FEDERAL ENERGY REGULATORY COMMISSION
WASHINGTON, D.C. 20426

AUG 3 1 1983

N840-A

James W. Shelton
Assistant District Manager for Minerals
United States Department of the Interior
Bureau of Land Management
505 Marquette Avenue, N.W., Suite 815
Albuquerque, New Mexico 87102

In Re: Docket No. RM79-76-204
(New Mexico-25)
Pictured Cliffs Formation
Rio Arriba and Sandoval Counties

Dear Mr. Shelton:

On May 20, 1983, the Commission received the recommendation by the State of New Mexico, Energy and Minerals Department, Oil Conservation Division (New Mexico), that the Pictured Cliffs Formation located in portions of Rio Arriba and Sandoval Counties, New Mexico, be designated as a tight formation. A Notice of Proposed Rulemaking concerning the recommendation was issued on June 15, 1983, and established a comment period ending July 30, 1983.

Included as part of New Mexico's recommendation is your letter of May 3, 1983, which concurred in part with the recommendation. Your letter additionally recommended that certain areas be included and others be deleted as discussed below.

With respect to areas which you recommend be added you indicate that certain Federal units appeared to be arbitrarily excluded based on acreage position. However, based on geologic parameters you believe these areas should be included. Our review of the data also indicates that Sections 26 through 28, E 1/2 of Section 33, Sections 34 and 35, and the S 1/2 of Section 36, Township 24 North, Range 3 West meet the geologic criteria and should be included in the area for consideration. The inclusion of this acreage is reflected in the Notice of Proposed Rulemaking issued on June 15, 1983.

With respect to the area which you indicate should be deleted your letter states that "although the Pictured Cliffs sands may be tight in the southwest corner of the proposed area, our data suggests that it is not part of the same trend as the Ballard Pictured Cliffs." The Commission's guidelines in this regard require only that the area being recommended exhibit tight formation characteristics as defined in the regulations. These guidelines would not necessarily require that the designated area be in the same geologic trend.

The comment period with respect to this formation ended on July 31, 1983. One comment opposed to New Mexico's recommendation was timely filed by Northwest Pipeline Corporation and one comment opposed to New Mexico's recommendation was untimely filed by Southern California Gas Company and Pacific Lighting Gas Supply Company (copies attached). We have requested that Northwest furnish the data referred to in its comments.

In light of your recommendation as well as the comments of Northwest Pipeline Corporation, Southern California Gas Company, and Pacific Lighting Gas Supply Company, we will continue to weigh the data submitted by New Mexico to the extent that it indicates that the whole of the proposed area meets the Commission's guidelines for designation as a tight formation.

Should you have additional evidence or comments regarding the exclusion of the southwest portion of the recommended area we would be most happy to consider them. Thank you for your cooperation.

Very truly yours,

Howard Kilchrist

Howard Kilchrist, Director
Division of Producer Audits
and Pricing

Attachments (2)

cc: W. Perry Pearce
Legal Counsel to the Oil
Conservation Division
Department of Energy and Minerals
P.O. Box 2088
Santa Fe, New Mexico 87501

William F. Carr
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P.O. Box 3249, Terminal Annex
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cc: John H. Belson
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J.S. Charles, Vice President
Regulatory Affairs
Northwest Pipeline Corporation
P.O. Box 1526
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Mary Duffin, Esquire
Northwest Pipeline Corporation
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Kim M. Clark, Esquire
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Washington, D.C. 20036

NORTHWEST PIPELINE CORPORATION

P.O. BOX 1526
SALT LAKE CITY, UTAH 84110-1526
801-583-8800

July 29, 1983

Honorable Kenneth F. Plumb
Secretary
Federal Energy Regulatory Commission
825 North Capitol Street, N.E.
Washington, D.C. 20426

Re: High Cost Gas Produced From Tight Formations, Docket No. RM79-76, New Mexico-25

Dear Mr. Plumb:

Transmitted herewith for filing are an original and fourteen (14) copies of Northwest Pipeline Corporation's comments in the above-captioned proceeding.

Respectfully submitted,

Mary Duffin

Mary Duffin
Attorney

MD/em
Encl.

UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

In the Matter of: High Cost Gas Produced from Tight Formations	Docket No. RM79-76 New Mexico-25

COMMENTS OF NORTHWEST PIPELINE CORPORATION

Northwest Pipeline Corporation ("Northwest") hereby submits its comments in the captioned docket. Northwest states as follows:

I.

Northwest Pipeline Corporation is a corporation organized and existing under the laws of the State of Delaware and has its principal place of business at 295 Chipeta Way, Salt Lake City, Utah 84108. All correspondence and communications concerning this Petition should be addressed to:

*J. S. Charles
Vice President, Regulatory Affairs
Northwest Pipeline Corporation
P.O. Box 1526
Salt Lake City, Utah 84110
Telephone: (801) 584-7082

Mary Duffin, Esquire
Northwest Pipeline Corporation
P.O. Box 1526
Salt Lake City, Utah 84110
Telephone: (801) 584-7051

*Kim M. Clark, Esquire
Akin, Gump, Strauss, Hauer & Feld
1333 New Hampshire Avenue, N.W., Ste. 400
Washington, D.C. 20036
Telephone: (202) 887-4000

*Designated to receive service in accordance with Section 1.17(c) of the Commission's Rules of Practice and Procedure.

II.

Northwest is engaged in the business of producing, purchasing, importing, transporting, and selling natural gas in interstate commerce. Northwest's gas transmission system extends from the gas producing areas of the San Juan Basin in New Mexico and Colorado through the states of Colorado, Utah, Wyoming, Idaho, Oregon, and the state of Washington, where it interconnects with the facilities of Westcoast Transmission Company, Limited at the International Boundary near Sumas, Washington. The major portion of Northwest's gas is sold for resale to certain municipalities, distribution and pipeline companies in the states of Colorado, Wyoming, Nevada, Idaho, Utah, Oregon, and Washington. Northwest Pipeline is a purchaser of natural gas produced from the Pictured Cliffs formation located in those portions of Rio Arriba and Sandoval Counties, New Mexico, which are the subject of this docket, and which have been designated by the New Mexico Energy and Minerals Department as tight formations. As such, Northwest is an interested party in the pending application.

On December 3, 1982, Northwest filed comments relative to the pending application when it was before the New Mexico Oil Conservation Commission. Northwest's comments before the New Mexico Commission were limited to that acreage which is part of the South Blanco Pictured Cliffs and Ballard Pictured Cliffs Pools, as those pools were established by the New Mexico Commission in Orders Nos. R156 and R577. Northwest's comments in this proceeding are also so limited.

Pursuant to New Mexico Commission Spacing Order No. R1670, the spacing in these pools has been established at four (4) wells per section. Records available to Northwest indicate that of the sixty-five (65) sections or partial sections included in the South Blanco Pictured Cliffs Pool, twenty-nine percent (29%) of the sections contain the maximum number of wells drillable in the section or partial section under current spacing rules. Fifteen percent (15%) of the sections or partial sections are seventy-five percent (75%) developed under current spacing rules. Thirty-seven percent (37%) of the sections or partial sections are fifty percent (50%) developed.

Records available to Northwest indicate that of the one-hundred three (103) sections or partial sections in the Ballard Pictured Cliffs Pool, forty-six percent (46%) of the wells contain the maximum number of wells drillable in the section or partial section under current spacing rules. Nine percent (9%) of the sections or partial sections are seventy-five percent (75%) developed, and four percent (4%) of the sections or partial sections are sixty-six percent (66%) developed under current spacing rules. Twenty-two percent (22%) of the sections or partial sections are fifty percent (50%) developed. In both the Ballard Pictured Cliffs and South Blanco Pictured Cliffs Pools, eighty-one percent (81%) of the sections are at least fifty percent (50%) developed.

Because of this significant degree of development within the boundaries of the South Blanco Pictured Cliffs and Ballard Pictured Cliffs Pools, Northwest submits that the Commission should carefully consider the need for an incentive price with respect to acreage located within the boundaries of the pools. The acreage within the pools may properly be deleted from the application and not given approval for tight sands incentive pricing, based on

the significant degree of existing development of the acreage, and the fact that where the developed acreage is not yet fully developed, it may be expected to be developed in the future without incentive pricing.

Additionally, Northwest has reviewed records available to it which relate to the South Blanco Pictured Cliffs and Ballard Pictured Cliffs Pools with respect to the permeability of certain acreage contained therein. Northwest reviewed complete production histories on twenty-five (25) wells, nineteen (19) of which are located in the South Blanco Pictured Cliffs Pool, and six (6) of which are located in the Ballard Pictured Cliffs Pool. Northwest has either connected these wells to its system or has a contract purchase interest in them. All of the wells reviewed had an initial delivery date of January, 1975, or later. Northwest discovered that of the twenty-five (25) wells reviewed, ten (10) of them, or forty percent (40%), do not meet the permeability standard of 0.1 millidarcy (md.) set down in FERC Order 99, issued in Docket No. RM79-76 (August 15, 1980). The twenty-five (25) well group had permeabilities ranging from 0.005 md. to 0.45 md., with an overall average permeability rate of 0.113 md. In view of this permeability data, Northwest submits that the acreage contained within the boundaries of the South Blanco Pictured Cliffs and Ballard Pictured Cliffs Pools may not qualify for incentive pricing pursuant to FERC Order 99.

Northwest recognizes that the Commission stated in Order 99 that, even if a formation does not meet the 0.1 permeability standard, the jurisdictional agency may still recommend the formation for tight sands pricing pursuant to NGPA Reg. Section 271.703(c)(2)(ii). This regulation states that "if the jurisdictional agency makes an adequate showing that the formation exhibits low permeability characteristics and the price established in paragraph (a) of this section is necessary to provide reasonable incentives for production of the natural gas from the recommended formation due to the extraordinary costs associated with such production," that the incentive price may still be granted even if the 0.1 permeability standard is not met. In this case, however, because of the significant degree of development in the South Blanco Pictured Cliffs and Ballard Pictured Cliffs Pools, production of gas from acreage in these pools manifestly does not entail the incurrence of "extraordinary costs," or, presumably, the development of the pool areas would be much more limited than it is.

III.

In view of the fact that permeability in numerous wells within the pools on which Northwest was able to obtain information significantly exceeds the permeability standard laid down in Order 99, and because the incentive price may not be necessary in order to compensate producers for "extraordinary" costs associated with drilling in the pool areas, Northwest urges the Commission to givew careful consideration to exclusion of the South Blanco Pictured Cliffs and Ballard Pictured Cliffs Pools from tight sands incentive pricing.

Further, because of the degree of development of the pool areas, Northwest urges the Commission to consider the underlying rationale for promulgation of the regulations which set forth the criteria applicable to receipt of tight sands incentive pricing as it considers the acreage contained

in the South Blanco Pictured Cliffs and Ballard Pictured Cliffs Pools which is part of this application. In Order 99, the Commission stated that, "consumers should not be required to pay a price higher than the otherwise applicable NGPA price unless there is a reasonable basis for assuming that a higher price is necessary and will result in an increased supply of gas." Northwest submits that the existence of the large number of wells within the South Blanco Pictured Cliffs and Ballard Pictured Cliffs Pools indicates that no incentive price is necessary with respect to said acreage. Further, Northwest submits that the probability is slight that the granting of an incentive price applicable to the acreage contained in these pools will result in an increase in gas supplies for the consuming public.

Northwest urges the Commission to carefully examine the existing degree of development and the permeability level of the acreage contained in the South Blanco Pictured Cliffs and Ballard Pictured Cliffs Pool areas of the application acreage to establish whether reliable evidence exists upon which a finding of the necessity of an incentive price with respect to said acreage can be based.

Respectfully submitted,

NORTHWEST PIPELINE CORPORATION

Mary Duffin, Attorney
Northwest Pipeline Corporation
Post Office Box 1526
Salt Lake City, Utah 84110
Telephone: (801) 584-7051

STATE OF UTAH)
: ss.
COUNTY OF SALT LAKE)

MARY DUFFIN, being first duly sworn, on oath, says that she is an attorney for Northwest Pipeline Corporation; that she has read the foregoing Comments of Northwest Pipeline Corporation and that, as such Attorney, she has executed the same for and on behalf of said Corporation with full power and authority to do so; and that the matters set forth therein are true to the best of her information, knowledge, and belief.

Mary Duffin
Mary Duffin, Attorney

SUBSCRIBED AND SWORN TO before me, the undersigned, this 29th day of July, 1983.

Notary Public for and in the
State of Utah,
Residing at Salt Lake City, Utah

My Commission Expires:

10-11-86

Rich

UNITED STATES OF AMERICA RECEIVED
FEDERAL ENERGY REGULATORY COMMISSION

OFFICE OF THE SECRETARY

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FEDERAL ENERGY REGULATORY COMMISSION

AUG -2 1983

OGC-NGPA

High-Cost Gas Produced from Tight Formations; Notice of Proposed Rulemaking	))))	Docket No. RM79-76-204 (New Mexico-25)

WRITTEN COMMENTS
SOUTHERN CALIFORNIA GAS COMPANY AND
PACIFIC LIGHTING GAS SUPPLY COMPANY

Pursuant to the procedures established by the Federal Energy Regulatory Commission (Commission) in its Notice of Proposed Rulemaking in the above docket, Southern California Gas Company (SoCalGas) and Pacific Lighting Gas Supply Company (PLGS) herein submit their comments on the recommendation of the New Mexico Energy and Minerals Department, Oil Conservation Division that the Pictured Cliffs Formation located in Rio Arriba and Sandoval Counties, New Mexico be designated as a tight formation. All correspondence and communication in connection with this filing should be addressed to:

Jeffrey E. Jackson
Attorney at Law
P. O. Box 3249, Terminal Annex
Los Angeles, California 90051
(213) 689-2075

John H. Belson
Regulatory Affairs
P. O. Box 3249, Terminal Annex
Los Angeles, California 90051
(213) 689-3765

I.

SoCalGas and PLGS are affiliated corporations which are organized and existing under the laws of the State of California. PLGS purchases gas from numerous sources and transports and sells that gas to SoCalGas which in turn, purchases, distributes and sells natural gas in the central and southern parts of the State of California. SoCalGas has over 3.8 million customers and provides natural gas service to a population of approximately 12.4 million.

II.

SoCalGas and PLGS are very much concerned with the upward trends in natural gas pricing at the wellhead. While the Natural Gas Policy Act of 1978 has gone a long way toward increasing the nation's short-term supply and availability of natural gas, its positive results have been accompanied by certain adverse impacts on gas distribution utilities such as SoCalGas. For example, natural gas prices in southern California and in other areas have already reached the market clearing level, a situation that, as markets for the gas are lost to alternative fuels, will further burden the residential consumer who is presently bearing the brunt of increased prices which have tripled in the past few years.

III.

In reviewing the subject application, SoCalGas and PLGS are concerned with the analytical approach employed by the applicant to try to qualify such a large area (approximately 234,000 acres) for tight formation designation. First, pertinent well testing, reservoir and geological data that are essential to a complete application apparently were not submitted. Secondly, well data showing good formation development and high production rates were inappropriately excluded from the average permeability calculation. Excluding unfavorable data in order to arrive at a low average in-situ permeability is unacceptable under the Commission's regulations. Finally, utilizing all of the limited data submitted, the calculated average in-situ permeability for the subject formation exceeds the allowable 0.1 millidarcy.

IV.

The in-situ permeability of tight formations is most accurately obtained from detailed analyses of core data, well logs and results of properly conducted well tests on a sample of wells representative of the reservoir under evaluation. In the subject proceeding, the applicant did not provide sufficient well test data or analysis to support the assertion that the reservoir qualifies as tight formation under CFR 271.703. In fact, the applicant stated on page 19 of the hearing transcript

that their study of the test results provided no precise permeability date for this area.

Because of inadequate well test data, the applicant attempted to arrive at an expected permeability value based on limited core analyses and unstabilized flow rate measurements. Core data from only four wells drilled in the 1950's were used by the applicant to calculate an average in-situ permeability. Most of the core data submitted were deemed inapplicable by the applicant and were excluded from the calculation. The applicant admittedly placed little confidence in using the core data method to arrive at a representative permeability value and stated that an analysis using Darcy's equation yields the best estimate of reservoir permeability value and stated that an analysis using Darcy's equation yields the best estimate of reservoir permeability of the Pictured Cliffs formation. However, flow rate data from only six wells were available for analyses. Overall, insufficient and inadequate reservoir data was presented to allow proper evaluation of the nearly 370 square miles proposed for designation.

In addition to not submitting sufficient well test data, the applicant has incorrectly excluded unfavorable data in the Darcy calculation and consequently arrived at an erroneously low value for the average in-situ permeability. The analytical approach for determining average permeability, as established by this Commission, is to calculate the arithmetic average of the

permeabilities of all productive wells tested in the application area. By using a representative sample in the analysis, reservoir inhomogeneities are properly reflected. Exclusion of unfavorable permeability or flow rate data is both misleading and inappropriate. In the subject application, the unstimulated short-term (24-hour) production rates for seven productive wells were submitted. Two of the seven wells had flow rates "too-small-to-measure" (TSTM) and one was a high producer. In calculating an average flow rate, the high flow rate data was incorrectly excluded based on the notion that the well had penetrated a highly prolific "sweet spot" at the same time the two wells which tested gas rates TSTM were included. The applicant provided little data to support the assertion that the "sweet spots" are abnormal formation developments and infrequent in occurrence.

The applicant also erred in using average values of reservoir parameters in the Darcy calculation. Such an approach does not correctly reflect localized differences in net pay thickness, static and flowing bottom hole pressures, wellbore radius and near-wellbore damages of individual wells. Using average values is especially inappropriate for nonhomogeneous formations such as the Pictured Cliffs where wells drilled from adjacent locations can exhibit significantly different reservoir characteristics. The permeability calculation based on Darcy's equation, as used by the applicant, is particularly sensitive to

the net pay thickness and bottom hole pressure at the drainage radius. In this submittal, the applicant used an average net pay thickness of 41 feet without providing any supporting data. This value does not agree with the core data summarized in applicant's Exhibit No. 19, which shows an average net pay thickness of 23 feet for the five productive wells (see Attachment 2). This discrepancy alone would increase the calculated average permeability by 80%, or from 0.04 md to 0.07 md. Similarly, no pressure data was submitted to substantiate the validity of assuming an average bottom hole pressure at drainage radius of 797 psi for all wells. An error of only 10% (resulting in a value of 717 psi) would yield a calculated permeability that is 24% higher than that estimated by the applicant. Furthermore, a variance of 20% could result in an error of as much as 56% in the calculated permeability. Hence, localized differences around each well must first be considered in calculating the individual well permeabilities and then the arithmetic average reservoir permeability calculated.

Although SoCalGas and PLGS do not support the applicant's approach of using average reservoir parameters to determine average in-situ permeability for tight formations, a revised analysis was prepared using all the available data to show the potential impact (see Attachment 3). The resulting arithmetic average of unstimulated flow rate for all productive

wells is 51.2 Mcf/day. Using this average flow rate and an average net pay thickness of 23 feet, the calculated in-situ permeability is 0.24 millidarcy. This revised in-situ permeability of 0.24 millidarcy exceeds the 0.1 millidarcy guideline to qualify for tight formation designation and demonstrates the hazard in excluding unfavorable data. The actual average reservoir permeability may be even higher if those tested wells that produced gas at rates that were too small to measure had near-wellbore damage or lower reservoir pressure or if individual wells were evaluated properly.

V.

In conclusion, SoCalGas and PLGS are firmly convinced that the subject application is incomplete and the analysis erroneous. Too little data was submitted to warrant consideration of such a large area. The applicant incorrectly excluded unfavorable data from the analysis and used unsupported data which is inconsistent with the methodology established by the Commission. The analysis by SoCalGas and PLGS utilizing the methodology recommended by the applicant and all of the limited data submitted indicates the average in-situ permeability exceeds the 0.1 millidarcy maximum allowable for tight formation designation.

For the reasons stated above, a tight formation designation for New Mexico-25 is inappropriate at this time. In the absence of additional data and additional analysis of that data demonstrating that the Commission's permeability guidelines are met, the Commission should reject the recommendation by New Mexico that this formation be designated a tight formation.

Respectfully submitted,

Jeffrey E. Jackson
Attorney for
SOUTHERN CALIFORNIA GAS COMPANY and
PACIFIC LIGHTING GAS SUPPLY COMPANY

VERIFICATION

STATE OF CALIFORNIA)
) ss.
COUNTY OF LOS ANGELES)

The undersigned, being first duly sworn, states that he is an attorney for Southern California Gas Company and Pacific Lighting Gas Supply Company, corporations; that he has read the foregoing document and knows the contents thereof and is informed and believes that the statements contained therein are true and correct; and that he is authorized to sign it on behalf of said corporations.

Jeffrey E. Jackson

SUBSCRIBED AND SWORN TO before me this 29th day of July, 1983.

Mae S. Yamamoto
NOTARY PUBLIC of the
State of California

OFFICIAL SEAL
MAE S YAMAMOTO
NOTARY PUBLIC - CALIFORNIA
LOS ANGELES COUNTY
My comm. expires AUG 30, 1985

CERTIFICATE OF SERVICE

I hereby certify that I have this day served the foregoing document upon each person designated on the official service list compiled by the Secretary in this proceeding.

Dated at Los Angeles, California this 29th day of July, 1983.

Jeffrey E. Jackson

Attorney for
SOUTHERN CALIFORNIA GAS COMPANY
and PACIFIC LIGHTING GAS SUPPLY COMPANY

Attachment 1

FIVE LAKES CANYON TIGHT GAS AREA

Unstimulated Natural Gas Production Tests
(From Exhibit No. 7 of the Application)

Note: (a) Wells 2 and 3 were cased hole tests. The well was evacuated of fluid, perforated, and tested for 24 hours.

(b) The other 6 wells were open hole tests. The well was air drilled through the Pictured Cliffs formation, then tested for 24 hours.

	OPERATOR	WELL	LOCATION	UNSTIMULATED NATURAL PRODUCTION RATE (MCFGPD
1.	Amerada Hess Corp.	Jicarilla H-4	SW/SE Section 9 T. 23 N., R. 2 W.	T.S.T.M.
2.	Amerada Hess Corp.	Jicarilla I-9	NW/SE Section 1 T. 23 N., R. 3 W.	24.5
**3.	Amerada Hess Corp.	Jicarilla I-10	NW/SW Section 2 T. 23 N., R. 3 W.	T.S.T.M.
4.	Amerada Hess Corp.	Jicarilla J-3	NW/NW Section 4 T. 23 N., R. 4 W.	T.S.T.M.
5.	Amerada Hess Corp.	Jicarilla D-3	NE/NE Section 1 T. 23 N., R. 5 W.	33.0
6.	Amerada Hess Corp.	Jicarilla F-15	NE/SW Section 18 T. 25 N., R. 5 W.	12.7
7.	Amerada Hess Corp.	Jicarilla B-17	NW/NE Section 20 T. 24 N., R. 5 W.	29.0
8.	Amerada Hess Corp.	Jicarilla C-3	NW/NW Section 35 T. 24 N., R. 5 W.	259.0

**Well data excluded - well not representative of area - dry hole.

Average of 7 wells (excluding #3) 51.2 MCFGPD.

Attachment 2

SUMMARY OF CORE PERMEABILITY DATA
(From Exhibit No. 19 of the Application)

	Well Name	Location	Total Sample Footage (ft)
1.	Amoco Production Company Jicarilla 358 No. 6	SW/NE Section 6 T22N, R2W	12
2.	Mobil Producing Texas and New Mexico Jicarilla A No. 1	SW/SE Section 18 T23N, R2W	16
3.	Amerada Hess Corporation Jicarilla B-4	SE/SE Section 19 T24N, R5W	24
4.	Amerada Hess Corporation Jicarilla F-5	NW/SE Section 16 T25N, R5W	41
5.	Conoco, Incorporated Jicarilla Apache AXI C-1	SW/SW Section 4 T23N, R5W	24
		AVERAGE	23

FIVE LAKES CANYON TIGHT GAS AREA
PICTURED CLIFF FORMATION

(From Exhibit No. 20 of the Application)

Calculation of Formation Permeability Using Darcy's Law

Darcy's Law: $Qg = .703\ kh \dfrac{(Pe^2 - Pwf^2)}{Ug\ T\ Z\ \ln(.61\ re/rw)}$

or $k = \dfrac{Qg\ Ug\ T\ Z\ \ln(.61\ re/rw)}{.703\ h\ (Pe^2 - Pwf^2)}$

where:

- k = permeability of formation - millidarcies
- Qg = gas flowrate, scf/day - average of 51,200 scf/day
- Ug = average gas viscosity - calculated to be 0.011 centipoise
- T = bottom hole temperature - 100°F - 560°R
- Z = average gas compressibility factor - calculated to be 0.927
- re = drainage radius for 160 acre spacing - 1489 feet
- rw = wellbore radius - 0.20 feet
- h = net pay height - average of 23 feet for the 5 productive wells with core data available in the tight gas area
- Pe = bottom hole pressure at drainage radius re - average of 797 psi for all wells in the tight gas area
- Pwf = flowing bottom hole pressure - assumed equal to atmospheric pressure for maximum flowrate - 12.2 psi surface, 13.0 psi bottomhole
- Gg = gas gravity - .7 - used for calculations of Ug and Z
- Pc = pseudo critical pressure - 688 psi used for calculation of Ug and Z
- Tc = pseudo critical temperature - 392°R used for calculation of Ug and Z

$$k = \frac{(51{,}200)\ (0.011)\ (560)\ (0.927)\ \ln\ (.61\ \ 1489/0.20)}{.703\ \ (23)\ \ (797^2\ -\ 13.0^2)}$$

$k = 0.24$ millidarcy