

# Measurements and Documentation of Buddhist Stone Inscriptions in China, Shandong

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**Key words:** Photogrammetry, Geoinformation/GI, GPS, Cartography, Documentation, Visualization, Art History.

## SUMMARY

The second half of the sixth century was a significant epoch for Buddhism in China. In this period China was divided into the Northern and the Southern Dynasties. Under the Northern Zhou Dynasty, Buddhism suffered from a great persecution initiated by Emperor Wudi. For several years, Buddhist activities on the territory of Northern Zhou dynasty came to an end. But in the decades before the Buddhist persecution, many before unknown Holy Scriptures had entered China from India, the homeland of Buddhism. These sutras and their following translations had caused a deeper understanding of the Buddhist teaching. To propagate the teaching, and to preserve the Holy Scriptures for future generations, Buddhist monks had parts of the transmitted sutras carved into the surface of naturally grown rocks in today's Shandong province. Sometimes they wrote up to three meter large characters on mountain slopes, sometimes they chiseled characters as small as two centimeters onto steles. Furthermore, some inscriptions can also be found on the interior walls of cave temples as part of the architectural layout. This network of Chinese stone inscription sites is most important for the art history in this region.

It is the task of this project to study, survey and measure all important Buddhist stone inscription sites in Shandong and some neighboring provinces. First, the inscription sites and the inscriptions themselves have to be located precisely. A very important point is the documentation of historical information in form of databases connected to geometrical information in 2D or 3D data. The field measurements are made with GPS for the global positioning, so that all studied areas can be connected in one system. We use Total Station for the topographic maps, and close up range photogrammetry for the inscriptions themselves. After the data have been collected during fieldtrips once a year, in a next step maps and 3D models are created. These maps and models are the basis for further studies of the network of inscriptions, which are often geographically related to each other. The art historians are interested in the geometry and orientations of single inscriptions, as well as the exact distance in between two or more inscriptions. The results of the art historical research and the models and maps created by us will be integrated into a large database. This database will enable users to formulate queries and view the results in a geographic and geometrical context on the computer screen.

The project is set up for 15 years and this is the third year of our research. With this paper I would like to present the project itself and the first results of the measurements and the analysis.

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## 1. INTRODUCTION

The second half of the sixth century was a significant epoch for Buddhism in China. In this period China was divided into the Northern and the Southern Dynasties. Under the Northern Zhou Dynasty, Buddhism suffered from a great persecution initiated by Emperor Wudi. For several years, Buddhist activities on the territory of Northern Zhou dynasty came to an end. But in the decades before the Buddhist persecution, many before unknown Holy Scriptures had entered China from India, the homeland of Buddhism. These sutras and their following translations had caused a deeper understanding of the Buddhist teaching. To propagate the teaching, and to preserve the Holy Scriptures for future generations, Buddhist monks had parts of the transmitted sutras carved into the surface of naturally grown rocks in today's Shandong province. Sometimes they wrote up to three meter large characters on mountain slopes, sometimes they chiseled characters as small as two centimeters onto steles. Furthermore, some inscriptions can also be found on the interior walls of cave temples as part of the architectural layout. This network of Chinese stone inscription sites is most important for the art history in this region.



Fig 1: "stone inscription"

It is the task of this project to study, survey and measure all important Buddhist stone inscription sites in Shandong and some neighboring provinces. First, the inscription sites and the inscriptions themselves have to be located precisely. A very important point is the documentation of historical information in form of databases connected to geometrical information in 2D or 3D data. Until now three large measuring campaigns were made in the last three years. Within these campaigns three large subprojects – the valley of Hondingshan, six inscription sites near the town of Zoucheng and the Holy Mountain Taishan – as well as nine smaller inscription sights in the Districts Dongping and Pingyin were documented. The analysis of the data is still in process or partly finish.

## 2. MEASUREMENTS

As subproject or inscription site we describe an area, where the inscriptions are located. This can be the top or a slope of a mountain, a valley, a rock surface on a plain or a stele erected on a special place e.g. near an ancient monastery. The size of an individual inscription site is differing very much. It starts from fifty square meters up to some hectares. Of course at each inscription site not only the inscription itself is measured but also the terrain and topography nearby the inscription.

To get 2D or 3D geometrical information of the stone inscription, the rocks or steles have to be measured with geodetic methods. The methods can be divided into different tasks and preciseness. Data recording of a particular inscription site is most efficient if conducted according to the following procedure:

- Survey and documentation of each singular inscription by means of terrestrial photogrammetry; either stereo photogrammetry or multi image triangulation (Fig. 2. left)
- Detailed data collection of the nearby topographic area by means of GPS or a total station on a scale of 1: 500 - 1: 1000 (Fig. 2. middle)
- geodetic integration of already existent topographic maps into the assembled point field for a better spatial relation to the surrounding area on a scale of 1 : 5.000 – 1 : 10.000 (Fig. 2.right)



**Fig 2:** Used measurement methodes

The inscription sites are very often far away from towns or areas with geodetic fix points. Furthermore, in China are different regional or local coordinate systems in use, which makes a connection to a common global coordinate system often very difficult or even impossible. Since we create and use our own local network of fix points which is connected to the global UTM system, measurements with GPS are necessary. By connecting to a global coordinate system we can get information about the orientation of the inscription sites to each other quickly. Often the inscription sites are communicating with each other or are standing in a spatial context.

The network of fix points so created is now the basis for all other surveying of the area. With GPS and total station the terrain in the area near the inscriptions is measured to set up a first CAD plan to get familiar with the topography of the site. The most important and most often used measurement method is the photogrammetry. With the help of the photogrammetry we have the possibility to get precise information about the surface of the inscriptions, and even more interesting, we get images of all the chiseled characters. Furthermore, employing photogrammetry allows a relative fast workflow during the field campaigns.

It is not necessary to go more into detail with the measurements because these are well known classical geodetic methods. The only point that still could be mentioned are the difficulties often encountered while surveying because of the topography. This means the circumstances in which the measurements have to be done during the fieldworks are often not really standard

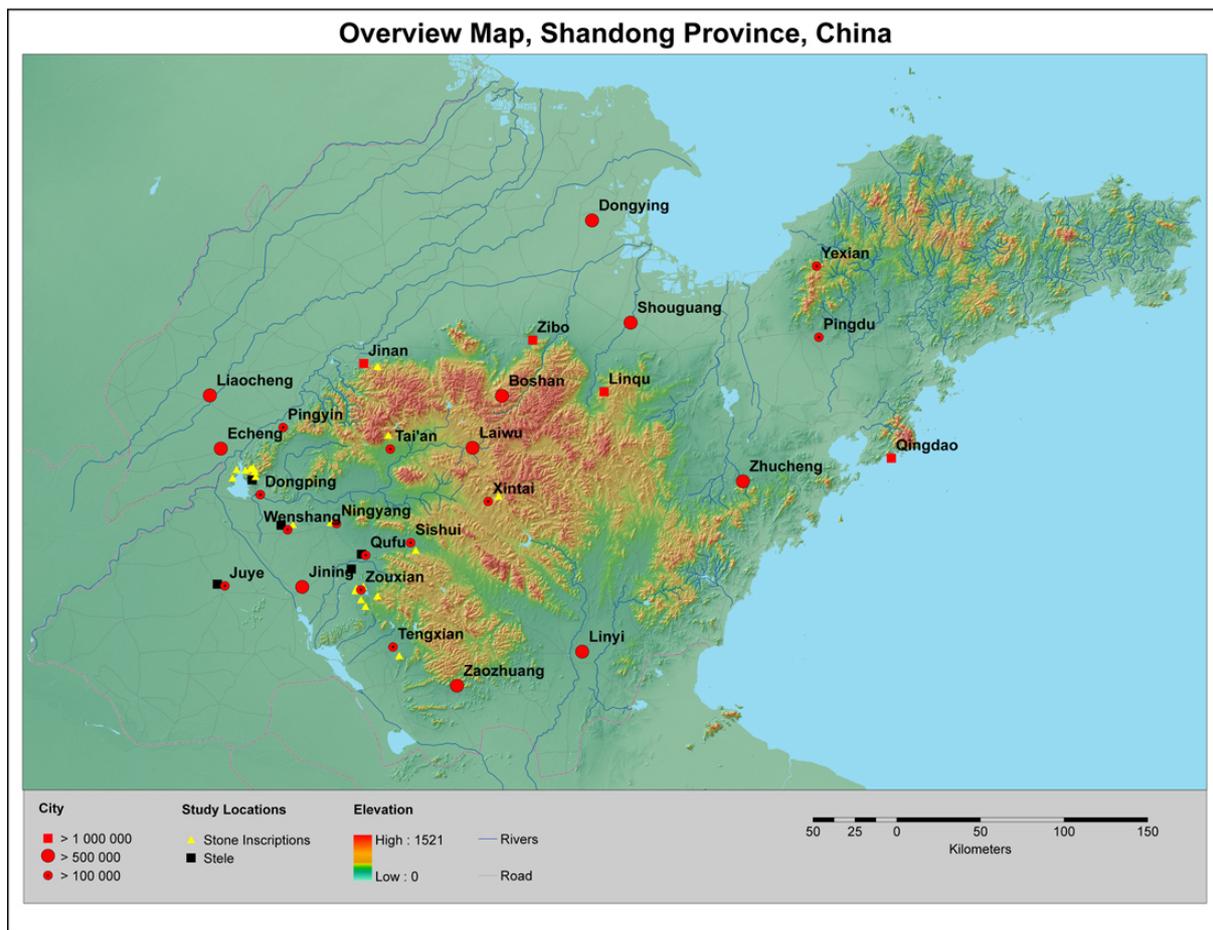
situations. Preferred locations for the inscriptions are areas with smooth and steep natural rocks. Therefore it is often difficult to find a good or optimum camera position for the photogrammetry measurements and also for the Total Station (Fig. 2. left and 2.middle).

### 3. MODELING AND DATA PROCESSING

The modeling can also be divided into different levels of detail. Here we speak about the documentation level of

- the whole province of Shandong (level 1)
- the regions or political districts of the province, like Dongping or Zoucheng (level 2)
- the inscription site, like a valley or a mountain (level 3)
- the inscription itself that could be a Buddha name, a sutra text or a commentary (level 4)
- each character of the inscription (level 5)

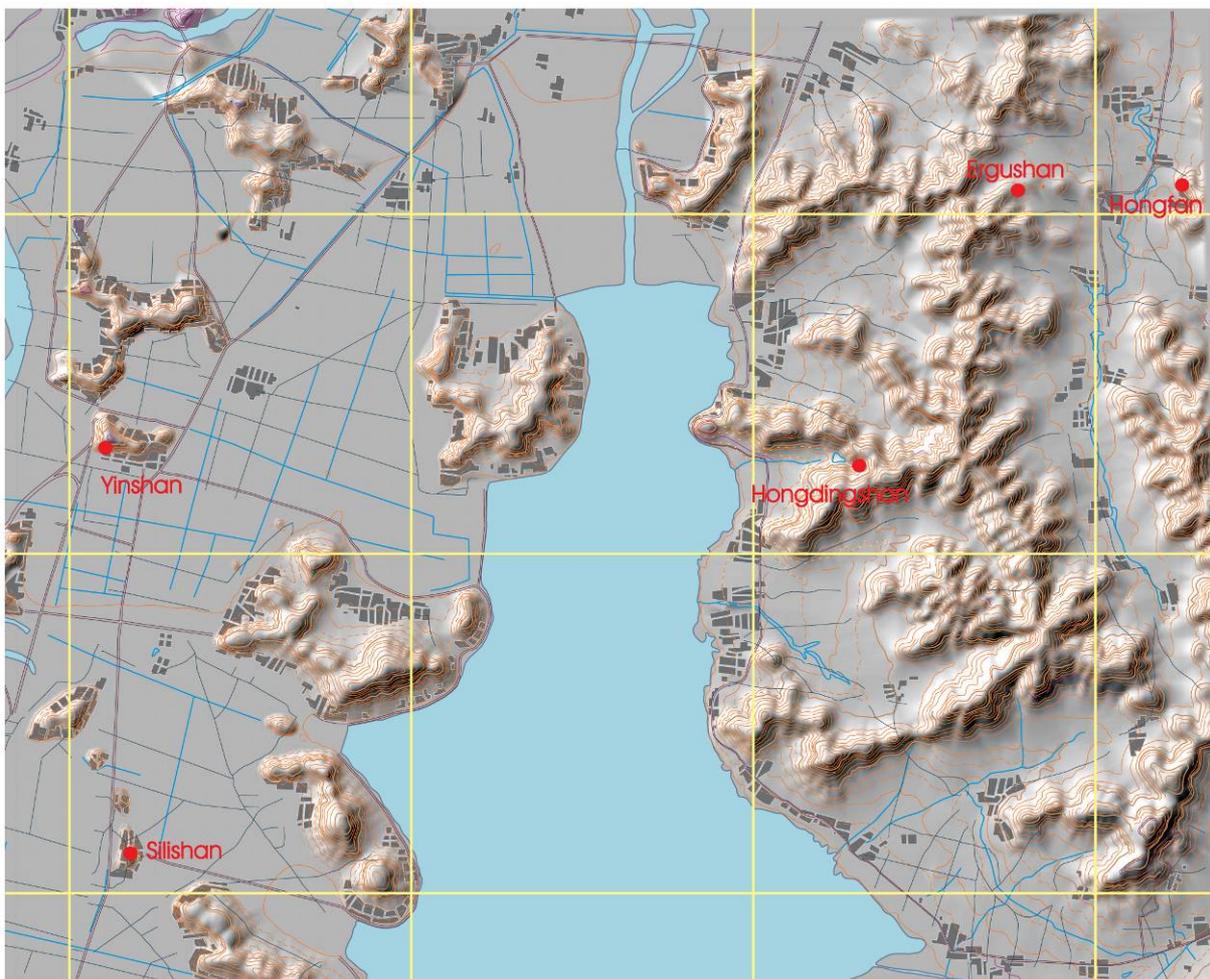
#### 3.1. Maps and Plans



**Fig 3:** Map of the province Shandong (presentation level 1)

To get an overview of all the inscription sites of our project it is best to create a map (level 1) (Fig. 3). This topographical map includes information about the different types of inscription sites. There are sites with inscriptions carved into naturally grown rocks and sites where the Buddhist texts are chiseled into steles. In the near future this map will be connected with the historical stone inscription database (see chapter 4); so that the map can be used as an entrance to the database, or vice versa the database can show the results of a query in the map. The next level of detail is the documentation of a region or a district, where inscriptions are located (level 2). The regional geographical documentation is also in the form of a map but here we use a more detailed map which resembles more a topographical map. We have chosen this kind of map format to see more easily if inscription sites have some kind of geographical connection. For example, we might ask if: other sites are visible from one special location or not.

One region in our project is the district of Dongping (Fig. 4). Within this district are five inscription places (level 3). These inscription places are documented either as CAD plans in a 2D way or as 3D Models.



**Fig 4:** Map of the district of Dongping (presentation level 2)

### 3.2. 3D-Models

The areas where stone inscriptions are located (level 3) are one central point in the geodetic part of this project. Most places are difficult to describe, document and present in a classical two dimensional way. Therefore, the most interesting sites of our project are documented as virtual 3D Models. These models are representing areas which are of high spatial interest for the understanding of the inscription site, which means that the inscriptions within this area are having a highly significant spatial context.

The models are created in different levels of detail. In the context of our hierarchy the models are representing level 3 and 4. For example, look at the model of the valley of Hongdingshan in the district of Dongping (figure 5, left). The whole valley is reconstructed to give an impression of this very outstanding place. When we come closer to the inscriptions themselves, the model also represents the exact place and orientation of the stone inscriptions (Fig.5. right). For better legibility, rubbings are mapped onto the inscriptions (see chapter 3.3.). The models allow three dimensional measurements to be taken in between the inscriptions as well as orientation measurements. With the help of the 3D Model, questions can be discussed like: What part of the rock has the monk seen during his meditation in front of one sutra or Buddha name? Which other inscription did he have in his sight area? Are these inscriptions connected to each other in any special, so far unknown context? Why have the monks chosen this place for meditation?



**Fig 5:** 3D Model of the valey Hongdingshan (presentation level 3 and 4)

Of course a 3D Model can only try to reconstruct reality and can not give any answer itself, but it is a useful tool to find similarities between different sites or inscription locations. In the future, when more sites have been documented as 3D Models it will be possible to find these similarities.

The already mentioned level 4 is the inscription itself (Fig. 5. right), which might be a name of a Buddha, a sutra text or a commentary. The precise geographical position of these inscriptions can also be found in the 3D Model, but an orthophoto of the rock or the stele is an even better representation of the inscription.

### 3.3. Orthofotos and “Orthorubbings”

All inscriptions which have been measured by means of photogrammetry can be transformed in orthophotos. Orthophotos can be considered as photo optical topographic maps on the basis of a standard scale. Just like maps, orthophotos might be used to withdraw exact measures. One important point for the project is to get exact sizes of all inscriptions and also of each character. The taken measurements are then included into the stone inscription database. For example, the character size, the style of the character and its calligraphy can help to gather information about the person who has chiseled the character. Because of a character’s calligraphy and location it might furthermore be possible to see (in a geographical context) in which region and at which time a certain person was creating inscriptions.

Therefore the orthophotos of the inscriptions play a key role for the location of each character in the project and its input into the stone inscription database.



**Fig 6:** Production of a stone inscription rubbing

Another reason for the creation of orthophotos is the fact that some characters cannot be measured immediately on the spot because they are not reachable. With the help of the

contact-less photogrammetry such characters can easily be measured later on, on the computer screen during the analysis of the measurements.

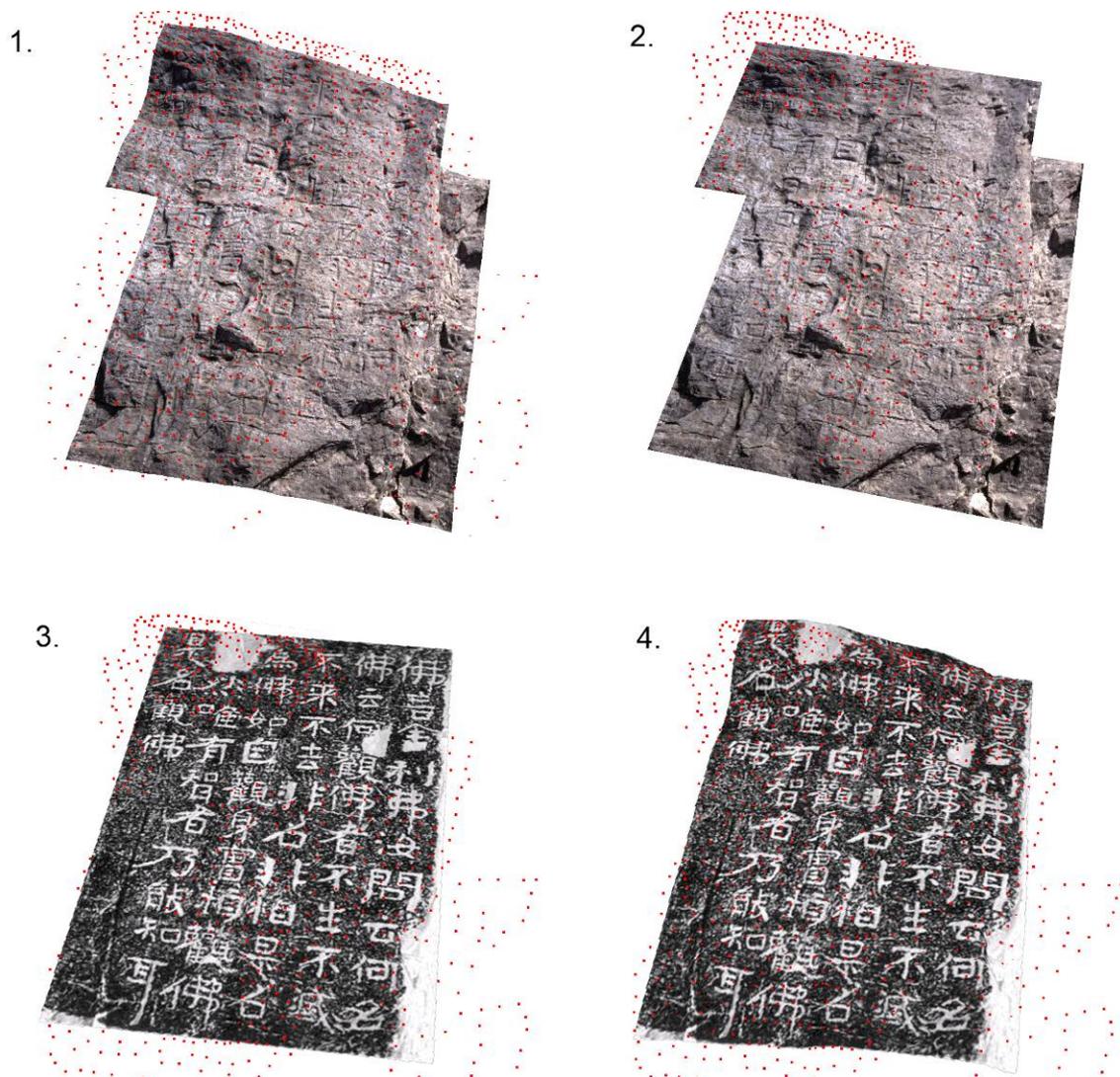
For an increase of legibility it is often necessary to take rubbings of the inscriptions. A rubbing is a special method to copy a text written on a rock or stele (Fig. 6). For a rubbing a special type of paper is used. This wet paper is wrapped onto the rock with the chiseled inscription and patted into the cavity of the characters. Is the paper dry, the non carved surface of the rock is colored with ink. Characters are often partly destroyed or weathered and thus no longer legible. When a rubbing is taken, nearly invisible characters re-appear on the paper that has been placed on the rock surface. Of course, the images generated by photogrammetry also include “invisible texts”; therefore it can be helpful to map the rubbings onto the orthophotos. The mapping of the rubbings onto the orthophotos is more precisely a correction of the distortion and a georeferencation.



**Fig 7:** Measure image with overlaid surface measurement

Figure 8 shows the workflow of an Orthorubbing production. First of all we have got the photogrammetry images which are analyzed in stereo mode. For a better impression the image is overlaid with the measured surface (Fig. 7). We start with the ortho rectification (flattening of the surface) which is indicated in Figure 8.1 and 8.2. For the rectification of an orthophoto

it is necessary to define an equalized plane, on which the image has to be projected. The next step is the just mentioned mapping of the rubbing (Fig. 8.3) which is adjusted by means of a polynomial transformation. Finally, the rubbing will be projected onto the 3D Model at the exact place of the inscription (Fig. 8.4). Apart from presenting the inscription in a legible way, what else can the ortho rubbing be used for? One question which was casually asked was: How was the procedure of the chiseling? Have the monks first written their texts onto a flat paper, which was then spread on the rock to finally chisel the characters, or did they immediately write the characters on the rock in ink, irrespective of the rock's roughness, and chisel them afterwards? Knowledge of the rock surface and the orthorubbing can help to understand by which procedure the inscriptions were done. Until now, no significant results have been achieved, but the question will be kept in mind and might be answered in the long run of the project.



**Fig 8:** Workflow of the "orthorubbing" production

#### **4. DATABASE**

The already motioned stone inscription database is the central point of the research project. All the information of the field documentation and the researches of the art historians will be included into this database. First of all, the text of the inscriptions is reconstructed and transcribed with modern Chinese characters, afterwards punctuated and finally translated into English. The database includes various information about each inscription concerning its state of preservation and different readings of single characters. Furthermore, the geodetic analysis of the measurements provides the size, the coordinates and the orientation in vertical and horizontal angle of the inscriptions. By means of these specifications it is possible to connect the inscriptions to geometry and locate them in spatial context. More metadata about the inscriptions are included into the database, like names of composers, calligraphers and sponsors, and relevant information contained in primary sources and secondary literature. Furthermore, each unique character is represented in the database as an image either of the orthophoto or the paper rubbing. In the future, when there are more subprojects included into the database, it will for example be possible to get information about how often one character has been chiseled in all of Shandong province. This might be interesting concerning the already mentioned question of identifying different calligraphers by their handwriting.

#### **5. PROSPECTS AND CONCLUSION**

So far, the survey of the stone inscriptions has been done mostly with photogrammetry methods. The main reason for this is the fast workflow during the fieldworks and the low measurement effort. Apart from speed, the preciseness of the measurements taken is also very high. Furthermore, photogrammetry is very flexible concerning the accuracy of the documentation, or the resolution of the measured surface. The resolution can easily be changed in accordance with the task to be accomplished. One more reason is the parallel documentation of the surface and the characters as an image. Until now we haven't used any Laser scanning technique. The main reason for that is that photogrammetry achieves a sufficient preciseness for the task of the project. Furthermore, the amount of raw data collected by laser scanning is not very efficient when we think about the documentation of all stone inscriptions in the province Shandong and some neighboring provinces.

The technique of laser scanning could deliver much better results for a few inscriptions, but it is doubtful if the project would profit at all from such a high accuracy. Anyways, we would like to test laser scanning during one of the next fieldworks. Perhaps the methods of laser scanning can help to bring to light some more characters on the stones, which are no more visible to the naked eye, but this is so far only hypothetical.

The term of this project is fifteen years, this year being the third year, therefore the results presented here can only be a first analyzing step. Perhaps in one of the next FIG conferences it will be possible to present more answers and results.

## CONTACTS

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