Characteristics of Loess in North Dakota for Potential Use as Microproppant

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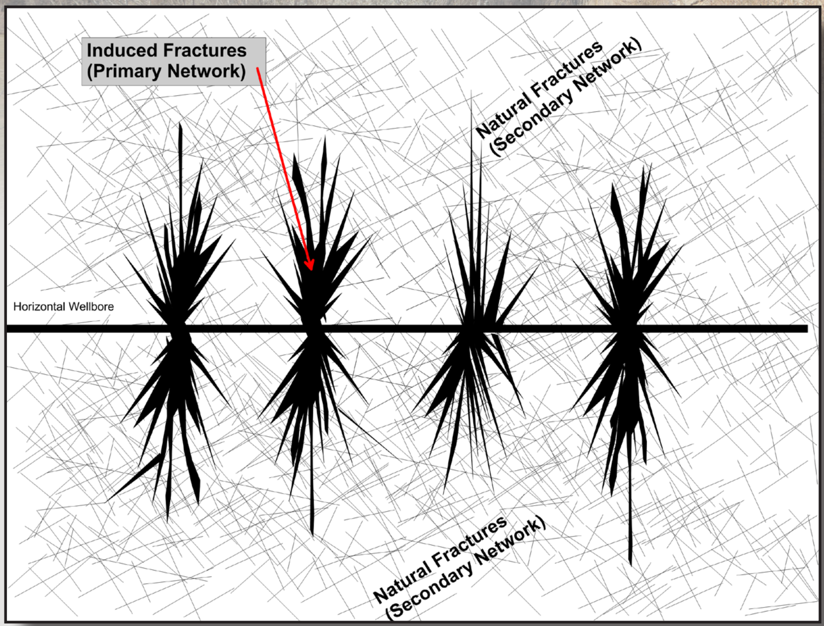

Figure 1. Conceptualization of natural and induced fracture networks in a reservoir rock with a horizontal wellbore.

The ever evolving tight shale plays in the U.S. have spurred interest in a new type of proppant, natural sediment proppants within the size range of silt! Smaller particles than sand and larger than clay particles, these aptly named ultra-fine or "microproppants" are being marketed as beneficial for propping the secondary fracture network in an oil and gas reservoir resulting in an overall increase in well production (Rassenfoss, 2017). In a shale reservoir rock there can be two fracture networks described, the natural fracture network, which is created from the geologic stresses and reservoir pressures at depth; and the induced fracture network which are the artificial fractures created in the reservoir rock during hydraulic fracturing (fig. 1). In petroleum engineering parlance the natural fracture network is referred to as the secondary fracture network. These fractures are often much smaller than the induced fractures but, depending on the density of the natural fracture network, have the potential to take on a significant amount of the fluid volume during a hydraulic fracturing stimulation. It is thought that if this secondary natural fracture network is unable to receive traditional sand-sized proppant due to the smaller size of these natural fractures, then a much smaller "micro" proppant may be able to continue to permeate the secondary fracture network and enhance the overall hydraulically fractured and total stimulated reservoir volume (Tanguay and Smith, 2018).

Some proppant manufacturers have introduced new microproppants with grain sizes equivalent to that of a human hair and with the consistency of rock flour. Sediment particle sizes in this range fall into the silt size category, which is generally defined as sedimentary particles sized between 0.0625 to 0.0039 millimeters. Silt is very common throughout the sedimentary surface geology of North Dakota and may be found as a component of all of the surficially exposed materials across the state including the glacial sediments found across most of North Dakota, within the individual sedimentary siltstone bedrock layers in southwestern North Dakota, or when transported and deposited by the wind as loess deposits, which can be found in varying thickness across the entire state (fig. 2). Loess

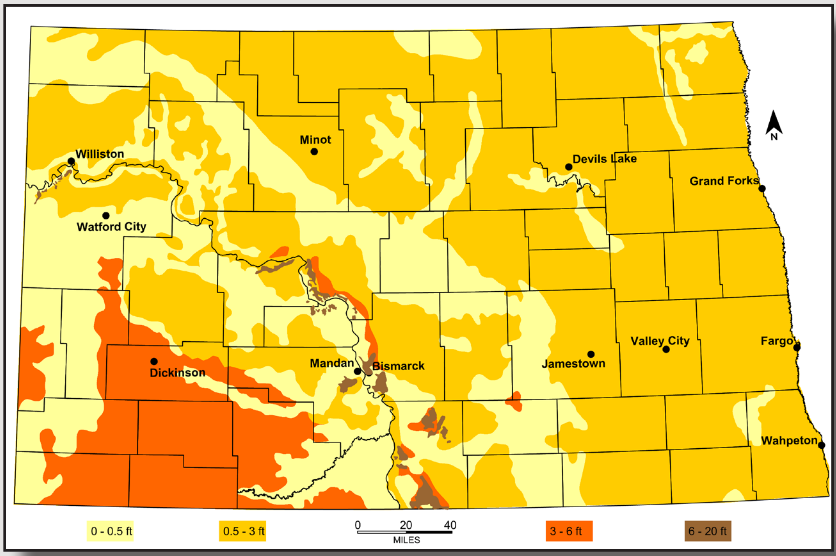

Figure 2. Generalized thickness of loess deposits of the Oahe Formation in North Dakota (adapted from Clayton et al., 1980 and inclusive of recent detailed geologic mapping in the Bismarck-Mandan area completed by Fritz, 2014; Mitchell, 2014a, 2014b, 2014c; and Murphy, 1997).

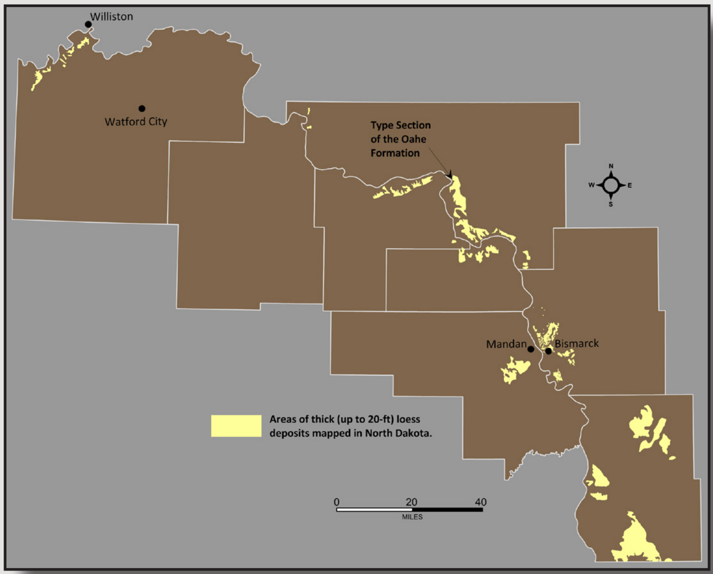

Figure 3. Areas of thick (up to 20 ft.) loess deposits mapped in North Dakota.

Figure 4. Outcrop of loess of the Oahe Formation mantling alluvial sediments along River Road (ND Hwy 1804) northwest of Bismarck.

(which rhymes with "bus") is the geological term for silt sized particles that are transported and deposited by the wind (i.e., an eolian deposit). Loess deposits are famous for their cliff-forming attributes with several outcrops in North Dakota displaying this distinctive characteristic (fig. 3). The thickest accumulations of loess occur along the southern and eastern sides of the Missouri River Valley and in Emmons County.

Loess is common in the Bismarck-Mandan area as well and is found mantling the glacial sediments of the Coleharbor Group and sandstone bedrock of the Cannonball Formation throughout the area. Loess deposits, which outcrop along the eastern edge of road cuts on ND Hwy 1804 in the Missouri River Valley northwest of Bismarck (fig. 4), display the vertical jointing characteristic of these types of deposits. Structurally, loess has a low material density and a high potential for the sudden collapse of structure (Lutenegger et al., 1979) along with low load bearing capacities upon saturation. Most importantly to the oil and gas community, loess has very fine grain sizes with high degrees of permeability (fig. 5).

Loess deposits in North Dakota are included in the Oahe Formation (Clayton et al., 1976; Clayton and Moran, 1979) which consists largely of unlithified clay, silt, sand, and gravel, that is further subdivided into four members, primarily based on color. From oldest to youngest, they are the Mallard Island Member, the Aggie Brown Member, the Pick City Member, and the Riverdale Member (fig. 6). Previous local studies of the Oahe Formation loess (Clayton et al., 1976; Frey et al., 2006) have characterized the members to be generally 10-20% sand, 60-75% silt, and 10-15% clay. The clay fraction is dominantly montmorillonite (i.e., smectites) that unfortunately have shrink-swell properties associated with them. The carbonate mineral fraction tends to be around 10% on average across the formation increasing with depth (fig. 7) and reacts vigorously with 10% dilute hydrochloric acid in the field. These deposits contain as much as 15% acid-reactive carbonate minerals and over 10% montmorillonite (smectite) clays. Smectite clays exhibit shrink-swell properties and would be considered to be a

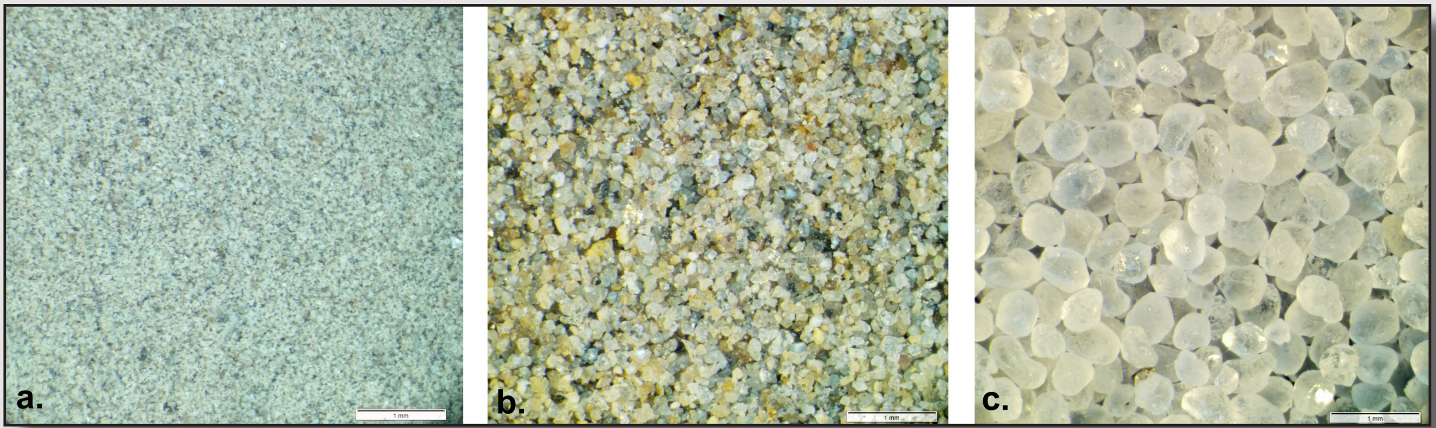

Figure 5. Photomicrographs (25x) of: (a) loess from the Pick City Member of the Oahe Formation, (b) sandstone from the Bullion Creek Formation, and (c) 40/70 Ottawa White silica sand proppant. The much smaller grain size of the loess of the Pick City Member is readily apparent from this comparison.

Figure 6. Exposed section of the Oahe Formation loess deposits north of Riverdale, North Dakota, near the type section first described by Clayton et al. (1976), illustrating the four members of the formation. Swallows favor burrowing their nests into the silty Oahe Formation sediments along the lake.

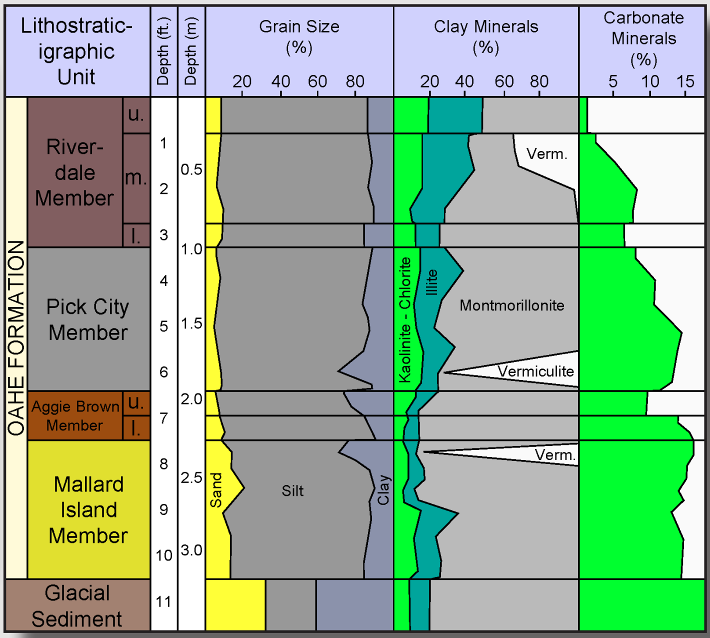

Figure 7. Textural and mineralogical characteristics of the Oahe Formation at the location of the type section at Riverdale, North Dakota on the eastern shores of Lake Sakakawea as investigated by Clayton et al., 1976.

deleterious component, in addition to the acid reactive carbonate minerals, if considered for use as a microproppant.

Taken together these two properties would render a given loess deposit with a considerable overall volume loss if the material were to be processed for use as proppant. As a part of ongoing investigations into the use of North Dakota's sand resources for potential use as proppant, the NDGS is also planning to test the members of the Oahe Formation loess and other sources in order to more fully characterize the sediments in this particle size range.

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