Widespread North American occurence of millstones made of imported French chert (French buhr) containing charophytes

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Abstract: Fossil charophytes belonging to the genus *Gyrogona* can be used to distinguish chert millstones made of French buhr (*pierre meulière*) from millstones made of domestic North American cherts. The occurrence of the charophytes *Gyrogona medicaginula* Lamarck and *Gyrogona* cf. *G. medicaginula* in millstones imported from France has been previously documented for Massachusetts, Vermont, and Ohio in the United States. Additional localities with millstones containing *Gyrogona* are documented in this paper for the states of Arkansas, California, Colorado, Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Nebraska, New York, North Carolina, Virginia, and Wisconsin in the United States, and in the Province of Ontario in Canada. These widespread occurrences demonstrate the utility of charophytes as indicators of provenance of stone used for millstones. The geologic age and depositional environment (marine) of chert-bearing beds known to have been used for manufacture of millstones in North America are also noted.

Keywords: millstones, long distance trade, charophytes, French buhr, *Gyrogona, meulière*

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Introduction

Several types of millstones, and stones intended to be used for manufacture of millstones, have been imported into North America. The main types imported were conglomerates from England, volcanic stones from Germany, and chert from France (Hockensmith 2009, 120-122). Local North American conglomerates, volcanic stones, and cherts, however, have all been used for millstones, complicating determination of provenance.

Chert from France, known in France as *pierre de meulière*, or simply as *meulière*, and in much of the rest of the world as French buhr, was the most highly prized stone (Ward 1986, 12) used for millstones in the 18th and 19th centuries. Large amounts of this stone, as well as complete millstones made of this stone, were exported from France into other European countries and North America (Kick 1888, 80; Belmont and Hockensmith 2006, 4; Belmont 2006, 138-140). This stone was highly regarded in North America (Raborg 1887, 581; Waterous Engine Works Co. 1891; Pozdoray 1905, 7; Clark 1916, 178; Rynne 2006, 197-98). There are many reports of this French stone having been used in millstone manufacture (Hamilton 1964, 4; Ball and Hockensmith 2007b), especially in eastern North America, and many millstones in North America (e.g., Howell and Keller 1977, 74; Leung 1981, fig. 7; Hockensmith 2009a, fig. 24) have been identified as being made of French buhr.

Cherts similar to French buhr in color and in having similar amounts of cellular porosity were quarried in North America, however. These domestic cherts were intended to be less expensive local alternatives to imported French stone. Local chert was quarried

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for use in millstone manufacture in Alabama, Arkansas, Georgia, Illinois, Indiana, Kentucky, Missouri, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, and Virginia (Table 1). Most of the domestic cherts quarried for millstones in those states are Paleozoic in age, but those of Alabama, Georgia and the Carolinas are Paleogene, or close to Paleogene, in age, closer in geologic age to those of the Paris Basin. It was claimed that the stone in Georgia was 'identical, in composition and geological position, with the French burrs' (Bishop 1868, 149). All of the North American cherts listed in Table 1, however, are marine in origin. Indeed, Charles Lyell (1850, 18) collected marine fossils in the buhrstone used for millstone in Georgia during his second visit to North America. These local cherts were also exported regionally (Hockensmith 2008).

Johansson (1957), in a study of samples from Vermont and Massachusetts, documented the presence of charophytes, a type of algae, in French chert used for millstones in New England, but his work has been almost entirely neglected. Recently Hannibal *et al*. (2014) have documented the presence of charophytes in imported French millstone in Ohio, and the presence of other types of fossils in local Ohio stone used for millstones. They noted that the French stone was a Tertiary freshwater stone and that the Ohio stone utilized was a local Pennsylvanian chert with marine fossils.

The purpose of this paper is to extend the work of these authors, documenting the widespread North American occurrence of diagnostic charophytes in millstones made of stone imported from France. These fossils can be used to distinguish French buhr from domestic cherts used for millstones.

Museum Specimens

Charophyte specimens referred to by the initialism CMNH in this paper refer to specimens that have been catalogued into the Invertebrate Paleontology Collection of the Cleveland Museum of Natural History. The steinkern of one of these (Fig. 1, CMNH 14687B) has been lost since it was photographed, but its natural mold remains. The museum number LC7573 denotes a millstone belonging to the Versterheim Norwegian-American Museum in Decorah, Iowa, that was formerly part of the Luther College collection and H.5797.1.B refers to a History Colorado millstone.

Use of Charophytes

Charophytes previously documented (Johansson 1957; Hannibal *et al*. 2014) as occurring in French buhr in the United States belong to the genus *Gyrogona* which is middle Eocene to lower Oligcene (Riveline 1986, 188). The species *Gyrogona medicaginula* Lamarck, identified in French buhr, is lower Oligocene. The chert itself, however, was formed consequent to the deposition of the protolith sediment.

Gyrogona has been reported as occurring in North American rocks (e.g., Peck 1934) but most, if not all, of the supposed North American occurrences of this genus are taxa which have been subsequently assigned to other genera (Peck and Eyer 1963). In the *Treatise on Invertebrate Paleontology*, Feist and Grambast-Fessard (2005, 125) noted a questionable North American occurrence. Despite this possibility, *Gyrogona medicaginula* is a freshwater form, so would not be found in the North American rocks known to have been used for millstones (Table 1), as these rocks are marine.

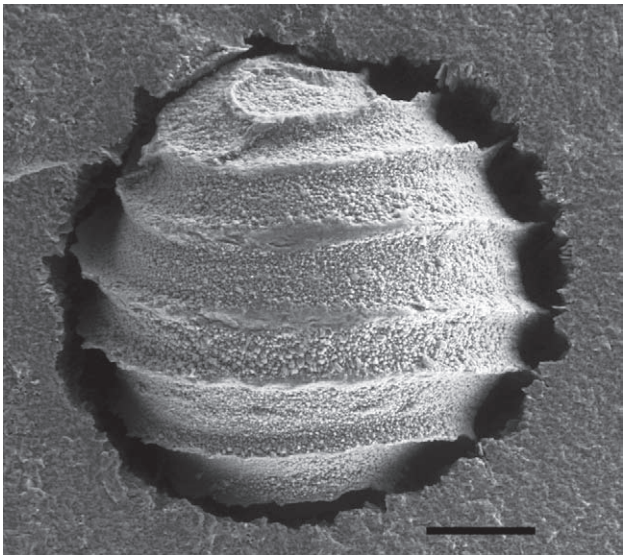

Fig.1: Lateral view of gyrogonite of Gyrogona medicaginula, CMNH 14687B, from chert piece presumably eroded from plaster top of millstone from Duncan Grist Mill, Killbuck, Ohio. Portions of sinestrially curved nodules seen at top; prominent midcellular crest seen on some cells on the right-hand side of the photo. Scale is 200 µm.

Fig. 2: Oblique basal view of natural mold of gyrogonite of Gyrogona cf. G. medicaginula, CMNH 14693A, showing spiral pattern, from chert piece presumably eroded from plaster top of millstone from Duncan Grist Mill, Killbuck, Ohio. Scale is 200 µm.

Gyrogonites, charophyte reproductive structures, are preserved in French buhr as steinkerns (internal molds), as well as external molds. The gyrogonites of *Gyrogona medicaginula* and *Gyrogona* cf. *G. medicaginula* (the latter being specimens that resemble the species but which do not show enough defining characters to be certain of the species identification), when measured in the field, typically ranged between about 0.5 and a little over 1 mm in diameter. They are more-or-less spheroidal in shape (however, they can be deformed). This taxon has distinctively shaped spiral cells (seen in the negative as steinkerns and in molds as preserved in French buhr) that have a prominent midcellular crest (Fig. 1, CMNH 14687B) and the apex of the gyrogonites have a rosette composed of sinestrally curved nodules. The basal view of the gyrogonite or its natural mold (Fig. 2, CMNH 14693A) preserves a spiral pattern. Identification to species level is difficult in the field, as important species-level characters, such as the configuration of the exterior outlines of the spiral cells and the sinestrally curved apical nodules, are not evident in most views. In this study the taxon was only confidently identified to species if specimens showed one or more of these definitive characters. Other very similar specimens have been assigned to *Gyrogona* cf. *G. medicaginula*. Charophyte thalli may also be preserved in French buhr. These consist of corticated tubes, with a number of smaller tubes surrounding a larger, central tube. Illustrations of thalli found in French buhr millstones can be seen in Hannibal *et al*. (2014, figs 7C-F, 8) as can additional illustrations of charophyte gyrogonites found in this stone.

Techniques

Beginning in the spring of 2009 and extending into the spring of 2016, chert millstones were located in the United States and Canada using methods outlined by Hannibal *et al*. (2014, 741) in their study of millstones in Ohio. An attempt was made to cover as wide an area as possible within this timeframe. Millstones were examined using a hand lens and/or field microscope and the presence of charophyte fossils (after they were first noticed in 2011) were recorded as was other information (location, size, etc.) about the millstones studied. Samples were studied using light microscopes and an Environmental Scanning Electron Microscope.

Results

Millstones containing charophytes referable to *Gyrogona medicaginula* and/or *Gyrogona* cf. *G. medicaginula* were located in Arkansas, California, Colorado, Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Nebraska, New York, North Carolina, Virginia, and Wisconsin in the United States, and in the province of Ontario, Canada (Fig. 3). These occurrences are listed in Table 2. The present location of these millstones is given.

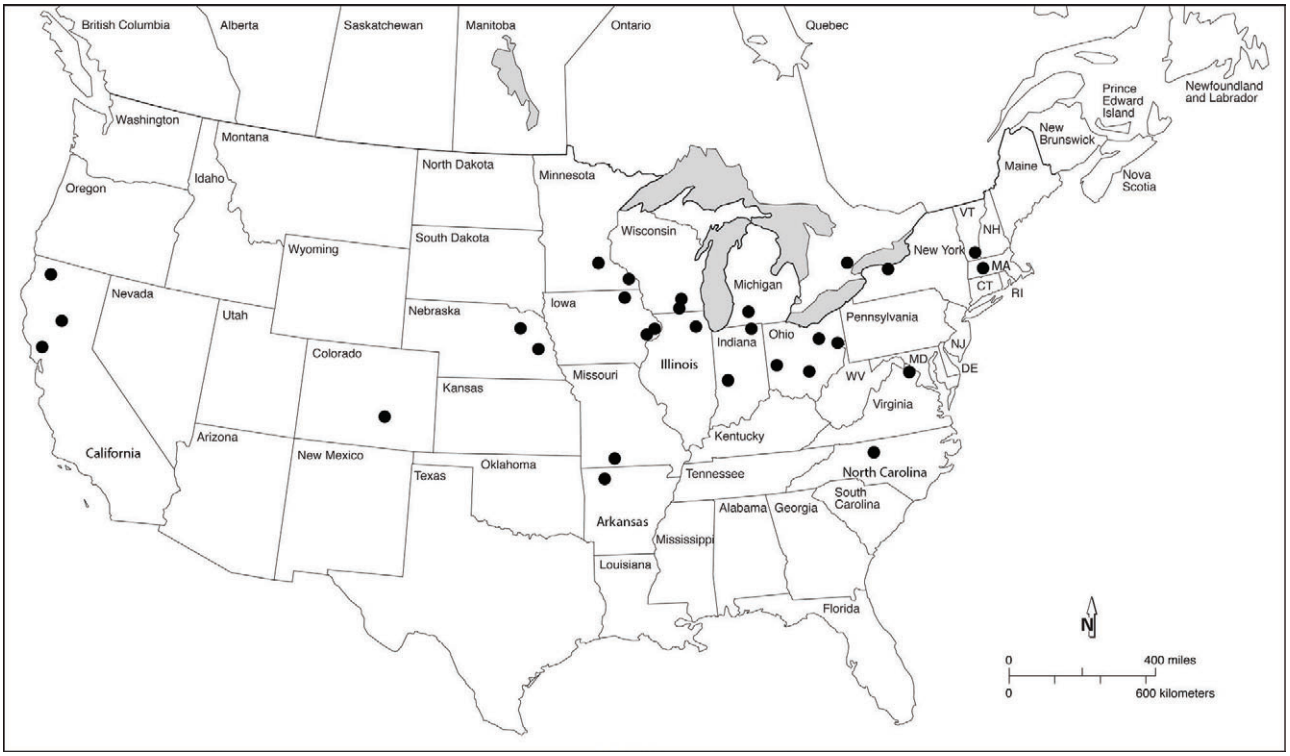

Fig. 3: Map showing representative localities in North America (United States and Canada) having French buhr millstones containing charophytes identified as Gyrogona medicaginula or Gyrogona cf. G. medicaginula; more detailed locations are listed in Table 2. Most dots represent a single locality, but two locations (one in Nebraska and another in Arkansas) represent two closely-spaced localities each.

Table 1. Geologic age and depositional environment of chert quarried or potentially quarried for millstones in North America. This list is based on a critical literature review. It is possible that chert was also used in California (Hockensmith, 2009a, 62-63; 2011, 235, 237) and Massachusetts. Evidence for its use in California is equivocal as the original description (Trask, 1854, 16) of one of these stones indicates that the stone used may have been a vesicular (= "cellular") volcanic rock instead of a chert. If one of the readily available California cherts were used, however, they would have likely been Mesozoic or Paleogene, and would have been marine. Hitchcock (1841, 218, 587) determined that a quartz-rich stone resembling chert utilized in western Massachusetts for millstones (Hockensmith, 2009a, 68) was a metamorphic rock.

State	Location(s) quarried	Geologic age	Depositional Environment	Selected references
Alabama	Millstone Mt., Winston County; (?) Jackson County	Eocene	Marine	Hockensmith 2009a, 61–62; Dean in Hockensmith 2009a, 62; Thomas 1942; McCalley 1886, 77-78
Arkansas	Along North Fork and Camp Creek Hollow, Izard, Lawrence, and Polk counties; (potential) between Batesville and Big Spring	Mississippian	Marine	Owen 1858, 37–38, 44–45; Hockensmith, 2009a, 62
Georgia	Burke County, Jefferson County; near Augusta, Augusta-Richmond County	Paleogene	Marine	Davis 1990, 1993; Safford 1880, 176; Cooke 1943, 64; Goad 1979; Bonner, 1964, 82; Hockensmith, 2009a, 63-65; (See also Lyell 1850, 18)
Illinois	Union County	Devonian	Marine	Hockensmith 2009a, 66; Anonymous 1906, 198
Indiana	Jennings County	Devonian	Marine	Owen 1987, 24
Kentucky	Franklin and Woodford counties	Ordovician	Marine	Hockensmih 2009a, 66-68; Hockensmith 2009b, 11-12, 17-18
Missouri	Cedar, Jasper, Madison, Newton, Washington, Webster counties; near the vicinity of the Bates Mill, Osage and Gasconade Rivers	Paleozoic (Lower Silurian), ?Ordovician, Lower Carboniferous	Marine	Wetmore 1837, 40, 73, 109, 152; North American Review 1839, 521-522; Broadhead *et al*. 1873, 11, 31, 231; Broadhead 1874, 55-56; Hockensmith, 2004 (see also Cullison 1944 and Ray, 2007)
North Carolina	Near Troy, Montgomery County; Willmington, New Hanover County; Pollocksville, Jones County; New Bern, Craven County	Paleogene	Marine	Emmons 1856, 218-219; Emmons 1858, 90, 102; Kerr 1875, 305
Ohio	Flint Ridge, Licking and Muskingum counties; Elk and Brown townships, Vinton County	Pennsylvanian	Marine	Hockensmith 2007, 2008; Hannibal *et al*. 2014
Pennsylvania	Allentown area, (?) Lehigh County	Carboniferous	Marine	Cleaveland 1822, 265-66 (see also Rogers 1840, 529 on possible stone)

Table 1. continued from previous page.

State	Location(s) quarried	Geologic age	Depositional Environment	Selected references
South Carolina	Along Savanna River, near Barnwell, Barnwell County, and Orangeburg, Orangeburg County	Paleogene (?) (Eocene?)	Marine	Tuomey 1848, 290; Hockensmith 2009a, 76
Tennessee	Claiborne, Jefferson, and Knox counties, Perry County; Williams County	Cambro-Ordovician; Mississippian	Marine	Ashley, 1919, 51; Safford 1869, 215, 221, 283, 511-512; Wilson 1986, 3, 5-6; Ball and Hockensmith 2007a; Hockensmith 2009a, 76-77
Virginia	Near Saltville, Smyth and Washington counties; Russell County	Mississippian	Marine	Martin and Brockenbrough 1835, 456; Fontaine 1869, 47; Keroher and others 1966, 2571; Rogers 1884, 173

Fig. 4: French buhr millstone at War Eagle Mill, Arkansas. Staff is marked with 10 cm increments.

In one case (that of a millstone now in a museum collection in Colorado) a former location where it was used (Nebraska) before being brought to Colorado is also noted. The diameter of the millstone(s) with charophytes is recorded so that the stone(s) listed can be identified in the future. This was done as some localities have numerous chert millstones, not all of which necessarily contain charophyte fossils. Millstones containing charophytes varied in size and configuration. They included monolithic millstones with simple land-and-furrow patterns (Figs 4-5), as well as multiple-piece millstones with varying numbers of segments and more complex patterns of dressing (Figs 6-8). The date of observations are also given; more details are recorded in Cleveland Museum of Natural History Invertebrate Paleontology field notebooks.

Samples were obtained from several sites in Ohio and Indiana. All of the Ohio specimens were pieces of scrap chert. Such scraps were once embedded in, or that were presumed to have been embedded in, plaster backing put onto millstones at the time of assembly (Ward 1986; Hannibal *et al*. 2014, 741). At one location, that in Indiana, small pieces of chert were collected at the base of a millstone from which they had eroded. These pieces included *Gyrogona medicaginula* (Fig. 9, CMNH 14794B).

Discussion

The widespread occurrences of charophytes in millstones demonstrate the usefulness of these fossils in identifying French buhr in North America. But, based on the widespread occurrences documented in this paper, it is likely that charophytes will be found in French buhr millstones in other parts of the world as well. French buhr was used world-wide (Belmont 2006, 138-141). It was widely used in continental Europe (Belmont 2006, 141), on the

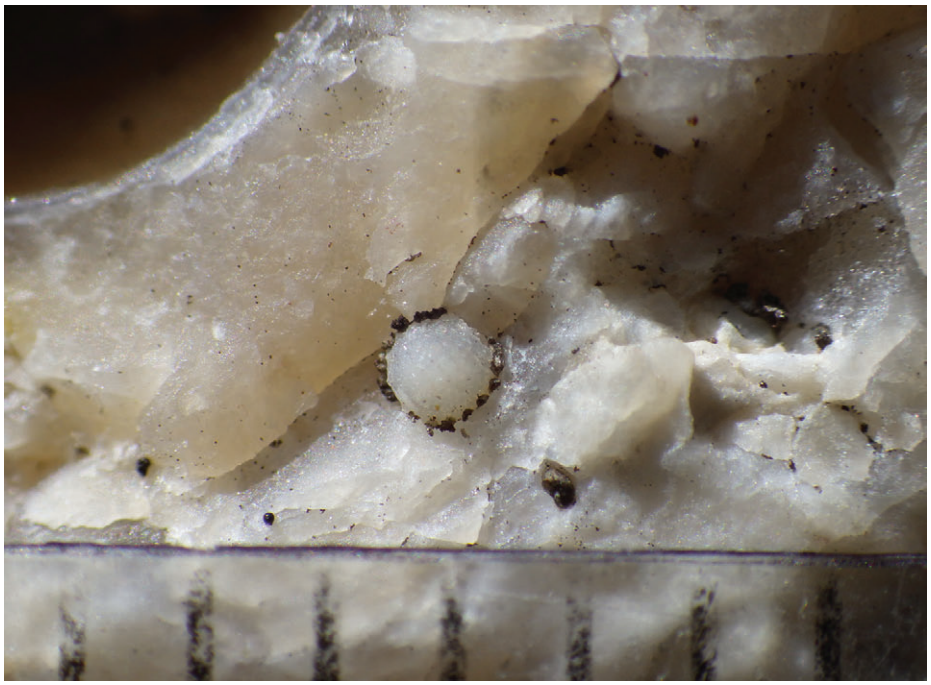

Fig. 5: Field photo of millstone at War Eagle Mill showing charophyte gyrogonite Gyrogona cf. G. medicaginula (center). Scale in 1-mm increments.

Fig. 6. Millstone at Meadowvale Village, Ontario. Staff is marked with 10 cm increments.

Island of Jersey (Renouf 2002, 333), in Ireland (Rynne 2006, 197), in Great Britain and in its colonies, including Canada (Leung 1981, 28, 38-39; Ward 1993, 8), South Africa, Australia, and New Zealand (Connah 1988, 131; Ward 1993, 8), and of course French Canada (Belmont 2006, 139-140). They were also almost certainly used in South America (Belmont 2006, 141). One caveat is necessary, however: Charophytes are not evident in all French buhr. A number of millstones probably made of French buhr, but lacking evident charophytes, were encountered during this study. Charophytes were either not present or were unnoticed in these stones that resembled French buhr in color and porosity. Thus other means of identification of French buhr are needed where these fossils are not present.

Fig. 7: French buhr millstone at Fort Jones Museum, Fort Jones, California. Staff is marked with 10 cm increments.

Fig. 8: French buhr millstone at Greenfield Mill, LaGrange County, Indiana. Staff is marked with 10 cm increments.

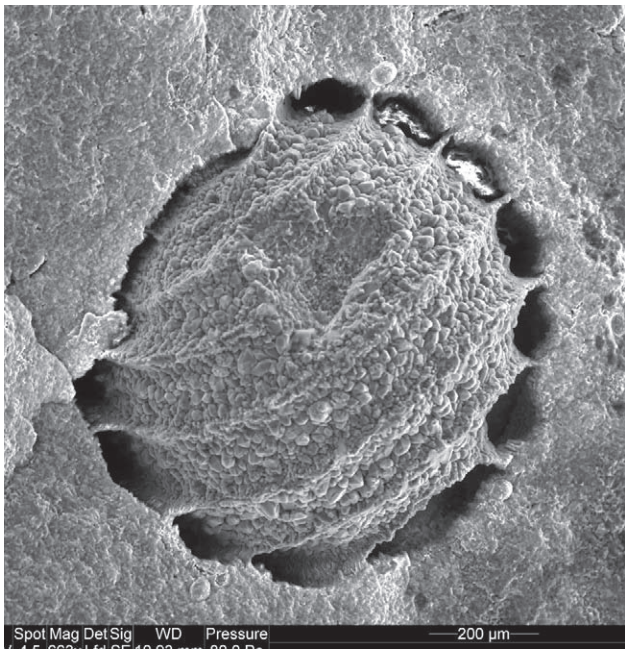

Fig. 9: ESEM microphotograph of gyrogonite Gyrogona medicaginula in chert fragment weathered from millstone at Greenfield Mill, La Grange County, Indiana, CMNH 14794B1. Scale is 200 µm.

Conclusions

The freshwater charophyte species *Gyrogona medicaginula* and *Gyrogona* cf. *G. medicaginula* occur in French buhr used for millstones in North America, but do not occur in North American cherts utilized for millstones. The widespread occurrences of millstones containing this taxon in North America demonstrate the utility of charophytes as indicators of provenance of French buhr serving for millstones. Thus it is likely that charophytes can be used worldwide as indicators of provenance of stone used in the manufacture of French buhr millstones.

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Table 2. North American examples of French buhr millstones containing charophytes.

State/Province	Present location of millstone(s); former location (if different)	Diameter of millstone(s) with charophytes	Charophytes	Date(s) observed/ remarks
Arkansas	Johnson Mill (pair), Johnson; War Eagle Mill (pair), Rogers	122-122.5 cm; 76 cm	*Gyrogona* cf. *G. medicaginula* (gyrogonites)	March 17, 2014; March 19, 2014
California	Bale Gristmill, near St. Helena; Bidwell Mansion State Historic Park, Chico; Fort Jones Museum, Fort Jones	2 pair 107-108 cm; 3 millstones 74-76 cm; 107, 108 cm	*Gyrogona* cf. *G. medicaginula* (gyrogonites)	Oct. 10, 2014; Oct. 11, 2014; Oct 12, 2014
Colorado (once used in Nebraska)	History Colorado Museum Support Center, Pueblo (originally used in Nebraska; then brought to Colorado)	79-80 cm (H.5797.1.B)	*Gyrogona* cf. *G. medicaginula* (gyrogonites)	Oct. 31, 2013
Illinois	Graue Mill, Oak Brook	121 cm	*Gyrogona* cf. *G. medicaginula* (gyrogonites)	Oct. 3, 2013
Indiana	Greenfield Mill, Greenfield Township; Portland Mills	121.5 cm; 109 cm	*Gyrogona medicaginula* (gyrogonites); *Gyrogona* cf. *G. medicaginula* (gyrogonites)	May 1, 2013; April 22, 2016
Iowa	Buffalo Bill Museum, LeClaire; Pine Creek Grist Mill, Wildcat Den State Park (stone originally from Muscatine); Vesterheim Norwegian-American Museum, Decorah	59.5 cm (center portion of millstone); 91.5 cm; 46 cm (LC7573) also at least 4 unbound segments 38-42 cm wide	*Gyrogona* cf. *G. medicaginula* (gyrogonites, also thalli at Pine Creek)	April 28, 2014; April 21, 2014; Oct. 24, 2014, May 16, 2015
Massachusetts	Unnamed locations (see Johansson 1957)	---	*Gyrogona* cf. *G. medicaginula* (gyrogonites)	Identified as *Chara medicaginula* in Johansson 1957
Michigan	Battle Creek Monument Park, Battle Creek	80 cm	*Gyrogona* cf. *G. medicaginula* (gyrogonites)	May 5, 2013
Minnesota	Edina Mills, Williams Park, Edina; Pickwick Mill, Pickwick	123 cm; 122 cm	*Gyrogona* cf. *G. medicaginula* (gyrogonites)	Aug. 21, 2015; Oct. 4, 2013
Missouri	Edwards Mill, Point Lookout	120 cm	*Gyrogona* cf. *G. medicaginula* (gyrogonites)	June 26, 2013
Nebraska	Moffitt Park, Seward; Neligh Mills Historic Site (partly millstones from Beatrice); Meadow Grove	76.5 cm; 76-79 cm, also 70 cm wide segment; 66 cm	*Gyrogona* cf. *G. medicaginula* (gyrogonites)	Oct. 8-9, 2013
New York	Daisy Flour Mill, Rochester	60 cm	*Gyrogona* cf. *G. medicaginula* (gyrogonites)	May 24, 2014

Table 2. continued from previous page.

State/Province	Present location of millstone(s); former location (if different)	Diameter of millstone(s) with charophytes	Charophytes	Date(s) observed/ remarks
North Carolina	Old Salem Village (private land within village)	122 cm, 50 cm, 39 cm	*Gyrogona* cf. *G. medicaginula* (gyrogonites and thalli)	Nov. 8, 2012
Ohio	Many locations (see Hannibal *et al*. 2014, 747-748)	See Hannibal *et al*. 2014, 747-748	*Gyrogona medicaginula, Gyrogona* cf. *G. medicaginula* (gyrogonites and thalli)	See Hannibal *et al*. 2014, 747-748
Vermont	Present location not known; originally found along Baker Brook, Williamsville	(Block of millstone; no size given)	*Gyrogona* cf. *G. medicaginula* (gyrogonites)	Identified as *Chara medicaginula* in Johansson 1957
Virginia	Aldie Mill, Aldie	circa 144 cm	*Gyrogona* cf. *G. medicaginula* (gyrogonites)	Nov. 7, 2015
Wisconsin	Beckman Mill, Beloit; Stoughton Historical Society, Stoughton	109 cm, also 3 unbound segments 23.5, 36, 49 cm wide; 120 cm	*Gyrogona* cf. *G. medicaginula* (gyrogonites)	Oct. 16, 2011; Oct. 27, 2014; May 22, 2015; Dec. 31, 2015
Ontario	Old Mill Lane, Meadowvale Village	121 cm	*Gyrogona* cf. *G. medicaginula* (gyrogonites)	May 25, 2014

Museum), Dan McGlasson, Dave Hoffman, Jim and Sheri Disrud, and Marty Densch (Beckman Mill), John Mintz (North Carolina Office of State Archaeology), Ed Osborne (Alabama Geological Survey), Dave Reed and Nigel Bush (Killbuck Museum), Cecelia Reuter and Chuck Fiock (Fort Jones Museum), Donna Roberts (Kingman Museum), Mike Roe (Bridgeton Mill), Michael Rosen-Molina (Bidwell Mansion State Historic Park), Thomas Sears and Mo Hartley (Old Salem, North Carolina), Whitney Templeton (Graue Mill and Museum), Todd Topper, Paula Manini, and James Peterson (History Colorado), and Josh Torres and Jeanne Minor (National Park Service, Rock Creek Park).

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