

THE USE OF SATELLITE IMAGERY IN AN ARCHAEOLOGICAL SURVEY IN IRAQI KURDISTAN

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Abstract

Using satellite imagery has recently become a standard procedure in survey projects carried out in the Near East, including Mesopotamia. Analysing the CORONA spy satellite program images dating back to the 1960s as well as the much more recent imagery from the LANDSAT, ASTER and QuickBird satellites is a starting point for any project of this kind, and during the long period of political unrest it constituted the only source for studying the ancient settlements of Iraq.

The Upper Greater Zab Archaeological Reconnaissance project, conducted by the Institute of Prehistory, Adam Mickiewicz University in Poznań in Iraqi Kurdistan since 2012 relied mainly on CORONA and QuickBird imagery. However, two seasons of field experience, allowing to verify provisional identifications of archaeological sites made on the basis of the satellite imagery, demonstrate that the efficiency of this method depends on numerous factors, and is particularly low in the highland areas. The paper discusses the reasons for this phenomenon and suggests some provisional solutions which may improve the effectiveness of the identification of archaeological sites in highland morphological zones based on satellite imagery.

Keywords: remote sensing, satellite imagery, survey, Mesopotamia

Resumen

En los últimos años, el estudio de las imágenes satelitales del terreno se ha convertido en un procedimiento habitual en los proyectos de prospección arqueológica desarrollados en la zona del Próximo Oriente y en particular, en Mesopotamia. El análisis de las fotografías conseguidas por medio del programa CORONA y, en un menor grado, también gracias a los satélites LANDSAT, ASTER y QuickBird es una etapa inicial de cualquier proyecto de estas características y en algunos casos, la única fuente para analizar la historia de los asentamientos, especialmente en el territorio de Iraq, en práctica inaccesible.

El proyecto de prospección superficial desarrollado desde 2012 por el Instituto de Prehistoria de la Universidad Adam Mickiewicz de Poznań en el territorio de Kurdistán iraquí también aprovecha las imágenes CORONA y QuickBird. No obstante, la práctica diaria ha demostrado que su eficacia en cuanto a la identificación de los yacimientos arqueológicos depende de una serie de factores, siendo relativamente baja en las zonas con muchas colinas. El autor pretende comentar las causas de tal situación y proponer soluciones que faciliten el empleo eficaz de las imágenes satelitales en los terrenos menos favorables.

Palabras clave: técnicas no invasivas, imágenes satelitales, prospección superficial, Mesopotamia

INTRODUCTION

In 2012 a research project entitled “Settlement History of Iraqi Kurdistan” was commenced by the present author on the basis of grant No 2011/3/B/HS3/01472 of the National Science Centre, Poland. An integral part of the research activities was a field survey Upper Greater Zab Archaeological

Reconnaissance carried out in years 2012-14 in Northern Iraq, on a territory located in the middle sector of the valley of the Greater Zab river, a tributary of the Tigris. The work permit, provided kindly by the General Direction of Antiquities of the Kurdistan Regional Government in Erbil¹, covers an area of c. 3 000 km², located both on the eastern and on the western bank of the river, immediately south of the southernmost ranges of the Kurdistan Mountains (Figure 1).

This project is one of four similar programs of field survey aiming at the creation of an archeological map of Northern Kurdistan, territory which was occasionally visited by archaeologists in the later 19th and early 20th century, but starting from 1961 was barely accessible for more extensive study because of the escalation of the guerilla war waged by the Kurds against the Baghdad government (Koliński 2009). For this reason, the Kurdish part of Iraq was never surveyed; the only sound information on its heritage was that included into the “Atlas of Archaeological Sites in Iraq” (Salman 1976), based on

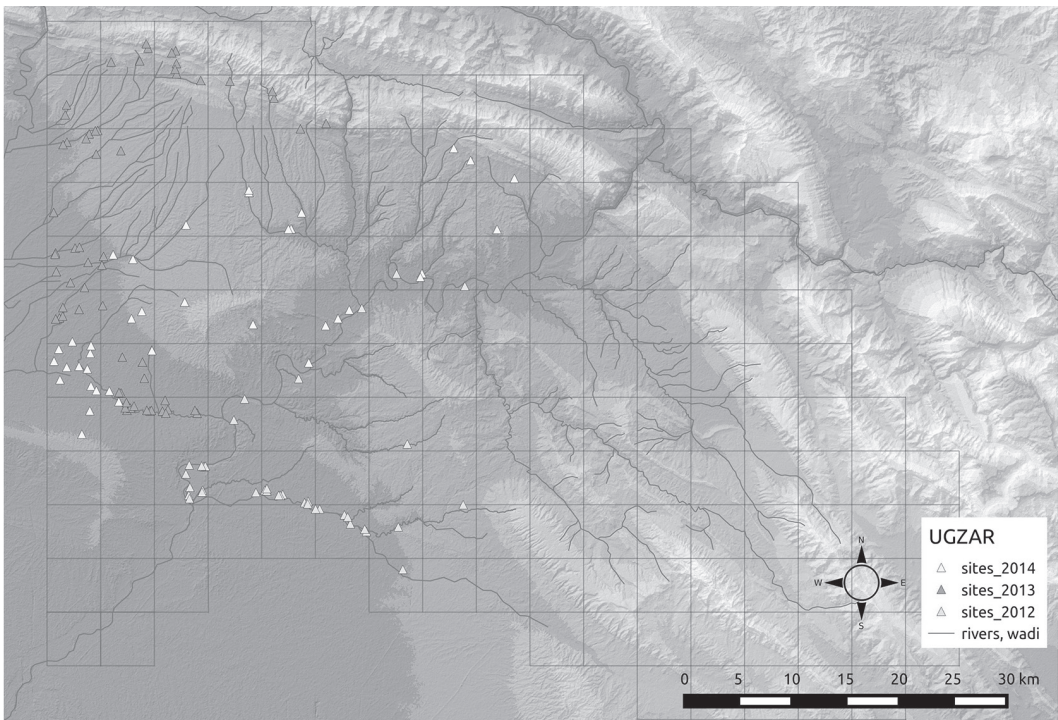


Figure 1. The area covered by the UGZAR project work permit with sites identified during field seasons 2012-2014 (drawn by Joanna Mardas).

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fragmentary information collected by local offices of the Antiquity Service of Iraq in 1930s, 1940s and 1950s. Only in 2005, a few years after Kurdistan became an autonomous part of Iraq, and turned out to be much safer than the other parts of Iraq, conditions for archaeological fieldwork improved. However, a massive influx of archaeologists occurred only when the “Arab Spring” rendered Syria inaccessible for any fieldwork in 2011.

Since late 1990s the use of satellite imagery became a standard procedure in the Near Eastern field surveys (Ur 2003: 104-5; 2013a), especially since the photographs of the CORONA spy satellite program became declassified in 1995 and were made available in the public domain. The CORONA program was run during the years 1959-72 and resulted in the execution of 145 spy missions (Day *et al.* 1998). The images were taken by optical cameras on black-and-white film, which was ejected from the satellite and picked up in the air by a special airplane. The images cover mainly the area of the former Eastern Block and of the Third World, including the Near East. The quality of images depended heavily on weather conditions and technology. Starting from 1967 high quality lenses were in use, as well as two cameras allowing for the stereographic processing of photographs obtained allowing for precise mapping of the areas in question. The CORONA imagery is now available through the US Geological Service² as scans of up to 6 feet per pixel resolution. Recently, orthorectified and georeferenced imagery from some CORONA missions has been made available at the web-site of the CORONA Atlas of the Near East³.

The advantage of the CORONA imagery stems from the fact, that is relatively good quality images were taken in late 60s and early 70s, that is before the intensification of agriculture and settlement caused by the oil boom of the 1970s in the Near East. It is thus possible to see in them not only ancient settlements (including inner structure of large cities – Ur 2013b), but some off-site features as well, for instance canals (Ur 2005), hollow-ways (Ur 2003), karaz etc (Ur *et al.* 2013a: figs 10, 14).

THE USE OF SATELLITE IMAGERY IN THE UGZAR PROJECT

The project team referred to the satellite imagery during two phases of the realisation of the project. The first phase consisted of analysing of the available CORONA images before going into field. The second involved referring to CORONA images and to imagery available on public platforms such as GoogleEarth™ and BingMaps™, using mainly the QuickBird imagery, during the field campaigns.

A virtual reconnaissance in order to, identify potential archaeological sites had been carried out on the basis of CORONA missions 1104 and 1107, available on the CORONA Atlas of the Near East web site, and mission 1039, provided by Dr. Jason Ur of Harvard University. These identifications were then compared to maps showing the distribution of archaeological sites published in the “Atlas of Archaeological sites in Iraq” (Salman 1976) leading to a conclusion that more sites could be present in the area than indicated by the “Atlas”.

During the season, satellite imagery was always referred to when a new site was documented (checking if it had already been identified in the reconnaissance phase, and if not, why). Recent satellite imagery was additionally used for navigation in the countryside (topographical maps of the area under scrutiny are not available) and for preparation of the site distribution maps of the project.

The result of the satellite imagery analysis was, in the case of the UGZAR project, much less spectacular than in another project carried out in Kurdistan, namely the Erbil Plain Archaeological Survey, directed by Jason Ur (Ur *et al.* 2013b). In the case of the UGZAR project, only 32 of 99

² https://lta.cr.usgs.gov/declass_1

³ <http://corona.cast.uark.edu/index.html>

sites registered during the 2012 and 2013 seasons were earlier identified on the CORONA imagery, amounting to 32,3% of all sites.⁴ The EPAS survey on the Erbil Plain enjoyed a much higher ratio of positive identifications: 79 of 112 sites resulting in a proportion as high as 71% (Ur *et al.* 2013a).

The aim of the present paper is to investigate why the use of a similar set of sources according to similar methodology in the UGZAR area yielded much less positive identifications than in the EPAS project. The present author would also like to outline some difficulties in the use of satellite imagery, in contrast to most publications focusing on the most successful examples of the employment of this method.

IDENTIFYING ARCHAEOLOGICAL SITES ON PANCHROMATIC SATELLITE IMAGERY

An important parameter of any imagery is its physical resolution, the sharpness of the picture, the clarity of small elements. As previously mentioned, in the case of CORONA imagery it depended on the type of camera and camera lens used by subsequent generations of satellites. The highest physical resolution is from pictures taken with a KH4B camera during some missions carried out between September 1967 and May 1972 (1,8 m/pixel), but an earlier model KH4A, which entered into service in August 1963 and was used for some missions as late as in October 1969 returned pictures with a lower resolution of 2,75 m/pixel (Fowler 2013: tab. 4.1). Both these resolutions are judged to be high enough to allow archaeological objects to be distinguished, both of site and non-site type (Ur 2003:105).

The identification of potential archaeological sites on panchromatic imagery is based on two different kinds of signatures. The first one, corresponding to “shadow marks” in the aerial photography, are shadows cast by morphological forms, for instance by settlement mounds, a form of archaeological site typical for the entire Near East and Balkans. They are formed by the accumulation of debris of decomposed dried mud brick used commonly in architecture, often reaching more than 10 m, and sometimes as much as 40 m in height. The second signature corresponding to aerial photography “soil marks”, refers to the difference in the colour of the soil, contrasting natural brown and red-brown xerosoils, typical for the area, with light (in fact grey, or yellow) spots marking places of ancient settlement (the difference results again from the use of dried mud bricks in architecture and from the admixture of ashes in the sediments). Signals of this kind are significantly clearer during the arid season and shortly after rain (Philip *et al.* 2002, 2005).

The clarity of shadow signature depends on the relative height of the site, on the gradient of its slope, on the season of the year and the season of the day. During summer and at midday, the position of sun is very high, and shadows are short, or even non-existent at all in case of sites with gentle slopes. Oppositely, shortly after sunrise and before sunset, and on winter days shadows are much longer and would mark even gentle slopes and tiny differences in height. In consequence, an imagery of lower resolution acquired during a more favourable season/time of the day usually provides much clearer shadow-based signatures, than one of a higher resolution, but acquired in less favourable light conditions (Figure 2).

Another source of possible differences in visibility may result from the angle between the surface and the axis of the lens. This difference is best illustrated by comparing images acquired on the same day by one of the CORONA missions using stereoscopic cameras fixed at an angle of 30° to each other,

⁴ These data reflect the situation after the 2012 and 2013 season. In the 2014 season 40 sites were evidenced, but only 9 of them was earlier identified on the satellite imagery, lowering the proportion of successful identification to 29,5%.

one directed forward and the other backward to the direction of the movement of the satellite. In the case illustrated in Figure 3, a small castle with towers and perimeter walls of stone (Qala Deiri, S037) is clearly visible on images taken by a camera tilted forward, but hardly noticeable on images taken by camera tilted in the opposite direction. This is more than surprising, because when visiting the site during the survey it turned out that the walls and towers of the castle stood several meters high. There might be a similar reason why some sizeable settlement mounds (as, for instance Gird-i Mamek, S003, 12 m. in height), were hardly noticeable on the CORONA imagery (Figure 4A). The site was, however, clearly identifiable on modern, high resolution imagery (Figure 4B) and in the field (Figure 4C).

Another problematic issue concerns the visibility of flat sites, and flat areas accompanying mounded sites (usually referred to as “lower town” areas) (Figure 5). They usually do not have well articulated morphology and, consequently, could hardly be identified on the base of shadow signatures. It was expected that colour signatures could serve as a tool for a potential identifications. However, during the field activities of the UGZAR project it turned out that the relatively high number of sites discovered by field-walking had not been earlier identified by examining the satellite imagery or even quite the reverse, in many cases when a site was tentatively identified on the base of colour signature, it turned out to result from natural phenomena, and not from the presence of a settlement. Both these situations require some explanation.

The identification of flat sites is more efficient in arid soil conditions, or just after rain; thus, it

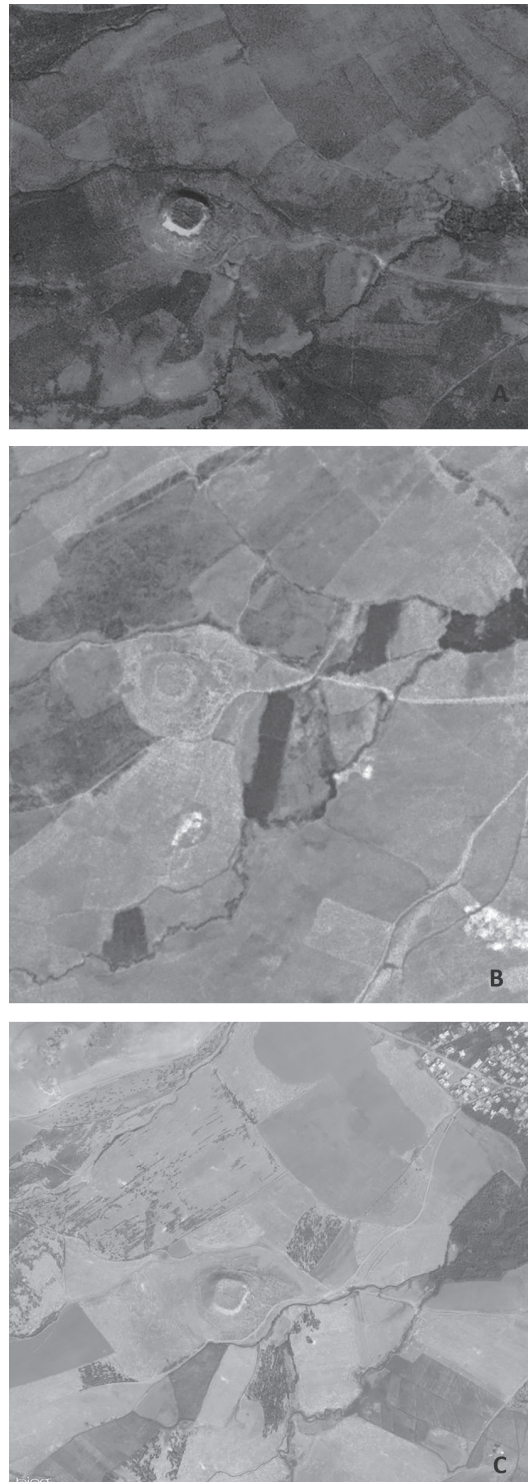


Figure 2. Tell Tlai on satellite imagery: A) CORONA mission 1039, 28.02.1967, resolution 2,75 m/px (courtesy Dr. Jason Ur); B) CORONA mission 1104, 16.09.1968, resolution 1,8 m/px (source: CORONA Atlas of the Middle Near East; courtesy of Center for Advanced Spatial Technologies, University of Arkansas/U.S. Geological Survey), C) QuickBird, resolution 0,5 m/px (source: BingMaps™, visited on 22.03.2013).

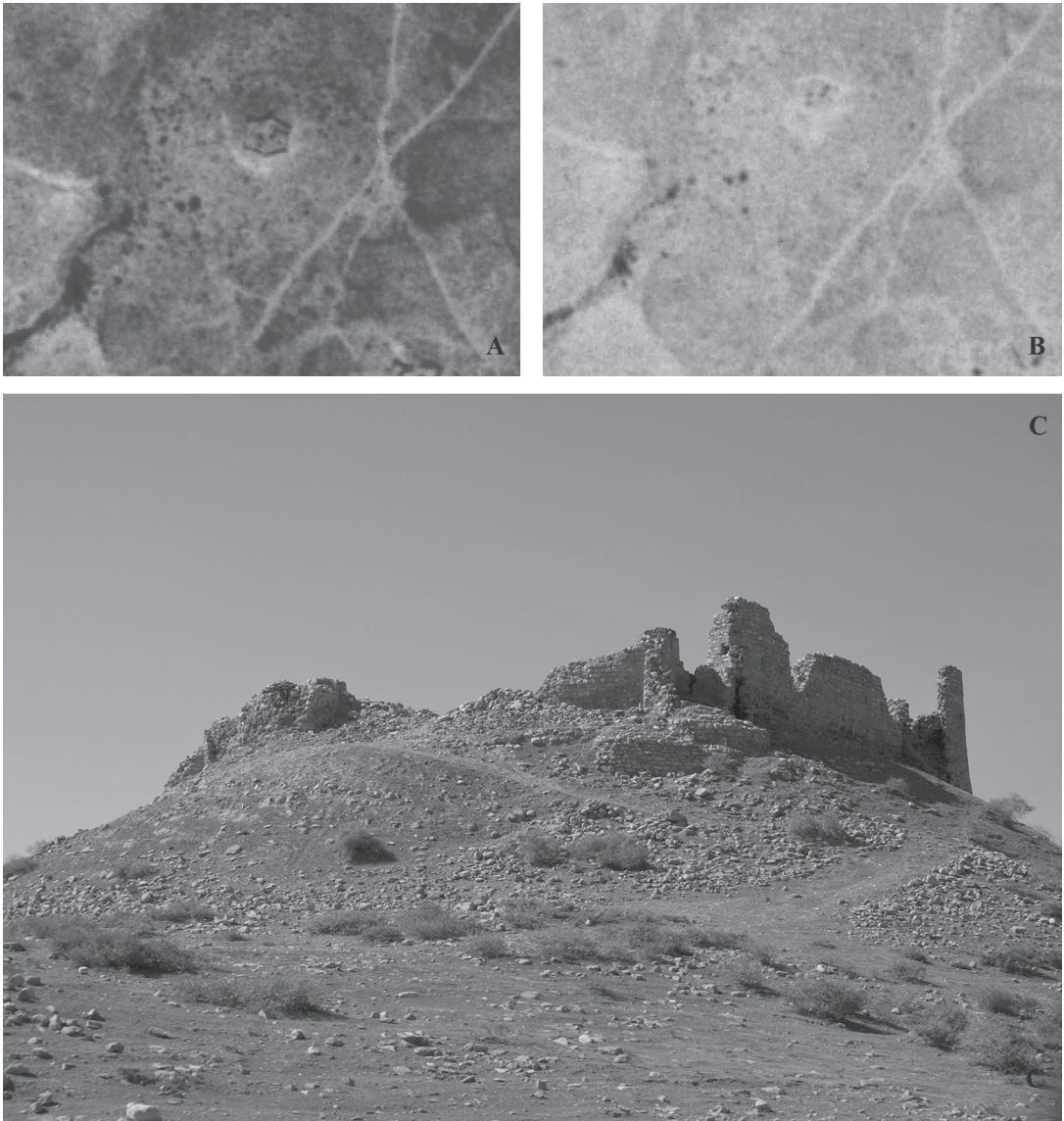


Figure 3. Qala Deiri castle on CORONA imagery: A) CORONA mission 1104, 16.09.1968 fore; CORONA mission 1104, 16.09.1968 aft (source: CORONA Atlas of the Middle Near East, courtesy of Center for Advanced Spatial Technologies, University of Arkansas/U.S. Geological Survey); C) The Qala Deiri castle photographed from the ground on 03.10.2012 (photo by Marcin Szablowski).

should be relatively easy in imagery acquired during late summer and autumn, especially because at this time of the year plant cover, which may potentially obscure the visibility of the surface of the earth is very limited. However, the differences in colour in many cases turned out to be so small, either on panchromatic or on multichromatic imagery, that after the second field season in 2013 it was decided

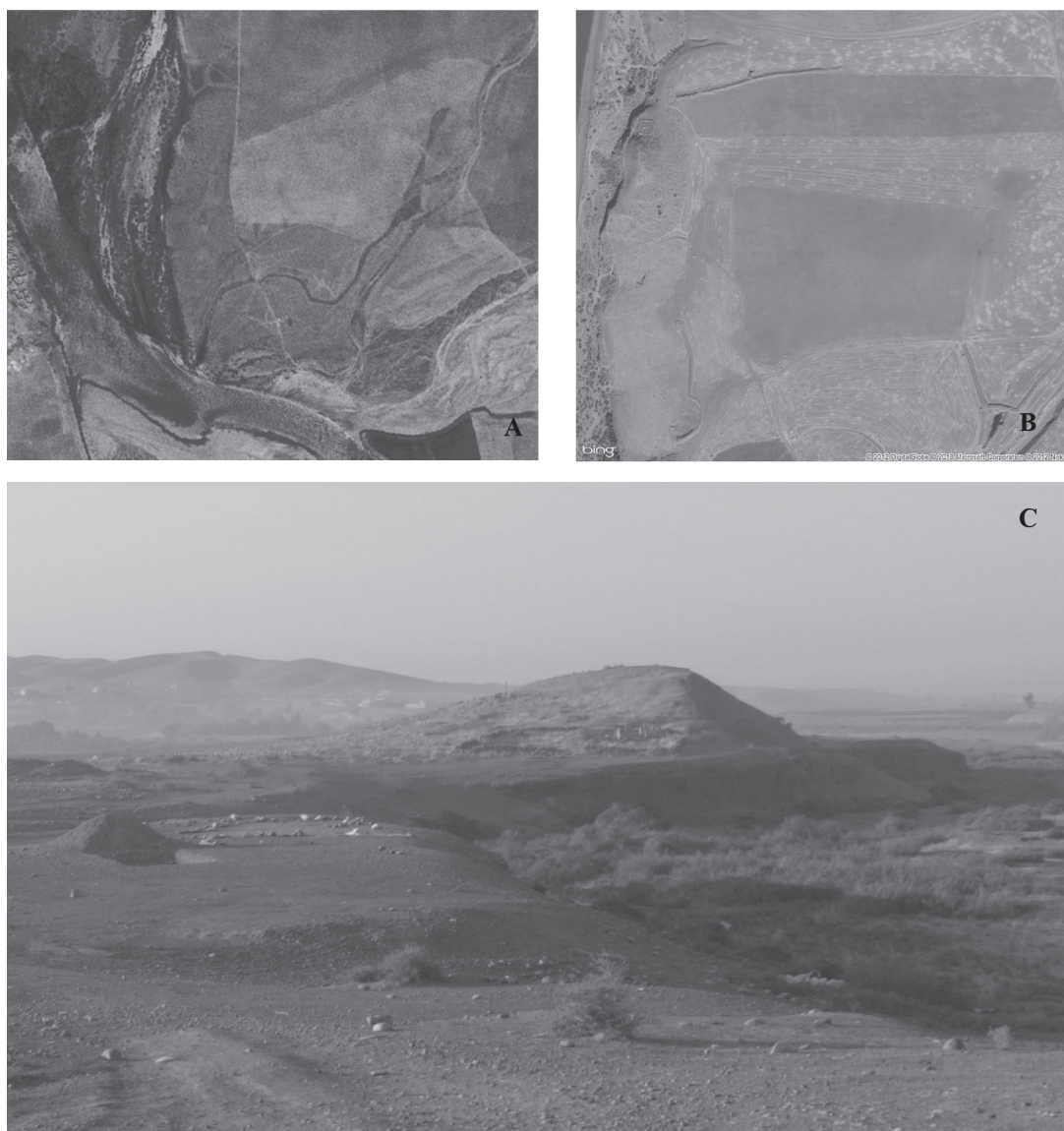


Figure 4. Site Gird-i Mamek (S003). A) CORONA mission 1107, 03.08.1969 (source: CORONA Atlas of the Middle Near East; courtesy of Center for Advanced Spatial Technologies, University of Arkansas/U.S. Geological Survey); B) Quickbird, (source: BingMaps™, visited on 22.03.2013), C) Gird-i Mamek seen from the North (photo by R. Koliński.)

that only on the alluvial plain would provisional identifications on the base of this kind of signature be verified by transects between mounded sites. On the other hand, spots where flat sites were identified by field-walking were later checked in the imagery, both from the CORONA and QuickBird satellites. Growing experience in recognising the signals that might suggest the presence of such a site turned out

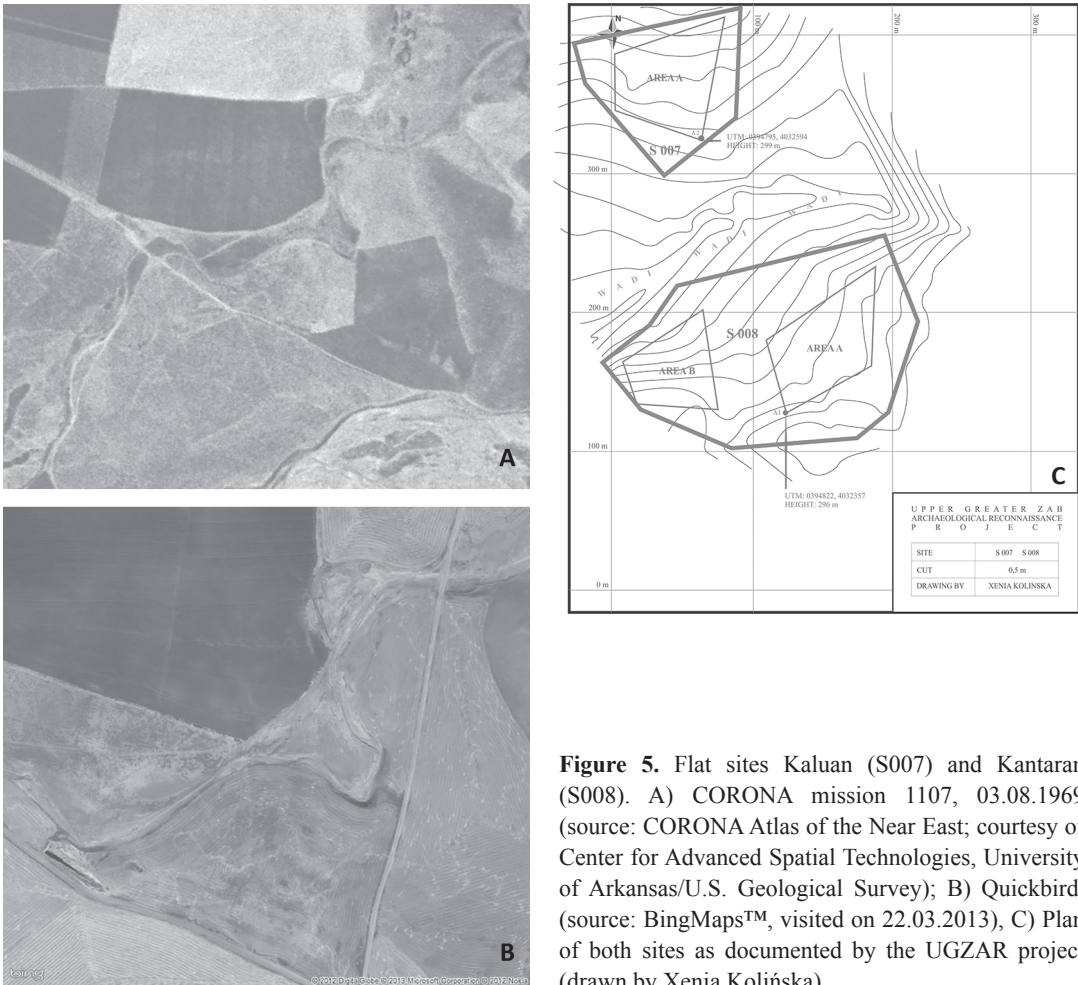


Figure 5. Flat sites Kaluan (S007) and Kantaran (S008). A) CORONA mission 1107, 03.08.1969 (source: CORONA Atlas of the Near East; courtesy of Center for Advanced Spatial Technologies, University of Arkansas/U.S. Geological Survey); B) Quickbird, (source: BingMaps™, visited on 22.03.2013), C) Plan of both sites as documented by the UGZAR project (drawn by Xenia Kolińska).

to be a turning point terms of increasing the number of confirmed provisional identifications. However, the percentage of positively verified provisional identifications remained quite low (at c. 20%) even during the 2014 field season.

The specific geology of the larger part of the surveyed area is responsible for the second situation. The main geological feature of the area is the so-called Bakhtiari formation consisting of a thick layers of conglomerate rock, present throughout the majority of the area between the Tigris river and Zagros mountains. The conglomerate is soft thus it is deeply cut by the valleys of seasonal streams, and of course by the Greater Zab river valley. It is usually covered by a thin layer of soil; only on the alluvial plain of Navkur, in the western part of the surveyed area, does soil build-up reach several meters in depth. Where the soil layer is thin, erosion caused naturally or by human activities such as deep ploughing, may result in the high number of small and medium size pebbles present on the surface. On the satellite imagery such concentrations of pebbles give an effect similar to soil discolouration, providing in this way a signal which might be easily misinterpreted as the location of an ancient settlement.

CONCLUSIONS

There is no doubt that satellite imagery is rightfully considered to be an extremely useful tool for the provisional identification of archaeological sites thus an efficient tool for pre-survey reconnaissance. However, most of the publications describing the use of this source, especially of the panchromatic CORONA imagery, focus on the successful applications of these data, omitting problematic cases.

The intention of this paper was to focus on cases when CORONA imagery turned out to be less efficient than expected before the start of the project. In conclusion, it would be necessary to present some suggestions on how to override problems of this kind.

Firstly, it is clear that the physical resolution of imagery is not the most important parameter of data. Imagery of lower resolution but acquired in more favourable conditions (considering light, plant cover, and humidity of soil) could prove to be more useful.

Secondly, the visibility of the archaeological objects may depend on the angle between the lens and the surface of the earth, or between the angle of the lens and the direction of the light. The smaller the angle between the lens and the light, the less clear is the shadow signatures, and with a difference close to 0 degrees, shadow signatures may become entirely invisible.

Thirdly, shadow signatures are an efficient means of identifying mounded sites and other heritage features on flat areas. In a hilly landscape, natural landscape formations are often difficult to distinguish from forms of a humanogenic nature, resulting in numerous false signals.

Fourthly, in a hilly landscape, colour signals could be misleading, as they are often caused by presence on the surface of stone pebbles coming from disintegrated conglomerate rock, present just under the shallow cover of soil.

Consequently, on a favourable terrain (like alluvial plains, river valleys) the use of CORONA imagery should be based on studying the imagery from numerous missions, acquired during different seasons of the year and on various times of the day. A review of the many missions would facilitate the choice of those which would provide the richest set of data for further study.

On less favourable territory (highlands, mountains) CORONA imagery may have very limited use, as demonstrated during the realisation of the UGZAR project. In such cases it is advisable to rely on multispectral imagery allowing the scrutiny of the terrain both in the visible and invisible spectrum of light waves. A methodology for a study of this type has been developed, for instance, by Jason Ur and Bjoern Menze for the use of combined LANDSAT, SPOT and ASTER imagery (Menze and Ur 2012) but has not yet been, to my knowledge, applied to the highland areas of the Near East.

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