Applications of small-format aerial photography in North Dakota

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Introduction

Modern earth science investigations typically involve a combination of techniques and data types ranging from satellite imagery, to ground observations, to subsurface geophysics. Within this spectrum of observational levels, airphotos are commonly used for viewing, mapping, and interpreting natural and cultural resources displayed at the Earth's surface. For more than half a century, airphotos have been utilized for surveys of various archaeological, biological, and geological resources. For example, airphotos are indispensable aids in the preparation of maps of surficial geology in North Dakota and elsewhere.

Conventional aerial photographs normally are acquired from airplanes flying 10,000 to 20,000 feet above the terrain. The photographs are taken with large-format cameras that use film 9 inches (23 cm) wide. Photo scale ranges from 1:10,000 to 1:40,000 and resolution is typically 1-2 meters. Pictures are taken vertically in overlapping sequence to provide complete coverage of large ground areas. The National Aerial Photography Program (NAPP) of the U.S. Geological Survey is a good example of this type of photography. This approach to aerial photography has proven invaluable for complete regional coverage in modern mapping programs, but it is expensive and time consuming.

In contrast, small-formal aerial photography (SFAP) is based on 35- or 70-mm film cameras and compact digital cameras operated at low height (Warner et al. 1996; Bauer et al. 1997). The cameras may be flown on manned aircraft, such as ultralight planes, helicopters, and hot-air balloons. Unmanned platforms include blimps, balloons, kites, and model airplanes. Pictures taken at low height reveal great detail about surface features, and SFAP has become popular for thorough investigation of small study sites. High-resolution SFAP has proven useful as a means to bridge the gap between ground-based observations and conventional airphoto or satellite imagery.

Unmanned small-format aerial photography

During the past few years, I have developed kite aerial photography as a means to acquire low-height, large-scale imagery (Aber et al. 1999, 2002). The method employs large kites to lift camera rigs above the ground (fig. 1). Larger, rigid kites are used for lighter wind (10-15 mph) and smaller, soft kites are best for stronger wind (15-25 mph). Various film and digital cameras may be used to acquire photographs in color-visible or color-infrared formats. A variety of camera lenses and filters can be applied to achieve special effects. The camera rigs are operated by radio control from the ground to pan (0-360°), tilt (0-90°), and fire the shutter. Single-camera rigs weigh 20 to 40 ounces.

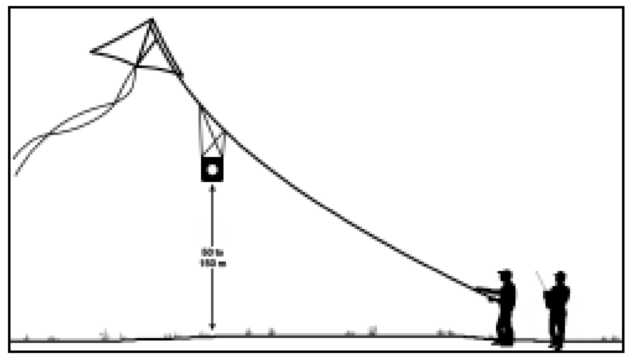

Figure 1. Cartoon showing setup for kite aerial photography. The camera rig is suspended from the kite line and is operated by radio control from the ground. Not to scale.

Although wind is a fact of life on the Great Plains, there are occasional days with clear sky and calm air. To deal with such conditions, I recently began using a small helium blimp as the lifting platform for SFAP (fig. 2). The blimp is 13 feet (4 m) long and holds about 250 cubic feet of helium. This gives a payload capability sufficient to lift the same camera rigs that are used with kite aerial photography. The blimp is flown manually with a tether to the ground, and camera rigs are operated via radio control. The blimp provides a stable platform in calm to light-wind conditions (0-10 mph).

Figure 2. Helium blimp in flight with camera rig suspended underneath. The blimp measures 13 feet (4 m) long and can lift up to 5 pounds payload.

As tethered platforms, kites and the blimp are restricted to a maximum height of 500 feet above the ground without filing a flight plan with the nearest airport. The normal height range for operation is 300 to 500 feet, and a laser range finder is used to determine platform height. This height is, in fact, difficult to achieve through routine field methods; it is too high to observe from the ground and too low to photograph from conventional airplanes or helicopters.

Pictures may be taken in vertical or oblique (side) views in all orientations relative to the study site and sun position. Oblique views are useful to depict the relationship of a particular study site within the surrounding landscape. For vertical pictures, ground area coverage is usually 1-2 acres, and digital resolution (pixel size) is typically 5-10 cm (2-4 inches). This resolution allows detailed mapping and interpretation in the very-large-scale range of 1:100 to 1:1000. As with conventional airphotos, many vertical views of a site are taken to provide complete, overlapping coverage. For accurate mapping, survey markers can be placed throughout a site. Such pictures may be rectified and assembled into mosaics for further mapping or display purposes.

Kite and blimp aerial photography have been employed for diverse applications, ranging from documentating active faults in California, to analyzing desert erosion in Africa, to mapping penguin nesting sites in Antarctica. My own work has focused on geomorphology, wetland environments, and historical archaeology, mainly in the Great Plains. Kite and blimp aerial photography have the advantages of relatively low cost, high portability, and easy field operation, and they can be used under a range of weather conditions.

In early October 2003, I had the opportunity to conduct SFAP in North Dakota in two settings of special interest—Devils Lake vicinity and the Missouri River valley near Washburn. I was assisted by William Jacobson and Shawn Salley from Emporia State University, Kansas. Jacobson is a graduate student conducting geological field research in the area near Devils Lake for his M.S. degree. Salley is an undergraduate student with wide-ranging geological interests.

Devils Lake vicinity

Devils Lake is much in the news lately because of its rising water level. This situation has been featured in the NDGS Newsletter in recent years (see vol. 23/1, 24/2, 26/1). The lake occupies a series of large basins scouped out during the last glaciation. Material shoved from the basins is piled in large hills to the south, including Sullys Hill, Crow Hill, and others. These features are textbook examples of the "hill-hole pair" type of glacial landform (Aber et al. 1989). Nearby is Devils Lake Mountain, a smaller example of this landform type. Also in this vicinity is Devils Heart Butte, a large conical hill of uncertain composition and origin (NDGS Newsletter 23/1, p. 13). At Devils Lake Mountain we used the helium blimp in near-calm conditions, and near Devils Heart Butte we flew a large kite on a light southwesterly wind. A variety of color-film and digital cameras were utilized with different lenses and fields of view. The seasonal conditions proved excellent for depicting geomorphic features as highlighted by autumn foliage.

Devils Lake Mountain is a hilly upland covering roughly two square miles. Adjacent to its northwestern side is a depression of approximately the same size and shape, which contains an unnamed lake. The crest of Devils Lake Mountain stands 185 feet above the lake in the source depression. Our blimp aerial photographs display the depression and hill in oblique views (fig. 3). From this same site, we were able to document the effects of high water in East Devils Lake (fig. 4). Devils Heart Butte is situated within the ice-shoved hilly terrain southwest of Black Tiger Bay of Devils Lake. Our kite aerial photographs depict the geomorphic setting of the butte and reveal a shallow spillway channel associated with the ice-shoved hills (fig. 5).

Knife River Indian Villages NHS

Knife River Indian Villages National Historical Site is located adjacent to Knife River close to its junction with the Missouri River in central North Dakota. These Hidatsa and Mandan Indian villages were settled beginning around A.D. 1300. Five hundred years later, they figured prominently in the Corps of Discovery, which spent the winter of 1804-05 nearby at Fort Mandan (see NDGS Newletter 26/2). It is

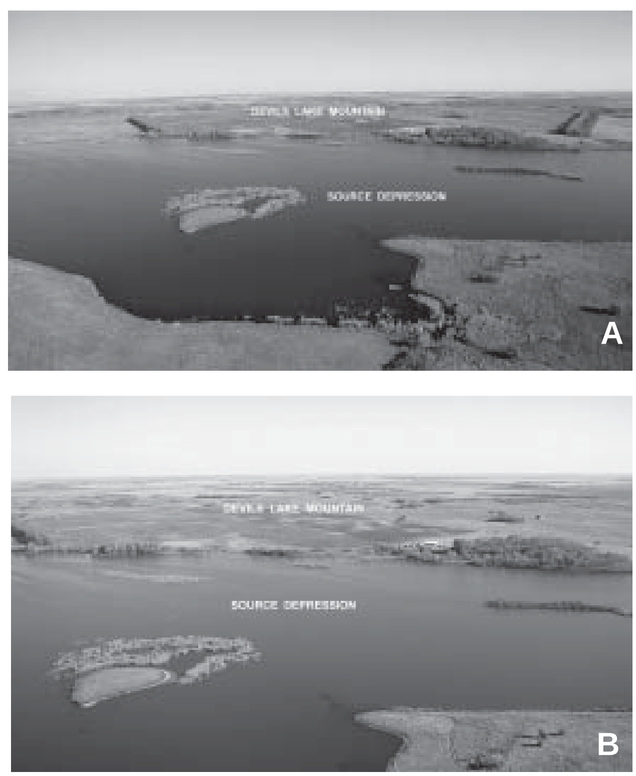

Figure 3. *Blimp aerial photographs of Devils Lake Mountain seen from the northwestern side. A - superwide-angle image. Nearly all of the ice-shoved hill and source basin are visible. B - standard, oblique view showing central portion of the hill and source basin.*

reputed that Sakakawea came from one of these villages. The remains of hundreds of earth lodges are preserved as circular depressions, each 30-40 feet in diameter. The remains are still quite distinct in spite of former agricultural land use at the site.

Figure 4. *View toward the northwest over the eastern margin of East Devils Lake. Note the old shoreline with dead trees now submerged. A rural road remains barely passable, just above water level.*

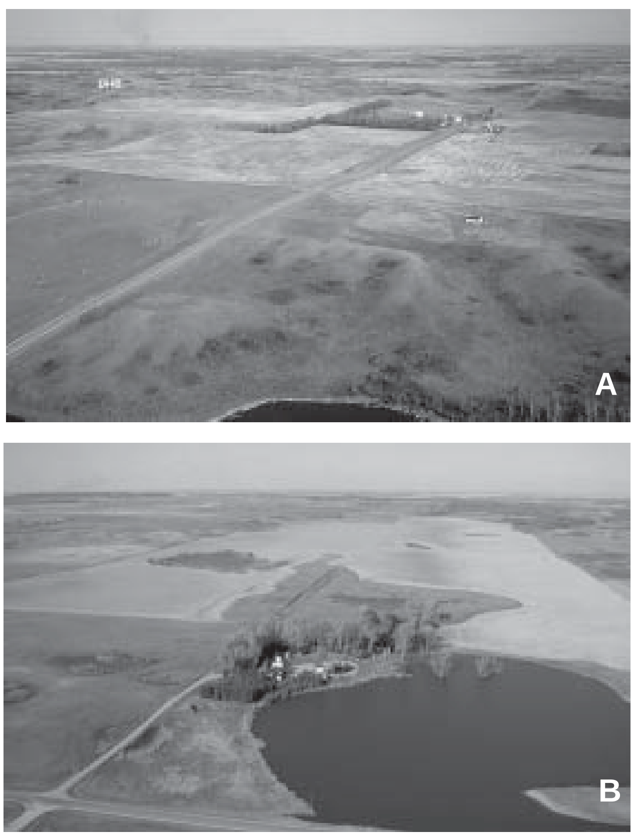

Figure 5. *Kite aerial photographs of Devils Heart Butte vicinity. A - view toward the northeast of ice-shoved terrain with Black Tiger Bay in the far background. Devils Heart Butte (DHB) is the conical hill in upper left portion of view. B - northward view with shallow spillway channel marked by small lakes in foreground. Sullys Hill is on the left horizon, and Devils Lake can be seen in the far background.*

Kite aerial photographs clearly depict earth-lodge depressions, which are revealed by shadows and distinctive vegetation (fig. 6A). Depressions mark the former interior floors of lodges, which were built at ground level (not dug out). Surrounding each depression is a raised rim composed of material that fell off the lodge wall and roof. Some portions of the site are mowed, so the lodge remains can be seen easily on the ground. Other portions are covered by prairie grass, shrubs and woods. Earth lodges in these unmowed portions are not readily visible from the ground, but are quite evident from above because of variations in vegetation cover.

Problems of site management include river eorsion, which has removed portions of some villages and burrowing animals. Gophers and ground squirrels bring up artifacts, which visitors are tempted to carry away. Both these conditions are depicted in the kite aerial photos (fig. 6B).

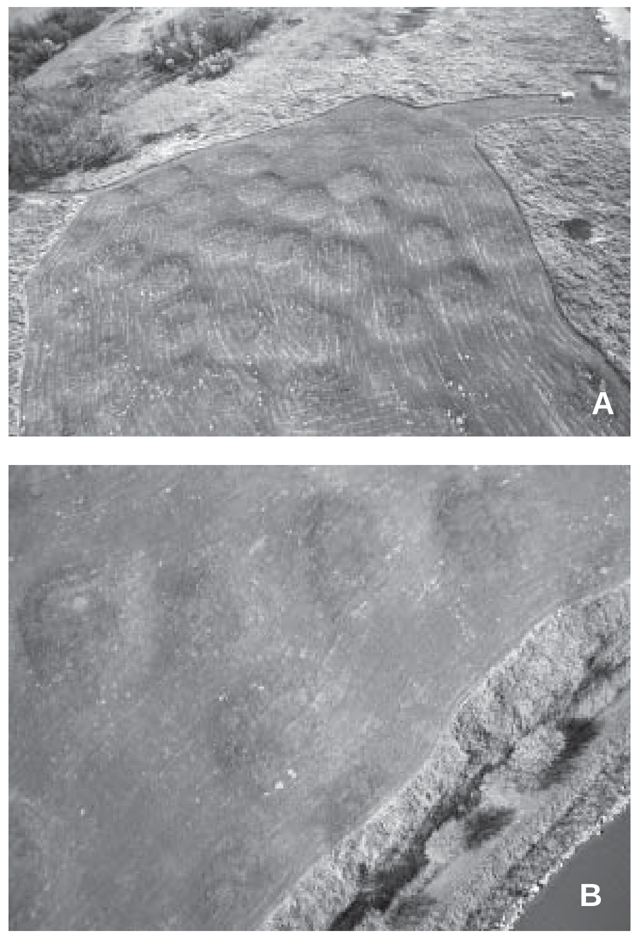

Figure 6. *Kite aerial photographs of Knife River Indian Villages National Historical Site. A - superwide-angle overview showing a portion of the Big Hidatsa Village site. Circular depressions mark the remains of earth lodges. Kite flyers are standing in the upper right corner. B - closeup vertical image of the Awatixa Village. Knife River, visible in lower right corner, has eroded away some of the site. Light patches are animal burrows.*

Conclusions

Kite and blimp aerial photographs demonstrate potential for closeup investigations of geologic, hydrologic, and archaeologic sites in North Dakota. Large-scale, high-resolution images provide surprisingly detailed views of these sites; such details may not be readily seen on the ground or in conventional airphotos and satellite images. Early autumn proved to be a good season for such imagery. Shadows from low sun and variations in fall foliage aid in identifying subtle features of interest. Given its relatively low cost, kite or blimp aerial photography could be utilized to document important or special geological sites throughout the state.

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Related websites

National Aerial Photography Program (http://edc.usgs.gov/products/aerial/napp.html).

Great Plains Aerial Photography (http://www.geospectra.net/kite/).