Using stable isotopes to trace contamination of the Madison Limestone aquifer by coal AMD, central Montana

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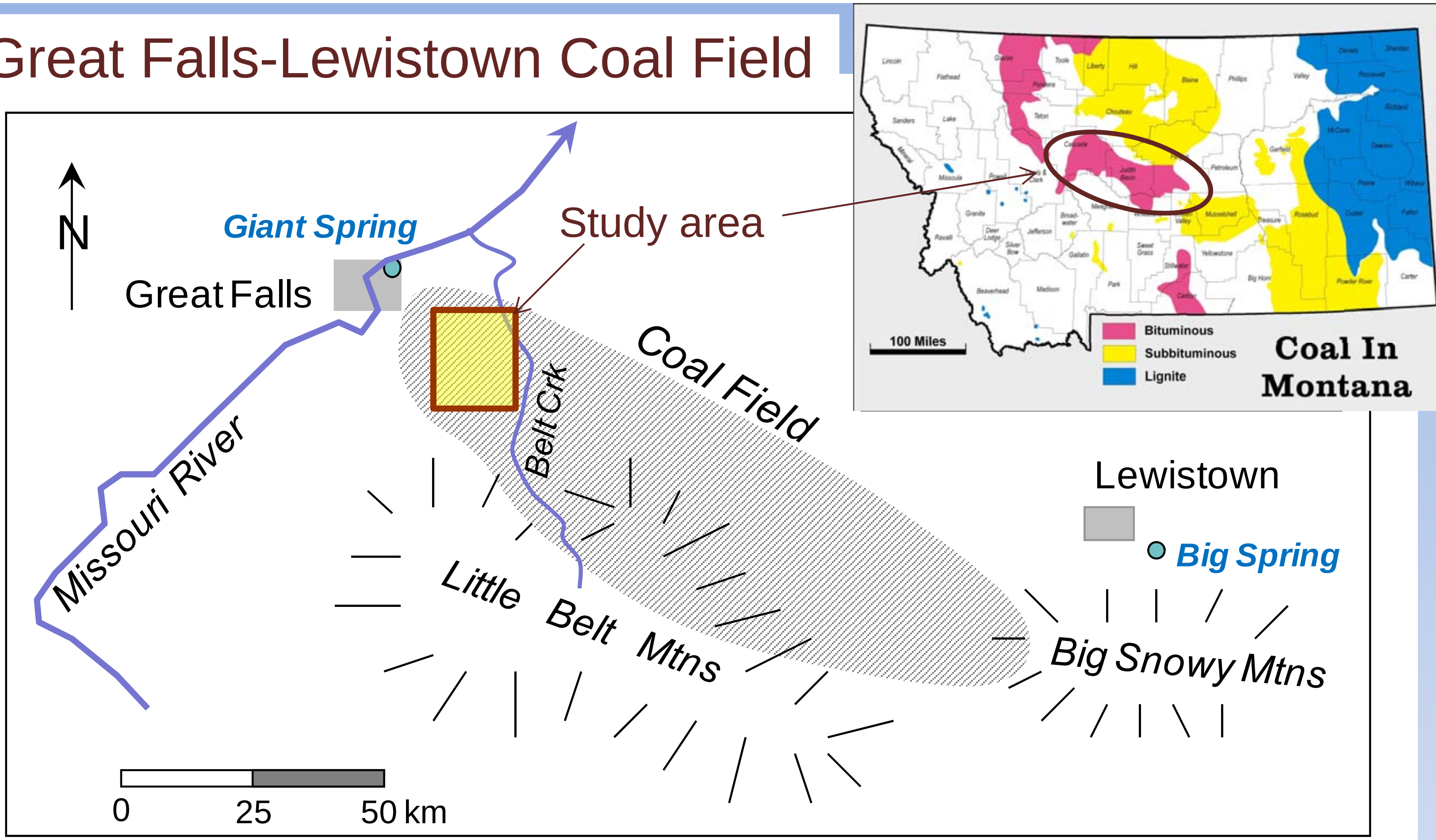
Great Falls-Lewistown Coal Field

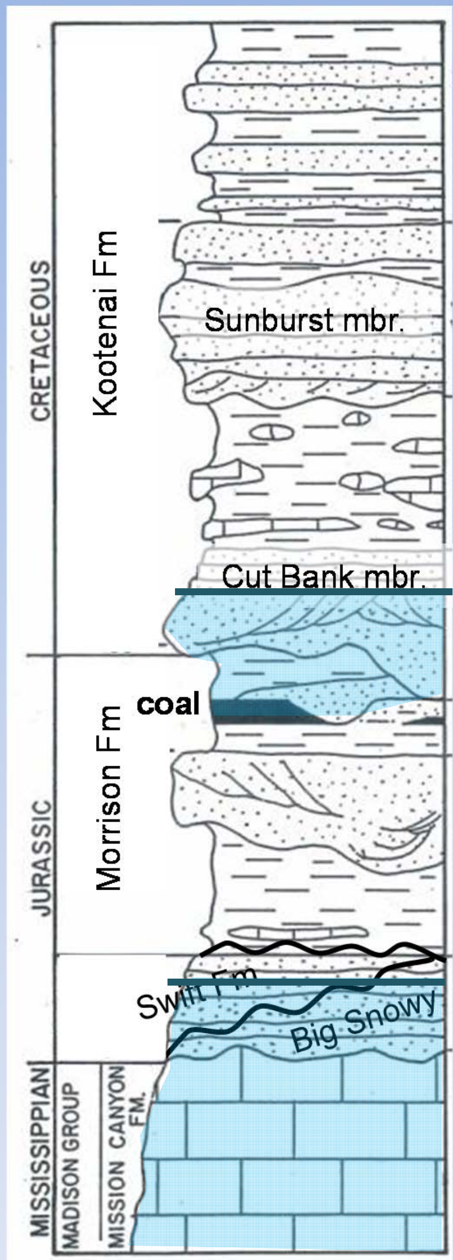


AMD Problems

Mining methods

- Shallow, undulatory dip of coal beds
- Underground, room & pillar mining
- Most mines worked updip so water would drain by gravity
- In cases where this was not possible, horizontal drains were tunneled to the nearest coulee
- All mining ceased by mid-1900s

Bituminous, high-S coal

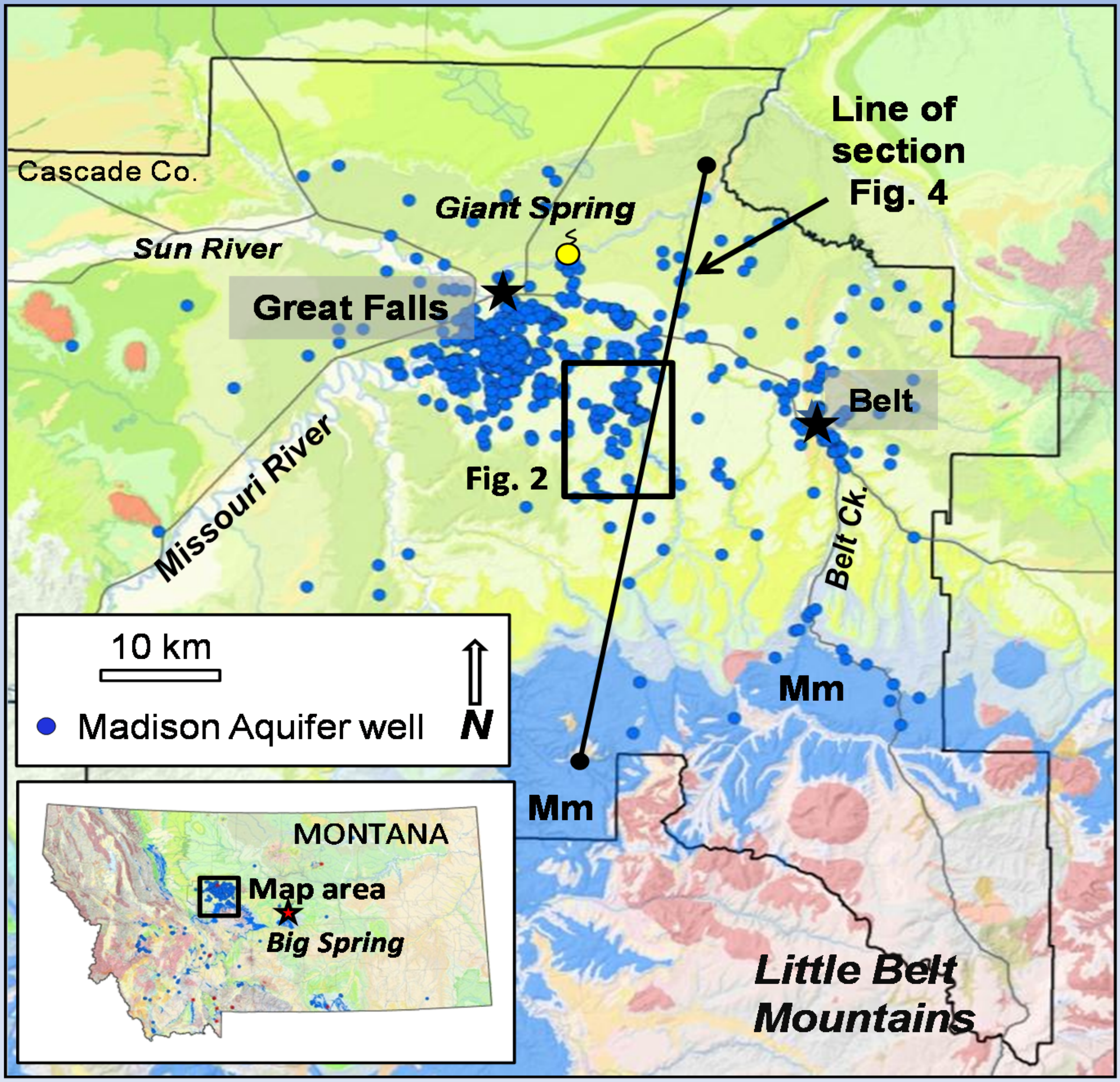


Perched groundwater

Regional groundwater

Madison limestone

The Madison Aquifer is an important drinking water source



Slide courtesy of John Lafave, Montana Bureau Mines and Geology

Is AMD from coal mines contaminating the Madison Aquifer?

- Undergraduate research project
- Sample domestic wells completed in Madison in old coal mine towns
- Field parameters (pH, SC, temp, alkalinity)
- ICP-metals
- water isotopes
- sulfate isotopes

Undergraduate student Allison Brown sampling a neighbor's well

Stable Isotope Background

	# protons	# neutrons	Total mass	Natural abundance
^{18}O	8	10	18	0.2%
^{17}O	8	9	17	<0.1%
^{16}O	8	8	16	99.7%
^{36}S	16	20	36	0.02%
^{34}S	16	18	34	4.21%
^{33}S	16	17	34	0.75%
^{32}S	16	16	32	95.02%

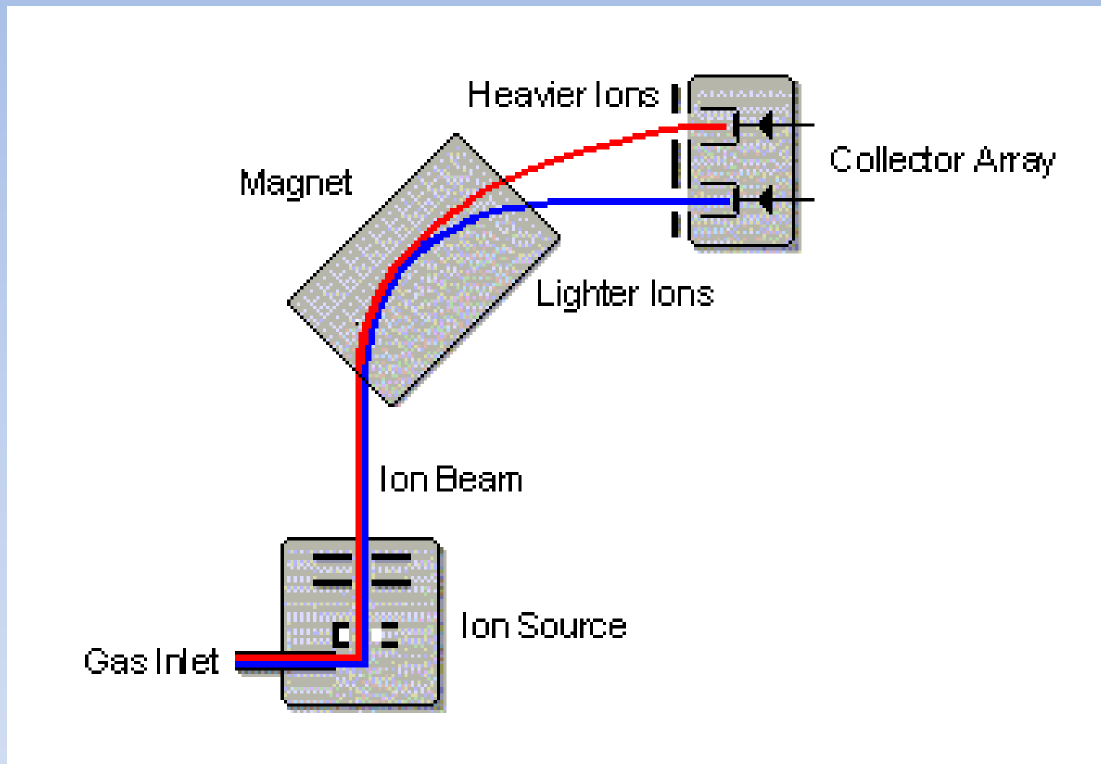
"Heavy S" → ^{34}S

"Light S" → ^{32}S

Isotope preparation

- Add $BaCl_2$ to make $BaSO_4$ precipitate
  - Filter, rinse, weigh and send to Reno

Stable Isotope Measurement

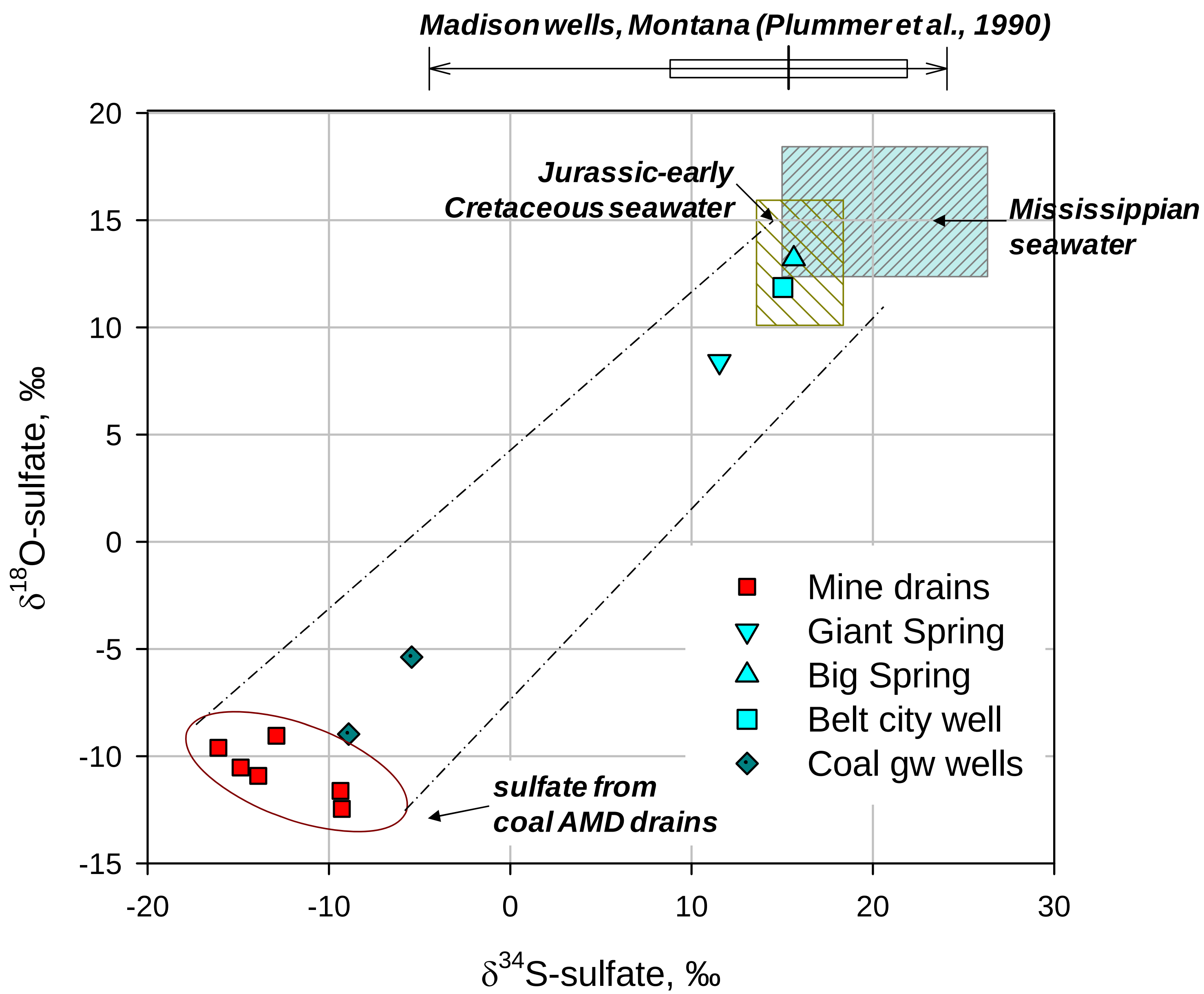


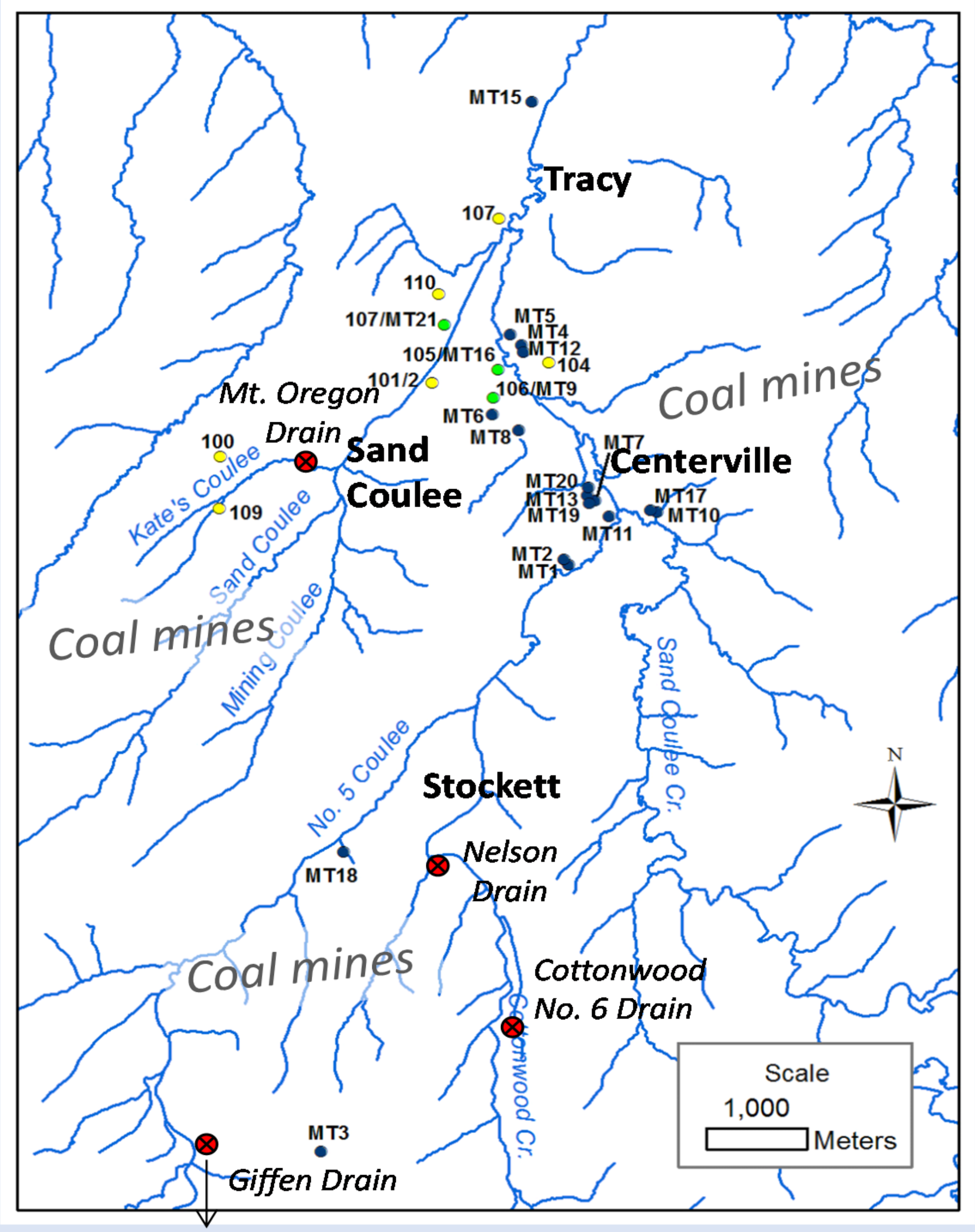
Isotope Ratio Mass Spectrometer (IRMS)
Univ-Nevada Reno (Dr. Simon Poulson)

Stable Isotope Notation

- δ (in ‰) = (R_{sample} / $R_{standard}$ - 1) ·1000
- *R = ratio of the heavy isotope to light*
  - *E.g., $^{18}O/^{16}O$, or $^{34}S/^{32}S$*
- If δ is negative the sample contains less heavy isotope than standard

Previous Work: Gammons et al. 2010 (Chem. Geol., v. 269)



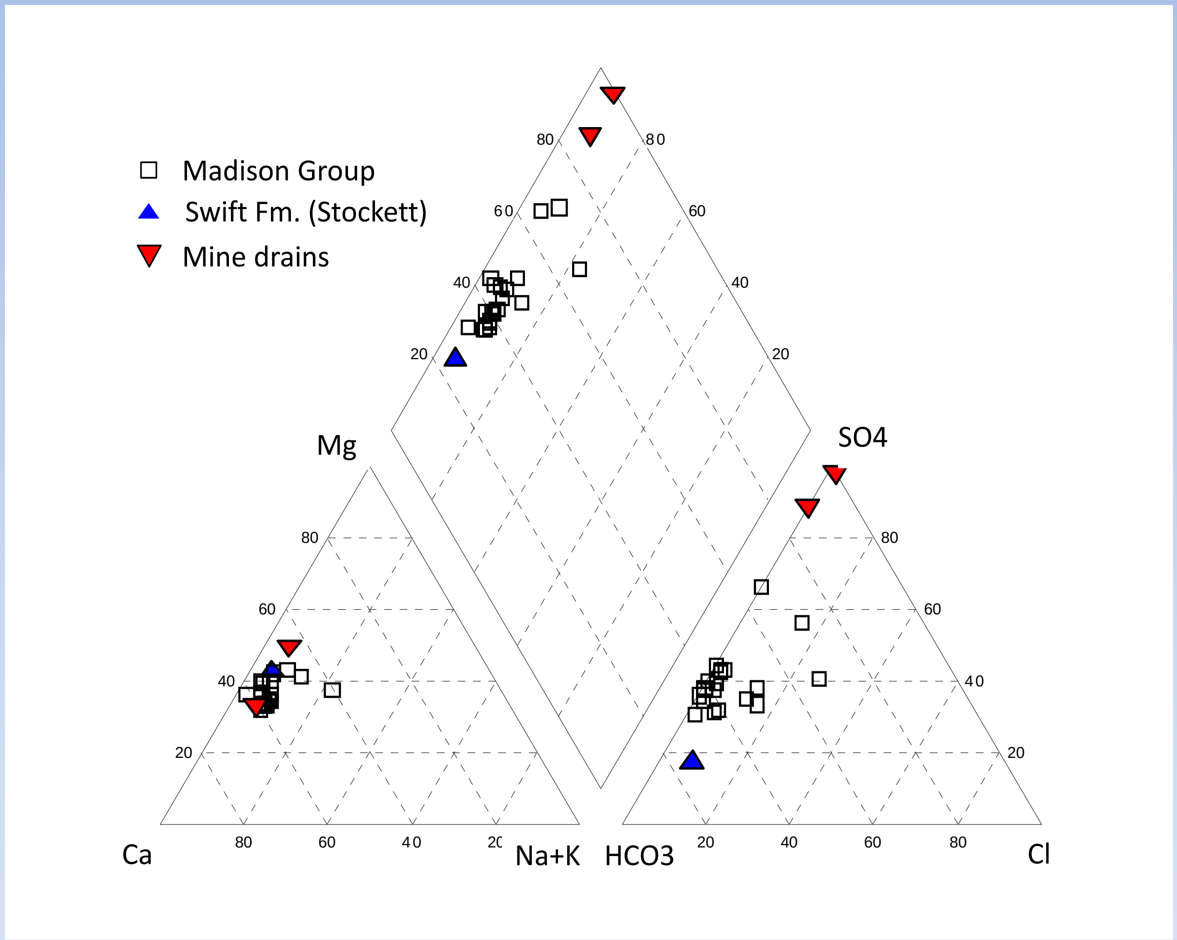


- Montana Tech:
  - 21 wells sampled
- MT DEQ
  - 9 wells sampled

Results 1 (cont.): major ions

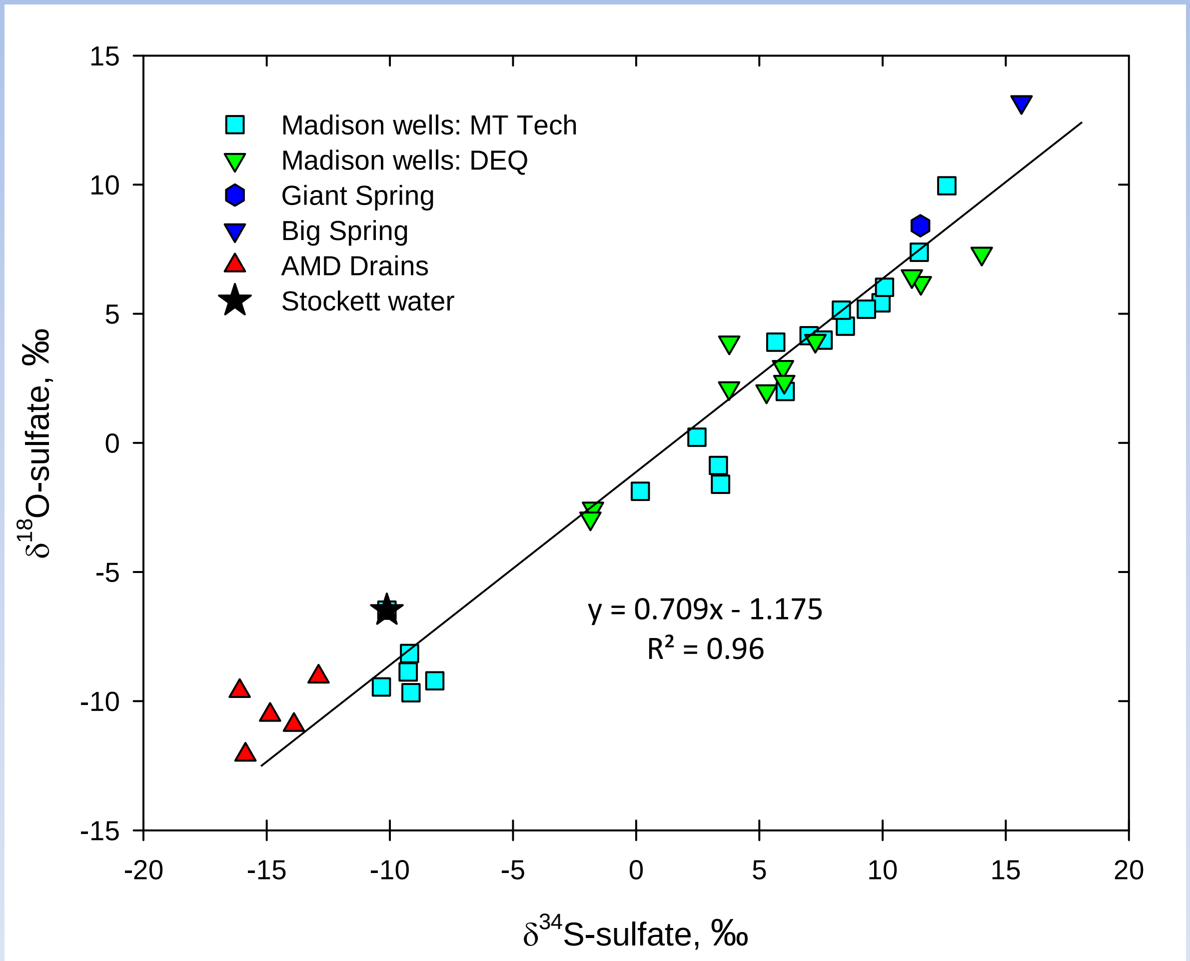
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	SO_4^{2-}
AB-1	88.9	38.3	7.8	7.4	460	135
AB-2	72.9	33.3	9.2	2.9	348	110
AB-3	70.0	25.2	3.0	1.2	326	95
AB-4	74.2	25.8	11.9	2.3	370	100
AB-5	77.0	26.9	12.4	2.5	396	130
AB-6	70.9	24.8	10.9	2.3	360	85
AB-7	86.6	47.5	28.2	3.9	476	140
AB-8	71.1	24.7	10.9	2.3	370	95
AB-9	72.7	28.7	11.8	2.4	382	105
AB-10	126	49.5	12.6	3.7	390	345
AB-11	70.3	26.3	12.9	2.5	364	85
AB-12	70.2	26.4	11.7	2.4	374	85

Results: Water chemistry

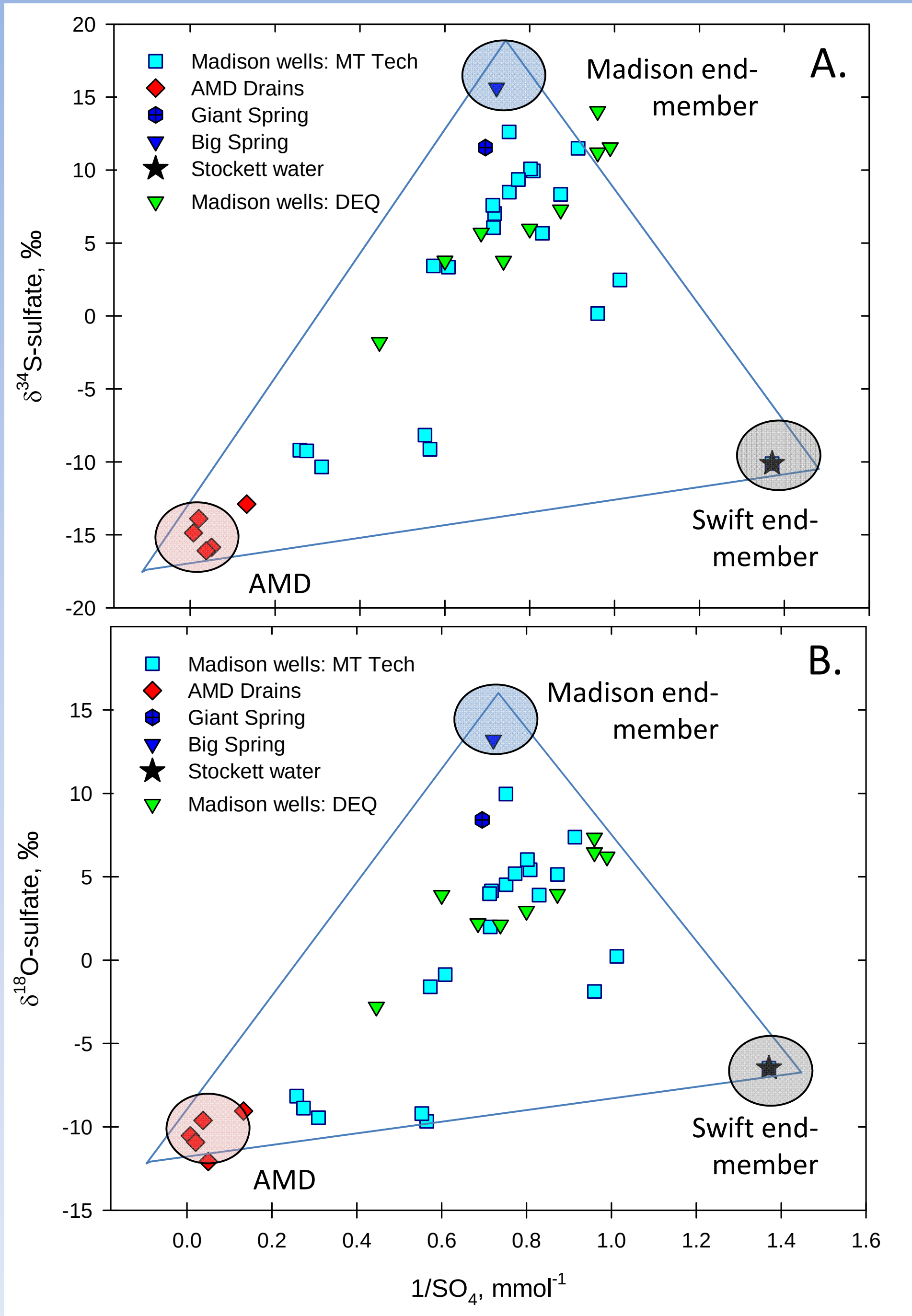


- All wells had near-neutral pH
- Low to moderate TDS
- No major problems with trace metals

Results: Stable Isotopes

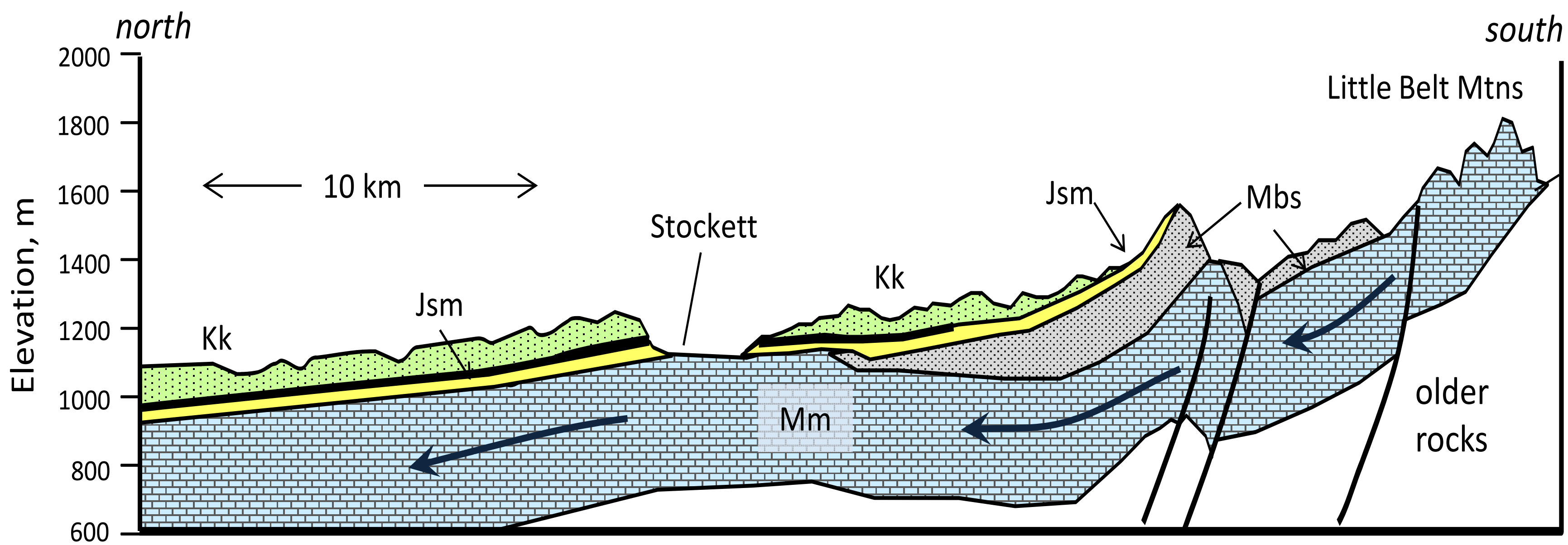


- All samples lie on an *apparent* two component mixing line
- Some wells appear to be *dominated* by AMD sulfate

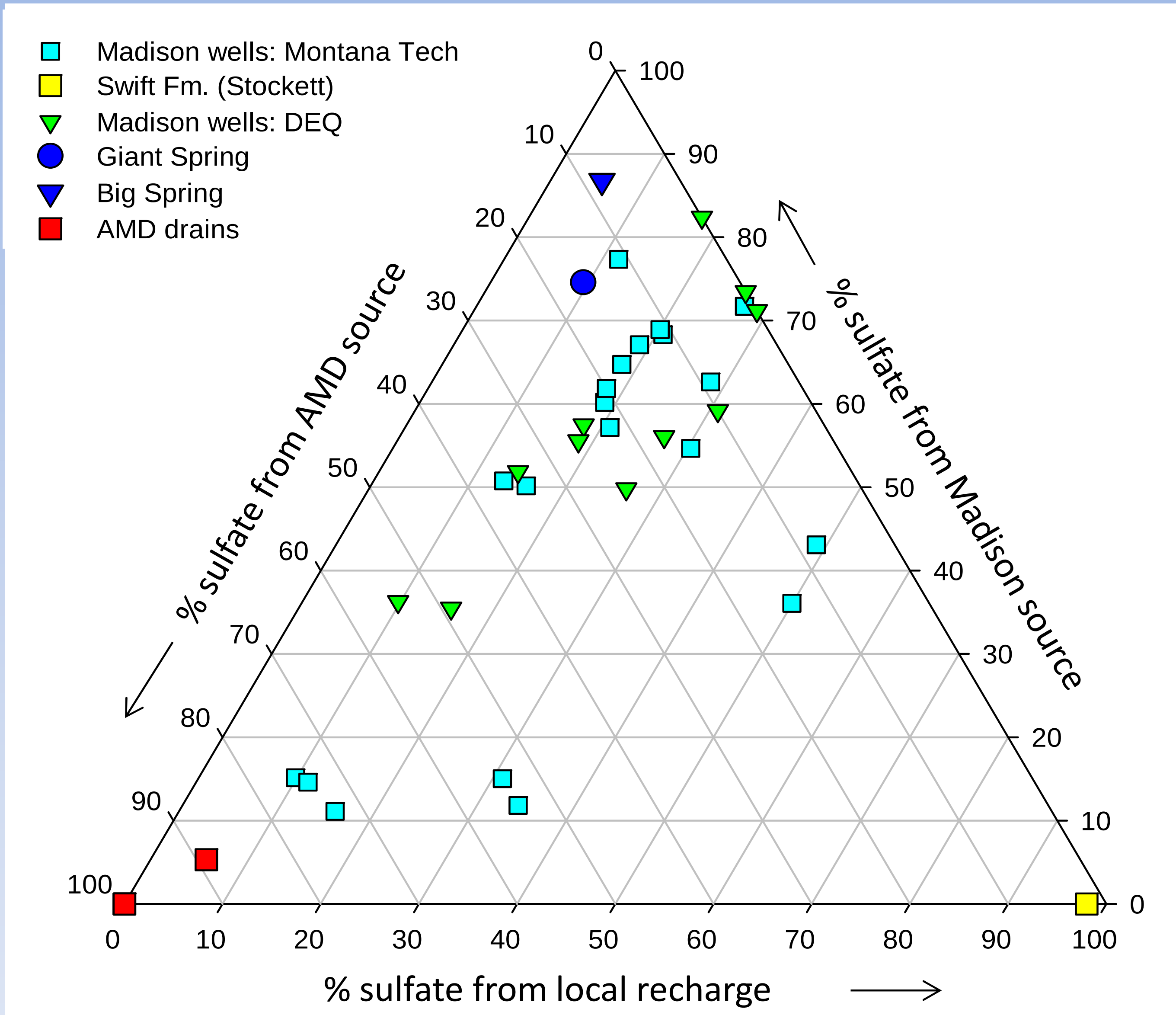


- When plot isotopes vs. reciprocal SO_4, a 3-component mixing model emerges

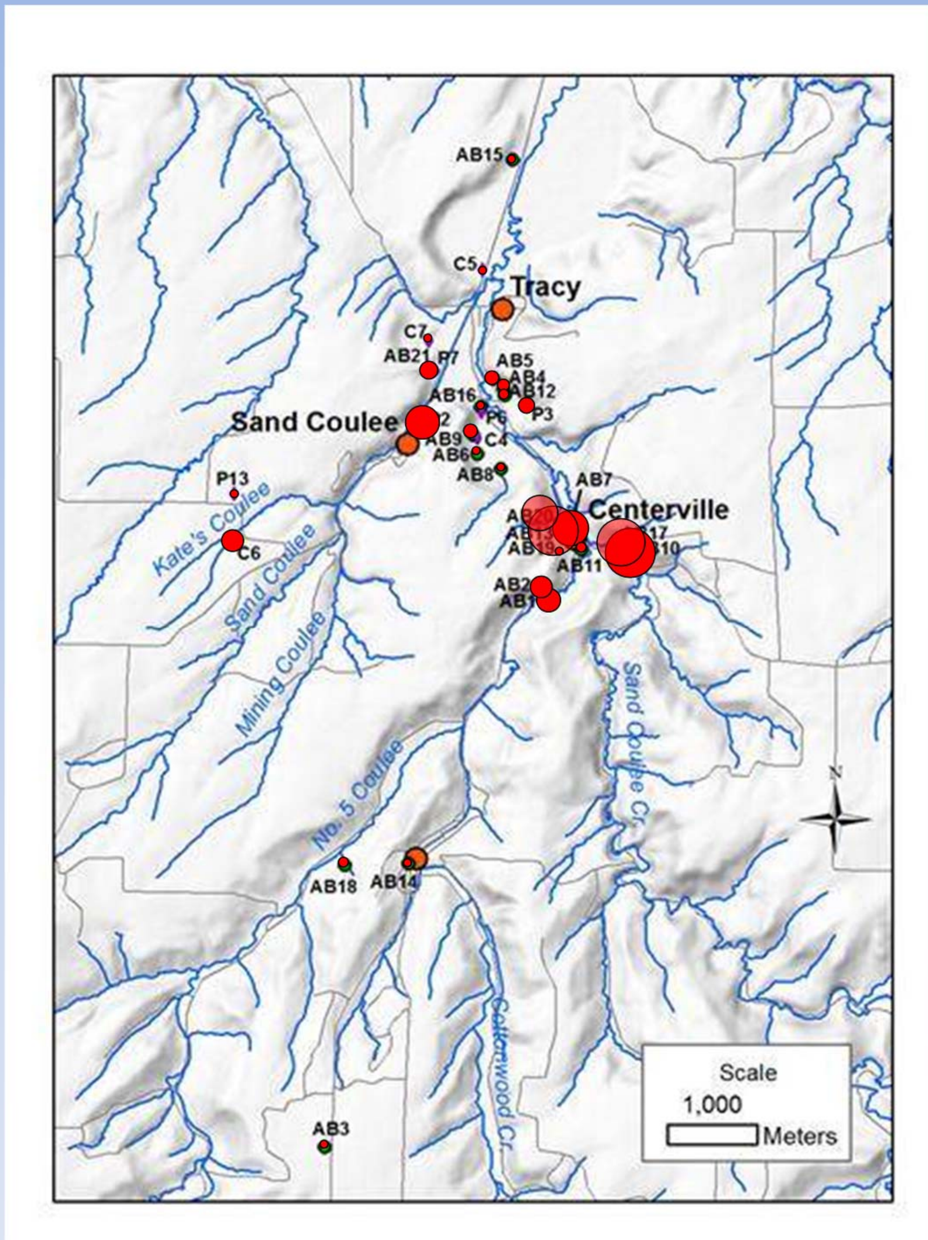
- End-members:
  - AMD sulfate
  - Madison sulfate
  - "Shallow" sulfate (e.g., Swift Fm.)


north
south
Little Belt Mtns
2000
1800
1600
1400
1200
1000
800
600
Elevation, m
10 km
Stockett
Jsm
Mbs
Kk
Kk
Jsm
Mm
older
rocks

End-member mixing calculations

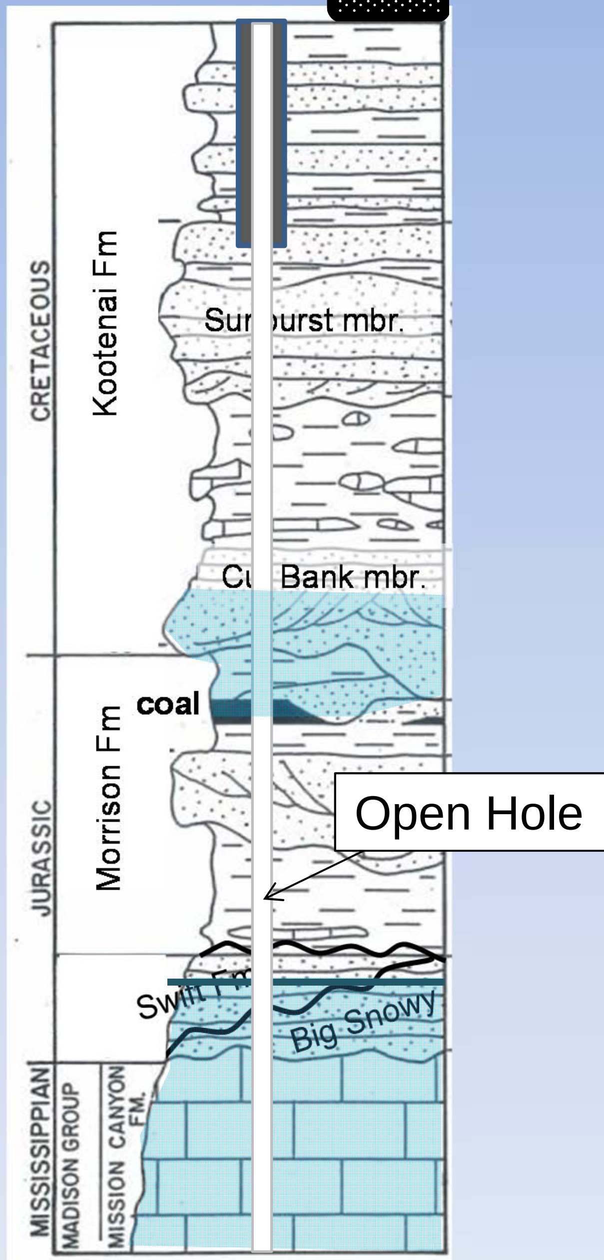


Gammons, MDOC Conference, May 2012

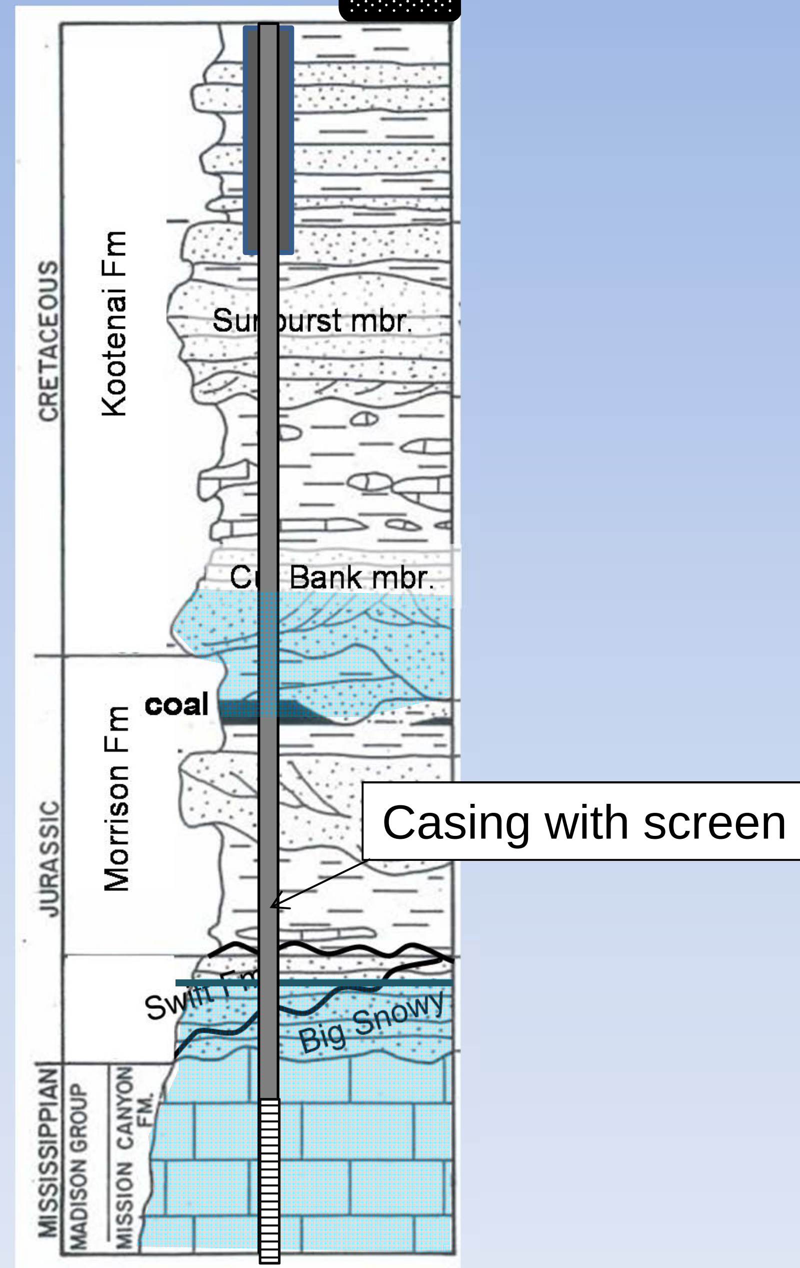


- Spatial variations
- Size of bubble correlates to proportion of sulfate from <u>AMD source</u>

Older wells



Newer wells



Conclusions

- Many of the wells in this study appear to be contaminated with AMD from coal mines
  - Water is still drinkable
  - Chemical buffering of Madison Limestone
- "Open hole" wells have higher probability of contamination
- Sulfate isotopes were very useful to trace sources of sulfate in the Madison Aquifer

Questions?

- Funded through the Montana Tech Undergraduate Research Program

Film of Fe-oxidizing bacteria
Kate's Coulee

References

- Gammons C.H., Brown A., Poulson S.R., and Henderson T. (in review) Using stable isotopes (S, O) of sulfate to track contamination of the Madison karst aquifer, Montana, from coal mine drainage. Submitted, March 5, 2012
- Gammons C.H., Duaime T.E., Parker S.R., Poulson S.R., Kennelly P. (2010) Geochemistry and stable isotope investigation of acid mine drainage associated with abandoned coal mines in central Montana, USA. *Chemical Geology* 269, 100-112.