#### Michigan's Geology and Groundwater



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#### Outline

- About the USGS
- Geology 101
- Michigan's geology
  - Bedrock geology
  - Glacial geology
- Understanding groundwater
  - Porosity and permeability
  - Baseflow
  - Monitoring



#### Who is the USGS?

- A Federal agency part of the Department of the Interior
- Established in 1879 with the mission of...

"classification of the public lands, and examination of the geological structure, mineral resources, and products of the national domain."



Figure 9: Charmon King, Directors of the U.S. Geoingical Instrum, 1478-1881

- The USGS is the Nation's largest water, earth, and biological science and mapping agency
- <u>Non-regulatory</u> scientific research agency in earth- and life-science disciplines



#### Who is the USGS?

#### Seven Mission Areas

- Climate and Land Use Change
- Core Science Systems
- Ecosystems
- Environmental Health
- Energy and Minerals
- Natural Hazards
- Water

















#### Water Mission Area of the USGS

- Water Science Centers in almost every state
  - Provide long-term, highquality data available to the public in perpetuity
  - Conduct interpretive studies to further our understanding of water resources
  - Work in cooperation with other federal, state, and local governments





### Geology 101

- Geology is the study of the earth including aspects of
  - Physics and chemistry
  - Astronomy
  - Meteorology
  - Biology
  - Hydrology

#### (...it's more than just rocks!)



## Geology 101

- Understanding geologic time scales
  - Thr dati Basic tenet: change is constant estimate that the earth is 4.6 billion years old

USGS

 Human existence only a very small fraction of geologic time











PreCambrian ("before life") Phanerozoic

Paleozoic Mesozoic Cenozoic Pleistocene (2.6 MY) Holocene (11,700 Y)



#### Bedrock geology

 Bedrock is the solid rock that underlies loose deposits such as soil or alluvium

 The bedrock geology of Michigan is quite complex and includes igneous, metamorphic, and sedimentary rocks, the surface of which have been significantly altered by glaciers





#### Two different bedrock settings:

 Western Upper Peninsula

 Sedimentary rocks of the Michigan Basin

#### Western Upper Peninsula



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**EMUDIX FORMATION** 

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 Ancient rocks over 1 billion years old

 Igneous and metamorphic rocks with significant iron, copper, gold, and silver deposits



 Limited groundwater is within fractures and joints

# Sedimentary rocks of the Michigan Basin

- Roughly circular outcrop pattern dipping towards the center
- Rocks are up to 16,000 feet thick
- Groundwater in fractures, bedding planes, and pores between sediment grains





#### **Geologic cross-section**





#### Michigan Basin mineral resources



cience for a changing wor



- Portland cement
- Sand and gravel, crushed stone (aggregate)
- Building dimension stone (sandstone, limestone)
- Oil and gas
- Salt, gypsum, coal, potash, and peat

## Glacial geology

- Many periods of glaciation throughout geologic history
- The most significant period was the Pleistocene Epoch which started about 2.6 million years ago.
- We are currently in an interglacial period







# Glacial geology



 Glacial ice over 10,000 feet thick moved over North America. In the

Almost all the landforms of Michigan (except for western UP) are a result of major erosional and depositional changes by glaciers and glacial lakes



- mica in vancys
- rerouted and (or) blocked drainage
- gouged out the Great Lakes and major basins



# Glacial geology

 Glacially influenced slopes and soils affect agriculture, water availability, and population density



 Almost all of our inland lakes, kettles or pot holes, and wetlands were created and (or) modified by glacial processes



#### **Glacial sediments**







- Glacially derived sediments include
  - Glacial erratics
  - Boulder fields
  - Gravels (kames and eskers)
  - Sands
  - Clay (glacial and lake)
  - Till versus drift
  - Sediment size determines groundwater availability

#### Wetlands and glacial geology



End moraines, coarse-textured till

Coarsetextured glacial till

> End moraines, mediumtextured till

Water

Ice-contact outwash sand and gravel Glacial outwash sand and gravel and postglacial alluvium



MDEQ Wetlands Map Viewer

Michigan Geological Survey, Quaternary Geology

#### Understanding groundwater

 Groundwater moves from areas of high water levels to low water levels
(hydraulic gradient)



- Groundwater can leak into or out of lakes, rivers, and wetlands depending on the hydraulic gradient
- Baseflow is groundwater flow to surface water during periods of no surface runoff



#### Understanding groundwater



Good porosity Poor permeability



Good porosity Good permeability

- Porosity = void space in rock or sediment
- Permeability = a measure of how easily a liquid or gas can move through pore spaces



#### How do we monitor groundwater?

- Water levels and waterchemistry samples are obtained through wells
- Many different drilling technologies and well configurations are available







# Hydrographs document changes in hydrologic conditions





**4 KOLOMETERS** 

-level maps show contours of water levels and flow directions

Groundwater

- con controls
- -590 Potentiometric contour—Shows altitude at which water would stand in tightly-cased wells; dashed where approximate. Interval is 10 and 20 feet. Datum is sea level.
- Quarry—Shows location of carbonate rock quarry.
- Well

[Average lake level approximately 572 feet above sea level]

#### Grannemann and others, 2000





science for a changing world

Michigan groundwater maps http://www.egr.msu.edu/igw/GWIM%20Figure%20Webpage/

General-vater Inventory and Mapping Project

#### How do we monitor surface water?





Gage height (stage) and streamflow are measured at gaging stations through a range of conditions





#### USGS National Water Information System (NWIS) Data

#### Streamflow



#### https://waterdata.usgs.gov/nwis



	Expla	nation	- Percer	ntile cla	sses	
•			•		•	•
Low	<10	10-24	25-75	76-90	>90	High
	Much below normal	Below	Normal	Above	Much above	



#### Bringing it all together

Bedrock geology varies across Michigan

 Glacial processes helped define the location and character of land forms, soils, lakes, streams, and wetlands



#### Bringing it all together

- Groundwater availability in bedrock is typically limited to fractures, joints, and bedding planes
- Groundwater availability in glacial sediments is typically limited by sediment size
- Groundwater constantly interacts with water in wetlands and maintains baseflow to streams



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