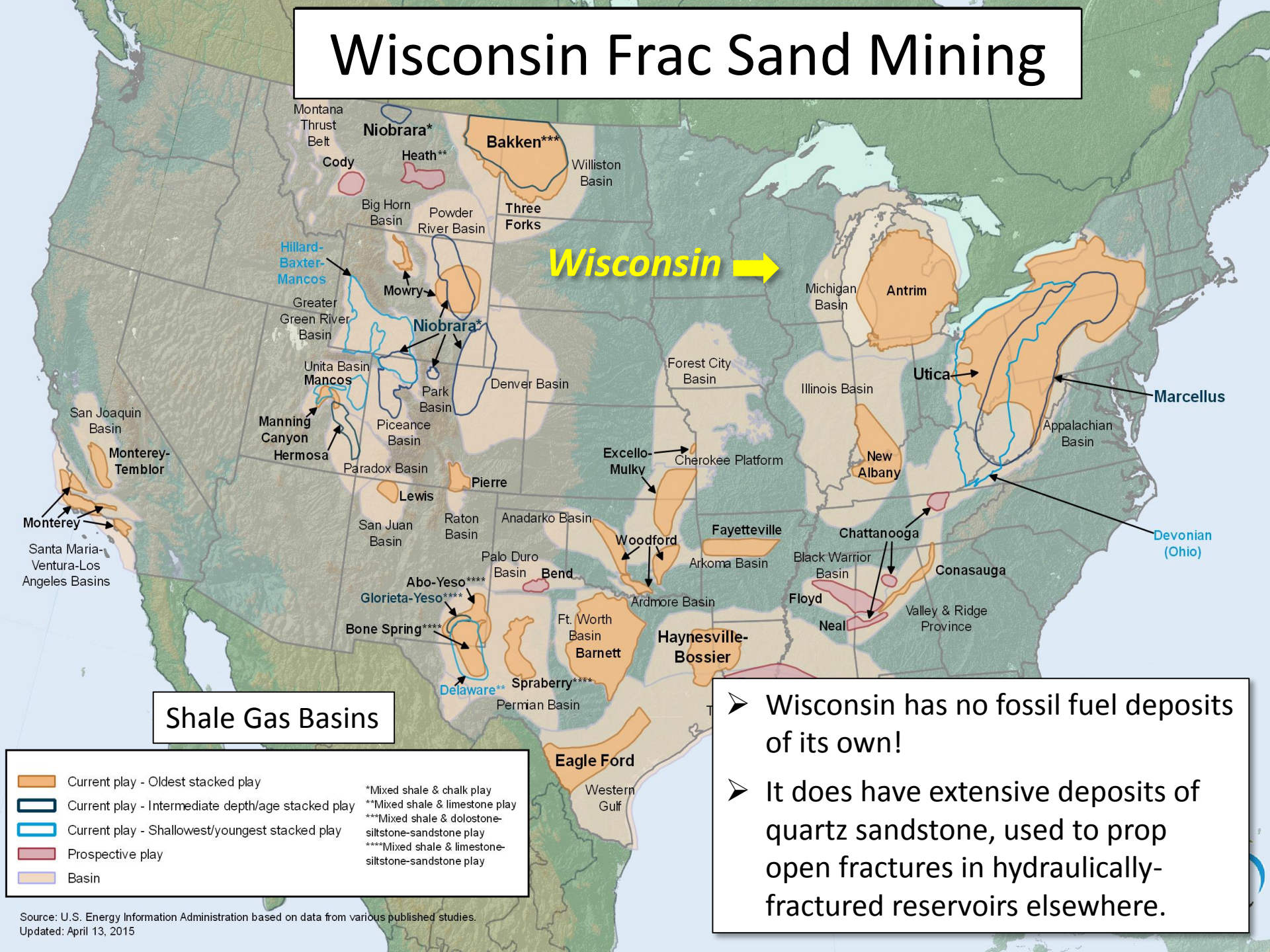
Wisconsin Frac Sand Mining



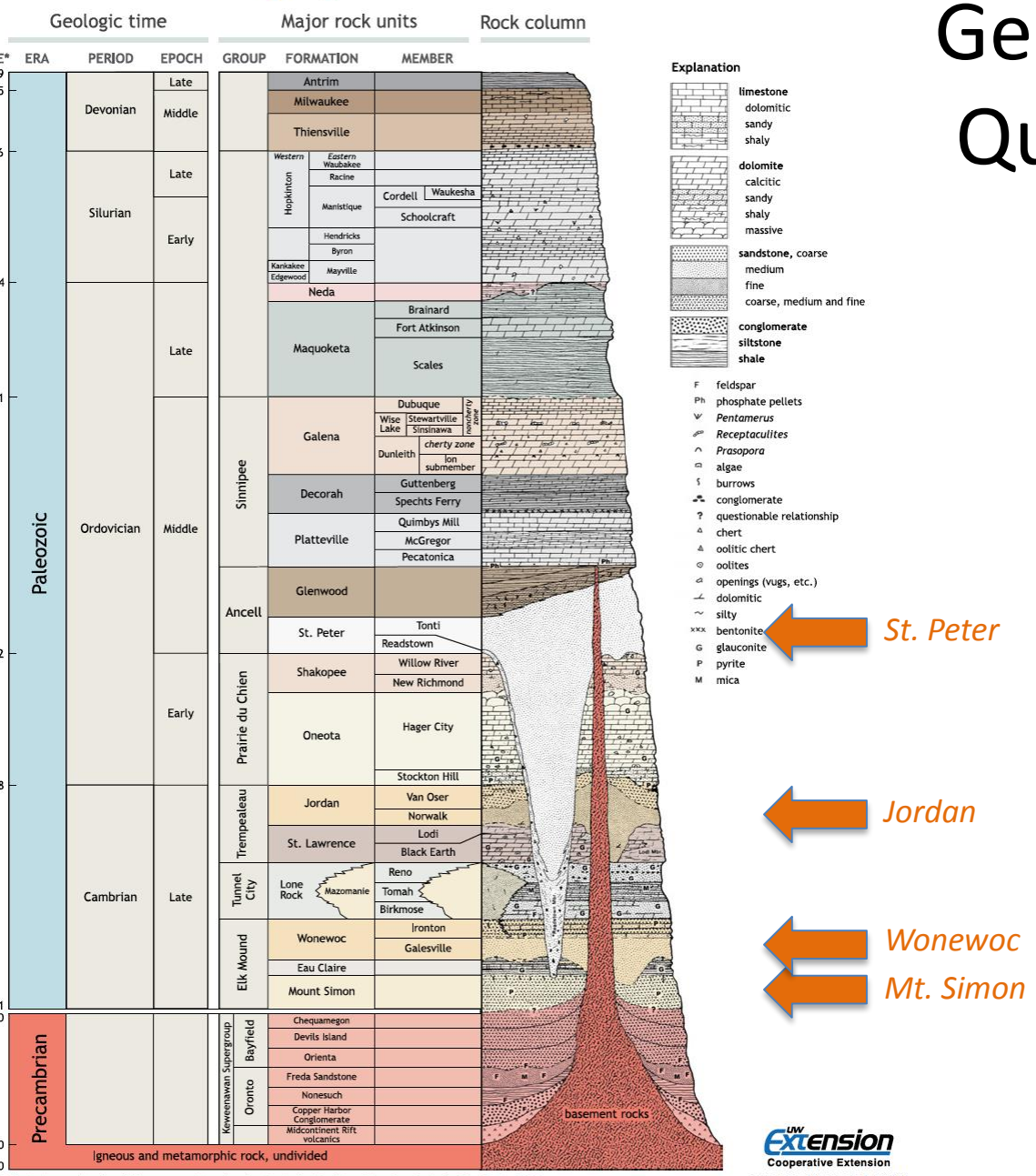
Shale Gas Basins

- Current play - Oldest stacked play
- Current play - Intermediate depth/age stacked play
- Current play - Shallowest/youngest stacked play
- Prospective play
- Basin

*Mixed shale & chalk play
**Mixed shale & limestone play
***Mixed shale & dolostone-siltstone-sandstone play
****Mixed shale & limestone-siltstone-sandstone play

Source: U.S. Energy Information Administration based on data from various published studies.
Updated: April 13, 2015

- Wisconsin has no fossil fuel deposits of its own!
- It does have extensive deposits of quartz sandstone, used to prop open fractures in hydraulically-fractured reservoirs elsewhere.



Geologic History of Quartz Sandstone

Quartz sandstone formations were deposited across the middle part of the U.S. during a unique interval of geologic time, between about 500 and 470 million years ago, during the Cambrian and Ordovician periods. Atmospheric CO_2 levels and temperatures were both much higher than at present, which likely helped to dissolve non-quartz sand grains.

The sand grains themselves are even older, dating back as far as 2.7 billion years

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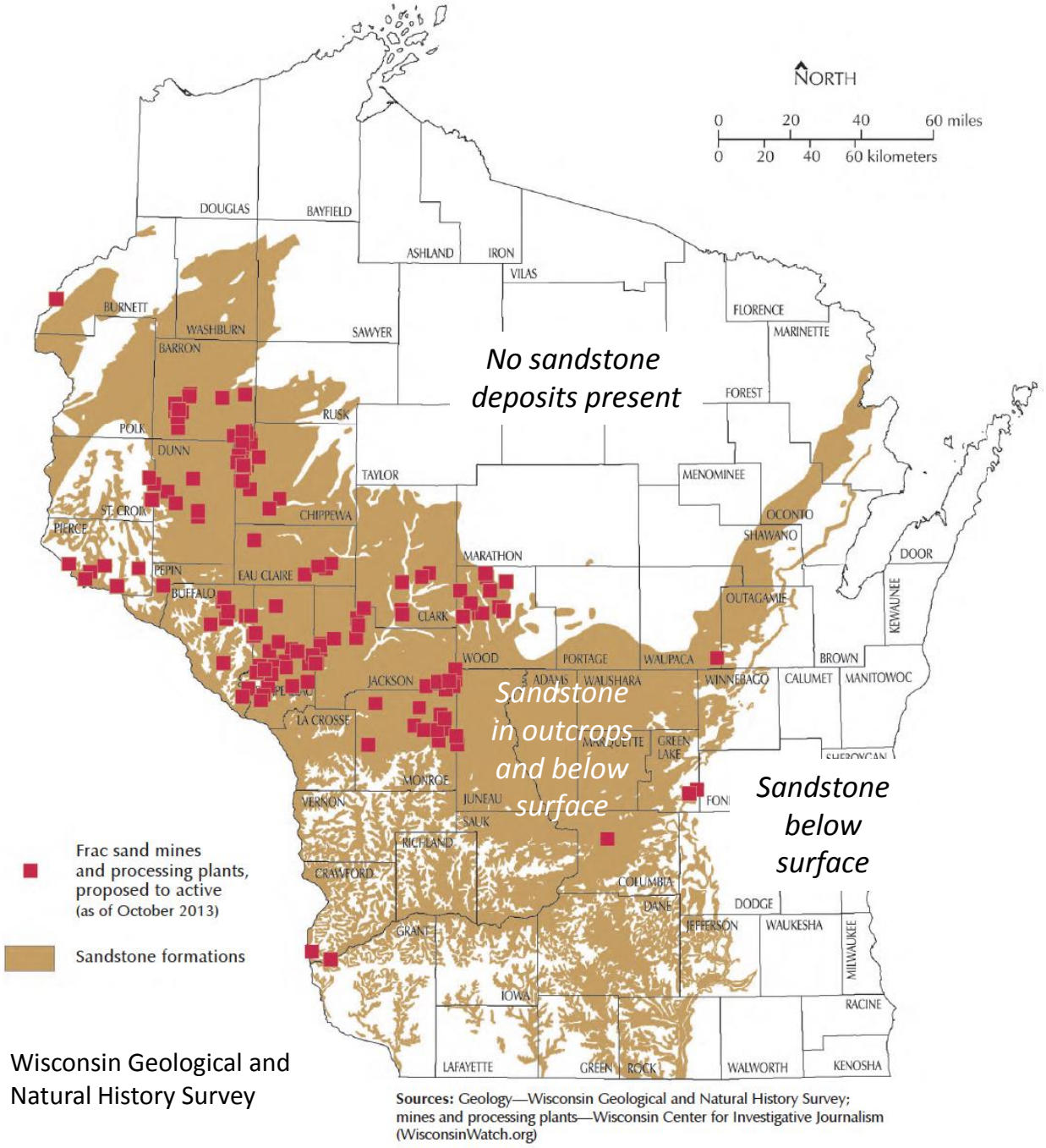


Wisconsin Geological and Natural History Survey

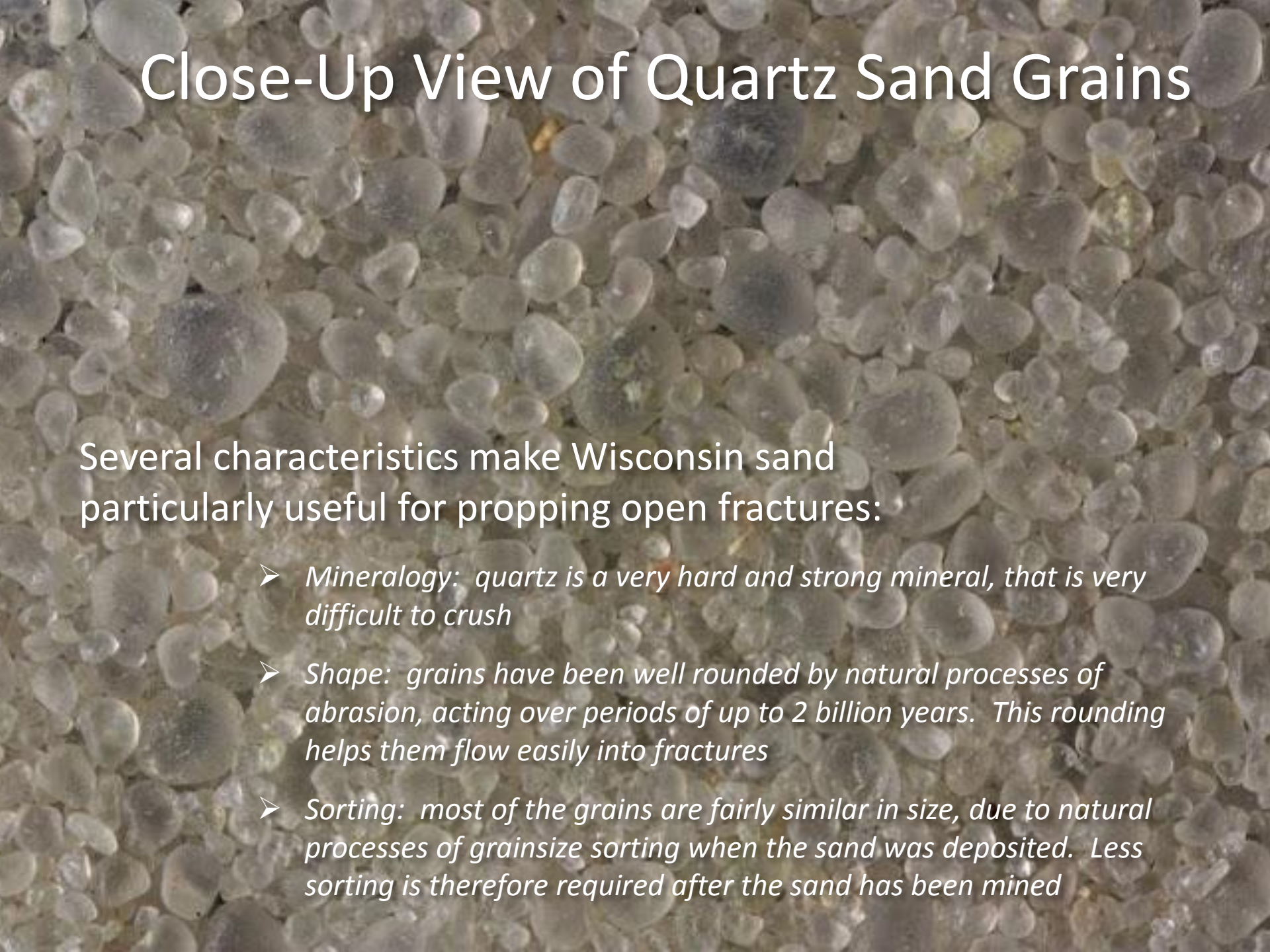
Sources: Geology—Wisconsin Geological and Natural History Survey; mines and processing plants—Wisconsin Center for Investigative Journalism (WisconsinWatch.org)

Geographic Distribution

Cambrian and Ordovician quartz sandstone deposits are exposed across much of the western and southern Wisconsin, and are present in the subsurface in eastern Wisconsin. They are absent in northern Wisconsin however, where granite and other Precambrian rocks are exposed at the surface.

In addition to their use for frac sand, these deposits represent an important groundwater aquifer for much of the state.

Close-Up View of Quartz Sand Grains



Several characteristics make Wisconsin sand particularly useful for propping open fractures:

- *Mineralogy: quartz is a very hard and strong mineral, that is very difficult to crush*
- *Shape: grains have been well rounded by natural processes of abrasion, acting over periods of up to 2 billion years. This rounding helps them flow easily into fractures*
- *Sorting: most of the grains are fairly similar in size, due to natural processes of grainsize sorting when the sand was deposited. Less sorting is therefore required after the sand has been mined*

Frac Sand Mine

Several factors conspire to make sand mining profitable in western Wisconsin. Sandstone is exposed at or near the surface, and is only loosely cemented together, making it easy to excavate.

Grain diameters commonly between about range is mostly between about 0.1 and 1.0 mm, useful for fracking. Sand mines are generally located near rail transport, which helps reduce cost.

Mining of frac sand has a substantial local economic impact, generally a positive factor.

Environment


Sand washing operation


Cranberry harvesting on reclaimed mine

Quartz is perhaps the least chemically reactive substance in nature, which in principle makes it one of the most benign mining products imaginable. Principal health risk is silica dust, which can be easily suppressed with water. Spillage of water from sand washing operations can potentially contaminate surface waters

Other problems may seem more mundane, such as truck traffic, noise, light pollution from night time operations, wear and tear on roads, etc. They can become signficant due to the large scale of mining however.

Mining also changes the natural landscape irreversibly. Reclamation may help to restore it, but can not replace the large volume of material removed.


Sieving machine with horizontal screens


Sieved sand, ready for loading on hopper cars

Sand Processing

Processing of mined sand is generally fairly simple. Sand must be dried, sorted using sieves into specific grainsize ranges, and loaded for transport. Sand companies may also coat the sand grains with resin to improve their proppant characteristics

Hydraulic fracturing for natural gas in shale requires relatively small grain sizes, in the range of about 0.2-0.4 mm (between #40 and #70 sieve sizes).

Hydraulic fracturing for unconventional oil requires relatively larger grain sizes grain sizes, in the range of about 0.4-0.8 mm (between #20 and #40 sieve sizes)

Demand for different sand size fractions changes continuously, depending on drilling activity. Much western Wisconsin sand used in Bakken Formation unconventional oil wells in North Dakota.