STRATIGRAPHIC MODELING WYODAK-ANDERSON COAL-SANDSTONE AQUIFERS AND WATER FLOW-CHEMISTRY, POWDER RIVER BASIN, WYOMING

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OUTLINE

- OVERVIEW
- STRATIGRAPHIC MODELING OF WYODAK-ANDERSON COAL ZONE AQUIFERS
- COMMUNICATION AND WATER-FLOW MODELING OF AQUIFERS
- VARIATIONS OF WATER COMPOSITION IN COAL AND SANDSTONE AQUIFERS
- SUMMARY AND PROGNOSIS

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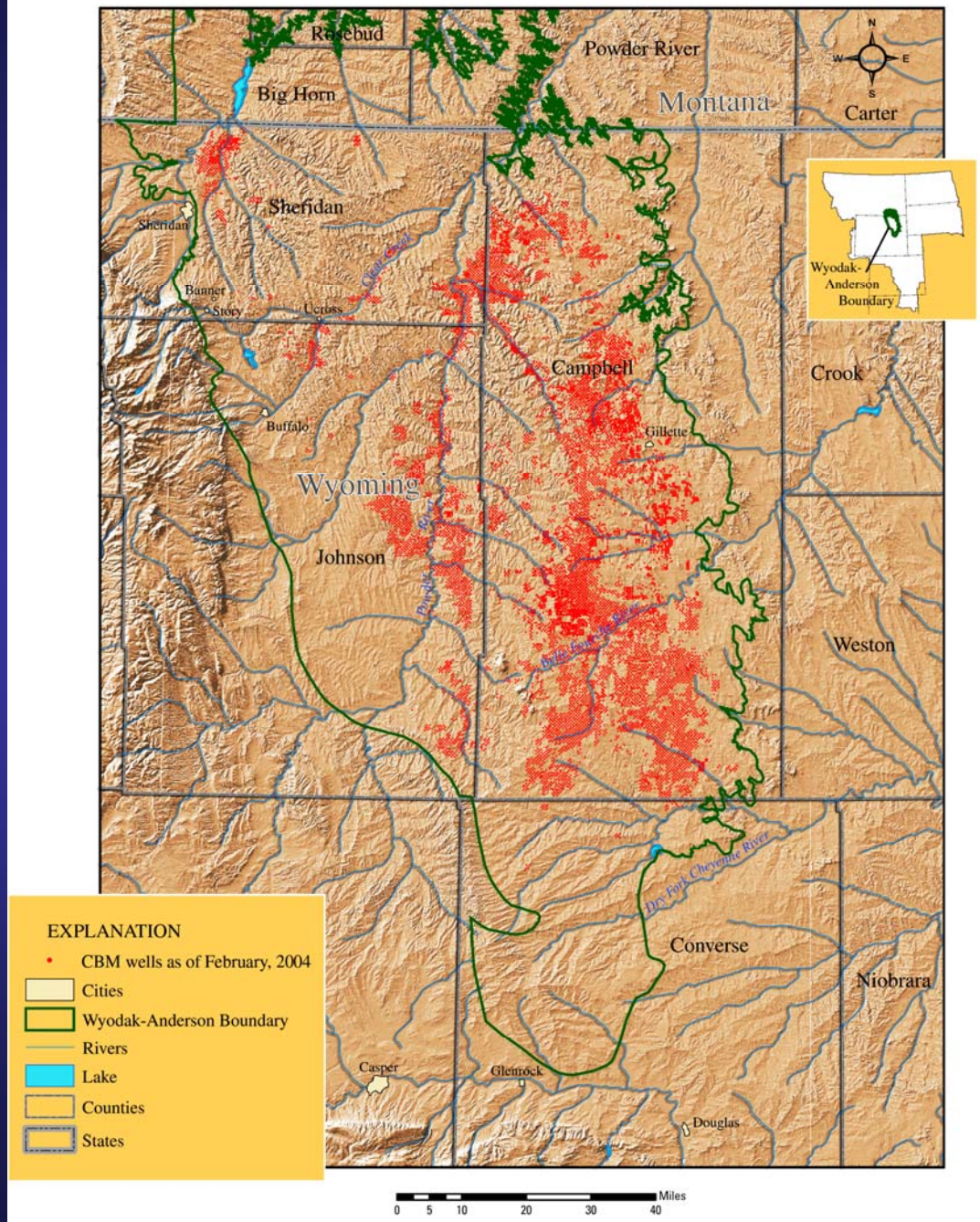
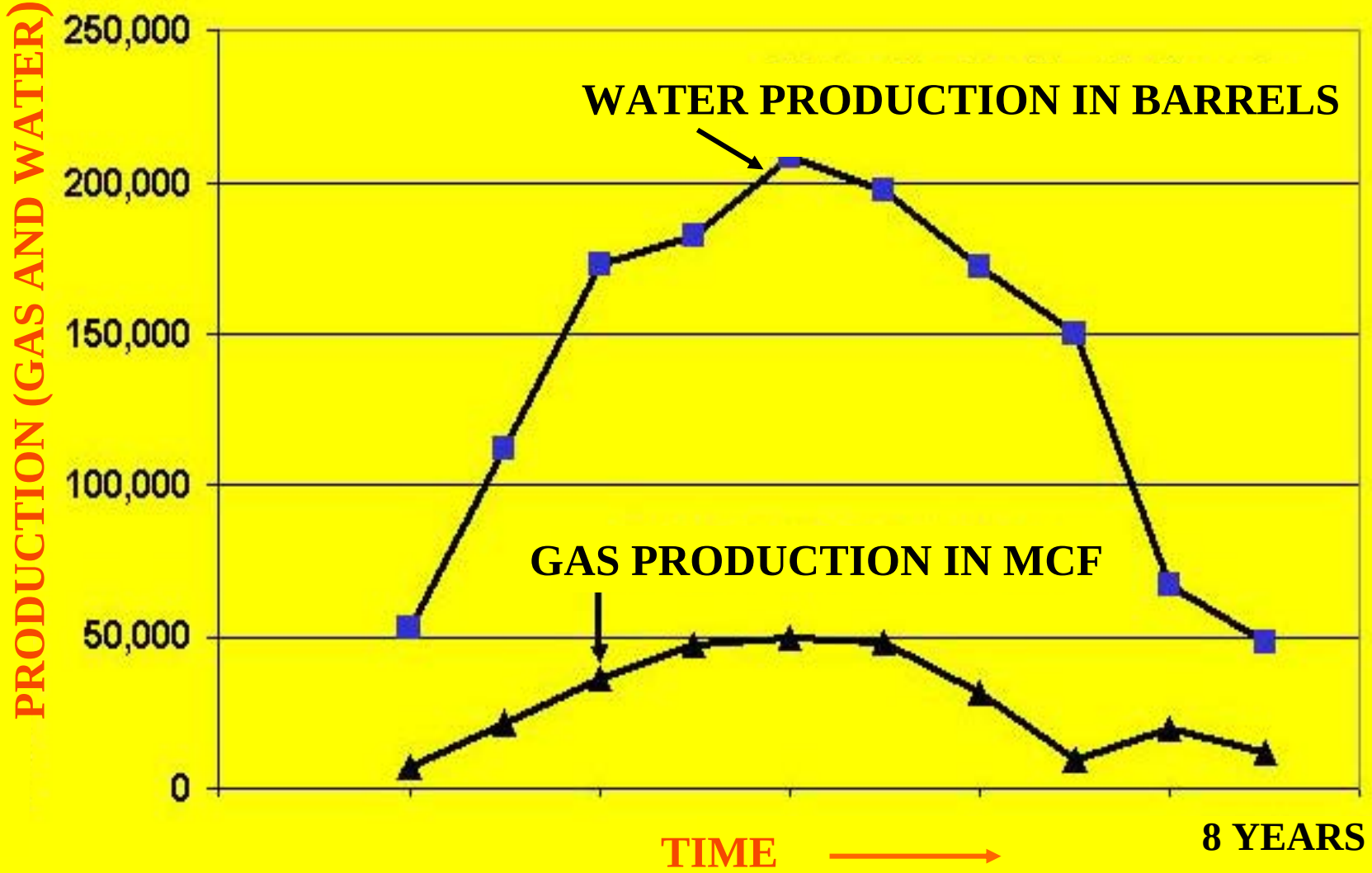
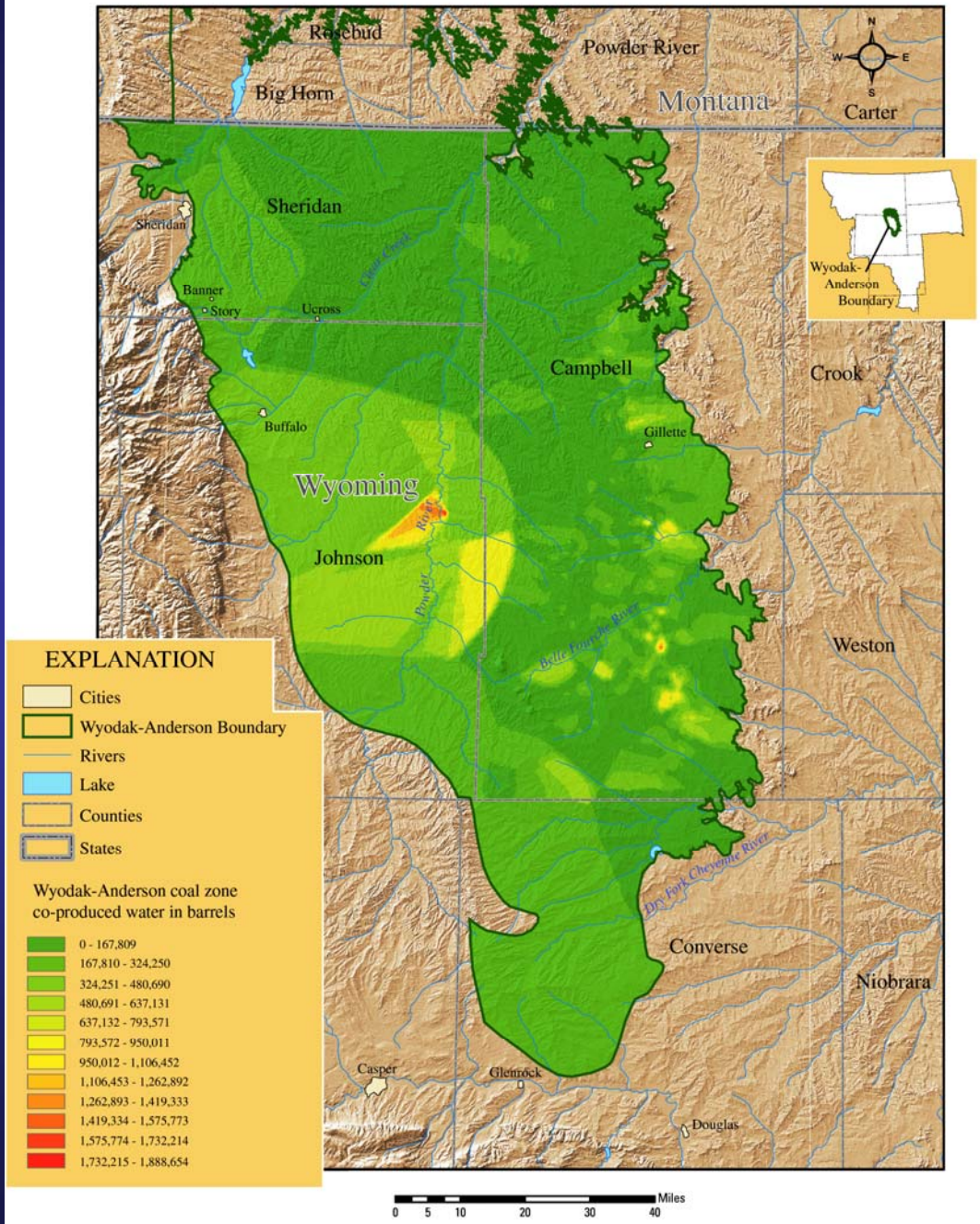
POWDER RIVER BASIN CBM WELLS



GAS AND WATER PRODUCTION

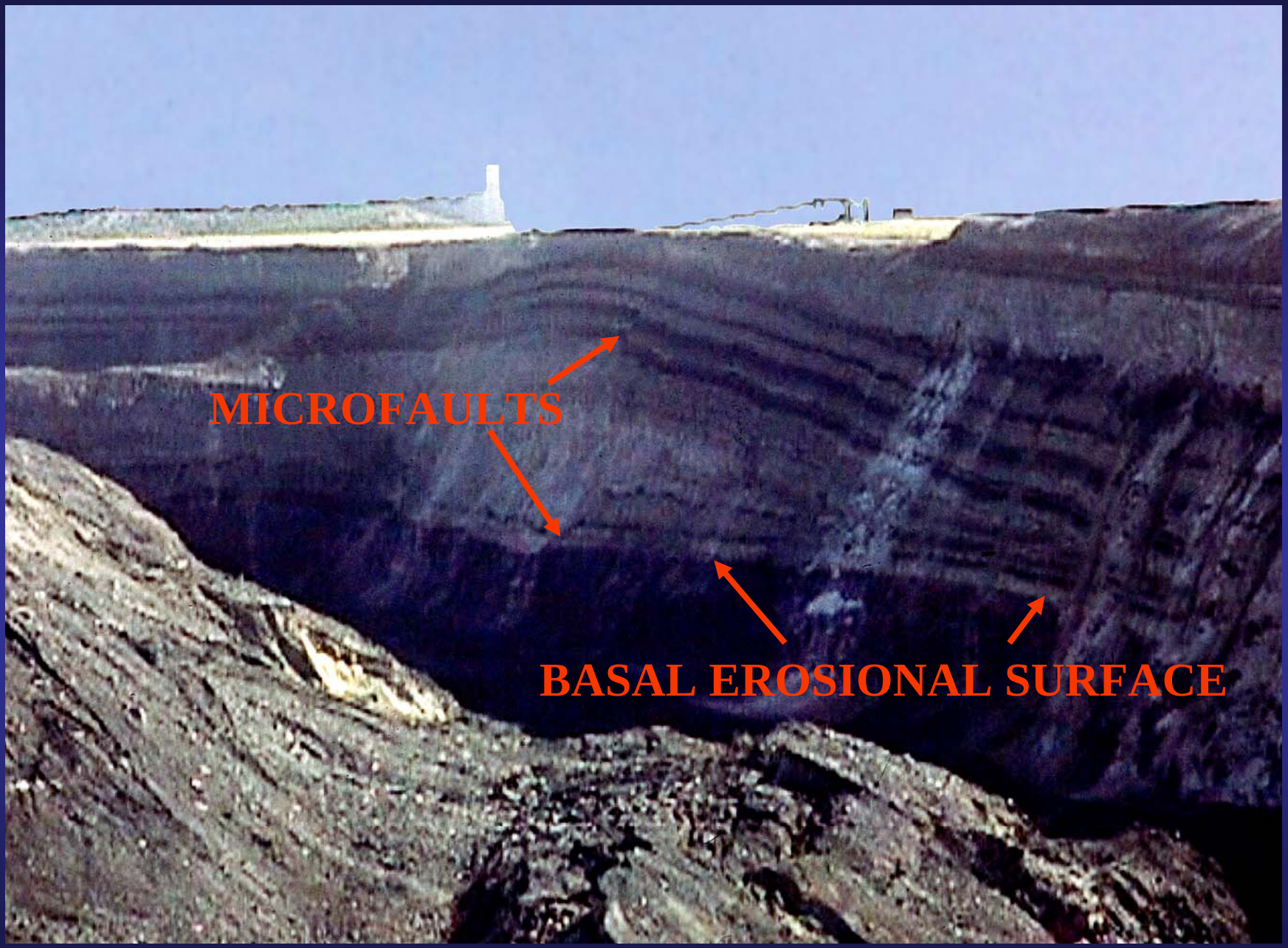


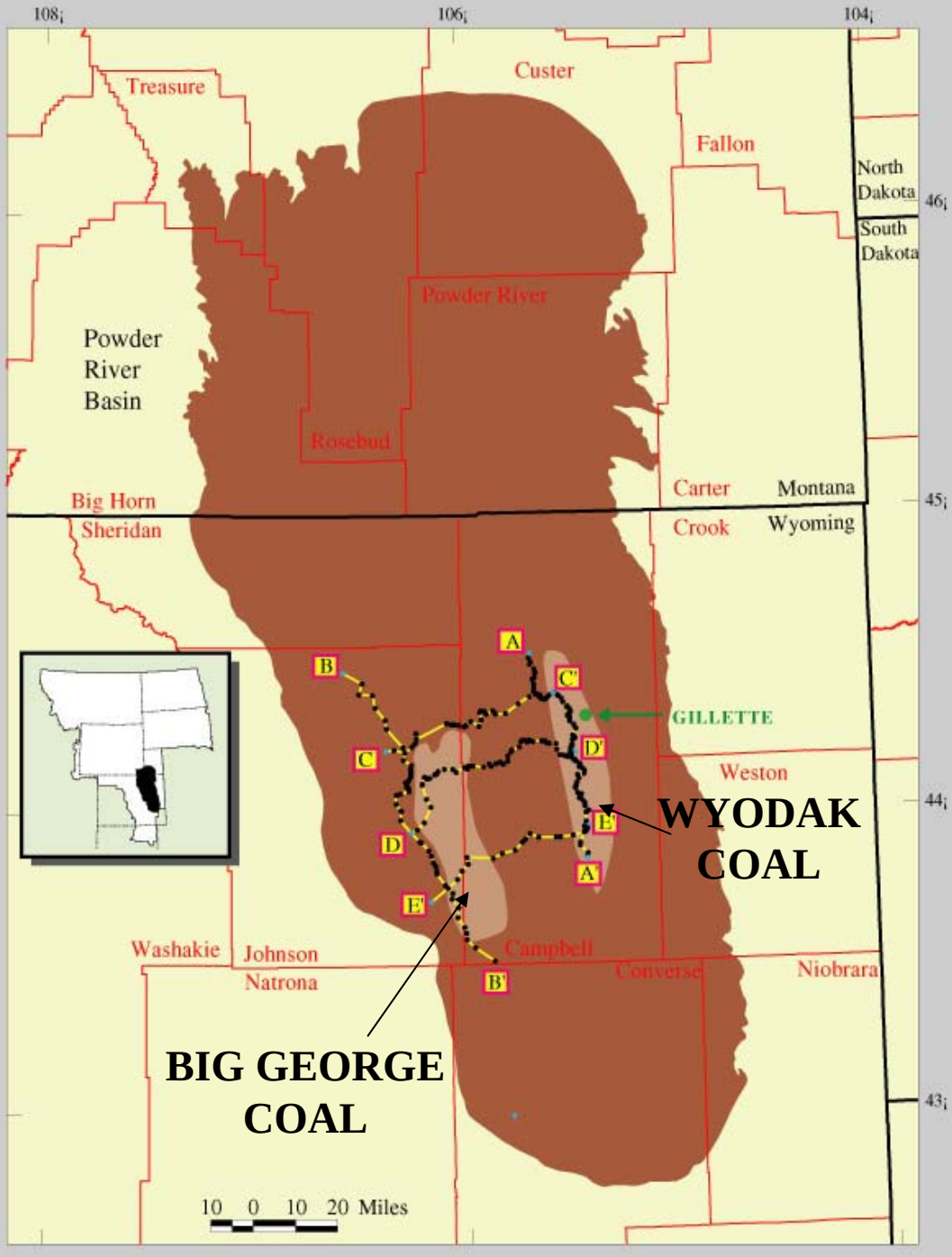
WYODAK-ANDERSON COAL ZONE PRODUCED WATER



ISSUES OF COAL AND SANDSTONE AQUIFERS IN CBM PRODUCTION

- STRATIGRAPHICALLY IN COMMUNICATION
- VOLUME
- CHEMICAL COMPOSITION


MICROFAULTS
BASAL EROSIONAL SURFACE

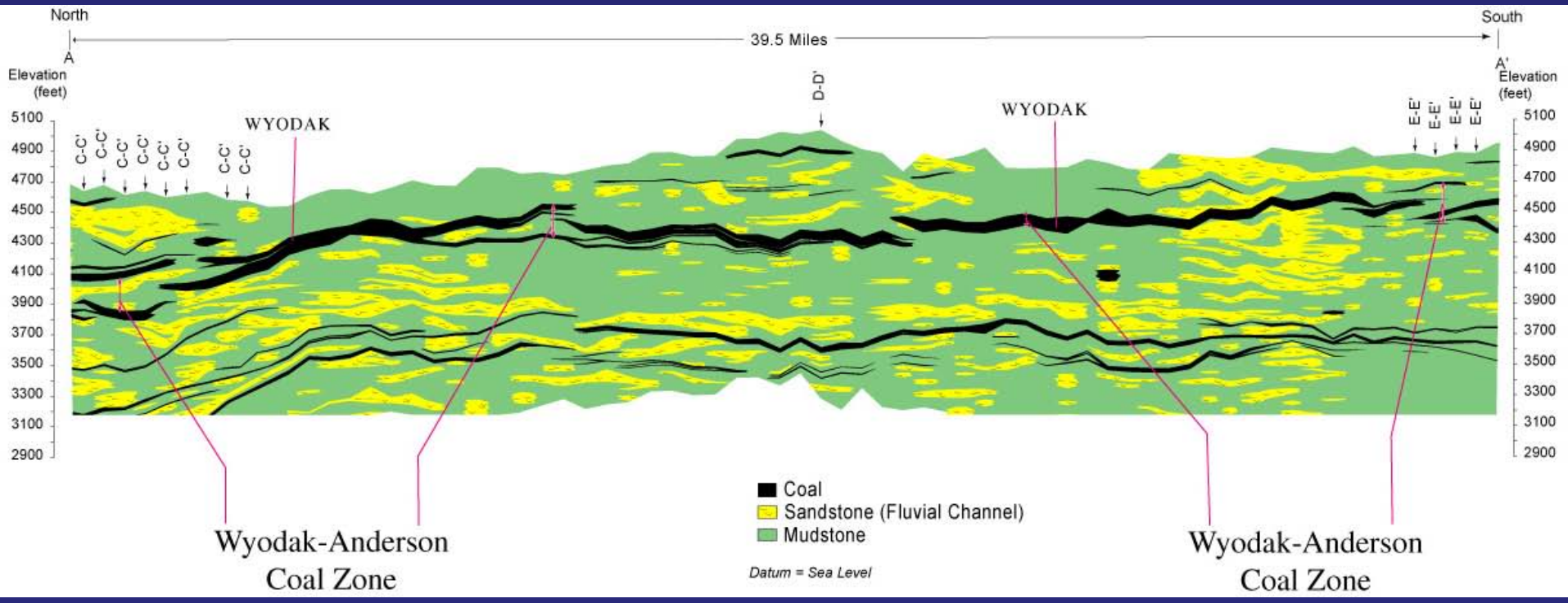

108
106
104
46
45
44
43
Treasure
Custer
Fallon
North Dakota
South Dakota
Powder River
Powder River Basin
Rosebud
Big Horn
Sheridan
Carter
Montana
Crook
Wyoming
A
B
C
D
E
A'
B'
C'
D'
E'
GILLETTE
Weston
WYODAK COAL
Washakie
Johnson
Natrona
Campbell
Converse
Niobrara
BIG GEORGE COAL
10 0 10 20 Miles

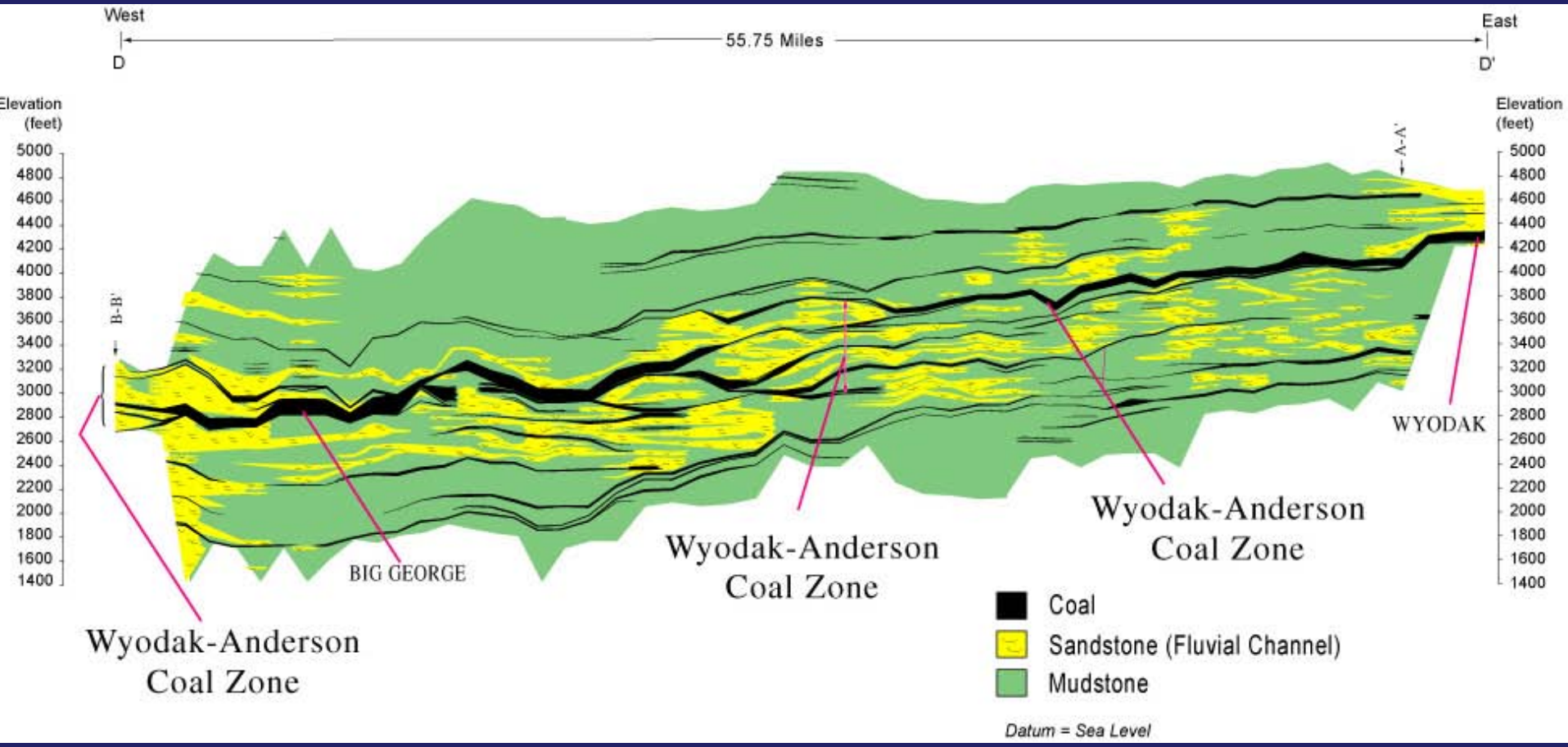
STRATIGRAPHY OF THE WYODAK-ANDERSON COAL ZONE

(USGS COAL-BED NAMES: PRE-1950)

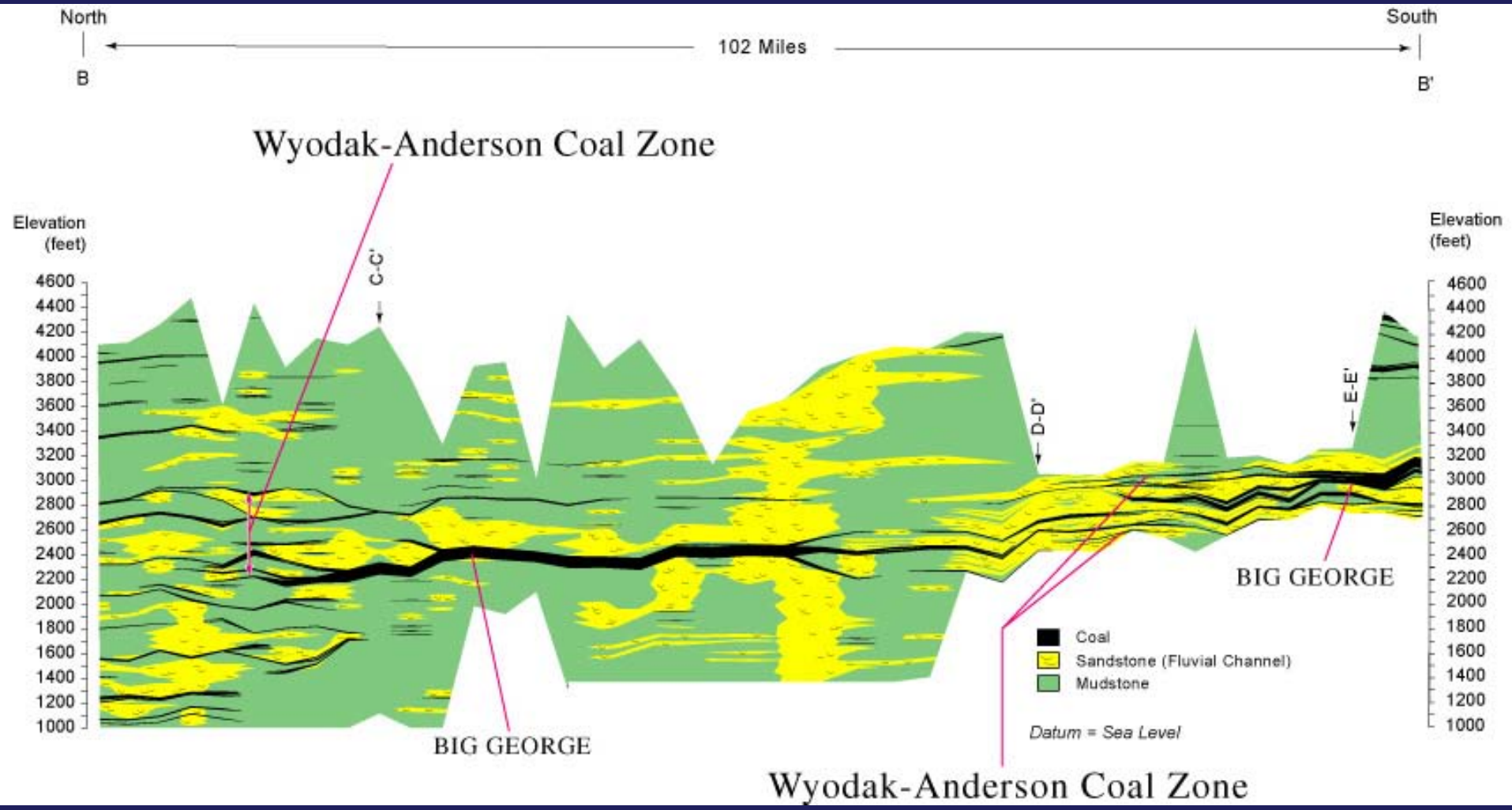
WEST-CENTRAL PRB		EAST PRB
	TOP	
	SMITH (SWARTZ)	
BIG GEORGE (MERGED)	ANDERSON CANYON (WERNER)	WYODAK (MERGED)

(STRATIGRAPHIC CORRELATIONS, 1980's)

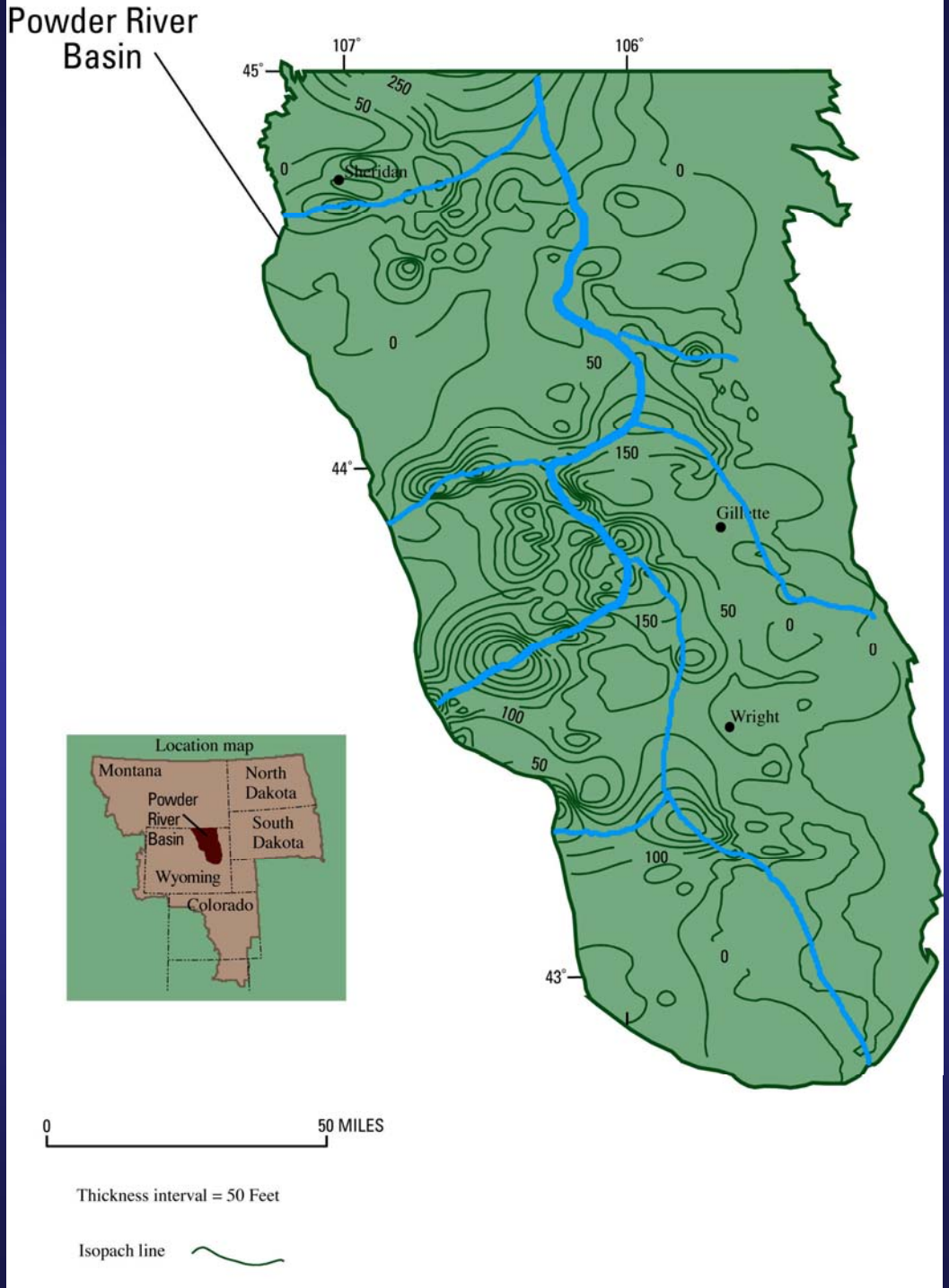

North
South
39.5 Miles
A
A'
Elevation (feet)
Elevation (feet)
5100
4900
4700
4500
4300
4100
3900
3700
3500
3300
3100
2900
C-C'
D-D'
E-E'
WYODAK
WYODAK
Coal
Sandstone (Fluvial Channel)
Mudstone
Datum = Sea Level
Wyodak-Anderson Coal Zone
Wyodak-Anderson Coal Zone

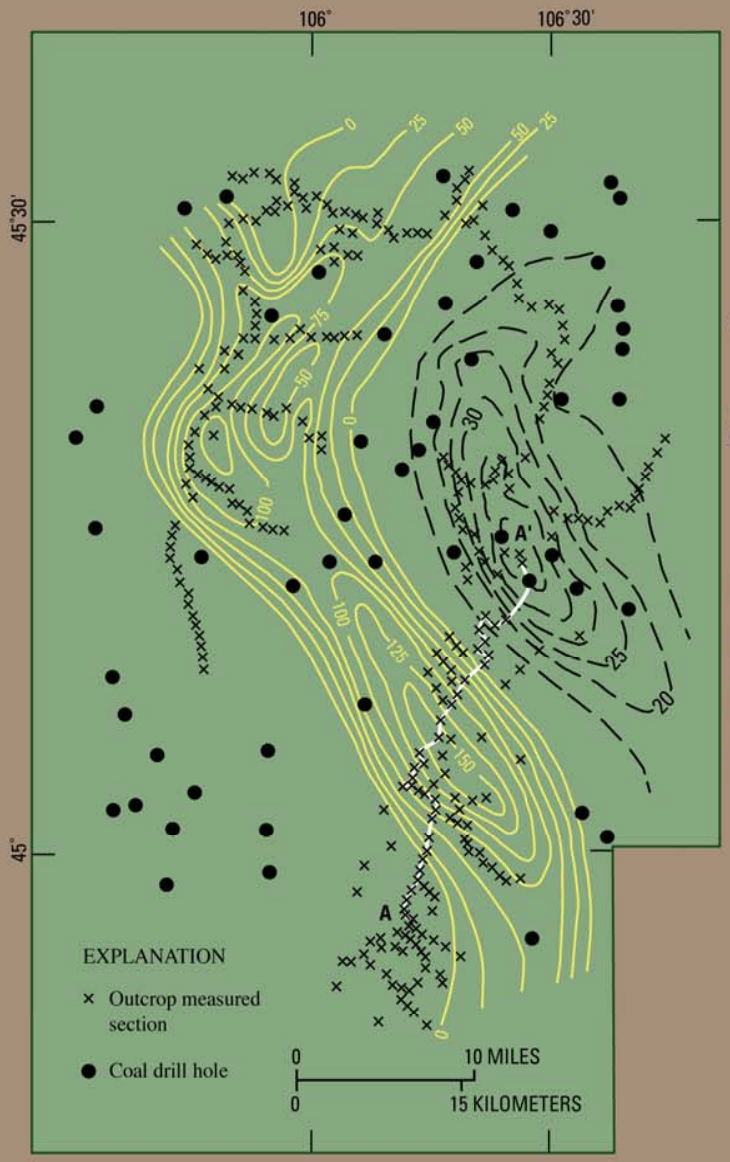

West
D
55.75 Miles
East
D'
Elevation (feet)
5000
4800
4600
4400
4200
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
B-B'
A-A'
BIG GEORGE
WYODAK
Wyodak-Anderson Coal Zone
Wyodak-Anderson Coal Zone
Wyodak-Anderson Coal Zone
Wyodak-Anderson Coal Zone
Coal
Sandstone (Fluvial Channel)
Mudstone
Datum = Sea Level

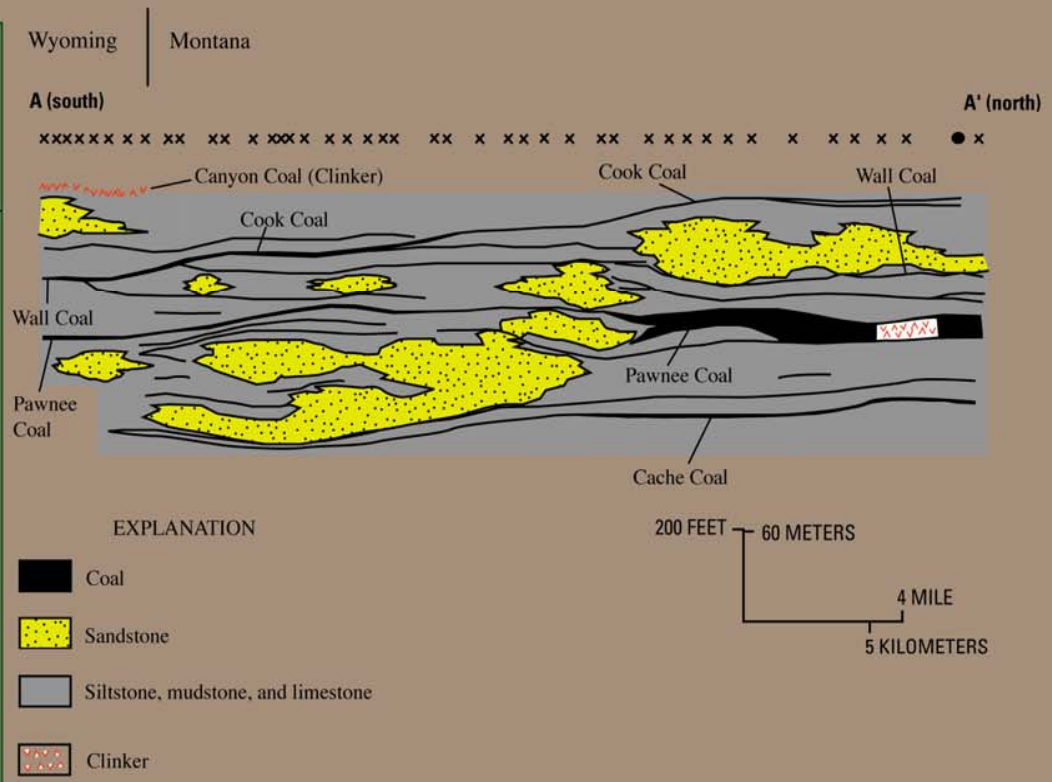
WYODAK COAL


North
South
102 Miles
B
B'
Wyodak-Anderson Coal Zone
Elevation (feet)
Elevation (feet)
4600
4400
4200
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
C-C'
D-D'
E-E'
BIG GEORGE
BIG GEORGE
Wyodak-Anderson Coal Zone
Coal
Sandstone (Fluvial Channel)
Mudstone
Datum = Sea Level

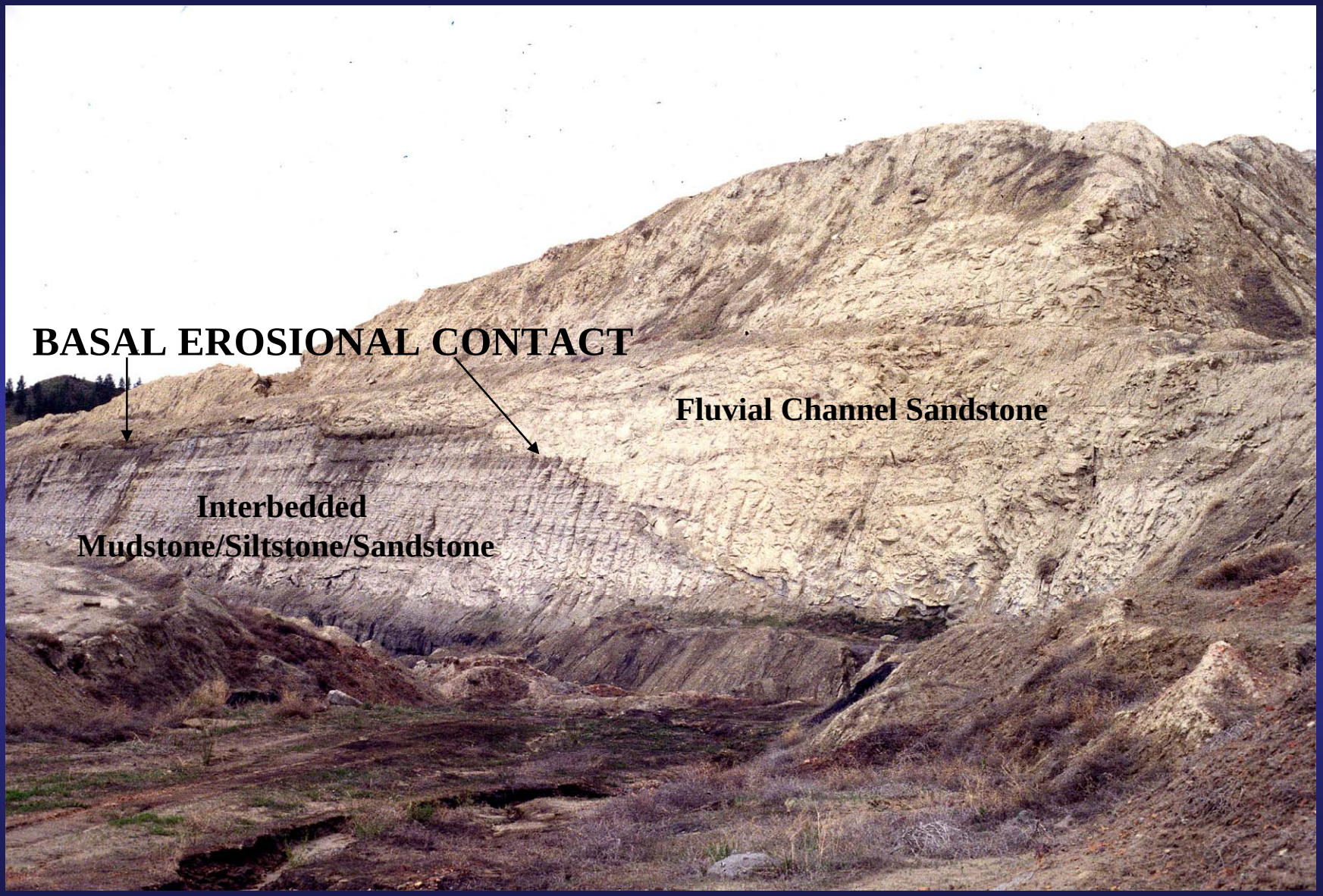
NET THICKNESS SANDSTONE ISOPACH MAP IN WYODAK-ANDERSON COAL ZONE

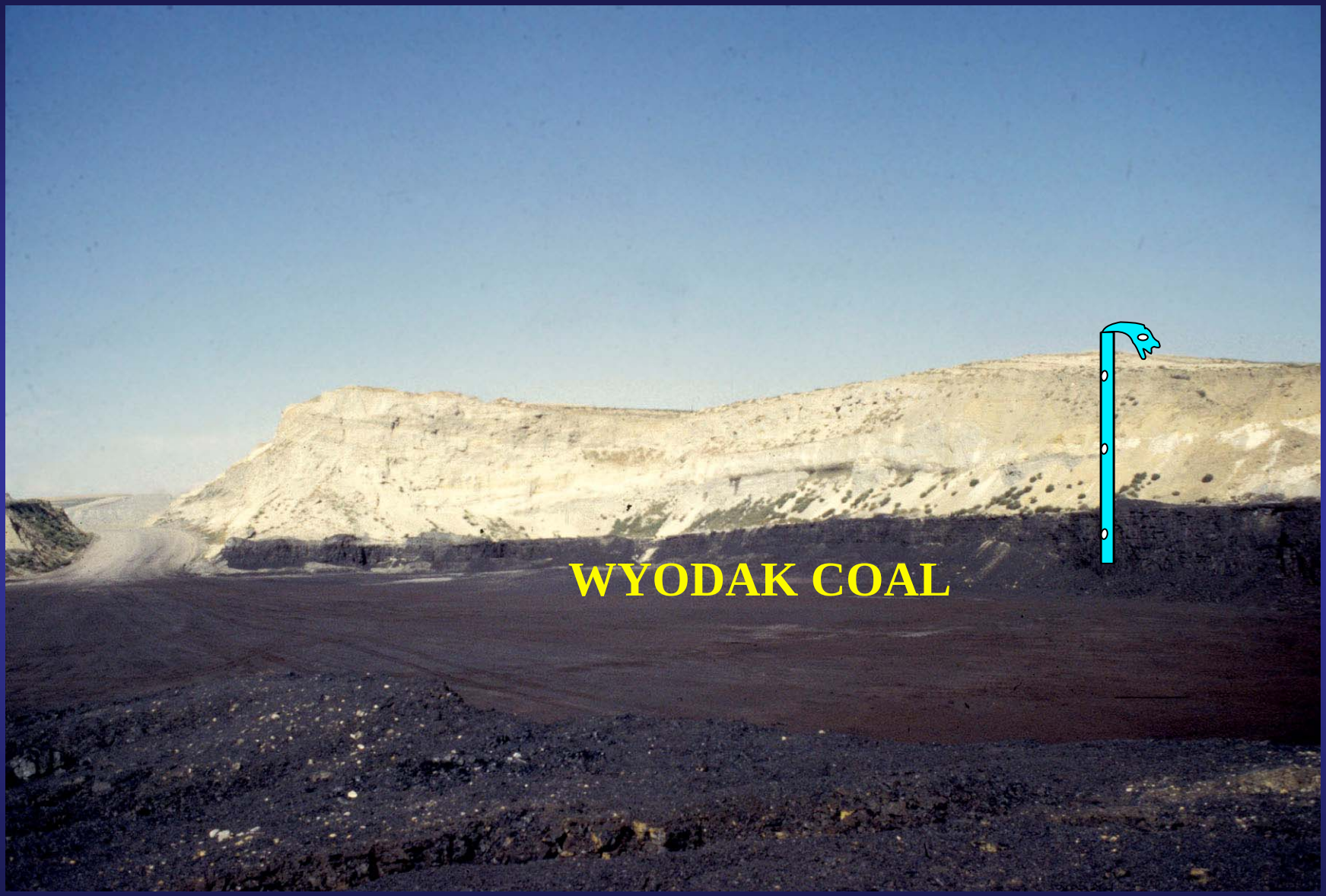


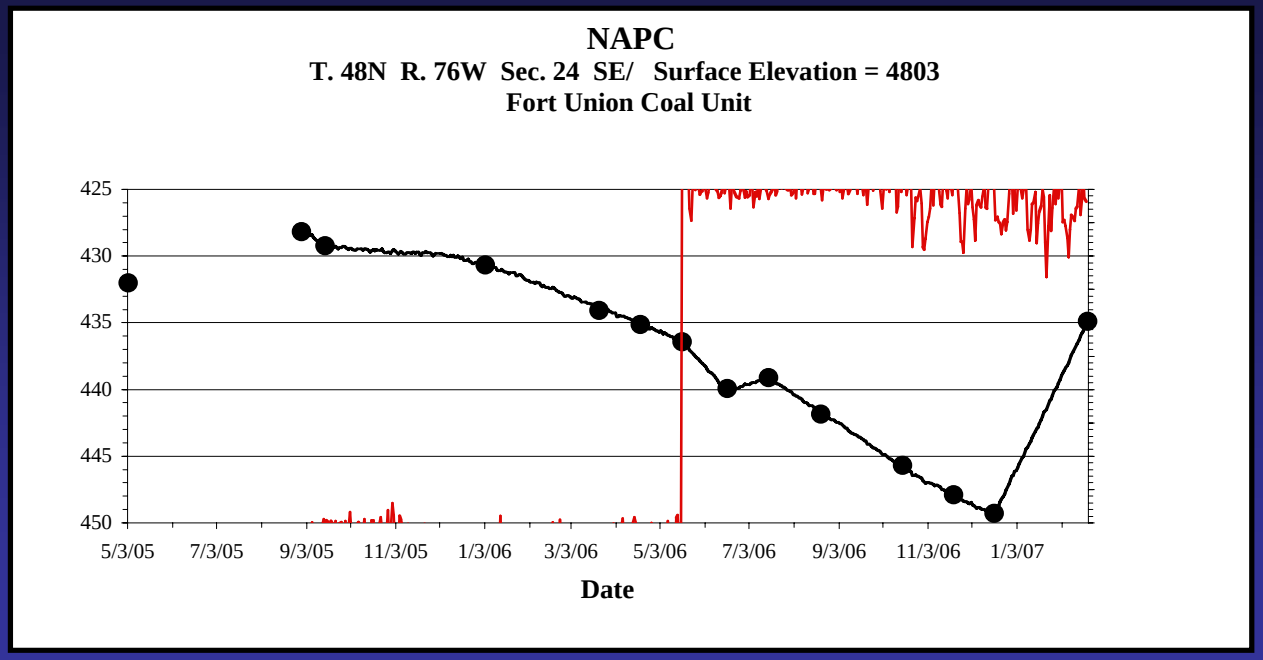

106°
106°30'
45°30'
45°
A
A'
EXPLANATION
Outcrop measured section
Coal drill hole
0
10 MILES
0
15 KILOMETERS

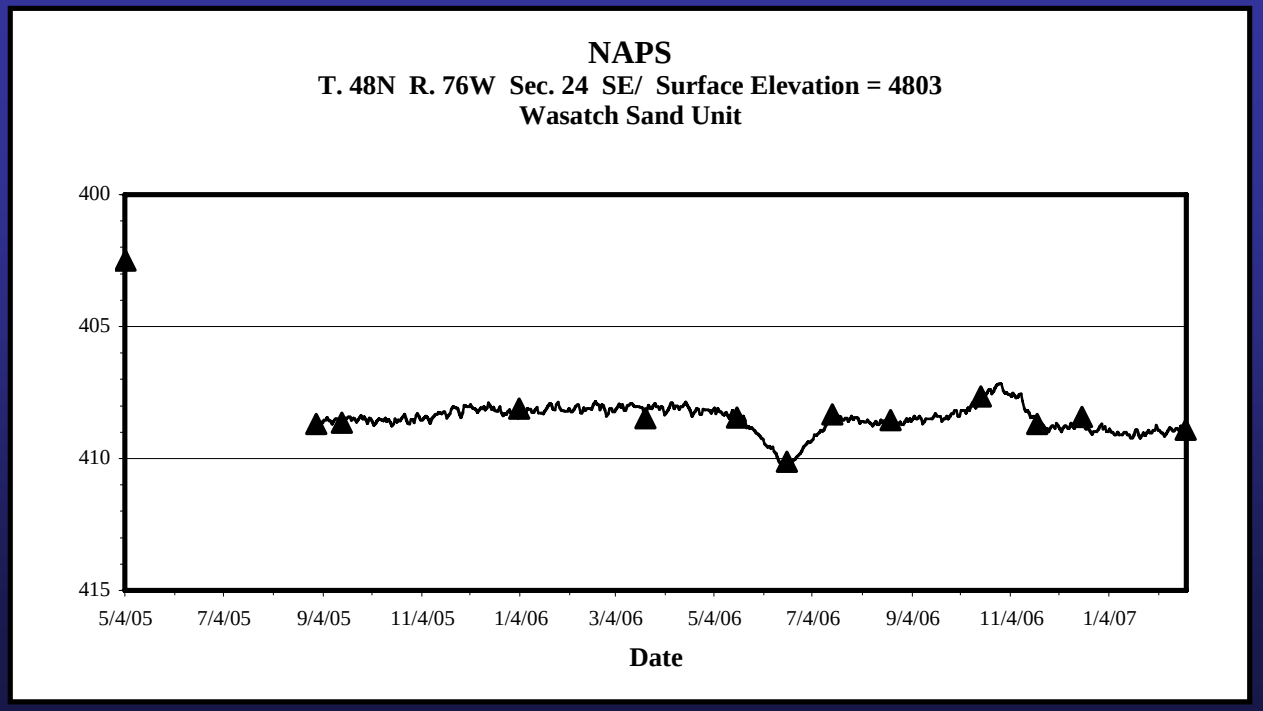

Wyoming
Montana
A (south)
A' (north)
Canyon Coal (Clinker)
Cook Coal
Wall Coal
Cook Coal
Wall Coal
Pawnee Coal
Pawnee Coal
Cache Coal
EXPLANATION
Coal
Sandstone
Siltstone, mudstone, and limestone
Clinker
200 FEET
60 METERS
4 MILE
5 KILOMETERS

Montana
North Dakota
Powder River Basin
South Dakota
Idaho
Wyoming
Nebraska

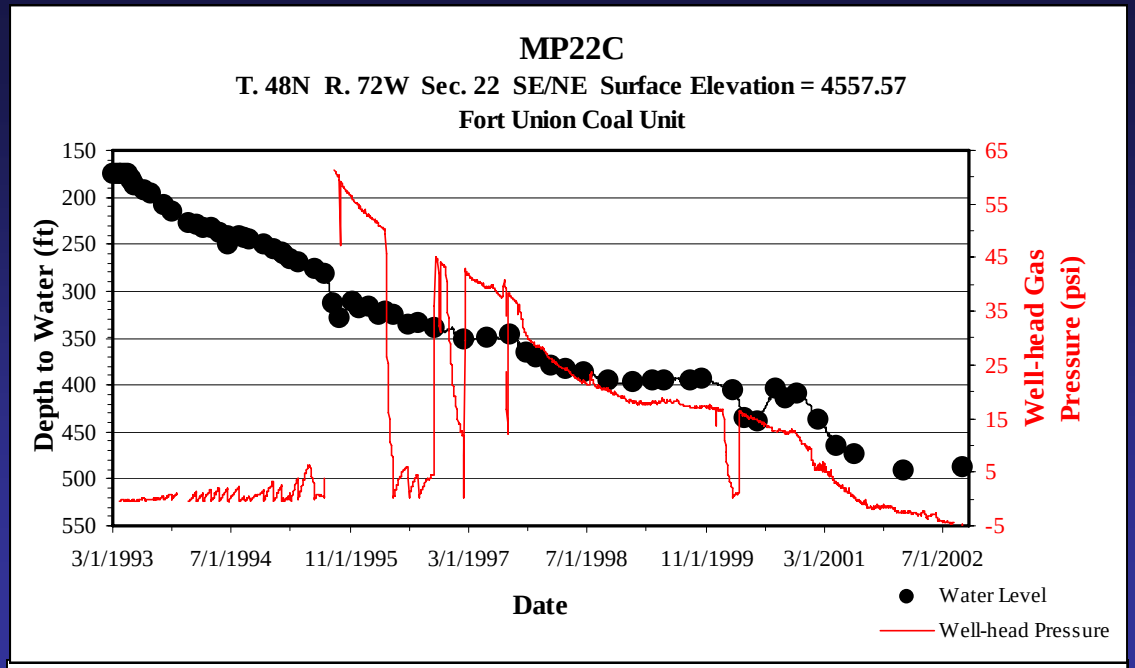

BASAL EROSIONAL CONTACT
Fluvial Channel Sandstone
Interbedded
Mudstone/Siltstone/Sandstone

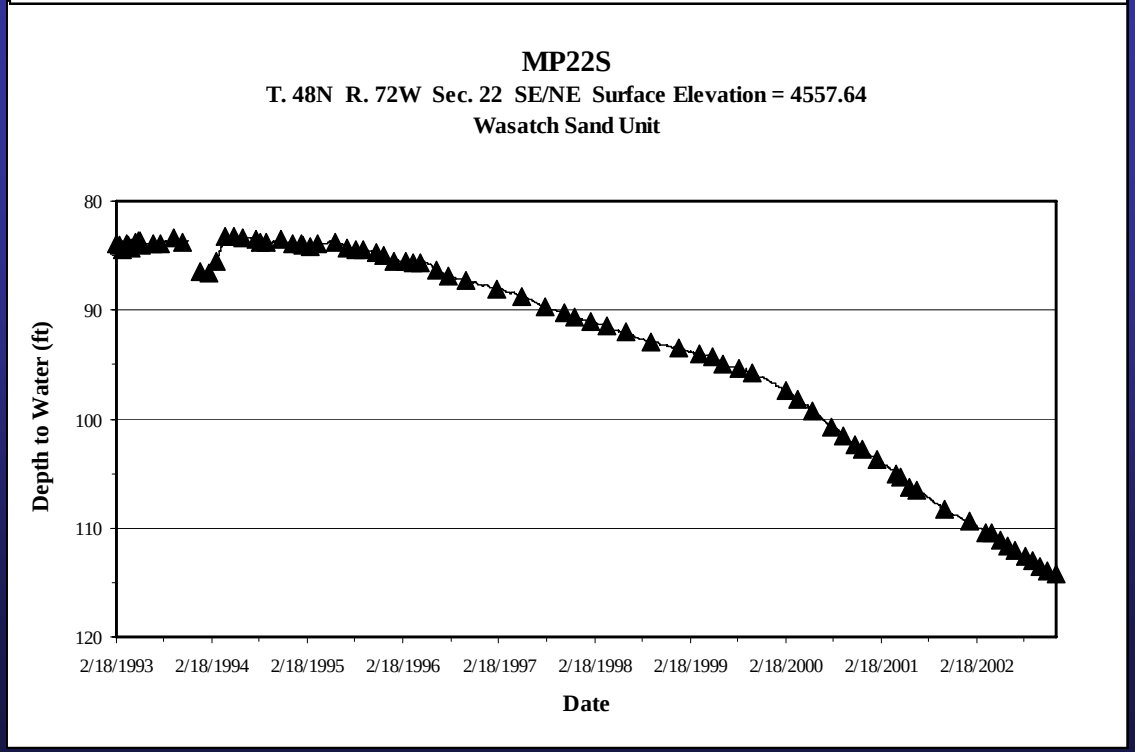

WYODAK COAL

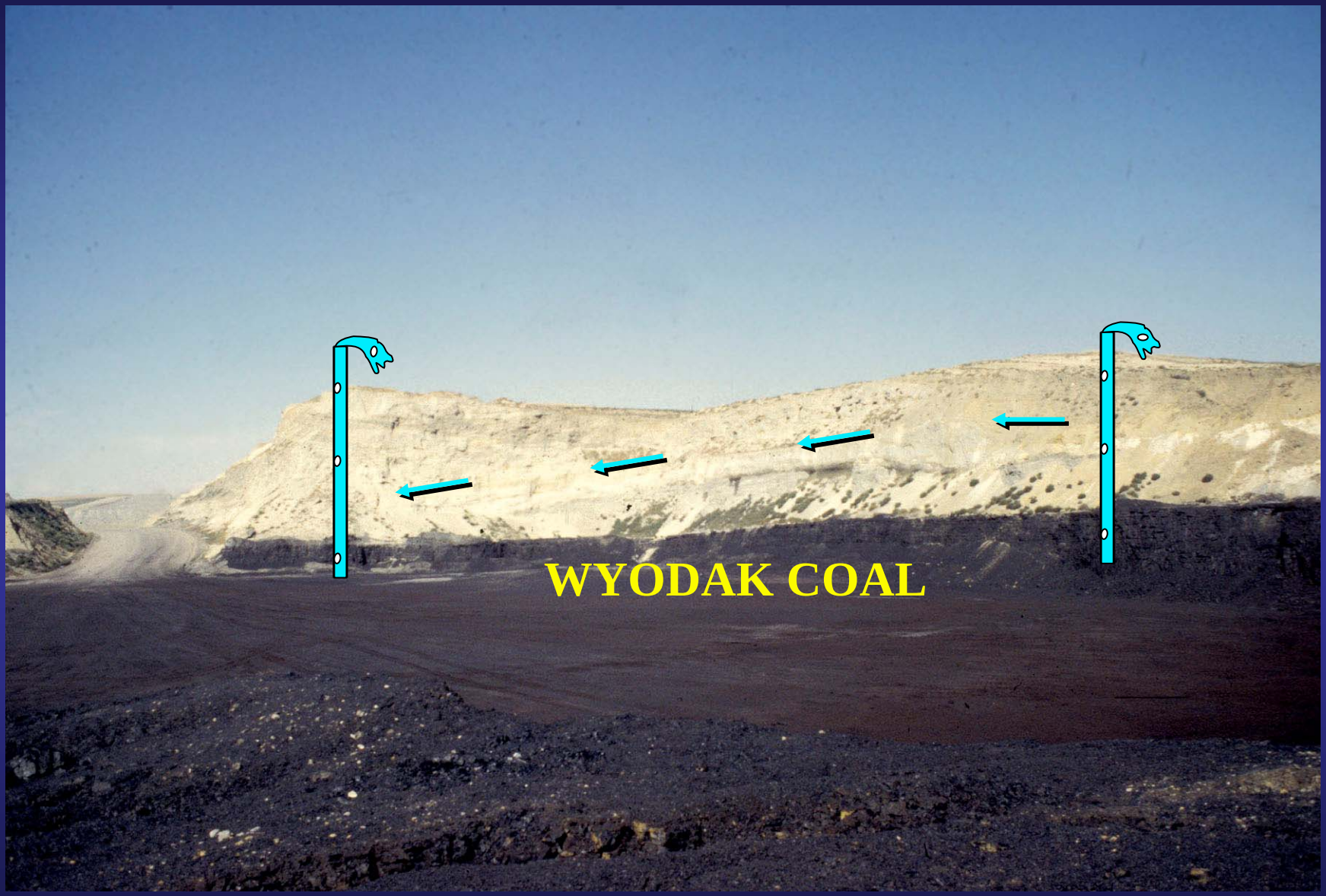

NAPC
T. 48N R. 76W Sec. 24 SE/ Surface Elevation = 4803
Fort Union Coal Unit
425
430
435
440
445
450
5/3/05
7/3/05
9/3/05
11/3/05
1/3/06
3/3/06
5/3/06
7/3/06
9/3/06
11/3/06
1/3/07
Date


NAPS
T. 48N R. 76W Sec. 24 SE/ Surface Elevation = 4803
Wasatch Sand Unit
400
405
410
415
5/4/05
7/4/05
9/4/05
11/4/05
1/4/06
3/4/06
5/4/06
7/4/06
9/4/06
11/4/06
1/4/07
Date

WYODAK COAL


MP22C
T. 48N R. 72W Sec. 22 SE/NE Surface Elevation = 4557.57
Fort Union Coal Unit
Depth to Water (ft)
150
200
250
300
350
400
450
500
550
Well-head Gas Pressure (psi)
65
55
45
35
25
15
5
-5
3/1/1993
7/1/1994
11/1/1995
3/1/1997
7/1/1998
11/1/1999
3/1/2001
7/1/2002
Date
Water Level
Well-head Pressure


MP22S
T. 48N R. 72W Sec. 22 SE/NE Surface Elevation = 4557.64
Wasatch Sand Unit
Depth to Water (ft)
80
90
100
110
120
2/18/1993
2/18/1994
2/18/1995
2/18/1996
2/18/1997
2/18/1998
2/18/1999
2/18/2000
2/18/2001
2/18/2002
Date


WYODAK COAL

Composition of Water in Coal Aquifers from Powder River Basin CBM Wells

pH	6.7 – 8.4	SAR	5.6 – 69
	mg/L		
TDS	270 – 2,780	Chloride	4.8 – 130
Sulfate	<0.03 – 530	Bicarbonate	290 – 3,250
Calcium	1.8 – 78	Potassium	3.1 – 58
Magnesium	0.6 – 46	Sodium	110 – 1,000
	µg/L		
Iron	2 – 17,500	Manganese	1.4 – 350
Arsenic	<0.2 – 4.8	Barium	14 – 2,680
Cadmium	<0.1	Chromium	<0.1 – 1.8
Lead	<0.1 – 0.76	Mercury	<0.005 – 0.25
Selenium	<2	Zinc	<1 - 90

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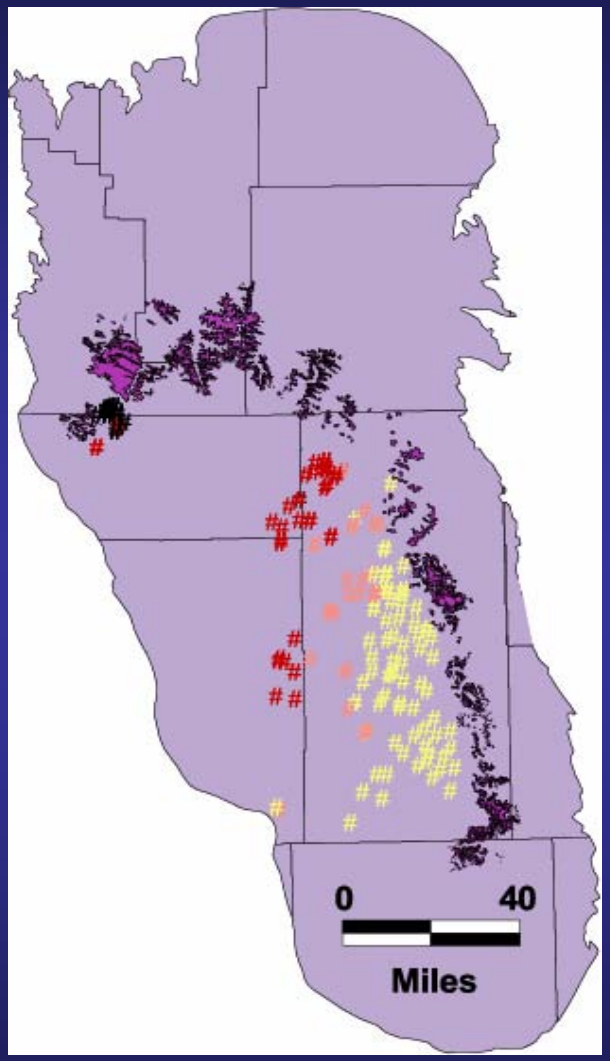
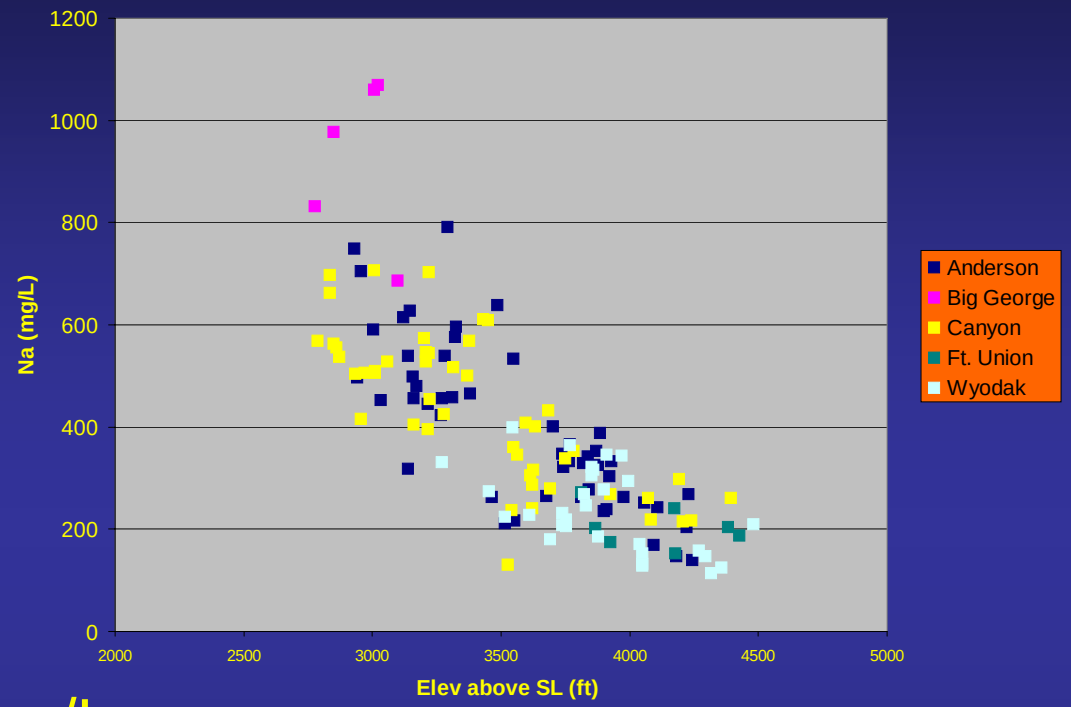
Sodium Adsorption Ratio



Sodium

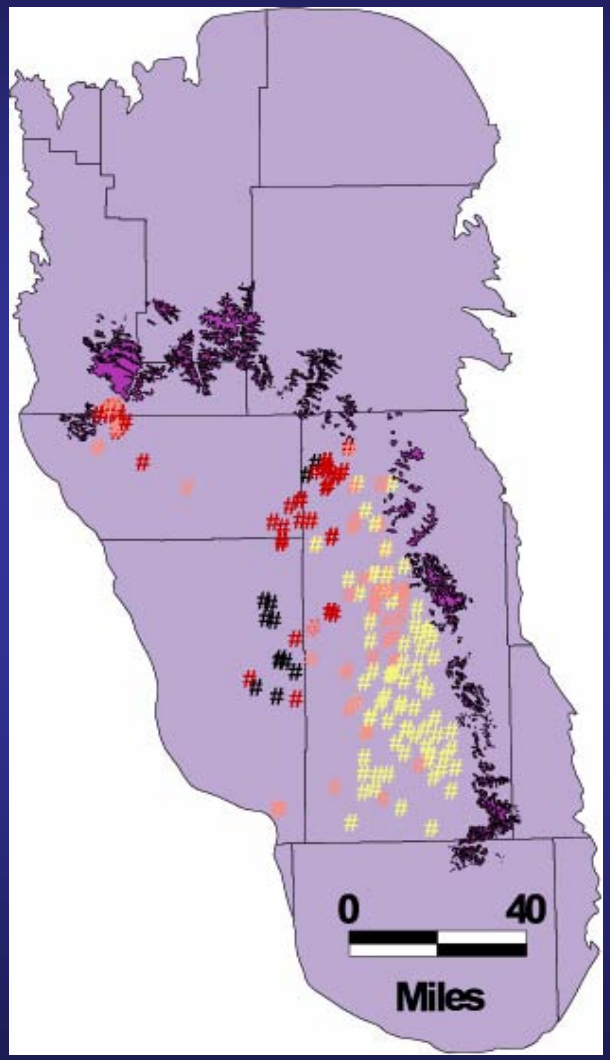


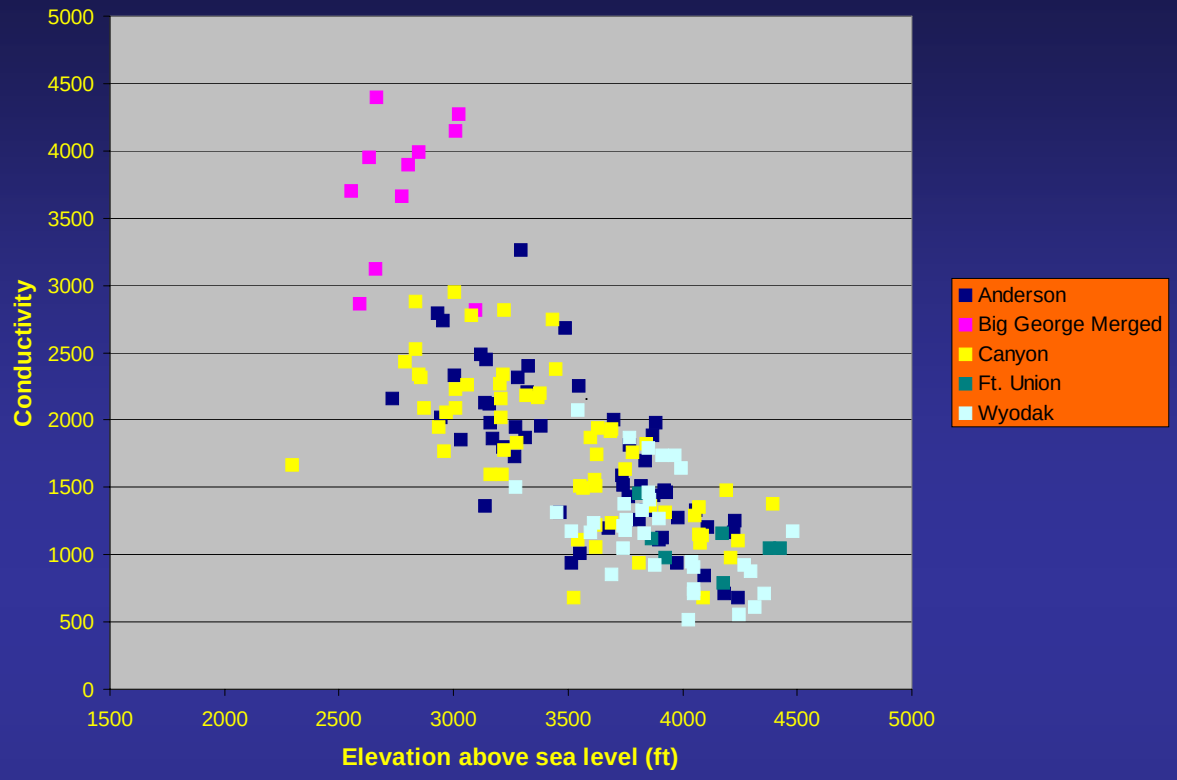
mg/L

- # 5.6 – 10.8
- # 10.8 – 18.1
- # 18.1 – 38.9
- # 38.9 – 68.7

•Exchange of Na^{+} for Ca^{2+} and Mg^{2+} causes swelling and dispersal of clays when hydrated, decreasing soil permeability and infiltration

Conductivity





μS/cm

#	516 – 1378
#	1379 – 2070
#	2071 – 2950
#	2951 – 4440

Composition of Water from Sandstone Aquifers Powder River Basin

pH	6.8 – 8.8 (7.8)	SAR	<1 – 42 (10)
TDS	270 – 5,620 (1900)	Chloride	1 – 53 (9)
Sulfate	<0.03 – 3,560 (119)	Bicarbonate	32 – 2,330 (757)
Calcium	3 – 600 (40)	Potassium	1.1 – 65 (7.6)
Magnesium	0 – 319 (25)	Sodium	13 – 943 (355)
Iron	0.01 – 120		(0.26)

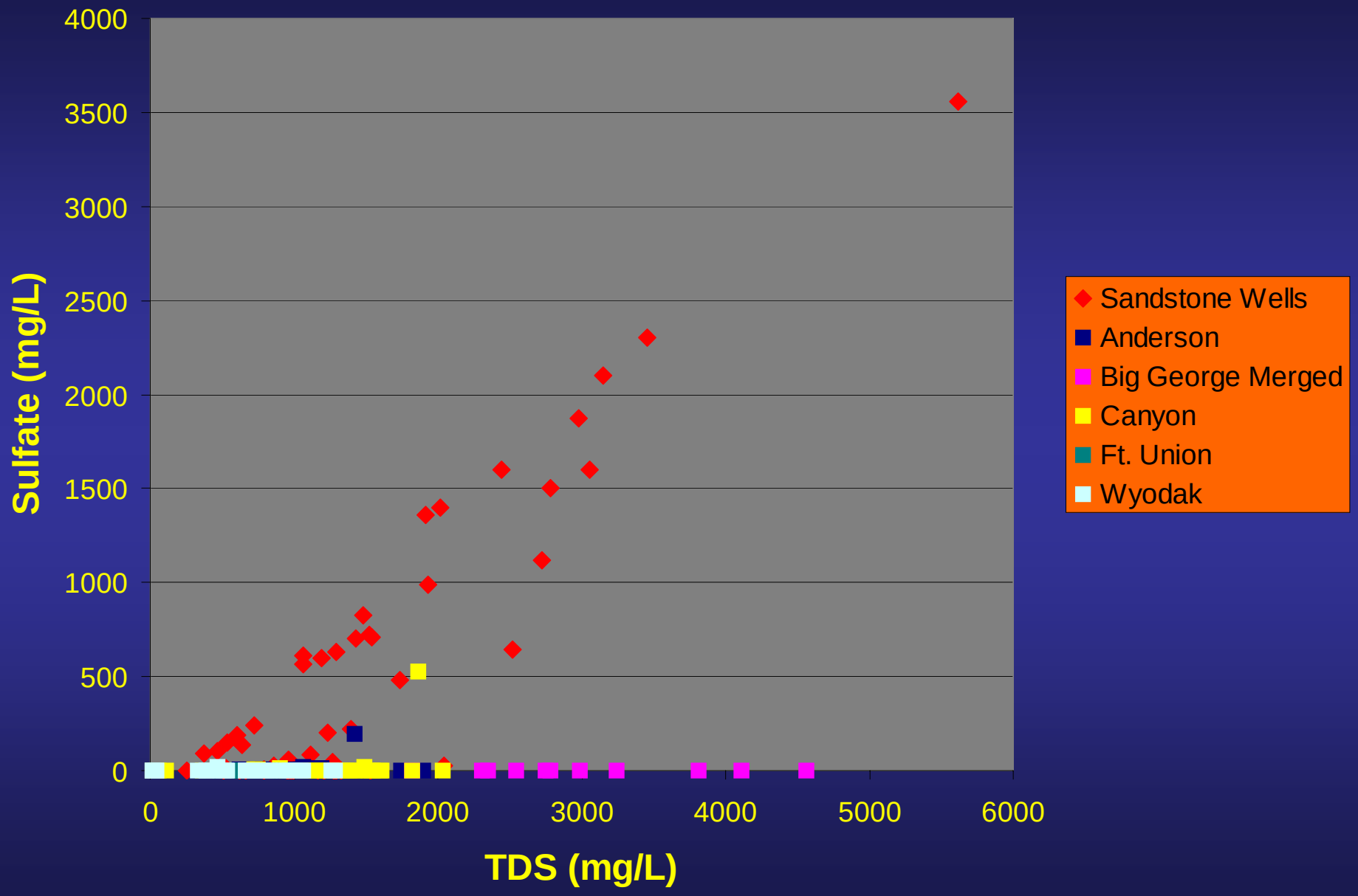
Median Values in ( ) ; n = 54

Comparison of Median Values of Water Composition

	Coal	"Shallow" Sandstone	"Deep" Sandstone
Ave. Depth (ft)	826	240	525
	mg/L		
n	164	28	26
TDS	988	1550	1010
Calcium	32	86	12
Magnesium	14	51	3
Sodium	336	306	395
Bicarbonate	1110	477	1129
Sulfate	0.25	706	2
Chloride	9.5	8	11

Shallow= Sulfate > 100 mg/L

Deep= Sulfate < 100 mg/L


4000
3500
3000
2500
2000
1500
1000
500
0
Sulfate (mg/L)
0
1000
2000
3000
4000
5000
6000
TDS (mg/L)
Sandstone Wells
Anderson
Big George Merged
Canyon
Ft. Union
Wyodak

SUMMARY

- WATER LEAKAGE FROM SANDSTONE TO COAL AQUIFERS IN THE WYODAK-ANDERSON COAL ZONE DURING CBM DEVELOPMENT IN THE PRB IS DOCUMENTED BY STRATIGRAPHIC AND WATER-FLOW MODELING

PROGNOSIS

- LONG TERM EFFECTS ARE DEGRADATION OF WATER QUALITY/CHEMISTRY IN COAL AQUIFERS AND

- DISRUPTION OF BALANCE OF THE VOLUME OF WATER BETWEEN THE AQUIFER TYPES

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THANK YOU AND QUESTIONS!