

# REMOTE SENSING IN THE ORKHON VALLEY

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## METADATEN



Projektverantwortlicher Dr. Christina Franken, Janna Fabry

Adresse Dürenstr. 35-37 , 53173 Bonn

Email [Christina.Franken@dainst.de](mailto:Christina.Franken@dainst.de)

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Partner Hochschule für Technik und Wirtschaft Dresden, Fakultät Geoinformation, Labor Photogrammetrie/Fernerkundung

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## OVERVIEW

Due to the global historical significance of the ancient sites in the Orkhon Valley, the entire region was declared a World Heritage Site by UNESCO in 2004. This poses great challenges to researchers, institutions and other stakeholders: to explore, protect and make the heritage

accessible to the public. The region is home to archaeological monuments that bear witness to the human settlement of the steppe, the development of a widely networked elite and the formation of states and great empires on the foundation of a predominantly nomadic economy. Particularly noteworthy are the urban deserts of the cities of Ordu Balik and Karakorum, which were important urban centres of the Uyghur and Mongol empires, respectively, in the Middle Ages.

Despite basic information obtained from historical sources, the history, structure and functions of the steppe capitals still raise many questions. The older excavations have often focused on monumental architecture such as palaces and temples, while research on the overall structure of the cities and their hinterland is still in its infancy. To address this question, Mongolian-German collaborative research projects began with surveys and excavations in Karakorum in 2000 and in Karabalgasun in 2007. Detailed plans of the ancient remains on the surface are a crucial prerequisite for further research and understanding of the steppe cities. For Karakorum, a digital surface model has already been captured by geodetic survey with a total station, meticulously measuring over 80,000 points. The much larger terrain of Karabalgasun was surveyed by helicopter in 2007 using Airborne LiDaR technology. The steppe offers almost perfect conditions for remote sensing techniques due to its sparse vegetation and settlement. The scan covered an area of about 40 km<sup>2</sup>, of which 20 km<sup>2</sup> were filled with walled enclosures and mounds representing the remains of the former settlement. Although the scan revealed much of the site, it also proved that it extended further, especially to the north and west.

However, LiDaR and geodetic surveys on foot are expensive, so the areas surveyed were limited. As research on urban sites in the steppe becomes more interested in issues of urban hinterland, urban sprawl and long-range settlement patterns, detailed mapping of large-scale areas is required. This poses the challenge of surveying large areas in a short time with affordable equipment and preparing the collected data for scientific analysis.

Therefore, satellite remote sensing was applied to cover the full extent of Karabalgasun. SENTINEL-2 satellite imagery, freely available for scientific purposes at Copernicus Open Access Hub, and image datasets provided by the RapidEye Science Archive allowed the area to be surveyed via multispectral data with resolutions between 6 and 10 m per pixel. The satellite images only showed larger enclosures clearly, while smaller structures remained indistinct or invisible. Two areas were particularly interesting. North of the already known site, near the flood plain of the Orkhon, the sentinel images showed some obscure rectangular structures. If it could be proven that these were former buildings, this would significantly change the original picture of the extent of the city. Another interesting area was to the west of the areas covered by the laser scan images. Several walled enclosures located along the Jarantain Gol, a small tributary of the Orkhon River, are visible on the satellite images. This raised the question of whether there is also continuous development there, comparable to other areas of the city,

with smaller buildings and enclosures, or whether they are just isolated outposts of the city. The analysis of the satellite images provided us with a basis for further planning of remote sensing activities on the site. When the opportunity arose to cooperate with the "Archaeoapter" project of the HTW Dresden and the FU Berlin, the following focal points of investigation were determined:

1. Areas adjacent to the city of Karabalgasun, with the aim of completing the

mapping of the site in areas where further archaeological remains can be expected according to satellite imagery.

2. The site of Karakorum and its immediate surroundings, with the aim of refining the digital elevation model and extending the study area beyond the recognisable ramparts of the city, as well as producing a detailed mapping of the area of the Erdene Zuu monastery.

## SPACE & TIME

### TIME

Between 745 and 840, the nomadic tribe of the Turkic people of the Uyghurs formed an empire far beyond the size of present-day Mongolia. The Uyghurs acted as close military allies of the Chinese Tang dynasty. Their support was so crucial to the Chinese dynasty that it granted favourable trading conditions and committed itself to tribute payments amounting to hundreds of thousands of silk bales per year. This wealth enabled the Uyghurs to participate in trade on the Silk Roads. They were significantly supported by the people of the Iranian Sogders from Central Asia as traders, advisors and administrators of their empire.



To facilitate trade, diplomacy and crafts, the Uyghurs founded urban settlements. Most prominent among them was their capital Karabalgasun, located in the "Ötükän yis" on the river Orkhon, in the sacred lands of the ancient Turkic peoples between the Khangai and Khentii mountains. The Arab traveller Tamīm ibn Baḥr reported, "[...] that this is a large city, rich in agriculture and surrounded by rustāqs full of cultivation and closely spaced villages. The city has twelve iron gates of immense size. The city is populous and densely packed and has markets and various trades [...]". In 840, the city was destroyed by the invading Turkic tribe of Kyrgyz from the upper Yenisei region. With the destruction of Karabalgasun, the Uyghur Empire also fell.

Only 30 km south of the ruins of the Uyghur metropolis, the Mongols founded Karakorum as the capital of their growing empire. Consequently, almost 400 years after the fall of Karabalgasun and the Uyghur Empire, the Orkhon Valley once again became the centre of a steppe empire. Some sources report that Genghis Khan himself chose the location of the city in 1220. In 1235, a city wall, palace and temple were built. Further information about Karakorum is provided by the accounts of travellers and chroniclers from different cultures. The city was a cosmopolitan centre populated by diplomats, nobles, merchants, missionaries and craftsmen from China, Central Asia, the Near and Middle East and even Western Europe. The heyday of Karakorum lasted until 1260, when Qubilai Khan took the throne of the empire and established his residences in Shangdu and Dadu (Beijing).

## **SPACE**

Due to its sparse vegetation and settlement, the Mongolian steppe offers almost perfect conditions for remote sensing techniques. Extensive land use by nomadic grazing minimizes the loss of archaeological material.

## **RESEARCH**

### **RESEARCH QUESTIONS**

Questions about urban development and its integration into the surrounding area and beyond are at the forefront of the investigations.

### **APPROACHES AND METHODS**

UAVs ("drones") in combination with photogrammetry methods have established themselves as a standard tool in archaeological documentation. Multicopters with good cameras are becoming safer and cheaper nowadays. In contrast to stereo-based approaches, single camera systems are often based on the principle of "structure from motion". In terms of software, in addition to many commercial products, there are also freely available packages such as VisualSFM and open source products such as MicMac, OpenMVG that can deliver comparable results. However, dealing with the free products is often a major challenge. This is especially true for the customisation of the free parameters, which offers the user maximum freedom on

the one hand, but can lead to unsatisfactory results on the other. The Archaeocopter project has been dealing with the handling and analysis of existing free software packages in the context of archaeological documentation since 2013. New software modules and alternative solutions are also freely available and are constantly being developed. As part of this project, a semi-automatic software called Archaeo3D was developed to optimise and control the entire reconstruction process. The resulting 3D models are heavily dependent on the quality and correlation of the input images. Videos and photos are automatically imported and processed. The software is able to rearrange or adjust the processing modules and adjust the parameters depending on the current hardware and the shooting situation and complexity. VisualSFM, COLMAP and CPMVS are the main tools used by Archaeo3D. To create a 3D model, standardised steps are first used to create a set of planned, high-resolution photographs, which are then photogrammetrically stitched together. This is in contrast to videogrammetry, which has its origins in robotics for localisation and recognition in real-time systems. However, with the Jkeyframer we have a tool that allows for two solutions:



## **RESEARCH HISTORY**

The nomadic empires of Central Asia are particularly interesting phenomena in the history of civilisation. Despite the small population and economy of the Eurasian steppes, they had an enormous impact on the course of human history. Although these empires relied on the military strength and mobility of a predominantly nomadic population, they repeatedly developed significant urban centres. For about twenty years, the German Archaeological Institute, the Mongolian Academy of Sciences and the National University of Ulaanbaatar have been jointly researching urban settlements in a nomadic environment, their characteristics and intercultural influences in Mongolia's Orkhon Valley.

## **RESEARCH OBJECTIVES**

Our aim is to create a comprehensive corpus of high-resolution cultural landscape data in the Karabalgasun and Karakorum area and the entire Orkhon Valley to provide a more holistic view of settlements and land use in the urban sites of the Orkhon Valley. Efforts are being made to improve existing visualisations and to create meaningful images of anthropogenically influenced landscapes that preserve the positive characteristics of the individual technologies applied. The project also focuses on the further development of methods.

# CULTURAL HERITAGE

## TEAM



## RESULTS

The 2018 remote sensing campaign achieved two important results.

First, it proved that a low-cost, photogrammetric approach to remote sensing need not be limited to single objects or small sites, but can also be applied across vast landscapes. Due to the sparse vegetation of the Mongolian steppe, airborne photogrammetric modelling is a cost-effective and relatively easy-to-use survey method. In this case, almost 50 km<sup>2</sup> were mapped within only eight days of intensive work.

Secondly, already the preliminary results have increased our knowledge about Karabalgasun. Despite some uncertainties in data quality, there is finally, almost 130 years after the first site measurements, a complete, high-resolution plan of the city's remains. According to an initial review of the new plan, Karabalgasun can be described as a nomadic type of urban settlement. The city had the shape of a segment of a circle with its convex side facing west and its flat side facing east. The so-called temple and palace complex or "imperial city" is located in the centre

of the straight eastern boundary. This is a genuinely nomadic urban layout that resembles a ruler's field camp.

This knowledge will contribute significantly to the debate on urbanism in nomadic settings. The new city plan now allows a detailed analysis of the general layout and the individual components of the city. Research on the organisation and use of urban space can now be advanced with a solid data base.

Also in 2018, the team collected data in Karakorum and the adjacent monastery of Erdene Zuu. In addition to mapping the medieval city deserts, a high-resolution 3D model was also created of the Erdene Zuu site by combining video and photogrammetry. The model can be used for teaching purposes in the future and documents the current state in great detail.

In the 2019 campaign, additional areas around Karabalgasun were mapped using the methods described above. In addition, data collection in Karakorum was supplemented in order to achieve complete results here as well.



**Karabalgasun**

## **PARTNER & FÖRDERER**

### **PARTNER**

*Hochschule für Technik und Wirtschaft Dresden,  
Fakultät Geoinformation, Labor  
Photogrammetrie/Fernerkundung*

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