Stable isotope geochemistry of pore waters from the New Jersey shelf: fluid origin

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Offshore fresh groundwater

Post et al. (2013) nature
Outline

- Stable isotopes analytical methods
- Modern or old? - Stable isotopes in hydrogeology
- The New Jersey shelf – older studies and conceptual models
- IODP Expedition 313 “New Jersey Shallow Shelf”
- Results of geochemical analyses
  - Water chemistry
  - Stable isotopes
- Fresh water - salt water stratification and fluid origin
- Implications for existing models
ANALYTICAL METHODS
Stable Isotopes

Standard delta notation in ‰:

\[ \delta = \left( \frac{R_{\text{sample}}}{R_{\text{reference}}} - 1 \right) \]

„light values“ ➔ lower numbers, i.e. more negative
„heavy values“ ➔ higher numbers, i.e. less negative

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<tr>
<th>Parameter</th>
<th>Water chemistry</th>
<th>Onshore scientific party</th>
<th>Bremen</th>
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</thead>
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<tr>
<td>( \delta^{18}\text{O} ), ( \delta^2\text{H} ), ( \delta^{13}\text{C}_{\text{DIC}} )</td>
<td>Water isotope analyses</td>
<td>Erlangen University</td>
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<td>( \delta^{13}\text{C}<em>{\text{carb}} ) and ( \delta^{18}\text{O}</em>{\text{carb}} )</td>
<td>Carbonate isotopes</td>
<td>LIAG, Hanover</td>
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<td>( \delta^{13}\text{C}<em>{\text{org}} ), ( \delta^{13}\text{C}</em>{\text{meth}} ) and gas concentrations</td>
<td>Isotope analyses of ( \text{C}_{\text{org}} ) and gas isotopes</td>
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<td>( \delta^{34}\text{S} )</td>
<td>Sulfur isotopes</td>
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<td>Mineralogy</td>
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STABLE ISOTOPES IN HYDROGEOLOGY

Modern water vs Paleowater
From precipitation to groundwater

Local meteoric water line (LMWL) – Erlangen city

$\delta^2H/\%o$ (VSMOW)

$\delta^{18}O/\%o$ (VSMOW)

van Geldern et al. (2014)
From precipitation to groundwater

Precipitation
- shallow
- deep aquifer

Groundwater

van Geldern et al. (2014)
Science

U.S. Geological Survey Core Drilling on the Atlantic Shelf

Geologic data were obtained at drill-core sites along the eastern U.S. continental shelf and slope.

John C. Hathaway, C. Wylie Poag, Page C. Valentine
Robert E. Miller, David M. Schultz, Frank T. Manheim
Francis A. Kohout, Michael H. Bothner, Dwight A. Sangrey

Older Studies and Conceptual Models

NEW JERSEY SHELF
Drilling Site
New Jersey – Onshore Geology

SEDIMENTARY ROCKS

CENOZOIC
- Holocene: beach and estuarine deposits, sand, silt, clay
- Tertiary: sand, silt, clay

MESOZOIC
- Cretaceous: sand, silt, clay
- Jurassic: siltstone, shale, sandstone, conglomerate
- Triassic: siltstone, shale, sandstone, conglomerate

PALEOZOIC
- Devonian: conglomerate, sandstone, shale, limestone
- Silurian: conglomerate, sandstone, shale, limestone
- Ordovician: siltstone, shale, quartzite, sandstone
- Cambrian: limestone, sandstone

IGNEOUS AND METAMORPHIC ROCKS

MESOZOIC
- Jurassic: basalt

PRECAMBRIAN
- marble
- granite, gneiss, granite
New Jersey - Aquifers

Figure 2a. Section A-A' showing potentiometric-surface contours in aquifers of the northern New Jersey Coastal Plain, 2003.

dePaul et al. (2003)
New Jersey Shelf Fresh Water Lens

Hathaway et al. (1979) - Science, v. 206, p. 515
New Jersey Shelf Fresh Water Lens

Hathaway et al. (1979) - *Science*, v. 206, p.515
Fresh Water Origin – Conceptual Models

van Geldern et al. (2013) - Geosphere
Water Origin – Before IODP Expedition 313

- Based on the results of the 1970s drillings different models have been proposed:
  - Fresh water is “old” (last glacial maximum (LGM) or older)
  - The most recent (Cohen et al., 2010): Fresh water lens below the New Jersey Shelf emplaced during the LGM (older than ~20.000 years)
- by a combination of:
  - Sub-glacial recharge from the continental ice shield
  - Meteoric recharge during sea-level low stands
- Nonrenewable resource
30 April to 17 July 2009

IODP EXPEDITION 313
IODP 313 - New Jersey Shallow Shelf (NJSS)

- Main objectives of NJSS:
  - Investigate global sea-level changes in the early and middle Miocene
  - Relation of sea-level changes to the architecture of sedimentary sequences
- “Mission Specific Platform” (MSP)
- 45 to 67 km offshore New Jersey
- Three drilling sites
- Depths from 631 to 755 mbsf
- Extensive petrophysical and logging data with good geo-chronology for correlation of seismic boundaries with lithology
- Detailed study of interstitial water chemistry
IODP 313 – “New Jersey Shallow Shelf”
Port: Atlantic City, NJ, USA

photo: ECORD
... 45 km offshore Atlantic City...

photo: ECORD
Core recovery and curation
Core analysis
Offshore Seismic Profile

Figure 3: Offshore Seismic Profile with common depth point (cdp) and fault markings. Units I to VII are labeled along with specific depths marked as m4.1, m4.2, m4.3, etc. The profile extends from NW to SE with two-way travel time in seconds on the vertical axis and common depth point (cdp) in kilometers on the horizontal axis.
Results – Pore Water Chemistry

WATER ORIGIN
Water Stable Isotopes

van Geldern et al. (2013) - Geosphere
Water Stable Isotopes

van Geldern et al. (2013) - Geosphere
Meteoric recharge onshore NJ

(a)

River water NJ (Coplen and Kendall, 2000)
Onshore groundwater NJ (Brown, 2005)
Offshore seawater NJ shelf (this study)
Drilling mud IODP Exp. 313 (this study)
OIPC

LMWL New Jersey
$y = 6.9x + 6.6$

GMWL
$y = 8x + 10$

OIPC
Water Origin

Figure 9: Diagram showing the water origin with isotope values. The graph plots δ²H [‰ VSMOW] against δ¹⁸O [%o VSMOW]. The data points represent different samples from various sources:

- M0029A (0 to 340 mbsf)
- M0027A (0 to 415 mbsf)
- Average river water NJ
- Modern seawater NJ shelf
- Modern meteoric recharge
- Pleistocene recharge with low isotope values

The graph also includes a line for the Geosea Water Line (GMWL) and markers for modern seawater and modern meteoric recharge.
Water Origin

![Graph showing chloride vs. δ¹⁸O for different samples.]

- M0027A (0 to 415 mbsf)
- M0029A (0 to 340 mbsf)
- M0027A (415 to 631 mbsf)
- M0029A (340 to 750 mbsf)

**Figure 9**
van Geldern et al. (2013) - Geosphere
Fresh Water – Salt Water

van Geldern et al. (2013) - Geosphere
Deep Brine

Two-way traveltime (s)

0
NW
M0027A
M0028A
M0029A
SE
0.2
0.4
0.6
0.8
1.0

Two-way traveltime (s)

0
NW
M0027A
M0028A
M0029A
SE
0.2
0.4
0.6
0.8
1.0

Two-way traveltime (s)

Unit I
Unit II
Unit III
Unit IV
Unit V
Unit VI
Unit VII

faults

faults

faults

faults

faults

faults

faults

faults

faults

faults
Conclusions – Fluid Origin

- More **complex geometry** than previously assumed “fresh water lens”
- Stable isotopes and water chemistry identified **three** fluid phases:
  1. fresh water that represents meteoric water
  2. salt water of marine origin
  3. saline brine from evaporites in the deep underground
- **No** indication for **Pleistocene** glacial melt waters
- Stable isotopes **might** indicate a **modern origin** of the fresh water by onshore meteoric recharge
- **Fresh water** was found in the **fine grained** sediments
- **Salt water** infiltrates along **coarse-grained**, sandy units
- Existing **groundwater models** of the Atlantic shelf have to be refined
Aknowledgments

- S. Meyer, S. Konrad, S. Krumm, and C. Weinzierl (FAU Erlangen)
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- P. Escher (IOW, Warnemünde)
- S. Schlömer, C. Poggenburg, D. Laszinski, and U. Berner with colleagues (BGR, Hanover)
- Integrated Ocean Drilling Program (IODP)

Full reference:
Water Stable Isotopes

van Geldern et al. (2013) - Geosphere