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A Summary of Remote Sensing Environmental Archaeology in the Study of Ancient Settlements

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Abstract: From an interdisciplinary point of view, this article discusses the application of a remote sensing environmental archaeology method in the study of ancient settlements by investigating the development and revolution of archaeology as well as the idea of remote sensing environmental archaeology. The study proposes a new method of multi-source information composition of remote sensing environmental archaeology to identify ancient settlements under the support of spatial analysis. Based on the characteristics of ancient settlements and their spatial relationship with their surroundings, remote sensing image recognition and geospatial analysis are applied to obtain the multi-source information composition of remote sensing environmental archaeology and then effectively determine the existence and the location of ancient settlements. In combination with field validation, the identification can be achieved. Based on the discussions, the technological integration of the remote sensing environmental archaeology method and its future application in the archaeology of ancient settlements are further explored.

Key words: Remote sensing environmental archaeology, settlement archaeology, spatial analysis, multi-source information composition, technology integration

INTRODUCTION

The application of remote sensing in archaeology is called the remote sensing archaeology. At present, the application of remote sensing technology in archaeology represents a new direction for improvement. Remote sensing archaeology is based on the broad sense of conducting nondestructive detection of targets on ground, underground and underwater. More specifically, it uses geophysical methods like electromagnetic waves, gravitational fields, magnetic fields, electrical fields and mechanical waves to detect and analyze ancient sites of different heights of aerospace, aviation, ground and underground platforms as well as regional environment. Potential or weak information that cannot be gained using the traditional methods can thereby be obtained.

With the development of environmental archaeology, combined with environmental archaeology methods, broad remote sensing archaeology studies the natural environment and its relationship with human society in all perspectives and it is used to discuss human activity in the changing environment. Broad remote sensing archaeology technology and environmental archaeology have changed from multidiscipline to an interdisciplinary approach. This new approach extends the content of broad remote sensing archaeology, integrating it into the broad remote sensing environmental archaeology (Wang *et al*., 2005). The remote sensing environmental archaeology uses marks on remote sensing images left by the environmental change to examine ancient geographical environmental changes and its relationship with ancient civilizations. As a supportive technology, the new broad remote sensing environmental archaeology technology is based on the information science, geology, archaeology and the historical geography. On-the-ground and underground information of historical sites is obtained by aviation and geophysical detection. The images are subjected to the macro-analysis and the underground micro-detection through their processing and integration of information to identify the natural and distribution characteristics of relics. Combined with the environmental archaeology technology, including dating techniques, spore-pollen analysis, elemental geochemical analysis and the identification of relics and remains, virtual and digital ancient natural environments can be rebuilt and the natural and human geographical environments can be restored. Compared with traditional archaeology, broad remote sensing environmental

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archaeology expands the research of single points to points, lines and planes and then to four-dimensional data, the information extraction processes will be increasingly more accurate and the study of archaeology will be deeper and greatly improved. Important historical problems will be resolved by reasonable explanations.

REMOTE SENSING ENVIRONMENTAL ARCHAEOLOGY METHOD OF ANCIENT SETTLEMENTS

General remote sensing environmental archaeology method for interpreting the location of ancient settlements: Researches using the remote sensing environmental archaeology method to interpret existence and location of ancient settlements have been carried out worldwide and a lot of achievements are being made in this field (Guo, 1999; De Laet *et al*., 2007; Lasaponara and Masini, 2007; Masini and Lasaponara, 2007; Rowlands and Sarris, 2007; Tian, 2007; Wang *et al*., 2005; 2006; 2012). Ancient settlements can be divided into two types based on the condition of preservation: cultural remains on the ground and remains underground (Wang *et al*., 2012). The first thing to do is to obtain an information source through regional remote sensing images. Remote sensing images can be classified by the height of platforms to ground remote sensing, airborne remote sensing and satellite remote sensing instruments (Guo, 1999). These images can also be classified by the way they are obtained, including camera, scanner and radar images which present the features of ground targets. With these features, the identification of targets can be established. The integration of remote sensing data of different sensors can be used to realize the integration of remote sensing information which is very useful in the comprehensive analysis of identification. The interpretation signs can be classified as direct and indirect. However, interpretation signs change with various factors. Thus, the influence of every factor should be considered when accessing and selecting remote sensing images. For example, it is very easier to perform multi- dimensional comprehensive analysis by choosing remote sensing images taken in early winter because of the lesser influence of plants.

After obtaining remote sensing images, they are then interpreted. For the remains of ancient settlements on the ground, the images are enhanced and classified to improve the interpretation and visual effect. Characteristic parameters are selected by performing spectral measurement and feature analysis and information extraction to realize the classification and set up interpretation signs. According to an expert's experience and knowledge, the existence and location of a target can be directly interpreted by its shape, size, tone, color, shade, texture, pattern, layout and relative position. Even the overall shape and distribution characteristics of ancient settlements can be outlined. This method is often used in archaeological studies west China, such as the study of ancient settlements of the Silk Road (Bi and Wang, 2007) and the Inner Mongolia (Zhang, 2007) by using the method of remote sensing environmental archaeology. It is difficult to directly interpret the remains of ancient settlements underground. Because these remains are human made, there are differences between these remains and undisturbed surroundings. These differences are preserved to varying degrees by surface moisture conditions, vegetation growth status, land use/cover and geomorphologic structures. The differences are recorded in remote sensing images and they provide the bases of interpretation for archaeology.

With the establishment of ancient settlement relic interpretation signs and information extraction, the existence and location of ancient settlements can be recognized and interpreted effectively. However, due to the influence of climate, soil and vegetation on archaeology marks and the constraints of the interpreting staff's experience and knowledge, the accuracy of the existence and location needs the combination of remote sensing environmental archaeology and geographical information spatial analysis methods for reasonable identification.

Ancient settlement identification through multi-source information composition of remote sensing environment archaeology supported by the geospatial analysis: The regularity of the distribution of ancient settlements is closely related to geographic locations, geomorphic types, the natural environment and economic types. For example, most ancient settlements were distributed along fossil river courses. The specific shape depends on the river's orientation and resource capacity on both sides of the river. Ancient settlements at the front of a mountain were generally distributed along the foot of the mountain. These settlements are similar to those of ancient coastal settlements at similar altitudes. In plains areas, ancient settlements were distributed in a scattered way in early times. With the development of society, the number of ancient settlement relics increased and settlement clusters groups were formed. These distribution features provide a basis for interpreting the existence and location of ancient settlements by spatial analysis.

Spatial analysis is a method of extracting implied information. Because of the close relationship between

the distribution of ancient settlements and their surroundings, due to the limitations of the use of natural resources, people had to live in a place that was both near and above the water to resist floods. Thus, the shapes of many ancient settlements are terraces, mounds and barren slopes. The existence and locations of ancient settlements can be effectively determined by these spatial distribution characteristics. And the distance of ancient settlements along the river can be estimated and the location of an ancient settlement can be determined effectively. Thus, the working thought of ancient settlement identification through the multi-source information composition of remote sensing environmental archaeology supported by spatial analysis is as follows (Fig. 1).

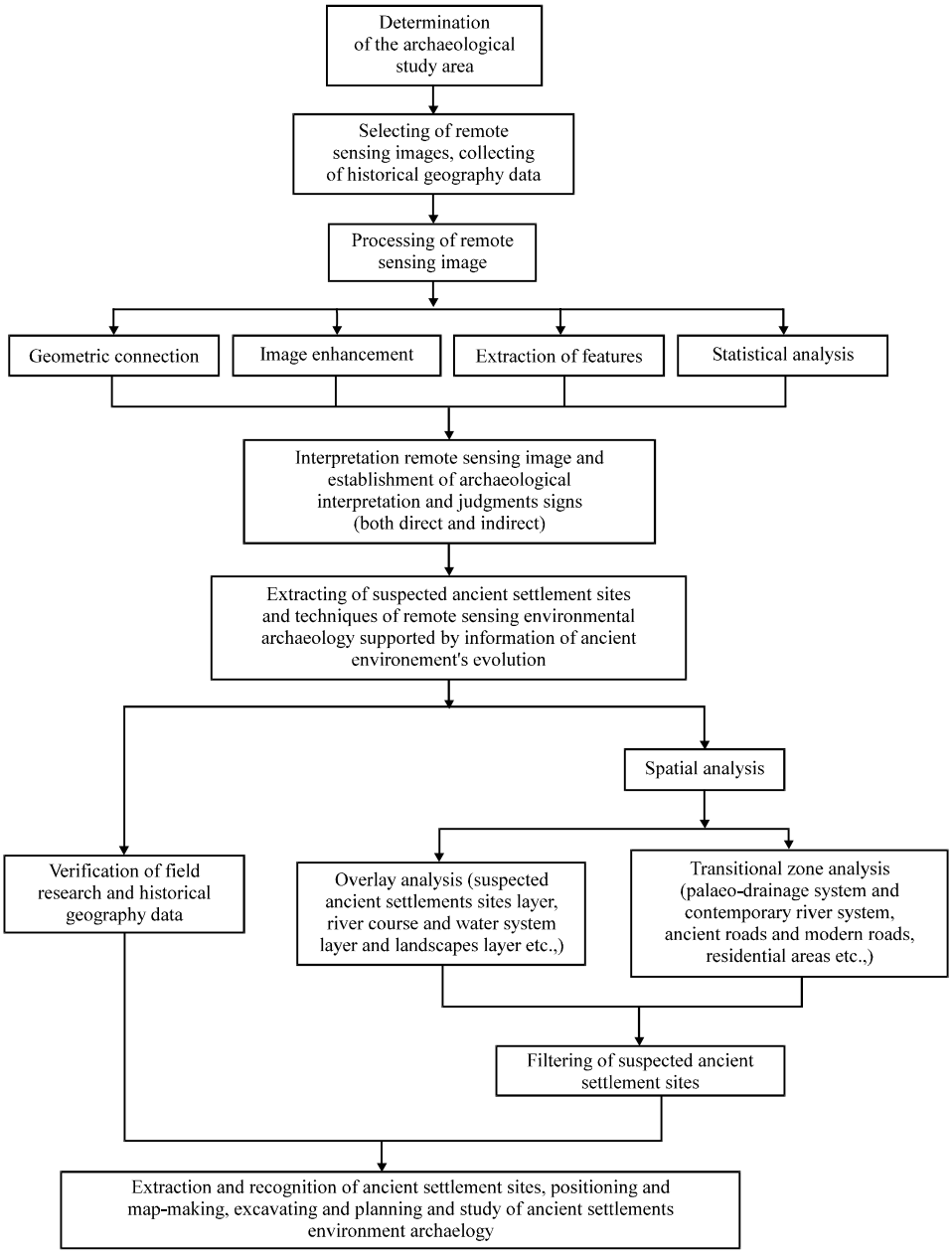

Fig. 1: Technical work-line of the detection of an ancient community site by multi-source information based on environmental remote sensing archaeology and spatial analysis

INTEGRATION OF ANCIENT SETTLEMENT REMOTE SENSING ENVIRONMENTAL ARCHAEOLOGY TECHNOLOGIES

The advantage of remote sensing environmental archaeology applied to ancient settlement archaeology is that it integrates modern with traditional remote sensing technology and new environmental archaeology practices. Traditional remote sensing technology often replaces the planes with points when performing research because of the limitations of ground conditions and objective factors. In this case, omissions of known study areas are inevitable. Some unknown information is difficult to discover and reveal and the form of detection is often destructive. Remote sensing environmental archaeology can remove these negative factors and extend the "point" research of traditional ancient settlement archaeology to systematic research of most ancient settlements sites in a macroscopic way. This approach uses nondestructive detection from planes to lines and then to points and it extends settlement archaeology in depth (Fig. 2).

For planes, multi-source remote sensing images of different sensors, such as aviation and space sensors and different periods are collected to conduct information composition and analysis. Combined with the spatial relationship analysis of GIS technology, the interpreting signs of ancient settlement sites are established, interpreted and analyzed. Then, the target region of ancient settlement sites is found. For lines, the route of the field and on-the-spot investigation of a study area is determined. Geophysical and geochemical methods (resistivity method, induced polarization method, self-potential method, electromagnetic method, Ground Penetrating Radar (GPR) method, seismic method, Mercury analysis test technology, phosphate exploration method, etc.,) are also used to establish the route. For the

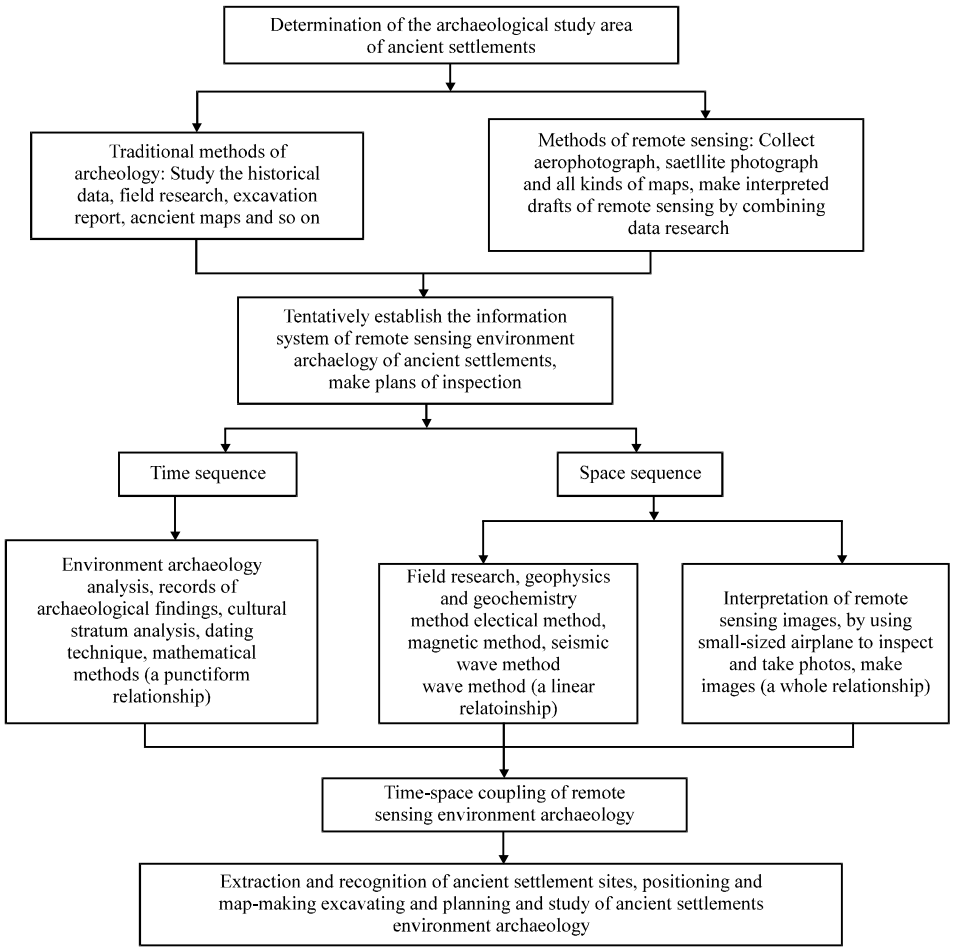

Fig. 2: Technical work-line of the detection of an ancient community site by multi-source information based on environmental remote sensing archaeology and spatial analysis

analysis of historical geography literature, ancient settlements extracted and identified, then they are positioned and mapped. For points, a detailed excavation plan is made. A culture relic archaeology institute can perform trenching to reveal study areas and even key sections and can conduct research of stratigraphy and utensil typology on cultural relics. The utensils are then placed under chemical analysis. For example, X-ray fluorescence can test microelements of ancient utensils and then explore information about the place of origin. Data from different ancient settlement sites can be analyzed to find the relationship between them by mathematical methods. Then, ancient human connections can be explored in different areas and a linear relationship established. The association of planes, lines and points is established by dating techniques (^{14}C dating technique), stratigraphic analysis and paleoclimate analysis. That is, spaces are strung together by a timeline to realize four-dimensional time-space coupling. Finally, layouts, structures, patterns, spatial distributions and mutual relationships are analyzed and compared to reveal the corresponding relationship of ancient settlements changes, ancient human activities and ancient environmental changes and to explore the laws of the rise and fall of cultures and civilizations.

CONCLUSIONS

Remote sensing environmental archaeology is an important way to discuss the relationship between ancient geographic environments and ancient settlements with ancient culture. The change of an ancient geographic environment has a significant impact on the change of settlements, civilization succession, politics and lifestyle. The combination of settlement archaeology and remote sensing environmental archaeology will play a unique role in revealing regional environmental change, ancient settlement change and the response of human activity.

Remote sensing environmental archaeology is an emerging technology and its application in ancient settlement archaeology needs further research, practice and development. First, more practice in the remote sensing environmental archaeology of ancient settlements should be performed. In particular, the extraction of weak information from a remote sensing environmental archaeology target should be highly valued to establish a spectral library of various typical targets of archaeology. Second, further studies of the interactions between electromagnetic waves and ancient settlements should be conducted, especially the mechanisms of the remote sensing information transfer of typical underground and hidden archaeology targets. The multi-source information composition of different platforms, periods and sensors as well as multi-spectrum, multidisciplinary and multi-information technology should be taken full advantage of to realize the composition of multi-source remote sensing information and the composition of remote sensing and non-remote sensing information. Different electromagnetic spectra and geospatial information should be given full play. Third, the integrated research of remote sensing environmental archaeology technology should be strengthened to achieve the visualization of ancient settlements and environments.

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