

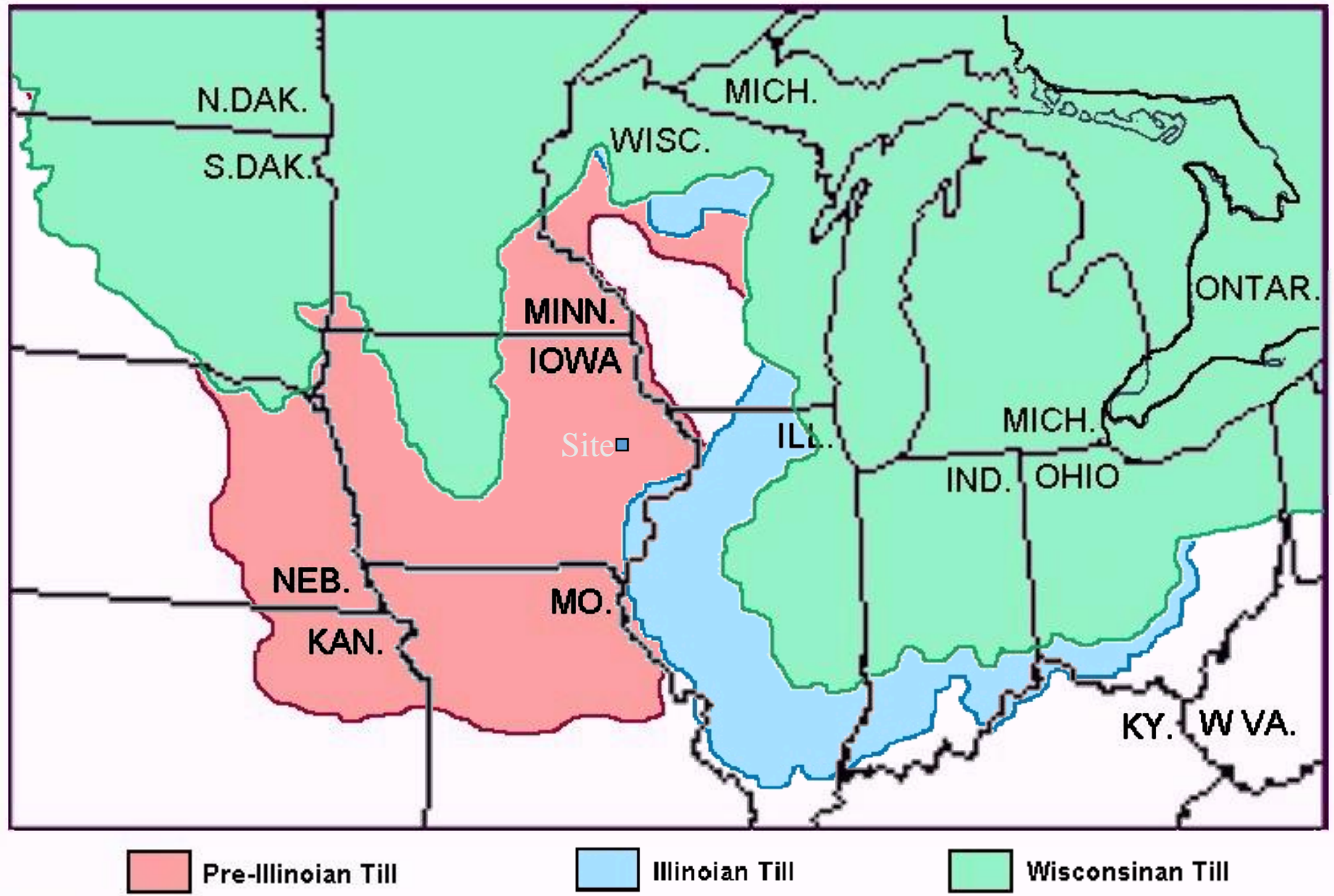
Old till is not *over the hill* for groundwater protection: Hydrogeology of Pre-Illinoian till in eastern Iowa



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Iowa Geological Survey
Iowa City, Iowa

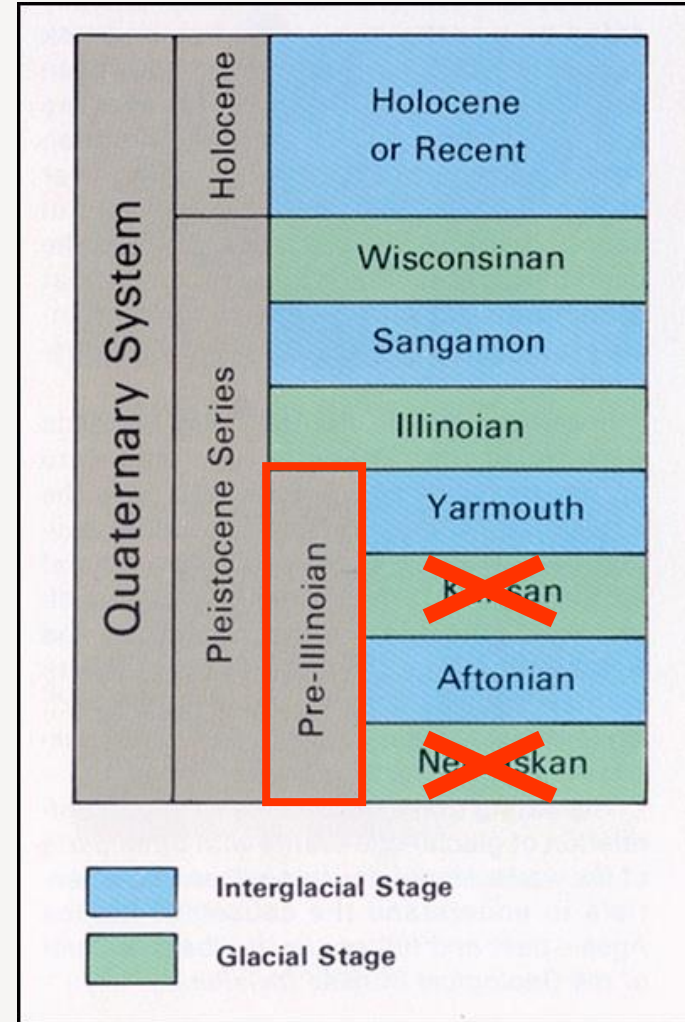


30,000 – 10,500 years

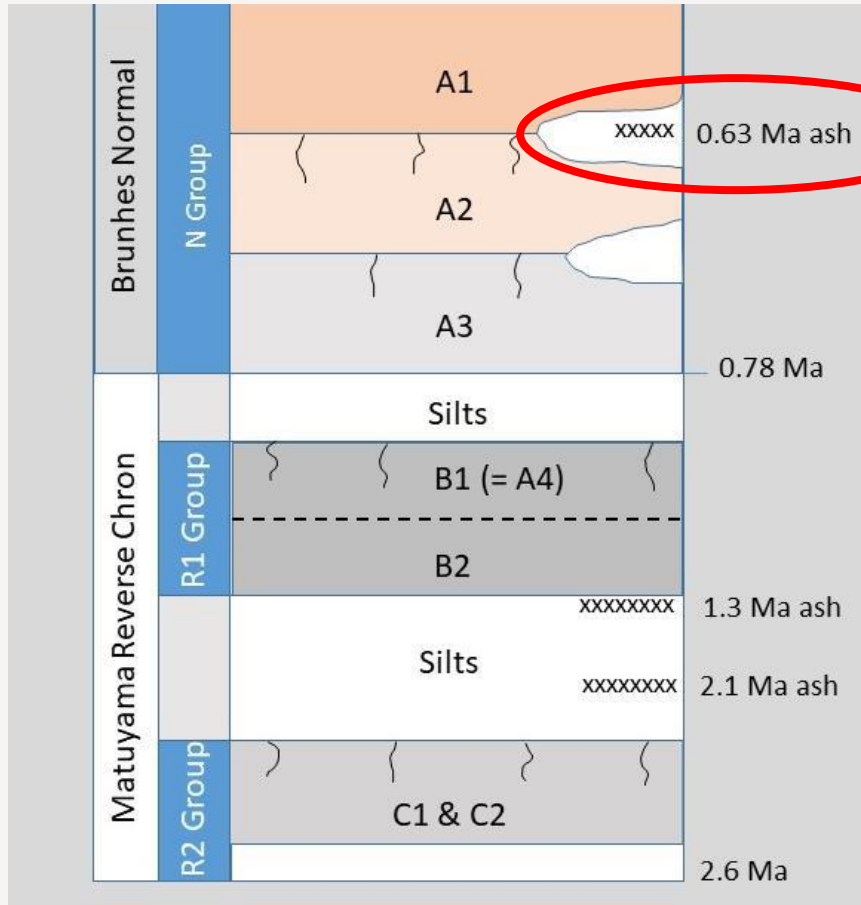




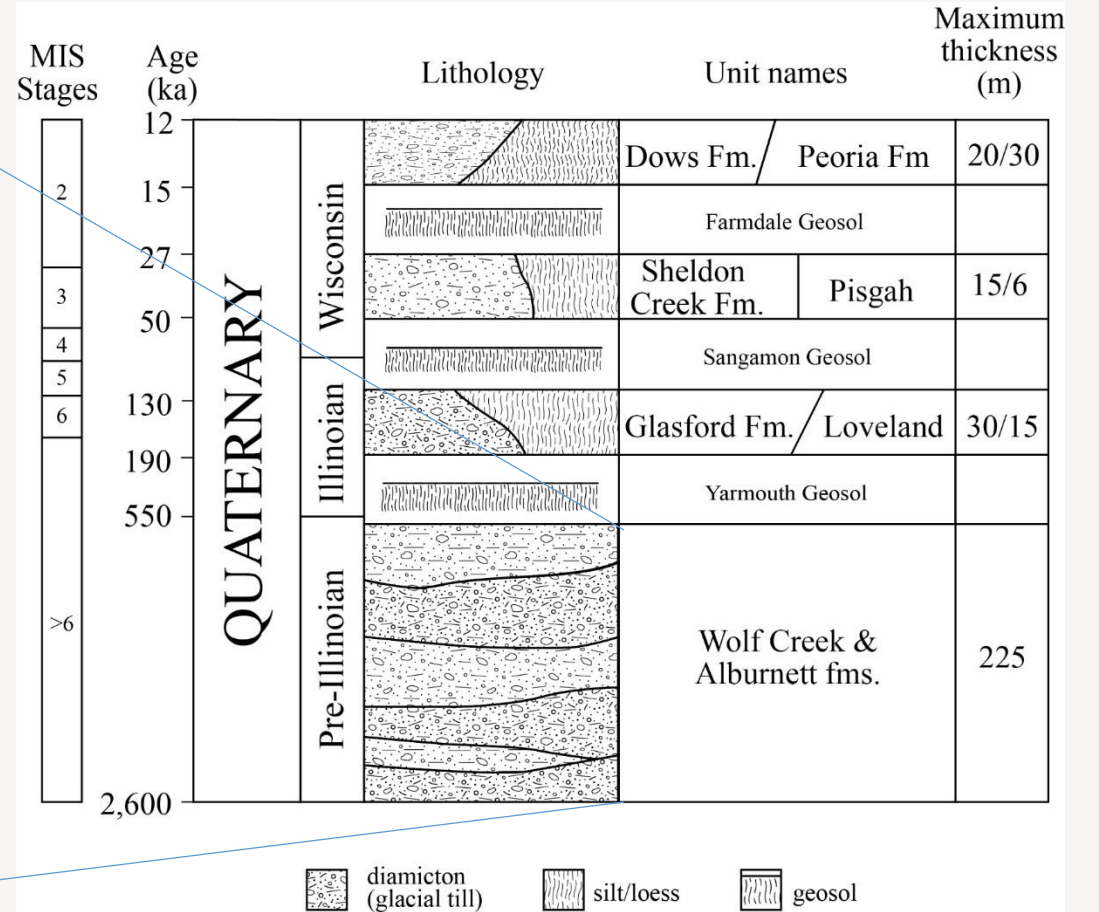
fresh glacial till



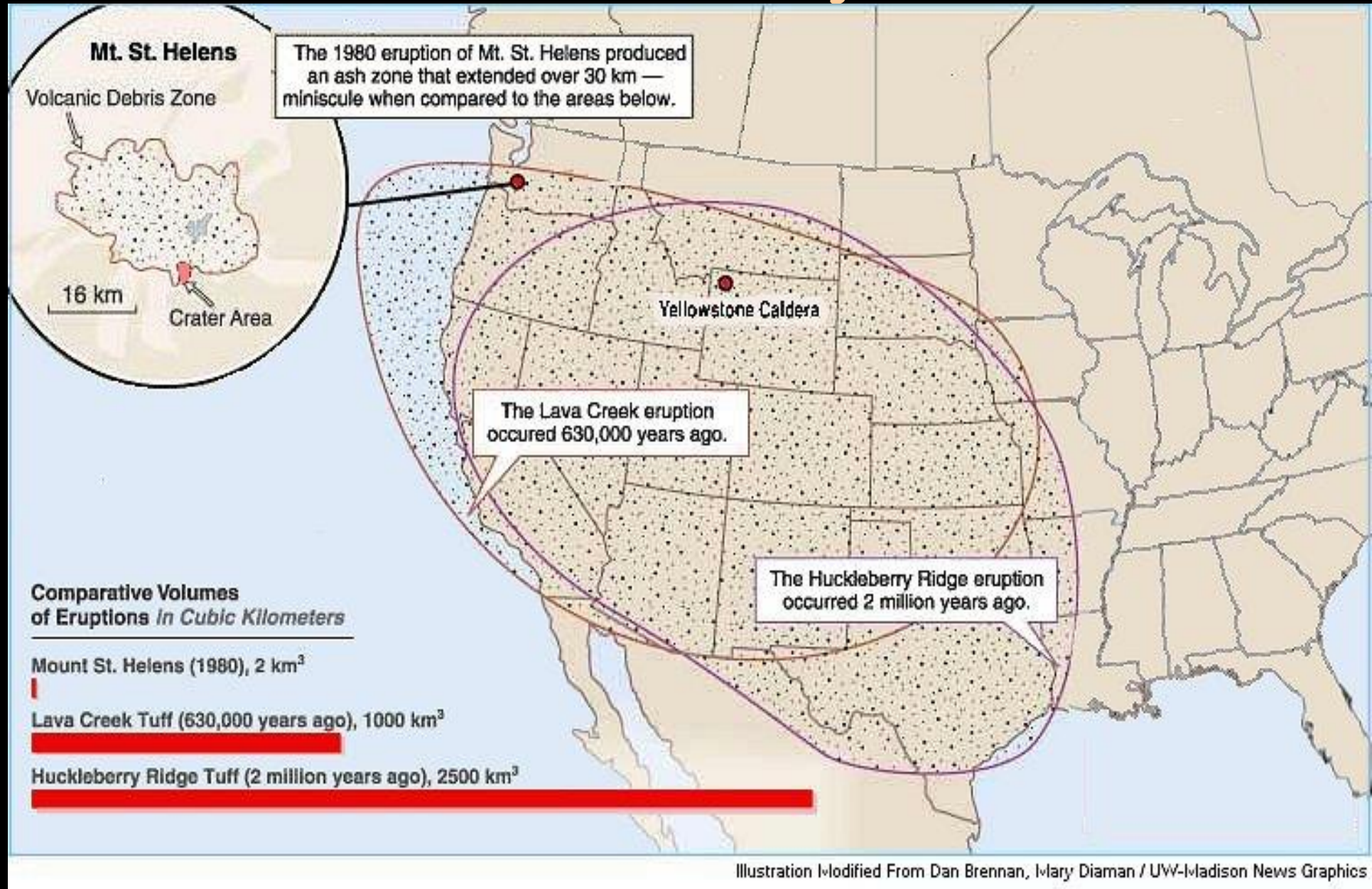
Western Iowa



Eastern Iowa



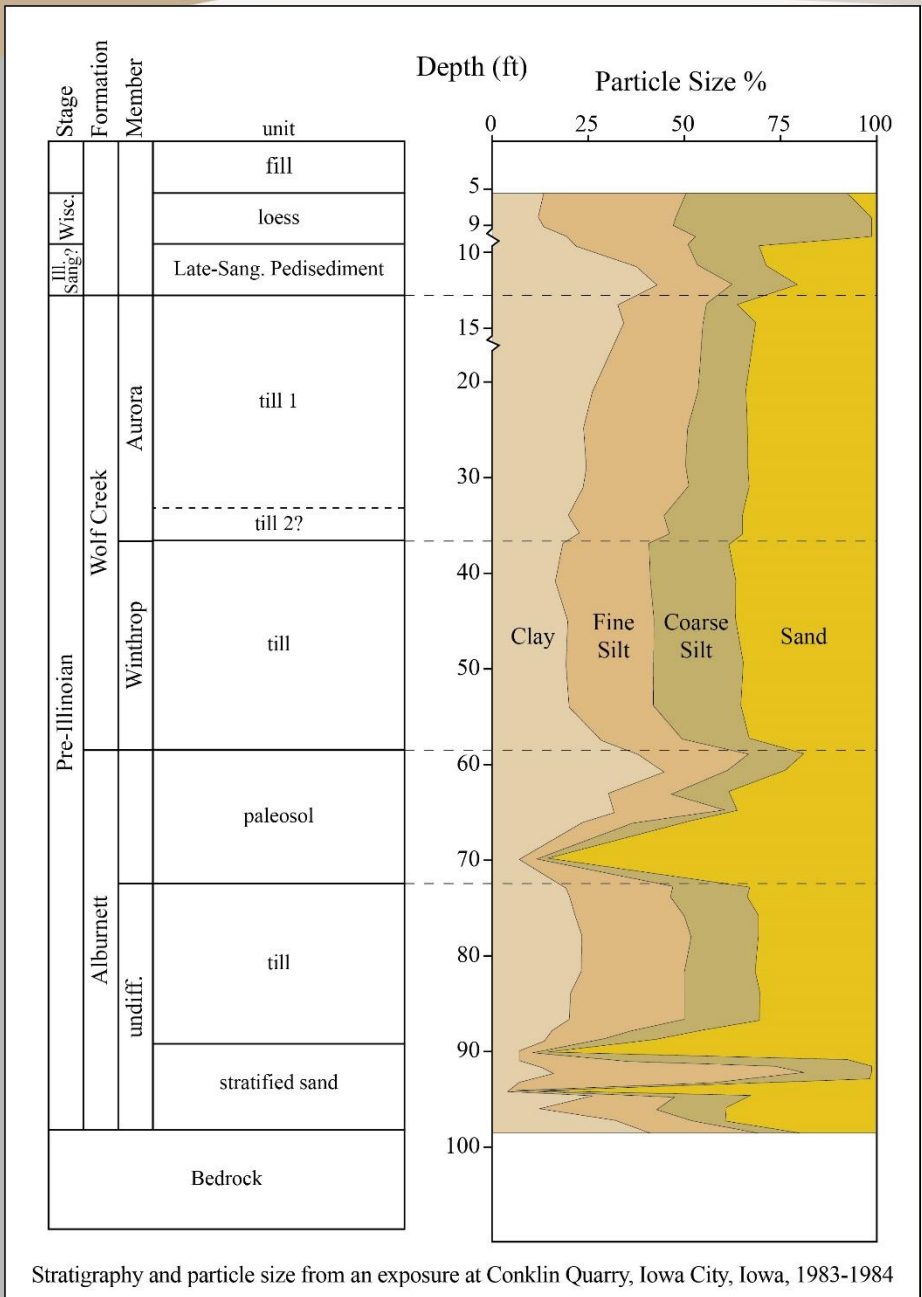
How do we know when these Pre-Illinoian glaciers were in Iowa ???



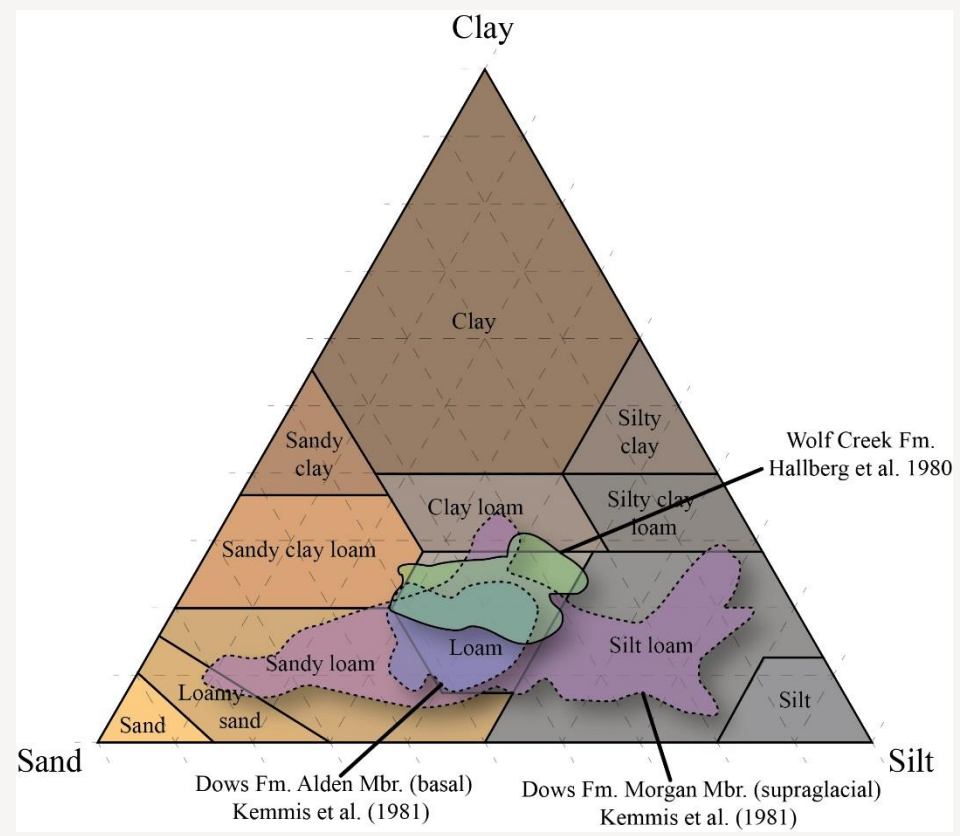
LARGEST PLEISTOCENE ERUPTIONS (Sarna-Wojcicki & Davis, 1990)

Iowa Ash Name

| NAME | age | source | km ³ |
|----------------------|---------|-------------------|-----------------|
| Mazama | 7 Ka | Mt. Mazama OR | 35 |
| Rockland | 400 Ka | Lassen Peak CA | 120 |
| Pearlette "O" | | | |
| Lava Creek | 620 Ka | Yellowstone Pk WY | 1000 |
| Bishop | 740 Ka | Long Valley CA | 500 |
| Tshirege | 1.15 Ma | Valles Caldera NM | 300 |
| Pearlette "S" | | | |
| Mesa Falls | 1.27 Ma | Yellowstone Pk WY | 280 |
| Otowi | 1.47 Ma | Valles Caldera NM | 300 |
| Pearlette "B" | | | |
| Huckleberry Ridge | 1.97 Ma | Yellowstone Pk WY | 2500 |

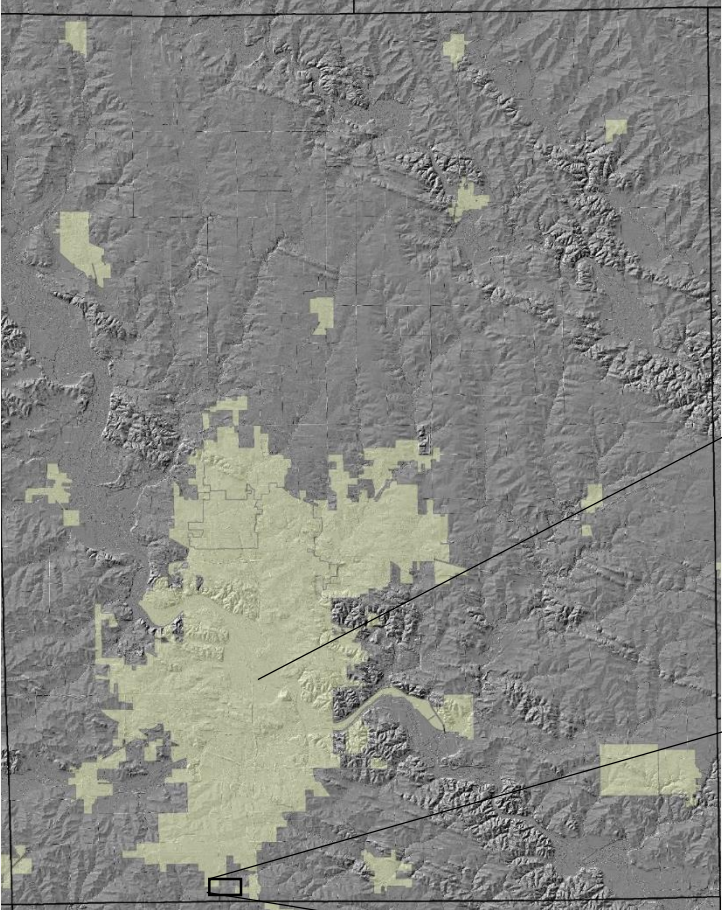


Very consistent texture across Iowa pre-Illinoian tills

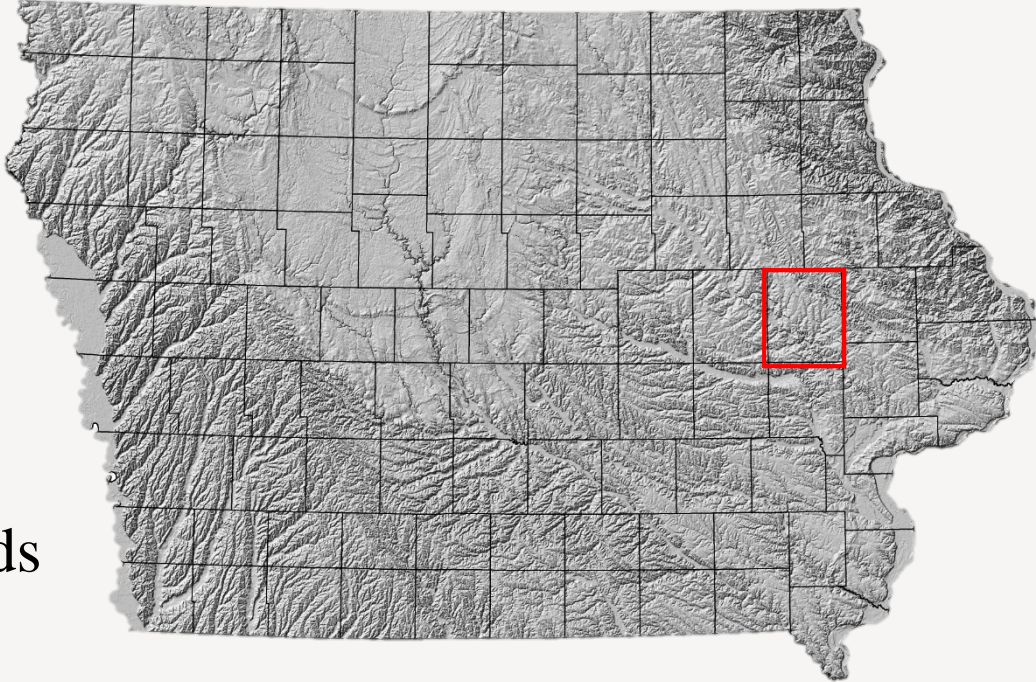


Stratigraphy and particle size from an exposure at Conklin Quarry, Iowa City, Iowa, 1983-1984

Eastern Iowa Till Hydro Site



Cedar Rapids



Site History

- 1989-1991 Hydrologic investigations conducted at I-380 rest stop site by IGS and USGS (primary oversight) as part of Aquitard Hydrology Project funded by 1987 Groundwater Protection Act
- 22 wells installed from 15 to 105 feet deep
- Groundwater samples were collected 4-8 times in 1990 and 1991 for nutrients, metals, herbicides
- Two data reports prepared by USGS, site monitoring abandoned after 1991 due to funding restrictions

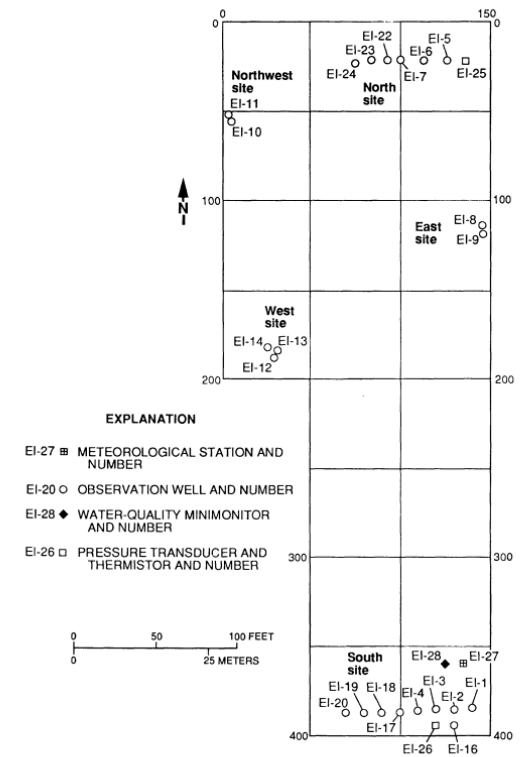
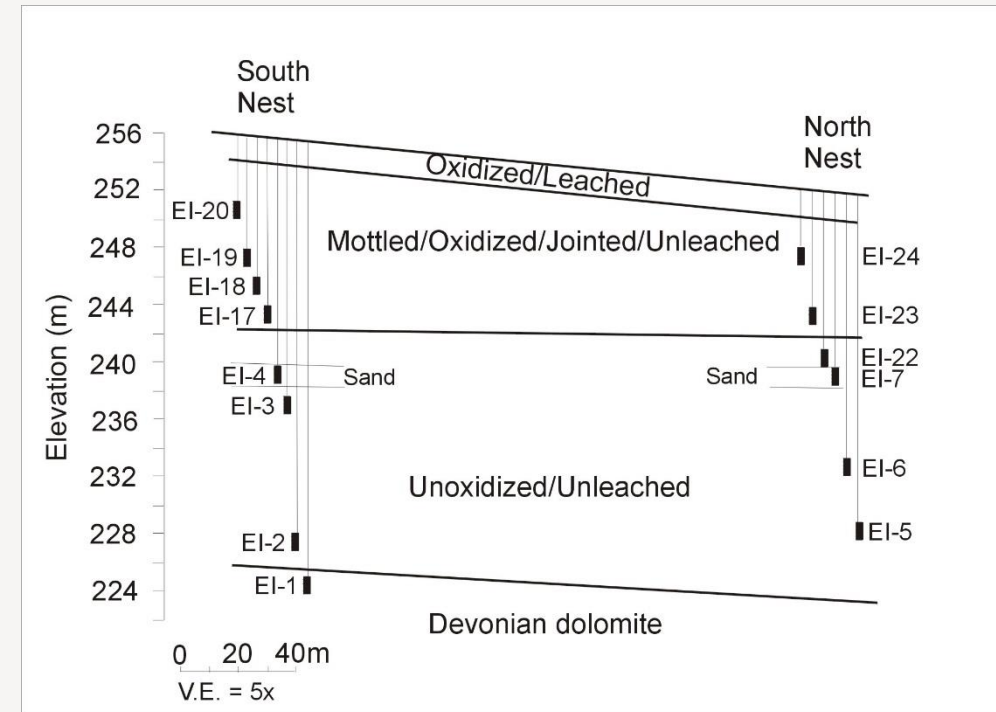


Figure 2. Location of meteorological station, observation wells, water-quality minimonitor, and pressure transducers and thermistors.

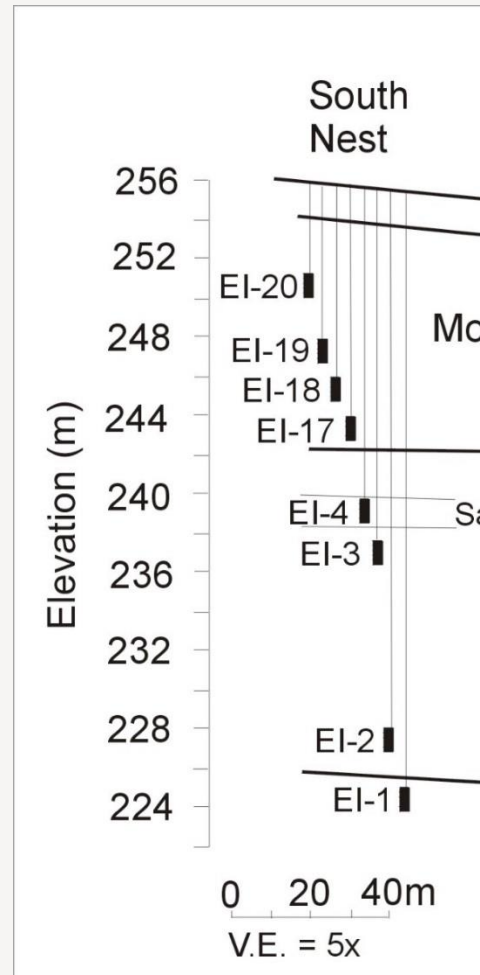
Site re-occupied by IGS

- IGS activities conducted at rest stop site from 2002-2003– concentrated at two well nests (8-well nest and 6-well nest):
 1. Soil core obtained at south nest to 98 feet
 2. Collection and analysis of soil samples
 3. Downhole water profiling in well columns
 4. Measured hydraulic heads, gradients, K
 5. Collection and analysis of water samples (nutrients, metals, ions, isotopes)

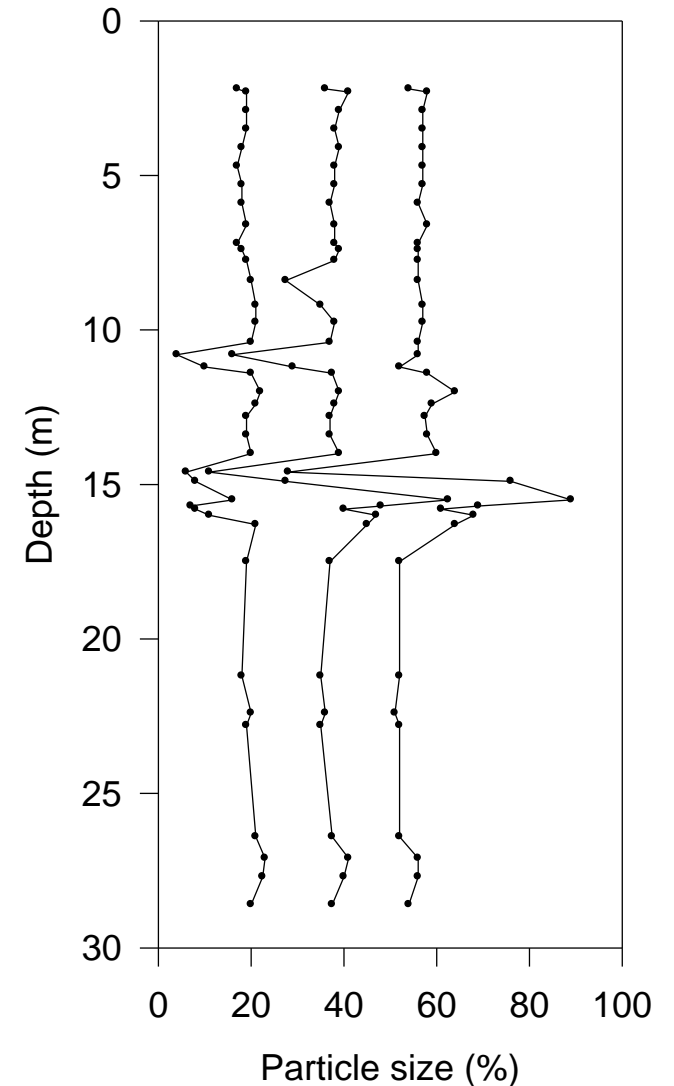


Site stratigraphy

- Approximately 30 m of undifferentiated pre-Illinoian till (Wolf Creek Formation?)
- Oxidized zone (~10-12 m) mottled, jointed and unleached
- Unoxidized zone (~16-20 m) reduced, unjointed, unleached
- 1 m sand unit, possibly continuous across site
- Texture of p-I till, averages approximately 40% sand, 37% silt and 23% clay
- Clay mineralogy: 62% expandables, 17% illite, 21% kaolinite + chlorite



Grain size data from core



Soil sampling results- south well area

Table 5. Nutrient concentrations in pre-Illinoian till collected from core EI-2.

| Depth (m) | Weathering Zone | Solids Concentrations (mg/kg by dry wt) | | | | |
|--------------|--------------------|---|---------|--------|---------|------|
| | | NH3 | NO2+NO3 | Kjed N | Total P | TOC |
| 1.1 | OL | <5 | <10 | 1900 | 450 | 1000 |
| 4.1 | OU | <5 | <10 | 1100 | 960 | 490 |
| 7.0 | OU | <5 | <10 | 1600 | 260 | 2900 |
| 10.0 | OU | <5 | <10 | 1100 | 370 | 4300 |
| 11.7 | OU | <5 | <10 | 930 | 420 | 4100 |
| 14.3 | UU | 13 | <10 | 780 | 300 | 6700 |
| 17.6-22.8 | UU | 1100 | <10 | 250 | 360 | 7800 |
| 22.8-29.8 | UU | 210 | <10 | 260 | 330 | 7300 |

Hydrogeology - measurements

- Hydraulic heads were measured on several occasions in 2002 before wells were purged
- After purging, slow recovery in unoxidized till wells prevented additional head monitoring
- K tests involved well recovery measurements after purging (unoxid till wells) and slug tests (ox till wells)

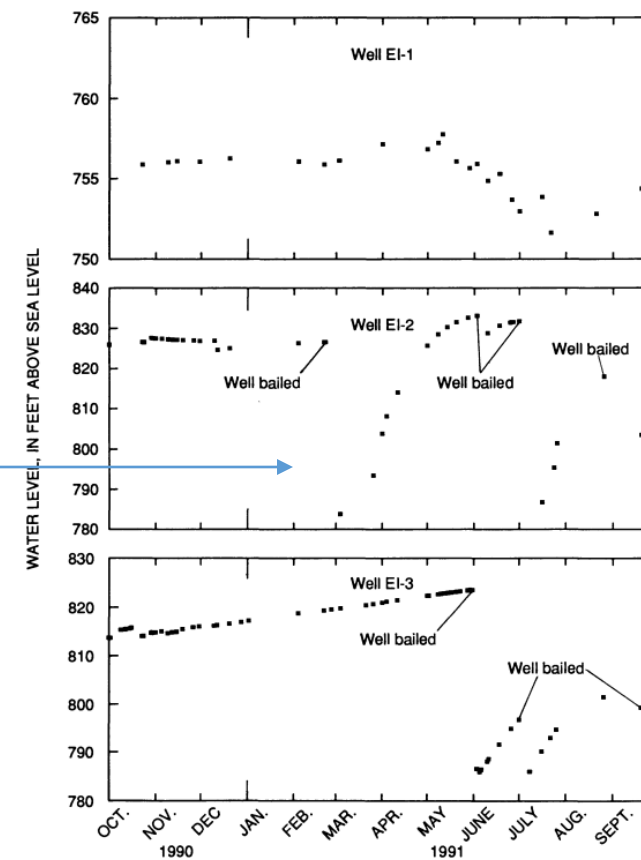


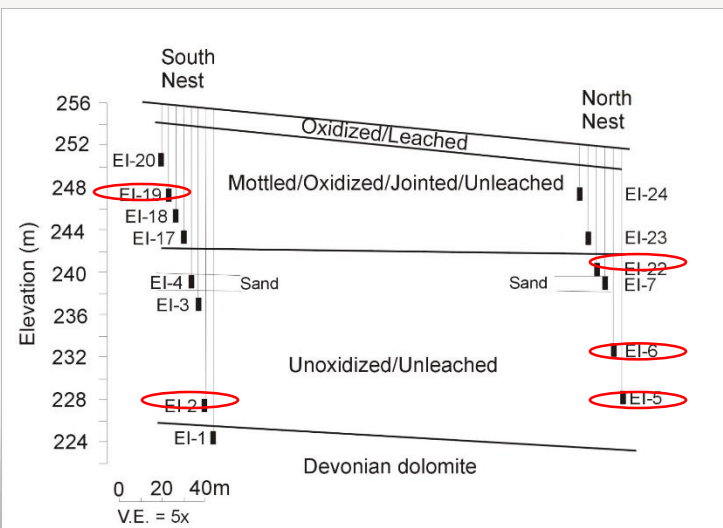
Figure 5. Water levels in observation wells measured intermittently, water year 1991.

How long does it take wells to recover from purging?

Table 1

Summary of monitoring well information and water level recovery data.

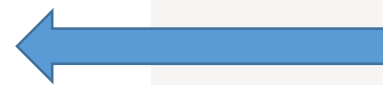
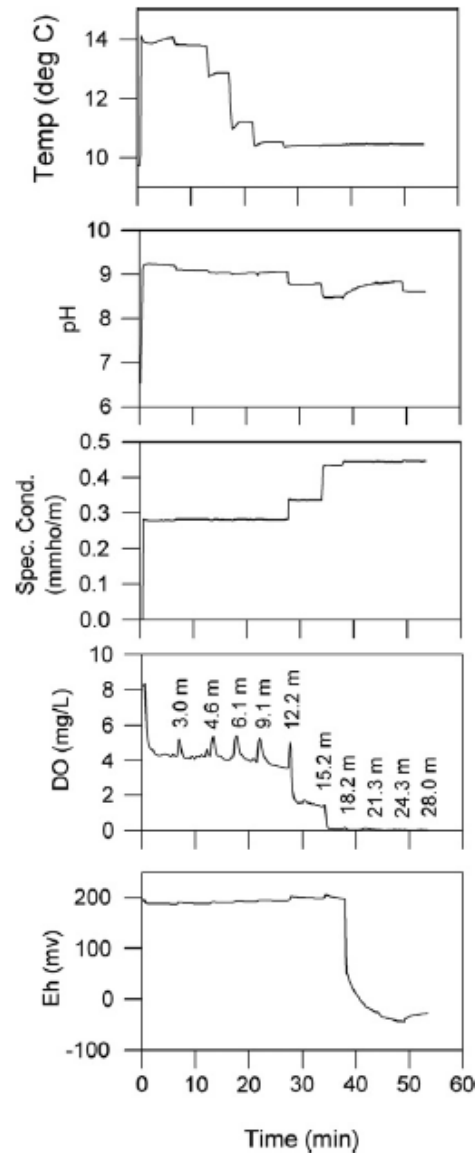
| Well ID | Well depth (m) | Weathering status of pre-Illinoian till | Static water level depth (m) | % Recovery from previous purging | | | Measured recovery rate (m/day) | Time needed for 100% recovery (days) |
|---------|----------------|---|------------------------------|----------------------------------|--------------|------------|--------------------------------|--------------------------------------|
| | | | | 11 year (%) | 14 month (%) | 1 week (%) | | |
| EI-2 | 28.27 | Unoxidized | 3.15 | 100 | 96.1 | 16.5 | 0.06 | 437 |
| EI-5 | 23.71 | Unoxidized | 4.99 | 100 | 90.6 | 12.2 | 0.04 | 464 |
| EI-6 | 18.85 | Unoxidized | 3.23 | 100 | 65.5 | 5.9 | 0.02 | 641 |
| EI-22 | 11.25 | Oxidized | 1.74 | 100 | 100 | 98 | 1.33 | 7 |
| EI-19 | 8.51 | Oxidized | 2.45 | 100 | 100 | 100 | 6.85 | 1 |



Remove water from well casing and it might take YEARS for water levels to recover

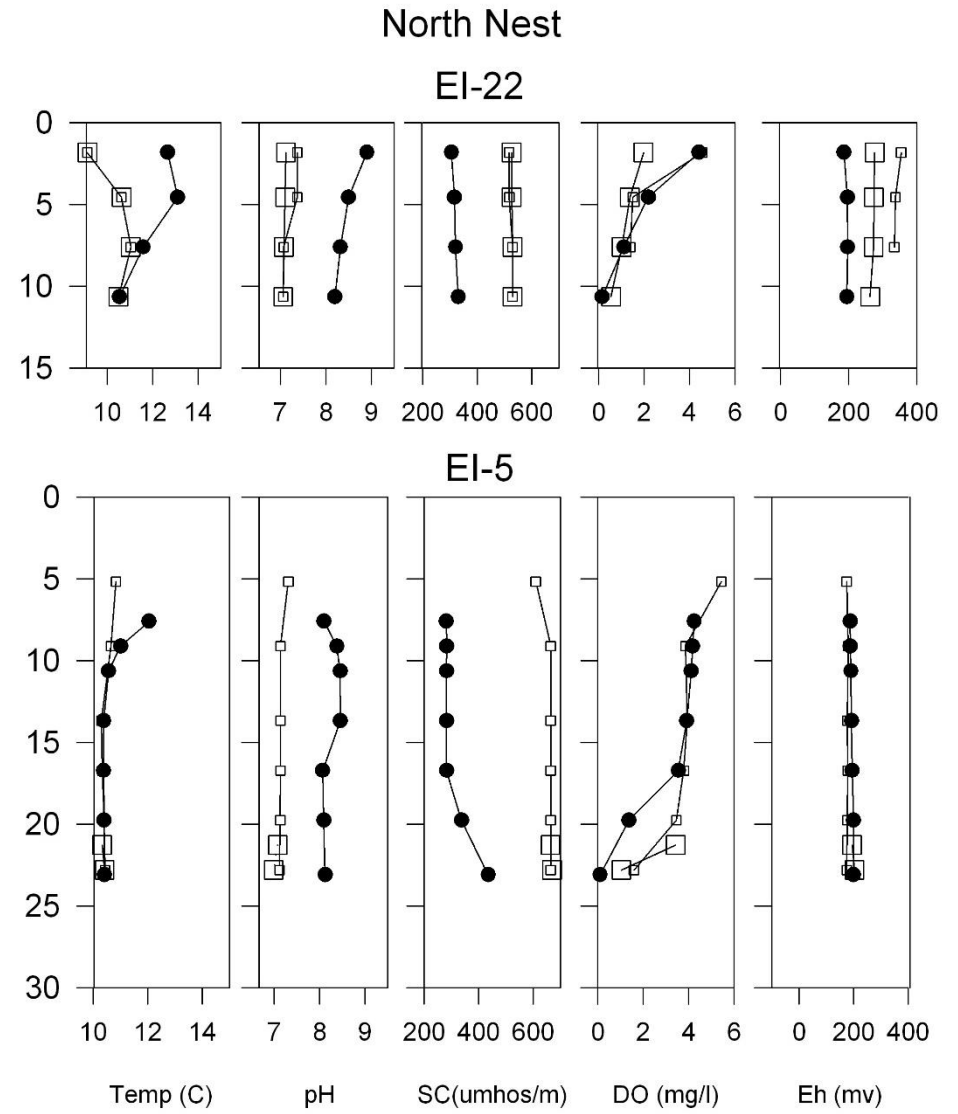
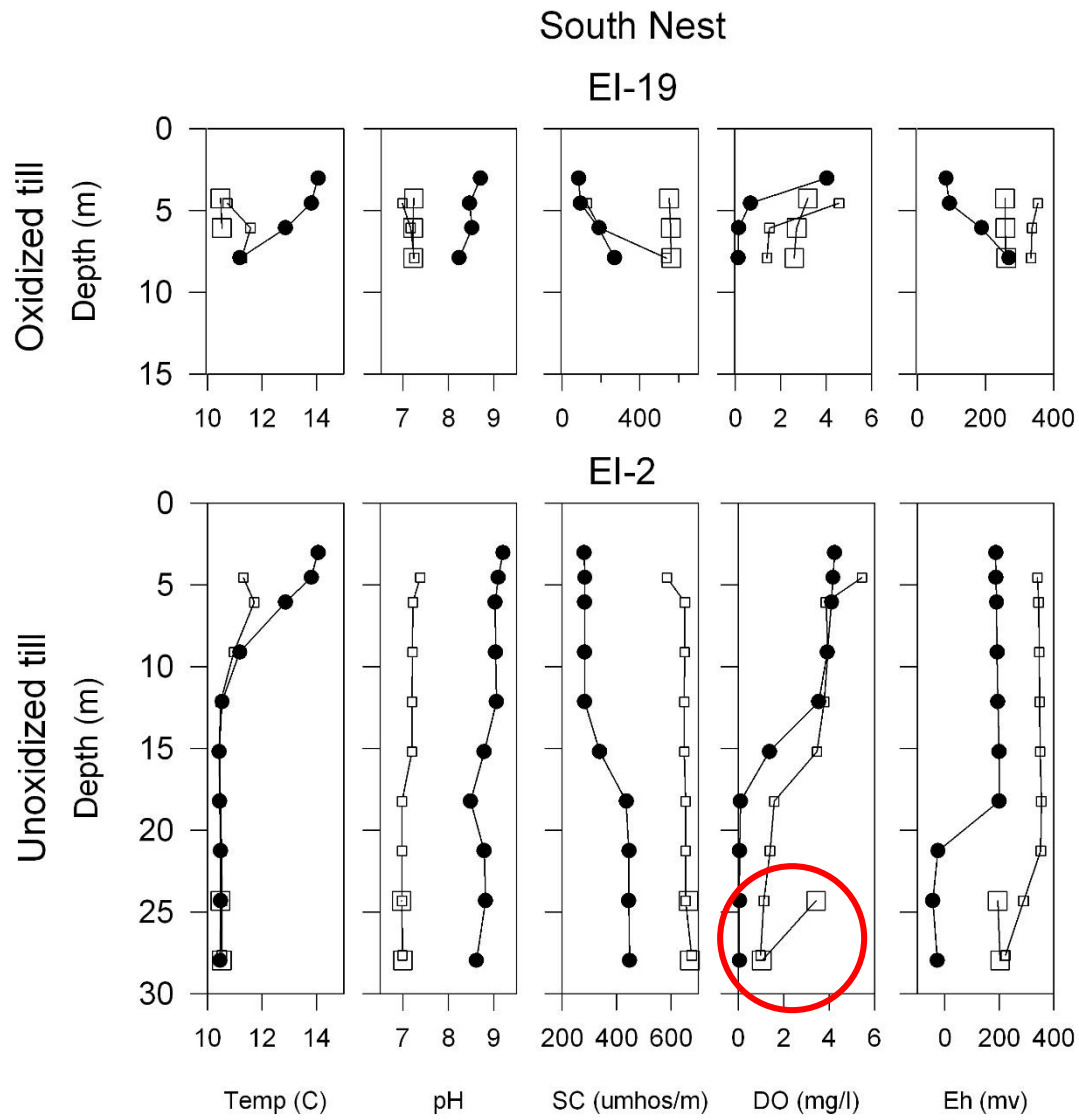
Stratification of water in well casing

Lowered Hydrolab Mini-sonde down well casing after well had been abandoned for 10 years



Major geochemical change in standing water column at 10-20 m depth

Fig. 2. Readings of temperature, pH, specific conductance, dissolved O₂ and Eh taken at 10 s intervals with MiniSonde when lowered in well EI-2 in October 2002.



● 11-year purging interval

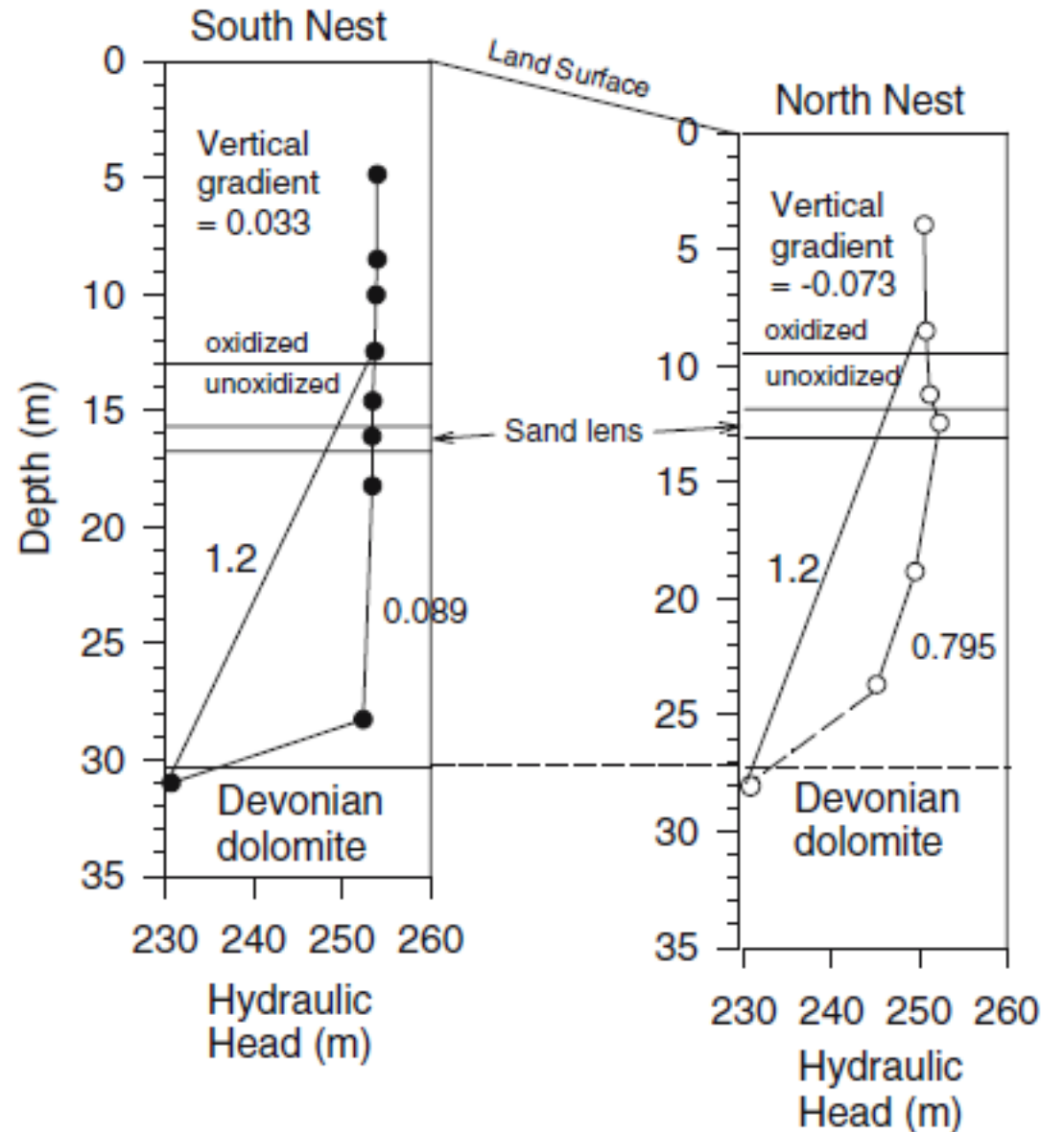
 ◻ 14-month purging interval

 ◻ 1-week purging interval

Hydraulic Heads and Vertical Gradients

Downward vertical hydraulic gradients from the water table to Devonian bedrock aquifer

Vertical gradient through entire profile was 0.95 downward but clear variations were evident



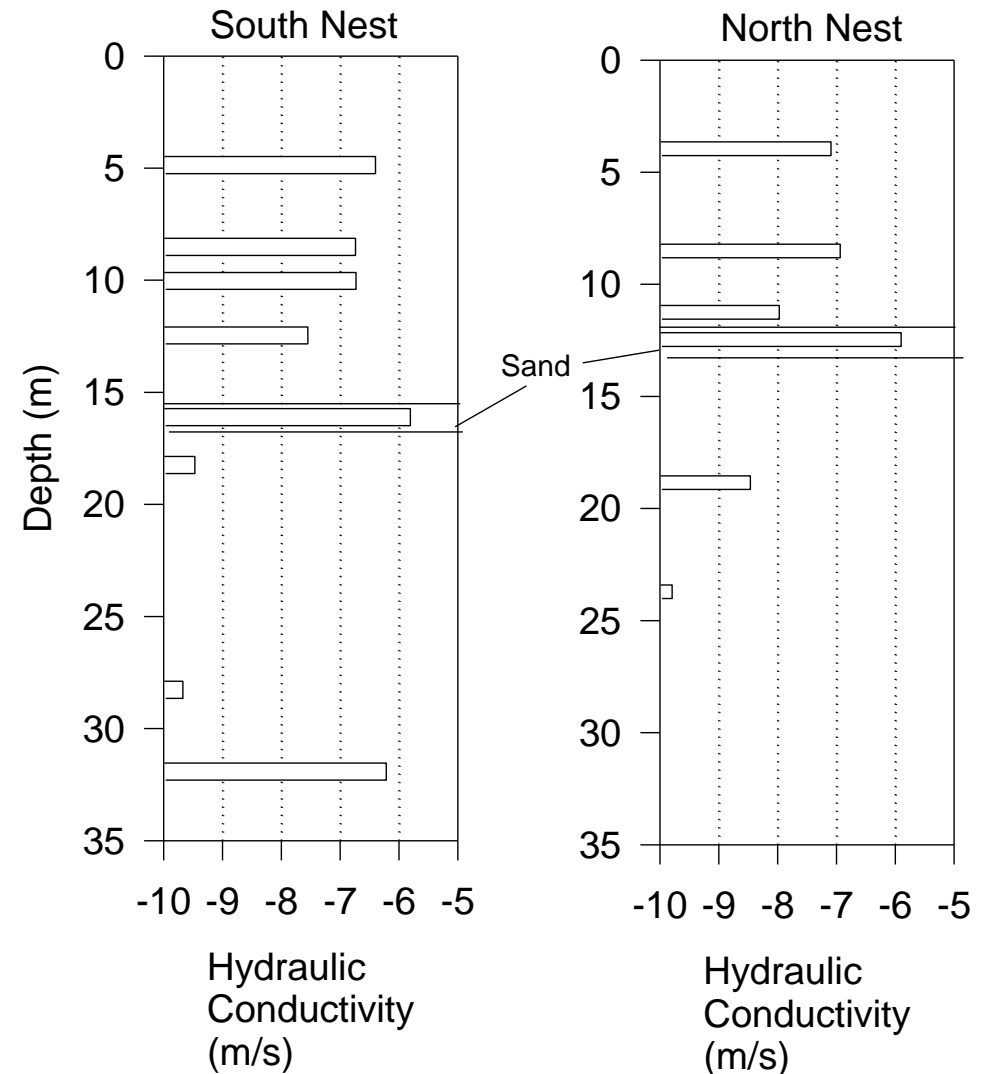
K Measurements

K decreased from oxidized to unoxidized till

K ranged from 8×10^{-8} m/s to 5×10^{-7} m/s with a geometric mean of 1.2×10^{-7} m/s

K measured in four unoxidized till wells ranged from 3×10^{-9} to 2×10^{-10} m/s with a geometric mean of 4.5×10^{-10} m/s

Devonian bedrock = 6.1×10^{-7} m/s



Vertical Travel Time

Darcy's Law - average linear velocity:

$$V = -K i / n$$

n is assumed to be 0.3 (local data)

Oxidized till = ~1.4 m/yr or ~70 years old at 10 m depth (base of oxidized till)

Unoxidized till: Use average i of 0.4, range in K

Upper range: ~0.2 m/yr or 2 m/10 years

Mid range: ~0.02 m/y or 2 m/100 years

Low range: ~0.002 m/y or 2 m/1000 years

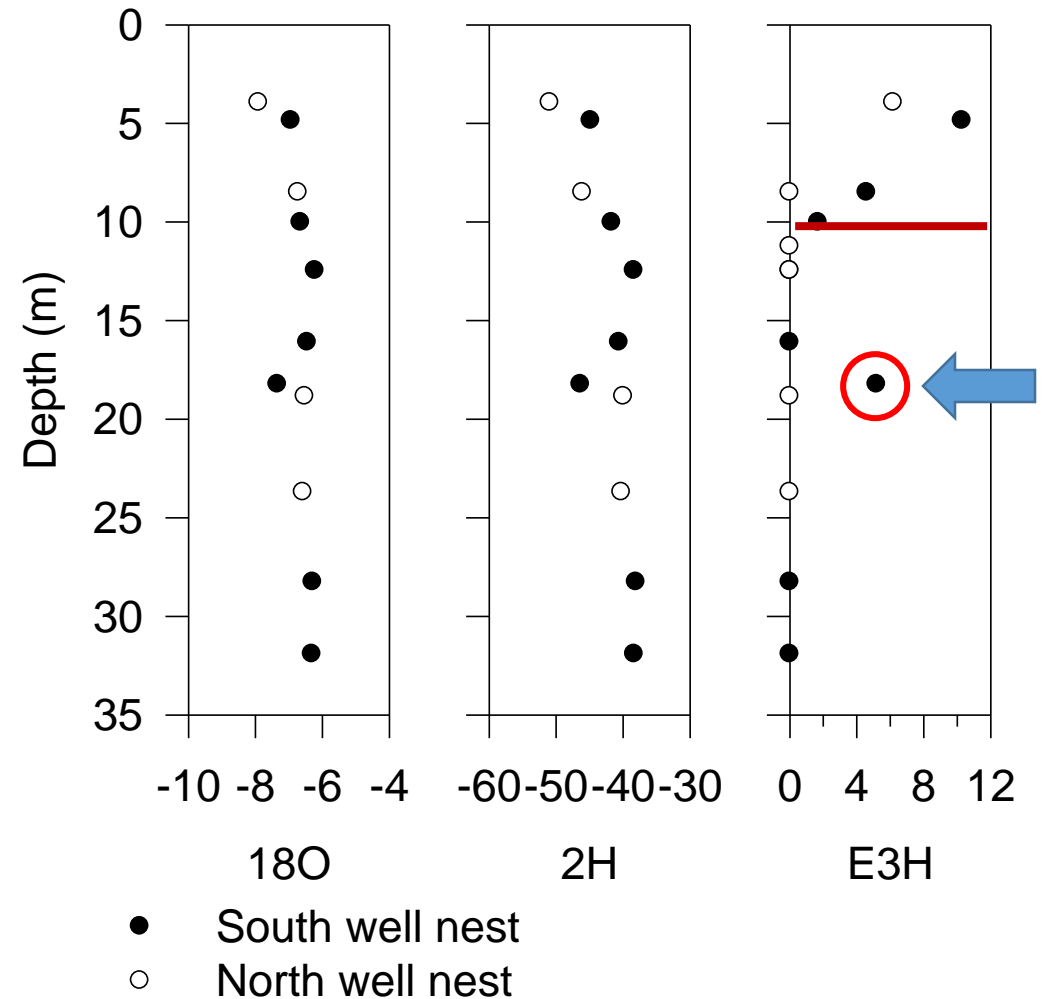
Groundwater Quality - isotopes

Tritium detected in five wells and declined with depth

Anomaly at EI-3

Groundwater in oxidized till < ~60 years old

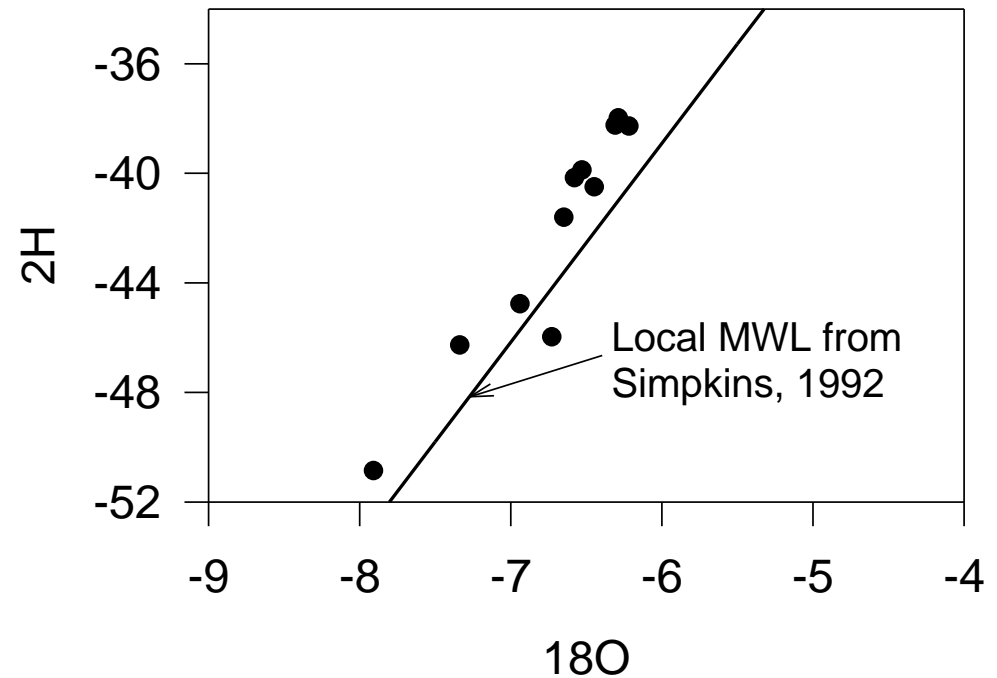
Slight shift in less negative ^{18}O values with depth but not much variations through till profile



Isotopes Plotted on Meteoric Water Line

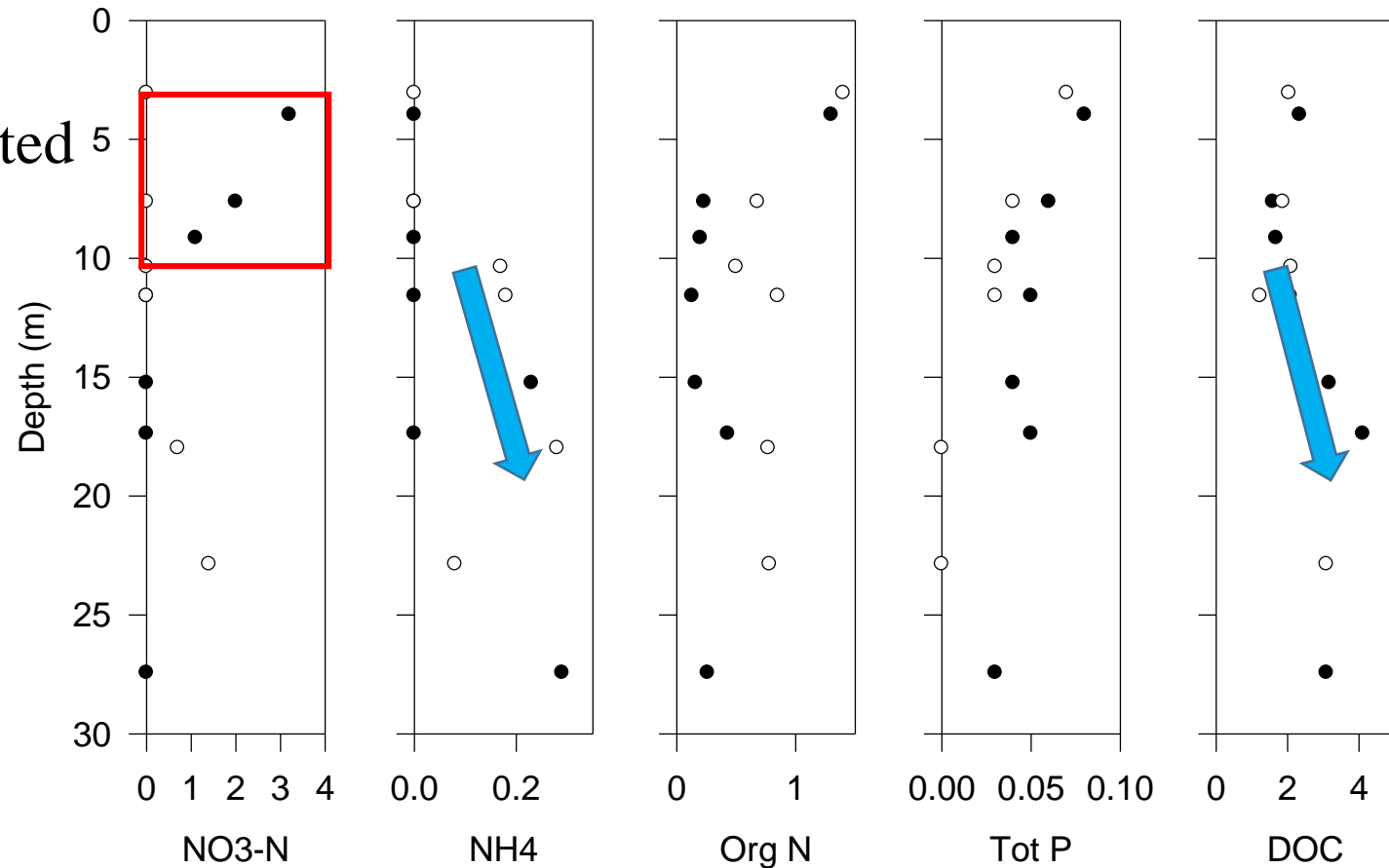
Stable isotopes plot on similar LMWL as reported in central Iowa

No substantial evaporative enrichment relative to local precipitation



Groundwater Quality - nutrients

Nitrate not detected below 9.1 m



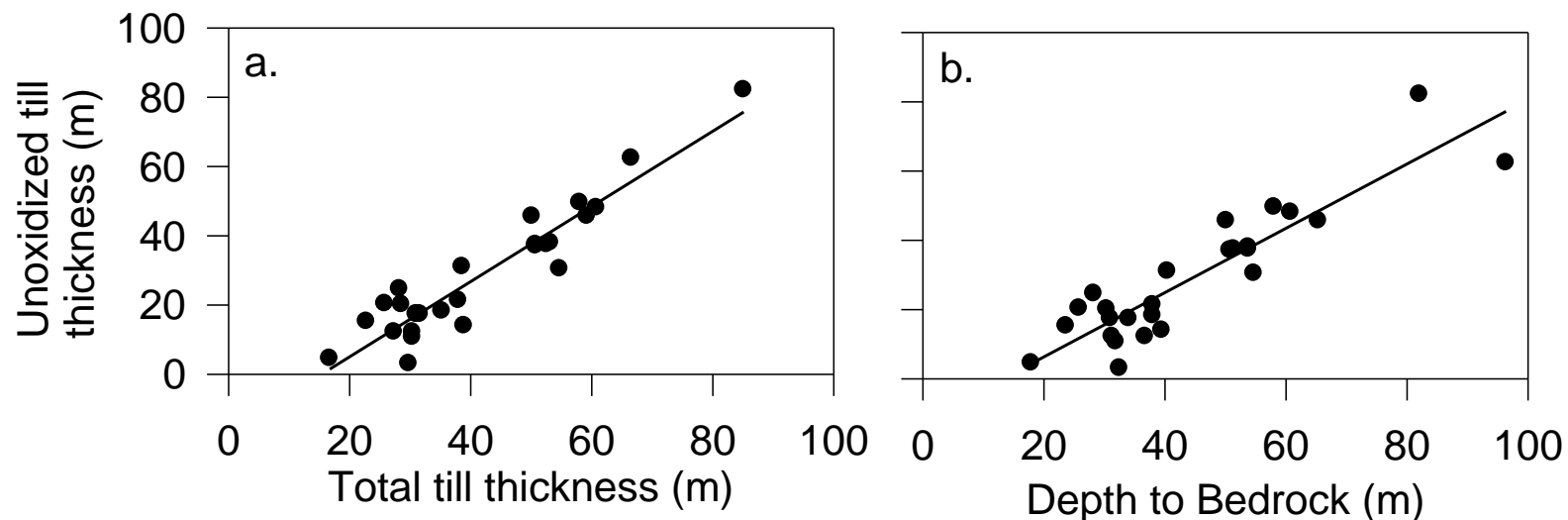
DOC concentrations increasing with soil TOC

Groundwater protection provided by “old” till

- Travel times based on thickness of unoxidized pre-Illinoian till
- Considered mid-range K estimate

| | | | |
|--|----------------|------------|--------------|
| FORM NO. 79—In stock and for sale by Ross-Martin Co., Tulsa, Ok. 22143 | | | |
| STATE | Iowa | Harper | (Keokuk) |
| NW, NW, NE | Town of Harper | | |
| SEC. | 30 | Well No. 3 | |
| TWP. | R2E | COMMENCED | COMPLETED |
| 76N | 10W | Feb 9 | Feb 12, 1970 |
| Latta & Sons Inc. | | | |
| CASING RECORD | | | |
| 163' of 6" csg set @ 162' | | | |
| 163' 4" | | | |
| LOGGED | | | |
| BY | | | |

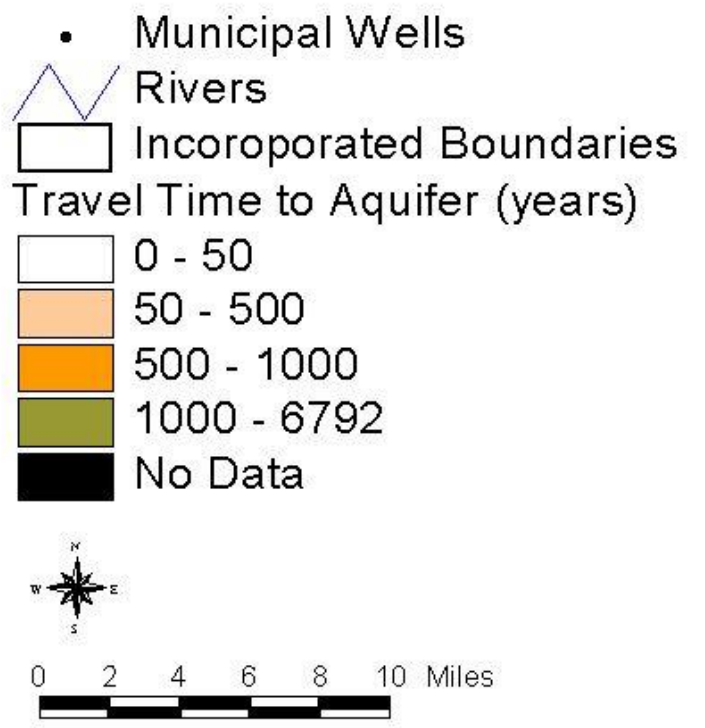
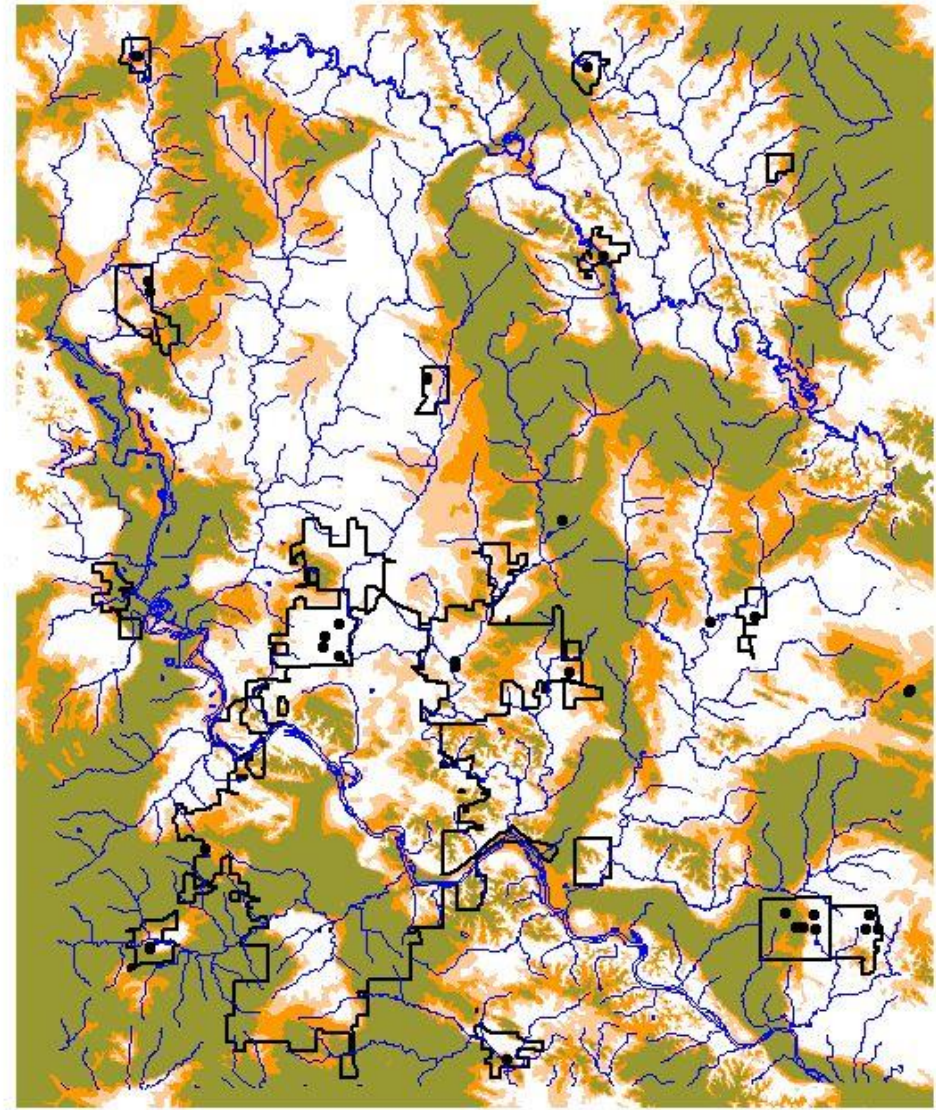
Developed relation between unoxidized till thickness and: a) total till thickness from strip logs; and b) depth to bedrock estimates from GIS layers



Thickness of unoxidized till contoured using velocity of ~6 cm/year

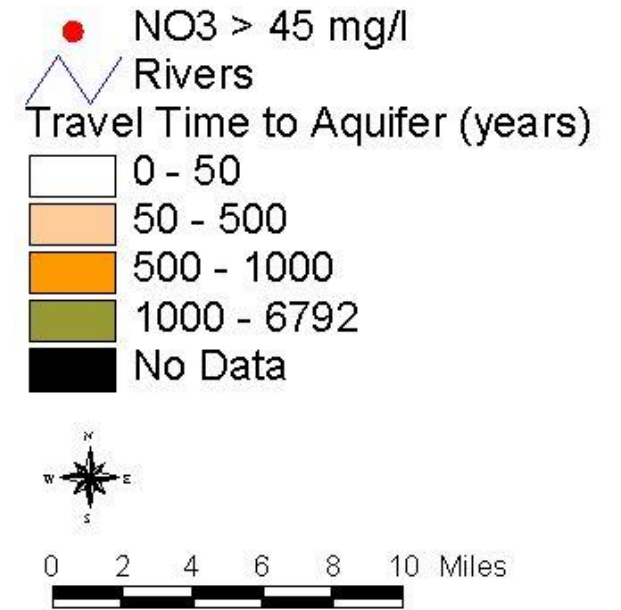
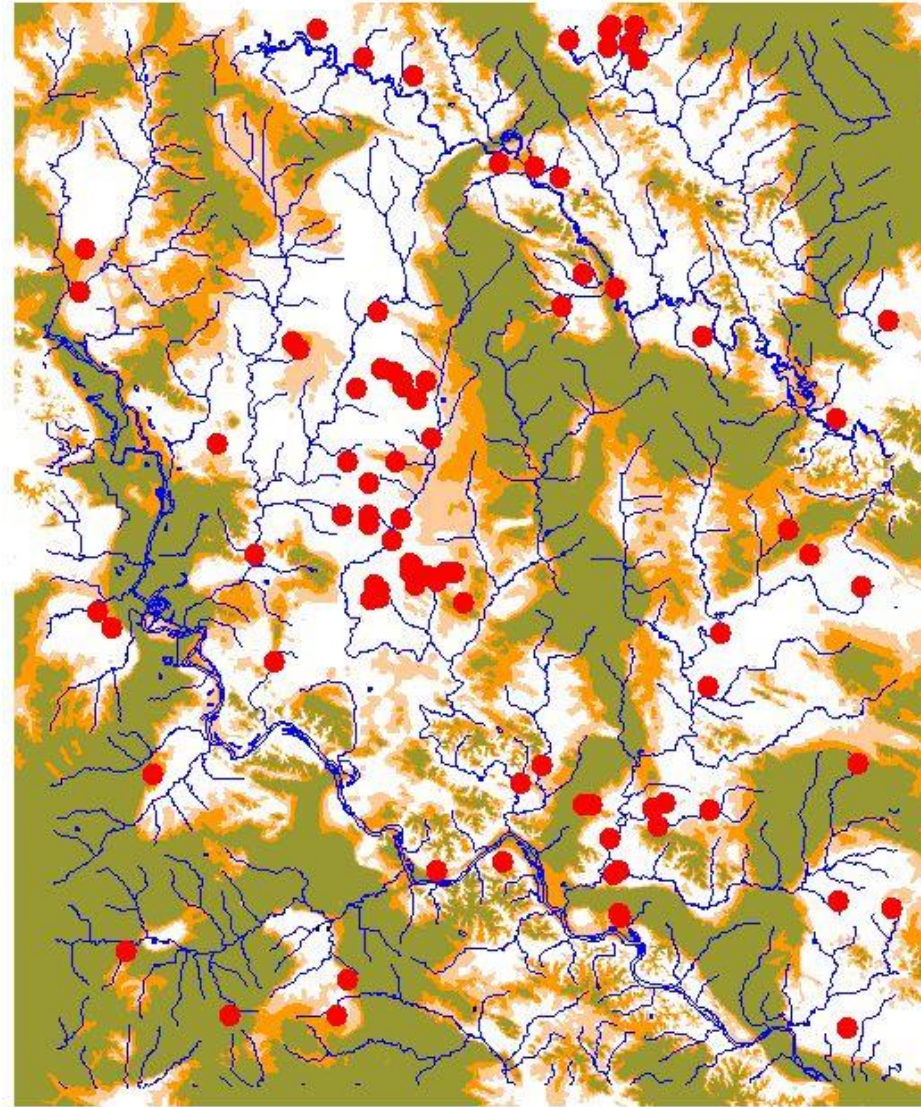
Bedrock areas overlain by less than 12 m of overburden considered vulnerable to contamination

Travel time <50 yr



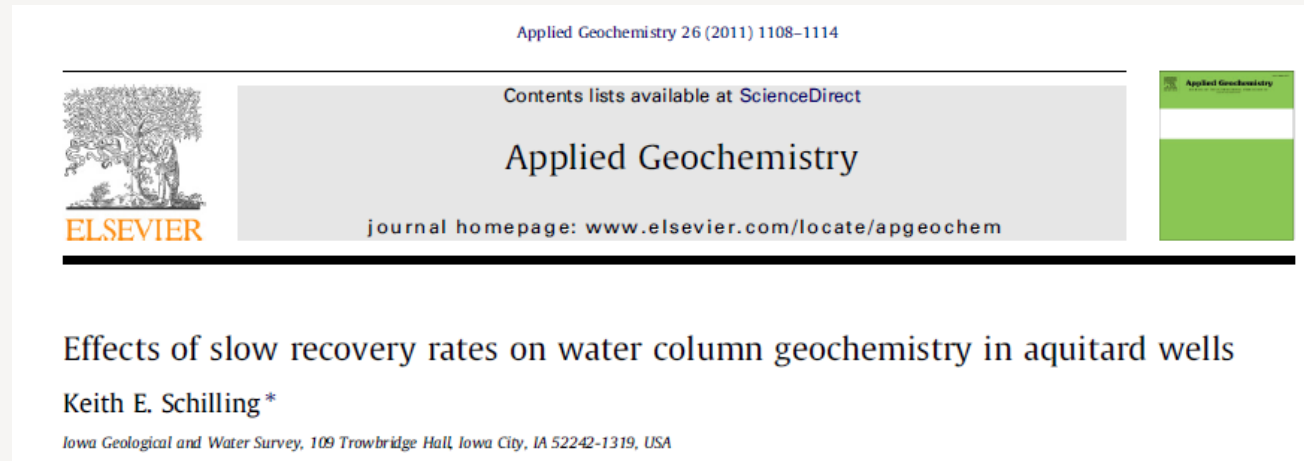
Private well NO₃
results plotted

Close relation
between vulnerable
bedrock aquifer
and lack of
unoxidized pre-III
till protection



Conclusions -

- As we all know... hydrogeology of aquitards difficult to characterize due to low K
- Aquitard sampling should consider geochemical changes that occur in water column before and after purging
- Downhole instrumentation preferred
- Perhaps identify DO or ORP stratification and sample below this boundary



True hydraulic head

Collecting water quality samples

Specific to “old” tills

- In old tills (>300,000 years), oxidized and weathered portion is a zone of recent groundwater circulation (evidenced by detectable tritium, stable isotopes and nitrate concentrations)
- Groundwater protection provided by unoxidized portion of till profile
- Vertical travel times through pre-Illinoian till orders of magnitude higher in oxidized compared to unoxidized till
- Thickness of unoxidized till controls vertical recharge rate to underlying aquifers
- Areas of enhanced groundwater protection can be identified based on unoxidized till thickness
- Bedrock aquifers are considered vulnerable to contamination when unoxidized till thin or absent



Environ Geol (2006) 50: 1255–1264
DOI 10.1007/s00254-006-0299-9

ORIGINAL ARTICLE

K. E. Schilling
S. Tassier-Surine

Groundwater flow and velocity in a 500 ka pre-Illinoian till, eastern Iowa

Announcement – New position open at the Iowa Geological Survey

- **Working Title:** Hydrogeologist
- **Classification Title:** Research Associate
- **Department:** IIHR—Hydroscience & Engineering and the Iowa Geological Survey
- **Pay Grade:** PRK2-4A; <https://hr.uiowa.edu/pay/plans>
- **Salary Range:** \$41,214 - \$66,000
- <https://uiowa.referrals.selectminds.com/jobs/hydrogeologist-2737>
- Main tasks – assistance with groundwater projects and modeling, geophysics, water quality