Saviours from space for **Siberia's frozen tombs**

A very fine feline image made of wood and covered in gold leaf, as found in a grave in Berel in east Kazakhstan. In the background, you can see a perfectly preserved horse's hoof, complete with skin and hair. The bodies of horses were not mummified, so their internal organs remain. The content of a horse's stomach can tell us a lot about vegetation, climate etc.

Hundreds of frozen tombs lie scattered across the Altai mountains straddling Russia, Kazakhstan, Mongolia and China. A major archaeological find dating back to the 1920s, these tombs belong to the lost Scythian culture which flourished 2500 years ago. Inside the tombs lie bodies which have often been so well preserved in the frozen ground that even the tattoos on their skin remain intact.

Grave robbers and fortune hunters have been the tombs' traditional enemies but, today, a new threat hangs over them. Climate change is causing the permafrost in this part of Siberia to thaw. 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 from space, to help local conservationists protect them.

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. The Silk Road lies nearby and, buried in the graves of the Scythians, one can find Chinese vases, Persian carpets, Indian silks...

The term 'Scythian' is a generic term for the various populations which inhabited the Eurasian Steppe during the Iron Age and thus does not cover a single civilization. The Scythian economy was based on a semi-nomadic way of life.

View of a coffin and sarcophagus in Berel in 2000 before they were hoisted out of the grave by the teams of Zeinolla Samashev from the Kazakh Institute of Archaeology and Henri-Paul Francfort from the Centre national de recherche scientifique *(CNRS) in France. Once removed from its resting place, the wooden tomb was treated immediately with chemicals to prevent it from disintegrating after being exposed to the air and dryness. Wood samples were also taken for the purpose of dating the find. This is done by comparing the growth rings on the timber*

People moved about with the seasons, taking their herds of horses, yaks, sheep and goats with them and always returning to home base in the summer. This way of life has partly survived until today. As a result, no large villages or cities have ever been built and ancient settlements are a rare find. The primary source of archaeological information about the Scythians thus comes from the burial mounds, or *kurgans*.

Buried with gold and horses

The Scythians were skilled warriors on horseback. Masters of horse breeding, they were traders but also feared for their raids on neighbouring territories. Some of these raids took them as far afield as Babylon or Eastern Europe.

The horses followed the Scythians into their tombs. The bodies of sacrificed horses have been found in the graves, together with artefacts and utensils made of wood, leather, cloth, silk, metal and gold. The ornaments are exquisitely made and in many cases exceptionally well-preserved.

Many of the tombs are buried in permafrost, which maintains temperatures at between 0°C and -20°C. 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 Open Initiative

The Open Initiative was launched by UNESCO and the European Space Agency in 2001 to support the World Heritage Convention and the World Network of Biosphere Reserves. Its main objective is to develop cooperation among space agencies, research institutes, academies of science and universities, NGOs and the private sector, in order to protect natural and cultural sites in developing countries.

These sites face a variety of potential and very real threats, such as uncontrolled agricultural expansion, deforestation, urban sprawl, armed conflict, poaching, natural catastrophes, climate change and ecologically damaging tourism. Developing countries often lack accurate cartography to manage and protect these sites effectively. Satellite imagery can bridge this gap.

As its contribution to the Open Initiative, UNESCO has set up a Remote Sensing Programme headed by Mario Hernandez. In close partnership with the country responsible for a given site, the Programme defines the overall requirements, brings on board the specialized partners who will be implementing the project and secures the requisite funding. The Programme also coordinates the training of the local staff who will be handling all the information derived from the satellite images at the end of the project.

Besides the Altai project, the Open Initiative is currently surveying the Iguazu Falls in Argentina, the ancient Machu Pichu site in Peru and vestiges of the Mayan civilization in Guatemala. It is also using satellite imagery to observe and safeguard the archaeological site of Uruk-Warka in southern Iraq. A sixth project was completed in 2003; it consisted in providing the Democratic Republic of Congo, Rwanda and Uganda with their first accurate maps of inaccessible mountain gorilla terrain, as part of efforts to save the last 650 or so mountain gorillas.

The Open Initiative has now attracted a large number of space agencies.

For details:
www.unesco.org/science/remotesensing

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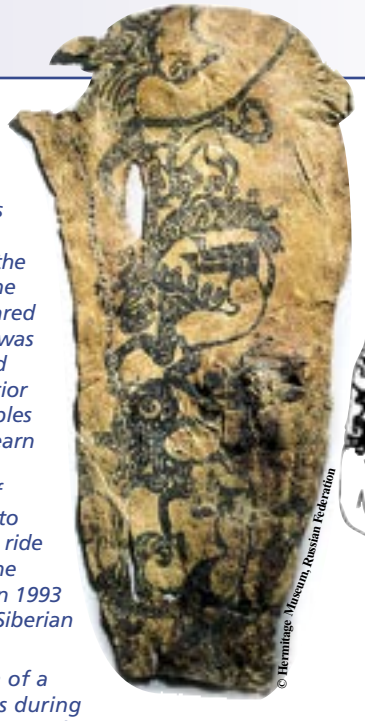

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Left: This 'Ice Maiden' was discovered on the Ukok Plateau in the Altai Mountains, which lies about 2500 m above sea level. She lived at the time of the Pazyryk culture (Scythians) of the late 5th century BP and was aged about 25 years when she died. She is also known as the Ukok Princess because of the finery found in her tomb and the fact that she was the sole occupant – a woman usually shared her tomb with a man. Her mummified body was also tattooed and weaponry had been placed in her grave, giving rise to the idea of a warrior princess or even Amazone. By analysing samples of her hair and skin, geneticists are able to learn more about the ethnic origins of the Pazyryk population. Chemical and physical analysis of her bones and soft tissue provides insights into her nutrition, health and way of life. Did she ride horseback, for instance? What diseases did she suffer from? The Ice Maiden was excavated in 1993 by archaeologist Natalia Polosmak from the Siberian Branch of the Russian Academy of Sciences

On the right, a segment of the right arm of a Scythian man buried in the Altai Mountains during the same period as the Ice Maiden. The site was first excavated by Russian archaeologist Mikhail Gryaznov in 1929. The drawing on the far right shows the location of all the tattoos on the man's body. The tattoos represent animals and mythical creatures

No detailed maps of the Altai

Ghent University and Gorno-Altaisk State University have been conducting joint research in the Altai Mountains since 1995. Their research has focused both on excavating burial mounds and on thorough surveys of other archaeological heritage in the mountains. In 2003 and 2004, the research team studied the organization of ritual and funerary sites in the Altai landscape through time (diachronically).

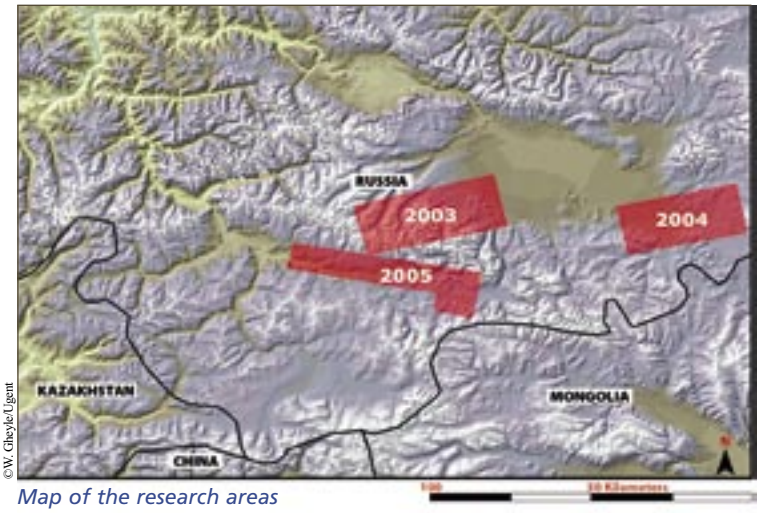
As this surveying work was hindered by the lack of detailed maps of the Altai Mountains, satellite images were used to make detailed topographic maps as background to the archaeological information.

A fresh start

In past decades, a horde of national and international research teams have flocked to the Altai Mountains. They have excavated dozens of *kurgans* in China, Kazakhstan, Mongolia and Russia. Unfortunately, some of these teams have limited their research to the isolated excavation of a single promising burial mound, with no thought for placing the monuments in their cultural context or studying

the position of the sites in the landscape as a whole. Moreover, attempts have been made in the past to come up with protection measures and conservation management plans for the *kurgans* but none of these has ever got far beyond the drawing board.

The project put together by Ghent University with the support of UNESCO and a generous contribution of €330,000 from the Flemish Community of Belgium now fills this gap. The project sets out to inventory all the frozen tombs in the Altai Mountains, together with other archaeological heritage, over a two-year period beginning in 2005. To do this, the University of Ghent is deriving maps from satellite imagery that show the detailed topography of the region and the resting place of each *kurgan*. In parallel, the project is assessing climate change in the Altai and analysing the threats which climate change poses to the frozen tombs.



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Map of the research areas covered in 2003, 2004 and 2005. This map was made using RADAR images from the Shuttle Radar Topography Mission

Of robbers and roads

For many of the tombs alas, help will come too late. They have been destroyed by grave robbers and fortune hunters, some many centuries ago, others only recently. As a deterrent, the Russian government now demands a research permit before a *kurgan* can be excavated.

Other tombs have escaped the robbers, only to have their long sleep disturbed by roadworks. The construction of roads is gradually opening up this formerly inaccessible territory. When they were in Dzhazator in 2005, for example, the team from Ghent saw several sites that had been disturbed by roadworks.

In this case, however, something can be done to protect the tombs. Having a detailed inventory of the location of all the archaeological monuments in the area will help local authorities plan infrastructure development, such as the path a pipeline should follow. The inventory will also prove invaluable to the authorities in regulating emerging tourist activities, such as rafting, alpinism or camping, and in building awareness of the need to preserve the *kurgans*.

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Here, a photo of Tuyuksu Glacier in Northern Tien Shan in July 1997. The glacier has retreated 362 m since 1955. No complete map showing the retreat of permafrost in the Altai mountains over time has ever been made, although the International Permafrost Association is looking for funding to monitor and map the permafrost of the entire Altai mountain range

A more insidious threat

The other threat to the frozen tombs is weather-related. As the Altai Mountains are situated on the border of the vast permafrost zone covering much of Siberia, permafrost in the Altai is very vulnerable to climate change. 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. Measurements taken at weather stations, borehole monitoring and research on glaciers all indicate that the climate in the Altai is changing considerably. Permafrost in the region could disappear completely 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.

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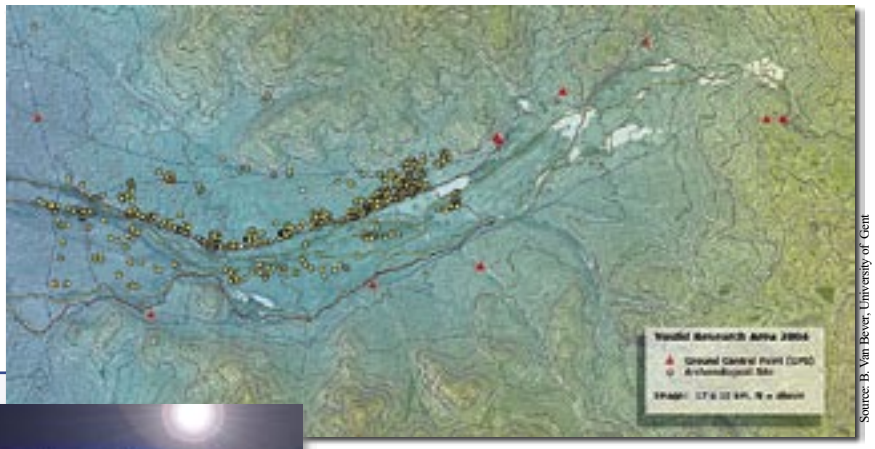
This ornament resembling a reindeer was found on a horse harness in Berel. All the ornaments preserved in permafrost for centuries must be treated with chemicals immediately after being recovered, or they will crumble with exposure to the air. It would thus be pointless for modern-day grave robbers to steal the artefacts, as they would walk away empty-handed

Satellites to the rescue

Within its 'Open Initiative', UNESCO has brought in additional expertise to complement that of the University of Ghent in remote sensing (*see box p. 51*). It was UNESCO, for instance, which brought in the Jet Propulsion Laboratory, a research centre of the US National Aeronautics and Space Agency (NASA), to provide the University of Ghent with ASTER satellite images to monitor the status of the glaciers in the Altai Mountains (see *A beginner's guide to remote sensing*). The glaciers will need to be monitored continuously over several decades to determine which of them are retreating or advancing, a clear sign of climate change. Indirectly, this may provide insights into the rate at which permafrost is thawing. Armed with this information, local conservationists will be able to establish priorities for preserving each of the tombs. They will be able to determine, for example, which tombs lie in the areas where the permafrost is thawing fastest.



Source: B. Van Bever, University of Gent

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 the tomb where it froze. Over time, this process created an iceblock which preserved the tomb and its entire contents. As modern approaches to archaeology seek to avoid excavating tombs, scientists are studying ways of preserving the tombs *in situ*, such as by creating a system of 'air conditioning' that would keep the tombs frozen.

Thanks to data from the CORONA reconnaissance satellite and the precise measurements taken using a Global Positioning System (GPS) receiver, the problem of the lack of detailed maps has been overcome. The CORONA satellite provides ground resolution of 1.8 m, which is good enough for the purposes of topographical mapping. It is also detailed enough to detect most archaeological structures more than 2–3 m in diameter, such as *kurgans* and other funerary or ritual monuments (see *A beginner's guide to remote sensing*).

During the survey campaigns of 2003 and 2004, the University of Ghent was able to generate detailed topo-graphic maps and height models (3D models) derived from CORONA satellite imagery of a total surface area of 600 km^2. It is possible to obtain a height model by combining two images of the same area using

A beginner's guide to remote sensing

© NASA

View of the Terra satellite platform launched in 1999 as part of NASA's Earth Observing System

Remote sensing is the science of deriving information about the Earth from images acquired at a distance. The most common forms of remote sensing are aerial photography and satellite imagery.

Remote sensing makes such extensive use of photogrammetry that it can become difficult to separate the two terms. Photograms may come in the shape of photographs or imagery stored electronically on tape or on disk; they may be video images or images taken using CCD cameras and other radiation sensors like scanners.

Satellite-based remote sensing usually targets the Earth's surface, changes in land cover, the oceans, snow and ice but it does also observe other areas, such as the atmosphere, the climate and recently even Mars and outer space.

Satellites may point to a fixed point on the Earth when they are in a geostationary orbit, as in the case of meteorological satellites, or they may cover almost the entire planet, as when they fly on an almost polar orbit. Each satellite 'scans' the Earth, capturing digital information that is transmitted to stations on the ground.

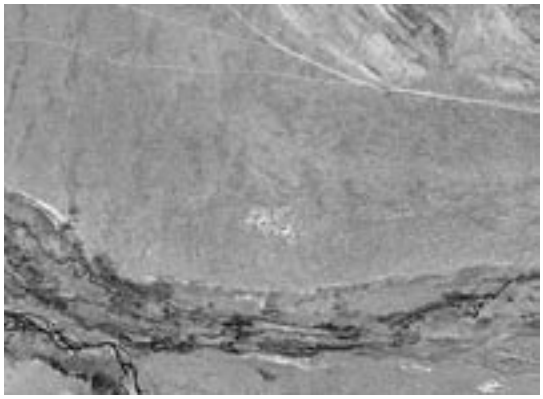
The following remote sensors are cited on these pages:

ASTER stands for Advanced Spaceborne Thermal Emission and Reflection Radiometer. ASTER is an imaging instrument flying on the Terra platform. ASTER is being used to obtain detailed maps of land surface temperature, reflectance and elevation. The thermal bands of ASTER's digital sensors are able to give an overview of ground temperatures on a large scale.

CORONA is a satellite which dates back to the 1960s and is no longer operational. It was originally a 'spying eye' of the American military. In line with US policy, which makes it possible to release selected military information into the public domain after a time, the images recorded by CORONA were released in 1996 and 2002. CORONA orbited the Earth at an altitude of 160–200 km, depending on the mission.

Landsat crosses the Equator from North to South at an altitude of 705 km. This satellite operates on a repetitive 16-day cycle and completes just over 14 orbits of the Earth a day at a speed of 7.5 km per second. Landsat 7 was launched at the same time as Terra, 27 years after NASA launched the first Landsat spacecraft within its Earth Observing System. The aim is to produce an uninterrupted record of the Earth's land surface for scientists and engineers working for state or local governments, agribusiness, the military, in commercial fields, academia or global change research and so on. Recently, Landsat 7 has been failing.

photo-grammetric computer software (see *A beginner's guide to remote sensing*). This enabled the Ghent team to document over 3000 archaeological monuments. The data were all fed into a database linked up to a Geographical Information System (GIS). The latter is a computer application which stores, views and analyses maps and other geographical information. Although the database and GIS are being used for research purposes, the database will also be offered to the Russian conservationists to help them manage development of the area and above all protect its archaeological heritage.



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Left: Satellite image taken in 1969 from a height of more than 150 km showing four Scythian burial sites. Note the parallel alignments of small dots, starting from the river bank, representing burial mounds in Yustid Valley. The sites were excavated by V. D. Kubarev in the 1980s and documented by the Ghent team in 2004. Right: Photo taken from a hilltop of aligned Scythian burial mounds

Since 2005, the University of Ghent has been carrying out a thorough inventory of the archaeological heritage of parts of the Russian and Kazakh Altai Mountains using satellite imagery, in partnership with Gorno-Altaisk State University and the Margulan Institute of Archaeology in Almaty. Satellite images are being used to create a cartographical archaeological inventory that fuses traditional field work, satellite image interpretation and GPS.

Dzhazator Valley in the south of the Altai Republic of the Russian Federation was chosen for the first mapping campaign from 8 July to 18 August last year. Over this six-week period, 1687 different archaeological structures were located and described. These structures were spread over 192 sites and an area of 284 km². The entire Dzhazator Valley was mapped in detail using CORONA satellite images. Part of the expedition focused on defining good ground control points for Aster and Landsat satellite images. These ground control points are being used to georeference the satellite images and produce height models and orthophotographs. The latter are aerial photographs which remove the distortions of points on the ground caused by relief, tilt and perspective.

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Archaeologist Kaatje De Langhe and geographer Matthijs Vanommeslaeghe are standing on a well-preserved burial mound, typical of a Scythian kurgan *in its undisturbed state. Here, they are measuring the location of this burial mound using a complex Global Positioning System (GPS) receiver during the 2005 campaign*

This is only the beginning

The project will need to extend over Russia's border into the neighbouring countries of Kazakhstan, China and Mongolia to map the archaeological heritage and monitor climate change throughout the Altai Mountains. This year, the University of Ghent is surveying the Valley of Kara-Kaba in east Kazakhstan and studying the effects of climate change on glaciers, together with the Margulan Institute of Archaeology of Almaty and geocryologist Sergei Marchenko from the International Permafrost Association. For this segment of the project, UNESCO will be bringing on board another Open Initiative partner, the Chinese Academy of Sciences.

Given the need for uninterrupted monitoring of climate change over long periods of time, this will be only the beginning...

Wouter Gheyle with the collaboration of
Jean Bourgeois, Jessica Bunning and Mario Hernandez[28]

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28. Jean Bourgeois is full professor and Wouter Gheyle is a scientific researcher at the Department of Archaeology and Ancient History of Europe at Ghent University in Belgium. Mario Hernandez is Head of UNESCO's Remote Sensing Programme and Jessica Bunning is a Programme Assistant at UNESCO