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Remote Sensing of Large-Scale Areas at the Urban Sites of the Mongolian Orkhon Valley Using Low-Cost Drones : preliminary Results and Some Thoughts on the Urban Layout of the Uyghur Capital Qara Balğasun.

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ABSTRACT

Remote sensing of large-scale areas at the urban sites of the Mongolian Orkhon Valley using low-cost drones.
Preliminary results and some thoughts on the urban layout of the Uyghur capital Qara Balğasun
Christina Franken, Hendrik Rohland, Marco Block-Berlitz, Tumurochir Batbayar, Ulambayar Erdenebat

In 2018 the Mongolian-German Orchon-Expedition (Mongolian Academy of Sciences, National University of Mongolia, German Archaeological Institute) together with Archaeocopter (Hochschule für Technik und Wirtschaft Dresden, Freie Universität Berlin) conducted large-scale surveys at the sites of the Uyghur capital Qara Balğasun and the ancient Mongol capital of Qara Qorum. Especially the enormous size of the site of Qara Balğasun poses a challenge for archaeological research. The unbuilt and sparsely vegetated Mongolian steppe provides ideal preconditions for image-based remote sensing methods. With off-the-shelf, relatively low-cost UAVs (Unmanned Aerial Vehicles) both sites have been surveyed with thousands of overlapping aerial images. Otho-images and digital elevation models have been generated by photogrammetric methods. The results enable the distinguishing of even faintest remains of ancient constructions. For the first time a complete map of the remains of Qara Balğasun has been achieved. This map delivers new insights concerning the Uyghur city. The area occupied by the city amounts to 44 km². Furthermore the new map allows a better understanding of the principles of spatial order on which the city is based. While former theories assumed Iranian-Sogdian or Chinese models of city planning, it seems now, that the layout of Qara Balğasun follows more native nomadic principles. The city is the encampment of a nomad ruler made permanent by the erection of buildings and thus an instance of a genuine steppe-nomadic kind of urbanity.

KEYWORDS

Remote Sensing, Large-scale documentation, low-cost drones, UAV, Photogrammetry, Mongolia, Qara Balğasun, Qara Qorum, Steppe empires, Steppe urbanism

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Remote Sensing of Large-Scale Areas at the Urban Sites of the Mongolian Orkhon Valley Using Low-Cost Drones

Preliminary Results and Some Thoughts on the Urban Layout of the Uyghur Capital Qara Balǧasun

1. Motivation and introduction

1   The nomad empires of Central Asia played an important, yet often underestimated role in the global history. In the recent decades, this role came to be more and more appreciated by scholars, especially with respect to the contemporary phenomena of globalization. This holds especially true for the Mongol Empire (Biran 2013). It had close relationships with or even incorporated neighbouring sedentary cultures like these of China, Persia, Muslim Central Asia and Eastern Europe. The mobile elites of the nomad empires became to be agents of cultural exchange between these cultures by the means of warfare, diplomacy, trade and scientific and religious debate (Allsen 2009). It is an interesting characteristic of the steppe empires, that they developed a certain degree of urbanisation. Since the year 2000, Mongolian and German Archaeologists are conducting research on the capital cities <u>Qara Balǧasun</u> of the Uyghur Empire and <u>Qara Qorum</u> of the Great Mongol Empire.

2   Both cities are ruined sites today. They are both located within the World Heritage Site „Orkhon Valley" at the upper and middle reaches of the Orkhon River in Mongolia (Fig. 1; Fig. 2). The Orkhon Valley has been an important and often considered as sacred land which served as centre for several nomad empires as that of the Turks, Uyghurs and Mongols. The whole area features a remarkable density of archaeological sites and a lively nomadic culture up to the present day.

3   Qara Balǧasun lies at that left bank of the Orkhon River and stretches for many kilometres through the valley (see Fig. 2). It was the capital of the Uyghur Empire from around 745 to 840 (Fig. 3). Qara Qorum was allegedly founded around 1220 as a

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Fig. 1: Map of Mongolia with the Orkhon Valley

Fig. 2: Map of the middle Orchon Valley

campsite of Chinggis Khan on the right bank of the Orkhon River, just 30 km south of Qara Balǧasun. It continued to be the capital of the Mongol Empire until 1260 and was an important ritual and political centre of the Yuan Dynasty in the years after. (Sagaster 1999; Hüttel 2007)
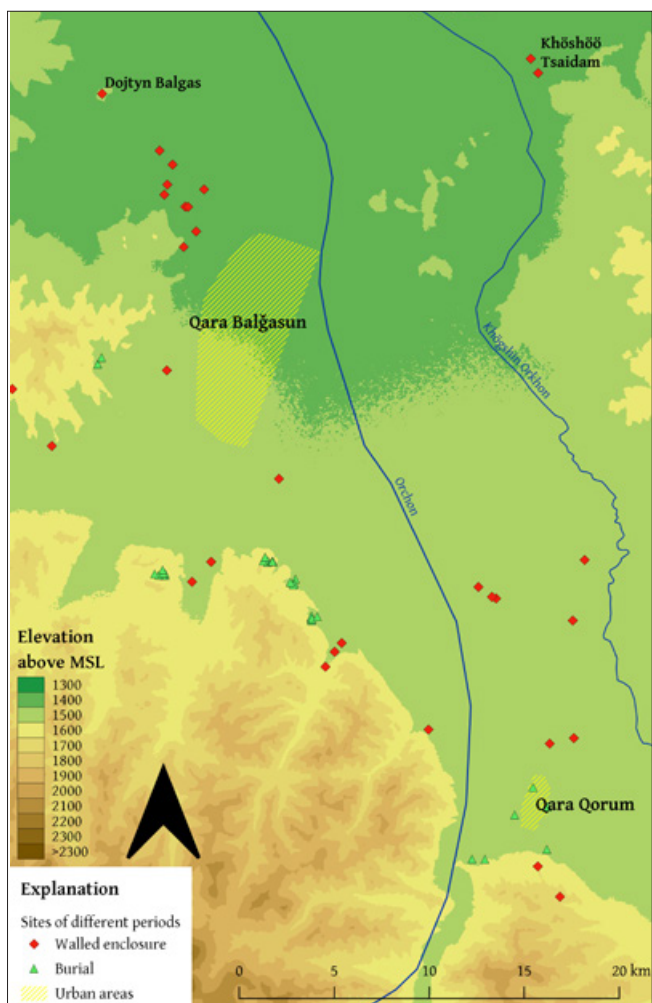
4   Mongol Qara Qorum has been the cosmopolitan centre of the greatest land-based empire the world has ever seen. Contemporaries describe it as a place where Mongol, Chinese, Muslim and also European craftsmen, artisans, scholars and diplomats gathered to attend to the court of the Great Khan. A similar cosmopolitan character can also be assumed for the earlier Uyghur capital Qara Balǧasun. The famous inscription stelae discovered on the site featured three different scripts and languages: runic-turkic script, Chinese Hanzi and also Sogdian script. (Radloff 1892: Tab. XXX–XXXV). Archaeological research in the recent years focused on three areas within the site: they were called HB 1, HB 2 and HB 3 (Fig. 7). HB 1 was presumably a Manichean temple-complex and contained the trilingual inscription stelae. HB 2 is the most magnificent structure of the whole area. It features an impressive wall, which is still rising up to 12 metres above the surrounding steppe. In the centre of this enclosure were the remains of presumable temples (Dähne 2017). In its south-eastern corner was a citadel with representative architecture (Franken et al. 2017; Franken et al. 2018). Because of this features it is likely to have been the most important space for ritual and political performances in the city. Therefore it might be termed the 'imperial complex' of Qara Balǧasun. HB 3 lies to the southwest of HB 2 and is characterized by densely built small structures that are enclosed by a common wall. Minor excavations and surveys yielded traces of silk processing and handicraft.

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Artefacts from the citadel in HB 2 prove intense exchange with China in the realms of building technique and –decoration. The close diplomatic relations to China were underlined by the recovery of so called Jade-Books from the site (Franken et al. 2017; Franken et al. 2018).

5   Especially the sheer size of the site of Qara Balğasun is a challenge for the archaeology of Qara Balğasun. The remoteness and the lack of infrastructure make the large-scale surveys necessary to cover its huge area a costly thing to do. Therefore a cost-efficient solution for obtaining high resolution, georeferenced elevation data of large areas in a short period of time had to be found.

Fig. 3: Aerial view of the so-called 'imperial complex' of Qara Balğasun. In the foreground raises the citadel above the ramparts
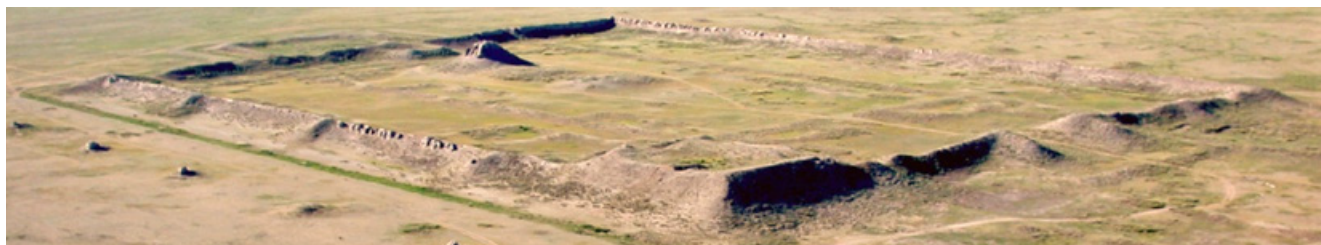
1.1 Urbanity of the medieval nomads

6   The nomad empires of the steppes had strong influence on Eurasian and thereby world history during the last two millennia. The far-flung empires of Xiong-nu, Turks, Uyghurs, Kidan, Kara-Kitai and Mongols amongst others had diverse relationships of trade, warfare, political, ethnical and cultural exchange with neighbouring and farther removed sedentary cultures. These relationships in connection with the high mobility of equestrian nomads turned the steppe empires into agents of cultural exchange between cultures even as far removed as Europe and China. The understanding of these relationships opens up the path to a broader view on the global history in pre-modern times. Some of the steppe empires developed a certain degree of urbanism. Today the remains of their urban centres are scattered through the Eurasian steppe zone. The scholarly discussion on steppe cities such as Qara Balğasun often focuses on how they were shaped by foreign influences such as Chinese and Iranian concepts of representation of power, architecture and city planning. Another important question is how they were shaped by the dynamics of the steppe empire itself. Some tend to ascribe their emergence primarily to the exchange with sedentary cultures (Barfield 1989; Khazanov 2005: 167–172) while others emphasize a more autochthonous interpretation, promoting a genuine nomadic urbanity, rooted more firmly in the economic and cultural conditions of the steppe and based on growingly complex nomadic societies emerging as early as the Bronze Age (Honeychurch – Amartuvshin 2007: 54–55; Waugh 2010; Houle 2010: 172–178). Often a position in between is proposed, emphasizing the nomadic adaption of foreign urban models to the needs and conditions of nomad societies. (Rogers et al. 2005). The data basis for such discussions is very scarce. Contemporary written evidence on Qara Balğasun and earlier places is very sparse. Archaeological excavations on the site have been undertaken sporadically from the beginning of the 20th century on, but have been mostly small in scale and cursorily published (Киселев 1957).

7   Since the year 2000 Mongolian and German scholars cooperate in the research on ancient steppe cities within two joined expeditions: The Mongolian-German Qara Qorum-Expedition, focused on the study of the capital of the medieval Mongolian empire, Qara Qorum, and the Mongolian-German Orkhon-Expedition, aiming to explore the cultural landscape of the World Heritage Site Orkhon Valley. The expeditions are carried out by the Mongolian Academy of Sciences, the German Archaeological Institute, the University of Bonn, and the Mongolian State University.

8   The Mongolian-German Qara Qorum-Expedition has been conducting diverse research in Qara Qorum and its vicinity, yielding insights into the architecture, urban planning, economy, social and religious life and foreign relationships of the city of Qara Qorum during the Middle Ages (Roth – Erdenebat 2002; Hüttel – Erdenebat 2009; Bemmann et al. 2010; Franken 2015). An important basis for that research was a mapping of the archaeological remains within the ramparts of the city, made by researchers and students of the University of Applied Sciences, Karlsruhe (Hüttel – Erdenebat 2009). Because this mapping was made by measuring with a total station, its spatial resolution is limited. It was also confined to the area within the ramparts of the city and therefore lacks information about the surrounding suburbs and the adjacent area of the monastery Erdene zuu, which is suspected to occupy the space of the medieval palace of the Mongol rulers (Hüttel 2009; Hüttel 2016).

9   The Mongolian-German Orkhon-Expedition is, as one of its projects, conducting research on the urban centre of the Uyghur steppe empire. The Uyghurs ruled over an area, which is today covered vaguely by the Mongolian State, the provinces of Inner Mongolia and Xinjiang Uyghur Autonomous Region of PR China and the Republics of Tuva, Buryatia, the Zabaykalskij Krai, the Irkutsk and the Amur Oblast of the Russian Federation. Their empire existed from the mid of the 8th century until 840 A.D., when their capital city was destroyed by the Yennisei-Kirgiz tribe. During the 100 years of its existence, the Uyghur Empire was an important military and political ally of the Chinese Tang-Dynasty (Mackerras 1968). Due to this relationship, the Uyghur rulers were able to extract huge amounts of tributes, disguised as gifts and trade goods, from China. One of the most important trading goods was silk. The Uyghurs also maintained close relationships to the Iranian Sogdian people of Central Asia, who served as agents to trade silk and other luxury goods from china to the West (Barfield 1989: 157–159). It was possibly the enormous wealth acquired by the Uyghurs and the close interaction with different sedentary people which led to the establishment of urban places throughout the empire. One of them was Ordu-Baliq, nowadays known as Qara Balğasun, the supposed capital city of the Uyghur Empire.

10   The Arabian traveller Tamim ibn Bar described the Uyghur capital as "[…] a great town, rich in agriculture and surrounded by rustāqs full of cultivation and villages lying close together. The town has twelve iron gates of huge size. The town is populous and thickly crowded and has markets and various trades (tijārāt)" (Minorsky 1948: 283, 2). Early in the archaeological research it became clear, that Qara Balğasun was a magnificent site. A map drawn by the expedition conducted by Willhelm Radloff in 1891 shows that the built-up area extended far beyond the impressive ruins that raise over the valley of the Orkhon River. Radloffs Expedition recorded a huge assemblage of archaeological structures in a detailed plan (Radloff 1892: Taf. XXVII). To gain reliable knowledge on the architecture, city layout and other aspects of urbanism in the steppe, the Mongolian-German Orkhon-Expedition is conducting research on Qara Balğasun since 2007. The get an overview of the ruins of the city, an Airborne LiDaR-scan was conducted in 2007 and yielded an exact mapping of the remains for the first time after the surveys of the 19th century. Excavations started in 2009 and the remains of temples and the supposed palace where unearthed (Hüttel 2010; Hüttel 2012; Dähne 2017; Franken – Rohland 2017). The sheer size of the city poses a challenge for the archaeological research. The LiDaR mapping has shown that the city covered an area of at least 20 km². After high-resolution satellite-imagery became more and more available in the recent years, a survey of Sentinel-2, RapidEye and other imagery has shown that the mapping of 2007 didn't even cover the whole area of the city. Therefore, it was necessary to find a cost-efficient way to complete our city map of Qara Balğasun and to survey its environments.

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1.2 Preparatory work, areas of interest and campaign objectives

11   When the Mongolian-German Orkhon-Expedition took up the study of the site in 2007, aerial imagery was available. A survey of images revealed, that Radloff had not recorded the entire site. An airborne laser-scan was conducted to obtain a detailed plan of the remains of the city. The laserscan survey was successful, revealing a complex urban site. The scan covered an area of about 40 km², 20 of which were filled with walled enclosures and mounds, being the remains of the former settlement (Hüttel 2010). Although the scan revealed a lot of the site, it also proved that that the city extended even further, especially to the north and the west. Since many debates on the nomadic cities focus around the question of foreign influence and autochthonous development in these early instances of urbanisation on the steppes, a complete plan of the site is absolutely necessary to advance the discussion. Therefore satellite remote sensing was applied to assess the full extent of Qara Balǧasun. SENTINEL-2 satellite imagery which is freely available for scientific purposes from the Copernicus Open Access Hub and an imagery grant from the RapidEye Science Archive with a set of RapidEye imagery enabled the study of the area with multispectral data with resolutions between 6 and 10 m per pixel. The satellite imagery showed only bigger walled enclosures clearly, while smaller structures remained obscure or invisible. Two sets of features were particularly interesting. To the north of the already known site, close to the floodplain of the Orkhon, the Sentinel imagery showed some obscure rectangular structures. If they could be proven to be former buildings, this would give an idea of the northernmost boundary of the site. The other interesting area lay west of the parts covered by the laser-scan imagery. On the satellite imagery, there are several walled enclosures visible along the Jarantain Gol, a small tributary of the Orkhon river. This raised the question, if there were, as in the other parts of the site, smaller buildings and enclosures situated between the bigger ones or if they were just isolated outposts of the city. The analysis of the satellite imagery provided us with a basis to plan further remote sensing activities on the site. When the possibility arose to cooperate with the Archaeocopter-Project of HTW Dresden and FU Berlin, the following areas of interest were determined:

• Area I: Areas adjacent to the city Qara Balǧasun. The object was to complete our mapping of the site in the areas where we expected, according to satellite imagery, further archaeological remains.

• Area II: The site of Qara Qorum and its immediate surroundings. In this case we wanted to refine the digital elevation model, extent it farther beyond the ramparts and to acquire a detailed mapping of the area of the monastery Erdene zuu.

12   This paper is structured as follows: First, Section 2 introduces related aspects of photo- and videogrammetry and gives a brief introduction to the combination of both. Then, Section 3 presents different stages of documentation focussing on the campaign in Mongolia 2018. Interim results are discussed in Section 4. Finally, conclusion and perspectives for future work are presented in Section 5.

2.   Theory and related work

13   UAVs in combination with methods of photogrammetry have established themselves as a standard tool of 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 structure-from-motion principle (Wei et al. 2013; Hartley – Zisserman 2004). On the software side, in addition to many commercial products, there are also freely available packages like VisualSFM and open source packages like MicMac (Deseilligny – Clery 2011), OpenMVG (Moulon et al. 2013), and Bundler (Snavely et al. 2006) that can deliver comparable results (Gehmlich – Block

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2015). However, handling the free packages is often a big challenge. In particular, the adjustment of free parameters, which allows the user maximum freedom on the one hand, 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 bridge solutions are also freely available and are constantly being further developed. Within the framework of the project a semi-automatic software called Archaeo3D was developed to optimize and control the complete reconstruction process. The resulting 3d models are strongly dependent on the quality and the correlation of the input images (Gehmlich – Block 2015). Videos and photos are automatically imported and processed. The software is able to reorder or adjust the processing pipeline's modules and adjust the parameters, depending on the current hardware and the recording situation and complexity. VisualSFM, COLMAP and CMPMVS (Jancosek – Pajdla 2011) are the most important tools used by Archaeo3D.

14   To create a 3D model, a standard pipeline is first used to create a set of planned, high-resolution photos, which are then merged photogrammetrically. In contrast, videogrammetry, which has its origin in robotics for localization and recognition in real-time systems (Nistér 2001; Seo et al. 2008). With the JKeyframer we have developed a solution that allows two solutions:

• A minimal image set for a rough 3D model is provided that shows that the data is sufficient to calculate a complete 3D model.

• An optimal image replacement is provided to create a high quality 3D model. Adaptively, an optimal solution is sought to solve the min-max problem (Brilakis et al. 2011).

15   It has turned out that the videogrammetry approach is more robust, faster, more flexible and not as error-prone as the classic photogrammetry approach. Since modern cameras usually save their positions with so-called geotags in EXIF format for photos taken, georeferencing can be performed automatically. This is not yet easily possible with videos, which makes additional manual georeferencing necessary.

3. Documentation Campaign 2018, Data Processing and quality

16   At the end of the excavation season 2018, the first two weeks in September were dedicated to data recording in the areas of interest presented in Section 1.2, in the Orkhon valley. Between summer and winter season, at a ground height of 1400 m above the mean sea level (MSL) in Mongolia, environmental conditions change very quickly. At that time, wind and fast changing weather are to be expected. These conditions demand a systematic approach to mitigate the risks of collecting improper data or even lose collected data. This included thorough planning and testing prior to the campaign, several hardware- and software backups and a minute recording of the parameters of every flight of the used UAVs.

17   For the huge areas around the site of Qara Balǧasun, a high-resolution digital surface model was the primary goal. To achieve this without gaps, a systematic, automated approach was tested and applied. To efficiently cover an area of 46 km² with adjoining image data tiles, the flights of the UAVs where planned in advance. In the field, the team used up to three drones simultaneously, following the prepared schedule. An all-terrain vehicle was equipped with a generator and served as mobile power-station for recharging the batteries of the UAVs. During the ten days of the campaign we conducted 204 documentation flights and collected 721 Gigabytes of image and video data. From the imagery, different data products can be derived, such as orthoimages and 3D-pointclouds. For our purposes, a 2.5D digital elevation model is the most interest-

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ing result, for it allows the application of terrain analysis algorithms like analytical hillshade, watershed, sky view factor, slope and the like (Kokalj – Hesse 2017). These methods allow the recognition of even minimal anomalies of the surface, which in turn can indicate the remains of ancient man-made structures.

18   The processing of such an amount of data is challenging. Smaller datasets of several hundred images can be processed on regular consumer hardware with sufficient memory and a capable graphics adapter. We strive to process and analyse the collected data with open source software to ensure that the whole process is reproducible and our approach can be used by others easily. However, the amount of data for an area of over 46 km² is so huge, that costly high-end hardware is required, which is normally only available to greater research institutions or companies. If one is ready to accept the drawback of a "black-box"-like processing of the data by proprietary software, commercial providers of mapping services are a viable and cost-efficient alternative. In this case a subscription of DroneDeploy.com was used to gain first results quickly. The provider uses the georeferenced images collected by the UAVs to calculate ortho-images, NDVI-images, 2.5D-elevation and terrain data and xyz-pointclouds. A dataset of up to 3000 images can be processed within a few hours. The results can be downloaded in different established formats for further analysis and processing. The quality of the data depends on the input imagery. As with all photogrammetric methods, lightning conditions, overlap between images, distinguishable features and image resolution are crucial factors. DroneDeploy allows for no tweaking of the processing, the results are delivered as is. The lightning conditions cannot be influenced in the field. However camera settings have to be consistent and adapted to the situation. Our team chose to fly the single tiles in a stripe-pattern with 70 % overlap. During data collection, changing weather and clouds altered the lightning conditions significantly, sometimes within the time of a single flight.

19   Using the collected images of the 2018 campaign, the DroneDeploy algorithms introduced a lot of artefacts into the elevation mapping. They are visible as rectangles,
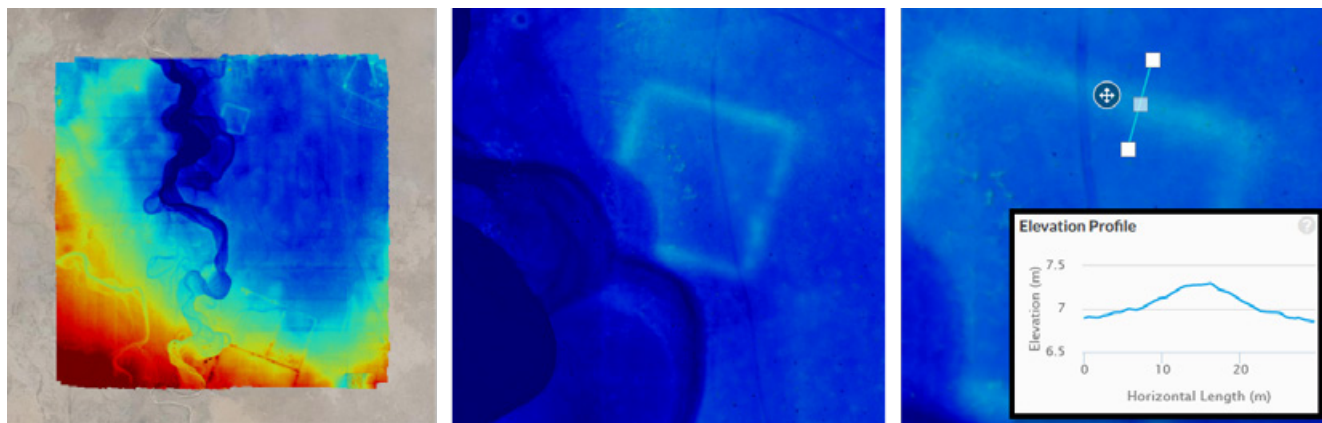
marking the edge of single images, and as general noise. These problems may arise from insufficient overlap between images or changing lightning conditions. Despite these drawbacks, the results of our campaign are very satisfying, especially with regard to Qara Balğasun. The georeferencing of the stitched orthomosaics and the elevation data is close to perfect. Our newly mapped areas fit almost seamlessly with the results of the laser scan from 2007. In spite of the mentioned artefacts, archaeological structures are clearly distinguishable. To make the elevation data better interpretable we used QGis to visualize it as shaded relief with fivefold exaggeration of the elevation. There are structures that rise only about 10 cm above the surroundings, sloping over a distance of more than 10 metres that are clearly visible on the plan (Fig. 4). Therefore the elevation

Fig. 4: The example shows a walled enclosure in the western parts of Qara Balğasun. The section graph on the right side shows that the structure raises only some 25 centimetres over a distance of more than 20 metres but is still clearly visible on the model

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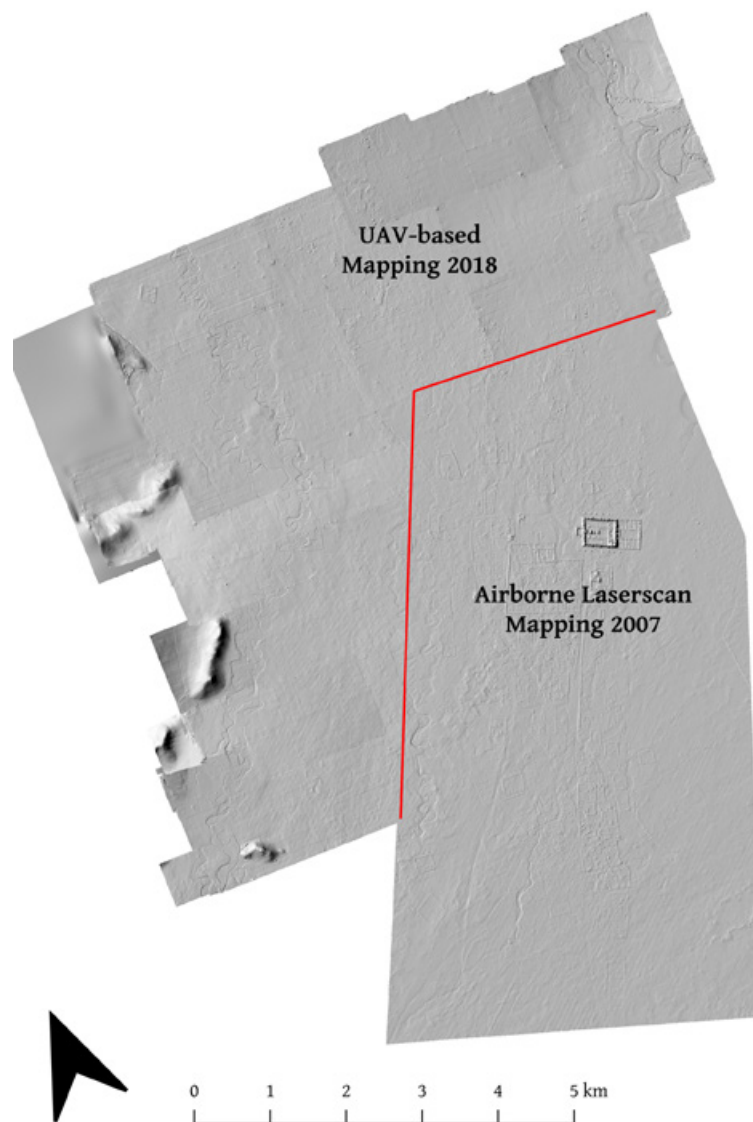
model allows us to recognize even faintest remains of walls and buildings in areas that have been under heavy agricultural use during the 20th century. While the laser scan of 2007 covered an area of 40 km², our recent campaign added further 44 km² to the digital elevation model of Qara Balǧasun (Fig. 5). Now we can say that our mapping covers the complete urban area of the site, disregarding only some outlying walled enclosures to the north along the Orkhon River and a small area at its southwestern corner that will be mapped in the upcoming campaign of 2019. As the next chapter will show, the fieldwork of 2018 already greatly improved our knowledge of Qara Balǧasun.

20   In the case of Qara Qorum, where we experimented with higher flight altitudes, even more noise was introduced by the algorithm. The DEM of this site is barely legible due to the noise. However the orthomosaic is very sharp and exposes a lot of structures in and around the site. Furthermore, imagery and videos were collected at the adjacent Erdene zuu monastery site to obtain a high resolution model of the area and the contemporary temple buildings. This data is still in processing at the deadline for this paper and will be presented elsewhere.

4. Interim results

21   The data obtained by our 2018 survey campaign yielded an enlarged and complete plan of the site of the Uyghur capital Qara Balǧasun. The resulting map already on the first glance contributes several new aspects to our knowledge of the site:
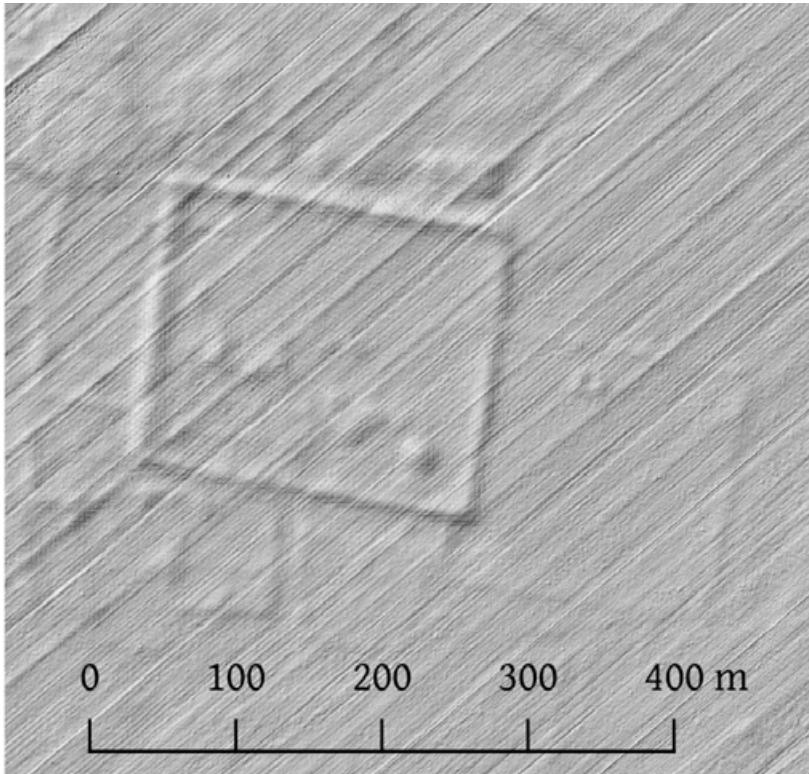
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• There are some areas where walled enclosures clearly overlap each other, indicating several phases of usage. (Fig. 6)

• The built up area stretches far further north from the palace/temple-city. This prominent structure thereby can no longer be considered to be situated at the northern edge of the city. It is situated right in the centre of the eastern edge of the urban area.

• To the west there are two more rows of densely built, smaller buildings and enclosures. Given this information and looking at the overall plan of the site, it becomes clear that the main organizational scheme is an arrangement several rows of buildings, with the largest and most prominent buildings in the eastern row while the other buildings and walled enclosures of different size gather behind and the sides of the imperial complex. They bend around the imperial complex of HB 2 in the form of a crescent. (Fig. 7)

22   With this layout in mind notions of Qara Balǧasun following a Chinese (Arden-Wong 2012) or Sogdian (Barfield 1989: 158; Dähne 2017: 15) concept of city planning have to be revised. Arden-Wong (Arden-Wong 2012: 36–37) proposed that the ground plan of the city was heavily influenced by Chinese models of city planning, especially by that of Tang period Chang'an. He emphasized that his thoughts had a preliminary character and therefore called for further archaeological investigations. In the light of the new plan of the city, the similarities to Chinese imperial cities of the era seem less convincing. The imperial complex can no longer be said to be situated at the northeastern corner of the site and thereby does not resemble the placement of the Daming Gong palace in Chang'An. Others of Arden-Wongs arguments, especially the application of geomantic principles in the planning of the city are still appealing. Also there is a marked Chinese influence on the architecture found inside the imperial complex and the city, especially in regard of building decoration and roof construction.

23   Also the similarities to Sogdian cities like Pandjikant proposed by Dähne, based on the assumption of a decentral position of a main street and the citadel, are not applicable to the plan of Qara Balǧasun available now. A main street running from a rectangular open space in the southern parts of the city over one and a half kilometres towards the imperial complex is still a significant feature of the city, but it is no longer the main outstanding element of its layout. Instead, the plan features a lot of streets

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Explanation

Fig. 7: Approximate outlines of the built-up areas of Qara Balǧasun
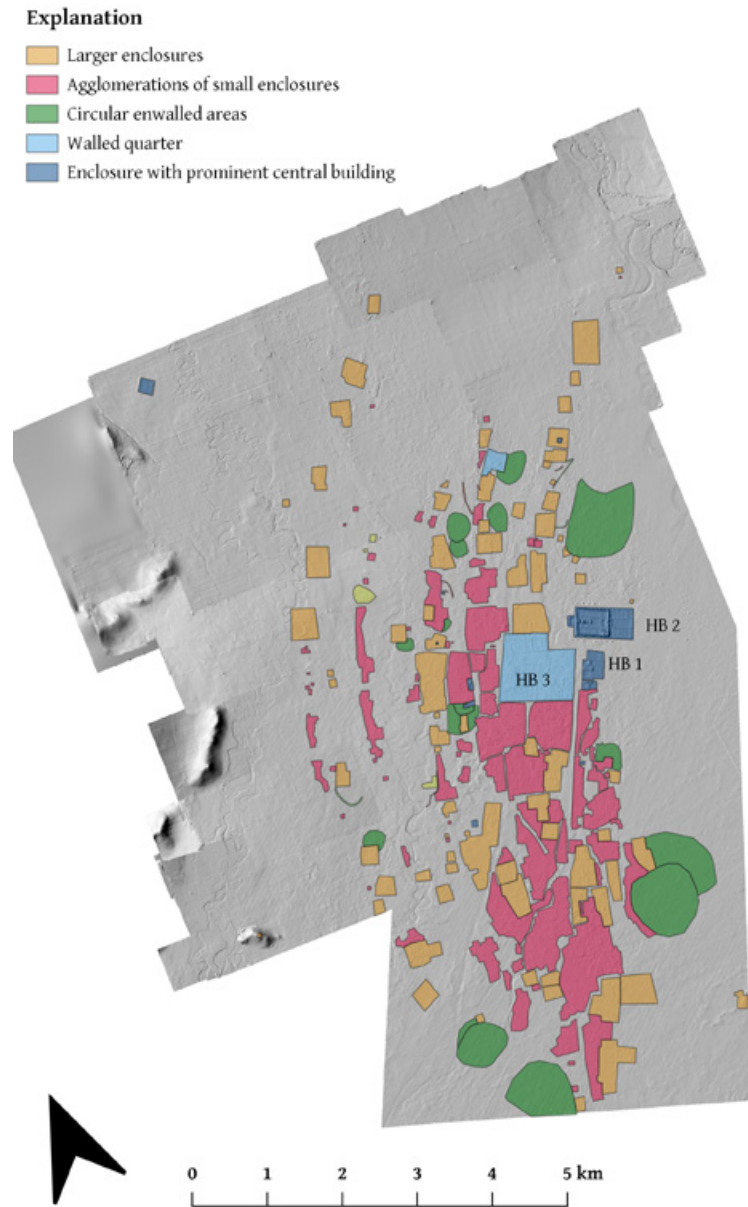
and open spaces between the densely agglomerated quarters of smaller lots and bigger enclosures. The fact that there were several occupation periods in some cases might be a hint towards a more seasonal occupation of parts of the city. Maybe some of the enclosures with only few or no buildings were put up as required when a group of people attended the court for some time and abandoned afterwards. Uyghur inscriptions allude to the setting up of stockades, when a royal camp was established (Moriyasu et al. 2009: 27).

24   According to new plan of the city, the imperial complex seems to be placed almost in the centre of the eastern border of the town. It is only a little off-centre to the north, but it is quite likely, that the Orkhon eroded the remains of the city in the northern parts. The traces of riverbeds in the valley show, that the Orkhon River once flew farther west into the bed of what is today called the "Khögshin Orkhon" – the old Orkhon. Anyway the buildings still visible gather to north and south of the "imperial complex", while the built up space is sharply delineated to the east. No building is set up east of this area. This is a genuine nomadic pattern, following the tradition of a nomad encampment as it is described in Willam of Rubrucks journey to the Mongols. He states "A court (curia) is orda in their language, and it means "middle," for it is always in the middle of the people, with the exception, however, that no one places himself right to

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the south, for in that direction the doors of the court open. But to the right and the left they may spread out as they wish, according to the lay of the land, so long as they do not bring the line of tents down right before or behind the court." (Rubruck – Rockhill 1967: 122). In Mongol times up to today, the south is the preferred direction for the orientation of gers (yurts), buildings, temples and burials in Mongolia. In the days of the ancient Turks and the Uyghurs it has been the east. In the light of these thoughts, Qara Balǧasun seems to be an instance of an urban place, which is mainly organized after the native principles of the steppe society, while Chinese and Sogdian technologies of building, craft and writing were applied in detail as needed.

5. Conclusions and future work

25   The remote-sensing campaign of 2018 has achieved two important outcomes. First it proved that a low-cost, photogrammetry-approach to remote sensing doesn't have to be limited to single objects or small sites but can also be applied in vast landscapes. Due to the sparse vegetation of the Mongolian steppe, airborne photogrammetric modelling is a cost efficient and relatively easy to apply survey method. In this case, almost 50 km² where mapped within only eight days of intense work. Second, the preliminary results already enlarged our knowledge on Qara Balǧasun. Despite some drawbacks in terms of data quality, there is finally, almost 130 years after the first site measurements, a complete plan of the remains of the city.

26   After a first review of the new plan, Qara Balǧasun can be described as a genuine nomadic type of an urban settlement. This knowledge will greatly contribute to the debate on urbanism in a nomad environment. The new map of the city now allows a detailed analysis of the general layout and of single components of the city. Questions of the organization and usage of urban space can be discussed on a solid data basis. After this first few insights there is yet more to come.

Also in 2018, the team collected data in Qara Qorum and the adjacent monastery of Erdene zuu. While the mapping of the site of the medieval city yielded unsatisfying results, in the area of Erdene zuu a high-resolution 3D-model was achieved by combining Video- and Photogrammetry. The model can in the future be used for educational and monitoring purposes.

27   In the upcoming campaign of 2019, further areas around Qara Balgasun will by mapped by the methods described above. It is our aim to collect to a comprehensive corpus of high-resolution data of the cultural landscape around the site and the whole Orkhon Valley. Furthermore, data collection in Qara Qorum will be repeated to achieve satisfying results here too. We are also experimenting with open source tools for processing of the collected data, to see if we can achieve better results than with the commercial solution employed so far. To sum up, the photogrammetric remote sensing approach tested in this project is cost-efficient and easy applicable way to gather important archaeological data at a large scale and in a short period of time. It is a method especially promising in the conditions of the Mongolian steppe with its numerous and large archaeological sites and good ground visibility.

Acknowledgements

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ZUSAMMENFASSUNG
Remote Sensing of Large-Scale Areas at the Urban Sites of the Mongolian Orkhon Valley Using Low-Cost Drones
Preliminary Results and Some Thoughts on the Urban Layout of the Uyghur Capital Qara Balğasun
Christina Franken, Hendrik Rohland, Marco Block-Berlitz, Tumurochir Batbayar, Ulambayar Erdenebat

Im Jahr 2018 führte die Mongolisch-Deutsche Orchon-Expedition (Mongolische Akademie der Wissenschaften, Mongolische Nationaluniversität, Deutsches Archäologisches Institut) in Zusammenarbeit mit Archaeocopter (Hochschule für Technik und Wirtschaft Dresden, Freie Universität Berlin) großflächige Geländeaufnahmen an der Uighurischen Hauptstadt Karabalgasun und der altmongolischen Hauptstadt Karakorum durch. Insbesondere die enorme Größe der Stadtwüstung Karabalgasun ist eine Herausforderung für die archäologische Erforschung. Die nicht bebaute und vegetationsarme mongolische Steppe bietet hervorragende Voraussetzungen für bildgestützte Fernerkundungsmethoden. Mit handelsüblichen, relativ kostengünstigen UAVs (Unmanned Aerial Vehicles) wurden beide Stadtruinen systematisch mit tausenden überlappenden Luftbildern erfasst. Durch photogrammetrische Methoden wurden aus den Bildern Orthofotos und digitale Geländemodelle erstellt. Diese ermöglichen es, selbst kleinste Reste von Bebauung zu erkennen. Auf diese Weise wurde erstmals ein vollständiger Stadtplan von Karabalgasun erstellt. Der Plan erbringt neue Erkenntnisse zu der Uighurischen Stadt. Die von der Stadt eingenommene Fläche beträgt demnach etwa 44 km². Darüber hinaus erlaubt der neue Stadtplan ein besseres Verständnis der Raumordnungsprinzipien, die der Stadt zugrunde liegen. Entgegen früherer Theorien, die primär iranisch-sogdische oder chinesische Stadtplanungsprinzipien am Werk sahen, folgt die Anlage von Qara Balğasun genuin nomadischen Vorstellungen. Sie ist somit ein verfestigtes Lager und damit Beispiel einer eigenständigen Urbanität, die aus den Traditionen der Steppe erwächst.

SCHLAGWORTE
Fernerkundung, Large-scale documentation, kostengünstige Drohnen, UAV, Photogrammetrie, Mongolei, Qara Balğasun, Qara Qorum, Steppenimperien, Steppenurbanismus

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