Proceedings of the Iowa Academy of Science

Volume 76 | Annual Issue Article 40

1969

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The Giant Boulders of the Iowan Drift and a Consideration of Their Origin

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Abstract. Samples of the large granitic boulders of the Iowan drift were analyzed and features of the boulder distribution were examined. The analysis gave evidence of a central body of single granite stock which included more than 80 per cent of all large boulders examined within the Iowan drift area. Characteristics of this main granite stock were then compared to the bedrock areas which could be considered source regions of the boulders. All evidence pointed toward a source region in the large granite body found in central and westcentral Minnesota. Weathering and structural features of the boulders suggested that they may have been formed by secular weathering prior to their glacial transport.

The Wisconsin stage, most recent of the four glacial ages of the Pleistocene in North America, is represented in Iowa by two major drift sheets—the early-Wisconsin age Iowan drift sheet and the late-Wisconsin age Mankato drift sheet. Prominent features of nearly all parts of the Iowan drift of northeastern Iowa are the great number of giant boulders which dot the landscape. Boulders are a common feature of all glacial drift regions. However, the Iowan erratics are peculiar in several ways:

1. Most of the Iowan boulders are light-colored, coarse-grained granites rather than the darker ferro-magnesian types commonly found in other glacial areas.
2. Very large boulders occur frequently.
3. Most large boulders are similar in granite composition.

This study was undertaken to analyze and compare the mineral compositions and structures of the large boulders of the Iowan drift; and thence to compare that information with the descriptions of granite outcrops in areas where the parent rock might be found.

Since the Iowan drift is almost entirely overlain by more recent glaciation in regions to the north of Iowa, little is known about the path traveled by the advancing ice. The materials picked up by the advancing ice are the best indicators of the direction of glacial advance. Tracing the Iowan boulder-indicators back to their origin gave information which, along with glacial striae and relief features, aided in determing the direction of advance of this lobe of the Iowan.

It was conjectured that the peculiar occurrence of these large boulders might also suggest evidence concerning the pre-glacial terrain of the area of boulder origin.

Iowan Boulders

A preliminary review of literature discussing the Iowan boulders

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and a study of the map by Alden and Leighton (1915) indicated that the boulders occurred in a general area covering fifteen counties of the Iowan drift surface in northeast Iowa (Fig. 1).

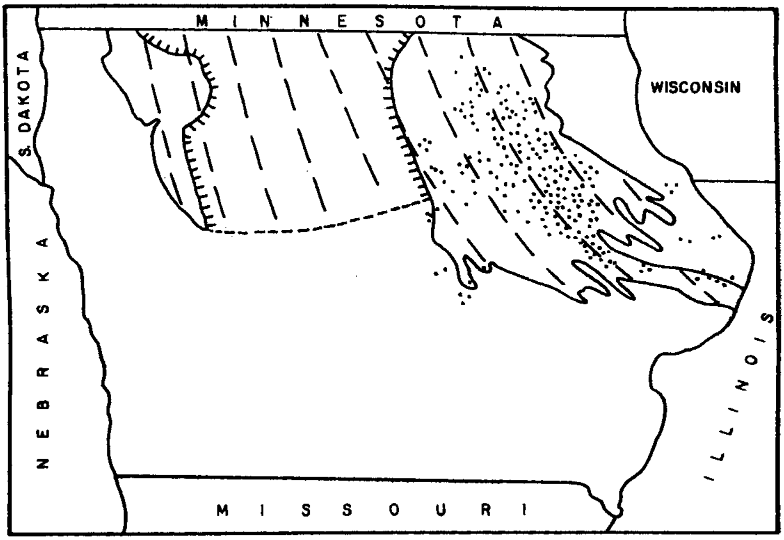

Fig. 1. Map of Iowa showing the extent of Iowan glaciation and the large boulders as mapped by Alden and Leighton (1915). Hachures indicate Iowan drift region overlain by the Des Moines lobe. (Modified from Kay et. al., 1943.)

Most of the areas showing heavy populations were located in the center of the boulder region, throughout Chickasaw and Bremer Counties, and a large part of Buchanan County (Fig. 2). Local accumulations were also observed in southwest Fayette County and northeast Blackhawk County. Boulders occurred less frequently and were generally smaller in the southern areas covering parts of Benton, Linn, Jones, and Delaware Counties. The size of some of the largest remaining boulders is illustrated in Figs. 3 and 4, and the remainder described in Table I (Appendix).

Method of Analysis

Each sample was described with the aid of a low-power microscope. Mineral characteristics and sizes were studied, along with features of weathering and the percentages of mineral content, Table II (Appendix). Comparisons were then made from these megascopic descriptions.

Preliminary field work in the boulder region (Fig. 5) revealed the great similarity among the granite types and also indicated that in general all boulders in a single locality were of the same stock.

Fig. 2. Boulder strewn field in the Iowan drift west of Fairbank, Buchanan County.

Fig. 3. A large Iowan boulder in eastern Grundy County (sample 17 in *Tables*).

Fig. 4. Probably the largest remaining boulder in the state, located near Nashua, Floyd County (sample 5 in Tables).

Characteristic Granite

The characteristic boulder granite of the central area was a light-colored porphyritic granite showing various degrees of weathering. Orthoclase phenocrysts were numerous and measured up to 15 mm. Local variations in biotite content were estimated between 3 and 15%. Both light and dark shades of smoky quartz were present, occasionally weathered yellow. Feldspar crystals were generally white or flesh colored, also showing occasional yellow staining.

Two typical samples of the characteristic granite were analyzed by means of a polarizing microscope. The average results were: 6 per cent plagioclase, 35 per cent orthoclase, 15 per cent microcline, 39 per cent quartz, and 5 per cent biotite. These results were well in accord with those determined by megascopic means.

The analysis of the Iowan boulders gave evidence of several features. A central group of similar granites included more than 80% of all large boulders. Weathering conditions suggested that the boulders may have been formed by secular weathering prior to their deposition on the Iowan plain. Finally, the distribution and mineral characteristics indicated deposition along a northwest-southeast axis. Using this information various factors concerning boulder origin were considered.

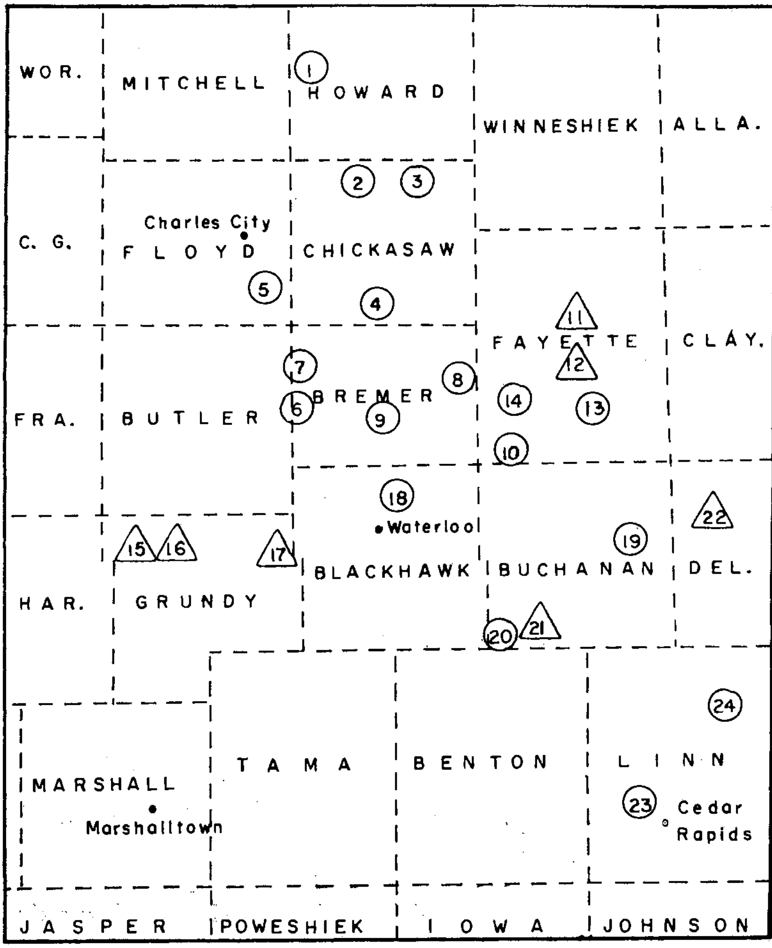

Fig. 5. Map of area covered in this study showing sample locations and granite variations. Circles identify granites exhibiting common characteristics, triangles identify those which do not.

Origin of the Iowan Boulders

The first step in considering the origin of the Iowan boulders was to locate available direction indicators. The direction of the source regions having been determined, all possible regions of bedrock granite were studied by literature description and field investigation and the general source area was determined. Finally, some features regarding the mode of origin of the boulders were considered.

Direction Indicators

Both the distribution of the Iowan erratics and minor changes in feldspar color evidence a northwest-southeast axis in the deposition of these boulders. This would mean that the Iowan glaciation had moved, generally, in a southeasterly direction.

The few glacial striae found in the underlying limestone of northeast Iowa support this direction of ice movement. There is some possibility that these striae may have been derived from the earlier Kansan advance (Alden and Leighton, 1915). Numerous striations and grooves of Iowan origin found in the Sioux quartzite of southeastern South Dakota show a definite south-southeast trend (Flint, 1955). The Iowan drift borders in eastern Iowa and central South Dakota are also strongly indicative of an advance in this direction. The westward extension of the Iowan drift into South Dakota adds proof to the Keewatin origin of the Iowan ice sheet.

Source Regions

Because of the apparent Keewatin origin of the ice, areas considered as possible source regions were already limited to Minnesota, the eastern margin of the Dakotas and southern Manitoba and Ontario. An origin to the northeast in the Lake Superior-northern Wisconsin area is not tenable because of the absence of evidence of Iowan drift in this area and, furthermore, the unglaciated areas of southeast Minnesota and southwest Wisconsin intervene in any but a round-about path to the present area of deposition.

The remaining source areas to be considered are shown on the map in Fig. 6. It should be noted here that numerous small granite intrusives are located throughout the northern half of Minnesota and southern Ontario which are not shown on Fig. 6. The Iowan boulders cover an area up to 80 miles wide and nearly 150 miles long. This immense area and volume of one type of granite certainly requires a relatively large source region. For this reason the small intrusives were omitted.

Most of the southern one-third of Minnesota is overlain by sedimentary rock. An exception are the granite outcrops along the Minnesota River in southwestern Minnesota, extending a short distance into South Dakota. Samples of these outcrops indicated a dark-red, coarse-textured granite with a gneissic structure; quite distinct from the Iowan boulder granite. A glacial advance from this region should also have passed over the Sioux quartzite outcrops just south of this region and one would expect to find frequent quartzite erratics in the Iowan drift. Pebble counts of the Iowan indicate very little quartzite, especially as compared to the Kansan drift of this same area (Kay et. al., 1943). Both the

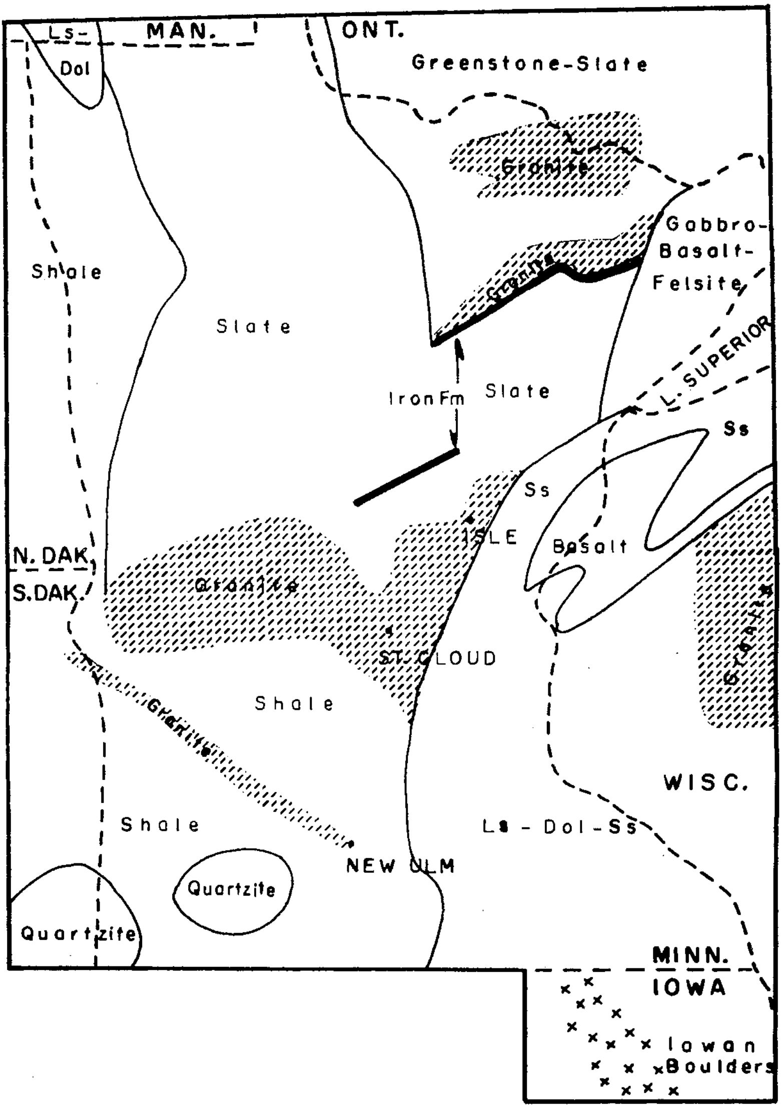

Fig. 6. Generalized bedrock map of Minnesota and adjacent regions. (Modified from Wright, 1962.)

quartzite and the coarse-textured granite are possible sources of the large boulders found in the Kansan drift of southern Iowa, but do not appear to be related to the Iowan granites.

The remaining bedrock in South Dakota and all of that found in eastern North Dakota is Cretaceous shale, eliminating these areas as source regions. The bedrock of southern Manitoba is largely carbonate with a small slate-greenstone region along the eastern border.

The most logical source regions are the large granite outcrops of central Minnesota and the batholiths located north of the Mesabi Iron Range. The granites of extreme northern Minnesota and southern Ontario consist of a number of distinct batholiths showing a variety of lithological characteristics. Grout (1929) described the granite of the Saganaga region of Minnesota-Ontario as having characteristic quartz phenocrysts. Those located in the Vermillion region are generally non-porphyritic (Grout, 1925). The Kekequabic granite stock showed only small quantities of quartz and biotite as described by Stark (1927). The Snowbank Lake region includes a variety of granites, most of them sugar-grained and generally high in hornblende content (Sanders, 1929). Each of these granites contains features by which it may be definitely distinguished from the prominent granite of the Iowan boulders.

Several other factors also aided in eliminating these Minnesota-Ontario granites as possible source regions. The frequent variation in the granite types would suggest a similar variation in the granite stock of the boulders. An origin in this area would have meant transporting the boulders over a distance of about 500 miles, while the number of extremely large boulders found in the drift area would conceivably indicate that these boulders have been transported somewhat shorter distances. Finally, the direction indicators discussed previously favor a source region further west; however, glacial ice flow is often very indirect being readily influenced by land elevations—generally flowing downhill. The combined strength of all of these factors makes a far northern source region very unlikely.

The only region remaining was the large area of granite bedrock found in central and west-central Minnesota. A number of features make this area a favorable source region. It is located directly in line with the present orientation of the Iowan boulder deposits. It is also reasonably close to the boulder deposits, being only 250-300 miles distant. Several granite outcrops in this region were examined and literature descriptions of others were studied; these showed favorable likenesses. The outcrops in the St. Cloud and Isle region are a variety of red, gray, and pink granites, medium to coarse grained, with angular feldspar crystals as long as ¾ inch in the pink varieties and about ¼ inch in the gray granites. The gray granites showed a greater resemblance to the boulder types, being finer grained than the pink varieties and having phenocrysts of comparable size. The mineral content of the gray granites was similar to that of the boulders, while the red granites had a somewhat higher feldspar content—about 75 per cent (Schwartz and Thiel, 1954).

More strong evidence that this is the boulder source region lies in the structure of the rock. The joints and sheet planning of the rock are at such distances that ten-foot blocks may be cut (Schwartz and Thiel, 1954). This solid structure is a must for boulders as large as the Iowan monoliths to withstand the stresses of extensive glacial transportation.

The combination of all of these factors make the central Minnesota source region reasonably certain. Attempts to determine the exact area of origin met little success. The entire bedrock area west of St. Cloud is overlain by 200 to 300 feet of drift and no outcrops were found (Leverett, 1932). Even in the area between St. Cloud and Isle most of the rock is deeply buried under glacial drift with only occasional dome-shaped masses occurring near the surface.

Some evidence favors an origin in the eastern half of the large granite bedrock area. The eastern half shows definite lithological relationships and in this region the bedrock appears near the surface in dome-like structures. Structural features of this nature are generally more exposed and are, therefore, most likely to be subject to boulder production, either by pre-glacial weathering or by glacial quarrying. Both of these features may occur in the western half of the granite area and thus favor the eastern region only because they are known to be present. It is also interesting to note the trend from pink and red granites near St. Cloud, to a gray granite at Isle, paralleling the trend in color of the boulder granites.

Reasonable evidence has been found to ascribe the boulder source region to the large granite body of central and west-central Minnesota. A more specific location can only be said to favor the eastern parts of this area because of the known evidence observed in that area.

Mode of Origin

The features and occurrence of the boulders suggested several factors regarding their origin and early history. The mere fact that very large boulders occur indicates that they were formed well below the outer surface of the original granite mass. Sheet structure in granite bodies becomes more widely spaced as depth increases, hence the size of the boulders produced will also increase with depth (Jahns, 1943). This is probably the predominant factor in accounting for the infrequent occurrence of extremely large boulders in most drift areas. Distance traveled and mode of transportation would be additional limiting factors.

In the earlier discussion of weathering features it was suggested that the boulders were formed by a process of secular weathering and exfoliation rather than by glacial quarrying. Glacial crushing and grinding tend to produce faceted rather than rounded surfaces. Since Illinoian glaciation appears not to have covered central and west-central Minnesota (Leverett, 1932), this allows over 500,000 years for boulder production by secular weathering. It is even possible that the source region escaped Kansan glaciation, increasing the time span considerably.

The boulders could not have been carried in the basal debris of the glacier, which acts as the grinding tool and thus readily grinds rock into much smaller pieces. The large boulders must have been carried above the basal material during most of transport and then deposited as the underlying ice melted away, leaving a wide deposition plain.

Summary and Conclusions

The analysis of boulder samples indicated that a central body of single granite stock included more than 80 per cent of all large boulders within the Iowan drift area. Distribution features and glacial striae gave evidence of a north or northwest direction of origin.

A study of the granite bedrock regions of Minnesota and adjacent areas ensued. The characteristics of the granite bodies eliminated all areas except the large granite mass in central and west-central Minnesota. The location of this area and the rock texture all confirmed this to be the source region. The exact location of origin could not be determined because of the extensive drift cover.

The variations and degrees of weathering of some of the boulders suggested that this had not entirely taken place since their deposition. It is very likely that the boulders were formed by a long period of secular weathering prior to their glacial transport.

Pebble analyses of the Iowan drift, traced back to source areas where possible, would yield further information regarding the path of the Iowan ice. A detailed petrographic study of the Iowan granite and the granite outcrops of central Minnesota should give evidence of the petrographic relationships and might also give evidence toward a more exact source area.

A complete study of the several large boulder areas in the Kansan drift of southern Iowa (Kay, 1916; Lugn, 1926; Tuttle, 1959), could throw additional light on the occurrence of extremely large boulders.

Acknowledgements

The authors are grateful to Dr. R. R. Haun for encouraging counsel and Dr. C. S. Gwynne of Iowa State University for several stimulating discussions during the course of this study.

Table 1. Location and Size of Boulders Sampled

Sample Number	Size* (feet)	County	Township	Section	Location ¼ sect	Miscellaneous Features
1	9x9x5	Howard	Jamestown	21	SE	contains aplitic dike
2	28x28x20	Chickasaw	Washington	3	SW	perched on a hill
3	13x10x8	Chickasaw	Stapleton	6	NE	two large boulders
4	10x10x2	Chickasaw	Jacksonville	10	SW	
5	40x30x12	Floyd	Riverton	22	SW	largest boulder found
6	12x8x2	Bremer	Lafayette	18	SE	located on a hillside
7	16x12x2	Bremer	Lafayette	6	NE	
8	10x8x8	Bremer	Sumner	10	NW	numerous boulders
9	8x6x4	Bremer	Warren	35	NE	
10	10x10x6	Fayette	Jefferson	31	SE	extremely faceted
11	8x5x4	Fayette	Center	4	SE	several large boulders
12	7x4x4	Fayette	Center	27	NW	contains granitic dike
13	4x4x4	Fayette	Smithfield	28	NE	igneous contact
14	18x18x10	Fayette	Fremont	23	NE	
15	8x6x2	Grundy	Pleasant Valley	31	NW	badly weathered
16	13x12x5	Grundy	Pleasant Valley	31	NE	
17	28x18x6	Grundy	Fairfield	13	NE	completely rounded
18	12x9x4	Black Hawk	Mount Vernon	36	N	badly faceted
19	15x6x4	Buchanan	Fremont	34	SE	many fractures
20	12x6x2	Buchanan	Jefferson	34	SE	badly faceted
21	8x5x4	Buchanan	Jefferson	31	NW	
22	7x4x3	Delaware	Honey Creek	—	—	
23	16x7x4	Linn	Clinton	30	SE	
24	10x10x7	Linn	Buffalo	29	NE	

*The third dimension—height—was measured above the drift surface, the boulder may actually extend one or two feet below the surface.

Table 2. Sample Analysis of Iowan Boulders

Sample Number	Rock Type	Mineral Composition Percentages (feldspar)	(quartz)	(biotite)	Weathering	Miscellaneous Characteristics
1	porphyritic granite	55	30-32	13-15	slight	biotite occurs in streaky aggregates
2	porphyritic granite	55-58	35	7-10	extensive	common flesh-colored feldspars
3	porphyritic granite	55-58	35	7-10	some	
4	porphyritic granite	55	40	5	slight	
5	porphyritic granite	55	30-35	10-15	various degrees	feldspars mostly pink-colored
6	porphyritic granite	55-60	35	5-10	extensive	biotite distribution is not homogeneous
7	porphyritic granite	55-60	35	5-10	some	fewer phenocrysts than most samples
8	porphyritic granite	55	40	5	some	local concentrations of quartz
9	porphyritic granite	55	40	5	slight	fine-grained
10	porphyritic granite	55-60	35	5-10	some	flesh-colored feldspars
11	micro-granite	68	30	2	slight	grain size up to 0.5 mm
12	biotite granite	52-55	30	15-18	slight	glassy luster, biotite occurs in aggregates

Table 2. (continued)

Sample Number	Rock Type	Mineral Composition (feldspar)	Percentages (quartz)	(biotite)	Weathering	Miscellaneous Characteristics
13	porphyritic granite	58-60	35	5-7	extensive	
14	porphyritic granite	58	35-38	5-8	extreme	
15	coarse granite	—	—	—	extreme	too badly weathered to determine composition
16	coarse granite	70	20-25	5-10	some	dark, uneven, coarse-grained granite
17	granite porphry	70	28	2	very little	phenocrysts measure several inches across
18	porphyritic granite	55-60	35	5-10	slight	flesh-colored feldspars
19	porphyritic granite	55-58	35	7-10	extensive	phenocrysts measure up to 15 mm
20	porphyritic granite	55	35-38	7-10	extensive	well defined feldspar crystal planes
21	normal granite	65	30	5	slight	fine-grained red granite
22	normal granite	60	38	2	slight	glassy luster
23	porphyritic granite	55	38	7	extensive	feldspar phenocrysts smaller than usual
24	porphyritic granite	55	38	7	extensive	flesh-colored feldspars

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