Boundaries or Networks in Historical GIS: Concepts of Measuring Space and Administrative Geography in Chinese History

Merrick Lex Berman

New research in historical geographic information systems (HGIS) on the changes of administrative geography over time has revealed a number of unique problems. In the first place, our current conceptions of bearings and distance must be reconciled with those of the past. This is a critical issue in the case of China because historical geographies are often reconstructed from textual evidence that contains measurements of distances and directions. And yet, lacking any way to check the consistency or accuracy of these figures, when positions based on this information are calculated using GIS we are bound to end up with false, or at best fuzzy, conclusions.

It is equally important to be conscious of the difference between claimed jurisdiction over a given territory and actual occupation or governance of that territory. Where two political entities lay claim to the same space, should a map be drawn from the point of view of one or the other or both? When dealing with subjective, contradictory historical evidence, historical GIS must provide a means of showing competing claims over the same territory.

Finally, the ways in which individual landholdings, towns, and villages were related to their superior jurisdictions must be reexamined. When working with modern census data, transportation networks, topography, and accurate locations, it is possible to construct elaborate models of administrative or economic systems in order to examine the rural-urban continuum. However when extrapolating backwards in time, not by decades but by centuries or millenia, is it reasonable to demarcate a boundary in between two higher jurisdictions when their respective subordinate units can barely be identified as points, let alone areas, and when those subordinate points are thoroughly interspersed with one another?

Merrick Lex Berman is Project Manager of the China Historical GIS Project at Harvard University.
Historical Geography Volume 33(2005): 118-33.

Based on these factors, I must question the appropriateness of defining historical administrative geographies with a conventional GIS model of bounded jurisdictions that leaves no areas undefined. The further one delves into the remote past, the more one must rely on information about administrative hierarchy, and the less certain one can be about jurisdictional areas. Therefore, in a system where areal measures can only be approximate at best, the application of network models that represent documented relationships between known points is potentially more appropriate for the task of defining ancient administrative geographies.

Defining the Roles of Historical Administrative Units

In modern times we are accustomed to thinking of states and their political divisions as existing in demarcated spaces, with clearly defined borders that can be measured and mapped. The administrative offices, or seats, of these political divisions also are clearly identifiable to us. Neither jurisdictional areas nor administrative seats are permanent, but they can at least be defined by known locations and boundaries. For example, the capital of Germany (represented as a point) can move from Berlin to Bonn, and back to Berlin again. And the island of Hong Kong (represented by a polygon) can be recorded as a particular kind of jurisdictional area within different political systems: a Crown Colony for a certain period of time, then a territory of the United Kingdom, and then a Special Autonomous Region of the People's Republic of China. These are definable as geographic objects. Berlin and Bonn can be represented with point locations, and Hong Kong island with a polygon. Nor would there be any problem in the reverse, representing Berlin and Bonn as polygons, and Hong Kong as a point.

Depending on the availability of historical sources, changes of historical administrative units can be traced backwards in time for a limited period with a reasonable degree of accuracy and confidence in their spatial representations. In Great Britain, various divisions such as poor law unions, registration districts, sub-districts, and parishes have been reconstructed from maps and various textual sources from present times back to the 1860s, when the civil parish system was created.[1] In Belgium, the administrative system was modeled on the French system, beginning in 1796. From that date, one can map clearly defined departments, districts, cantons, and municipalities in Belgium and trace their changes up to the present.[2]

When we move backwards in time to earlier epochs, several important factors begin to limit our ability to define historical administrative units. The first is the scarcity and inaccuracy of map sources. The second is the lack of completeness in coverage, both in maps and textual sources. Third, the very conception of territory and how it relates to historical administrative structures may not be best reflected by our modern no-

tions of bounded jurisdictions. For all of these reasons, when approaching pre-modern, medieval, and ancient sources it is necessary to define and set limits to the types of administrative units that will be treated in historical GIS, and establish which GIS data type can best represent the roles that they played in the administrative hierarchy.

What kinds of administrative units should be used to frame the geographical structure of a national GIS? In the case of China, there were as many as 1,600 county seats, hundreds of thousands of towns and villages, and up to several million rural settlements over the length and breadth of the Empire and over the course of time.[3] In China, the county (*xian*) has been the fundamental reporting unit since the Qin Empire (222 BC to 206 BC), so counties can be established as the basic units, while the balance of administrative hierarchy would include all jurisdictions superior to the county.

What of smaller localities below the county—towns, villages, and rural settlements—should be included in the historical GIS database? Although towns and villages are frequently listed or mentioned in Chinese local gazetteers, the spotty coverage and lack of uniformity in their descriptions places them below the threshold of functional units in the administrative hierarchy. Nonetheless, as named places, towns and villages serve an extremely important role for the contextualization of spatial data. Therefore, as many town and village locations as possible should be included in the database, making note of the parent jurisdictions of each.

Which GIS data type can best represent historical Chinese administrative units? This question is raised in order to highlight the discrepancy between extant historical sources, which contain inconsistent narrative descriptions of administrative units, and the nature of vector-based GIS software, which represents geographical entities as point, line and polygon features on a projected surface. The spatial objects depicted in GIS have the appearance of accuracy and precision, regardless of the uncertainty or error contained in the source materials from which they were produced. Even when metadata describing the degree of possible planimetric error in the data is provided, the visual impact of spatial data presented as maps tends to conceal rather than reveal uncertainty. These problems are only compounded when one attempts to map change over time.[4]

For the GIS to represent the real changes of historical Chinese counties (*xian*) over time, both the location of the administrative office, or county seat, as well as some method of tracking changes in the jurisdictional area must be accounted for. There is clearly a higher degree of confidence about the location of county seats represented as point features than there is about locations of jurisdictional boundaries. Indeed, moving backwards in time there are fewer and fewer extant map sources. Lacking base maps, the reconstruction of ancient boundaries must proceed by juxtaposing segments of more recent boundaries with estimated segments that enclose point locations of subordinate towns and villages. This can

only be accomplished by maximizing the number of town and village points in order to increase the number of possible atomic elements that are then aggregated into a known jurisdiction. In China, the lack of cartographic sources showing county boundaries before the Ming Dynasty (1368 AD to 1644 AD) necessitates the maximization of points for all earlier periods. Which is to say that there exists some cartographic basis for trying to draw realistic county boundaries for nearly five centuries of Chinese history (with marginal geographic accuracy), and none whatsoever for the preceding 2,000 years.

Paul Wheatley, in his comprehensive work on the origins of ancient Chinese cities, noted the constant and abrupt fluctuations of boundaries in the Eastern Zhou period (770 BC-240 BC). Wheatley goes on to point out that the method of "connecting the outermost localities assigned" to a particular state in a particular source can be used to depict the extent of the core territory of that state.[5] Even so, the general extent of ancient territories can only be estimated in this way, because the effective control of the state must have extended for some unknown distance beyond those outlying subordinate localities (Figure 1, left side).

Is it really worth the trouble of trying to depict the administrative structure of ancient states as areal extents in GIS when concrete evidence about where exactly to draw the outer boundaries lines is lacking, and when there is no way to inform the end-user about the degree of uncertainty associated with the boundaries one employs? Indeed, why must historical records describing superior and subordinate units in the administrative hierarchy be defined by bounded areas at all? Does it not make more sense to reconstruct historical administrative hierarchies as line networks connecting superior and subordinate point nodes, rather than polygons representing discrete areas? After all, once the hierarchical structure of subordinate points has been established, GIS techniques, such as aggregations of Tiessen polygons, can be used to create estimated boundaries as needed (Figure 1, right side).

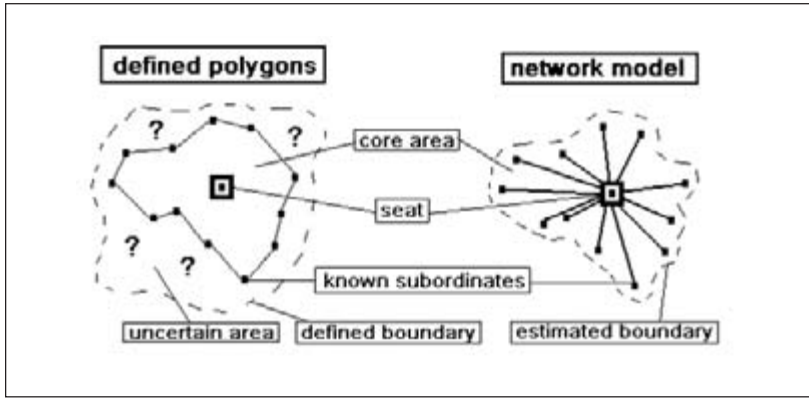

Figure 1. Defined polygons compared with network model.

Perhaps the argument that it is better to depict relationships between known points as a network of lines rather than as uncertain spheres of influence around those points is not sufficiently proven. Therefore let us turn to some specific Chinese examples, in order to determine whether or not there are some compelling reasons in the historical record that make one approach preferable to the other.

Conceptualizing the Measurement of Space in China

There are many ways to approach the idea of measuring space in China, including cosmological divisions of heaven and earth, detailed examinations of local economic systems, and the relationships between central places and peripheral hinterlands. For the purposes of this brief survey I will not go into the more detailed analysis of regional systems, such as the hierarchical regional space of G.W. Skinner.[6] Instead I will introduce several ways in which space has been measured, divided, and administered in the historical sources on geographic information in China. An examination of these ideas will help to decide which spatial objects must be used to represent historical administrative divisions in China, and to determine the parameters for use of spatial objects in the broader field of historical GIS.

As early as the Warring States period (beginning in the fifth century BC), political philosophers debated the central role of land tenure in China as a means of measuring and apportioning space for private and communal use. The "well-field land system" resurrected by Mencius (circa 300 BC) promoted the idea of dividing space into nine equal areas on a grid, the shape of which looks like the Chinese word for "well" (Figure 2, left side). Of the nine equal squares, eight parcels were to be cultivated privately and one, in the center, was to be cultivated in common. The harvest of the common field was to be presented to the state as tax. An even more complex system was proposed by Shang Yang (circa fourth century BC) in which parcels were neatly divided by roads and irrigation ditches, and individual fields were enclosed by dikes with special ramparts that could be easily identified from one season to the next (Figure 2, right side).[7]

Were such systems of land tenure ever really used? Mencius was writing about a practice purported to have existed in the Western Zhou period (eighth century BC). In reality, the diversity of the terrain would not accommodate the well-field system. This was a purely theoretical division of space. By imposing bureaucratic order on the natural landscape, Mencius reveals the tension between geographies based on villages with real dimensions in the natural landscape, and presumptive jurisdictions that must fit into an administrative hierarchy. Passages in the Rites of Zhou [*Zhou Li*] indicate that during the Zhou period there were core areas of political control, centered on city-states, and also hinterlands where little if any

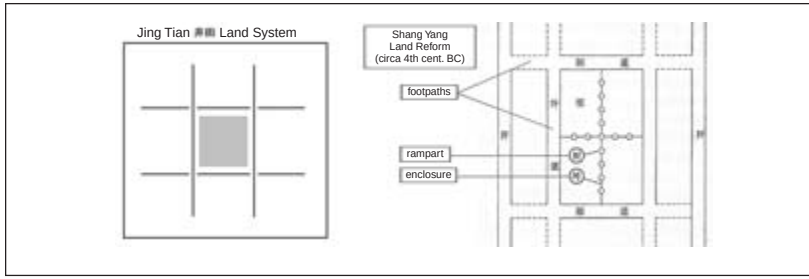

Figure 2. Well-field system and Shang Yang's distributed land system.

political administration existed. Terms used to describe the core and periphery in the Rites of Zhou related to the people who lived there: the *guoren,* meaning the "subjects" of the state, and *yeren*, the "outsiders." [8] Of course the *yeren* were considered to be vassals too, along with all under heaven, but they were nonetheless existing outside of the immediate influence of the state. It is therefore much more realistic to think of the state [*guo*] as an aggregation of subordinate localities under the rule of a walled capital city, the influence of each diminishing as distance from their walled administrative center increased.

This capital-centric view of territory harks back to term *guo* itself, which in Archaic Chinese refers at once to the territory of the state and to the walled town where the ruler presides.[9] The idea becomes firmly rooted in the Confucian theory of Five Domains, in which the political power of the Chinese ruler radiates outward from the capital through a series of surrounding zones, progressively diminishing in each zone, until ending up in the Wild zone.[10] Although mythical in nature, the Five Domains captured an essential quality of the capital-centric view of space.

The problem with both the well-field system and the Five Domains theory as a means for representing spatial dimensions is that maps based on them are reduced to geometric diagrams with symbolic rather than practical value. On the other hand, the idea of core and periphery can be easily envisioned if we sketch the natural environment of an administrative seat. Here we have a town as central place, surrounded by both wall and moat. Outside the town are various land-holdings (a "suburban" area for want of a better term) that form the core territory, beyond which lies a hinterland of villages and hamlets at the periphery (Figure 3).

Mapping Space in China

Though we lack physical examples of maps from the Warring States period, many famous passages about the strategic importance of maps for military campaigns and political control are found in the centuries preceding the first unification of China as a single empire (fifth to third centuries BC).[11] Indeed, a fabled assassination attempt on the King of Qin,

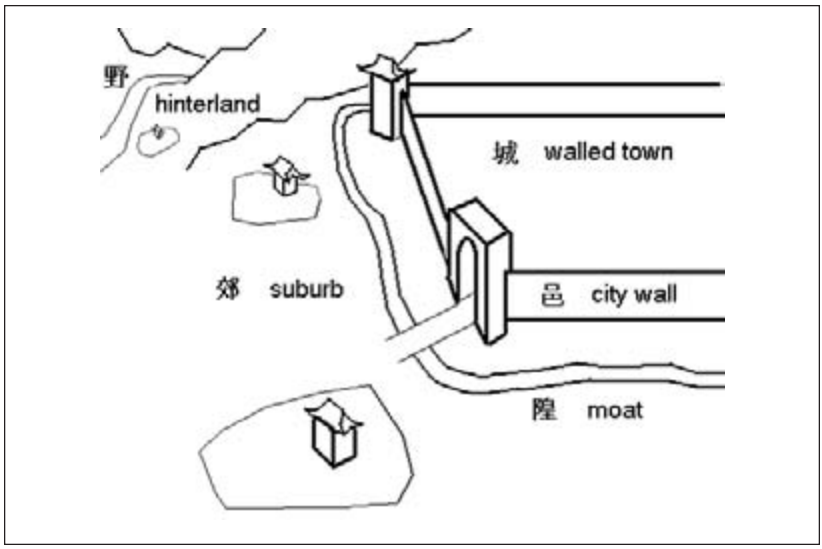

Figure 3. Traditional Chinese view of a central place and its hinterland.

who was to become China's first emperor, had to do with the presentation of a rolled-up map which concealed a poison-tipped dagger.[12] In these accounts, the topographic features, courses of rivers, locations of mountain passes, settlements, fortifications, and relative distances between the features are given the greatest importance. Therefore, it is not surprising to see attention to these details in the earliest extant maps (first century AD) discovered at Mawangdui, which include separate maps for topography, military posts, and the city plan.[13] Separating the city plan makes sense, because it is for a totally different scale. But it is very interesting to see topography and military posts split into separate maps covering the same extent in space, serving as prototypical thematic maps.

Further advances in cartography are reflected in the principles of map making developed by Pei Xiu (third century AD). The six principles—proportional measure, regulated view, road measurement, leveling heights, determining diagonal distance, and straightening of curves—have been studied in great detail.[14] Unfortunately, we do not have any extant examples of maps from Pei Xiu's time. It is not until the Song Dynasty (dating to the twelfth century AD) that we have extant maps, remarkable maps of the entire Empire engraved on stone tablets. One of these maps is the *Jiu Yu shouling tu* (1121 AD), which preserves the names and locations of some 1,400 administrative units, along with major rivers, mountains, and the coastline. Another is the *Yujitu* (1136 AD), which contains the first known use of the Chinese cartographic grid, along with a measurement of scale, each side of a grid square being said to equal 100 Chinese *li* (where one *li* is approximately 500 meters).[15]

Compare the *Yujitu* to a page from Shui Anli's *Lidai dili zhizhangtu,* a late eleventh century atlas containing forty-four historical maps of dynastic territories (Figure 4). Note that the representation of Shandong Peninsula and the Bohai Sea in the gridded *Yujitu* (map on left) is much more realistic that the generalized version shown in the *Lidai dili zhizhangtu* (map on right). On the other hand, note that the *Lidai dili zhizhangtu* includes a great deal of information about the historical administrative divisions, both as general locations and place-names on the map, and as detailed notes in the margin. This difference exemplifies a disparity in the functionality of maps, which on the one hand were used as simple guide maps and on the other as spatially accurate made-to-scale maps. Therefore, in an eleventh-century AD work, *Essentials of Prefectural and County Government,* the reader is admonished against placing much trust in the spatial accuracy of guide maps, from which we can "get only a rough, general understanding" of an area.[16] This warning on reliability from 1,000 years ago confirms that information derived from pre-modern map sources is contextual and relative—a town was located on the south bank of a stream, or a town was located in a valley between two named mountains. We should not read these sources as if they were spatial analogues like modern maps.

Similar caution must be used when dealing with large-scale local maps resembling cadastral surveys, which were undertaken primarily for the purpose of assessing taxes. One product of such surveys are "fish-scale" maps, which contained general maps showing the relative positions of parcels, and "fish-scale" register tables with related information such as owners' names, the land area, soil fertility, and descriptions of other properties adjacent to each parcel (Figure 5).[17] Fish-scale maps and registers are quite rare, and can only be used as an example of the sort of information

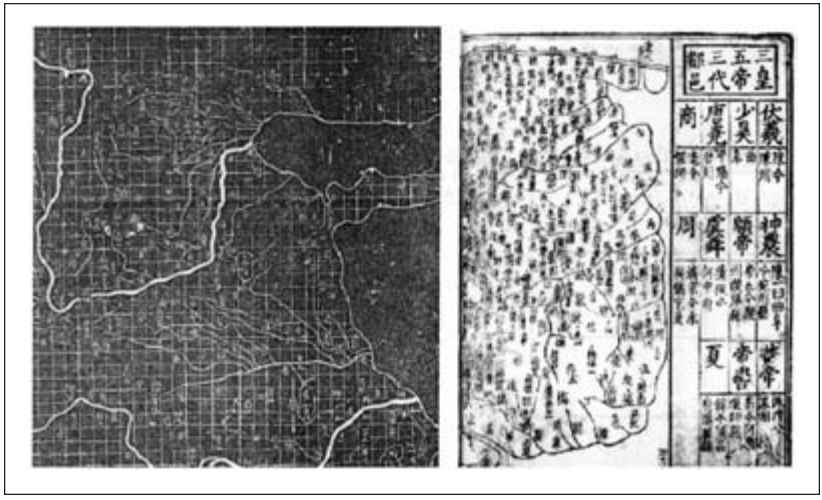

Figure 4. A map made to scale (*Yujitu,* left) and a guide map (*Lidai dili zhizhangtu,* right).

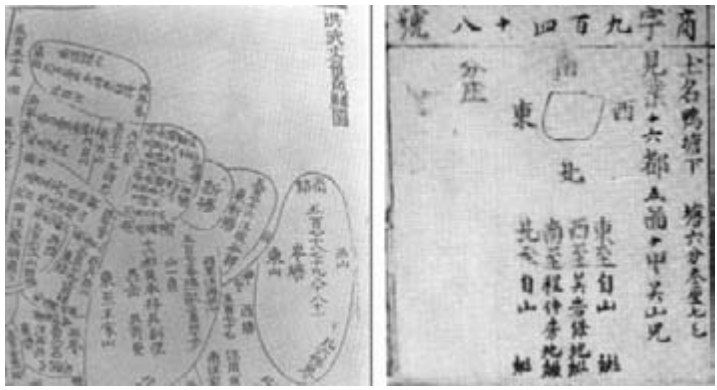

Figure 5. Fish-scale cadastral survey (*yulintu*) and fish-scale register.

that was collected for cadastral surveys in very limited areas beginning with the Ming period. For the greater part of Chinese history, the most detailed source for information on administrative geographies are gazetteer [*fangzhi*] sections of dynastic histories and county-level gazetteers [*xianzhi*], the latter of which only began to appear in the tenth century AD.

The earliest national gazetteer is Ban Gu's *Han Shu dilizhi* (Gazetteer of Han Dynasty) (first century AD), which recorded information about administrative regions and their subordinate units. This type of administrative geography information became a standard component of each successive dynastic history. When county gazetteers [*xianzhi*] began to appear they contained much more detailed information, such as the year when an administrative office was established, a chronological account of changes in its status, description of its location, natural features in its vicinity, a list of officials who were appointed to serve there, taxable items and tax revenues collected there, lists of official buildings, offices, temples and shrines, an account of important families and individuals who resided in the region, and a host of other items. Over the course of centuries, the contents of *xianzhi* were periodically redacted and collected into national gazetteers. The information accumulated in Chinese gazetteers, on both the national and local levels, fills thousands of volumes. The reconciliation of the contents of these gazetteers in order to reconstruct a picture of the historical administrative hierarchy over the course of time is called *yange dili* (geography of administrative change).[18] Such geographies provide the methodological basis for the compilation of the China Historical GIS (CHGIS).[19]

National gazetteers, in addition to collecting information for all the prefectures and counties of the empire, contained simple guide maps. These guide maps, combined with more detailed maps found in county gazetteers, and textual descriptions, provide the best source of information on

the administrative system and its changes over time. Since the entries in gazetteers contain cumulative information, later editions become compendiums of administrative changes. Unfortunately, the constant revision and redaction of this information, over the course of centuries and dozens of editions, also results in numerous errors, omissions, and conflicting accounts. Even a systematic attempt to develop a historical GIS database from the dynastic geography tradition is not a straightforward task.

Based on the preceding survey of the various traditions of defining and measuring space in China, three general approaches emerge. The first is one that measures individual fields and parcels, either theoretically, as in the well-field system, or as cadastral surveys found in fish-scale maps. The second measures space as a sphere of influence radiating from a central place or administrative seat. The second approach is seen in the Five Domains theory and in the relationship between core and periphery, or "subjects" and "outsiders." The third approach expands on the central place idea to encompass a complete political system, either as one independent state among others or as a single empire. The third approach seeks to incorporate all the administrative divisions and subdivisions of the political system in question into a single administrative hierarchy.

Digitizing Historical Administrative Units as Features in GIS

Now to return to the original question. What GIS data types can best represent the available information on historical administrative divisions in China? It is evident that the idea of bounded space, or specific areas of jurisdictions, were of great importance to the administration of the Chinese empire. However, it is equally clear that the textual source materials describing historical administrative divisions are much more abundant than historical maps showing their areas of jurisdiction. Where maps are available, they provide general positions of administrative seats and towns relative to one another and to natural features such as rivers and mountains, and often as not they are enriched with other named places, such as temples, shrines, bridges, passes, and markets.

Maps drawn with a grid-scale technique appeared in Ming and Qing gazetteers in the seventeenth to nineteenth centuries, but with such poor geographic accuracy as to make the georeferencing of historical features to features found in present-day digital base maps extremely difficult. Although Matteo Ricci (1552-1610 AD) is often cited as introducing European cartographic techniques to China, such as the concept of a projected surface of a spherical earth rather than a flat earth, not until the decades following the Manchu conquest of China (1644 AD) were such techniques used to survey the empire. The application of these new techniques to the compilation of county-level maps for local gazetteers did not begin until the very end of the nineteenth century.[20] As late as 1879 AD the

compilers of the Imperial gazetteer wrote, "As far as maps are concerned, the Kangxi edition of this gazetteer is too sketchy, and the distances and locations of mountains, streams, and cities and their outskirts are topsy-turvy and confused. We rechecked the area following these maps, from beginning to end, and there was not one correct place. This is probably a result of clerks and laborers being delegated the task, while [those in charge] did not personally pass through the area and conduct a detailed examination."[21] Thus, for the greater part of the 2,000 years of dynastic history in China, one must rely primarily on textual sources with rough guide maps to assist in establishing locations.

In light of these realities, we have opted for the method of maximizing point locations of named features, rather than trying to define county boundaries throughout the period of coverage for the CHGIS database. To obtain historical point locations for the CHGIS project, we first scan each county map from the last set of gazetteers commissioned by the Qing Empire (these date roughly 1908 AD to 1911 AD). The selected maps cover most of the core eighteen provinces of the late Qing territory, and though the cartographic accuracy varies by region, the map sheets remain in good enough condition and were printed with fine enough detail to provide a strong basis for late Qing administrative geography.

It should be noted that the scanned images were not rubber-sheeted or georectified using GIS software. Since the surveying techniques used to create the late Qing maps were so inadequate, the level of distortion in georectified versions of the map images renders them nearly useless. That being said, the unrectified scanned images were perfectly clear for gauging relative positions. The scans were consulted on one screen while the features in the GIS application were input with "heads-up" digitization on another. The base map used for GIS input was the 1:1 million scale ArcChina,[22] supplemented with many other layers of hydrography data, digital elevation models, and road networks. Each historical town location was georeferenced to its correct modern location and given a point feature in GIS. Spatial data notes were kept for each record to indicate whether the new point had been matched to an existing point location in the ArcChina base map, or whether it had been placed in an estimated location for which there was no corresponding feature in ArcChina. As an aide to finding the exact locations, contemporary geographic features were printed out on A4-sized paper for each county, and these draft maps were extensively annotated with handwritten notes, indicating the exact locations of administrative seats, along with dates and changes of location (Figure 6).

Finally, when the point locations of all the identifiable towns, together with the county seats, prefecture seats, and provincial seats had been digitized into GIS, county boundaries were digitized to reflect the 1911 AD source maps. This was done by making sure that the subordinate points shown on the historical maps are all contained within the

Figure 6. Late Qing county map (left) and annotated draft map (right).

county boundary. In addition the boundary was "snapped" to the segments of the contemporary boundary in the ArcChina base map for those specific segments where the historical evidence indicates that they were identical. Other segments of the county boundary were "snapped" to natural features in the ArcChina base map where applicable, such as the shores of rivers, lakes, or coastlines.

Implementing the Network Model

As mentioned above, the CHGIS project did not attempt to reconstruct the county boundary changes backwards through time. However, locations of all administrative seats as points were recorded as was the superior administrative division for each administrative seat. For example, Guangze Xian (county) was part of Shaowu Jun (military prefecture), which was part of Fujian Sheng (province).

As an experimental means of representing the administrative hierarchy at a particular time, I decided to leverage the known point locations for each unit and the known administrative hierarchy relationships to construct a network model. To do so, I ran a query on the table containing the administrative hierarchy information for the province of Fujian. The results for the year 1050 AD showed that Fujian Sheng had the following immediately subordinate units: Shaowu Jun, Ting Zhou, Jian Zhou, Quan Zhou, Nanjian Zhou, Zhang Zhou, Xinghua Jun. To create a network of arcs between the superior unit to each subordinate, I extracted the x, y coordinates for the point locations of each of these into a flat file, using a format that can be processed by the "generate" command in ArcInfo. The "generate" command creates arcs between each pair of coordinates. This process was then repeated for another iteration from each subordinate prefecture-level unit to their own subordinate counties. The result-

ing network of the administrative hierarchy looks like a matrix radiating from the capital.

The network can be extracted and displayed for any particular year in the database. Compare for example Fujian province in the years 1050 AD and 1250 AD (Figure 7). The provincial seat moved between these two dates, and several counties were established. When viewed as a network, top-level changes in the administrative hierarchy have a greater visual impact than they would have if only the point symbolizing the capital had changed.

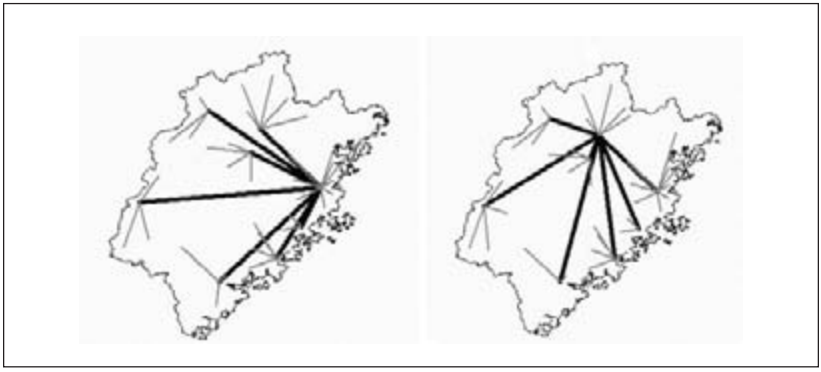

Figure 7. Fujian network in 1050 AD (left) and in 1250 AD (right).

In addition to being able to visualize changes in the administrative structure based on available point data (obviating the need for reconstructed boundaries), the network model also can be extended downwards to any number of iterations, or can be used to develop alternative network infrastructures based on other kinds of data, such as linguistic similarities, provenance of historical artifacts, or statistical data that can be georeferenced to historical point locations. For example, should we have sufficient economic data related to each town and central place, we could develop an economic hierarchy just as easily as an administrative hierarchy.

Advantages of the Network Model

Finally, there is the issue of whether we can or cannot clearly define boundaries for pre-modern territories. In the previous discussion, I examined the lack of reliable cartographic information in Chinese sources that prevents us from defining boundaries. But is this only applicable to China, or is it true for all historical GIS that deal with pre-modern and ancient materials? In nineteenth-century Vietnam, intermingled land parcels owed taxes to various distant administrative centers. A detailed study of the relationships of tax payments by land-holders to their superior tax-collecting administrative units revealed that there was no way to define a

clear boundary between the superior jurisdictions.[23] Any attempt to draw a distinct boundary that separated land-holdings according to their parent jurisdictions would result in an impossibly complex border, gerrymandered in every direction, with numerous exclaves. Is it reasonable to believe that such a boundary really existed in the minds of the local administration? Or did they only care about the relationship of the landholder to the tax collecting office? A network model could better represent the interpenetration of the lower echelons of the network in the Vietnamese case, and would not make any undocumented assertions about exactly where a boundary existed (Figure 8).

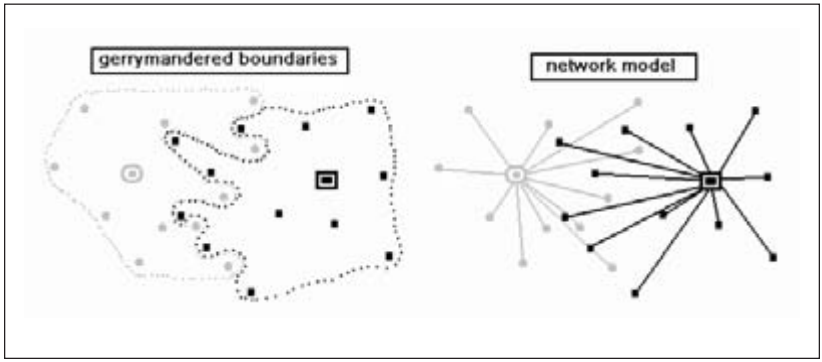

Figure 8. Comparison of defined boundaries and network model.

To pursue the argument on a theoretical level, the problem with a gerrymandered boundary is that it does not rationally deal with distribution of localities subordinate to two or more adjacent jurisdictions. When the situation gets too complex, it becomes impossible to draw an inclusive boundary for each. In that case it becomes necessary to rationalize a boundary in between adjacent jurisdictions and posit the existence of enclaves and exclaves. However, which territory should be extended to the outer perimeter of subordinate localities, and which should retreat, leaving behind a few exclaves? This inherent bias in the rationalization of the boundary is based on conjecture, not on the evidence (Figure 9). Should gray push its own boundary to the right, leaving a few enclaves of black? Or should black extend its boundary to the left, creating several gray enclaves? If there is no real evidence to justify one bias over another, and when one considers the utterly disparate outcomes, I would argue that rationalizing gerrymandered boundaries is not a valid solution.

Does the evidence found in pre-modern historical sources justify spending a great deal of time trying to reconstruct estimated boundaries? My answer is no. Instead, I would propose that network models based on known locations of administrative seats be automated in GIS, after which estimated boundaries enclosing what Wheatley described as "core territo-

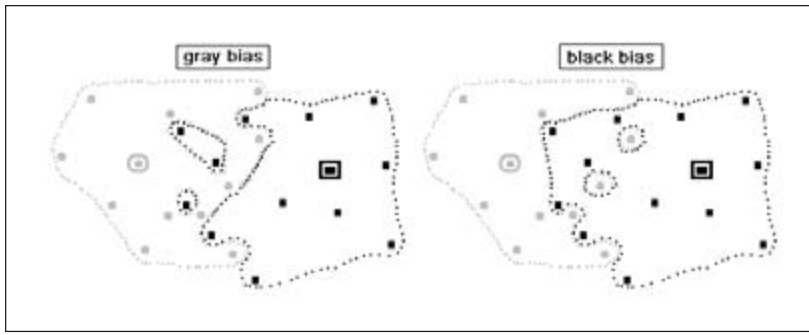

Figure 9. Inherent bias in rationalizing boundaries.

ries" can be produced. By using the strengths of GIS techniques we can test our assumptions about historical territories according to the facts at hand, namely the relationship of administrative capitals to subordinate units and their respective locations as points. As for the areas that overlap when estimated boundaries are calculated, these should be at least as valuable as hand-drawn guesses about borders one cannot prove (Figure 10).

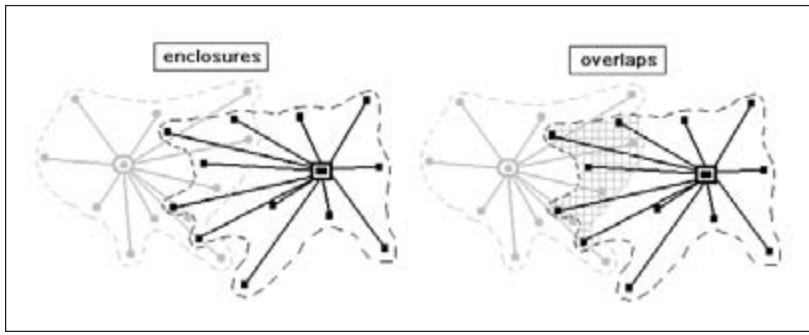

Figure 10. Estimated boundaries and overlaps.

In conclusion, I would argue that for the purposes of any historical GIS that must delve into pre-modern and ancient times, it makes more sense to capture each administrative unit as a point location and to model the administrative hierarchy as a network. Subsequently, the networks can be used to visualize where boundaries (or approximate boundaries) probably existed in between higher-level administrative units. This will avoid the time-consuming process of reconstructing boundaries based on scant evidence and will reveal areas of interest, such as overlapping areas between jurisdictions, where we can focus our time and resources before drawing conclusions about historical boundaries.

Notes

1. I.N. Gregory, C. Bennett, V.L. Gilham, and H.R. Southall, "The Great Britain Historical GIS Project: From Maps to Changing Human Geography," *Cartographic Journal* 39 (2002): 37-49.
2. Martina De Moor and Torsten Wiedemann, "Historical GIS for 200 Years of Belgian Territorial Structures" (Shanghai: International Workshop on Historical GIS, 2001): 3-7. This paper is available at http://www.fas.harvard.edu/~chgis/meetings/papers/demoor_shanghai.pdf.
3. Qinming Jin and Wei Li, "China's Rural Settlement Patterns," in Ronald G. Knapp, ed., *Chinese Landscapes, The Village as Place* (Honolulu: University of Hawaii Press, 1992): 19.
4. Brandon Plewe, "The Nature of Uncertainty in Historical Geographic Information," *Transactions in GIS* 6:4 (2002): 431-56.
5. Paul Wheatley, *The Pivot of the Four Quarters* (Chicago: Aldine Publishing, 1971): 170-3.
6. G. William Skinner, "Cities and the Hierarchy of Local Systems," in G. William Skinner, ed., *The City in Late Imperial China* (Stanford: Stanford University Press, 1977): 253-351.
7. Lin Yuan, *Liang Zhou tudi zhidu xinlun* [New Essays on the Land System in the Two Zhou Periods] (Changchun: Northeast Teachers University, 2000): 226.
8. Dingxin Zhao, "The Rise of Early Chinese Empire and Patterns of Chinese History," in *Comparative Politics Workshop* (Chicago: University of Chicago, Dept of Political Science, 2004): n.p. [section titled "Western Zhou Order and Its Decline"]. This paper is available at http://cas.uchicago.edu/workshops/cpolit/papers/winterschedule.html.
9. Bernhard Karlgren, *Grammata Serica Recensa* (Stockholm: Museum of Far Eastern Antiquities, 1957): 244.
10. Changfu Li, *Yu Gong shi di* [Commentary on the Geography in Yu Gong] (Zhengzhou: Zhengzhou shuhuashe, 1982): 148-51.
11. Cordell D.K. Yee, "Chinese Maps in Political Culture," in J. Brian Harley and David Woodward, eds., *The History of Cartography*, Vol. 2, Book 2, *Cartography in the Traditional East and Southeast Asian Societies* (Chicago: University of Chicago Press, 1994): 72-73.
12. Yee, "Chinese Maps in Political Culture," 73.
13. Yingchun Jin and Fuke Qiu, *Zhongguo ditu shihua* [On the History of Chinese Maps] (Beijing: Kexue chubanshe, 1984): 33-52.
14. Cordell D.K. Yee, "Taking the World's Measure: Chinese Maps Between Observation and Text," in J. Brian Harley and David Woodward, eds., *The History of Cartography*, Vol. 2, Book 2: *Cartography in the Traditional East and Southeast Asian Societies* (Chicago: University of Chicago Press, 1994): 110-3.
15. Cordell D.K. Yee, "Reinterpreting Traditional Chinese Geographical Maps," in J. Brian Harley and David Woodward, eds., *The History of Cartography*, Vol. 2, Book 2: *Cartography in the Traditional East and Southeast Asian Societies* (Chicago: University of Chicago Press, 1994): 46-52.
16. Yee, "Chinese Maps in Political Culture," 91.
17. Yee, "Chinese Maps in Political Culture," 85-6.
18. The *yange dili*, which focuses on the divisions and sub-divisions in the administrative hierarchy, has also been called dynastic geography. It has been criticized for paying too much attention to textual studies rather than physical ground surveys and archaeological evidence. See Xiaofeng Tang, *From Dynastic Geography to Historical Geography* (Beijing, Commercial Press, 2000): 25-6.
19. China Historical GIS is a joint research project of the Harvard Yenching Institute and Fudan University (http://www.fas.harvard.edu/~chgis).
20. Cordell D. K. Yee, "Traditional Chinese Cartography and the Myth of Westernization," in J. Brian Harley and David Woodward, eds., *The History of Cartography*, Vol. 2, Book 2: *Cartography in the Traditional East and Southeast Asian Societies* (Chicago: University of Chicago Press, 1994): 171, 191-95.
21. Yee, "Traditional Chinese Cartography," 194.
22. ESRI, *ArcChina Digital Map Database of China* (Redlands, Calif.: ESRI, 1996-2000).
23. Brian Zottoli, "Examining Pre-Modern Vietnam With Historical GIS," paper presented at the ECAI International Workshop on Historical GIS, Shanghai, 2001.