Localization of Scytho-Siberian burial mounds by means of CORONA satellite imagery, Kosh-Agatsh region, Altai Republic, Russia

W. Gheyle & J. Bourgeois
Department of Archaeology, Ghent University, Ghent, Belgium
R. Goossens & A. De Wulf
Department of Geography, Ghent University, Ghent, Belgium
T. Willems
Department of Applied Mathematics and Computer Science, Ghent University, Belgium

Keywords: heritage preservation, Scythian burial mounds, global change, CORONA, DEM

ABSTRACT: A research team from Ghent University (Belgium) is, since 1995, executing archaeological research in the Altai Republic, Russia. Together with colleagues from the Gorno Altaisk State University, they are studying and documenting the archaeological heritage in the region, with a focus on the numerous Scythian burial mounds or *kurgans*, dating from the 8th to 2nd Century BCE (Iron Age). Many of these tombs are frozen, as they are located at high altitude and/or in local permafrost zones. The perfectly conserved grave inventory forms a unique documentation on this semi-nomadic steppe civilization. Recently, global change is endangering the subsistence of these frozen tombs. Problems of localization and the non-existence of adequate maps were solved by using stereoscopic images from the high-resolution CORONA espionage satellite, for the first time during the fieldwork of July-August 2003. The resulting contour maps, DTM-s and orthophotos form the background for the archaeological inventory, and are together with the archaeological database the first detailed form of information on the cultural heritage in the region. The resulting information will be used in scientific research (the diachronically study of the archaeological sites in the landscape) and in heritage management, as the inventory is a first step in the possible protection of the endangered tombs. Parts of the Altai Mountains are inscribed as a Natural Heritage Site, and the Altai Mountains are subject of UNESCO’s Man and the Biosphere program.

1 INTRODUCTION

The Altai Republic, part of the Russian Federation, is situated in Central Asia at the meeting point of four countries: Mongolia, China, Kazakhstan and the Russian Federation itself (Fig. 1). As a result of the rich collections of Tsar Peter the Great (1672-1725), the discovery of the frozen burials at Pazyryk in the middle of the last century and the recent finds at Ukok (Altai), Berel’ (Kazakhstan) and Arzhan (Tuva Republic), all of which have been dated to the so-called Scytho-Siberian period between the eighth and second century BCE, the Altai region has become archaeologically quite famous (see a.o. Schiltz 1994).

The history of Belgian archaeological research in the Altai Mountains started with the exhibition “The Gold of the Scythians” organised in 1991 at the Royal Museums of Art and History in Brussels. Immediately after this, co-operation with archaeologists from the Hermitage Museum, and later from the Academy of Sciences of Siberia, was set up. Cooperation with the Department of Archaeology and Ancient History of Europe at Ghent University commenced in 1995. From 1996 onwards, fruitful co-operation with the Department of History of the Gorno-Altaisk State Univer-
sity began. After several excavation campaigns in 1995-1996, research increasingly focused on the inventory of the archaeological heritage, for purposes of analysis, preservation and protection (Bourgeois et al. 1999, Bourgeois et al. 2000: 173-201).

![Figure 1. The Altai Republic, situated in Central Asia, with indication of research area 2003 and some famous archaeological sites. The Altai Mountains cover the entire republic and parts of Kazakhstan, China, Mongolia and the Republic of Tuva. 1: Pazyryk; 2: Tuekta; 3: Bash Adar; 4: Berel'; 5: Ak Alakha; 6: Moinak-2; 7: Kizil; 8: Sebystei; 9: Kalanegir; 10: Irbistu; 11: Elangash; 12: Ujmontski Steppe; 13: Maima (after Bourgeois et al. 2000: 34).](image)

2 OBJECTIVES

In the Altai region, the best topographic maps have a scale of 1:200,000, while classified military maps go up to 1:100,000. For the exact localization of sites, this is insufficient. In Sebystei (1996-1997), the archaeologists tried to solve this problem by making their own topographic map of the research area with help of a dual-frequency 24-channel GPS Phase-receiver. They measured some 3000 topographic points in an area of some 10 square kilometres. This resulted in a very detailed and useful topographic map. However, this GPS method of map-making is too time-consuming if
the area of research is considerably larger. The Department started, therefore, internal research on the use of CORONA satellite photography for morphographic and topographic mapping, and for archaeological survey (Gheyle & Trommelmans 2002, Gheyle et al. 2004). As a result of the positive results of this research, a project funded by the Research Council of Ghent University entitled “Archaeological Survey and CORONA Satellite Imagery in the Altai Mountains (South Siberia). A Multidisciplinary Contribution to the Study of Occupational Patterns of Nomadic Populations (1000 BCE-present)”, started in January 2003. The plan of this current project, in cooperation with the Department of Geography, is to evaluate the methodology used, expand the research area and gather Ground Control Points (GCPs) for the further processing of the satellite imagery. The archaeological question was focussed on the structuring of the landscape by these nomadic populations. For this purpose a field campaign was executed in July and August 2003, and a second one is planned for the summer of 2004.

3 ARCHAEOLOGY AND MAPPING

The CORONA satellite is an American espionage satellite. During the operational phase of CORONA between 1960 and 1972, more than 100 spacecrafts delivered over 800,000 high resolution images. The camera systems were improved from a ground resolution of 40 feet, (KH-1) to a better resolution of 9 feet (KH-4A) and even 6 feet (KH-4B). CORONA works with two stereoscopic cameras. As a result, the images can be used for cartographic mapping techniques with specialised software (see Campbell 1996, Goossens et al. 2001, MacDonald 1995, Peebles 1997 & Ruffner 1995). CORONA satellite photography has been applied in a number of cases for archaeological survey (a. o. Kennedy 1998, Philip et al. 2002 & Ur 2003). Although these survey projects use the same satellite imagery as that used in the work we are presenting here, the method of approach is different, in many cases neglecting the photogrammetrical and stereoscopic properties of the imagery. Recent research by Altmaier & Kany (2002) and Sohn, Kim & Yom (2004) proposes some correction methods.

For the selected research area, only CORONA KH-4A images were available, with a best ground resolution of 9 feet. In the future (campaign 2004) we will be able to work with KH-4B imagery. The KH-4A negatives were scanned at the Institute of Photogrammetry and GeoInformation in Hannover with a Vexcel Ultrascan 5000 with 10 microns pixel size (geometrical accuracy of 1-2 microns), after doing some tests with a Leica S1 PRO digital scanning camera and a Flextight Precision III scanner (respectively 3175 and 3200 dpi, with tests up to 5760 dpi). In a next phase, the images were geometrically corrected with the ILWIS 3.2 software, to prepare them for stereoscopic viewing. Under a conventional Wild stereoscope, a morphographic map can then be made. These maps, showing all relief elements in detail, are very useful in the field and help us to interpret the archaeological landscape. Stereo viewing also proved to be useful in the survey of archaeological structures, which was done directly from the satellite images.

A detailed topographic map, as a background for the archaeological information, was developed by importing the images in VirtuoZo V.3. This program automatically corrects the distortion in the images, makes a relative orientation, and shows the stereo-image directly on the computer, through 3D visualization. The program is also able to calculate the absolute coordinates of all the pixels of the imported images, in three dimensions. To make this possible, you have to insert a minimum of 6 ground control points (GCP) per image. These GCPs have to be easily recognisable on the images, in order to link the images with the coordinates. In practice, we had to measure all these points with different GPS receivers in the field, because no coordinates were known. The VirtuoZo process results in a Digital Terrain Model (DTM), a contour map and eventually an orthophoto (i.e. a corrected photomap, Fig. 2).

Localization of Scytho-Siberian burial mounds by means of CORONA satellite imagery, Kosh-Agatsh region, Altai Republic, Russia
4 FIELD CAMPAIGN JULY-AUGUST 2003

From July 6th to August 16th 2003, the first Altai campaign planned in the current project was executed. As research area, we chose four parallel valleys on the southern border of the Chuya steppe (Kosh-Agatsh region, southern part of the Altai Republic, Russia), covering an area of some 15 by 30 kilometres (Fig. 3). The four valleys are, from east to west: the Sebystei (object of the inventory of 1996-1997), the Ozék, the Irbistu and the Elangash Valley.

4.1 Geographical fieldwork

4.1.1 The GPS receivers

In a first phase, we collected the necessary GCPs for the correction of the images (43 in total), which were spread as much as possible over the total research area. The accuracy of the position determination that can be obtained by the stand-alone use of a GPS system is in the 10 m range (95% of the time, planimetric). However, higher accuracy was required for our application. For this reason, it was necessary to use differential techniques. The measurements were carried out with 3 different GPS receivers; the most sophisticated being the C-Nav from C&C Technologies. We compared the results obtained by these different devices in order to determine which one is best suited for archaeological purposes and best for mapping, taking into account their accuracy and practical characteristics (weight, power supply, technical properties etc.).
The first system that was used in the field was the C-Nav system provided courtesy of C & C Technologies. This system, originally developed by NASA’s Jet Propulsion Laboratory (JPL), is operated commercially by NavCom Technology. Its performance is superior to the more experimental systems that have also been used. We therefore regard the C-Nav’s results as a benchmark for the two other systems detailed below.

The second receiver that was used was the Garmin 12XL, a common hand-held receiver for recreational use. In this case, a post-processing scheme was employed to increase positioning accuracy. Raw satellite observation data from the Garmin 12XL were obtained and recorded in the field by means of the GRINGO software package. After the expedition, observation data from surrounding permanent GPS reference sites (Novosibirsk, Krasnoyarsk and others) were acquired. Next, in order to obtain improved position reports, the different data collections were processed in an integrated way (see Willems et al. 2002).

The Motorola Oncore VP, a specialised bare-bones receiver, was the third receiver used in the field. Raw satellite observation data were obtained and recorded in the field by means of a software package specifically developed for this expedition. Post-processing, analogous to the scheme described for the Garmin 12XL, was employed in order to increase position accuracy.
4.1.2 Positioning results and discussion

The C-Nav’s results are of high accuracy (standard deviation report of 0.58 m supplied by the receiver) and stability (standard deviation of 0.03 m over the measurement period). This justifies the use of the C-Nav’s mean position as a benchmark for the Motorola Oncore VP and the Garmin 12XL. The multi-station differential post-processing results of the Motorola Oncore VP and the Garmin 12XL are similar, with the Motorola Oncore VP (standard deviation of 1.74 m and 0.59 m mismatch, as compared to the C-Nav mean) performing slightly better than the Garmin 12XL (standard deviation of 2.19 m and 0.74 m mismatch, as compared to the C-Nav mean).

It seems clear that the proposed techniques involving the Motorola Oncore VP and the Garmin 12XL are useful when the stand-alone GPS accuracy is insufficient and traditional differential operation is infeasible. Their main disadvantage is that the results are not available in real time. It is self-evident that when the highest possible accuracy needs to be attained, much more costly equipment such as the C&C C-Nav system remains indispensable.

4.2 Archaeological survey

4.2.1 Method

The second phase of the research involved the ‘pure’ archaeological part of the fieldwork. With a cross-country vehicle, all accessible parts of the area were surveyed in detail. In total 751 structures from 136 different sites were recorded during the survey: 152 were localised by using a Garmin Vista hand-held GPS receiver, 599 other structures by measuring azimuth and distance.

With these measurements, a detailed ground plan was made using AutoCAD (Fig. 4). These plans were precisely located on the generated topographical map using the GPS data, by incorporating the information in AutoCAD Map and later in a Geographic Information System. All structures were described in detail. Function, period and cultural attribution are based on morphologic elements and on comparisons with other sites and regions. Only excavation could confirm or change this attribution.

![Figure 4. An example of an archaeological cluster, consisting of a core of Scythian burial mounds (kurgans) in a north-south orientated row and 21 related structures from different periods: site Elangash 01 (Kosh-Agatsh region, Altai Republic).](image-url)
4.2.2 Survey results
Taking into account the 322 previously inventoried archaeological structures in the Sebystei Valley (1996-1997) and the work in the Kalanegir Valley (1996-1997), we now have detailed information of about 1100 structures in the research area. All information was fed into a database specially devised for this application, linked with an image database and a bibliography and complete with detailed description of all individual structures and site plans. Some sites contain one single structure, for example a kurgan, but many others are more complex, with up to 100 different structures.

With the exception of very steep slopes, rough parts of the terrain and snowy highlands, especially in the Elangash and Irbistu Valleys, where no archaeological monuments were discovered, the sites are spread over all accessible parts of the research area (Fig. 3). Especially flat surfaces, such as terraces or the beginning of the steppe, and gentle slopes, seemed to be used for the construction of ritual or burial monuments (Fig. 2). The sites cover all periods from the Early Bronze Age to the Ethnographic Period. It is interesting to see that the location of monuments in the landscape differs from period to period. Some of the observed patterns are very striking, but it is too early to understand their meaning, as much research still has to be done.

5 CONCLUSION AND FUTURE PERSPECTIVES

By continuing the survey, we hope to obtain a general understanding of the location of cemeteries (via the satellite images and survey campaigns) and other archaeological sites (through literature and campaigns, as these features are not visible on the satellite imagery) in the landscape. Interrelationship and patterning are some keywords. Secondly we see the inventory as a contribution to the work of protecting and preserving the archaeological heritage. In recent times, much of the closed character of the Altai Mountains has disappeared; roads are being built and tourism is flourishing. In these circumstances, it is all the more important that people are informed of the beauty of the archaeological heritage, and learn how to handle it with care. Moreover, we are planning to study the problem of disappearing permafrost. Global change seriously endangers the subsistence of permafrost in the Altai Mountains. This means many of the Frozen Tombs of the Scythian type Pazyryk culture, famous since the discoveries of Rudenko and Gryaznov in Pazyryk (Altai Republic) and more recently on the plateau of Ukok (Altai), in Berel’ (Kazakhstan) and Arzhan (Republic of Tuva, Russia), risk to thaw, thereby loosing all of their valuable frozen content.

It is our intention to start an international project on this matter and to include the Frozen Tombs in the list of Endangered World Heritage. An archaeological survey of the entire research area should result in an inventory of all archaeological monuments. An accurate map, based on satellite images, will form the basis of this inventory. The sites have to be monitored on the presence and evolution of permafrost, after which the most threatened ones have to be selected. Techniques will be searched to protect them from thawing, or as a last solution, tombs that are certainly going to be destroyed due to climatic change should be excavated with the most recent scientific techniques of excavation, restoration and conservation.

ACKNOWLEDGEMENTS

Special thanks to Rector Yuri Vasiljevich Tabakaev, Gorno-Altaisk State University (Altai Republic) and Prof. Dr. Alexander Viotovich Ebel, who assisted us during the fieldwork and made all practical arrangements on site. Also we would like to thank Prof. Dr. Karsten Jacobsen for the scanning of the images. This project is funded by the Special Research Fund of Ghent University (2003-2004). For the campaign of 2004, additional funding was obtained from the Belgian Federal Science Policy Office.
REFERENCES


Contact: Wouter GHEYLE, Ghent University, Department of Archaeology, Blandijnberg 2, 9000 Ghent, Belgium. Wouter.Gheyle@UGent.be (+32 9 264 4106).