ABSTRACT

Title of Thesis: Accuracy And Distortion In Historical Maps: A Study Of Augustine Herrman's 1673 Map Of The Chesapeake Bay

Name of degree candidate: Walter Johan Fijn

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Thesis directed by: Joseph Wiedel, Professor, Department of Geography

Augustine Herrman's 1673 map has been generally accepted in historical cartography as a classical example of a mother map. As a source of original geographic information of the seventeenth century, the map needs to be evaluated by techniques which have not been used in traditional historical cartography. The established constructs of historical cartography limit the scope of comparative mapping analysis as a geographic study. The accepted presentations of temporal sequencing and physical comparison of early maps and charts as historical documents are incorporated in this study. These traditional techniques are augmented by the assessment of the map's accuracy which focuses on the best-fit method comparing the projection conformity of the Herrman map to contemporary nautical charts of the same region. Once the historic map and the contemporary charts were digitized,

the best-fit method employed the use of the Affine computer program to evaluate the conformity of the projections.

By establishing the Herrman 1673 map as an original source of geographic information, the map's value can be appraised by evaluating its accuracy and reliability. Furthermore, the analytical methodology of this thesis increases the utility of maps as historical source materials by determining the locational accuracy of features, presenting a method for correcting map projection distortion, and tracking the origin of the map features.

The results of this study illustrate the distortions of the Herrman map by projection superimposition and control point network used in the best-fit analysis. The analysis concluded that the latitudinal properties of the Herrman map were relatively accurate but, the longitudinal properties were distorted when compared to contemporary nautical charts. The amount of distortional off-set (length) was determined for a line of latitude as 5.66 mm. and 12.83 mm. along a line of longitude at a map scale of 1:372,250.

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ACCURACY AND DISTORTION IN HISTORICAL MAPS: A STUDY OF AUGUSTINE HERRMAN'S 1673 MAP OF THE CHESAPEAKE BAY

by

Walter Johan Fijn

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Advisory Committee:

Professor Joseph Wiedel, Advisor
Professor Robert Mitchell
Professor Paul Groves

CHAPTER I INTRODUCTION

INTRODUCTION

Early works in historical cartography use maps as historical documents which present the extent of geographical knowledge of study areas. When available, historical maps appear to be one of the best sources of geographical knowledge, especially if the maps are based on original survey work. To be useful to historical cartographers, maps do not always need to be highly or uniformly accurate to yield valuable insights into past environments, as suggested by DeBoer and Carr (1969). Historical maps must be evaluated for their usefulness to be utilized as source documents of historical cartographic research.

This study attempts to use an approach for detailed cartographic element identification and analysis in historical cartographic research. Traditionally, analytical methods used in the discipline of historical cartography employ three descriptive methods for analysis; the study of outlines of map design, toponymy[1]

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[1] Toponymy is the comparative analysis of placename nomenclature on early maps.

(nomenclature), and carto-bibliography. This study follows the suggestions made by Stevens [1969], that detailed technical evaluations must be included in comparative cartographic research to assist historians and geographers alike in determining the value of maps as historical source documents.

An attempt is made in this study to contribute to the knowledge of the discipline of cartographic history by using a methodology that incorporates a less subjective approach to the analysis of maps. The addition of the reliability assessment methodology combined with the traditional aspects of historical cartographic research on maps will broaden the field beyond the subjective analysis used in methodologies in many prior studies. Furthermore, the methodology used in this study should increase the usefulness of maps as historical source materials by incorporating a technique for determining the locational accuracy or distortion of features, presenting a method for correcting map projection distortion, and tracking the originality of the map features.

Geographers evaluate and use documents as original source data in historical geographic and historical cartographic research. Among these sources of historical data, early maps and charts are generally assumed to be

original and primary to subsequent information. Although these accepted assumptions are currently being employed in research, the use of analytical methods in document/data evaluation may reveal characteristics of the sources which are difficult to determine by a subjective analysis frequently used in the past.

Research studies in historical cartography of the early colonial period of America employ the analysis of mother maps[2] in the middle Atlantic region. Several early explorations in the region resulted in maps and charts that are now accepted as being the progenitor to other mapping sources. Among these maps are the John Smith maps, Augustine Herrman map, Robert Morden maps, John Thornton maps, John Ogilby map, and several others.

Most of the comparative cartographic research in the literature does not employ a methodology that includes a map feature analysis. Comparative cartographic studies frequently look at only the temporal sequence of maps and physical comparisons of the graphics. In the mid-1980's studies began to suggest improvements in the techniques of

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[2] The mother map term has long been used in historical cartography. The use of the term refers to the map as being the source, progenitor, or prototype map. Thus, a mother map is a source map influencing the mapping or geographical knowledge of an area.

analysis by introducing the identification of similar source maps and their genetic kin by using forensic identification procedures. However, these authors have not adequately answered the call for more analytical studies as presented in professional meetings as early as the 1970's. What is lacking in these studies is a more rigid mathematical analysis. This study employs a best-fix statistical analysis of an original source of geographical information and incorporates it into the methodology to show the reliability of the charted information. This methodology and analysis are applied to the Augustine Herrman map in this study of the mapping of the Chesapeake Bay region.

This study will evaluate the Augustine Herrman map of 1673 (Figure 1) as the mother map or prototype map of the early Maryland colonial region. Its influences as the originator of geographical information of the region negates the historical value of later maps of the seventeenth century as primary source data. In summary, the goal of this study is to examine the accuracy and reliability of the Herrman map as a historical source document portraying the geography of the Chesapeake Bay region in 1673. The cartographic information depicted on the map will be related to contemporary charts of the area. The result will be a better understanding of the

reliability of historic maps as source documents used in research.

BACKGROUND

Augustine Herrman's 1673 map of the Chesapeake Bay is regarded as the most accurate map of any of the Middle Atlantic colonies published in the seventeenth century. [Morrison, Papenfuse, et al.] It succeeds John Smith's map as the prototype for subsequent Chesapeake Bay area cartography, and remains influential until superceded by the Hoxton chart of 1735 and the Fry and Jefferson map of 1753.

John Smith's maps of the Virginia colony were the only major maps showing detail of the Chesapeake Bay region prior to the Herrman 1673 map. Although John Smith is credited as being one of the first explorers of the region, his maps did not contain enough geographical information beyond the immediate waters of the Chesapeake Bay. Smith's map lacked information on the coastal area of what is now known as the "Del-Mar-Va" peninsula and the extent of the Maryland colony.

Cecil Calvert, second Lord Baltimore and an early promoter of colonization of Maryland, had attempted to secure a map of the colony better than those made by

Captain John Smith and John Ogilby. "One of the two Dutch ambassadors, Augustine Herrman, who had been quick to point out the deficiencies of Philip Calvert's maps in 1659, was persuaded to return to Maryland to reside and to draw his own map of the province. More than a decade later he finished his assignment, and in 1673, it was published and offered for sale. It was a singular achievement and made Herrman Maryland's first cartographer. His superb map provided a model for future map makers that would be copied extensively, with and without acknowledgment, for generations to come. Herrman first offered to map the Chesapeake for the Dutch in a letter to the governor of New Amsterdam, Peter Stuyvesant, written in October 1659, in which he mentioned the need for a good map of the area." [Papenfuse, Coale, et al. p.65] Herrman, turned away by the Dutch, perhaps for the lack of funding such an endeavor, offered to make an accurate map of Maryland in exchange for a 20,000 acre grant of land in Cecil County. It took Herrman ten years to survey and construct the map. Captain John Smith's maps of the Chesapeake Bay may have served as reference for the construction of Herrman's map, but Smith's maps were not considered to be geographically accurate. Therefore, a completely new and accurate survey of the area was desperately needed. With the state-of-the-art surveying science of the period, Herrman was able to

determine latitude with fair accuracy, but longitude presented problems.

The improvement in longitudinal accuracy of maps and charts would have to await the development of a reliable seagoing chronometer. The first instrument to meet this requirement was completed in 1735 by John Harrison of Yorkshire, England, thus enabling mariners and surveyors to determine longitude accurately. It may be coincidental that the first major resurvey of the Chesapeake Bay area by Hoxton in 1735 is marked by the introduction of this reliable seagoing chronometer. Until the time of Hoxton's survey, Herrman's map was copied and his geographical knowledge of Maryland was widely disseminated through derivatives, thus establishing Herrman's 1673 map as the mother map of the 17th century for the Chesapeake Bay region. It is also interesting to note that the diffusion of geographic information was not hampered by the acquisition of a fourteen year license, similar to a copyright of the Herrman map.

RESEARCH PROBLEM

Geographers and Cartographers need to know more about the validity of maps as documents so they can assess and attempt to correct for any distortion in the historical

information mapped. It is generally accepted in historical cartography that the Augustine Herrman's 1673 map is a classical example of a mother map of the Chesapeake Bay region. J. Keith's, "Augustine Herrman, Maryland's First Mapmaker", R. Morrison's, "On The Map, Maryland And The Chesapeake Bay", and E. Papenfuse's, "The Hammond-Harwood House Atlas of Historical Maps Of Maryland...", among some other sources, refer to the Herrman 1673 map as the most accurate map of the Middle Atlantic colonies published in the seventeenth century. However, the literature does not reveal the degree to which the Herrman map influenced the cartography of the Chesapeake Bay, nor it's accuracy of geographical information. Therefore, the problem in historical cartography is determining the reliability of Herrman's map on the cartography of the Chesapeake Bay and establishing the full extent of its influence upon the mapping of this region. The temporal and spatial impact of this map is traced by comparative cartographic techniques.

The comparative cartographic technique is also useful in evaluating the accuracy aspect of historical maps. The best-fit method is employed in this study as a comparative cartographic analysis. As Chardon (1982) indicated that if a surveyor's intent is essential for a valid

understanding of his map, then the evaluator's purpose is no less meaningful for a reliable assessment of his use of that same map. The method of determining the accuracy of the Herrman map is by superimposing it onto contemporary nautical charts. The facsimile of the Herrman map is reduced photographically to eliminate any distortions due to paper alterations or matching of the four sections of the Herrman map format. This reduction is electronically digitized to help bring other map documents into a common scale. At a common scale, the Herrman map is superimposed onto official government charts where relatively permanent control points are used as fixed reference points for the alignment of the overlay plots.

The main objective is to evaluate the map's validity by employing a technique to assess the map's accuracy and reliability. The full impact of this mother map on the mapping of the Chesapeake Bay region is examined. The extent of this map's influence and the spatial distribution of its geographical information among the European nations of this period is studied.

RESEARCH OBJECTIVES

The intent of this thesis is to further develop the

carto-genetic[3] methodology for identifying traits of a mother map, as introduced by Harley. Until the 1960's, historical cartography's traditional concepts limited the development and the scope of this branch of geographic study. Since the 1960's shift to quantitative studies in geography, new concepts have expanded the methods used in historical cartographic research beyond the traditional studies that examined the temporal sequence and physical comparison of early maps and charts. Statistical methods and computer mapping techniques are incorporated into this study in an attempt to evaluate the accuracy of maps as historical documents.

This research attempts to broaden and augment the established constructs and scope of form, content, and symbology with an analytical approach which is lacking in previous research. This study will incorporate a best-fit analysis in the methodology along with the carto-genetic research in the examination of Augustine Herrman's map of 1673. Failing to employ comparative techniques in historical cartography is to ignore the basic principle that reliance in a historic document may change when it displays the examined and verified characteristics of a

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[3] Carto-genetics is the genealogical trace of comparative cartographic map elements or features that are identified through a long sequence of development in the variants (progeny or derivatives) of the mother map.

larger group of genealogical relationships. [Harley, 1968] This relationship of unique or common cartographic elements can only be derived from a study employing the comparative examination of the evolutionary sequence of these traits in a map as either a prototype or a mature version. This is important in historical cartography, because only through detailed technical evaluation will mutual traits and innovations in geographical knowledge be determined.

The techniques involve detailed examination of similar cartographic elements and unique elements that provide evidence to each map's (or map elements) origin. The full impact of this mother map of the Chesapeake Bay region depends on the degree of the map's influence and the spatial distribution of its geographical information among the European nations of this period. This distribution is graphically represented by the construction of a diffusion diagram. The diffusion diagram illustrates both the temporal and spatial significance of the Herrman map's influence on mapping of the Maryland region.

The application of the suggested methodology combined with the traditional aspects of historical cartographic research of maps broadens the field beyond the subjective analysis of visual comparison methodologies of prior

studies. Past research studies have suggested the relationships between maps based on their similar appearance. However, this study bases the relationships on forensic techniques by gathering empirical information of map similarities and best-fit qualities. This study suggests that the variants of the Herrman map may not be as useful as historical documents of original geographic knowledge as has generally been believed. Determining a source document's originality and accessing it's quality is primary to historical and cartographic research. By establishing the Herrman map as the originator of geographical information of the Chesapeake Bay region, this mother map negates the historical value of later maps as original sources for the purpose of cartographic research. Once the map can be established as the original source map, the accuracy of this original source map should be established to determine the map's usefulness in historical and cartographic research. The findings and the discussion of the results from this research adopting an analytical methodology, rather than subjective, can be applied to future historical cartographic research regardless of the geographical area and time period.

The techniques and the additional data provided over that available in previous studies in the field of comparative cartographic research brings a degree of

originality to this study. The modifications used in the methodology and incorporated into this study contribute to the knowledge and enhance past concepts of the discipline of comparative cartographic study by providing a method to test the originality and accuracy of source maps used in research.

CHAPTER II LITERATURE REVIEW

INTRODUCTION

For almost as long as Man has charted his world, comparisons between these graphic interpretations are made. In the past, geographers and cartographers have taken an interest in the analysis of the information which can be extracted from maps. This chapter will present a conceptual framework of the research in historical cartography.

HISTORICAL CARTOGRAPHIC CONCEPTS

There exists an intellectual justification for cartographic history as related to the histories of other scientific or technological disciplines, as stated by Harley and Woodward. [1989] Some historians of cartography and geography have created strong associations with the history of science. Although scholars have tended to maintain their primary alignment with geography and map librarianship or with the world of collecting and antiquarian map selling, rather than with the wider history of science, there is development in the scientific and technological analysis in cartographic applications.

Harley and Woodward have indicated that the present

status of historical studies within cartography tends to be less technical, but more descriptive with the statement,"... even today, in cartography as well as in geography, a frequent reaction to the study of the history of the maps is that it is a pursuit for the non-quantitative, the non-scientific or the superannuated - in short, for those who have ceased to make a contribution to the more substantive issues of their contemporary subject." [Harley and Woodward, 1989 p.6] This thesis disagrees. In reviewing the literature, the author finds some studies in historical cartography and historical geography do include a more scientific approach in the analysis of historical mapping. The authors of research studies in cartography that have used less of a subjective technique include Tobler (1966), Petchnik (1976), Chardon (1982), Loomer (1986), and Yerci (1989), among others. This is a recent shift in historical studies since the advent of computer science and computer assisted mapping. The historical study of early maps is not a newly developed discipline within cartography. Moreover, both the history of cartography and comparative cartography are interdisciplinary studies performed by historians and geographers, as well as map collectors and map dealers. One of the forerunners in the comparative study of early cartography may be traced to the early 15th century. "Andrea Bianco had added to his atlas of portolan charts,

drawn at Venice in 1436, a circular mappamundi of traditional type and a Ptolemaic world map - thus presenting in juxtaposition the old world picture and the new, the geographical lore of the Christian Middle Ages and the lately discovered geography of Ptolemy." [Skelton, 1965 p.43]

More recently, studies that address the temporal sequence and physical comparison of early maps and charts in historical cartography are being contested by newly redefined concepts in the discipline. Cartography is a dynamic science that is constantly developing and re-evaluating earlier concepts. These concepts include an analytical approach to early map comparisons. The mathematics of geometry and statistical analysis aided by the use of computer technology as a tool redefine the traditional concepts. The redefined concepts in comparative cartography include a more detailed use of physical manifestations, strongly stressing that a technical evaluation be added to comparative cartography. [Woodward, 1974] The physical manifestations of maps as source documents in historical research overlap with the analysis in other cartographic research problems. The concepts evaluating the physical manifestations of maps overlap with those in Geographic Information Systems, as a cartographic discipline. Specific map elements and

features analyzed and evaluated are common in both technical and non-technical approaches to comparative cartography. Whereas, technical evaluation using the computer as a tool, allows other physical manifestations of maps to be examined. Research in comparative cartography now includes evaluating the projections of early maps. This is a tedious and time consuming effort when examined by non-computer techniques. Technical examination of detailed map elements have been adopted from the photogrammetric field of cartographic study. Comparative cartographic concepts have been redefined to include the techniques of aerial photo interpretation and analytical comparison. The examination of photographs and imagery in both analog and digital form by comparative methods helps to redefine the traditional concepts in historical and comparative cartography by the utilization of technology and mathematical analysis.

Before the 1960's, traditional studies in historical cartography were typically those of annotated carto-bibliographies or chronological bibliographies. These techniques usually were descriptions of physical map comparisons and their differences entered in a bibliography. "The practice of comparing apparently identical copies of old maps in hope of discovering... variations has so developed during the last half century

that it has become, what may be almost termed, a science which has added considerable importance and interest to the collecting of maps...." [Stevens and Tree, 1967 p.69]

Moreover, the redefined concepts in historical and comparative cartography suggests that detailed technical evaluations need to accompany the traditional techniques of the study to provide a broader scientific approach necessary for the evaluation of source maps (or mother maps). [Harley, 1968] This redefined methodology used in comparative cartography, as suggested by Harley, does not appear in the literature of previous comparative cartographic research.

THE MOTHER MAP ISSUE: A STUDY OF CARTO-GENETICS

This method of analysis, suggested in this thesis, will include identification of related source maps (mother map or progenitor) and their variants (progeny). Carto-genetic analysis involves identifying and comparing similar cartographic elements through time as presented on succeeding maps of the period (Figure 2). The mother map (progenitor, prototype, or source map) contains cartographic features that are embodied into subsequent editions or other maps. A genealogical trace of these cartographic features can be identified and compared on the variants (progeny or derivatives) of the mother map

(Figure 2).

This study emphasizes and continues the approach of detailed cartographic element identification and analysis in historical cartographic research. The detailed technical evaluations, as suggested by Harley, must be included in comparative cartographic research to assist historians and geographers alike in determining the value of maps as historical source documents. Some of the current issues in historical cartography covering the early colonial period of America incorporate the analysis of mother maps in the middle Atlantic region. Explorations of the region in the 1600's and 1700's resulted in maps and charts that are now accepted as the progenitor to other mapping sources.

The literature reveals supporting claims to the acceptance of Herrman's map as a prime example of a mother map of the middle Atlantic region. In the illustrated collection, "The Hammond - Harwood House Atlas Of Historical Maps Of Maryland, 1608-1908", Papenfuse and Coale (p. 67) exclaim that "Cartographic knowledge of Maryland did not advance much beyond Herrman's map, except for Walter Hoxton's Chart of 1735, until the 1750's." The authors continue, "If Augustine Herrman profoundly influenced the mapping of Maryland, he was no less

THE MOTHER MAP CONCEPT

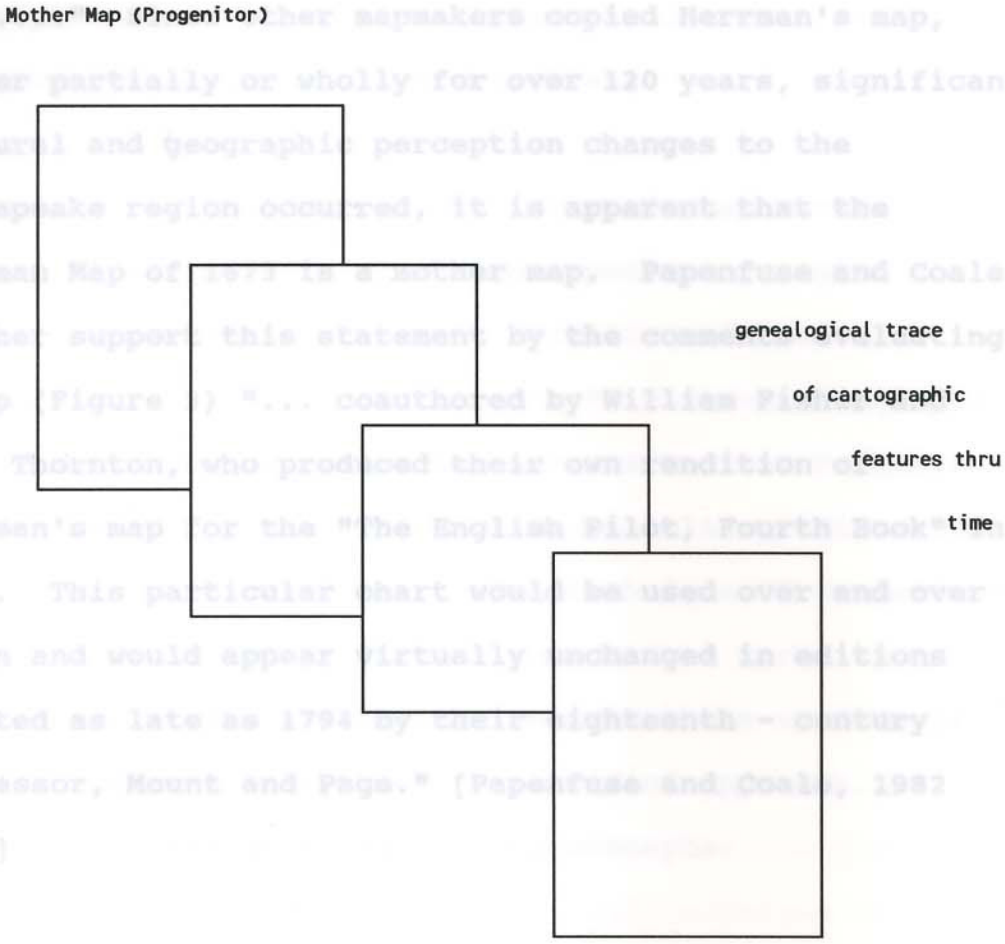

Chart comparison of similar cartographic features through time as illustrated on succeeding charts of the period. The influence of Herrman's map (mother map) may have extended past it's variants.

Figure 2. The Mother Map Concept

influential in the charting of the Chesapeake Bay. His publisher, John Seller, used a much reduced version of Herrman's map in the "Atlas Maritimus" published in 1675...." Since other mapmakers copied Herrman's map, either partially or wholly for over 120 years, significant cultural and geographic perception changes to the Chesapeake region occurred, it is apparent that the Herrman Map of 1673 is a mother map. Papenfuse and Coale further support this statement by the comments evaluating a map (Figure 3) "... coauthored by William Fisher and John Thornton, who produced their own rendition of Herrman's map for the "The English Pilot, Fourth Book" in 1689. This particular chart would be used over and over again and would appear virtually unchanged in editions printed as late as 1794 by their eighteenth - century successor, Mount and Page." [Papenfuse and Coale, 1982 p.69]

THE PREVIOUS WORK IN THE FIELD

As mentioned in an earlier section of this study, a forerunner of the comparative study of early cartography may be traced to the early 15th century by the works of Andrea Bianco. [Skelton, 1965] In the 1920's, "The German geographer Max Eckert systematically analyzed the character and evolution of different types of map[s] and established genetic principles for their formal study."

[Skelton, 1972 p.43] Many of these studies in comparative historical cartography were physical comparisons of a sequence of maps, explaining their differences in a description under each established chronological entry in a carto-bibliography. [Modelski, 1986]

Examples of the descriptive forms of comparative historical cartography of the Chesapeake Bay region can be found in C. Verner's, "Smith's Virginia and Its Derivatives" (1968), R. Morrison's "A Carto-bibliography of the Maryland-Chesapeake Region" (1982), and Papenfuse's and Coales "The Hammond-Harwood House Atlas of Historical Maps of Maryland..." (1982). The technique of comparative analysis, as stated by Stevens, has become more "scientific". The methodology used in these studies is lacking the more analytical "scientific" approach, as presented in Harley's redeveloped concepts.

New concepts of the discipline, as mentioned in earlier sections of this study, have been suggested by Skelton as early as 1966, and expanded by Harley in 1968, and Woodward in 1974. These newly redefined concepts added to the traditional methodology are what can be considered as the current state of comparative historical cartography.

THE CURRENT STATE OF THE ART

The review of related literature revealed one study that has used the suggested framework of comparative analytical methods combined with traditional concepts for studying source maps in the Ukraine by Andrew Modelski in 1986. The Modelski study employed the previously suggested analytical methodology with "[his] own procedures for carto-genetic map analysis." [Modelski, 1986] One of Modelski's procedures include the detailed use of physical manifestations stressing technical evaluation to be added to comparative cartographic methods. Although Modelski's study represents unique methods of technical evaluation of river lengths on comparative maps, however, it does not focus on empirical techniques as part of the analysis for the other carto-genetically related physical map features of his study.

A review of the literature reveals other new ways of exploring old maps. An unconventional technique of map study and analysis is the proven "experimental" method demonstrated by Dr. Waldo Tobler for testing the hypothetical construction of some medieval maps on known projections. [Tobler, 1966] Tobler mathematically analyzes the angle and distance of map control points based on feature locations on the medieval maps and re-constructs possible map projections based on the analysis of the findings. Barbara Bartz Petchenik also used this

technique of pattern deformation applied to the Mitchell map of 1755. "This technique [is] used to show the deformation present on Mitchell's map, as compared to an accurate modern map... the resulting pattern... [illustrates] the nature of the inaccuracy." [Petchenik, 1976 p.58] The areas of greatest distortion on the Mitchell map are possibly linked to the lack of geographical knowledge of remote interior lands of colonial America. Another new technique found in the literature relates to Dr. Alexander B. Taylor's adaption of the "calculus of variants" to the collation of place names, and so to the determining of genetic relationships, in a series of early maps. [Taylor, 1965] This is a statistical analysis of variant spelling of map nomenclature showing comparative map relationships. This technique is valuable as applied to this study, whereas, nomenclature variations and locational properties of place names are examined to show genetic relationships and map distortions.

The theme of exploring the inaccuracies of historic maps using an analytical approach is identified in the literature. Roland Chardon's 1982 paper, "A Best-Fit Evaluation of DeBrahm's 1770 Chart of Northern Biscayne Bay, Florida," uses the comparative analytical method in his research. "The goal of this paper is to examine the

accuracy and reliability of DeBrahm's charts, as they portray the natural environment.... An appropriate historical context will be explored in detail; in addition, the information depicted on the charts will be related to more recent maps and air photographs. The result will be a better understanding of the liability of these 1770 charts as historical documents." [Chardon, 1982, p.47]

The DeBrahm's chart was described to exhibit several flaws uncharacteristic for the cartographer's reputation. The reliability and accuracy aspect was further explored by the best-fit method to determine the map's adequacy as a basis for reliable environmental reconstruction of the general Bay area. The best-fit method used in evaluating the DeBrahm's chart identified seven areas containing relatively permanent geomorphic features selected as reference areas on which to place the overlay (the DeBrahm chart) correctly with the contemporary NOS chart. The technique resulted in relatively poor fit at the river mouth basepoints despite the similarities to modern maps and its cartographic advantages as permanent landmarks. The mainland portions of the historical map could not be used as a baseline for the rest of the overlay. A different set of base (control) points were used in the best-fit method which yielded better results of matching

the two maps. "Starting again, but this time with the assumption that DeBrahm's prime surveying objectives - Dartmouth Inlet and Cape Florida - should also be the reference points, and that his 'true meridian' was correctly aligned,.... The fit was remarkable...." [Chardon, 1982 p.55] Chardon's assessment of the DeBrahm's map had discovered meridional errors in the mainland orientation. The azimuthal error in the ' wrong meridian was determined by the best-fit adjustments which described the reliability of the DeBrahm map as a source of populating an environmental database for geographical comparisons. This best-fit technique was the basis for the accuracy assessment of the Herrman 1673 employed in this thesis.

The comparative analytical method in historical cartographic research is found throughout the current literature. Photogrammetric techniques and computer analysis were used in Scott Loomer's, "Mathematical Analysis Of Medieval Sea Charts." Here again, the theme of accuracies or inaccuracies of charts is the driving force behind this research. "What accounts for the accuracy of the portolan chart? What methods did the medieval chartmaker employ in constructing these charts? These questions have long interested cartographic historians. Although many theories have been proposed in

an attempt to resolve the mystery, no analytical study of a significant number of charts has been conducted." [Loomer, 1986, p.123] The accuracy question and the analytical approach to examining the accuracy properties of medieval charts presents valuable issues for evaluating source maps as used in historical cartography. Although Loomer used photogrammetric techniques in his study, this research uses comparative analysis of form, control point location, and toponymy to determine map element relationships and distortion properties.

A short paper entitled, "The Accuracy Of The First World Map Drawn By Piri Reis," by M. Yerci, (1989) which continues the theme of using comparative analytical methods to determine the accuracies of ancient maps as historical documents is one of the most recent studies published. The Turkish cartographer's map of 1513, "... was compared with a newly compiled atlas map and the differences were evaluated using simple statistical techniques." [Yerci, 1989, p.155] Yerci continues, "Any comments about 'correctness' [accuracy] however, rely on a statistical analysis." Yerci determined the relative distances of the control points of the Piri Reis map and the modern atlas map of the world by registering the two maps on top of each other. Calculating the averages of the distances between the shoreline control points, Yerci

was able to evaluate the accuracy of the historical map. The determination of a map's accuracy (or inaccuracy) needs to be confirmed by statistical analysis, and not by "eye-balling" or some other subjective technique which cannot be duplicated.

The outline (shoreline) of the historic world map was visually registered with the shoreline of a contemporary atlas map. "Registration was checked area by area for line elements of approximately the same length of which 15 were chosen at different points on the map. Each section line was sampled at 2 mm. intervals and at each point the deviation between the new and old map was measured." [Yerci, 1989 p.155] Simple standard deviations were computed for each section which indicated the degree of deformity of the old verses new map comparisons. Again, a for of best-fit technique was employed to determine accuracy or reliability of the old map. The charted relationship between the African and South American continent of the two overlays exhibited remarkable good fit qualities for a map constructed in 1513 compared to a contemporary atlas map.

SUMMARY

The selected recent literature reveals the 'current state-of-the-art' in historical cartographic research, as

employing mathematical methods of analytical comparison combined with the traditional concept for studying source maps. The trends seem to be shifting to an empirical analysis using statistical evaluations in determining the accuracies of maps used as historical documents. Technological advancements in the mathematical and computer sciences have played a new role in the comparative cartographic technique. Harley and Woodward remind the cartographers of the 'computer age' of their traditional historical cartographic backgrounds; "Nor does the digital age ... render [the] classic interpretive skills redundant." Furthermore, Harley and Woodward [1989, p.11] state, "A first major role for the history of cartography lies in its traditional emphasis on the critical evaluation of maps as historical documents (Harley 1968).... In recent decades cartographers have substantially upgraded their quantitative and computing skills, but the systematic study of 'map as record' has received far less attention. Yet, ironically, much of the work in this area, including the exploration or new techniques for testing the planimetric and topographical accuracy of maps, has been undertaken by historians of cartography (Blakemore and Harley 1980), whose proficiency in map evaluation is of general applicability." [Harley and Woodward, 1989, p.11]

This study supports the comments of Harley and Woodward, but disagrees that maps as historical records do not receive equal attention in comparative analytical methodological research. Reoccurring themes in recent historical cartographic studies emphasize the evaluation of maps as legitimate historical geographic data. Moreover, determining the accuracy of historical maps plays an important role as a topic of cartographic research. Computer database files used in geographic information systems and multi-purpose cadastre systems depend on accurate map information used for multiple inquires and analysis of these systems. The need for accurate base map information may continue to drive cartographic research in developing new ways in determining map accuracy and determining the originality of geographic information.

The best-fit method, as described in the research literature, serves as the basis for the comparative cartographic techniques used in this thesis. The use of the best-fit method is perhaps the best research technique for determining the reliability of Herrman's 1673 map. Although the literature indicates that the Herrman map is the most accurate map of the seventeenth century, now a method to determine the degree of accuracy is used to establish it's correctness and to justify the map's use as

a valid source document for geographical research.

CHAPTER III METHODOLOGY

INTRODUCTION

This chapter contains a discussion of methods used in cartogenetic-identification of map elements to establish the mother map and to evaluate the degree and pattern of distortion. Image distortion is inevitable when cartographers transform the spherical earth's surface into a flat map. The impact of this projection distortion would theoretically be minimized by centering and aligning each projection on the area of interest to the researcher. This has been generally impractical until computer technology has made it possible to choose, center, and align projections at will.

METHODS OF ANALYSIS

The historical method relies heavily on source detection, evaluation, and analysis of findings in determining solutions or conclusions to the research problem. [Haring and Lounsbury, 1983] This thesis follows these general guide lines of the historical method with a specific detailed technique used in this carto-genetic study. As described in Chapter I of this thesis, carto-genetic methodology and comparative techniques add to the historical geographic field by analyzing the quality of historical map information. In this chapter, the data set

categorization, the established methodology of prior studies and the definition of the adopted methodology, the conversion of the graphic source into a digital form, and the procedures for the analysis are discussed.

The methodological steps in the analysis are simplified cartographic processes. The simplified steps used in this study are:

1. the selection of cartographic features found on the maps;
2. classify these features by grouping them into categories;
3. trace these features that can be compared onto the maps of the area, thus establishing the mother map; then,
4. choose control points for statistical analysis;
5. electronically digitize the maps;
6. realign the subject maps for best-fit; and,
7. measure the differences of the two data sets.

DATA SET DESCRIPTION

The primary data for this research is derived from the cartographic classification and analysis of map elements taken from the individual maps and charts of the middle

Atlantic region. The Augustine Herrman map of 1670 (published in 1673) is used as the bases for the research, since it is wholly unique and original, except for the Indian names that may have been borrowed from Captain John Smith's maps. Three major sources of maps of this period of Chesapeake exploration, are located at the Library of Congress, the Maryland Hall of Records, and the private collection of the Huntingfield Corporation, Rock Hall, Maryland. Other sources of information and collections found in atlases and catalogue publications among the individual map sheets comprise approximately 50 maps and charts identified as variant maps of the Herrman map (partially listed in the carto-bibliography), which make the resource pool for the analysis. The comparative cartographic technique using the best-fit method of the maps from the primary data set and contemporary nautical charts and digital data from U. S. Department of Commerce, NOAA/National Ocean Service generated the secondary data set for this research.

ESTABLISHED METHODOLOGY

The established methodology has been briefly described in prior chapters of this thesis. This section will detail the established methodology used in this study as introduced by Modelski in 1986. The procedure of this analysis follows and traces the genetic influence of a

cartographer's regional map upon the cartography and physical appearance of a larger geographical area. [Modelski, 1986] The methods of analyzing the comparative map element's form, symbology, nomenclature, as well as, the locational displacement of control points will be used in this thesis. The carto-genetic table, introduced by Modelski, is a useful graphic representation in which to display the analysis of selected map elements in an evolutionary succession, much like a genealogist's construction of a 'family-tree'. This thesis includes a carto-genetic table which contains selected symbols and text traceable from map to map (Table 1). The range of the identified carto-genetic features will delineate the extent of the influence of the specific map elements of the mother map on subsequent maps of the region. The comparative cartographic approach in traditional descriptive cartography together with the detailed analytical methods of the best-fit method, is the basic framework of the established methodology.

THE NEW METHODOLOGY

This thesis introduces a less subjective approach to the analysis of detailed cartographic element identification, then incorporates analysis to show the reliability of the mother map. This is lacking in previous studies using comparative cartographic

techniques. The redefined concepts developed in this study are based on the cartographic element identification and empirical analysis of feature location. The results present insight to the maps' reliability by using comparative analysis techniques of the digital map images determining the locational distortion of the historic map elements.

Cartographic features or elements of the selected maps are systematically identified and grouped into categories, for comparison. These elements are traced, both visually and empirically, through a long sequence of carto-genetically related maps. These maps have been determined to be influenced by the mother map by their cartographic element structure and symbolic content. The cartographic element identification and analysis examines the evolutionary process or the compilation of information from a manuscript. The manuscript affects the status of the final map as a prototype (source or mother map) or as a fresh, new source of geographical knowledge. Whereas, information used in the compilation of a map may have been taken from previous mapped knowledge of the specific geographic area. Using previous mapped information to create a new manuscript created by another cartographer leads to copying mapped errors in nomenclature and feature distortions, as well as unique cartographic features,

which is traced to be derived from the mother map.

The methodology includes the examination and selection of cartographic features to ascertain and arrange a sampling sequence. This method groups the identified unique traits or map-genetic elements for tracing through variant maps of the period. These elements are identified, arranged, compared, and traced in a cartographic-genetic element table (Table 1), which lists the major chronological maps determined to be variants in this study. The primary conditions for establishing the connectivity of the number of unique elements from the mother map, which have been discovered in the variant maps, follows the identification of unique features, such as the double row of trees, and misspelled nomenclature.

To determine if similar values were present in the related maps, and which of the maps were related as directly influenced by the Herrman's map, further analysis is required. This analysis determines shape and size of the sequence of maps to standardize comparisons. Longitude corrections for the various maps can be calculated. The calculation of percentage of error between the control points of the various maps can be applied to further facilitate the analysis in making comparisons. Additional research can develop other criteria used to help identify the prototype variants, and

Table 1. Carto-Genetic Element Table

Characteristic Shape -	A)	Overall shape of the entire Delmarva peninsula (the Eastern Shore)
	B)	Specific shoreline and bends and bulges
	C)	Specific shoals or low water
Physical Features -	A)	Double row of trees marking boundary line
	B)	Soundings marking water depths
	C)	River confluences
Nomenclature -	A)	Specific nomenclature location (type placement)
	B)	Unique spelling (incorrect/incomplete)

establish the sequence of the evolution, diffusion, and dissemination of the geographical knowledge presented on the mother map of the new colony.

THE "OLD" AND THE "NEW" METHODOLOGY

The major differences between the previous methodologies and the proposed methodology of this research carries Modelski's study to a natural conclusion using additional best-fit methods to determine the accuracy and reliability of source information. The incorporation of empirical spatial data furthers the analysis beyond Modelski's and other traditional approaches to research.

Deformation analysis techniques are used as a measure in the variation between the Herrman map and a contemporary chart. To establish the nature of the inaccuracies of the Herrman's map the utilization of best-fit comparative mapping techniques are also employed.

PROCEDURES

Harley indicated an important function for the history of cartography exists in the critical evaluation of maps as historical documents. Furthermore, studies in geography use the skills of cartographic evaluation of source in contemporary studies and research. No previous

study has been found comparing historical maps as source documents to contemporary charts utilizing modern techniques derived from computer mapping analysis. Visual comparison is the most common method of analyzing a historic map, adding empirical results from the best-fit approach using computer mapping analysis appears to be unique to this study.

Historical documents, such as maps, need to be evaluated for their accuracy to determine their usefulness in subsequent research. "Maps do not always need to be highly or uniformly accurate to yield valuable insights into past environments, as DeBoer and Carr (1969) demonstrate, but they must be properly evaluated in order to do so." [Harley, 1989 p.52]

This project explores the accuracy aspect of the Herrman map, and evaluates its usefulness as a historic document. To accomplish this, several different methods of evaluation were necessary. One of the first and perhaps the most common method of comparative analysis, is to visually compare it to contemporary charts of the geographic area. Determination of the scale of the Herrmans map is made to facilitate the comparative analysis. The Herrman map and NOS nautical charts were reduced to a matching scale. Determination of this scale

for the Herrman map was made by evaluating the latitude scale as it appears on the bottom of the map.

The Augustine Herrman's west oriented map does not contain a complete printed geographical projection graticule. Instead, one degree marks of latitude, subdivided by five minute increments are printed on the bottom of the map. The lines of latitude were extended across the map perpendicular to the printed latitude scale which has a north-south orientation as established by the map's compass rose. Thereby, providing a partial geographic framework to establish the scale of the Herrman's map as roughly one inch equals six nautical miles, as represented by the relative fraction ratio of 1:372,250.

This calculation was determined by one minute of latitude equals one nautical mile (NM). One English nautical mile is 72,960 inches on the surface of the earth. Thus, the measured scale printed on Herrman's map suggests that 1" = 6.12 NM. Once a uniform scale had been determined, and sizing of the documents by reduction could be achieved, electronic digitizing could commence using the NOS Intergraph Digitizing facility. This effort to capture the Herrman map and NOS nautical chart shoreline provided a graphic output (Figures 4 and 5). This data

capture allows visual comparisons and allows one to analyze the errors and deviations of the distortions and inaccuracies of the Herrman map. This method assumes that the NOS contemporary shoreline data is accurate to the National Mapping Standards. Thus, the NOS data is used as the basis for evaluation and to establish a mathematical control.

Base Map Preparation

To permit the comparison to contemporary shoreline data of the geographic area, both the Herrman map and the NOS nautical charts were digitized. The largest scale coverage of NOS nautical charts is 1:20,000. However, this shoreline data reduced to the Herrman map scale (1:372,250) would cause the shoreline features to coalesce. The absence of adequate line generalization software requires the shoreline to be captured at a scale close to the scale of the Herrman map. Manual line generalization at the scale of 1:250,000 allows for an intelligible shoreline plot to be digitized at a similar scale.

This shoreline data plotted at a scale of 1:675,000 (1" = 9.26 NM) for the final base map allowed for the generalizing of the intricate (detailed) shoreline of the Chesapeake Bay to resemble that of the Herrman's map. The base map was electronically captured and plotted in a

Mercator projection (Figures 4 and 5). Thus, no projection transformations needed to be applied for the comparison since, Herrman's map is assumed to be a Mercator projection, which is the projection specifically designed for navigation.

The basis for this assumption is that nearly all charting of this time period was constructed using the Mercator's projection. Gerhard Mercator first created a map in 1569 using a projection which had meridians (longitude) as straight and equally spaced parallel lines and, at right angles to the parallels (latitude), lines which are also shown as straight parallel lines. This projection construction of lines of latitude is also evident on the Herrmans map. This projection became known as the Mercators projection and had the advantage of its simplicity and convenience for laying off courses as straight lines for navigation. The loxodrome or rhumb line is a line that crosses the successive meridians at a constant angle on this projection and thus is particularly suited for sea navigation for which it was designed. A ship on one course following the plotted rhumb line will pass all points along that line exactly as they are charted. Likewise, Portolan charts of the fourteenth and fifteenth century were compiled as exploratory surveys of the times using loxodromic (rhumb) lines. These charts

were basically a Mercator projection, being correctly based on a relationship of bearings and distance. The adoption of the popular Mercator projection became the standard for mapping in the late sixteenth century and is still used for the contemporary nautical charting of today. Therefore, it is certain that Herrman's map was constructed utilizing Mercator's projection.

Control Points / Comparative Map Elements

For a comparative analysis, the identification of control points common to both the NOS data set and to the Herrman map needed to be established. Identified control points used consist of physiographic features - headland points, river confluences, river mouths, etc., and settlement locations. The distribution of the selected control points lie mainly along the longitudinal axis based on the premise that the greatest distortion exists along the Y axis of Herrman's map. The selection of settlement locations were identified by the similarity of the place names. Dissimilar place names of like geographic settlement locations found on the Herrman map and on contemporary maps were not included as part of the control point database. Physiographic features selected as control points were identified based on small geomorphological changes in the shoreline. The shoreline

features chosen as control points are selected in areas of little or no geomorphological displacement based on 150 years of evidence collected from NOAA/NOS. This is to provide a network of control points for the identification and establishment of map distortion, rather than control point movement (natural shoreline migration). The physiographic / shoreline control points selected have been examined and determined to have changed comparatively little at the map scale, based on research studies provided by NOAA and the Corps of Engineers. These shoreline movement studies used aerial photography and field surveys as far back as 1845. Maps showing the changes in mean high water shoreline were created at a scale of 1:24,000 (Figure 5). At this scale, the shoreline change for the approximately 150 year period was relatively small. At the scale of 1:372,250, Herrman's map is 64.5% smaller in scale than the NOAA/COE shoreline maps. Thus, even smaller amounts of shoreline movement would be perceptible on the Herrman map. Reducing these shoreline movement maps (Figures 6-9) to the digital map overlays of the Herrman's map and the contemporary NOS shoreline map of a scale of 1:675,000 reduces the change in shoreline depicted to virtually no graphic change in shoreline movement. Therefore, relatively little shoreline or physiographic feature movement of the selected control points has occurred since the time

Herrman surveyed the Chesapeake Bay region. Consequently, any locational disagreements with modern surveys suggests map distortions rather than actual natural feature's (control point's) movement.

The Best-Fit Method

The best-fit method uses physical realignment of the two superimposed maps, of uniform scale, based on the indicated projections. In this case, the Herrman map had only the latitude portion of the graticule for comparison. The best-fit of the longitude graticule was a combination of visual clues of the shoreline, and the alignment of the established latitude. An average shift in alignment for the entire map revealed similarities in the latitude, but distortions in the longitude (Figures 10 and 11). This method is rather quick and simple, however, obvious short comings are evident in this type of comparison. Constant local shifting is required to obtain a best-fit on a specific large scale geographic area. This is of little benefit when the purpose is to analyze the entire map's accuracy.

Local shifting of the map may not be the best method and redefining the scale of the map based on the analysis

of the control points can be employed as another technique. An assumption may be made as to the variation in the scale in the X or Y direction of the Herrman map. Thus, an inconsistent or variable distortion may exist, which can be rectified by the determination of the scale by analysis of the distribution of the control points.

Therefore, other methodologies must be explored to obtain a less subjective analysis of this cartographic evaluation. In digital form, the scale of the Herrman map can be changed to distort for an electronically best-fit of the map. Goodness-of-fit statistics can also be obtained. Moreover, reconstruction of the Herrman map can be performed based upon the results of the goodness-of-fit analysis. This reconstruction essentially distorts locally the digital data within grid cells to coincide with the established 'standard' or accurate map (NOS shoreline). Redrawn maps of the newly distorted map can then be produced to show how the Herrman map in its modified form, adjusted grid, and correspondingly shifted data will appear.

For the computer analysis of the Herrman map, three digital files were created; the Herrman map, the NOS charts, and the third file created by the transformation of the first file 'corrected' to the standard second file

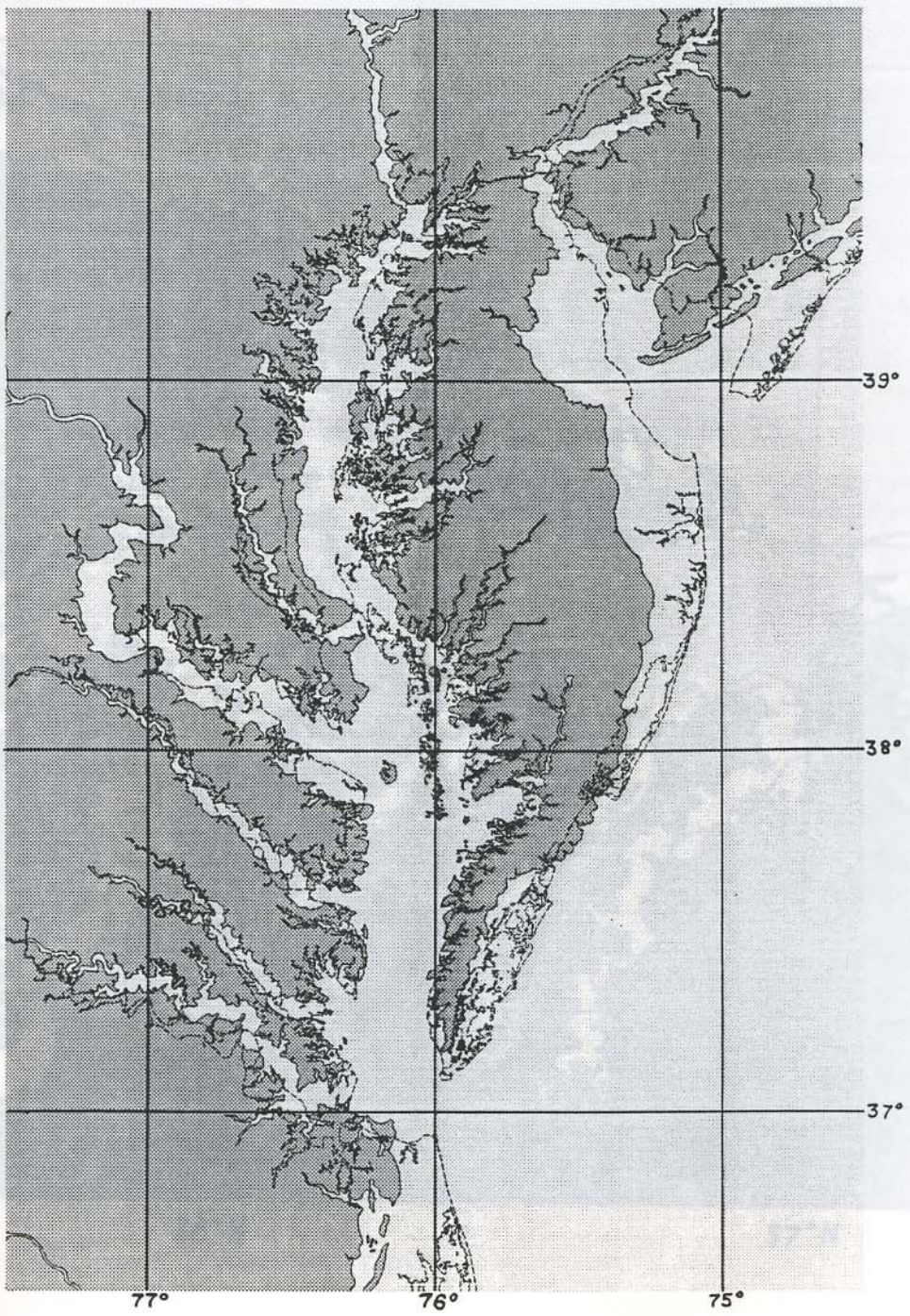

Figure 10. Best-Fit Comparison

(for more detail see Fig. 10 in pocket)

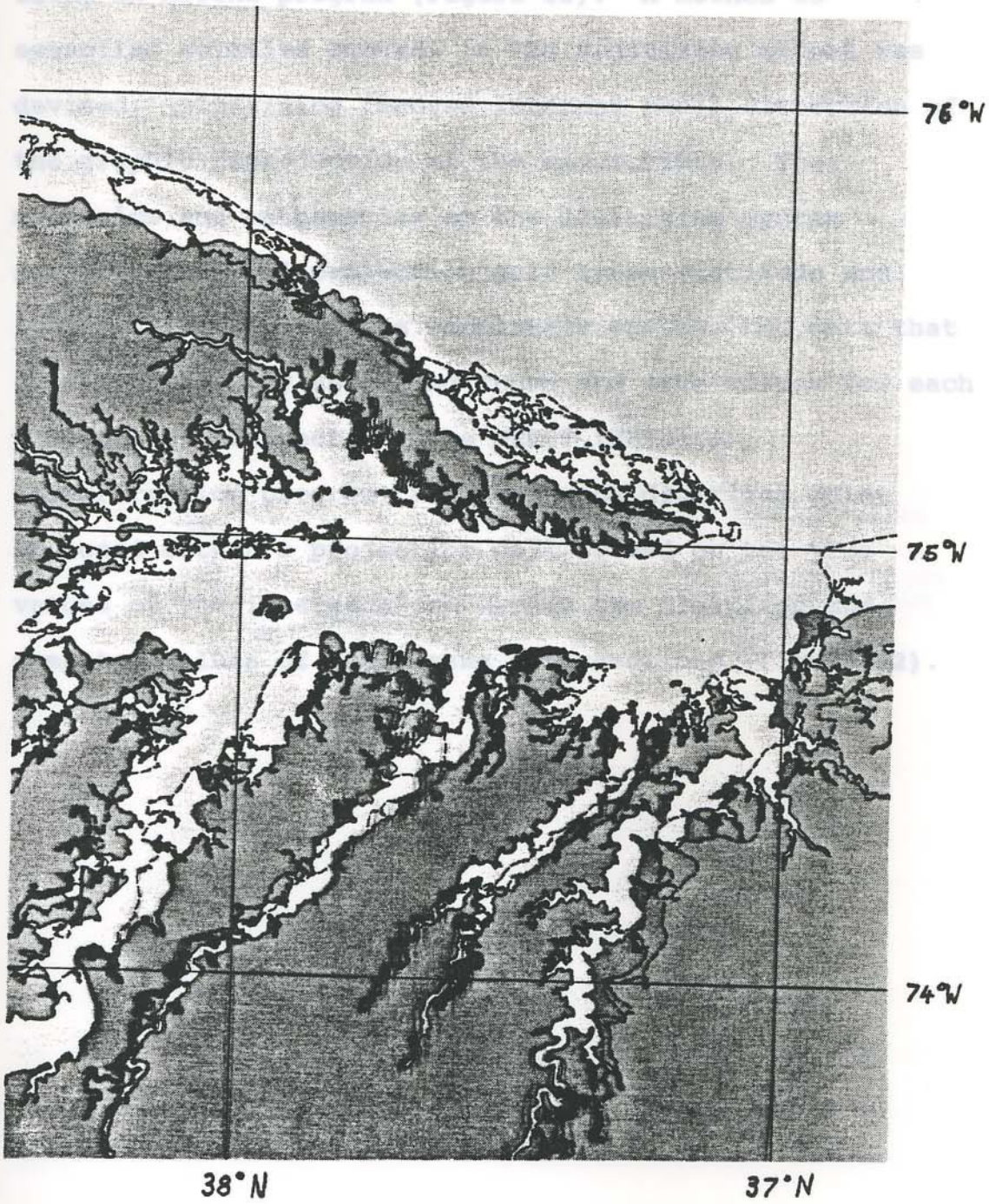

Figure 11. Best-Fit Comparison, Enlarged Portion

(for more detail see Fig. 11 in pocket)

using an Affine program (Figure 12). A method to establish relative control in the digitizing effort was devised. Digitizing removed inherent media distortion of the graphic reproduction of the manuscripts. The mechanics and mathematics of the digitizing system requires that all projection grid lines (latitude and longitude) intersections completely enclose the data that is digitized. By assigning known and true values for each projection intersection, the MERCT (Mercator transformation program) adjusted each digitized point enclosed within a projection cell, based on the true values of the intersections versus the digitized and computed values of those same intersections (Figure 12).

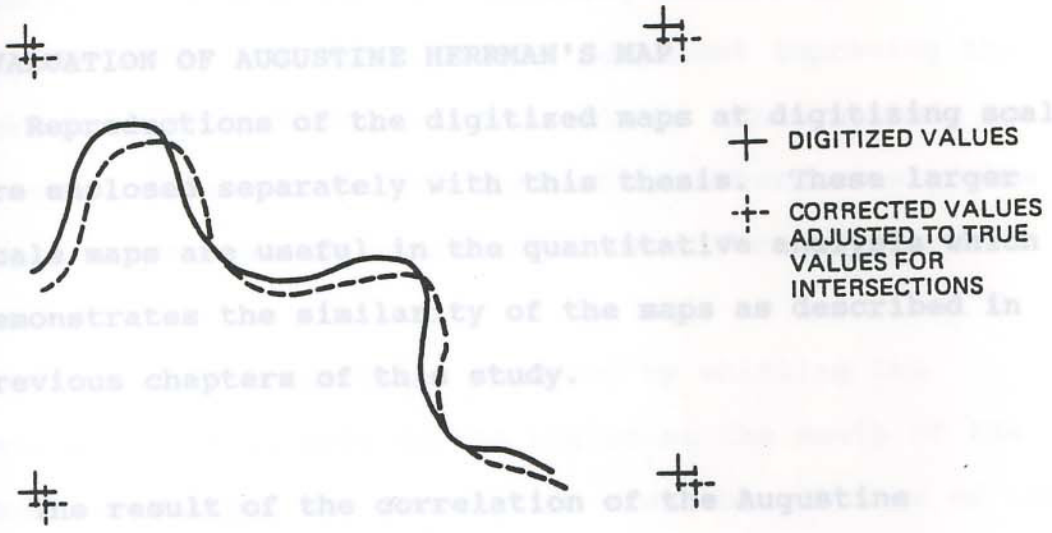

Figure 12. Affine Program Concept Computer Transformation

CHAPTER IV ANALYSIS

INTRODUCTION

The statistical methodology for analysis of the collected data can now be discussed. The results of the correlation of the two test maps, the best-fit qualities, and the calculation of error are presented for analysis.

EVALUATION OF AUGUSTINE HERRMAN'S MAP

Reproductions of the digitized maps at digitizing scale are enclosed separately with this thesis. These larger scale maps are useful in the quantitative analysis which demonstrates the similarity of the maps as described in previous chapters of this study.

The result of the correlation of the Augustine Herrman's map to a contemporary nautical chart is shown graphically in Figure 13. Overall fit can be characterized as poor, but a definite relationship exists in latitudinal location of features. Considering the date of the Herrman map (surveyed over a 10 year period and completed in 1670), this could be anticipated. Surveying methods and instruments used at that time allows for the assumptions of inaccuracies and distortions of the surveyed results depicted in the map. Among these assumptions, latitude was relatively accurately plotted

being obtained by the use of the sextant, however, longitude would most likely be distorted because of the lack of an accurate sea-going chronometer needed in establishing time.

The best-fit qualities of the digitized overlays has been examined several ways. The local shifting, block by block, to match alike corresponding centers of registration, resulted in local agreement improving the correlation for that particular block. This method, however, re-oriented the alignment of other areas of the maps, which made the correlation worse for those areas.

The best-fit qualities improved by shifting the overlays locally only in the region at the mouth of the Chesapeake Bay. The presumption that the entrance of the bay is where Herrman started his mapping and this would then be the control upon which he would base his measurements. One can expect the entrance of the bay to be used as the orientation or starting point of the survey for the bay's interior. Therefore, the assumption can be made that for best control one should establish the mouth of the Chesapeake Bay as the beginning point of the survey and anticipate errors in survey computations to increase further away from the established control (starting point). This potential for surveying error would be

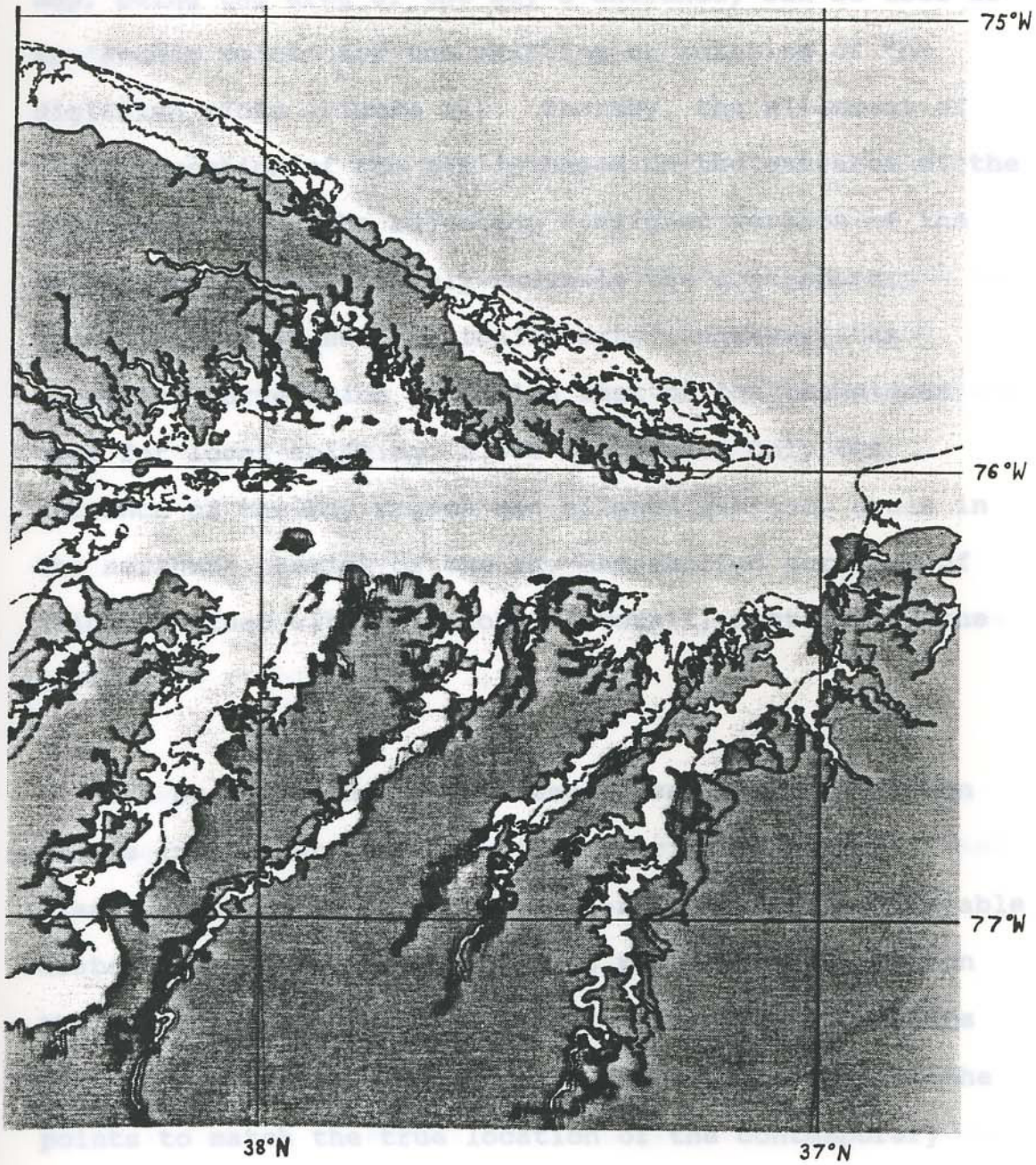

Figure 13. Correlation of Two Overlays

(for more detail see Fig. 13 in pocket)

expected to accumulate with distance away from the starting point. Thus, the area of least distortion of the map, being the area of the bay's entrance, can be used as an 'anchor point' for the shifting or rotating of the digitized plots (Figure 14). Thereby, the alignment of the Y direction of the map is based on the entrance of the Chesapeake Bay. The adjusted, realigned version of the Herrman map should closely resemble the contemporary shoreline of the NOS nautical charts. However, the resulting correlation resembled that of the techniques used for local shifting, block by block. Only the entrance of the bay region was aligned whereas, areas in the northern portion of the bay had shifted more out of alignment than with the global (overall) best-fit of the maps.

This suggests that a skewness or variable distortion exists in the Herrman map which contributes to the misalignment of the standard best-fit technique. Variable distortion can be corrected using the Affine package on the Intergraph digitizing system. This package adjusts the digitized points of one file and forces a fit of the points to match the true location of the contemporary digital data (Figure 12). However, this technique would not reveal the truly unique character and distinct variations in the Herrman map. The corrected Herrman map

would be forced to look like the contemporary NOS nautical charts, thus defeating the propose of analysis. Therefore, the Affine package was not utilized in this study's final analysis.

Relying on the aforementioned best-fit analysis of the comparison of the two overlays, certain statistical analysis could be made. For the distance measurements in the analysis of control points on different maps, the standard deviation is used as a measure of dispersion from a known control point on a map. For a set of control points, distance calculations were expressed in millimeters. For the set of ten identified control points, the mean, standard deviation, and correlation are calculated (Tables 2 and 3).

The measure of central tendency includes determining the average of the measured distances as treated in a set of data. This average indicates where the frequency distribution is centered and also presents the typical value of measurements for the control points (Table 2). In addition to establishing the average of the data set, it is important to establish the degree of variance about the calculated average. The control points were divided into two data sets to evaluate the distribution of error or distortion along both the x and y directions.

Table 2. Mean, Standard Deviation, and Correlation

OVERALL CONTROL POINTS

Representative set of Control Points	Distance
1	21
2	9
3	17
4	12
5	23
6	4
7	11
8	3
9	7
10	12

Mean: 10.82

Standard Deviation: 6.98

Correlation: -0.49

* All measurements in millimeters at map scale

Table 3.

CALCULATION OF PERCENT ERROR BETWEEN CONTROL POINTS OF HERRMANS MAP AND NOS NAUTICAL CHARTS

Control point	Percent error
Turkey Point	2.0
Cape Charles	4.3
Cedar Point	2.4
Herrington	3.1
Cove Point	7.6
Watkins Point	6.0
Cape Henry	4.1
Jamestown	7.0
St. Clements Island	3.6
St. Marys City	2.7
Somerset	7.8
New Castle	12.2

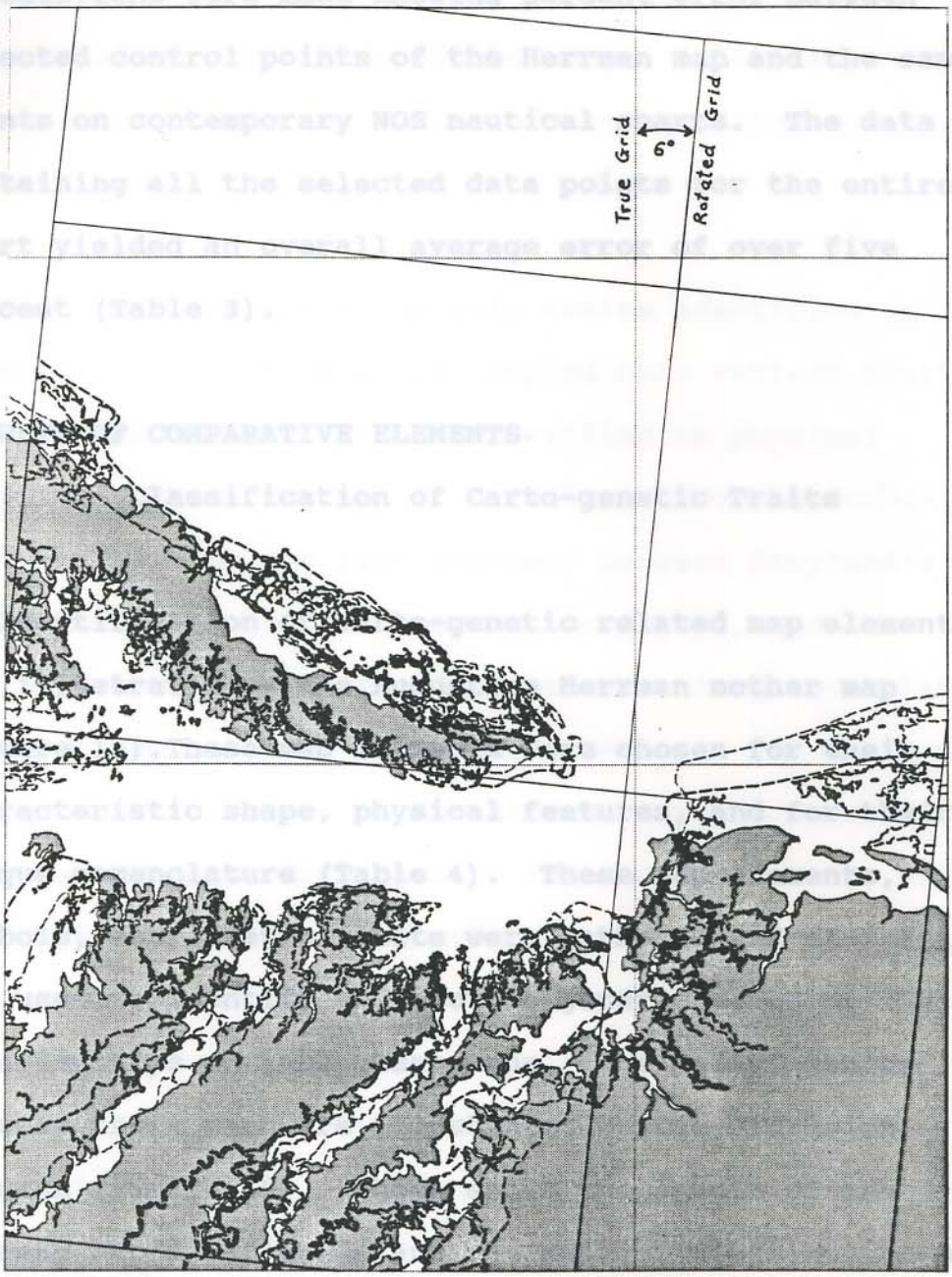

Figure 14. Rotated Plots Centered On the Entrance to the Chesapeake Bay (for more detail see Fig. 14 in pocket)

Calculations were made showing percent error between selected control points of the Herrman map and the same points on contemporary NOS nautical charts. The data set containing all the selected data points for the entire chart yielded an overall average error of over five percent (Table 3).

RESULTS OF COMPARATIVE ELEMENTS

Classification of Carto-genetic Traits

Identification of carto-genetic related map elements are illustrated on the Augustine Herrman mother map (Figure 15).These map elements were chosen for their characteristic shape, physical features, and for their unique nomenclature (Table 4). These map elements, symbols, and genetic traits were gathered and classified and used to identify and provide genetic clues of relationships on subsequent maps. The relationships between these maps are illustrated on the Diffusion Diagram (Figure 16), which shows the length of the Herrman map's influence and the spatial distribution of its geographical information among the European nations of this period.

Among these map element features, a short description of the elements is provided which has been identified on

the variant or carto-genetically related maps. The characteristic "S" shape of the entire Delmarva peninsula and specific bends and bulges of the shoreline are typical genetic traits.

Two clear and strong genetic traits identified on Herrman's map that have been copied onto variant charts (for nearly 121 years), are classified as physical features. These two specific features are the double row of trees marking the 1668 boundary between Maryland's and Virginia's claim on the Delmarva peninsula, and the characteristic scalloped shaped shoals along the Atlantic shore of the Delmarva peninsula. However, the most copied carto-genetic feature of the Herrman's map contains the mistaken "Charles City County" for Charles County, which is further garbled or abbreviated as "Charles" (representing a city or town) and "City C." (representing a presumed county). These classifications of carto-genetic traits have been found and identified as late as 1794. Although the Thornton and Fisher map, published in "The English Pilot" in 1794, is clearly out of date for the middle of the eighteenth century, and represents superceded geographical information, it is a direct descendant and a close copy of the Augustine Herrman map.

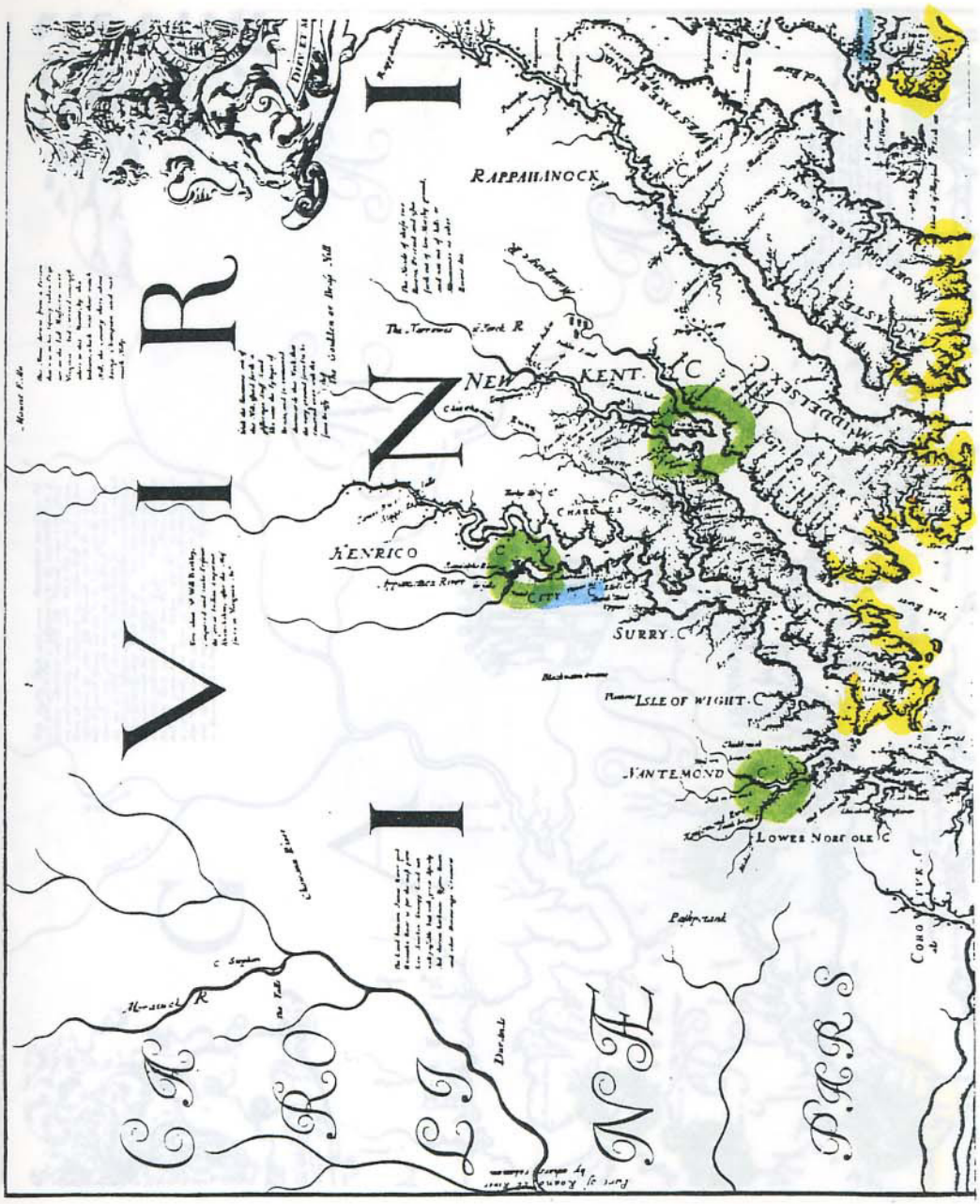

Figure 15a. Identified Carto-Genetic Features

(for more detail see Fig. 15a in pocket)

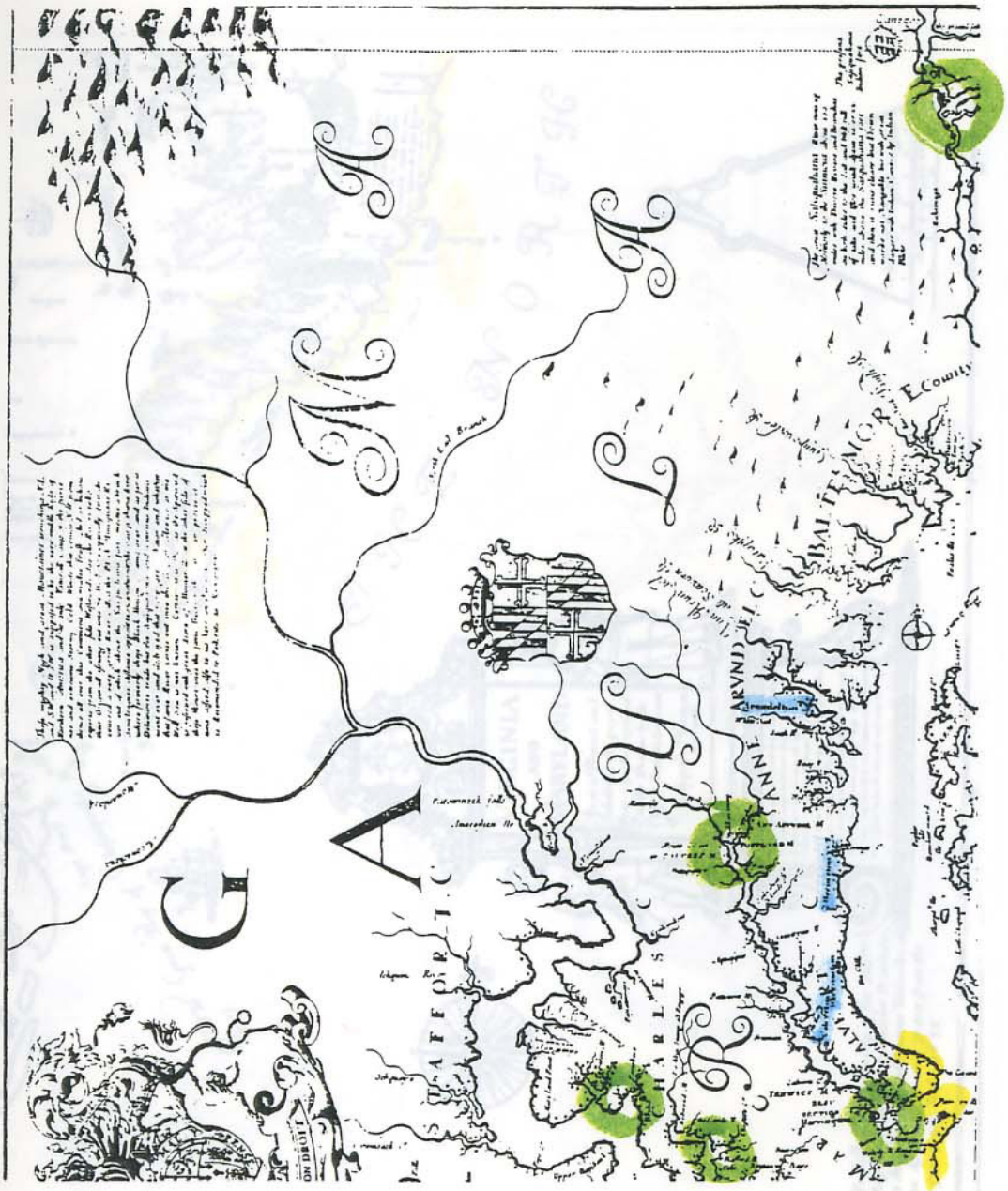

Figure 15b. Identified Carto-Genetic Features

(for more detail see Fig. 15b in pocket)

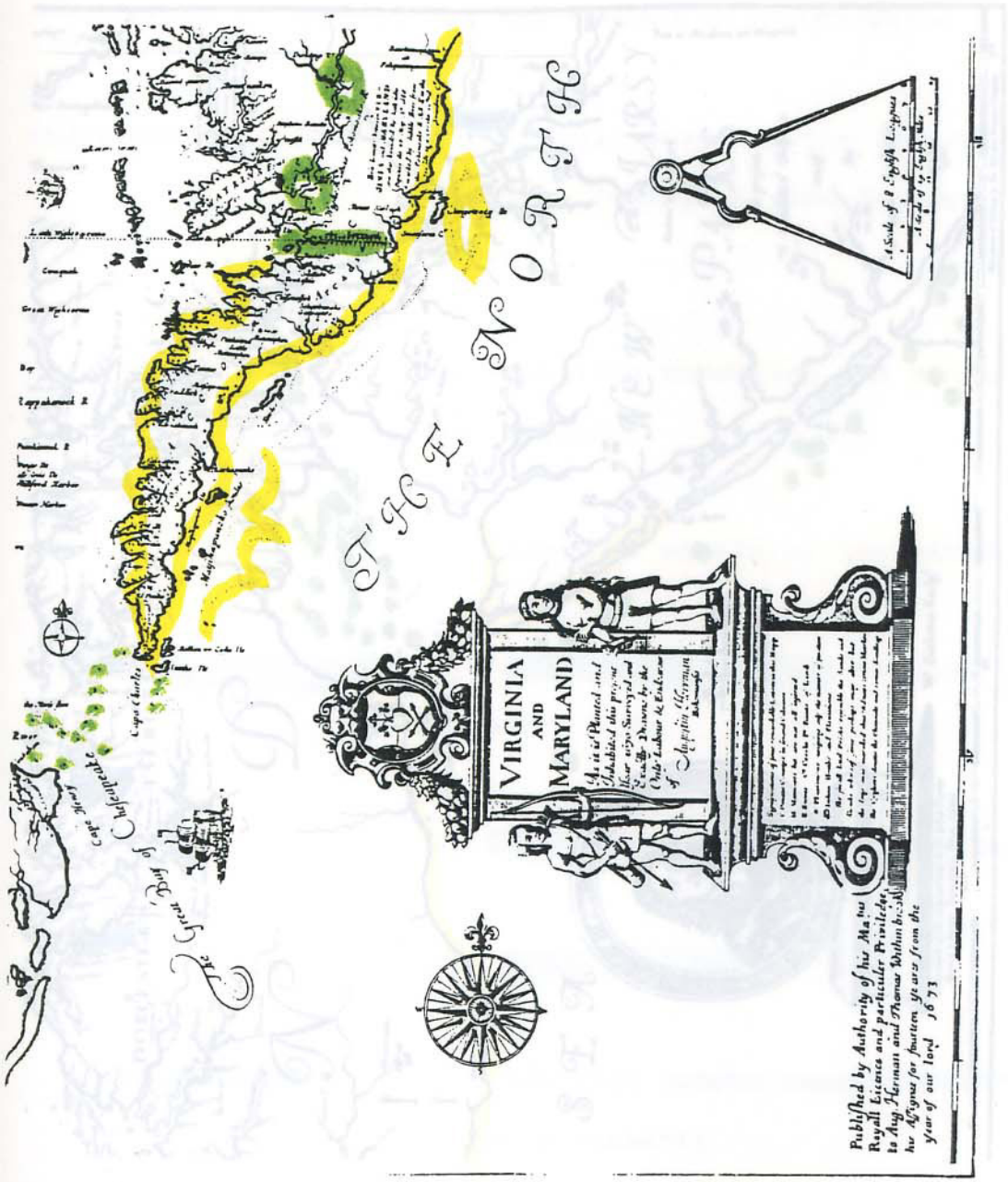

Figure 15c. Identified Carto-Genetic Features

(for more detail see Fig. 15c in pocket)

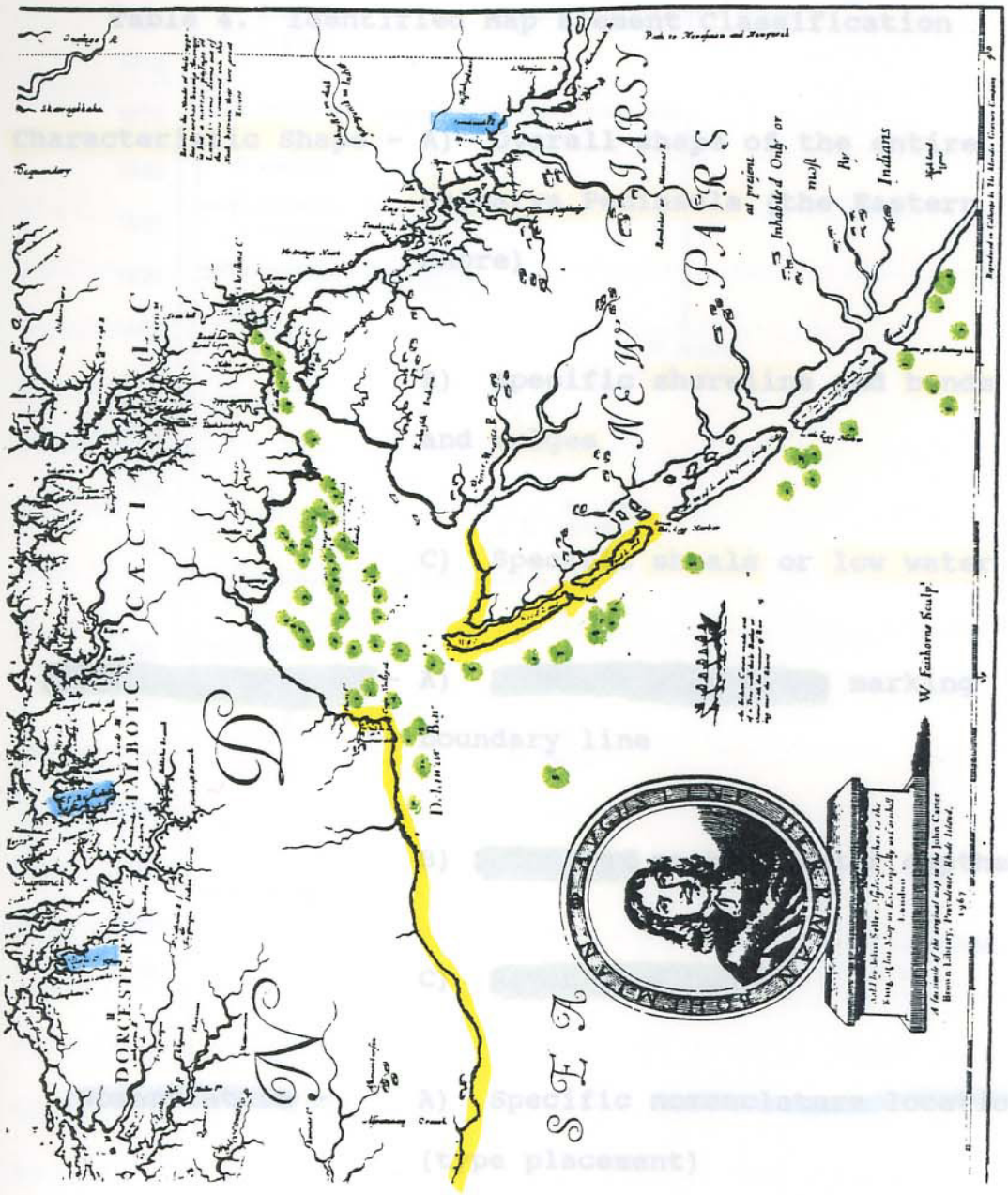

Figure 15d. Identified Carto-Genetic Features

(for more detail see Fig. 15d in pocket)

Table 4. Identified Map Element Classification

Characteristic Shape -	A) Overall shape of the entire Delmarva Peninsula (the Eastern Shore)
	B) Specific shoreline and bends and bulges
	C) Specific shoals or low water
Physical Features -	A) Double row of trees marking boundary line
	B) Soundings marking water depths
	C) River confluences
Nomenclature -	A) Specific nomenclature location (type placement)
	B) Unique spelling (incorrect/incomplete)

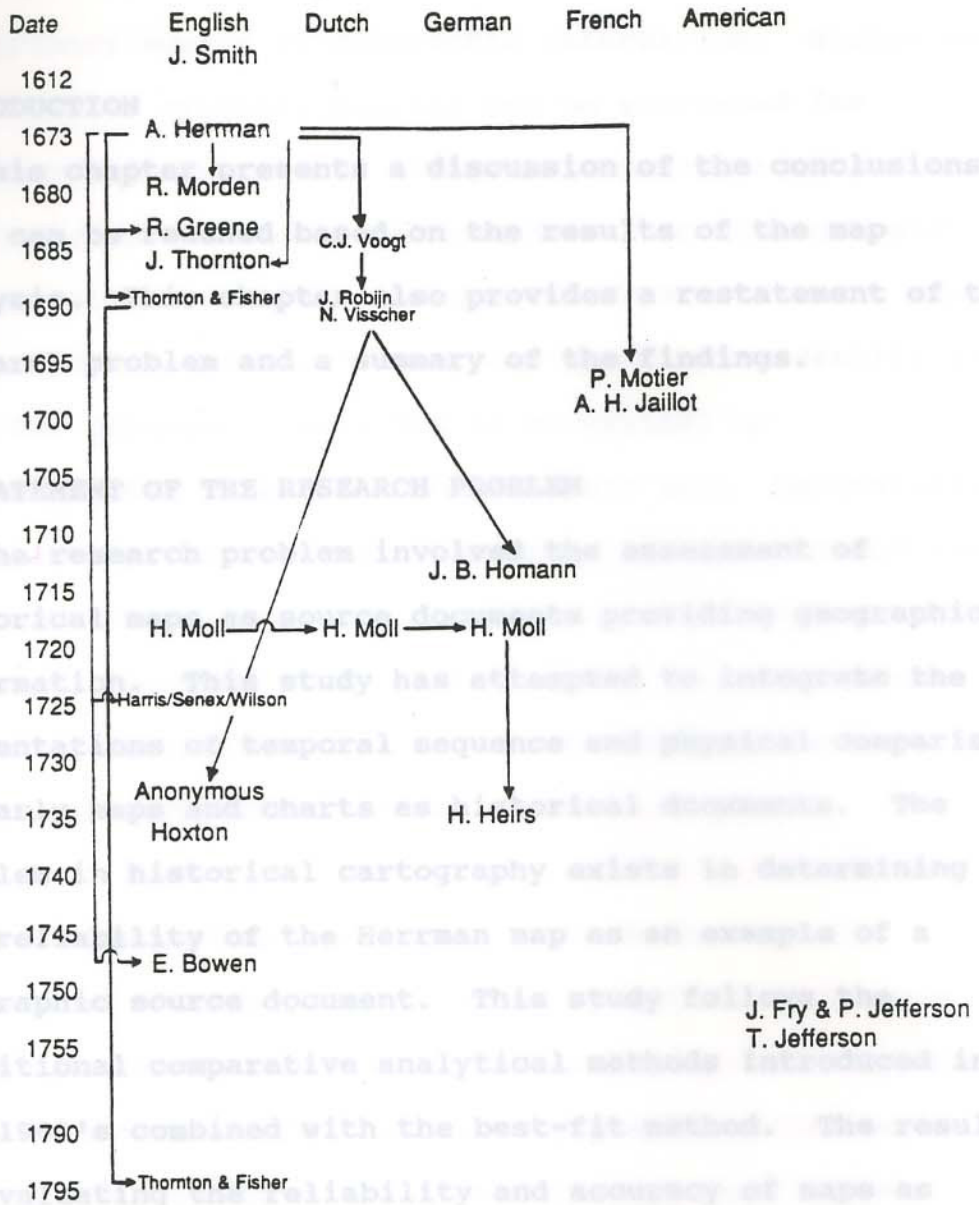

Figure 16. Diffusion Diagram

CHAPTER V CONCLUSIONS

INTRODUCTION

This chapter presents a discussion of the conclusions that can be reached based on the results of the map analysis. This chapter also provides a restatement of the research problem and a summary of the findings.

RESTATEMENT OF THE RESEARCH PROBLEM

The research problem involved the assessment of historical maps as source documents providing geographical information. This study has attempted to integrate the presentations of temporal sequence and physical comparison of early maps and charts as historical documents. The problem in historical cartography exists in determining the reliability of the Herrman map as an example of a geographic source document. This study follows the traditional comparative analytical methods introduced in the 1960's combined with the best-fit method. The results of evaluating the reliability and accuracy of maps as source documents in geographic research have been demonstrated by results which are less subjective than traditional comparative methods.

In past historical analysis, charts and maps have been frequently overlooked as a graphic source of historic

geographic information. This study uses the mother map as the primary source of geographic information. Historical maps used as original sources can be evaluated for accuracy and distortion. Geographic distortions can then be corrected for locational purposes. An archaeologist, for example, could take coordinates from a historic map, corrected for its distortion, and be able to identify and plot the geographic position of historical or archaeological sites on a contemporary map. Determination of these maps as original sources of information and the accuracy of their content, has been a major concern. This research, however, proposes techniques that can be used to evaluate and correct maps and charts making them more useful as historic documents.

These evaluation techniques include the visual comparison of maps which is aided by adjusting the map images photomechanically or electronically to bring the scales into agreement. Extracting graphic evidence as cartographic features are traced through maps of the geographic area to show the diffusion of these map elements through a spatial and temporal sequence of nearly a century and a half of mapping. Focusing on the best-fit method as a computer mapping technique for establishing the accuracy of mapped features, an evaluation of the maps reliability is made.

SUMMARY OF THE RESULTS

Calculations were made showing percent error between selected control points of the Herrman map and the same points on contemporary NOS nautical charts (see page 91 in the appendix). The control points were selected based on stable natural landforms, as analyzed by shoreline movement studies, and settlement locations. The distortions calculated yielded an overall average error of over five percent. This is an average error showing distortion or poor topographic surveying results evident in maps of the time period. Most other maps of this period have a range of overall average error of 5% to 11%. The Herrman map can now be described in terms of its accuracy relative to other historical maps providing numerical results.

The amount of map distortion in the Herrman map is shown graphically by Figure 17. The latitude and longitude grid lines of a Mercator projection are straight and parallel and intersect at 90°. However, the latitude and longitude grid lines illustrated on the Herrman map in Figure 17 indicate the distortion as compared to the contemporary graticule of the same area. The image area of the map displays the shoreline as distorted since the grid lines in this projection should be parallel straight

lines rather than curvilinear and converging. The angle and amount of off-set from a true contemporary projection indicates the direction and angle of map image distortion. The direction and length (amount) of distortion is greatest in an east-west (Y) direction on the Herrman map. The lines of latitude are relatively straight and parallel as compared to the lines of longitude.

Analysis of the control points reveal the amount of distortion as related to direction and orientation plane of reference. As listed in the appendix of this thesis (pages 91 and 92), the latitudinally oriented control points have a comparably smaller measured distance between the Herrman map and the NOS base map than the longitudinally oriented control points. This is further supported by the standard deviation of the two data sets. There is a smaller amount of deviation with the latitudinally oriented control points as shown both graphically and listed statistically.

The greatest distortion exists in the determination of longitude positions by the surveying techniques of the seventeenth century. As the surveyor traveled along the shoreline in a east-west direction, greater error in accurate positioning occurred which is evident in the greater deformation of the longitude grid illustrated in

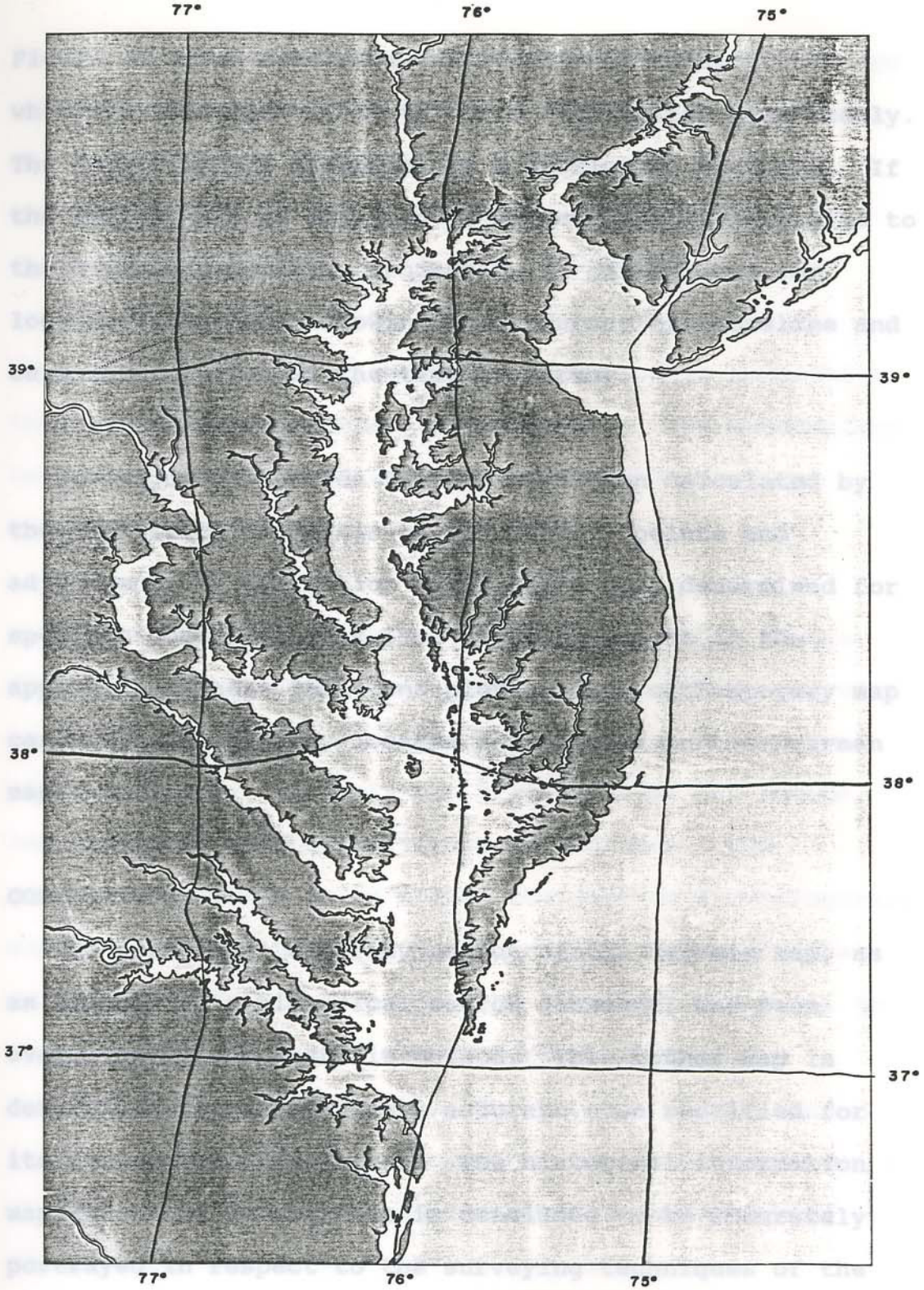

Figure 17. Herrman's Map with Deformation Latitude & Longitude Grid
(for more detail see Fig. 17 in pocket)

Figure 17. The map image and locations are distorted which the deformation of the grid illustrates graphically. The detail in the shoreline is historically accurate. If the Herrman map is adjusted or mathematically rectified to the corrected Mercator projection it can be used for locational purposes showing the accuracy of shoreline and cultural features at the time of survey.

The major distortion factors have been calculated by the statistical analysis of the control points and adjustments or correction values have been determined for specific control points (see pages 93 and 94 in the appendix). These locations plotted on a contemporary map can now be accurately located and plotted on the Herrman map.

CONCLUSIONS

The positional accuracy aspect of the Herrman map, as an example of a historical source document, has been evaluated by the best-fit method. This mother map is determined to be relatively accurate once rectified for its projection distortions. The historical information mapped on the Herrman map is concluded to be accurately portrayed in respect to the surveying techniques of the time. The methodology employed in this study has contributed to the field of historic cartographic analysis

in two steps. First establishing the originality of maps and charts as historical source documents by determining the mother map of the study area. Secondly, evaluating the accuracy of the mapped elements on the historical document. The focus on the best-fit methodology has evaluated the reliability and accuracy of the Herrman map as a historical source document in terms less subjective than traditional comparative techniques. The methodology used in this study can be applied to most historical geographic research.

A practical use of this research may overlap in the field of archaeology. For example, a researcher may want to locate a historic site which has been portrayed on a historical map. However, the historic site may not be identified on contemporary maps of the area. The simplified problem is to locate the site on a contemporary map by using the historic map as a guide. Comparative cartographic techniques employing a best-fit analysis to determine the amount of map distortion is a direct application to this example. Knowing the distortion factor of the historical source map allows calculations to be determined for needed adjustments or rectification of the historic map to the contemporary map. The archaeological site can then be accurately located and plotted on the contemporary map.

SUGGESTIONS FOR FUTURE RESEARCH

The comparative cartographic methods focusing on the best-fit technique can be expanded for future research. With a grid system of coordinates available, a map user can compare the spatial character of the map with that of the real world or to compare the geometry of one map projection with that of another. It is then important for the map user to determine on what perspective (projection) the map is based and how that portrayal effects the information on the map. This would allow the user to compare different maps constructed on entirely different projections. The failure to correctly identify the projection of the selected maps hinders the successful comparison of the maps. Future research needs to focus on mathematical determination and analysis of the geometric properties of graphic source documents. Cartographers often fail to identify the projection of source maps needed for research, which is then discarded because questionable usefulness or incompatible geometric properties. Valuable information is then discarded or not used.

Another area for further research requires the assessment of the quality of the projection used in the creation of historic maps. An analysis incorporating

measures of mean square distortions of line lengths in principle directions about a point and the relationship of angular and areal distortion of a map, has been suggested by Bayeva. Additionally, a new method modifying the Tissot's Theory of Distortions has been suggested for use in analyzing map projection distortions. This new method, as stated by Laskowski (1989), presents the Singular Value Decomposition which offers a powerful conceptual and computational tool for analyzing [map] distortions. This "Singular Value Decomposition" method basically measures comparable line segments of digitized lines on different maps and computes the mean square distortions of each comparable line segment pair. Obviously, this is a computational intensive technique which requires a powerful computer. The advantage of this technique exists in evaluating the geometric properties of points and lines which is independent of projection determination required by other comparative techniques.

If the selection of projections is critical in the construction of a map, then evaluation of the comparative quality or assessment of the distortion is necessary in determining the accuracy of a map. This is especially true in a cartographic assessment utilizing quantitative methods for evaluating historic maps as source documents for geographical research.

A final suggestion for future research continues to use computer assisted cartographic techniques in establishing the scale of various maps or other graphic source documents. A variable scale computer program can be utilized to determine the scale of documents constructed on a non-static, inconsistent scale. This research would also resolve the problem of unstable and changeable map medium, which creates errors in comparative analysis.

To conclude, this research certainly creates more factors which need to be examined in comparative cartographic research. Computer technology, especially in computer mapping, continues to provide methods which were not thought of years ago. Technological advancements undoubtedly will allow for new ways for map analysis. It is hoped that this study may contribute to the development of cartographic research.

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APPENDIX

DIGITAL SHORELINE DATA SET WITH PROJECTION GRID LATTICE DESCRIPTION

Geographic window:

N 40°00'00" (Maximum Latitude)
N 36°30'00" (Minimum Latitude)

W 77°30'00" (Maximum Longitude)
W 74°30'00" (Minimum Longitude)

Scale: 1:675,000

Original Plot Size: 39.5 cm X 58.5 cm

Number of Data Points: Approx. 110,000 per file
(after point elimination)

Projection Grid Interval: 600 seconds

EAST-WEST ORIENTED CONTROL POINTS (ALONG A LINE OF LATITUDE)

Control points	Comparable Distance	Ranked
1	3	11
2	7	9
3	4	7
4	11	4
5	9	3

Standard Deviation: 3.73 mm

Correlation: -0.104

Mean: 5.66 mm

* All measurements in millimeters at map scale

NORTH-SOUTH ORIENTED CONTROL POINTS
(ALONG A LINE OF LONGITUDE)

Control points	Comparable Distance	Ranked
1	9	23
2	21	21
3	17	17
4	7	9
5	23	7

Standard Deviation: 8.17 mm

Correlation: -0.06

Mean: 12.83 mm

* All measurements in millimeters at map scale

CALCULATION OF PERCENT ERROR BETWEEN CONTROL POINTS OF HERRMANS MAP AND NOS NAUTICAL CHARTS

Control point	Percent error
Turkey Point	2.0
Cape Charles	4.3
Cedar Point	2.4
Herrington	3.1
Cove Point	7.6
Watkins Point	6.0
Cape Henry	4.1
Jamestown	7.0
St. Clements Island	3.6
St. Marys City	2.7
Somerset	7.8
New Castle	12.2

LONGITUDE CORRECTIONS (shift values) FOR SPECIFIC LINES OF LONGITUDE

Geographic Coordinates

Control points	Herrman Map	Contemporary location (NAD '83)
1	38°23'23" 76°22'34"	38°23'11" 76°22'55"
2	39°27'27" 75°59'37"	39°27'00" 76°00'30"
3	38°12'03" 76°44'20"	38°12'45" 76°44'40"
4	38°10'53" 76°25'49"	38°11'15" 76°26'05"

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Title: A New Map of Virginia and Maryland

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Title: A Mapp of Virginia, Maryland, New Jarsey, New York and New England

Author: Christopher Browne
Date/Place: 1685;London
Title: A New Mapp of Verginia, Maryland and the Improved Parts of Pennsylvania and New Jersey

Author: Herman Moll
Date/Place: 1708 [1721]; Amsterdam
Title: Virginia and Maryland

Author: Herman Moll
Date/Place: 1708 [1721]; Amsterdam
Title: Nieuwe Kaart van Virginie en Mariland

Author: Homann Heirs
Date/Place: 1737; Nuremberg
Title: Virginia und Maryland

Author: Emanuel Bowen
Date/Place: 1747 [1752?]
Title: A New and Accurate Map of Virginia and Maryland

Author: John Baptist Homann
Date/Place: 1714, Germany
Title: Virginia, Marylandia et Carolina

Author: John Thornton and William Fisher
Date/Place: 1689; London
Title: Virginia, Maryland, Pennsilvania, East & West New Jarsey

Author: Jacobus Robijn
Date/Place: 1692 [1717]; Amsterdam
Title: Virginische Paskaart

Author: Pierre Mortier
Date/Place: 1696 [1701?]
Title: Carte Particuliere de Virginia, Maryland, Pennsilvanie, La Nouvelle Jarsey Orient et Occidentale