COALBED METHANE IN THE UNITED STATES: A GIS STUDY

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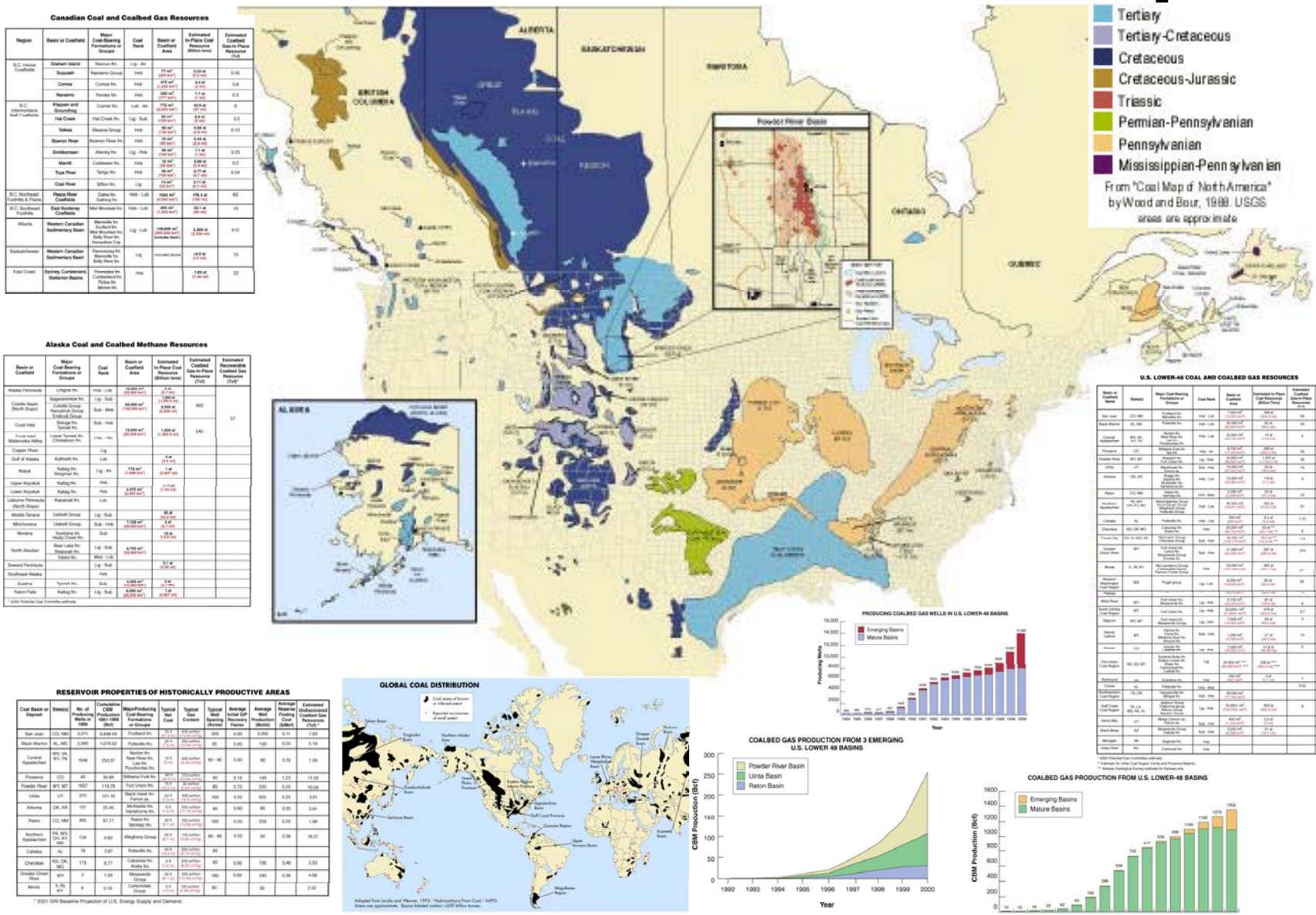
PROJECT OVERVIEW

- Built map of Coalbed Methane (CBM) fields in US
  - Created CBM field outlines from states' well data
  - Expanded upon GTI's 2001 CBM Resource Map
- Compared CBM basins by:
  - Past production, present reserves, future resources
  - GIS helps visualize basin differences
- Integrated Coal Mine data into map
  - Characterized basins by active mine gas emissions

GTI's 2001 CBM Resource Map



Coalbed Methane (CBM) defined

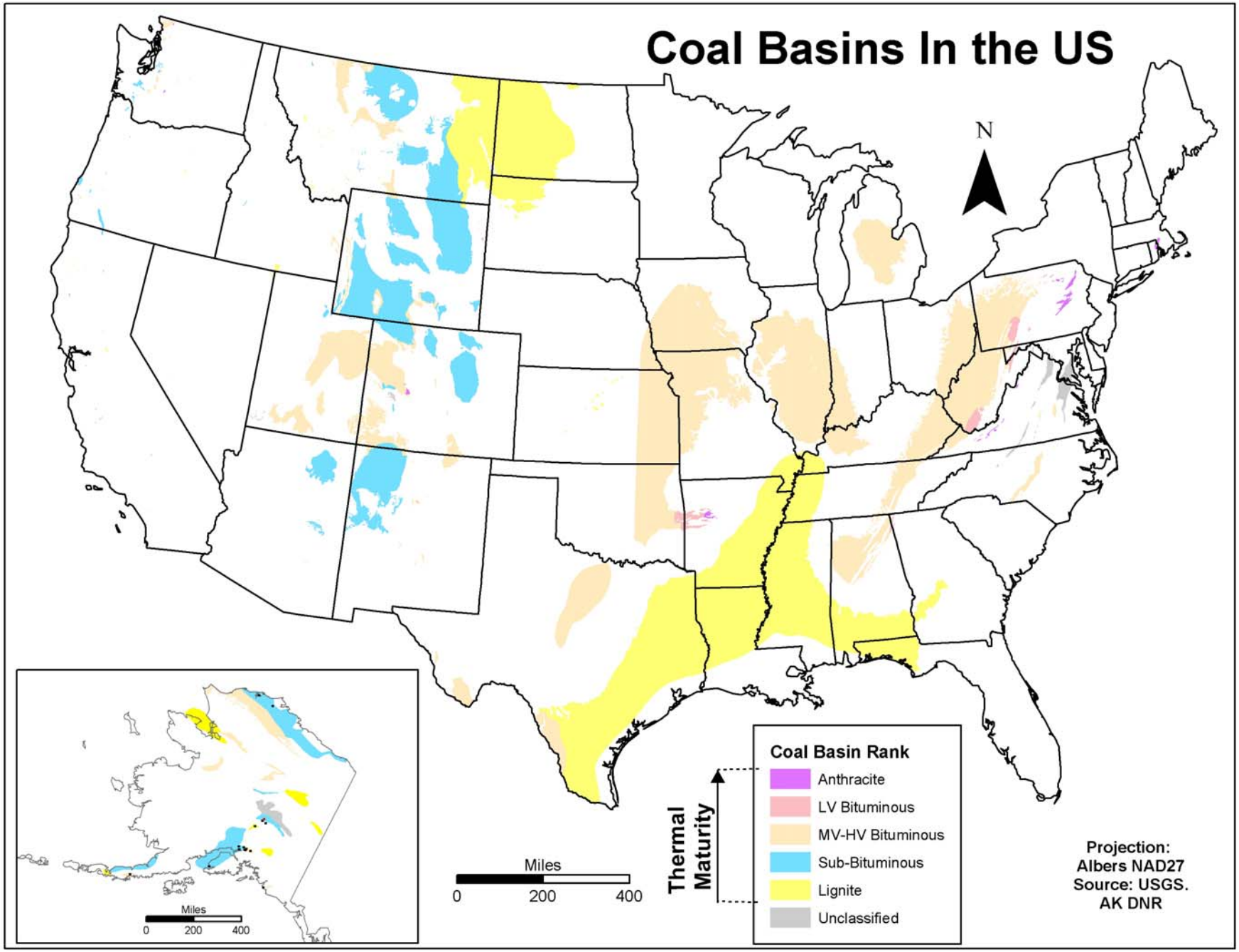
- Natural gas generated by & stored within coal seams underground
- Recoverable by conventional gas wells
- **CBM** - gas recovered from virgin coal seams using gas wells
- **CMM** -“Coal Mine Methane” – when released during mining operations

CBM History & Importance

- History of gas production from coal seams
  - Began as projects to remove CMM for miners' health & safety; vented to atmosphere
  - Captured as local power source
  - 1980's: large-scale commercial CBM production
- Importance of CBM to US gas supply
  - 8% of US gas production (EIA, 2003)
  - 10% of US gas reserves (EIA, 2003)
  - 15% of undiscovered US gas resources (PGC, 2002)

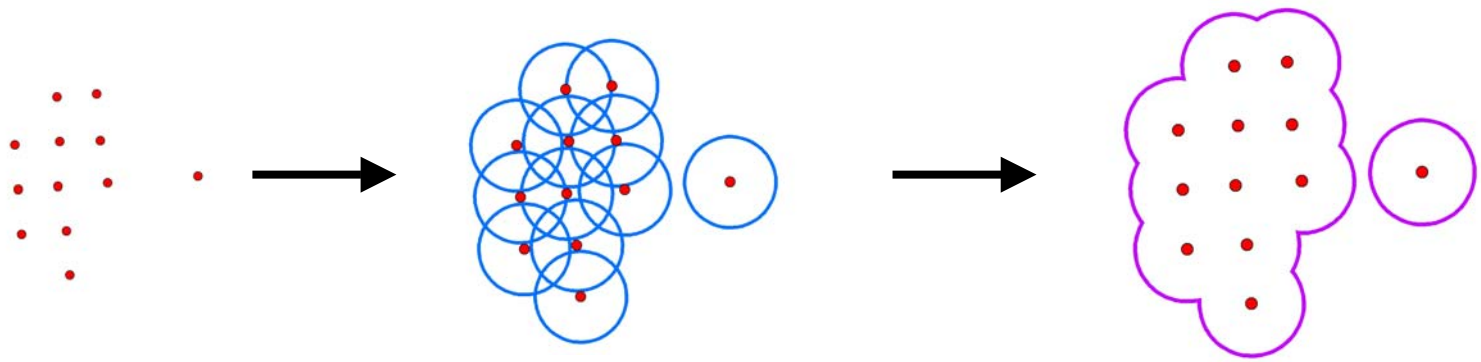
Coal Basins of the US

- CBM within coal basins
- USGS: coal basin update underway
  - Tully (1996) OFR #96-92, for Lower 48 States
  - Milici (1995) NOGA, for E. Coast basins
  - Prof. Papers 1625 A-D (1999-2002) for Rockies & IL
- Alaska DNR: coal basin update underway
  - Merritt & Hawley (1986), coal resources
  - Ehm (1983), oil & gas basins
- Classify basins by rank = thermal maturity of coal


Coal Basins In the US
N
Miles
0
200
400
Thermal Maturity
Coal Basin Rank
Anthracite
LV Bituminous
MV-HV Bituminous
Sub-Bituminous
Lignite
Unclassified
Projection:
Albers NAD27
Source: USGS.
AK DNR
Miles
0
200
400

Create CBM field outline layer from well data

- Obtained digital well data from 18 states:
  - Web download - 5
  - Purchased - 3
  - Obtained works in progress – 7
  - USGS or PTTC source – 3
- Buffer wells with a radius in ArcGIS, then union polygons by FIELD_NAME



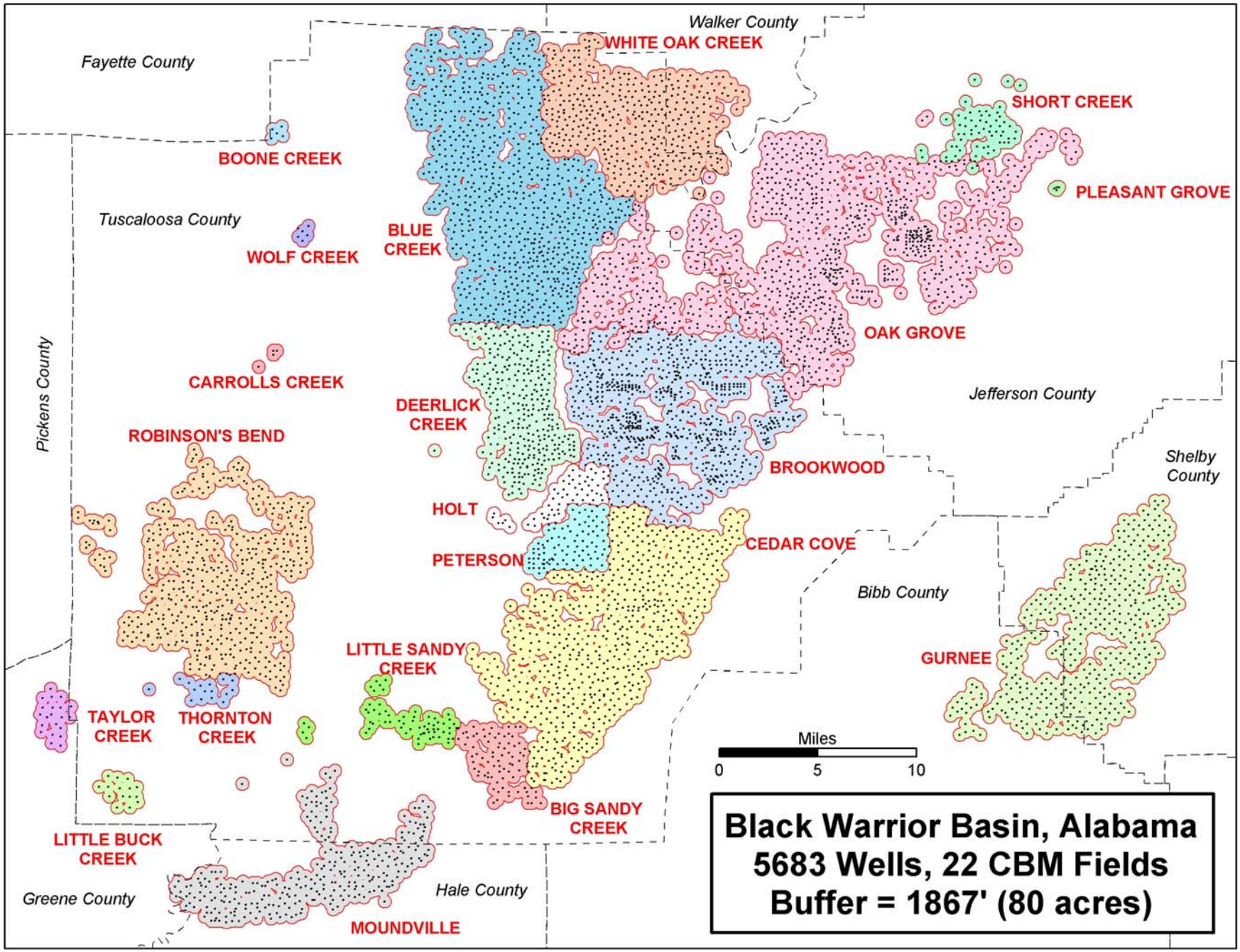
How determine Buffer Distance?

- Buffer dist. = function (standard well spacing unit size)
- States' minimum well spacing rules as starting point
  - NM: 320 ac/well in San Juan, 160 ac/well in Raton

Stand. Spacing Unit (ac / well)	Corresponding Buffer Radius
20	933'
40	1320'
80	1867'
160	2640'
320	3734'

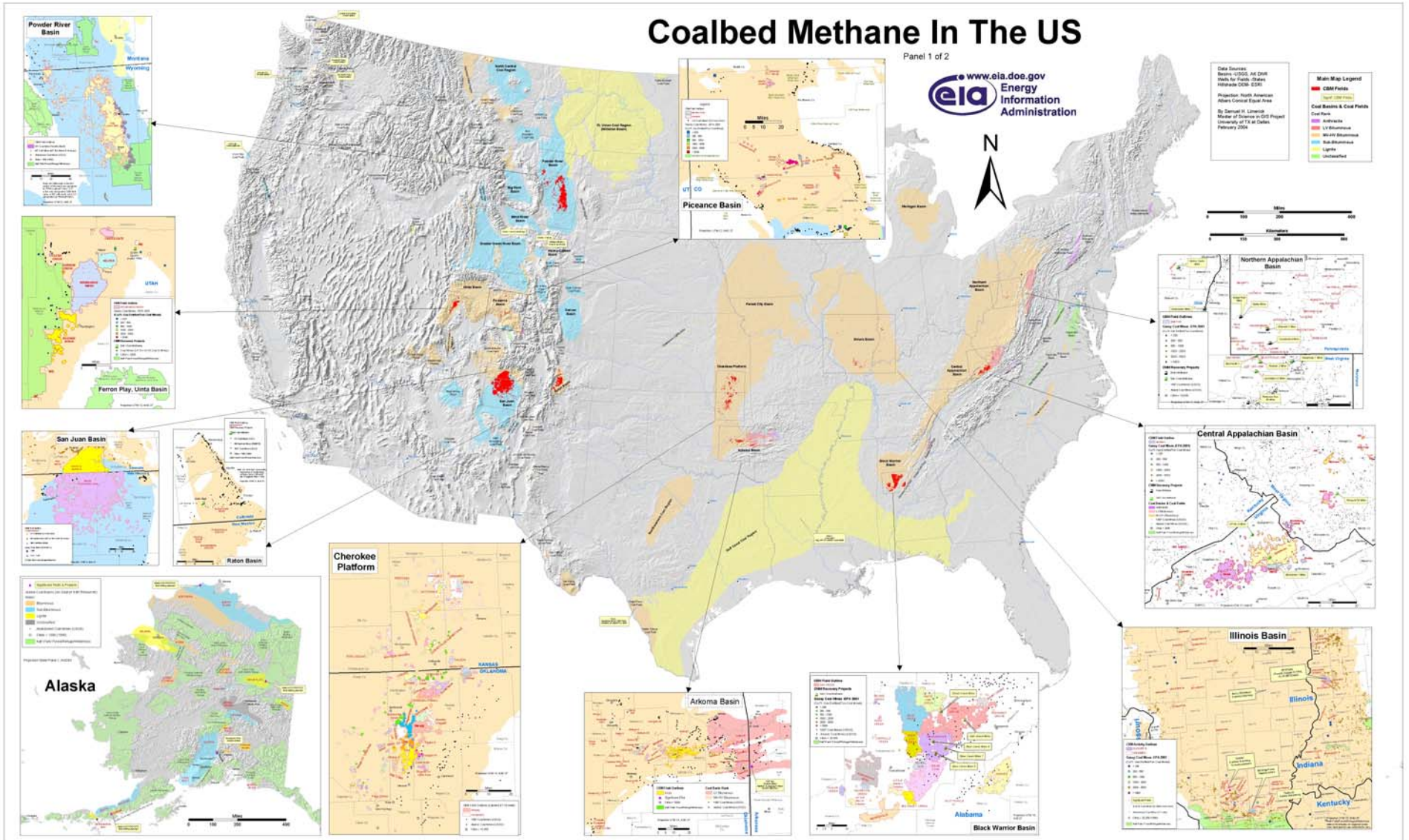
← Max Buffer

- Automate with VBA (code by K. Kuykendall)


Walker County
Fayette County
WHITE OAK CREEK
SHORT CREEK
BOONE CREEK
PLEASANT GROVE
Tuscaloosa County
BLUE CREEK
WOLF CREEK
OAK GROVE
Pickens County
CARROLLS CREEK
Jefferson County
DEERLICK CREEK
ROBINSON'S BEND
Shelby County
BROOKWOOD
HOLT
CEDAR COVE
PETERSON
Bibb County
LITTLE SANDY CREEK
GURNEE
TAYLOR CREEK
THORNTON CREEK
Miles
0
5
10
BIG SANDY CREEK
LITTLE BUCK CREEK
Greene County
Hale County
MOUNDVILLE
Black Warrior Basin, Alabama
5683 Wells, 22 CBM Fields
Buffer = 1867' (80 acres)

The Big Map

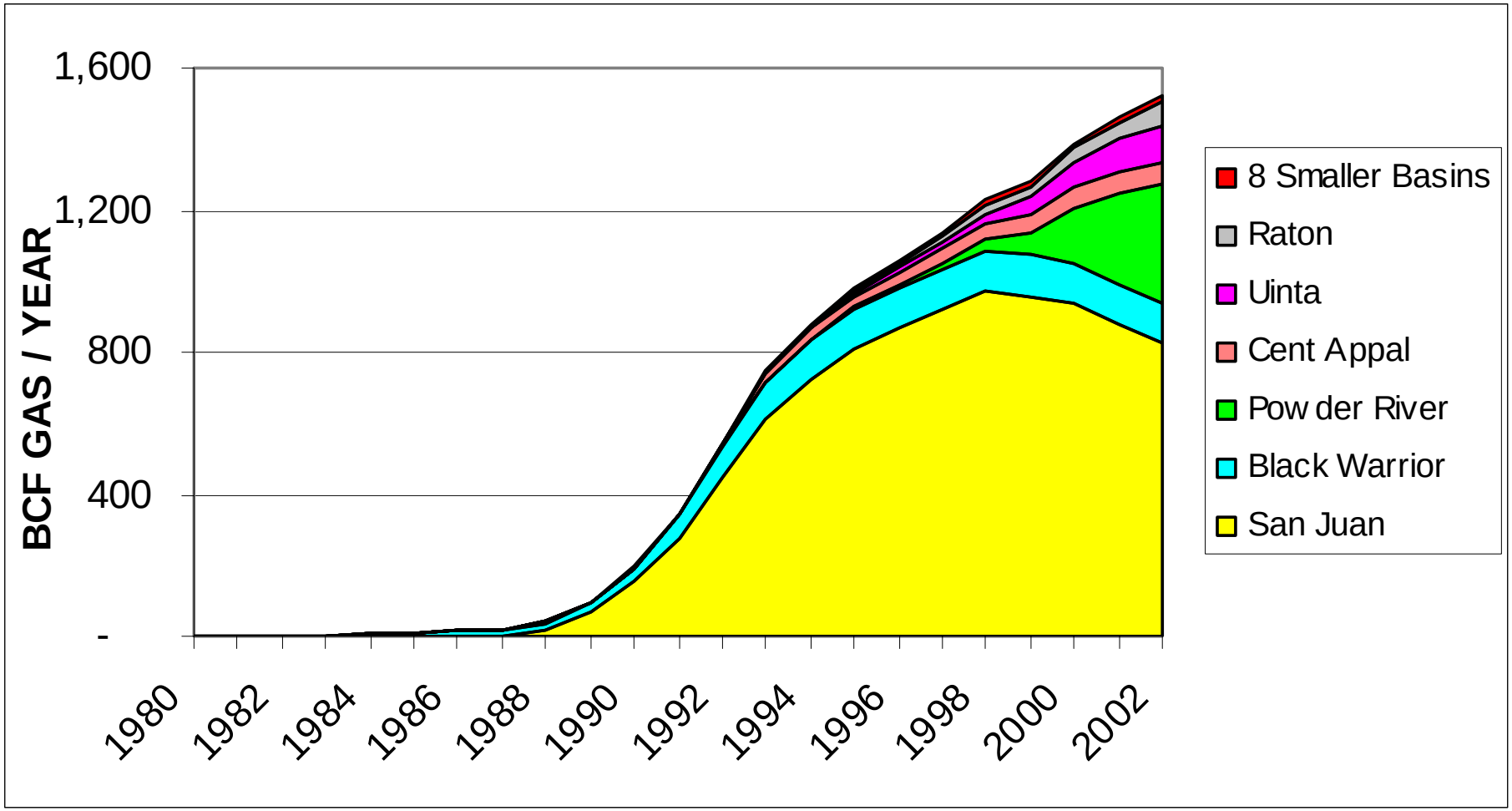
Available at www.eia.doe.gov >Natural Gas > Resources & Reserves > Maps



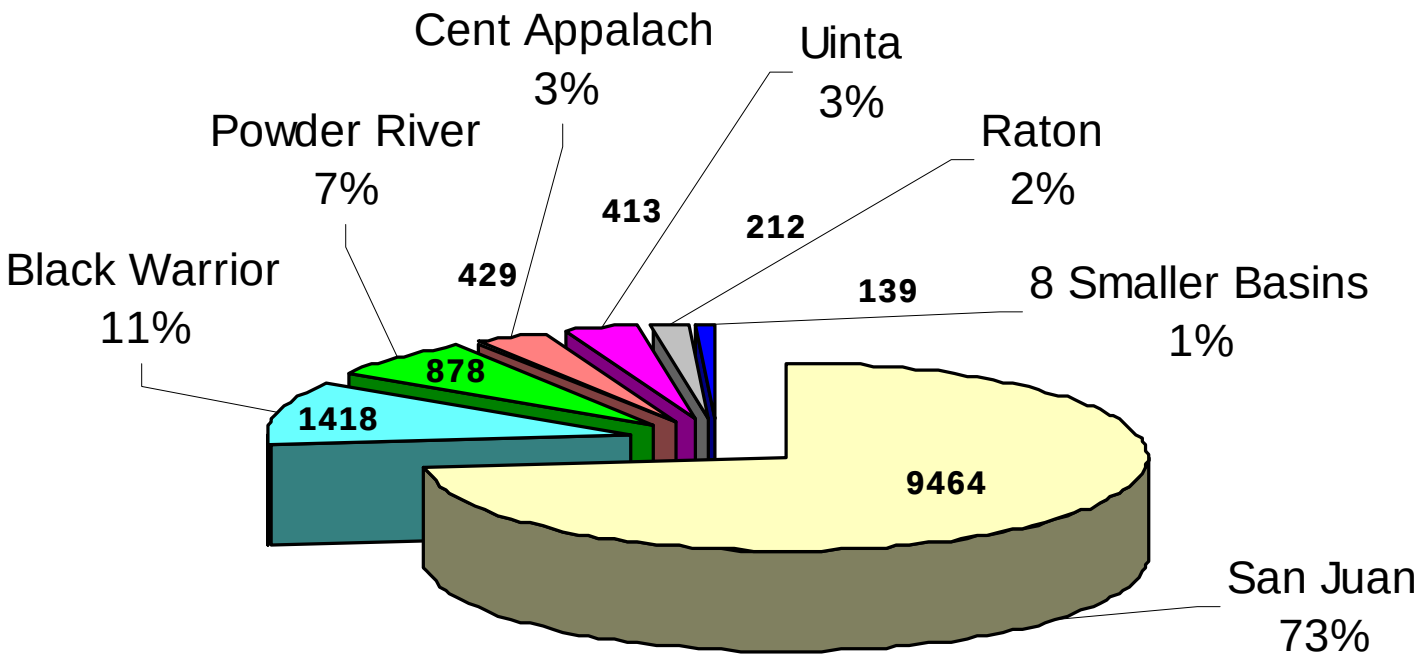
CBM Annual Gas Production by Basin…The Past

- Data from States' Oil & Gas Commissions
  - Classify production by basin
- Data accuracy caveats….usually under-reported:
  - Some states track production by lease, not well
  - If CBM field names not unique from non-CBM, difficult to separate production
  - Wells recompleted from non-CBM zones may not be recorded
  - Older wells: didn't separate CBM from non-CBM
  - Some states don't enforce reporting rules

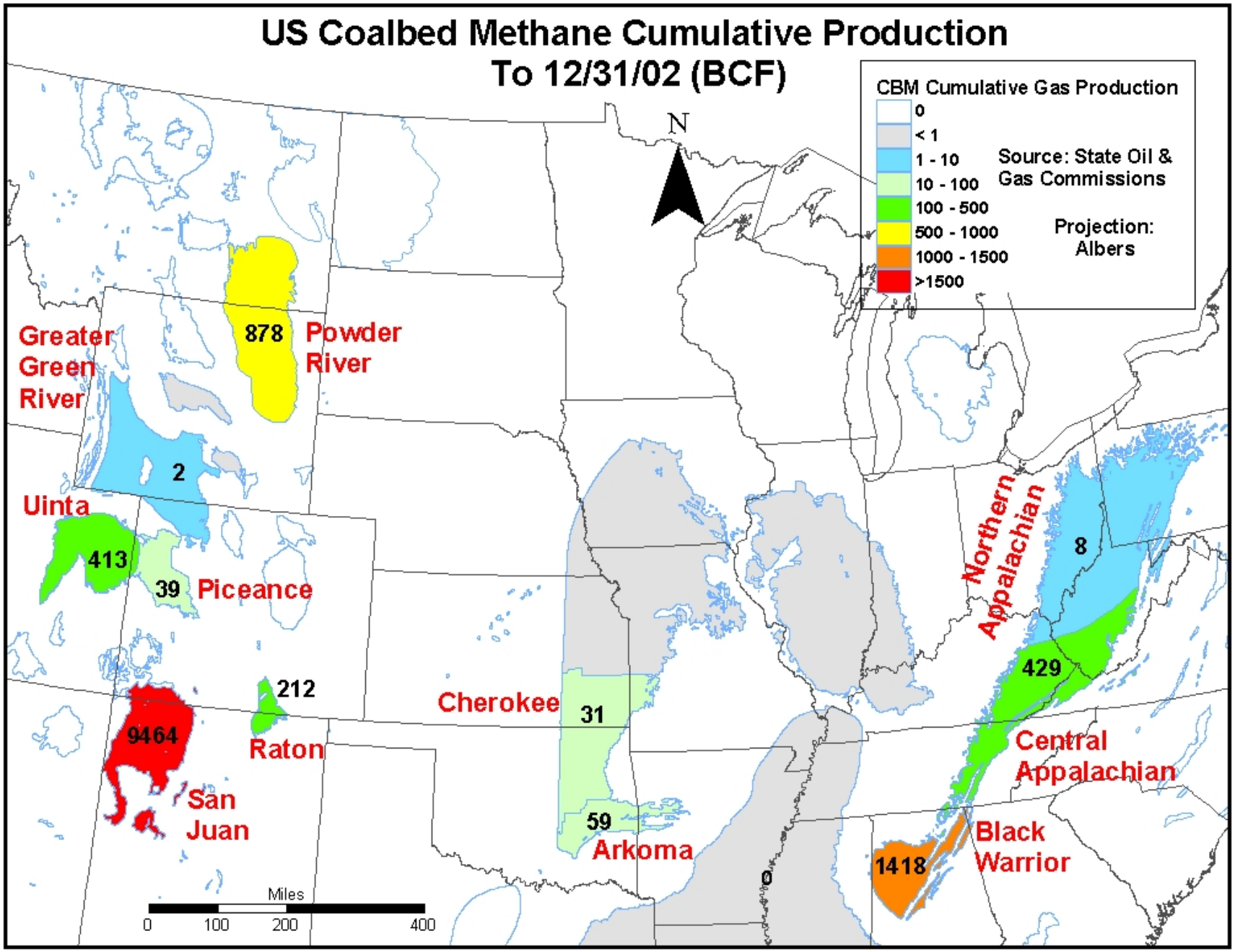
Annual CBM Production by Basin



CUMULATIVE US COALBED GAS PRODUCTION (BCF)
(12-31-2002)



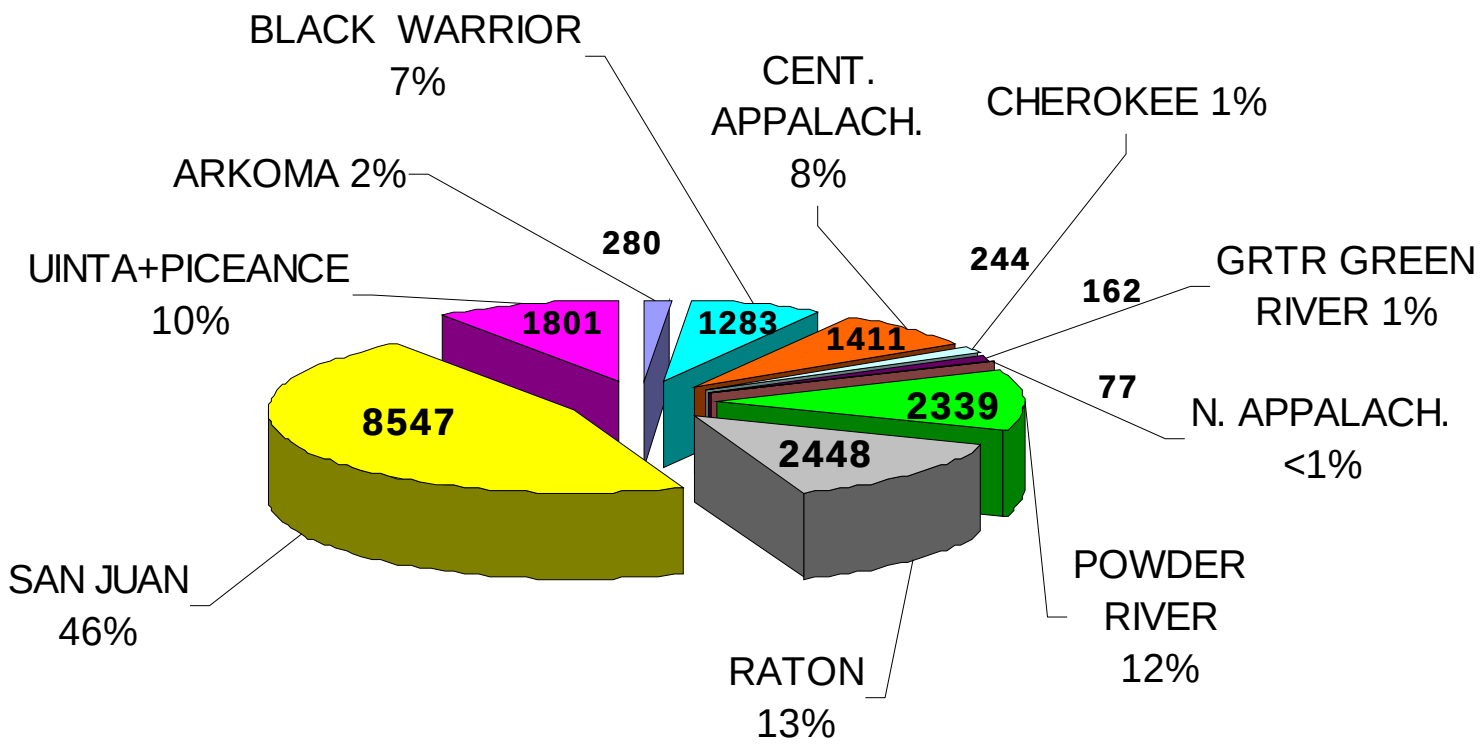
TOTAL CUMULATIVE PRODUCTION = 12,953 BCF GAS


US Coalbed Methane Cumulative Production
To 12/31/02 (BCF)
CBM Cumulative Gas Production
0
< 1
1 - 10
10 - 100
100 - 500
500 - 1000
1000 - 1500
>1500
Source: State Oil & Gas Commissions
Projection: Albers
N
Greater Green River
2
878
Powder River
Uinta
413
39
Piceance
212
Raton
9464
San Juan
Cherokee
31
59
Arkoma
Northern Appalachian
8
429
Central Appalachian
1418
Black Warrior
Miles
0
100
200
400

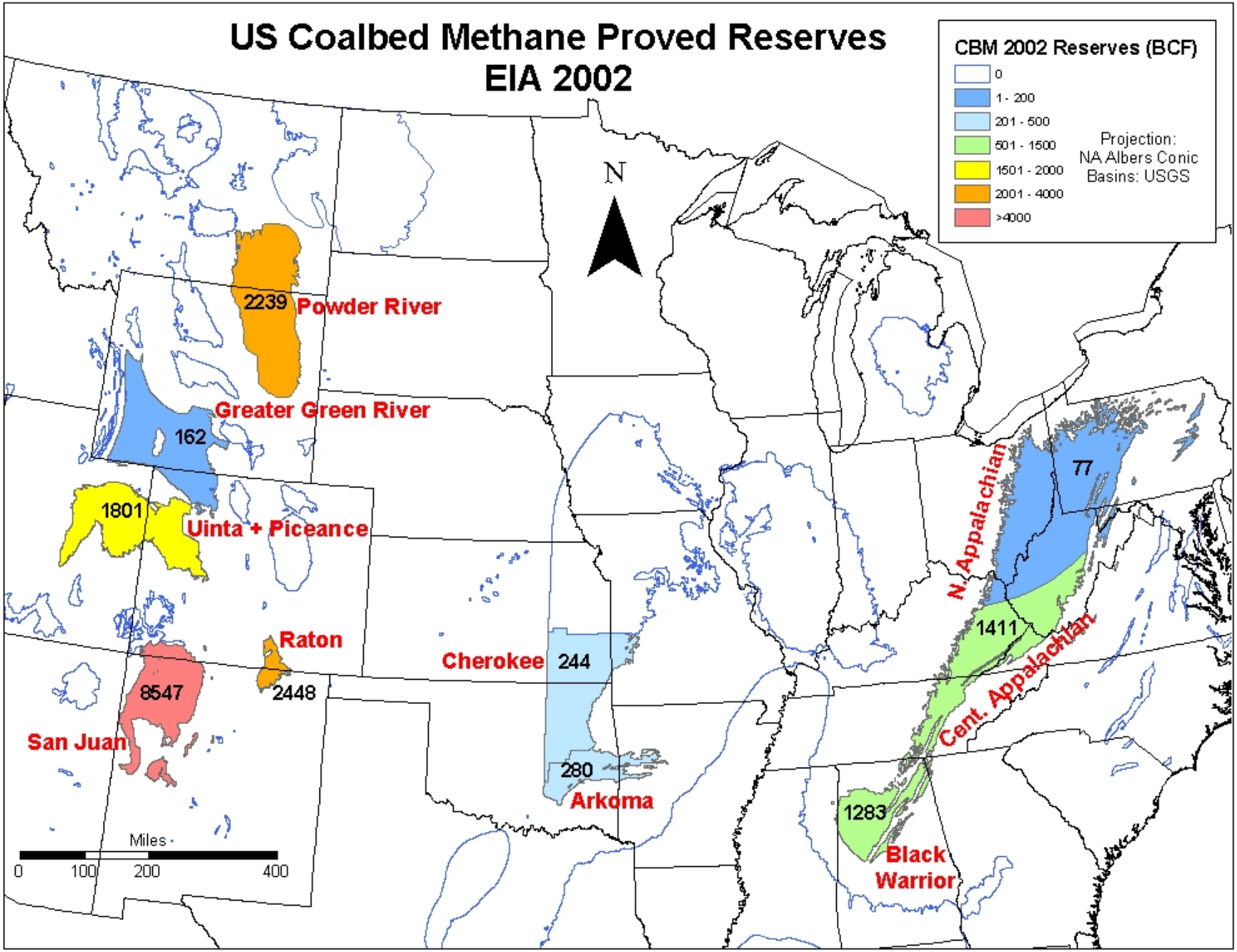
CBM Proved Reserves by Basin…….The Present

- Source: 2002 EIA Reserves Survey
  - Classify by basin
- Data Caveats
  - Does not include small operators
  - Uinta + Piceance basins aggregated for operator confidentiality

2002 CBM Reserves (BCF)- Energy Information Administration



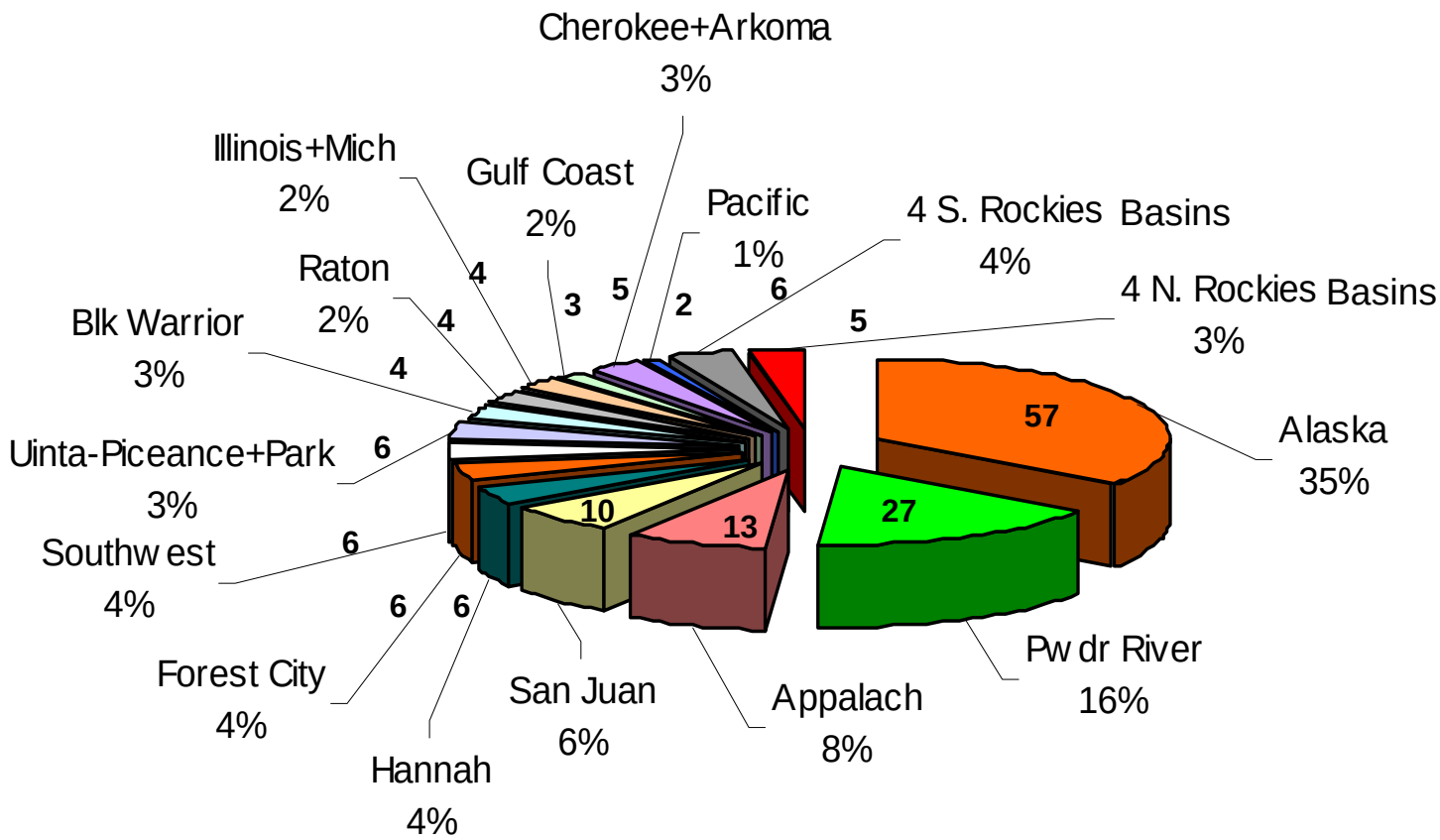
Total 2002 CBM Reserves = 18,491 BCF


US Coalbed Methane Proved Reserves
EIA 2002
CBM 2002 Reserves (BCF)
0
1 - 200
201 - 500
501 - 1500
1501 - 2000
2001 - 4000
>4000
Projection:
NA Albers Conic
Basins: USGS
N
2239
Powder River
Greater Green River
162
1801
Uinta + Piceance
Raton
2448
8547
San Juan
Cherokee
244
280
Arkoma
77
N. Appalachian
1411
Cent. Appalachian
1283
Black
Warrior
Miles
0
100
200
400

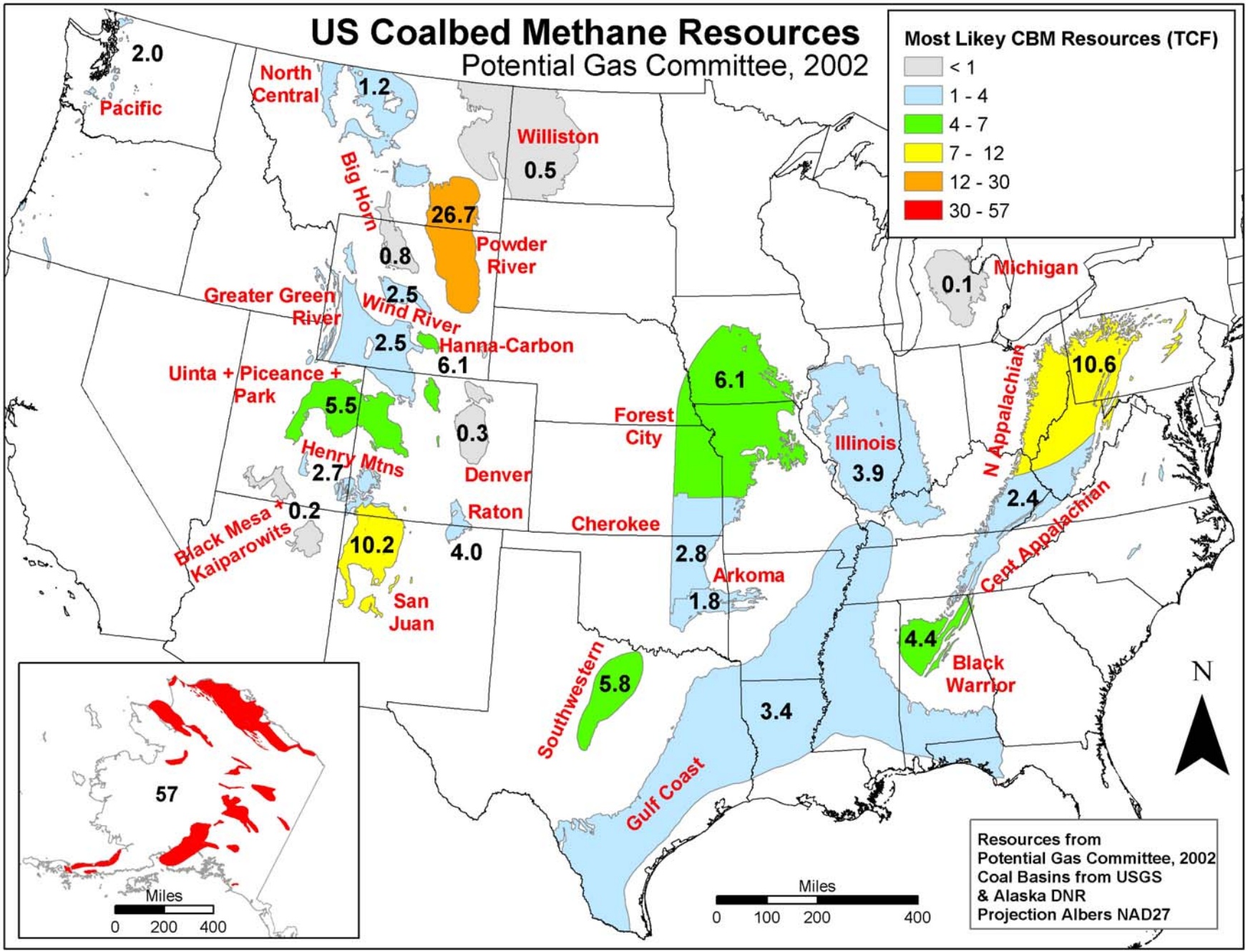
CBM Undiscovered Resources by Basin….. The Future

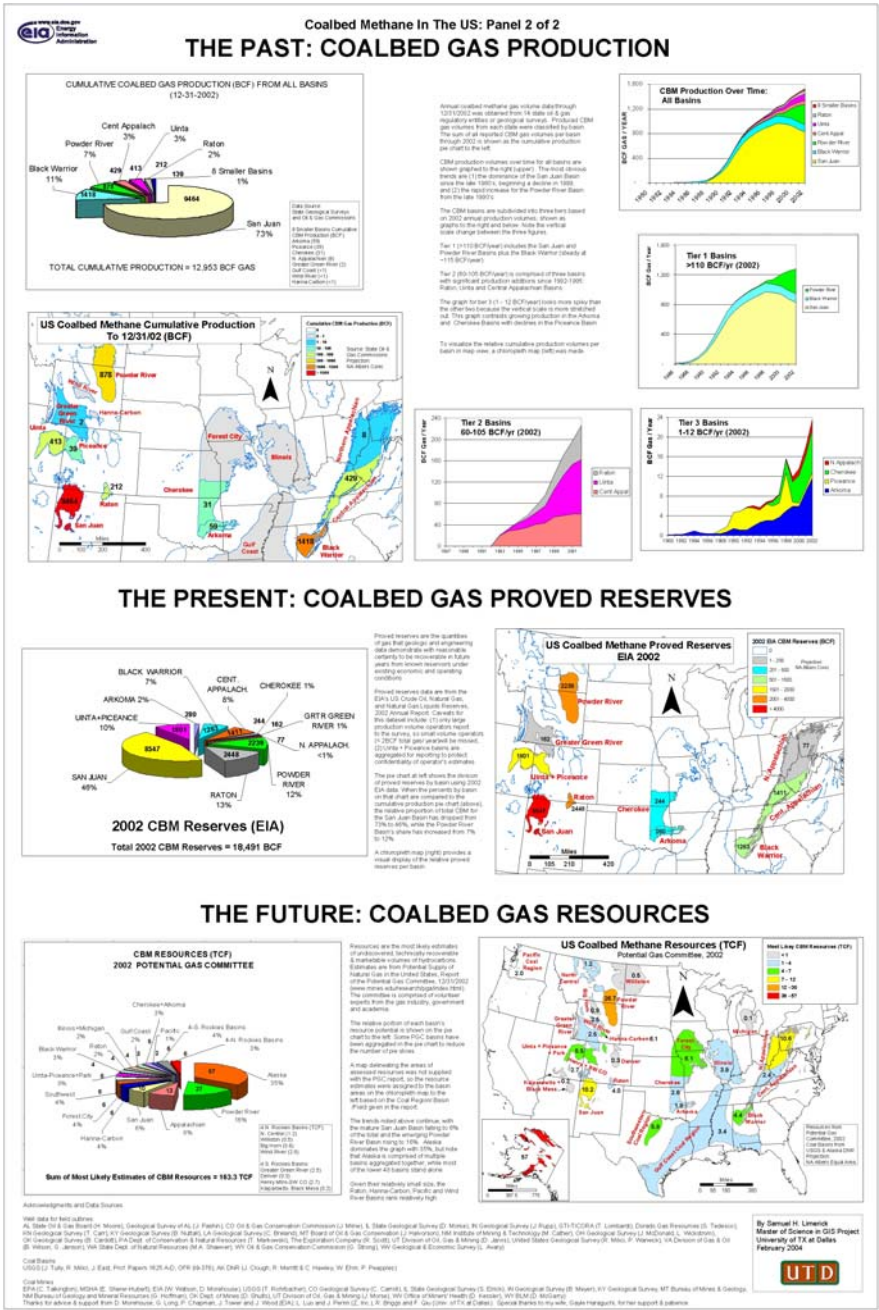
- Source: Potential Gas Committee, 2002
  - Volunteer experts (gas industry, govt. agencies, academics)

CBM RESOURCES (TCF)
2002 POTENTIAL GAS COMMITTEE



Sum of Most Likely Estimates of CBM Resources = 163.3 TCF


US Coalbed Methane Resources
Potential Gas Committee, 2002
Most Likey CBM Resources (TCF)
< 1
1 - 4
4 - 7
7 - 12
12 - 30
30 - 57
2.0
Pacific
North Central
1.2
Williston
0.5
Big Horn
26.7
Powder River
0.8
Greater Green River
2.5
Wind River
2.5
Hanna-Carbon
6.1
Uinta + Piceance + Park
5.5
Henry Mtns
2.7
0.3
Denver
Raton
0.2
Black Mesa + Kaiparowits
10.2
San Juan
4.0
Forest City
6.1
Cherokee
2.8
Arkoma
1.8
Southwestern
5.8
Gulf Coast
3.4
Michigan
0.1
Illinois
3.9
N Appalachian
10.6
2.4
Cent Appalachian
4.4
Black Warrior
57
Miles
0 200 400
Miles
0 100 200 400
N
Resources from
Potential Gas Committee, 2002
Coal Basins from USGS
& Alaska DNR
Projection Albers NAD27



The Side Panel

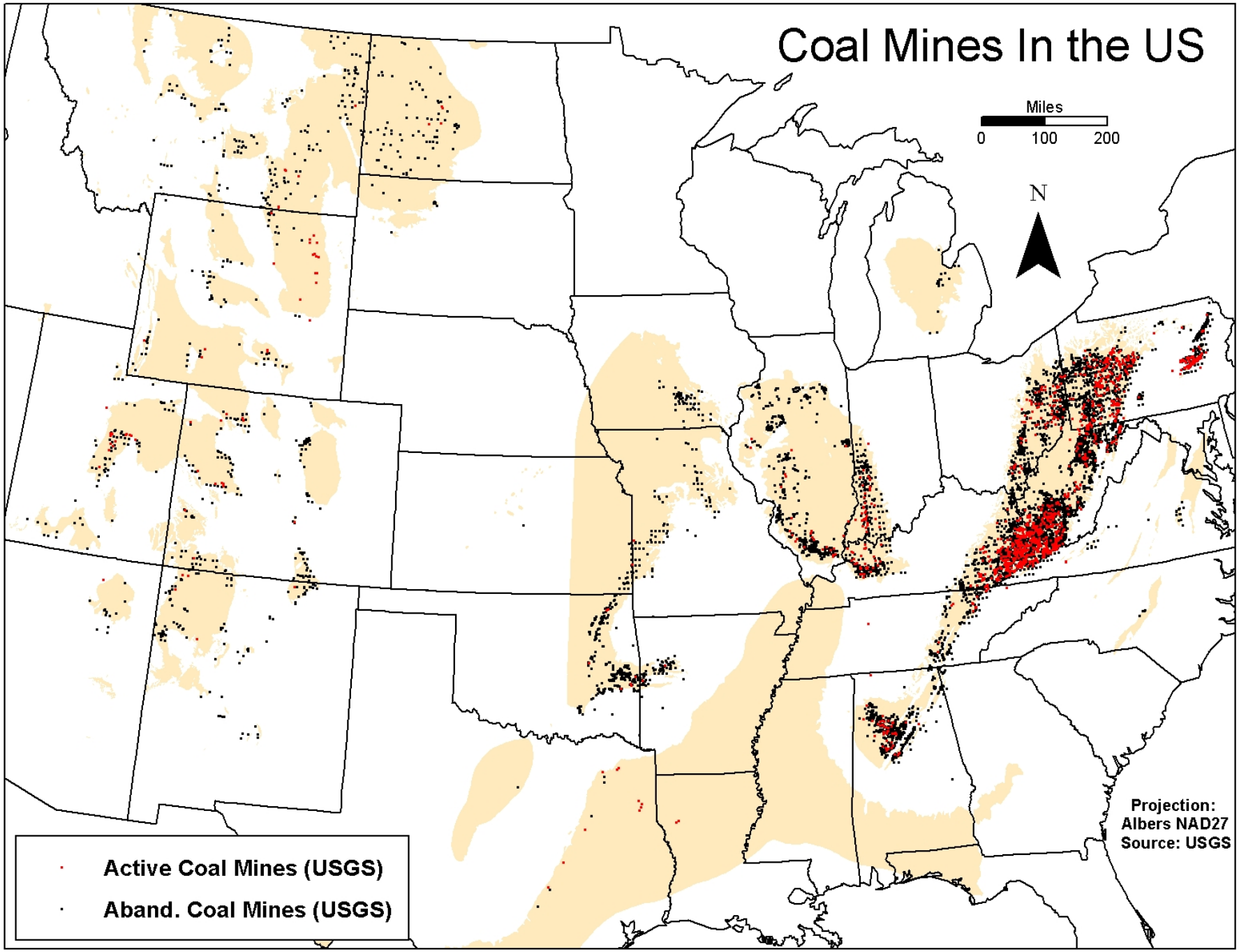
- Production
- Reserves
- Resources

- Data Sources

Available at www.eia.doe.gov > Natural Gas > Resources & Reserves > Maps

Coal Mine data sources at regional scale

- Active Mines: ~1500 (USGS, MSHA, EIA)
  - Approx. equal #'s underground & surface (strip)
    - Portal vs. centroid
  - Locations only partially verified
- Abandoned mines: >20,000 (USGS)
  - Only a partial estimate
- 15 CBM states have detailed mine data
  - More upgrade $ since 2002 Quecreek, PA accident

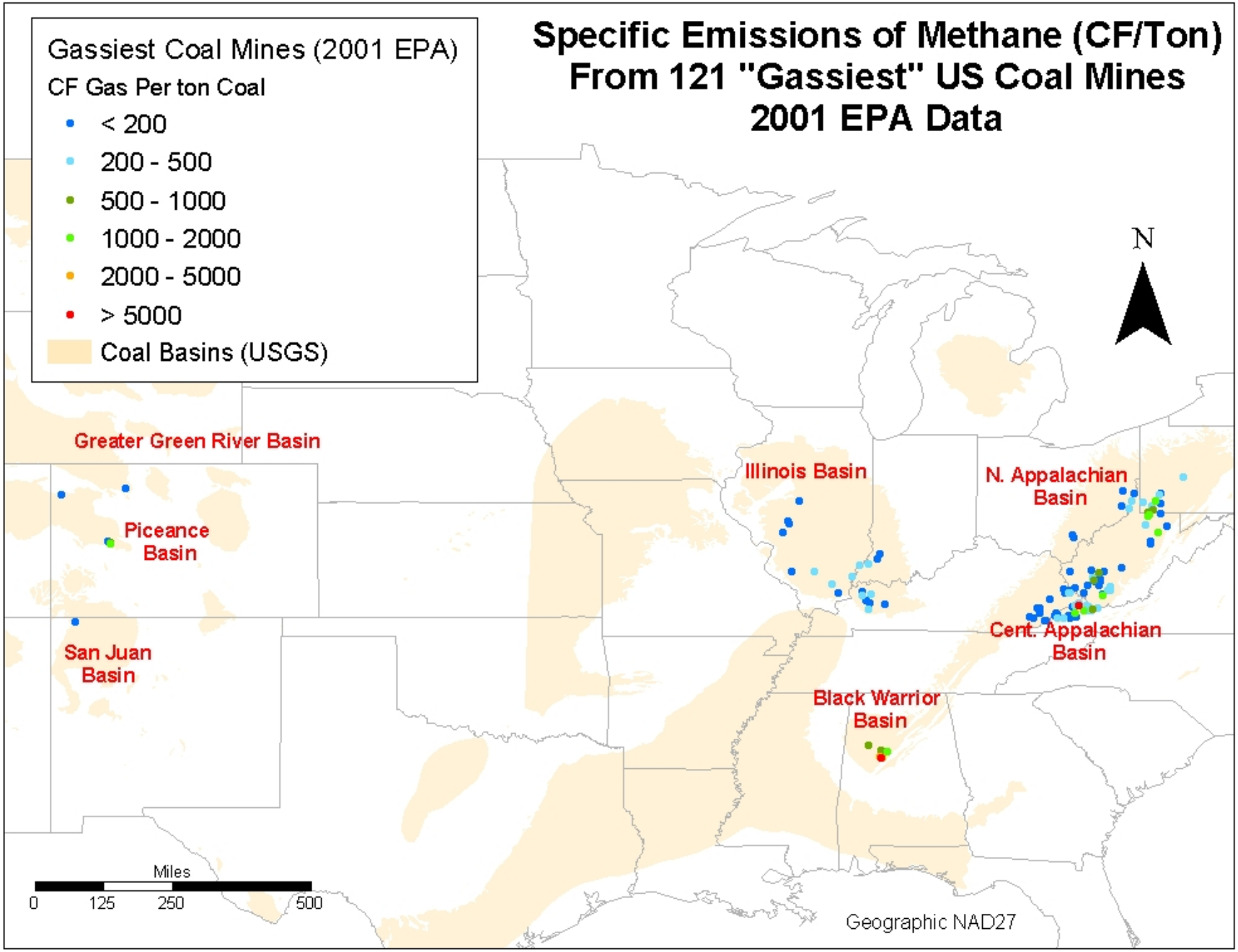

Coal Mines In the US
Miles
0
100
200
N
Active Coal Mines (USGS)
Aband. Coal Mines (USGS)
Projection:
Albers NAD27
Source: USGS

Coal Mine Gas Emissions

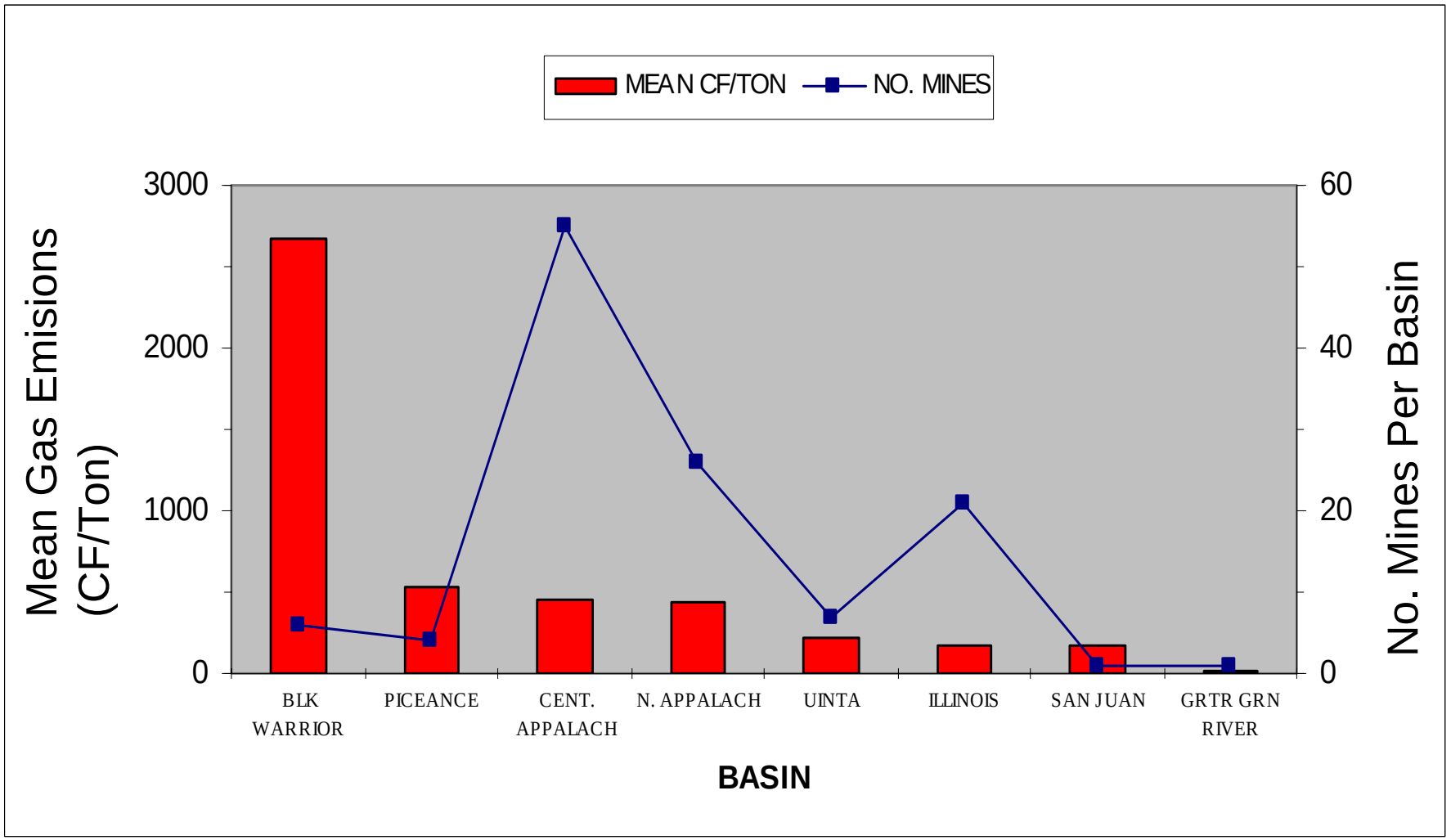
- US Bureau of Mines- measure emissions for safety
  - Irani et al. (1972, 1974), Trevits/Finfinger et al. (1993)
  - ~ 500 mines, most in Appalachian region
- Good correlation between mine gas emission rate & coal production rate
  - Normalize to compare “gassiness” of mines: *Specific Emissions* = annual CF gas emitted/ ton coal mined
- All of above: no digital files, no locations

EPA's Coalmine Emission Outreach Program (CMOP)

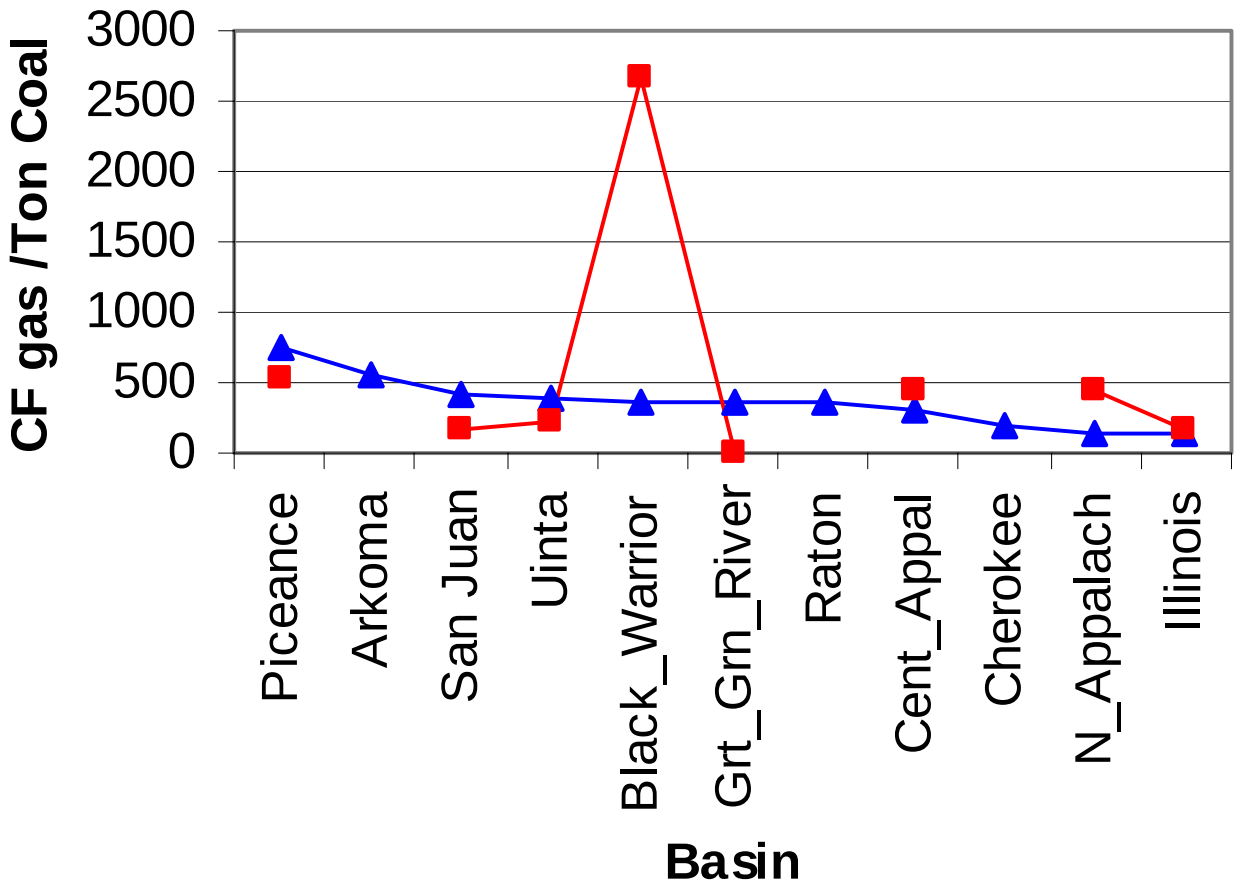
- Track "gassiest" active underground coal mines to promote CMM recovery since 1994
  - For profit & greenhouse gas reduction
    - methane = 21 X potency of CO2 as greenhouse gas
- 2001 EPA emission data for 121 gassy mines
  - Measured by MSHA 4x per year
  - Link by MSHA-ID to:
    - Mine location shapefile
    - File with tons coal mined/yr
- Calculate *Specific Emissions* & map


Specific Emissions of Methane (CF/Ton)
From 121 "Gassiest" US Coal Mines
2001 EPA Data
Gassiest Coal Mines (2001 EPA)
CF Gas Per ton Coal
< 200
200 - 500
500 - 1000
1000 - 2000
2000 - 5000
> 5000
Coal Basins (USGS)
N
Greater Green River Basin
Piceance Basin
San Juan Basin
Illinois Basin
N. Appalachian Basin
Cent. Appalachian Basin
Black Warrior Basin
Miles
0
125
250
500
Geographic NAD27

Location of the “Gassiest” Coal Mines (EPA data)



Mean Mine Emissions by Basin (EPA) vs. Typical Gas Content (GTI)



The correlation is not too bad, except For Black Warrior (probable measurement error)

Conclusion

- CBM Fields in the US mapped
  - Big map available from EIA as *pdf*
  - Field outline shapefile available on request
- CBM Production/Reserves/Resources
  - Summarize with maps & charts
- GIS used to
  - Characterize coal basins by mine gassiness