Environmental Remote Sensing Information Technology in Archaeology and Cultural Heritage Conservation

Wang Changlin[1)] Nie Yueping[1)] Yang Lin[2)] Fan Xiangtao[1)]
1) Institute of Remote Sensing Applications, Chinese Academy of Sciences
P.O. Box 9718, Beijing 100101, China
Email: [wcl, nieyp]@irsa.ac.cn, fanxt@163bj.com

2) China National Museum
East Side, Tiananmen Square, Beijing, China
Tel. 86-10-65265857, Fax. 86-10-65265857
Email: lbyanglin@263.net

Abstract: The great Chinese people possess abundant historic cultural heritage. Remote sensing in China has been used in different fields and significant results have been achieved. Remote sensing archaeology, however, is relatively weak, compared to the work in western countries. With the establishment of the Joint Laboratory of Remote Sensing Archaeology (JLRSA), in affiliation to the Chinese Academy of Sciences, Ministry of Education, and State Administration of Cultural Relics, remote sensing archaeology is being vigorously developed, and several subordinate regional centers of the JLRSA have been established. This paper introduces some achievements have been made using aerial and spaceborne remote sensing as well as virtual reality technologies in investigation, monitoring and presentation of natural and cultural heritages in China.
Keywords: Remote Sensing, Archaeology, Cultural Heritage, Information Extraction

1. Introduction

China is a country with more than a historical records of over 5000 years in the world. Cultural heritage spreads everywhere in the whole country, and Chinese culture and technology were distributed in and brought to many countries of the world along the silk road, a way being blazed in 2 BC from the business routes of land and sea. Therefore, to acquire the human cultural heritage information is of great importance to study ancient China and the complete human history. Archaeology, born in the beginning of the 19th century in the western countries, came to China in early 20th century. Up to now, several branches of archaeology have been established, such as environmental archaeology, remote sensing archaeology, underwater archaeology, archaeometry etc. These have exhibited a vigorous development of archaeology, and increased depth and width of archaeology, in particular the combination of human sciences and natural sciences in theory, methodology and technology. Spatial information acquisition and processing technology represented by earth observation technology, geographic information system, global positioning system, and virtual reality is an important means to understand the laws of spatial and temporal distribution of cultural heritage, to reconstruct ancient civilization history, to build cultural heritage information management system, and to display spatial information of cultural heritage using multi-scale and full dimensional digital earth technology.

With the rapid development of remote sensing, particularly the high resolution optical remote sensing satellites and high resolution multi-mode synthetic aperture radar satellites, the importance of applying airborne and spaceborne earth observing technology to natural cultural heritage conservation and archaeological research has caught a great amount of attention worldwide. Compared to the western countries, application of aerial photos to archaeology in China was about 70 years behind. Satellite images were applied to archaeological interpretation in late 1970s, but they had little use due to very coarse resolution. With the advance of remote sensors, both airborne and spaceborne platforms, the importance of space technology for archaeology has been realized, and organizations dedicated to archaeological research have been established. In 1993, the Open Research Laboratory of Remote Sensing in Urban and Environmental Archaeology was set up in East China Normal University. In 1996, Center of Remote Sensing and Aerial Archaeology was established in National Museum of Chinese History. In November 2001, in order to enhance the strength of space technology application in archaeology, the Joint Laboratory of Remote Sensing Archaeology (JLRSA), affiliated to the Chinese Academy of Sciences, Ministry of Education, State Bureau of Cultural Relics, was founded. The JLRSA has three departments: Research Department at the Institute of Remote Sensing Applications, Chinese Academy of Sciences;

Information Department at the National Museum of China; and Training Department at the East China Normal University. At present, there are 10 provincial centers of the JLRSA. In April 2004, the JLRSA became a subordinate organization of the National Center of Remote Sensing in China.

The aims of establishing the JLRSA are, by implementing complementary advantages and fully exploiting the strong disciplinary strengths in each organization,

- to promote the integrated use of natural sciences and humanistic sciences,
- to undertake national key archaeological project and achieve high-level scientific results with remote sensing technology,
- to foster experts on remote sensing archaeology at different levels,
- to become a base for international academic exchange, and,
- to be a center of remote sensing archaeology in China.

Since the establishment of JLRSA, some activities on remote sensing archaeology have been conducted. In December 2002, the first National Remote Sensing Archaeology Symposium was held in Beijing. In November 2003, China's top science forum named "Xiangshan Science Meeting" was held with the theme of "Understanding Historic Cultural Heritage with Space Technology", and participants from archaeologists and remote sensing experts discussed the roles of remote sensing archaeology and problems encountered in applying remote sensing to archaeological research. The International Conference on Remote Sensing Archaeology was successfully convened from October 18 to 21, 2004, on which the participants have shared experiences of their research work, and interests on international cooperation in the field of remote sensing archaeology were discussed.

2. Role of Remote Sensing in Archaeology

Compared with traditional field archaeology, remote sensing archaeology can acquire much more information unavailable or difficult to be obtained in many aspects. As remote sensing provides images for the study area at different scales and resolutions, applications of remote sensing in archaeology range from environmental and landscape archaeology to detailed excavation site mapping. Especially, as a complementary source of airborne remote sensing, the availability of high resolution satellite remotely sensed data such as Quickbird, IKONOS, or in the future Radarsat-2 has facilitated the use of remote sensing data for archaeological research (e.g. Fowler, 2001; Evans, et al. 2003; Blom, 2001). The wide spatial and spectral coverage of remote sensing makes it a powerful means in multivariate environmental archaeological site inventory, geophysical prospecting, and cultural heritage management (Sheets, 2004; Becker et al., 2004; Grøn et al., 2004; An 2004). The penetration capability of synthetic aperture radar is particularly useful in detecting archaeological features underneath a homogenous sand cover or in palaeo-environmental study (MaCauley et al., 1982). The non-destructive advantage of remote sensing, for example ground penetrating radar, to archaeological objects makes the technique useful for detecting and studying the structure and distribution of ancient remains without exposing them, thus, it saves manpower, time, and money (Williams et al., 2004). Close-range photogrammetry enables us to capture information of historical cultural heritage in digital ways, and reconstruct the archaeological matters with computer technology (Sechidis et al., 2004). Virtual reality technology allows the computer reconstruction of palaeoenvironment and ancient scenes with its strong 3-D spatial representation, man-computer interface ability (Forte and Siliotti, 1997; Balzani et al., 2004; Miyatsuka et al., 2002). Remote sensing plays a key role in providing spatial information in building archaeological database for virtual reality. The products from both close range photogrammetry and virtual reality can be put on the internet, therefore, archaeological information and views of the archaeological scenes can be acquired from far-distance.

3. Achievements of Remote Sensing Archaeology in China

Remote sensing has been exploited for archaeological research in China, especially in recent years. The first national conference on remote sensing archaeology, held in December 2002 in Beijing, exhibited many achievements in this field. As early as in the 1960s, aerial photos were used to analyze the distribution of ancient tombs and other remains in building San Men Xia reservoir of the Yellow River. In the 1970s, aerial photogrammetric mapping was made for "Shouchu City" of the Warring States Period (403-221 BC) in Anhui province. The application of remote sensing archaeology in the lower reach of the Yangtze River area has revealed 28,087 sites suspected of containing historic remains of the Wuyue culture from Western Zhou (1100-771 BC) period to the "Chun-Qiu" period (722-481 BC).

Archaeologists investigated the sites as determined from remotely sensed data and confirmed that an accuracy of 95% was achieved (Liu, 2003). After establishment of the Center of Remote Sensing and Aerial Archaeology in National Museum of Chinese History, a number of aerial photo surveying activities were conducted for many archaeological sites in China, such as Yanshi Er Li Tou and Shixianggou Shang City, Luoyang Dongdu remains in Henan Province. Through cooperation between Shandong Institute of Cultural Relics and the Institute for Pre-and Protohistory of the Ruhr-University Bochum Germany, detailed study was made for ancient cities and tombs in Linzi county. This project published China's first aerial atlas of archaeology (Li and Pingel, 2000), which constitutes an archaeological information system. Such a system integrated satellite and airborne remote sensing images with excavation reports, investigation reports, archaeological maps and terrain maps. The positioning accuracy of the distribution of cultural relics has been greatly improved through the use of this system, and archeologists found that spatial information index and analysis were more convenient for their research. In 2000, the Institute of Remote Sensing Applications, Chinese Academy of Sciences took visible and color infrared images for a tomb area of Han Dynasty in Lao Shan, Beijing, and found 4 abnormal suspectable sites for further verification. Aerial photo surveys for the status of the Great Wall in Ningxia and Beijing were investigated by the Aerial Geophysics Survey and Remote Sensing Center for Land and Resources, Ministry of Land Resources (Li, et al., 1997; Zeng and Gu, 1998), so as to make a detailed investigation for the Great Wall conservation and protection. The joint work made by the National Museum of Chinese History and Inner Mongolia Institute of Cultural Relics produced a book on the atlas of aerial archaeology for the southwest part of Inner Mongolia (Yang Lin and Ta La, 2002). The aerial photogrammetric surveying work has been extended to other parts of Inner Mongolia and Shaanxi provinces in recent years, and achieved satisfactory results. In 2002, the National Museum of Chinese History purchased from the United States over 10,000 aerial photos taken by Japanese during the Second World War. Digitization, documentation, and analysis of these photos are in progress. These materials will provide valuable information to study history and archaeology, as China's rapid economic construction has caused the surface great changes and damaged or buried plenty of historic cultural remains.

Close range photogrammetry has played an important role in preservation and reconstruction of ancient remains. Digital photos, a form of remote sensing, of Mogaoku frescos in Dunhuang area have laid a preliminary foundation to reconstruction of sculpture and frescos. With laser and holographic imaging, the plundered and damaged cultural relics of the silk-road could be vividly recaptured and displayed by using virtual reality techniques (www.xinhuanet.com, 2004). Remote sensing provides an innovative information technology for repairing and protecting cultural relics, and recording the excavation scenes and reconstructing the environmental setting of ancient sites.

Applications of satellite images for archaeological research have also been practiced since 1970s. The Archaeology Institute of Chinese Social Sciences utilized the processed Landsat TM images and identified construction sites and tombs of Yin Xu ruins in An Yang city of Henan province (Yang et al., 2001; Liu, 1999). The Great Wall segments in a desert region of north central China, at the boundary of Ningxia and Shaanxi provinces, were revealed by SIR-C/X-SAR images. Three Walls were identified, two of them were built in the Ming Dynasty, and one in the Sui Dynasty. The Great Wall of the Sui dynasty was built in year 585 with rammed earth. It is now discontinuously elongated, about 4m in width and 1 to 3m in height. The Great Wall of the Ming dynasty was built in 1513 with rammed earth. The remnant wall is about 6 to 8m in height and 6 to 8m in basal width. As the radar beam was perpendicular to the Great Wall, resulting in a corner reflector effect, which enables SAR to detect two generations of walls effectively. In the area where sand covers the Wall segments, the penetration ability of long wavelength SAR reveals the Wall's feature and displays them on the SAR images. In terms of wavelength, L band is obviously better than C band for revealing the Wall's feature. In terms of polarization, HH polarization is better than HV polarization. On the L-HH and C-HH images, the Great Wall of both Ming and Sui dynasties are shown, but it is hard to see both of them existed simultaneously on both images. Trees lining a road parallel to the Wall show up as bright feature because the L-HV and C band channels are sensitive to complex vegetation structure. The Great Canal of Sui and Tang Dynasties has also been studied with Landsat TM images and Radarsat images, and good results have been achieved (Wang, 2004).

Aerial photo and high resolution Quickbird image were used to study the ancient Hun Capital "Tongwancheng Town" for its environmental change (Yin, 2004; Deng and Xia, 2001). The Tongwancheng Town is the world's only ruins of ancient Huns, ancient Chinese nomadic tribe which fought across northern China, central Asia and Europe. The ruined town was built between 413 and 418, and was devastated by Song Dynasty troops. It is located in Jinbian county in the Northern Shaanxi province and in the southern edge of Maowusu desert. The Tongwancheng Town comprises three parts: the palace section and the inner and the outer sections. The palace section is where the imperial palace located, the inner section consists of government offices and the dwelling region of officials and royal relatives, while the outer section is the residential area of the common people. Built according to the terrain, the northwestern part of the town is higher and the southeastern part is lower, which effectively impeded cold winter wind blown from the north and fully took advantage of the river resources in the north of the town. It can be seen from the Quickbird image and landcover classification map (Fig. 1) that 76% of Inner section is occupied by moving sand, and the entire area is dominated by desert, whereas the flat area is used as farmland. As the town site is under the threat of desertification, the State Council designated Tongwancheng town as a cultural relics under top state protection in 1996, and the Shaanxi provincial government selects the Tongwancheng capital site as a candidate for the world cultural and natural heritage list. A recent research to the plant remains at Tongwancheng site indicates that in the past 1600 years, the Maowusu desert has advanced to the south about 200 km, and average desertification rate is about 125m per year. Cypress, arbor and shrub were grown in this area (Science Time, 2004). This further confirms a famous Chinese archaeologist view that the area once was a beautiful place with rich water, grass and trees (Hou, 1973).

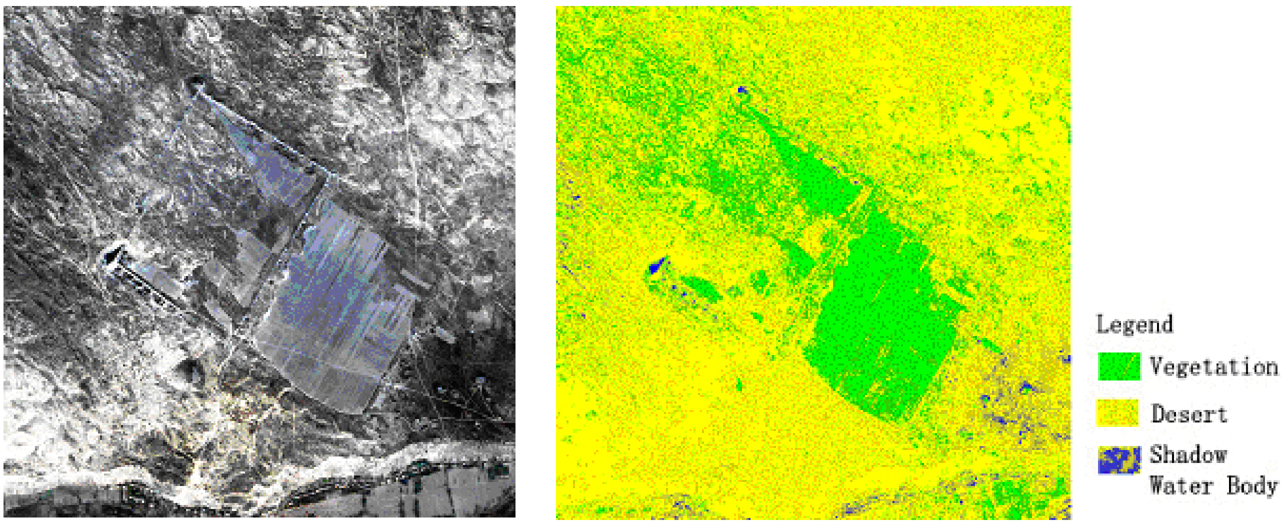

Fig. 1 Quickbird image generated from fusion of bands 3, 2, 1 and a panchromatic band, and landcover classification map, showing the extent of desertification.

Integrating geophysical prospecting, aerial remote sensing, and satellite remote sensing has been utilized in several research projects. In 2002, the National High-Tech Program of China sponsored a project to use integrated technology to detecting and identifying Qinshihuang mausoleum, which was made for the first emperor of Qin Dynasty (259-210BC) who unified the countries in the Warrior States period and became the first emperor of China. The objective of the project is to use remote sensing and geophysical methods to conduct non-destructive prospecting, and to detect relic distribution of Qinshihuang mausoleum, and to provide scientific evidence about the presence or not of the underground palace in Qinshihuang mausoleum (Yu and He, 2003). The research teams completed hyperspectral imaging of 60 km^2 in the mausoleum area, and collected panchromatic, color infrared and thermal images of early years, and conducted field geophysical surveying in 6 categories (23 sub-categories). Satisfactory results have been obtained and the presence of underground palace is confirmed (Tan et al., 2004; Zhou et al., 2004, Wan et al. 2004). A new research project with integrated technology for Jinsha remains in Sichuan Province is on agenda, supported by China’s Ministry of Science and Technology. Based on literature study to the history of Western Zhou dynasty (Zhu 2003), the area of undiscovered mausoleum of that period (1100-771 BC) in Shaanxi province has been delineated, and the integrated technology will be used in the research.

Environmental evolution and causes of the disappearing of ancient cities (e.g., Loulan City in Lop Nur) were studied with remotely sensed data. The Lop Nur River, which supplied water for Loulan, a busy commercial city on the ancient Silk Road, has dried up and civilization there moved elsewhere in China. The kingdom of Loulan was ruled by the government of the Han Dynasty. Troops of the Han Dynasty were stationed in Loulan. Researchers at the Aerial Geophysics Survey and Remote Sensing Center for Land and Resources, Ministry of Land Resources of China, used Landsat TM images to study the causes of the vanishment of Loulan city, and they found there were two lakes in the upper reach of Kong Que River (Peacock river), and formation of the lakes is probably due to landslides occurred in ancient times (He and Sun, 2001). The landslides blocked the river supply to Loulan city, and thus resulted in the perish of the ancient city.

Nowadays, China has 30 cultural heritage sites inscribed by the UNESCO, and more historical sites are going to submit applications. Remote sensing images, in particular the high resolution satellite imagery or aerial imagery, are necessary documents for submitting the application proposal. In this sense, remote sensing images provide an important role in monitoring the conservation status of the world cultural heritages. They also serve as a necessary information source to the decision-makers in government for planning and construction of tourism projects for the purpose of advancing economic development.

Spatial information acquired with space technology is vitally important for reconstructing ancient landscape and palaeo-environment. For geological and environmental research in an arid area, a unique advantage of radar remote sensing is that radar waves can penetrate a certain layer of dry sand (a few centimeters to meters thick) to reach the buried bedrock. The penetration capability allows us to reveal the subsurface geological structure and old drainage paths (McCauley et al., 1986; McCauley et al., 1982, Blom et al., 1984). Based on the analysis of SIR-A, SIR-B, SIR-C, Radarsat Scan SAR, Landsat MSS and Landsat TM images acquired on different dates and the investigations made in several field trips in Alashan Plateau of Inner Mongolia, a number of old river valley and lake basins buried by wind-blown sand were recognized (Fig.2). Two parallel old drainage systems in the north and middle of the study area are delineated. The study suggests that the moving sand belts mainly follow the old drainage courses. This study also establishes a preliminary drainage evolution model for an area of about 300 000 km^2 since the Tertiary, and finds that the Alashan Plateau was once an area with many rivers and lakes with a warm and humid climate. The relief reversion caused by neotectonic movement since "Qinghai-Tibet movement" is also analyzed (Guo et al., 2000).

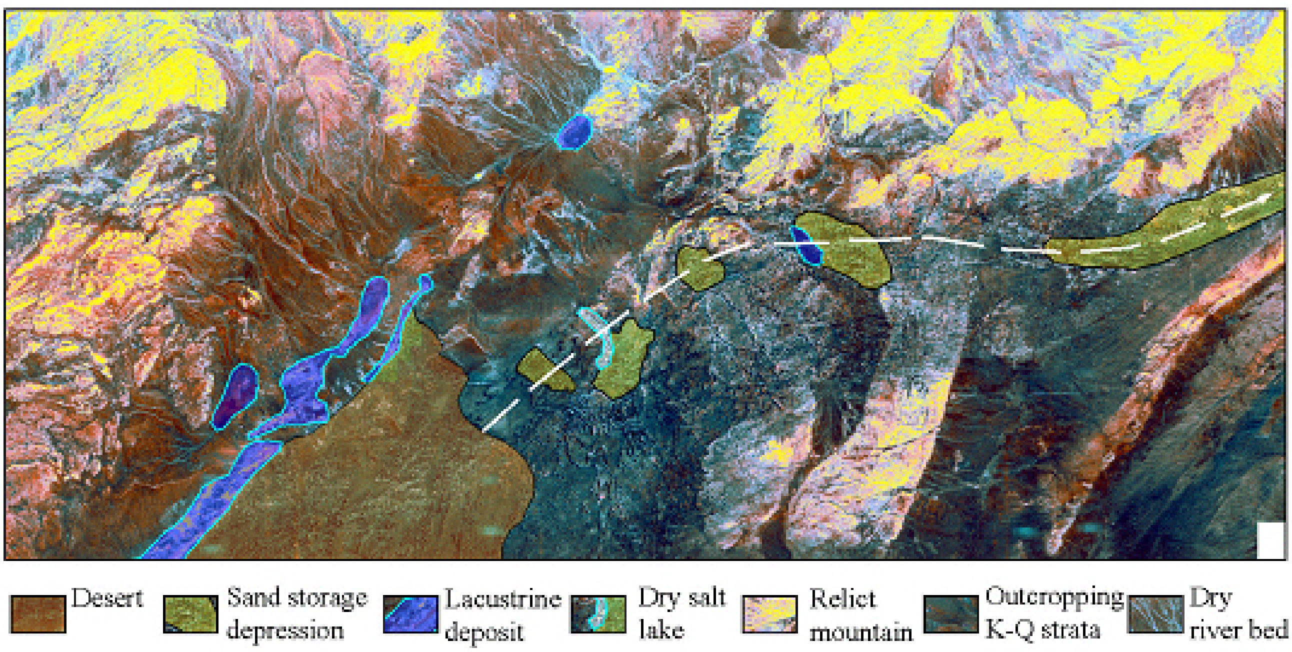

Fig. 2 Palaeo-environmental evolution study with SIR-C data showing drainage pattern in Alashan plateau, Inner Mongolia

Virtual reality technology is now being applied in several research projects. Many organizations, culture and relic departments and institutions have also paid great attention to the application of virtual reality. One of noticeable achievement is "Digital Forbidden City", which utilizes high performance graphic computer workstations, and produces 3-D scene in reality on a large screen (www.dmp.com.cn). With this technology, the staff at the Palace can monitor the status of exhibition, the rare articles and buildings in the Forbidden City can be shown vividly, and the audiences can access each place of the Palace to see every scene and article. With virtual reality technique, the Shanhaiguan Great Wall has been constructed with a 3-D model on the basis of Quickbird image, topographic terrain data at 1:50,000 scale, and on-site photos. The virtual reality technology can be used in many aspects in archaeology, such as reconstruction of the lost cities (e.g. Loulan city), and to rebuild the ancient environment and civilization.

4. Problems Concerned with Remote Sensing Archaeology

Although there are many successful stories with remote sensing archaeology at home and abroad, many questions related to this subject still exist. Many people, especially those working in the social sciences, still have doubt about the ability of remote sensing in archaeological research. There is certainly incorrect information with ancient remains extracted from remotely sensed data. We don't know much about the interacting mechanism between ancient remains and remotely sensed data, and how to correctly understand the ancient landscapes from remotely sensed information. We believe that with fusion of social sciences and natural sciences, a better understanding to the applications of remote sensing in archaeology on the theories, methods and techniques will be made. We not only should conduct remote sensing archaeology research at small scale (micro-scale), but also at macro-scale, including Silk Road, Great Wall, and Great Canal. For micro-scale remote sensing archaeology, emphasis should be placed on the important mausoleum, such as the finding of the mausoleum of Western Zhou dynasty. Through research on remote sensing archaeology, the status of this branch in remote sensing could be improved in China, and more contribution could be made to China's 5000 years civilization.

References

An Jin Jie, 2004, Spatial Querying Method of Remote Sensing Archaeology Data**,** In Proceedings of International Conference on Remote Sensing Archaeology, 18-21 October, Beijing, pp. 113-120.

Blom, R. G., R. J. Crippen and C. Elachi, 1984, Detection of Subsurface Features in Seasat Radar Images of Means Valley, Mojave Desert California, Geology, Vol. 12, pp. 346-349.

Chen Shupeng, Guo Huadong, 2003, Remote Sensing and Digital Earth, Science Progress in China. Science Press. Pp.401-425.

Damian Evans, Roland Fletcher, 2003, Remote Sensing at Angkor: Mapping Settlement Structure Using Imaging Radar, Aerial Survey and GIS . In: The Fifth World Archaeological Congress. Washington D.C.

Deng Hui, Xia Zhengkai, 2001, From the rise and decline of Tongwancheng to see the impact of man's activity on the area with vulnerable ecological environment, Journal of China Historical Geography, 16(2): 104-113.

Fan Xiangtao, Hou Tao, Li Hongga, Wang Changlin, Nie Yueping, 2004, Study on the Reconstruction of Ancient Great Wall of Shanhaiguan Area Using Virtual Reality Technology, In Proceedings of International Conference on Remote Sensing Archaeology, 18-21 October, Beijing.

Forte M. and Siliotti, A. (eds.), 1997, Virtual Archaeology: Re-Creating Ancient Worlds, New York, 294pp.

Guo Huadong, Liu Hao, Wang Xinyuan, Shao Yun, Sun Yan, 2000, Subsurface old drainage detection and paleoenvironment analysis using spaceborne radar images in Alxa Plateau, Science in China, 43(4), 439-448.

Becker, H, M. Ciminale, D. Gallo, 2004, Integrated Technologies for Archaeological Investigation: the Celone Valley Project, In Proceedings of International Conference on Remote Sensing Archaeology, 18-21 October, Beijing.

He Yuhua, Sun Yongjun, 2001, Exploring the disappearing mystery of the Loulan Ruins with satellite data, Land Resources Remote Sensing, vol. 2, 64-67.

Hou Renzhi, 1973, From the ancient ruins of ancient city tobeside Hongliuhe river to see the Maowusu desert migration change of Maowusu desert, Cultural Relics, 1: 35-41.

Sechidis L., D. Kaimaris, S. Sylaiou, O. Georgoula, P. Patias, 2004, From 3D Model to Stereoscopic Video: Example of an Ancient Theatre, In Proceedings of International Conference on Remote Sensing Archaeology, 18-21, October, Beijing.

Li Chuangrong, Volker Pingel, 2000, The Archeological Aerial Photo_Atlas of Linzi, China, The Topographical Publishing House of Shangdong Province, 424P.

Li Feng, Gu Wei, Chao Canxia, 1997, Aerial remote sensing investigation for Great Wall in Ningxia, Land Resources Remote Sensing, 3:7-17.

Liu Jianguo, 1999, Remote Sensing Archaeology Research for Yin Xu in Anyang, Archaeology, vol. 7.

Liu Shuren, 2003, From the Understanding of Historical Cultural Heritage “The Great Wall” and Others to view the science content of space archaeology, Proceedings of Xiangshan Science Meeting, No. 216.

Fowler M. J. F., 2001, A High-resolution Satellite Image of Archaeological Features to the South of Stonehenge . International Journal of Remote Sensing, 22 7 1167 1171.

MaCauley, J. F., G. G. Schaber, C. S. Breed, M. J. Grolier, C. V. Haynes, B. Issawi, C. Elachi, R. G. Blom, 1982, Subsurface Valleys and geoarchaeology of the eastern Sahara Revealed by Shuttle Radar, Science, Vol. 218, pp. 1004-1020.

Marcello Balzani, Nicola Santopuoli, Alessandro Grieco, Nicola Zaltron, 2004, Laser Scanner 3D Survey in Archaeological Field: the Forum of Pompeii, In Proceedings of International Conference on Remote Sensing Archaeology, 18-21, October Beijing.

McCauley J., C.S. Breed, G.G. Schaber, et al., 1986, Paleodrainages of the eastern Sahara-the radar rivers revisited (SIR-A/B) implications for a Mid-Tertiary Trans-African Drainage system . IEEE Trans. Geoscience and Remote Sensing GE-24(4):624-648

Miyatsuka, Y., K. Uno, K. Sakamoto, 2002, Archaeological Visualization for Yangtze River Civilization in China. ISPRS Commission V, WG V/6.

Ole Grøn, Lars Aurdal, Finn Christensen, Anke Loska, 2004, Mapping and Verifying Invisible Archaeological Sites in Agricultural Fields by Means of Multi-Spectral Satellite Images and Soil Chemistry, In Proceedings of International Conference on Remote Sensing Archaeology, 18-21 October, Beijing.

Patrick Ryan Williams, Nicole Couture Deborah Blom, Benjamin Vining ,Christopher Dayton, John Janusek , 2004, Ground-Based Remote Sensing and Early State Development in the South-Central Andes, In Proceedings of International Conference on Remote Sensing Archaeology, 18-21 October, Beijing.

Payson Sheets, 2004, The Origins of Monumentality in Ancient Costa Rica, Revealed by Satellite and Aircraft Remote Sensing”, in In Proceedings of International Conference on Remote Sensing Archaeology, 18-21 October, Beijing.

Ronald G. Blom, Robert E. Crippen, at el., 2000, Remote sensing, shuttle radar topographic mapper data, and ancient Frankincense trade routes. IGASS .

Science Time, 2004, The Chinese Academy of Sciences Quantitatively Study the Desertification Rate with Plant Remains, Dec. 12.

Tan Kelong, Wan Yuqing, Duan Qingbo, Zhou Xiaohu, Song Dewen, Niu Xinlong, 2004, The Application of Remote Sensing Technology in Archaeological Study of Qinshihuang’s Mausoleum, In Proceedings of International Conference on Remote Sensing Archaeology, 18-21 October, Beijing

Wang Xin-Yuan , Zhou Ying-Qiu, Lu Yingcheng, Gao Chao 2004, On Remote Sensing Archaeology Analysis for Transformation of Traffic Function of Sui dynasty Tongji Canal, In Proceedings of International Conference on Remote Sensing Archaeology, 18-21 October, Beijing

Yang Lin, Ta La, 2002, Report of Aerial Photographic Archaeology in Southeastern Inner Mongolia, Science Press, 235p.

Yang Ruixia, Guo Yangshan, Zan Zhiming, 2001, Application of Remote Sensing Technology to Archaeology in Henan Province, Land Resources Remote Sensing, vol. 2, 19-24.

Ying Ning, 2004, Environmental Changes and Archaeological Study Using Multi-source Remote Sensing datasets of Typical area in West China, M.Sc Thesis, Institute of Remote Sensing Applications, Chinese Academy of Sciences, 63p.

Yu Wenxian, He Kaitao, 2003, New Earth Observing Technology and Information Extraction to Ancient Remains, Proceedings of Xiangshan Science Meeting, No. 216.

Zeng Chaoming, Gu Wei, 1998, Aerial Remote Sensing Investigation for the Great Wall in Beijing, Journal of East China Normal University, Special Issue of Archaeology Remote Sensing, pp. 131-136.

Zhu Fenghan, 2003, Exploration and Study of the Spatial and Temporal Distribution of Historical Cultural Heritage, Proceedings of Xiangshan Science Meeting, No. 216.