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The 1837 Ioway Indian Map Project: Using Geographic Information Systems to Integrate History, Archaeology and Landscape

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Using Geographic Information Systems to Integrate
History, Archaeology and Landscape

by

Mary Kathryn Whelan

In partial fulfillment of the requirements for a
Master of Science degree in Geographic Information Systems
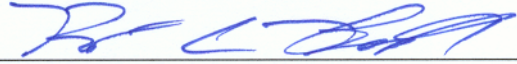
Committee in charge:
Professor Karen Kemp, chair
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Robert Booth, ESRI

July, 2003

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The report of Mary Kathryn Whelan is approved.

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July, 2003

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ABSTRACT

The 1837 Ioway Indian Map Project: Using Geographic Information Systems to
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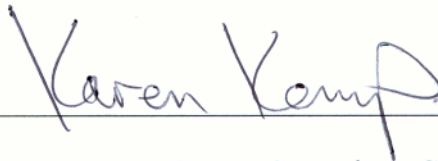In 1837 the Ioway Indians drew a map to bring to treaty talks with the United
States government. The 1837 Ioway Map project uses Geographic Information Systems
(GIS) to help extract cultural, archaeological, and historical information from this rare
document. Project goals include: documenting Ioway cartographic conventions;
georeferencing the Ioway map to a modern base map; extracting spatial, historical,
ecological and archaeological information from the georeferenced map; and designing a
variety of digital (CD, web site) and non-digital (museum exhibit) presentation formats
to broadly disseminate the project results.

Centered on what is now the state of Iowa, the 1837 map shows 51 rivers, nine
lakes, 23 villages, and over two dozen important Ioway Indian trails. Map features are
unlabeled, but historic records indicate that it was designed around two major rivers, the
Mississippi and the Missouri. GIS tools were helpful in evaluating the probable
identifications of a number of the other hydrographic features. The Ioway encoded
information about village size and population in their symbology, information that was
systematically documented using pan, zoom, measurement, and geostatistical tools,
with the results stored in attribute tables.

Six different georeferencing methods were applied, three raster to vector (ESRI
Georeferencing tools), and three vector to vector (ESRI Spatial Adjustment tools).
None was completely successful in rectifying the Ioway map to a modern base map.
Information on village and trail locations was arrived at through evaluation of the
results of the six georeferencing methods in conjunction with other archaeological and
historical data. Once villages and trails had been positioned on the base map, a series of
overlay analyses provided additional historical and cultural information. The 1837
Ioway villages and trails were compared with villages on the 1847 Ioway map; with
historic and prehistoric archaeological sites in Iowa; and with Midwestern natural
resource locations. Results demonstrate that GIS tools can extend the geographic,
historic and archaeological analysis of this valuable historic document.

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I. Introduction

In 1837 a delegation of Ioway Indians, led by a man named *Na'je Niŋe* (translated as "No Heart of Fear"), traveled to Washington D.C. to conduct treaty negotiations with representatives of the United States government. They brought with them one of only two maps known to have been drawn by the Ioway (Figure 1)[1]. Like all historic Native American maps, it represents the world using indigenous conventions, in this case, physical and cultural geography through Ioway eyes. The map illustrates the rivers that served as both highways and home sites, the villages that figured prominently in Ioway history, and several of their important over-land transportation routes. According to archaeologist and ethnohistorian William Green "The Ioways prepared and presented the 1837 map to support their historical claim to land that the U.S. Government was purchasing via treaties" (2000:2).

Native American maps provide scholars with rare and valuable information concerning indigenous cultural and historical traditions (Lewis 1987; 1998a; 1998b; Warhus 1997). After having lived throughout the Americas for more than 13,000 years, their knowledge of the physical and social landscape was extensive. Western travelers and explorers like Lewis and Clark depended on Native people to guide them across the continent, counted on their detailed familiarity with trails and waterways, their knowledge of the distribution of food, shelter, friends and enemies (Wood 1987; Ronda 1987). But Native American geographic wisdom was maintained primarily by means of oral tradition, rather than in written form (Basso 1996; Lewis 1987; 1998a; 1998b). None of the Native North American nations drew with ink on paper or used an alphabetic system of writing until after European colonization. Consequently, a Native American cartographic tradition, as Western people would understand it, did not begin until the seventeenth-century (Warhus 1997:24). This is one of the reasons the 1837

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[1] The two historic maps produced by the Ioway are the 1837 No Heart map (discussed in this report) and the 1847 *Waw-non-que-skoon-a* map. The 1847 map was drawn in response to an inquiry from Henry Rowe Schoolcraft (1853). Nineteenth century artist, and U.S. Army Captain, Seth Eastman redrew *Waw-non-que-skoon-a*'s map for publication in Schoolcraft's report to Congress (1853: Plate 30). The Schoolcraft reproduction is shown here in Figure 2. At the time he wrote "The original is retained in the Indian Bureau" (1853:257) but its current location is unknown. It may reside in an archive or it may be lost.

Eastman's redrawing significantly changed *Waw-non-que-skoon-a*'s map. As Schoolcraft put it "…[it] has been reduced in size, and its rigid lines adapted to the surveys of the public lands on the Missouri and Mississippi" (1853:256-257). Because of these changes, the Eastman rendering is of limited value for understanding Ioway cartographic conventions, leaving the No Heart map as the only currently available example of historic Ioway cartography. However, the village locations illustrated in the redrawn *Waw-non-que-skoon-a* map provide an interesting comparison with the No Heart village locations, as discussed in Chapter VI.

Figure 1 - Scanned Image of the 1837 Ioway Map

From Wood 2001, Plate 18

An Atlas of Early Maps of the American Midwest: Part II

Figure 2 - The 1847 *Waw-non-que-skoon-a* Map, as Redrawn by Seth Eastman

(from Schoolcraft 1853, Plate 30)
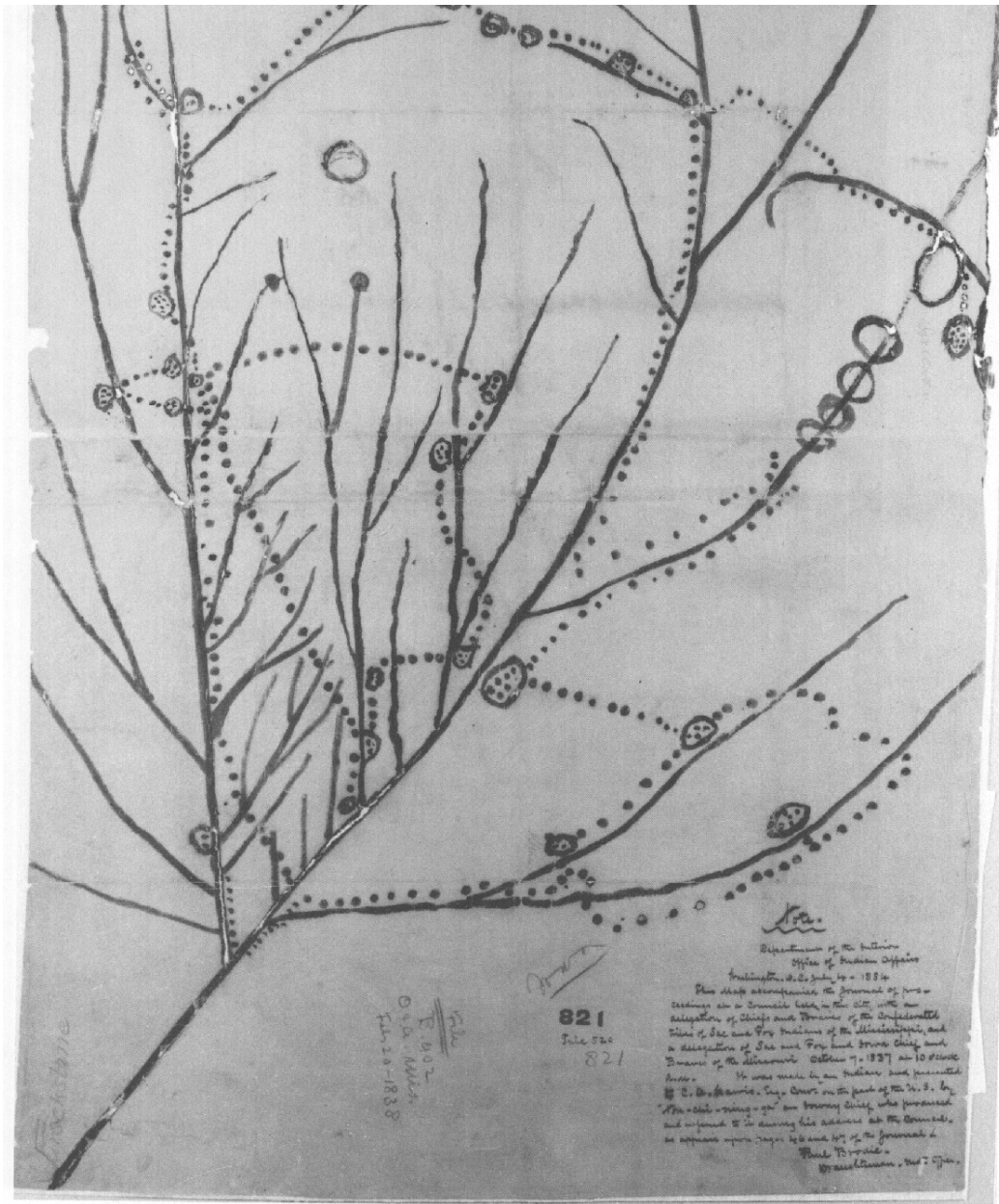
Ioway map is such a valuable historical and cultural resource: it offers a rare glimpse of the nineteenth-century Midwest from a Native American, rather than a EuroAmerican, perspective.

Ioway Map Project Goals

The 1837 Ioway Map Project uses GIS to help extract historical, archaeological, and ecological information from a rare historic document. The project goals are:

1. to document historic Ioway cartographic conventions;
2. to georeference the Ioway map to a modern base map;
3. to use spatial analysis to extract information from the georeferenced map; and
4. to present this information in a variety of formats (CD; museum display; web site) to a diverse set of audiences.

The cartography the Ioway used in the production of their 1837 map is difficult for twenty-first century Americans to interpret. It is based on a mixture of traditional Ioway symbolism, more widely shared pan-Indian iconography, and symbolic elements borrowed from western cartography (Lewis 1987; Green, pers. comm.). Their selection of features to include on the map, and their decisions about how to render those features, add cultural and historic value to this document. Ironically, it is these same aspects that make the map frustratingly difficult to use. Scale, orientation relative to north, symbology, and content are different from modern expectations. The first goal of the Ioway Map Project is to use GIS to uncover some of the meanings the Ioway embedded in their cartographic symbolism and design (Chapter IV).

Visualizing the parts of the Ioway world depicted on the map is difficult because the map lacks identifying labels and the river courses are simplified. Scale is inconsistent across the map, making accurate measurement nearly impossible. Georeferencing the historic map to a modern base map aids in the location of villages and travel routes with reference to modern landscape features (Chapter V). Significantly, it also serves as an independent check on the hydrographic identifications researchers have made thus far.

Using the georeferenced Ioway map, researchers are better able to visualize the landscape context of the Ioway map features (Chapter VI). Archaeologists and historians are interested in identifying the locations of the Ioway villages in order to look for archaeological sites and historical information linked with the villages illustrated on the map.   In a few cases, archaeological sites have been matched to mapped villages (Green 2001) but the georeferenced locations allow further investigation.   The georeferenced Ioway village locations can also be examined in relation to other information such as the locations of villages of other tribes, distance to significant ecological resources (e.g., the prairie-forest ecotone, bison ranges), or proximity to geological resources such as chert quarries.

GIS helps researchers manage and coordinate information depicted on the historic Ioway map. Attribute information such as village name, dates of occupation, and river segment names are linked to the map through database tables. These attributes can then be linked, in a larger relational database management system, to other historic documents, photographs, text descriptions of Ioway history and culture, and bibliographic reference material.

The final goal of the project is to use geographic information systems to enhance the analytical and educational value of the 1837 Ioway map by communicating our findings as widely as possible (Chapter VII). The results of the Ioway Map Project will eventually be available in multiple formats. First, a CD containing the base map and Ioway map files will be available to individual researchers (August, 2003). Second, a museum exhibit is planned for the Logan Museum at Beloit College, Beloit, Wisconsin. Exhibit dioramas will be enhanced with the addition of a computer workstation that allows visitors to explore the Ioway map using GIS tools. Finally, a web site, hosted by Beloit College, will be added to provide an interactive web-based educational site that allows individuals to query the map and obtain detailed information on Ioway history. Contingent on funding, the museum exhibit and web site presentations will be future expansions of the project.

II. Historic Native American Maps

GIS can play an important role in visualizing and analyzing historic maps, as demonstrated in Anne Kelly Knowles' (2002) recent book Past Time, Past Place: GIS for History.   In an informative chapter by David Rumsey and Meredith Williams (2002:1) they argue

> Maps record the geographical information that is fundamental to reconstructing past places, whether town, region, or nation. Historical maps often hold information retained by no other written source, such as place-names, boundaries, and physical features that have been modified or erased by modern development. Historical maps capture the attitudes of those who made them and represent worldviews of their time.

Analyzing historic maps with GIS emphasizes the "information" component of geographic information systems, but translating and interpreting that information is not entirely straightforward.

Late 18th and Early 19th Century Cartography

In most Native North American cultures, oral tradition (including music and dance, as well as narratives and names) was the repository of historical, cultural and geographic information (Warhus 1997; Lewis 1998b). This fact presents contemporary scholars with an intriguing problem: traditionally, Native American cartography was "sketched" in spoken language not on paper. Other puzzling differences follow from the 'oral not written' distinction: it was more ephemeral and less permanent; it was changeable rather than fixed; it incorporated non-geographic as well as geographic information; it often treated time as a map feature, mixing information from mythic time with historic and modern information. A number of linguistic anthropologists working with contemporary Native people have stumbled on, and been amazed by, the richness of geographic and historic information encoded in such diverse oral traditions as Hawaiian hula dance (Kaeppler 1993), Plains Indian sign language (Farnell 1994), and Apache place names (Basso 1996).

But the concept of "spoken maps," an oxymoron in western thought, presents real challenges in interpretation and understanding. Warhus acknowledges this when he describes traditional Native American maps as "oral documents" and states "Unlike western cartography, where the 'map' becomes one's picture of the landscape, Native American maps are always secondary to the oral 'picture' or experience of the landscape" (1997:3). He goes on to explain,

> To read these Native American maps it is necessary to suspend western preconceptions of what makes a map. Unlike western cartography, where the

primary document is the physical map and the conventions of scale, longitude, latitude, directions, and relative location are believed to "scientifically" depict a static landscape, Native American maps are pictures of experience (*ibid*.).

Since at least 1,000 A.D. the Ioway had been creating maps as oral documents, blending natural and cultural information as they constructed their world. As a drawing produced by Ioway Indians, the No Heart map comes out of this centuries-old tradition of Native American cartography and should be analyzed, in part, within that context.

But the Ioway in 1837 were at a cultural watershed as colonization irreparably changed their traditional world. The 1837 map is also a contemporary product, generated as a rhetorical tool to help persuade U.S. government officials during treaty talks, and it must be understood within the context of that world. After decades of contact with Europeans and EuroAmericans, the Ioway were using elements familiar to them from western maps of the time (pen and ink on paper, for example), elements they thought would be compelling to their EuroAmerican audience.

Lewis (1987; 1998a) and Wood (1987) both discuss Native American – EuroAmerican cartographic encounters, addressing the issues raised above. Between 1511 and 1925, Lewis argues, a great deal of geographic and cartographic information was acquired by Europeans from Native Americans, most of it in gestural or oral form (1998a:14-18). Increasingly, as colonization proceeded, Europeans and EuroAmericans asked for information in graphic form though few of these maps survive. Historic period European maps thus represent a Native American worldview filtered by European and EuroAmerican cartographers. This is clear when the 1837 Ioway map is compared with non-Native maps of the area from the eighteenth- and nineteenth-centuries (Figures 3, 4, 5 and 6). A number of similarities are visible, particularly the locations of landmarks, the stylized and simplified river courses, the general shape and outline of physical and hydrographic features, and the inclusion of information on Native American villages and territories.

Because Eastern North America was settled early by Europeans, western-style maps of this region were abundant and could be based on first-hand knowledge as well as survey and astronomical data. In contrast, the region that stretched from the Mississippi River to the Rocky Mountains, vast and relatively inaccessible by water, was among the last places to be charted by EuroAmerican cartographers (Wood 1987). This took place primarily during the nineteenth-century, bracketed by the 1803 Louisiana Purchase and the explorations of the Lewis and Clark expedition (1803-1806), and the 1878 defeat of western Indian tribes and admission of the last western states (Oklahoma and New Mexico, 1912) into the Union.

Eighteenth and early nineteenth-century maps of the continental interior were often conjectural; what detail they possessed was based on Native American input as well as on descriptions from fur traders, missionaries, and others familiar with the region. One of the best early maps of this region is shown in Figure 3, the 1718 version

of Guillaume de l'Isle's map of the Mississippi River and the area that would become the Louisiana purchase (Cohen 2002:48-51; Buisseret 1990:72-73). Delisle was a renowned cartographer in his day and his maps are now prized for their accuracy (he refrained from including fanciful or unsubstantiated features) and attention to detail.

> Delisle knew more about the Missouri Valley and the Mississippi River than any other mapmaker of his time. His 1718 map was copied by French, Dutch, German, and English mapmakers and was the main source of all subsequent maps of the Mississippi during the eighteenth century (Cohen 2002:50).

The detail reproduced in Figure 3 shows the general area depicted on the 1837 Ioway map. Similarities between the two maps are striking, including the chain of small lakes near Green Bay, the generalized nature of most river courses, the reduced number of tributary streams shown along the Mississippi and Missouri Rivers, and the inclusion of symbols for Indian villages (with variable numbers of houses shown). The similarities make sense since most of the information on Delisle's map would have come from members of Midwestern Indian tribes, including eighteenth-century Ioways.

Western maps of this region did not improved greatly until after the Lewis and Clark expedition. The lack of information is clearly illustrated in Figure 4, which shows a detail from the "Untitled Map of Lake Michigan to the Pacific Ocean" drawn by Nicholas King in 1803. King was appointed to the post of Surveyor in the Office of the Surveyor, City of Washington, District of Columbia, by President Thomas Jefferson. His 1803 map was used by Jefferson and Meriwether Lewis in planning the Lewis and Clark expedition, and it represents valuable "…evidence of an explorer's geographical knowledge of the area to be explored on the eve of an expedition" (Cohen 2002:82).   Again the map extent in Figure 4 is limited to the general region depicted on the 1837 Ioway map. Interestingly, most river names are in French, reflecting the legacy of Delisle's maps. The course of the Missouri River is more accurately rendered than in the 1718 Delisle map, but most of the area around the Mississippi and Missouri Rivers is devoid of topographic, hydrographic, and cultural detail. Having just completed the Louisiana Purchase, Jefferson desperately needed more accurate geographic information.

Figure 5, an 1806 map by Nicholas King based on the manuscript map drawn by William Clark, illustrates how quickly Jefferson got his wish. By the winter of 1804-1805, Lewis and Clark had reached the Mandan Indian villages in North Dakota. During that long, cold encampment Clark recorded their geographical findings for the area between St. Louis and the Missouri River – Knife River junction in central North Dakota. He also collected geographic information from the Mandan and other Indian people (Cohen 2002:86-89). King was able to produce this much more detailed map based on the drawings and descriptive information Clark sent back to Washington. The improved accuracy in scale and hydrographic detail (particularly concerning the Missouri River) is noticeable.

Figure 3 – Detail from "Carte du Mississippi" by Guillaume de L'Isle (1718).
(published in Cohen 2002: 50-51)

Figure 4 – Detail from the "Untitled Map of Lake Michigan to the Pacific Ocean"
by Nicholas King (1803).
(published in Cohen 2002:82-83)
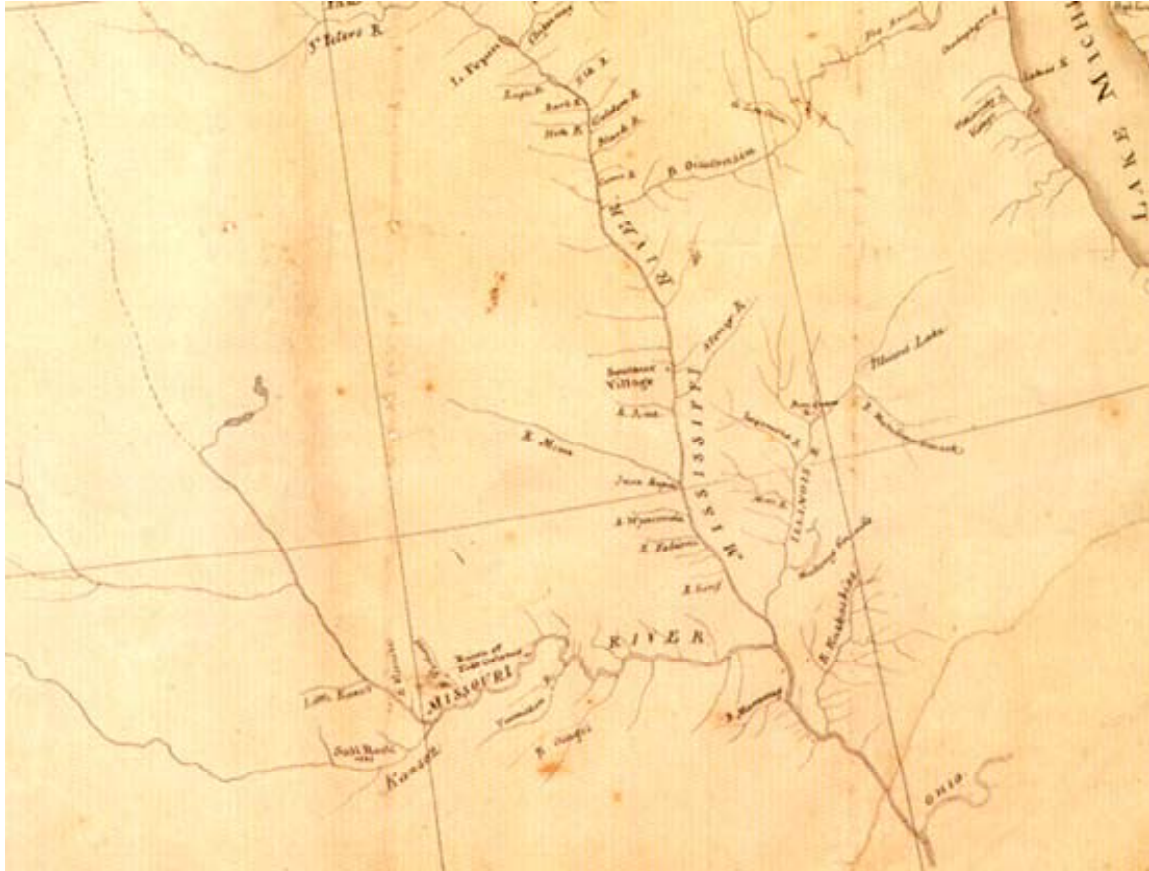
Finally, Figure 6 is a detail from the hydrographic map of the upper Mississippi River produced by Joseph Nicollet in 1847 (Cohen 2002:123-125). A French astronomer and cartographer by training, Nicollet lived and traveled in Minnesota during the 1830s and 1840s. The U.S. government hired him to survey and map the region surrounding the upper Mississippi River and his hydrographic map is "…one of the most important contributions ever made to American Geography" (Cohen 2002:123). The topographic accuracy and detail of Nicollet's map are far superior to any of the previous maps of the region. Information on the locations of Indian villages and territories is particularly valuable since relocation to reservations had been on-going for decades.

The Ioway would no doubt have seen examples of western maps like these, perhaps with an odd sense of deja vu since much of the westerner's cartographic information had come from their ancestors. In drawing their 1837 treaty map, the Ioway would have integrated their own centuries long graphic traditions with their experience with western maps and western cartographic traditions.

Previous Research on the 1837 Ioway Map

Three scholars have undertaken detailed research on the No Heart map, making significant contributions to its modern interpretation: Mark Warhus (1997), G. Malcolm Lewis (1979; 1987; 1998a; 1998b), and William Green (1995; 1999; 2001). Warhus (1997:37-43) devotes seven pages of his book on Native American cartography specifically to the No Heart map. The greatest value of his work is the historical context that he describes. Warhus explains the political tensions that existed between the Ioway and the American government, and the Ioway and some of their Indian neighbors (particularly the Mesquaki). After describing the geographic extent of the map (Minneapolis to the north, Green Bay to the east, St. Louis to the south, and the Missouri River west of Omaha to the west), he points out that the map represents a history of the Ioway from the days of their creation. The Ioway speak a Siouan language and are closely related to many of the other Siouan speaking tribes including the Oto, Missouria, and Winnebago. All of these tribes trace their origin to a common place (Green Bay) and time of creation. Archaeologists and ethnohistorians have argued that the time frame of their creation is likely to be ca. 1000 A.D., the time when Oneota culture spread west across Wisconsin to the Missouri River. A number of ethnohistorians and archaeologists, beginning with Mott in 1938, have argued that the Oneota are the prehistoric ancestors of the Ioway.

Malcolm Lewis has long been a leading figure in research on Native American maps. He co-edited the award winning Cartography in the Traditional African, American, Arctic, Australian, and Pacific Societies volume (volume two, book three in The History of Cartography series, University of Chicago Press) in addition to contributing substantial chapters on Native American cartography. Lewis reported his findings on the 1837 Ioway map in several publications (1979; 1987; 1998b). He began by assuming two things: first, that the map captured Midwestern landscape features

Figure 5 – Detail from "A Map of the part of the continent of North America between the 35th and 51st degrees of north latitude [sic]" by Nicholas King (1806). (published in Cohen 2002:86-87)

Figure 6 – Detail from "Hydrographical Basin of the upper Mississippi River" by
Joseph Nicollet and Henry Emory (1843).
(published in Cohen 2002:125)

significant to the Ioway; and second, that topological relationships were correct although elements such as scale, distance and direction were distorted. He analyzed it by recopying the lakes and river segments, leaving off the transportation routes and village locations (shown here in Figure 7a). Having essentially created a hydrographic layer, Lewis next used the topological relationships to attempt to match the streams and lakes on the Ioway map with their modern equivalents (shown here in Figure 7b). Lewis' work provided a useful starting point for deciphering the Ioway map. His transformations of the original established a base map that is easier for modern viewers to interpret.

Green (1995; 1999; 2001) extended Lewis' and Walrus' research in a number of ways. As the state archaeologist in Iowa for more than a decade, he brought a valuable anthropological perspective and depth of understanding to his work. After an extensive search of archaeological and ethnohistoric sources, he was "…able to determine that nearly all of the map's elements represent actual cultural and physical features" (Green 2001:15). Next, he examined the 60 rivers and lakes depicted on the map and was able to refine and correct several of Lewis' hydrologic identifications. Finally, Green focused on the locations of the 23 Indian villages and 26 trails shown on the map. He was "…able to suggest the likely sites (or general locations) and occupation dates of most of the villages" (2001:15).

There is undoubtedly much more material embedded in the *No Heart* map but accessing it is difficult. Until now, researchers have relied on visual inspection of the Ioway map and physical (analog) comparison of it with other paper maps. GIS provides computerized tools that have the potential to simplify and extend their research significantly. Using GIS investigators can digitally examine, manipulate, measure, visualize (draw), and re-present maps and large quantities of spatially referenced information. The information is tied to a specific area but because it is computer-based, users can zoom in or zoom out, changing the scale of the image and thus changing the associated context of information. Georeferencing the Ioway map to a modern base map could help to position the Ioway villages and travel routes with respect to modern landscape features. The georeferenced map permits overlay analysis, simplifying the task of comparing Ioway village locations with other cultural or natural features on the landscape. Finally, GIS allows researchers to easily visualize their results, changing the colors and symbolization on the map to highlight similarities or contrasts, and linking map features with other data.

Figure 7a - Lewis' Redrawing of the 1837 Ioway Map Hydrography (from Lewis 1998b:137)
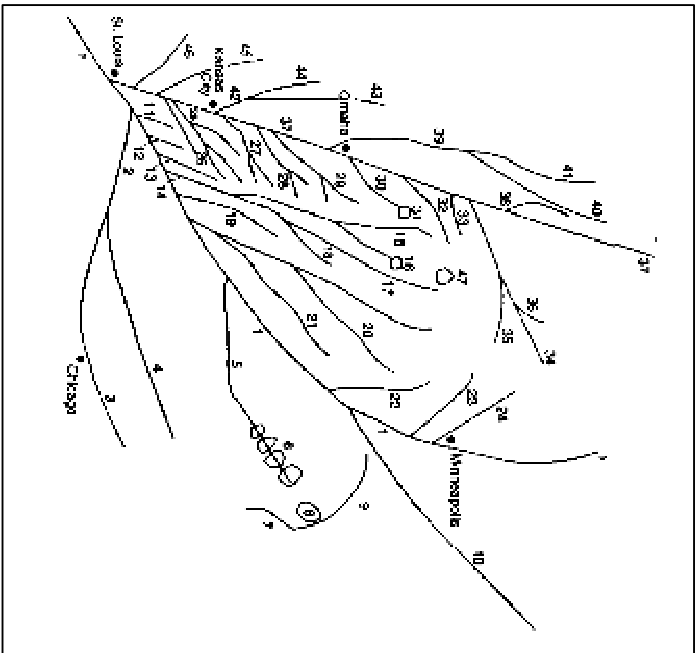
1. Mississippi River
2. Illinois River
3. Des Plaines River
4. Fox River (Ill. - Wisc.)
5. Rock River (Ill. - Wisc.)
6. Series of small lakes and
   swamps on the upper
   Rock River
7. Green Bay?
8. Lake Winnebago
9. Fox River (Wisconsin)
10. Wisconsin River
11. Cuivre River
12. Salt River
13. South Fabius (13a) or
    Wyanconda (13b) or
    Fox (Iowa) River (13c)
14. Des Moines River
15. Raccoon River (West and
    East Forks)
16. Storm Lake
17. W. Fork Des Moines River
18. E. Fork Des Moines River
19. Skunk River
20. Iowa River
21. Cedar River
22. Turkey River
23. Root (23a) or
    Zumbro (23b) or
    Cannon (23c) River
24. Minnesota River
25. Chariton River
26. Grand River

Figure 7b - Lewis' Identification of the Ioway Map Hydrography (from Lewis 1998b:137)

27. Platte River
28. Nodaway River
29. Nishnabotna River
30. Boyer River
31. Blackhawk Lake
32. Little Sioux River
33. Floyd River
34. Big Sioux River
35. Rock River (Minn-Iowa)
36. Skunk Creek?
37. Missouri River
38. Niobrara River
39. Platte River
40. North Platte River
41. South Platte River
42. Kansas River
43. Republican River
44. Smoky Hill River
45. Osage River
46. Gasconade River
47. Heron Lake

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III. Methodology

Data Collection and Preparation

The original 1837 No Heart map is curated by the Cartographic and Architectural Branch of the National Archives and Records Administration (NARA) in College Park, Maryland (Record Group 75, Central Map File, Map 821). It is quite large, reportedly 69 cm by 104 cm or approximately 27.17 inches wide by 40.95 inches long (Green 2001:14). The map's size, fragile condition, and historic value led the NARA to encapsulate it in mylar, and permissible uses of the original are somewhat limited. The NARA does sell photographs of the original.

For this project I utilized a scanned image of the map made from a folio-size reproduction published in Wood (2001:Plate 18). The full-page published reproduction is 35 percent of the original size, and was made from a photograph of the original provided by the National Archives. After obtaining an unbound copy of Wood's book, I used a large format drum scanner located in the offices of ESRI (Redlands, California) to make a .tif image, a raster format file that can be stored and read by ArcGIS software. The published reproduction was scanned at a resolution of 200 pixels per inch.

In all, I used 51 files to complete the work reported here, 15 base map files, 5 files related to the Ioway map, 25 files generated during the georeferencing process, and 6 files related to the spatial analysis component of the project. Appendix A contains a description of each data file as well as comments about any modifications I made to it. This information is repeated in the metadata embedded in each file and accessible using ArcCatalog. A brief tabulation of the Project data files is presented below.

Base Map files:
1. **BigCities.shp** - point locations for U.S. cities including only selected cities in the project area
2. **ProjAreaDrainage.shp** - generalized line file of the major river drainages in the project area
3. **ProjAreaDtlst.shp** - detailed polygon file of the nine project area states; boundaries are more accurate than in the standard state.shp file
4. **Clip_Hydroln.shp** - line file of U.S. aqueducts, canals, inter-coastal waterways, rivers and streams; this contains most of the rivers in the project area but the lines are more generalized than the lines for each of the state river files
5. **ProjAreaMjlakes.shp** - detailed polygon file of major water features (including bays, canals, lakes, reservoirs, and large rivers) in the project area
6. **Shadedrelief**
7. **Elevation**
8. **NA_Selectbigr.shp** – selected large rivers included by the Ioway on their 1837 map
9. **NA_Projectrivsel.shp** – selected rivers included by the Ioway on their 1837 map

10. **NA_ProjRivselect.shp** – selected rivers included by the Ioway on their 1837 map
11. **NA_Iariverselect.shp** – Iowa rivers included by the Ioway on their 1837 map
12. **Clip_riverastreams.shp** – generalized rivers and streams line file clipped to the 9 state study area
13. **Clip_lakesarivers.shp** – generalized lakes and rivers polygon file clipped to the 9 state study area
14. **Clip_mjwater.shp** – large rivers line file clipped to the 9 state study area
15. **Country_bkgrd.shp** – countries of the world polygon file clipped to North America

Ioway Map files:
1. **Iowaym2.tif** – the unaltered .tif image file generated by scanning the Ioway map published in Wood (2001:Plate 18).
2. **IowayRivSegmts.shp** – the digitized river segments from the Ioway map
3. **IowayTrails.shp** – the digitized trails shown on the Ioway map
4. **IowayVillages.shp** – the digitized outlines of the villages shown on the Ioway map
5. **IowayLakes.shp** – the digitized outlines of the lakes shown on the Ioway map

Georeferencing files:
1. **FinalTiePts.shp** – the 53 control points used in georeferencing; points include stream confluences and lake center points
2. **VillageTiePts.shp** – best approximation digitized locations of the geographic location of the Ioway villages
3. **TrailTiePts.shp** - best approximation digitized locations of the geographic location of the Ioway trail segments
4. **1strectifyiowaym2.tif** – 1st order polynomial georeferenced Ioway map
5. **2ndrectifyiowaym2.tif** – 2nd order polynomial georeferenced Ioway map
6. **RectifyIowaym2.tif** – 3rd order polynomial georeferenced Ioway map
7. **SpAdj1iowaytrails.shp** – georeferenced Ioway map trails using Affine Spatial Adjustment tools
8. **SpAdj1iowayvillages.shp** – georeferenced Ioway map villages using Affine Spatial Adjustment tools
9. **SpAdj1iowayrivsegmts.shp** – georeferenced Ioway map rivers using Affine Spatial Adjustment tools
10. **SpAdj1iowaylakes.shp** – georeferenced Ioway map lakes using Affine Spatial Adjustment tools
11. **SpAdj3iowaytrails.shp** – georeferenced Ioway map trails using Similarity Spatial Adjustment tools
12. **SpAdj3iowayvillages.shp** – georeferenced Ioway map villages using Similarity Spatial Adjustment tools
13. **SpAdj3iowayrivsegmts.shp** – georeferenced Ioway map rivers using Similarity Spatial Adjustment tools
14. **SpAdj3iowaylakes.shp** – georeferenced Ioway map lakes using Similarity Spatial Adjustment tools

15. **SpRubShiowaytrails.shp** – georeferenced Ioway map trails using Rubbersheet Spatial Adjustment tools
16. **SpRubShiowayvillages.shp** – georeferenced Ioway map villages using Rubbersheet Spatial Adjustment tools
17. **SpRubShiowayrivsegmts.shp** – georeferenced Ioway map rivers using Rubbersheet Spatial Adjustment tools
18. **SpRubShiowaylakes.shp** – georeferenced Ioway map lakes using Rubbersheet Spatial Adjustment tools
19. **Georef2ndvillages.shp** – digitized locations of the Ioway villages based on the 2nd order polynomial georeferencing procedure
20. **Georef1stvillages.shp** – digitized locations of the Ioway villages based on the 1st order polynomial georeferencing procedure
21. **Georef3rdvillages.shp** - digitized locations of the Ioway villages based on the 3rd order polynomial georeferencing procedure
22. **Rubbervillages.shp** – digitized locations of the Ioway villages based on the Spatial Adjustment rubbersheet method
23. **Adjust3villages.shp** – digitized locations of the Ioway villages based on the Spatial Adjustment affine transformation method
24. **Adjust1villages.shp** – digitized locations of the Ioway villages based on the Spatial Adjustment similarity transformation method
25. **ReverseSt.shp** – project area state locations georeferenced back to the Ioway map using Spatial Adjustment Affine transformation process

Spatial Analysis files:
1. **Oneotaarea.shp** – polygon of the cultural area encompassed by the Oneota
2. **Oneotasites.shp** – point file containing locations of Oneota sites in Iowa
3. **Chert.shp** – polygons illustrating the location of different Midwestern stone tool raw material deposits
4. **Historic_sites.shp** – point file containing the digitized locations of selected historic sites in Iowa
5. **School_vills_pts.shp** – point file containing the digitized locations of the Ioway villages illustrated on the 1847 Schoolcraft (1853) map
6. **Midwest_precip.shp** – polygon file containing NOAA data on average annual precipitation for the Midwestern states

The base map files were obtained from the eight disc CD set distributed by ESRI with copies of their software products. According to the metadata, the data are current as of 2000. The ESRI source data were used because they were good quality, covered the area of interest for the project, could be obtained at no cost, and they included metadata. In most cases I altered these original data through geoprocessing (e.g., clipping) or by selecting sub-sets of the data in the original file. Details can be found in Appendix A. In contrast, Ioway map, georeferencing and spatial analysis files were generally created by me during the processing and analysis steps in this project. Detailed information on the production of these files is also available in Appendix A.

Data Quality and Error Management

Because error is an inevitable component of human activities, error management and quality control are important elements of any GIS project. In this section I briefly address three aspects of quality control: positional accuracy and resolution; attribute accuracy; and logical consistency (Burrough and McDonnell 1998:220-263; Longley et al. 2001: 326:343). Positional accuracy refers to the relationship between an object or feature's location on a map and its location on the Earth's surface. This is central to the Ioway Map Project because the goal is to translate village and trail locations from the No Heart map to a modern base map. These locations need not be highly accurate to be of value, however. There is no universal level of accuracy that can be applied in all situations. Instead, accuracy should be appropriate to the data available, the type of analysis being performed, and the questions being asked.

In some respects, the Ioway map resembles a schematic drawing more than a map. Topological relationships appear to be reliable but scale varies, which makes positional accuracy difficult to evaluate. As suggested in Chapter II, the Ioway encoded a variety of information on their map, but accurate position was likely not one of the traits they were trying to maximize. It is unrealistic to expect the resulting georeferenced map to be highly accurate in a western sense. Instead, reasonable goals for georeferencing are to transform the map into a format more useful for modern audiences while remaining faithful to the information the Ioway chose to include. Realistically, locations of Ioway features georeferenced to a modern base map will perhaps only be accurate within tens of kilometers. This is sufficient to help researchers visualize the Ioway features "in the neighborhood" where they likely existed, using a modern base map, but accuracy should not be over-interpreted to mean a location accurate to meters or tens of meters.

Attribute accuracy ensures the validity of attribute data. In the case of the Ioway map, little attribute data exist on the map itself making data completeness a problem. Lewis (1987) attempted to identify all of the rivers and lakes portrayed on the Ioway map. Green (2001) refined Lewis' hydrologic identifications and extracted a substantial amount of additional information from historic and archaeological records, providing attribute data for many of the villages. I generated attribute tables for each of the digitized Ioway map feature layers (villages, trails, rivers, lakes) based on the work of Lewis and Green (Appendix G). These tables represent the state of research on each attribute field to date rather than established fact. When alternative possibilities existed (e.g., river segments that correlated with one of two or three different real-world streams) this information was also included in the attribute table.

Logical consistency, or the reasonableness of the data as they appear on a map, is also a concern. For example, foot trails should not appear to cross a lake surface, and village locations should not be mapped in the middle of a lake or river. The georeferencing tools used in this project apply consistent algorithms to the data but it is then up to the human analyst to examine and adjust the results for logical consistency. I

used several different georeferencing tools and approaches (see below and Chapter V) and results do occasionally violate logical consistency rules. I comment on these instances (Chapter V), but I did not change the results, leaving that task to researchers who want to apply these results. The one exception to this was the locations of Ioway villages. Georeferencing all four of the feature classes together resulted in a generalized "best fit" of all Ioway data to a base map. However, better results were obtained for each individual feature class if it was georeferenced alone or with only one other feature class. Ioway villages and trails were georeferenced together based on control points for the villages provided by Green (pers. comm.). These locations are slightly different from the locations that result if all four classes are adjusted together based on stream confluence tie points. Using Green's expertise and extensive historical and anthropological research is preferable, in my view, to arbitrarily accepting the computer generated positions using stream confluences. His suggested locations were utilized when possible.

Map Projections

Monmonier (1993:21) states that cartographers must begin each assignment by making three crucial decisions, determining map scale, map projection, and map symbolization. The Ioway Map Project covers an area of over 800,000 square kilometers (Figure 8), including all of the state of Iowa and portions of each of the seven adjacent states (Minnesota, Wisconsin, Illinois, Missouri, Kansas, Nebraska, and South Dakota). Their selection of this Midwestern area determined map scale for this project. The majority of the maps created for inclusion in this report are 1:5,000,000 or 1:6,000,000 scale to accommodate the full extent of the features on the Ioway map. This is a relatively small-scale map and limits the detail that can be portrayed.

Geographic analysis in such a large region necessitates careful consideration of map projection. A map projection translates the position of features from the curved, three-dimensional surface of the Earth to equivalent locations on a flat, two-dimensional map surface. In the process, one or more of the following spatial properties is necessarily distorted: angles, areas, distances, and directions. Cartographers classify map projections based on the properties that are preserved; equal area (or equivalent) maps preserve area, equidistant maps preserve distances, conformal maps preserve angles, and so on (Longley et al. 2001:89-95). Map projections are also classified based on the surfaces on which they are developed conceptually: cylindrical (cylinder); conic (cone); or Azimuthal (plane). When constructing a map, cartographers decide which properties are necessary and select a map projection to suit the particular purpose and scale of the map.

One key objective of the Ioway Map Project is to use GIS to understand the projection the Ioway applied in drawing their map. Once understood, features on their map can be re-projected accurately onto a modern base map. In practice, a consistent, modern projection had to be selected first for use with the GIS data layers. I used the Universal Transverse Mercator (UTM) projection which combines the characteristics of

Figure 8 - General Area Depicted on the 1837 Ioway Map
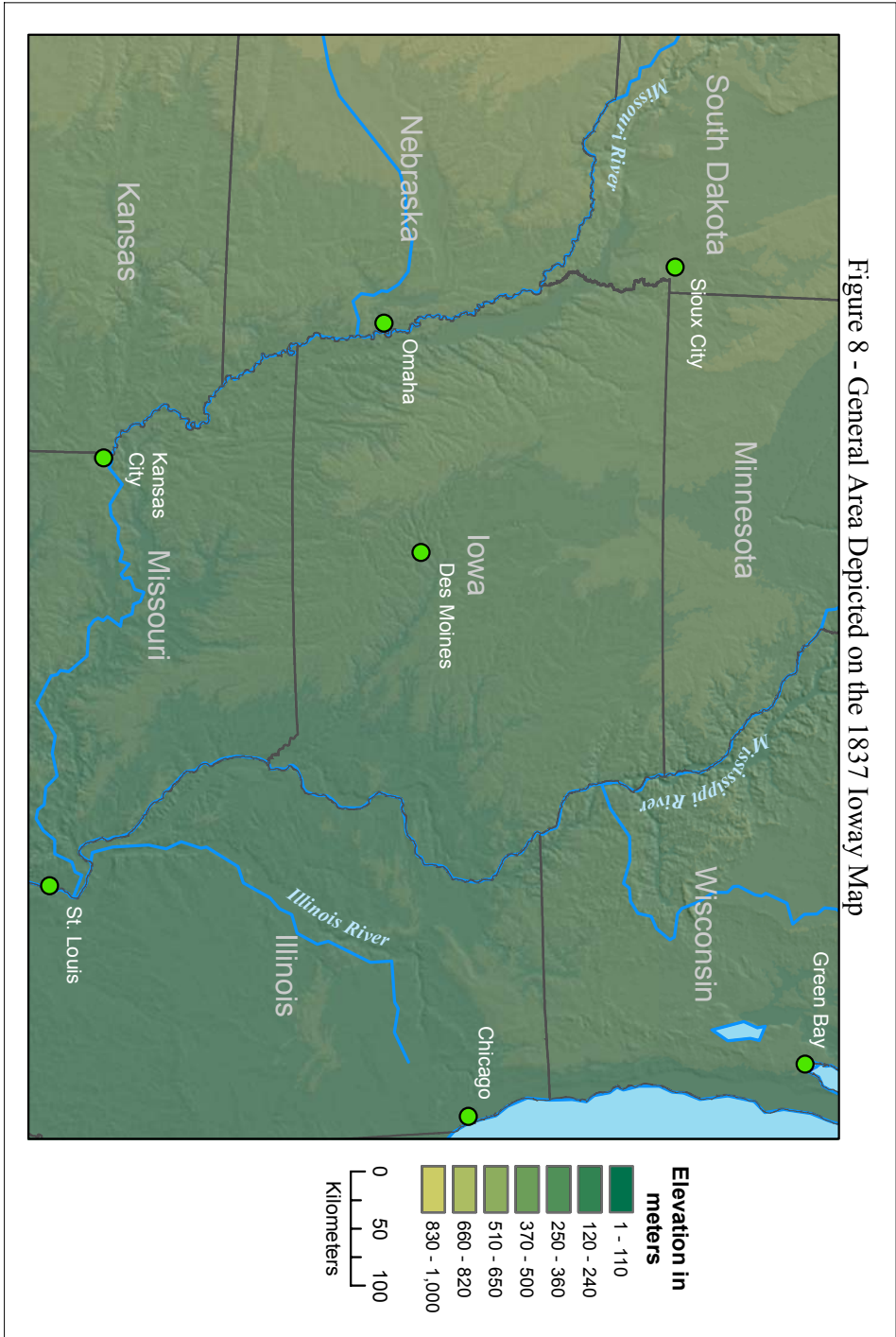
a Transverse Mercator map projection with a grid coordinate system. The Transverse Mercator is a cylindrical projection with a transverse aspect, that is, locations on the Earth are projected onto a cylinder that has been oriented transverse (or east-west) relative to the Earth's axis (Jones 1997:72-78). Distortion is minimal near the central meridian but increases with distance away from that line. The UTM projection divides the Earth into long (north-south), thin (east-west) strips or zones of 6 degrees width (longitude), each of which uses the Equator and its own central meridian. The relatively small east-west distance helps to minimize distortion within a UTM zone.

A UTM projection allows relatively accurate distance measurement and is commonly used by archaeologists. UTM Zone 15 North includes nearly all of the states of Iowa, Minnesota, and Missouri, minimizing distortion for the area covered by most of the Ioway map. UTM can be problematic if the map area crosses multiple zones because distortion is greatest near the edges of each zone. However, only small western (UTM Zone 14 N) and eastern (UTM Zone 16 N) portions of the Ioway map fall outside Zone 15. The distortion introduced by using UTM Zone 15N is acceptable.

Registration and Georeferencing

Georeferencing in its broadest sense means locating spatial data within a common geodetic coordinate system (Burrough and McDonnell 1998:76-78). In this project that process was begun with the selection of a datum (North American Datum 1983) and a projection (UTM Zone 15N). The base map and spatial analysis files were already in defined projections and these could be easily re-projected to the common UTM projection using ArcToolbox, ArcCatalog, or ArcMap. However, the scanned Ioway map image (.tif file) was geographically unregistered, that is, there were no real world geographic coordinates associated with features or locations on the image. The .tif file does have an arbitrary set of coordinates (scanner coordinates) associated with it. When the .tif file is added to an ArcGIS map document, the lower left hand corner of the scanned map corresponds to coordinates 0,0. Georeferencing, in this case, is the process of converting the 0,0 scanner coordinates to geographically registered coordinates on the base map. After georeferencing, the features on the Ioway map have coordinate values that can be linked with locations on the Earth's surface.

When the .tif map file is georeferenced, the data are changed in four ways within the x and y axes: rotation, scale, skew, and translation. Because the coordinate system

Figure 9 – Illustration of the changes introduced into a georeferenced image
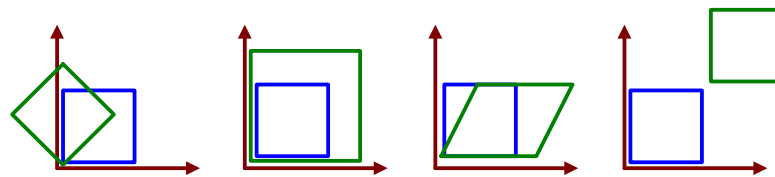
and spatial extent of the Ioway map changes, the map appears to move under (or in among) the base map layers as shown in Figure 26 (page 47). There are a number of mathematical formula that accomplish the actual transformation, some using polynomial equations to translate scanner units to a grid coordinate system, and others using triangulation (Jones 1997:79-81).

I applied both types of transformations (polynomial and triangulation) using ArcGIS Georeferencing tools and ArcGIS Spatial Adjustment tools. The Georeferencing tools use first order (Affine), second order, and third order polynomial equations to transform coordinates on the Ioway map into coordinates on the base map. The Spatial Adjustment Affine, Projective, and Similarity transformations also use the polynomial equations. However, Spatial Adjustment contains a rubbersheeting method that applies triangulation formulas. Each approach yielded slightly different results, none of which was entirely satisfactory. The results are discussed and illustrated in Chapter V.

To use the Georeferencing tools in ArcMap the Ioway map must be in a raster format (.tif file) and the base map in vector format. The Spatial Adjustment tools in ArcMap transform vector files to other vector files. Regardless of the tool used, the basic method is the same. First, control points must be identified on each map. Because these must be the same locations (identical position) on both maps, hydrographic features were used. Normally hydrographic features are not recommended as control points because rivers change course over time, lakes rise and fall, and geographic landforms are reshaped. In this case, however, these were the only available features that could be located on both maps with any level of confidence.

A set of 59 control points was selected and digitized on the base map (finalTiePts.shp; see Appendix G for details) including every river junction that appears on the Ioway map and a location along the shoreline for each of the nine lakes that appear on their map. Figure 10 illustrates the distribution of the control points across the base map. The Spatial Adjustment rubbersheeting operation required additional control points at the origin of each of the rivers on the Ioway map, and these were added for a total of 98 possible control points (Figure 11). Once the control points were established, I simply used the mouse to click on a control point in the origin map (the one to be georeferenced) then moved to the destination map and clicked the equivalent location there, thus establishing a link; the links appear as virtual lines like those shown Figure 11. Selecting the "rectify" option from the Georeferencing toolbar, or the "adjust" option from the Spatial Adjustment toolbar, applies the mathematical formulas and completes the process.

Figure 10 – 59 Control Points used in the Georeferencing Operations
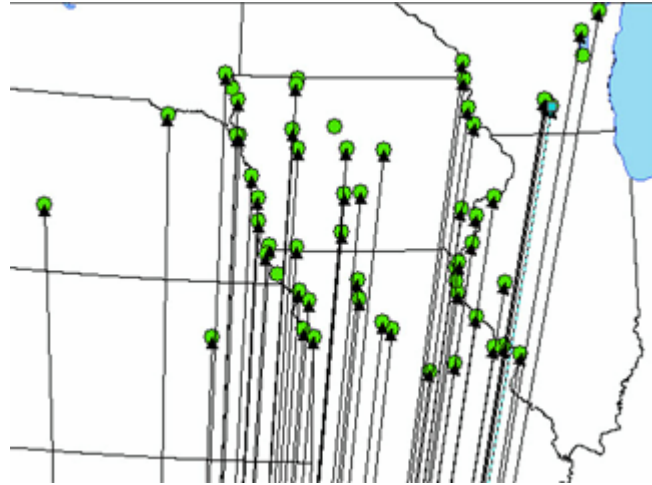
Figure 11 – Additional Control Points used in the Rubbersheet Transformation
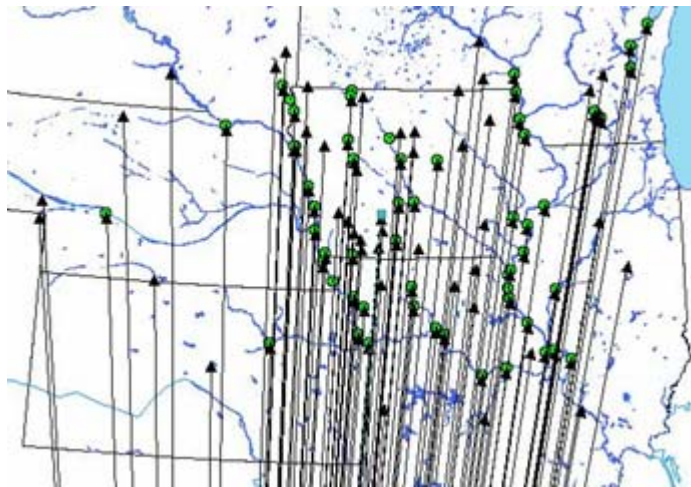
IV. Ioway Cartographic Conventions

As argued above, the Ioway used their map as a means of communicating selected aspects of their history and culture to representatives of the U.S. government in the context of treaty talks and land claims negotiations. Their map was intended for an audience of Europeans or EuroAmericans, although the Ioway apparently used a combination of western and indigenous cartographic design and presentation elements (Chapter II). GIS techniques, from simple pan, zoom and measurement tools to the more sophisticated mathematical transformations associated with georeferencing, help to identify the Ioway's cartographic choices.

The Context of Production

There is no title on the Ioway map, and no single author is credited with producing it (Green 2001:14). The National Archives[2] catalogs it as "untitled manuscript map." Lewis cites a number of examples from the historic literature of individual Indians drawing maps, apparently at the spur of the moment, when asked to do so by a European or EuroAmerican (1998a:18-26; 1998b:115-137). Schoolcraft, reporting on the production of the other (1847) Ioway map wrote "It was drawn in the rough, by Waw-non-que-skoon-a, with a black-lead-pencil [sic], on a large sheet of white paper, furnished at the mission-house…" (1853:256). It is possible that a single Ioway individual drew the 1837 map in a manner similar to this.

Although it is sometimes referred to as the "No Heart," or the "Non-Chi-Ning-Ga" map, after *Na'je Niŋe* the head of the Ioway delegation, there is no evidence that he drew it. In his 1998 chapter on Native American maps and map making, Lewis states "A map by Non-Chi-Ning-Ga, an Iowa Indian,…" (1998b:134) but it is unclear why he concludes that No Heart was the author. Green transcribed a section of the map annotation (added in 1884, apparently when the map was curated) as "It was made by an Indian and presented to C.A. Harris, Esq., comr. on the part of the U.S. by 'Non-chi-ning-ga' an Iowa chief who produced and referred to it during his address …" (2001:14). Although written forty-seven years after the event, this would indicate that the map author's identity was unknown, and was not No Heart.

In a different publication, Lewis appears to suggest that the 1837 Ioway map was drawn in Washington D.C. during the treaty talks when he writes "..an Iowa chief's map was produced, apparently spontaneously, in trying to resolve a dispute between two groups of Indians concerning land" (1998a:113). It seems more likely that the map was drawn before the Ioway delegation traveled to Washington, however. The Ioway understood the seriousness of their position and the importance of these negotiations (Warhus 1997). They had lost considerable land in treaty talks in 1825, had had years of contact with American government officials, and had seen and understood the

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[2] The 1837 Ioway map is curated by the National Archives and Records Administration (NARA), College Park, Maryland, in the Cartographic and Architectural Branch. The map's catalog identification is Record Group 75, Central Map File, Map 821.

usefulness of paper maps in other contact situations. It seems plausible that one or more Ioway planned the creation of the map, and its content, drafted the document, and provided it to the members of the delegation.

Map Annotation

The 1837 map is drawn with ink on paper, probably using a quill pen or brush. Green (2001:14) reports that the original is 69 centimeters wide (27.17 inches) by 104 centimeters long (40.95 inches). This odd paper size came about because the Ioway joined two nearly square sheets of paper with some form of adhesive (Green pers. comm.). There is a zone of overlap of roughly two inches (5 cm) near the middle of the map. The original single sheets were roughly 69 centimeters wide and between 56 and 60 centimeters long. The Ioway may have obtained the paper from missionaries or traders in their area, and it might be worthwhile to research what kinds of paper would have been available in the region at that time (blank stock for newspapers, wrapping paper, journal or book paper, etc.).

The fact that the Ioway used two pieces of paper indicates that they had a fairly clear notion about the area they wished to depict, the scale at which they wished to depict features, and therefore the size their map needed to be. Still, some of the river features on the map (e.g., the Missouri River) appear cramped. It would be interesting to know if the spatial positioning of the two major rivers, the Missouri and the Mississippi, was influenced by the size and shape of the available paper. When the map is oriented along its long axis, the Mississippi River line feature follows a reasonably accurate (though simplified) course from north to south, and then moves off course southwest (perhaps to continue to show its course while still fitting it on the page?). If the map is skewed slightly (30-45 degrees), the Mississippi's course improves. The Missouri River is less accurately rendered, running nearly vertically from north to south along the western edge of the map (Figure 12). It is not clear whether this is the way the Ioway understood the spatial positioning of these rivers, or whether they were trying to render geographic features in topologically correct positions rather than with accurate scale and position.

Examination of the map (.tif file) using low power magnification (ArcGIS zoom to 1:4 scale, or between 2x – 4x magnification) is helpful in studying the annotation, point, polygon and line features, and the symbology. There are several text labels, as well as a large text block (Figure 13), although it is unlikely that any of this was written by the Ioway. The large block of text at the bottom is headed by an elaborate rendering of the word "Note," in which the "N" has been stylized and appears almost like an "X." The text block describing the map's provenance was added in 1884 by a draftsman or clerk (Paul Brodie) working for the Office of Indian Affairs. It briefly describes the occasion at which the map was presented, the date and time of the talks (October 7, 1837, 10 o'clock), the participants in the talks, and the fact that the map was drawn by the Ioway (Green 2001:14). The "**821**" stamp and pencil mark, as well as the identifying phrase "tube 520" were apparently added at the National Archive since these correspond with parts of the map's NARA catalog number.

Figure 12 - The 1837 Ioway Map with Selected Features Labeled
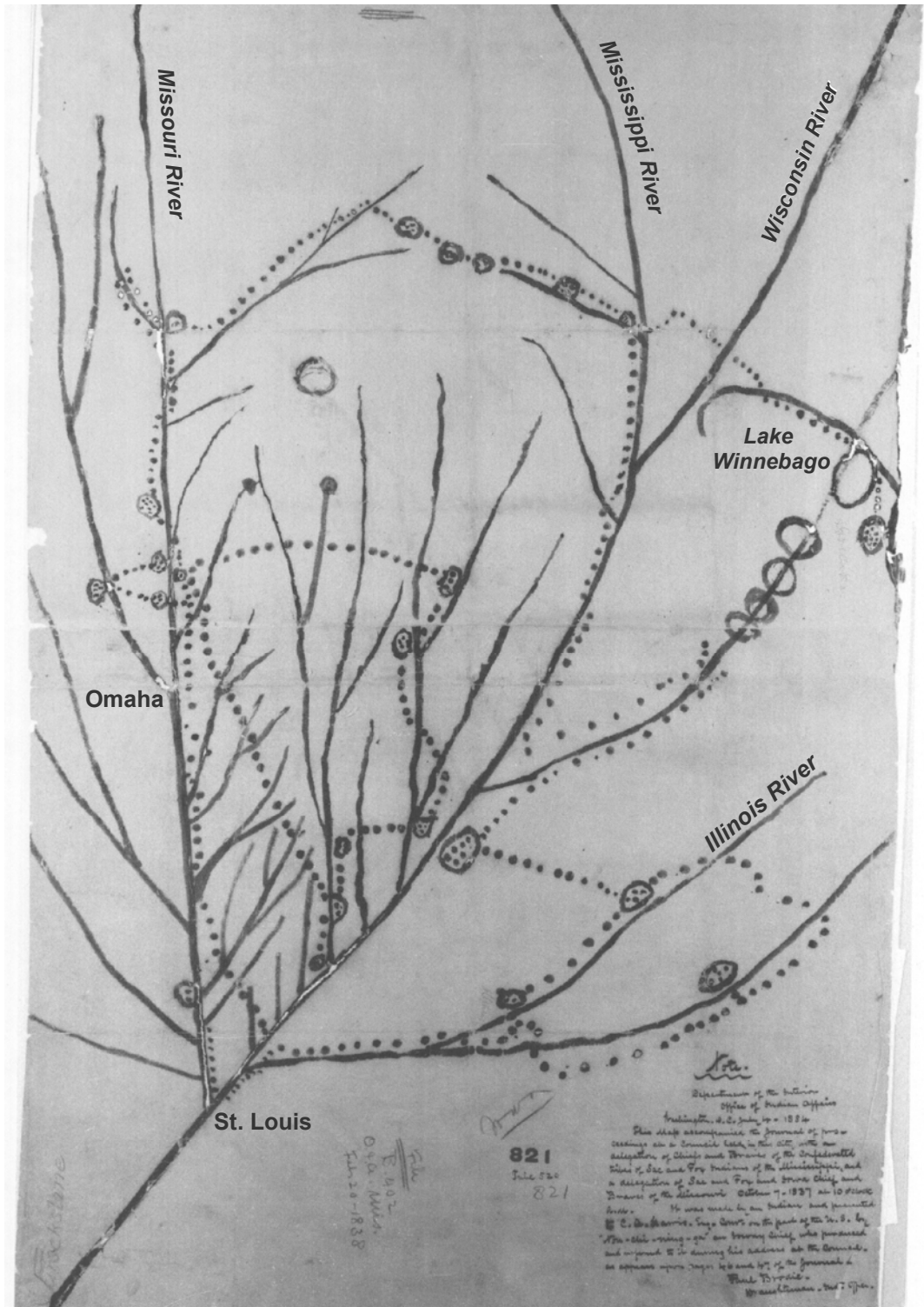
Figure 13 – Large section of annotation on the 1837 Ioway Map (magnified)
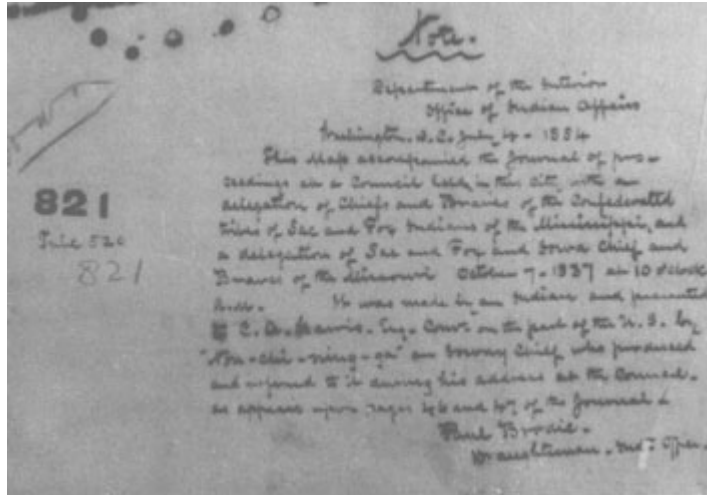
After examining the map, and reading the transcript of the treaty talks at which it was used, Green concluded that several of the place names added to the map in pencil were annotations that were made during the negotiations (for example, Green Bay is identified as the Ioway's ancestral home). These helped to link map features with place names and events described by No Heart and other delegates in their discussions (2001:15). These annotations have also helped more recent scholars correctly identify the river and lake features on the map (Lewis 1987; Green 2001).

Feature Selection

Every map represents a model of the world, the selection of a very limited number of features and relationships from among the universe of possible features in the world. The Ioway map, for example, covers more than 800,000 square kilometers of the Midwest, an area that contains well over 14,000 named hydrographic features. Yet their map includes only 51 rivers and 9 lakes. Their choices, and the features they chose not to render, are likely to be informative about how the Ioway conceptualized the hydrography of their territory.

The red lines in Figure 14 highlight the rivers and lakes shown on the Ioway map against a background of the general hydrographic features (symbolized in blue) in the area. The Ioway included most of the large rivers and lakes in Iowa on their map, with the exception of the Wapsipinicon and Maquoketa Rivers in the eastern part of the state. All of the rivers in Iowa were simplified, however, as shown by the large number of blue tributary streams in Figure 14. Interestingly, streams of similar size that enter from the western side of the Missouri River are not included on the Ioway map although regularly spaced streams on the eastern side are present. This pattern also holds true to some extent along the Mississippi River. Outside what is now the state of Iowa, only the very largest rivers were rendered: the Wisconsin, Rock,

Figure 14 - Rivers Selected by the Ioway for Inclusion on their 1837 Map
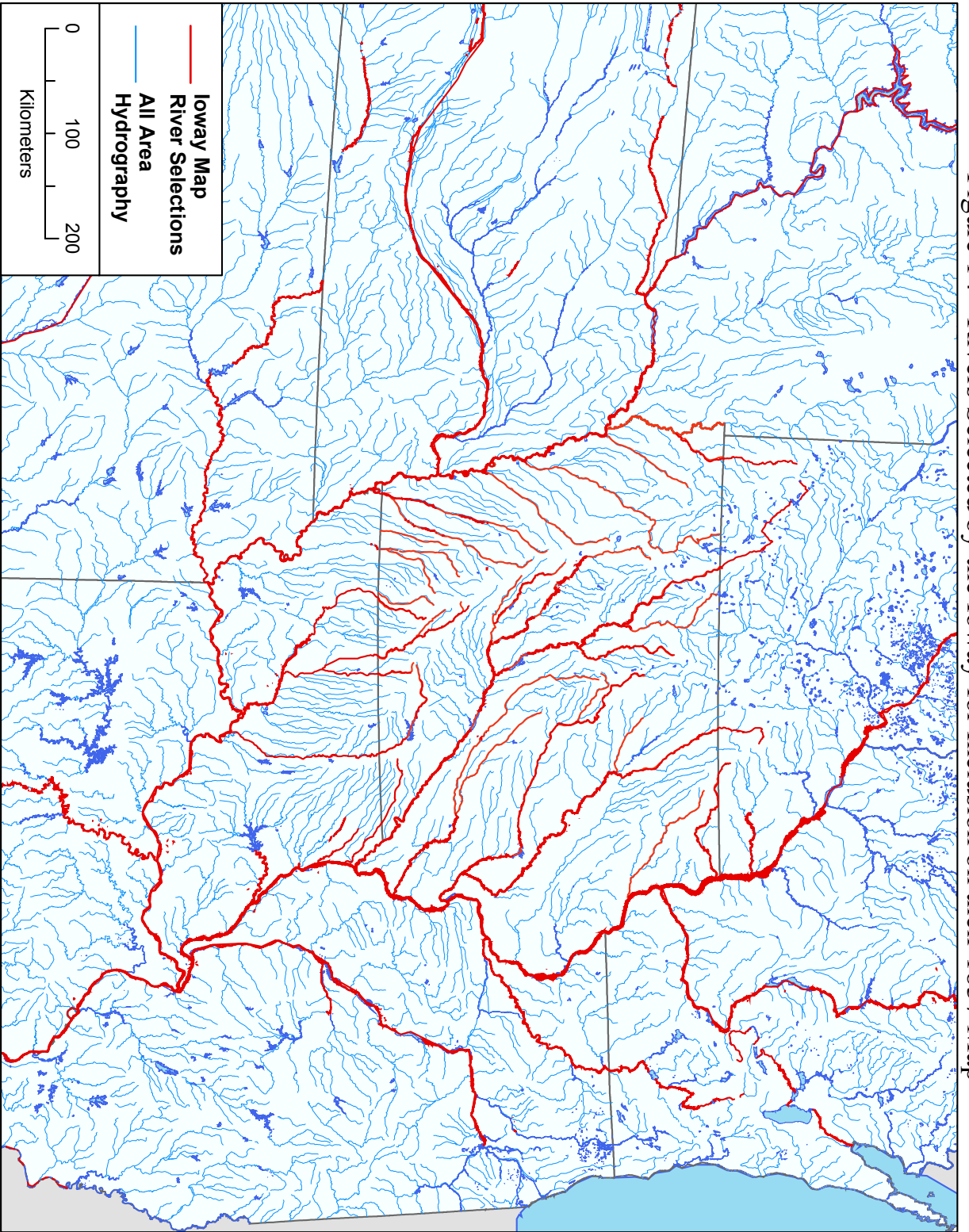
Illinois, Niobrara, Platte, and Kansas. The lone exception to this is their inclusion of the Sangamon River, a tributary of the Illinois. If the rivers selected by the Ioway were meant to delineate their territory, its boundaries clearly lay between the Missouri and the Mississippi Rivers in what are now the states of Iowa and northern Missouri.

Map Symbology

The Ioway used only four, straightforward symbols on their 1837 map: lines representing river segments, polygons representing villages and lakes, and points representing trails and perhaps houses within village polygons. However, using only this limited range the Ioway were able to encode a great deal of information. No detailed description or analysis of the map's symbology has yet been published, so some preliminary remarks are provided here.

Magnified examination of the point, line, and polygon features sometimes reveals the order in which the features were drawn (Figure 15). The major river segments (Mississippi and Missouri) were apparently drawn first, anchoring the space and establishing the outlines of the Ioway's territory. Along most of the length of the

Figure 15 – Confluence of the Upper Iowa and Mississippi Rivers (magnified)
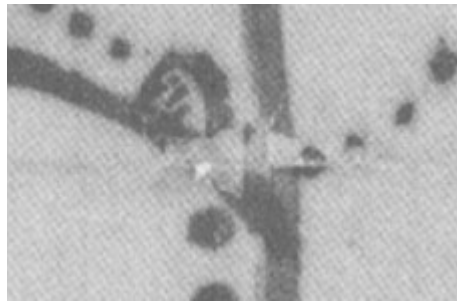
Mississippi River, the tributary streams cover the larger river, indicating that they were drawn after that stream. The superposition of tributary streams atop the main river at the confluences is clear, indicating that the ink used to draw the Mississippi River had had time to dry before the tributary streams were drawn. Trail points and village polygons cover river segment lines at several locations (illustrated above) and were drawn after the hydrographic features were in place.   Again, with only rare exceptions, the inked polygon, point and line features were not smudged and blurred, but clear. The hydrologic features were drawn and allowed to dry before other sets of features (villages and trails) were added. This might not have taken a great deal of time, but I think it does indicate that drawing the map was not a hasty endeavor dashed together at the last minute.

Because some lines have been inked and re-inked, one on top of another (the Missouri River and its tributaries appear to fall into this category), it is not possible to conclusively determine the order in which all map features were drawn. However, based on feature superposition, a reasonable scenario is that the Mississippi and

Missouri Rivers were drawn first, then the tributary streams, next the villages, then the house points within the villages, and finally, the trails. GIS conventions like "cover" and "covered by" may not have been familiar to the Ioway, but it would be interesting if they were choosing to indicate stream order and tributary relationships by carefully selecting the order in which some line features cover others.

Interestingly, line width also varies across the map, although no systematic relationship was found between line width and stream order. Figure 16 shows

Figure 16 – Magnified section of the Ioway Map, showing varying line weights

thinner tributary stream features joining wider main stream features along the Missouri River. It may well be accidental – it is not always easy to control line width with a nib pen – but it is possible that the Ioway were trying to convey something by using variable line weights. Similarly, the size of the trail points varies. In the illustration above there is an alternating pattern of larger, then smaller, then larger points coming down from the north. Differences in trail point size was helpful in trying to follow the path of one particular trail when several crossed. Again, this may mean nothing, but it may have been a deliberate convention used by the Ioway to convey information about particular trails (see below for further discussion of trails).

Village symbols differ in size (area) and in the number of points each contains (Table 1). Village size was measured in square inches, calculated for each village polygon by ArcMap. Table 1 also shows a transformed village area, converted to correspond to the full size of the actual map (the .tif file used in ArcMap is 1/3 the actual map size). Average village area is 0.593 square inches (actual map size = 0.17 square inches). The smallest village is 0.021 sq. in. (Village I) and the largest is 0.162 sq. in. (Village P). Area values were classified into four categories, using the standard deviation method available in ArcMap[3], and the results mapped in Figure 17. A majority of the polygons fall into the very small and small classes (the average village area = small) and are scattered throughout the Ioway's territory.

Table 1
Ioway Map Village Area and Estimated Number of Houses

Village ID[1]	Digitized Area[2] sq. inches	Original Area[3] sq. inches	Area Rank[4]	Min. # of Houses	Max. # of Houses
A	.1059	0.30	**medium**	9	12
B	.0248	0.07	very small	4	8
C	.0530	0.15	small	4	7
D	.0470	0.13	small	2	3
E	.0584	0.17	small	1	4
F	.0621	0.18	small	3	5
G	.0538	0.15	small	2	2
H	.0569	0.16	small	8	8
I	.0207	0.06	very small	1	3
J	.0438	0.13	small	3	5
K	.0374	0.11	very small	1	3
L	.0469	0.13	small	3	4
M	.0601	0.17	small	4	5
N	.0648	0.19	small	3	7
O	.0280	0.08	very small	1	1
P	.1621	0.46	**very large**	7	8
Q	.0896	0.26	**medium**	4	4
R	.0571	0.16	small	2	5
S	.1096	0.31	**large**	5	5
T	.0599	0.17	small	2	4
U	.0306	0.09	very small	4	5
V	.0523	0.15	small	4	4
W	.0386	0.11	very small	4	6

[1] Village ID is the identification letter assigned by Green (2001).

[2] Area is measured in square inches, calculated by ArcMap from the digitized outline of each village polygon in the scanned map image (.tif).

[3] Measurements in column 2 were multiplied by 100 and divided by 35 to convert them to values that approximate those on the original size map in the National Archive. The scanned map used in this project was 35% of the original size.

[4] Rank values were calculated in ArcMap using the Standard Deviation classification method. Mean village size = 0.059274 sq. in., standard deviation = 0.031136 sq. in. (original size map: mean = 0.1694 sq. in.; standard deviation = 0.0890 sq. in.)

Figure 17 - Classification of Villages by Area

Ioway Village Sizes

🟩	very small
🟨	small
🟧	medium
🟥	large
🟥	very large
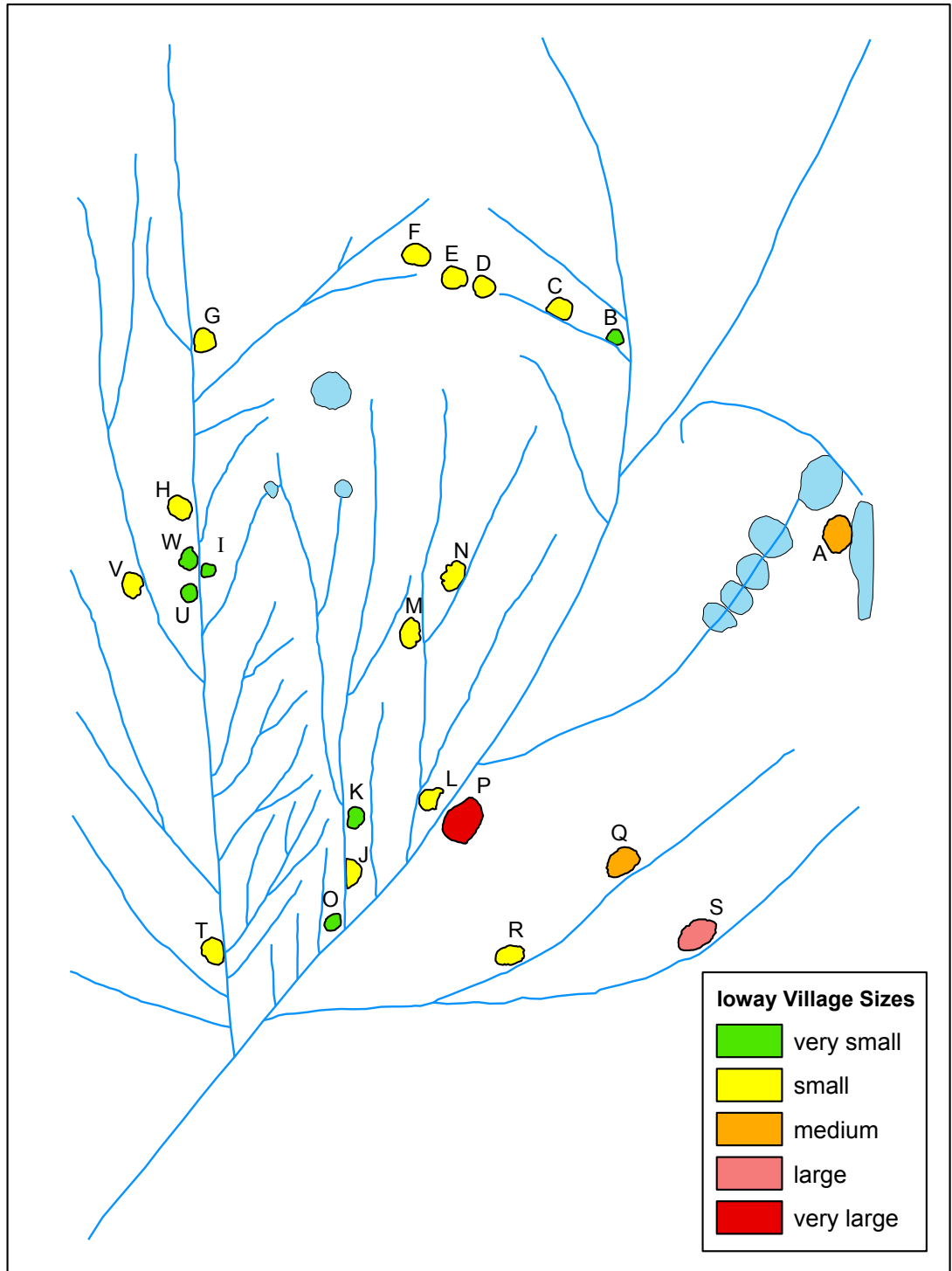
The four largest villages, A, P, Q and S, are clustered in the eastern third of their land. Green (2001:14-15) identified Village A as the origin site of the Ioway near Green Bay based on information recorded in the transcript of the 1837 treaty talks. Villages Q and S are Kickapoo or Potawatomi villages, neighboring tribes visited occasionally by the Ioway in the early nineteenth-century. Only Village P is an Ioway village, identified by Green as Upper Iowa town occupied from the late 1700s to the early 1800s.

Every village contains at least one point; the maximum number of points in a village was 12 and the average was 3.5 (Table 1). It is likely that the points inside the village symbols were meant to represent houses (or numbers of families, or numbers of different social or political groups), a convention that was well established across the Plains (Wood 1987; Lewis 1998b; Ronda 1987). It was sometimes difficult to accurately count the number of points per village because the start or end point of a trail overlapped the village outline. However, if I assume that line precedence (superposition) is consistent and meaningful, I could estimate the number of house points per village.

I assumed two topological rules: trail points can cover village polygon outlines, and village polygon outlines must contain house points. Using these rules I visually inspected each village polygon (using zoom tools) and counted the minimum and maximum number of houses each contains, as shown in Table 1. Minimum number of houses is the number of points unquestionably visible within a village polygon. Maximum number of houses is the number of points that might be indicated, although some of these might be points that actually belong to incoming or outgoing trails. After adding minimum and maximum house number values as attribute fields in the villages layer, I classified the values into four categories using Jenks[3] natural breaks. Figures 18 and 19 show the spatial distribution of the classified values, and lead to several interesting observations. First, Village A (the ancestral home of the Ioway along Green Bay) is an outlier on both maps, containing the largest number of houses. Since the Ioway had not lived in this region for centuries (sometime between 1000 and 1600 A.D.), the points within this village likely represent something other than a factual memory of house numbers. The large number of points could be accidental, but it is

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[3] ArcMap 8.x includes six geostatistical methods for classifying data: manual; equal interval; defined interval; quantile; natural breaks (Jenks); and standard deviation. These are selected in the "Layer Properties" menu, under the "Symbology" tab. The data are displayed on a histogram with the class breaks shown using vertical lines. Once the number of classes and method of classification have been selected, ArcMap allows the user to assign a color scheme to display the classified data on the map.

According to the ArcMap Help file, in Jenks natural breaks "Classes are based on natural groupings of data values. ArcMap identifies break points by looking for groupings and patterns inherent in the data. The features are divided into classes whose boundaries are set where there are relatively big jumps in the data values."

Figure 18 - Classification of Villages by Minimum Number of Houses
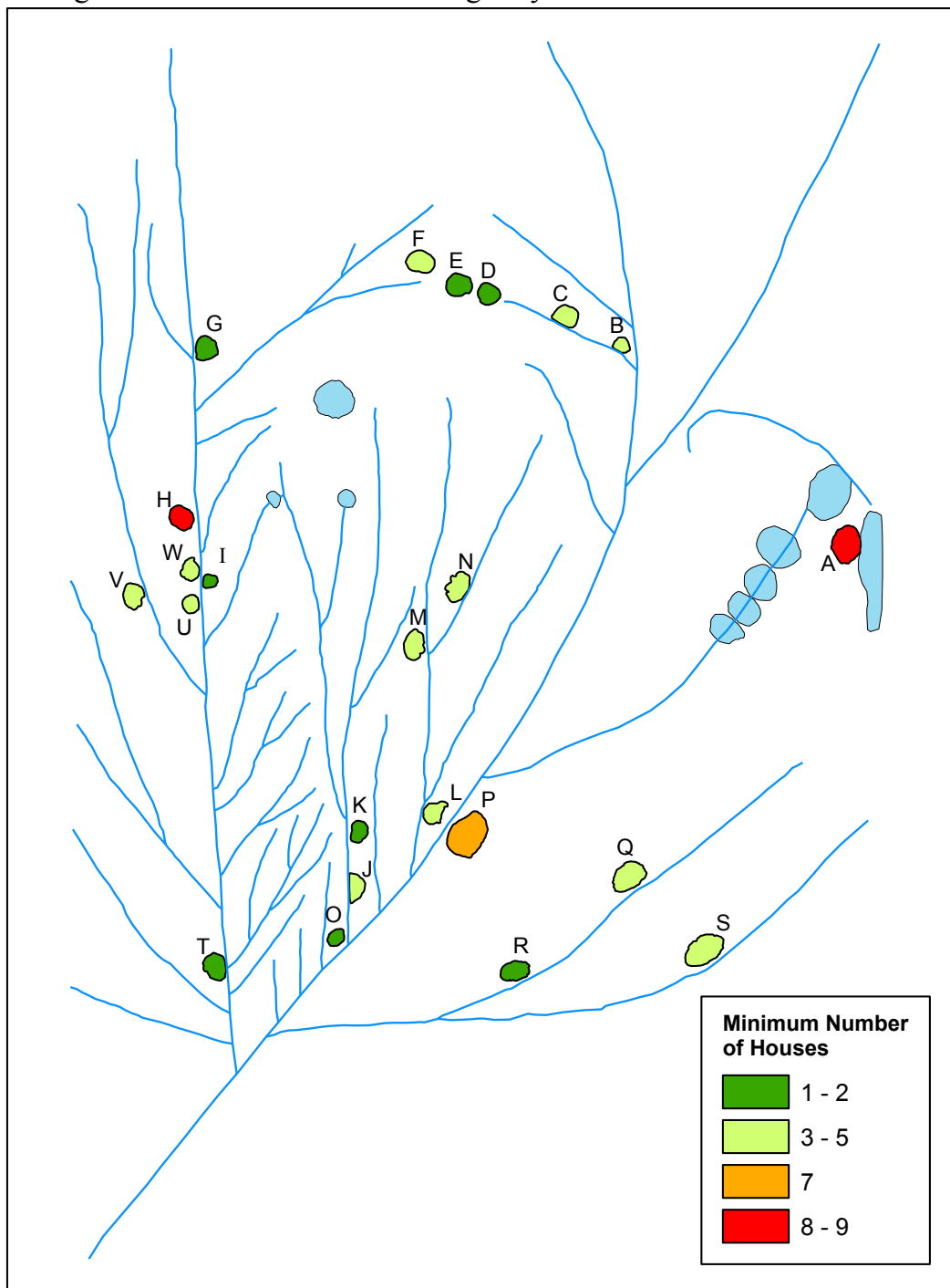
Figure 19 - Classification of Villages by Maximum Number of Houses
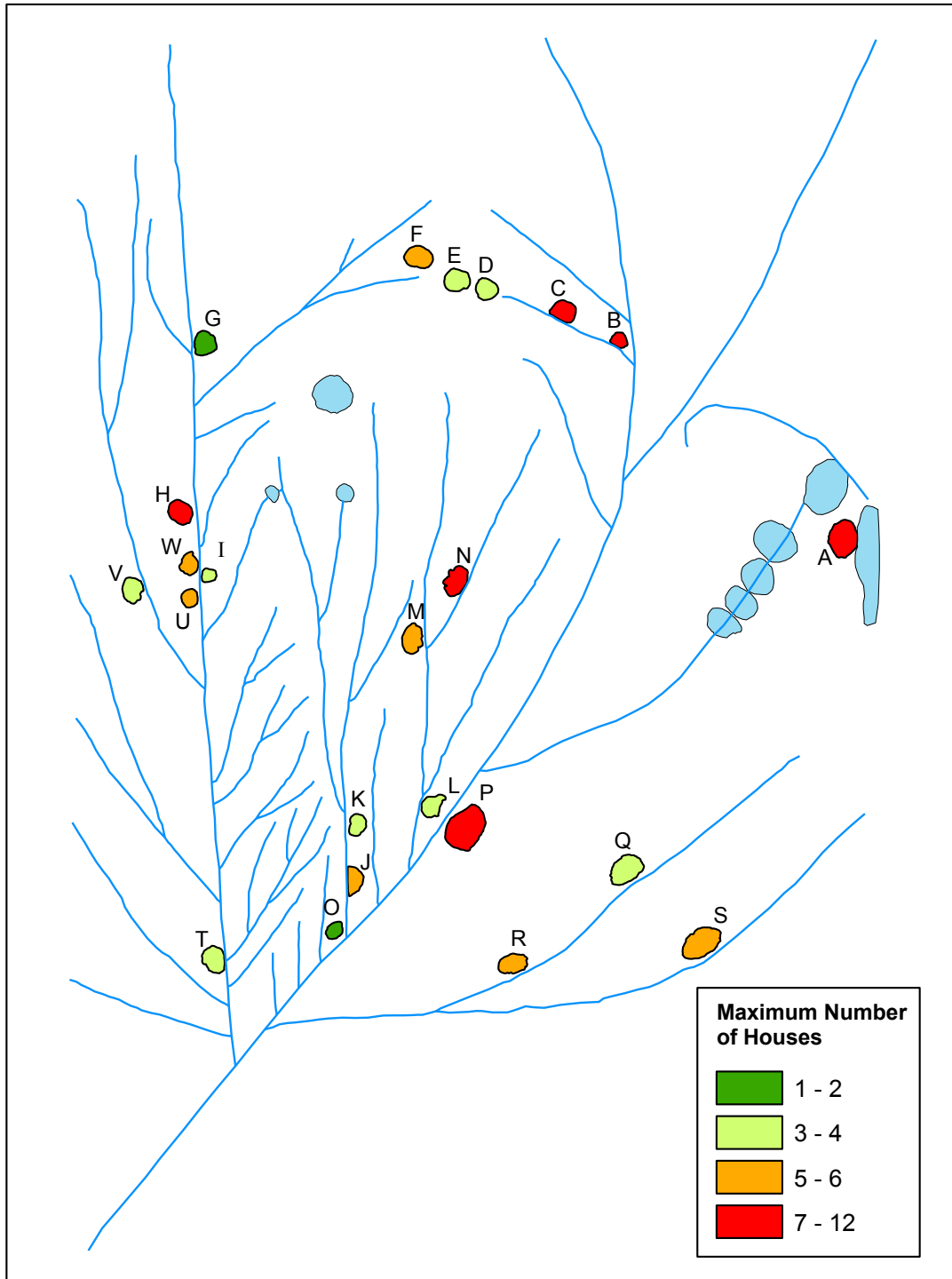
intriguing to consider the possibility that the 9-12 points refer the number of divisions this ancestral group later split into, divisions that eventually developed into the Ioway, Otoe, Missouria, Winnebago, and other distinct tribes.

Two other villages, H and P, have consistently large numbers of houses, whether using a conservative minimum count or a more generous maximum count. Village P also has the largest area, three times the average village size and more than one-third larger than any other village. It may in fact represent an amalgamation of two villages (Green pers. comm.). The large number of houses in village P probably corresponds to its large area. Village H, in contrast, was of only average size (area) but contained eight clearly distinguishable houses. Village H is older than village P, likely occupied from 1715 until the mid-1700s, based on Green's research (2001:15). He reports that during the treaty talks No Heart explained that the Ioway went to settle with the Omaha at one of their villages, which Green suggests is likely to be Village H. If this is correct, the combined Ioway and Omaha population could account for the larger number of houses.

It is unclear how much importance to attach to the house points and village size data. Although the suggestions above are plausible, there are other explanations for the variations in size and number of points, including that they are not meaningful. There is a weak correlation between village area and the number of houses ($r^2 = 0.3717$), and the scattergram (Figure 20) shows considerable dispersion around the linear regression

Figure 20 – Scattergram of village area and number of houses
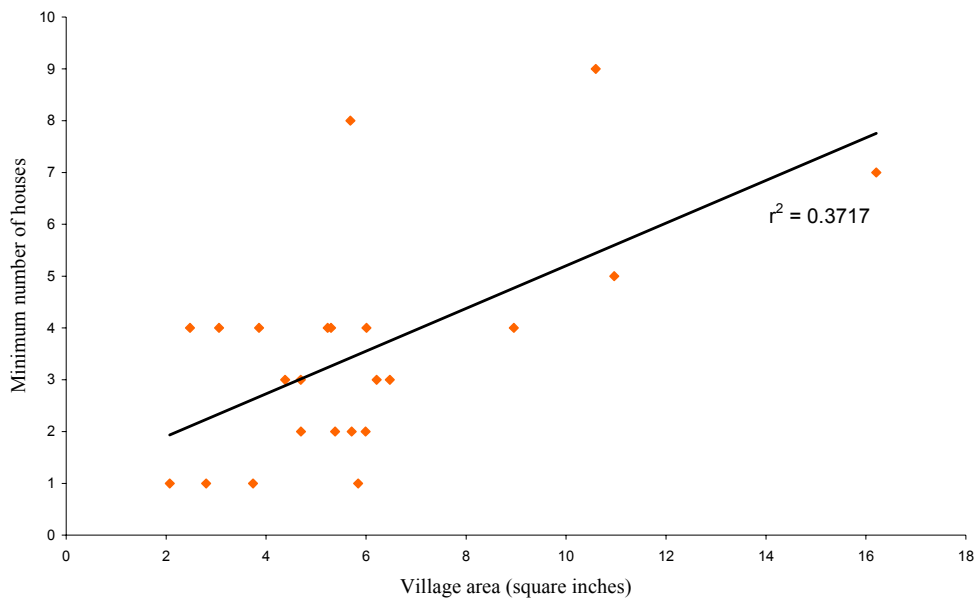
Table 2

Trail Distance and Number of Points per Trail on the Ioway Map and the Base Map

Trail ID	Number of Pts in each trail	Start Village	End Village	Ioway Map Distance (inches)	Base Map Distance (km)
1	32	A	B	4.1	350
2	5	B	C	0.7	81
3	6	C	D	0.9	64
4	1	D	E	0.3	156
5	2	E	F	0.5	79
6	24	F	G	3.0	320
7	26	G	H	3.7	632
8	5	H	I	0.8	53
9	23	I	J	3.9	366
10	3	J	K	0.6	132
11	5	K	L	1.0	179
12	12	L	M	2.1	274
13	3	M	N	0.8	49
14	16	N	I	2.9	246
15	3	J	O	0.7	78
16	41	LAKE 6a	B	7.1	440
17	20	LAKE 6a	P	3.5	295
18	11	P	Q	1.9	123
19	19	Q	S	4.2	383
20	46	R	T	7.9	558
21	28	T	I	4.9	528
22	6	Trail 21	Trail 20	1.3	No data
23	7	R	Q	1.7	42
24	5	W	V	0.7	83
25	4	V	U	0.7	68
26	2	U	Trail 21	0.3	21

line. The Ioway may not have intended to portray village area precisely (or proportionately) on their map. Similarly, the numbers of house marks within a village may have been meant only as a symbol of village significance (important village = large number of points; average village = average number of points). Further research, particularly if archaeological data on village area and number of houses is available, is needed before conclusions can be drawn.

The final topic to address in symbology is trails. In most cases, trails connect village polygons. Each trail varies in its distance from streams and in the size and number of points used to create it (Table 2). One possible interpretation of this is that the Ioway were consciously trying to encode information about trail location and travel time, as historians have argued with reference to other Native American maps (Lewis 1987; 1998b; Ronda 1987).   If we assume that one point represents some standard measure of time or distance (e.g., one day's travel), this could provide interesting information on route selection and travel speed. Given the uneven scale on the Ioway map, this is a difficult proposition to test. Table 2 provides base line data on the number of points in each trail, its start and end village, the length of each trail measured on the Ioway map (distance in inches) and on the base map (distance in kilometers). Figure 21 illustrates the locations of the villages and trails on a modern base map, determined from their proximity to identified rivers and using information from georeferencing and guidance from domain expert Dr. William Green (see Chapter VI for details).

Figures 22, 23, and 24 show three scattergrams (with linear regression lines) that describe the relationships among distance and trail point count from Table 2. Figure 22 plots the number of points in a trail against its length in inches on the original Ioway map.   These are highly correlated ($r^2 = 0.9571$) suggesting that the Ioway were trying to provide information on travel time or distance. The four trails that fall outside a 90 percent confidence interval are of particular interest. Trail 1 (between Villages A to B), Trail 6 (between Villages F to G), and Trail 7 (between Villages G to H) contain more points (days of travel?) than the map distance would require. Trail 19 (between Villages Q to S) contains too few points (days of travel?) relative to the map distance involved. Trail 1 relates to the origin journey the Ioway made centuries earlier and may be anomalous for that reason. Trail 19 involves non-Ioway villages and this could be a factor (unfamiliarity?).

A potentially complicating factor in the interpretation of trail distances is that from the 17th through the 19th centuries the Ioway had three available modes of transportation: boat (canoe), horseback, and foot travel. The distance one could travel in a canoe (potentially one point on a trail) is not the same as the distance one could travel on foot or on horseback (also potentially illustrated as one point on a trail). Some of the trails are clearly overland routes (eliminating boat travel as a possibility) while others follow streams closely. It is undoubtedly too much to hope that the Ioway distinguished foot, horseback, and boat travel by using different size points on the various trail segments. Further investigation is beyond the scope of this report, but these observations do reinforce the value of GIS as an analytical tool.

Figure 21 - New Village Positions based on Best Approximation of
Georeferenced Village Locations
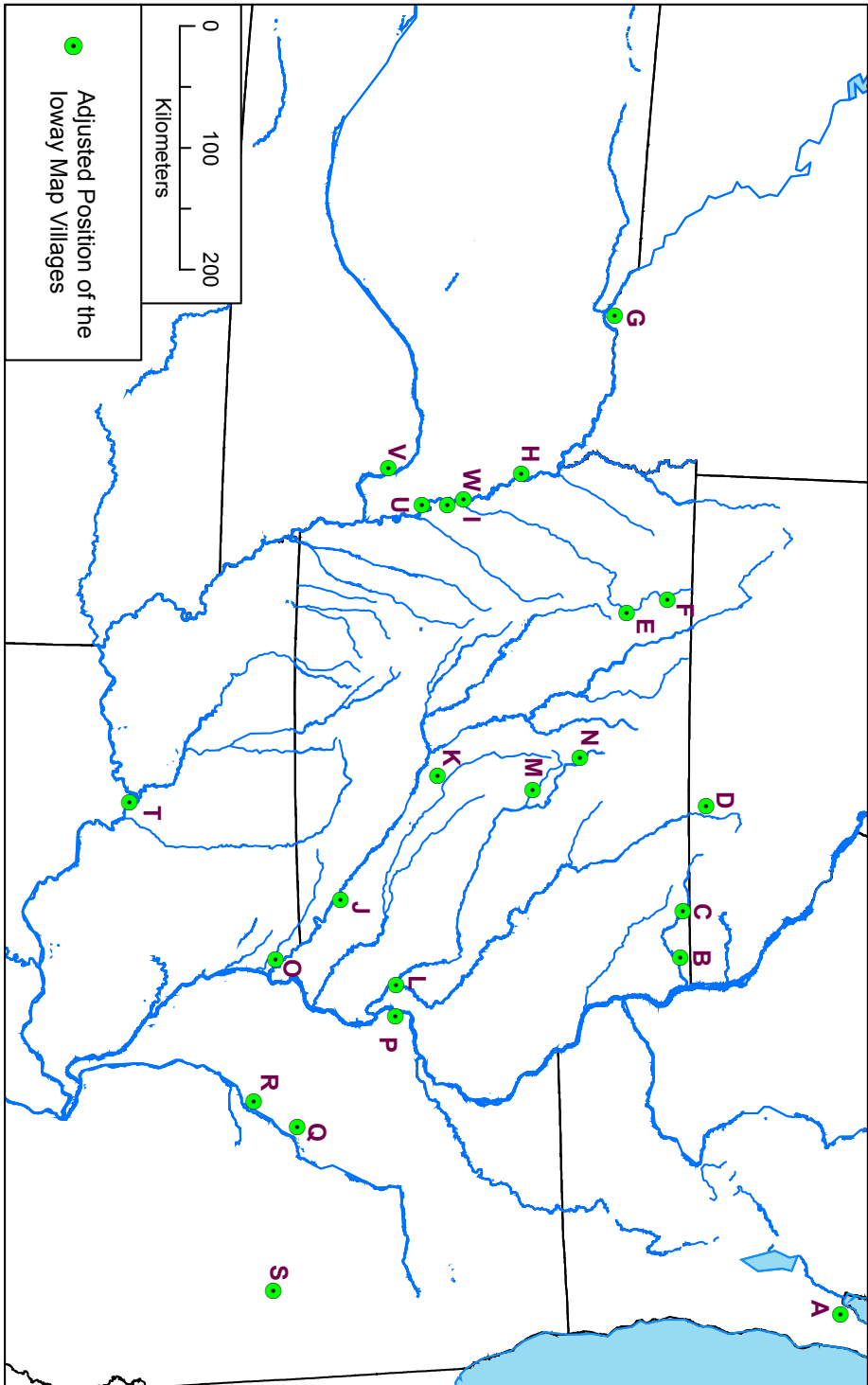
Figure 22 – Scattergram of trail distance and number of points in each trail
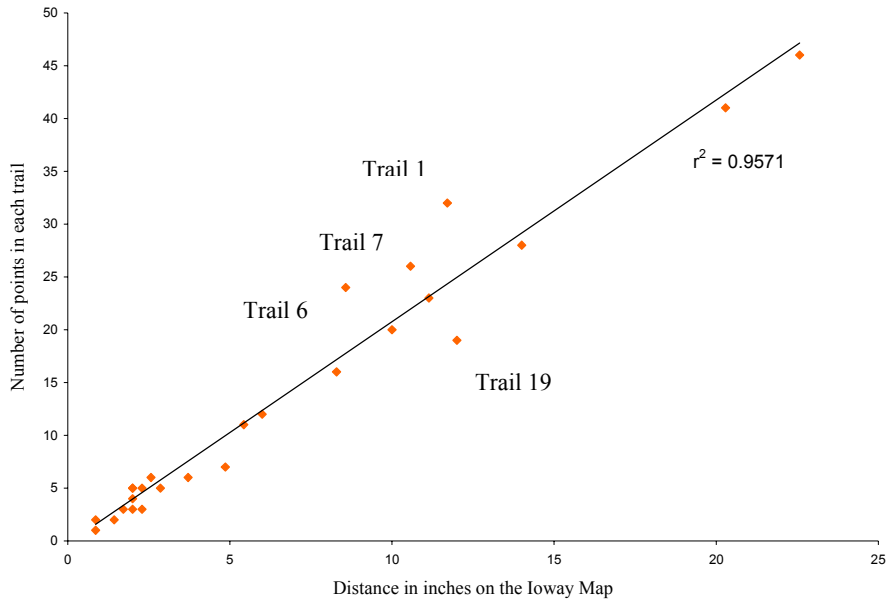
Figure 23 shows a scattergram of trail distance, measured in kilometers on the base map, and trail distance (converted to centimeters) on the Ioway map. The data are somewhat dispersed around the linear regression line but show a surprisingly high correlation ($r^2 = 0.7041$). This suggests that distance values on the Ioway map can be predicted by distance values on the base map. Such a result is rather unexpected given

Figure 23 – Scattergram of trail distance on the Ioway Map and the base map
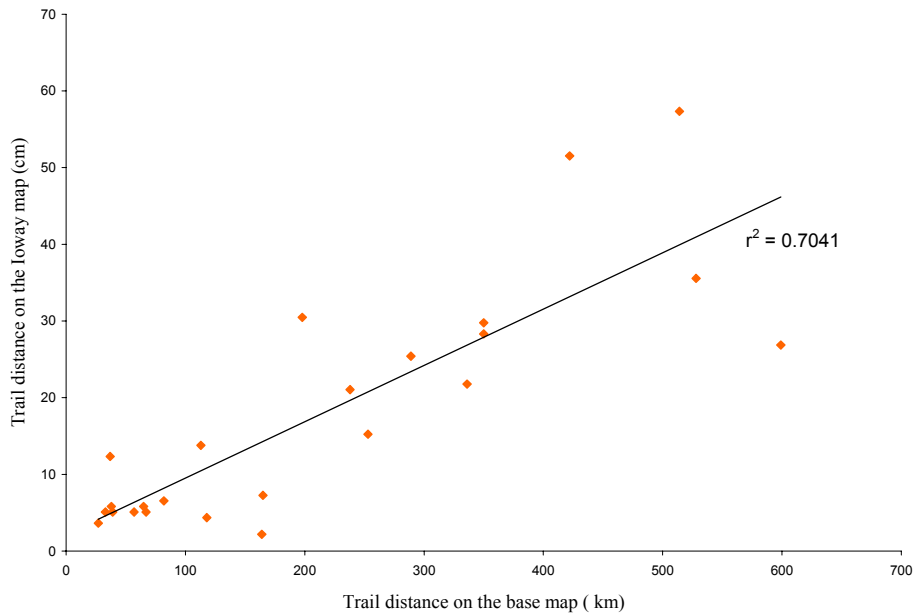
the unevenness of the scale on the Ioway map (discussed below in detail).   Figure 24 plots base map distance (measured in kilometers) and the number of points in each trail.

Figure 24 – Scattergram of trail distance on the base map and number of points per trail
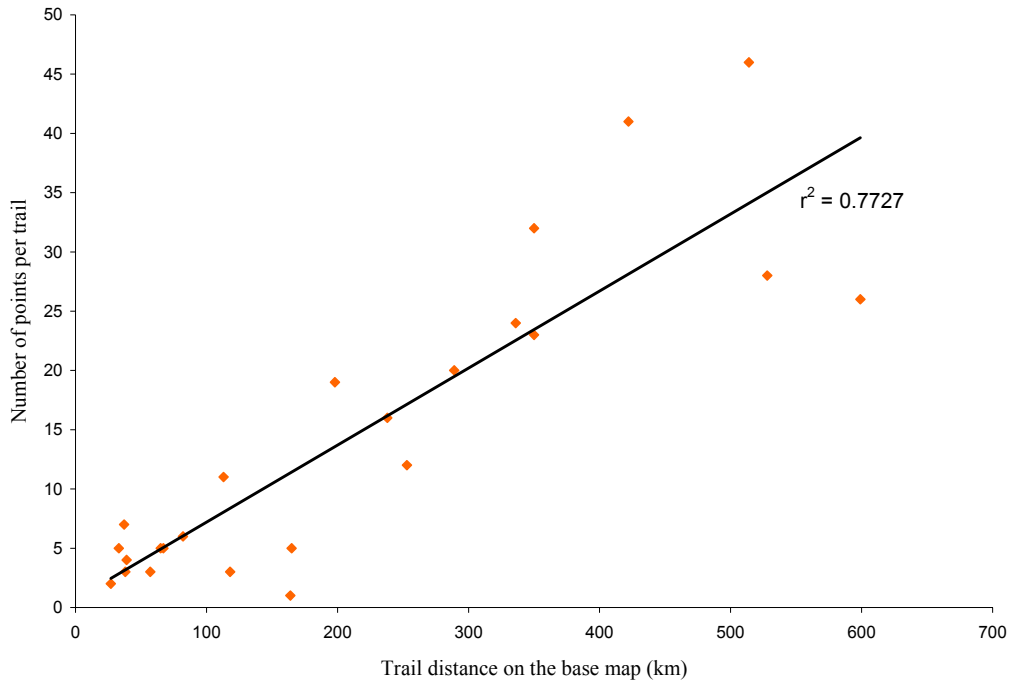
Again the data are dispersed but show an unexpectedly high correlation ($r^2 = 0.7727$). The results in Figures 22, 23 and 24 suggest that, although scale was not uniform across the Ioway map, there is significant information about distance and travel embedded in the Ioway map.

Scale and Distance Measurements

        Native American maps were commonly drawn at varying scales (Rhonda 1987; Lewis 1998b). This was often done intentionally, as a way to encode information about the landscape. For example, long travel segments that involved no particular danger or decision making were sometimes compressed while shorter segments were expanded to indicate problems or important features of the area. A fuller investigation of scale on the Ioway map is worthwhile.

        In theory, the phrase "map projection" can be used to refer to any transformation employed by a cartographer to model the three dimensional world in a smaller, two dimensional map space. In modern cartography our expectation is that a map will have a single, consistent mathematical projection throughout. The Ioway apparently used several projections because scale and distance measurements are not consistent across the map. I documented the different Ioway scales at 43 locations across the map as shown in Table 3. Measurements were complicated somewhat because I was using a

Table 3 - Variety of Map Scales Identified on the 1837 Map

River Measured Along	From River Confluence	To River Confluence	Ioway Map Distance (cm)	Base Map Distance (km)	Ioway Scale 1 cm = x km
Mississippi	Root	Upper Iowa	3.46	41.01	11.85
Mississippi	Upper Iowa	Wisconsin	9.67	59.82	6.18
Mississippi	Wisconsin	Turkey	3.97	35.54	8.95
Mississippi	Turkey	Rock	22.85	195.94	8.57
Mississippi	Rock	Iowa	10.05	76.88	7.65
Mississippi	Iowa	Skunk	3.61	57.48	15.92
Mississippi	Skunk	Des Moines	3.54	56.52	15.96
Mississippi	Des Moines	North Fabius	3.17	58.77	18.51
Mississippi	North Fabius	Salt	2.70	62.05	23.00
Mississippi	Salt	Cuivre	2.98	77.40	25.99
Mississippi	Cuivre	Lower Illinois	1.43	28.84	20.23
Mississippi	Lower Illinois	Missouri	3.76	35.59	9.46
Illinois	Sang/Illinois	Mississippi	14.17	135.18	9.54
Missouri	Niobrara	Big Sioux	4.61	164.11	35.58
Big Sioux	Big Sioux/Rock	Missouri	11.79	83.81	7.11
Missouri	Big Sioux	Floyd	2.44	5.08	2.08
Missouri	Floyd	Little Sioux	9.27	91.95	9.92
Missouri	Little Sioux	Boyer	7.22	53.34	7.39
Missouri	Boyer	Platte	3.96	59.68	15.07
Missouri	Platte	Nishnabotna	7.87	69.34	8.81
Missouri	Nishnabotna	Nodaway	1.44	112.16	78.09
Iowa	S. Fork Iowa	Cedar	12.09	217.84	18.01
Iowa	Cedar/Iowa	Mississippi	6.26	42.53	6.80
Des Moines	Boone	Raccoon	9.21	95.68	10.39
Raccoon	North Raccoon	Des Moines	15.96	34.59	2.17
Platte	N/S Platte	Missouri	22.85	480.89	21.05
Nishnabotna	E. Nishnabotna	Missouri	8.66	22.57	2.61
Nodaway	E. Nodaway	Missouri	6.78	87.77	12.95
Kansas	Repub/Kansas	Missouri	7.01	223.53	31.87
Thompson	Weldon	Grand	2.97	41.46	13.94
Thompson	Grand	Missouri	2.96	74.42	25.11
Missouri	Osage	Gasconade	2.49	51.72	20.79
Missouri	Gasconade	Mississippi	2.48	20.43	8.23
Missouri	Chariton	Osage	1.50	131.41	87.65
Missouri	Thompson	Chariton	2.20	92.58	42.05
Missouri	Kansas	Thompson	4.89	175.87	35.99
Missouri	Platte (MO)	Kansas	2.67	30.97	11.58
Des Moines	Raccoon	Mississippi	10.28	246.14	23.95
Thompson	Twelvemile	Weldon	3.76	99.24	26.37
Platte (MO)	102	Missouri	5.13	61.99	12.09
Missouri	Nodaway	Platte (MO)	5.47	105.00	19.18
Big Sioux	Rock (IA)	Skunk Creek	4.32	92.53	21.44
Big Sioux	Rock (IA)	Beaver Creek	4.32	28.59	6.62

.tif file generated from the 1/3 size reproduction of the Ioway map in Wood (2001). To compare distances as the Ioway drew them with distance on the base map I first measured an identifiable stream reach (a segment of a river between two known points, usually the confluence points of other rivers) on both the Ioway map and the base map. I could then compare the lengths of the same river reaches on both maps, establish a ratio between them, and standardize this. The final column in Table 3 shows that standardized result: 1 cm of distance along a given stream reach on the Ioway map is equivalent to a given number of kilometers on the base map (the details of this procedure are described in Appendix F).

The results were interesting. Scale on the Ioway map varied from as large as 1 cm = 2.08 km, to as small as 1 cm = 87.65 km. Figure 25 is a map that illustrates the variety of Ioway scales, classified into seven categories using Jenks natural breaks. The dichromatic color ramp is useful here because it allows a viewer to easily distinguish river segments that have a scale that is very different from the scale of adjacent segments. In this case, areas of darker green adjacent to areas of darker red signal a dramatic change of scale. This is particularly evident along the Missouri River and its tributary streams.

Further research is certainly warranted in areas where abrupt changes in scale are present. I expected that parts of their territory that were very familiar might have been drawn using one scale while areas that were less familiar would be drawn at another scale. That pattern was not apparent in Figure 25. Assuming the changes in scale are intentional, correlations with trail distance information, village locations, the presence of other tribes, locations of natural and cultural resources, and other factors should be investigated.

There is another use for Figure 25. Abrupt changes in scale could indicate that a particular river or tributary has been misidentified. As it happens, several segments of the Missouri River between the Nishnabotna and Mississippi Rivers contain adjacent segments with high contrast. The hydrologic identifications made by Lewis and Green were based on their study of modern base maps and on their research into Ioway history, culture and archaeology but they lacked any independent way to verify their attributions. Figure 25 could be highlighting potentially problematic river identifications.

In addition, the map in Figure 25 can be used interactively to select one alternative identification over another. For example, Green (2001:15) identified a small tributary stream that enters the Big Sioux River from the west as either Skunk Creek or Beaver Creek. Measuring the segment distances for each alternative, Skunk Creek falls into the yellow category (1 cm = 21.44 km), adjacent to a green segment, while Beaver Creek falls into the same green classification as the adjacent segment (1 cm = 6.62 km scale). This would argue in favor of Beaver Creek as the correct

Figure 25 - Variety of Map Scales Identified on the 1837 Ioway Map

Ioway Map Scales

—— 2.08 - 2.61
—— 2.61 - 9.92
—— 9.92 - 15.07
—— 15.07 - 21.05
—— 21.05 - 26.37
—— 26.37 - 42.05
—— 42.05 - 87.65
—— Unknown Scale

Ioway Village
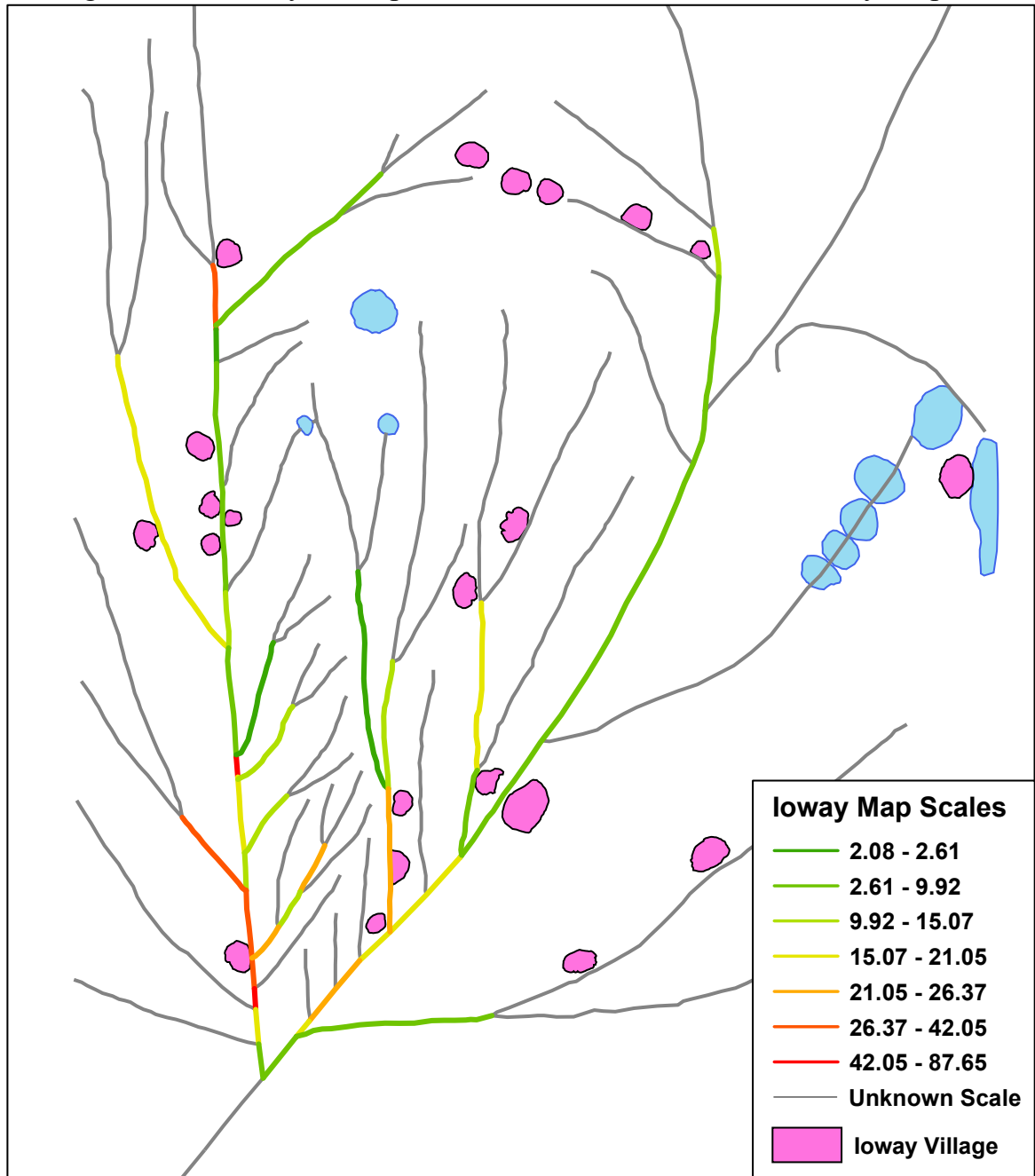
identification. This is certainly not a fool-proof method, since the Ioway may have had good reasons for abruptly varying the scale on their map, but it does offer a new source of independent information.

V. The Georeferenced Ioway Map

One of the advantages of using GIS in this project is that it allows easy digital manipulation of the data. ArcGIS 8.2 (and later versions) provides two different georeferencing methods: standard Georeferencing tools and Spatial Adjustment tools (new in ArcGIS 8.2). Both of these options were used in the analysis of the Ioway map, and the results are described below. The objective is to make the 1837 map more useful by registering it in modern geographic space. The georeferenced Ioway map data can then be visualized in relation to other data layers such as natural or cultural resources (Chapter VI). Any correlations that appear during spatial analysis can be ground checked by field workers because all of the data layers have an established connection to real world geography.

ArcMap Georeferencing Toolbar Results

The ArcMap Georeferencing toolbar allows users to adjust a raster data layer (e.g., the Ioway map .tif file) to one or more vector data layers (in this case, the base map files). There are three transformation options: first order polynomial (affine), second order polynomial, and third order polynomial. Because one goal of this project was to explore the advantages and disadvantages of the different georeferencing tools, I georeferenced the Ioway map using all three of these options. The result of the affine transformation is shown in Figure 26, the second order transformation is shown in Figure 27, and the third order transformation is shown in Figure 28. In each case, the green control point represents a base map location that should correspond to a river confluence on the Ioway map. This rarely occurs and a close examination of each map shows the variable nature of the correspondence.

When three and only three control points are used, the transformation exactly matches each control point location on the source map (Ioway map) with a control point location on the target map (base map). As more control points are utilized, however, the raster cells in the source map are increasingly skewed (warped) in order to accommodate the new data points. The control points on source and target maps will no longer match exactly, a difference that is shown by blue lines during the georeferencing process. This error is calculated and tracked in ArcMap as the residual value for each link, and is stored in a Links Table (Figure 29). The screen shot below illustrates a portion of the Links Table for the Ioway map project affine transformation with 20 of the links added. Individual links with unacceptably high residual error can be deleted from the Links Table, resulting in their deletion from the map. A total root mean square error (RMS Error) is also computed, a figure that provides an overall evaluation of the consistency of the transformation process. The lower the error, the better the adjustment or fit of the image to the geographic space.

Figure 26 - First Order Polynomial Transformation of the 1837 Ioway Map
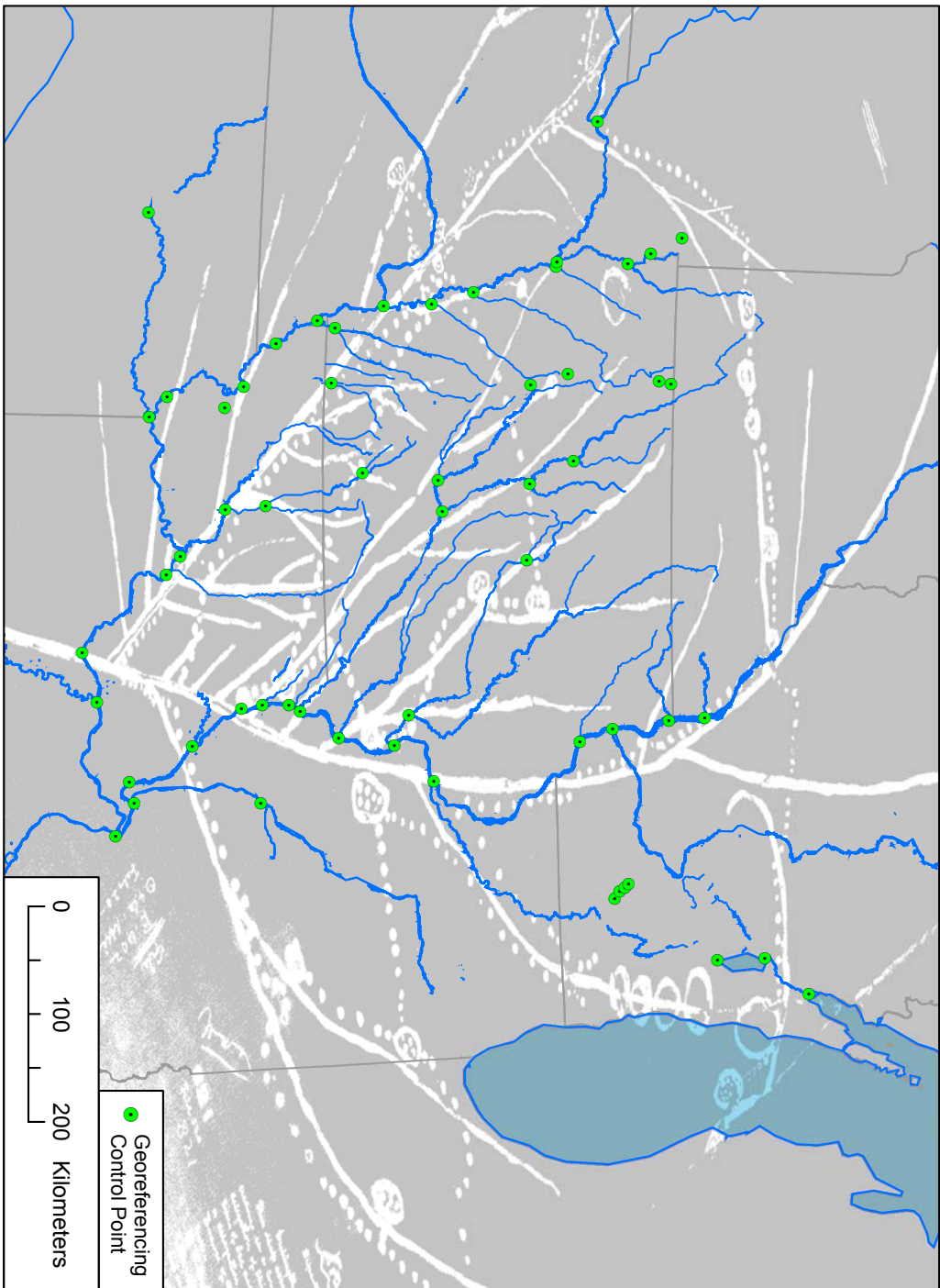
Figure 27 - Second Order Polynomial Transformation of the 1837 Ioway Map
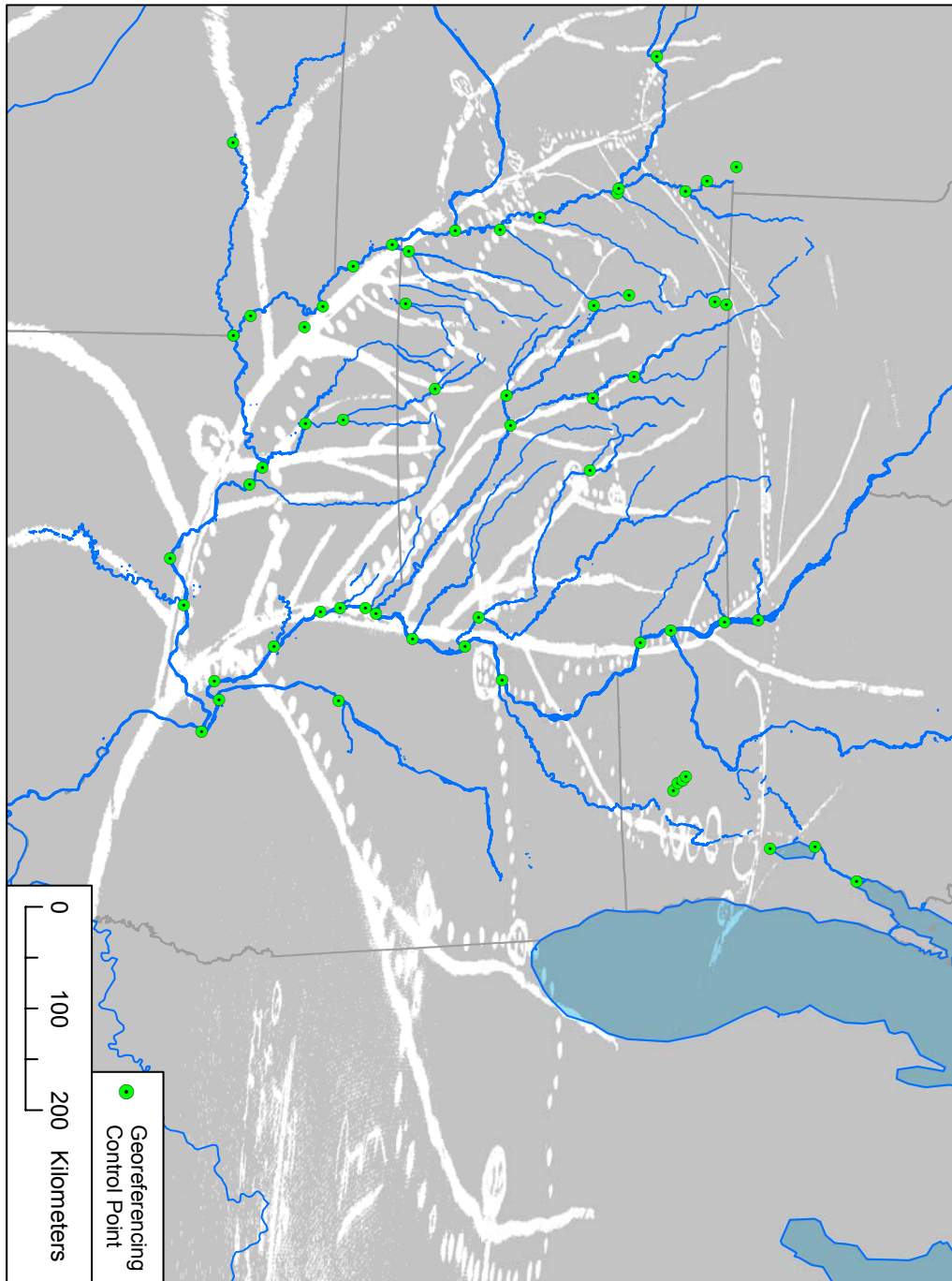
Figure 28 - Third Order Polynomial Transformation of the 1837 Ioway Map
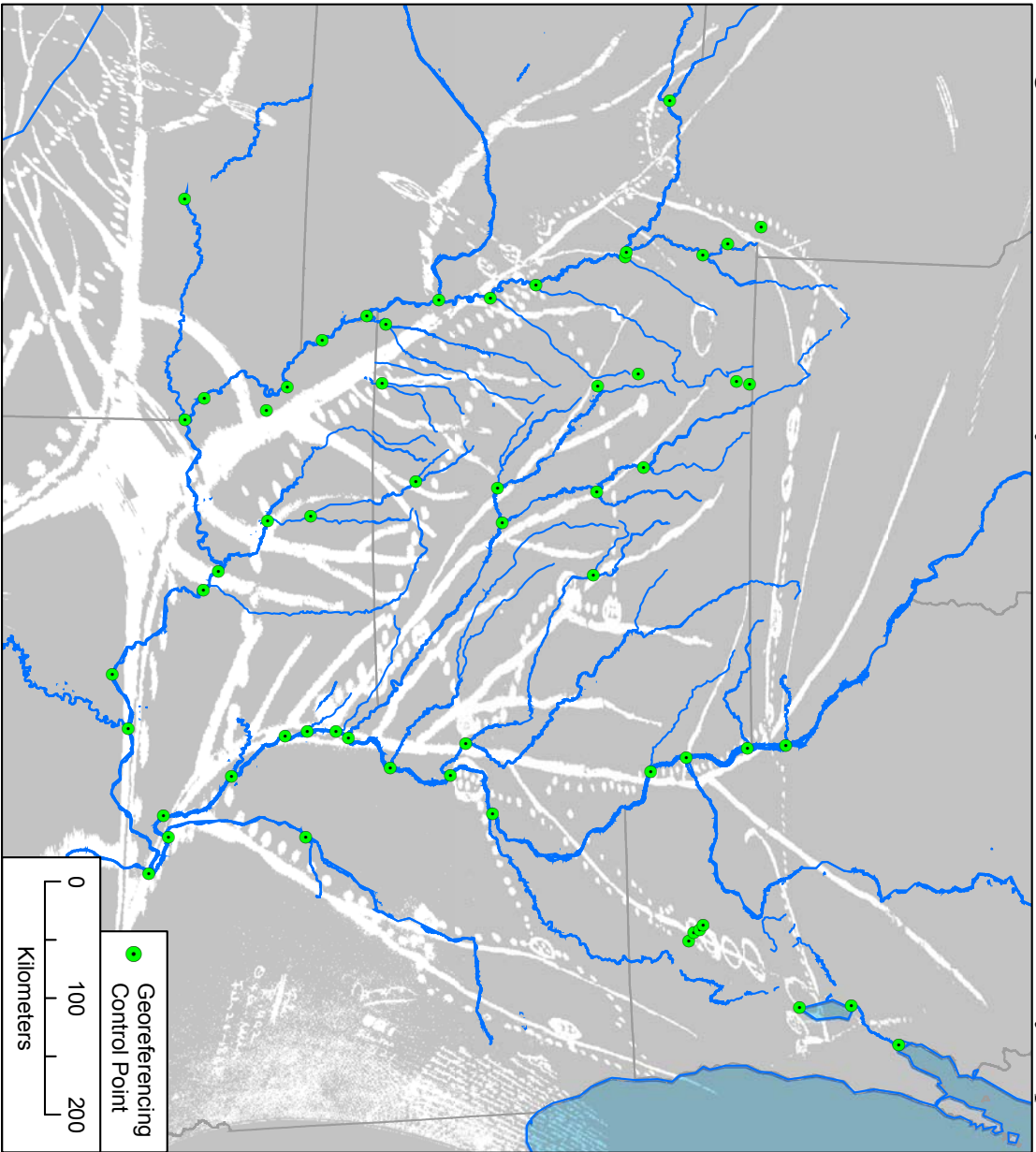
Figure 29 – The Links Table in ArcMap, showing the residual values and Root Mean
Square Error (RMS) for control points

Link	X Source	Y Source	X Map	Y Map	Residual
1	6.984280	12.005452	640000.473948	4851429.721064	104746.5086
2	6.923887	10.239580	650208.438713	4761259.365642	66210.8113
3	5.285970	6.910511	699546.935076	4596230.601945	19888.9309
4	2.533838	3.603535	750236.103622	4299472.338745	157446.4688
5	2.115722	9.282541	245292.503044	4630257.151161	54709.4332
6	3.467021	8.594964	418827.904045	4597931.929406	32548.2505
7	4.743890	4.202260	724357.216486	4443993.754971	86328.0930
8	2.870823	4.021535	719207.981715	4315262.885703	115482.3375
9	2.475963	3.939022	625050.545908	4281425.057210	65742.0867
10	3.007536	4.217825	703760.277403	4308642.440998	102661.935.
11	3.258299	4.512222	665508.819106	4371168.863214	48386.2152
12	3.499367	4.779791	632406.595580	4415305.161249	22356.9861
13	3.801353	5.067761	633877.805515	4470475.533792	50866.9680
14	4.148007	5.435470	658152.769434	4506520.177187	53073.3184
15	4.632066	6.617446	638291.435318	4571253.414305	33411.5563

☑ Auto Adjust   Transformation: |&1st Order Polynomial (Affine) ▼| Total RMS Error: 88610.24152

| Load... | Save... | | | OK |

As shown in Figures 26, 27, and 28, the original Ioway map is increasingly distorted (warped) by the second and third order transformations. While this results in a less aesthetically pleasing map, it does force the Ioway map hydrographic features into closer alignment with the base map. RMS error decreases with each transformation, although it is always large:

1st Order Transformation RMS error = 88610.24
2nd Order Transformation RMS error = 83876.85
3rd Order Transformation RMS error = 83876.76

The transformation can be changed or undone until the "rectify" option is selected on the Georeferencing toolbar. Then the raster data are permanently changed using whatever options were in place. Each of these rectified images can be examined with other data layers (Chapter VI) to investigate the relationship between village and trail locations and natural and cultural features.

In terms of the Ioway Map Project, the 3rd order transformation results in the closest fit between Ioway map feature locations and base map feature locations. Interestingly, the third order polynomial rectification apparently distorts the original Ioway map to such an extent that it creates a duplicate of it, appending the duplicate image along the southwestern portion of the original (an example of translation).

Another, unexpected use of the rectified images is also possible: testing the accuracy of the river identifications made by Lewis, Green and other historians. As mentioned above, the hydrographic features on the Ioway map were identified based on historical documents (including a transcript of the treaty talks) and other sources of information (e.g., archaeological data). All are reasonable, and all may be correct, but there has not been an independent method to check on the validity of the identifications. The blue residual lines visible during georeferencing could be used in this way.

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Although the length of any individual residual line does not necessarily indicate its absolute accuracy, one approach would be to change the links that have the highest residual error. Adjacent or alternative hydrologic features could be used to see if the "goodness of fit" improved.

Spatial Adjustment Toolbar Results

The Spatial Adjustment tool bar allows users to georeference vector files to other vector files. To take advantage of this option I digitized the Ioway map (Figure 30), creating four layers: river segments, lakes, villages, and trails. Five options are available in the Spatial Adjustment environment, three of which were applicable to the Ioway map data: Affine Transformation, Similarity Transformation, and Rubbersheet. The other two options (Projective Transformation and Edge Snap) are useful for aerial photographs (Projective) or to line up adjacent data sets (two USGS quad maps for example), but were not appropriate for this project.

After digitizing the Ioway map, each of the three options was applied as shown in Figures 31, 32, and 33. Figure 31 illustrates the results of the Affine adjustment. This is similar to the first order polynomial generated by the Georeferencing tool (Figure 26) but because only the feature polygons, lines and points (objects) are adjusted, not the neighboring (empty) map cells, the result is less cluttered and more aesthetically pleasing. The transformation uses a "goodness of fit" approach which in this case results in control points that are many kilometers away from what should be their actual location on the base map. In the Affine adjustment, the overall shape of the best fit is wider in an east-west direction (note the Illinois and Sangamon River segments that extend into Lake Michigan) and narrower in a north-south direction than the Similarity adjustment.

Figure 32 shows the results of the Similarity transformation. The results show some improvement in the locations of spatial features (e.g., the Illinois and Sangamon River segment positions improve) but the changes are not as good as the 2nd order or 3rd order Georeferencing tool transformations seen in Figures 27 and 28. Again, the map has better aesthetic qualities (less clutter, less obvious distortion) than Figures 27 and 28. Interestingly, the overall shape of the Similarity transformation is more vertical (broader north-south than east-west), the opposite of the Affine transformation result.

Figure 33 shows the results of the Rubbersheet transformation. In this case, a very different algorithm, one involving triangulation, is used to calculate the position of the georeferenced coordinates. Rubbersheeting anchors the control points so that the source control points (Ioway map) are moved to the exact location of that control point on the target map (base map). Because of this, I initially thought that this would be the most promising of the Spatial Adjustment tools. However, georeferencing results using this tool were problematic. When the standard 50 control points were used, the Ioway map features within those points (one could think of it as within that convex hull) were transformed in a reasonable way, but the river segments, village outlines, lakes and trails that were outside the control points were severely distorted. I attempted to correct

Figure 30 - Digitized Features on the 1837 Ioway Map
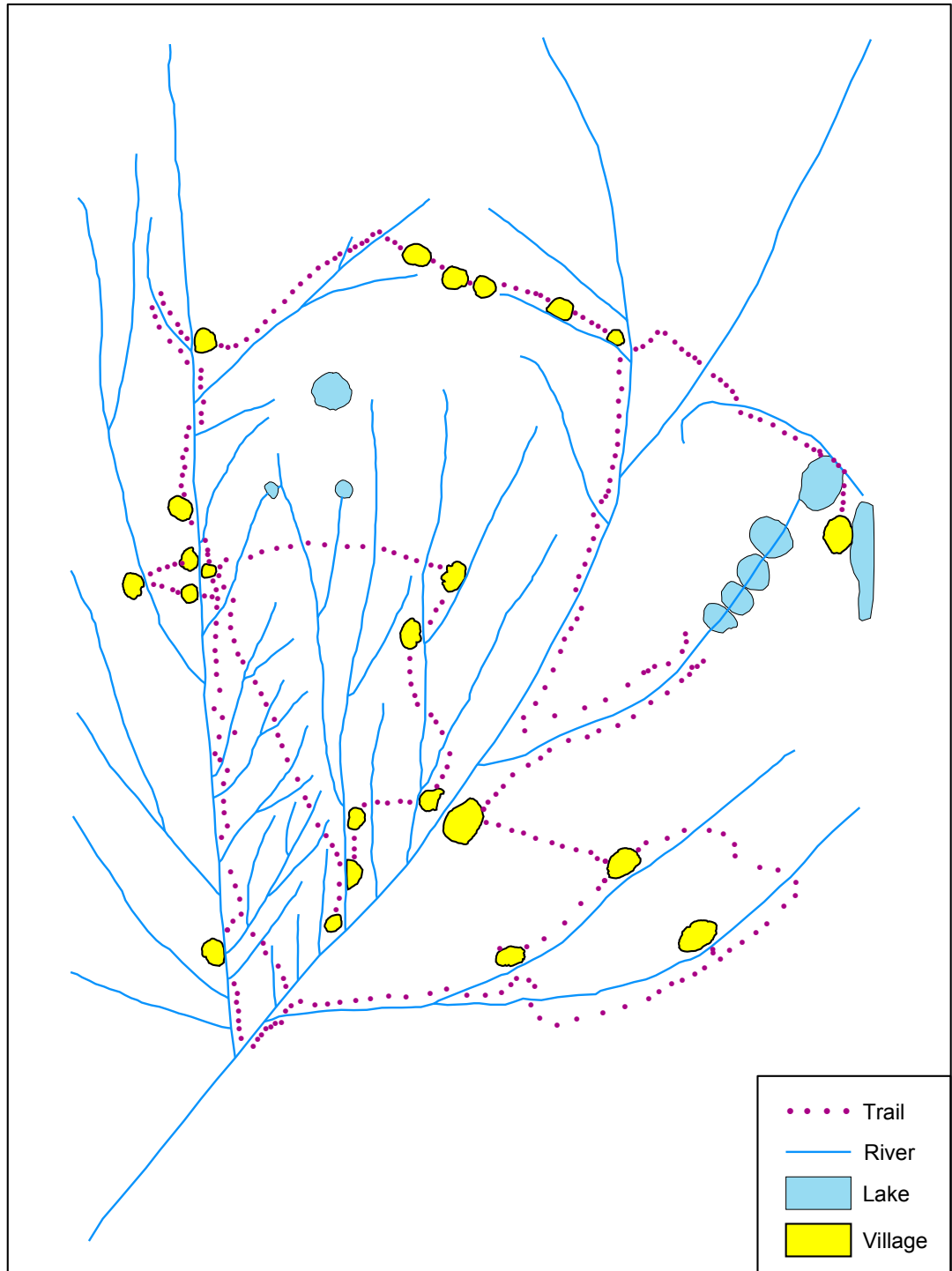
Legend:
- Trail
- River
- Lake
- Village

Figure 31 - Affine Transformation of the Ioway Map
using Spatial Adjustment Tools

Control Point
Ioway Map River
Ioway Map Lake
Ioway Map Village

0   100   200
Kilometers

Figure 32 - Similarity Transformation of the Ioway Map
using Spatial Adjustment Tools

0   100   200
Kilometers

- Control Point
- Ioway Map River
- Ioway Map Village
- Ioway Map Lake

Figure 33 - Rubbersheet Transformation of the Ioway Map using Spatial Adjustment Tools

Legend:
- Control Point
- Ioway Map River
- Ioway Map Village
- Ioway Map Lake

Kilometers
0   100   200
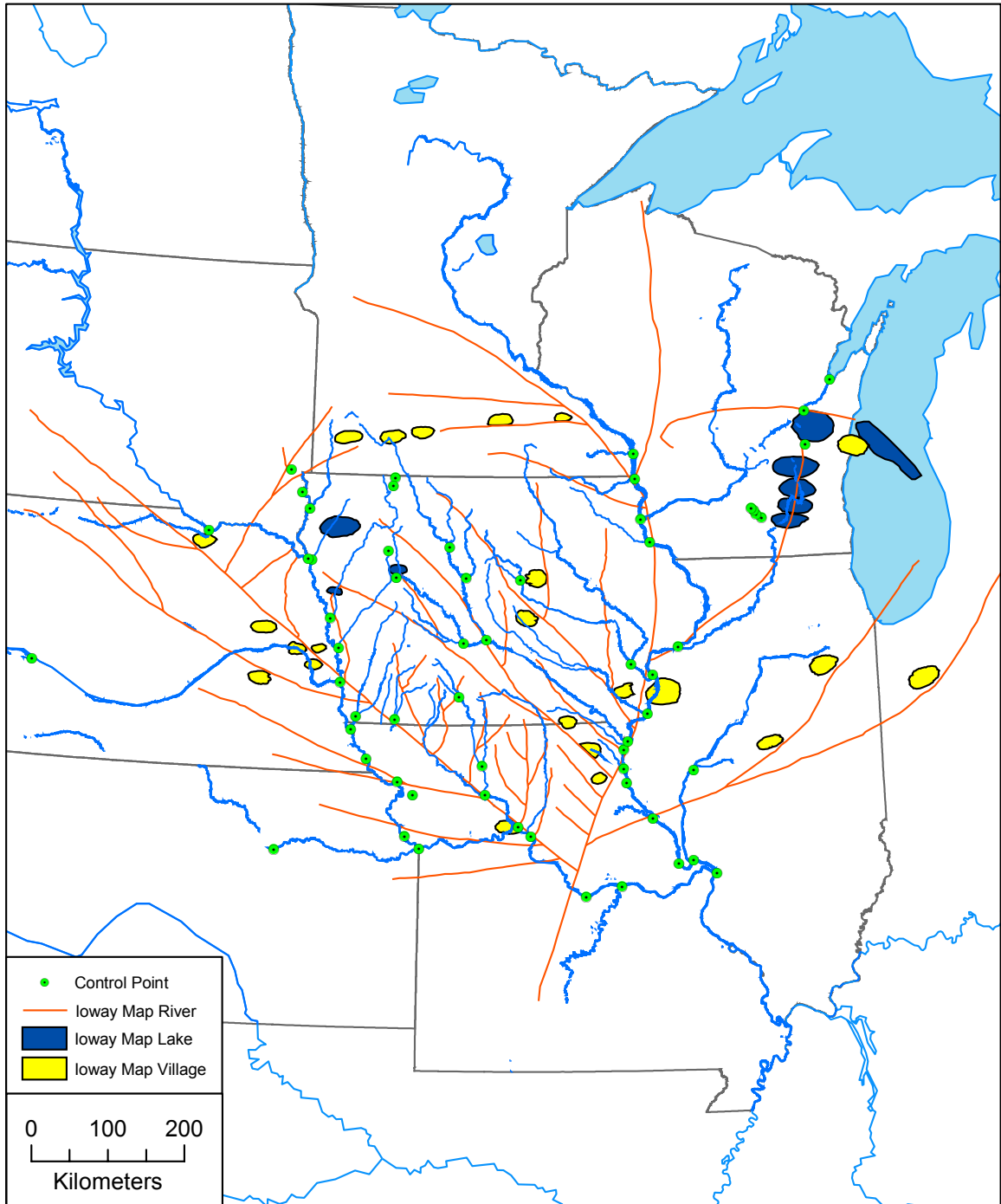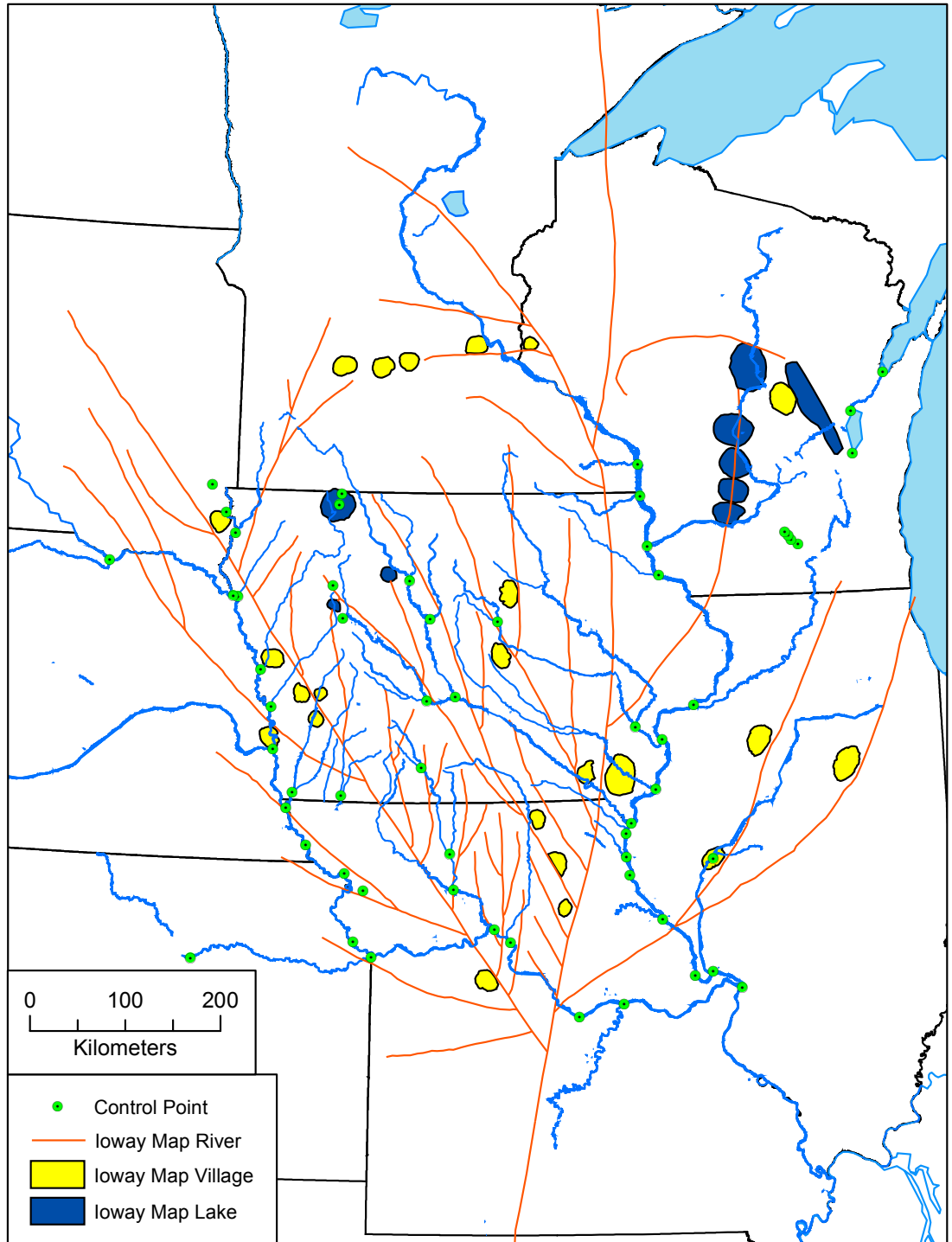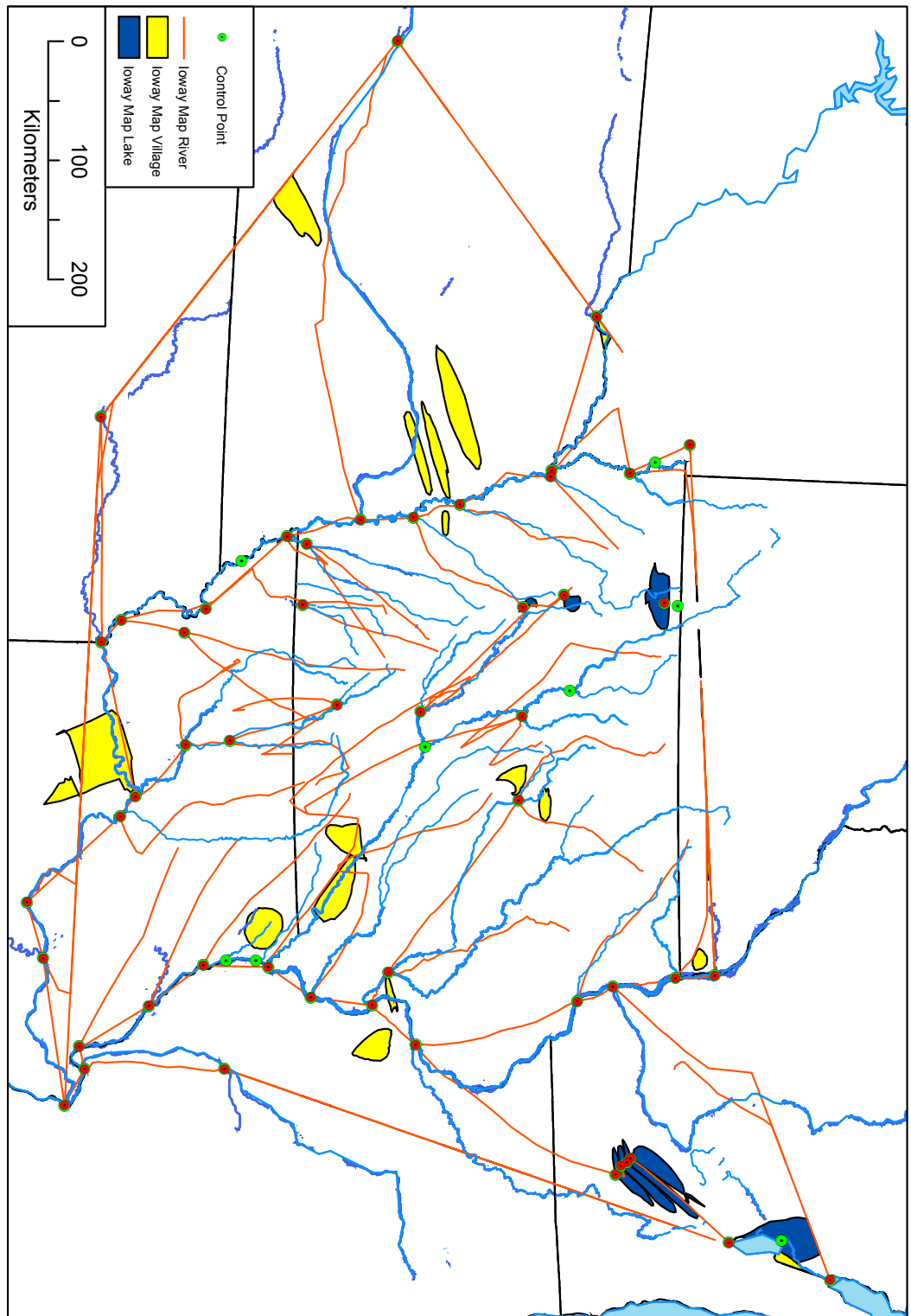
this by establishing 46 additional control points to "tie down" the ends of each river to an arbitrary upstream point on that same river in the base map. The results are still less than satisfactory, as seen in Figure 33.

Finally, using the Spatial Analysis toolbar I was also able to reverse the process, georeferencing the state outlines from the base map to the Ioway map (Figure 34). The result is an interesting cartogram, a graphic depiction that intentionally distorts geographic space in order to more accurately reflect some other attribute or thematic value (Slocum 1999:181).

Comparison of the Different Georeferencing Methods

The three Georeferencing toolbar transformation methods, and the three Spatial Adjustment toolbar transformation methods, each have strengths and weaknesses. None of them provided all of the characteristics desirable for this project. The raster to vector transformations work well but because they involve raster data, all of the cells around the actual map features are also transformed, creating a great deal of clutter, confusion, and distracting distortion on the resulting maps. The vector to vector transformations involve only the map features (solving the clutter problem) but none of those transformations resulted in an acceptable adjustment. The Affine and Similarity methods compromise spatial position to an unacceptable degree. Rubbersheeting corrects this problem but line and polygon features that lie outside the control points are badly distorted.

Figures 35 and 36 compare the strengths and weaknesses of the different methods, illustrating their differences using only the village locations. In Figure 35 a different color is assigned to each of the different methods, allowing users to easily make visual comparisons among the methods. The general shape of the different spatial adjustment methods (stretched north-south, or stretched east-west) is clear, as is the distortion of the rubbersheet method. The standard Georeferencing toolbar transformations (in shades of purple) illustrate the generally tighter and tighter clustering of village locations as higher order transformations are applied.

Figure 36 compares the six georeferencing methods by assigning a single color to each Ioway village. This figure nicely illustrates the variation in position for a single village, as seen for example in Village A (in yellow, near Green Bay) and Village S (in purple, below Lake Michigan). The distance between the eastern-most location of Village A (in Lake Michigan) and its western-most location, is over 200 kilometers; similarly the difference between the eastern- and western-most locations of Village S is over 350 kilometers. The most compact groupings (Villages M and N in the center of the state of Iowa) have a dispersion that is between 60 and 80 kilometers. This provides an interesting measure of the relative accuracy of the different methods. Variation in village position along the margins of the Ioway map is greater than in the center of the map, as a direct result of the dispersion and density of control points.

Figure 34 - Project Area State Outlines Georeferenced to the 1837 Ioway Map
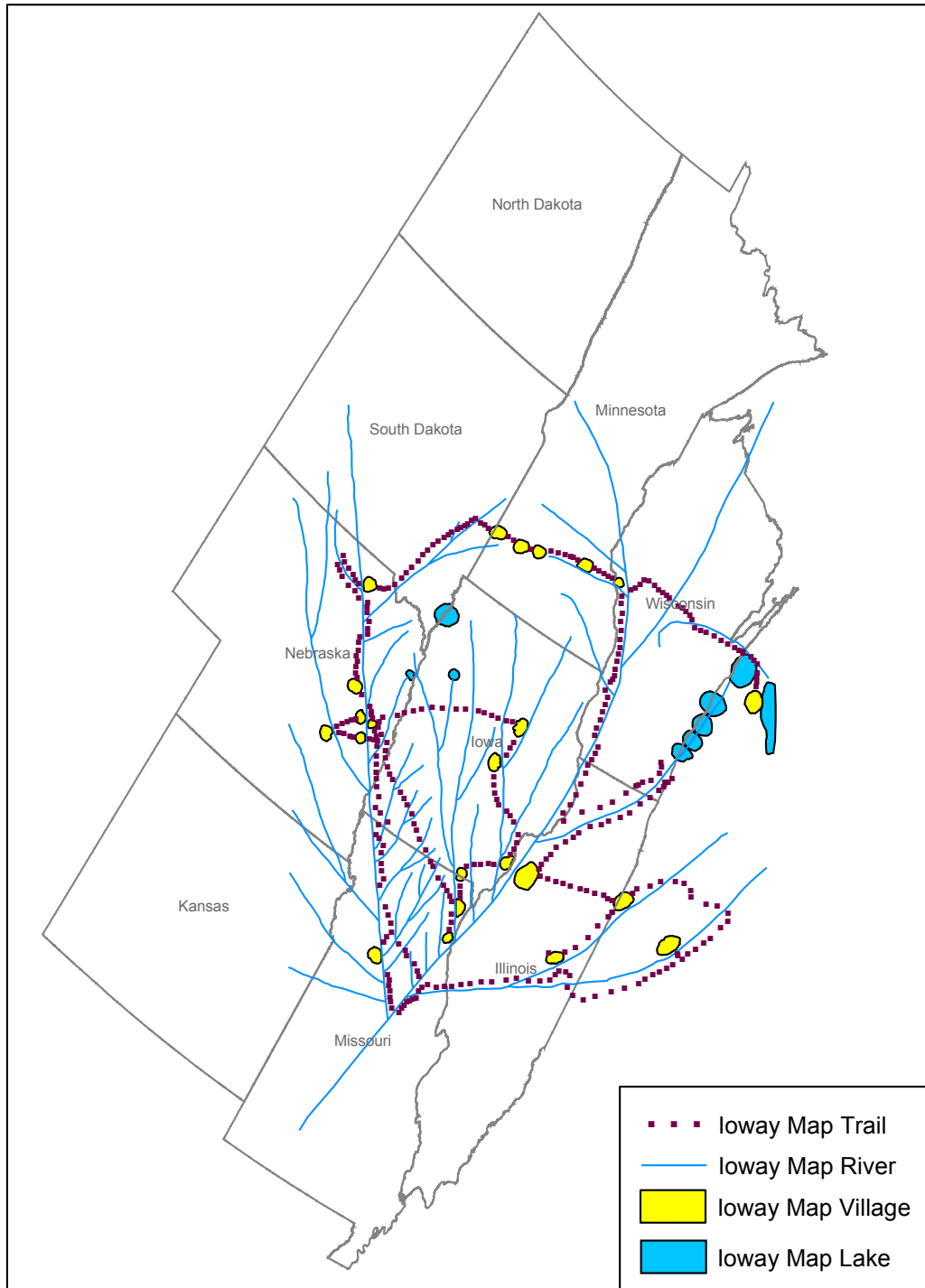
Figure 35 - Ioway Map Village Locations Symbolized by Georeferencing Method

Legend:
- Digitized Village Locations
- 1st Order GeoRef Villages
- 2nd Order GeoRef Villages
- 3rd Order GeoRef Villages
- Spatial Adjust 1 Villages
- Spatial Adjust 3 Villages
- RubberSheet Villages

Kilometers
0   100   200
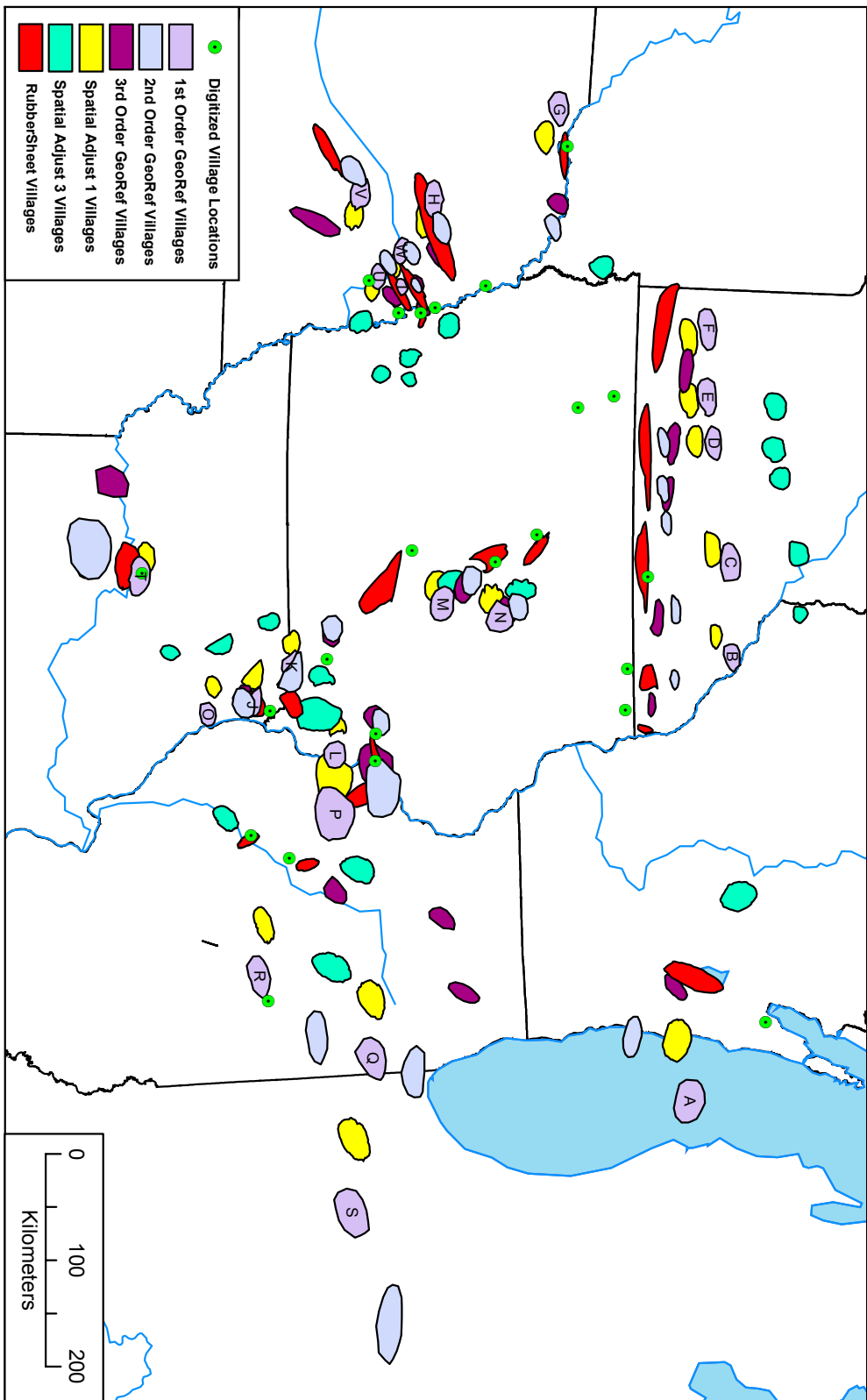
Figure 36 - Differences in Ioway Map Village Location Depending on the Georeferencing Method Used
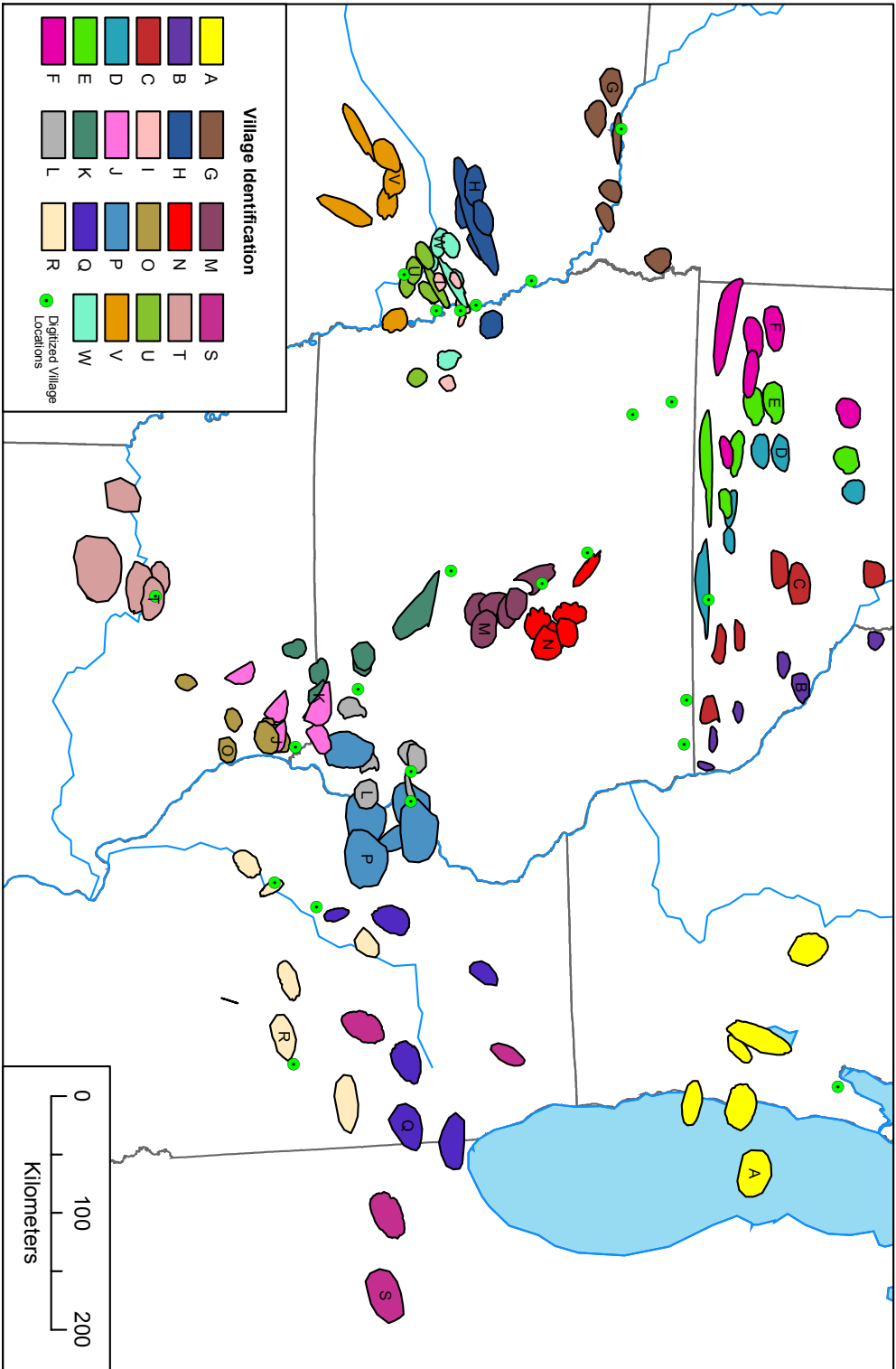
Georeferencing did provide useful information concerning the Ioway map. Each of the transformation methods, in conjunction with the map measurement data, illustrates some variation of "the world according to the Ioway," warped onto a modern basemap that contemporary people can more easily visualize and understand. The fact that none of the georeferencing methods resulted in an exact fit between Ioway map and base map indicates that the Ioway designed their map with priorities other than geographical accuracy, as we would understand it, in mind. This is valuable ethnographic and historical information to retain. Furthermore, the residual values found in the Links Table (Georeferencing toolbar) could provide valuable assistance in more accurately identifying the rivers.

VI. Spatial Analysis with the Georeferenced Map

None of the six georeferencing transformations described in Chapter V produced the anticipated results. The georeferenced locations of Ioway river segments, lakes, villages, and trails varied considerably depending on the method used, and few of the locations agreed with the placements expected by domain expert Dr. William Green. In fact, a visual comparison of village locations near stream confluences on the Ioway map with their georeferenced positions on the base map demonstrates that their adjusted placements are often unacceptably far from where they should be. For example, Village A, which is clearly mapped by the Ioway next to the shore of Green Bay, Wisconsin, is always georeferenced at least 75 kilometers from Green Bay, and in most cases between 100-120 kilometers from that location (Figure 36).

The georeferencing methods applied above used hydrographic features to generate control points but it is village and trail features that researchers are most interested in using for spatial analysis. To begin using overlay analysis, the third project goal, I needed to obtain more accurate information on village and trail segment positions. I consulted domain expert Dr. William Green, who first examined the georeferenced locations of the villages that resulted from each of the six methods, using Figures 35 and 36. He next compared this data with information from archaeological, ethnographic and historical sources on known Ioway villages. Finally, Dr. Green provided me with a "best approximation" location for each of the 23 villages. I digitized these locations on the base map of the area and the result was a new set of control points representing probable village locations (Figure 37). Using these new control points I again georeferenced the Ioway map to the base map, using the vector to vector Spatial Adjustment Rubbersheet transformation method. I selected this method in order to ensure that each village was anchored to its control point location, and to ensure that trail features were repositioned along with the villages. This time only village and trail features were adjusted, not hydrographic features. Figure 38 illustrates the results.

The locations of the new control points are less objective than those based on stream confluences, but may be more useful. Topological relationships are maintained, as is the general position of each village as seen on the original Ioway map (i.e., if a village is located near a particular stream confluence on the Ioway map, it was digitized near that same stream confluence on the base map). Eleven of the 23 villages are very close to stream confluences, and their positions are probably reasonably accurate.

Because the rubbersheet method was selected, the georeferenced village locations (though distorted in shape) are positioned at their corresponding control points. However, because of distortion, some of the detailed meandering of the trails is lost with this method.   Figure 38 illustrates this, showing the trail locations arrived at using rubbersheeting (orange) and the approximate trails locations arrived after consultation with Dr. Green and using the Ioway map itself as a guide. Many of the trails that clearly deviate on the Ioway map are straightened after georeferencing (e.g.,

Figure 37 - Best Approximation (Digitized) of the Ioway Map Village and Trail Locations
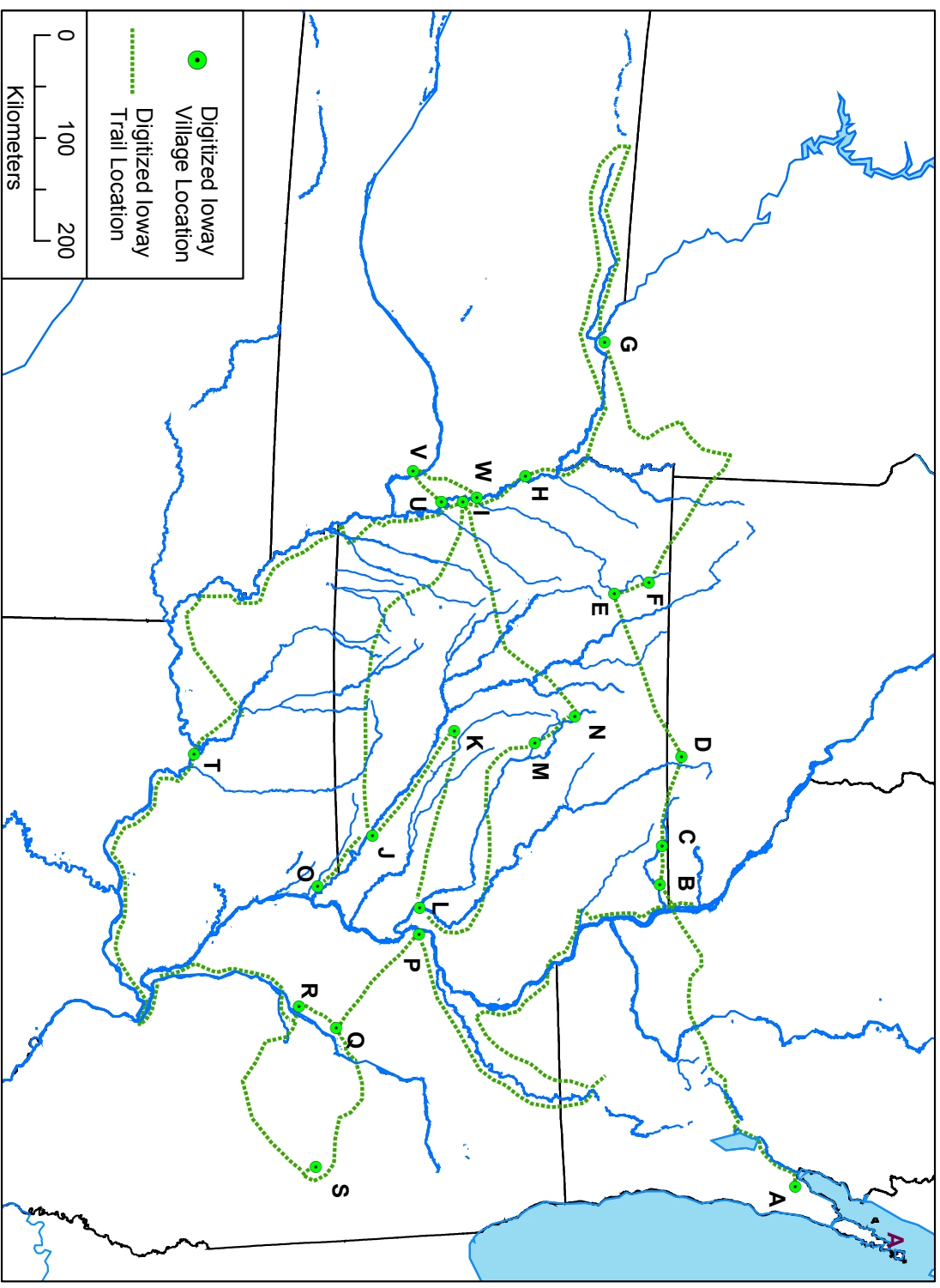
Figure 38 - Digitized Ioway Map Village and Trail Locations
Compared with Rubbersheet Locations

Legend:
- Digitized Village Location
- Digitized Trail Location
- Rubbersheet Trail Locations
- Rubbersheet Village Locations

Kilometers
0   100   200
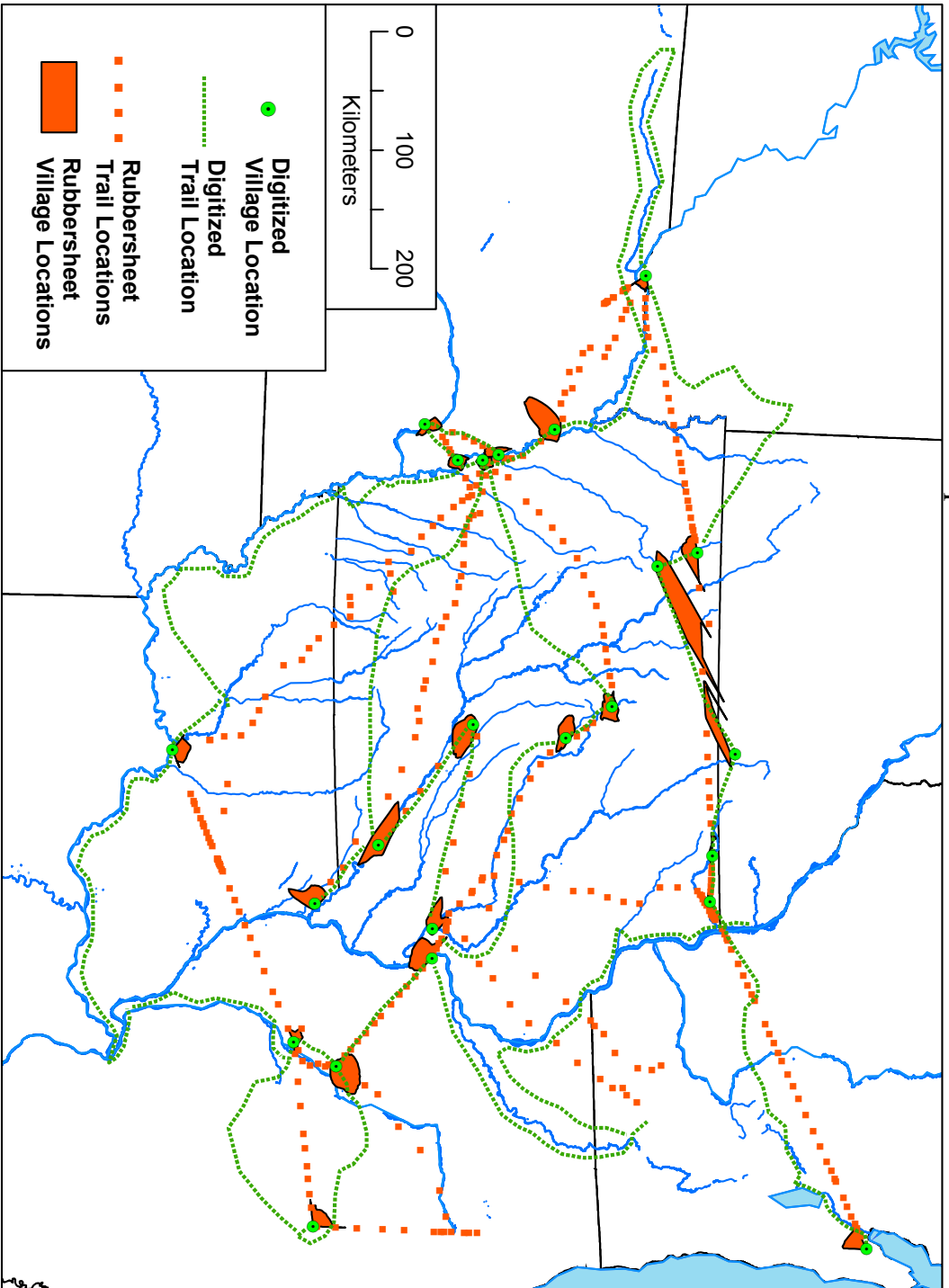
the trail from Village A to Village B). I experimented with the other Spatial Adjustment methods, but once again none of them produced trail results that maintained the detail of the individual trail segments. The solution was to consult Dr. Green as domain expert and digitize the trails according to his instruction, using georeferencing information, the original Ioway map, and his knowledge and expertise. The green village and trail locations shown in Figure 38 are the result. These features are used in the spatial analysis overlays outlined below. The five examples described in this chapter are only a small sample of the possible spatial analyses that could be undertaken now that the features on the Ioway map have been georeferenced. Chapter VII outlines several additional research avenues that might prove interesting but are beyond the scope of this project.

Village Locations and Historic Archaeological Sites

Green described the villages shown on the Ioway map as occupations that illustrate recent Ioway history, showing tribal movements back and forth across Iowa and surrounding states during the 17th to the 19th centuries. For example, he writes "The map depicts a move across Wisconsin to the Upper Iowa River in northeastern Iowa (sites B and C) where the Ioways lived from the 1650s or earlier into the 1680s" (2001:15). Sites of this age are generally classified as "historic," to distinguish them from older pre-contact or prehistoric sites. Historic sites in Iowa date to the beginning of the 17th century, the period when French and other European explorers began to arrive, make contact with, and write records about Midwestern Native Americans.

With European and later EuroAmerican arrival (and sometimes in advance of their actual physical presence) came dramatic changes in Native American language, culture, and technology. Native American sites containing evidence of these changes have been difficult to locate but are of great value to researchers interested in Native American history and colonization. Logically, the villages shown on the No Heart map should date to the historic period. Figure 39 shows the distribution of selected historic sites in Iowa (after Alex 2000:217, fig. 11.3) in relation to the trails and villages on the No Heart map. The villages the Ioway depicted are likely to be a selection, not the entire universe of their settlements, in much the same way that the rivers and lakes they illustrated represent only a sample of their hydrographic universe.

Several locations appear to correspond, including the Bertrand site with Villages I, W, and U; Village E with the Gillette Grove and Millford sites; Village B with the Flynn site; and Village J with the Iowaville site. Green (2001:15-17) had predicted several of these associations, and in fact that knowledge guided his positioning of the villages. This introduces a certain amount of circularity into the interpretation of this figure, but it is still of value because other, unexpected correlations are present. For example, Village O is very near what is thought to be the original location of Fort Des Moines. Figure 39 contains only a small sample of the historic sites known for Iowa, and does not include data from any of the surrounding states. Additional information will continue to improve the usefulness of this illustration.

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Figure 39 - Locations of Historic Archaeological Sites and
Georeferenced Ioway Villages and Trails

Legend:
- Historic Arch. Site
- Ioway Map Village
- Ioway Map Trail

Kilometers
0   100   200

Site labels: Bertrand Site, Blood Run Site, Milford Site, Gillette Grove Site, Fort Leavenworth, Fort Des Moines (2 positions), Buxton Site, Bonaparte Site, Gilbert's Trading Post, Plumb Grove Site, Fort Atkinson, Fort Snelling, Iowaville, Fort Des Moines (I), Fort Madison, Sukepuk Davenport House, Bowen's Prairie, Kettle Chief's Village, Turkey River Subagency, Flynn Site

<u>Village Locations and Prehistoric Archaeological Sites</u>

Oneota is a term used in North American archaeology to refer to an archaeological culture in existence across large parts of the upper Midwestern U.S. between A.D. 1000 and 1700 (Mott 1938; Green 1995; Alex 2000). According to Alex, the youngest Oneota sites in Iowa "almost certainly represent settlements of the protohistoric and early historic Ioway and probably the Missouria, Oto, Winnebago, Omaha, and Ponca" (2000:187). Oneota pottery styles, stone tool types, and basic economic activities are similar across a ten state area (hence the classification as a single culture) but given that the known descendants belong to at least five different (albeit related) tribes, it is unclear if Oneota is really a single culture. An analogous situation might be a modern person expecting the distribution of Coca Cola machines or Kentucky Fried Chicken restaurants around the world to define a single "culture."

Still, it is clear that the Oneota are closely tied to the Ioway, and examining Ioway villages and trails in relation to the distribution of Oneota artifacts, and in relation to specific Oneota sites, is worthwhile. Figure 40 illustrates that comparison, with site locations taken from Alex (2000:187, fig. 10.2). The exact extent of Oneota culture is a matter of some debate and the outline shown here is based on Fagan (2000:451). There is a noticeable correlation between the extent of Oneota culture and the area shown on the Ioway map, the territory they claimed as their historic homeland. This reinforces the widespread assertion (first stated by Mott in 1938) that the Ioway are indeed descendants of the Oneota.

Seven of the 23 Ioway villages (B, E, F, K, L, M, and P) overlap or intersect with locations of known Oneota sites in Iowa, and it would be worthwhile to pursue those associations, attempting to determine if the age of the Oneota site is within a century of the Ioway village for example. Possible connections between Ioway village locations and Oneota sites in other states should also be examined. The majority of the Ioway sites do not correlate, however. There could be a number of reasons for this (including a lack of archaeological research in a given area) and this too suggests possible directions for further research.

<u>The 1837 and 1847 Ioway Maps Compared</u>

In the early 19th century, Henry Rowe Schoolcraft began collecting information on Native American tribes across the United States. His relatively systematic inventory included census counts as well as detailed answers to dozens of questions. One inquiry related to the ways in which members of each tribe understood geography, maps, and their physical landscape. Schoolcraft's results were published in 1853 in a massive three volume report to the U.S. Congress. It contains a wealth of valuable information on Native American languages, cultures, and history.

Figure 40 - Locations of Oneota Archaeological Sites and Georeferenced Ioway Villages and Trails
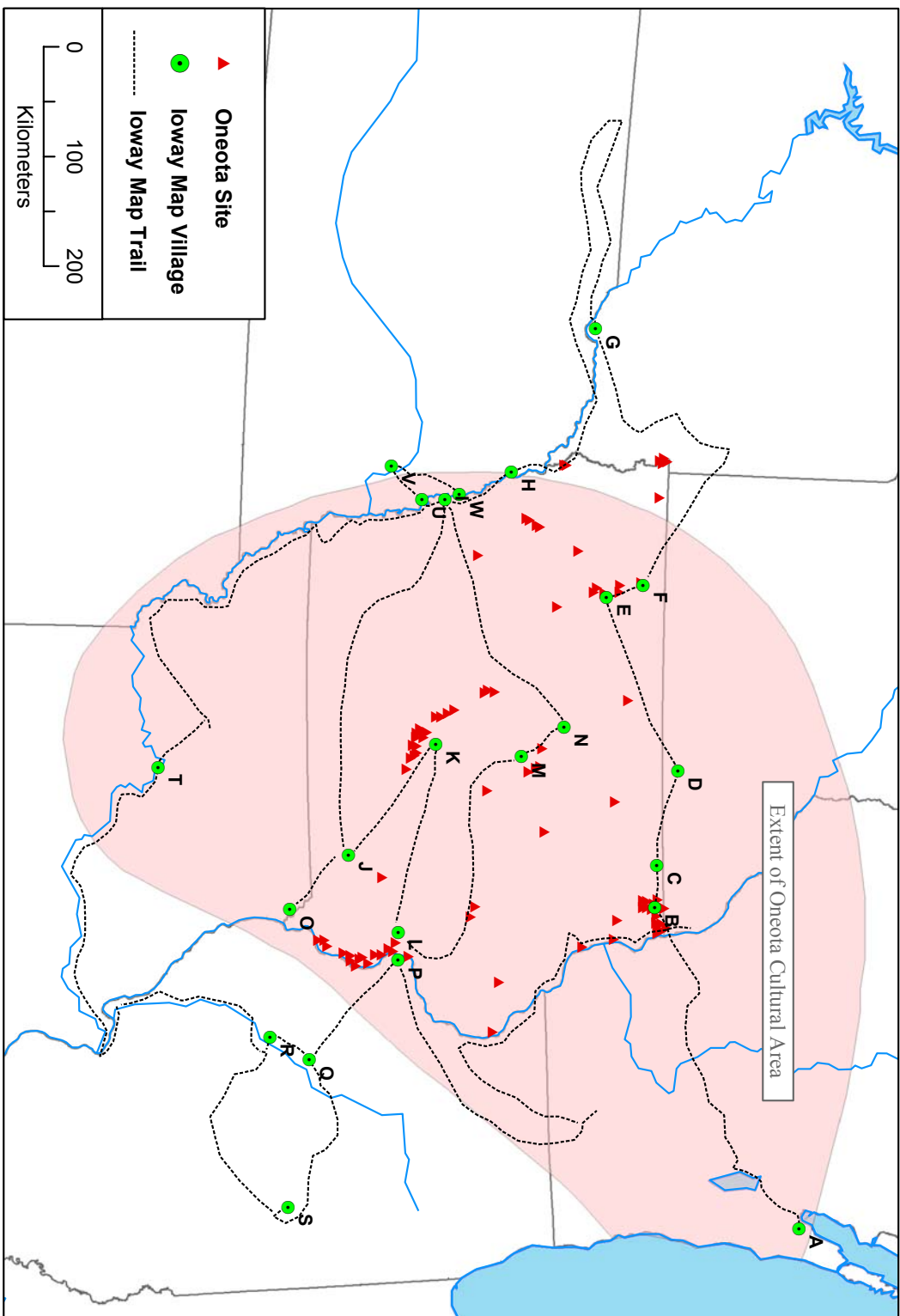
As mentioned above (Chapter I, footnote 1) Schoolcraft's report includes a description of the second of the two historic maps produced by the Ioway, the 1847 *Waw-non-que-skoon-a* map. The location of the original map, if it still exists at all, is unknown. At the time Schoolcraft stated "The original is retained in the Indian Bureau" (1853:257) but it has never been found. Unfortunately, the original map was significantly altered when Schoolcraft asked nineteenth-century artist Seth Eastman to redraw it for publication (1853: Plate 30). The Eastman version is shown in Figure 2.

Eastman's redrawing significantly changed *Waw-non-que-skoon-a*'s map. As Schoolcraft put it "…[it] has been reduced in size, and its rigid lines adapted to the surveys of the public lands on the Missouri and Mississippi" (1853:256-257). I scanned the Eastman map and georeferenced it to the base map, using the stream confluences as control points. Eastman labeled the rivers, and their positions correspond reasonably well with comparable locations on the base map. Next, I digitized the 15 Ioway village locations illustrated on the redrawn *Waw-non-que-skoon-a* map, creating a shapefile that could be compared with the village locations on the No Heart map. The results are shown in Figure 41.

Figure 41 is startling because of the lack of correspondence among the settlements. Villages on the *Waw-non-que-skoon-a* map occur across southern Iowa and northern Missouri, while villages on the No Heart map occupy central and northern Iowa as well as southern Minnesota. Only two pairs of villages are immediately adjacent (1837 Village U and 1847 Village 4; 1837 Village T and 1947 Village 12) and a third pair is close (1837 Village J and 1847 Village 2). The other 20 No Heart and 12 *Waw-non-que-skoon-a* villages appear to represent distinct settlements. Green (2001:17) commented that the lack of correlation between the two maps:

> ….may be due to No Heart's knowledge that most of that land [the more southerly villages in Missouri] had been ceded before the 1837 council and thus would not be relevant to his argument. No Heart also may have omitted those villages because he was affiliated with the Mahaska faction that had acceded to removal rather than with the group (Big Neck's) that had continued to live in Missouri.

Overlay analysis like this – a very basic GIS tool – actually permits visual inspection of the different village locations with an ease that has not been possible previously. The proximity of the 1837 and 1847 villages can be evaluated, distances can be measured, and locations (at least within 50-75 kilometers) can be established.

Stone Tool Resource Locations (Chert)

Green (2001) interpreted the villages on the Ioway map as historic occupations that spanned the 1600's to the 1800's. During these centuries the Ioway, like other Native American people, altered their material culture significantly. European-style clothing and technology were widely adopted while traditional items (e.g., stone tools,

Figure 41 - Locations of 1847 Ioway Villages (Schoolcraft Map) and Georeferenced 1837 Ioway Villages and Trails (No Heart Map)
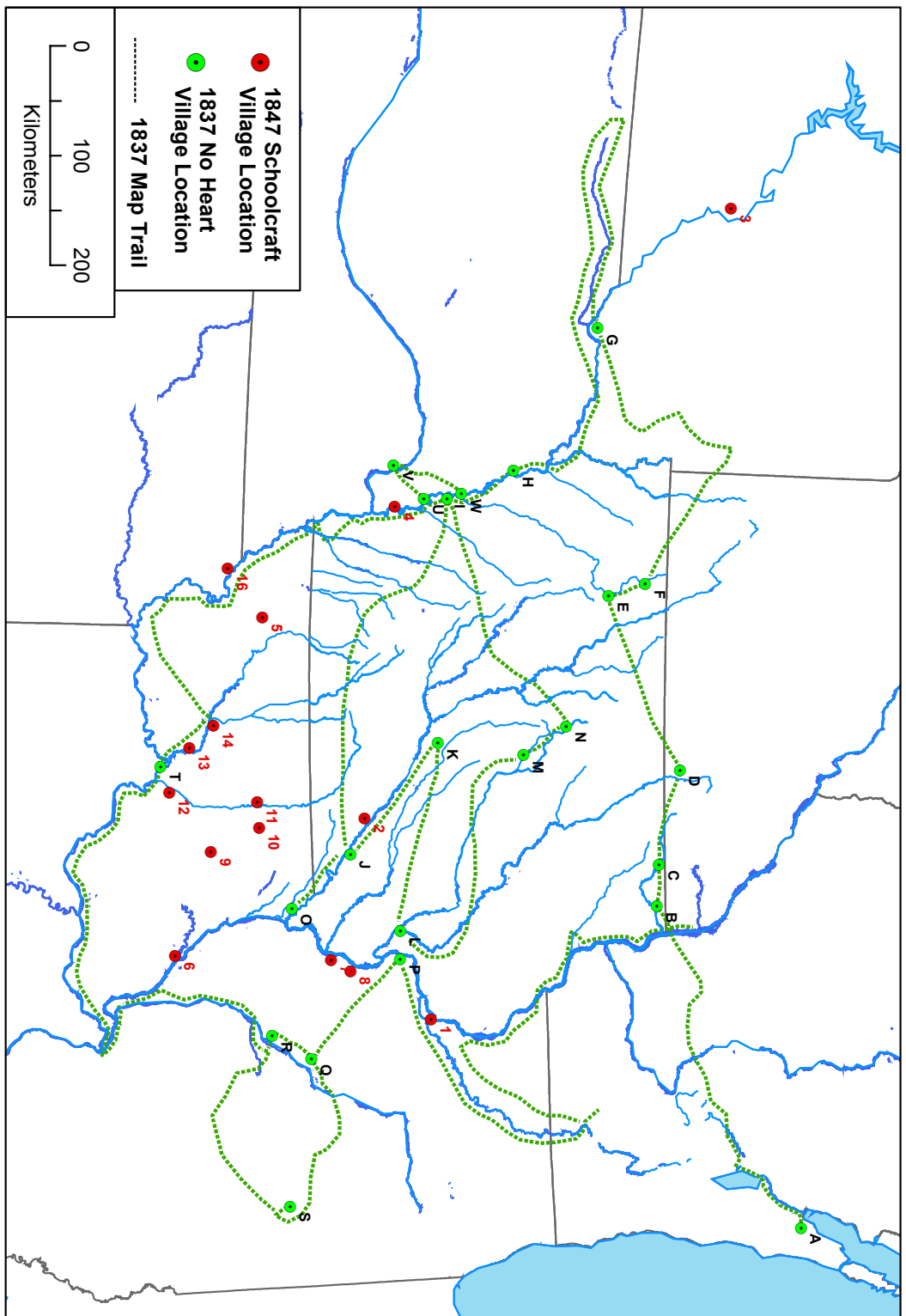
pottery) ceased to be produced. However, if the villages and/or trails are slightly older (e.g., Oneota-age), or were positioned in the vicinity of other older, prehistoric occupation sites, their locations could correlate with the distribution of stone tool raw material quarries. Using the mapped locations of Midwestern raw materials published in Morrow (1984; 1994) I digitized a shapefile containing stone tool raw material distribution, and compared it with the Ioway trail and village locations. The results are shown in Figure 42.

Several village and trail locations do appear to correlate with specific quarries. However, caution needs to be exercised as a number of these correlations could be spurious. Quarries were located in areas where chert layers outcrop at the Earth's surface, but these often correspond to river valleys because the downcutting of the stream exposes otherwise deeply buried strata. Trails and villages also occur along streams, usually for wholly independent reasons (e.g., transportation, fishing, agriculture).

Still, two interesting correlations between trails and stone tool resources are visible in Figure 42. The trails on the Ioway map rarely run directly from an origin point to a destination point. More often they detour up, out, and around locations on the landscape, in some cases, crossing and re-crossing the same stream numerous times. Two curious illustrations of this may relate to the distribution of stone tool materials. The trail from Village F (in northwestern Iowa) to Village G (in northeastern Nebraska) makes a significant detour northwest into Minnesota before turning south to Village G in Nebraska. This brings it within 25 kilometers of the red pipestone quarry in Minnesota. The second example is the trail from Village G to Village H. Village H is located 150 kilometers southeast of Village G, yet the trail from G first goes 200 kilometers (!) due west, turns around and comes 200 kilometers back to G, and then travels southeast to Village H. While there could be many explanations for this (e.g., bison hunting with western neighbors, trading with Plains Indian tribes) one possibility is that the trail links Village G with the Bijou Hills silicified sediment quarries in South Dakota. The trail from G ends within 25 kilometers of the mapped extent of that raw material.

Midwestern Ecological Characteristics

Iowa and the surrounding states are located in the transitional zone between the humid, forested east and the more arid, western prairies. A diversity of micro-environments crisscross the area, however, related to latitude (which influences the length of the growing season and annual temperature ranges), precipitation, prevalence of fire, elevation and other physical factors. Native people in the Midwest traveled widely throughout this ecological mosaic, farming, hunting, fishing, and collecting many of the naturally available resources. Figure 43 illustrates one of these environmental parameters, mean annual precipitation, in relation to the 1837 Ioway villages and trails.

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Figure 42 - Locations of Midwestern Chert Deposits and Georeferenced Ioway Villages and Trails
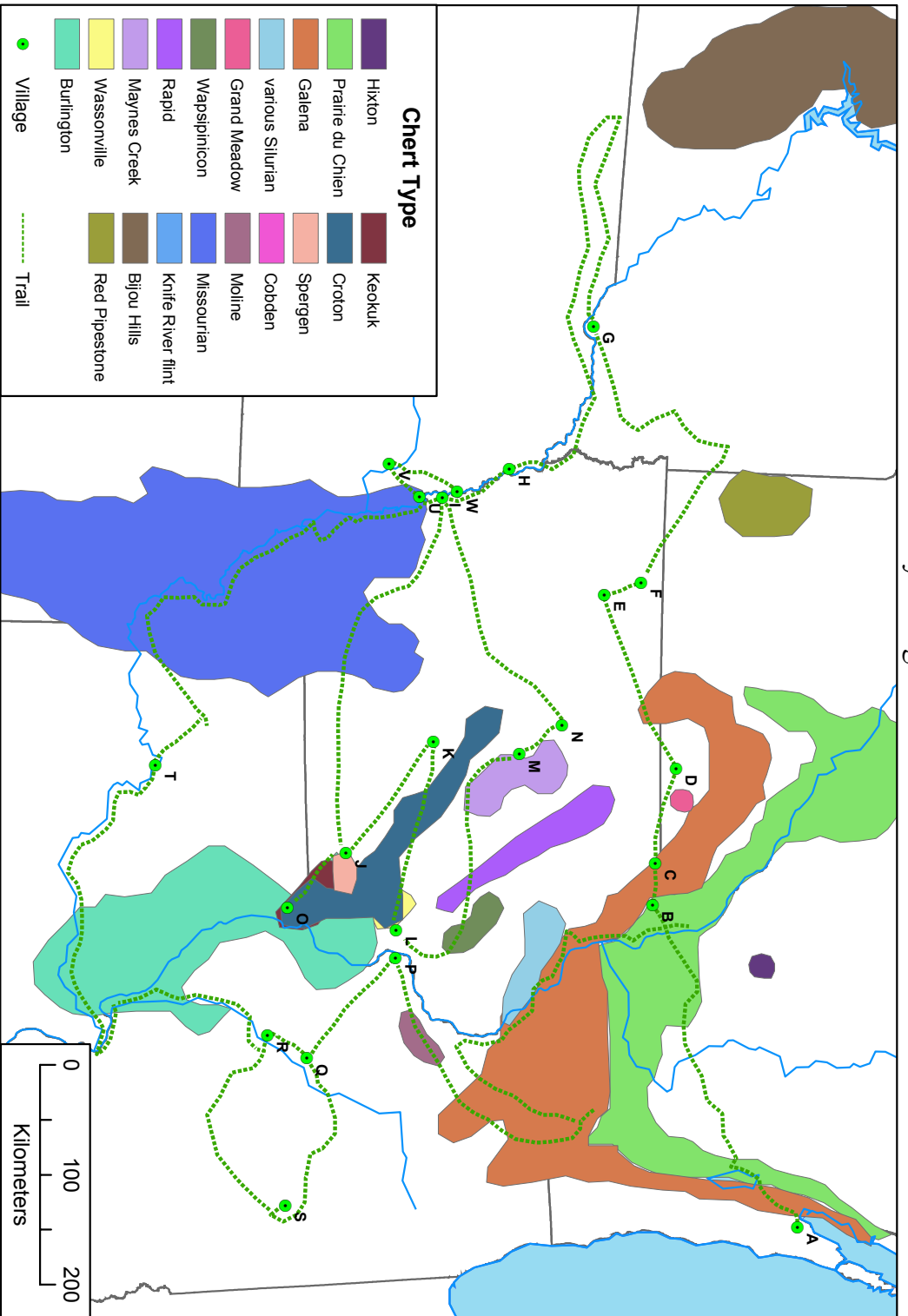
Figure 43 - Average Annual Precipitation in the Midwest and Georeferenced Ioway Village and Trail Locations
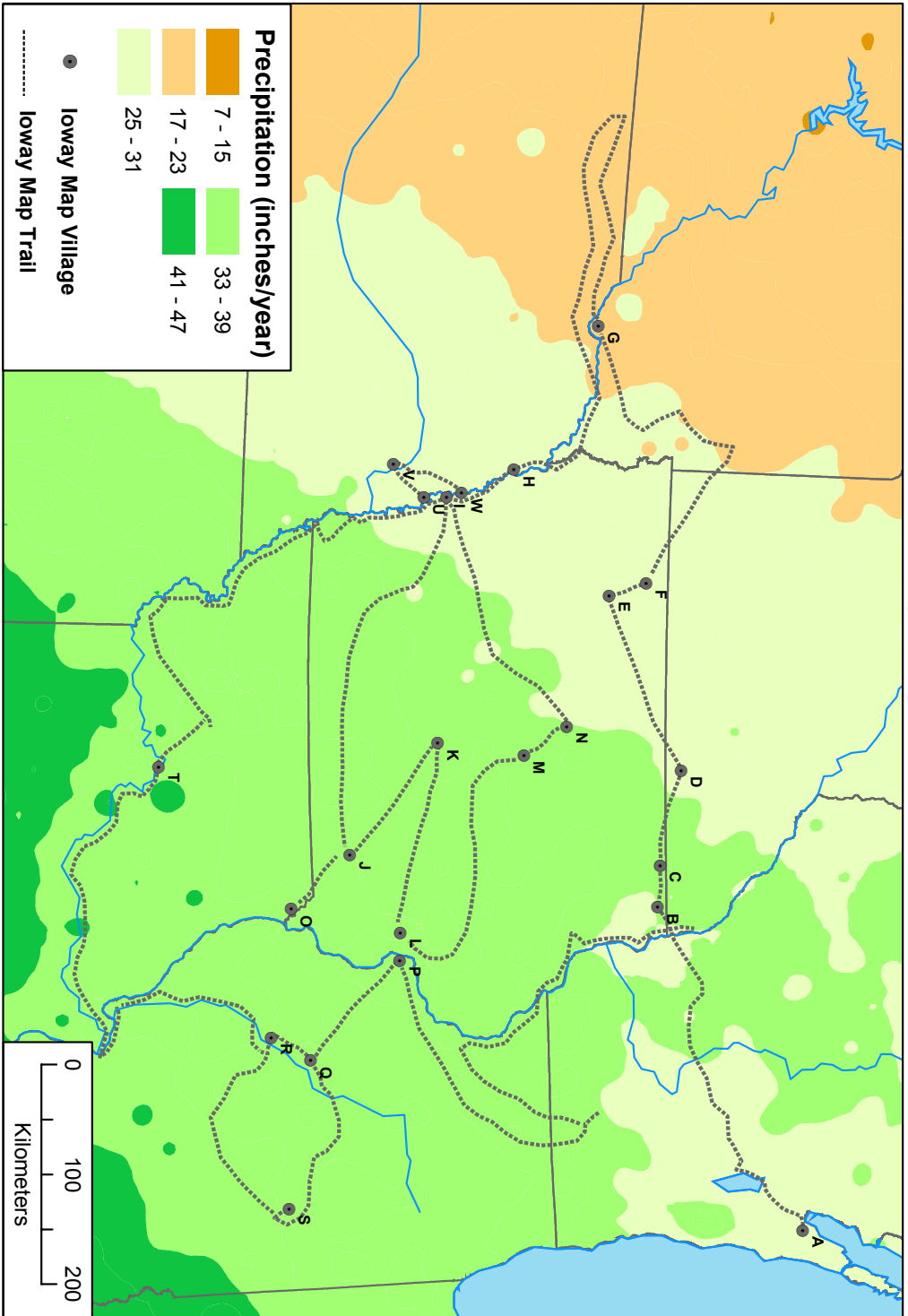
The ecotone between prairie and forest vegetation was an important element in Native American economies. Bison and other grassland species predominated west of the Missouri River, while white-tail deer and forest species were abundant east of the Mississippi. The Ioway were adept at traveling seasonally, harvesting resources from a diversity of micro-environments. Figure 43 helps researchers visualize which villages were located in which micro-climate. The western-most villages are locations where summer bison hunting would be possible. The far western trail (which does end near the Bijou Hills silicified sediment quarry) may well have been the travel route to and from an area of short-grass prairie where bison are more abundant.

VII. Conclusions – GIS in Aid of Historical and Archaeological Research

A Geographic Information System provides computerized tools that allow users to enter, store, examine, organize, manipulate, visualize (draw), and re-present maps and other spatially referenced information. There are three key strengths that make GIS an important component of the 1837 Ioway Map Project. First, it allows researchers to accurately store and manipulate spatial and attribute information. Second, it allows users to query the spatial and attribute data using a wide variety of criteria (e.g., names of features, locations of feature, size or other numeric attributes of features, relationships of features to each other [e.g., things within one mile of other things]). Finally, GIS allows users to easily visualize these aspects, changing the colors and symbolic representation of the map to highlight contrast or similarity, and linking map features with other data. The five different thematic maps presented in Chapter VI are examples of the utility of visualization for historic and archaeological research.

Cartographic Results

The 1837 Ioway map was a rhetorical tool intended by the Ioway to help persuade U.S. government officials to allow the Ioway to remain in their traditional homeland. They encoded information concerning their history, culture, and perhaps politics (e.g., the differences between the 1837 and 1847 Ioway maps) with their cartographic choices. Basic GIS tools (zoom, measurement, thematic symbolization) provided assistance in deciphering some of the information the Ioway stored in their map. Although the map maker (or makers) is unknown, the Ioway clearly spent time and effort in its production, as seen in the line superposition data.

Village sizes do vary although these are only weakly correlated with the number of (house?) points contained in each village. The distribution of small, medium and large size villages examined across the landscape (Figure 17) could be providing information on population changes through time (if villages were occupied sequentially, as Green argues), inter-tribal settlements (joint Omaha-Ioway villages, for example), or economically more powerful (and less powerful) villages. Similarly, the numbers of (house) marks within a village may have been a symbol of village importance, something that can now be checked against historical and archaeological information for a given area.

The number of points in each trail does seem to correlate with trail length, both on the Ioway map and on a modern base map. Variability in trail point sizes may have symbolized differing modes of transportation (canoe versus horseback, for example) or differences in the length of time a journey took due to other factors (landscape impediments, time spent harvesting resources along the way, dangers from hostile neighbors, etc.). By capturing this variation using GIS tools, new avenues of research can be explored.

Lacking annotation, the Ioway map is difficult for modern people to use. Only sixty of the more than 14,000 Midwestern hydrographic features were included, but

which sixty? GIS expanded the available methods for determining the correct identification of river features. By pinpointing locations with abrupt changes in map scale, researchers can target those areas and experiment with alternative river attributions. The residual values calculated between source and target map control points during georeferencing provide an additional means for evaluating river identifications. Large residual values may indicate that an incorrect attribution has been made.

The documentation of this information is important (and easily stored in a GIS database) and suggests directions for additional research by historians, archaeologists and others interested in Native American studies. These modern tools add to the cultural and historical value already present in this unique document.

Georeferencing Results

Georeferencing locates the Ioway map features on a modern base map, but accurate identification of the hydrographic features is a prerequisite for successful georeferencing. The Ioway map is challenging to work with, however, primarily because of the variable scales used. Although none of the six georeferencing methods was completely successful in translating the Ioway's vision to a modern map space, all of them provided some useful information. Figures 35 and 36 summarize the possible locations for each of the villages, and this alone is helpful. Villages are often clustered within a single county, and perhaps county-level accuracy is the limit to which this kind of map can be registered.

The locations on the Ioway map that are difficult to warp to the modern map may be providing clues to additional ethnographic information. As was the case with abrupt changes in map scale, some of the areas on the map that are most difficult to georeference may be pointing to cultural information that the Ioway were recording in those locations. Joyce Marcus (1973) for example, argued that the Maya associated each of their four most powerful cities with a cardinal direction (describing them as "northern city," "eastern city," etc.). The fact that the actual geographic location of each city did not correspond with a northern or eastern quadrant of their territory was apparently immaterial to the Maya. I do not mean to suggest that same conclusion here, only that the Ioway may have had reasons apart from geographic accuracy for their placement of map features. In Figure 36, the possible georeferenced positions of Villages H, M, N, U and W all cluster reasonably tightly, while Villages B, C, D, E, and F are much more dispersed. This could be meaningless, but it might signal that Villages B-F were intentionally positioned differently by the Ioway, for non-geographic reasons.

Spatial Analysis Results

GIS provides the tools to integrate disparate kinds of information (historic sites, other tribes' village locations, physical landscape features, etc.) and examine it in relation to Ioway map features. The GIS tools applied in this project facilitate comparison of the village and trail locations in ways that are difficult using only paper

maps. Even taking the accuracy problems into consideration, overlay analysis provides visual evidence that promotes creative thinking and additional research. This was particularly clear in the case of the trails. In a number of instances, trails meander widely rather than taking a direct route from starting village to destination village. The ability to examine trail locations relative to chert resources, vegetation zones (precipitation is a reasonable proxy for this), or historic site locations allows the rapid evaluation of "what if" scenarios. Once a visual correspondence has been found, focused in-depth research can follow.

Additional Ioway Map Project Components

A number of additional research avenues are possible, and although they are outside of the scope of this project, a few bear mentioning. While georeferencing the Ioway map to a modern base map can be problematic, it would be interesting to attempt to georeference it to other historic maps. In particular, maps of the Plains and Missouri River from the 18th and early 19th centuries could provide interesting information on neighboring tribal boundaries and villages. These might also be more similar to each other than any one is to a modern map of the region. Possible candidates could include the 1702 de l'Isle map and maps generated around the time of the Lewis and Clark expedition (e.g., the Pitot/Lafon 1802 map; the Samuel Lewis 1804 map; many of Clark's expedition maps; see Wood 1987 for other suggestions). Similarities among these maps (e.g., in scale, in the placement of physical features, in the simplification or stylization of lines) and the Ioway map would help to elucidate general cartographic conventions of the time.

An archaeological extension of this project would be to compare surveyed areas of Iowa (and surrounding states) with the georeferenced Ioway village locations. In areas where archaeological surveys have been done, a lack of correspondence could indicate that the village's position is wrongly georeferenced.

Presentation Venues for Ioway Map Project Results

The Ioway produced the No Heart map to serve as a bridge between Ioway and EuroAmerican cultures, translating not only notions of geographic space but also of history and identity from the world of aboriginal Ioway culture to that early world of non-Native Americans. Today the map can serve as a portal connecting 21st century Native and non-Native Americans with 19th century cultures, landscapes and history. Because the Ioway Map Project is computer-based, its products are scalable and can be presented on a number of platforms: individual researchers can use a CD containing the Project results on a desk-top computer; museum visitors could have access to an exhibit that contained traditional elements (physical artifacts, diorama) as well as a computer work-station with a virtual exhibit (supported by an intra-net application); and a global community of Internet users could visit a Project web-site and navigate among the many paths as their interests dictate.

A CD of project results is currently available, and creation of a museum exhibit and internet web site are planned for the near future. The Project is based at the Logan Museum of Anthropology, Beloit College (Beloit, Wisconsin), where museum director Dr. William Green has been researching the 1837 *No Heart* map for several years. Both the museum exhibit and Project web site would be hosted at Beloit College.

The audience for this project is potentially quite broad, including scholarly researchers in history, archaeology, geography, and American Indian Studies; K-12 and college students; members of the general public; and members of the two bands of the Ioway tribe. Since their removal in 1837, the Ioway have lived on two reservations, one in Kansas (the Iowa Tribe of Kansas and Nebraska) and the other in Oklahoma (the Iowa Tribe of Oklahoma). Both bands have expressed an interest in incorporating research on the 1837 map into tribal instructional programs. The 1837 *No Heart* map represents a historical watershed for the Ioway, symbolizing the painful 1830's decade of removal from their Iowa homeland after centuries of turmoil and change during colonization.

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Appendices

A. Descriptions of the GIS data files
B. Instructions on assembling an Ioway Map ArcView Project
C. File management tips before using georeferencing tools
D. Instructions on using the standard georeferencing tools
E. Instructions on using the spatial adjustment tools
F. Ioway Map Measurement Methods
G. Attribute Tables for Ioway Map feature layers

Appendix A - Description of the GIS data files

I used 51 files to complete work on the Ioway Map Project, 15 base map files, 5 files related to the Ioway map, 25 files generated during the georeferencing process, and 6 files related to the spatial analysis component of the project. Below is a description of each data file as well as comments about any modifications I made to it. This information is repeated (and in some cases elaborated on) in the metadata attached to each file and accessible using ArcCatalog.

Base Map files:

Data files in this category were obtained from the eight disc CD set distributed by ESRI with copies of their software products. According to the metadata the information in these files is based on the Tiger line files, current as of the 2000 census. ESRI source data files were used because they are of good quality, cover the area of interest for the project, could be obtained at no cost, and include metadata. In most cases I altered the original data through geoprocessing (e.g., clipping) or by selecting sub-sets of the data in the original file (e.g., selecting certain rivers or cities).

All of the original ESRI files had the same coordinate system: GCS North American, 1983. I did not change this directly. Instead, I added them to an ArcMap data frame that had a NAD 83 UTM zone 15N (Iowa) projection.   ArcMap then changed the files to match this projection "on-the-fly".

16. **BigCities.shp** - point locations for U.S. cities including only selected cities in the project area
17. **ProjAreaDrainage.shp** - generalized line file of the major river drainages in the project area
18. **ProjAreaDtlst.shp** - detailed polygon file of the nine project area states; boundaries are more accurate than in the standard state.shp file
19. **Clip_Hydroln.shp** - line file of U.S. aqueducts, canals, inter-coastal waterways, rivers and streams; this contains most of the rivers in the project area but the lines are more generalized than the lines for each of the state river files
20. **ProjAreaMjlakes.shp** - detailed polygon file of major water features (including bays, canals, lakes, reservoirs, and large rivers) in the project area
21. **Shadedrelief**
22. **Elevation**
23. **NA_Selectbigr.shp** – selected large rivers included by the Ioway on their 1837 map
24. **NA_Projectrivsel.shp** – selected rivers included by the Ioway on their 1837 map
25. **NA_ProjRivselect.shp** – selected rivers included by the Ioway on their 1837 map
26. **NA_Iariverselect.shp** – Iowa rivers included by the Ioway on their 1837 map
27. **Clip_riverastreams.shp** – generalized rivers and streams line file clipped to the 9 state study area

28. **Clip_lakesarivers.shp** – generalized lakes and rivers polygon file clipped to the 9 state study area
29. **Clip_mjwater.shp** – large rivers line file clipped to the 9 state study area
30. **Country_bkgrd.shp** – countries of the world polygon file clipped to North America
31.

I modified 8 of the files as follows:

- I did a "select by attribute" query on 3 shape files – cities.shp, dtl_cnty.shp, and dtl_st.shp – so that the selection included only the following 9 project states: Illinois, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin
  - o I saved these selections as new shape files named ProjAreaCities.shp, ProjAreaDetailCnty.shp, and ProjAreaDetailSt.shp
- I did a "select by attribute" query on the drainage.shp file so that the selection included only those major waterways that intersect a Project area state. In practice, this meant that I selected the Mississippi drainage (and its major tributary rivers), the Nelson/Saskatchewan drainage (yielding the Red River of the North), and the St. Lawrence drainage (yielding the outline of the Great Lakes).
  - o I saved this selection as ProjAreaDrainage.shp
- I clipped 3 shape files – hydroln.shp, lakes.shp, mjwater.shp, and rivers.shp – using the ProjAreaDetailSt.shp file.
  - o I saved these clipped shape files as ProjAreaHydro.shp, ProjAreaMjLakes.shp, and ProjAreaMiscWater.shp
- I did not modify the 8 state river files (iarivers.shp, ilrivers.shp, ksrivers.shp, mnrivers.shp, morivers.shp, nerivers.shp, sdrivers.shp, wirivers.shp).
- I did not include North Dakota features (e.g., cities, rivers) in anything except the overall Project Area boundary files because the Ioway map does not extend into North Dakota. However, since the Missouri River drains down out of North Dakota, and since it makes for a more reasonable looking Project Area outline (the gap above South Dakota is a bit disconcerting to the eye if NoDak is left out) I included NoDak.

Ioway Map files:

Ioway map were created by me during the data capture and processing steps in this project.

6. **Iowaym2.tif** – the unaltered .tif image file generated by scanning the Ioway map published in Wood (2001:Plate 18). I created a .tif file of the Ioway map based on the 11 inch by 17 inch reproduction of the Ioway map published by Wood (2001:16). The copy of the book I used was not bound, so I was able to remove the page with the Ioway map on it and scan it using one of the large format, high resolution drum scanners located at ESRI in Redlands, California. The resulting Iowaym2.tif file was the file I added to ArcMap and used in the initial raster to vector georeferencing.

7. **IowayRivSegmts.shp** – the digitized river segments from the Ioway map
8. **IowayTrails.shp** – the digitized trails shown on the Ioway map
9. **IowayVillages.shp** – the digitized outlines of the villages shown on the Ioway map
10. **IowayLakes.shp** – the digitized outlines of the lakes shown on the Ioway map

Using the Iowaym2.tif file in ArcMap I screen digitized the river, lake, village and trail features, creating 4 new shape files: IowayLakes.shp (polygon), IowayRivSegmts.shp (line), IowayTrails.shp (multipoint), and IowayVillages.shp (polygon). I created a personal geodatabase (ReDigIowayMap.mdb) to hold these files, and then used ArcToolBox to create a network from the river segments shapefile. I used these vector files when rubber sheeting the Ioway map features to the base map with the Spatial Adjustment tools (vector to vector).

Georeferencing files:

Georeferencing files were created by me during the data processing steps in this project.

26. **FinalTiePts.shp** – the 53 control points used in georeferencing; points include stream confluences and lake center points. I created this shape file to use in georeferencing modern hydrographic features with locations on the Ioway map. I relied on Green's (2001:15) identification of the names of each hydrological feature on the Ioway map. The Ioway map includes 52 locations that can potentially be used as control points, including 43 river confluences and 9 lakes (if points are placed in the center of a lake). However, Green was uncertain of the exact identification of 6 rivers and one lake or bay:
    * Green Bay or Lake Michigan, West Shore
    * North Fabius or Wyaconda or Fox River (of Missouri)
    * Des Moines River or West Fork Des Moines River
    * Boone River or East Fork Des Moines River
    * Twelvemile Creek ? [no alternative given]
    * Nishnabotna River or Tarkio River
    * Skunk Creek or Beaver Creek ?
    The TiePoints.shp file was created in NAD 83, UTM Zone 15 to match the projection of the other base files.
27. **VillageTiePts.shp** – best approximation digitized locations of the geographic location of the Ioway villages
28. **TrailTiePts.shp** - best approximation digitized locations of the geographic location of the Ioway trail segments
29. **1ˢᵗrectifyiowaym2.tif** – 1ˢᵗ order polynomial georeferenced Ioway map
30. **2ⁿᵈrectifyiowaym2.tif** – 2ⁿᵈorder polynomial georeferenced Ioway map
31. **RectifyIowaym2.tif** – 3ʳᵈ order polynomial georeferenced Ioway map
32. **SpAdj1iowaytrails.shp** – georeferenced Ioway map trails using Affine Spatial Adjustment tools

33. **SpAdj1iowayvillages.shp** – georeferenced Ioway map villages using Affine Spatial Adjustment tools
34. **SpAdj1iowayrivsegmts.shp** – georeferenced Ioway map rivers using Affine Spatial Adjustment tools
35. **SpAdj1iowaylakes.shp** – georeferenced Ioway map lakes using Affine Spatial Adjustment tools
36. **SpAdj3iowaytrails.shp** – georeferenced Ioway map trails using Similarity Spatial Adjustment tools
37. **SpAdj3iowayvillages.shp** – georeferenced Ioway map villages using Similarity Spatial Adjustment tools
38. **SpAdj3iowayrivsegmts.shp** – georeferenced Ioway map rivers using Similarity Spatial Adjustment tools
39. **SpAdj3iowaylakes.shp** – georeferenced Ioway map lakes using Similarity Spatial Adjustment tools
40. **SpRubShiowaytrails.shp** – georeferenced Ioway map trails using Rubbersheet Spatial Adjustment tools
41. **SpRubShiowayvillages.shp** – georeferenced Ioway map villages using Rubbersheet Spatial Adjustment tools
42. **SpRubShiowayrivsegmts.shp** – georeferenced Ioway map rivers using Rubbersheet Spatial Adjustment tools
43. **SpRubShiowaylakes.shp** – georeferenced Ioway map lakes using Rubbersheet Spatial Adjustment tools
44. **Georef2ndvillages.shp** – digitized locations of the Ioway villages based on the 2nd order polynomial georeferencing procedure
45. **Georef1stvillages.shp** – digitized locations of the Ioway villages based on the 1st order polynomial georeferencing procedure
46. **Georef3rdvillages.shp** - digitized locations of the Ioway villages based on the 3rd order polynomial georeferencing procedure
47. **Rubbervillages.shp** – digitized locations of the Ioway villages based on the Spatial Adjustment rubbersheet method
48. **Adjust3villages.shp** – digitized locations of the Ioway villages based on the Spatial Adjustment affine transformation method
49. **Adjust1villages.shp** – digitized locations of the Ioway villages based on the Spatial Adjustment similarity transformation method
50. **ReverseSt.shp** – project area state locations georeferenced back to the Ioway map using Spatial Adjustment Affine transformation process

Spatial Analysis files:

Spatial analysis files were created by me during the data processing and analysis steps in this project.

7. **Oneotaarea.shp** – polygon of the cultural area encompassed by the Oneota
8. **Oneotasites.shp** – point file containing locations of Oneota sites in Iowa
9. **Chert.shp** – polygons illustrating the location of different Midwestern stone tool raw material deposits

10. **Historic_sites.shp** – point file containing the digitized locations of selected historic sites in Iowa
11. **School_vills_pts.shp** – point file containing the digitized locations of the Ioway villages illustrated on the 1847 Schoolcraft (1853) map
12. **Midwest_precip.shp** – polygon file containing NOAA data on average annual precipitation for the Midwestern states

Appendix B – <u>Instructions on Assembling an Ioway Map ArcView Project</u>

I used ArcGIS 8.3 to complete the Ioway Map Project. This version of the ESRI software uses map documents rather than the Project (.apr) files familiar from ArcView 3.x. Among the data files included on this CD is a MapDocuments folder that contains the 26 map documents (.mxd) I created. These should be accessible as map documents to anyone using ArcGIS version 8.3 or higher. With ArcGIS 8.1 or 8.2 simply open a new map document (rename it or use the Figure number as a name) and add the data layers below in the order in which they are listed.

To re-create the map documents as projects within ArcView 3.x:

1. Start ArcView with a new view (that should be one of the choices at the opening screen);
2. Click "yes" to add data to the view now;
3. Navigate to the drive and directory containing the contents of this CD;
4. A list of all shapefiles will appear in the window; note that the Data Source Types drop-down box shows Feature Data Source
5. To add images (.tif files or rasters for example) you must change the drop-down box to Image Data Source; doing this should bring up a list of the available .tif files
6. For any given map (Project), add its data layers (image and/or feature data) in the order listed below
7. Be sure to set the projection for each data layer to ensure that they appear in the same geographic space

- <u>Figure1</u> (Scanned Image of the 1837 Ioway Map)
  - Iowaym2.tif
- <u>Figure8</u> (General Area Depicted on the 1837 Ioway Map)
  - BigCities
  - ProjAreaDetailSt
  - ProjAreaDrainage
  - ProjAreaMjLakes
  - ProjAreaDetailSt (again)
  - Shadedrelief (raster dataset)
  - Elevation (raster dataset)
- <u>Figure12</u> (The 1837 Ioway Map with Slected Features Labeled)
  - Iowaym2.tif
- <u>Figure14</u> (Rivers Selected by the Ioway for Inclusion on their 1837 Map)
  - NA_SelectBigr
  - NA_ProjectRivSel
  - NA_ProjRivSelect
  - NA_IARiverSelect
  - Clip_RiversAStreams
  - Clip_LakesARivers
  - Clip_MjWater

- o Clip_Hydroln
- o ProjAreaDetailSt
- o ProjAreaMjLakes
- o Country_Bkgrd
- Figure17 (Classification of Villages by Area)
  - o Villages
  - o Lakes
  - o Rivers
  [all from the Digitized Ioway Map]
- Figure18 (Classification of Villages by Minimum Number of Houses)
  - o Villages
  - o Lakes
  - o Rivers
  [all from the Digitized Ioway Map]
- Figure19 (Classification of Villages by Maximum Number of Houses)
  - o Villages
  - o Lakes
  - o Rivers
  [all from the Digitized Ioway Map]
- Figure21 (New Village Positions based on Best Approximation of Georeferenced Village Locations)
  - o VillageTiePts
  - o NA_SelectBigr
  - o NA_ProjectRivSel
  - o NA_ProjRivSelect
  - o NA_IARiverSelect
  - o ProjAreaDrainage
  - o ProjAreaDetailSt
  - o ProjAreaMjLakes
- Figure25 (Variety of Map Scales Identified on the 1837 Ioway Map)
  - o Villages
  - o Lakes
  - o Rivers
  [all from the Digitized Ioway Map]
- Figure26 (First Order Polynomial Transformation of the 1837 Ioway Map)
  - o FinalTiePts
  - o NA_SelectBigr
  - o NA_ProjectRivSel
  - o NA_ProjRivSelect
  - o NA_IARiverSelect
  - o ProjAreaDrainage
  - o ProjAreaDetailSt
  - o 1stRectifyIowaym2.tif
  - o ProjAreaMjLakes
- Figure27 (Second Order Polynomial Transformation of the 1837 Ioway Map)

- o FinalTiePts
- o NA_SelectBigr
- o NA_ProjectRivSel
- o NA_ProjRivSelect
- o NA_IARiverSelect
- o ProjAreaDrainage
- o ProjAreaDetailSt
- o 2ndRectifyIowaym2.tif
- o ProjAreaMjLakes
- Figure28 (Third Order Polynomial Transformation of the 1837 Ioway Map)
  - o FinalTiePts
  - o NA_SelectBigr
  - o NA_ProjectRivSel
  - o NA_ProjRivSelect
  - o NA_IARiverSelect
  - o ProjAreaDrainage
  - o ProjAreaDetailSt
  - o RectifyIowaym2.tif
  - o ProjAreaMjLakes
- Figure30 (Digitized Features on the 1837 Ioway Map)
  - o TravelRoutes
  - o Villages
  - o Lakes
  - o Rivers
  - [all from the Digitized Ioway Map]
- Figure31 (Affine Transformation of the Ioway Map using Spatial Adjustment Tools)
  - o FinalTiePts
  - o NA_SelectBigr
  - o NA_ProjectRivSel
  - o NA_ProjRivSelect
  - o NA_IARiverSelect
  - o IowayRivSegmts (change this name after you adjust the data)
  - o IowayLakes (change this name after you adjust the data)
  - o IowayVillages (change this name after you adjust the data)
  - o ProjAreaDrainage
  - o ProjAreaDetailSt
  - o ProjAreaMjLakes
- Figure32 (Similarity Transformation of the Ioway Map using Spatial Adjustment Tools)
  - o FinalTiePts
  - o NA_SelectBigr
  - o NA_ProjectRivSel
  - o NA_ProjRivSelect
  - o NA_IARiverSelect
  - o IowayRivSegmts (change this name after you adjust the data)

- o IowayLakes (change this name after you adjust the data)
  - o IowayVillages (change this name after you adjust the data)
  - o ProjAreaDrainage
  - o ProjAreaDetailSt
  - o ProjAreaMjLakes
- Figure33 (Rubbersheet Transformation of the Ioway Map using Spatial Adjustment Tools)
  - o FinalTiePts
  - o NA_SelectBigr
  - o NA_ProjectRivSel
  - o NA_ProjRivSelect
  - o NA_IARiverSelect
  - o IowayRivSegmts (change this name after you adjust the data)
  - o IowayLakes (change this name after you adjust the data)
  - o IowayVillages (change this name after you adjust the data)
  - o ProjAreaDrainage
  - o ProjAreaDetailSt
  - o ProjAreaMjLakes
- Figure34 (Project Area State Outlines Georeferenced to the 1837 Ioway Map)
  - o IowayTrails
  - o FinalTiePts
  - o IowayRivSegmts
  - o IowayLakes
  - o IowayVillages
  - o ProjAreaDetailSt (change this name after you adjust the data)
- Figure35 (Ioway Map Village Locations Symbolized by Georeferencing Method)
  - o VillageTiePts
  - o GeoRef2ndVillages
  - o GeoRef1stVillages
  - o RubberVillages
  - o GeoRef3rdVillages
  - o Adjust3Villages
  - o Adjust1Villages
  - o ProjAreaDrainage
  - o ProjAreaMjLakes
  - o ProjAreaDetailSt
- Figure36 (Differences in Ioway Map Village Locations Depending on Georeferencing Method Used)
  - o VillageTiePts
  - o GeoRef2ndVillages
  - o GeoRef1stVillages
  - o RubberVillages
  - o GeoRef3rdVillages
  - o Adjust3Villages

- o Adjust1Villages
- o ProjAreaDrainage
- o ProjAreaMjLakes
- o ProjAreaDetailSt
- Figure37 (Best Approximation (Digitized) of the Ioway Map Village and Trail Locations)
  - o Ioway Village
  - o NA_SelectBigr
  - o NA_ProjectRivSel
  - o NA_ProjRivSelect
  - o NA_IARiverSelect
  - o Ioway Trail
  - o ProjAreaDrainage
  - o ProjAreaDetailSt
  - o ProjAreaMjLakes
- Figure38 (Digitized Ioway Map Village and Trail Locations Compared with Rubbersheet Locations)
  - o VillageTiePts
  - o TrailTieLine
  - o BGrubber_IowayTrails
  - o BGrubber_IowayVillages
  - o NA_SelectBigr
  - o NA_ProjectRivSel
  - o NA_ProjRivSelect
  - o NA_IARiverSelect
  - o ProjAreaDrainage
  - o ProjAreaDetailSt
  - o ProjAreaMjLakes
- Figure39 (Locations of Historic Archaeological Sites and Georeferenced Ioway Villages and Trails)
  - o Historic_Sites
  - o VillageTiePts
  - o TrailTieLine
  - o ProjAreaDrainage
  - o ProjAreaDetailSt
  - o ProjAreaMjLakes
- Figure40 (Locations of Oneota Archaeological Sites and Georeferenced Ioway Villages and Trails)
  - o OneotaSites
  - o VillageTiePts
  - o TrailTieLine
  - o OneotaArea
  - o ProjAreaDrainage
  - o ProjAreaDetailSt
  - o ProjAreaMjLakes

- <u>Figure41</u> (Locations of 1847 Ioway Villages (Schoolcraft Map) and Georeferenced 1837 Ioway Villages and Trails (No Heart Map))
    - School_Vills_Pts
    - VillageTiePts
    - TrailTieLine
    - NA_SelectBigr
    - NA_ProjectRivSel
    - NA_ProjRivSelect
    - NA_IARiverSelect
    - ProjAreaDrainage
    - ProjAreaDetailSt
    - ProjAreaMjLakes
- <u>Figure42</u> (Locations of Midwestern Chert Deposits and Georeferenced Ioway Villages and Trails)
    - VillageTiePts
    - TrailTieLine
    - Chert
    - ProjAreaDrainage
    - ProjAreaDetailSt
    - ProjAreaMjLakes
- <u>Figure43</u> (Locations of Midwestern Chert Deposits and Georeferenced Ioway Villages and Trails)
    - VillageTiePts
    - TrailTieLine
    - ProjAreaDrainage
    - ProjAreaDetailSt
    - ProjAreaMjLakes
    - Midwest_prece_polygon

Appendix C - <u>File Management Tips before using Georeferencing Tools</u>

Before you begin working with the georeferencing tools, it is IMPORTANT to remember that both sets of tools (standard georeferencing and spatial adjustment)

permanently change your data files.

Even though both tool bars allow you to "undo" the georeferencing, this will not return the data file to its original state. The spatial reference information will already have been changed permanently.

To avoid unhappy consequences, here is a simple step-by-step process:

1. Open ArcCatalog or Windows Explorer
2. Create a directory to hold the project files (I used IowayProject)
3. ArcGIS will run faster on a hard drive (C drive) rather than on a network drive so save the project directory on your hard drive (usually your C drive)
4. Within the project directory, create at least these 5 sub-directories:
   - OriginalFiles (not-to-be-touched original copies)
   - DataFilesInUse (duplicates of the OriginalFiles that you can use)
   - MapDocuments(if you are using ArcGIS)
   - SpAdjFiles (for spatial adjustment tool files)
   - GeoRefFiles (for georeferencing tool files)
5. The OriginalFiles sub-directory should hold all of the files listed in Appendix A
6. The DataFilesInUse folder should also hold all of the files listed in Appendix A
7. The SpAdjFiles folder should contain a copy of the 4 digitized Ioway Map files: IowayRiverSegments, IowayTrails, IowayLakes, and IowayVillages. <u>Once you have</u> put the copies into this folder, <u>rename each one of them</u> (SpAdjIowayRiv for example). If you intend to use several of the Spatial Adjustment methods (there are 4 that could be used with these data) <u>copy a new, complete set of the 4 digitized files for each method and rename each one uniquely to that method</u> (e.g., SpAdjIowayRiv1, SpAdjIowayRiv3, SpAdjIowayRiv5, etc.). Remember that even if you use the "undo" button, the files have been altered somewhat and will not return to their original content.
8. The GeoRefFiles folder should contain a copy of the Ioway Map .tif file. This entire file will be changed after any georeferencing operation. Include a new copy for every different georeferencing method you intend to use. Rename each copy uniquely (e.g., 1GeoRef_Iowaymap.tif, 2GeoRef_Iowaymap.tif, 3GeoRef_Iowaymap.tif, etc.).

Appendix D – <u>Instructions on using the Standard Georeferencing Tools</u>

1). The <u>Standard Georeferencing tools are available in all ArcGIS 8 versions</u>. These tools allow you to georeference a raster file to another vector file.

2). <u>Georeferencing permanently changes the data you adjust</u>. Before you begin, make a backup copy of your data files and save it in a new directory (please refer to Appendix C). Then, in case of failure, error, or corruption of your data during adjustment, you can go back to the original files, make another copy, and try again.

3). Georeferencing is a straightforward process that simply requires a base map with vector files, and a copy of an image or .tif file. I used the Iowaym2.tif file and the following base map layers:
- FinalTiePts
- NA_SelectBigr
- NA_ProjectRivSel
- NA_ProjRivSelect
- NA_IARiverSelect
- ProjAreaDrainage
- ProjAreaDetailSt
- 1stRectifyIowaym2.tif
- ProjAreaMjLakes

For information on each of these data files please refer to Appendix A.

4). For this project I created 4 folders, each holding an identical copy of the files above. The 4 folders were: GeoRef1; GeoRef2; GeoRef3; and BackUpFiles. I did this because I wanted to have one unaltered set of files (BackUpFiles) and one set of files associated with each of the 3 transformations I performed on the data. The 3 transformations were
1. an Affine Transformation (1stOrderGeoRef.mxd with data files from GeoRef1 folder);
2. a 2nd Order Polynomial Transformation (2ndOrderGeoRef.mxd with data files from GeoRef2 folder). I renamed the .tif file 2ndRectifyIowaym2.tif.
3. a 3rd Order Polynomial Transformation (3rdOrderGeoRef.mxd with data files from GeoRef3). I renamed the .tif file RectifyIowaym2.tif

5). To use the Georeferencing tools you must add the Georeferencing tool bar.

6). From the Georeferencing tool bar drop down menu, select "transformation" and pick one of the 3 possible methods (1st, 2nd, 3rd).

7). Check that the "Layer" box shows the Ioway Map .tif file (it should, by default, unless you have other .tif files in the map document)

8). The Ioway Map .tif file does not appear in the same geographic space as the basemap layers. Use the "zoom to layer" tool to move back and forth between the regions. Starting on the Ioway Map, select a river confluence and mark it using the "Add Control Points" tool. <u>Be sure to set the control point *first* on the Ioway Map, and then on the base map</u>. Zoom to the basemap and click the "Add Control Points" tool on the corresponding FinalTiePts location. You should see a link line appear on the map, and if you open the Links Table, you should see the residual information on this link.

9). A 1st order polynomial transformation requires 3 control point links, a 2nd order polynomial transformation requires 6 control point links, and a 3rd order polynomial transformation requires 9 control points. The more points the better, however, for all of the methods. I used at least 49 ties points for each method (please refer to Appendix A for details on the locations in the FinalTiePts file).

10). If the "Auto Adjust" box is checked (look at the Links Table or in the drop down Georeferencing menu) the adjustment should have happened as soon as you entered enough control points for the given method. Once all of your common locations are linked, go to the Georeferencing menu and click "Rectify." Remember, once you have used the "rectify" button, your original data have been changed permanently. Even if you "undo," the files will not be returned to their pre-adjustment form.

11). Remember to rename the rectified Ioway Map .tif file (with something indicating the adjustment method). This file (layer) is now available and can be added to any map document.

12). Experiment with the symbology to help clean up the .tif file appearance. I used the following settings:
- Classified (1 class)
- Manual (break point at 224)
- Exclude values 0 – 140
- Color ramp black to white
- Transparency 70%

Appendix E - <u>Instructions on using the Spatial Adjustment Tools</u>

1). The <u>Spatial Adjustment tools are only available in ArcGIS 8.2 and higher</u>. These tools allow you to georeference or rubbersheet vector files to other vector files. The standard georeferencing tools in ArcGIS only register raster files to vector files.

2). <u>Spatial Adjustment permanently changes the data you adjust</u>. Before you begin, make a backup copy of your data files and save it in a new directory. Then, in case of failure, error, or corruption of your data during adjustment, you can go back to the original files, make another copy, and try again.

3). Spatial Adjustment is temperamental about the X,Y domain of your data. If the data you want to adjust is in "scanner space" (i.e., the file comes from scanned and/or digitized vector files) its spatial domain will need to be adjusted so that it will "fit" in the geographic or projected space of the files you are adjusting it to.

4). I took the following steps to ensure the point 3). above was accounted for:
- I scanned the Ioway map from a copy published in a folio volume (see Appendix A for details of this procedure).
- I digitized the river segments on the Ioway map in segments, from source to mouth, following the center of the river line segment as closely as possible.
- I digitized the trails on the Ioway map as multi-point features. I used Green's (2001) determination of where the start point and end point of a single trail was, and digitized these from start node to end node.
- I digitized the lakes on the Ioway map as polygon features.
- I digitized the perimeter of the villages on the Ioway map as polygon features.
- I created a personal geodatabase from to contain these files (ReDigIowayMap.mdb).
- I exported the files from a geodatabase (ReDigIowayMap.mdb) to a new geodatabase (GeoReferenceFiles.mdb) in order to have access to the tools that allow me to adjust the X, Y domain. I made sure that the maximum X and maximum Y values were the same as the values for the clipped project states shapefile (142.577207309759). I changed the minimum X and minimum Y values to 0, to accommodate the points in "scanner space."
- Finally, I exported the files from the geodatabase to simple shapefiles so that I could work with them using Spatial Adjustment.

5). After making 4 backup copies of the following files, I added them to a new ArcMap session:
- finalTiePts.shp
- ProjAreaCities.shp
- IowayTrails.shp
- ProjAreaHydro.shp
- ProjAreaDrainage.shp
- IowayRivSegmts.shp

- ProjAreaMjLakes.shp
- ProjAreaMiscWater.shp
- ProjAreaDetailSt.shp
- ProjAreaDetailCnty.shp
- IowayVillages.shp
- IowayLakes.shp
- iowaym2.tif

For information on each of these data files please refer to Appendix A.

6). I created 5 directories, each holding an identical copy of the files above. The 5 directories were: MIPAdjust1; MIPAdjust3; MIPreverseAdj; MIPrubbersh; and BaseMapFiles. I did this because I wanted to have one unaltered set of files (BaseMapFiles) and one set of files associated with each of the 4 transformations I performed on the data. The 4 transformations were

- an Affine Transformation (SpAdjust1.mxd with data files from MIPAdjust1);
- a Similarity Transformation (SpAdjust3.mxd with data files from MIPAdjust3);
- a Rubber Sheet Transformation (SpAdjRubber.mxd with data files from MIPrubbersh); and
- a reverse transformation where I adjusted modern "accurate" state and city features to fit in the Ioway map (SpAdjReverse.mxd with data files from MIPreverseAdj).

7). To use Spatial Adjustment, you must add the editor tool bar and the Spatial Adjustment tool bar.

8). Start an editing session.

9). From the Spatial Adjustment drop down menu, select "set adjust data," and click the "all features in these layers" radio button. First push the "clear all" button, and then put a check mark in these four boxes: IowayTrails, IowayRivSegmts, IowayVillages, and IowayLakes. Click "OK."

10). From the Spatial Adjustment drop down menu, use the Adjustment Methods menu and select the adjustment type you want to use. I used 3 types, Transformation Affine; Transformation Similarity; and Rubber Sheet. When you use Rubbersheet, you must set another property: use the Options menu, select Rubbersheet, and then choose either Natural Neighbor or Linear for the adjustment method.

11). From the Snapping menu on the Editor toolbar, select the layers and nodes or edges you want to snap to.

12). Finally on the Editor toolbar, set the snapping tolerance in the Options menu.

13). The Ioway Map layers do not appear in the same geographic space as the basemap layers. Use the "zoom to layer" tool to move back and forth between the regions. Starting on the Ioway Map, select a river confluence and mark it using the New

Displacement Link tool. Zoom to the basemap and click the New Displacement Link tool on the corresponding FinalTiePts location.

14). All of the transformation methods require at least 4 tie points. I used 50 ties points for each method (please refer to Appendix A for details on the locations in the FinalTiePts file). Once all of your common locations are linked, go to the Spatial Adjustment menu and click "Adjust." You can use the "undo" arrow if your adjustment is not satisfactory, or if you want to try a different transformation method using the same control points.   However, once you have used the "adjust" button, your original data have been changed permanently. Even if you "undo," the files will not be returned to their pre-adjustment form.

Appendix F – <u>Ioway Map Measurement Methods</u>

- The original 1837 Ioway map is reported to be "69 by 104 cm" which converts to 27.17 inches (width) by 40.95 inches (length) (Green 2001:14)

- The map is reproduced as Plate 18 in Ray Wood's 2001 book and that plate was made from a photograph of the original map (provided by the National Archives)

- Plate 18 was reproduced by Wood "at 35 percent of original size" (p. 14)

- This means that Plate 18 in Wood's book is a map that measures 9.51 inches wide (35% of 27.17 inches) by 14.33 inches long (35% of 40.95 inches)

- The Ray Wood book was printed with pages that were 11 inches by 17 inches

- I made a scan of Plate 18 in Wood's book, using ESRI's large format drum scanner (thank you ESRI) (i.e., I scanned the 11 x 17 inch page, which happened to be unbound in the book copy I was using; fortunately)

- Therefore, the map image on my *.tif* is based on a 35% reduction, i.e., the Ioway map I measured from in ArcMap was 9.51 inches by 14.33 inches

- When I measured the stream segment lengths in ArcGIS I set both the map units and the display units to inches (in General Properties of the Data Frame)

- I recorded the lengths of all river segments where I had a stream confluence to provide fixed start and end points

- I put these measurements (inches) into an Excel table, and created a second column where I converted the Plate 18 reproduction to full size (D.C. original) by multiplying by 100 and then dividing by 35. Finally, I converted this inches value to centimeters (to compare with the base map km)

- I then used a base map and measured the distances along those same stream segments, setting display units to kilometers. I used a UTM projection (UTM zone 15 north; map units in meters)

- As a check on my measurements, I used a xerox copy of Plate 18 (11 x 17 inch page, 9.51 x 14.33 inch map) and measured 10 distances in inches on this map. I compared these values with the values I obtained using the measuring tool in ArcMap.

- I measured 45 river segments (see Excel sheet Revised_MapMeasure) on both the base map and the Ioway map

- On the Ioway map, I zoomed in and measured down the middle of the stream channel

- In each case I was measuring along the line I had digitized (on the "ReDigitizedMap.mxd" layer)

- Start points and end points were the point in the middle of each stream where the 2 streams joined (abeam)

- Measurements on the Ioway map vary (I re-measured several river segments 3 or 4 times) but should be accurate to a tenth of an inch (possibly one one hundredth of an inch but it depends on rounding)

- Measurements on the base map also vary, and should be accurate to +/- 5 miles

- I endeavored to measure down the middle of the channels on the base map but I followed all the curves (I didn't simplify them)

Appendix G - Attribute Tables for Ioway Map Feature layers

1. **IowayVillages.shp (polygon)** – new shapefile created from screen digitized village polygons on the Iowaym2.tif file. Attributes for Ioway Villages include:

Object ID: auto-generated sequential number
SHAPE: polygon
ID: an automatically generated unique identification number
Shape_Length: length of village perimeter
Shape_Area: area of village polygon
Name: name of the historic village (if known)
Date_Occupied: date range for village occupation, from Green 2001
ArchSiteName: name of the archaeological site (if known)
SiteFileNumber: site number of the archaeological site (e.g., 13LA12)
References_: bibliographic references that mention this historic village or archaeological site
Village_Nu: single letter code used by Green in his 2001 article to identify the village
Culture: historic cultural group who occupied the village (usually but not always Ioway)
Min_House: minimum number of house symbols visible within village
Max_House: maximum number of house symbols visible within village

2. **IowayRivSegmts.shp (line)** – new shapefile created from screen digitized river segments on the Iowaym2.tif file. Attributes for Ioway River Segments include:

Object ID: auto-generated sequential number
SHAPE: polyline
ID: an automatically generated unique identification number
Shape_Length: length of river segment
River_Name: modern river name
Green2001_ID: numeric code used by Green in his 2001 article to identify the river
Alt_Name_1:   alternative river name if researchers are unsure of which river it is
Alt_Name_2:   additional alternative river name if researchers areunsure which river it is

3. **IowayLakes.shp (polygon)** – new shapefile created from screen digitized village
   polygons on the Iowaym2.tif file. Attributes for Ioway Lakes include:

Object ID: auto-generated sequential number
SHAPE: polygon
ID: an automatically generated unique identification number
Shape_Length: length of lake perimeter
Shape_Area: area of lake polygon
Name: modern lake name
Green2001_ID: numeric code used by Green in his 2001 article to identify the
                                        lake
Alt_Name: alternative lake name if researchers are unsure of which lake is
                                        depicted on the Ioway map

4. **IowayTrails.shp (multipoint)** – new shapefile created from screen digitized village
   polygons on the Iowaym2.tif file. Attributes for Ioway Trails include:

Object ID: auto-generated sequential number
SHAPE: multipoint
ID: an automatically generated unique identification number
Name: arbitrary identification name, "route 1" etc.
Date: time route was used, based on Green 2001 article
Start_Vill: the letter code (from Green 2001) for the village near the
                                        beginning of the route
From_Region: a general description of starting region (e.g., near confluence of
                                        Skunk River & Mississippi)
End_Vill: the letter code (from Green 2001) for the village near the end of
                                        the route
To_Region: a general descirption of ending region (e.g., near confluence of
                                        Big Sioux River & Missouri)
References_: bibliographic references that mention this travel route or travel
                                        episode