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Aerial Archaeology at Double Ditch State Historic Site, North Dakota

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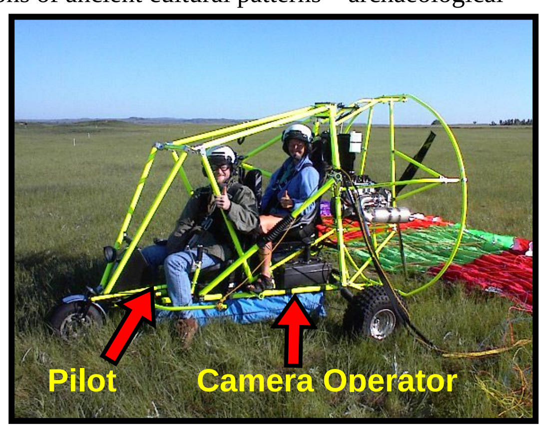
Abstract
Two seasons of aerial survey at Double Ditch have yielded complete coverage of the site by digital color video, high resolution color stills, and thermal imaging (10 micron band). These data were acquired from a low and slow flying powered parachute platform, from 250-500 m above the ground, yielding high resolution scenes with little blurring. The multiple data sets offer a number of contrasts: tall versus short vegetation after mowing, dry versus wet conditions after rain, evening versus early morning. After the difficult task of mosaicing dozens of scenes based on ground control points in each flight, it is possible to examine shadowing from different angles or vegetation differences in normal light scenes. Moreover, the thermal data (sensitive to a tenth of a degree C) may be differenced and compared across the various contrasts to yield subsurface insights from thermal variations.

The Double Ditch site (32BL8) is a large fortified earthlodge village located on the Missouri River near present day Bismarck, North Dakota. Double Ditch is distinctive in the size and number of its midden mounds, some almost 3 m tall, nearly 100 shallow depressions 12-18 m in diameter that signify the loci of former houses or earth borrowing areas, and its readily apparent double fortification system of ditches from which it derives its name. The site was occupied by the Mandan, perhaps as early as the 15th century (Ahler et al. 2004), with occupation terminating in the 1780s owing to a smallpox epidemic. In 2003 and 2004 significant aerial reconnaissance and remote sensing was undertaken at this important site.

Aerial Archaeology
Pilots during World War I noticed that an aerial platform allows entirely new perspectives about landscapes and that cultural patterns could be discerned over broad areas. They also noticed many indications of ancient cultural patterns—archaeological signatures that could be seen only from the air. In the 1920s O.G.S. Crawford pioneered aerial archaeology by codifying “archaeological recognition elements” seen from the air. They include vegetation or crop marks, shadow marks, snow and frost marks, and soil marks that give indications of what lies beneath the surface (Scollar et al. 1990). The first two are relevant to the aerial data obtained at Double Ditch.



Aerial Platform & Equipment
A two-seat powered parachute was employed for aerial data acquisition (Hailey 2003). The pilot, Tommy Ike Hailey in the front seat, controls the aircraft and acquires color video and still imagery, but the primary camera operator, Jo Ann Kvamme, occupies a rear seat and concentrates on more difficult to capture thermal data. Digital color video as well as still imagery from two digital cameras was obtained. Thermal data were collected in the 10 micron band using a Raytheon Palm IR-250 interfaced with a digital video recorder. This instrument records data as an 8-bit gray-scaled image with sensitivity to about 0.1^{o} C. Advantages of the powered parachute include its ability to fly low and slow, promoting high-resolution data with a minimum of blurring, and its safety. Oblique and near-vertical imagery was obtained in a half-dozen flights at altitudes commonly between 800-1200 feet above the site.

Vegetation Marks
Double Ditch was not mowed during the 2003 field season. The relatively tall and thick vegetation that resulted allowed differential growth over the many different features that occur across this site. One argument in favor of vegetation pattern studies is that one can regard each plant as an individual

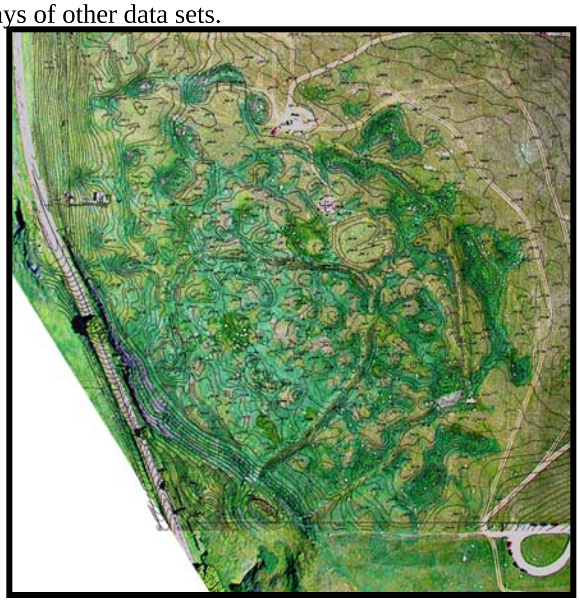
"sensor" that responds to soil conditions immediately below it—that millions of plants exist across a site offers rich potential. House depressions, soil borrowing basins, and fortification ditches are readily distinguished from surrounding areas of fill and middens by their tan color and dominance of prairie grasses. The taller midden mounds are covered with a thick mat of vegetation that generally appears blue-green from the air, while smaller middens and areas of fill resulting from eroded earthlodge roof sediments and village activities appear a robust green to olive green.

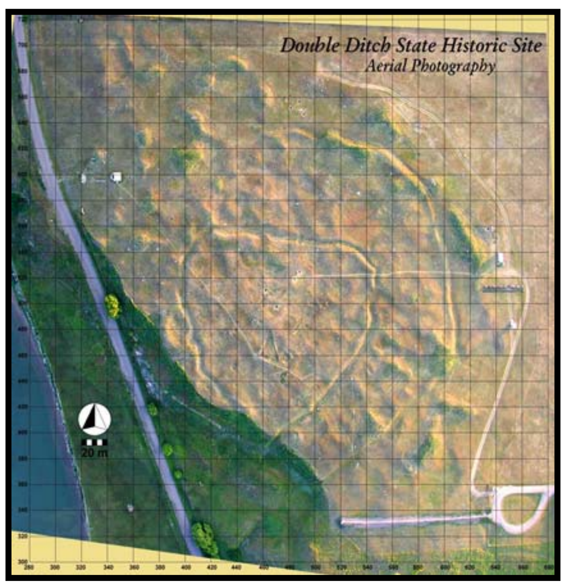
Shadow Marks

Low sunlight angles may be used to highlight subtle changes in microtopography through shadowing. Unfortunately, this required flights taking place by sunrise and at sunset, which made for long days at this far northern site near the summer solstice. A comparison between morning and evening shadow marks indicates that very different surface features are revealed. The morning shadows, for example, indicate prominent ridge-like features through the site center and a series of steps akin to terraces (currently unexplained) at the far northwest corner of the park. The evening shadows better indicate the outer fortification ditch and the prominence of some mounds. The potential of these data will be better realized after comparison against a wide-area mapping of the microtopography with a total station, reported by Markussen et al. (2004).

Orthophoto Maps

Ground control markers, a series of meter-long crosses made on nylon or of metal flashing (better for thermal data) were distributed across the site at pre-surveyed points systematically spaced every 60 m. By utilizing a series of still frames shot at approximately the same time, together with the readily recognized ground control points for spatial control, it is possible to create an ortho-rectified photo-mosaic of the entire site. Image rectification and registration techniques available in GIS were employed that "rubber-sheet" slightly oblique imagery into a correct spatial projection in a local coordinate base (Burrough & McDonnell 1998). Two initial mozaics, approximately spatially correct, have thus far been generated that will offer potential for site interpretation and serve as a base for overlays of other data sets.

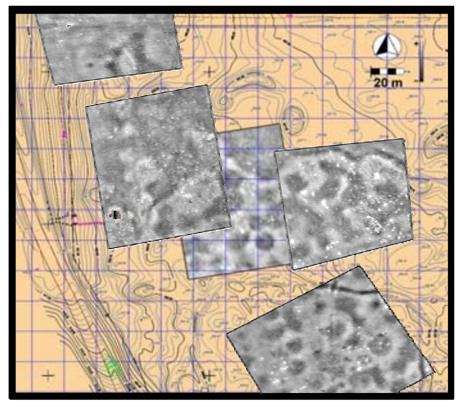




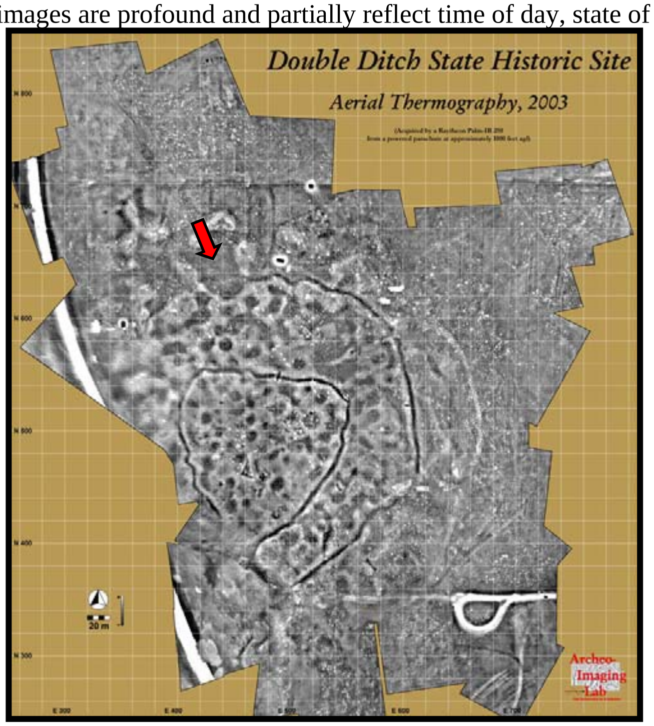
Thermal Remote Sensing

Thermal remote sensing detects radiation *emitted* from the earth and is therefore independent of normal light, making data acquisition possible during the day or night. In general, dense materials—stone, packed earth—tend to resist temperature change and retain the day's warmth. Moist areas tend to be cooler owing to the effects of evaporation, temperature variations occur across plant types caused by evapotranspiration, the cooling mechanism of plants, and vegetated surfaces generally are much cooler than bare, open earth (Scollar et al. 1990). Because the sun so profoundly heats the ground surface, making it difficult to detect temperature contrasts between various features, thermal imaging tends to be most productive before sunrise and after sunset. Although the surface cools rapidly after sunset, evening images tend to better show near-surface temperature contrasts affected by the day's sunshine while pre-sunrise images made after a full night of cooling tend to better reveal deeper thermal variations. Fundamental thermal signatures at Double Ditch are illustrated here with dark areas indicating relatively cool contexts and bright areas relatively warm ones.

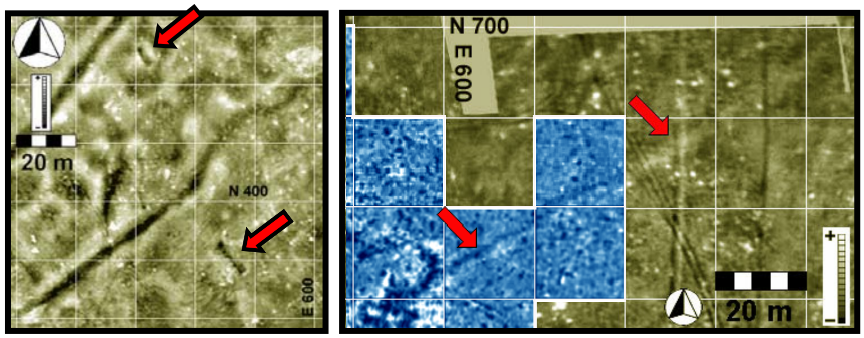
The thermal camera is extremely sensitive to platform motion, which causes blurring, so each frame of the video recordings had to be reviewed to select only the clearest imagery, at 30 frames/second! Clear frames were "captured" from the video, each covering an area of approximately 70 x 90 m on the ground. Ground control points were then identified in each and rubber-sheeting was employed to rectify the images to the local coordinate base of the site. This process has so far yielded two complete site mosaics, each composed of 30-50 individual still frames. One is based on an evening flight under long vegetation in 2003 and the other is from a short-vegetation morning flight in 2004.



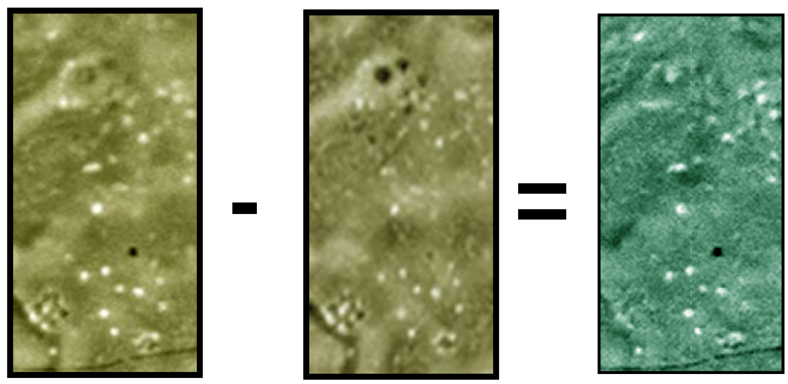
Only limited analyses have thus far been undertaken, but the potential of these data for better understanding aspects of Double Ditch is exciting. Differences between the images are profound and partially reflect time of day, state of the vegetation, and the



impact of recent rains in the 2004 scene. Although they have not been calibrated to each other, mound and fill areas clearly stand out in the evening image, with retention of the day's warmth compared to the more thermally equalized morning image. Areas of what has been termed "planar borrowing" may also be well indicated in the 2003 image, particularly on the north end of the village (arrow, above) where thermal differences seem most apparent and strong excavation evidence of this phenomenon exists (Ahler et al. 2004).



The thermal data well-indicate a number of features of potential interest. One collective goal of the Double Ditch Project was to relocate excavations reported by Will and Spinden (1906). While most are topographically indicated it was learned they cannot hide from aerial thermography where they are seen as relatively cool anomalies (left), probably owing to moister, less compacted soil and somewhat denser vegetation. Another anomaly of high interest is a linear one (right) that has been interpreted as a probable village trail feature (Kvamme 2004) that also happens to be magnetically indicated (magnetometry in blue). It may be revealed as a "warm" anomaly due to soil compaction.



Thermal differencing is also being attempted, but is only in its initial stages. If one takes an evening thermal image and then subtracts corresponding data from the next morning, for example, thermal change or heat loss can be indicated. Such a tactic has the potential of showing differences in deposits, including deeper ones that retain or loose heat energy through the night. A difficulty with any kind of image differencing is the requirement of absolutely accurate image registration. A 20 x 40 m segment is investigated here where an evening flight of June 29 is differenced with a morning flight of June 30, 2004. A contemporary trail seen in the evening image (left, at bottom) is invisible in the morning (middle) as is an aluminum ground control marker seen as a cool (black) point near the left image center (owing to thermal equalization). Broader areas of change may indicate deposit differences or major subsurface features, but significant additional work will be needed to realize archaeological potential in this domain.

Conclusions

An aerial perspective offers much at Double Ditch, by making the considerable structure inherent to this site readily apparent. Variations in vegetation and topography (seen by shading) complement geophysical and microtopographic data sets and generate insights by themselves. We believe the thermal data offer considerable potential for better understanding several aspects of this site, including areas of deposition and extraction, and thermal differencing may potentially be the key that unlocks Double Ditch's secrets.

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