The Potential of the Hazen-Stanton Dunes for use as Natural Sand Proppant

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GEOLOGIC INVESTIGATION NO. 216
NORTH DAKOTA GEOLOGICAL SURVEY
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Abstract

The Hazen-Stanton Dunes are an accumulation of windblown (eolian) sand found in North Dakota's coal country just west and south of the confluence between the Knife and Missouri Rivers between the cities of Hazen and Stanton in southeastern Mercer County. This investigation also includes the Basto Dunes, a smaller, localized eolian sand deposit located across the Missouri River just east of Stanton. These deposits cover approximately 34 square miles (21,760 acres) and are estimated to contain as much as one billion tons of sand with favorable potential for use as natural sand proppant. The high-dunes area near Hazen contains an estimated 134 million tons. The sand is dominantly fine to very-fine grained 100 mesh sand (50/140), with corresponding crush-resistance testing values (10,000 psi) ranging from 4K to 8K. Mineralogical analysis by X-ray diffraction (XRD) on unwashed (bulk) sand from the Hazen Dunes indicated a quartz content of 77%, feldspar at 20%, generally less than 4% clay minerals (no montmorillonite reported) and zero carbonate content. Turbidity values ranged from 32.8 to 98 Formazin Turbidity Units (FTU). Shape factors of particle sphericity and roundness were, on average, 0.69 and 0.47. Clusters were reported in the field of count on the #70 sieve for sample HD-3b from the Hazen Dunes. Bulk density of the sand tested, on average, was 86.8 pounds per cubic foot (pcf). Results suggest these particular sand deposits are of a quality and character that may be acceptable for proppant use in the Williston Basin. Their suitability to ultimately be determined by the requirements and specifications of the individual operators.

Introduction

The Hazen-Stanton Dunes are an accumulation of eolian (windblown) sand found in North Dakota's coal country southwest of the confluence between the Knife and Missouri Rivers, between the cities of Hazen and Stanton in southeastern Mercer County (fig. 1). These sand deposits straddle the east-west trending HWY-200 which travels between the two cities. These sands are the windblown accumulate sourced from sediments within the Knife River Valley, presumed to be erosionally and depositionally active between 8,500 and 4,500 b.p. (Reiten, 2006). Also found in this area are the Basto Dunes, which is a relatively smaller localized deposit of eolian sand (Anderson, 2018) located across the Missouri River just east of Stanton.

With the emergence of renewed interest by the oil and gas industry in locating potential in-basin sand resources for use as proppant, the Geological Survey collected several representative sand samples from the surface sands in Hazen-Stanton Dunes area during the 2018 field season (Plate I). Three samples (HD-3a, SD-2, and BD(c)) were tested and evaluated by EOG Resources (fig. 2). One sample (HD-3b) was tested and evaluated by Assured Testing Services, an independent materials testing lab.

On the cover: View to the northwest across the Hazen Dunes area in eastern Mercer County, North Dakota. Vegetation stabilized sand dunes are prominent in this area with dunes reaching heights of up to 60-ft.

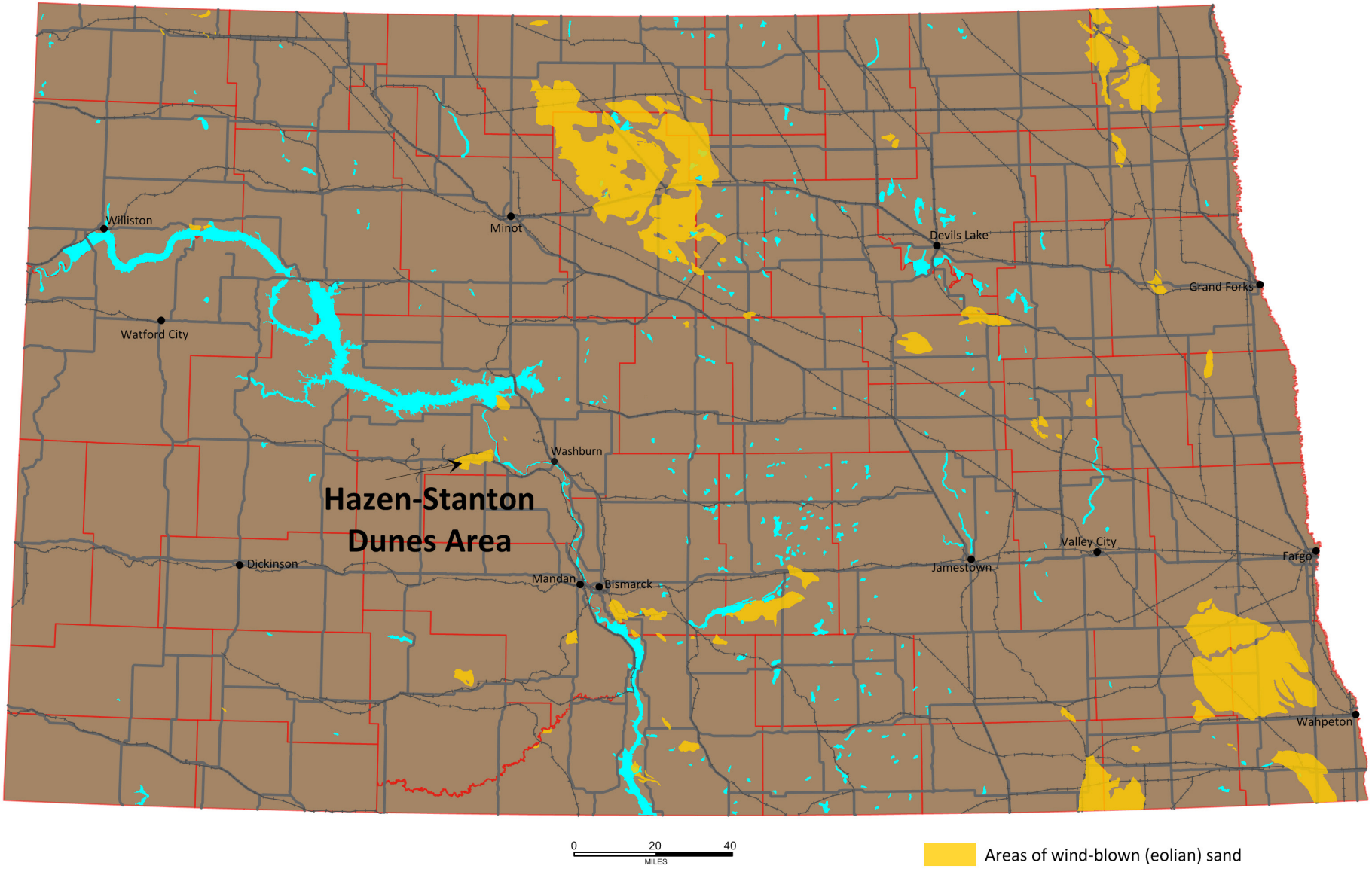

Figure 1. Location of the Hazen-Stanton Dunes in southeastern Mercer County along with other accumulations of eolian deposits across the state.

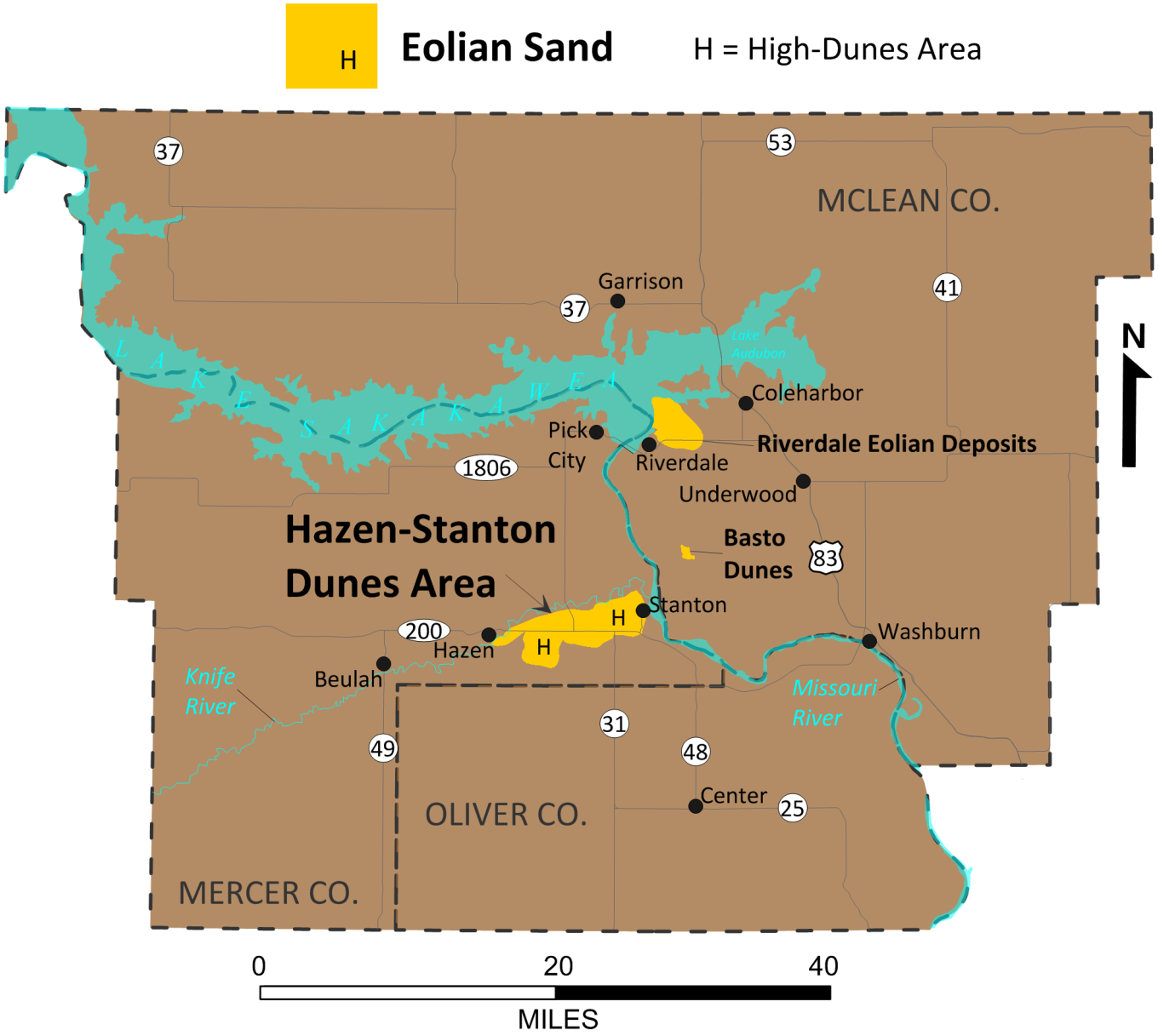

Figure 2. Location of the Hazen-Stanton and Basto Dunes and other eolian deposits in the area south of Lake Sakakawea and west of U.S. Highway 83 where samples were collected from the high-dunes areas for evaluation for use as proppant.

Geomorphology

The Hazen-Stanton eolian sand deposit can be subdivided into three areas based on geomorphological expression. These are high-relief (>10-ft) dunes (figs. 3 & 4), low-relief (<10-ft) dunes, and interdune areas consisting of tabular and rippled sheet sands. The latter are found surrounding and in-between the dune areas just southeast of Hazen and west of Stanton (fig. 5). The Basto Dunes are a single accumulation of high-relief dunes covering approximately one square mile across the Missouri River to the east of the Stanton Dunes area (fig. 6).

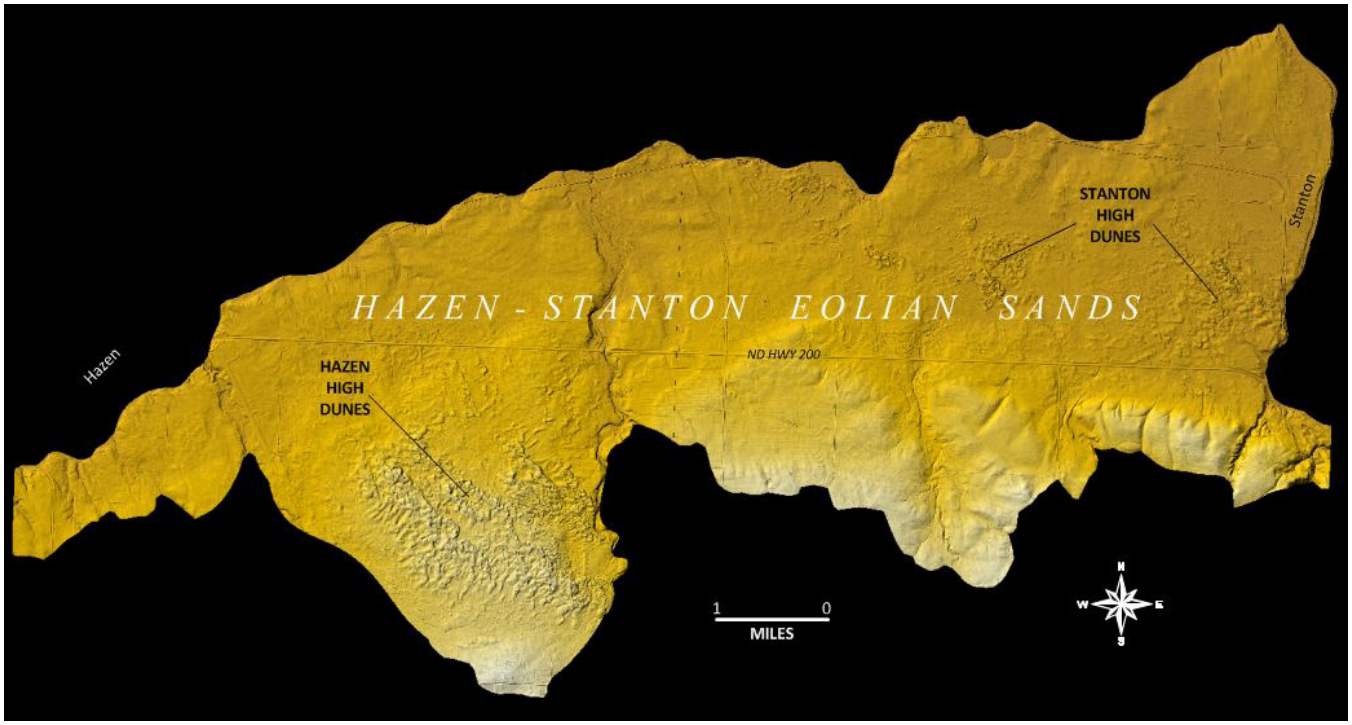

Figure 3. 3D LiDAR surface map of the Hazen-Stanton Eolian Sands in southeastern Mercer County, North Dakota. This expansive area contains three large areas where dunes 30-ft or more in height can be found.

Figure 4. Vegetation-stabilized dune in the Hazen High-Dunes area (144-86-23-NE). The relief on this particular dune is just over 60 feet. This dune is located on the northern edge of the NW to SE trending High Dunes Area of the Hazen-Stanton dune field.

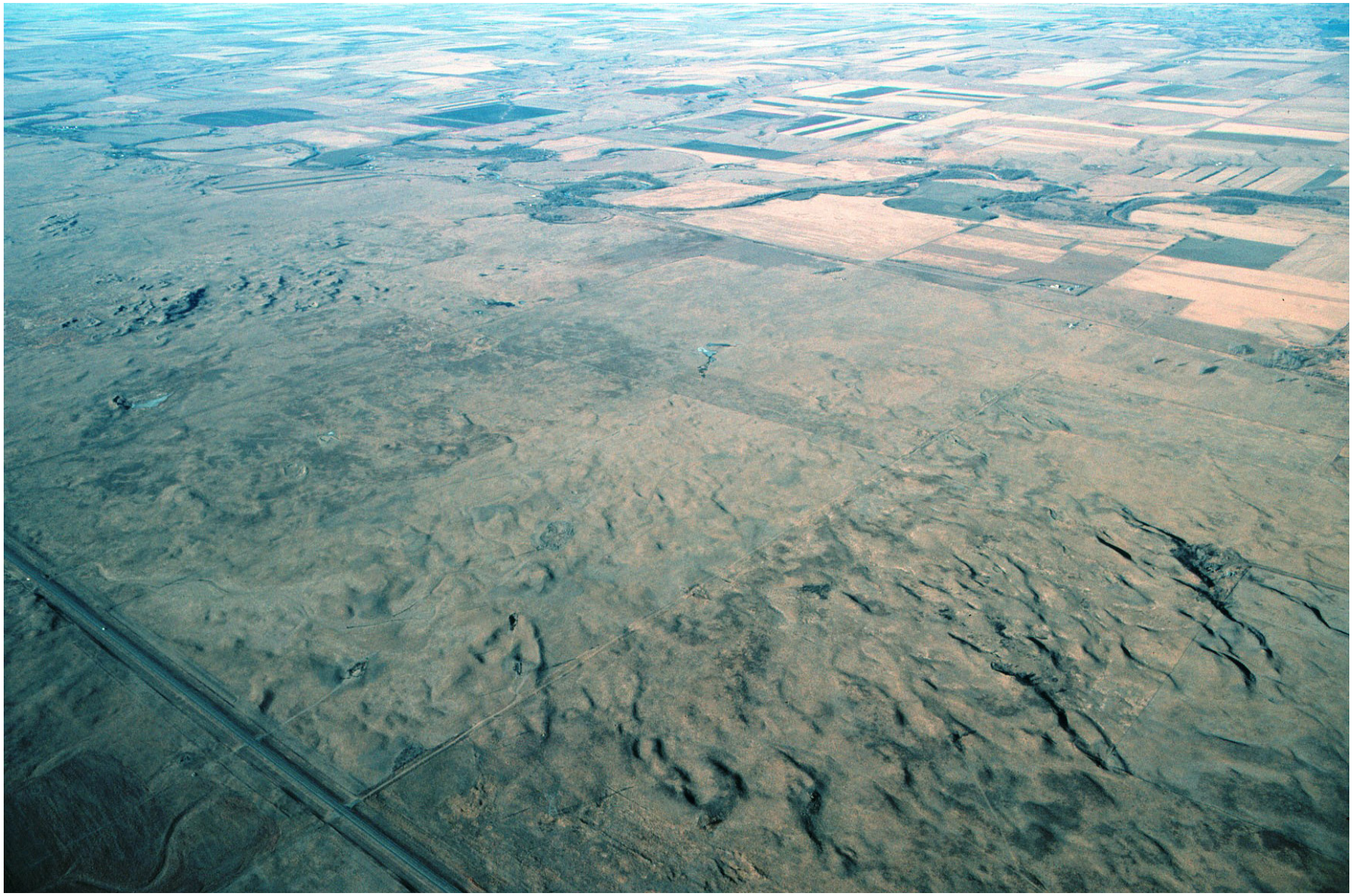

Figure 5. Aerial view to the northwest across the Stanton Dunes in the foreground. The two high-dune areas are separated by low-relief dunes and sheet and tabular sands with low relief.

Figure 6. Exposure of eolian sand from within a blowout in the Basto Dunes high-dunes area in southwestern McLean County.

Sand Deposit Resource

Overall, the Hazen-Stanton dunes (including the Basto Dunes) cover an area of approximately 34 square miles (21,760 acres) and are estimated to contain as much as one billion tons of sand with favorable potential for use as natural sand proppant. Just one square mile within this deposit may contain as much as 44 million tons of sand available for production and processing. Ultimately, these volume estimates will be reduced by field factors such as shallow water tables or the presence of shallow sedimentary bedrock of the Sentinel Butte Formation. Average depth of sand estimates, based on available drilling records for the area, suggest an average deposit depth of approximately 31 feet. The Hazen high-dunes cover a nine square mile area and contain an estimated 134 million tons of sand, as determined from LiDAR based volumetric assessments.

The eolian sands in these areas tend to be well sorted, fine-grained, sub-angular to sub-rounded grains that tend to be "cleaner" from a mineralogic and textural perspective than both the surrounding sediments and the underlying bedrock sandstones, as previously investigated by Anderson (2011), found in this area (figs. 7 & 8).

These characteristics, as well as their location adjacent to a major transportation route, make these sands good candidates for local sources of proppant sand (fig. 9).

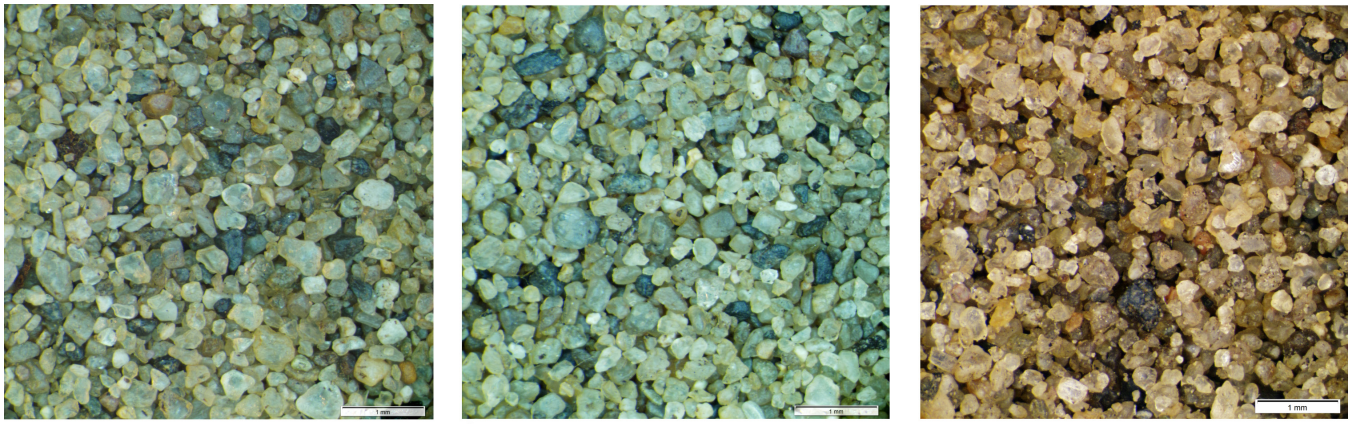

Figure 7. Bulk sample photomicrographs (25x) of eolian sand from the Hazen (a.), Stanton (b.), and Basto (c.) Dunes from the high-dunes areas found in southeastern Mercer and southwestern McLean County, North Dakota.

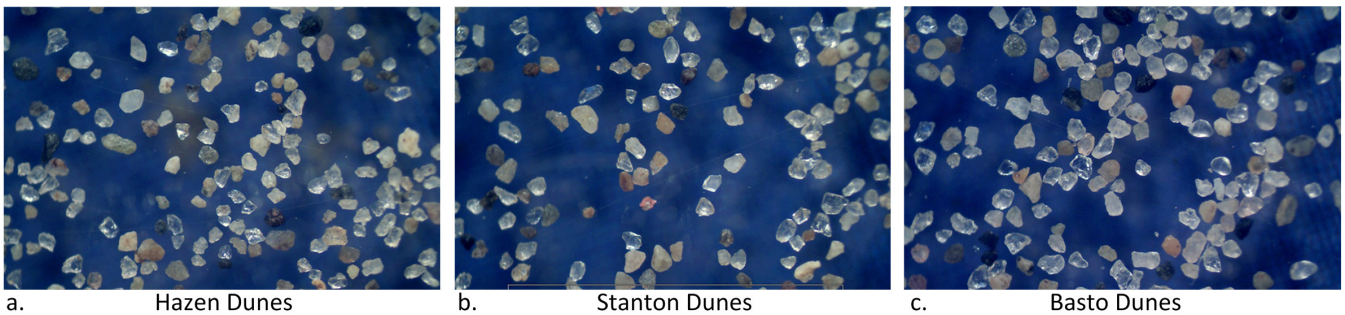

Figure 8. Monolayer photomicrographs of eolian sands from the Hazen Dunes (a.), the Stanton Dunes (b.), and the Basto Dunes (c.). The similarity in textural and mineralogical composition can be observed along with the roundness and angularity of individual sand grains. Photomicrographs a. and b. are at 30x magnification. Photomicrograph c. is at 25x magnification.

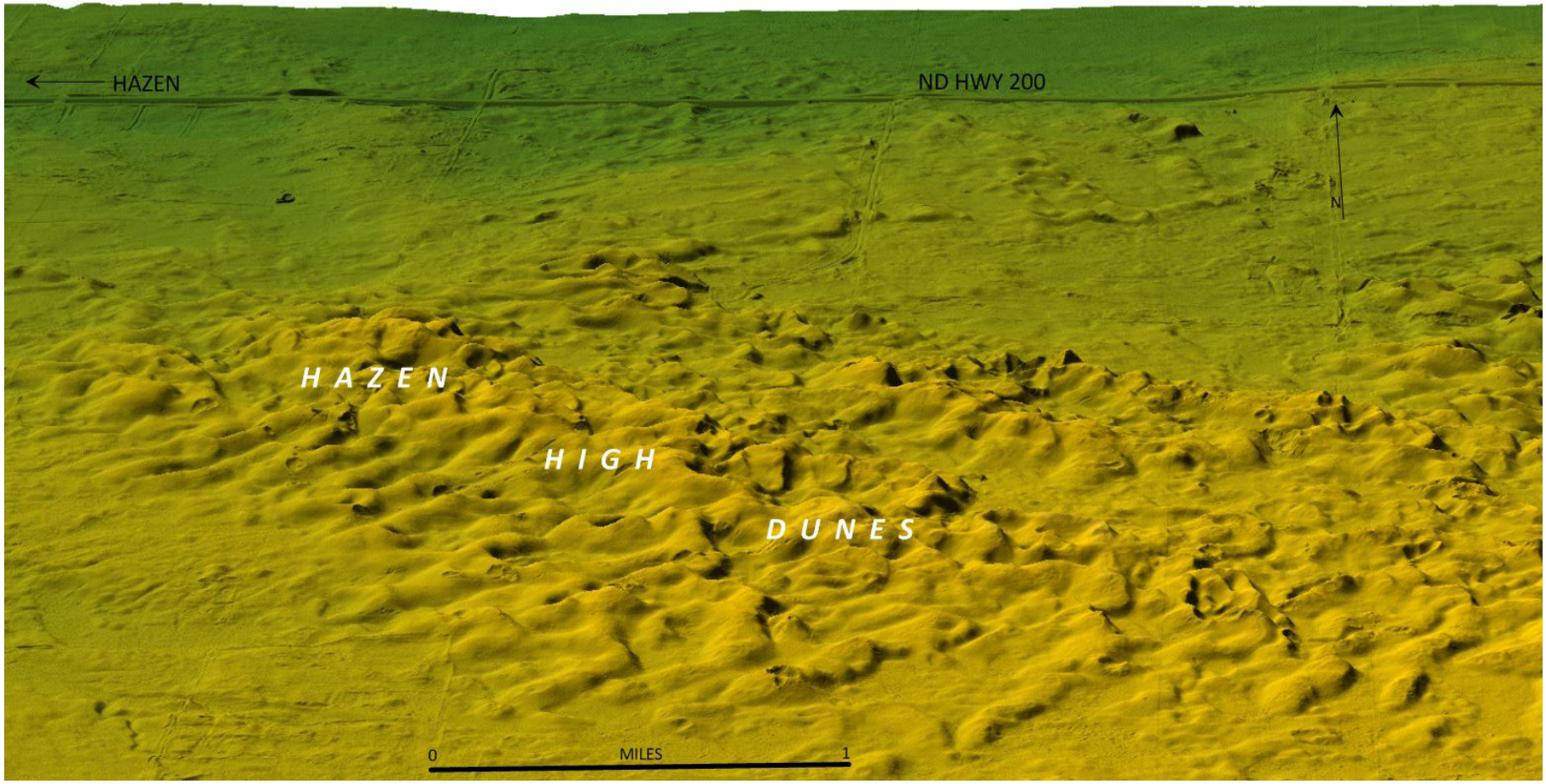

Figure 9. 3D Perspective view towards the north across the Hazen Dunes High Dunes Area southeast of Hazen, North Dakota. This northwest to northeast trending dune field area covers an area of 4,420 acres (approx. seven square miles).

Proppant Testing Results

The Hazen-Stanton Dunes consist predominantly fine to very-fine grained, sand commonly referred to as 100 mesh sand (i.e. 50/140 and 70/140 sand), with corresponding crush-resistance testing values (10,000 psi) reported of 4K to 8K (fig. 10). Acid solubility was tested on sample HD-3b, and returned a value of 5.53%. Field reactivity testing was performed on the remaining samples and showed no reactions to dilute (10%) hydrochloric acid, suggesting an absence of carbonates. Further XRD mineralogical analysis of sample HD-3a confirmed the absence of carbonates in the sand. Turbidity values ranged from 32.8 to 98 FTU. Shape factors of particle sphericity and roundness were, on average, at 0.69 and 0.47. No clusters were reported in the field of count from SD-2, HD-3a, and BD(c). The bulk density of the sand samples from the Hazen-Stanton area averaged 86.8 pounds per cubic foot (pcf) (table 1).

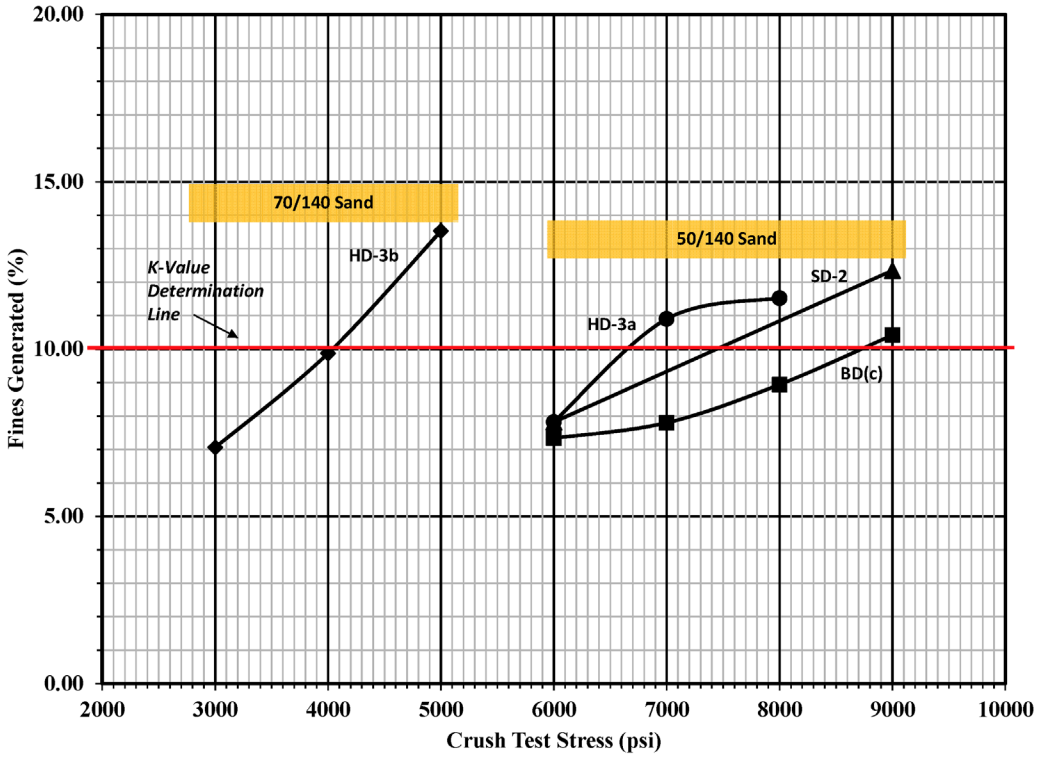

Figure 10. Crush resistance curves for eolian sands tested from the Hazen, Stanton, and Basto Dunes. K-Value determinations are found at the point where 10% or more of fines are generated upon crush rounded down to the nearest 1000 psi.

Table 1. Hazen-Stanton Area Dune Sand Proppant Testing Characteristics

Sample No.	SD-2	HD-3a	HD-3b	BD(c)
Tested Size Cut	50/140	50/140	70/140	50/140
Crush Resistance (K-Value)	6K	6K	4K	8K
Acid Solubility (%)	NT	NT	5.53	NT
Turbidity (FTU)	47	98	32.8	38
pH Water	8.52	8.30	NT	NT
Sphericity	0.69	0.69	0.70	0.68
Roundness	0.46	0.44	0.60	0.38
ISO Mean Particle Dia. (mm)	0.218	0.192	0.219	0.199
Median Particle Dia. (mm)	0.209	0.182	0.203	0.192
% Clusters	NIFC	NIFC	#70 Sieve	NIFC
Bulk Density (g/cm^3)	1.40	1.40	1.37	1.39
Bulk Density (pcf)	87.4	87.4	85.5	86.8
Absolute (Grain) Density (g/cm^3)	NT	NT	2.66	2.69

SD-2, HD-3a, and BD(c), tested by EOG Resources-Weatherford Lab.

HD-3b tested by Assured Testing Services.

Gradational analysis performed on these samples indicate that these eolian sands are very-well sorted (table 2), fine to very-fine grained sands (fig. 11) (consistent with other eolian sands found across the state and reported by Anderson in 2018), and consist dominantly of 100 mesh (50/140) sand (table 3).

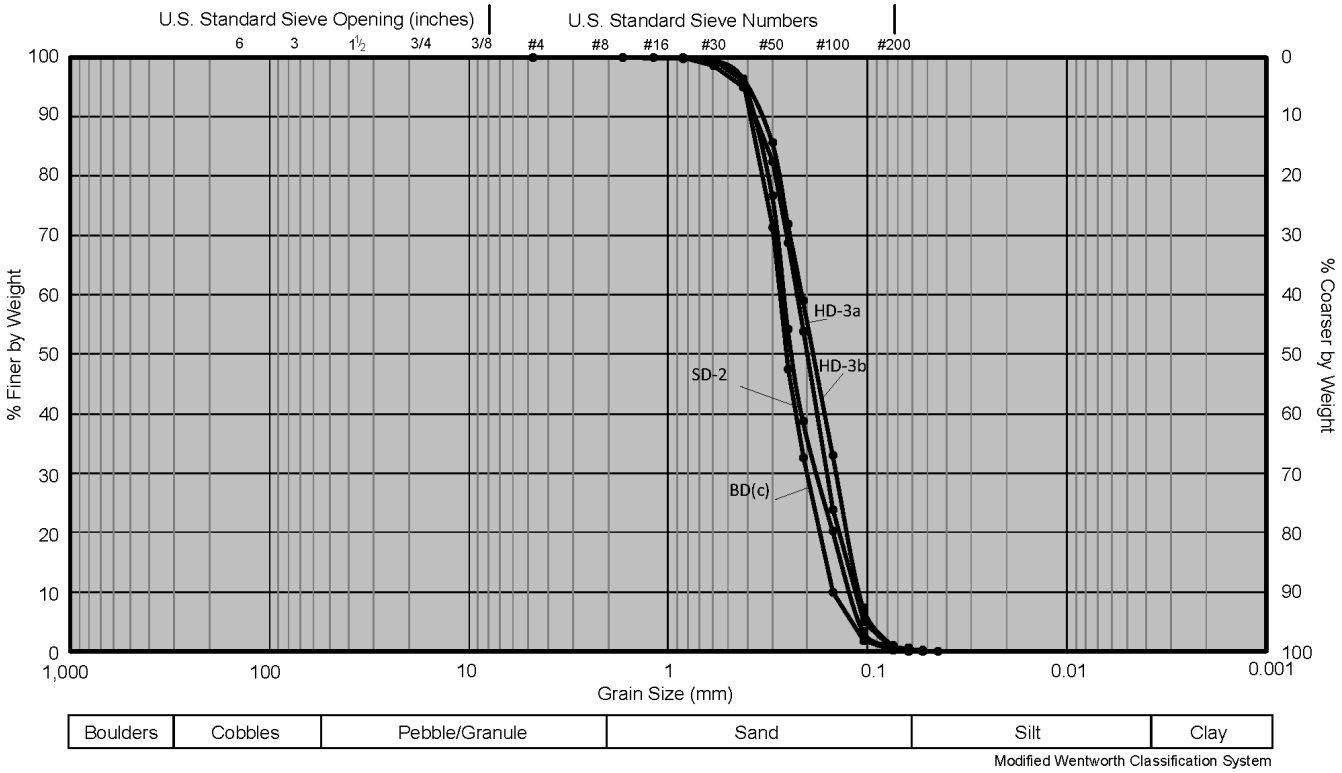

Figure 11. Gradational curves of sand from the Hazen-Stanton Dunes. Steep curves like this are indicative of samples that are well sorted and contain a relatively small range of grain sizes.

Table 2. Gradational Summary of Individual Grain-Size Fractions

Sieve No.	SD-2	HD-3a	HD-3b	BD(c)
4	0.00	0.00	--	0.00
12	0.07	0.06	--	0.00
16	0.00	0.06	--	0.00
20	0.06	0.09	--	0.05
30	0.37	0.58	1.40	0.39
40	3.45	2.78	3.70	3.62
50	19.35	10.74	12.50	24.61
60	22.54	13.85	13.60	23.81
70	15.47	12.87	15.00	14.97
100	18.48	26.00	30.00	22.69
140	16.78	25.63	18.90	7.97
200	2.43	6.54	4.40	1.63
230	0.42	0.61	--	0.14
270	0.33	0.16	--	0.06
325	0.15	0.05	--	0.03
Pan	0.10	0.04	0.50	0.04

Reported as % weight retained, -- sieve fraction not reported.

Table 3. Percent Sand In-Size Class

Sand Size Class	SD-2 (%)	HD-3a (%)	HD-3b (%)	BD(c) (%)
40/70	57	37	41	63
50/140	73	78	78	69
70/140	35	52	49	31
70/270	38	59	37	32

A composite sample (BD(c)) consisting of eleven individual sand samples from the Basto High Dunes (figure 12), was also submitted for testing. The higher crush values reported for this material is likely influenced by the size fraction being tested and sample quartz content. Crush testing was completed on the largest reported size class, based on the initial gradational analysis.

Sand Mineralogy

Mineralogical analysis by X-ray diffraction (XRD) on unwashed (bulk) sand from the Hazen Dunes (HD-3a) resulted in a quartz-dominated, feldspar/clay mineralogy devoid of carbonates (Table 4). These sands have a quartz content of 77%, feldspars content of 20%, and generally contain less than 4% clay minerals (no montmorillonite reported). No carbonates were detected.

Table 4. XRD Mineralogy

Analysis (Crystalline Phase)

Mineralogy (%)	HD-3a
Quartz	77
Dolomite	--
Calcite	--
Quintinite	--
Albite	9
Orthoclase	11
Montmorillonite	--
Muscovite	3
Clinochlore	<1

[1] *Unwashed (Bulk) Sample Analysis.*

-- Mineral Not Detected

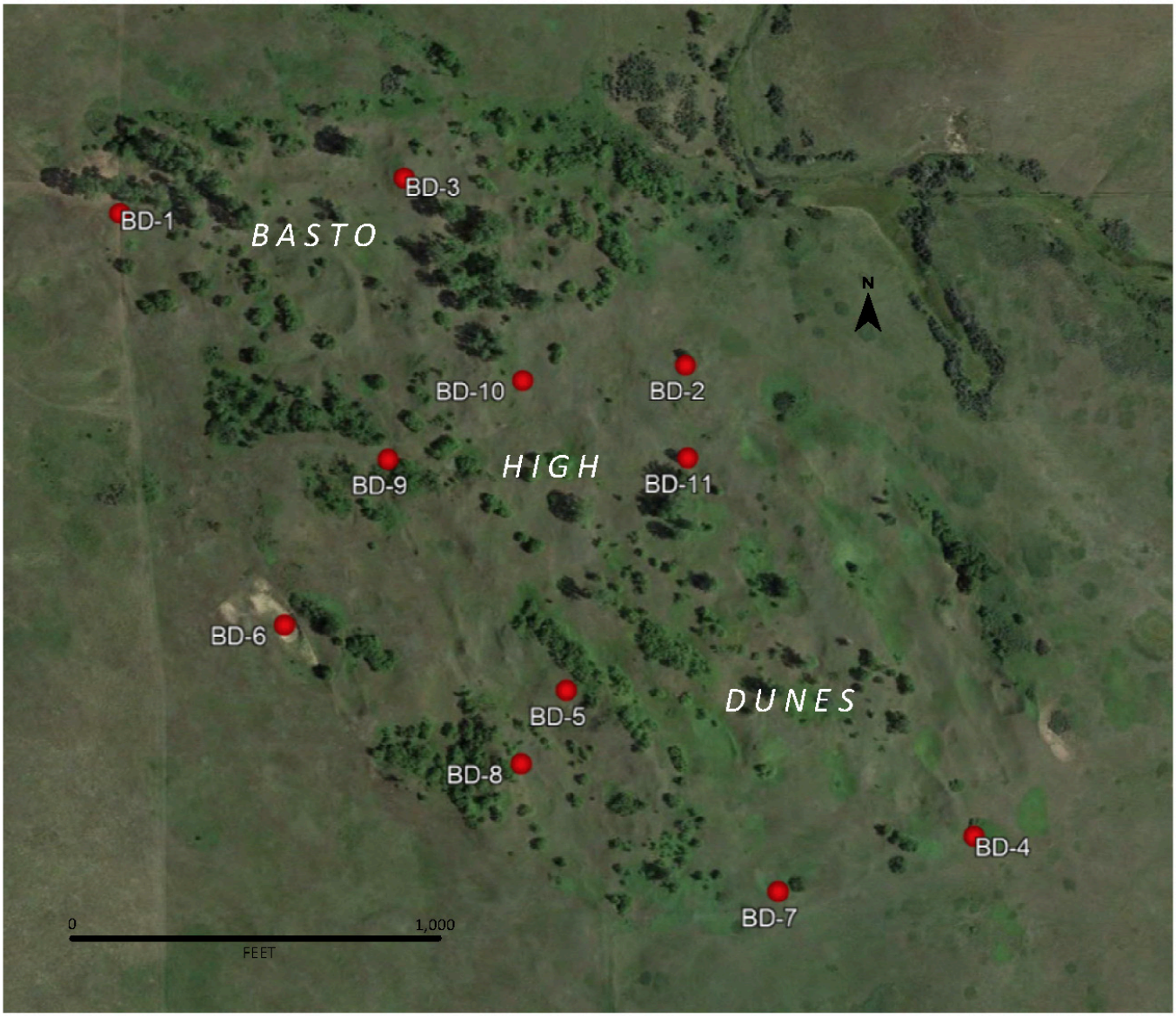

Figure 12. Field sampling locations across the Basto High Dunes in southwestern McLean County, North Dakota. Sample BD(c) is a composite dune sample from these 11 locations.

Summary

The initial testing results indicate that these particular sand deposits are of a quality and character that may be acceptable for proppant use. While these results approach the higher-quality specifications of natural sand proppant for use in the hydraulic fracturing of oil and gas wells, they are of lesser overall quality than the "Ottawa White" type sands that continue to be mined and imported into the Williston Basin from upper-Midwestern sources in Minnesota and Wisconsin. The Geologial Survey continues to evaluate the eolian sand deposits across North Dakota for use as natural sand proppant.

Analytical Services

Sand testing services were provided by EOG Resource's Weatherford Lab in Weatherford, Texas and Assured Testing Services in Ridgway, Pennsylvania, using applicable testing standards, specifications, and guidelines published by the American Petroleum Institute (API, 1995 a & b), the International Organization for Standardization (ISO, 2006), and industry specific guidelines.

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North Dakota Geological Survey
Geologic Investigations No. 216 - Plate I

Eolian Sands of the Hazen-Stanton Dunes Area

2019

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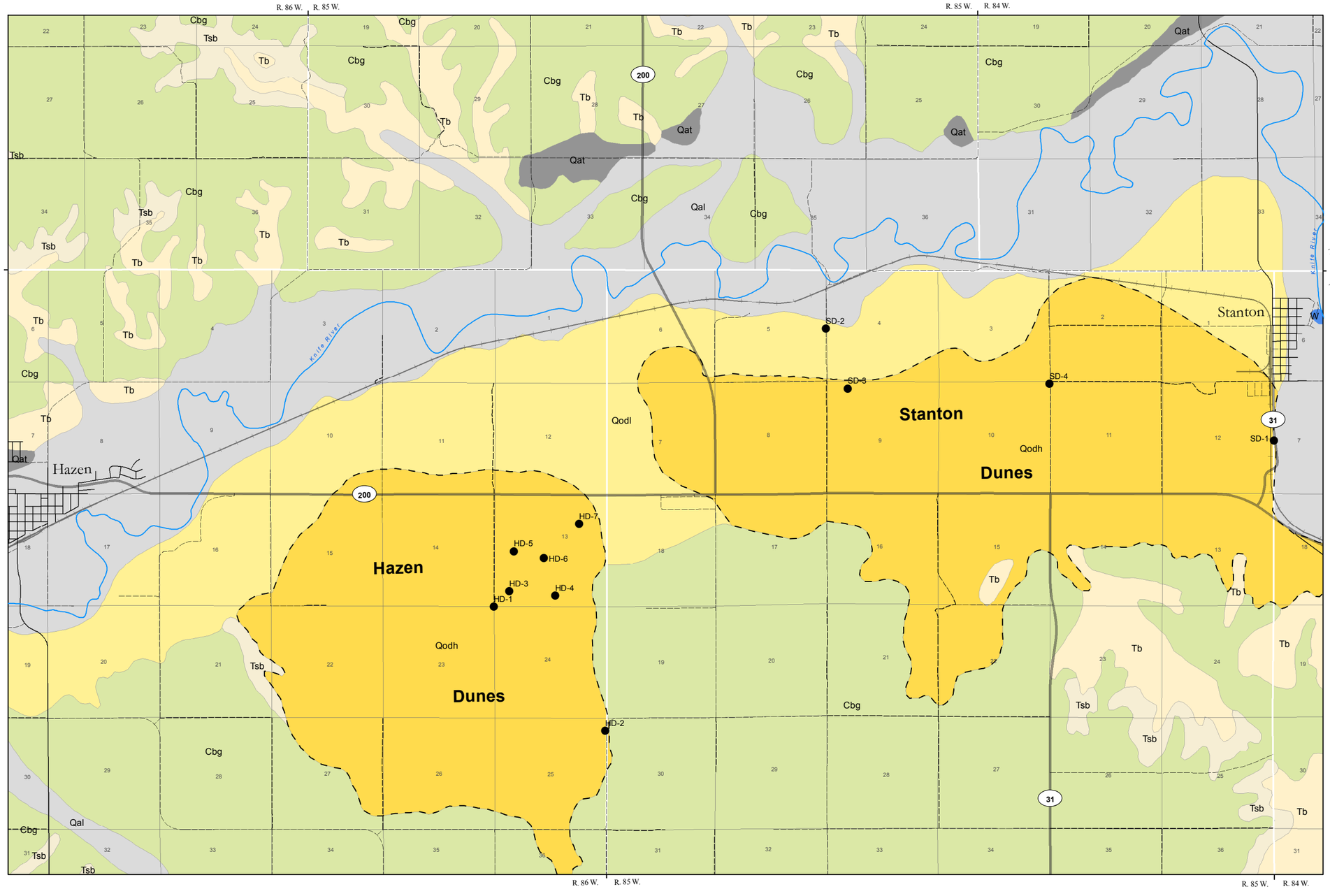


Mercator Projection
North American 1983 Datum

EXPLANATION

QUATERNARY

Qodh **Oahe Formation: Eolian Sand in High-Relief Dunes**

Windblown sand; well sorted, medium to fine-grained sand occurring commonly as localized vegetation stabilized dunes up to 30 feet (10 meters) high.

Qodl **Oahe Formation: Eolian Sand in Low-Relief Dunes**

Windblown sand; well sorted, medium to fine-grained sand occurring commonly as localized vegetation stabilized dunes less than 10 feet (3 meters) high and as older undulating tabular sand deposits.

Qal **Oahe Formation: Quaternary Alluvium**

Unconsolidated sand, silt, gravel, and clay derived from the Knife River and Missouri River floodplain and erosion along tributary drainages.

Qat **Oahe Formation: Quaternary Alluvium in Terrace Deposits**

Unconsolidated sand and gravel, silt and clay as localized fluvial terrace deposits along the borders of the Knife River floodplain.

Cbg **Coleharbor Formation: Glacial Till**

Unsorted mixture dominantly of clay with silt and sand interspersed with pebbles, cobbles, and boulders.

TERTIARY

Tsb **Sentinel Butte Formation**

Bedded siltstones, sandstones, lignites, claystones, and shales.

Tb **Bullion Creek Formation**

Bedded sandstones, siltstones, claystones, lignite, and shale.

● Locations of Samples Collected During Investigation

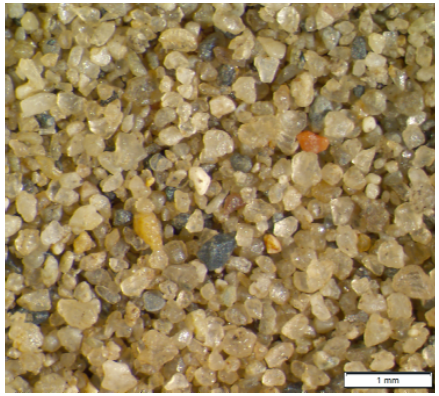
Geologic Symbols

– – Approximate contact between two geologic units

Other Features

- Paved Road
- Unpaved Road
- State Highway
- Section Boundary
- Water

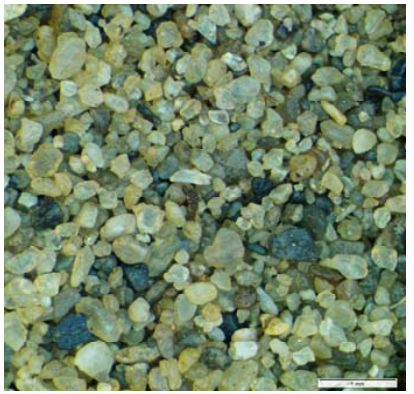
Cartographic Compilation: Navin Thapa



a. HD-1

b. HD-2

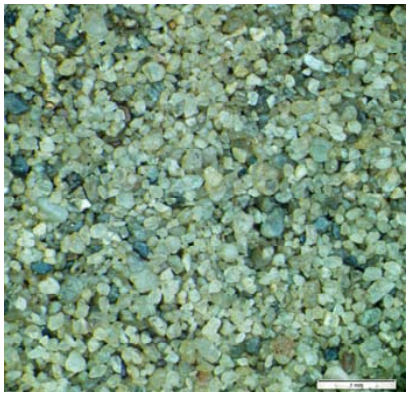
c. HD-3



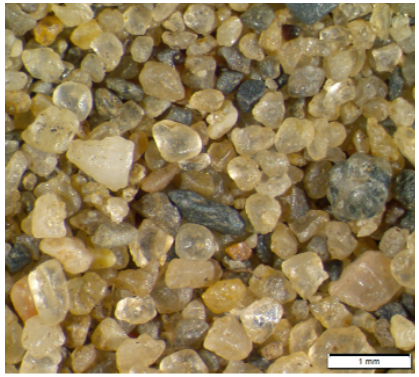
d. HD-4

e. HD-5

f. HD-6



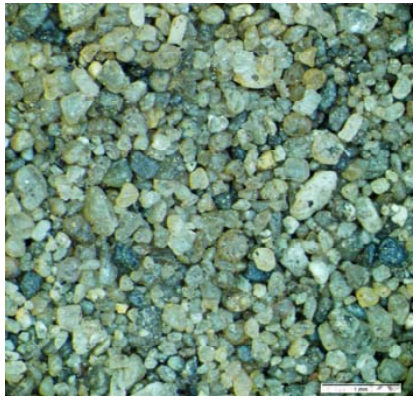
g. HD-7



h. SD-1

i. SD-2

j. SD-3



k. SD-4

l. BD(c)

Plate II. Photomicrographs (25x) of eolian sand of the Hazen Dunes locations HD-1 through HD-7 (a-g), and Stanton Dunes SD-1 through SD-4 (h-k), in southeastern Mercer County, North Dakota, along with the Basto Dunes BD(c) (l) from southwestern McLean County.