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Potential of kite aerial photography for Quaternary investigations in Poland

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Aerial photographs taken from kites provide a versatile and low-cost means to acquire high-resolution, large-scale imagery for special Quaternary investigations. Kite aerial photographs (KAP) are typically taken from heights of 50–150 m using light-weight automatic cameras. Pictures may be acquired in vertical and oblique vantages. Scanning of photographs and digital processing allow for resampling, enhancement, and analysis of images. We have utilized basic KAP at five sites in eastern and northern Poland in order to evaluate the potential of KAP for Quaternary investigations. Our preliminary results suggest that KAP may provide detailed and repetitive imagery of geomorphic conditions, soils, land cover/use, and other surface features related to Quaternary processes, landforms, and deposits. However, KAP will not replace conventional aerial photography for general survey and mapping purposes.

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INTRODUCTION

Aerial photography is an indispensible source of information for all manner of Quaternary investigations of biological, cultural, and physical aspects of the Earth's surficial environment. Conventional panchromatic (black-and-white), vertical, stereo-photographs are widely utilized for geologic and geomorphic mapping. Such photographs typically are taken at medium to small scales from heights of several 1000 m. The resolution of such photographs is generally on the order of 1–2 m, and they are usually acquired only infrequently for most developed countries, including Poland.

In Poland, airphotos are employed for routine geologic mapping at the Polish Geological Institute. These photographs are usually vertical, panchromatic, and 1:10,000 in scale. Airphoto coverage of the country is not uniform; good airphotos are not readily available for all parts of the country, including most cities and some other important Quaternary sites. Available airphotos may not represent the best season for photointerpretation purposes, and most are more than 10 years old. Thus, while the cost for purchasing conventional airphotos is modest (app. 20 PLN each), the usefulness of these airphotos is limited for certain types of Quaternary applications.

For many Quaternary site investigations, large-scale imagery with sub-meter resolution is beneficial, and multi-season or multi-year photography may be useful or necessary. This is particularly true in the following kinds of situations:

— sites of limited opportunity, such as temporary excavations in gravel pits, rock quarries, archeologic sites, or construction sites; the availability of such situations may be only days or weeks, in which aerial photography could be acquired;

— sites of rapid environmental change, where either natural or culture processes are altering land-use or land-cover conditions quickly; sites of rapid erosion, sedimentation, deforestation, or changes in human land use are candidates for frequent, multi-year monitoring with airphotos;

— sites where high-resolution imagery is necessary for accurate mapping or identification of sub-meter-sized objects; detailed geomorphic investigations plus palaeontologic and archeologic sites are prime candidates for such airphotos, in which individual cobbles, furrows, fossils, artifacts, and other small objects may be recognized.

However, acquiring such customized images may be prohibitively expensive with conventional aerial cameras and manned platforms, especially in situations where financial support for Quaternary studies is limited. Many people and much equipment are necessary to carry out conventional aerial

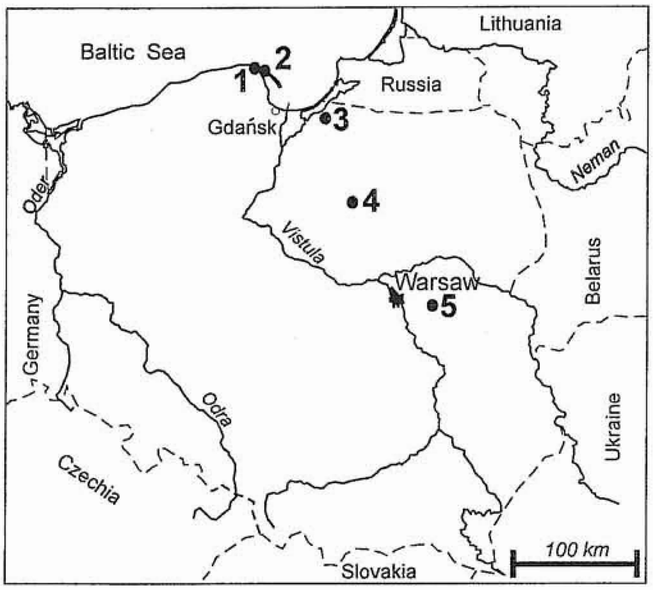

Fig. 1. Sketch map of Poland, showing major cities and numbered KAP field sites

1 — Chłapowo, 2 — Władysławowo, 3 — Majewo, 4 — Mława, 5 — Mrozy

photography. Customized airphoto missions require special planning, a trained pilot and photographer, and a suitable airplane and camera equipment, which must be available at certain times of year under favourable (cloud-free) weather conditions. The cost may be thousands of US$ for a successful mission.

Kite aerial photography (KAP) has emerged in recent years as a low-cost means to acquire low-height, large-scale, high-resolution imagery of the Earth's surface for detailed site investigations. KAP is a type of small-format aerial photography (SFAP) based on 35- and 70-mm film (Warner *et al.*, 1996), which has been utilized since the 1960s in the United States and Canada, primarily in forestry (Meyer, 1997; Zsilinszky, 1997). We have used KAP at five sites in eastern and northern Poland, in order to test the potential of this field technique for obtaining scientifically useful imagery (Fig. 1).

KAP HISTORY AND APPLICATIONS

Kites have been utilized for lifting photographic cameras since the late 19th century (Blachut and Burkhardt, 1988; Beauffort and Dusariez, 1995). KAP became quite popular in the early years of the twentieth century, in fact, before being replaced by photographs from airplanes in the 1920s and '30s. For the next several decades, KAP was virtually a lost art (Hart, 1982). A renaissance for kite aerial photography began in the 1980s and has continued to the present. This renewed utilization of KAP is based on several factors:

— availability of high-performance kites and kite-handling equipment;

— development of high-quality, light-weight, automatic cameras and means for controlling cameras while in flight;

— need for low-height imagery in situations where manned aircraft could not operate safely or effectively;

— low-cost alternative to conventional means or other methods for acquiring comparable aerial photographs.

Kite aerial photography has been utilized lately for various kinds of scientific survey and mapping projects, including palaeontology (Bigras, 1997), wildlife behaviour (Carlson, 1997), archeology (Bults, 1997; Gawronski and Boyarsky, 1997), and forest cover (Aber *et al.*, 1999*a*). Warner (1996) coined the term *kiteography*, which is the use of KAP in making large-scale topographic maps, based on photogrammetric principles. Overlapping, stereo-pairs of photographs may be digitally processed to create maps and 3-dimensional displays of the ground, and infrared photographs are especially useful for identifying vegetation and hydrologic phenomena.

Relatively few Quaternary studies have been conducted on the basis of small-format aerial photography. Marzolff and Ries (1997) have developed a hot-air blimp and dual-camera system for acquiring multi-band photography. The subject of their investigation was land degradation on abandoned farms in semi-arid regions of Spain. Aber *et al.* (1999*b*) utilized kite aerial photography for detailed (metre-scale) mapping of small, intricate stream channels in a prairie setting of south-central Kansas. These studies demonstrated the potential of SFAP to provide high-resolution imagery for site investigations of Quaternary landforms and processes.

METHODS OF KITE AERIAL PHOTOGRAPHY

Kite aerial photography involves the use of large kites, either rigid or airfoil types, for lifting a camera rig above the ground. The camera rig is normally suspended from the kite line some distance below the kite, in order to minimize vibration and sudden movements. The camera is positioned typically 50–150 m above the ground. The primary technical limitation for KAP equipment is weight; KAP rigs in use today normally weigh less than about 1 kg. In Poland, we utilized two kinds of KAP rigs with inexpensive point-and-shoot cameras:

— simple camera rig, in which the camera position (tilt and direction) is set prior to each flight; an *intervalometer* controls the camera to take pictures at a present time interval;

— radio-controlled rig, in which the single camera can be rotated, tilted, and triggered by radio signals from the ground.

Shutter speed and aperture are adjusted automatically for each shot by the camera, and focus is fixed on infinite. Images are exposed on 35-mm film; standard colour-slide film of ISO 200 speed is utilized most usually. Oblique (side) vantages are taken to provide general overviews of site conditions and to reveal relations to surrounding terrain. Overlapping vertical views may be taken for detailed survey and mapping purposes. More sophisticated KAP camera rigs include stereo systems and dual visible/colour-infrared cameras with high-quality lenses and advanced exposure controls (Aber, 1999). These were not tested in Poland, however, for logistical reasons.

Weather conditions are a key factor for successful KAP. Clear sky and wind speed of 10–30 km/h are optimum; thus acquisition of kite aerial photographs depends upon suitable weather, as does any kind of aerial photography. Safety is

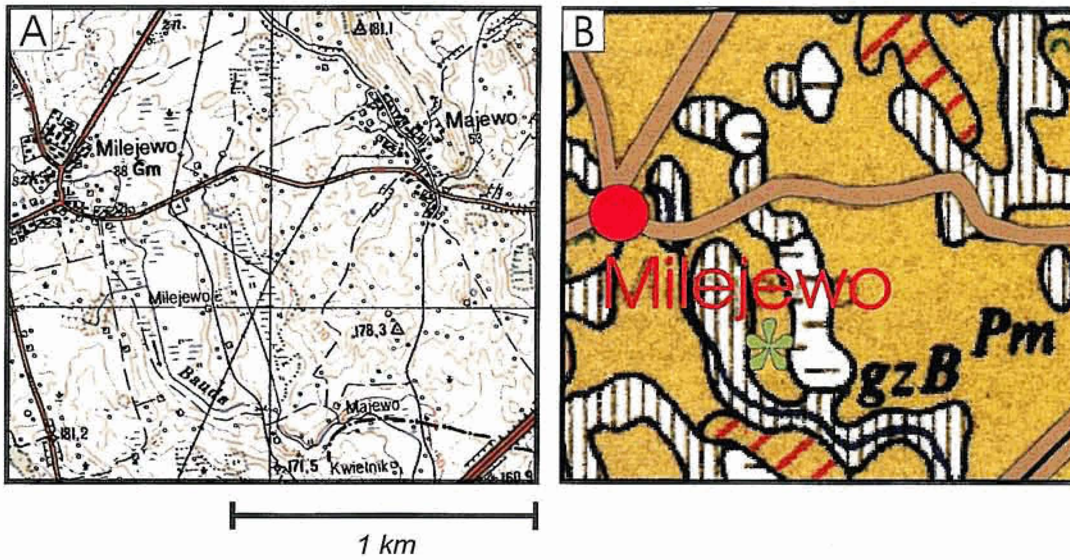

Fig. 2. Majewo–Milejewo vicinity, near the center of Elbląg Upland (*cf.* Fig. 1)

A. Topographic map. Note the well-defined ice-shoved ridge immediately north and east of Majewo. Headwater terrain of the Bauda River shows more subdued topography in the area south-west of Majewo and south-east of Milejewo. Portion of topographic map, 326.1 Elbląg, 1:50,000, contour interval = 10 m. **B**. Portion of the surficial geologic map of Elbląg (Makowska, 1978). Most of the surficial sediment is identified as till of the Pomeranian Phase (gzBPm); however, there is no indication of glacial geomorphology. White asterisk marks the low ridge seen in the kite aerial photograph (Pl. I, Fig. 2)

another important consideration, as the kite should not be flown near towers, power lines, major highways, airports, or other features that might cause risk or damage in the event of a kite crash. In most situations, 150 m is the maximum height for flying a kite without special permission.

POLISH KAP

Our primary objective was to test the potential of KAP for Quaternary investigations under field conditions in Poland. Thus, we did not carry out detailed mapping or specialized photography at any of the study sites; rather we attempted to conduct basic KAP in a variety of settings under different weather conditions. All KAP was done in late September and early October, 1998, a time of year that was considered favourable in terms of variations in vegetation cover, moderate sun angle above the horizon, relatively dry upland soils, and mild weather conditions. The authors operated the KAP equipment and travelled to field sites in a small car. No other people, vehicles, or support equipment were needed in the field.

During approximately two weeks, weather varied from warm with clear sky and virtually no wind to heavy cloud cover with strong, cold northerly wind. Several days provided good KAP conditions during this period; on days with unfavourable weather, we travelled and scouted potential sites for KAP on subsequent days. Kite aerial photography was conducted at five sites (Fig. 1) in the east-central lowland and northern Baltic coastal regions. The circumstances and results for each site are described briefly, and two sites (Władysławowo and Majewo) are elaborated for KAP potential.

Chłapowo. This site is located on the Baltic cliff near the northernmost point of land in Poland. KAP was conducted from the cliff top in late morning under partly sunny sky with a strong northerly wind (40 km/h). The northerly wind blew the kite away (south) from the cliff, so it was possible to obtain photographs of the coastal landscape and inland terrain, but not the cliff face. For this site, a southerly wind would be more favourable to acquire images of the cliff face, which exposes a thick sequence of undisturbed, fine sand, silt and brown coal. These sediments are Miocene, which in this vicinity may be found up to 10 m above present sea level (Skompski, 1989, 1998). Continual erosion of cliffs in this vicinity provides sand for replenishment of the beach along Hel Peninsula, immediately to the east (Cieślak, 1993). Multiple, overlapping KAP images of the cliff face could be utilized for detailed mapping of this significant sedimentary sequence.

Władysławowo. KAP was conducted from the beach immediately east of the fishing harbor at Władysławowo, located at the northwestern end of Hel Peninsula. Weather conditions were similar to those encountered at Chłapowo. Strong northerly wind carried the KAP rig southward over the middle of the peninsula, from which vantage we were able to take oblique photographs of both the beach and lagoon sides of the peninsula and adjacent mainland (Pl. I, Fig. 1). In this case, we were able to acquire useable airphotos under partly cloudy conditions that would have hampered conventional aerial photography.

Hel Peninsula is a famous recreational district in Poland. The peninsula represents a delicate balance between supply and erosion of sand. Construction of the fishing harbor at Władysławowo has interrupted the natural supply of sand derived from the mainland and transported along the coast onto Hel Peninsula to the south-east. A sand pumping system was put into operation in 1992 in order to move sand around the harbor at Władysławowo (Cieślak, 1993). The effectiveness of this system could be evaluated with frequent oblique and vertical photographic coverage of selected portions of the peninsula. Given the favourable wind that often blows along the Baltic coast, KAP would be a feasible means for repeated (multi-seasonal and annual) imagery to monitor conditions of beach erosion and growth.

Majewo. This site is near the center of Elbląg Upland, a large glaciotectonic complex (Aber and Ruszczyńska -Szenajch, 1997). The upland covers approximately 400 km^2 and rises nearly 200 m a.s.l. In the district north and east of Majewo, distinct ice-shoved ridges and intervening valleys that form a pronounced valley-and-ridge topography characterize the upland. However, the area between Majewo and Milejewo has a gentle, undulating topography (Fig. 2A). KAP was carried out here on two days — first under heavy cloud cover using the manual KAP rig. The resulting pictures lack good definition of land cover features, because there are no shadows and colour is poorly distinguished. The second attempt took place under nearly ideal conditions — completely clear sky and gentle northerly wind (8–10 km/h). Under such light-wind conditions, we used a large airfoil kite (3 m^2) to lift the radio-controlled KAP rig, and we put out 300 m of kite line.

The resulting photographs depict the patchwork of agricultural fields that follow the undulating topography in the region between Majewo and Milejewo. Oblique views reveal a subdued ridge-and-swale topography in the headwaters of the Bauda River (Pl. I, Fig. 2). The subtle ridges and swales define a gentle arcuate trend, concave toward the north-east and parallel to the large ice-shoved ridges north-east of Majewo. The map of surficial geology for this region indicates a cover of till of the Pomeranian Phase of the last glaciation over most of the landscape (Fig. 2B). On this basis, we interpret the ridge-and-swale topography of the Bauda headwaters as the result of glacial smoothing of pre-existing ice-shoved ridges during the Pomeranian readvance.

Mława. This site marks the boundary between lowlands underlain by outwash sediments to the south and a hilly end moraine immediately to the north (Michalska, 1961, 1967). Age of the Mława end moraine is uncertain, although it is situated beyond the limit of late Vistulian Glaciation. At this site we collected KAP with both the manual and radio-controlled KAP rigs under mostly sunny sky with a moderate northerly wind (20 km/h). We lifted the KAP rigs with an airfoil kite of moderate size (1 m^2). The KAP images display the sharp contrast between forested hills of the end moraine and cleared land of the outwash plain to the south.

Mrozy. The village of Mrozy is situated in the lowland plain, which extends across central Poland (Różycki, 1972*a*, *b*). This village was our only attempt to conduct KAP from a suburban setting. KAP within cities is often difficult because of many obstructions and danger to people and structures. In this case, we flew the KAP rig from a football (soccer) field that was surrounded by tall trees on three sides. Fortunately the field was open on the upwind side, so we were able to launch the kite and obtain enough height to clear the trees on the downwind side. We utilized a large rigid kite (3 m^2) with the radio-controlled KAP rig under partly sunny conditions. Our KAP results depict the pattern of village planning, in which houses and structures are situated along the primary transportation routes, i.e. roads and the railroad.

RESULTS AND DISCUSSION

Our results suggest that kite aerial photography may be utilized in different situations to acquire low-height, high-resolution imagery for various Quaternary investigations in Poland. KAP has the advantage of being highly portable and quick to set up in the field; within a period of several days, we were able to visit and photograph five sites at widely separated locations. The total cost of KAP equipment we utilized in the field is on the order of $1000, and travel costs within Poland were only a few $100. Of course, once acquired, the equipment costs can be spread over multiple missions and several years. Thus, the "cost per mission" becomes quite modest in comparison to acquiring customized conventional airphotos for special situations.

KAP also lends itself to more specialized techniques, such as stereo and colour-infrared imagery, again at small cost compared to conventional aerial photography. The limited ground area depicted per photograph offsets the advantage of high resolution; thus, many images are necessary to cover sites more than a few hectares in area. The cameras normally employed for KAP do not have the geometric fidelity of aerial mapping cameras. In this regard, conventional airphotos are certainly more useful for medium-scale mapping and photogrammetry over broad regions.

Based on our experience, we offer the following considerations for Polish KAP:

1. Polish weather varies substantially on daily and regional bases. Effective KAP must be "scheduled" in such a way that appropriate weather conditions can be utilized when and where available. In other words, the KAP equipment should always be ready for use, and the photographer should be prepared to alter his/her work schedule accordingly.

2. Preliminary scouting of possible KAP sites is an effective way to utilize periods of unfavourable weather. Knowing where to go and how to set up quickly make for much more efficient work when good weather comes.

3. There is no single kite or camera rig that is best for KAP. A suite of large and small kites, both airfoils and rigid types, is recommended to take advantage of a wide range of flying conditions and various kinds of KAP rigs.

4. Although forest and other obstacles are common, good KAP sites can be found almost everywhere in Poland. Fallow fields, beaches, parks, roadsides, and other open areas are

suitable for KAP. In general, trespass regulations are less strict in Poland than in the United States; however, access restrictions do apply in certain national parks, around military areas, *etc.*

CONCLUSIONS

Kite aerial photography represents a low-cost alternative to conventional aerial photography for acquiring large-scale imagery in special situations. Good candidates for KAP are sites of limited opportunity or rapid environmental change, where sub-metre resolution is needed for detailed mapping or interpretation. KAP has certain advantages in portability, flexibility, and repeatability for field operations, but it will not replace conventional aerial photography for general survey and mapping purposes. The Baltic coastal region is considered most favourable for KAP in Poland.

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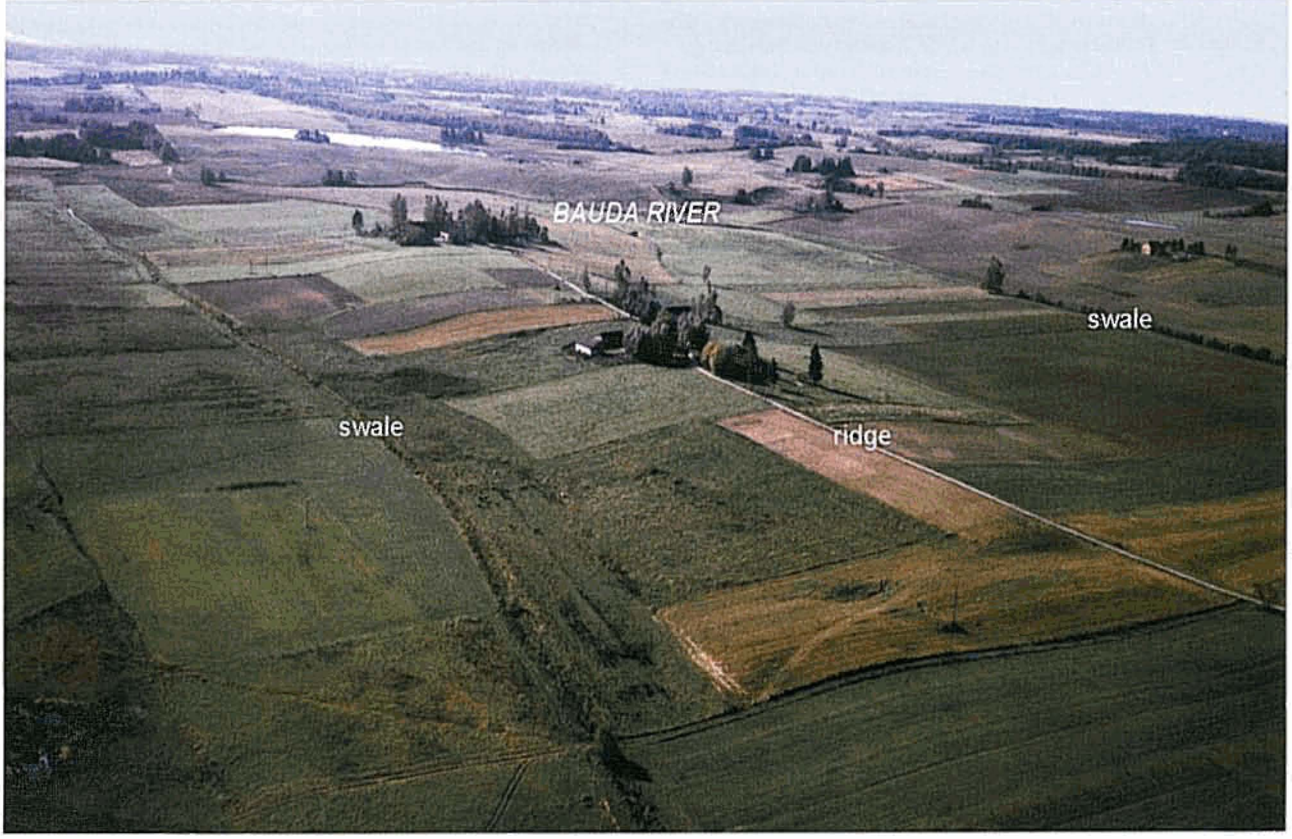
1. Scene at Władysławowo, northern coast of Poland. This view toward the north-west shows the Baltic beach in the foreground with the fishing harbor in the background. Image derived from original colour-slide photograph; photo date 10/98



2. View of agricultural landscape south-east of Majewo, northern Poland. This view toward the south depicts the subtle ridge-and-swale topography in the source region of the Bauda River. The swales and ridges trend SE–NW in a gentle arcuate pattern that parallels larger ice-shoved ridges north of Majewo. Note the level of detail visible in this view, in which individual crop rows and plow furrows can be seen. Compare with topographic and geologic maps (Fig. 2). Image derived from original colour-slide photograph; photo date 10/98