Geochemistry and Inverse Modeling of the Memphis Aquifer in Tennessee, USA

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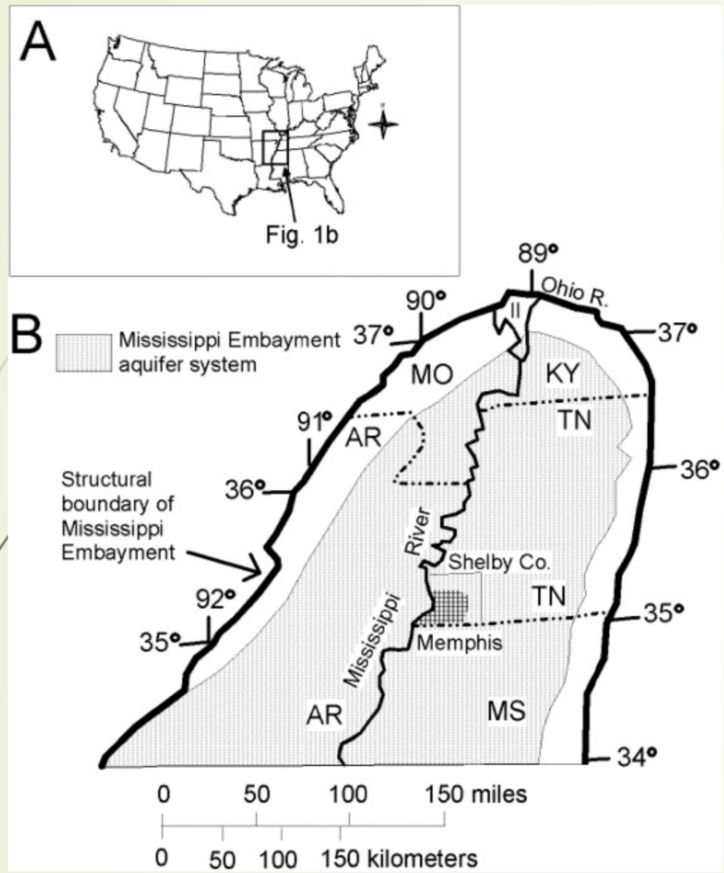
Outline

- Location
- The Study
- Geochemistry of the Memphis aquifer
- Phreeqc Inverse Model results
- Tritium Dating
- Conclusion

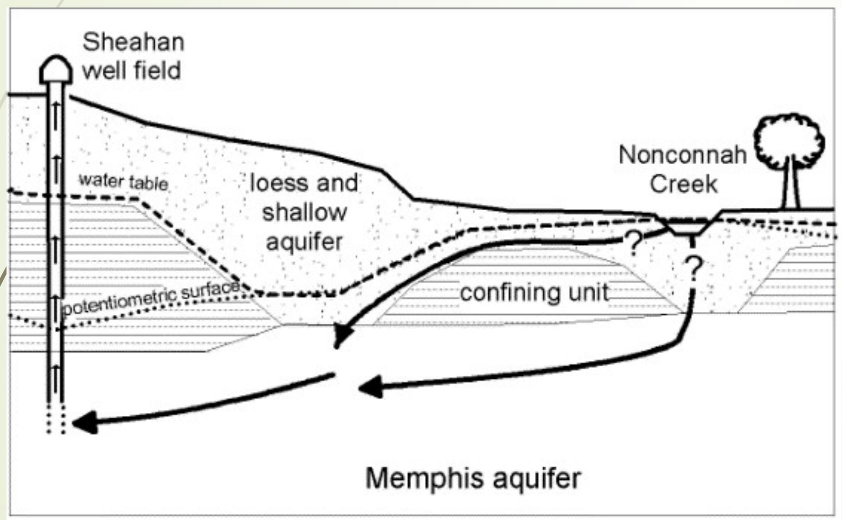


Memphis Aquifer

- Provides drinking water to the people of Memphis, TN and surrounding areas
- Sand dominated
- 122 to 274 m thick
- Average withdrawals of 617 million l/day

The Study

- Leakage in a semi-confined aquifer results in contamination of the Memphis aquifer by means of the Nonconnah Creek
- Scientists believe the leak is causing a change in the geochemistry of the groundwater and the contamination could lead to a change in the quality of the drinking water for the people of people of Memphis



A discontinuity of the impermeable clays in the confining unit result in contamination

Well Sites used for analysis

- 95 - Initial site: Deepest sample taken showing little chemical or isotopic influence from leakage
- 87 - Final site: Shallowest sample taken showing the most chemical and isotopic influence from leakage

Major Ion Geochemistry of well sites 95 and 87

Well	Depth	pH	Eh	T	Condc	Na+	K+	Mg2+	Ca2+	Fe2+	Cl-	SO42-	NO3-	HCO3-	Charge	O2	3H
	(m)	(°C)	(µS/cm)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)				
95	237	6.59	204	19.6	117	4.6	0.9	3.9	10.2	0.26	1.3	2.8	0.2	68	-6.8	2.6e	<0.4
87	95	5.49	174	17.1	129	13	0.7	3.2	6.6	0.61	6	9.1	0.6	40	7.8	0.66	2.3

Inverse Modeling

- Used to determine possible dissolution and precipitation of minerals from a change in chemistry between two solutions

```
SOLUTION 1
    temp        19.6
    pH          6.59 charge
    pe          4
    redox       pe
    units       mg/kgw
    density     1
    Ca          10.2
    Cl          1.3
    Fe(2)       0.26
    Mg          3.9
    N(5)        0.2
    Na          4.6
    O(0)        2.6
    S(6)        2.8
    -water      1 # kg
```

```
SOLUTION 2
    temp        17.7
    pH          5.49 charge
    pe          4
    redox       pe
    units       mg/kgw
    density     1
    Ca          6.6
    Cl          6
    Fe(2)       0.61
    Mg          3.2
    N(5)        0.6
    Na          13
    O(0)        0.66
    S(6)        9.1
    -water      1 # kg
```

Results

Phase Mole Transfers

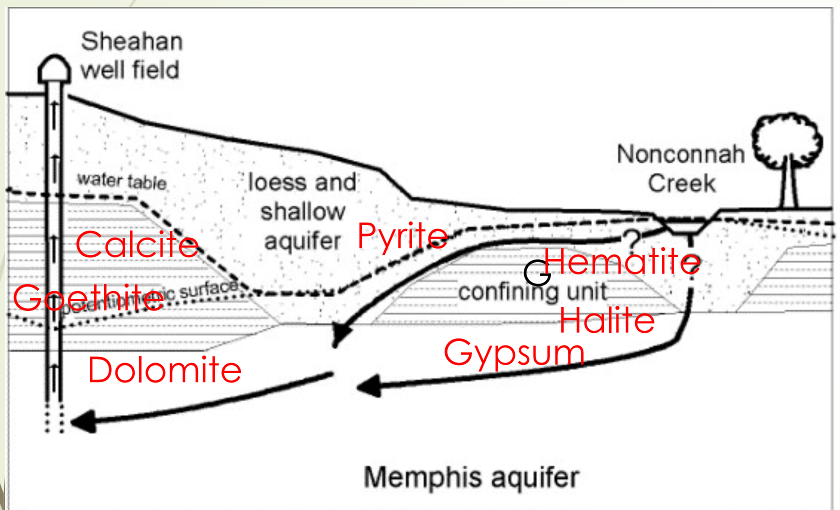
Well 95 to 87

Gypsum	6.380e-03	0.000e+00	0.000e+00	CaSO4:2H2O
Goethite	-4.237e+03	0.000e+00	0.000e+00	FeOOH
CO2(g)	1.283e-02	0.000e+00	0.000e+00	CO2
Pyrite	7.890e-04	0.000e+00	0.000e+00	FeS2
Halite	4.564e-03	0.000e+00	0.000e+00	NaCl
Calcite	-6.665e-03	0.000e+00	0.000e+00	CaCO3
Hematite	2.118e+03	0.000e+00	0.000e+00	Fe2O3
Dolomite	-3.082e-03	0.000e+00	0.000e+00	CaMg(CO3)2

Mole transfers that are a positive value indicate dissolution took place, while negative Values indicate precipitation took place

Results

- Precipitation of the minerals Goethite, Calcite, and Dolomite
- Dissolution of the minerals Gypsum, Pyrite, Halite, Hematite



These minerals are potential reactants that traveled through the flow path by the way of the leakage in the confining layer

Tritium Dating

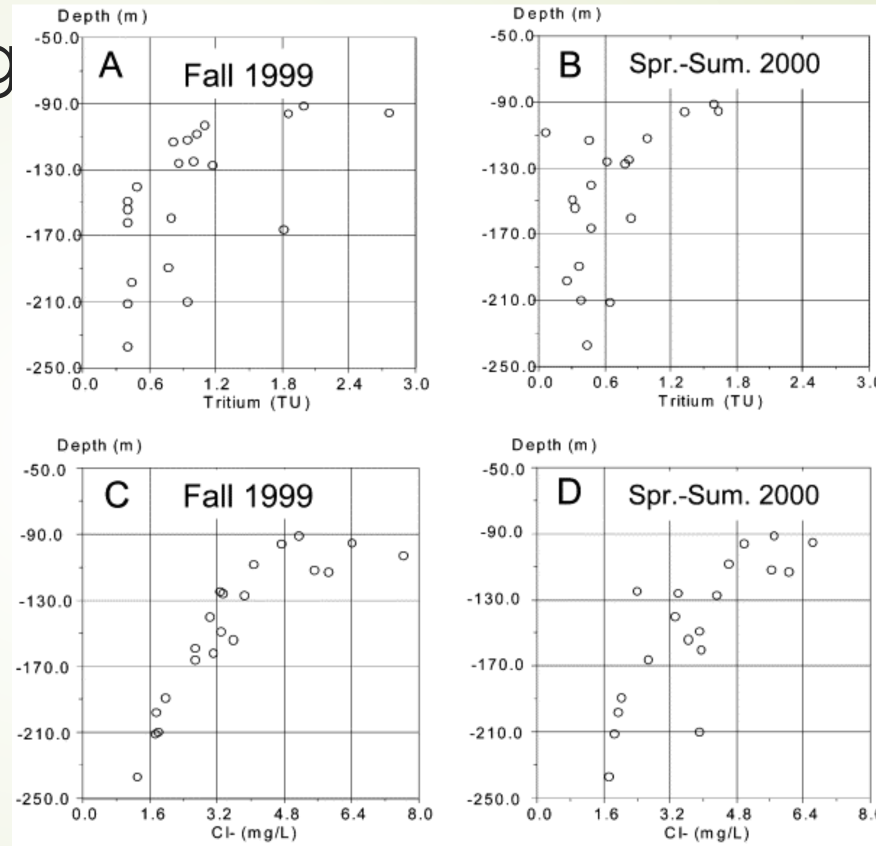
- Used to determine the age of the water being recharged into the aquifer, and whether the water is native or from a leak in the confining unit
- Tritium is a radioactive isotope of hydrogen
- Comprised of two neutrons and one proton
- Half-life of 12.4 years
- Measured in tritium units (TU)
- 1 TU is defined as one tritium in 10^18 atoms of hydrogen
- 2 natural sources of tritium
  - Alpha decay of lithium-7
  - Secondary neutron cosmic ray bombardment of nitrogen, which decays to cabon-12 and tritium

Tritium Dating, the He-3 Method

- Tritium decays to He-3 by beta particle emission, by knowing the decay rate, an accurate recharge age of groundwater can be obtained.
- Groundwater Age (in years) = -17.8ln (1+ He-3/H-3)
  - He-3 - Component of He-3 from the decay of tritium
  - H-3 - Tritium concentration in tritium units (TU)
- Tritium Dating can be used to date groundwater from several months to 30 years in age.
- Typically measured by mass spectrometry
- Can cost up to $1000 per sample analyzed

Tritium Dating

- The study determined tritium concentration decreases with depth
- Indicates that oldest water is deep and youngest water is shallow
- Lower row shows chlorine levels increasing with shallower depth
- This could be a problem for the quality of drinking water



Geochemistry + Tritium Dating

- The change in geochemistry and the differences in tritium concentration between the wells indicate different origins
- The deep water, which is relatively low in major ions and tritium is "native" to the aquifer, making it older in age
- The shallow water, which is higher is major ions and tritium is thought to come from the leak in the aquifer, making it younger in age

Conclusion

- Groundwater chemistry changed dramatically from well site 95 to well site 87, with most ions increasing as they approach shallower depths
- Change in geochemistry is thought to be caused by a leak in the confining unit of the aquifer
- Phreeqc inverse modeling indicates the precipitation of goethite, dolomite, and calcite
- This leak in the aquifer could possible lead to contamination problems for drinking water in the future

The End

Questions?

References

Larson, D., Gentry, R.W., Solomon, D.K., 2002. The Geochemistry and mixing of leakage in a semi-confined aquifer at a municipal well field, Memphis, Tennessee, USA. Applied Geochemistry 18 (2003) 1043-1063.

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