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Chemical and isotopic composition of water from the Wasatch and Fort Union Formations in areas of coalbed methane development, Powder River Basin, Wyoming

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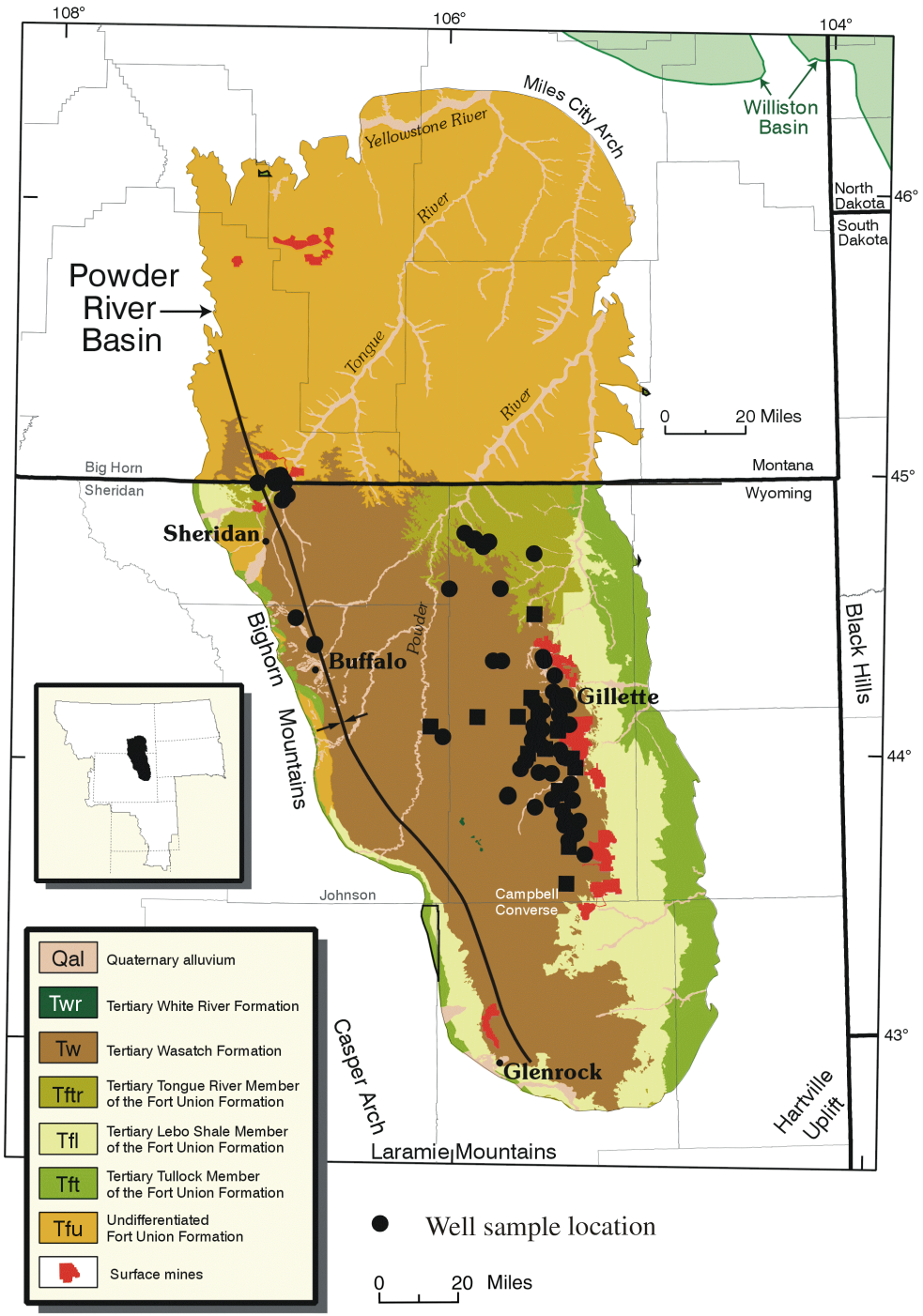
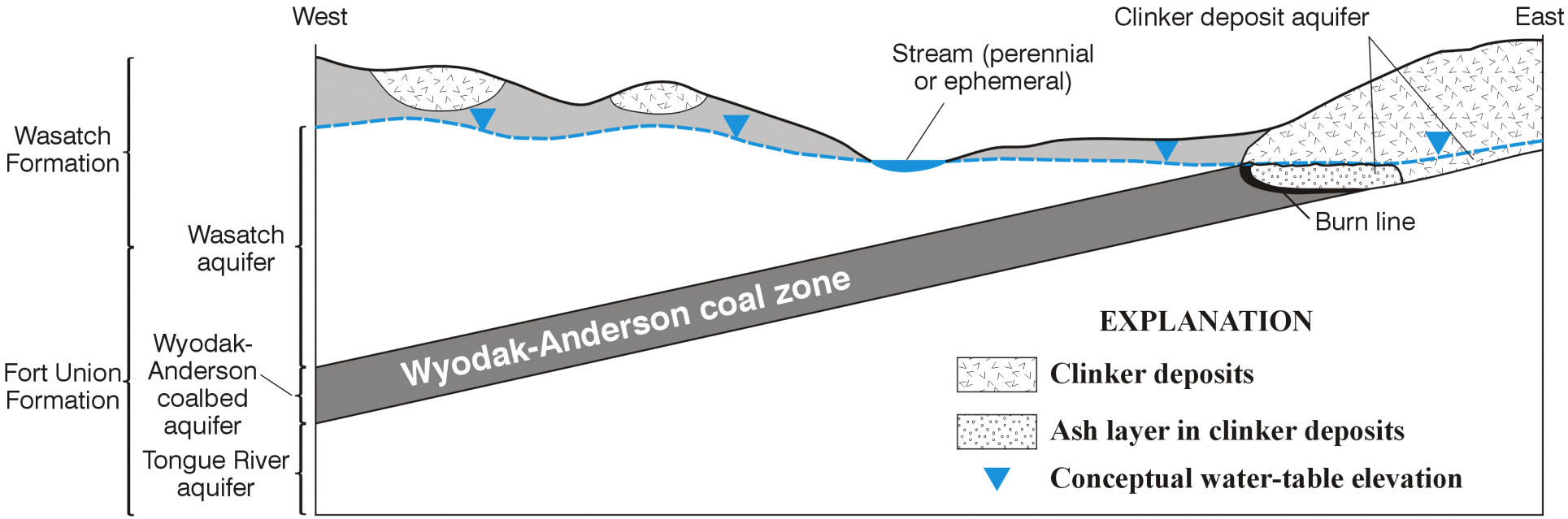
U.S. Geological Survey


108°
106°
104°
Miles City Arch
Williston Basin
Yellowstone River
River
North Dakota
South Dakota
46°
Powder River Basin
Tongue
River
0 20 Miles
Big Horn
Sheridan
Montana
Wyoming
45°
Sheridan
Bighorn Mountains
Powder
Buffalo
Gillette
Black Hills
44°
Johnson
Campbell
Converse
Qal Quaternary alluvium
Twr Tertiary White River Formation
Tw Tertiary Wasatch Formation
Tftr Tertiary Tongue River Member of the Fort Union Formation
Tfl Tertiary Lebo Shale Member of the Fort Union Formation
Tft Tertiary Tullock Member of the Fort Union Formation
Tfu Undifferentiated Fort Union Formation
Surface mines
Casper Arch
Glenrock
43°
Hartville Uplift
Laramie Mountains
Well sample location
0 20 Miles



Relation of Cenozoic stratigraphic units to hydrogeologic units, Powder River Basin, Wyoming.

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Chemical composition

- Major-ion composition
  - Examination in relation to vertical dimension and between aquifers

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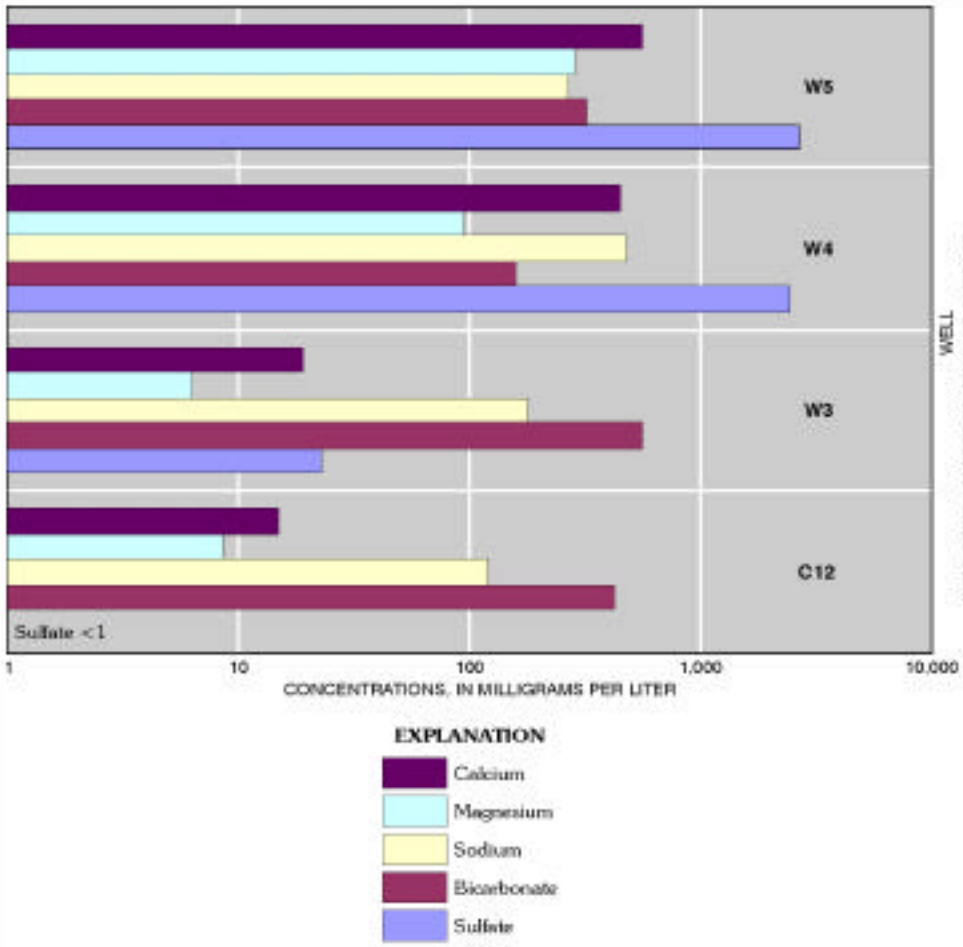
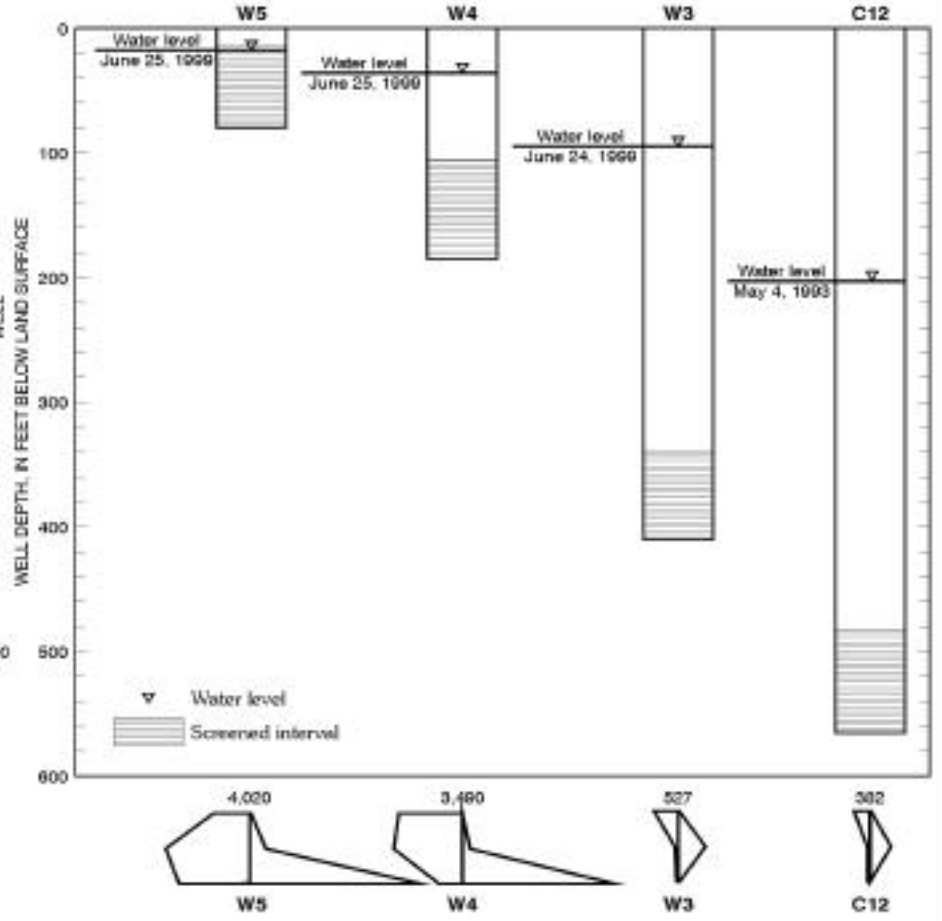
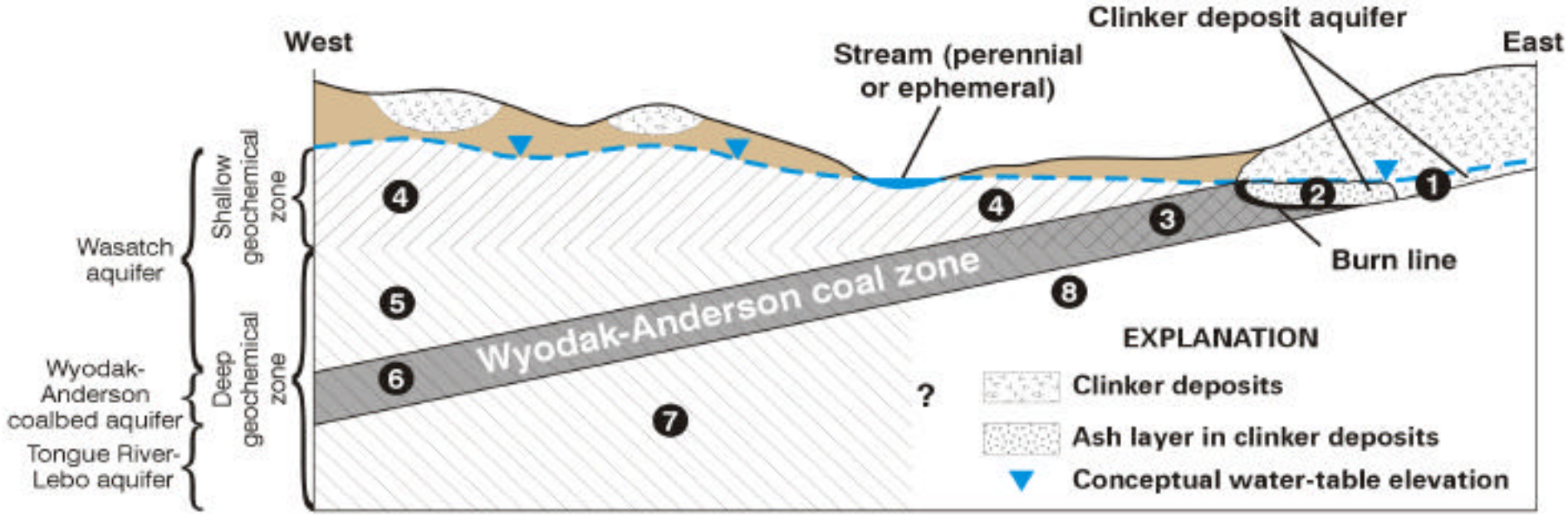

W5
W4
W3
C12
Sulfate <1
1
10
100
1,000
10,000
CONCENTRATIONS, IN MILLIGRAMS PER LITER
EXPLANATION
Calcium
Magnesium
Sodium
Bicarbonate
Sulfate


W5
W4
W3
C12
Water level
June 25, 1999
Water level
June 25, 1999
Water level
June 24, 1999
Water level
May 4, 1993
0
100
200
300
400
500
600
WELL DEPTH, IN FEET BELOW LAND SURFACE
Water level
Screened interval
4,020
3,460
527
382
W5
W4
W3
C12



Conceptual model of major-ion composition in relation to hydrogeologic units

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Chemical composition

- Major-ion composition
  - Geochemical processes affecting ionic composition in study area
    - Dissolution and precipitation
    - Cation exchange:
      - $Na_2X + Ca^{2+} <\ -- > CaX + 2Na^{+}$
      - $Na_2X + Mg <\ -- > MgX + 2Na^{+}$
    - Bacterially-mediated sulfate reduction
      - Generalized: $2CH_2O + SO_4^{2-} + H^{+} = HS^{-} + 2H_2O + CO_2$

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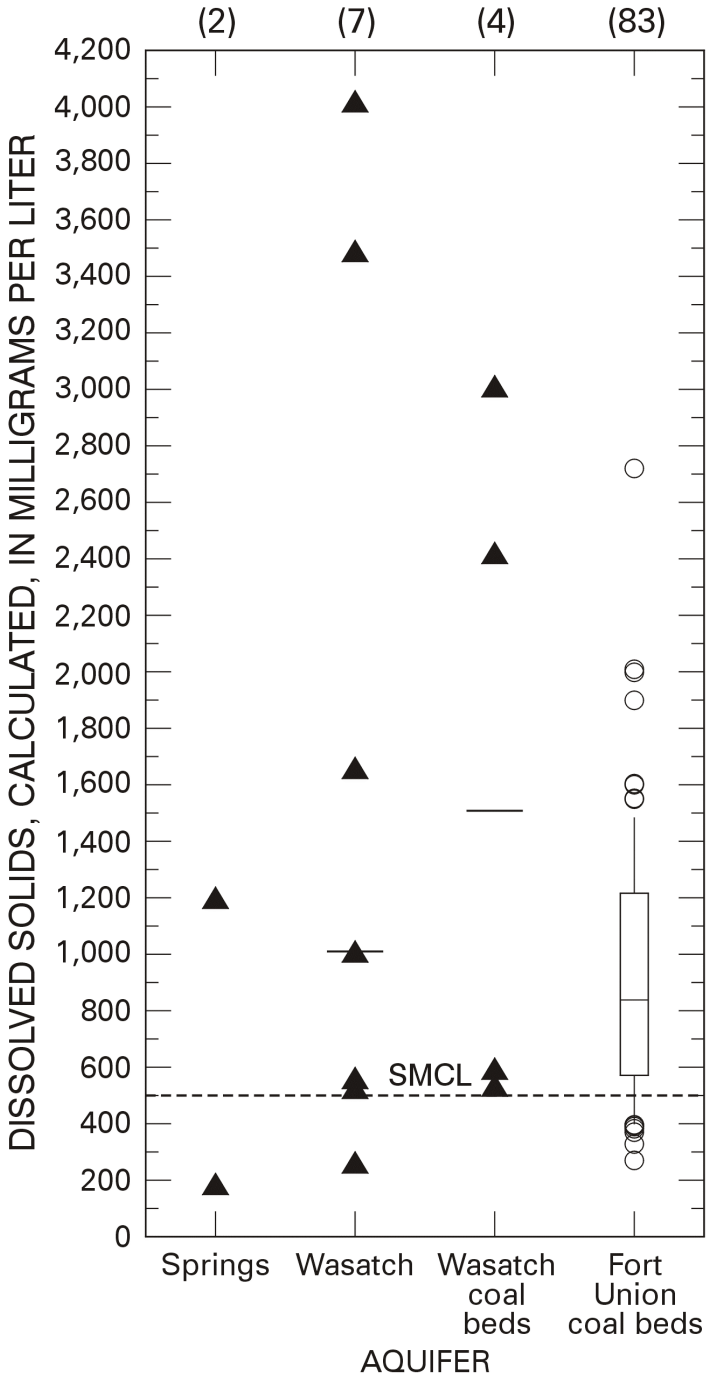
(2)
(7)
(4)
(83)
4,200
4,000
3,800
3,600
3,400
3,200
3,000
2,800
2,600
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
DISSOLVED SOLIDS, CALCULATED, IN MILLIGRAMS PER LITER
SMCL
Springs
Wasatch
Wasatch coal beds
Fort Union coal beds
AQUIFER

Chemical composition

- Major-ion composition
  - Areal distribution of dissolved solids in Fort Union coal beds
    - Dissolved solids lowest south of the Belle Fourche River
    - Increase from south to north and east to west
    - Increase in dissolved solids result of increase in sodium and bicarbonate content of water

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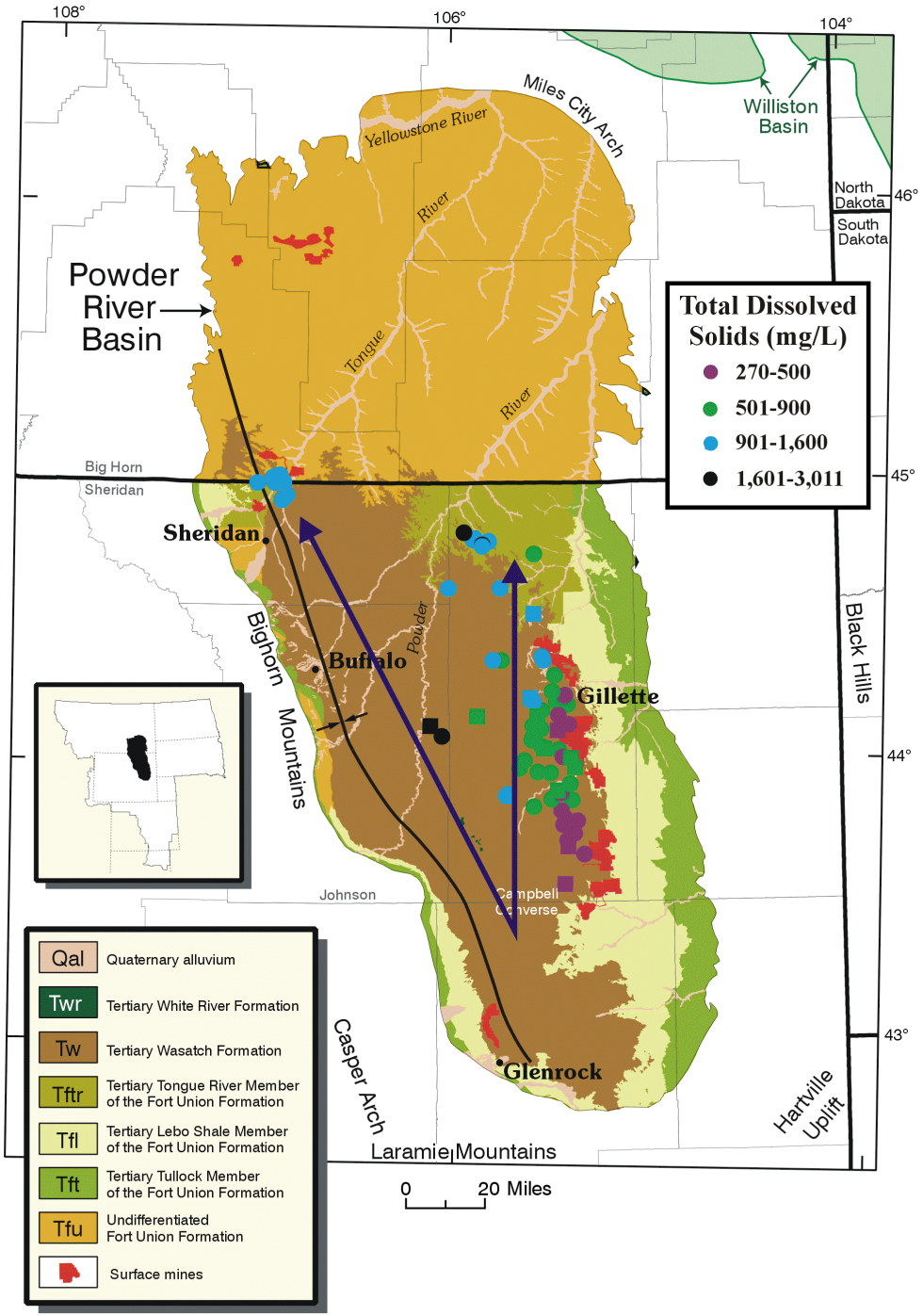
108°
106°
104°
Miles City Arch
Williston Basin
Yellowstone River
River
North Dakota
46°
South Dakota
Powder River Basin
Tongue
River
Total Dissolved Solids (mg/L)
270-500
501-900
901-1,600
1,601-3,011
Big Horn
Sheridan
45°
Sheridan
Bighorn Mountains
Powder
Buffalo
Gillette
Black Hills
44°
Johnson
Campbell
Converse
Qal Quaternary alluvium
Twr Tertiary White River Formation
Tw Tertiary Wasatch Formation
Tftr Tertiary Tongue River Member of the Fort Union Formation
Tfl Tertiary Lebo Shale Member of the Fort Union Formation
Tft Tertiary Tullock Member of the Fort Union Formation
Tfu Undifferentiated Fort Union Formation
Surface mines
Casper Arch
Glenrock
43°
Hartville Uplift
Laramie Mountains
0
20 Miles

Chemical composition

- Major-ion composition
  - Sodium-adsorption ratio (SAR)
    - General trend is same as dissolved-solids concentrations
    - SAR in Fort Union coalbed aquifers ranges from about 6 to 60 with a median of about 9

Chemical composition

- Trace elements in Fort Union coalbed aquifers
  - Low to non-detectable concentrations for most trace elements
    - Except iron, manganese, and barium
    - Some exceedances of SMCLs – iron and manganese
    - Barium – relatively high compared to most ground waters
      - Barium probably controlled by low sulfate concentrations

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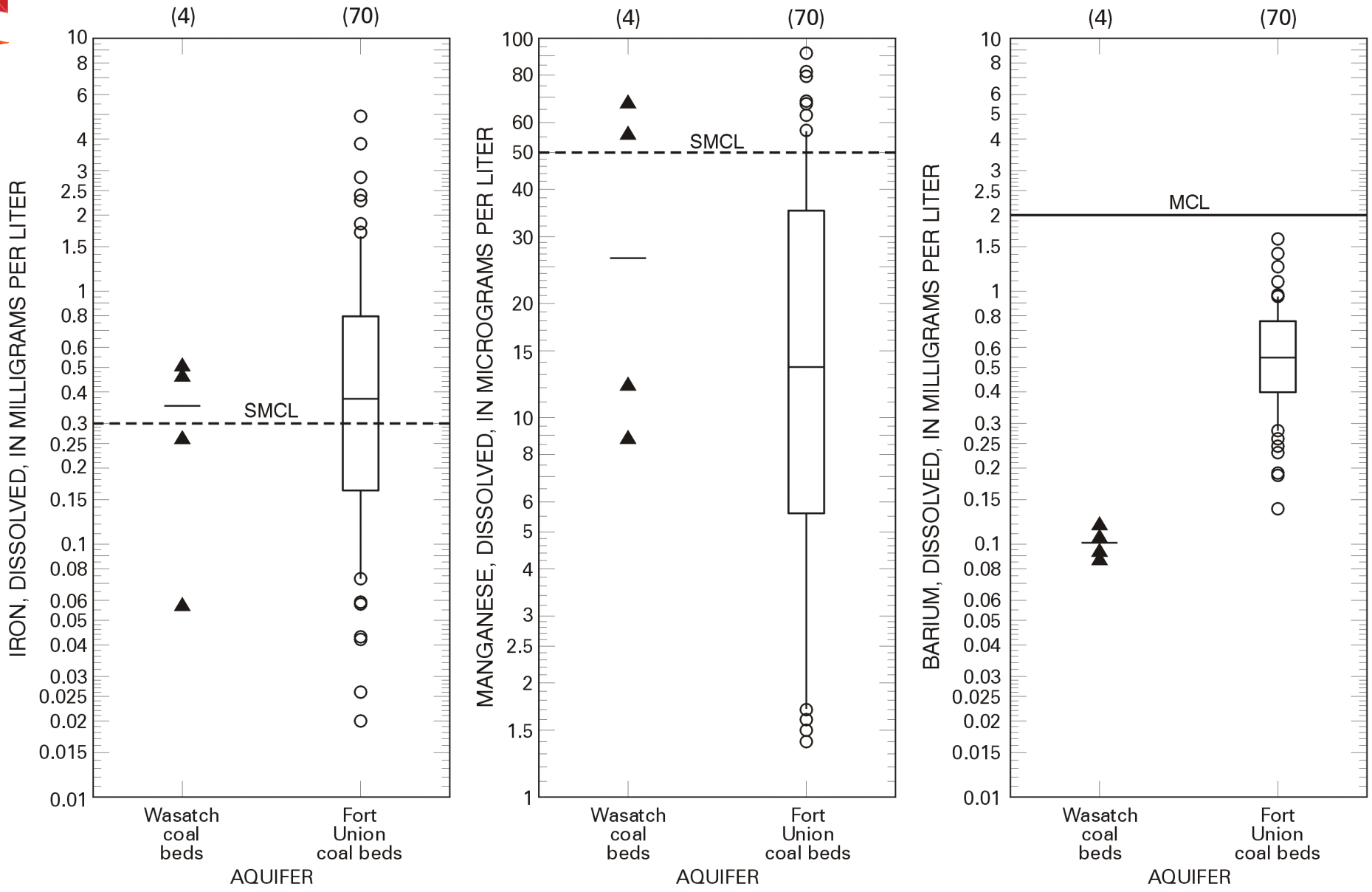
(4)
(70)
IRON, DISSOLVED, IN MILLIGRAMS PER LITER
SMCL
Wasatch coal beds
Fort Union coal beds
AQUIFER
MANGANESE, DISSOLVED, IN MICROGRAMS PER LITER
BARIUM, DISSOLVED, IN MILLIGRAMS PER LITER
MCL

Isotopic composition

- Tritium
  - Radioactive isotope of hydrogen (^{3}H)
  - Unstable (undergoes radioactive decay with a half-life of about 12.43 years)
  - Incorporated directly into water molecule so tritium is excellent tracer in hydrologic studies (conservative – not affected by hydrologic and/or geochemical processes)
  - Produced naturally in atmosphere
  - Atmospheric testing of nuclear weapons beginning in about 1952 greatly increased concentrations in atmosphere several orders of magnitude greater than natural concentrations

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Isotopic composition

- Summary of tritium results
  - Tritium concentrations in two springs suggest both were recharged after 1952 and contain modern (post-bomb) water
  - Tritium concentrations in six of eight samples collected from Wasatch and Tongue River aquifers suggest recharge prior to 1952 (submodern or pre-bomb water); remaining two samples suggest mixture of pre- and post-bomb water
  - Tritium concentrations in all samples collected from coalbed aquifers (13 samples) suggest recharge prior to 1952 and all contain pre-bomb or submodern water

Isotopic composition

- Oxygen and hydrogen isotopes
  - Plot of paired oxygen-18 and hydrogen-2 values on global meteoric water line

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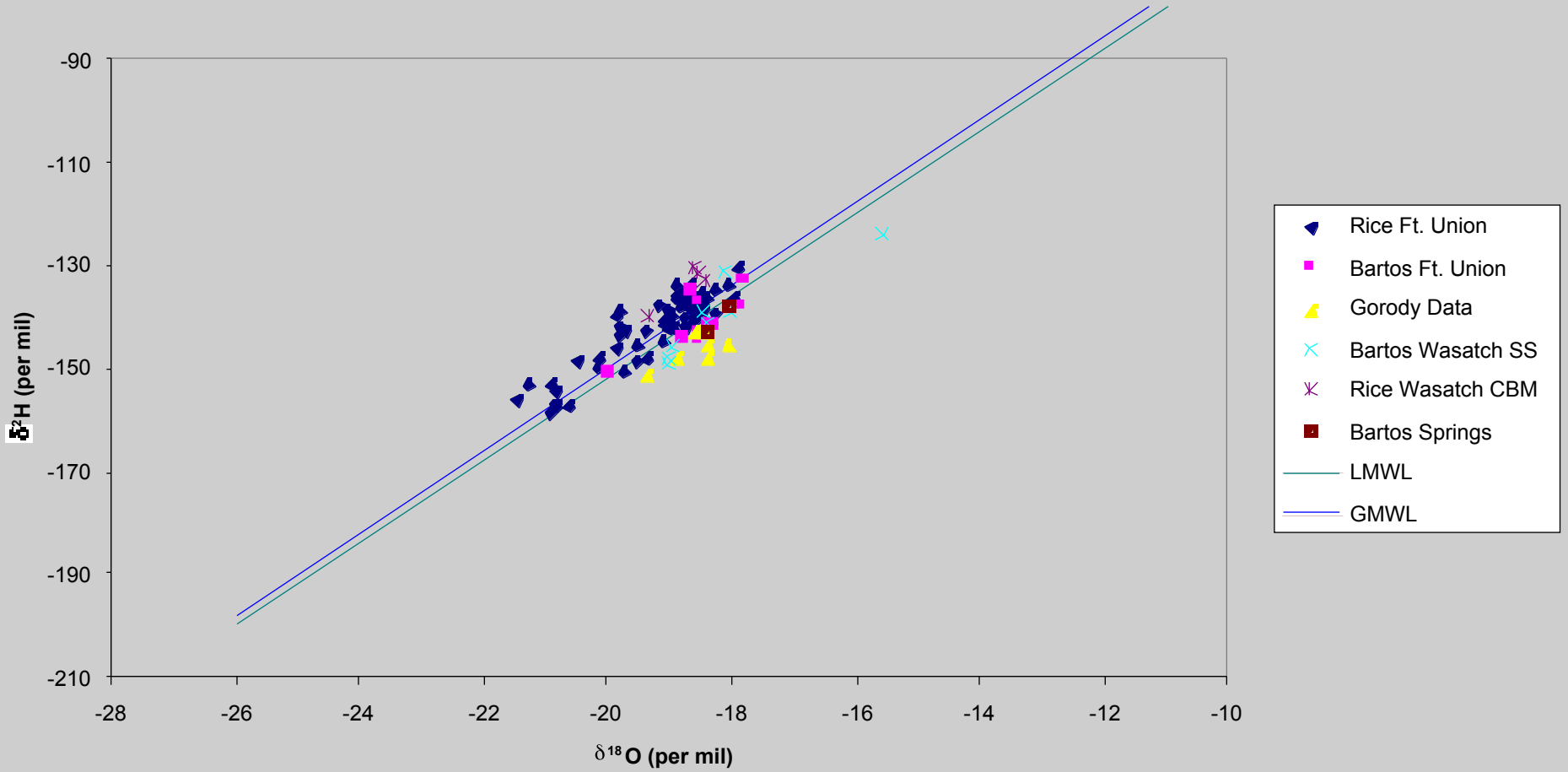
-90
-110
-130
-150
-170
-190
-210
δ²H (per mil)
-28
-26
-24
-22
-20
-18
-16
-14
-12
-10
δ¹⁸O (per mil)
Rice Ft. Union
Bartos Ft. Union
Gorody Data
Bartos Wasatch SS
Rice Wasatch CBM
Bartos Springs
LMWL
GMWL

Isotopic composition

- Oxygen and hydrogen isotopes
  - Values plot close to the meteoric water line, suggesting the water is of meteoric origin
  - Water samples are intermixed on the plot and do not group into separate areas of the graph based on aquifer of origin
    - Could indicate intermixing of the waters in the aquifers
    - Could indicate that the different aquifers are subject to similar recharge and/or evolutional paths for the water so that the net difference in the oxygen-18 and hydrogen-2 values is minimal

Summary

- Different geochemical zones or hydrochemical facies in aquifer(s) above Wyodak-Anderson coal zone
- Ionic composition in different zones probably reflects geochemical processes (described by earlier investigators) as ground water moves vertically and horizontally along a flowpath
- Generally, TDS concentrations appear to increase to the north and northwest in the Fort Union coalbed aquifers

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Summary

- Trace elements generally at low to nondetectable concentrations (except iron and manganese)
- Tritium concentrations suggest that water in Fort Union coalbed aquifers and most overlying aquifers is prebomb (greater than about 50 years old)
- Oxygen and hydrogen isotopes suggest water is of meteoric origin

Publications

- Published literature
  - Currently available
    - Rice, C.A., Ellis, M.S., and Bullock, J.H., Jr., 2000, Water co-produced with coalbed methane in the Powder River Basin, Wyoming: preliminary compositional data: USGS Open-file report 00-372, 17 p.

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