



FRACTURE SAND IN OHIO

INTRODUCTION

The use of hydraulic fracturing is a critical component in the development of shale hydrocarbon resources in Ohio. During hydraulic fracturing, a prepared sand known as a *proppant* is forced into the fractures created by the pressurized fluid. The sand “props” the fractures open, allowing gas and fluids to more easily flow to the wellbore. The first well hydraulically fractured in Ohio was drilled in 1952 in Stark County.

General requirements for fracture sand are that it consists of round to subrounded, nearly pure quartz grains; there should be no carbonates or other impurities that would affect the viscosity of the carrier fluids or potentially create fines that could reduce fracture permeability. Solubility should be <3% in hydrochloric acid (HCl). Uniformly graded sand gives better permeability as a proppant and improves fracture conductivity. Variations in particle size distribution can yield large variations in fracture conductivity; for instance a 5% increase in fines can exceed a 60% loss in propped fracture conductivity.

A typical fracture treatment in a vertical well completed in the Silurian-age “Clinton” sandstone in Ohio uses approximately 10 tons (t) of sand, whereas a horizontally-drilled shale well fracture treatment may use more than 5,000 t of sand. So it is not unreasonable to expect the Ohio market for fracture sand to increase substantially as shale reservoirs in the state are developed. Several companies in Ohio report production of fracture sand as part of their industrial sandstone mining operations.

FRACTURE SAND TESTING AND WELL PERFORMANCE

The potential of sandstone to be used as a proppant can be determined through laboratory testing. Tests used to determine if material meets American Petroleum Institute (API) and/or International Organization for Standardization (ISO) specifications include Krumbein shape factors (grain shape); acid solubility; crush resistance; sieve analysis for particle-size distribution; turbidity; and bulk density/specific gravity.

Grain shape is one of the most important physical characteristics of a proppant. In general, more round and spherical particles create more pore space, resulting in higher fracture conductivity. Round particles normally have a higher crush resistance due to less contact with the stress of overlying sediments. A visual inspection of a representative sample (minimum of 20 particles) under low magnification and comparison to a Krumbein chart can determine whether the sandstone meets the 0.6 or greater shape factor, as per API/ISO recommendations.

The second essential test for proppant suitability is acid solubility. Minor amounts of carbonates can have detrimental effects on the fracture fluid chemistry and the producing formation. Fine particles that may be generated due to geochemical interactions will lead to a loss in fracture conductivity. A sample is tested with a HCl solution; the allowable loss is 2% for coarser material and 3% for finer-grained samples. A field test using 10% HCl on a representative sample may give a good indication of whether the sandstone will meet the API/ISO acid solubility requirements.

The strength of the proppant is a critical factor in the design of a hydraulic fracture treatment. The crush resistance test procedure recognizes that proppants are used in multiple layers, so the load-bearing capacity of a single grain is not as important as the response of the confined grain packs. The crush resistance test is conducted by applying a load representing a fracture closure stress pressure to a specified volume and weight of the sample.

The load is increased in increments of 1,000 pounds per square inch (psi) until the fines generated exceed 10% by weight of the sample. Verification of the stress is accomplished by lowering the stress in 1,000 psi increments until fines generated are less than 10%; this bracketed pressure, rounded downward, results in the *k-value*. The k-value is used as a comparison of potential proppants, not necessarily as a recommendation of closure stress ranges for the proppant.

Particle size distribution of a sandstone deposit is important for determining mining economics. The larger proppant sizes have higher fracture permeabilities and are in higher demand, especially for liquid hydrocarbon reservoirs. The smaller proppant sizes have lower fracture permeabilities but may be more suitable for shale formations. A minimum of 90% of the tested sand sample should fall between the designated sieve sizes, with not more than 1% smaller than the last sieve size (200 mesh or 0.75 microns, approaching silt size).

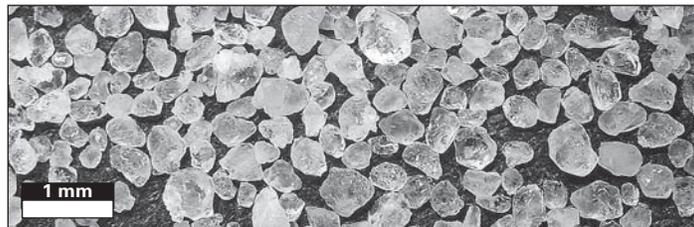


Photo showing grain size and shape of an Ohio sandstone that has been used as a fracture sand.

Other factors considered in evaluating a potential proppant include turbidity and specific gravity. A turbidity test is used to determine the amount of suspended or colloidal particles (clay) that may adversely affect fracturing fluids. Measuring specific gravity and bulk density of the proppant gives an indication of purity of the material.

GEOLOGY OF POTENTIAL FRACTURE SAND SOURCES IN OHIO

Sand-and-Gravel Deposits

The surficial geology of Ohio has been profoundly affected by Pleistocene glaciation; approximately 75% of the state is covered by glacial deposits. The composition of the sand and gravel related to these glacial deposits is strongly correlated with the local bedrock geology. Pebble counts performed during sand-and-gravel resource mapping in western Ohio reveal carbonate contents that vary from 75 to 94%, reflecting the limestone- and dolomite-dominated bedrock. No sand-and-gravel deposits in western Ohio would be acceptable as fracture sand due to acid solubility loss.

The bedrock geology of eastern Ohio consists of Devonian-through Permian-age interbedded sandstone, siltstone, and shale, with lesser amounts of clay, coal, and limestone. Pebble counts completed during sand-and-gravel resource studies in northeastern Ohio show a highly variable lithology. Carbonate contents vary from 0 to 51%; sandstone contents range from 5 to 81%; and siltstones vary from 1 to 100%. There also can be significant amounts of ironstone, chert, clays, and organics (0–63%). Some localized sand-and-gravel deposits may exhibit characteristics favorable for a potential fracture sand. Sand-and-gravel operators in eastern Ohio should consider field checking

a representative sample of sand for shape and acid solubility. If the initial field testing is positive, laboratory testing could be completed to ascertain fracture sand suitability.

Sandstone Deposits

Near-surface sandstone deposits greater than 20 feet (ft) thick in Ohio include, in ascending stratigraphic order, the Devonian-age Sylvania Sandstone of the Detroit River Group; the Devonian-age Berea Sandstone; the Mississippian-age Black Hand Sandstone and Buena Vista Sandstone of the Cuyahoga Formation; the Pennsylvanian-age Sharon and Massillon sandstones of the Pottsville Group; and several Pennsylvanian-age and Permian-age sandstones of limited geographic extent in eastern Ohio. Many of these sandstone deposits have been quarried historically for building stone or for industrial uses. In 2012, building stone quarries in Ohio produced from the Berea Sandstone, Buena Vista Sandstone, and the Massillon sandstone. Sandstones for industrial uses were produced from the Black Hand Sandstone, the Sharon sandstone, and the Massillon sandstone.

The Sylvania Sandstone is the oldest Devonian strata exposed in northwestern Ohio and is the lowermost unit of the Detroit River Group. It is generally overlain by the Dundee Limestone and underlain by the Silurian-age Salina Group. The Sylvania is a white, friable sandstone with well-rounded quartz grains that may contain scattered masses of calcite, celestite, and dolomite. The Sylvania contains interbedded, arenaceous dolomite with bands of chert. Thickness of the Sylvania Sandstone varies from 0 to 95 ft. The Sylvania was not produced in Ohio during 2012; but it is exposed in the lower portion of at least one quarry in Lucas County and was historically used in the Toledo glass industry.

The Berea Sandstone outcrops from northeastern to southern Ohio in the center of the state. The Berea is the uppermost unit of Devonian-age strata in Ohio and has been quarried extensively since the 1850s for use as a building stone. It is overlain by the Sunbury Shale and underlain by the Bedford Shale. Thickness varies statewide from 5 ft to more than 120 ft in the quarries of northern Ohio. The Berea Sandstone is light brown, medium to coarse grained with subrounded quartz. Silica content is generally greater than 91% with approximately 4% aluminum oxide and less than 1% iron oxide.

The Mississippian-age Buena Vista Sandstone of the Cuyahoga Formation outcrops in a limited area of south-central Ohio. The Buena Vista Sandstone is light gray with fine- to medium-grained, subrounded quartz grains. It is thin to medium bedded and associated with thin beds of shale or siltstone. The Buena Vista Sandstone is 20 to 30 ft thick north of Portsmouth, Ohio, and has been quarried as a building stone since the early 1800s.

The Black Hand Sandstone of the Cuyahoga Formation outcrops from south-central to northeastern Ohio. It is overlain by siltstones and sandstones of the Logan Formation and underlain by the Sunbury Shale. The Black Hand has conglomeratic to silty facies but can be a massive, coarse-grained sandstone up to 100 ft thick in quarries consisting of greater than 98% silica. The

Black Hand is currently quarried in Knox County for industrial sand, including use as a hydraulic fracture proppant. Published physical properties data for the Black Hand include shape factors of 0.6–0.7, acid solubility of 1.5–1.7%, and turbidity of 92–100.

The Sharon sandstone is the lower-most unit of the Pennsylvanian-age Pottsville Group in Ohio. Due to the major unconformity at the Pennsylvanian/Mississippian boundary in eastern Ohio, the Sharon is highly variable in thickness. The Sharon is a massive, fine- to coarse-grained, high-silica sandstone and pebble conglomerate. Thickness ranges from 10 to 60 ft in quarries. Silica content can exceed 99%. Currently in Ohio, the Sharon sandstone and conglomerate are quarried for glass manufacture and other industrial purposes, including hydraulic fracturing. A Sharon sandstone mining operation in southern Ohio reported shape factors of 0.6–0.7, solubility of 2.9%, turbidity of 19, crush resistance of up to 6,000 psi, and acceptable size distribution in the smaller size fractions.

The Massillon sandstone is part of the Pottsville Group in Ohio. In some areas, the Massillon has been eroded away or replaced by shales and siltstones. The Massillon is a light-brown to white, fine- to medium-grained, high-silica sandstone. The Massillon can be up to 100 ft thick in east-central and northeastern Ohio and is quarried for both industrial sand and building stone. Published physical properties data for the Massillon in Perry County include shape factors of 0.5–0.6, acid solubility of 1.9%, and turbidity of 78.

Additional Pennsylvanian-age and Permian-age sandstones in Ohio can be more than 100 ft thick locally and have been used in some areas as building stones. The sandstones can be fine to coarse grained with subrounded to subangular quartz and feldspar grains. They often contain significant amounts of mica and other accessory minerals. A well-sorted, clean, friable sandstone phase with noncalcareous cement may have potential as a proppant.

FURTHER READING

- Ehlers, G.M., Stumm, E.C., and Kesling, R.V., 1951, Devonian rocks of southeastern Michigan and northwestern Ohio: Prepared for the stratigraphic field trip of the Geological Society of America Detroit meeting, November, 1951, 40 p.
- Fuller, J.O., 1967, Sharon conglomerate, a source of high silica raw material: Columbus, Ohio Department of Natural Resources, Division of Geological Survey Reprint Series 6, 8 p.
- Risser, M.L., 1986, Sand and gravel resources of Columbiana County, Ohio: Columbus, Ohio Department of Natural Resources, Division of Geological Survey Report of Investigations No. 131, map, scale 1:62,500.
- Stout, Wilbur, 1944, Sandstones and conglomerates of Ohio: Ohio Journal of Science, v. 44, no. 2, p. 75–88.
- Slucher, E.R., Swinford, E.M., Larsen, G.E., Schumacher, G.A., Shrake, D.L., Rice C.L., Caudill, M.R., and Rea, R.G., 2006, Bedrock Geologic Map of Ohio: Columbus, Ohio Department of Natural Resources, Division of Geological Survey Map BG-1, scale 1:500,000.
- Wolfe, M.E., 2012, 2011 Report on Ohio mineral industries—An annual summary of the state's economic geology: Columbus, Ohio Department of Natural Resources, Division of Geological Survey, 32 p., 8 appendices.

Generalized column of bedrock units in Ohio that may be suitable for proppants (bold) and related units

Time-stratigraphic units	Group/Formation	Members or beds
Permian/Pennsylvanian	Dunkard-Allegheny Groups	Undefined
	Pottsville Group	Massillon sandstone Sharon sandstone
Mississippian	Logan Formation	Black Hand Sandstone
	Cuyahoga Formation	Buena Vista Sandstone Sunbury Shale
Devonian		Berea Sandstone Bedford Shale
		Dundee Limestone
		Sylvania Sandstone
Silurian	Detroit River Group	
	Salina Group	

