COMPREHENSIVE STUDY APPLICATION OF PHOTOGRAMMETRY IN SURVEY OF HISTORICAL MONUMENTS

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ABSTRACT

This paper reports on the study and application of close-range photogrammetry in surveys of 16 well-known historical monuments such as Emperor Qin Shi Huang's Mausoleum and the Terra-cotta Warriors and Horses, Bampo site and the newly excavated underground palace of the Fa Meng Si Temple of Fu Feng County, which have been carried out by Photogrammetry & Remote Sensing Centre, the Ministry of Coal Industry of China for more than 8 years. the instruments and equipment used, procedures of operation and some technical problems are also discussed. In this study, photogrammetric and Remote Sensing techniques were applied and more than 130 drawings at various scales ranging between 1:1 and 1:10000 and a great deal of date were made and used for the protection and research of historical monuments. These research results were highly appraised by the experts in the field concerned. As examples, several representative projects are described and some of the results and drawings are included in this paper.

Komplexuntersuchung und-anwendung von Photogrammetrie in der Archaeologie und Kulturgegenstandspflege
Zusammenfassung

Der Ueberblick von den Untersuchungen und Anwendungen der Nahbereichsphotogramme trie wird hier beschrieben, die seit mehr als acht Jahren von dem Zentrum fuer Photogrammetrie und Fernerkundung des Kohlenministeriums von China in beruemten Kulturgegenstandsstellen des Landes, Z.B, dem Museum fuer Terrakottakrieger und-Pferde der Qin-Dynastie, dem Banpo-museum, dem neu ausgegrabenen unteridischen Palast des Famen-Tempels in Schanxi u.s.w. insgesamt 16 Siedlungen durchgefuehrt sind. Es umfaßt u.a. die angewanten Instrumente, Arbeitsverfahren und Untersuchung des wichtigen technischen Problems. In diesen Untersuchungen werden Photogrammetriesche und fernerkundische Technologie Komplex verwendet, ueber 130 Blaetter von Reihenkarten mit unterschiedliche Mabstaeben zwischen 1:1---- 1:10000 und eine Menge Daten geliefert. Diese Karten und Daten sind schon in der Pflege und Untersuchung des Kulturgegenstands verwendet und von dem Spezialisten hoch bewertet. Hierbei werden einige typische Ingenieurbeispiele vorgestellt und ein Teil von Ergebnissen und Karten beigegeben.

1. INTRODUCTION

China is a country with an ancient civilization, where a large number of important historical monuments and museums vividly show the general picture of her long and giorious history. Her culture attracts scholars and tourists from all over the world.

Since 1980, P & R S Centre, under the support of the provincial department of cultural relics, has carried out a great deal of research work and experiments on the application of P & R S techniques in the survey of 16 historical monuments. These famous historical relics, dating back to the ancient times about 1000 to 6000 years ago, include historical sites (such as Bampo neolithic village, the site of Daming Palace of the Tang Dynasty and the Fa Meng Si Temple of Fu Feng

County), architectural heritage(such as the Bell Tower, the City Wall of Xi'an and ancient pagodas), grottoes (Great Buddha Temple of Bin Xian County), stone carvings (those of Shungling and Zhao ling Mousoleums), frescoes and bombs(Emperor Qin Shi Huang's Mausoleum and the Terra-cotta Warriors & Horses Pits). More than 130 drawings at various scales ranging between 1:1 and 1:10000 have been made by using low-altitude photography and close-range photogrammetric and remote sensing techniques. Numerous data have provided a reliable reference for the protection of historical monuments, maintenance of architectural heritage, archaeologic research and the development of tourism. Research results were highly appraised by the experts in the field concerned and won the Scientific and Technological Progress Prize of Shaanxi Province in 1987.

2. ACCURACY TEST AND ACTUAL ACCURACY

2.1. Indoor Contro Field

A number of control points, with clear marks, were laid out in the system according to certain requirements, and their spatial coordinates were determined. the system had a steel frame structure, with the dimensions 3.9m x 1.0m x 2.8m, containing 50 black-and-white circular targets well distributed in three planes on the frame and the wall. The control field was established with traditional intersection and two kinds of algorithms were used, one of which was computed using resection and intersection, while the other was photogrammtric measurement with pseudoscopic image of theodolite. In our study, The MSE of coordinate was $\pm$ 0.103mm, and the relative accuracy was about 1/50000 to 1/60000, which were determined with 50 control points in different observation directions.

2.2. Accuracy Test

In order to study the accuracy of close-range stereo photogrammetric operation and to make comparisons between different computation methods, simulation and operation tests were carried out with Jenoptic Jena UMK 10/1318, 19/1318 and OPTON SMK-120. the tests were carried out in the indoor field where the distance Y was 6m. In thetests, normal and convergent steropairs were photographed and then they were processed by applying such analytical procedures as collinearity, coplanarity and Direct Linear Transformation(DLT). The following results have been obtained by comparison:

1) Positional accuracy depended upon the measuring instrument, or we could say, measurement error was one of the main sources which has an effect on positional accuracy.

2) Accuracy of horizontal photography was better than of oblique photography.

3) No remarkable difference has been found between different algorithms in computing the accuracy of points to be determined.
Comparatively speaking, DLT approach was slightly better than the others.

4) In order to improve the accuracy of points to be determined, it is advisable to use multistation photography, to take compensation of systematic error into account and to adopt bundle adjustment.

2.3. Actual Accuracy

So far as ordinary objects were concerned, the optimum accuracy in analog approach was about Y/2000 to Y/4000 and the relative accuracy of a point in high-precision analytical approach was Y/5000 to Y/45000.

3. SOME TECHNICAL ASPECTS IN PHOTOGRAMMETRIC SURVEY OF HISTORICAL MONUMENTS

3.1. Controls and Relative Controls

In close-range photogrammetric surveys, there frequently exists certain circumstances that may permit or require relative controls. The versatility of the means of controls may sometimes play an obvious role in simplifying and reducing the control surveys. While mapping thematic maps of historical monuments, either tradition control survey or the survey, of separating horizontal from vertical can be used. In the latter, the scale can be reduced according to horizontal distance and elevation can be determined with below-order levelling, so that the levelling of a model can be achieved. As an example, the combination of controls and relative controls was used in surveying the Great Buddha Temple because of the short object-distance(only 4m) and the higher Buddhist statue(about 20m). From the top of the Buddhist statue were suspended several plumblines to which targets were fixed. Forward intersection and resection were carried out to the bottom of the statue and the coordinates of points at the top of it were determined from the plumblines. During the survey of stone sculptures "The Six Zhaoling Steeds", relative controls were set up respectively for horizontal and vertical, and contours were directly mapped by means of wedge-shaped rule.

3.2. Photography

photographic procedure includes locating camera stations, selecting photographic material, filters and illumination devices. Either singlecamera or stereoscopic photography can be used to obtain stereopairs. To increase the accuracy of measurements and facilitate the identification of control points, artificil targets may generally be required.
Filters are particularly important in the photography of frescoes. While taking infrared photography, the use of filters of different wavelengths combined with corresponding photographic materials will facilitate the spectral separation in multispectral photography.

3.3. Selection of Projection Plane

Selection of projection plane is necessary for graphic presentation ofobjects in the best way and optimum accuracy. If a plane type or nearplane object is being photographed, such as frescoes and facade of a building, the photographic base line should be parallel with the plane surface as far as possible. As for the irregular objects such as stone carvings and terra-cotta figures, the selected projection plane should be targeted in-situ. For those which can be expanded, such as arched frescoes, they can be partially photographed and mapped according to error requirements, or the arched shape can be formulated and then corrcted point by point.

3.4. Stereoplotting

The special characteristics of close-range photos that the image may sometimes concentrate onto a centain part and depth of field too deep would resuld in a number of difficulties in the procedure of image orienyation. Therefore, it may be necessary to make the following remarks:
1) Accuracy of centering the photo in the registering frame should increase with the depth of field.
2) The procedure of orientation can be speeded up if relative orientation and levelling of model are carried out simultaneously.
3) Analytic plotters which have the advantages of both analog and analytic approaches are particularly suitable for processing close-range photos.

4. EXAMPLES OF APPLICATION

ILLUSTRATION

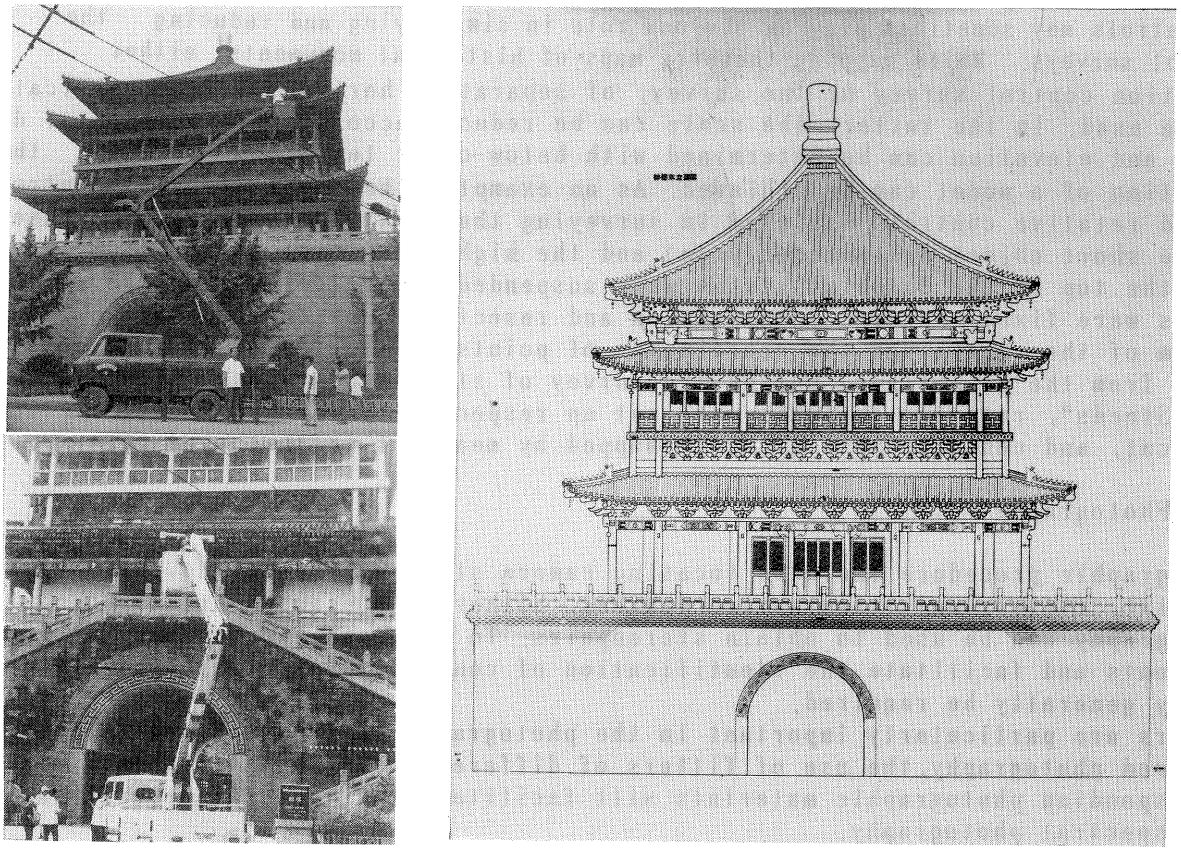

Fig.1. Architectural photogrammetric survey of Xi'an Bell Tower. Left: the operating site. Right: the east elevation of the Bell Tower. Scale: 1:50.

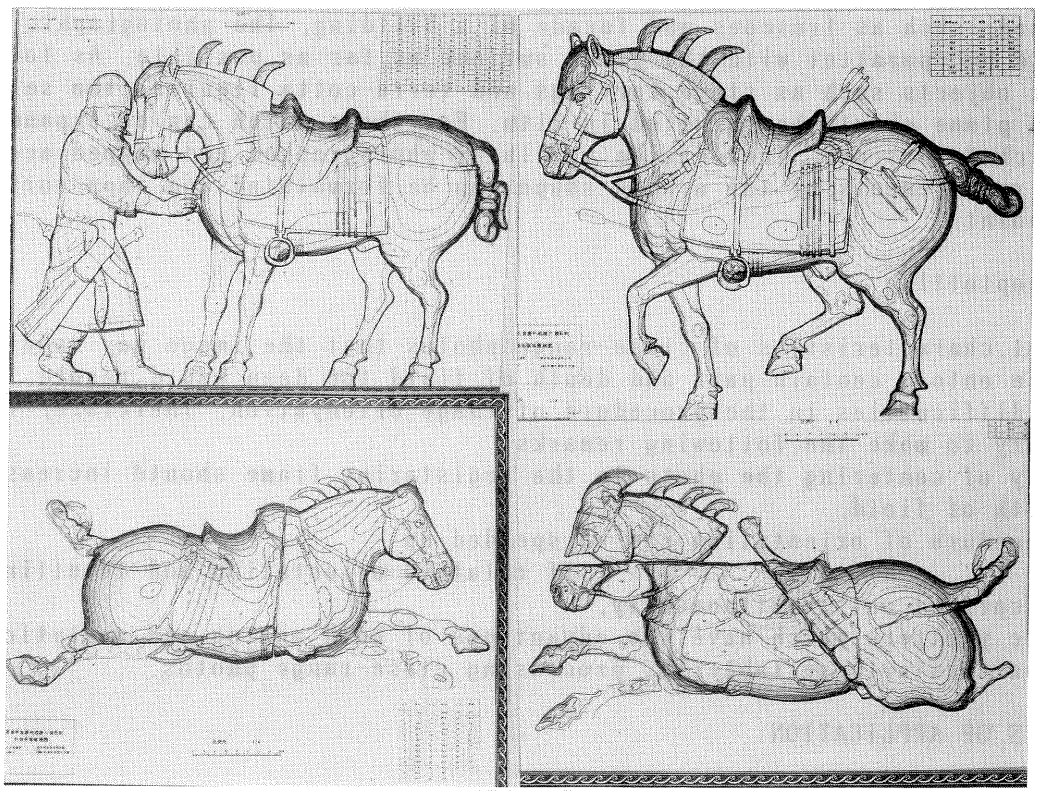

Fig.2. Contour drawing of the stone sculptures "the Six Zhaoling Steeds" of the Tang Dynasty. Scale: 1:4.

4.1. Photogrammetric Survey of Architectural Heritage

SMK-120 and UMK 10/1318 were used to acquire photography. Accuracy of control points was ±1cm and the photo scale was 1:500 to 1:600, while the map scale was 1:50. Elevation drawings and plans of Xi'an Bell Tower were made with Stereometrograph F and graphic accuracy of 5cm was achieved (Fig.1).

Then ortho plans at a scale of 1:50 were produced from aerial photos of 1:4000 scale. Densification of some characteristic points by using coplanarity approach and DLT resulted in an accuracy of 2cm.

4.2. Rapid Mapping of Histirical Sites

The archaeological excavation of the Fa Meng Si Temple of Fu Feng County in Shaanxi Province is the most important discovery for the archaeological study of the Tang Dynasty and Buddhism. Plans and ortho plans of its underground palace were mapped from the photography taken with SMK-120&Mamiya RB-67. Meanwhile, contour drawings for the extremely rare Tang Dynasty gold and jade articles, which are extremely valuable for research, have been made.

In the site of Daming Palace of the Tang Dynasty, low-altitude pfotography by virtue of captive balloon was used for making plans and ortho plans of the site.

4.3. Stone Carvings and Frescoes

While carrying out photogrammetric surveys of the famous stone sculptures of the Six Zhaoling Steeds, an SMK-120 with close-up lens was used to take photos at a distance of 1.5 meters from the stone sculptures. The Photo scale was 1:25. Drawings were mapped in WILD BC-2 analytical plotter with the help of relative controls. The Map scale was 1:4 and the contour interval was 2.5mm(Fig.2),(Fig3).

Metric and non-metric cameras were used for taking photography of frescoes (fig.4), which would be handled in office work with large rectifiers and plotters or processed in computer-assisted image processing systems.

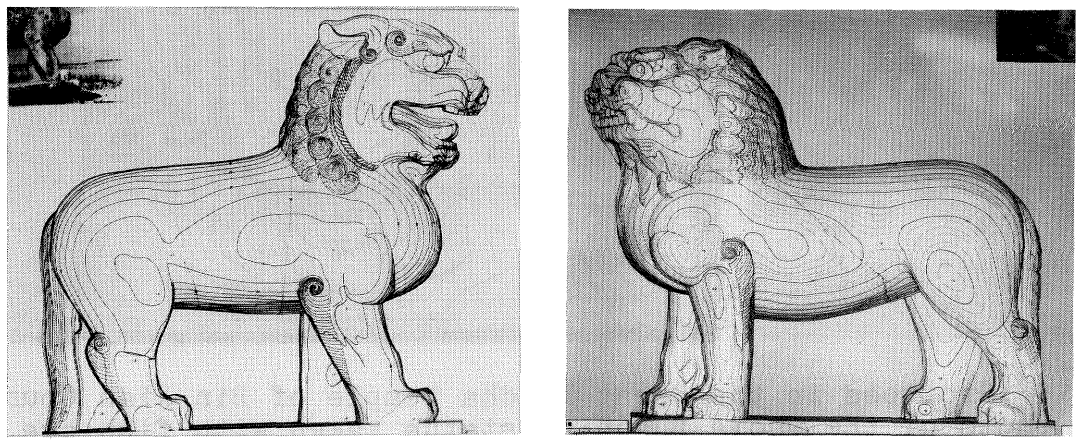

Fig. 3. Contour drawing of Shungling Stone Carvings of the Tang Dynasty. Left: male lion. Right: female lion. Scale of the drawing: 1:10.

Fig.4. Frescoes at Yao Wang Mountain of Yao Xian County. Left: photo of the site. Right: line drawing. Scale of the drawing: 1:15.

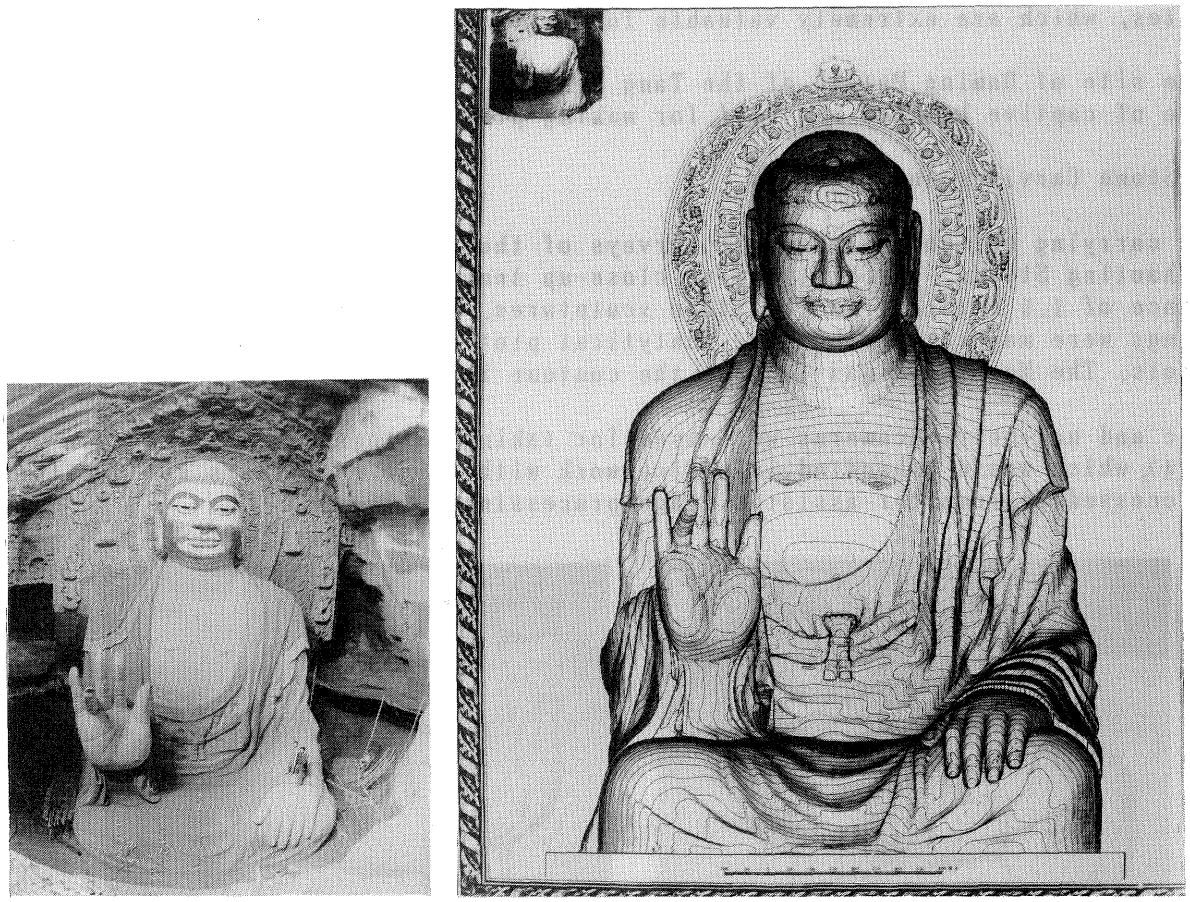

Fig. 5. Grottoes in the Great Buddha Temple of Bin Xian County Left: photo of the whole Buddhist statue taken with fish-eye lens, at the lower right corner stand two surveyors.The Buddhist statue is 20 metre high. Right: contour drawing of the statue. Scale of the drawing: 1:50.

4.4. Survey of Grottoes

An example is the survey of the Great Buddha Temple of Bin Xian County, in Shaanxi Province. While photographing the site, a series of measures were adopted because blind spots and "ITO" phenomenon frequently occured due to the short object-distance(only 4m), the higher Buddhist statue and the deep depth of field. (Fig.5).

1) Selecting and strictly determining the reference projection plane.
2) Using intersection in conjuction with relative controls.
3) Applying non-metric cameras and adopting partial photography and close-up shots to reduce blind spots and "ITO" phenomenon.
4) Suitably allocating and adjusting the illumination in grottoes.
5) Selecting appropriate photographic plates and film.
6) Paying more attention to the appearance of the Buddhist statue and providing technological design for colour printing.

4.5. Survey of Bampo Site

Vertical aerial photography taken from super-low camera altitude was used for carrying out photogrammetric surveys of the excavation site in Bampo Museum Hall. In the project , 20 drawings of cultural relics were produced at a scale of 1:25 and the contour interval of 2cm by using SMK-120 camera together with stereoplotters. Meanwhile, photogrammetric experiments on non-metric cameras were made. And then 2 maps of Bampo site at 1:80 scale were produced through reduction compilation from original drawings at 1:25 scale(Fig.6). At thesame time, the experiment on densification of control points was carried out with analytical aerial triangulation, in which the horizontal accuracy of ± 1.5cm and vertical accuracy of ± 2.0cm were achieved.

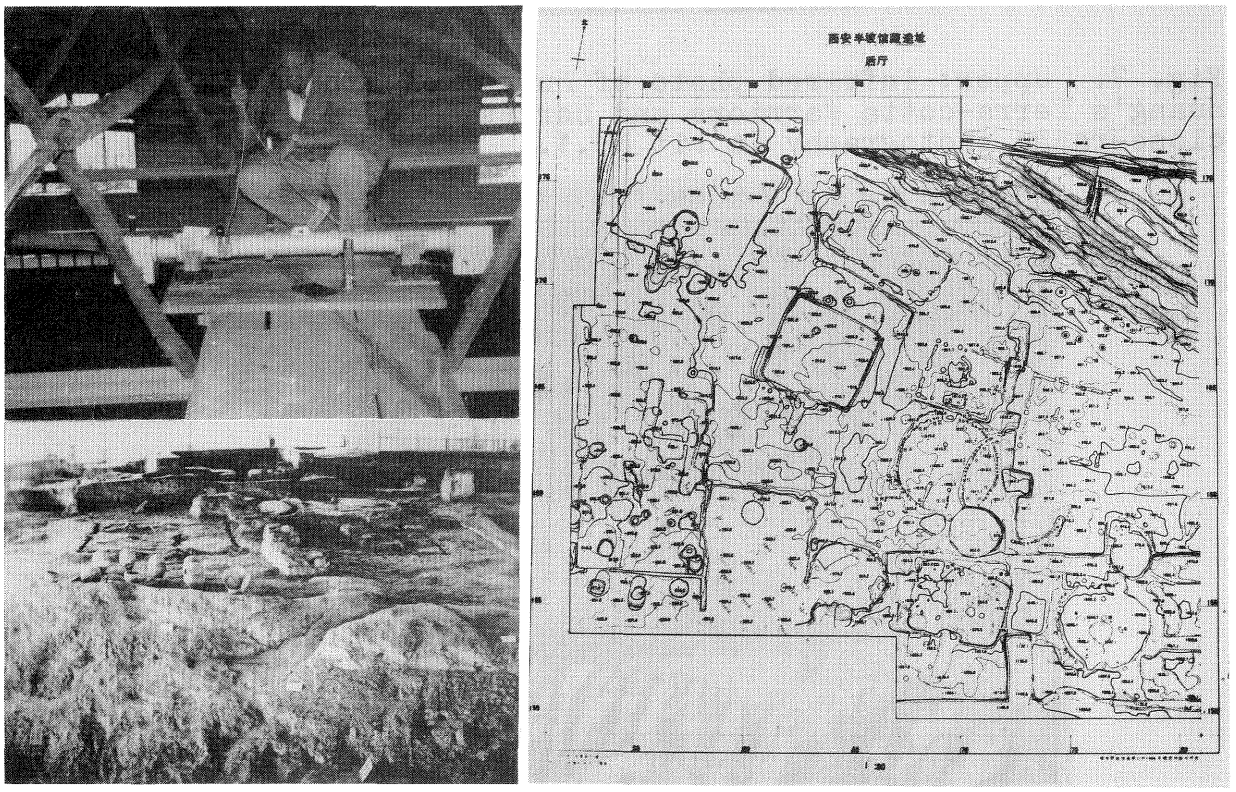

Fig.6. Survey of Xi'an Bampo Site. Stereo cameras are set up on the ceiling of the Museum Hall which is 6m high. Left: operating site. Right: drawing of Bampo Site. Scale of the drawing: 1:80.

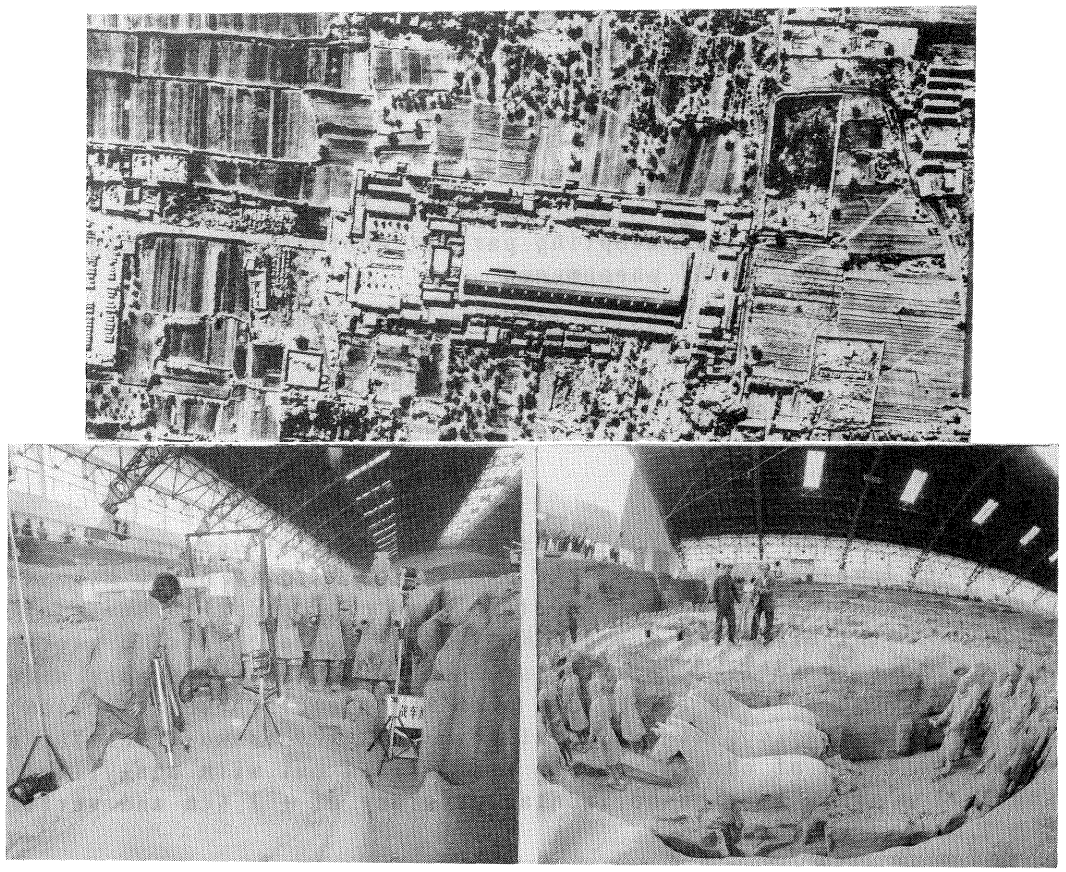

Fig. 7. Upper: infrared photo of Museum of Emperor Qin Shi Huang's Terra-cotta Warriors and Horses. Lower: taking close-range photography in Pit No.1.

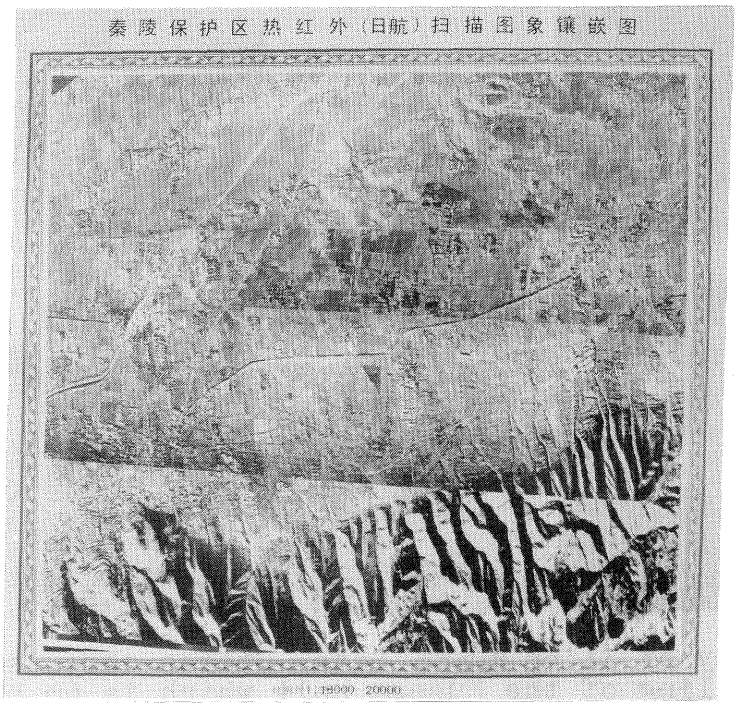

Fig.8. Thermal-IR imagery mosaic of the area of Emperor Qin Shi Huang's Mausoleum, the centre of which is the Mausoleum.

4.6. Application of Remote Sensing in Detection of Archaeological Sites & Tombs

Our centre has completed remote sensing flights over the area of Emperor Qin Shi Huang's Mausoleum, which covers 60 square kilometres. Black-and-white photography, colour infrared photography and thermal infrared scanning have been carried out, as well as close-range photogrammetric surveys of various kinds of terra-cotta warriors and horses(Fig.7). Thematic maps of the Museum of Terra-cotta Warriors and Horses of the Qin Dynasty and contour drawings of representative clay warriors, horses and weapons have been made on the basis of those photographic data. Meanwhile, the sites of the inner and outer boundaries of the Mausoleum and the location of Terra-cotta Warriors and Horses Pits No.2 and No.3 have been diter-mined by photo interpretation. Through interpretation of infrared and thermal infrared imagery(Fig.8) in identifying a group of archaeological sites, 28 among 33 sites have been proved to be in conformity with actual conditions. Furthermore, the southern boundary of Hua Qin Palace of the Tang Dynasty, which had been buried for more than 1000 years, was discovered and the range of the active flowing slope within the scenic spot was determined.

Another example in the successful application of remote sensing techniques is identifying the location of the biggest mausoleum for Emperors in ancient CHINA ----Zhaoling Mausoleum with 167 attendant tombs, whichhas achieved better results.

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