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Detect, map, and preserve Bronze & Iron Age monuments along the pre-historic Silk Road

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Abstract. Central Asia is rich in cultural heritage generated by thousands of years of human occupation. Aiming for a better understanding of Central Asia's archaeology and how this unique heritage can be protected, the region should be studied as a whole with regard to its cultural ties with China and combined efforts should be undertaken in shielding the archaeological monuments from destruction. So far, international research campaigns have focused predominantly on single-sites or small-scale surveys, mainly due to the bureaucratic and security related issues involved in cross-border research. This is why we created the *Dzungaria Landscape Project*. Since 2013, we have worked on collecting remote sensing data of Xinjiang including IKONOS, WorldView-2, and TerraSAR-X data. We have developed a method for the automatic detection of larger grave mound structures in optical and SAR data. Gravemounds are typically spatially clustered and the detection of larger mound structures is a sufficient hint towards areas of high archaeological interest in a region. A meticulous remote sensing survey is the best planning tool for subsequent ground surveys and excavation. In summer 2015, we undertook a survey in the Chinese Altai in order to establish ground-truth in the Hailiutan valley. We categorized over 1000 monuments in just three weeks thanks to the previous detection and classification work using remote sensing data. Creating accurate maps of the cemeteries in northern Xinjiang is a crucial step to preserving the cultural heritage of the region since graves in remote areas are especially prone to looting. We will continue our efforts with the ultimate aim to map and monitor all large gravemounds in Dzungaria and potentially neighbouring eastern Kazakhstan.

1. Introduction

During the Iron Age, large parts of the Eurasian steppe belt from Western China to Eastern Europe were inhabited by nomadic pastoralists. Many of these cultures built grave mounds (so called kurgans) to bury their dead and thus left distinctive marks in the landscape. There are tens of thousands of these monuments distributed over the steppe zones of Eurasia and not even a rough overview has been established yet. Iron Age grave mounds are also a primary target for looting, since they are known to contain valuable objects. A large part of these monuments has already been robbed and destroyed by looters. In order to effectively protect and study the Iron Age in Xinjiang and neighbouring Kazakhstan, the area should be studied as a whole and combined efforts should be undertaken to protect these extraordinary archaeological monuments. Until now, international research campaigns have focused predominantly on single-sites or small-scale surveys confined to today's borders, mainly due to bureaucratic and security related problems in cross-border research.

With remote sensing, large areas can be searched for material remains. The rather large and distinct burial mounds are suitable for remote sensing based landscape archaeological analysis and for creating an inventory. Since the acquisition of large chunks of optical data is expensive, we jointly analysed the possibility of using synthetic aperture radar (SAR) data for the detection of burial mounds. To analyse large areas, automated or semi-automated detection methods are required. Certainly so, if we want to get a complete overview over the burial mounds in Dzungaria and eastern Kazakhstan. The size of a burial mound has commonly been interpreted as a measure for social status. Simplistically speaking, the larger the mound the more important the person buried within it and the richer the artefacts and treasures buried with the dead. Therefore, our focus is on the rather large burial mounds which would equal to the most substantial loss of cultural heritage if robbed. The main objective of our *Dzungaria Landscape Project* is to establish a method which allows for efficient large-scale detection of big grave mounds with diameters of 20 m and more. It has been shown that very often larger Bronze and Iron Age monuments form nuclei for smaller archaeological structures [1],[2]. The automatic classification of kurgan structures, especially of dense structures of kurgans forming archaeological 'hotspots' is essential to get an overview over the regional spatial distribution of the sites. The detection of so-called princely graves can thus reveal interesting archaeological hotspots in a given landscape as a first step for further, more detailed archaeological inquiries and measures for heritage protection.

In section 2, we describe our previous work using remote sensing for the detection of burial mounds in the Altai region. In section 3, we describe the planned extension of the work on a larger scale. Finally, we draw the conclusions.

2. Previous work in the Altai Mountains

2.1. Selecting an area of interest: Hailiutan valley, Chinese Altai

As a first test site we selected an archaeologically rich landscape in the foothills of the Southern Chinese Altai Mountains based on an automated large-scale survey. The area around the village Hailiutan close to the airport of Kanas is a broad valley with an extensive alluvial plain as its centre. It is part of the territory of both Bu'erjin and Habahe County. Framed by mountain ranges to its North and its South the valley lies on 1150-1300 m a. s. l. Steep mountain passes allow access to the plain from the Dzungarian steppe. The area lies on the border of two climatic zones: the Dzungarian steppe to its South and the alpine climate of the high Altai to its North and thus encompasses two major living environments of antique Central Asian nomadic pastoralists.

2.2. Selecting an area of interest: Hailiutan valley, Chinese Altai

For the detection of burial mounds covering a wide area, automated or semi-automated detection methods are preferred. In a previous study, we tested three different approaches for the automatic detection of grave mounds in IKONOS-2 datasets [3]. We used convolution with ring templates exploiting the shape characteristics of the gravemounds and implemented and tested class-specific Hough Forests for object detection. We achieved the best results with class-specific Hough Forests (see Figure 1).

In this experiment, we showed that archaeological features that are clearly visible with a strong contrast against the background can be detected quite well and are relatively robust to changes in threshold value using class-specific Hough Forests. Monuments that are well identifiable, but for example have been changed in their appearance by ploughing or vegetation, are still detected at a reasonable rate; however, changes in the parameters for a higher detection rate of these structures lead to an increase in the false positives. Burial mounds that are hardly identifiable visually in the remote sensing data are also not identified by the algorithm (see [3]).

Generally, large burial structures are clearly identifiable and automatically detectable in IKONOS-2 and WorldView-2 data. Because the structures are often spatially clustered with smaller mounds being in proximity to larger mounds, the detection of larger mounds is sufficient to detect larger clusters of archaeologically important structures.

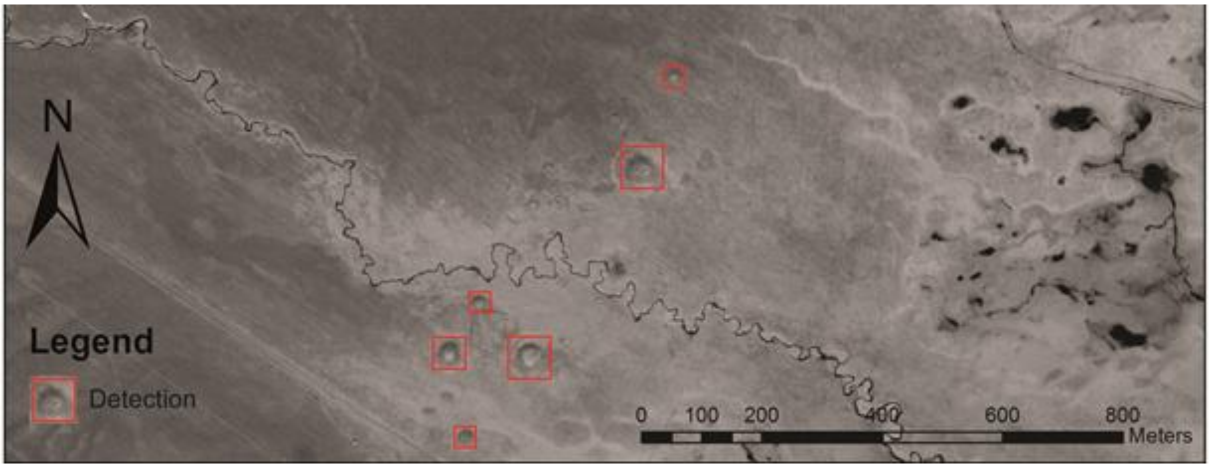

Figure 1. Detections on IKONOS-2 data (Caspari et al., 2014)

2.3. Detecting burial mounds from Synthetic Aperture Radar (SAR) satellite data

Based on the promising results for detecting burial mounds from high-resolution optical data, we tested the detectability of such mounds in very high resolution SAR data. SAR has some advantages over optical data, especially regarding continuous monitoring and detecting relative small height differences using interferometry. Getting larger data coverage from SAR can also be more economical than optical data acquisition, making it an interesting alternative for covering large areas.

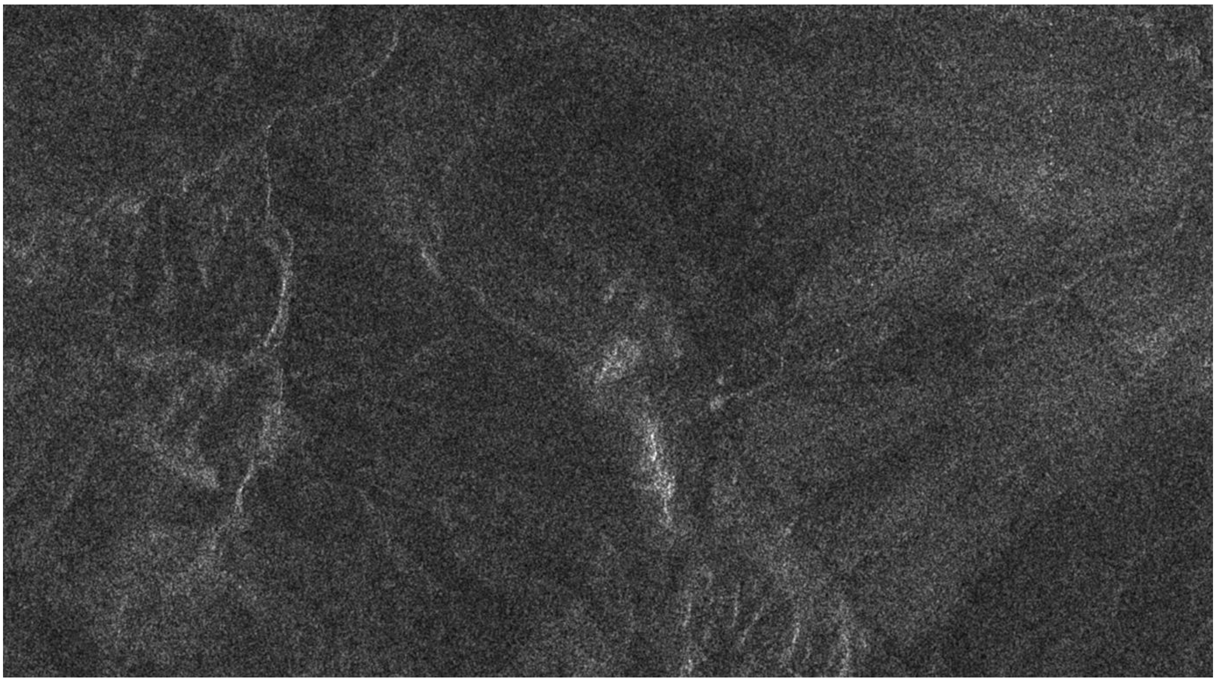

Figure 2. TerraSAR-X stripmap image from 2014-6-5 © DLR, 2014

For our experiments we used TerraSAR-X data acquired with different SAR modes [4]. First, we acquired TerraSAR-X stripmap data with approximately 3 m spatial resolution. Furthermore, we acquired TerraSAR-X spotlight data with approximately 1.6 m resolution. Finally, we used the new TerraSAR-X staring spotlight mode [5] with around 0.25 x 0.9 m resolution. As the dimension of the larger burial mounds we are interested in exceed 10 m, they should be identifiable in the test data.

However, as we can see in Figure 2 even large burial mounds are hardly identifiable in the stripmap images with around 3m resolution. This situation improves when using spotlight images as shown in Figure 3 However, the detectability even of larger mounds is still very limited in the spotlight images.

Figure 3. TerraSAR-X spotlight image from 2015-7-14 © DLR, 2015

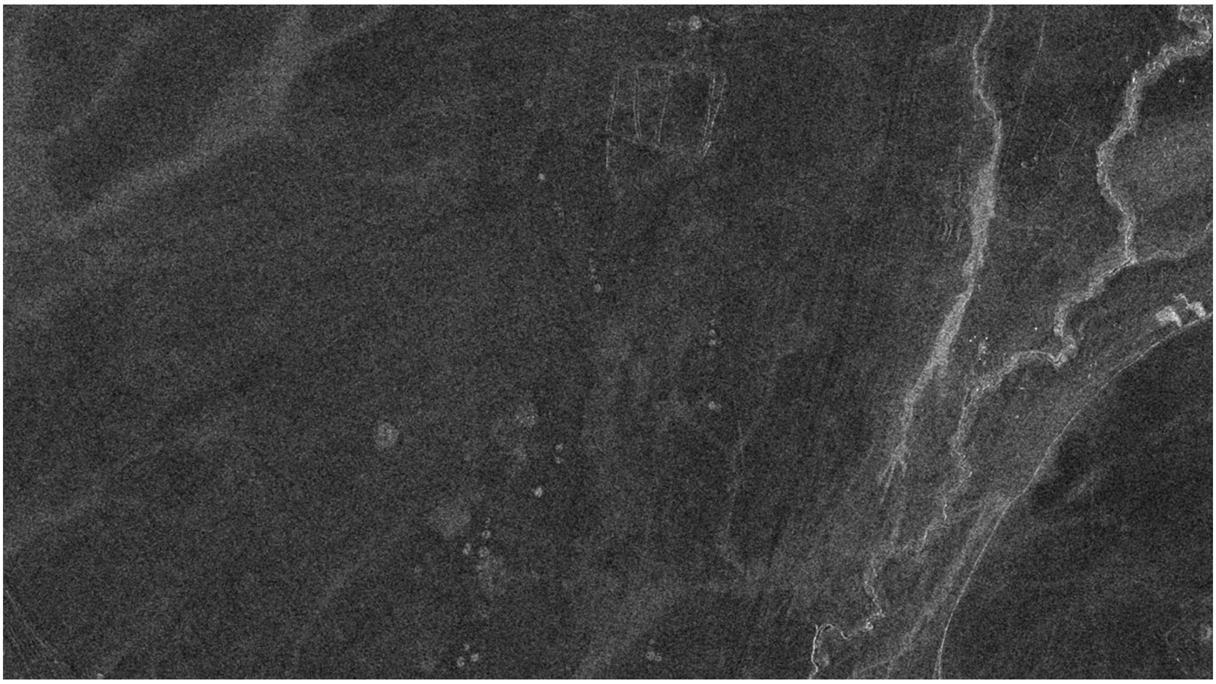

Figure 4. TerraSAR-X staring spotlight image from 2015-9-5 © DLR, 2015

The situation is different though when we are using TerraSAR-X staring spotlight images with very high spatial resolution. As we can see in Figure 4, burial mounds of different sizes are clearly identifiable in the staring spotlight data. There are several reasons for this. First, the higher spatial resolution alone already allows for a better identification. Additionally, the speckle effect disturbs the clear identification of mounds in the SAR image and we can use the additional spatial resolution in azimuth for a four time multi-looking of the TerraSAR-X staring spotlight image for a reduction of the speckle in the staring spotlight image. This tremendously increases the detectability. Unfortunately, with the stripmap and spotlight data, multi-looking would reduce the spatial resolution even further. Therefore, the increase in radiometry from multi-looking is rendered useless due to the loss of spatial resolution.

Using staring spotlight data, automated detection methods can also be applied. Using Hough-Forests, good detection rates for larger mounds can be achieved. As shown below in Figure 5, larger mounds can be detected in both cases. Increasing the detection rate for the smaller mounds would increase the false detection rate though, so that we cannot expect a complete detection with automated methods, but instead a good detection of clusters of burial mounds.

Figure 5. Example of classification results from TerraSAR-X staring spotlight data (left) and IKONOS-2 data (right)

Unfortunately, although we demonstrated that burial mounds are detectable in very high-resolution staring spotlight data, this does not help us regarding our goal of detecting the burial mounds on a larger, regional scale. Staring spotlight images only cover a small area and are, by design, not suitable for large area coverage. To cover the Dzungarian steppe, stripmap data or even ScanSAR / TOPS data would be better suited. But, with that data we cannot detect even larger burial mounds.

2.4. Ground survey

In summer 2015, we conducted a field survey in the Hailiutan valley, based on the area of interests detected with optical and SAR remote sensing as described above. Our survey was based on field walking with the aim of mapping all visible sites in the area. We worked with small and very mobile teams usually consisting of 3-4 people. In this way, we were able cover an area of well over 140 km^2 in just about three weeks of intensive fieldwork. The remote sensing data helped us immensely with planning and allocation of our efforts. In total, the team mapped close to 1’000 structures.

We found that the construction of grave mounds appears to be constrained by certain environmental factors which – if taken into account – reduce the amount of data which has to be processed considerably. Our survey showed that the centre of the basin was not favoured for the construction of funerary monuments since it is rife with rivulets, the soil therefore has a high moisture content and is suboptimal for construction. Thanks to the ground truth we were also able to improve the accuracy of our remote sensing survey. Especially short-lived circular soil features like the one’s resulting from herding activities and the placement of yurts led to false positive marks before the field survey (see Figure 6.)

Figure 6. Temporary soil marks that looked like archaeological features in remote sensing data.

Already through a rough analysis of the archaeological features we were able to divide them according to our dating hypotheses and assign them to specific periods. We analysed the archaeological landscape of the valley of Hailiutan which has been occupied at least since the Bronze Age. During the Early Iron Age, we see an upsurge of anthropogenic building activity in the area. During this time the southern foothills of the Altai Mountains seem to have been an important passage way and the home base of a highly developed culture with intensive ties to both modern day Kazakhstan and the northern Altai.

3. Extension to a regional scale

Extending the *Dzungaria Landscape Project*, we aim to map the complete plain for large archaeological features, especially Iron Age grave mounds. Special attention will be given to the passage ways into the west, since these have been early on places of intensive cultural interaction that connect eastern Chinese cultural influences with Central Asia. Our aim is to integrate the archaeological research in Dzungaria with the efforts of our colleagues in Kazakhstan and create research interfaces through remote sensing by providing a standardized methodology.

As a first step we need to complete several case studies through remote sensing. This will help us document the variety of monuments in northern Xinjiang and establish a system for classification. Throughout these case studies we will be using both optical and SAR imagery and continue to assess the validity and accuracy of our predictions through on-ground surveys. The case studies will follow a north-south line from the foothills of the Altai Mountains to the northern flank of the Tianshan. Through this methodology we might be able to relate specific cultural phenomena to environmental circumstances, thus increasing the specificity of our survey results.

In a second step we need to conduct small scale excavations at a number of monuments in order to obtain dating material and further develop our methodology for protection. Knowing the date and the preservation circumstances of individual monuments will enable us to make recommendations for protection measures from environmental factors and anthropogenic destruction like looting, agricultural activities or construction.

The third step will then consist of building up a geographic information system which points out areas of high archaeological density. Such a dataset will help local heritage administration to consistently monitor, protect and - if not possible - excavate the cultural treasures of northern Xinjiang and eastern Kazakhstan.

4. Conclusion

Over the past three years we have built a strong network of remote sensing specialist and archaeologists, which are able to perform the tasks described above. From the large-scale automatic scanning of thousands of square kilometres of data to landscape archaeological analysis as well as excavation and survey-based ground truth we have developed a process that will help further our understanding of the cultural heritage of Xinjiang and Kazakhstan. In order to show the cultural connection this part of China established during prehistoric times with Central Asia and to protect the valuable heritage of this region we need to continue our research within the frame of the Dzungaria Landscape Project.

We have obtained good results in detecting large Iron Age gravemounds from both optical and SAR data. Due to the valuable objects contained in those mounds they are especially prone to looting activities and – as a matter of fact – a large proportion of those mounds has already been destroyed. Mapping all large gravemounds in Dzungaria will provide a cultural heritage management tool in order to preserve these magnificent monuments for future generations. Furthermore, it will increase our understanding of the archaeology in Xinjiang and neighbouring Kazakhstan thus showing the culturally strong connection these regions had in the past. But further effort is needed to accomplish this aim.

Relations to the local cultural heritage administration and the Academy of Social Sciences have to be built so we can establish further ground truth. We need to obtain excavation data of a small number of gravemounds to be able to give accurate advice on how to preserve and monitor monuments of specific types. We also need to continue to acquire data and ground surveys. But, step-by-step we will complete the largest archaeological survey China has ever seen.

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