Evaluation of Eolian Sands in North Dakota for Proppant Use

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The evolving success of the Bakken/Three Forks oil play in North Dakota has created an unprecedented demand for natural proppants in the Williston Basin as well as across the nation (Benson and Wilson, 2015). This success has been achieved through the hydraulic fracturing of oil and gas wells, and placement of proppants in fractures during the stimulation of completed wells. It has been estimated that the demand for proppants in the Williston Basin will be over 100 million tons (USGS, 2017) and potentially billions of dollars in order to fully develop all the Bakken\Three Forks reservoirs in the state. High-quality natural sand proppants from the upper-Midwest (fig. 1) continue to be transported into the Williston Basin, including recently expanded domestic sources (Redden, 2018).

Figure 1. Photomicrograph of Ottawa "Northern White" silica proppant sand from the St. Peter Sandstone produced by U.S. Silica in Ottawa, Illinois. This highly desirable natural proppant is typically 99% quartz with very well-rounded and sorted grains resulting in a high level of resistance to crushing within fractures in an oil and gas reservoir.

Developing trends in oil and gas well production economics, along with continued increases in natural sand proppant consumption (Matthews and Ailworth, 2017), have relaxed the initial desire for high quality proppants like Ottawa sands (fig. 1). The high prices associated with transporting high quality proppants from their source areas in the upper-Midwest (fig. 2), dominantly in Wisconsin and Minnesota, has resulted in an evolving trend in other U.S. shale basins to develop more cost effective local sand resources with acceptable proppant quality measures. The "Brady Brown" and "Hickory" type sands, the emerging eolian (wind-blown) sands in Texas's Permian Basin, along with emerging sand sources in Nebraska and Oklahoma, are now being considered across the industry (Askren, 2017) (fig. 2). Reevaluating domestic, and more importantly, basin regional and local sand resources with a potential to meet the growing demand for acceptable quality natural sand proppants, is becoming economically preferable. The industry is also moving from coarser to finer grained sands with many sand producers now reprocessing their finer-grained, previously considered waste sands, for use as a potential proppant product (Syverson, 2017).

Figure 2. Locations of the major and emerging source areas of natural sand proppants in the U.S. (shaded in yellow) along with major U.S. Sedimentary Basins with tight shale plays (shaded gray). North Dakota's eolian sand resources, if found to be viable alternatives, could significantly reduce the costs associated with shipment of high-quality proppants from the upper-Midwest and Texas.

To address this rapidly changing production dynamic, the Geological Survey (NDGS) responded to industry requests for additional geologic information on potentially viable sand deposits in the state. The NDGS is continuing to evaluate North Dakota's eolian and bedrock sandstone resources for potential use as natural sand proppant and recently completed NDGS Geologic Investigation No. 207 (Anderson, 2018). This report compiles previous proppant testing and characterization work on selected eolian sand resources with recent sedimentological work on additional eolian sands in the state (fig. 3). Investigative results on bedrock sand sources as well as additional eolian sands are anticipated to be published in the coming months.

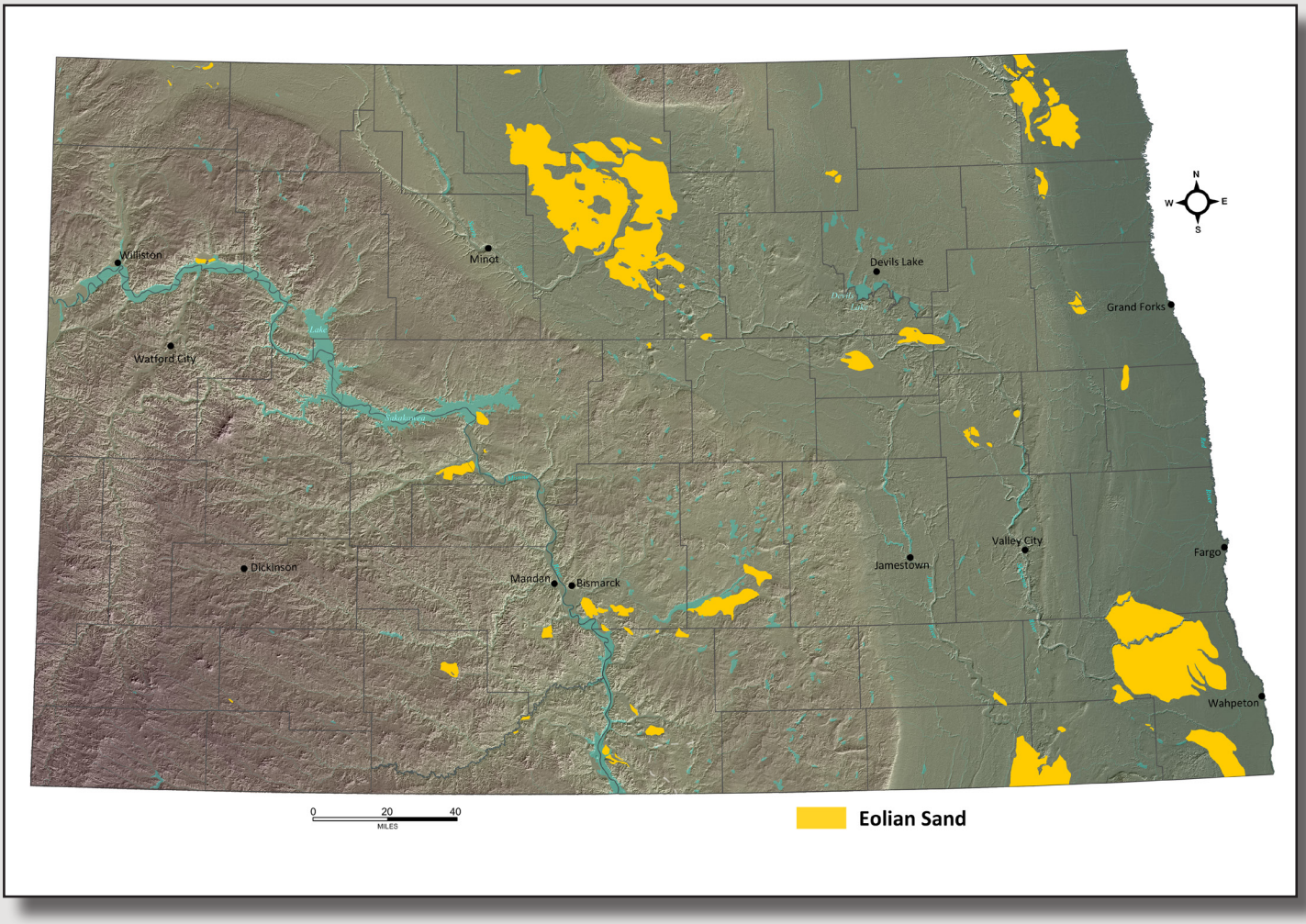

Figure 3. Location of eolian sands in North Dakota that are currently being investigated for possible suitability as natural sand proppant.

In previous proppant sand investigations (Anderson, 2011), the focus had been on identifying and characterizing potential high quality surficial proppant sand resources. The results of these studies showed that, compared to other high quality proppant sand deposits across the U.S., North Dakota's sand resources did not meet many of the desired specifications. North Dakota sands did approach the specifications for sphericity and roundness. However, as oil well completion economics continue to evolve, so does the need to reconsider North Dakota's surficial sand resources as potentially viable proppants.

Figure 4. Photomicrograph (25x) mosaic of selected eolian sands from (a) the Denbigh Dunes west of Minot, (b) the Hazen-Stanton Dunes in eastern Mercer County, and (c) the Horsehead Valley East dune field in west-central Emmons County.

Key Proppant Quality Factors

Mineralogical purity and uniformity are arguably the key quality considerations for natural proppant sand deposits. These two characteristics affect all of the testing specifications (API, 1995) that are currently used to determine proppant quality factors, most importantly crush resistance (fig. 5). At the most fundamental level, the closer a given sand deposit or refined product approaches a pure quartz sand paired with a high degree of sand grain size similarity and uniformity (geologists use the terms "sorting", "roundness", and "sphericity" respectively to describe these properties) the higher the overall proppant quality. Essentially, the more spherical and closer to pure quartz it is, the better.

Any departure from mineralogical purity and/or textural uniformity results in a proppant whose strength and resistance to the high heat and pressure at depth is diminished (in addition to lower fracture permeability). However, this is perhaps not necessarily inadequate given other factors in the well-design formula (table 1). This is where North Dakota's sand resources may prove to be viable, cost-effective locally sourced natural proppant sand alternatives. So far this year, the Geological Survey has collected 32 sand and sandstone samples from 13 counties across North Dakota with plans to collect an additional 30 samples in the coming months.

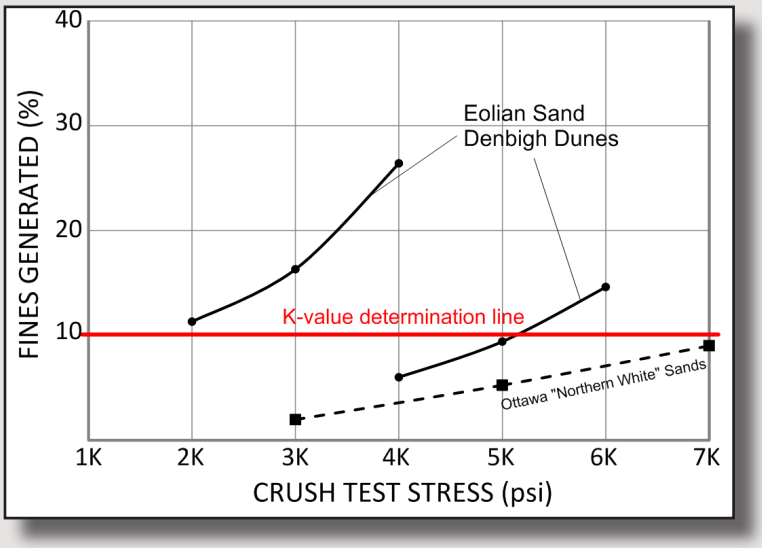

Figure 5. Crush resistance curves for natural sand proppants in use in the oil and gas industry and eolian sand sources in North Dakota. A "K-value" is determined as the amount of pressure required to crush the sample in order to turn 10% of the sample into fines (shown on the graph as the red line). The testing values determined here are on selected and sized "cuts" from the eolian sand of the Denbigh dunes east of Minot, and are representative of a sized sand product and not from a bulk "pit run" type of sample, which generally would produce lower values. The crush resistance values for 40/70 and 30/50 eolian sands tested from the Denbigh Dunes area were <2K and 5K, respectively.

Table 1. Crush resistance testing values for eolian sand from the extensive Denbigh Dunes area east of Minot (from Anderson, 2018).

Sample	1	2
Tested Stress (psi)	% Fines Generated on Crush	
2,000	11.3	--
3,000	16.3	--
4,000	26.4	6.0
5,000	--	9.4
6,000	--	14.6
K-Value	<2K	5K

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