

THE FROZEN TOMBS OF THE ALTAI MOUNTAINS INVENTARISATION AND CONSERVATION

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ABSTRACT

Thousands of frozen tombs lie scattered across an area straddling Russia, Kazakhstan, Mongolia and China. These tombs, a major archaeological find dating back to the 1920s, belong to the lost Scythian civilization which flourished 2500 years ago. Inside the tombs lie bodies which have often been so well pre-served in the frozen ground that even the tattoos on their skin remain intact.

For thousands of years, the Altai Mountains have been an important passage between the Mongolian and Kazakh steppes. The area is a rich source of archaeological information on commercial routes and other exchanges between populations. As the Scythian populations inhabited the entire Eurasian Steppe stretching from the Black Sea to Mongolia, the frozen tombs are a unique source of information about one of the most intriguing cultures of their time.

The kurgans are literally packed in ice. After burial, each tomb was covered with stones which formed a permeable mound. Rainfall was able to penetrate into the tomb where it froze. Over time, this process created an ice block which preserved the tomb and its entire contents.

Climatic change is causing the permafrost in this part of Siberia to thaw. With the permafrost that preserves the kurgans now gradually thawing, the frozen tombs and their precious contents will soon no longer be packed in the ice that has preserved them for so long. Permafrost could disappear completely in some areas of the Altai by the middle of this century. After 2500 years of perfect conservation, the remaining kurgans and the insights they provide into the ancient nomad Scythian culture could be lost for ever. In a race against time, UNESCO and the University of Ghent in Belgium are helping teams in Russia and Kazakhstan to pinpoint the location of the remaining tombs to protect them from disappearing.

Satellite images (Corona, ASTER and Landsat) are being used to create a cartographical archaeological inventory that fuses traditional field work, digital photogrammetry, satellite image interpretation and GPS. The inventory of the Scythian tombs is based on photogrammetry of the Corona data, while the study of the permafrost is based on thermal images from Landsat and Aster. In 2005-2006, a project put together by Ghent University with the support of UNESCO and a generous contribution from the Flemish Community of Belgium is continuing this survey, and is analysing the threats which climatic change poses to the frozen tombs.

1. INTRODUCTION

CORONA satellite photography has been applied in several archaeological survey projects in recent years. In many cases, however, the imagery was not used following the basic rules of remote sensing. The aim of this paper is to overview and to highlight some of the errors or mistakes, and to suggest some solutions.

It is important to realize the complexity of geographical data such as satellite imagery. It appears that archaeologists sometimes do not take into account this complexity and use the data in a wrong way. The intensifying interdisciplinarity of the archaeological research is only to be welcomed; however, interdisciplinarity also means cooperation and knowledge of the basic rules of the other sciences involved. Geography and archaeology must cooperate, but a geographer is not an archaeologist, and vice versa.

As a case study, we will discuss a project done at Ghent University, aiming at an archaeological survey of Bronze Age, Iron Age, and Turkish monuments in the Altai Mountains (South Siberia, Russian Federation and Kazakhstan), using satellite images for mapping and for landscape interpretation.

The Altai Mountains are spread over the territory of four neighbouring countries: the Altai Republic (part of the Russian Federation), Mongolia, China, and Kazakhstan. The rich archaeological heritage of the region is known from as early as the 17th Century. In the 20th Century, the discovery of the frozen burials at Pazyryk (Altai) (Rudenko, S.I., 1970) as well as the recent finds of frozen graves in Ukok (Altai) [19], Berel' (Kazakhstan) (Polos'mak, N.V. & Seifert, M., 1996) and

Arzhan (Tuva Republic) (Patzinger, H. et al., 1996), have made the Altai region quite famous archaeologically. All of these finds have been dated to the so-called Scytho-Siberian period, from the eighth to the second Century BCE.

In 2005-2006, Ghent University is a main partner in the first phase of the international project, "Preservation of the Frozen Tombs of the Altai Mountains." In collaboration with different UNESCO sectors (Culture, Science), and funded by the UNESCO/Flanders Trust Fund for the Support of UNESCO Activities, the main objective is the protection of the frozen tombs in the area and the monitoring of permafrost. With the support of the authorities of Russia, Kazakhstan, China, and Mongolia, it may be possible to inscribe these valuable monuments on the World Heritage List. Until now, archaeological research in Altai by Russian or European teams was mostly focused on excavations of isolated monuments or the biggest structures of promising sites without much consideration for the context of a monument within a site or the relation of different sites in the landscape. Survey projects were also set up in the last decade, but the way of mapping sites and the geographical background is in some cases inadequate and can be improved with simple techniques, as we will demonstrate later on in this paper.

2. THE USE OF CORONA SATELLITE IMAGERY IN ARCHAEOLOGY

The CORONA satellite is a well-known American espionage satellite. During the operational phase of CORONA between 1960 and 1972, more than 100 spacecrafts delivered over

800,000 high-resolution images, with a resolution going from 40 feet up to 6 feet, depending of the sensor type (Mac Donald, R. 1995). In 1996, a large part of the imagery was released and made available on the Internet, and in 2002 a second part was released. Since September 2004, the imagery is no longer available as film negatives, but only as digital images (scan resolutions of 23 Micron, 14 Micron and 7 Micron (only for KH-4A and KH-4B)). A database of the imagery can be found on the website of the United States Geographical Service (<http://edcns17.cr.usgs.gov/EarthExplorer>), but the images can only be ordered by contacting the USGS Customer Service (further details and prices: <http://edc.usgs.gov/products/satellite/declass1.html>). Their high resolutions, their low price per square kilometer (next to a handling fee and the costs for the medium [CD, FTP or DVD] one only pays \$24.00 for an entire scanned negative, in all resolutions), and their high availability make them a valuable instrument for scientific research, among others in geography and archaeology. Another advantage is that the imagery dates from the 1960s and 1970s and becomes a historical source since in many areas the landscape has changed drastically in the last 30 years. Almost immediately after 1996, archaeologists started to use CORONA for the detection of archaeological remains. During several projects in recent years, ancient roads, ruins, settlements, irrigation networks, etc. were detected on the images and mapped in detail (Kennedy, D. 1998; Philip, G. et al. 2002; Ur, J. 2003, Hritz, C. 2003, Challis, K. et al. 2003, [5] and De Meyer, M., 2004).

3. CORONA IMAGERY

In most archaeological survey projects the imagery is used for a strictly visual interpretation of archaeological remains in the landscape. One must, however, not forget that complex geographical data needs to be handled in a very specific way. A close look at the research involving CORONA satellite imagery shows that, in most cases, the teams did not make use of the full capacity of the documents, or were even making mistakes while handling them. We would like to point out two main problems: They can be summarized as problems of stereoscopy and problems of image distortion.

The CORONA sensors produce a forward and afterward image of the same area, with a different viewing angle. The images from space are recorded in an oblique and converging way--with a different viewing angle. For CORONA this principle is illustrated in figure 1 showing the forward and afterward looking cameras.

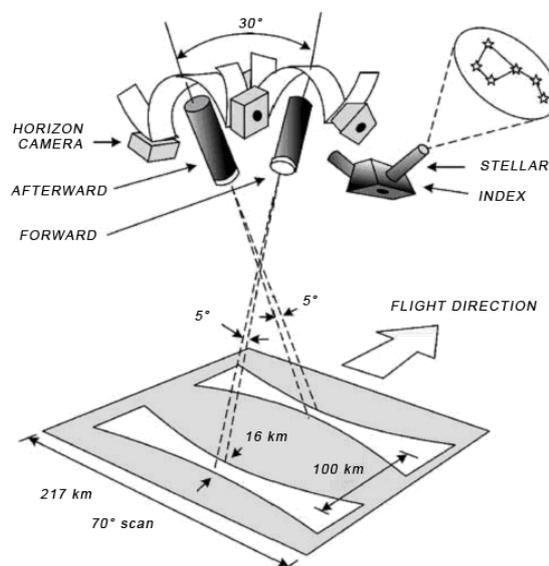


Figure 1. Stereoscopic cameras mounted in the CORONA satellite, KH-4B (Sohn, H.G., 2004)

Since the Corona images were taken by a panoramic camera and a rotator, the images are characterised by strong deformations. These deformations are illustrated in figure 2.

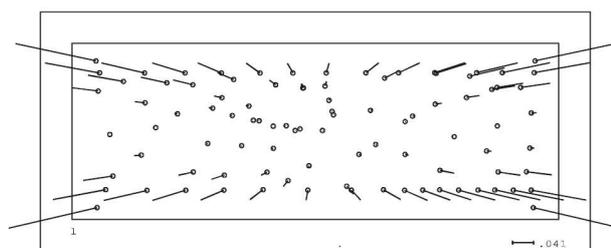


Figure 2. Image displacements in a KH-4B image, away from nadir point (Schneider, Th, et al, 2001).

4. PROCESSING OF THE IMAGES

The deformations in the images and the S-shaped distortion, caused by the rotation of the camera in combination with the forward movement of the satellite, can nowadays be eliminated by digital restitution methods and photogrammetrical techniques. During the restitution process, the parallaxes in the forward image compensate the parallaxes in the backward image. Other tilt movements are also corrected. After the orientation process, based on at least 6 but preferably more Ground Control Points (GCP) the two images are matched. Then, a Digital Surface Model (DSM) is created. This model can further on be used for geographical analysis, mapping of slopes, river terraces, alluvial plains etc. The DSM is further used to produce the orthophoto map and contour map. These products have the characteristics of real cartographic material. Interpretations and drawings on these ortho images are geometrically correct and can be inserted in a GIS.

5. USED METHODOLOGY

Imagery: DS1110-1152DA052, DS1110-1152DF046: CORONA KH-4B sensor, mission DS 1110-1, revolution 152 D, negatives A 052 (afterward image) and F 046 (forward image), 30 May 1970.

The negatives were scanned as one image at the Institute of Photogrammetry and GeoInformation in Hannover with a

Vexcel Ultrascan 5000 with 8 microns pixel size (about 3175 dpi) (geometrical accuracy of 1-2 microns).

For the photogrammetrical restitution of the images, we need Ground Control Points: these are points in the landscape with known coordinates in X, Y and Z. As we did not have this information, we had to collect the GCP's in the field. These points were collected during field work during summer time from 2003 until 2006. These points were collected using C-Nav GPS- technology. (Roscoe, J. 2001).

Overview GPS measurements 2004 - Yustid Valley

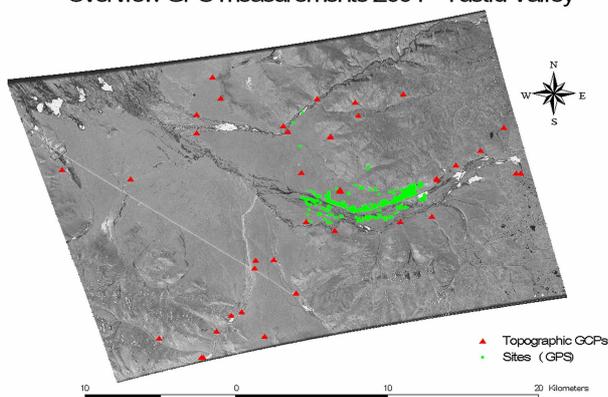


Figure 3. An overview of the GPS measurements in the Yustid Valley during the 2004 campaign. The GCP's are spread as much as possible over the total area under view, both in planimetric as altimetric (steppe, lower valleys, upper valleys, mountains, etc.).

In the field, the points to measure with GPS have to be carefully selected: the four most important requirements for those points are:

- Selection of geographically stable points over the last 40 years (e.g. no river boards as they move from year to year)
- Need for unique and clear identification of those points on the CORONA images, on both the forward and backward images
- Uniform spread of these points over the images
- Stable positioning with the GPS receivers (more or less flat surface).

Corners of old farms (if built before 1969, thus present on the images), crossings of clearly visible tracks and roads and, of course, the (larger) archaeological monuments themselves, often meet these requirements.

6. PRODUCTION OF DEM'S AND ORTHOPHOTO FOR ARCHAEOLOGIC PURPOSES

A small-scale map, as background for the archaeological information, was developed by importing the images in a digital photogrammetric work station. We used the VirtuoZo V.3 software (Supresoft Inc.; <http://www.supresoft.com/english/products/virtuozo/virtuozo.htm>). This program automatically corrects the images and shows the stereo-image directly on the computer, through 3D visualization. After inserting the GCP's and their coordinates, the program is able to calculate the absolute coordinates of all the pixels of the imported images, in three dimensions. The VirtuoZo process results in a complete Digital Surface Model, an orthophoto (i.e. a corrected photomap) and a contour map. (Jacobson, K., 2003). The resulting map has a scale of 1:20,000. In general, the minimum scale of mapping on the basis of

photographic products is considered to be 1/10 of the nominal photo scale. The CORONA KH-4B negatives have a nominal photo scale of 1:247,500 (in normal circumstances resulting in a map of 1:25,000).

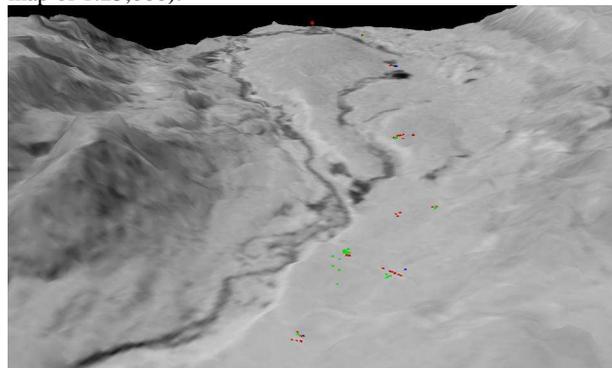


Figure 4. An example of a part of the Valley of Irbistu: 3D view composed of an overlay of the resulting orthophoto on the generated DSM. The precisely located archaeological monuments (GPS), visible here on the river terraces (dots), were added in a GIS.

7. CONCLUSION

The aim of this paper was to present a proper methodology for the use of CORONA satellite imagery in archaeological research. As we showed with the results of our campaigns in Altai in 2003 until 2006, CORONA-imagery is most suitable for archaeological purposes, especially in remote areas. Used in the right way (i.e. using both forward and afterward images and processing them correctly), the images can form the basis for the production of a Digital Surface Model, an orthophoto without any distortion or parallax, a contour map, and finally, topographical and archaeological mapping at a scale of 1/20,000.

To produce these maps, a certain amount of Ground Control Points is needed. A stand-alone differential GPS system (as C&C C-Nav) gives the best and most reliable results, but when combining a (cheaper) common hand-held GPS receiver with a post processing scheme, accuracies of 1-2 m (planimetry) can be obtained. It appears that this accuracy is sufficient to produce maps with CORONA KH-4A (best resolution of 9 feet) and 4B (up to 6 feet).

We showed that when using CORONA data without any restitution or correction, as has been done mostly until now, unreliable documents are produced that can not be seen as a true map.

Concerning the research project, it is our intention to continue the survey and inventory in other parts of the Altä Mountains. In this context it is worth mentioning that local authorities are working out a program to protect this area, and are planning to install a cultural and natural reserve. For this purpose, they want an inventory of the archaeological heritage in the area, for reasons of protection and possible opening to the public (cultural tourism). Remote sensing and archaeology can contribute to a better understanding and management of the archaeological heritage of this prominent area.

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