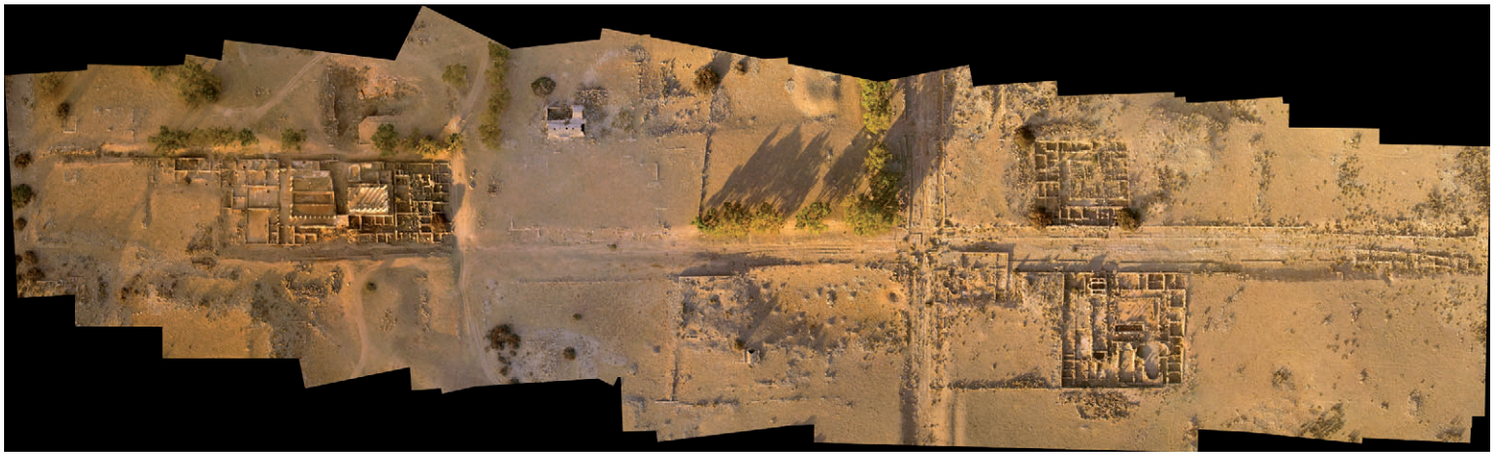
Miron Bogacki

Archaeological kite aerial photography in Ptolemais in years 2006-2008

Photographs taken with a camera suspended from a kite have been used in topographic surveys of Ptolemais since 2006. This documentation technique dates back to the 19th century[1]. For Libya examples of such images are known i.a. from Cyrene[2], as well as from the site of Old Germa, where they were taken by Toby Savage in 2001[3].

In Old Tolmeita kite aerial photographs were shot for the first time in 1989, as part of research conducted by J.H. Little[4]. Besides limited archaeological investigation, the campaign yielded a series of photographs used to create a photomosaic covering the north-eastern part of the city and the *cardo*. The mosaic consisted of eight photographs. In 2007 it was possible to assemble a similar photographic map, but it was composed of over 30 photographs and it covered a larger part of the city (fig. 1).



■ *fig. 1*
The cardo *– a mosaic of stitched kite aerial photographs (photos M. Bogacki)*

Due to its geographic setting, Ptolemais receives frequent and strong winds from the sea. They were the main reason for choosing a kite as the carrier for the camera. Desert winds from the south ("ghibli") also occur in Cyrenaica. They, however, are particularly bad for photography, as they carry dust that limits visibility and damages electronic equipment.

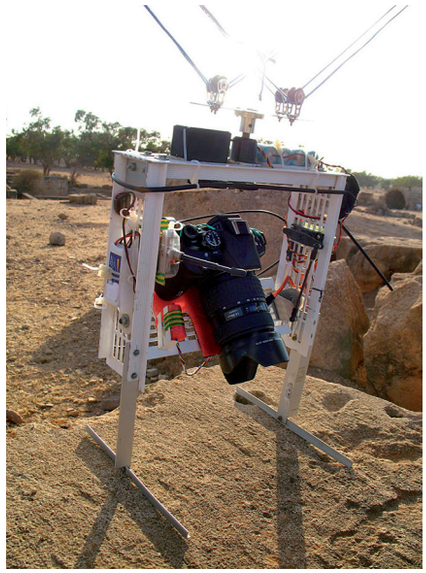
Aerial photographs were taken throughout four excavation campaigns. The first expedition took place in September 2006, the second at the turn of April 2007, the third in September 2007, and the fourth in May

1 J.S. Aber, History of kite aerial photography, in: http://www.geospectra.net/kite/history/history.htm (2008).

2 M. Luni (ed.), Cirene "Atene d'Africa", Monografie di Archeologia Libica 28 (Roma 2006) 133, 136, 137, 147, 150.

3 N. Brooks, in: http://en.wikipedia.org/wiki/Germa.

4 J.H. Little, Note on the 1988/89 seasons at Tolmeta, LibSt 21, 1990, 23.



■ *fig. 2*
Remote-controlled camera rig

of 2008. The seasons turned out to be well selected, as the weather conditions were favourable for work most of the time. The wind blew mostly from the north or north-east and was strong enough for the kite to lift the camera, weighing ca. 3.5 kg, along with the rig (fig. 2).

Photographs were taken mostly in the morning, right after sunrise, and in the afternoon. At those times, thanks to the Sun's low position and the resulting shadowmarks, any protrusions and cavities in the terrain were visible more clearly[5]. This was the fundamental indicator for locating new structures and buildings and verifying the ones that were already known. Prior to departure for Ptolemais the analysis of cropmarks was also planned[6]. However, it turned out that a continuous fence no longer surrounds the area of the ancient city and as a result goats and sheep that roam freely in it graze on all vegetation, bringing it down to one level. This hindered the analysis of the distribution and growth of vegetation in the photographic material. The third group of indicators used in aerial photography are soilmarks[7]. However, their visibility on site is very poor, since the ground is dry and mostly uncultivated.

The carriers for the camera were two so-called flow foil kites (fig. 3). A "flow foil" is a kind of aerodyne, very stable in flight and with good pull. Its sparless

■ *fig. 3*
Kites for aerial photography

construction takes up very little space in the luggage when packed. It has a flying angle of 45-60 degrees, unlike framed kites used in the Sudan, for instance, which launch almost vertically[8]. Kites were flown on various altitudes, from 5 m to ca. 300 m a.s.l. To launch they require a stretch of open field at least 50 m in length. For the first campaign only the smaller sail measuring 350 by 280 cm was brought. It is suited to a wind range of 1.0-5.0 Bft. From the second campaign onwards also a second kite was used, Fotokite 400, measuring 300 by 400 cm. Thanks to its greater pull it lifted a camera even in light wind conditions. Like the smaller model, it is

5 D.R. Wilson, Air photo interpretation for archaeologists (Gloucestershire 2000) 38-40.

6 *Ibidem*, 41-43.

7 *Ibidem*, 53-61.

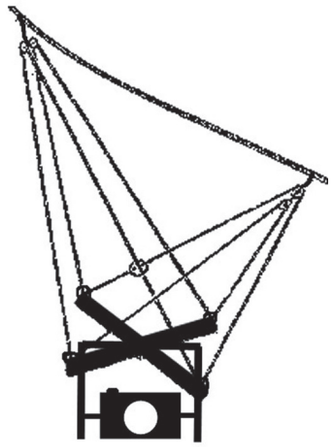
8 B. Żurawski, Areofotografia w prospekcji i eksploracji archeologicznej w Nubii sudańskiej w latach 1913-1993, in: Nauki przyrodnicze i fotografia lotnicza w archeologii, *Bibliotheca Fontes Archaeologici Posnanienses* 9 (Poznań 1998) 251.

■ *fig. 4*
S. Lenarczyk flying a kite (photo M. Bogacki)

suited for wind speeds of 1.0-5.0 Bf, but due to its strong pull it was used mostly in light winds.

There are no significant topographic obstacles on site, and trees, which could hinder movement with the kite attached to the operator, are scarce (fig. 4). It was therefore possible to take photographs all over the ancient city[9]. We also managed to document part of the eastern and western necropoleis, as well as the area to the north that is occupied by modern buildings, the Old Tolmeita. Both vertical[10] and oblique images were shot. The first campaign yielded only vertical photographs, as the rig did not permit camera movement up and down. Before the second campaign the cradle was modified to allow oblique pictures. During the four campaigns several tens of thousands of pictures were taken in total, altogether weighing ca. 430 GB.

Two digital cameras were attached to the kite. During the first and second seasons it was a Konica Minolta A 200, in the third and fourth campaign it was the SLR Olympus E-510 ZUIKO 14-54 mm lens. The Minolta was selected because for its class it provided good parameters of the image sensor. Compared to the more advanced SLR models, it was also distinguished for its light weight and image preview on an LCD screen. It is a very useful feature in kite aerial photography be-



■ *fig. 5*
"Picavet" suspension

cause the preview can be sent to the photographer on the ground by a radio-controlled transmitter. However, working with this camera also revealed its flaws. It turned out that the built-in light meter made errors when calculating the aperture and most of the images were more or less overexposed. For this reason, in the third campaign this camera was replaced by the newer Olympus. It is a heavier camera, but thanks to a better-quality lens and sensor it was possible to take much more precise photographs. It is also equipped with an optical image stabiliser, useful for avoiding blurred images that result from camera shake during flying. It was also one of the few SLRs available then that had live image preview, the so-called LiveView. Memory cards used had a capacity of 2GB and 8GB, enabling the shooting of up to 600 photographs. The images were mostly recorded in RAW format.

To control the camera suspended from the kite a special rig was designed. Its creation was possible thanks to experience gained in preparing an earlier structure for

9 The area of the city was examined in a prior topographic survey by W. Małkowski, cf. W. Małkowski – J. Żelazowski, Some remarks on the history and topography of Ptolemais in the light of Polish research, in this vol., 35-56.

10 Photographs were classified as vertical if the tilt of the camera's image sensor was less than 5% from the level of the Earth's surface.

■ *fig. 6*
LCD panel for preview of the taken photographs

a helium balloon[11] and using schemes available online[12]. Its structural elements were mostly made of aluminium. Additions were servomechanisms[13] used in remote-controlled models and controls for engine operation, releasing the shutter and transmitting the image from the camera to the ground. The cradle also carried batteries that powered all the equipment. The lower part of the rig enabled the camera to be tilted up and down. Attached to the upper part was a powered revolving axis, thanks to which the entire structure could rotate by 360 degrees. In order for the cradle to remain parallel to the earth's surface its weight was properly balanced and a "picavet" suspension was used[14]. This solution is lightweight, portable and simple to make. A cross with pulleys on each of the four arms was attached to the upper part of the cradle, on the rotating part of the axis. A line passed through these pulleys and its ends were fixed in two points of the kite line (fig. 5).

The rig and camera were operated using a radio-control mechanism adopted from flying models. It was adapted to control servomechanisms for tilting the camera vertically and rotating it sideways. An additional channel was set up in it to turn on the camera's autofocus and release the shutter. The radio transmitter was built into a plastic board, which also carried a 7-inch LCD panel (fig. 6). The panel served to control composition of the taken images. It was possible thanks to a radio transmission of a video signal from the camera suspended from the kite. The entire device was portable, so the photographer was able to move together with the kite operator.

Two persons were usually needed during picture taking. Due to the significant pull of the kite, holding the line and simultaneous control of the camera setting was impossible. The kite operator held on to the kite line, moved following the photographer's instructions and regulated the flying altitude by spinning out and reeling in the line. Various types of lines, 2 mm to 3 mm in diameter, were used. Their length totalled to about 600 metres, and their maximum pull according to the producer ranged from 60 to 200 kg. While working in the field it was necessary to make a loop on the line to keep the kite on a set elevation. Protective gloves were very useful when holding the line. Sometimes a third person assisted with reeling the line onto the spool to keep knots from forming. Such help was especially useful in strong winds when the kite and camera were reeled in. Two people wound the line on the spool and the third one kept the camera from hitting the ground.

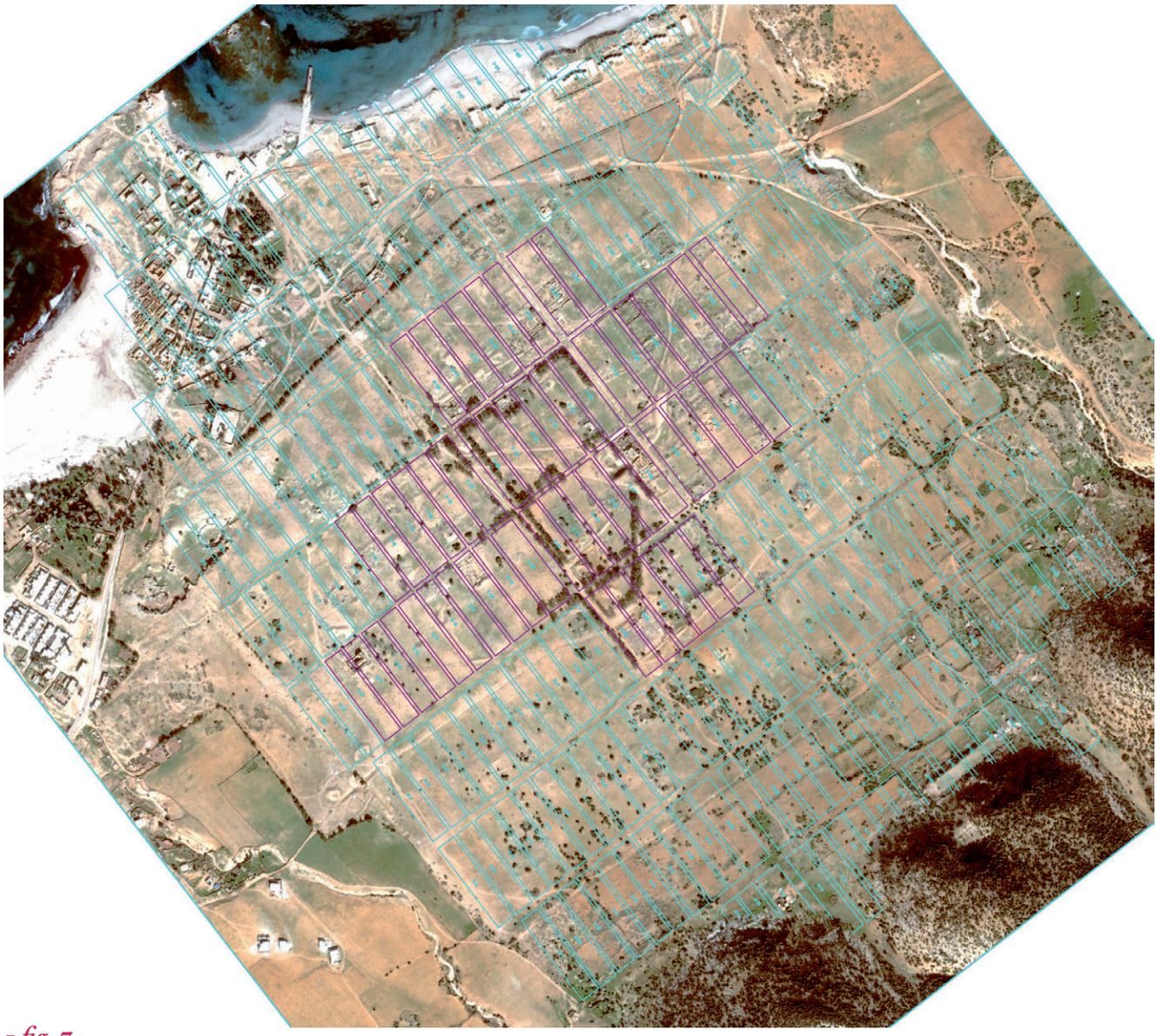
The photographer, as the second member of the team, monitored the camera image on the LCD screen and took pictures. There were sometimes difficulties with identification of the exact location of the area seen on the panel and with excessive camera movement due

11 Together with Michał Dąbski of the Institute of Archaeology, University of Warsaw, we built a special helium balloon with a camera suspended from it in orded to photograph Polish archaeological sites.

12 S. Haefner, in: http://scotthaefner.com/kap/equipment/rig/ (2011).

13 A miniature engine used in models.

14 C.C. Benton, Picavet suspension, in: http://arch.ced.berkeley.edu/kap/equip/picavet.html (2010).



■ *fig. 7*
A plan of Ptolemais drawn by W. Małkowski with insulae *marked to facilitate the sorting and finding of the vertical images*

to strong, gusty wind. At times, when the line was fully extended, the LCD panel lost the camera image due to the limited range of the radio transmitter conveying the video signal.

One photographic session usually lasted two to three hours. Shooting time was limited by the capacity of the camera's memory card and battery life. If weather conditions permitted, photographs were taken twice a day, starting 7:00 a.m. and 5:00 p.m. Pictures shot in mid-day sun, from noon to 2:00 p.m., came out much worse. The shadow was shorter, soil colours varied little and were more overexposed, and the visibility of particular architectural elements was much poorer.

In the first season only vertical shots were taken. It was possible to build a large library of pictures of individual buildings, streets and the excavated area. Among the photographed structures were Palazzo delle Colonne, Via Monumentale, Odeon and West Central Basilica. These images were used in topographic and geophysical surveys. Also the progress of works in the area and vicinity of the House of Leukaktios and individual elements of this building, like mosaics and walls, were documented. The experience of the first season was

■ *fig. 8*
The House of Leukaktios in the final stage of archaeological works in October 2007 (photo M. Bogacki)

invaluable, as it permitted to improve the photographing method in subsequent seasons. After this month of work it was thought necessary to add the option of tilting the camera up and down (which also turned out useful for vertical photographs). The range of the transmitting device was increased. Finally, the reel and lines needed to be with ones made of more durable material.

In the spring of 2007 the field season lasted three weeks. Fourteen photographic sessions were conducted. Thanks to the extended range of the radio transmitter it was possible to photograph from greater altitudes. The introduction of camera tilting, in turn, allowed for oblique shots to be taken. Such images were of no use for plan drawing and studies on topography, but they opened new possibilities of viewing the site and searching for elements of the city known e.g. only from written sources or descriptions of previous researchers. Besides taking supplementary pictures of different quarters within the city walls, the team was also able to document a part of the eastern necropolis and the vicinity of the Tauchira Gate.

Due to the large number of pictures it became important to come up with an easy and straightforward way of accessing them. The vertical images were grouped according to the area they covered. The *insulae* of the ancient city were assigned letters of the alphabet in order from south to north and numbers rising from west to east (fig. 7). The remaining oblique photographs were divided into general views of different parts of the city and images of buildings and structures of Ptolemais.

During the campaign in spring 2007 it was also possible to correlate the aerial photographs with geophysical

■ *fig. 9*
Tauchira – city walls (photo M. Bogacki)

surveys of the Early Christian monuments in Ptolemais. Vertical and oblique photographs were taken of five buildings with apses, which may have functioned as Early Christian churches. The method of geophysical prospection in which kite aerial views serve as one of the layers of multidimensional documentation is described by Krzysztof Misiewicz in this volume[15].

From October 2007 onwards kite aerial photographs were shot with the newer Olympus camera, which was launched fourteen times in three weeks. The main objective that season was to document the *insula* of the House of Leukaktios as fully as possible. A greater part of the excavated area was to be backfilled after that campaign. Thanks to favourable weather conditions it was possible to reach this goal and photograph all the mosaics and rooms of the villa from various altitudes and in different stages of excavation works (fig. 8). Capturing the more important buildings in the city on both vertical and oblique images continued as well. The broad *cardo* was documented in a series of pictures later stitched into a photomosaic, which showed the street in its entirety (fig. 1). Most of the buildings and structures along the ancient street now called the Via Monumentale were also photographed.

During the spring campaign in May 2008 the greatest obstacle for photography was the weather. Over the three weeks in the field the wind conditions were favourable only for four days. However, it was possible to document the state of archaeological work at the House of Leukaktios, as well as take supplementary photographs

15 K. Misiewicz, Geophysical prospection in Ptolemais – interim report, in this vol., 57-75.

■ *fig. 10*
Rectified images of the Via Monumentale (photos M. Bogacki)

of the eastern necropolis and several buildings in the city. In cooperation with the Libyan Department of Antiquities a photographic session of the ancient city of Tauchira was carried out (fig. 9). The images were used to search for analogies between the two sites.

Positive examples of the use of kite aerial photography in Ptolemais can be presented based on a series of shots of the House of Leukaktios, Western Basilica, as well as pictures of the vicinity of the Odeon and Palazzo delle Colonne.

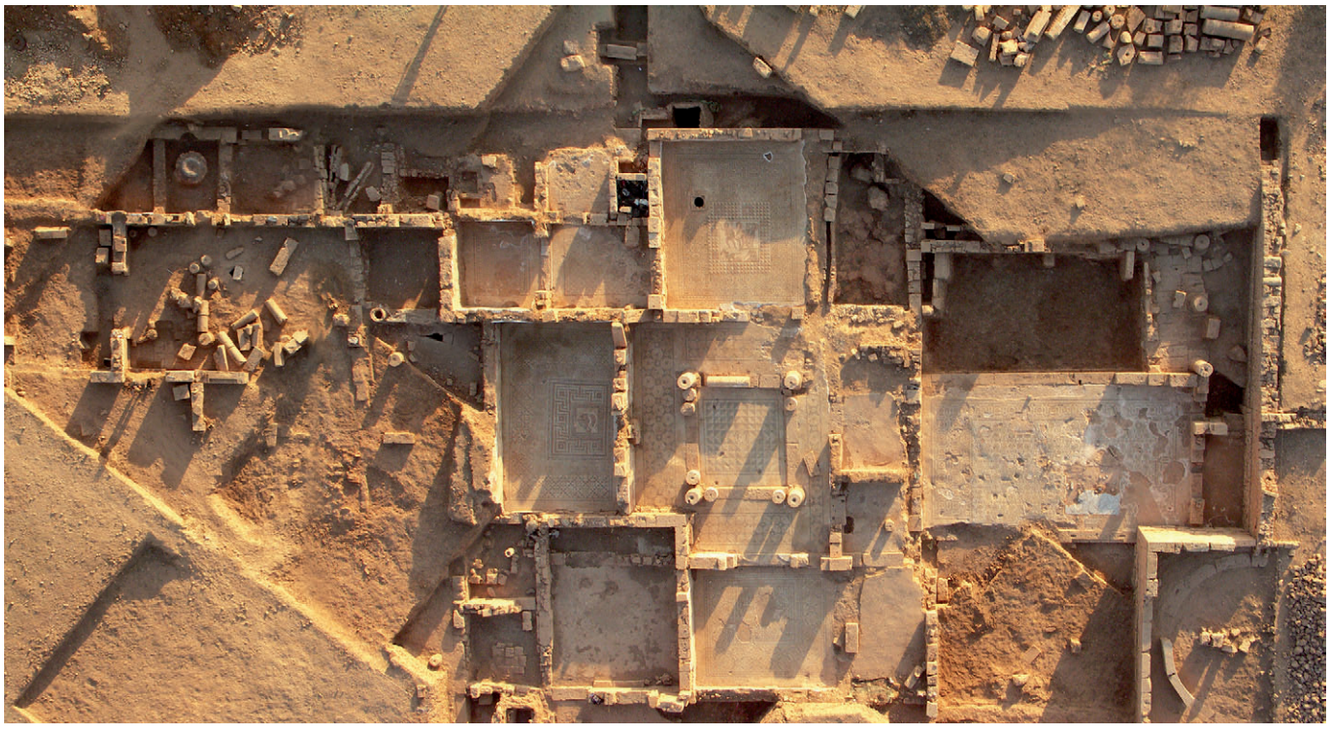
The area excavated by the Polish Archaeological Mission (fig. 11, 12) was the most important object of kite aerial photography. The images were shot in higher resolution to permit the viewing of the uncovered area in the context of an *insula*, as well as from a lower level, zooming in only to the area of the Polish excavations. Various structural elements were also photographed in order to obtain a higher resolution of images of rooms and mosaics. The best light for the later archaeological interpretation of the photos was observed at dawn and in the late afternoon. It gave a uniform yet textured image and the rays of the sun were often softened by clouds. In such conditions the transition between the shadows and the lit areas was soft.

Three photographs from 2006 were taken in the late afternoon and they were subsequently stitched together into a mosaic using a graphics-editing program. As a result it was possible to obtain greater accuracy of the image even though the camera was poorer than in subsequent seasons. The 2007 image was already taken with the newer Olympus SLR with a better lens. An individual picture is easier to rectify and turn into an orthophotograph. The early hour with its overcast sunshine was selected intentionally, so that high contrasts would not interfere with the view of the site. Pictures taken in direct sunlight give a more striking effect and are better for site promotion purposes, but they constitute poorer, less clear documentation.

Four shots presenting the Western Basilica give an overview of this building in different scales. Photographs taken at the highest altitude in the spring (fig. 13) and in autumn (fig. 14) show the context of the building. The low angle of the light on the autumn pictures brings out every mound and rock found in the vicinity of the church, giving an overview of the surrounding structures. The vegetation in the image taken in spring may hint at structures or voids below the surface. A hindrance in observation were loose stone blocks deposited throughout the large area around the basilica by earlier researchers on Ptolemais. On the high-altitude views one can attempt to identify the boundaries of the

■ *fig. 11*
Villa with a View 2006 – a mosaic composed of two pictures

■ *fig. 12*
Villa with a View (House of Leukaktios) – October 2007 (photo M. Bogacki)



■ *fig. 13*
The Western Basilica from the highest altitude (photo M. Bogacki)

■ *fig. 14*
The Western Basilica and surroundings – a vertical image (photo M. Bogacki)

■ *fig. 15*
The Western Basilica (photo M. Bogacki)

■ *fig. 16*
The Western Basilica – an oblique image (photo M. Bogacki)

■ *fig. 17*
The supposed forum of Ptolemais – 2006 (photo M. Bogacki)

■ *fig. 18*
The supposed forum of Ptolemais – 2007 (photo M. Bogacki)

whole church complex, distinguish the dumps of earlier excavators and trace the limits of *insulae*. However, they do not offer as much detail as the low-altitude images (fig. 15), which even show details of the walls. The oblique shot, in turn, places the ruins of the basilica in the context of the entire city, giving an idea of their surroundings (fig. 16). This view is more natural to the human eye and it allows an assessment of the height of the monuments.

The area to the north-east of the Odeon was identified as the old agora thanks to geophysical surveys[16]. On the first image from 2006 (fig. 17) the low-angle evening light brings out the edges of *insulae* and the canal running across the photograph. Fig. 18, in turn, covers only the area of the supposed agora. There is a clear difference in the air transparency and the character of light in the two pictures. The area on the 2007 photo is lit by soft early-afternoon light and the one from 2006 is taken in harsh evening light. The 2007 image is better for the observation of soil- and cropmarks, since shadows do not interfere with the analysis. The earlier photograph, in turn, gives a better rendering of the terrain.

Palazzo delle Colonne as the most recognised monument of Ptolemais was repeatedly photographed with a camera suspended from a kite. Its location near the House of Leukaktios also favoured its documentation. The exposed parts of the complex, along with the huge cistern abutting it on the west, were photographed already in 2006 (fig. 19). Taken in the autumn of 2007, in turn, were images for the photomosaic (fig. 20), as well as a more detailed low-altitude picture (fig. 21) and an oblique shot with the Square of the Cisterns in the background (fig. 22). The mosaic of images presents Palazzo delle Colonne in the context of the entire *insula*, while the close-up permits to view some of the mosaics and the central part of the palace in high resolution. As in the case of the Western Basilica the oblique image shows this Hellenistic building from a more natural perspective, as part of the city. Interpretation of the image is hindered by debris that obscures the photographed area. Dirt encroaches on Palazzo delle Colonne, as no conservation work is carried out in the complex.

To sum up the four seasons of kite aerial photography at Ptolemais, one can list the following results. Vast photographic documentation of the city from various altitudes and viewpoints was collected. Besides several hundred oblique images, vertical shots of the following

16 K. Misiewicz, At search of forum at Ptolemais. Interpretation of results of geophysical surveys at the central part of the city, in: E. Jastrzębowska – M. Niewójt (ed.), Archeologia a Tolemaide (Roma 2009) 133-145.

■ *fig. 19*
Palazzo delle Colonne – 2006 (photo M. Bogacki)

■ *fig. 20*
Palazzo delle Colonne – mosaic consisting of six photographs (photos M. Bogacki)

■ *fig. 21*
Palazzo delle Colonne – central part of the palace, 2007(photo M. Bogacki)

structures were obtained: House of Leukaktios, Palazzo delle Colonne, the Headquarters of the Dux, Western Basilica, West Central Basilica, Odeon, amphitheatre, Byzantine Theatre, Square of the Cisterns, Roman Villa, House of Paulus, House of the Triapsidal Hall, East Fortress, Open Reservoir, Doric Temple, Stadium, Tauchira Gate, East Gate.

The registration of hundreds of vertical images leads to their use in further studies, photogrammetric projects, photomosaics, plans and maps. To date, the pictures were rectified and orthophotomaps were created according to a city plan drawn based on total station measurements using Autodesk Autocad Raster Design software[17], of the following: Via Monumentale (fig.10), House of Leukaktios, Palazzo delle Colonne, Headquarters of the Dux, West Central Basilica, Western Basilica and House of Paulus. The areas documented on photomosaics include the eastern necropolis, the *cardo* (fig.1), and Via Monumentale.

The extent of the city was verified based on visible remains of city walls, which were documented in their entirety on the eastern and western sides of the city. Photomaps have been made of the buildings with apses, which may have been Early Christian churches.

In the *insula* of the House of Leukaktios the subsequent phases of excavation were documented. Vertical shots of all mosaics and rooms of the villa were taken. The overviews have contributed to the effective promotion of the excavations and the ancient remains of Ptolemais, i.a. at photo exhibitions at the Museum in Tripoli in 2007 and in Warsaw in 2006 and 2008[18].

17 W. Małkowski, The city plan of Ptolemais, in: E. Jastrzębowska – M. Niewójt, Archeologia a Tolemaide..., 125-132.

18 The 2006 exhibition took place in December at the Institute of Archaeology at UW. The 2008 exhibition was opened also in December at the Royal Castle in Warsaw.

■ *fig. 22*
Oblique image of Palazzo delle Colonne with the Square of the Cisterns in the background (photo M. Bogacki)

Aerial photographs are also used to demonstrate the destructive effects of new road building and housing projects on the state of preservation of the ancient city of Ptolemais.

Given the sheer bulk of collected documentation, the proper storage and retrieval of data has been a challenge. The steps taken so far, such as linking the individual images of the city to an *insula* grid, seems to be a step in the right direction. There are plans to create a database with integrated access to all data, not only aerial photographs. The next step will be to use photogrammetry programmes operating based on photographs taken in a specific way and with a calibrated camera. Such software will facilitate the creation of orthophotographs and of a digital model of the ancient city and the excavation site. As the results obtained thus far have shown, kite aerial photography is a very useful tool in the archaeological investigation of Ptolemais.

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Photo M. Bogacki