

MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS

**BY
BILL DONOVAN, P.E.**

**AUTOMATED MUDLOGGING SYSTEMS
780 E. PHILLIPS DR. S.
LITTLETON, CO 80122
(303) 794-7470 VOICE
(303) 794-4838 FAX**

COPIES OF THIS PAPER ARE ON OUR WEBSITE

www.mudlogger.com

CORPORATE MOTTO

“WE DON’T PASS GAS”

**MUDLOGGING GAS CONTENT RESULTS
COMPARED TO PRODUCTION HISTORY FOR CBM WELLS**

ACKNOWLEDGEMENTS

- THANKS TO JACK MC DERMOTT AND PHIL JACOB, EMPLOYEES OF AUTOMATED MUDLOGGING SYSTEMS WHO GATHER GOOD DATA
- THANKS TO J. M. HUBER CORPORATION FOR RELEASING DATA; ESPECIALLY TO BRIAN HUGHES AND SCOTT ZIMMERMAN
- THANKS TO DUGAN PRODUCTION CORPORATION; ESPECIALLY TOM DUGAN, JIM JACOBS AND KURT FRAGRELIUS
- THANKS TO MY TEACHERS AT THE COLORADO SCHOOL OF MINES; DR HILCHIE AND DR PICKETT
- THANKS TO THE SPE OFFICERS; MIKE EBERHARD, THE SPE PROGRAM CHAIRMAN AND YOU, THE AUDIENCE

**MUDLOGGING GAS CONTENT RESULTS
COMPARED TO PRODUCTION HISTORY FOR CBM WELLS**

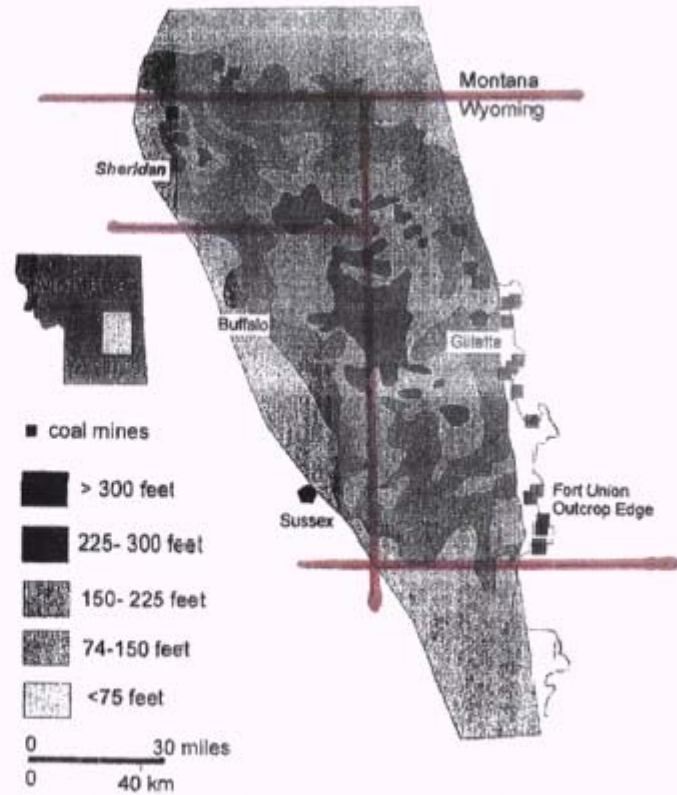
OUTLINE

- **INTRODUCTION AND ACKNOWLEDGEMENT**
- **PREMISES**
 - 1) **CBM GAS AND WATER PRODUCTION IS VARIABLE**
 - 2) **MUDLOG GAS CONTENT IS PREDICTIVE**
 - 3) **DESORPTION ISOTHERM DATA IS LESS PREDICTIVE**
- **RESULTS OF FOUR TOWNSHIP STATISTICAL STUDY**
- **RESULTS OF MUDLOGGING GAS CONTENT STUDY**
- **BACK CALCULATED VOLUMETRIC GAS CONTENT
COMPARED TO MUDLOGGING GAS CONTENT**
- **BACK CALCULATED VOLUMETRIC GAS CONTENT
COMPARED TO DESORPTION ISOTHERM VS DEPTH
CORRELATION**
- **OVERVIEW OF FACTORS AFFECTING CBM RESERVES**
- **MUDLOGGING GAS CONTENT METHOD HIGHLIGHTS**
- **SUMMARY**

MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS



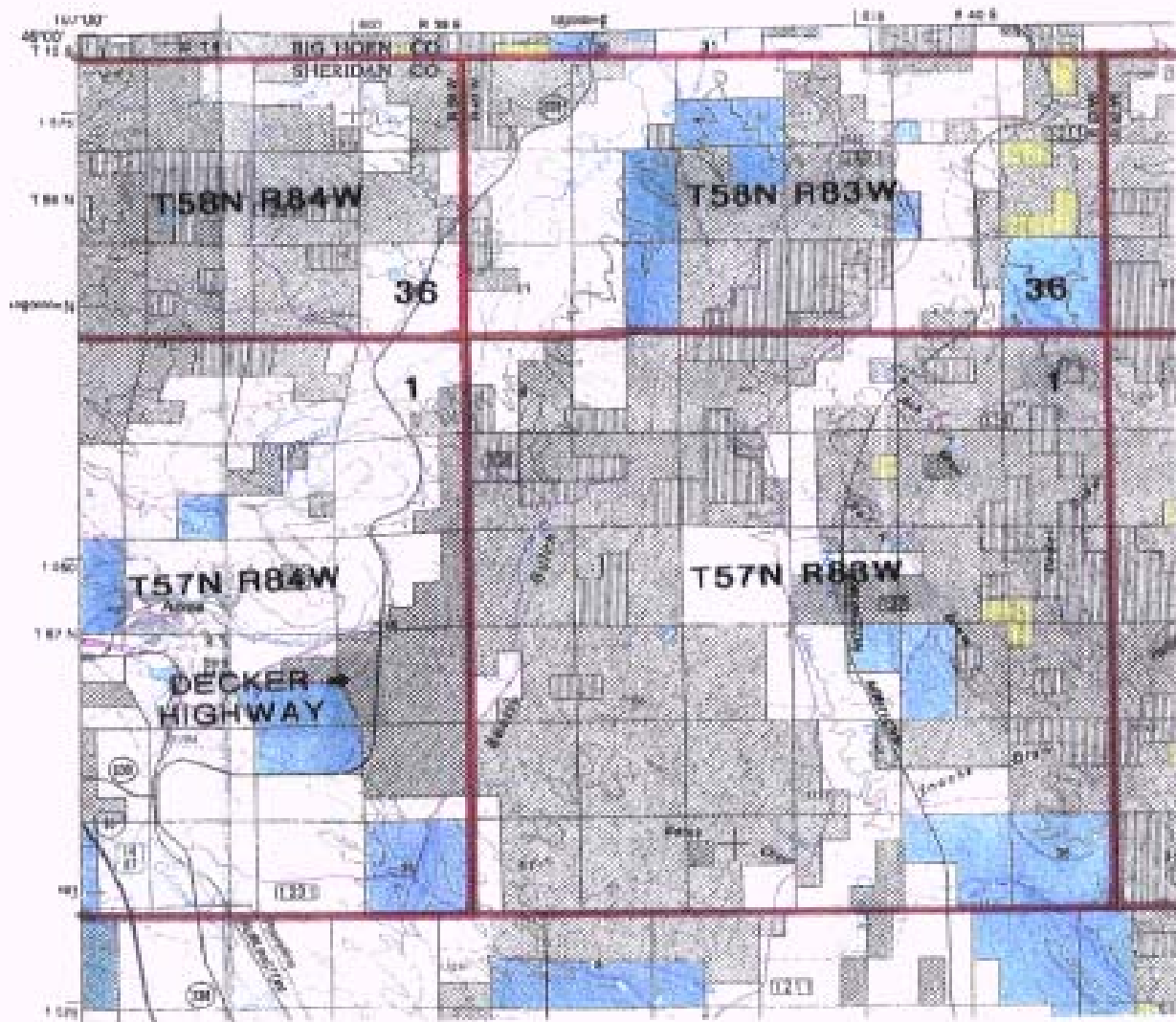
Geologic map of the Powder River Basin.



Net coal map of Fort Union Formation (modified from Montgomery, 1999)

FROM BUSTIN 1999

MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS

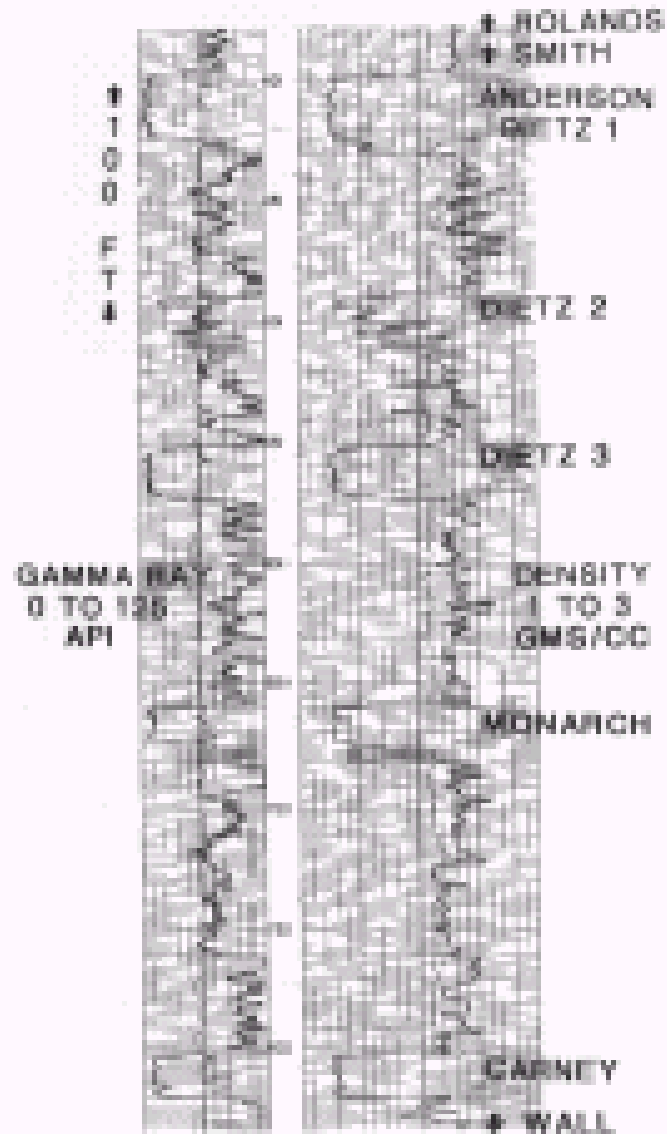


SHERIDAN, WY

↑ NORTH
← → 1 MILE

BLM
TOPOGRAPHIC
MAP

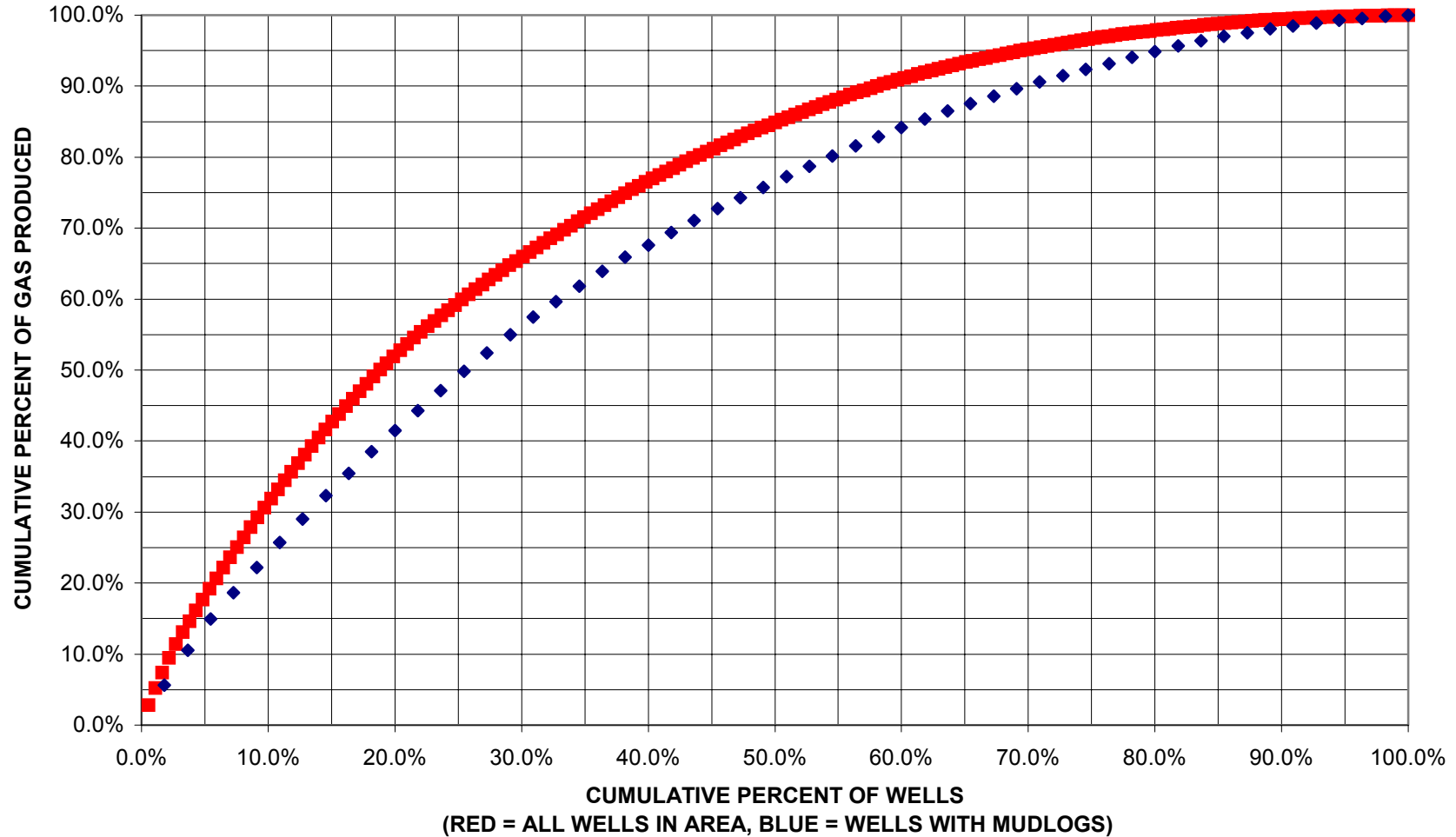
MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS



ERA	PERIOD	GROUP OR FORMATION	
Cretaceous	Fluvial	North Park and/or Benson's Park	
	Fluvial	White River	
	Fluvial	Bridge Green River Wind River	"Washakie"
	Fluvial	Fort Union	Fort Union
		Lance	

MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS

CUMULATIVE PERCENT OF WELLS VERSUS CUMULATIVE PERCENT OF TOTAL GAS PRODUCTION FROM WELLS PRODUCING 24 MONTHS OR MORE



MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS

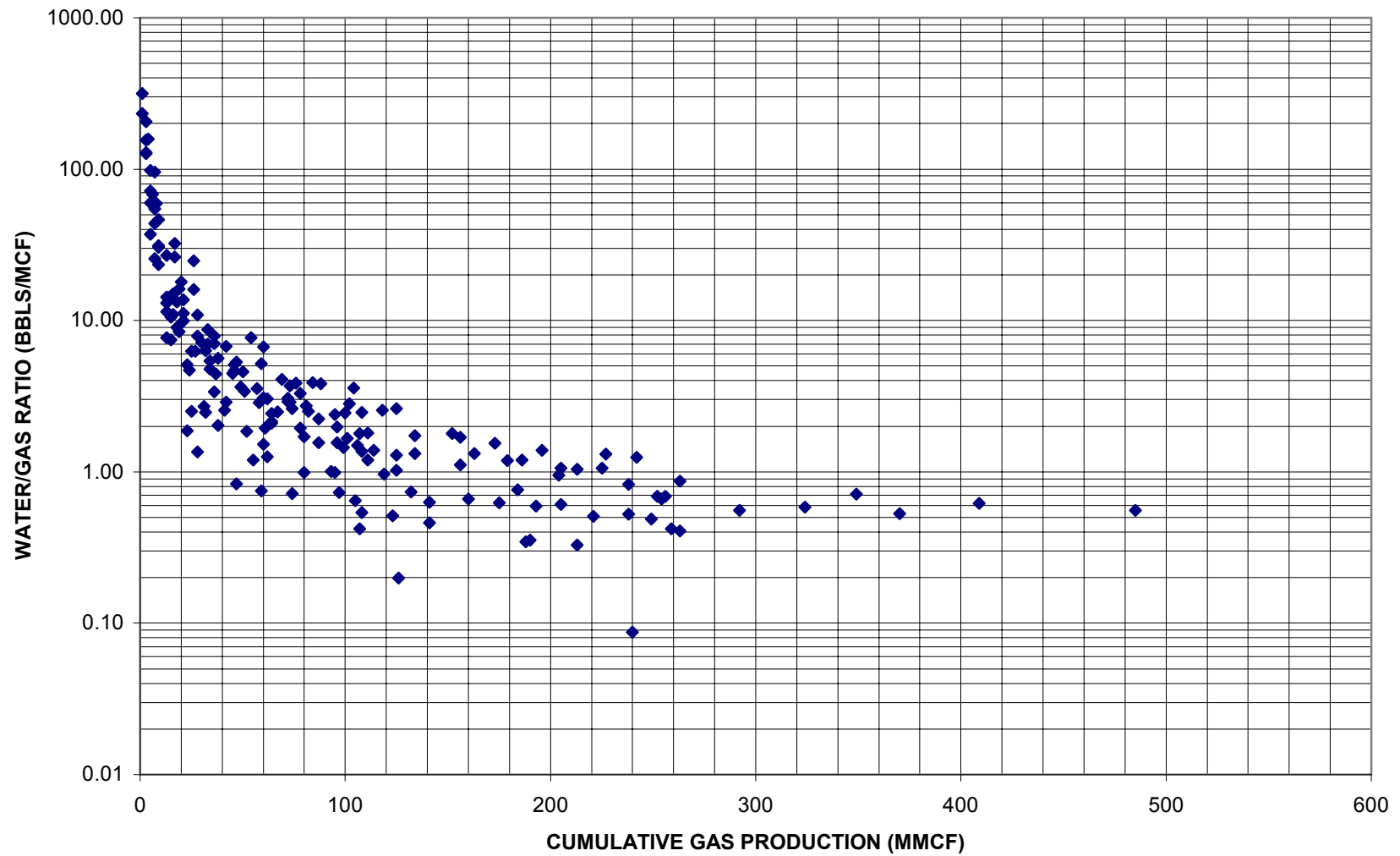
**20% OF THE WELLS PRODUCED 50% OF THE CUMULATIVE GAS PRODUCTION
50% OF THE WELLS PRODUCED 85% OF THE CUMULATIVE GAS PRODUCTION
THE REMAINING 50% OF THE WELLS PRODUCED ONLY 15% OF THE
CUMULATIVE GAS PRODUCTION**

DATA SET SUMMARY, WHICH SUPPORTS PREMISE 1: CBM GAS PRODUCTION IS VARIABLE

- CRITERIA FOR SELECTION ARE; 1) CBM WELLS, 2) GEOGRAPHIC LOCATION AND 3) LENGTH OF PRODUCTION
- 186 WELLS MET THE CRITERIA TO BE IN THE DATA SET
- PRODUCTION IS FROM SMITH, ANDERSON/DIETZ 1 (35%), DIETZ 2, DIETZ 3 (10%), MONARCH (20%), CARNEY (5%), CARNEY AND LOWER CARNEY (5%), DIETZ 3 AND MONARCH (8%), ANDERSON AND DIETZ, DIETZ AND SMITH COALS
- FOUR TOWNSHIP AREA: TOWNSHIPS 57 AND 58 NORTH AND RANGES 83 AND 84 WEST, SHERIDAN COUNTY, WYOMING
- PRODUCTION PER WOGCC AS OF 5/16/03 AND IS 24 MONTHS OR LONGER
- 90% OF THE WELLS HAVE BETWEEN 24 AND 37 MONTHS OF PRODUCTION
- SINGLE ZONE (83%) AND DUAL ZONES (17%)
- CUMULATIVE GAS PRODUCTION RANGES FROM 20 TO OVER 480 (MMCF) MILLION STANDARD CUBIC FEET OF GAS SALES
- CUMULATIVE WATER PRODUCTION RANGES FROM 25 TO OVER 675 (MBW) THOUSAND STANDARD BARRELS OF WATER PRODUCTION

MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS

CUMULATIVE GAS PRODUCTION VS. CUMULATIVE WATER/GAS RATIO



MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS

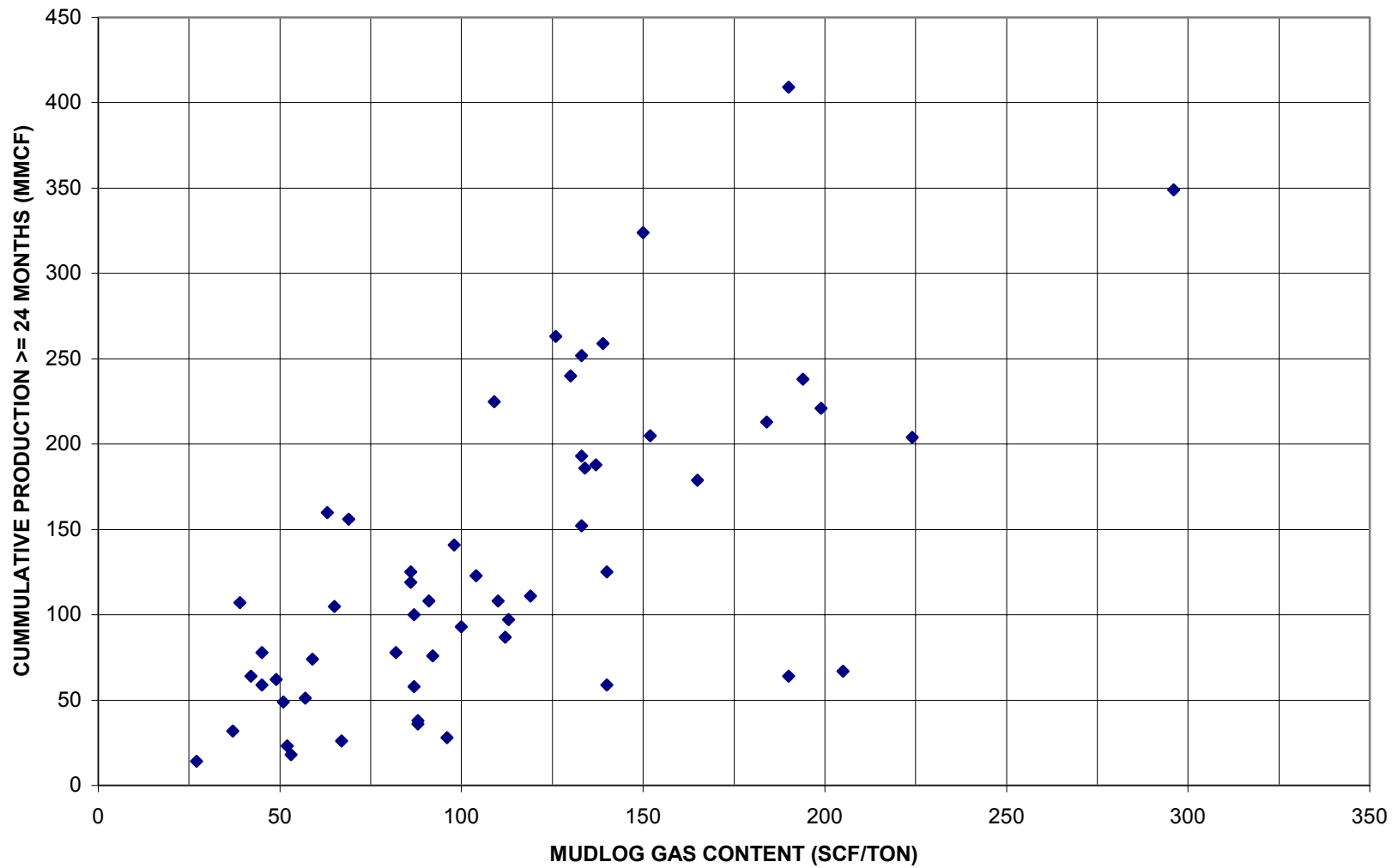
**WELLS WITH LOW WATER/GAS RATIOS PRODUCE MORE GAS
WELLS WITH HIGH WATER/GAS RATIOS FAILED TO PRODUCE SIGNIFICANT
AMOUNTS OF GAS AFTER 24 MONTHS OF PRODUCTION**

**DATA SET SUMMARY, WHICH SUPPORTS PREMISE 1: CBM WATER
PRODUCTION IS VARIABLE**

- SAME WELLS AS PRESENTED BEFORE AND SAME CRITERIA
- CRITERIA FOR SELECTION ARE; 1) CBM WELLS, 2) GEOGRAPHIC LOCATION AND 3) LENGTH OF PRODUCTION
- 186 WELLS MET THE CRITERIA TO BE IN THE DATA SET
- PRODUCTION IS FROM SMITH, ANDERSON/DIETZ 1 (35%), DIETZ 2, DIETZ 3 (10%), MONARCH (20%), CARNEY (5%), CARNEY AND LOWER CARNEY (5%), DIETZ 3 AND MONARCH (8%), ANDERSON AND DIETZ, DIETZ AND SMITH COALS
- FOUR TOWNSHIP AREA: TOWNSHIPS 57 AND 58 NORTH AND RANGES 83 AND 84 WEST, SHERIDAN COUNTY, WYOMING
- PRODUCTION PER WOGCC AS OF 5/16/03 AND 24 MONTHS OR LONGER
- 90% OF THE WELLS HAVE BETWEEN 24 AND 37 MONTHS OF PRODUCTION
- SINGLE ZONE (83%) AND DUAL ZONES (17%)
- CUMULATIVE GAS PRODUCTION RANGES FROM 20 TO OVER 480 MMCF OF GAS SOLD
- WATER/GAS RATIO RANGES FROM 300 TO 0.1 BBLS OF WATER/MCF OF GAS

MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS

MUDLOG GAS CONTENT VS GAS PRODUCTION



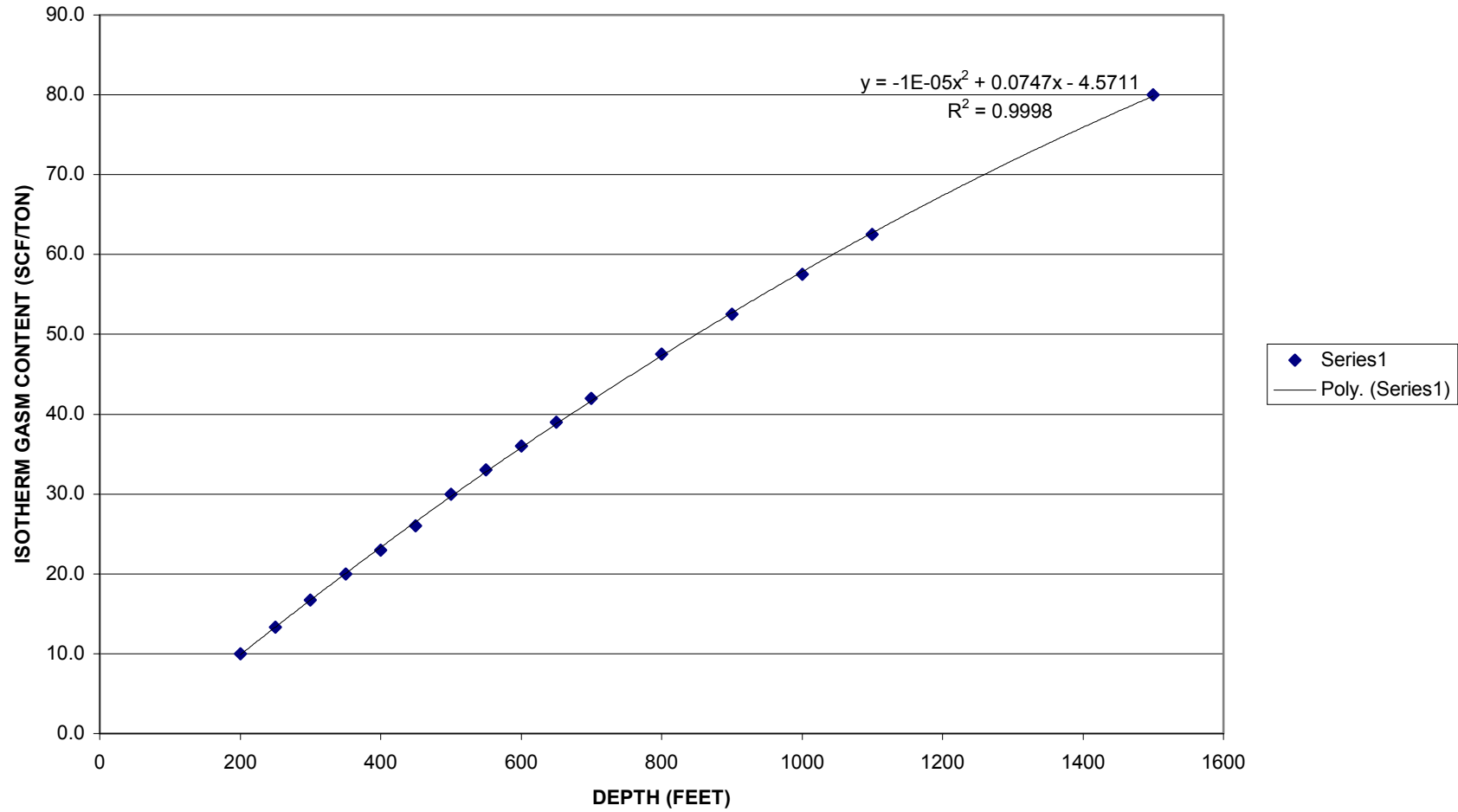
MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS

DATA SET SUMMARY, WHICH SUPPORTS PREMISE 2: MUDLOG GAS CONTENT IS PREDICTIVE

- CRITERIA FOR SELECTION ARE; 1) CBM WELLS, 2) GEOGRAPHIC LOCATION, 3) LENGTH OF PRODUCTION AND 4) MUDLOG DATA
- 55 WELLS MET THE CRITERIA TO BE IN THE DATA SET
- PRODUCTION IS FROM ANDERSON, DIETZ 3, MONARCH AND CARNEY COALS. ANDERSON COAL COMPLETIONS PREDOMINATE IN THIS DATA SET
- FOUR TOWNSHIP AREA: TOWNSHIPS 57 AND 58 NORTH AND RANGES 83 AND 84 WEST, SHERIDAN COUNTY, WYOMING
- ONLY WELLS MUDLOGGED BY AUTOMATED MUDLOGGING SYSTEMS FOR JM HUBER PRESENTED
- THESE WELLS ARE THE EARLIEST WELLS DRILLED IN THIS AREA. CURRENT WELLS USE BETTER DRILLING METHODS AND MUDLOGGING TECHNIQUES
- CALCULATED GAS CONTENT RANGES FROM 0 TO 300 SCF/TON
- CUMULATIVE GAS PRODUCTION RANGES FROM 0 TO 400 MMCF OF GAS SOLD
- PRODUCTION DATA IS FROM THE WOGCC AS OF 5/16/03 AND IS 24 MONTH OR LONGER
- ONLY SINGLE ZONE COMPLETIONS
- NO TOPSET MUDLOG DATA USED
- MUD DRILLING FLUID PREDOMINATELY USED
- AIR DRILLED WELLS TENDED TO FLOW AND FLOW RATES ARE REPORTED IN LIEU OF GAS CONTENT
- NOT CORRECTED FOR ZONE THICKNESS
- WELLS BROUGHT ON LINE AS PODS
- NO CORRECTION FOR MECHANICAL FAILURES, LINE FREEZES OR PIPELINE CAPACITY LIMITATIONS
- DATA FROM CERTAIN DRILLING RIGS EXCLUDED
- SIMPLEST METHOD FOR CALCULATING GAS CONTENT USED. NO CORRECTIONS MADE FOR RECYCLED GAS AND/OR MUD PUMP VOLUME.

MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS

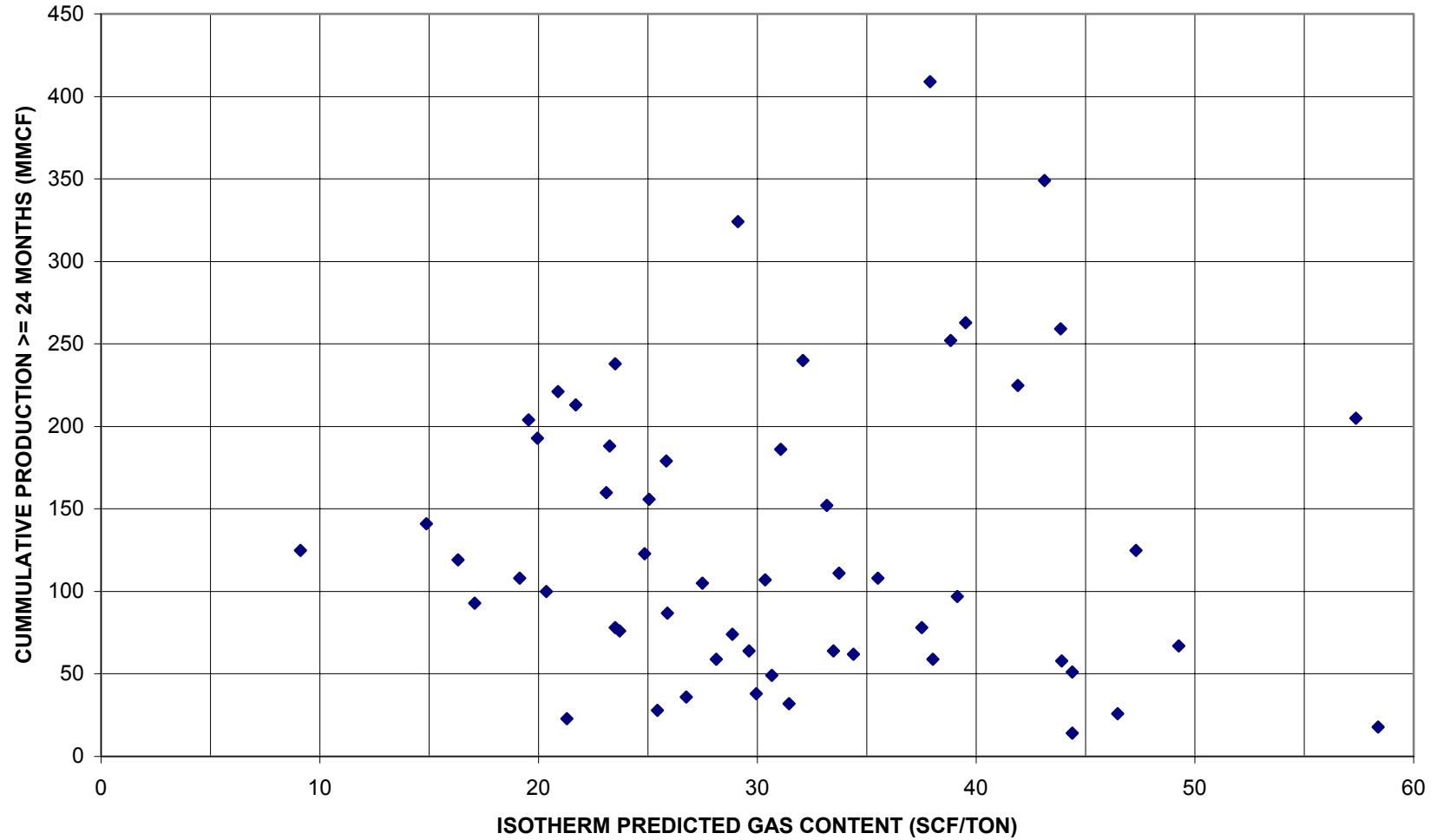
POWDER RIVER BASIN GAS CONTENT ISOTHERM



PERSONAL COMMUNICATIONS WITH DR. J GOOLSBY, GOOLSBY AND FINDLEY, ASSOCIATES

MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS

ISOTHERM PREDICTED GAS CONTENT VS GAS PRODUCTION EXPANDED SCALE



**MUDLOGGING GAS CONTENT RESULTS
COMPARED TO PRODUCTION HISTORY FOR CBM WELLS**

**“BACK CALCULATED” VOLUMETRIC GAS CONTENT BASED ON
PRODUCTION**

COMMON FORM OF VOLUMETRIC GAS-IN-PLACE (GIP) EQUATION FOR CBM RESOURCES

$$G = 1.3597 \times A \times H \times \rho_b \times GC$$

G = GAS-IN-PLACE (MCF)

A= DRAINAGE AREA (ACRES)

H= COAL THICKNESS (FEET)

ρ_b = COAL DENSITY (GRAMS/CUBIC CENTIMETERS)

GC = COAL GAS CONTENT (SCF/TON)

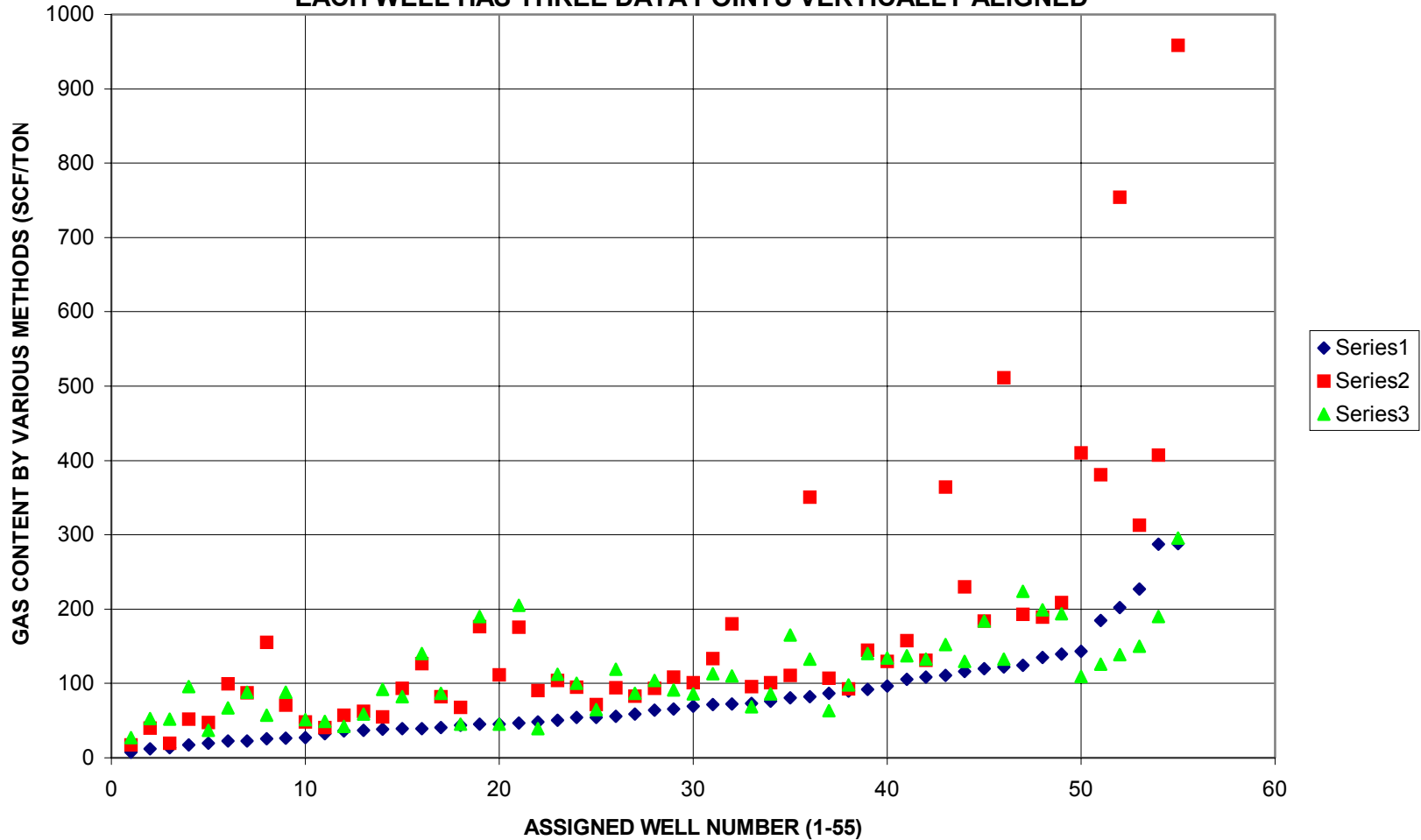
“BACK CALCULATED “ GAS CONTENT BASED ON PRODUCTION OR RESERVES

$$GC = \frac{G}{\left(1.3597 \times A \times H \times \rho_b \right)}$$

1. USE CUMULATIVE GAS PRODUCTION FOR LOW ESTIMATE OF GAS CONTENT
2. USE CUMULATIVE GAS PRODUCTION PLUS 48 TIMES CURRENT MONTHLY PRODUCTION FOR HIGH ESTIMATE OF GAS CONTENT
3. USE DRAINAGE AREA OR SPACING UNIT FOR “A” (40 ACRES)
4. USE COAL THICKNESS FROM LOGS FOR “H”
5. USE LOG OR MEASURED DENSITY FOR COAL DENSITY

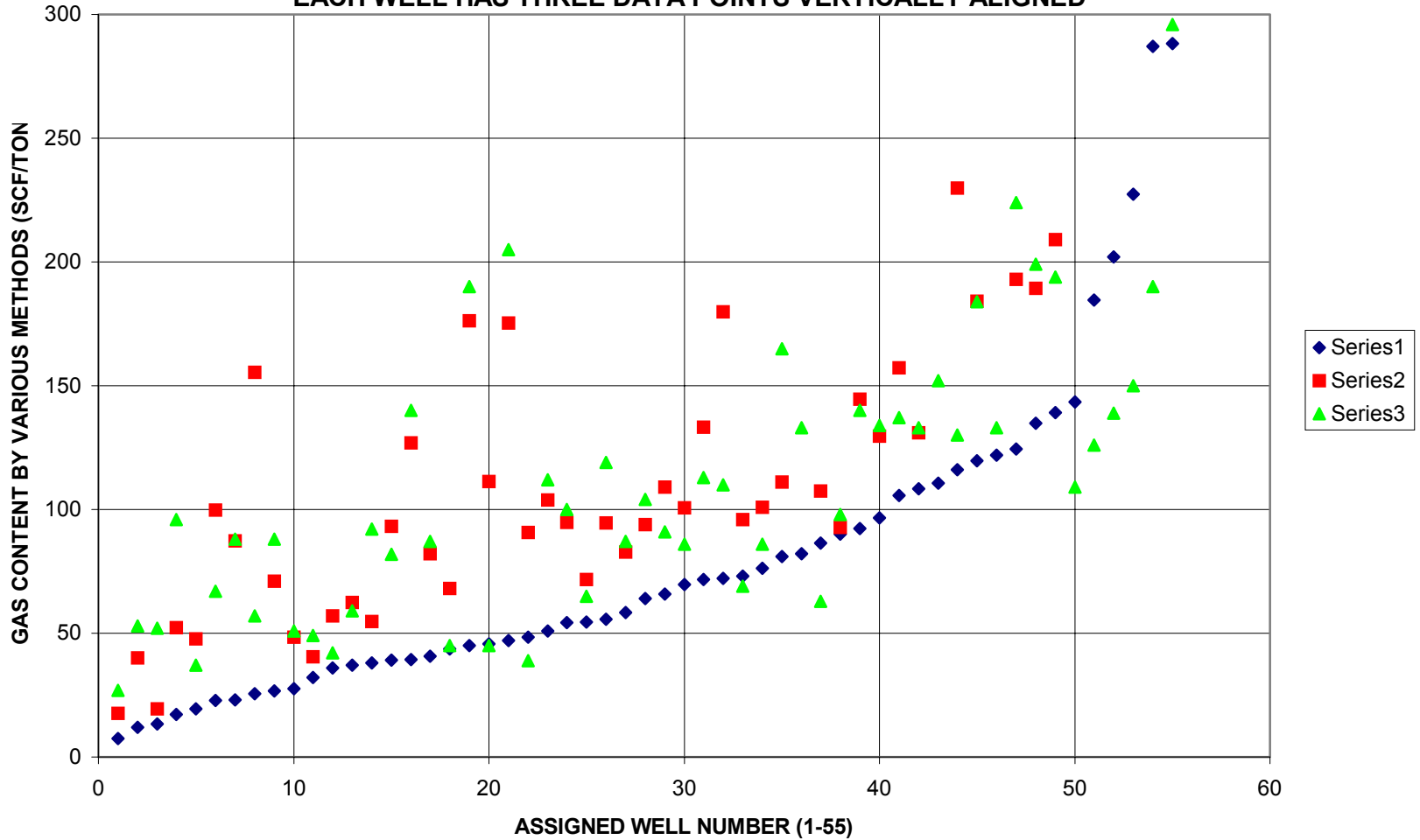
MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS

MUDLOG PREDICTED GAS CONTENT (GC) OF WELLS IN STUDY
GREEN IS MUDLOG GC , BLUE IS VOLUMETRIC GC USING ≥ 24 MO CUM PROD
AND RED IS VOLUMETRIC GC USING CUM PROD + 48 MO OF CURRENT PROD
EACH WELL HAS THREE DATA POINTS VERTICALLY ALIGNED



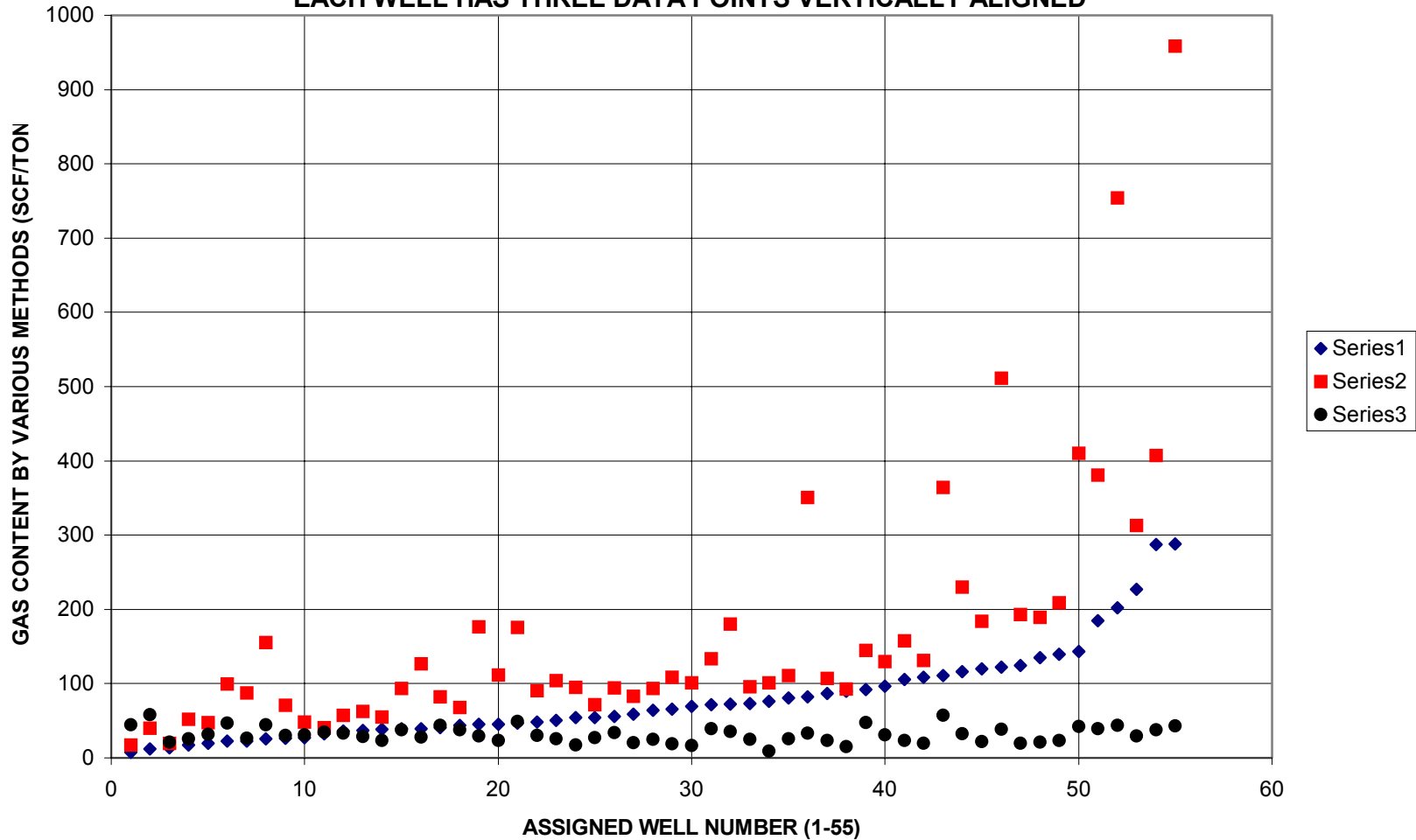
MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS

MUDLOG PREDICTED GAS CONTENT (GC) OF WELLS IN STUDY
 GREEN IS MUDLOG GC , BLUE IS VOLUMETRIC GC USING ≥ 24 MO CUM PROD
 AND RED IS VOLUMETRIC GC USING CUM PROD + 48 MO OF CURRENT PROD
 EACH WELL HAS THREE DATA POINTS VERTICALLY ALIGNED



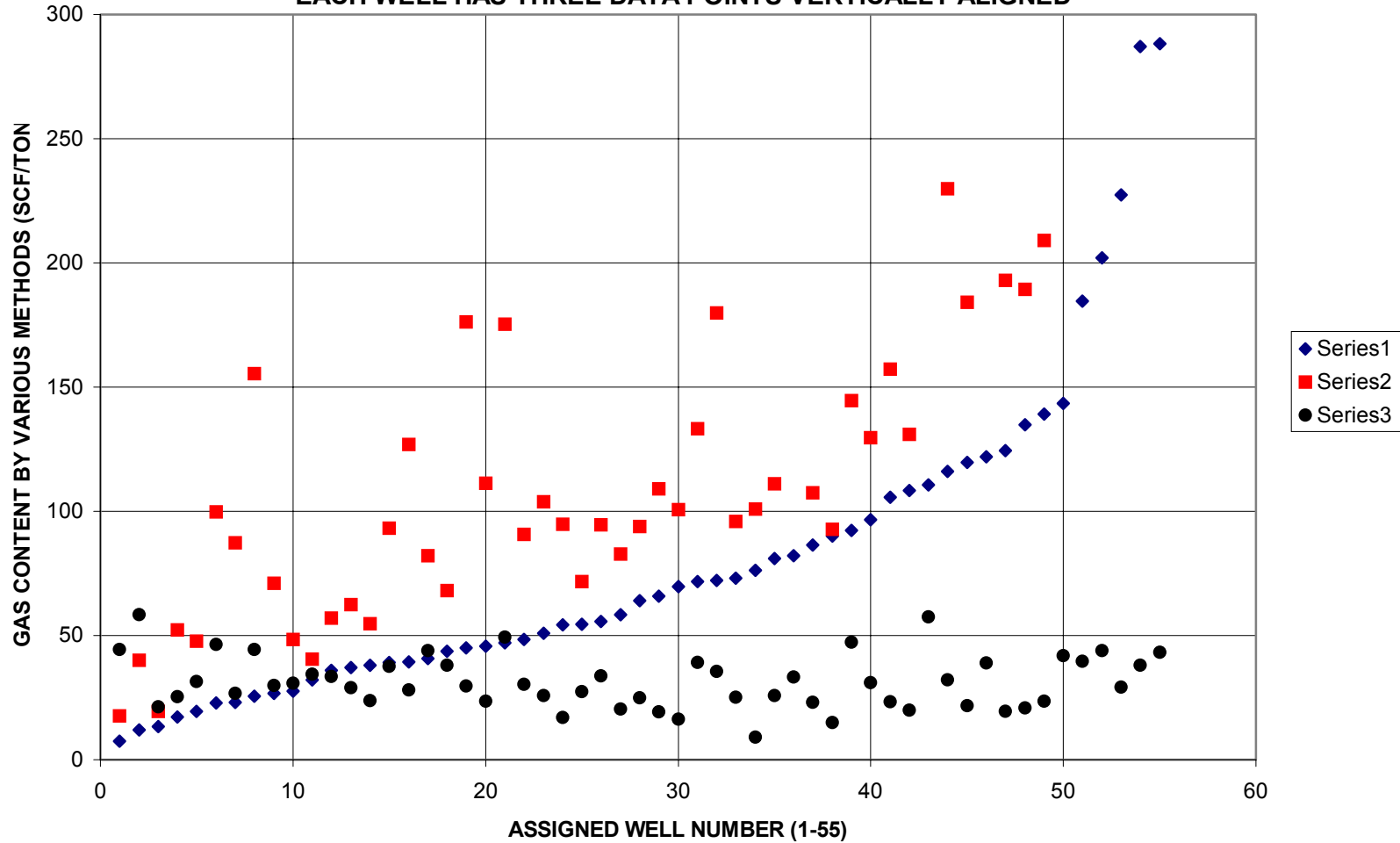
MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS

ISOTHERM PREDICTED GAS CONTENT (GC) OF WELLS IN STUDY
BLACK IS ISOTHERM GC , BLUE IS VOLUMETRIC GC USING ≥ 24 MO CUM PROD
AND RED IS VOLUMETRIC GC USING CUM PROD + 48 MO OF CURRENT PROD
EACH WELL HAS THREE DATA POINTS VERTICALLY ALIGNED



MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS

ISOTHERM PREDICTED GAS CONTENT (GC) OF WELLS IN STUDY
 BLACK IS ISOTHERM GC , BLUE IS VOLUMETRIC GC USING ≥ 24 MO CUM PROD
 AND RED IS VOLUMETRIC GC USING CUM PROD + 48 MO OF CURRENT PROD
 EACH WELL HAS THREE DATA POINTS VERTICALLY ALIGNED



MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS

OVERVIEW OF FACTORS AFFECTING CBM RESERVES

GAS CONTENT (SCF/TON)

- CORRELATION WITH COAL RANK IS WELL KNOWN (HIGHER RANK, HIGHER GAS CONTENT)
- CORRELATION WITH MOISTURE CONTENT LESS WELL KNOWN (HIGHER MOISTURE, LOWER GAS CONTENT)
- CORRELATION WITH STRUCTURAL HIGHS SUPPORTS MOISTURE CONTENT CONCEPT
- FREE GAS BENEFICIAL, BUT LOW POROSITY OF COAL AND LOW GAS EXPANSION FACTORS AT SHALLOW DEPTH LIMIT GAS RESERVE VOLUME
- FRACTURES AND CLEATS SHOULD BE DRAINED FIRST. IF FREE GAS IS PRESENT GAS SHOULD BE PRODUCED INITIALLY. WATER IS TYPICALLY PRODUCED INITIALLY
- CORE DESORPTION GAS CONTENT TYPICALLY UNDERSTATES ACTUAL GAS CONTENT
- RE-ADSORPTION ISOTHERM GAS CONTENT MORE CLOSELY AGREES WITH MUDLOGGING GAS CONTENT

HEIGHT OR ZONE THICKNESS (FEET)

- THICKNESS MAY BE GREATER THAN CLEAN GAMMA RAY INDICATES
- BROWN SHALES, “BITUMINOUS SHALES” OR CARBONACEOUS SHALES OFTEN CONTAIN GAS
- MUDLOGGING HELPS DEFINE GASSY BROWN, BITUMINOUS AND CARBONACEOUS SHALES.
- THE DIETZ 2 WHICH IS LAMINATED HAS HIGHEST MUDLOGGING GAS READING IN THE STUDY AREA

COAL DENSITY (GRAMS PER CUBIC CENTIMETERS)

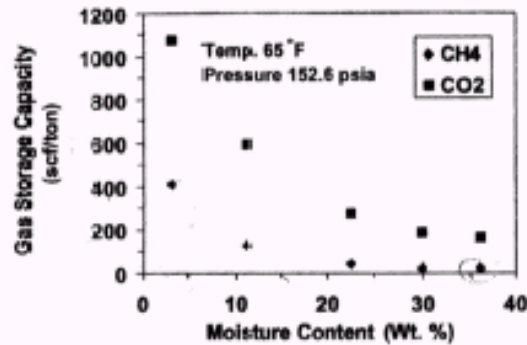
- EASILY MEASURED FROM LOGS AND SAMPLES

DRAINAGE AREA (ACRES)

- SPACING UNIT USED AS DRAINAGE AREA
- ADJACENT WELLS COMPETE FOR RESOURCE AND HAVE INTERFERENCE BOUNDARIES
- WATER AND GAS RATES DON'T INDICATE HIGH PERMEABILITY
- USE OF WATER TREATMENTS DON'T INDICATE HIGH PERMEABILITY
- WHY DO BETTER WELLS HAVE HIGHER MUDLOG GAS CONTENT, IF GAS IS COMING FROM A LARGE DRAINAGE AREA?
- ARE WELLS FLOWING WHEN HIGHER MUDLOG GAS CONTENT. THIS IS DETERMINED AT COMPLETION WHEN ACCURATE RESERVOIR PRESSURES CAN BE MEASURED AND APPEARS NOT TO BE THE CASE
- FAULTING AND STRATIGRAPHIC PINCH OUT LIMIT DRAINAGE AREA
- CBM PRESSURE DEPLETES WITH TIME, IT IS NOT A STEADY STATE SYSTEM

MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS

LABORATORY DATA THAT SUPPORTS MOISTURE CONTENT AFFECT ON GAS CONTENT



SPE 59786

Properties of Paleocene Fort Union Formation Canyon Seam Coal at the Triton Federal Coalbed Methane Well, Campbell County, Wyoming

Charles R. Nelson, SPE, and David G. Hill, SPE, Gas Research Institute, and Timothy J. Pratt, SPE, TICORA Geosciences, Inc.



Figure 4. Effect of Moisture on the Gas Storage Capacity of Canyon Seam Subbituminous Coal.

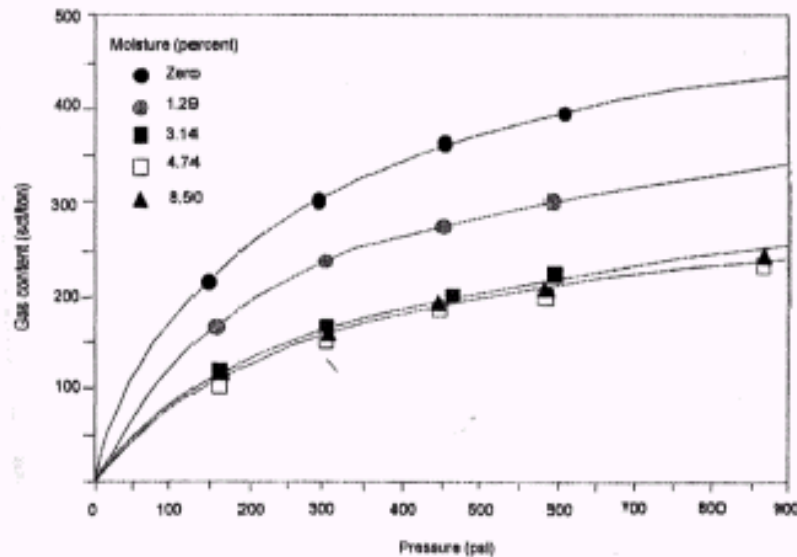


Figure 7-13. Variation in sorption capacity with moisture content. The sorption capacity decreases with increasing moisture content up to the equilibrium moisture content of the coal after which moisture is thought to act as a simple diluent. Modified from Joubert et al. (1974).

AFTER BUSTIN 1999

MUDLOGGING GAS CONTENT RESULTS COMPARED TO PRODUCTION HISTORY FOR CBM WELLS

MUDLOGGING GAS CONTENT METHOD HIGHLIGHTS

THE MINIMUM THAT MUST BE RECORDED IS:

- DRILLING RATE IN COAL
- GAS READINGS IN COAL
- DRILL BIT DIAMETER
- CALCIUM CARBIDE LAG VOLUME
- RESULTANT GAS READING RESPONSE

DRILLING PRACTICES THAT OPTIMIZE MUDLOGGING GAS CONTENT DETERMINATION:

- MUD PUMP ANNULAR VELOCITY GREATER THAN 100 FEET PER MINUTE
- NO BALLED BITS
- NO WASHED OUT LINERS
- NO LEAKING VALVES
- NO WASHED OUT SEATS
- NO PLUGGED JETS
- LIGHTLY TREATED DRILLING MUD WITH LOW VISCOSITY
- STANDARD GOOD DRILLING PRACTICES

SUPPORT OPERATORS SHOULD PROVIDE:

- CHECK RIG ANNULAR VELOCITY FOR HOLE SIZE AND DRILL PIPE USED
- LCM MATERIAL ON LOCATION
- LARGE PITS OR MUCK PITS DAILY
- NO POLYMERS
- REQUIRE EQUIPMENT BE REPAIRED WHEN IT BREAKS
- IF DRILLING RATE SLOWS ATTEMPT TO DETERMINE THE CAUSE

**MUDLOGGING GAS CONTENT RESULTS
COMPARED TO PRODUCTION HISTORY FOR CBM WELLS**

SUMMARY

**MUDLOGGING GAS CONTENT IS AN EFFECTIVE
WAY TO PREDICT PRODUCTION PERFORMANCE.**

**MUDLOGGING GAS CONTENT IS ESPECIALLY
EFFECTIVE IN AREAS WHERE PRODUCTION
PERFORMANCE VARIES.**

**MUDLOGGING GAS CONTENT MEASUREMENT IS
INDEPENDENT OF ANY RATIONALE OR THEORY
THAT PREDICTS THE AMOUNT OF GAS PRESENT
BEFORE DRILLING.**