The 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 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. It proposes the 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 its spatial relation with surroundings, remote sensing image processing and spatial analysis (overlay analysis and buffer relationship) are applied to realize multi-source information composition of remote sensing environmental archaeology and then effectively determine the existence and the location of ancient settlements. By combining field validation, the identification can be achieved. The method of environmental remote sensing archaeology for the study of the landscape pattern of ancient settlements is mainly used in two aspects: one is the layout and inner structure, the other is the distribution of ancient settlements and their mutual relations. And the method is multi-source remote sensing data composition analysis with aerial remote sensing techniques as the core. Based on these discussions above, technology integration of the remote sensing environmental archaeology method and its future application in the ancient settlements archaeology are further explored.

Key words: remote sensing environmental archaeology, ancient settlements archaeology, spatial analysis, multi-source information composition, the landscape of ancient settlements, technology integration

CLC number: K916 **Document code:** A

Archaeology is a science of studying ancient material remains and exploring human social history. In the middle of 19th century, the true meaning of archaeology came out based on combining the methods and research results of geology and paleobiology. The prehistoric archaeology is the first archaeology and the pioneers are geologists(Zhou K S,2007). The completed archaeology formed when the method of prehistoric archaeology was applied to the study of historical period of archaeology(Yan W M,2003). Stratigraphy and typology are the two pillars of the theory and method of archaeology. Until 1950s, archaeologist had set up several archaeological culture sequences in the worldwide. The tenet of this period was "reconstruct the disappeared life"(Gu J X,1997).

From 1960s to 1980s, archaeology entered into a new revolutionary period. There were two main

Received: ; **Accepted**:

Foundation: National Nature Science Foundation of China (No. 40571162) and Nature Science Foundation of Anhui province(No. 050450401)

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development in western archaeology, one of which was settlement archaeology(Chen C,2003; Zhang G Z,2002). Soviet Academy of Science and Academy of Science of Ukraine laid the foundation of the study of worldwide archaeology settlements by investigating and excavating Tripolye culture in Ukraine between 1934 and 1940. So Soviet is the first one to adopt the method of settlements archaeology(Yan W M,1997a). The study of settlements archaeology in China started during Yin dynasty ruins excavation in 1930s(Yan W M,1997b). Then it developed in depth gradually. Settlements archaeology was no longer confined to a study of a single settlement. It was also a discussion of ancient social patterns, social organizing structures and the environment through settlements structures. Experts, represented by Zhang G Z(1986), Yan W M(1997a) and Zhang Z P(1999), thought settlements archaeology is not only focused on social relationship, but also emphasize the relationship with environment. This is the development trends of settlements archeology. Settlements archaeology conducts research on the overall region settlements and historical evolution and take environment as an important factor of ancient cultural evolution. There is a positive correlation between the activities of human being/land use and climate change(Björn E.Berglund.,2003). The location, the shape and the shift of settlements are all directly related to environmental change. It is very important to review the shifts and rise and fall of settlements to restore historical environment, explore information of environment changes and clarify the formation and the features of geography at that time(Wang J H,2003; Han M L,2000; Deng H,2002).

As to environment archaeology, Butzer K.W., an American scholar, published ***Environment and Archaeology*** in 1964, which became the symbol of the rise of environment archaeology. Nowadays, the study of environment archaeology is proceeding as the level of local study, small areas study and large areas study. The theories, techniques and practice have taken quite great development(Dincauze,D.F.,2000; Redman,C.L.,1999; Margarita C, et al.,2002; Lynley A. Wallis,et al.,2001). The study of environment archaeology in China has also made gratifying achievements from 1980s(Zhou K S & Kong Q M,1991; Zhou K S & Song Y Q,2000; Zhou K S *et al*.,2006). In recent years, the scholars focused on Yangtze River delta, Pearl River Delta, Beijing, Tianjin, Shandong, Henan and Great Wall zone, discussing the influence of natural geography and climate on the shape and distribution of settlements(Zhang H Y,1995; Chen Z Y *et al*.1997; Cao B W,1997; Zhu C *et al*.,2003; Yang R X *et al*.,2004). Combining geonomy and archaeology and getting natural stratum and cultural stratum together, it integrated the results of human activity (relics, remains) into the whole environment system and made up the inaccuracy of age-dating of stratum because of timing at a millennium rate which could not fulfill the study of human-geo relationship(Song Y Q,2002).

For the moment, there are still difficulties in settlements archaeology and environment archaeology. Archaeologist cannot directly observe and traditional technology cannot fully understand and excavate the ancient society, the information of environmental change and the relationship between them included in ancient settlements, relics and remains. This is what new technology and new method are going to resolve. Remote sensing technique is a new technique to explore human culture inheritance and has played a unique role in reflecting spatial differentiation and regional processes of development(Chen S P & Zhao Y S,1999; Guo H D,1992; Luan S N,2004). Successful examples in the worldwide are using different heights of remote sensing platforms of aerospace, aviation and ground with physical method of earthquake waves, electrical and magnetic method to conduct the research of remote sensing environment archaeology of ancient settlements(Wang X Y,2003; H.-J.Pachur and F.Rottiger,1997; Liu S R,1998; Guo H D,1999). ***Geophysics***, the famous magazine, introduced that using geophysics and geochemistry to conduct archaeological detection(Wynn J．C．,1986). In China, the staff

of underwater archaeology research laboratory of the Museum of Chinese History applied shallow seismic method to the exploration of the Yuan Dynasty wreck in the sea area of Sandaogang, Suizhong, Liaoning Province and confirmed in 1993. In 1997, high density resistivity method was adopted to probe the underground ruins of ancient city wall of Song Kingdom in East Zhou Dynasty located in Shangqiu Prefecture, Henan Province and gratifying result was achieved. From 1996 to 2000, remote sensing data was used to detect sites group successfully in Linzi, Shandong Province. Ground Penetrating Radar geophysical technology is taking full advantages of probing buried objects fast and accurately(Yao M,2001). In recent years, a series of national and international academic conferences of remote sensing archaeology have been held in China(Chinese Academy of Sciences-Ministry of Education-Joint laboratory of Remote Sensing Archaeology of the State Administration of Cultural Heritage,2002;The Preparatory Group of the 216th Academic Conference of Xiang Shan Scientific Conference ,2003;Guo H D,2004). Application of the broader term of remote sensing in archaeology including electromagnetic wave detection and geophysical probing has drawn attention(Song B Q & Shao X H,2000).

In the study of ancient settlements archaeology, remote sensing environment archaeology method is introduced to realize the infiltration of archaeology and remote sensing. Archaeology can make a whole deep understanding of natural and social environment ancient people confronted with and examine the complex relationship between environmental evolvement and human development from a rational and thoroughly perspective.

1 The Connotations of Remote Sensing Environment Archaeology

In 1960s, thanks to the development of technology, archaeology speeded to a new stage which includes the application of remote sensing technology in archaeology. This is called remote sensing archaeology. With trends like this, application of remote sensing technology in archaeology represents a new direction for improvement.

Remote sensing is a comprehensive technology of earth observation developing in 1960s(Guo H D *et al*.,2001). Usually there are broad sense and narrow sense. Broadly, remote sensing is a detection technology using electromagnetic waves, gravitational field, electric field and mechanic waves (sound waves, earthquake waves) to sense an object or phenomenon from a distance, without making physical contact with the object. In a narrow sense, remote sensing is a modern technique that using various sensors (eg. cameras, scanners and radars) on platforms at varied heights to obtain information and features of electromagnetic waves of targets upon ground(Barry S. Siegal & Alan R. Gillespie,1980; Chen S P *et al*.,1998). Therefore the research of shapes, sizes, locations, features and the relationships with environment can be conducted through data processing and transmission. Remote sensing archaeology is based on broad sense, conducting nondestructive detection on targets on the ground, underground and underwater. More specifically, it uses geophysical methods such as electromagnetic waves, gravitational field, magnetic field, electric field and mechanic waves to detect, record and analyze ancient sites of different heights of platforms of aerospace, aviation, ground and underground as well as regional environment. Then potential and weak information which cannot be gained by using traditional archaeology method can be obtained.

The origins of remote sensing archaeology technology can be traced back in 1858. G.F. Tournachon, a French writer and artist, took a bird eye view of Paris by hot air balloons for the first time. O.G.S. Crawford, the founder of aerial photography archaeology, Britain geographer and archaeologist, established three marks of aerial remote sensing archaeology detection in his famous book ***Wessex from above*** in 1922: shadow mark, soil mark and vegetation mark. With this, basic theory of aerial remote sensing archaeology had been established and broad remote sensing environment archaeology

stepped onto the history stage. In 1972, the successful launching of U.S. Earth Resource Technology Satellite completed the system of broad remote sensing archaeology technology and made archaeologists review their so familiar but so strange area from an unprecedented perspective. Besides, the introduction of geophysics methods, such as magnetic method, electric method, gravity probe and mechanic waves detection, enable broad remote sensing to conduct underground probe and analysis. With this, broad remote sensing archaeology technology is supported by space remote sensing detection technology, aviation remote sensing detection technology, on the ground and underground geophysics detection technology.

With the rise and development of environment archaeology, combined with the method, broad remote sensing archaeology researches the natural environment and its relationship with human in all periods and discusses human activity in the changing environment. Broad remote sensing archaeology technology and environment archaeology moved from multi discipline to inter discipline. This extends contents of broad remote sensing archaeology and makes it develop to the integration of broad remote sensing environment archaeology technology(Wang X Y,2005). Remote sensing environment archaeology uses marks on the remote sensing images left by environmental change to discuss ancient geographical environmental change and its relationship between ancient civilizations. As the supportive technology, broad remote sensing environment archaeology technology is based on information science, geological, archaeology and historical geography. On the ground and underground information of historical site is obtained by the detection of Aviation and geophysics. Images are under macro-analysis and underground micro detection by processing and integrating information to recognize nature and distribution characteristics of relics. Combining with environment archaeology technology including dating techniques, pollen analysis, elements geochemical analysis and identification of relics and remains, virtual and digital ancient natural environment can be rebuilt and natural and human geography environments can be restored. Compared to traditional archaeology, broad remote sensing environment archaeology expand research of single point to points, lines and planes and then to four-dimensional (Fig. 1). With the introduction of new technology, information extracted will be more and more accurate and the study of archaeology will be deeper and improved. Many important historical problems will be solved by reasonable explanation.

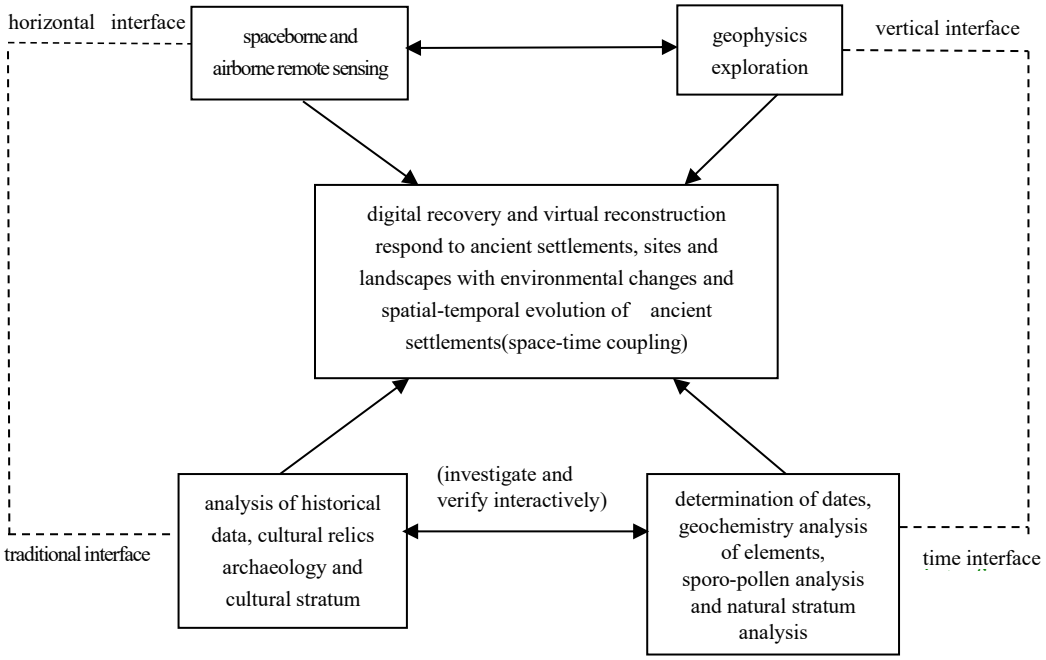

Fig.1 Connotation of generalized environmental remote sensing archaeology

2 The Remote Sensing Environment Archaeology Method of Ancient Settlements

As a means of archaeology, ancient settlements archaeology should follow the basic methodology of archaeology. At the moment, traditional systematic regional survey is considered to be the most effective method of investigating settlements. Through dragnet investigation over a certain area, distributions, quantities, ages, features and conditions of settlements in this area can be mastered. However, because of some objective reasons, such as large amount of ancient settlements and features not so obvious of a large part of settlements(such as underground or underwater ancient settlement site), archaeology needs a great deal of money, manpower but with low efficiency and long hours while in fact, lack of money and manpower often happens. Besides, in some areas with inconvenient transportation, tough natural conditions and complex topographical features, such as desert, grassland and remote mountainous areas, it is difficult to use traditional archaeology method. In order to achieve the aim of the research effectively, remote sensing environment archaeology method is playing a unique part in it.

2.1 Remote Sensing Environment Archaeology Method Interpreting the Existence and Location of Ancient Settlements

2.1.1 General Remote Sensing Environment Archaeology Methods of Interpreting the Existence and Location of Ancient Settlements

Researches of using remote sensing environment archaeology method to interpret the existence and location of ancient settlements have been carried out in the worldwide and achievements are made in this field(Guo H D,1999; Anhui Institute of Cultural Relics and Archaeology & The Museum of the city of Huai Bei in Anhui Province,2002; Rosa L & Nicola M,2007; Aled R & Apostolos S,2007; V.De Laet et al.,2007; Nicola M & Rosa L,2007; Tian Q J,2007). Ancient settlements can be divided into two types based on the condition of preservation: remains on the ground and remains underground(Belvedere O et al.,2001). The first thing to do is to get information source of regional remote sensing image. Remote sensing images can be classified by the height of platforms to ground remote sensing, airborne remote sensing and satellite remote sensing. They can also be classified by the way images obtained to camera images, scanner images and radar images. These images present the features of ground targets. With these features, the identification of targets can be set up. Integrating remote sensing data of different sensors to realize the integration of remote sensing information, which is very useful to comprehensive analysis of identification. Interpretation signs can be divided into direct interpretation signs and indirect interpretation signs. However, interpretation signs are changing with various factors. So affect and influence of every factor should be considered when accessing and selecting remote sensing images. For example, it is easier to do multidimensional comprehensive analysis by choosing remote sensing images taken in early winter because smaller influence of plants.

After obtaining remote sensing images, it is the time of interpreting them in archaeology. To the remains of ancient settlements on the ground, the images are enhanced and classified to improve the interpretation and visual effect. Select characteristic parameter by doing spectral measurement and feature analysis and information extraction to realize classification and set up interpretation signs. According to expert's experience knowledge, the existence and location can be directly interpreted by the shape, size, tone, color, shade, texture, pattern, layout and relative position of the target. Even the overall shape and distribution characteristics of ancient settlements can be outlined. This method is often used in the archaeology study of west China, such as the study of ancient settlements remote sensing environment archaeology of Silk Road(Liu S R,1996) and Inner Mongolia area(Zhang D Y,2007).

As to the remains of ancient settlements underground, it is hard to directly interpret. Since these remains are human made, there are differences between remains and undisturbed surroundings. These differences are reserved to varying degrees by surface moisture conditions, vegetation growth status, land use modes and geomorphological structures. The differences are recorded in the remote sensing images and provide bases of interpretation analysis for archaeology. Indirect interpretation signs of targets can be set up to interpret. These interpretation signs are as follows.

①Shadow mark: In the remote sensing environment archaeology, some indiscoverable marks can be found by observing the spread of sunlight and shadow. This is shadow mark. The obvious degree of shadow is related to slanted sunshine and specific circumstance of ancient settlements. So in practice, select appropriate observation time and the directions of sunlight in accordance with specific conditions of ancient settlements so that faint information can be visible. Shadow effect achieves the best result when it is sunny as there is little dust effect. Ancient settlements underground can also lead to the differences of soil layer thickness and soil moisture and then cause the growth difference between vegetation and surroundings. These differences can be showed by shadow, then ancient settlements underground can be discovered.

②Soil mark: The difference between light and dark of soil caused by soil quality can be seen from the new-plowed fields. It is because activities of ancient human interrupted the natural order and structure of soil layers. Soil particles of ancient settlements were changing due to the activities of human, which leading the differences of ability of absorbing water and retaining moisture between these soil and surroundings. In most cases soil particles of relics are finer than natural ones. After the rain the moist degree and water content will be different. The existence of ancient settlements can be interpreted based on these differences. Normally, the color of surface is darker than surroundings if remains underground are ditches and moats. On the contrary, the color of surface is lighter than surroundings if relics underground are wall footings, packed dirt and roads. It is better to take the image in spring or autumn after plowing or under less cloud cover.

③ Vegetation mark: The differences of moisture and nutrient between underground remains and surroundings affect the growth and color of plants on the ground. The existence of ancient settlements can be discovered based on these differences. Generally speaking, soil particles of remains are finer and moister than natural ones. Besides, much soil of ancient settlements contains organic matter, humic matter and more nutrient. Plants grow better in the soil of ancient settlements. In addition, the rocky soil which was loosened by human activities is beneficial to the growth of plant rhizomes and plant will be more flourishing than surroundings. This vegetation mark is called positive vegetation mark. On the contrary, if rhizomes encounter wall footings, packed dirt and roads, roots cannot deeply penetrate. Plants will be smaller and yellower than surroundings because of lack of water and nutrient. This is called negative vegetation mark. Vegetation mark is directly related to the growth of plants, so it is the best time to observe vegetation mark during growth stage. The length of time of vegetation mark can be presented by different colors (green – yellow) or different tones (dark green – light green). In a certain time, if the difference of colors is not obvious, ancient settlements can be traced by observing the heights of plants.

④Frost and snow mark: In the early winter or late winter, by observing the spread of frost and snow around ancient settlements with uneven earth's crust, the existence of relic can be showed. This is called frost and snow mark. To ancient settlements underground, because of the different moisture of soil, different temperatures lead to different rates of melting. Positive and negative frost and snow marks arise. Generally speaking, if relics underground are ditches or moats, soil particles are finer and

more moist than surroundings. In late autumn and early winter, water contained in the relics will change from liquid state to solid state during the suddenly first frost or snow. In this process, heat is released and melts frost and snow on the relics. This is negative frost and snow mark. In late winter and early spring, frozen relics need more heat to thaw out and the snow will melt slowly. It is positive frost and snow mark. If relics underground are wall footings, packed dirt or roads, positive frost and snow mark appears in most time in winter. It is because in early winter soil layer on the relics will soon freeze while in early spring relics and frozen soil needs more heat to melt due to the slow rate of melting.

By studying the processing of the remote sensing images with the setting up of ancient settlements relics interpretation signs (direct signs and indirect 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 constraints of interpreting staff's experience and knowledge, the accuracy of the existence and location needs to combine remote sensing environment archaeology method and geographical information spatial analysis method to realize the reasonable recognition.

2.1.2 Ancient Settlements Recognition of Multi-Source Information Composition of Remote Sensing Environment Archaeology Supported by Spatial Analysis

The regularity of distribution of ancient settlements is closely related to geographic locations, geomorphic types, natural environment and economic types. For example, most ancient settlements were distributed along fossil river courses. The specific shape depends on river orientation and resource capacity of both sides of the river. Ancient settlements at the front of mountain were generally distributed along the foot of the mountain. They are similar to those coastal ancient settlements of similar altitudes. In the plains area, ancient settlements were distributed in a scattered way in the early time. With the development of society, the number of ancient settlements relics increased and settlement clusters groups were formed. These distribution features provide a basis for interpreting existence and locations of ancient settlements by spatial analysis. Spatial analysis is a technology that obtaining relative spatial locations, distributions, shapes, formation and evolution of geographic objects from spatial data. The applications of spatial analysis in remote sensing archaeology are spatial overlay analysis and buffer analysis.

Spatial overlay analysis is a method of extracting implying information. Generally speaking, because of the close relationship between the distribution of ancient settlements and surroundings, using remote sensing to study long periods of environmental change history and extract spatial relationship features of river course (including fossil river course), roads, residential areas, landscapes and landforms. These must be closely related to the distribution of ancient settlements, especially the evolution of palaeodrainage system. The evolution of the ecological environment in one area showed up first in river system, then affect human activities. Using specific spectrum characteristics of objects on remote sensing images, the routes and directions of river system can be reflected by analyze soil moisture, soil saltiness and sediment composition. In topography and morphology, due to the limitation of the use of natural condition, people had to live in the place which was near the water and above the water to resist floods. High ground, mound ground, river terrace and manmade highland are used to live in. So shapes of many ancient settlements are terrace, mound and barren slope. Existence and locations of ancient settlements can be effectively determined by these spatial distribution characteristics. Spatial buffer analysis is to set up a polygon of which the bounding region is determined by a set of points, lines and plans at a specified distance from all nodes along segments to

present the influence rage of a certain geographic entity to neighborhood area. In general, people would not conduct agricultural production in an area which was more than an hour's walk away(Tang Z W,2004). This is considered as diseconomy. So the distance of ancient settlements along the river can be estimated and the location of ancient settlement can be determined effectively by doing a buffer with a certain distance from river system.

So, the working thought of ancient settlements recognition of multi-source information composition of remote sensing environment archaeology supported by spatial analysis is as follows. First, after determine the study area, selecting remote sensing images and collecting historical geography literatures, process and interpret the remote sensing images and initially set up the interpreting signs of ancient settlements. Then many suspected sites of ancient settlements can be determined. Second, by processing the remote sensing images of the study area, apply remote sensing environment archaeology to interpreting the river course (including fossil river course, fossil river system), roads, residential areas, landscapes and landforms. And use GIS software to do digitized map. Third, by spatial overlay analysis, data layers formed by related theme layers, including suspected ancient settlements sites layer, river course and river system layer (including interpreted fossil river system), roads layer, residential areas layer and landscapes and landforms layer, overlay to produce a new data layer and combining with buffer analysis of fossil and contemporary river system, roads, residential areas, synthesize properties of layers and realize the composition of remote sensing information and non remote sensing information. This is multi-source information composition of remote sensing environment archaeology. Last, combining spatial relationship and distribution rule of ancient settlements and surroundings with multi-source composition information, eligible ancient settlements sites are filtered from suspected ancient settlements sites. And verifying by field research and historical geography literatures, existence and locations of ancient settlements can be determined and ancient settlements recognition of multi-source information composition of remote sensing environment archaeology supported by spatial analysis can be realized (Fig.2).

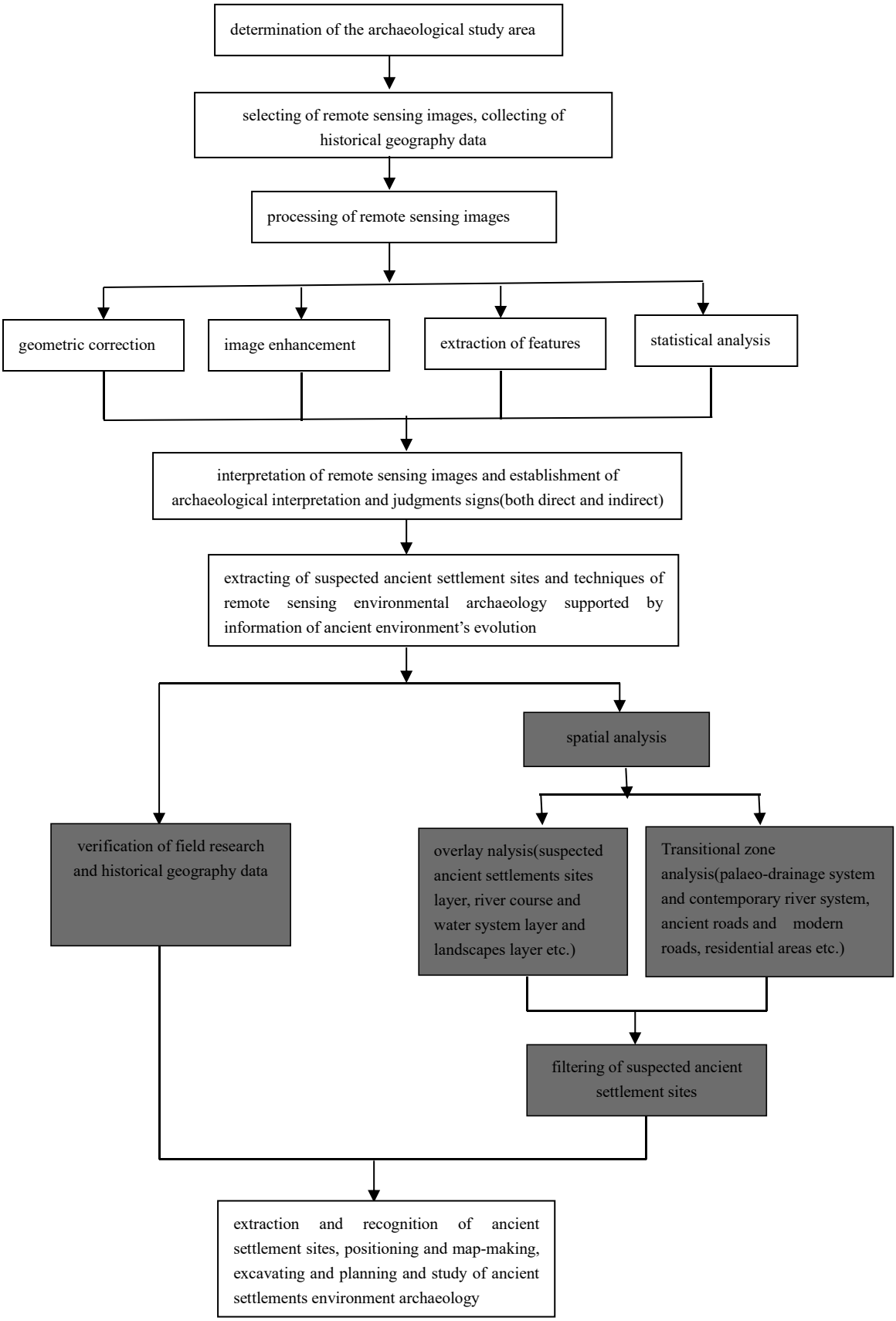

Fig.2 Technical work-line about the detection of ancient community site by multi-source information based on environmental remote sensing archaeology and spatial analysis

2.2 The Study of Remote Sensing Environment Archaeology Method to Ancient Settlements

Landscape Patterns

The study of ancient settlements landscape form consists of ancient settlements layout and internal structure and spatial distribution of ancient settlements and their relationships. The study of ancient settlements layout and internal structure is micro ancient settlements landscape form study and the layout is often closely related to the internal structure. Differences exist between ancient settlements structures due to different periods. This leads to the historical evolution of ancient settlements patterns. Remote sensing environment archaeology method offers help to the study of ancient settlements patterns and play unique roll in revealing overall ancient settlements layout and internal structure of a large area under non-destructive detection condition. An Italian named Leopoldo Franco found 1255 ancient ports and revealed the layout and structures and the cultural meaning by conducting remote sensing environment archaeology research of Mediterranean coast(Leopoldo F,1996). He also proposed the protection countermeasure.

Now the study of application of remote sensing environment archaeology method to ancient settlements distribution and internal structure is mainly about airborne hyperspectral remote sensing images and panchromatic aerial images. It applies mainly to larger scale ancient settlements(The Remote Sensing and Aerial Photography Archaeological Center of the Museum of Chinese History et al.,2002;Shang Dong Institute of Cultural Relics and Archaeology,2000), such as the research of remote sensing environment archaeology of ancient cities. The aerial remote sensing image is a central projection image of transient imaging. The geometrical relationship of the image is stable and with the smaller of geometry, it is easier to recognize subtle archaeology phenomenon. It has been already used in the remote sensing archaeology of ancient cities in Beiting, Gaochang and Hanchang'ancheng(Liu J G & Wang Q S,2006).

Airborne hyperspectral remote sensing images include wave band range from visible light to thermal infrared band. Using hyperspectral images of 0.45-1.1μm to recognize abnormal information of soil, look for spectral absorption band features of burnt-soil and rammed earth, etc and analyze corresponding wave bands. High brightness of thermal infrared represents abnormal area. So use single band images (eg. thermal infrared band) to composite pseudo-color images and improve the displays of large scale images and keep features of details. This method applies to the images processing of gentle terrain. The method of compositing pseudo-color images can highlight background abnormal information and keep part abnormal information. It can also clearly reflect the layout and internal structure information of ancient settlements such as mounds, drainage channel, etc. This method was used in the research on Qin emperor mausoleum and achieved good results(Zhou X H et al.,2007). By processing and analyzing airborne hyperspectral remote sensing images, experts confirmed the existence of westward funeral pathway of the tomb and the distribution and controlled scope of the drainage ditch.

The response of panchromatic aerial images to the change of brightness of terrain and surface is the most obvious. The reasons of surface brightness change are various, including ground humidity, vegetation type and coverage, soil type and grain size, terrain slope and aspect, etc. Most large ancient settlements are tombs and buildings, many remaining relics on the ground surface gradually disappear because of long-term weathering, denudation, scour, sediment cover, grave robbing and large scale artificially transforming. However, these information may probably be kept in the early panchromatic aerial images. Moreover, with the help of stereocompilation technology, terrain features can be expressed by Digital Elevation Model. Highlight differences of terrains by doing three-dimensional projection transformation and changing the parameters of observer's location, observation height and

distance and solar elevation angle, etc. typical success example is the remote sensing environment archaeology of structures of ancient Yuhang Pingyao, Liangzhu, Zhengjiang Province(Zhang L & Wu J P,2007). This research used panchromatic aerial images of different periods to interpret ancient settlements building structures and northwest ancient water conservancy project of Liangzhu culture.

In addition, multi-source remote sensing data composition, which is the remote sensing data composition of different sensors or different periods, can complement advantages of different remote sensing data sources and enlarge applications of remote sensing data. It is favorable to the comprehensive analysis of image data and further study of archaeology targets. The studies of Tongwanc city, Jingbian, Shanxi Province and ancient great wall in Yulin successfully use multi-source remote sensing data composition to extract information of Great Wall. Anhui cultural relic archaeology institute and geological remote sensing station cooperated successfully to do remote sensing archaeology detection of Shouxian Shouchun city by using different scales black and white aerial photographs, color infrared aerial photographs and satellite images from 1954 to 1980 and discovered Zhanguo Chudu Shouchun city and north west Han Shouchun city and Tang Song Shouchun city(Yin N,2004).

Discussing spatial distributions and mutual relationships of ancient settlements in large spatial scale is a macroscopic way of study ancient settlements landscape forms. The research of ancient settlements spatial distributions and mutual relationships is helpful for us to understand social economic production situation and the relationship between survival of ancient human and environment of the day. However, it is difficult to see the big picture by traditional ancient settlements spatial distributions and mutual relationships due to the large size of study area, heavy workload of fieldwork and field investigations and limitation of people's vision. Field investigation is more tough especially for particular environment such as mountain fields, deserts, grasslands and areas of water network. Remote sensing image is high overlooking image so that it can provide wider environmental observation view and overcome terrain obstacles. Remote sensing environment archaeology not only realize the integration of airborne survey and ground survey, but also hold spatial distribution features of ancient settlements from a macroscopic view. It can change tough field investigation into indoor analysis and speed up work to effectively reveal mutual spatial relationships between ancient settlements. For example, in the archaeology study of Tudun tomb(Gong X C,2001), Nanlingxian, Anhui Province, remote sensing environment archaeology was effectively used to determine the spatial distributions and mutual relationships of Tudun tomb and speculate the origin of culture combining the analysis of geographic environment.

3 The Integration of Ancient Settlements Remote Sensing Environment Archaeology Technologies

The advantage of remote sensing environment archaeology applied to ancient settlements archaeology is that it integrates modern remote sensing technology with traditional remote sensing technology and new environment archaeology practice. Traditional remote sensing technology often replaces the planes with points when doing research because of the limitations of ground conditions and objective factors. In this case, omissions of known study area are inevitable, some unknown information is hard to be discovered and revealed and it is often destructive detection. Remote sensing environment archaeology can remove these negative factors and extend the "point" research of traditional ancient settlements archaeology to systematical research of most ancient settlements sites from a macroscopic way. It uses nondestructive detection from plane to line and then to point and extends settlements archaeology in depth (Fig.3).

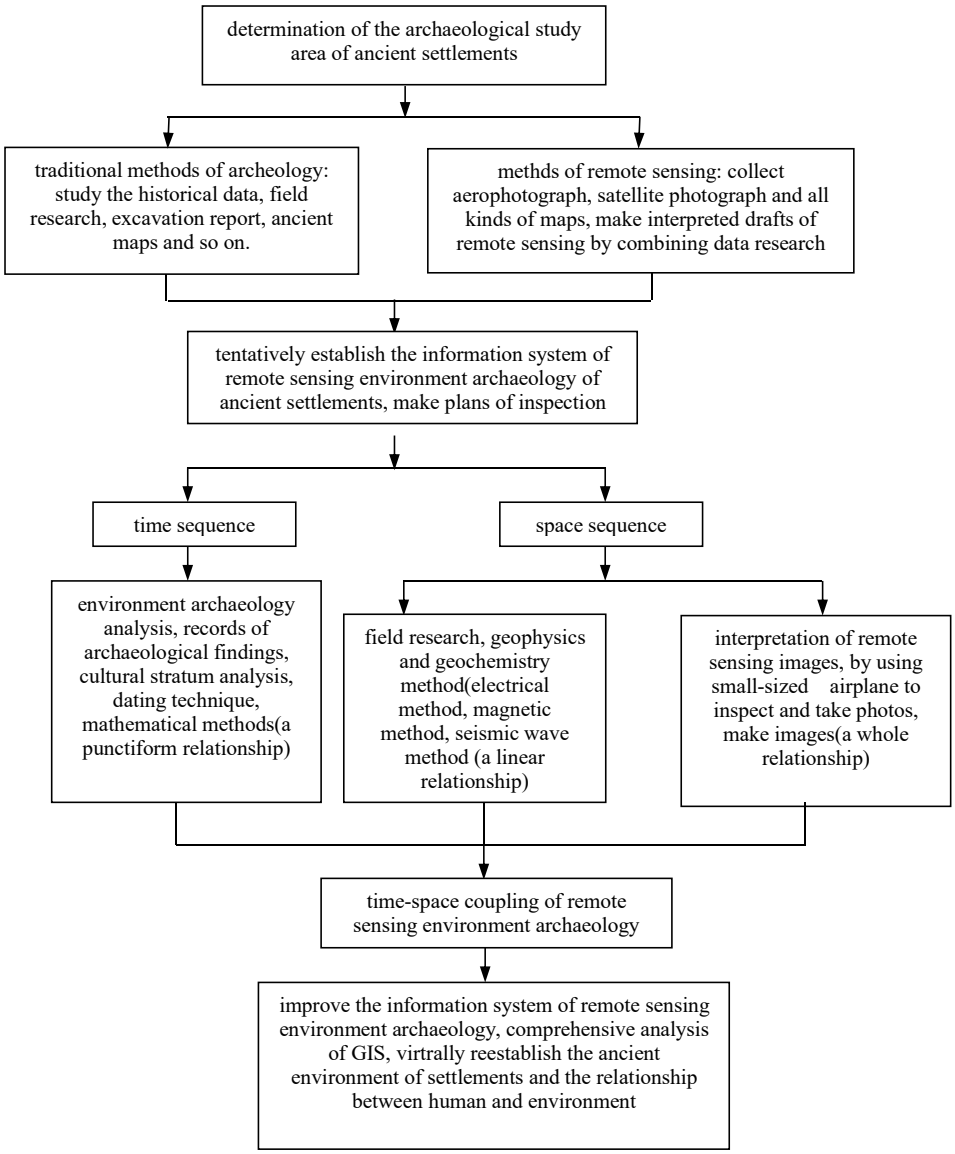

Fig.3 Technical integration of environmental remote sensing archaeology of community sites

For planes, collect multi-source remote sensing images of different sensors such as aviation and space and different periods to conduct information composition and analysis. Combining with spatial relationship analysis of GIS technology, set up interpreting signs of ancient settlements sites and interpret and analyze them. Then find the target region of ancient settlements sites. For lines, determine the route of field investigation and on-the-spot investigation of study area, and use geophysics and geochemistry method (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.) to establish the route. With the analysis of historical geography literatures, extract and recognize ancient settlements, then position them and mapping them. For points, detailed excavation plan is made. Culture relic archaeology institute will do trenching reveal about study areas even key sections and conduct research of stratigraphy and utensil typology on cultural relics. Utensils are under chemical analysis. For example, X Ray Fluorescence can test microelements of ancient utensils and then explore the information about the place of origin. Data from different ancient settlements sites can be analyzed to find the relationship by mathematical methods. Then explore ancient human connections in different areas and set up a linear relationship.

Association of planes, lines and points is set up by dating techniques (^{14}C dating technique), stratigraphic analysis and paleoclimate analysis. That is, string spaces by timeline to realize four-dimensional time-space coupling. And at last analyze and compare layouts, structures, patterns, spatial distributions and mutual relationships to reveal corresponding relationship of ancient settlements changes, ancient human activities and ancient environment changes and explore rise and fall laws of cultures and civilizations.

4 The Future of Remote Sensing Environment Archaeology in Settlements Archaeology

From 1960s to 1980s, international scientific community organized International Biological Program (IBP), Man And Biosphere (MAB), International Geosphere Biosphere Program (IGBP) and Global Change Study. These programs reflect the development direction of scientific studies in this area changes from nature to the combination of humanity with nature. Remote sensing environment archaeology is an important way to discuss the relationship between ancient geographic environment and ancient settlements with ancient culture. The change of ancient geographic environment has significant impact on the change of settlements, civilization succession, political change and lifestyle change. The combination of settlements archaeology and remote sensing environment archaeology will play a unique role in revealing regional environment change, ancient settlements change and the response of human activity.

Remote sensing environment archaeology is an emerging technology and course and the application in ancient settlements archaeology needs further research, practice and development. First, more practice of remote sensing environment archaeology of ancient settlements should be done. Especially the extraction of weak information of remote sensing environment archaeology target should be highly valued to set up spectral library of various typical targets of archaeology. Second, further conduct the researches of interactions between electromagnetic wave and ancient settlements, especially the mechanism researches of remote sensing information transfer of underground hidden typical archaeology targets. Take full advantage of multi-source information composition of different platforms, different periods, different sensors, multi spectrum, multidisciplinary and multi information technology to realize the composition of multi-source remote sensing information and the composition of remote sensing information and non remote sensing information. Give full play to different electromagnetic spectrums and geospatial information. Third, strengthen the integration research of remote sensing environment archaeology technology to achieve visualization of ancient settlements and ancient environment.

Remote sensing environment archaeology has broad application prospect in settlements archaeology. It is an indispensable part in the present third national archaeological survey and will work better in the ancient settlements archaeology. We are doing response study of ancient settlements changes to environment changes including Chaohu lake basin. That is, rebuild ancient environment change in the study area and its impact on ancient human activities and ancient settlements changes by remote sensing environment archaeology. Chaohu lake region is the transition zone of north and south fauna of Chinese quaternary period. Its unique geographic location and environment made it the birthplace of Hexian Longtandong apes (about 300,000 years ago)(Yang Z D & Gong X C,1998) and Chaoxian homo sapiens (or late homo erectus) (Huang P H et al.,1995). Currently, known early Qin ancient settlements around the Chaohu lake can be divided into two types by periods. One is Neolithic ancient settlements distributed mainly over 40 places, such as Hanshan, Feixi, Lujiang. Lingjiatan site, which is the national key cultural relic preservation organ, was a prosperous ancient settlement 5,300 years ago. It already formed center settlements and settlement clusters(Shen G J et al.,1994; Anhui Institute

of Cultural Relics and Archaeology,1989,1999; Shuo Z,2000) and its jade production technique was closely related to the culture of late Songze and Liangzhu of Tai lake basin(Zhang C,2003). The other outstanding one is the Shang Dynasty ancient settlements and nearly 300 relics have been found with denser distribution. According to historical documents, Juchaoguo (also known as Nanchao, Chaoboguo) was important to Yin and Zhou Dynasties. Inscriptions of bronzes ***Food Container Made in honor of a famous minister in the ancient time,Free Ticket for transportation of a famous minister in ancient time*** and had recorded Chaoguo(Wei S S,1999). Chaohu lake basin in Han Dynasty was still a relatively developed area. There were many ancient settlements and tombs. A lot of precious cultural artifacts of Han Dynasty were unearthed in Beishantou and Fangwanggang of Chaohu lake city. After Han Dynasty, the number of ancient settlements and tombs decreased sharply. Importantly, obvious changes of geographic environment happened in the period of 4,000 years (6000-2000a B.P.) in Chaohu lake basin(Wang X Y,2005). This is a noticeable environment-culture response phenomenon. Looking for the changes of ancient settlements spatial distributions from 6000 to 2000a B.P. under the influence of natural geographic elements, revealing the impact of regional environment change on rise and fall of civilizations, the study of remote sensing environment archaeology applied in settlements archaeology will be the successfull guarantee of solving problems. It will be a new technology of exploring humanity cultural heritage and has broad applied prospects.

Remote sensing reflects the spatial distribution and geographic environment of ancient settlements from a macroscopic view. Many details need to be explored and confirmed by field archaeology. Traditional settlements archaeology method is still very important. So only combine the technology of remote sensing environment archaeology with traditional settlements archaeology can remote sensing environment archaeology technology works to its advantage. Then archaeology techniques and methods can be developed and remote sensing environment archaeology of ancient settlements can be realized.

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