Origin and Erosion of Spirit Mound

Cody Miller

Abstract

Spirit Mound is one of the few locations where we can stand in the exact location that Lewis and Clark stood 206 years ago, which makes the mound historically and culturally significant. However, little work has been done to understand the geological significance of the mound. Previous studies have correctly assumed that it has a glacial origin and is classified as a roche mountonee. To test this, Spirit Mound was measured using an autolevel and stadia rod and soils were augered to reveal evidence of past erosion. The survey measurements began at a benchmark and were taken every 20 meters along a north-south transect of Spirit Mound. The longitude and latitude were also recorded every 20 meters using a global positioning system device. Soil samples were collected at eleven different locations around the mound via hand auger. Samples were taken at 30 centimeter intervals to a maximum depth of 2 meters. Spirit Mound contains a core of Niobrara Chalk with a mantle of glacial till extending southward. It also appears streamlined and is oriented roughly north-south. Based on the survey data, the mound is likely a rock-cored drumlin. Land use of Spirit Mound has likely caused some erosion since the time of Lewis and Clark. A feedlot used to occupy the eastern side of the mound, resulting in decreased density of vegetation and increased cattle traffic. This likely led to localized erosion, supported by a buried soil found on the northeast margin of the mound. Some erosion from the top of Spirit Mound is also evident. Today, erosion is limited to the hiking trail during intense summer rain storms.

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Introduction

In 1804 Captains Meriwether Lewis and William Clark led a "Corps of discovery" into the newly acquired Louisiana Territory. The two Captains came across a mound rumored to be inhabited by little devils that shot arrows at anyone who dared to approach (Moulton, 1985). Lewis and Clark decided to investigate the mound. On August 25, 1804 Lewis and Clark stood atop of what is today known as Spirit Mound (Moulton, 1985). Spirit Mound has evolved since the time of Lewis and Clark, when it was covered by prairie grasses. In recent decades, this historic landmark was home to a cattle feedlot, farmhouse, concrete trench silo, numerous small buildings, and a tree shelterbelt (Elhoff, 2003). Concerned about the preservation of one of South Dakota's most precious historic landmarks, local Vermillion townspeople Jim Antonen, Loren Carlson, and Larry Monfore formed the Spirit Mound Trust in 1986. The goal of the trust was to raise the money necessary to purchase the mound and restore it back to its natural state (Elhoff, 2003). It was not until 2001 that the Trust could accomplish this feat (Elhoff, 2003). Today Spirit Mound, or Paha Wakan as the American Indians call it, is of great historical and cultural significance to the surrounding area. However, little work has been done to understand the geological significance of the mound.

Spirit Mound was formed by continental glaciation during the last ice age and appears to be streamlined, oriented parallel to the flow of the ice, with a bedrock core on its north end and glacial till extending from the south end. Streamlined glacial landforms include roche moutonnee, crag and tail, drumlin, rock-cored drumlin, and drumlinoids. Based on soil samples and surveying, the mound is likely a rock-cored drumlin. Land use of Spirit Mound has likely caused some erosion since the time of Lewis and Clark. Rain could have easily eroded bare patches on the mound during the feedlot years because of the decreased density of vegetation and increased cattle traffic. However, soil sample data suggests that erosion was localized, and only the northeast corner of the mound experienced any significant erosion.

Background

Several times during the last 2,000,000 years, during the Pleistocene epoch, continental glaciers moved south across eastern South Dakota. As each ice sheet advanced, it transported large erratics and smaller debris that formed glacial till. As the ice sheet melted, it deposited the material caught in the ice sheet's lower layers. The glacier deposited the debris and retreated. The last episode of glacial ice advances about 15 ka (Sweeney and Rathbun, 2010). It was the last episode of glaciations that deposited many of the glacial landforms that are exposed today. This includes Spirit Mound, a streamlined glacial feature oriented roughly north-south, formed by the movement of ice. Spirit Mound is surrounded by ground moraine composed of boulder-clay till mantled by thin, discontinuous loess (Christensen and Stephens, 1967). Spirit Mound Creek flows just south of Spirit Mound to the Vermillion River and resides in what has been interpreted as a glacial meltwater channel (Christensen and Stephens, 1967).

Streamlined glacial features generally form parallel to ice flow and can be used to determine local flow directions and flow conditions. These features include roche moutonnee, crag and tail, drumlin, rock-cored drumlin, and drumlinoid and are summarized here.

Roche Moutonnee

The Spirit Mound Trust defines Spirit Mound as a roche moutonnee (Spirit Mound Trust, 2003). A roche moutonnee is a streamlined mound of bedrock worn smooth and rounded by glacial abrasion (Sugden et al., 1992). Roche mountonnees usually exhibit groves and striae because of the weight and forward movement of the glacier on the bedrock. Roche mountonnees are widespread and usually found in groups. They generally vary from 1-50 meters in height and can be hundreds of meters long (Johansson et al., 2001). Although most roche mountonnees are small, some like the ones in Scotland can reach 160 meters high (Sugden et al., 1992). Roche Mountonnees have an abrading side and a plucking side. As the glacier moves over bedrock, rocks on the bottom of the glacier abrade the bedrock. This occurs on the stoss or abrading side (Sugden et al., 1992). The plucking side occurs on the lee slope of a roche mountonnee. Plucking occurs when the bottom of the glacier melts. The melt water seeps into the cracks of the bedrock and refreezes. Parts of the loose bedrock are then attached to the glacier and eroded away (Sugden et al., 1992). The stoss side of a roche mountonnee faces the upglacier side, whereas the lee side faces the downglacier side.

Drumlin

Drumlins occur when glaciers override previously deposited end moraines. The shear stress from the glacier flattens the end moraine out into a streamlined oval shape. The lee side of the drumlin indicates the direction of ice flow, and are oriented the opposite of roche mountonnee, with the lee side facing the upglacier. Because drumlins form from end moraine deposits, they are composed of till. Drumlins are usually 800 to 1200 meters in length, 30 to 45 meters high, and approximately 400 to 600 meters wide (Briner, 2007). Larger drumlins tend to be composed of coarser grained till than smaller drumlins (Briner, 2007). However, the finest grain till is usually found in the inter drumlin areas (Briner, 2007). The shape of the drumlin can be related to the speed of the ice sheet. Long and thin drumlins are formed from a fast moving ice sheet. Short and wide drumlins form from a slow moving ice sheet (Briner, 2007). Like roche moutonnees, drumlins are usually found in clusters (Briner, 2007).

Scientists still debate about how exactly drumlins form. Hart (1997) outlines three major processes for drumlin formation based on examples from around the world: 1) deformation of till (Boulton model), 2) erosion of till, and 3) deposition of till (Shaw model). The two leading theories are Shaw's melt-water hypothesis and Boulton's deformation-bed model (Johnson et al., 2010) Boulton predicts that when a glacier moves over a potentially deformable bed such as an end moraine, the velocity of the glacier could increase (Hart, 1997). In Boulton's model, till is deformed over a more competent core of rock or till. There is a divergence and convergence of deformed sediment around the core. Shaw argues that melt water from the basal side of the glacier deposits subglacial sediment into molds and erosional zones on the underside of the glacier into streamlined mounds (Shaw, 1983).

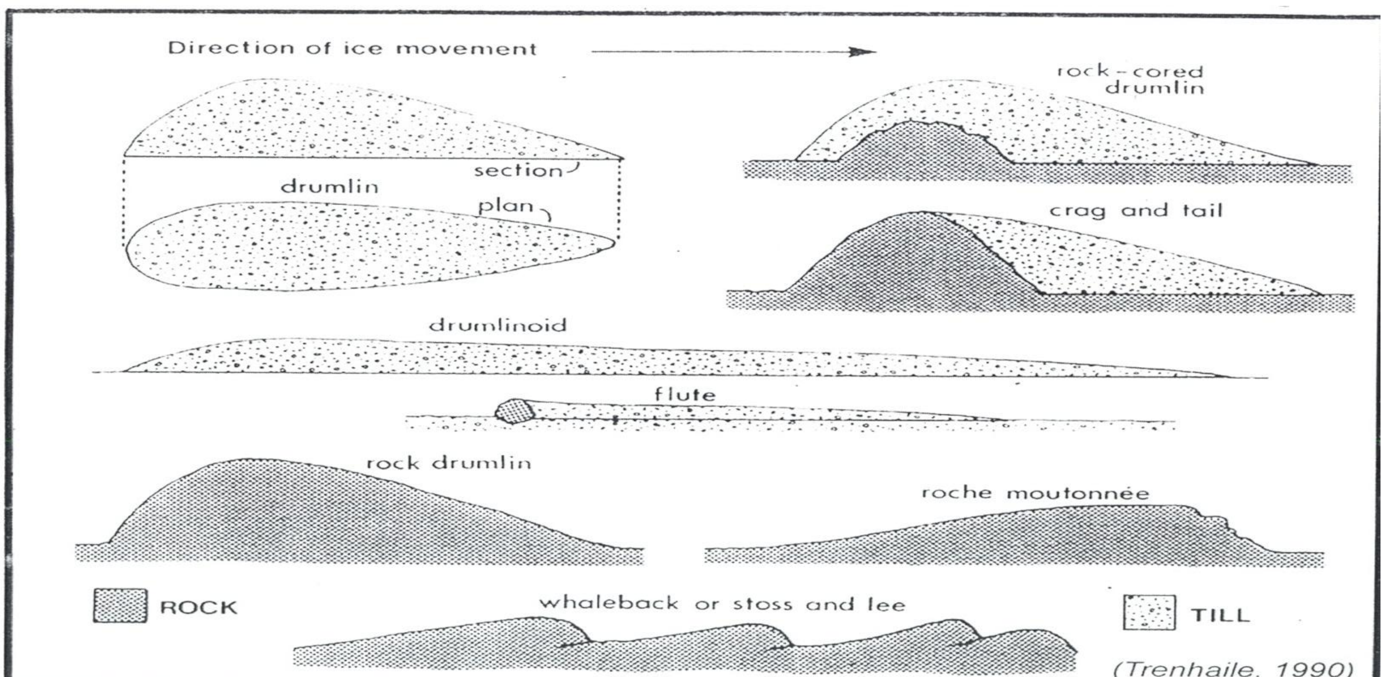
Scientists are unsure about the formation of drumlins because there are no active drumlin zones in the world. However, recent activity of the Mulajokull Glacier in Iceland proves that Boulton’s theory is correct in that case. The Mulajokull Glacier receded and unveiled more than 50 drumlins that formed during 1992 surge of the glacier (Johnson et al., 2010) Drumlins usually form during a glacial surge (Johnson et al., 2010). A surging glacier can move more in a day than a normal glacier does in a year (Johnson et al., 2010).

Other drumlin features include rock cored drumlins and drumlinoids. Rock-cored drumlins are similar to drumlins because they are both formed by glaciers reshaping end moraine deposits. However, rock cored drumlins form when an end moraine is reshaped over uplifted rock. The rock core helps identify it as a rock cored drumlin. Rock cored drumlins are primarily formed by the deposition of glacial till around the core, and the till contains pieces of the core rock scattered throughout (Hart, 1997). Rock cored drumlins are usually fewer in number and less streamlined than regular drumlins (Hart, 1997). Drumlinoids are similar to drumlins. However, drumlinoids are smaller in height and usually much longer. Like drumlins, drumlinoids are composed of glacial till (Trenhaile, 1990)

Crag and Tails

Crag and Tails form when a glacier or ice sheet passes over an area that contains an exceptionally resistant rock formation, usually granite, a volcanic plug, or some other volcanic structure. The force of the glacier erodes the surrounding softer rock, which leaves the resistant rock or crag projecting out from the surrounding land. The weight of the glacier flattens the surrounding softer rock and forms a gradual slope of softer material or the tail. Together the resistant rock and softer surrounding rock form a crag and tail.

Figure 1.



Shape and composition of streamlined glacial features (Trenhaile, 1990)

Methods

Spirit Mound was measured using an autolevel and stadia rod. The measurements began at a known elevation of 1194 feet above sea level (USGS, 1969), located at the intersection of highway 19 and 312th street (42 degrees 52 minutes latitude and -96 degrees 57 minutes longitude). From the starting point measurements were taken every 20 meters until the southern tip of Spirit Mound was reached along the hiking trail. A north-south elevation transect of Spirit Mound was then measured from the trail reference point. The longitude and latitude were also recorded every 20 meters using a global positioning system device. The survey data was used to measure the elevation and length of Spirit Mount, however, the width was not determined. The data was also used to construct a north-south oriented topographic profile of the mound. Measurements of the size of the flat area at the summit were also taken.

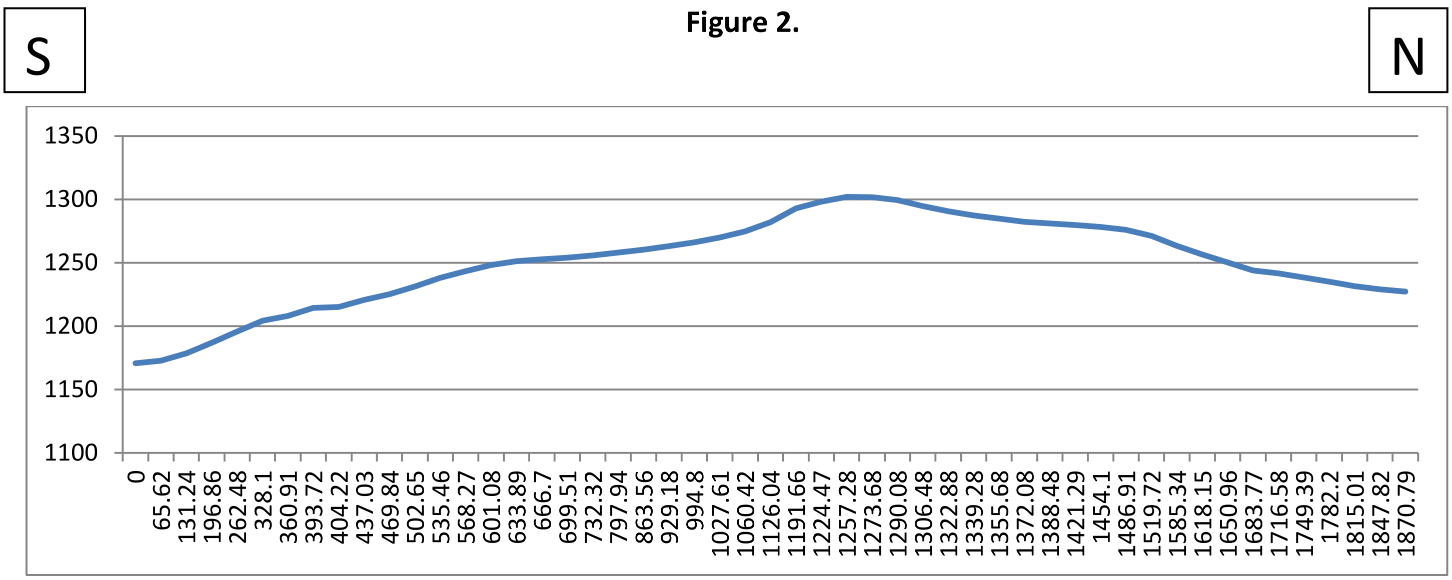
The soil of Spirit Mound was also examined. At eleven different locations around the mound hand auger samples were taken at 30 centimeter intervals to a maximum depth of 2 meters. Two auger holes were drilled north, northeast, northwest, southeast, and southwest of the mound at the footslope and toe slope. One more sample was taken from the middle of the stoss side of the mound. Soil color of the A, B, and C horizons was described using a Munsell soil color chart.

Results

Survey results show that the mound is 83 feet high from the trail on the south side (at 1218.6 ft) to the peak, making the elevation of the mound 1302.01 feet above sea level (note: English units are used so that comparison to Lewis and Clark's measurements can be made).

This compares to the Vermillion Quadrangle map where the elevation can be estimated at 1305 feet (USGS, 1969). The flat area at the top of the mound is 27 by 34 feet. The length of Spirit Mound was measured at 1279 ft (426 yards). The width was not measured, but can be estimated from the map at 787 ft or 262 yards. The general shape of the mound is asymmetrical from side view, with the steeper side facing north, and the stoss side stretching to the south.

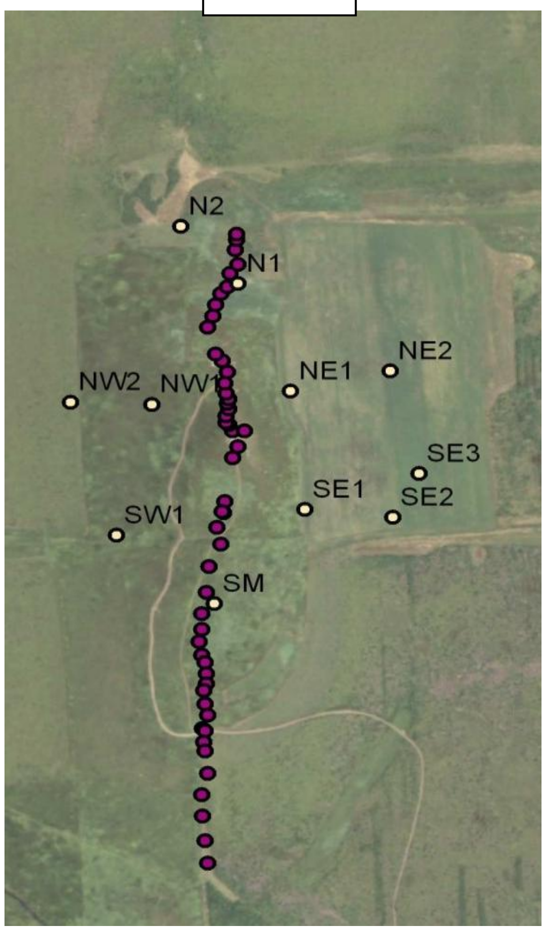
Figure 2.



Topographic profile depicting height and length of Spirit Mound (Measured in feet)

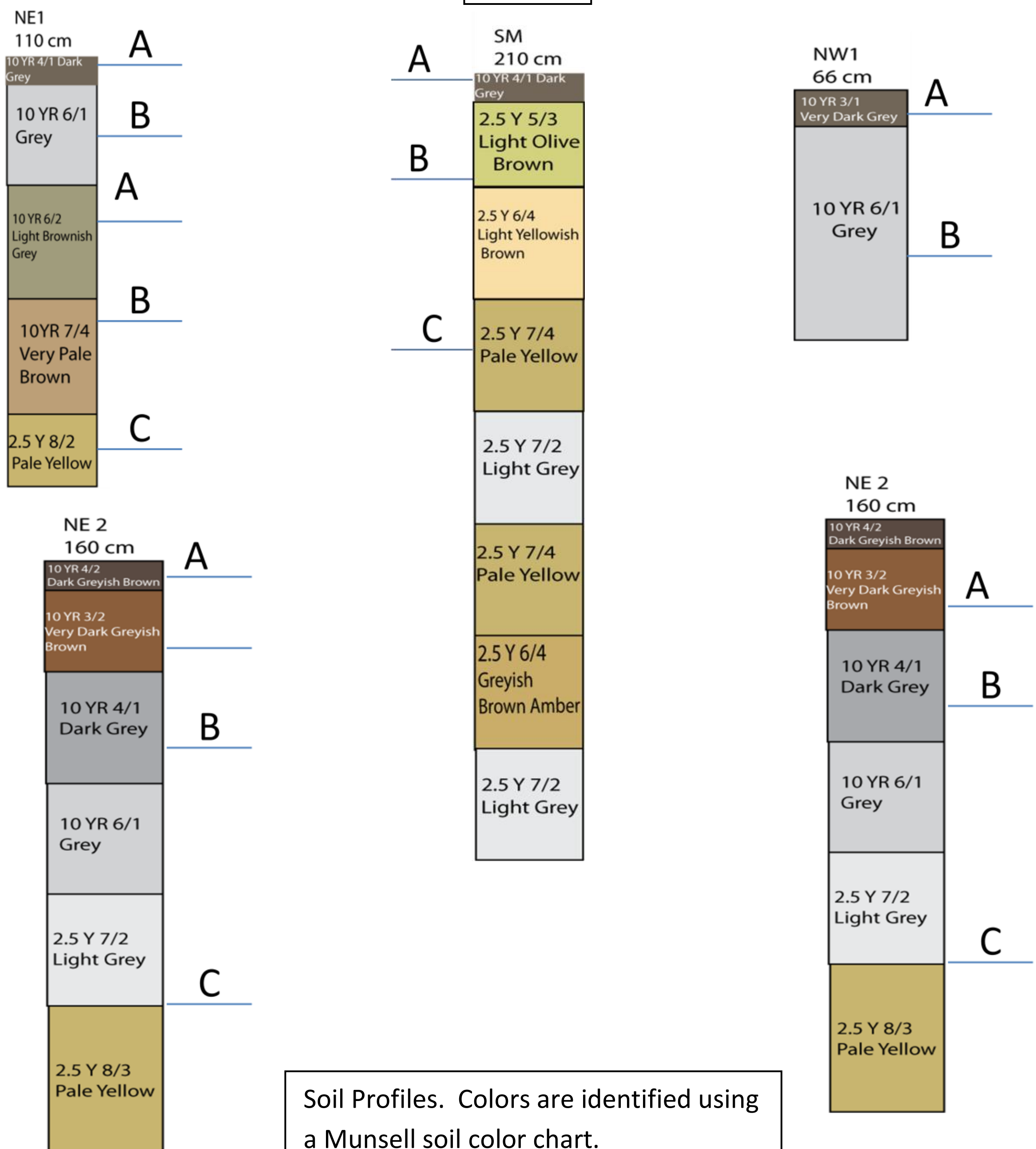
Lewis and Clark determined the mound to be 65 to 70 feet high, the length at approximately 300 yard, and the width at 60 to 70 yards. They measured the top of the mound at 12 by 90 feet (Moulton, 2002). The A horizon samples fell into the 10YR 4/1 to 10YR 4/2 (dark gray to dark grayish brown) soil color category. The B horizons are 2.5Y 6/4 to 2.5Y 6/2 (light yellowish brown to light brownish gray). The glacial till (C horizon) fell between 2.5Y 7/2 and 2.5Y 7/4 (light gray to pale yellow) soil color. The majority of the auger holes consisted of a dark A horizon from 0-30 centimeters. From 30-60 centimeters a transition from an A to B horizon occurred. Glacial till was typically found at a depth of 120 centimeters. All of the samples taken were peppered with Niobrara chalk, which is the bedrock exposed on the north side of Spirit Mound. However, northeast of the mound an A horizon was found buried beneath the B horizon. Auger hole depth was limited to Niobrara Chalk or interception of glacial cobble that the auger could not penetrate.

Figure 3



Aerial Map with plotted survey points and auger holes

Figure 4



Soil Profiles. Colors are identified using a Munsell soil color chart.

On the northeast margin of the mound an A horizon was found buried beneath the B horizon. The first A horizon was between 0-30 centimeters. The B horizon was between 30-60 centimeters. The second A horizon was found at 60-90 centimeters.

Areas of erosion can be seen on both east and west sides of the mound in the form of catsteps, or terracettes. Catsteps form when a dense population of heavy animals is herded on a hill or mound. The weight from the animals causes erosion of surface soils, which forms steps in the hill. In addition, a small eroded rill extends from the trail at the summit 10 feet or more down the east side of the mound. This rill appeared 3 or 4 years ago (Mark Wetmore, personal communication). Localized erosion on the trail leading up to the mound was also documented in the summer of 2010 following frequent, heavy rainfall.

Discussion

Although the measurements made in this study differ from measurements taken by Lewis and Clark, it does not mean that the mound has changed significantly since 1804. Lewis and Clark gave no point of reference for their measurements, making it difficult to make direct comparisons. Also Lewis and Clark may simply have estimated the mound's size and did not have modern surveying equipment. In general, modern measurements are compatible with those made by Lewis and Clark. There is a large discrepancy, however, in the size of the flat area at the summit of the mound. Lewis and Clark measured it half as wide and three times as long. Some erosion could account for some shortening in the long direction and widening in the width, potentially the result of cattle grazing. A photograph from 2002 showing the Daughters of the American Revolution rock plaque, which used to be at the summit, rests on a pillar of soil which may suggest 6 inches or more of erosion from the top of Spirit Mound since the rock was emplaced in 1921. In addition, the presence of terracettes does indicate a downward movement of soil on the western and eastern sides of the mound.

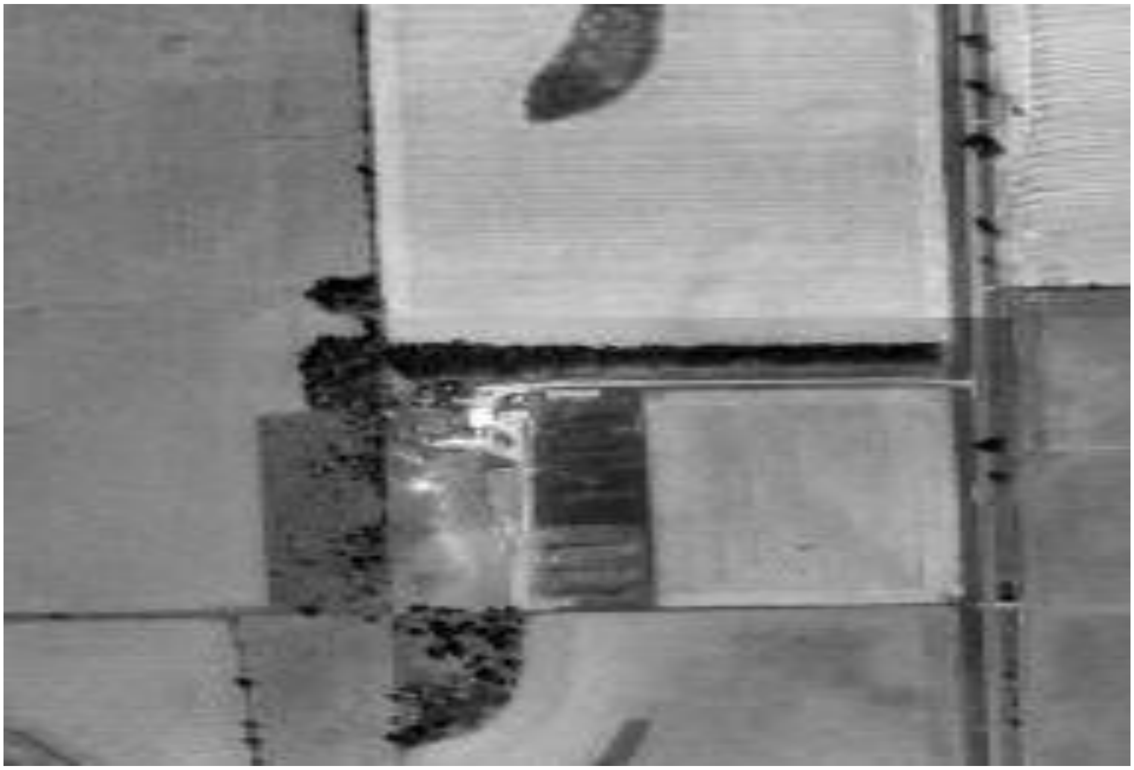
Figure 5

Daughters of the American Revolution Plaque. Erosion is clearly visibly on the soil underneath the plaque

The buried A horizon on the northeast corner indicates erosion. Soil from the top of the mound eroded down to the base of the mound. The eroded soil covered the existing soil at the base of Spirit Mound forming two A horizons, one is at the surface and the other is buried. The erosion more than likely occurred during the mound's feedlot years because of the lack of vegetation. Photos of the feedlot in the 1980s show some areas of exposed soil on the northeast margin of the mound, making erosion more likely.

Figure 6

Feedlot near Spirit Mound. Several bare patches are visible, which will increase the likelihood of surface soil erosion. (Spirit Mound Trust, 2003).



Aerial photo of the Spirit Mound feedlot (USGS). Bare patches are visible on the northeast side of the mound.

The classification of Spirit Mound as a roche mountonnee is incorrect, primarily because the mound is not entirely constructed of bedrock, and secondly, the orientation of the lee and stoss sides of Spirit Mound is inconsistent with roche mountonnee genesis from ice flowing north to south. Based on the orientation of the lee and stoss sides, the presence of the Niobrara Chalk core, and because several pieces of the Niobrara Chalk and other pebbles were found in the auger samples, I classify the mound as a rock-cored drumlin. An ice sheet passed over uplifted chalk and reshaped an end moraine in a streamlined fashion. The mound is also higher than a typical drumlin, indicating that a rock is located underneath the glacial till therefore increasing its height. Although drumlins usually occur in clusters, there are cases of lone drumlins (Johnson et al., 2010). Spirit Mound is a lone rock-cored drumlin. According to the topographic map there is another much smaller feature nearby that could be argued to be streamlined, however Spirit Mound is not typical “basket of eggs” topography.

Conclusion

Spirit Mound is one of the few locations where we can stand in the exact location that Lewis and Clark stood 206 years ago. The mound was naturally formed from glacial movement during the last glacial maximum in the Pleistocene epoch. The mound is a rock-cored drumlin because it is streamlined, composed mainly of till, contains a core of Niobrara Chalk, and pieces of Niobrara Chalk are scattered throughout the till. It indicates ice movement from north to south, which is consistent with other interpretations in the region. The mound is taller than typical drumlins, its height accentuated by the rock core. Geologically, Spirit Mound has not changed much since the time of Lewis and Clark. It has experienced localized erosion on the northeast corner of the mound. The erosion occurred because of the lack of vegetation and heavy cattle traffic during the mound’s feedlot years. Today, the trail at Spirit Mound is most susceptible to erosion during heavy rainfall as noted in 2010. Special attention should be given to maintaining and reinforcing the trail so that erosion is limited so that Spirit Mound can be preserved for generations to come.

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