Geological and engineering data that support the recommendation are set forth, indicating the source of that data. In support of its recommendation, the Commission will show that the recommended portion of this formation meets all guidelines required by law. 18 C.F..R. §271.703 (c) (2) (1980). Calculations will show that estimated average in-situ gas permeability throughout the pay section of the formation is expected to be 0.1 millidarcy (md) or less. Stabilized production rate of wells completed for production in the respective formation, without stimulation, will be shown to be within the scale set forth at 18 C.F.R. §271.702(c) (i) (B) (1980). Production history will demonstrate that no well drilled into the Travis Peak is expected to produce more than five barrels of crude oil per day. A list of wells which have produced natural gas from the recommended formation is submitted (See Exhibit 12). Existing state and federal regulations are discussed to the extent to which they will assure that development of these formations will not adversely affect any fresh water aquifers that are or are expected to be used as a domestic or agricultural water supply. Finally, conclusions are stated based on the data discussed

I.

GEOGRAPHICAL AND GEOLOGICAL DESCRIPTION

Geographically, the recommended formation is located in the northeastern part of the State of Texas. The area referred to covers Railroad Commission Districts 5 and 6 (See Exhibit 1). The northern limits of the Travis Peak formation lie beyond the Texas-Oklahoma state line. The western edge is determined by the outcrop of the Travis Peak, west of District 5. The Angelina-Caldwell flexure to the south caused a barrier which reduced sedimentation of the Travis Peak formation. This flexure extends from Trinity through Sabine counties in Texas and into Louisiana. The Travis Peak depositional basin extends into northern Louisiana and Arkansas.

The Travis Peak formation is encountered below the last limestone zone of the overlying Sligo/Pettit formation (See Exhibit 2). Red shales and sandstones show a well-defined change in depositional environment. The top of the Travis Peak formation is found at a depth of 3,140 ft. in Lamar County in the northern area of the East Texas basin to 10,850 ft. in the southern area of Cherokee County. In the study area, the Travis Peak formation thickness ranges from approximately 500 ft. to 2,500 ft. The section is composed of lenticular, alternating sandstone and shale beds. The base of this formation is the top of the Cotton Valley Group where a black shale zone is found (See Exhibit 2). The Travis Peak formation is Lower Cretaceous Age, which occurred approximately 135 million years ago.

The East Texas syncline was a subsiding basin during the time of Travis Peak deposition. Lower Cretaceous seas were bordered by low lands which supplied the fine grained clastics and muds. The Travis Peak sandstones and shales were deposited in a closely related suite of environmental conditions. These include beach, runnel, and upper shoreface environments. Moderate to high energy conditions are shown by the high degree of sorting and rounding of grains, occasional cross-bedding, fossil fragment zones, concentration of heavy minerals, and lack of burrowing or other bioturbation. Neutral to oxidizing conditions are determined by neutral gray to tan and brownish red to red rock sample color and a general lack of minerals such a pyrite and siderite usually associated with reducing conditions. Diagenesis of these sandstone zones has greatly reduced the porosity of these potential reservoirs by the formation of secondary quartz overgrowths. Further reduction of porosity has been caused by calcite cementing, possibly from dissolution of fossil shell fragments. Both secondary quartz overgrowths and calcite cement resulted in the reduction of primary intergranular porosity. Clays are present in Travis Peak samples as clasts and pebbles. Matrix clay is minor.

Because the Travis Peak formation is shown to be a continuous geologic formation present everywhere within Railroad Commission Districts 5 and 6 (See Exhibits 7 & 8), the Commission recommends that the Travis Peak formation be designated as a tight sand formation in all of the counties in District 5 and 6, being listed as follows:

1. Anderson
2. Angelina
3. Bosque
4. Bowie
5. Camp
6. Cass
7. Cherokee
8. Collin
9. Dallas
10. Delta
11. Ellis
12. Falls
13. Fannin
14. Franklin
15. Freestone
16. Gregg
17. Harrison
18. Henderson
19. Hill
20. Hopkins
21. Houston
22. Hunt
23. Johnson
24. Kaufman
25. Lamar
26. Leon
27. Limestone
28. Marion
29. McLennan
30. Morris
31. Nacogdoches
32. Navarro
33. Panola
34. Rains
35. Red River
36. Robertson
37. Rockwall
38. Rusk
39. Sabine
40. San Augustine
41. Shelby
42. Smith
43. Tarrant
44. Titus
45. Upshur
46. Van Zandt
47. Wood

The majority of the information for the Travis Peak formation is derived from a fourteen-county area--Cherokee, Freestone, Gregg, Harrison, Henderson, Leon, Limestone, Marion, Nacogdoches, Panola, Rusk, Shelby, Upshur and Wood

(See Exhibit 13). Results of in-situ permeability and stablized production rate determinations have been reviewed and the Commission finds the data representation to be a valid statistical sampling of the Travis Peak formation in Railroad Commission Districts 5 and 6 (See Exhibit 15). Based on this review, the entire geologic and geographic area covering Railroad Commission District 5 and 6 is recommended as tight.

II.

GEOLOGICAL AND ENGINEERING DATA

PERMEABILITY

Average in-situ permeability throughout the pay sections of the Travis Peak formation is expected to be 0.1 md or less. Several methods were employed to determine the effective permeability, including pressure buildup analysis, core analysis and pressure drawdown analysis. Results for permeability were obtained from 606 successful completions in the Travis Peak formation (See Exhibit 15). From these results in-situ permeability versus cumulative frequency was plotted (See Exhibit 16). The results show that sixty-six percent of the permeability values for all wells (pre-stimulation and post-stimulation) fall below 0.1 millidarcy. Sixty-seven percent of the permeability values are less than 0.1 millidarcy if only pre-stimulation data is considered. From these results, the expected value of permeability to be found in a well drilled to and completed in the Travis Peak in Districts 5 and 6 is less than 0.1 millidarcy.

STABILIZED PRODUCTION RATES

Stabilized flow rate at atmospheric (wellhead) pressure prior to any treatment was supplied by various operators for some of the wells. For others, this was computed by Core Laboratories, Inc. from data submitted by the operators. After determining permeability, various equations were utilized in determining stabilized flow rates prior to stimulation, In the absence of pre-stimulation data, post-treatment production data was used to determine formation permeability and stabilized flow rate. (See Exhibit 14).

Results for stabilized flow rate were obtained from 606 successful completions in the Travis Peak formation (See Exhibit 15). Stabilized flow rate versus cumulative frequency was plotted, and the data shows that sixty-eight percent of these 606 completions have stabilized flow rates below the maximum permissible rate. Based on this study, the expected stabilized flow rate for a well drilled to and completed in the Travis Peak will be less than the maximum permissible rate.

PERMEABILITY AND STABILIZED FLOW RATE ADJUSTMENTS

In addition to wells that have been completed in the Travis Peak, there have been approximately 1,300 wells which penetrated the Travis Peak but were not completed in the Travis Peak because it was too tight. Sufficient test data to determine in-situ permeability and stabilized flow rate are not generally available for these wells. However, if the 1,300 wells were not completed because the Travis Peak was too tight in these wells, i.e., less than 0.1 millidarcy, and if these wells had been included in the previous results, then the chance of achieving a well with a permeability less than 0.1 millidarcy would be increased to eight-four percent. Similarly, the chance of achieving a well with a stabilized flow rate less than the maximum permissible rate would be increased to eighty-four percent.

OIL PRODUCTION RATES

The Travis Peak is primarily a gas reservoir. The Railraod Commission's production reports for 1980 indicate that ninety-six percent of the production from the Travis Peak on a BTU basis was natural gas. Of the active Travis Peak completions in 1980, only eleven percent produced as much as five barrels of crude oil per day. A review of the completion reports for Travis Peak oil wells indicates that the normal completion procedure includes hydraulic fracturing. Since the 1980 reported production rates are post-stimulation, the production rates prior to treatment would be significantly lower.

A study of the completion reports for gas wells completed in the Travis Peak shows that the liquids produced from such gas wells is condensate, not crude oil. Gas wells comprise about eight percent of the completions in the Travis Peak. Based on that data, the Commission finds that the Travis Peak is primarily a gas formation and that a well drilled to the Travis Peak would not be expected to produce five barrels or more of crude oil per day.

III.

WELLS IN RECOMMENDED FORMATION

A list of wells which have produced from the recommended formation has been compiled (See Exhibit 12).

IV.

PROTECTION OF FRESH WATER

Existing state or federal regulations will assure that development of the Travis Peak will not adversely affect any fresh water aquifers that are or are expected to be used as a domestic or agricultural water supply. In Texas, the Railroad Commission has the statutory responsibility for protecting surface and subsurface water from oil and gas production-associated activities. TEX. WATER CODE ANN. §26.131 (Supp. 1980) ("The Railroad Commission of Texas is solely responsible for the control and disposition of waste and the abatement and prevention of pollution of surface and subsurface water resulting from activities associated with the exploration, development, and production of oil or gas or geothermal resources.") The Commission is required by statute to enforce proper casing and plugging that will protect surface or fresh water. TEX. NAT. RES. CODE ANN. §§91.011, 91.012 (1979). Legislation also allows the Commission to adopt and enforce rules and orders which relate to the prevention of pollution in regard to drilling, producing, and operating oil and gas wells. Id. at §91.191. The Commission has done so through adoption of statewide rules with safeguards for protection of any fresh water aquifers that are presently being used or are expected to be used as a domestic or agricultural water supply. See Statewide Rules, Tex. R.R. Comm'n., Oil and Gas Div. Additionally, federal statutues promote the protection of waters from a wide range of activities, including some which are oil and gas related. Together, state rules in Texas and federal regulations will protect any fresh water supply that may be affected by drilling in the aforementioned recommended tight formation.

In the recommended area, usable-quality water is protected to at least 3,000' in some areas (specifically Anderson and Cherokee Counties). The top of the recommended formation ranges from 3,140' to 10,850'. The extensive rock strata between any fresh water and the Travis Peak formation will prevent communication. No fresh water supply will be affected by drilling in the afore-mentioned recommended tight formation.

V.

CONCLUSION

In alignment with the procedures outlined at 18 C.F.R. §271.703(c)(3) (1980), the contents of this recommendation evidence that the Travis Peak is within FERC guidelines for being designated as a tight formation as that term is outlined at 18 C.F.R. §271.702(c) (2) (1980). Estimated average in-situ permeability throughout the pay section is expected to be 0.1 md or less. The stabilized production rate of wells in the Travis Peak has been determined to be in accordance with the table set forth at 18 C.F.R. §271.702(c) (B) (1980). No well drilled into this formation is expected to produce more than five barrels of crude oil per day. In summation, this recommendation contains the required information which proves that the guidelines for a tight formation under 18 C.F.R. §271.702(c) (2) are met by the subject formation. Based on the research and analysis conducted in the preparation of this recommendation, the Commission has no knowledge of information which is inconsistent with this conclusion.

THEREFORE, the RAILROAD COMMISSION OF TEXAS hereby recommends to the FEDERAL ENERGY REGULATORY COMMISSION that the TRAVIS PEAK FORMATION in Texas be designated as a tight formation.

Issued in Austin, Texas on OCTOBER 26, 1981.

RAILROAD COMMISSION OF TEXAS

Jim Nugent
CHAIRMAN

Mack Wallace
COMMISSIONER

Buddy Temple
COMMISSIONER

ATTEST:

Elizabeth Marrapoulis
Secretary

TESTIMONY BEFORE THE FEDERAL ENERGY REGULATORY COMMISSION

WASHINGTON, D. C.

November 12, 1982

Mr. Chairman:

My name is Myron Dorfman, and I am Director of the Texas Petroleum Research Committee, which is the research adjunct of the Texas Railroad Commission. I also serve as Chairman and Harkins Professor of the Department of Petroleum Engineering at The University of Texas at Austin. Commissioner Nugent, Chairman of the TRC, has asked me to appear today on behalf of the Texas Railroad Commission to state my views regarding methodology of determining average permeability and flow rates in tight reservoirs.

It has been recognized throughout the industry for several decades that permeability follows a Lognormal Distribution, which is a skewed geometric distribution rather than a Normal or Gaussian Distribution, and numerous papers have been published on this subject. A Lognormal Distribution is one in which the variable, in this case permeability, is said to be Lognormally distributed if the logarithm of the particular variable is Normal or Gaussian, rather than the variable itself. This distribution is common in nature, and shows concordance with our concepts of how mineral deposits are formed. For example, a statistical analysis of the size distribution of oil and gas fields follows a lognormal plot, and the average field size is only .3% of the largest giant fields. (Kaufman, 1965) An arithmetic average value would result in an absurdly high value, which would bear no relationship to "expected" or "most probable" occurence, which is the purpose of such a statistical analysis. Similarly, grain size distribution in nature is lognormal, with clay size particles representing over 50% of the spectrum of clastic particles, as exemplified in the Mississippi River where clay represents some 84% of particles at it's mouth; this is why the river is "muddy". A frequency plot of grain size is always lognormally distributed, with the average size considerably lower than arithmetic or Normal Distribution average.

Many other examples occur in nature, such as decay rate of neutrons into thermal neutrons, and this lognormal parameter is used in well logging to determine residual fluid saturations based upon pulsed neutron bombardment and consequent decay of neutrons when encountering hydrocarbons.

To show an example of such lognormal distribution, the following table indicates core permeabilities from a barrier-bar 8' thick in the East Texas area:

Depth in ft.	Permeability in md.
3,991	493
3,992	22
3,993	50
3,994	41
3,995	53
3,996	69
3,997	17
3,998	2.01
3,999	Shale

This barrier-bar is typical of many reservoirs, and is the equivalent of a Padre Island, Texas, buried in the subsurface and enveloped in shale. If we were to take an arithmetic average permeability of these 8', the result would be 747.01/8 = 93.4 md. Now, consider the likelihood of encountering a sandstone with this permeability -- just lay out horizontally the 8' of core and ask yourself "what is the probability of encountering a zone with 93.4 md. permeability?" The answer, of course, is essentially zero. There is a 12½% probability of 2 md., a 75% probability of 17-69 md., and a 12½% probability of over 400 md. being drilled. Clearly, an arithmetic average permeability is not the way to find the "most probable value" of permeability.

However, if we take the logarithm of each permeability value and divide by 8 we get 12.42/8 = 1.55; the anti-logorithm is $10^{1.55}$ = 35.5 md. This represents the most "probable value" of permeability based upon Lognormal Distribution, and is in accord with the probability distribution discussed earlier. I repeat, this process has been found feasible and accurate in the sediments bearing petroleum throughout the world. Although the above example is not in the "tight" zone range, it remains typical for any geological system, regardless of where the decimal point is located on the permeability scale.

Another typical example is found in an early paper (Warren, Sibka and Price, 1961) in which the results are confirmed by pressure buildup tests:

Zone	# of Samples	PERMEABILITY Arithmetic Avg.	Lognormal Avg.	Buildup Test
Bromide Sand, Oklahoma	203	2.97	.39	.30
	134	12.56	.86	.50
	305	31.55	.83	2.80
	223	7.49	1.30	.80
	173	37.80	.88	1.00
	173	4.58	.83	.20
	160	148.00	17.20	5.72

Although pressure buildup tests may be affected by various mechanical factors, note that in every case the arithmetic average is an order of magnitude greater than the average permeability by both pressure buildup tests and by log-normal distribution average permeability. This paper represents a clearcut example of actual field testing validating the use of Lognormally Distributed permeabilities, and the great discrepancy that occurs by use of Normal Distribution in computing "average permeability".

To better illustrate graphically the discrepancies that may occur using arithmetic averaging in determination of average permeability, Table I shows a frequency distribution of permeabilities in the Bradford Sand, of Devonian age, in Pennsylvania. Permeabilities range from .05 md. to 100 md. A total of 481 samples are contained in this set, taken from Levorsen, 1967. Note that the arithmetic average permeability, shown as K_{avg} = 7.17 md., whereas the lognormal average permeability, shown as K_{log} = 1.78 md.

Now turn to the two attached graphs showing the plots of these values. The first shows a cartesian plot of permeability, with the arithmetic average value. Note that the plot is a curve, and the arithmetic average represents approximately 30% of the frequency distribution of samples. This plot is heavily skewed upward in value by a relatively few high permeabilities.

The second plot, on semi-logarithmic paper, represents a much more accurate method of permeability representation. Note that the values when plotted on log paper fall in a straight line. The lognormal average permeability, calculated at 1.78 md. falls very close to the 50% frequency as it should, and the arithmetic average shows the discrepancies that result from a few high permeability values.

Every practicing petroleum engineer is aware of the fact that permeabilities are plotted lognormally for every purpose, and such a plot yields a straight line as lognormal distribution suggests. In using statistical methodology to determine "most probable value", the invalidity of arithmetic averaging as applied to permeability determinations is well established and it's use is incorrect, and meaningless.

Regarding flow rate, the same argument can be made. Flow rates in petroleum reservoirs involving single-phase fluids are based upon Darcy's Law, as follows:

$$Q = \frac{kA}{\mu}\frac{dP}{dX}$$

Where: Q = Flow rate
k = Permeability
A = Cross sectional area
dP/dX = Pressure drop per unit length
μ = Fluid viscosity

Since all values other than permeability are given quantities, the flow rate of a well is directly proportional to the permeability, and since we have already shown that permeability distribution is lognormal, it naturally follows that flow rates must also be lognormal. Therefore, Lognormal Distribution must be used in determining the average flow rate. All AOF (Actual Open Flow) and Isochronal Well Tests used to determine flow rate of gas wells are plotted on log paper, for this reason. (Frick, 1962)

The references below give considerable documentation on both the mathematical formulation of Lognormal Distribution, and actual data from the field used by the authors to show the correct useage of Lognormal Distribution, for determination of average permeability, as well as flow rates of gas wells.

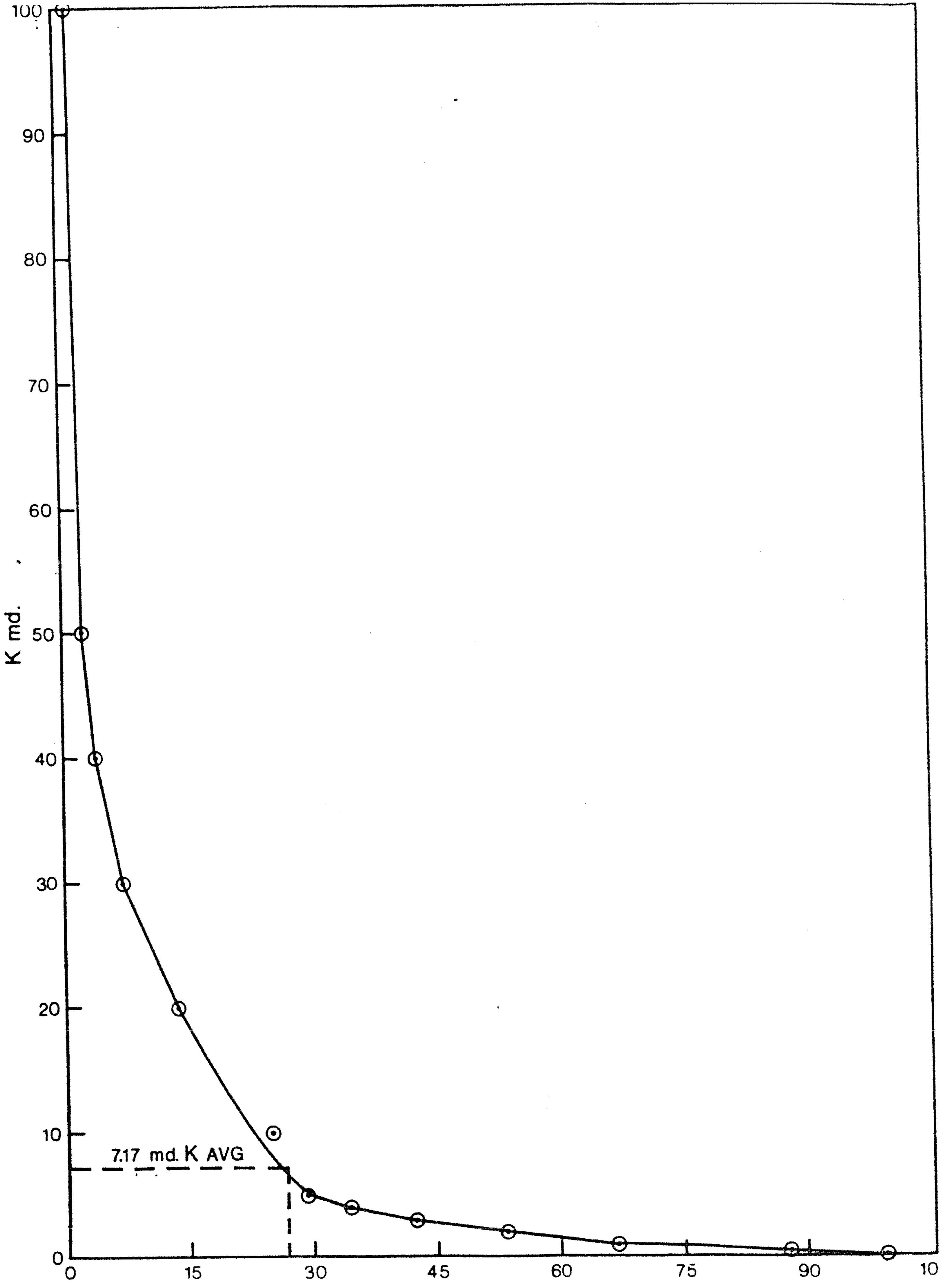
References

Levorsen, A. I., 1967, Geology of Petroleum. Freeman & Co.

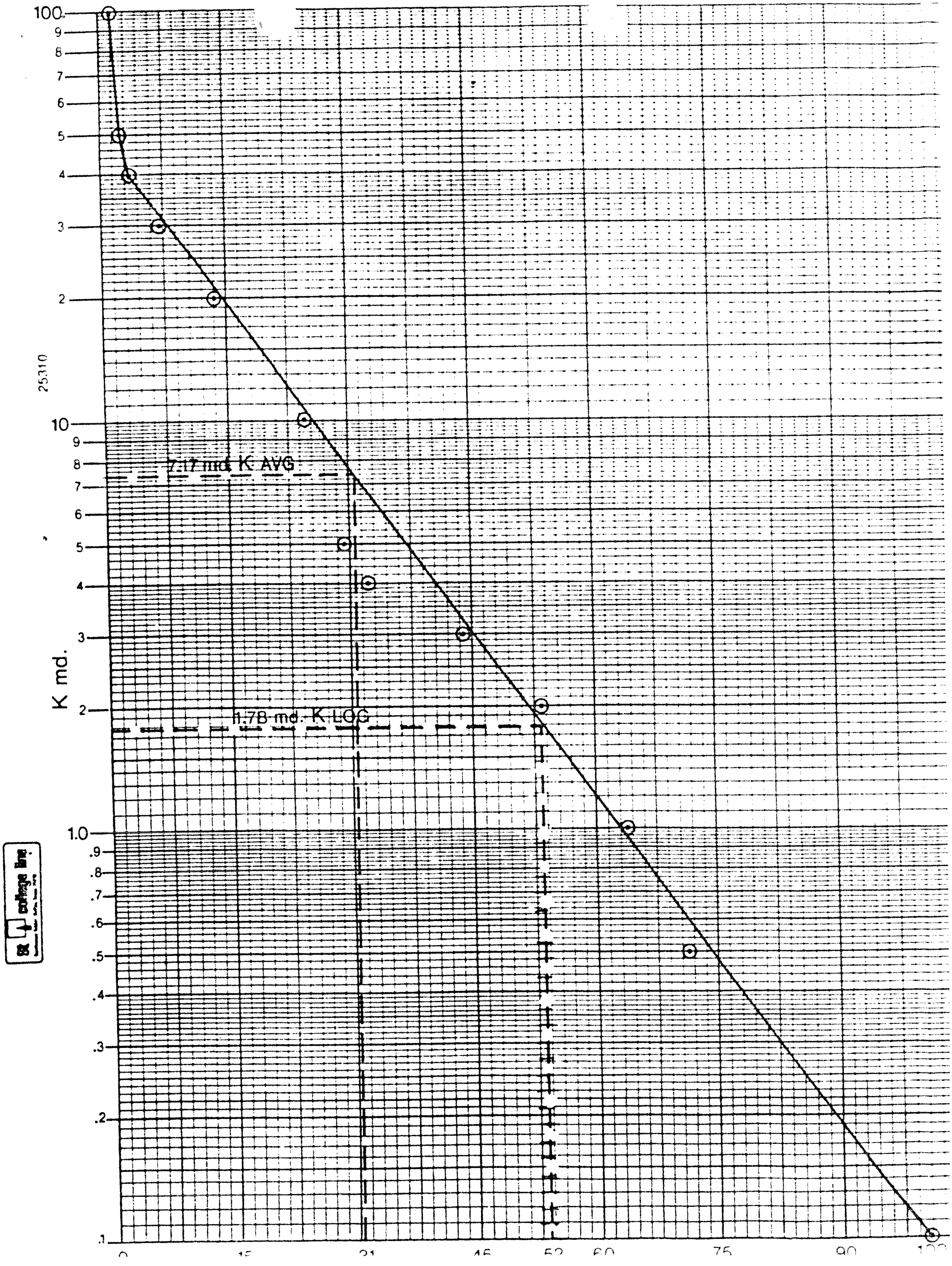
Warren, J. E., Skiba, F. F. and Price, H. S. On Evaluation of the Significance of Permeability Measurements, AIME Trans. 1961.

Kaufman, G. M. Statistical Analysis of the Size Distribution of Oil and Gas Fields, AIME Trans. 1965.

Frick, T. C. Petroleum Production Handbook Vol. I, 1962, McGraw-Hill Inc.



K md.
100
90
80
70
60
50
40
30
20
10
0
7.17 md. K AVG
0
15
30
45
60
75
90
10



100
10
1.0
K md.
7.17 md. K AVG
1.78 md. K LOG
0
15
31
45
53
60
75
90
25310
college line

TABLE I

BRADFORD SAND (DEVONIAN), PENNSYLVANIA

K md.	# OF SAMPLES	# X K	FREQUENCY %	K_{LOG}	# X K_{LOG}
.05	29	1.45	6	-1.3	-37.7
.1	29	2.9	6	-1.0	-29
.5	100	50	20.8	- .3	-30
1.0	67	67	14	0	0
2.0	52	104	10.8	.3	15.6
3.0	38	114	8	.477	18.1
4.0	26	104	5.4	.602	15.6
5.0	15	75	3.1	.698	10.5
10	58	580	12	1.0	58
20	32	640	6.6	1.3	41.6
30	16	480	3.3	1.477	23.6
40	7	280	1.5	1.602	11.2
50	5	250	1.0	1.698	8.5
100	7	700	1.5	2.0	14
	481	3,448.35	100.0		120.0

K_{AVG} = 3,448.35/481 = 7.17 md.

K_{LOG} = 120/481 = .2495 $10^{.2495}$ = 1.78 md.

(FROM LEVORSEN, 1967)

APPENDIX C

Well Code, Exhibit 15

PROPOSED EXCEPTIONS TO DESIGNATION OF TRAVIS PEAK FORMATION AS A TIGHT FORMATION INSOFAR AS ONLY THE TOP 200' OF TRAVIS PEAK FORMATION IS CONCERNED.

Well Code: 055, 069, 070, 091, 110, 188, 193, 218, 228, 251, 269, 414, 583, 586, 612, 613, 614, 616, 669, 696, 765, 813, 826, 840, 855, 858, 868, 873, 881, 884, 890, 896, 913, 927, 936, 954, 1007, 1015, 1034, 1045, 1058, 1083, 1106, 1161, 1163.

TIME LINE FOR RAILROAD COMMISSION REVIEW OF TRAVIS PEAK TIGHT SAND APPLICATION

October 26, 1981	Order of RRC recommending all oil and gas wells in Travis Peak Districts 5 and 6.
January 22, 1982	FERC notified RRC of its objections.
1982	Myron Dorfman, Bob Whiting asked to study geometric v. arithmetic averaging.
1983	RRC staff study of evidence in view of FERC positions assigned to Gregory Waner.
September 19, 1983	RRC enters new order recommending gas wells only and excluding top 200 feet of certain shallow wells.

DOCKET NO. 5-76,659
EXHIBIT NO. Ex 1
DATE 3/13/90

SCHEDULE PROPOPOSED BY EP OPERATING COMPANY

* I. Discovery

A. April 2: -16 Requests for document discovery and depositions

B. April 12: -30 Delhi responses due

C. May 8: Hearing, if needed, for discovery disputes

D. May 17: Documents to be produced

E. May 31 - June 3: Deposition of Delhi experts

II. Depositions of testifying experts: August 28 - September 7

III. Hearing: September 18

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