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Quartz Grain Surface Textures as Indicators of Infilling Processes and Depositional Environments Associated With Ice-Wedge Casts in Northeast Iowa

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QUARTZ GRAIN SURFACE TEXTURES AS INDICATORS OF INFILLING PROCESSES AND DEPOSITIONAL ENVIRONMENTS ASSOCIATED WITH ICE-WEDGE CASTS IN NORTHEAST IOWA

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Abstract

Ice-wedge casts and polygonal patterned ground are common features of the Iowan Surface of Northeast Iowa. Paleoenvironmental studies in Iowa and adjacent states indicate that tundra conditions existed in Northeast Iowa between 21,000 and 16,500 years BP, the coldest part of late Wisconsinan time. Degradation of permafrost and formation of ice-wedge casts must have occurred near the end of this cold climate episode, which also promoted extreme erosion of the landscape in Northeast Iowa. The sediment-filled wedges in Northeast Iowa occur in pre-Illinoian till with the infilling material consisting mostly of sand. The details of the infilling history of the wedges are largely unknown.

Since quartz grain surface textures can be successfully used as fingerprints to identify sediment transport processes and depositional environments, we examined surface textures of quartz grains from ice-wedge casts using binocular and scanning electron microscopy in an effort to clarify this infilling history. Features indicative of glacial, fluvial, and eolian transport are evident. Preliminary results indicate that surface texture signatures and rounding of sand grains do not vary significantly throughout the wedges implying that the infilling of the wedges was fairly uniform and the infilling material homogeneous. Observation of the wedges does suggest that there were smaller periods of localized infilling such as slumping or brief washing in of material.

Introduction

Sand-filled wedges are a common feature in the pre-Illinoian glacial till of northeast Iowa. These wedges have characteristics of secondary wedge structures known as ice-wedge casts (Walters, 1994). The formation of such features requires a permafrost environment to give rise to physical parameters necessary for processes involved in ice-wedge development. Permafrost is commonly defined as ground that has been frozen (0°C or colder) for more than one year. Beyond the technical definition of permafrost, average ground temperatures of -5°C or colder are required to form deep, widely spaced cracks, such as those developing ice-wedges (Williams and Smith, 1989). Based on botanical evidence, the late Wisconsinan time, 21,000 to 16,500 year BP, would have provided the coldest environment in northeast Iowa during the last period of mid-continental glaciation (Baker, Schwert, Bettis, Kemmis, Horton, and Semken, 1991). This climate would have provided the environment necessary for large-scale ice-wedge polygon development.

During this relatively colder time, thermal contraction and cracking of the ground would have been likely to occur. Tensile stress in the cold ground builds up until it reaches a physical limit, the tensile strength of the soil, and causes a crack to form which relieves this stress. This type of cracking of the ground surface will form a polygonal network of nearly vertical cracks (Williams and Smith, 1989). Williams and Smith (1989) describe the process of these cracks filling with water to become ice-veins. After these ice-veins have been established they form a zone of weakness for cracking during subsequent winters. As these cracks reopen they fill with water and refreeze, growing the ice-wedge each year that the climate is adequate for this development. Once formed, this polygonal network has wedge-shaped troughs which display a V shape when viewed in cross section.

Following this period of glaciation, the area between the Des Moines Lobe and the Lake Michigan Lobe ice advances would have seen a warming in the climate. With this warming, the ice-wedges would have melted, leaving a roughly wedge-shaped void where the ice had previously been. Some slumping of material from the wall of the wedge cavity would have caused slightly irregular wedge shapes. These voids eventually fill with sediment to form the features currently seen on the Iowan Erosion Surface known as ice-wedge casts. This process of secondary wedge filling indicates a "wet" permafrost as opposed to a "sand wedge" which is a primary infilling of a crack with sediment, due to an arid environment (Dixon and Abrahams, 1991). These sand wedges are primary infilling features as the wedges that become filled with sediment were not previously filled with ice.

Field observations and sampling

A known site of ice-wedge casts, approximately six km northeast of Waterloo, was visited on October 7, 2006. Several ice-wedge casts were exposed due to mechanical removal of material at this site. This removal of material created a vertical face that exposed the several wedges and caused their wedge shape to be easily recognized. Three wedges were selected for observation and three sand samples were collected from each of these wedges for lab observation. The material filling the wedges was visually observed to be mostly sand, consistent with sediment studies from other wedges in northeast Iowa (Lewis, 1990).

The first wedge measured approximately 1.7 meters deep and 88 cm wide at the top (Fig. 1). The wedge was located in clayey glacial till and was composed mostly of medium to fine grain, loose, brownish sand. There was no obvious stratification, and some material in the 15 cm of the top of the wedge, nearest the surface, seemed to be disturbed as though some bioturbation had taken place. This wedge, as well as the other three sampled, was oriented in an east-west linear direction with an exposed cross section such that the left of the cross section was to the north. This wedge was not perfectly wedge shaped and was wide at the top with the main vein of the wedge protruding from the right (south) side of the wedge instead of being centered about the wide top.

Three samples were taken from this wedge. The samples were taken at depths of 10 cm, 55 cm, and 150 cm (Fig. 1). I refer to these samples as "wedge y, sample x" where y denotes the wedge number with wedge 1 being the north-most wedge and 3 being the south-most wedge. Similarly, I used x to denote the sample number with sample 1 being the sample from the lowest part of the wedge and 3 being from the portion of the wedge nearest the surface.

Figure 1. Ice-wedge cast 1, from top to bottom: sample 3, sample 2, sample 1.

Wedge 2 was located in blue-gray clayey till about six meters south of wedge 1. The wedge was about 180 cm deep and about 65cm wide at its top, with an orientation trending southward with depth. The sand located in this wedge was observed to be quite similar to that of wedge 1. The contact surface between the sand and surrounding till was noted to be very abrupt, causing the wedge's shape to be well defined (Figs. 2, 3 and 4). A few wisps of whiter sand were also noticed in the wedge (seen at tip of knife in Figures 3 and 4). Such distinguishing sand lends itself to the idea of distinct periods of infilling. The samples from this wedge were taken from 30, 90, and 170 cm below the surface.

Figure 2. Ice-wedge cast 2, sampled similarly to ice-wedge cast 1.

Figure 3. Transition between clay rich till and sediment filled wedge.

Figure 4. Noticeably different texture from till to wedge, also whiter sand at tip of knife.

Wedge 3 was located about 6 meters south of wedge 2. This wedge had an odd shape as it was approximately three meters wide at the top with a depth of about 170 cm extending down the left quarter of the wedge (Fig. 5). It is likely that this wedge exposure was located at a node in the polygonal network. The sand in this wedge was similar to that of wedge 2 with wisps of whiter sand, but there were several joints (cracks) in the indurated sand. A small amount of stratification was noted which may represent pulses of deposition by flowing water during the infilling of the wedge. The movement of water transporting iron may have also played a role in forming the induration that was noticed in this sand. The samples in this wedge were taken at depths of 90, 45, and 90 cm with sample 1 being taken approximately 30 cm south of sample 3. Sample 3 was taken in an area including one of the whiter wisps of sand.

Figure 5. Ice-wedge cast 3 extending beyond the edges of the photograph.

Lab observations

A visual inspection was made with a binocular microscope for general characteristics of the sand samples. Seventy (70) grams of sand from each sample were inspected. Samples from wedge 1 were mostly medium to fine grain, rounded to subrounded sand. The vast majority of the sand was quartz with some feldspars and lithic fragments of granite. There were some organic materials in the samples such as rootlets, soil, and possible byproducts of burrowing animals. Although there were some consolidated areas of whiter sand, the majority of the sand was iron stained (Table 1).

In wedge 2, the sand was mostly rounded to subrounded, heavily frosted, medium to fine sand as well. Samples 2 and 3 from this wedge showed some induration. There were also some consolidated areas of whiter sand in sample 1. The majority of the sand from this wedge was heavily iron stained though (Table 1).

Wedge 3 samples showed induration with holes up to 7mm in diameter in tact, likely caused by burrowing animals in the sand. The sand grains were generally subrounded, frosted, medium to fine with the majority being quartz. Like the other two wedges, the sand from this wedge showed significant iron staining (Table 1).

Wedge # / Sample #	1	2	3
1	7.5 YR 5/6 Strong brown	10YR 6/4 Light yellowish-brown	10YR 5/8 Yellowish brown
2	10YR 5/8 Yellowish brown	10YR 5/8 Yellowish brown	10YR 6/8 Brownish yellow
3	7.5 YR 5/6 Strong brown	10YR 5/4 Yellowish brown	10YR 5/8 Yellowish brown

Table 1. Munsell soil color descriptions

Sample preparation

Quartz grains have received considerable attention in grain surface texture studies such as those done by Lewis (1990) and Mahaney (2002). Quartz is fairly chemically resistant to weathering and has a hardness of 7.0 on the Mohs hardness scale (Press and Seiver, 1998). This remarkable medium is able to receive surface microtextures and hold them for a substantial amount of time before they become weathered beyond recognition or overprinted. Due to the chemical and mechanical resistance of quartz to weathering, the majority of today's sands are rich in quartz. This is the case with sand found in the ice-wedge casts from this study.

Samples collected were generally iron stained and with many displaying various degrees of induration. Koch (2005) describes iron-clay bands in sands from northeast Iowa, likely a secondary deposit due to groundwater infiltration, which seems to be consistent with sand from the wedges in this study. With the surface of individual grains being of interest to this study, the samples needed to be cleaned to separate grains and remove surface deposits and stains. This was accomplished with a two part process of cleaning with hydrochloric acid (HCl). The first step was to boil each sample in a solution of 10% HCl for 10 minutes as was done by Lewis (1990). The samples were then rinsed with distilled water and dried. Following this, samples were placed in an ultrasonic cleaner with 10% HCl for 1 hour. The combination of these two steps separated the grains and removed iron stains, calcium and other mineral deposits from the grain surfaces.

Scanning electron microscope (SEM) analysis methods

Following the cleaning process, most of the quartz grains were from the fine to very fine fractions with a few from the medium fraction. This was fairly representative of the samples as a whole, but seen more clearly once the grains had been separated, keeping in mind that only a portion of the sand collected from each sample was cleaned. In an attempt to avoid post-depositional fragments due to processes such as frost cracking, the smaller quartz grains were not the focus of the SEM study. Approximately 15 of the larger medium size grains from each of the cleaned samples were mounted on stubs for scanning electron microscope (SEM) study. Once mounted, the stubs were coated with 40 nm of gold using a Hummer VII sputter coater (Fig. 6). The actual thickness of the gold layer likely varied from the 40 nm specified to the machine, but the surface appeared to be sufficiently well coated to provide enhanced SEM electron flow. The goal in coating the samples was to provide a more conductive path for electrons to obtain clearer images without compromising the surface textures of the quartz grains.

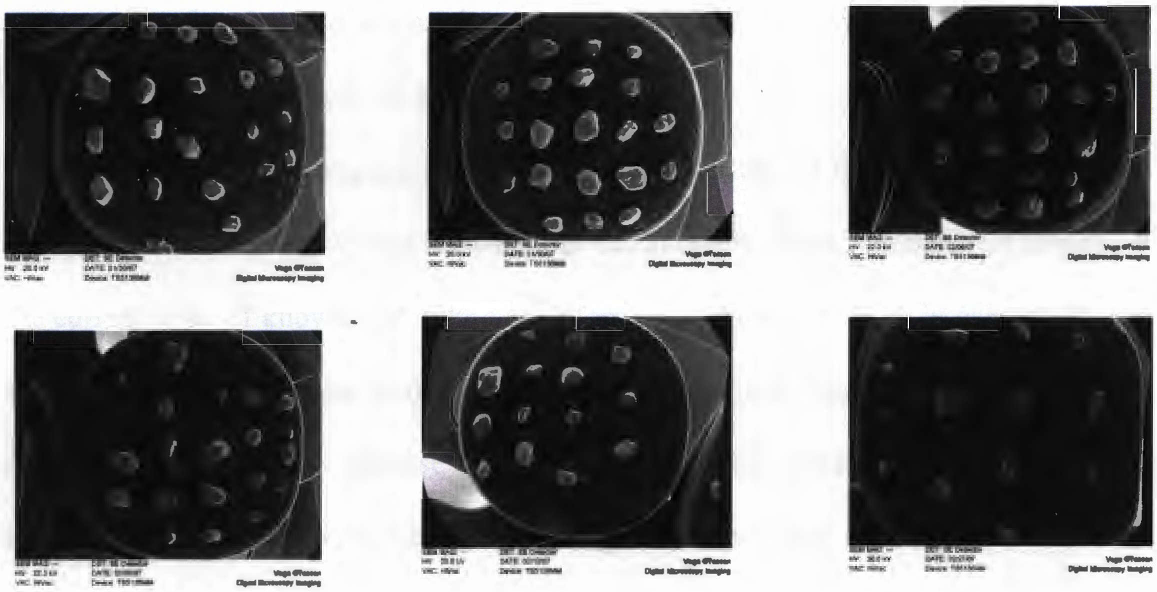

Figure 6. Quartz grains mounted on stubs for scanning electron microscope photography.

A Vega 5136MM scanning electron microscope was used to capture digital images of several quartz grains from each sample prepared. To ensure a representative sample of surface textures, approximately eight grains from each sand sample were captured under SEM magnification. A total of 72 grains were observed under SEM magnification. Care was used during the selection and image capturing process to provide unbiased and representative quartz grain samples.

Under SEM magnification microtextures indicative of glacial, eolian and fluvial transportation environments can be seen on quartz sand grains. Although many of these microtextures can be found on grains from more than one of these environments, there is at least one microtexture unique to eolian, fluvial and glacial transportation environments. These unique textures were targeted in this study to determine the transportation environment that was present during the infilling of these wedges. During SEM imaging, signatures from all three of the major transportation methods were seen in our samples. Many of the grains showed signatures of at least two distinct methods and overprinting was easily seen on several grains.

As with any geological analysis, the interpretations of these surface textures as indicators of transportation and depositional environment should be taken in context of the current body of knowledge. The new information should be taken in context of what is already known to provide a stronger inference for the likely history. As a story is made more credible by many witnesses, the presence of these surface textures should give testimony to the paleoenvironment and infilling of these wedges.

Statistical analysis methods

Statistical analysis was performed on the sand samples in an effort to determine trends for surface texture indications differentiated by wedge, depth, and individual samples. The SEM magnified grains were assigned a number from 0 to 0.5 indicating their edge rounding by visual inspection using the Powers roundness scale (Fig 7). This number was used as an indication of depositional environment with well rounded grains indicating an eolian environment, subrounded and subangular grains being an indicator of fluvial environments, and angular grains being an indication of glacial environments. As used in this statistical work, very angular assigned 0, angular assigned 0.1, subangular assigned 0.2, …, well rounded assigned 0.5. These assignments were weighted for each transportation type so that an angular grain would receive a high indication for glacial, medium indication for fluvial and weak indication for eolian. A moderately rounded grain would receive a strong indication for fluvial and weaker indications for glacial and eolian. A well rounded grain would receive a high indication for eolian, moderate indication for fluvial and weak indication for glacial (See Figures 8, 9, and 10).

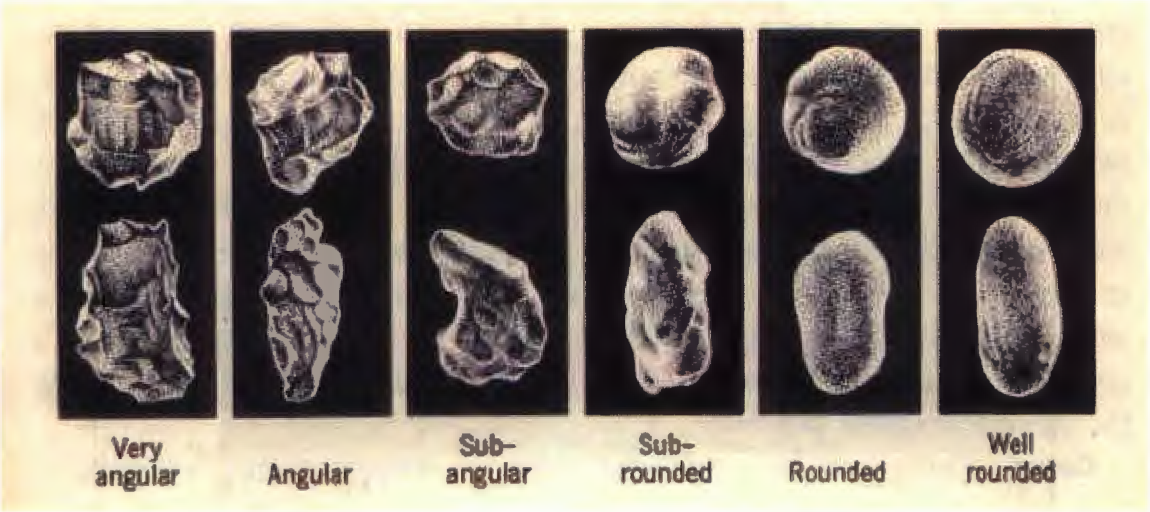

Figure 7. Powers roundness scale. Image from http://people.uncw.edu/dockal/gly312/grains/grains.htm, originally from Powers, M . C., (1953).

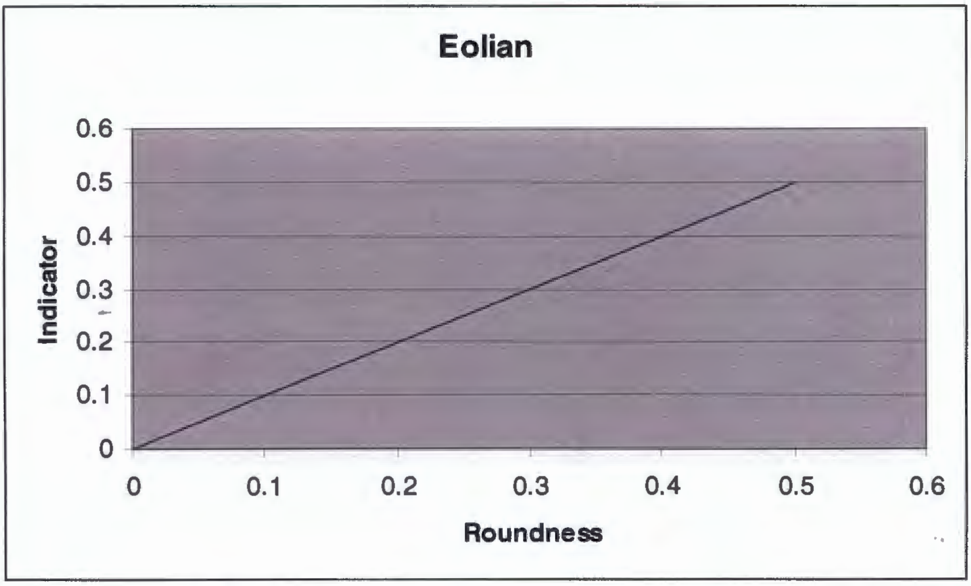

Figure 8. Eolian indication determined by roundness.

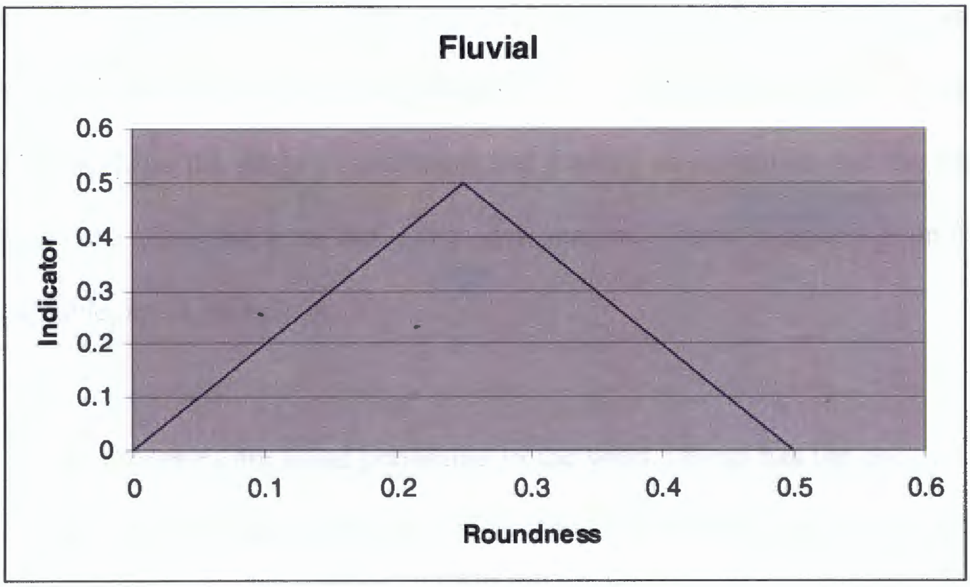

Figure 9. Fluvial indication determined by roundness.

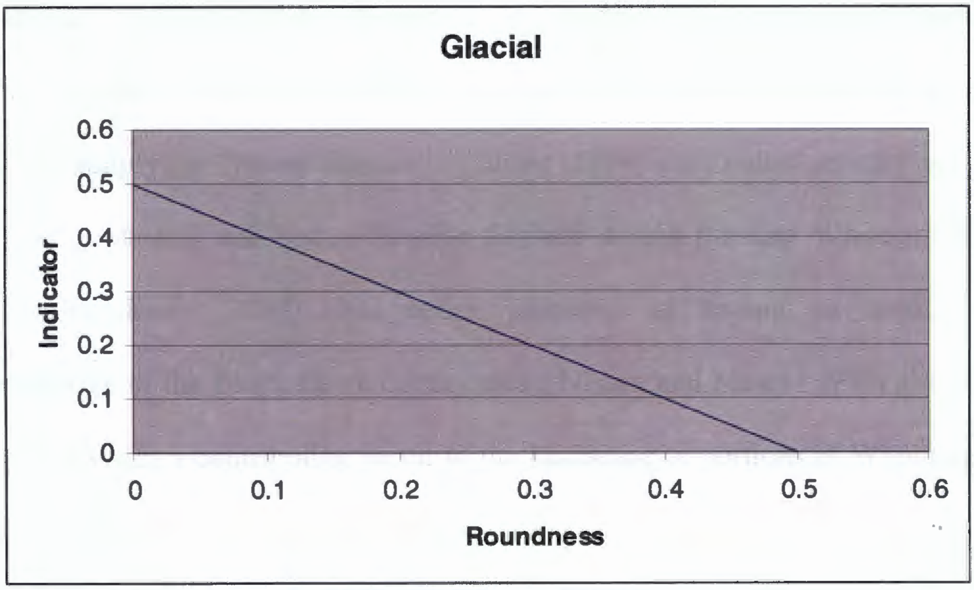

Figure 10. Glacial indication determined by roundness.

The second component of the indication number for each grain was based on the percentage of the grain surface covered by a texture strongly indicative of eolian, fluvial, and glacial environments. Each environment was assigned a percentage and weighted from 0 to 0.5 (0 being 0% surface coverage and 0.5 being 100% surface coverage). The sum of this value and the rounding value were used in the statistical analysis to give an indication for each environment. This sum gave rise to a value for each grain from 0 to 1 for each environment with 0 being an extreme indication that the grain was not deposited into the wedge from the given environment and 1 being an indication that the grain was almost certainly deposited from the given environment. For a complete grain by grain indication table, see Appendix A.

Eolian

Eolian processes are those pertaining to the wind. Wind has the ability to shape surfaces of the earth on large and small scales. As large-scale eolian activity is moving large quantities of sand to sculpt a large geologic feature, it is also sculpting individual grain surfaces. Eolian activity is thought to have had a large impact on the landscape in which the studied ice-wedge casts are located. This area is known as the "Iowan Erosion Surface" or simply the "Iowan Surface". Zanner (1994) cites eolian activity as having a major role in shaping the Iowan Erosion Surface during the late Wisconsinan time.. More locally, Koch (2005) cites eolian processes as having an impact on the geomorphology of the Black Hawk county area. Nissen and Mears (1990) also interpret eolian processes as a contributing factor to the landscape of portions of Wyoming where ice-wedge casts are found.

Eolian signatures were found on many sand grains viewed in this study. Most grains were rounded to subrounded with a few being subangular and none being classified as angular. A typical rounded quartz grain has no obvious corners and is nearly spherical (Figure 11). This rounding is generally a sign of eolian transport. The microtexture diagnostic of eolian transport is upturned plates (Mahaney, 2002). These upturned plates are seen under SEM magnification as being somewhat similar to a peeling fingernail. The plate becomes partially separated from the surface and the upturned edge is seen as a lighter shaded arc.

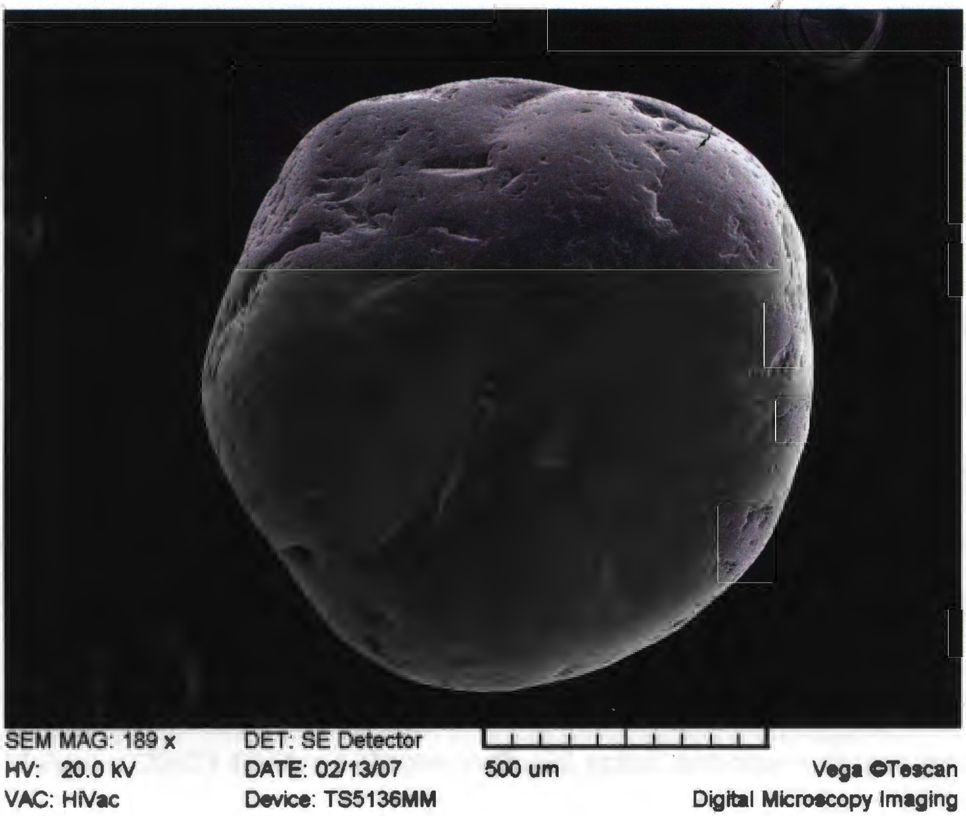

Figure 11. Typical rounded grain with upturned plates. This grain also shows v-shaped percussion marks.

Due to mechanical and chemical weathering after deposition, these upturned plates may become partially eradicated. This leads to a surface texture that Elzenga et. al. (1987) refer to as an "orange peel structure" forming with the solution/precipitation of silica. This microtexture is seen plainly on most of the grains seen in our samples, but is a weathered version of the more diagnostic texture of upturned plates, so caution must be exercised when interpreting this microtexture.

The distinctive signature of upturned plates and/or orange peel texture appeared to be present on 70% of grains in wedge 1, 36% of grains in wedge 2, 74% of grains in wedge 3, and 60% of all grains studied. Alternatively, 27% of sand grains from the lower samples of the wedge, 62% of the lower-middle grains, 71% of upper-middle grains, and 67% of upper grains showed eolian signatures. During statistical analysis it was determined that although samples means varied, there was no significant statistical difference between the samples. Statistical analysis was based on surface texture and edge rounding as indicators of eolian derivation as described above.

Fluvial

Fluvial transportation is the movement of material by running water. Like wind, water is also a powerful geomorphic agent. The sand grains in this study may have been moved by rivers such as the Cedar River to the west of the sample area as well as by intraglacial rivers formed by glacial melt water moving on or below the surface of the glacier. The glaciofluvial movement may have occurred several hundred miles from the wedges in the area of previously active glaciation of the Des Moines lobe.

Mahaney (2002) devotes a chapter to fluvial grains and cites v-shaped percussion marks as the most diagnostic microtexture for fluvial grains (Fig. 12). This signature was seen on many of the grains examined in this study. Statistical analysis showed some variation among the samples with respect to fluvial indication. Similarly though, there was no significant difference between grains from any of the samples based on surface textures and rounding as indicators of previously being in a fluvial movement.

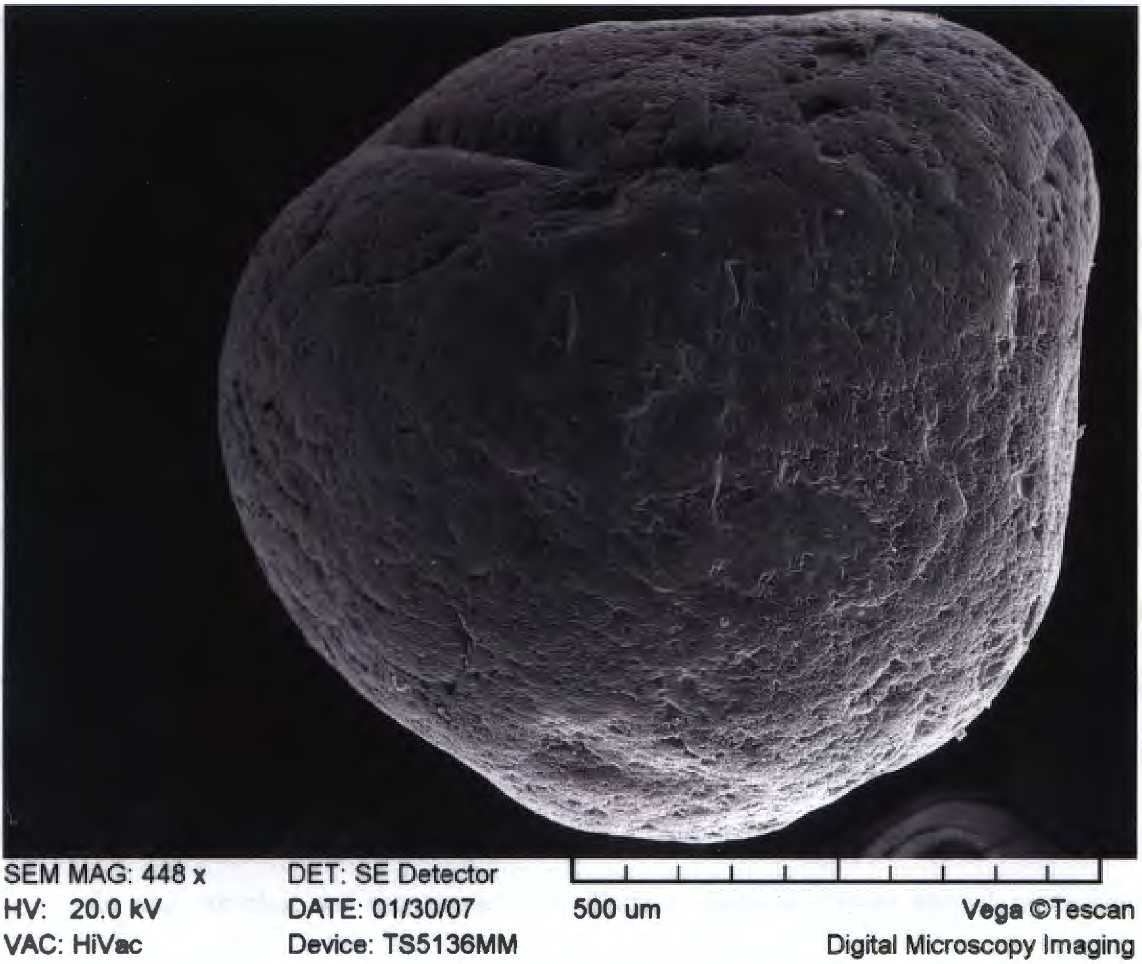

Figure 12. V-shaped percussion marks seen in the central portion with an orange-peel texture dominating the surface.

Glacial

Glacial transportation, as the name might suggest, is movement of material by glaciers. Because the underlying bedrock in Iowa is limestone, it is widely accepted that quartz sand grains were transported southward to the study area by glacial processes. Quartz is an abundant mineral in granitic glacial erratics found in large quantities in northeast Iowa. These erratics are too big to have been transported by wind, and the majority are too large to have been transported by water. As glaciers transport large materials, it is likely that the contact with ice or other objects in the ice will cause some degree of erosion on these granitic rocks, causing separation of mineral grains from the parent rock. In this way, glacial movement can both free and further transport quartz grains.

In light of the history that we are building with the ice-wedge casts, we assume a cold, periglacial environment during the formation of the wedges, and a warmer climate during sediment infilling. Thus, the grains found in the wedges are unlikely to have been deposited there as a direct result of glacial movement. A secondary form of transportation probably moved the majority of this material into the wedge. It is technically possible for some sediment to have been on the surface directly above the wedges during formation that would have become the lowest level of infilling. This would likely be a very small amount of sediment and almost certainly not a dominate part of our samples. With this in mind, it is quite probable that glacial signatures would be overprinted to some degree or perhaps completely eradicated by overlying signatures.

In our samples, we saw some very distinct signatures from glacial movement including parallel to subparallel lines created by conchoidal fracturing (Fig. 13). These subparallel lines are the diagnostic feature that Mahaney (2002) designates as being distinct to glacial transport. Although this signature is diagnostic, it may be the hardest to interpret in this situation. Given the history, many of these signatures may be blurred or completely erased. Although quartz is relatively stable, it does still weather and change over time; this just happens a bit more slowly in this resistant mineral. With these changes, the earlier signatures can become difficult or impossible to interpret. The grain in Figure 13 is a bit more idealistic than most of the grains that we saw showing glacial signatures. Most of the grains in this study have been rounded and weathered to some degree as seen in Figure 14.

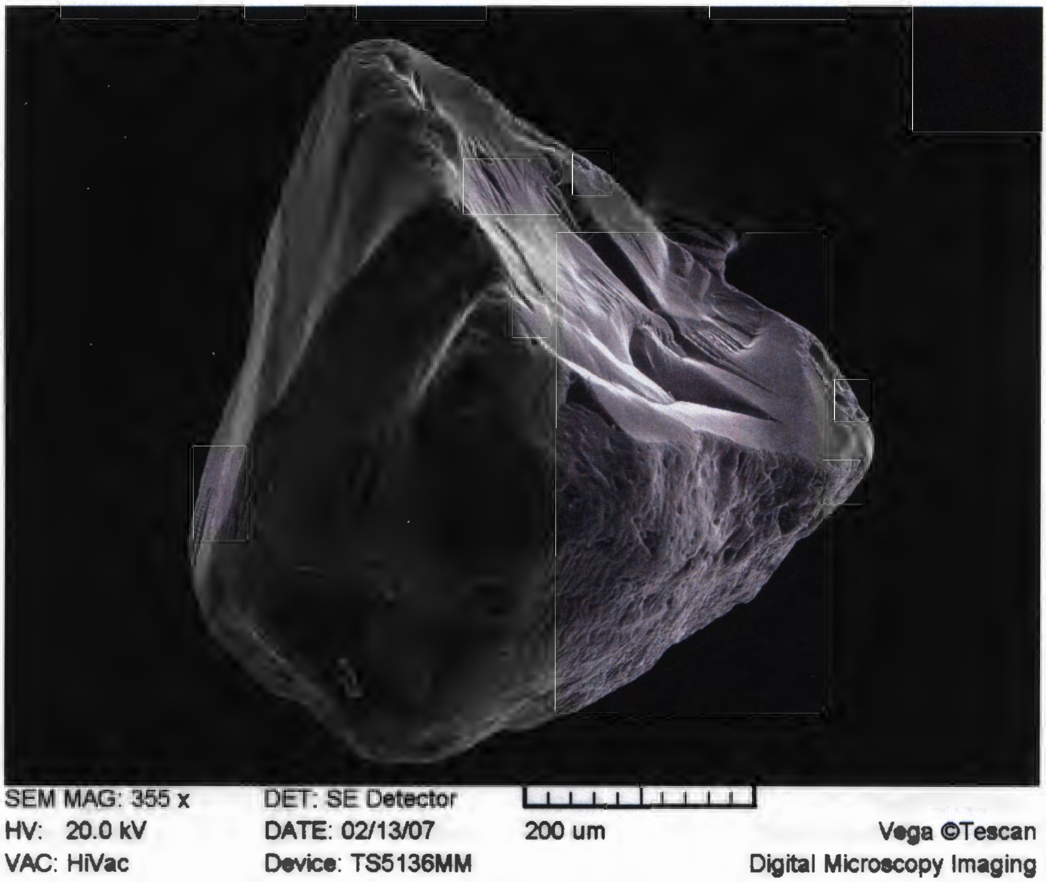

Figure 13. Quartz grain showing subparallel lines of conchoidal fractures.

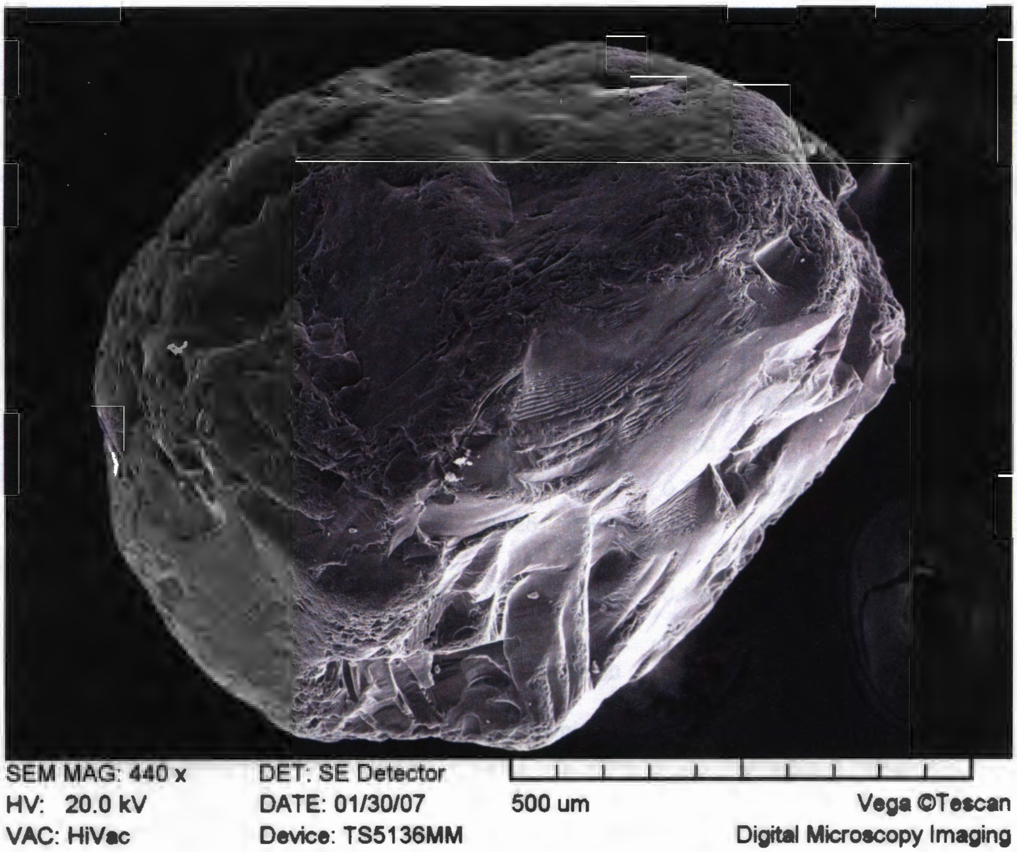

Figure 14. A more typical grain showing subparallel lines along with rounding, upturned plates and v-shaped percussion marks.

Statistical analysis of glacial signatures showed no difference between the samples with respect to surface texture and rounding as indicators of glacial transport. For a summary of sample and wedge summary statistics, see Figure 15.

	Eolian				Fluvial				Glacial			
	mean	min	max	std.dev.	mean	min	max	std.dev.	mean	min	max	std.dev.
Sample												
1	0.617	0.300	1.000	0.218	0.400	0.150	0.550	0.550	0.317	0.000	0.550	0.284
2	0.444	0.000	0.750	0.174	0.422	0.075	0.600	0.925	0.434	0.150	0.925	0.275
3	0.564	0.150	0.850	0.119	0.406	0.250	0.550	0.800	0.358	0.100	0.800	0.261
4	0.569	0.150	0.750	0.134	0.397	0.200	0.600	0.850	0.359	0.150	0.850	0.225
5	0.391	0.125	0.800	0.104	0.413	0.225	0.500	0.850	0.547	0.125	0.850	0.212
6	0.392	0.000	0.750	0.195	0.447	0.050	0.700	0.950	0.467	0.150	0.950	0.270
7	0.359	0.125	0.700	0.144	0.428	0.250	0.650	0.800	0.513	0.175	0.800	0.247
8	0.400	0.150	0.825	0.148	0.442	0.175	0.600	0.750	0.447	0.000	0.750	0.290
9	0.555	0.325	0.725	0.105	0.508	0.325	0.650	0.550	0.293	0.150	0.550	0.131
Wedge												
1	0.541	0.000	1.000	0.266	0.409	0.075	0.600	0.149	0.370	0.000	0.925	0.259
2	0.450	0.000	0.800	0.223	0.419	0.050	0.700	0.147	0.458	0.125	0.950	0.241
3	0.438	0.125	0.825	0.204	0.459	0.175	0.650	0.132	0.417	0.000	0.800	0.239

Figure 15. Summary of statistical indicators toward the given environment with samples 1-3 being from wedge 1, samples 4-6 being from wedge 2 and samples 7- 9 being from wedge 3.

Summary and conclusions

All of the grains viewed showed some degree of edge rounding with the vast majority showing upturned plates and/or orange peel textures. This shows a strong indication that eolian transportation played a key role in the recent history of many of these grains. Glacial signatures were less numerous on the grains and overprinted in some cases. Glacial transportation was not likely to be the most recent transportation to act on these grains, but based on the underlying bedrock and likely origin of these quartz grains, it is no stretch to infer that these grains were almost certainly glacially derived at some point in their distant history. Fluvial signatures were seen frequently on grains, but were generally isolated and did not appear to dominate the surface of the majority of grains. It is likely that fluvial transportation played a role in transporting these quartz gains nearer to the wedges in which they were deposited.

Statistical analysis indicated that there was no statistically significant difference between any of the samples at an alpha-level of 0.05. This suggests that the wedges were filled with material that had been transported in approximately the same way during the entire episode of infilling. The depositional environment seemed to be fairly steady for this duration based on this statistical analysis. Although the amount of time it must have taken to fill the wedges is largely unknown, it appears that the environment was not significantly varied from the beginning to the end of this period.

Even though the eolian, fluvial, and glacial indicators varied slightly with means of 0.468, 0.433, and 0.419 and standard deviations of 0.229, 0.142, and 0.244 respectively, statistical analysis determined that even the indicators of transportation failed to show significant differences. With a 90% confidence interval, we estimate that the true signature indicators for all sand grains from such wedges is (0.092,0.844) for eolian, (0.200,0.667) for fluvial, and (0.017,0.820) for glacial. Because all of these intervals intersect one another, we cannot be confident that the true values vary from one another. This implies that based on surface texture and rounding indications, it is likely that all three transportation types described in this paper played important roles in transporting quartz grains from their originating bedrock to their location in ice-wedge casts of northeast Iowa.

Suggestions for further studies

Due to the extensive work in preparing an adequate number of representative grain samples, the research done in this study was neither complete in analysis of the data gathered nor exhaustive in the area studied. At the beginning of this project, it did not seem to be as extensive of an undertaking as it turned out to be to really understand these surface textures. A thorough analysis of SEM surface textures would include a detailed analysis of several dozen surface textures for each grain. A person who is so inclined could make a follow up on this research by examining each grain from this study in detail and diagnose the individual surface textures described in Mahaney (2002) or Elzenga et. al. (1987). Other studies that would be interesting in light of the findings presented here include a study of more wedges or other sand-rich features, such as dunes or stringers, in the Waterloo area or other parts of northeast Iowa. The comparison of grain samples from other wedges or features may lead to a better understanding of depositional environments in northeast Iowa during late Wisconsinan time.

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Appendix A

Surface coverage percentages may total more than 100% due to strong overprinting. E rep, F rep, and G rep were used as statistical representatives for eolian, fluvial and glacial components of that grain respectively. Rep=(surface coverage)/200+F(rounding) where F(rounding) is described in Figures 8, 9 and 10 so that rounding and microtexture coverage were weighted equally in the rep number.

	Eolian % of surface coverage	**Fluvial** % of surface coverage	**Glacial** % of surface coverage	**Rounding**	**E rep**	**F rep**	**G rep**
Wedge1							
Sample1							
	100	30	0	5	1	0.15	0
	50	20	40	3	0.55	0.5	0.4
	20	30	50	2	0.3	0.55	0.55
Sample2							
	30	10	60	2	0.35	0.45	0.6
	40	30	30	3	0.5	0.55	0.35
	60	30	10	3	0.6	0.55	0.25
	70	20	10	4	0.75	0.3	0.15
	50	40	10	3	0.55	0.6	0.25
	10	30	60	1	0.15	0.35	0.7
	70	20	10	3	0.65	0.5	0.25
	0	15	85	0	0	0.075	0.925
Sample3							
	70	30	20	3	0.65	0.55	0.3
	10	10	80	1	0.15	0.25	0.8
	50	25	25	3	0.55	0.525	0.325
	15	15	70	2	0.275	0.475	0.65
	80	20	10	4	0.8	0.3	0.15
	90	10	0	3	0.75	0.45	0.2
	70	30	0	4	0.75	0.35	0.1
	20	20	60	2	0.3	0.5	0.6
	90	10	0	4	0.85	0.25	0.1
Wedge2							
Sample1							
	70	10	20	3	0.65	0.45	0.3
	10	0	90	1	0.15	0.2	0.85

	70	10	20	3	0.65	0.45	0.3
	30	40	30	3	0.45	0.6	0.35
	70	20	10	4	0.75	0.3	0.15
	80	15	5	3	0.7	0.475	0.225
	70	10	20	4	0.75	0.25	0.2
	30	10	60	3	0.45	0.45	0.5
Sample2							
	20	10	70	2	0.3	0.45	0.65
	5	5	90	1	0.125	0.225	0.85
	40	10	50	2	0.4	0.45	0.55
	40	20	40	3	0.5	0.5	0.4
	80	15	5	4	0.8	0.275	0.125
	20	20	60	2	0.3	0.5	0.6
	40	10	50	2	0.4	0.45	0.55
	20	10	70	2	0.3	0.45	0.65
Sample3							
	60	60	10	3	0.6	0.7	0.25
	40	40	20	4	0.6	0.4	0.2
	20	40	40	1	0.2	0.4	0.6
	10	10	80	2	0.25	0.45	0.7
	30	40	30	3	0.45	0.6	0.35
	10	20	70	2	0.25	0.5	0.65
	25	45	30	3	0.425	0.625	0.35
	0	10	90	0	0	0.05	0.95
	70	20	10	4	0.75	0.3	0.15
Wedge3							
Sample1							
	10	10	80	1	0.15	0.25	0.8
	80	5	15	3	0.7	0.425	0.275
	10	30	60	2	0.25	0.55	0.6
	25	25	50	3	0.425	0.525	0.45
	35	50	15	4	0.575	0.45	0.175
	20	20	60	1	0.2	0.3	0.7
	30	50	20	3	0.45	0.65	0.3
	5	15	80	1	0.125	0.275	0.8
Sample2							
	40	30	30	3	0.5	0.55	0.35
	10	20	70	2	0.25	0.5	0.65
	20	80	0	4	0.5	0.6	0.1
	60	30	10	3	0.6	0.55	0.25
	10	20	70	1	0.15	0.3	0.75
	40	30	30	2	0.4	0.55	0.45
	65	35	0	5	0.825	0.175	0
	10	20	70	1	0.15	0.3	0.75
	5	10	85	2	0.225	0.45	0.725

Sample3

40	40	10	3	0.5	0.6	0.25
25	25	50	2	0.325	0.525	0.55
40	40	20	3	0.5	0.6	0.3
50	25	25	3	0.55	0.525	0.325
50	15	35	2	0.45	0.475	0.475
65	25	10	4	0.725	0.325	0.15
70	30	0	3	0.65	0.55	0.2
75	15	10	3	0.675	0.475	0.25
60	30	10	4	0.7	0.35	0.15
35	50	15	3	0.475	0.65	0.275