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AN ASSESSMENT OF BATTLEFIELD MAP EFFECTIVENESS

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AN ASSESSMENT OF BATTLEFIELD MAP EFFECTIVENESS

By

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ABSTRACT

AN ASSESSMENT OF BATTLEFIELD MAP EFFECTIVENESS

By

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Battlefield map effectiveness was investigated in a perception experiment with three variables: method of symbol explanation, method of terrain representation, and military experience or interest. Maps of two hypothetical battles were used in the experiment and were preceded by either a "natural" legend or conventional legend. Subjects viewed one map of each battle; battles were alternately configured with different methods of terrain representation. Experience and interest was determined by questionnaire. Test responses were examined to determine the influence of each variable on map effectiveness. The results suggest that: (a) the "natural" legend promotes understanding of battlefield map symbols in certain map reading tasks and is at least as effective as the conventional legend in others; (b) the interpretive method of terrain representation facilitates performance of military terrain analysis tasks; and (c) military experience and interest facilitates performance in tasks requiring symbol identification or overall integration of map information.

To my family

who have always encouraged and inspired me

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CHAPTER I

MAPPING BATTLE SITUATIONS

Introduction

Battlefield maps portray the spatial relationships between opposing military forces through the course of battle and are a primary tool in the study of current military geography. The spatial study of battles undoubtedly has both utilitarian and educational value for the professional soldier and military scholar. Knowledge of military history and military geography aids in developing and applying useful ideas, theories and interpretations of the practice of the military profession (Jessup and Coakley, 1982). Battlefield maps describe both current and past events that may be of common interest to society in general. In such circumstances maps should be understandable regardless of soldierly or scholarly experience; effective maps may overcome a lack of experience and promote better understanding. As such, a cartographic study that evaluates the communication effectiveness of battlefield maps is worthy.

This research is an empirical examination of three variables potentially contributing to the effectiveness of battlefield maps in the study of military geography. The variables are: symbol explanation and type of legend, interpreted terrain as a separate category of thematic information, and the experience and interest of the map user. The purpose is to provide cartographers with a set of design principles for mapping battle in an historic and geographic context.

The Nature and Purpose of Battlefield Mapping

The issue of battlefield map effectiveness is actually one of cartographic communication. A number of early studies (Kolacny, 1969; and Ratajski, 1973) identified critical elements in the communication process: the cartographer and the map user, the medium of communication (the map), and the cartographer's and user's knowledge and experience. The idea of improving communication has since become one of the organizing themes of the profession, providing cartographers with a basis for developing hypotheses and research methods and for evaluating results (Morrison, 1984).

The communication effectiveness of battlefield maps has largely been ignored. Petchenik (1978) attributed the lack of research in historical battlefield mapping to: (1) the deviation of historical military mapping from the mainstream of cartographic activity, (2) the peripheral nature of military history to American historical thought and writing, combined with (3) the subordination of maps to development of text in military works, and (4) the lack of professional cartographic input into the design and production of battlefield maps. She suggested that battlefield map ineffectiveness is caused by a low regard for maps as data and for the meaning of maps, or by the failed communication of information to the map user. Petchenik's analysis provoked several relevant questions; how are battlefield maps categorized, what are their purposes, and what can they communicate to the student of military geography?

Historical battle maps can be categorized by scale and purpose, as "thematic" or "reference" maps, or by the operations that can be

performed on them. Petchenik (1978) developed a typology by scale and purpose for twentieth century military maps. The first type, small scale place-name maps, are simple reference maps that show the locations associated with military activity described in an accompanying text (Figure 1). The second type, small to medium scale place-name and line maps, are purported to show troop movements between locations over a period of time (Figure 2). The third type, the large scale battlefield map, shows the disposition of military forces throughout the course of a single battle (Figure 3). This third type, described by Petchenik as the type "that everyone expects to see and that hardly anyone understands," is the most common and is the focus of this study.

Maps may also be categorized as either "thematic" or "reference," with battlefield maps perhaps more closely representing the former. Dent (1985) argued that the single graphic theme of a thematic map distinguishes it from a reference map. Battlefield maps illustrate the distribution of military units through the course of a battle and have a single theme. However, the distribution of military activity on a battlefield map is strongly related to the physical and cultural landscape represented by the base map; as such, battlefield maps also exhibit the qualities of reference maps. Petchenik (1979) suggested that map classification should depend on the operations that can be performed on it. She argued that reference maps require the map reader to learn where things are, whereas thematic maps cause the reader to understand distributions. Battlefield maps provide an inventory of the unique characteristics of military forces as associated with particular places and they also illustrate the distribution of those forces over time.

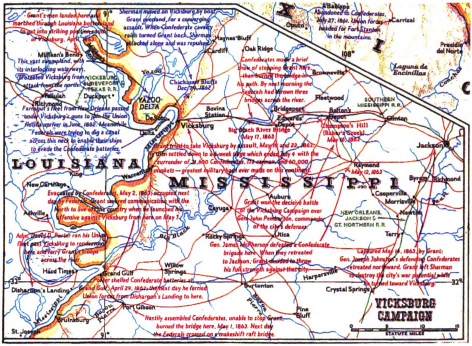


Figure 1. An example of a small scale place-name map. Source: Robert P. Jordan, *The Civil War.* (National Geographic Society: Washington, D.C., 1969)

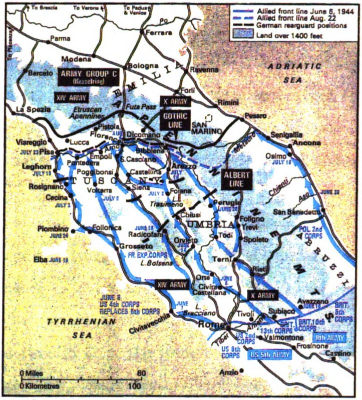


Figure 2. An example of a small scale place-name and line map. Source: Simon Goodenough, War Maps. (St. Martin's Press: New York, 1982)

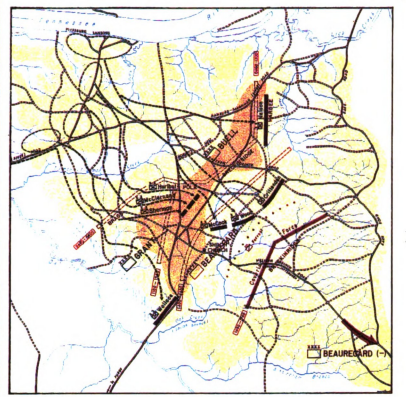


Figure 3. An example of a large scale battlefield map. Source: Thomas E. Griess, *Campaign Atlas to the American Civil War.* (Avery Publishing Group, Inc: Wayne, 1986)

Just as a map may be classified by the operations that may be performed on it, so may its effectiveness be defined in relation to its intended use (MacEachren, 1982). What is the purpose of military historical geography, and what is its relationship to battlefield mapping?

Peltier (1961) described military geography as a "borderline science between military science and scientific geography," arguing that military science is operational and therefore cannot be strictly objective. He suggested that solutions to military problems could be accommodated through an application of systematic geographic principles and knowledge; one such systematic approach is historical. History and geography are interdependent and distributions are the result of

historical processes (Thompson, 1962). Thompson suggested that in relation to the systematic sciences, history provides an orientation in time, whereas geography provides one in space. The interests of the military historian and the military geographer are therefore compatible, yet discrete. The chronology, significance and outcome of events is of key importance to the military historian; these are of no less concern to the military geographer. The military geographer is concerned not only with relating the questions of "what, why, and when" to historical events, but also with gaining a spatial understanding of those events and applying it to military operations; much of that spatial understanding is gained through map analysis.

The tasks which can be performed on a battlefield map determine the manner in which the map aids the study of military historical geography. Three potential categories of map reading tasks may be performed on maps: navigation, measurement, and visualization (Board, 1978). A summary of map reading tasks by category is in Table 1. It is possible that any or all of the tasks could be executed in the study of military geography. However, there should be a practical limit to any research problem, since "valid experimental conclusions can only be obtained by asking questions and by testing hypotheses which are based upon the ways in which readers use maps" (Board, 1978). Which tasks are therefore most appropriate for a cartographic communication experiment designed to assess battlefield map effectiveness? Navigation is seldom used for battlefield maps in a military historical context, whereas measurement and visualization tasks are most likely to be performed. Measurement requires the map reader obtain and possibly compare some

Table 1. Summary of Map-Reading Tasks. Source: Christopher Board, "Map Reading Tasks Appropriate in Experimental Studies in Cartographic Communication," *The Canadian Cartographer*, Vol. 15, No. 1, p. 6

NAVIGATION	MEASUREMENT	VISUALIZATION
Search	Search	Search
Identify and locate own position on map	Identify	Identify
Orient map	Count	Describe
Search for optimum route	Compare	Compare/recognize
Search for landmarks *en route*	Contrast	Contrast
Recognize landmarks *en route*	Estimate	Discriminate/Distinguish
Search for destination	Interpolate	Delimit
Identify destination	Measure	Verify
Verify		Generalize
		Prefer/like

precise cartographic information. Visualization requires the reader obtain an overall view of the geographical landscape and is basic to explaining distribution patterns (Board, 1978).

Understanding Battlefield Map Symbols

Map symbols generally provide information regarding the location, type, quantity and quality of objects or occurrences in space. The effectiveness of a map is therefore largely dependent on the user's understanding of the symbols. Much of the cartographic literature concerned with symbol understanding has either recommended specific forms or developed rules for devising or proving new sets (Hopkin and Taylor, 1979). However, it is not the intent of this study to develop new symbols for battlefield maps, nor to evaluate the effectiveness of

those currently used. Rather, the purpose is to identify the characteristics of battlefield map symbols and, based on these characteristics, understand how they may be effectively learned. Cartographic literature (DeLucia and Hiller, 1982) suggests that understanding of battlefield map symbols will be enhanced with a "natural" legend accompanied by an explanation of battlefield map construction, rather than a conventional legend. A "natural" legend format depicts the map symbols in a context more closely resembling their actual situations within the body of a map, whereas a conventional legend catalogues them. This suggestion is based on the premise that standard battlefield map symbols are too complex and varied to be understood solely through inference typically required by conventional legend types.

Battlefield map symbols often follow a conventional standard. Hopkin and Taylor (1979) argued that the association of specific meanings with specific symbols is fundamental to all effective means of graphic communication and can be accomplished through standardization. It is therefore not surprising that the need to derive and adopt standard symbols has been the focus of a number of cartographic studies (Ratajski, 1971; Board, 1973; Robinson, 1973; Morrison, 1974 and 1984). It is generally accepted that reference maps lend themselves more easily to the adoption of standard symbols than do most thematic maps; the effectiveness of certain symbols on thematic maps varies and is dependent on the specific information depicted (Hopkin and Taylor, 1979). Although battlefield maps may be categorized as a type of thematic map, their symbols lend themselves to standardization better than do others.

Thematic information on military operations maps and overlays is portrayed with standard symbols (Field Manual 101-5-1, 1985). Standardization provides military commanders and planners with a common graphic means of depicting operational intentions, thereby reducing the possibility of confusion or misinterpretation between users. Battlefield map symbols are similar in character to those found on standard military operational maps and appear to have evolved from them. Evidence of this evolution is found in several historical battle atlases (Esposito, 1959; Chandler, 1980; Goodenough, 1982). It is possible that techniques used to learn standard military map symbols may be applied to battlefield mapping.

Unlike those found on many thematic maps, standard battlefield map symbols are both qualitative and quantitative; they not only portray the quantities and characteristics of various military units, but also portray the activities of these units, control measures, and other tactical information of interest. Hopkin and Taylor (1979) argued that cartographic researchers have been preoccupied with the psychophysical scaling of quantitative map symbols. As a result, the understanding of symbols which are both qualitative and quantitative has not been wholly addressed in the cartographic literature.

Standard battlefield symbols are abstract, complex, and varied. Abstract symbols require sophistication of the user and must be accompanied by a detailed legend (Dent, 1985); the complexity of battlefield map symbols compounds the legend's requirement for detail. As evidence of this complexity, a diagram illustrating the components of a typical military unit symbol is shown in Figure 4. Although it might

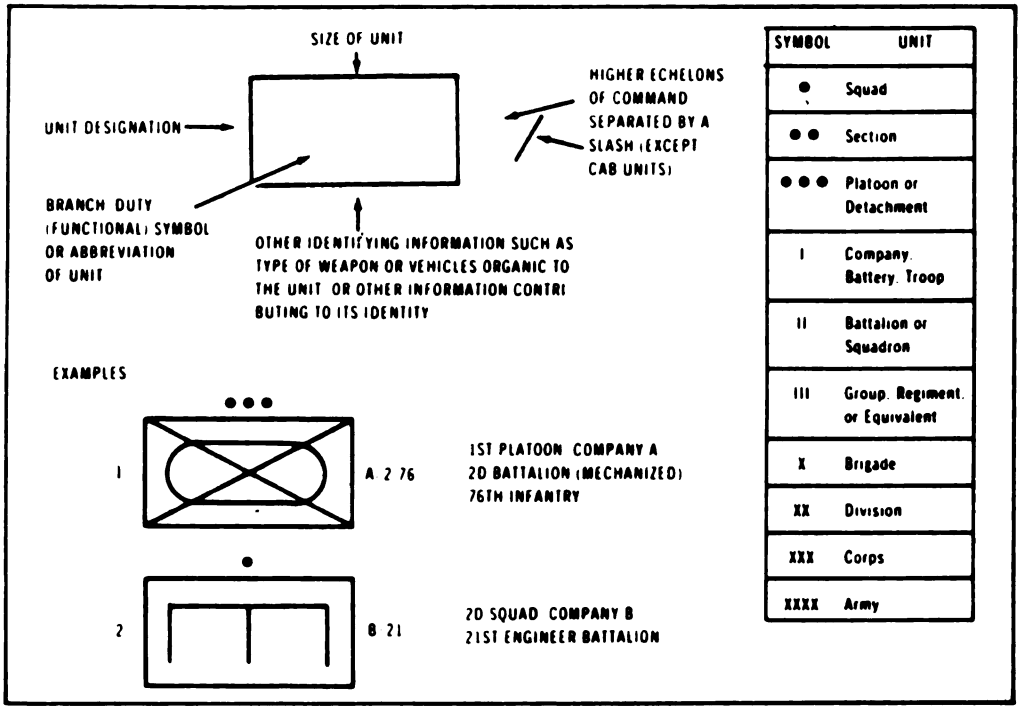


Figure 4. Components of a standard military unit symbol. Source: Field Manual 5-34, *Engineer Field Data.* (Government Printing Office: Washington, D.C., 1987), p. 10-26.

be argued that the complexity of the symbols is justified by their utility, there is no empirical evidence to either dispute or support that claim. Nevertheless, the issue is not the utility of complex symbols, but rather the effect of complexity on learning.

Several authors have determined that complex and numerous symbol sets are difficult to learn (Harrison, 1959; Williams and Falzon, 1963; Easterby, 1963; Van Roy and Morrison, 1973). The complex idea represented by a symbol must be expressed in words (Blaut, 1954), and the application of Blaut's notion usually occurs in the form of a legend. According to DeLucia and Hiller (1982), the legend of a thematic map is crucial to map understanding because the map user "depends upon it to decode and comprehend the symbols used." With battle atlases, a legend is typically found in the introductory pages of the atlas, although supplemental legends may accompany individual maps.

Several typical battlefield map legends are shown in Figures 5 and 6. These legends do not depict all of the symbols found in their respective atlases; a single battlefield map symbol is a compound structure and may be constructed from several others. Therefore, it is difficult for a map user to learn all possible combinations and impractical for all of those combinations to appear in any legend. As such, two "cardinal rules" (Robinson, Morrison and Sale, et al., 1984) are violated: "no symbol that is not self-explanatory should be used on a map unless it is explained in a legend" and; "any symbol explained should appear in the legend exactly as it appears on the map."

A conventional approach to legend design may be inappropriate for battlefield maps. Perhaps instead of illustrating possible symbol combinations, the legend might illustrate the procedure for constructing map symbols from several basic ones. Once familiar with the construction technique, the map user may be able to dissect and understand any battlefield map symbol (Field Manuals 101-5-1, 1985, and 21-30, 1970). Similarly, instead of cataloging symbols, the legend could show the context in which they are used. Rarely does an adequate explanation of symbol construction or illustration of symbol usage accompany battle maps or atlases. Apparently, the map reader is expected to infer the meaning of combinations not illustrated in the legend. The lay user is likely to encounter difficulty in understanding the significance of even the basic symbols, one of Petchenik's (1978) major criticisms of most battle maps.

An alternative to the conventional legend is a "natural" legend combined with an illustrated description of symbol construction. DeLucia and Hiller (1982) determined that map performance efficiency and

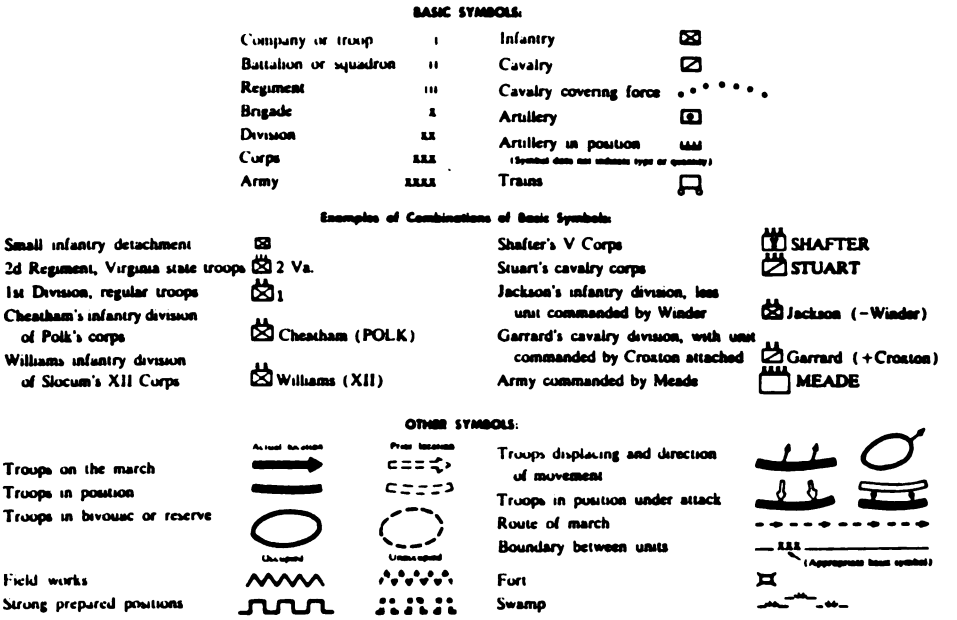


Figure 5. Conventional battlefield map legend. Source Vincent J. Esposito, Ed., *The West Point Atlas of American Wars.* (Frederick J. Praeger Press: New York, 1959)

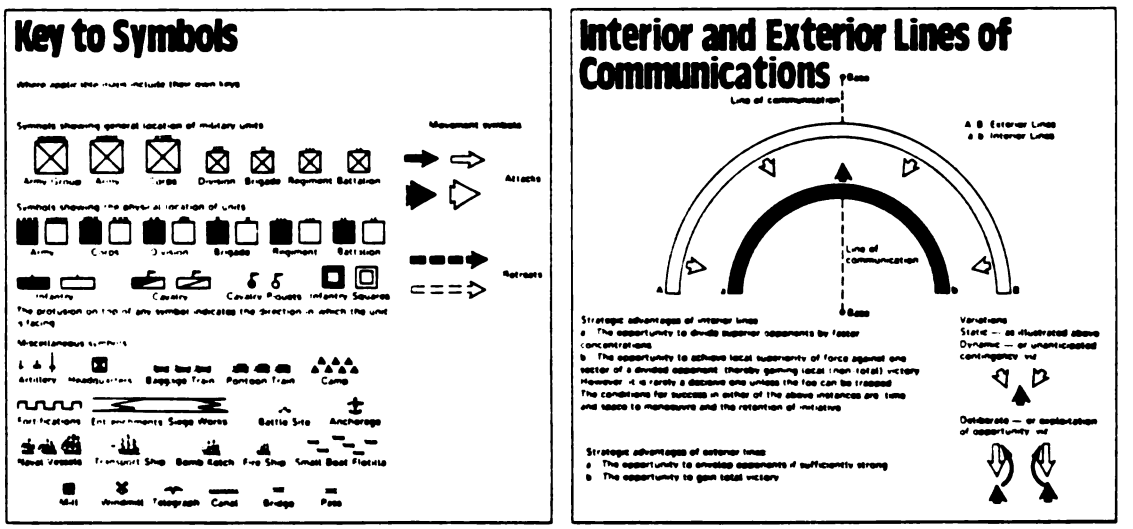


Figure 6. Conventional battlefield map legend. Source: David Chandler, Ed., *Atlas of Military Strategy.* (arms and Armor Press: London, 1980)

understanding is improved using a natural, rather than a conventional legend. An example of a natural legend is shown in Figure 7. The legend could be complemented by an illustrated description; the descriptive approach has been used to summarize the principles of military map interpretation (McGrath, 1975) and to teach military map reading, navigation and graphic representation (U.S. Army Infantry School Student Handbooks 7-6 and 21-21, 1985; and Command and General Staff College, 1985). The illustrated description graphically depicts the construction, use and meaning of battlefield map symbols and their components. Theoretically, the combination of an illustrated description of symbol construction with a natural legend would not only provide more information to the map user, but would provide the information in a context that facilitates better understanding of battlefield maps.

Terrain as a Category of Thematic Information

Terrain can be defined as the surface of the earth with all its natural and artificial features, and an understanding of the effects of terrain on past military operations is of paramount importance to the student of military geography (Thompson, 1962). Therefore, an effective thematic battlefield map should do more than represent the physical aspects of terrain; it should present an analysis of the military aspects of terrain and their effects on battle.

Thematic battlefield maps often portray only the physical aspects of terrain and ignore the military aspects. Contemporary military doctrine (Field Manuals 21-32,1979; 34-1, 1984; and 101-5-1, 1985) considers five military aspects of terrain: (1) observation and fields of fire; (2) cover and concealment; (3) obstacles; (4) key terrain;

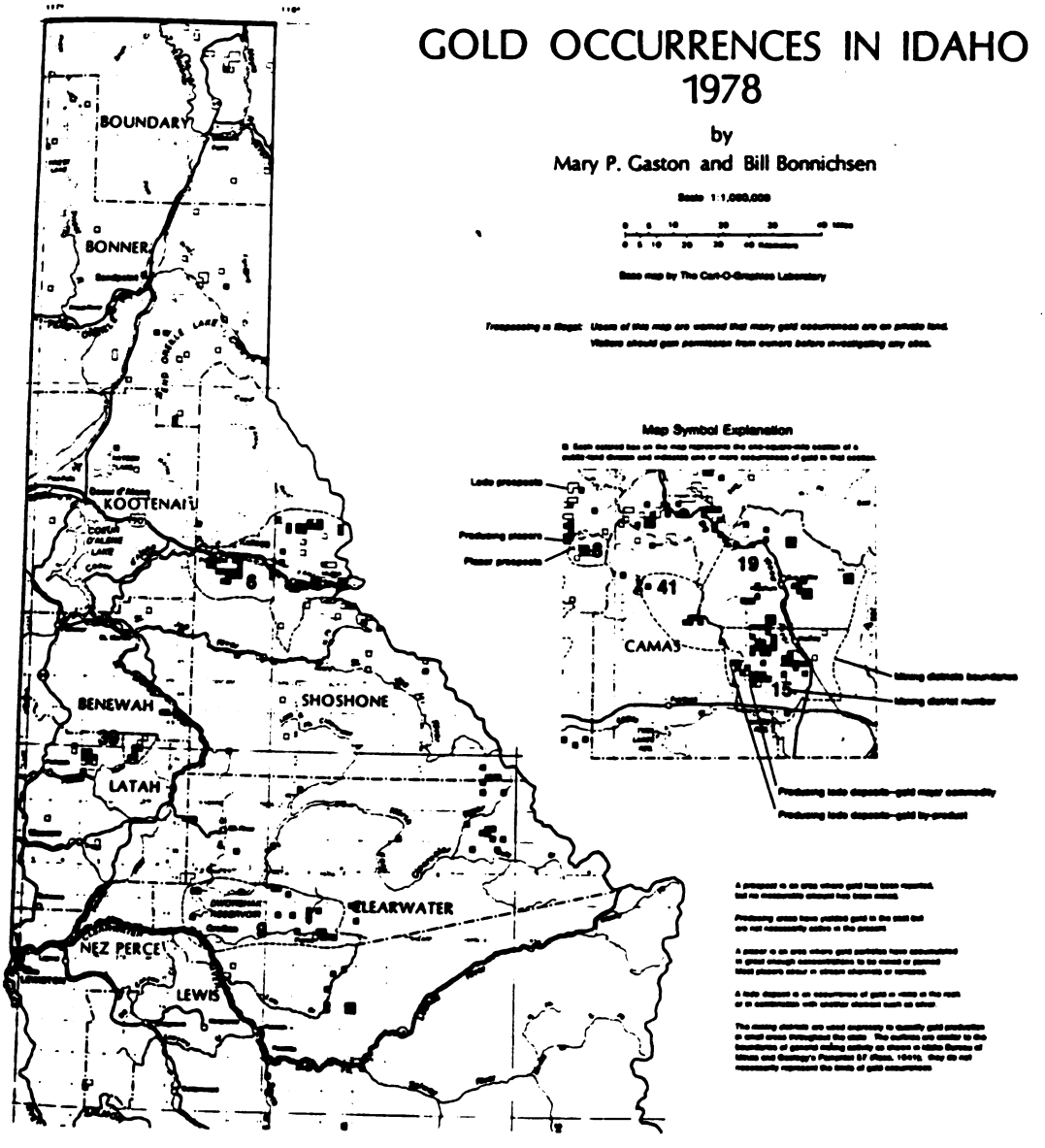


Figure 7. An example of a natural legend format. Source: A.A. DeLucia and D.W. Hiller, "Natural Legend design for Thematic Maps," *The Cartographic Journal*, Vol. 19, No. 1, p. 47.

(5) avenues of approach. The cartographic methods of portraying terrain are varied (Robinson, Morrison and Sale, et al.,1984), and several of these methods have been applied to battlefield maps (Figures 8 through 10). Although the maps in Figures 8 through 10 differ in method of terrain portrayal, they all portray the physical, rather than the military, aspects of the terrain.

Thematic maps consist of at least two elements, a geographic or base map, and one or more thematic overlays. The purpose of the geographic base is to provide locational information relevant to the thematic information, and it has been argued that it should include only the amount of information necessary to convey the map's message (Dent, 1972). On battlefield maps, the terrain is often depicted as only geographic base information, and not as a category of thematic information. Miller and Voskuil (1964) argued that thematic maps should present not only facts, but the results of analysis and synthesis. What was the significance of a particular hilltop, ridge or valley? Which rivers acted as obstacles? Why did a force fail to engage the enemy from a particular position? Battlefield maps that represent only the physical aspects of the terrain cannot, by themselves, answer these questions. With maps of this type, the map user's understanding of the relationship between the military aspects of terrain and the outcome of battle becomes dependent on either written description or inference based on a prior knowledge of tactics. An alternative to portraying only the physical aspects of terrain is to interpret certain military aspects of terrain, and present them as an additional category of thematic information.

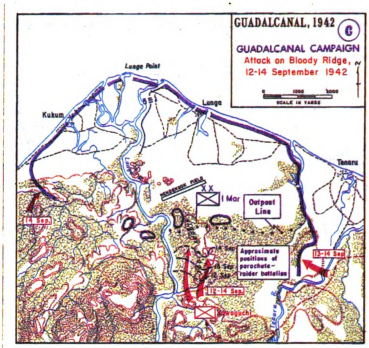


Figure 8. An example of a battlefield map with hachures used to represent landforms. Source: Thomas E. Griess, Ed., *Atlas of the Second World War - Asia and the Pacific.* (Avery Publishing Group, Inc: Wayne, 1985)

The military has applied thematic mapping techniques in the preparation of terrain analysis products for operational maps (Leestma, 1967; Field Manual 21-33, 1978; Howard, 1980; Field Manual 34-1, 1984) and it is possible that this approach may be applied to historical battlefield maps. It has long been recognized that graphics are basic to many aspects of military intelligence and operations planning (Field Manual 5-105, 1987), and multiple terrain factor overlays, the products of terrain analysis, are often used in the planning process. These products are either overprinted on topographic map sheets of varying scale, or are reproduced as transparent overlays. The relationship between the military aspects of terrain and the elements of terrain information are shown in Table 2, as are potential military terrain analysis products.

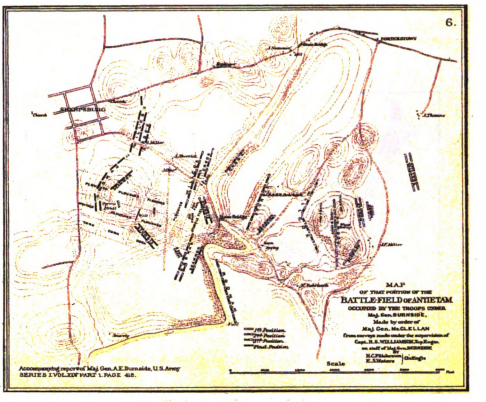


Figure 9. An example of a battlefield map with contours used to represent the terrain. Source: Thomas Yoseloff, Pub., *The Official Atlas of the Civil War.* (Thomas Yoseloff, Inc: New York, 1958)

The military's operational approach can be adapted to produce a thematic terrain overlay for a battlefield map. Design of such a thematic overlay would require sufficient generalization to avoid overwhelming the user with every nuance of the military aspects of terrain. Unlike its operational counterpart, a terrain overlay for a battlefield map is not a planning tool, but is meant to convey the relative importance of terrain through the course of battle. The influence of certain military aspects of terrain on the outcome of an historic battle is known, and it is only those aspects that the cartographer need depict.

Several cartographic principles must be applied in the design of a thematic terrain overlay for a battlefield map. Regardless of whether

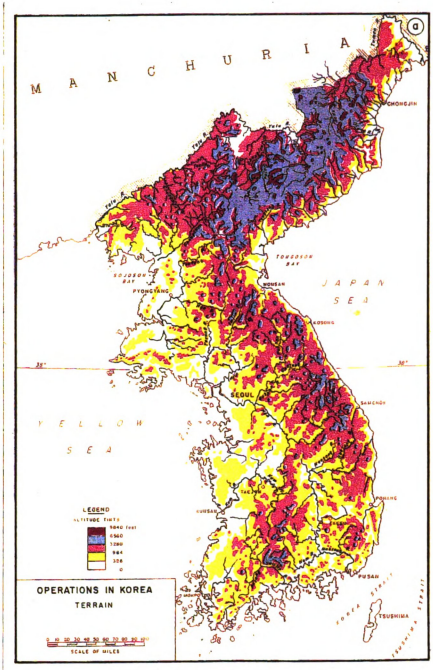


Figure 10. An example of the use of layer tinting in terrain representation. Source: Vincent J. Esposito, Ed., *The West Point Atlas of American Wars.* (Frederick J. Praeger Press: New York, 1959)

Table 2. Relationships between the Military Aspects of Terrain, Elements of Terrain Information, and possible Terrain Analysis Products. Source: U.S. Department of the Army, Field Manual 5-105, *Topographic Operations*. (Government Printing Office: Washington, D.C.,1987), p. 1-4.

Military Aspects of Terrain (OCOKA)	Elements of Terrain Information	Examples of Terrain Analysis Products
Observation/ fields of fire	•Vegetation (summer and winter). •Surface configuration. •Battlefield environmental effects on the terrain. •Urban areas.	•Horizontal line-of-sight for direct-fire weapons and radar. •Emplacement suitability and performance ratings for ground surveillance.
Cover and concealment	•Vegetation (summer and winter). •Surface configuration. •Obstacles (micro relief). •Battlefield environmental effects on terrain. •Urban areas.	•Cover potential from direct and indirect fire (good/fair/poor). •Concealment potential from horizontal and vertical observations.
Obstacles	•Vegetation (summer and winter). •Surface configuration. •Drainage characteristics. •Natural and man-made obstacles. •Micro relief. •Surface materials (wet and dry). •Urban areas.	•Location of existing natural and man-made obstacles. •Mobility potential on the battlefield.
Key terrain	•Urban areas. •Lines of communication. •Surface configuration. •Drainage characteristics.	•Location of key terrain features, both natural and man-made.
Avenues of approach	•Vegetation (summer and winter). •Urban areas. •Surface configuration. •Surface materials (wet and dry). •Drainage characteristics. •Lines of communication.	•Identification of areas where movement of friendly and enemy forces may occur. •Speed prediction. •Drop zones. •Landing zones. •Landing beaches. •Map-of-the-Earth navigation.

the overlay is a transparent flap or printed on the map itself, it must be designed as part of the map, not as an addition to it. It is commonly accepted that a range of visual importance must be established on a map (Robinson, Morrison and Sale, et al., 1984). Dent (1972) argued that on a thematic map, distributions should be assigned an order in the visual hierarchy. The base map should be at the lowest visual plane in the hierarchy and the less important distribution (the military aspects of terrain) should appear as an intermediate level in the order between the primary distribution (military units and movement) and the geographic base. Finally, as with the geographic base, only the information necessary to convey the terrain's significance should appear on the thematic overlay.

Map User Experience

A third element in battlefield map learning is user experience since most cartographers agree that greater experience results in increased map effectiveness. Experience could include map reading ability, military background, or visual-spatial abilities. Whatever the source of familiarity, user experience could influence battlefield map effectiveness. Underwood (1981) investigated the relationship between geographic training and map reading ability. She concluded that experience provides "cues" for successful interpretation and may compensate for a lack of visual-spatial ability. Therefore, the factor of experience may be most important in understanding and overcoming complex visual displays. Olson (1975) cited a number of cartographic studies that concluded that experience does not necessarily result in less user error. She suggested that some of the abilities necessary for effective map reading are perceptual and may not be acquired solely

through geographic or related training. However, experience may overcome deficient perceptual skills. Map user skills may be increased by providing inexperienced users with an improved legend type and description of symbol construction. Similarly, deficient perceptual skills may be accommodated by interpreting the military aspects of terrain through the addition of a category of thematic information. This theory is an extension of Olson's (1975) conclusion that map design modification and experience are complementary factors in improving map communication.

Problem and Hypotheses

This study examines the contribution of three variables to the effectiveness of battlefield maps in the study of military historical geography: (1) symbol explanation and type of legend; (2) terrain as a category of interpreted thematic information; and (3) experience and interest of the subject. Psychophysical testing techniques are employed to measure and evaluate communication effectiveness. Specifically, this study focuses on the following research questions:

1. How do map users effectively learn battlefield map symbols? Can knowledge of battlefield map symbols be effectively gained through use of a conventional legend or through a natural legend? Should symbol construction be explained by an illustrated description?

2. How do battlefield maps most effectively communicate information about the battle setting? Is terrain effectively portrayed as geographic base map information or should the interpreted military aspects of terrain be represented as an additional category of thematic information?

3. What is the relationship between the prior military experience or interest of the map user and battlefield map effectiveness? Is performance of battlefield map reading tasks dependent on map user experience or interest, and if so, which tasks? Are any combination of battlefield map variables independent of experience or interest?

A review of the cartographic literature suggests that the research questions may be addressed through the testing of the following hypotheses:

1. The understanding of battlefield map symbols will be significantly greater among subjects viewing a natural legend accompanied by an illustration of battlefield symbol construction than among subjects using a conventional legend without an accompanying illustration.

2. The understanding of the military aspects of terrain and their impact on battle will be significantly greater with battle maps having additional interpreted terrain information, than with maps without such information.

3. There will be a significant positive relationship between task-related military experience and interest of map users and information gained from a battlefield map.

Few cartographic assessments of battlefield mapping exist. This research will provide a better understanding of the relationship between accuracy of battlefield map interpretation and the variables under investigation. Results of this study may be applied to the design of battlefield maps and atlases as well as the organization of military texts and manuals.

CHAPTER II

RESEARCH DESIGN AND METHODS

Introduction

There are few empirical battlefield map effectiveness studies which are suitable design models for this research, although numerous precedents in psychophysical testing procedures have been established. Board (1978) argued that all cartographic evaluation requires an empirical approach and suggested four points to be considered in developing tests of map effectiveness: (1) What type of map? (2) What is the intended audience? (3) Under what conditions will it be used? (4) What map reading tasks are appropriate to the stated purpose? Several cartographers have argued that the fourth consideration has not been sufficiently addressed in many psychophysical studies. McCleary (1975) stated that testing should approximate a real map using environment with consideration given to the map's purpose. Board (1978) contended that experimentation using inappropriate tasks makes little contribution to evaluating map effectiveness and improving map design. He developed a model for evaluating map effectiveness in terms of user requirements; this model is shown in Figure 11. The design and implementation of this research was guided by Board's procedure.

Test Structure

The test structure and composition of the sample population were guided by the research hypotheses. Examination of the first hypothesis required a measurement and comparison of map use accuracy between

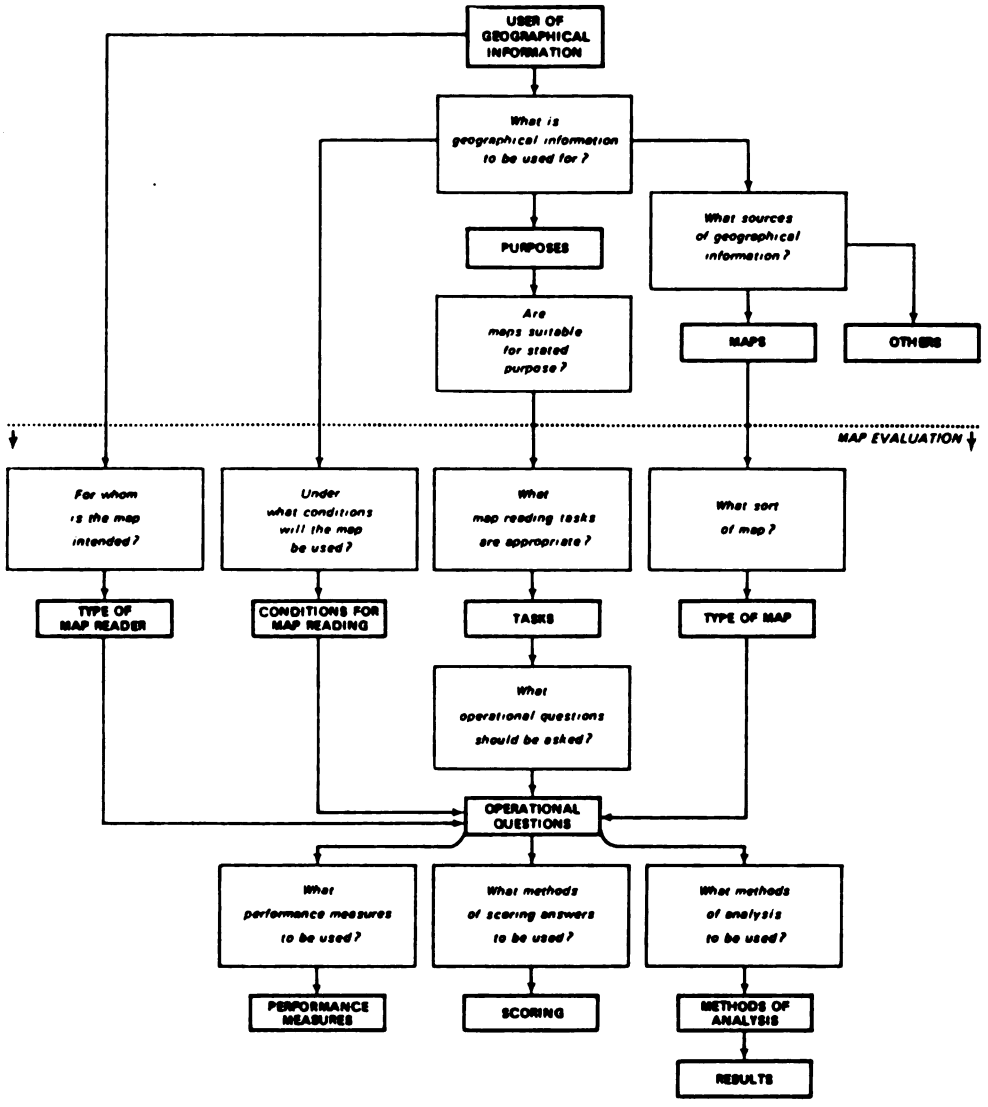


Figure 11. A procedure for map evaluation in terms of user requirements. Source: C. Board, "Map Reading Tasks Appropriate in Experimental Studies in Cartographic Communication," *The Canadian Cartographer*, Vol. 15, No. 1, p. 4.

subjects viewing a conventional battlefield map legend and those viewing a natural legend accompanied by an illustration of symbol construction. Similarly, testing of the second hypothesis required a measurement and comparison of responses between subjects viewing battle maps with interpreted terrain information, and those viewing maps lacking interpreted terrain information. Examination of the third hypothesis required a test sample population with a wide range of quantifiable experience and interest. In consideration of these requirements, a three variable, four part experiment was designed to investigate the effectiveness of battlefield maps in the study of military historical geography. The test structure is shown in Figure 12.

Each test subject was provided an 8.5" x 14" test booklet, a consent form, an answer sheet, and a questionnaire. Subjects were divided into groups numbered one through four, and worked with one of four possible test configurations.

Part I, entitled "Battlefield Map Symbols" required that subjects study a battlefield map legend, construct a five component military unit symbol, and then match ten map symbols found on a battlefield map with their associated descriptions. There were two configurations of Part I; groups 1 and 2 were provided a conventional legend, whereas groups 3 and 4 were provided a natural legend accompanied by an illustration of military unit symbol construction. The requirements for symbol construction and matching were identical for both configurations.

Parts II and III of the test each required that subjects study a battle. The narrative of each battle was accompanied by a series of maps which were alternately configured with or without interpreted terrain information. There were four configurations of Parts II and III

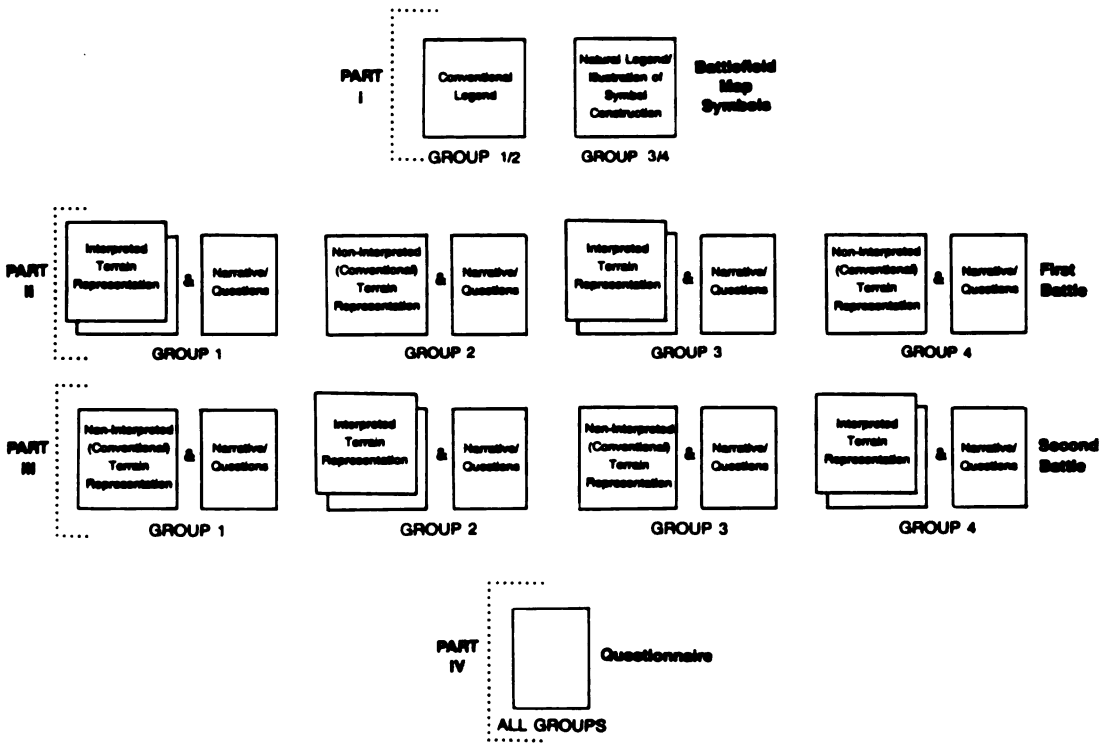


Figure 12. Schematic of a three variable, four part experiment designed to investigate the effectiveness of battlefield maps.

(two battles x two forms of terrain depiction) and each group was exposed to two configurations. Subjects were required to study each series of battle maps and accompanying narrative, and then respond to fifteen test questions. Test questions were identical for each battle, regardless of configuration.

The final part of the test was a questionnaire designed to assess each subject's level of military experience, familiarity with battlefield maps and symbols, and interest in military history or military geography. The questionnaire also solicited each subject's preferences, as well as their opinion regarding the content, quality and administration of the test.

Design of the Test Instruments

To make the evaluation of map effectiveness directly applicable to cartographic design problems involving battle portrayal, actual battles were used to construct the test maps for Parts II and III. Two battles were chosen from the 1973 Arab-Israeli War: the Egyptian attack and subsequent Israeli counterattack across the Suez Canal, and the Israeli defense of the Golan Heights. The battles were chosen because: (1) It was believed that the test subjects could better relate their experience to contemporary battles, thereby stimulating interest; the selected battles could be represented at a relatively large scale and modern equipment and tactics were employed throughout their duration. (2) They represented two levels of tactical complexity, making it possible to evaluate each test variable in these terms; complexity was included because of its possible adverse impact on effectiveness (Monmonier, 1974; Jenks, 1975; MacEachren, 1982). (3) They occurred in distinct phases which could be represented in a sequential series of maps. (4) The effects of terrain significantly affected their outcome.

Each of the battles in Parts II and III was presented as a sequential series of maps, with each map representing a portion of the battle through time, rather than as a single map. This decision was based on the accepted theory that a sequential and partitioned presentation of information will complement both user learning strategies and perceptual abilities (Bartram, 1978; Shimron, 1978; Thorndyke, 1980; Griffin, 1983; Eastman, 1985; Fontanella, 1988). The data for the test maps in Parts II and III were compiled from several

sources (Herzog, 1975; Eshel, 1978; Badir, et.al, 1978; O'Ballance, 1978; Aker, 1985).

Several measures were taken to eliminate the possibility that a subject's familiarity with either battle might influence experimental results. The area represented was mapped with an unconventional orientation and several of the easily identifiable terrain features were relocated or distorted. Place names, dates, and the names and unit designations of the participants were changed. The battles were renamed using real but little-known places in Africa and Asia.

The two map configurations for each battle were identical, except for the addition or absence of the interpreted terrain information. Battlefield map symbols and colors for opposing forces and for terrain information were selected from those standard on military operations maps (U.S. Dept. of the Army Field Manual 101-5-1, 1985) and were similar in form and scale for all parts of the test. A shaded relief method was used to represent topography on all maps and was chosen for its ease of construction, suitability for quality reproduction, and aesthetic appearance. Following established cartographic principles (Dent, 1972; Board, 1978), a visual hierarchy from the highest order (the distribution of military forces) through intermediate (the interpreted terrain information) to the lowest (the geographic base maps) was established by varying the color saturation and intensity for the opposing force symbols versus the terrain symbols, and by rendering the base map in a subdued grey tone. The maps in each series were numbered sequentially and labeled with dates corresponding to the phase of the battle, and a legend was provided below the maps. Test map

configurations for Part II are found in Figures 16 and 18, whereas test maps for Part III are found in Figures 20 and 22.

The graphic design considerations used for Part I were identical to those used to display the two battles in Parts II and III. The natural legend base map found in the second configuration, and the test map found in both configurations, were made to resemble the maps found in subsequent parts. Symbols found in both legend configurations were identical in type, form, color and scale. The conventional legend used in the first configuration was modeled after the legend found in *The West Point Atlas of American Wars* (1959). The illustration of symbol construction found in the second configuration was modeled after a similar illustration appearing in *Operational Terms and Symbols* (Dept. of the Army Field Manual 101-3-1, 1985). Unlike Parts II and III, test questions for Part I appeared on the same page as the graphics. The two configurations of Part I are in Figures 13 and 14.

Battles in Parts II and III were each described by a short narrative. This measure was taken not only to create a test environment which simulated the study of military historical geography, but also because cartographic literature suggests that it may not be possible to design battlefield maps that are completely self-explanatory (Petchenik, 1977). These narratives were each designed as "propositional" text that refers the reader to locations and distributions on the map. It has been shown that propositional information in text contributes to the understanding of spatial relationships (Petchenik, 1977; Shimron, 1978; Perrig and Kintsch, 1985).

The narratives were divided into distinct parts, each part corresponding and referring to one of the maps in each sequential

Part I: Battlefield Map Symbols

This part consists of two sections. You are to follow the instructions contained in each section. Mark all your responses on your answer sheet; please do not mark in this test booklet.

Section A: Unit Symbol Construction

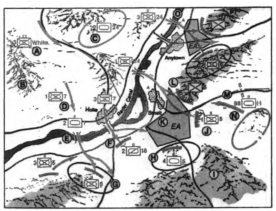
In the space provided on your answer sheet, construct the unit symbol for:
Company A, 307th Engineer Battalion (Airborne), less detachments.

Section B: Matching

The map below, labeled **TEST MAP**, illustrates fifteen symbols as they would be shown on a battlefield map. The legend located on the right side of this page explains the meaning of the symbols; these symbols are used throughout this booklet. Descriptions of ten of the symbols contained on the map are listed below. You are to match the number found next to each symbol with its associated description.

Example: A brigade boundary. **Response:** M

1. An assault bridging site used by the 3rd Brigade, 24th Division.
2. White's 3rd Infantry Division (Mechanized).
3. Hilly terrain posing an obstacle to cross-country mobility.
4. A mechanized infantry battalion occupying a strongpoint.
5. An armored brigade in reserve.
6. An armored battalion displacing forward.
7. A mechanized infantry brigade on the march.
8. A cavalry squadron under attack by a mechanized infantry brigade.
9. An engagement area overwatched by three battalions.
10. The objective of 2nd Brigade, 7th Division.



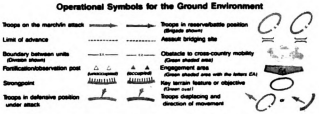
TEST MAP

Military Unit Symbols

Examples of Combination of Symbols

Company A, 1st Battalion (Mechanized), 15th Infantry	A 1-15	Sorbor's 15th Artillery Brigade less detachments	15 Sorbor (-)
7th Armored Brigade of the 6th Division	7 6	White's Armored Cavalry Regiment with attachments	White (+)
Dabbs's 2nd Infantry Division of Staley's Corps	2 Dabbs (Staley)	110th Airborne Infantry Regiment commanded by Sharon	110 Sharon
Holling's XII Corps	XII Holling	4th Army commanded by Winkler	4 Winkler

Operational Symbols for the Ground Environment



Note. Opposing forces are shown in blue and red. Terrain information is shown in green.

Figure 13. Conventional legend configuration of Part I
(Reduced from the original 8.5" by 14" format).

Part I: Battlefield Map Symbols

This part consists of two sections. You are to follow the instructions contained in each section. Mark all your responses on your answer sheet; please do not mark in this test booklet.

Section A: Unit Symbol Construction

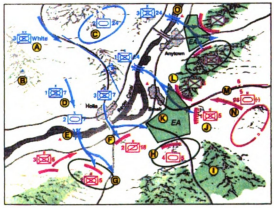
In the space provided on your answer sheet, construct the unit symbol for:
Company A, 307th Engineer Battalion (Airborne), less detachments.

Section B: Matching

The map below, labeled TEST MAP, illustrates fifteen symbols as they would be shown on a battlefield map. The legend located on the right side of this page explains the meaning of the symbols; these symbols are used throughout this booklet. Descriptions of ten of the symbols contained on the map are listed below. You are to match the number found next to each symbol with its associated description.

Example: A brigade boundary. Response: 5

1. An assault bridging site used by the 3rd Brigade, 24th Division.
2. White's 3rd Infantry Division (Mechanized).
3. Hilly terrain posing an obstacle to cross-country mobility.
4. A mechanized infantry battalion occupying a strongpoint.
5. An armored brigade in reserve.
6. An armored battalion displacing forward.
7. A mechanized infantry brigade on the march.
8. A cavalry squadron under attack by a mechanized infantry brigade.
9. An engagement area overwatched by three battalions.
10. The objective of 2nd Brigade, 7th Division.



TEST MAP

Construction of the Military Unit Symbol

Unit Size Symbols

The size of the unit is shown by the appropriate size indicator placed directly above the basic symbol.

Company, Troop or Battery	|
Battalion or Squadron	||
Regiment or Group	|||
Brigade	X
Division	XX
Corps	XXX
Army	XXXX

Unit size increases

Unit Role Symbols

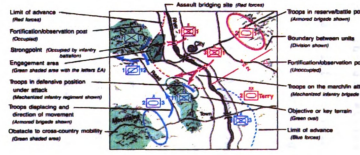
Branch or functional symbols are placed inside the basic symbol. Symbols may be combined with one another, as appropriate, to show the exact function (i.e., the armor symbol combined with the cavalry symbol to represent armored cavalry).

Airborne	Infantry
Armor	Airborne Infantry
Artillery	Armored Cavalry
Cavalry	Mechanized Infantry
Engineer	Self-propelled Artillery

Examples of Combination of Symbols

Company A, 1st Battalion (Mechanized), 16th Infantry	A 1-16	Burton's 10th Artillery Brigade less detachments	10 Burton (-)
7th Armored Brigade of the 6th Division	7 6	White's Armored Cavalry Regiment with attachments	White (R)
Dolezal's 2nd Infantry Division of Bixby's Corps	2 Dolezal (Bixby)	15th Airborne Infantry Regiment commanded by Sharon	15 Sharon
Hollingʼs XII Corps	XII Hollingʼs	4th Army commanded by Winkler	4 Winkler

Operational Symbols for the Ground Environment



Note: Opposing forces are shown in blue and red. Terrain information is shown in green.

Figure 14. Natural legend configuration of Part I
(Reduced from the original 8.5" by 14" format).

series. The narrative, test instructions and test questions were all located on the page facing the map, and the test subjects were able to study all three without turning the page. The narratives, test questions, and instructions for Parts II and III are found facing their associated battlefield maps in Figures 15 and 17, and Figures 19 and 21, respectively.

Test questions used in Part I, "Battlefield Map Symbols," were designed to measure the effectiveness of legend type on symbol understanding. Part IA, "Unit Symbol Construction," required subjects to identify and graphically describe the components of a military unit symbol. The unit symbol in question did not appear in any of the examples of symbol combinations, thus requiring the subject to synthesize information gained from the legend. For Part IB, "Matching," three categories of questions were formulated. The first set of questions required subjects to identify symbol types and functions. In order to not restrict performance evaluation to simple identification tasks, the other categories of questions were designed to assess overall integration of map information gained by viewing a particular legend type. The second category of questions required subjects to associate a unit symbol with an operational symbol: e.g., to associate a unit with its activity. The final category of questions required subjects to visualize complex relationships between several map elements: e.g., between several units, or between several units and the terrain. In order to build subject confidence, questions were arranged in a hierarchy of difficulty.

Part II, "The Arrakeen Crossing," and Part III, "The Defense of the Logone Plateau," simulated an environment for the study of military

Part II: The Arrakeen Crossing

Instructions:

The map on the facing page and its accompanying narrative describe a fictional battle. Fifteen statements pertaining to this battle are listed below. You are to study the map and the narrative and then determine whether each statement is true or false. You should mark your response on your answer sheet. If you cannot tell whether a statement is true or false, then you should mark your answer sheet accordingly. Note that the map on the facing page does not provide additional terrain information (typically shown in green). If possible, you are to infer this information from the base map, the disposition of forces as shown on the map, and the narrative.

Narrative: The Arrakeen Crossing

Map 1: September 9-16, 1983

At 1745 hours on 9 September 1983, 11 divisions of the Baluchistani 1st and 2nd Armies mounted a surprise assault crossing of the Haradh Canal. The objective of the Baluchistani commander was to defeat Arrakeen forces along the canal, to secure a bridgehead, and to secure a route through the Mushash Mountains. Arrakeen defenses along the canal consisted of a series of heavily fortified, lightly manned positions; these positions were quickly overcome by the attacking Baluchistanis.

The following morning, 3 Arrakeen reserve armored divisions under Uri, Ebron, and Harman mounted a coordinated counterattack in an attempt to roll up the Baluchistani bridgehead. The attack skirted the impassable terrain lying east of Parallel Road. The attack failed and the Arrakeens were forced to establish hasty defensive positions west of Parallel Road.

Throughout the next three days, Baluchistani forces mounted a series of unsuccessful small-scale attacks aimed at probing and penetrating the Arrakeen positions. At dawn on the 15th of September, the Baluchistanis rolled forward again in an armored thrust to reach the vital passes. Having gained time to harden and reinforce their defensive positions, the Arrakeen divisions easily defeated the Baluchistani attack.

Map 2: September 16-18, 1983

On the morning of 16 September, Uri's division advanced to a point opposite Linah at the tip of Lake Juhaym, where Arrakeen reconnaissance had found a weak point in the Baluchistani defenses. In an effort to open up a corridor through which heavy bridging equipment could be moved, Uri ordered a diversionary attack by Suled's brigade. This attack effectively masked Uri's main move to the west, enabling him to maneuver around the Baluchistani flank and to capture crossing sites along the canal.

On 17 September, Breher's brigade became heavily engaged as the Baluchistanis attempted to close the Al Asat Corridor. That same day, Khalid's brigade poured across the canal, and was virtually unopposed as it enlarged the Arrakeen bridgehead. Throughout that night and through the morning of the 18th, Uri's thinly manned shoulder held on stubbornly as the Arrakeens broke up repeated attacks from the north. Meanwhile, Harman and Ebron withdrew from their defensive positions and headed towards the crossing sites.

Map 3: September 18-22, 1983

Despite constant air attack and artillery bombardment, the Al Asat Corridor remained open and Ebron and Harman moved their divisions across the canal and into Baluchistan. Once across the canal, the Arrakeen tankers easily overcame local resistance and fanned out to occupy positions at the base of the Bodrat Hills. With their main force on the east bank of the canal, the Baluchistanis were unable to stop the Arrakeen armor from operating at will in their rear areas. On 22 September, with their 2nd Army completely encircled and the city of Port Haradh under seige, the government of Baluchistan sought a cease-fire agreement to end the hostilities.

Questions: The Arrakeen Crossing

1. The Arrakeens responded to the Baluchistani attack with 6 armor divisions (Map 1).
2. Uri's division consisted of armor, mechanized infantry, and airborne infantry brigades (Map 2).
3. The Baluchistani 1st Army established defensive positions only along the Hawran and Tobal Ridges (Map 2).
4. Elements of Uri's division counterattacked the invading Baluchistanis during 10-15 September, captured crossing sites along the canal on 16 September, made the initial canal crossing on 17 September, and by 22 September were threatening the city of Port Haradh (Maps 1-3).
5. By 16 September, Harman's armor division had halted the advance of nearly the entire Baluchistani 2nd Army (Maps 1-2).
6. Breher and Suled's attack on the Baluchistani defenses protected Khalid's brigade as it crossed the canal (Map 2).
7. Khalid was forced to respond to an attack on his left flank prior to crossing the canal (Map 2).
8. As Ebron moved on Port Haradh, he was restricted to the roads by the difficult terrain west of the Dukhan Hills (Map 3).
9. It was the impassable terrain, and not the Arrakeen forces, which halted the Baluchistani attack west of Parallel Road (Map 1).
10. The Haradh Canal was quickly crossed by the Baluchistanis in their initial assault, the Baluchistanis never considered the canal to be a significant obstacle (Maps 1-3).
11. Lake Juhaym effectively protected the Arrakeen's left flank as they crossed the canal (Maps 2-3).
12. Although the passes through the Mushash Mountains were Baluchistani objectives, it is unlikely that the Arrakeens considered them key terrain features as well (Map 1).
13. As Khalid enlarged the Arrakeen bridgehead, the city of Linah was bypassed in favor of securing both the town of Ma 'Qala and the hills west of the canal (Map 2).
14. The Hawran, Tobal, and Rawah ridges east of the canal were intermediate Baluchistani objectives in their drive towards the Zard Pass (Map 1).
15. In theory, Uri's occupation of the high ground at Basra, Magwa, Nisab and Ashur would be only marginally effective in blocking reinforcements from the north. Baluchistani armor reserves could easily have bypassed Uri by maneuvering southward through the Bodrat Hills (Map 3).

Make no marks in this test booklet.

Figure 15. Instructions, narrative, and questions used in the non-interpreted terrain version of Part II *(Reduced from the original 8.5" by 14" format).*

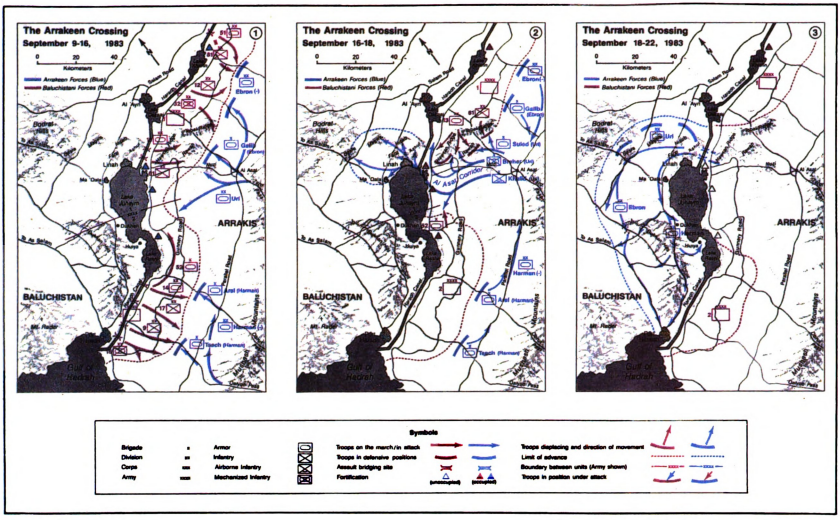


Figure 16. Non-interpreted terrain configuration of test maps used in Part II
(Reduced from the original 8.5" by 14" format).

Part II: The Arrakeen Crossing

Instructions:

The map on the facing page and its accompanying narrative describe a fictional battle. Fifteen statements pertaining to this battle are listed below. You are to study the map and the narrative and then determine whether each statement is true or false. You should mark your response on your answer sheet. If you cannot tell whether a statement is true or false, then you should mark your answer sheet accordingly.

Narrative: The Arrakeen Crossing

Map 1: September 9-16, 1983

At 1745 hours on 9 September 1983, 11 divisions of the Baluchistani 1st and 2nd Armies mounted a surprise assault crossing of the Haradh Canal. The objective of the Baluchistani commander was to defeat Arrakeen forces along the canal, to secure a bridgehead, and to secure a route through the Mushash Mountains. Arrakeen defenses along the canal consisted of a series of heavily fortified, lightly manned positions; these positions were quickly overcome by the attacking Baluchistanis.

The following morning, 3 Arrakeen reserve armored divisions under Uri, Ebron, and Harman mounted a coordinated counterattack in an attempt to roll up the Baluchistani bridgehead. The attack skirted the impassable terrain lying east of Parallel Road. The attack failed and the Arrakeens were forced to establish hasty defensive positions west of Parallel Road.

Throughout the next three days, Baluchistani forces mounted a series of unsuccessful small-scale attacks aimed at probing and penetrating the Arrakeen positions. At dawn on the 15th of September, the Baluchistanis rolled forward again in an armored thrust to reach the vital passes. Having gained time to harden and reinforce their defensive positions, the Arrakeen divisions easily defeated the Baluchistani attack.

Map 2: September 16-18, 1983

On the morning of 16 September, Uri's division advanced to a point opposite Lnah at the tip of Lake Juhaym, where Arrakeen reconnaissance had found a weak point in the Baluchistani defenses. In an effort to open up a corridor through which heavy bridging equipment could be moved, Uri ordered a diversionary attack by Suled's brigade. This attack effectively masked Uri's main move to the west, enabling him to maneuver around the Baluchistani flank and to capture crossing sites along the canal.

On 17 September, Breher's brigade became heavily engaged as the Baluchistanis attempted to close the Al Asat Corridor. That same day, Khalid's brigade poured across the canal, and was virtually unopposed as it enlarged the Arrakeen bridgehead. Throughout that night and through the morning of the 18th, Uri's thinly manned shoulder held on stubbornly as the Arrakeens broke up repeated attacks from the north. Meanwhile, Harman and Ebron withdrew from their defensive positions and headed towards the crossing sites.

Map 3: September 18-22, 1983

Despite constant air attack and artillery bombardment, the Al Asat Corridor remained open and Ebron and Harman moved their divisions across the canal and into Baluchistan. Once across the canal, the Arrakeen tankers easily overcame local resistance and fanned out to occupy positions at the base of the Bodrat Hills. With their main force on the east bank of the canal, the Baluchistanis were unable to stop the Arrakeen armor from operating at will in their rear areas. On 22 September, with their 2nd Army completely encircled and the city of Port Haradh under siege, the government of Baluchistan sought a cease-fire agreement to end the hostilities.

Questions: The Arrakeen Crossing

1. The Arrakeens responded to the Baluchistani attack with 6 armor divisions **(Map 1).**
2. Uri's division consisted of armor, mechanized infantry, and airborne infantry brigades **(Map 2).**
3. The Baluchistani 1st Army established defensive positions only along the Hawran and Tobal Ridges **(Map 2).**
4. Elements of Uri's division counterattacked the invading Baluchistanis during 10-15 September, captured crossing sites along the canal on 16 September, made the initial canal crossing on 17 September, and by 22 September were threatening the city of Port Haradh **(Maps 1-3).**
5. By 16 September, Harman's armor division had halted the advance of nearly the entire Baluchistani 2nd Army **(Maps 1-2).**
6. Breher and Suled's attack on the Baluchistani defenses protected Khalid's brigade as it crossed the canal **(Map 2).**
7. Khalid was forced to respond to an attack on his left flank prior to crossing the canal **(Map 2).**
8. As Ebron moved on Port Haradh, he was restricted to the roads by the difficult terrain west of the Dukhan Hills **(Map 3).**
9. It was the impassable terrain, and not the Arrakeen forces, which halted the Baluchistani attack west of Parallel Road **(Map 1).**
10. The Haradh Canal was quickly crossed by the Baluchistanis in their initial assault; the Baluchistanis never considered the canal to be a significant obstacle **(Maps 1-3).**
11. Lake Juhaym effectively protected the Arrakeen's left flank as they crossed the canal **(Maps 2-3).**
12. Although the passes through the Mushash Mountains were Baluchistani objectives, it is unlikely that the Arrakeens considered them key terrain features as well **(Map 1).**
13. As Khalid enlarged the Arrakeen bridgehead, the city of Lnah was bypassed in favor of securing both the town of Ma 'Qala and the hills west of the canal **(Map 2).**
14. The Hawran, Tobal, and Rawah ridges east of the canal were intermediate Baluchistani objectives in their drive towards the Zard Pass **(Map 1).**
15. In theory, Uri's occupation of the high ground at Basra, Magwa, Nisab and Ashur would be only marginally effective in blocking reinforcements from the north; Baluchistani armor reserves could easily have bypassed Uri by maneuvering southward through the Bodrat Hills **(Map 3).**

Make no marks in this test booklet.

Figure 17. Instructions, narrative, and questions used in the interpreted terrain version of Part II *(Reduced from the original 8.5" by 14" format).*

Figure 17. Instructions, narrative, and questions used in the interpreted terrain version of Part II *(Reduced from the original 8.5" by 14" format).*

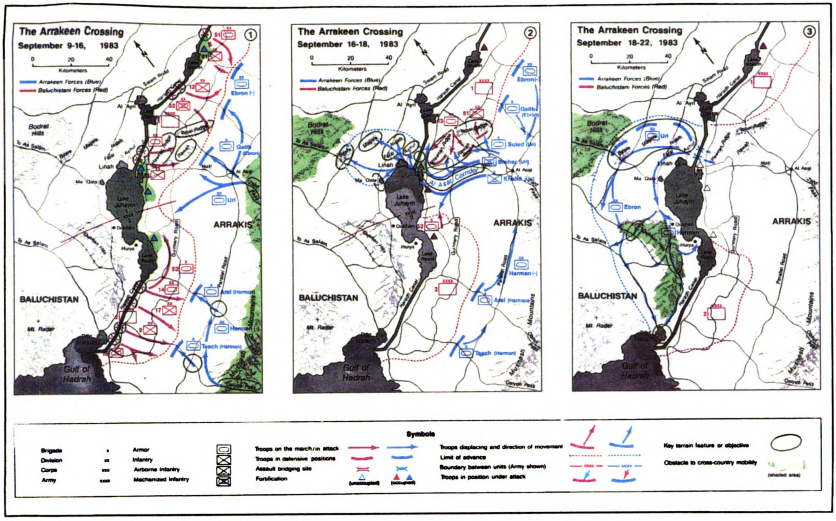


Figure 18. Interpreted terrain configuration of test maps used in Part II *(Reduced from the original 8.5" by 14" format).*

Part III: Defense of the Logone Plateau

Instructions:

The map on the facing page and its accompanying narrative describe a fictional battle. Fifteen statements pertaining to this battle are listed below. You are to study the map and the narrative and then determine whether each statement is true or false. You should mark your response on your answer sheet. If you cannot tell whether a statement is true or false, then you should mark your answer sheet accordingly. Note that the map on the facing page does not provide additional terrain information (typically shown in green). If possible, you are to infer this information from the base map, the disposition of forces as shown on the map, and the narrative.

Narrative: The Defense of the Logone Plateau

Map 1: August 6-9, 1981

At 1400 hours on 6 August 1981, Baganese forces launched an attack on Kadunian positions along the Logone Plateau. The Baganese plan called for forward divisions to breach Kadunian defenses, after which reserve divisions would penetrate through the gaps down to the Mondo River. The main weight of the attack was to be through the Buna Gap; units would then branch off to secure the southern bridges over the River Mondo and to block reinforcements from the east of Lake Marsabit. Simultaneous attacks would occur through the Tsavo and Din Gaps in the north, furthermore, there would be a heliborne assault on the Mt. Kilifi observation post.

The two Kadunian brigades occupying the Logone, Elat's 77th in the north and Omur's 13th in the south, fought fiercely against overwhelming numbers. Omur's brigade was destroyed, but it provided the time necessary for Kabar and Ranal to mobilize and halt the advance. In the center, the Baganese 2nd division passed through the breach in the Buna Gap, but was halted west of Oil Road. In the north, Elat positioned his unit along the Zari Ridge and destroyed Baganese forces as they successively attacked through the Tot Valley. A Kadunian attempt to regain Mt. Kilifi on 9 August failed.

Map 2: August 9-11, 1981

By 9 August, reserves were flooding into the area as the Kadunians attempted to consolidate their forces. The Kadunian commander had decided to push the enemy back into his own territory, before possible Gombari reinforcements could turn the tide back into Baganese favor. Kadunian forces reoccupied border positions as the Baganeses forces regrouped in anticipation of a Kadunian counterattack.

The Kadunian plan called for Delep to lead the attack in the north, break into the Baganese positions on their 4th division's front, and then push as fast as possible to Campari Ridge. Ranal was to attack eastwards and secure the road junctions leading to Arusha. In the south, Kabar was to fix the 6th Baganese division in place. Furthermore, another attempt would be made to recapture Mt. Kilifi.

Map 3: August 11-19, 1981

At 1200 hours on 12 August, Delep initiated the Kadunian attack. Presenting tough resistance, the 4th Baganese division gave ground slowly. In the center, Ranal's division set about the task of cracking Baganese positions and slowly forced the 5th division northward to Campari Ridge. On 17 August, Gombari armor was observed racing northward to aid the stricken Baganese. Ranal turned southward, occupied ambush positions, and forced a Gombari retreat. That same day, Kabar launched an attack in the south in an effort to widen the breakthrough.

By 19 August, Bagana was no longer able to mount a significant threat to the Kadunians, although they had effectively blocked any further penetration into their territory. The Kadunians, having defeated the Baganese and seeing no gain through further territorial additions, agreed to a cease-fire and withdrew to the original international border.

Questions: Defense of the Logone Plateau

1. Two Kadunian mechanized infantry brigades initially occupied the Logone Plateau **(Map 1)**.

2. Each of the 3 forward Baganese divisions were a balanced (equal) mix of armor and mechanized infantry brigades **(Map 1)**.

3. The 179th Armor Brigade attacked the Mt. Kilifi observation post and held it through 11 August **(Maps 1-3)**.

4. Elements of the Baganese 5th Division failed to reach Oil Road by 9 August, subsequently withdrew, and by 19 August had occupied a strongpoint on the Campari Ridge **(Maps 1-3)**.

5. Ranal and Kabar's Kadunian divisions halted the advance of the Baganese 1st, 5th and 6th divisions **(Map 1)**.

6. Ranal's defeat of the Gombari armor on 17 August effectively protected Delep's right flank, allowing Delep to continue the attack **(Map 3)**.

7. The steep high ground in the north protected Delep's left flank during his attack on the Baganese 4th Division **(Map 3)**.

8. The Kadunian fortifications east of Pemba Road did not pose an obstacle to the cross-country mobility of the attacking Baganese 5th Division **(Map 1)**.

9. Much of the movement on the Logone Plateau was restricted to roads due to the roughness and compartmentalization of the terrain **(Maps 1-3)**.

10. Initial Kadunian attempts to regain Mt. Kilifi failed because they attacked with infantry; the terrain was equally suited to an armor attack **(Maps 1-2)**.

11. 3 Baganese brigades entered Elat's engagement area in the Tot valley and were subsequently destroyed **(Map 1)**.

12. The 5th Baganese Division, counterattacking from its strongpoint, attacked Ranal's division once it entered an engagement area **(Map 3)**.

13. An initial objective of the Baganese 4th Division was to seize the Tot Valley **(Map 1)**.

14. Control of the Tsavo, Din, and Buna Gaps was key only to the initial Baganese attack during 6-9 August, and not to the Kadunian counterattack during 9-11 August **(Maps 1-2)**.

15. It is likely that the Gombari commander considered the outcrops at Keli, Wyasi and Dewa as key terrain in his planned attack into the flanks of Ranal's division **(Map 3)**.

Make no marks in this test booklet.

Figure 19. Instructions, narrative, and questions used in the non-interpreted terrain version of Part III *(Reduced from the original 8.5" by 14" format).*

to the original international border.

Make no marks in this test booklet.

Figure 19. Instructions, narrative, and questions used in the non-interpreted terrain version of Part III *(Reduced from the original 8.5" by 14" format).*

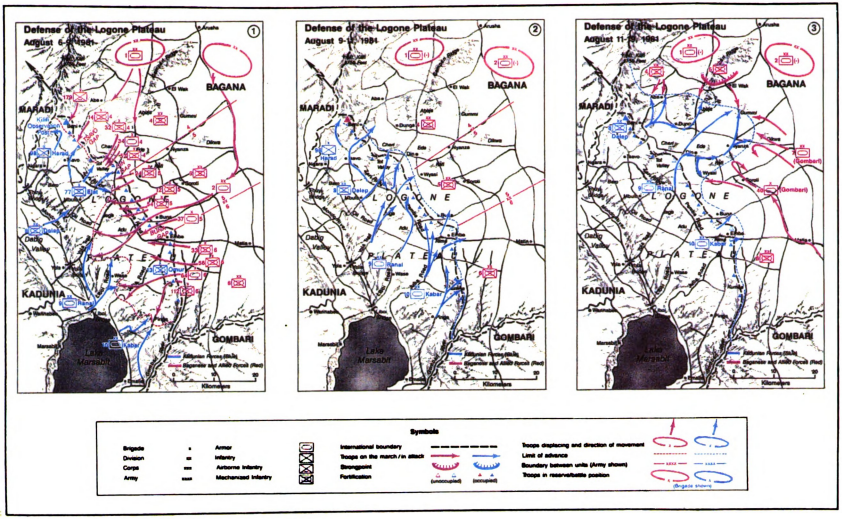


Figure 20. Non-interpreted terrain configuration of test maps used in Part III *(Reduced from the original 8.5" by 14" format).*

Part III: Defense of the Logone Plateau

Instructions:

The map on the facing page and its accompanying narrative describe a fictional battle. Fifteen statements pertaining to this battle are listed below. You are to study the map and the narrative and then determine whether each statement is true or false. You should mark your response on your answer sheet. If you cannot tell whether a statement is true or false, then you should mark your answer sheet accordingly.

Narrative: The Defense of the Logone Plateau

Map 1: August 6-9, 1981

At 1400 hours on 6 August 1981, Baganese forces launched an attack on Kadunian positions along the Logone Plateau. The Baganese plan called for forward divisions to breach Kadunian defenses, after which reserve divisions would penetrate through the gaps down to the Mondo River. The main weight of the attack was to be through the Buna Gap; units would then branch off to secure the southern bridges over the River Mondo and to block reinforcements from the east of Lake Marsabit. Simultaneous attacks would occur through the Tsavo and Din Gaps in the north; furthermore, there would be a heliborne assault on the Mt. Kilifi observation post.

The two Kadunian brigades occupying the Logone, Efat's 77th in the north and Omur's 13th on the south, fought fiercely against overwhelming numbers. Omur's brigade was destroyed, but it provided the time necessary for Kabar and Ranal to mobilize and halt the advance. In the center, the Baganese 2nd division passed through the breach in the Buna Gap, but was halted west of Oil Road. In the north, Efat positioned his unit along the Zari Ridge and destroyed Baganese forces as they successively attacked through the Tot Valley. A Kadunian attempt to regain Mt. Kilifi on 9 August failed.

Map 2: August 9-11, 1981

By 9 August, reserves were flooding into the area as the Kadunians attempted to consolidate their forces. The Kadunian commander had decided to push the enemy back into his own territory, before possible Gombari reinforcements could turn the tide back into Baganese favor. Kadunian forces re-occupied border positions as the Baganeses forces regrouped in anticipation of a Kadunian counterattack.

The Kadunian plan called for Delep to lead the attack in the north, break into the Baganese positions on their 4th division's front, and then push as fast as possible to Campari Ridge. Ranal was to attack eastwards and secure the road junctions leading to Arusha. In the south, Kabar was to fix the 6th Baganese division in place. Furthermore, another attempt would be made to recapture Mt. Kilifi.

Map 3: August 11-19, 1981

At 1200 hours on 12 August, Delep initialed the Kadunian attack. Presenting tough resistance, the 4th Baganese division gave ground slowly. In the center, Ranal's division set about the task of cracking Baganese positions and slowly forced the 5th division northward to Campari Ridge. On 17 August, Gombari armor was observed racing northward to aid the stricken Baganese. Ranal turned southward, occupied ambush positions, and forced a Gombari retreat. That same day, Kabar launched an attack in the south in an effort to widen the breakthrough.

By 19 August, Bagana was no longer able to mount a significant threat to the Kadunians, although they had effectively blocked any further penetration into their territory. The Kadunians, having defeated the Baganese and seeing no gain through further territorial additions, agreed to a cease-fire and withdrew to the original international border.

Questions: Defense of the Logone Plateau

1. Two Kadunian mechanized infantry brigades initially occupied the Logone Plateau **(Map 1)**.

2. Each of the 3 forward Baganese divisions were a balanced (equal) mix of armor and mechanized infantry brigades **(Map 1)**.

3. The 179th Armor Brigade attacked the Mt. Kilifi observation post and held it through 11 August **(Maps 1-3)**.

4. Elements of the Baganese 5th Division failed to reach Oil Road by 9 August, subsequently withdrew, and by 19 August had occupied a strongpoint on the Campari Ridge **(Maps 1-3)**.

5. Ranal and Kabar's Kadunian divisions halted the advance of the Baganese 1st, 5th and 6th divisions **(Map 1)**.

6. Ranal's defeat of the Gombari armor on 17 August effectively protected Delep's right flank, allowing Delep to continue the attack **(Map 3)**.

7. The steep high ground in the north protected Delep's left flank during his attack on the Baganese 4th Division **(Map 3)**.

8. The Kadunian fortifications east of Pemba Road did not pose an obstacle to the cross-country mobility of the attacking Baganese 5th Division **(Map 1)**.

9. Much of the movement on the Logone Plateau was restricted to roads due to the roughness and compartmentalization of the terrain **(Maps 1-3)**.

10. Initial Kadunian attempts to regain Mt. Kilifi failed because they attacked with infantry; the terrain was equally suited to an armor attack **(Maps 1-2)**.

11. 3 Baganese brigades entered Efat's engagement area in the Tot valley and were subsequently destroyed **(Map 1)**.

12. The 5th Baganese Division, counterattacking from its strongpoint, attacked Ranal's division once it entered an engagement area **(Map 3)**.

13. An initial objective of the Baganese 4th Division was to seize the Tot Valley **(Map 1)**.

14. Control of the Tsavo, Din, and Buna Gaps was key only to the initial Baganese attack during 6-9 August, and not to the Kadunian counterattack during 9-11 August **(Maps 1-2)**.

15. It is likely that the Gombari commander considered the outcrops at Keli, Wyasi and Dikwa as key terrain in his planned attack into the flanks of Ranal's division **(Map 3)**.

Make no marks in this test booklet.

Figure 21. Instructions, narrative, and questions used in the interpreted terrain version of Part III *(Reduced from the original 8.5" by 14" format).*

Figure 21. Instructions, narrative, and questions used in the interpreted terrain version of Part III
(Reduced from the original 8.5" by 14" format).

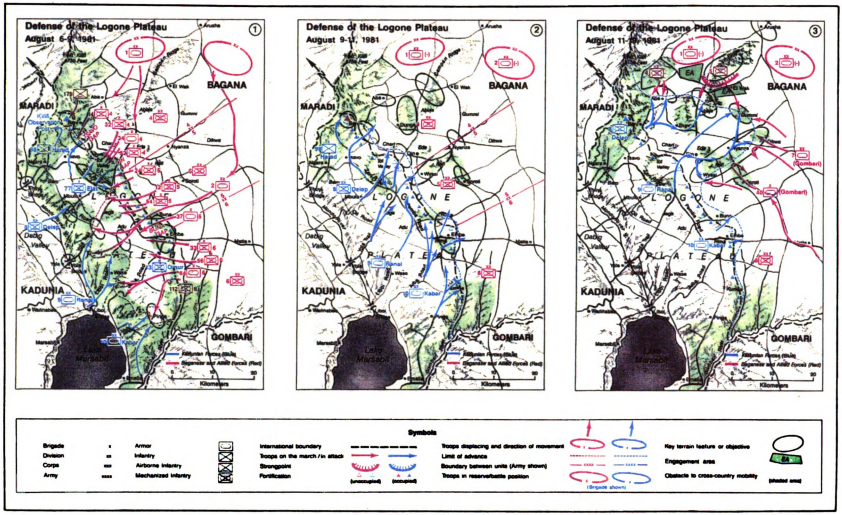


Figure 22. Interpreted terrain configuration of test maps used in Part III
(Reduced from the original 8.5" by 14" format).

historical geography. Test questions for these parts were designed to evaluate the subjects' comprehension of the relative position, movement and combat power of the battle participants, the sequence and importance of battlefield events, and the impact of terrain on the outcome of battle. As in Part I, questions were arranged in a hierarchy of difficulty, but were of the "true-false" variety. In order to discourage subjects from guessing, a "cannot answer" option was provided.

Six categories of test questions were formulated for Parts II and III. Confronted with an actual study scenario, it was expected that the legend viewed in Part I would influence the subjects' test performance. In order to assess the impact of legend type on subject comprehension, the first three categories of questions were identical to those used in Part I.

The last three categories of questions were designed to assess the subjects' understanding of the impact of terrain on the outcome of battle. An understanding of three military aspects of terrain were evaluated. The first category asked subjects to identify obstacles to unit movement, the second category required that subjects identify engagement areas, and the third category required that subjects locate key terrain features and likely unit objectives.

Written instructions for each part were designed to eliminate as many misinterpretations and incomplete responses by test subjects as possible. Instructions for those configurations lacking interpreted terrain information differed slightly from the others; for these configurations, subjects were instructed to base their terrain analysis

on the topography and disposition of forces as shown on the base map, as well as the narrative.

Part IV of the test was a questionnaire designed to assess the subjects' expertise and interest in battlefield mapping and in the study of military historical geography. Subjects were asked to identify recent duty positions requiring familiarity with military symbols, graphics, and operational terms. Subjects were also asked to rate their familiarity with military symbols, their interest in the subject matter, and the usefulness of maps in the study of military history or military geography. Subjects were asked for their opinion regarding the content, quality and administration of the test. The questionnaire is shown in Appendix A.

Forty test booklets, ten per configuration, were produced in the Michigan State University Center for Cartographic Research and Spatial Analysis. Consent forms. answer sheets and questionnaires were inserted into the completed test booklets prior to distribution to test subjects. The answer sheet and consent form used in the test are in Appendices B and C, respectively.

A small preliminary test with six subjects was conducted to determine whether the experiment was reasonable in terms of difficulty, and to determine the time necessary to complete each test part. It was found that subjects had little difficulty in understanding the instructions, and that approximately 12 to 15 minutes were required to complete each part, I through III. Five minutes were required to complete the questionnaire. Pre-test subjects were slightly confused by the requirements for Part IA, "Unit Symbol Construction," and advised that a basic symbol "box" be added to the answer sheet for this section.

Test Administration

In order to assure a wide range of task-related experience, subjects were drawn from the Regular Army, the U.S. Army Reserve. the Michigan Army National Guard, and the Michigan State University Reserve Officer's Training Corps. The test sample composition by participating organization is shown in Table 3.

The test was administered at various unit locations to 186 soldiers and cadets. The conduct of the test was under normal viewing conditions in large unit classrooms, where subjects had room to spread out the test materials. A typical testing environment is shown in Figure 23. In order to assure an equal distribution of ranks among the test groups, booklets were first distributed to officers and cadets, then to non-commissioned officers, and lastly, to other enlisted personnel. The group composition by grade is in Table 4.

The test was administered using a prepared script (Appendix D) and administrative assistance was provided by each unit. A brief oral introduction was given to the subjects before distributing the test booklets. The introduction included a short description of battlefield maps and their uses and an explanation of the purpose of the experiment. Fifteen minutes were allotted to complete each part of the test, and the elapsed time was provided at five minute intervals; a two minute warning was also provided. Test subjects were not allowed to work on any part of the test other than the one directed, although they were allowed to examine the legend in Part I while working on Parts II or III. Consent forms were collected prior to testing in order to maintain anonymity of the test subjects; all other test materials were collected upon

Table 3. Test Sample Composition by Participating Organization.
Organization, test site and number and grade composition of participants are shown.

	17th Engineer Bn. (Combat)	4th Bn.,20th Field Artillery	119th Field Artillery Bn.	HSU ROTC Spartan Bn.
Component	Regular Army	US Army Reserve	Michigan Army National Guard	Army ROTC
Test Site Location	Ft. Hood, TX	Lansing, MI	Lansing, MI	HSU Campus
Participants:				
Commissioned Officers	6	5	4	0
Non-Commissioned Officers	13	17	12	0
Enlisted Personnel	33	51	12	0
ROTC Cadets	0	3	1	20
TOTAL	52	76	29	20

Figure 23. A typical testing environment. Soldiers of the 4th Battalion, 20th Field Artillery (U.S. Army Reserve) participate in the experiment.

Table 4. Group Composition by Grade. *Number of subjects in each grade category are shown by group.*

Grade Category	Group 1 (n=46)	Group 2 (n=42)	Group 3 (n=45)	Group 4 (n=44)
Commissioned Officers:				
Field Grade Officers *Major - Colonel*	0	0	1	0
Company Grade Officers *2nd Lieut. - Captain*	3	4	3	4
Non-Commissioned Officers:				
Senior NCOs *Sergeant First Class - Master Sergeant*	1	1	1	1
Junior NCOs *Sergeant - Staff Sergeant*	11	9	9	9
Enlisted Personnel: *Private - Specialist*	26	23	24	23
ROTC Cadets: *Freshmen - Seniors*	5	5	7	7

completion of the test. Color deficient subjects were asked to identify themselves prior to testing and were released from participation.

Upon completion of the experiment, tests with incomplete responses, and those in which the instructions were not followed, were discarded. Nine tests were eliminated, resulting in a total sample of 177 subjects.

CHAPTER III

DATA ANALYSIS AND RESULTS

Introduction

Quantitative measures were used to examine the influence of three variables on battlefield map effectiveness. The method of terrain representation and method of symbol explanation and legend type are addressed in relation to: (1) their effects on symbol understanding and overall integration of map information, (2) their combined effects on overall test performance, (3) their individual effects on performance of specific map reading tasks, and (4) their effects on communication failure. The latter part of this chapter addresses the effects of experience and interest on test performance.

Effects on Symbol Understanding and Overall Integration of Map Information

The first objective of this study was to determine the extent to which battlefield map effectiveness is influenced by the form of symbol explanation; communication effectiveness was hypothesized to be greatest amongst subjects viewing a natural legend and illustration of symbol construction. The central tendency of the responses for symbol construction and matching tasks in Part I, "Battlefield Map Symbols," was determined and the mean percentage of correct responses for groups viewing each of the legend types in Part I was compared. The Student's T Test was used to determine whether a significant difference in mean values existed.

Table 5 shows the results for the symbol construction section of Part I. Natural legend groups achieved greatest accuracy when asked to construct a military unit symbol, yielding scores significantly higher than the conventional legend groups.

Results were similar for the matching portion of Part I (Table 6). As expected, the natural legend groups scored significantly higher than did conventional legend groups in the simple symbol identification category. The natural legend groups also scored higher in both categories requiring overall integration of map information. The category requiring the visualization of complex relationships between map elements yielded statistically significant results; despite the statistical insignificance of the results in the second category, the directionality of the results still suggests the possibility that associations between unit and operational symbols is improved when a natural legend is viewed. The results from Part I alone strongly suggest that map symbol understanding is improved when a natural legend and illustration of symbol construction is used.

Combined Effects on Overall Test Performance

A second objective of this study was to determine the extent to which effectiveness is governed by the method of terrain representation. Communication effectiveness was hypothesized to be greatest among subjects viewing maps in which the military aspects of terrain were interpreted and presented as an additional category of thematic information. Only the last three categories of questions asked in Parts II and III were directed towards an understanding of the effects of terrain on the outcome of battle; the first three categories were directed towards symbol understanding and overall integration of map

Table 5. Effects of Legend Type on Subjects' Ability to Construct a Military Unit Symbol. *Mean percentage of correct responses by military unit symbol component are compared.*

Symbol Component	*Conventional Legend* Percent Correct	*Natural Legend* Percent Correct	Student's T * *Significant at α=.05*
Unit Designation	65.9%	83.7%	2.852 *
Unit Size	35.2%	66.8%	4.425 *
Higher Echelons	45.4%	61.7%	2.857 *
Unit Role	77.3%	90.4%	2.478 *
Unit Skill	78.4%	88.2%	1.762 *
Overall	60.5%	78.2%	4.167 *

Table 6. Effects of Legend Type on Subjects' Ability to Match Symbols to Associated Descriptions. *Mean percentage of correct responses by map reading task category are compared.*

Category/ Question	*Conventional Legend* Percent Correct	*Natural Legend* Percent Correct	Student's T * *Significant at α=.05*
Category I: Identify Symbol Type & Function	72.7%	86.9%	3.560 *
Category II: Identify Unit with Activity	64.5%	71.9%	1.546 NS
Category III: Visualize Complex Relationships	64.4%	75.7%	2.116 *
Part IB Overall	66.9%	77.5%	2.605 *

information and were identical to those in Part I. The overall results from Parts II and III can therefore be interpreted as the combined effects of legend type and method of terrain representation on battlefield map understanding.

Evaluation of the influence of each variable on map effectiveness was again accomplished through a statistical comparison of mean percentage of correct responses (Table 7). Groups with varied legend types and similar methods of terrain representation were compared first; for the simple battlefield map display in Part II, groups using the natural legend scored significantly higher than those using the conventional legend. Natural legend groups also scored higher with the complex map display in Part III, but the differences were not statistically significant.

The next comparison was between groups with varied methods of terrain representation and similar legend types. It was found that in each case, groups viewing the interpreted terrain representation scored significantly higher than those viewing the non-interpreted terrain representation.

By comparing the remaining configurations of legend types and methods of terrain representation, it was found that the interpretive method of terrain representation yielded higher scores in nearly all cases, regardless of the type of legend viewed. Statistically significant differences occurred only with the combination of natural legend type and interpreted terrain representation.

In order to gain an understanding of how legend type relates to subsequent battlefield map effectiveness in a simulated study environment, performance on Part I was correlated with performance on

Table 7. Effects of Varying Legend Type and Method of Terrain Representation on Test Performance in Parts II and III. *Mean percentage of correct responses are compared by test part and group.*

Results of Varying Legend Type While Method of Terrain Representation is Held Constant

Groups Compared	Test Part.	*Type of Legend / Method of Terrain Representation*		Student's T * Significant at α=.05
1 vs. 3	Part II	*Conventional/Interpreted* 61.9%	*vs. Natural/Interpreted* 71.1%	2.982 *
2 vs. 4	Part II	*Conventional/Non-Interpreted* 52.5%	*vs. Natural/Non-Interpreted* 63.6%	3.298 *
2 vs. 4	Part III	*Conventional/Interpreted* 58.6%	*vs. Natural/Interpreted* 63.5%	1.487 NS
1 vs. 3	Part III	*Conventional/Non-Interpreted* 52.5%	*vs. Natural/Non-Interpreted* 53.9%	0.539 NS

Results of Varying Method of Terrain Representation While Type of Legend is Held Constant

Groups Compared	Test Part	*Method of Terrain Representation / Type of Legend*		Student's T * Significant at α=.05
2 vs. 1	Part II	*Non-Interpreted/Conventional* 52.5%	*vs. Interpreted/Conventional* 61.9%	2.798 *
4 vs. 3	Part II	*Non-Interpreted/Natural* 63.6%	*vs. Interpreted/Natural* 71.1%	2.390 *
1 vs. 2	Part III	*Non-Interpreted/Conventional* 52.5%	*vs. Interpreted/Conventional* 58.6%	1.901 *
3 vs. 4	Part III	*Non-Interpreted/Natural* 53.9%	*vs. Interpreted/Natural* 63.5%	3.389 *

Results of Varying Both Type of Legend and Method of Terrain Representation

Groups Compared	Test Part	*Type of Legend / Method of Terrain Representation*		Student's T * Significant at α=.05
2 vs. 3	Part II	*Conventional/Non-Interpreted* 52.5%	*vs. Natural/Interpreted* 71.1%	6.548 *
4 vs. 1	Part II	*Natural/Non-Interpreted* 63.6%	*vs. Conventional/Interpreted* 61.9%	0.488 NS
1 vs. 4	Part III	*Conventional/Non-Interpreted* 52.5%	*vs. Natural/Interpreted* 63.5%	3.610 *
3 vs. 2	Part III	*Natural/Non-Interpreted* 53.9%	*vs. Conventional/Interpreted* 58.6%	1.552 NS

Table 8. Correlation Between Test Performance on Part I (Military Symbol Identification) and Test Performance on Parts II and III. *Spearman's Rank Order Correlation Coefficient (r) is used.*

	Part I *r*	Student's T * *Significant at α=.05*
Part II	0.615	10.312 *
Part III	0.350	4.943 *
Parts II & III Combined	0.626	10.619 *

subsequent parts of the test. Table 8 shows the results of these correlations; statistically significant positive correlations suggest that subsequent map effectiveness is strongly related to symbol understanding gained from the legend viewed.

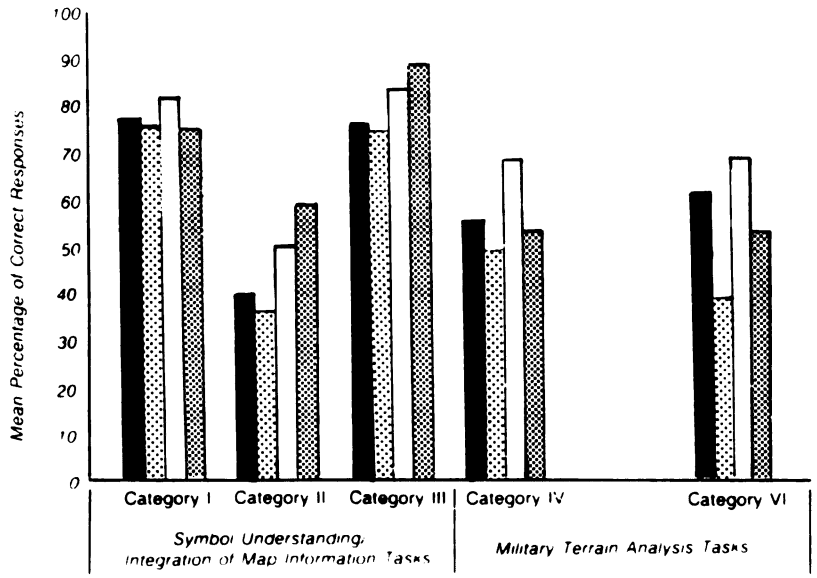
This initial analysis indicates that when a battlefield map user is confronted with a combination of tasks requiring symbol identification, integration of map information, and an understanding of the effects of terrain on the outcome of battle, then overall map effectiveness is influenced by both legend type and method of terrain representation. The findings specifically indicate that battlefield map effectiveness is significantly improved by the interpretive method of terrain representation and that the natural legend type significantly improves battlefield map understanding only in simple map displays. Finally, battlefield map effectiveness is most improved when the natural legend type is used in conjunction with the interpretive method of terrain representation.

Individual Effects on Performance of Specific Map Reading Tasks

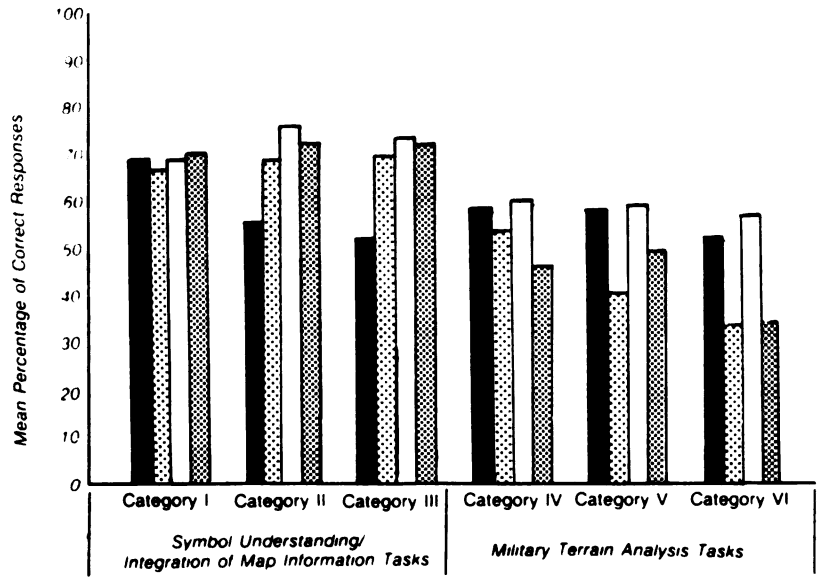
Mean correct responses were calculated by task category and statistically compared for each possible configuration of legend type and method of terrain representation. Figure 24 is a graphic summary of the results by each category of map reading task and for each configuration; detailed statistical summaries are found in Tables 13 through 17, Appendix E.

The interpretive method of terrain representation significantly improves performance in most terrain analysis tasks without significantly degrading symbol understanding or overall integration of map information (Tables 13 and 14). In nearly all of the symbol understanding and integration of map information categories, the differences between group means were statistically insignificant. Furthermore, the directionality of the responses did not consistently favor any one method of terrain representation. These results suggest that any increased map complexity created by the addition of a separate category of terrain information does not significantly affect symbol understanding or overall integration of map information. As expected, the interpreted terrain method was most effective in performing military terrain analysis tasks; nearly all terrain analysis tasks yielded statistically significant results in favor of the interpretive method of terrain representation.

The results for each of the symbol understanding/ integration of map information categories suggests that the extent to which the natural legend type improves understanding is highly varied (Tables 15 and 16). The natural legend did not yield significantly higher scores in any of



Results from Part II: The Arrakeen Crossing
(Simple Map Series)



Results from Part III: The Defense of the Logone Plateau
(Complex Map Series)

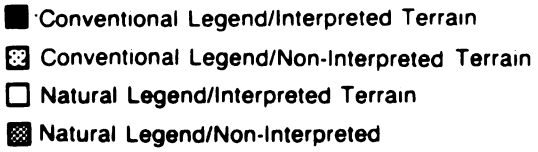


Figure 24. A graphic summary of the results by category of map reading task for each configuration of legend type and method of terrain representation. *The height of each bar represents the mean percentage of correct responses.*

the symbol identification tasks (category I) and, when paired with the interpreted terrain representation, failed to yield significant results in the simple map series (Table 16). An explanation for this particular result is that the interpreted terrain information reduces effectiveness in these categories by contributing "noise" to the map. Theoretically, the additional noise would adversely affect both conventional legend and natural legend groups; however, it was found that the conventional legend groups scored slightly higher when configured with the interpreted terrain representation. Another possibility is that the interpreted terrain method may have slightly improved performance in integration of map information tasks in a manner similar to the natural legend, hence the improved performance of the conventional legend groups.

The natural legend type appears to somewhat improve subjects' ability to perform some military terrain analysis tasks. However, the inconsistency of the results across similar task categories and different levels of map complexity suggest that the overall effectiveness of legend type on terrain interpretation is negligible.

A comparison between what may be termed the "worst case" and "best case" configurations (between combinations of conventional legend/non-interpreted terrain representation and natural legend/interpreted terrain representation) yielded fewer insignificant results across all categories than any comparison thus far (Table 17). These results suggest once again that <u>overall</u> battlefield map effectiveness is most improved by a combination of a natural legend and interpreted terrain representation. By comparing configurations of conventional legend/interpreted terrain representation and natural legend/non-

interpreted terrain representation, the broad categories in which each variable is most effective is clarified; the natural legend yielded higher scores in nearly all symbol understanding and integration tasks, whereas the interpretive terrain method yielded higher scores in all military terrain analysis tasks (Table 17).

Effects on Communication Failure

Maps can fail to communicate information in several ways; they can fail to present information in a manner accessible to the reader (non-communication), they can relay incorrect information to the reader (mis-communication), or can be misinterpeted by the reader. An analysis by task category was performed in an effort to measure communication failure. Communication failure ratios were calculated by dividing the percent selection of "cannot answer" responses (a measure of uncertainty, and by extension, of non-communication) by the percent of total incorrect responses (a measure of failure). The ratios indicate the extent to which communication failure due to non-communication occurred. Figure 25 is a graphic summary of the results; detailed statistical summaries are found in Tables 18 and 19, Appendix E.

Several trends are apparent in Figure 25. First, communication ratios are fairly low throughout most categories. Assuming that the percent selection of "cannot answer" responses is a reliable measure of subject uncertainty, then the majority of lost effectiveness is attributable either to mis-communication or misinterpretation of information, and not to non-communication. There is no consistent pattern of relationships established by legend type alone. However, in the symbol understanding and integration tasks, there appears to be greater uncertainty among the conventional legend/non-interpreted

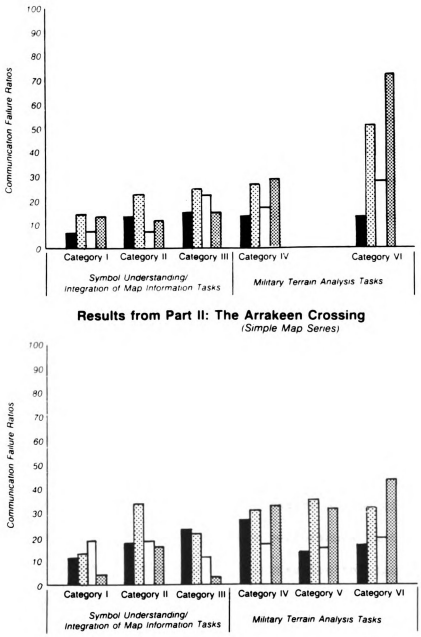


Figure 25. A graphic summary of communication failure ratios by map reading task for each configuration of legend type and method of terrain representation. *The height of each bar represents the communication failure ratio.*

terrain groups than among the natural legend/non-interpreted terrain groups; this trend reverses itself in the terrain interpretation tasks. As expected, non-communication is most evident in military terrain analysis tasks, especially among the non-interpreted terrain configurations.

A statistical comparison of overall test subject uncertainty by groups of varied configurations yielded several significant results (Table 19): (1) the natural legend type had lower values than the conventional legend type only when both were combined with the non-interpreted form of terrain representation, and (2) in all other comparisons, the interpretive terrain method had lower values, regardless of legend type or degree of map complexity. Furthermore, differences were most profound between configurations combining the natural legend with the interpreted terrain representation and those combining the conventional legend and non-interpreted terrain representation.

These results are consistent with earlier analyses and further suggest that not only does the interpretive method of terrain representation significantly improve performance in terrain analysis tasks, it does so by significantly increasing the amount of information obtainable from the map.

Effects of Experience and Interest on Test Performance

A final objective of this study was to determine the extent to which battlefield map effectiveness is influenced by the prior military experience or interest of the subject. It was hypothesized that effectiveness would be directly related to experience and interest.

Experience and interest were determined by questionnaire, the results of which are shown in Table 9.

The questionnaire not only solicited information which could be used to assess the subjects' experience and interest, but also sought the subjects' map preferences, as well as their opinions regarding the content, quality and administration of the experiment. The majority of the test sample came from the reserve components, whereas less than one-third came from the regular army. Few subjects (25.4%) rated themselves as unfamiliar with military symbols, graphics, or operational terms, yet most (64.4%) had not held a duty position requiring this familiarity. A somewhat disturbing result is that less than one-quarter of the subjects had been encouraged to study military history or military geography as part of their professional development. Although the majority of subjects (89.8%) indicated some level of interest in military history or military geography, only 11.3% had taken part in a course as part of their military or civilian education. Most subjects felt that maps were necessary in understanding military history or military geography, and the majority preferred the maps with the interpreted terrain information. When confronted with maps lacking interpreted terrain information, only 25.4% relied on their experience or training to perform military analysis tasks. Subjects were asked to rate the legend used in terms of its helpfulness in learning battlefield map symbols. The natural legend was rated slightly more helpful in learning battlefield map symbols than was the conventional legend. Most subjects found the narrative helpful in answering the questions, and found the test interesting. Subjects' comments most relevant to this study are shown in Table 9.

Table 9. Questionnaire Responses. ***Percent of subjects selecting particular responses are shown unless otherwise indicated.***

Military Component:

29.3%	Regular Army	15.8%	National Guard (Michigan)
41.3%	US Army Reserve	13.6%	Reserve Officer's Training Corps

Rank/Grade ***(Number of subjects by rank):***

96	Junior Enlisted Personnel *(Private through Specialist)*	24	Cadets *(Freshmen through Seniors)*
42	Non-Commissioned Officers *(Sergeant through Master Sergeant*	15	Commissioned Officers *(2nd Lieutenant through Colonel)*

Number of duty positions held requiring familiarity with military symbols, graphics and operational terms.

64.4%	No positions	8.5%	Two positions
20.3%	One position	6.8%	Three positions

Military Symbol Familiarity

4.0%	Expert	41.8%	Familiar
28.8%	Somewhat familiar	25.4%	Unfamiliar

Encouraged to study military history/military geography for professional development?

21.5%	Yes	78.5%	No

Partipated in military history/military geography course

11.3%	Yes	88.7%	No

Interest in military history/military geography

10.2%	Very interested	31.1%	Somewhat interested
24.8%	Interested	10.2%	Little interest/No opinion

Usefulness of maps in understanding military history/military geography

68.9%	Necessary	13.1%	Useful
10.7%	Very useful, but not necessary	5.6%	Somewhat useful
		1.7%	Useless

Effectiveness of legend in learning battlefield map symbols

Total Sample	*Conventional Legend Groups*	*Natural Legend Groups*	
48.0%	40.9%	55.1%	Very helpful
19.2%	25.0%	13.5%	Helpful
19.8%	20.5%	19.2%	Somewhat helpful
10.2%	11.3%	8.9%	Confusing
2.8%	2.3%	3.3%	Very confusing.

Table 9 (Continued). Questionnaire Responses.

Terrain analysis strategy for maps without interpreted terrain information

33.9% Relied on the map
21.5% Relied on the narrative
25.4% Relied on prior experience and training
12.4% Guessed
6.8% Did not answer

Preferred map form.

62.2% Maps with interpreted terrain information
9.6% Maps without interpreted terrain information
24.2% Both were equally effective
4.0% Both were equally ineffective

Effectiveness of narrative

17.5% Very helpful
33.9% Helpful
27.7% Helpful
20.9% Unnecessary

Opinions of the test

Difficulty		*Interest*		*Map Comprehension*	
37.8%	Difficult	52.0%	Interesting	18.1%	I understood the maps.
3.4%	Easy	6.2%	Boring	14.6%	The maps were confusing.

Narrative Comprehension		*Time Allotted*	
18.6%	I understood the narrative.	22.0%	Sufficient time was provided.
16.4%	The narrative was confusing.	23.2%	Insufficient time was provided.

Additional comments:

2.3% The test stimulated interest in military history/geography.
2.3% The subjects would have performed better with prior training.
1.7% The use of notional (foreign) names made the test difficult.
1.1% The test illustrated a useful way to teach map symbols.
0.6% Experience was needed in order to perform well.
0.6% The legend (conventional) could be improved.

Five variables were likely to be indicative of task-related experience or interest as applied to this study: (1) length of military service, (2) recent duty positions requiring familiarity with military symbols, graphics, and operational terms, (3) subjects' assessment of personal level of familiarity with military symbols, graphics, and operational terms, (4) subjects' assessment of personal level of interest in military history or military geography, and (5) formal education in military history or military geography.

In order to assess the relationship between experience or interest and battlefield map effectiveness, each of the variables were assigned either ratio-interval (actual years of service, duty positions, or military history/military geography courses) or ordinal values (a ranking of low to high familiarity or interest). Subsequently, each variable was correlated with test performance on each part of the test (Table 10). The results suggest that of the five experience or interest variables, only length of military service is not directly related to battlefield map effectiveness.

Results could be biased by an unequal distribution of experience or interest variables among groups of varied map configurations. Steps were taken during test administration to insure an approximate equal distribution of ranks throughout all groups; although this procedure may have increased the probability of an equal distribution of experience and interest, it did not guarantee it. An analysis of variance (ANOVA) was conducted to inspect for possible bias (Table 11). The between group variation for each of the experience or interest variables was found to be insignificantly different, suggesting that differences existing between groups are due to reasons other than experience or

Table 10. Correlations Between: Test Performance on Parts I, II and III; and Interest and Experience Variables. *Spearman's Rank Order Correlation Coefficient (r) is used; the test statistic is a One-Tail Student's T at α=.05.*

Variable	Part I	Part II	Part III	Total
Military Service	r=0.010 T=0.132 NS	r=0.016 T=0.212 NS	r=0.099 T=1.316 NS	r=0.045 T=0.596 NS
Duty Positions	r=0.325 T=4.546 *	r=0.189 T=2.546 *	r=0.197 T=2.658 *	r=0.326 T=4.562 *
Level of Familiarity	r=0.307 T=4.267 *	r=0.172 T=2.309 *	r=0.139 T=1.857 *	r=0.288 T=3.978 *
Level of Interest	r=0.368 T=5.236 *	r=0.305 T=4.905 *	r=0.165 T=2.213 *	r=0.206 T=5.236 *
Formal Education	r=0.195 T=2.630 *	r=0.132 T=1.762 *	r=0.116 T=1.545 *	r=0.206 T=2.785 *

* *Significant at α=.05*

Table 11. Test Sample Homogeneity. *Experience and interest variables are compared by group; the test statistic is the One-Way Analysis of Variance (ANOVA) F-Test at α=.05. Mean values are shown.*

Variable	Group 1 *(n=46)*	Group 2 *(n=42)*	Group 3 *(n=45)*	Group 4 *(n=44)*	ANOVA F * *Significant at α=.05*
Military Service	5.537	5.354	5.400	4.528	0.312 NS
Duty Positions	0.500	0.619	0.622	0.568	0.176 NS
Level of Familiarity	1.130	1.130	1.244	1.295	0.378 NS
Level of Interest	1.935	2.000	2.178	1.932	2.152 NS
Formal Education	0.109	0.095	0.089	0.295	0.455 NS

NS *Insignificant at α=.05*

interest, such as the configuration of legend type and method of terrain representation.

The next step in the analysis was to determine the extent to which each of the experience and interest variables influenced battlefield map effectiveness. Subject responses were grouped based on: (1) the number of recent task-related duty positions held; (2) proclaimed level of familiarity with military symbols, graphics, and operational terms; (3) formal education in military history or military geography; (4) proclaimed level of interest in military history or military geography. A series of analysis of variance F-tests and paired Student's T-tests by task category were subsequently performed between groups. Significant results are summarized in Table 12; detailed summaries are found in Appendix E (Tables 20 through 23).

The differences between group performance in tasks requiring symbol construction, symbol identification, and overall integration of map information (all of Part I, and categories I through III in Parts II and III) were found to be statistically significant in favor of the group with the most task-related experience, whereas the differences between group performance in terrain analysis tasks (categories IV through VI) were statistically insignificant (Table 20).

Similar results were found when subject responses were grouped and compared by proclaimed level of familiarity with military symbols, graphics and operational terms (Table 21) and by extent of formal education in military history or geography (Table 22). The difference between group means for terrain analysis tasks in the simple map series and for all tasks in the complex map series were statistically insignificant.

Table 12. Effect of Experience and Interest Variables on Test Performance. *Significant results and test statistics are shown by major task categories for each variable.*

Category/ Questions	Task-Related Duty *(ANOVA F)*	Proclaimed Familiarity *(ANOVA F)*	Formal Education *(Student's T)*	Proclaimed Interest *(ANOVA F)*
PART I: Military Symbol Identification				
Part IA: *(Construction)*	8.370 *	5.506 *	2.794 *	3.312 *
Part IB *(Matching)*	5.629 *	4.812 *	3.613 *	8.345 *
PART I OVERALL	7.197 *	6.090 *	3.485 *	8.345 *
PART II: The Arrakeen Crossing (Simple Map Series)				
CATEGORIES I-III *(Quest. 1-7)*	6.276 *	2.890 *	2.808 *	6.154 *
CATEGORIES IV&VI *(Quest. 8-15)*	0.742 NS	1.838 NS	1.420 NS	1.187 NS
PART II OVERALL	3.050 *	2.589 NS	2.483 *	4.783 *
PART III: The Defense of the Logone Plateau (Complex Map Series)				
CATEGORIES I-III *(Quest. 1-6)*	3.743 *	2.117 NS	1.558 NS	2.586 *
CATEGORIES IV-VI *(Quest. 7-15)*	1.137 NS	0.814 NS	1.425 NS	0.617 NS
PART III OVERALL	3.123 *	1.638 NS	1.503 NS	2.231 NS
PARTS I-III TOTAL	7.168 *	5.249 *	3.610 *	8.260 *

* *Significant at α=.05*
NS *Insignificant*

The final variable examined was the proclaimed level of subject interest (Table 23). Again, significant differences in favor of the high interest groups were found only in symbol construction, symbol identification and overall integration of map information tasks.

All results suggest that battlefield map effectiveness is related to the experience and interest of the map user. However, this relationship only exists with those tasks requiring symbol construction, identification, and overall integration of map information, and is most profound when simple, rather than complex, map displays are viewed. No relationship exists between any of the experience or interest variables and performance in terrain analysis tasks.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Summary of the Research

Military historians and geographers use battlefield maps as a means of communicating the spatial relationships occurring throughout the course of battle. The successful communication of battle information often requires the map reader to perform a series of visualization and measurement tasks. Of these tasks, those likely to be performed in the study of military geography include symbol identification, integration of map information, and military terrain analysis. The communication effectiveness of battlefield maps has largely been ignored, primarily due to the deviation of this type of mapping from the mainstream of cartographic thought. As a result, cartographers have often followed conventional methods without giving consideration to the tasks that are performed on battlefield maps. The goal of this research was to provide the battlefield cartographer with a set of empirically derived design principles. The study focused on three research questions: (1) How do map users effectively learn battlefield map symbols? (2) How do battlefield maps most effectively communicate information about the battle setting? (3) What is the relationship between the prior military experience or interest of the map user and battlefield map effectiveness?

Previous literature suggests that the characteristics of battlefield map symbols makes them unique, and therefore, conventional methods of symbol explanation are not likely to be effective. An

alternative method is to illustrate the construction of military unit symbols and then to show them, in conjunction with other operational symbols, in the context in which they are used. Application of this method results in what is known as a "natural legend." The natural legend format has been shown to improve efficiency and understanding of topographic maps, and may produce similar results with battlefield maps.

Also considered is the effectiveness of battlefield maps in depicting the influence of terrain on the outcome of battle. Battlefield cartographers have conventionally portrayed only the physical aspects of terrain and ignored the military ones. The understanding of the effects of terrain on the outcome of battle are likely to be improved if the pertinent military aspects of terrain are interpreted and presented as an additional category of thematic information. The military has successfully applied thematic mapping techniques in determining the effects of terrain on planned military operations. This approach may be successfully modified and applied in the design of historical battlefield maps as well.

A final consideration is the relationship between the experience and interest of the map reader and battlefield map understanding. The cartographic literature suggests that some map reading tasks are dependent on prior training of the map reader, whereas others may be dependent on visual-spatial or perceptual abilities. Two complementary approaches are therefore possible in improving map effectiveness: design modification and improvement of reader skills. Categorization of battlefield map reading tasks by their dependency on either experience or perceptual abilities may aid in the design process; improvement of user skills are likely to be influenced by legend type, whereas the

interpretive method of terrain representation may help overcome deficient perceptual abilities.

Conclusions

The results indicate that the effectiveness of battlefield maps is influenced by the methods of symbol explanation and terrain representation, as well as the prior military experience or interest of the map reader. Based on the assumption that the maps used in the study were typical specimens of their kind, each research hypothesis can be provisionally accepted.

The natural legend format promotes understanding of battlefield map symbols in certain map reading tasks and is at least as effective as the conventional legend in others; this finding complements those of Delucia and Hiller (1982). The effects of the natural legend were most profound in the performance of tasks requiring overall integration of map information. The natural legend aids the reader in acquiring an overall view of the "geographical landscape," which, as Board (1978) suggested, is basic to understanding spatial distributions.

The natural legend combined with the illustration of unit symbol construction facilitates map reader understanding of military unit symbol composition. The illustrated description is therefore a viable and space-saving alternative to the "cataloging" of complex military unit symbols typically found in a conventional legend format. Furthermore, this method can be expected to have application in other forms of mapping that require an explanation of complex symbols.

The influence of terrain on the outcome of battle can not be effectively determined from geographic base map information alone. However, the military aspects of terrain can successfully be interpreted

as an additional category of thematic information. The interpretive method of terrain representation appears to facilitate the map reader's ability to perform military terrain analysis tasks without degrading performance in other tasks. Furthermore, this method may help clarify spatial relationships and promote overall integration of map information in the absence of, and in a manner similar to, the natural legend. This last finding is not fully understood and merits further investigation.

Overall map communication effectiveness was most improved in cases where the natural legend was combined with the interpretive method of terrain representation. However, the influence of these methods was least important in tasks performed on the complex map series. This finding supports earlier suggestions (Monmonier, 1974; Jenks, 1975; MacEachren, 1982) that map complexity reduces map effectiveness; these methods will not overcome insufficient map generalization, and are not substitutes for good map design. The natural legend format and the interpretive terrain method can be viewed as complementary, since improvements in understanding induced by each method generally apply to different categories of map reading tasks. Furthermore, application of these alternative methods should be based on the map's intended use.

Prior experience and interest facilitated reader understanding in symbol identification tasks and tasks requiring the overall integration of map information, but not in military terrain analysis tasks. Furthermore, experience and interest was found to be less influential in the performance of tasks on the complex map series than on the simple map series. Battlefield cartographers may apply these findings in the map design process; those tasks dependent on experience will only be successfully performed by inexperienced subjects if the cartographer

incorporates a training mechanism into the map's legend design. Furthermore, successful performance in tasks which are independent of experience are likely to be determined by the visual-spatial abilities of the subject, which in turn may be accommodated by design modification.

Recommendations for Further Study

This research is one of the few empirical studies of battlefield map effectiveness. Further studies focusing on the following topics may improve understanding of battlefield maps:

1. The relationship between battlefield maps and their accompanying narrative. Certain descriptive information cannot be learned directly from a battlefield map and so must be contained in some form of narrative (Petchenik, 1977). Several studies (Petchenik, 1977; Shimron, 1978; Perrig and Kintsch, 1978) have suggested that certain forms of text contribute to map effectiveness, yet none have been applied to battlefield maps.

2. The relationship between battlefield map complexity and effectiveness. Studies of this type have been limited to the mapping of statistical surfaces (Monmonier, 1974; Jenks, 1975; MacEachren, 1982). Although this topic was qualitatively addressed in this study, it merits further investigation.

3. Alternative symbol sets for battlefield maps. Conventional military symbols were applied to historic battle maps in this study, yet their effectiveness in this capacity was not evaluated. Alternative methods of symbolization should be sought and evaluated.

4. Battle simulations and interactive mapping. Computer and video technology have made simulations and interactive mapping possible, and these techniques may be applied to historic battlefield mapping.

APPENDIX A:

Questionnaire

APPENDIX A

Questionnaire

Part IV: Questionnaire **Booklet No._____(Fill in)**

This questionnaire is designed to assess your military experience and interest. Fill in the blanks as appropriate; for multiple choice questions, circle the response that best describes your opinion.

1. For military and former military only: (Circle your class or status)

Cadet (Class:____) Active Duty Reserve/NG Prior Service

2. For non-military: (Circle your class/position)

Fresh. Soph. Junior Senior Grad. Faculty Other

3. What is your current grade? (Former military should indicate the highest grade held) _____(Fill in)

4. Length of military service: _____(Fill in)

5. What were your last three duty positions? Please annotate those positions that required familiarity with military symbols, graphics and operational terms. (Fill in; include your current position if AD/Reserve military)

1) _____ 2) _____

3) _____

6. Describe your familiarity with military symbols, graphics, and operational terms by circling the appropriate response.

a. Very familiar (expert).
b. Familiar.
c. Somewhat familiar.
d. Unfamiliar.

7. Did your supervisors ever encourage you to study military history/military geography as part of your professional development?

Yes No

8. Have you ever taken part in a military history/military geography course as part of your military or civilian education? If so, how long was the course (semester, term or total hours)?

Yes (Length:_____) No

9. Which words best describe your interest in military history/military geography?

a. Very interested.
b. Interested.
c. Somewhat interested.
d. Little interest.
e. No interest.

CONTINUED ON THE NEXT PAGE

APPENDIX A (continued)

10. How useful are maps in understanding military history/military geography?

a. Necessary.
b. Very useful, but not necessary.
c. Useful.
d. Somewhat useful.
e. Useless.

11. How well did the legend studied in Part I help you to learn battlefield map symbols?

a. It was very helpful.
b. It was helpful.
c. It was somewhat helpful.
d. It was somewhat confusing.
e. It was very confusing.

12. Only one of the two sets of maps viewed included interpreted terrain information (shown in green). In general, how did you answer questions regarding the effect of terrain on military operations when you viewed the maps without the interpreted terrain information?

a. The map provided sufficient terrain information.
b. The narrative provided the needed information.
c. I relied on my experience and training.
d. I guessed.
e. I could not answer these questions.

13. Which map form, the maps with interpreted terrain information, or the maps without the interpreted terrain information, did you find more effective?

a. The maps with interpreted terrain information (shown in green).
b. The maps without interpreted terrain information.
c. Both were equally effective.
d. Both were equally ineffective.

14. How well did the narrative assist you in answering the questions?

a. It was very helpful.
b. It was helpful.
c. It was somewhat helpful.
d. I didn't need it to answer the questions

15. Select the words or statements that best describe your opinion of this test. You may circle more than one choice.

a. Difficult.
b. Easy.
c. Boring.
d. Interesting.
e. I understood the maps.
f. The maps were confusing.
g. I understood the narrative.
h. The narrative was confusing.
i. Sufficient time was provided.
j. Insufficient time was provided.

16. Additional comments:

APPENDIX B:

Answer Sheet

APPENDIX B

Answer Sheet

ANSWER SHEET **BOOKLET NO._____(Fill in)**

Mark all your answers on this sheet; do not mark in the test booklet .

Part I: Military Symbol Identification.

Section A: Unit Symbol Construction **Section B: Matching**

Using the basic symbol provided, construct the unit symbol for:

Company A, 307th Engineer Battalion (Airborne), less detachments

Example **M** **(Answer)**

1._____
2._____
3._____
4._____
5._____
6._____
7._____
8._____
9._____
10._____

Part II: The Arrakeen Crossing

Circle "T" for true, "F" for false, and "C" for can't tell.

1. T F C
2. T F C
3. T F C
4. T F C
5. T F C
6. T F C
7. T F C
8. T F C
9. T F C
10. T F C
11. T F C
12. T F C
13. T F C
14. T F C
15. T F C

Part III: The Defense of the Logone Plateau

Circle "T" for true, "F" for false, and "C" for can't tell.

1. T F C
2. T F C
3. T F C
4. T F C
5. T F C
6. T F C
7. T F C
8. T F C
9. T F C
10. T F C
11. T F C
12. T F C
13. T F C
14. T F C
15. T F C

APPENDIX C:

Consent Form

APPENDIX C

Consent Form

CONSENT FORM

1. I freely consent to take part in a cartographic study being conducted by CPT Joseph F. Fontanella under the supervision of Dr. Richard E. Groop, Associate Professor of Geography, Michigan State University.

2. The objective of the study is increased understanding of historical battlefield map reading and design.

3. The study has been sufficiently explained such that I have a clear idea of what I will be required to do during the course of the test.

4. I understand that I am free to discontinue my participation in the study at any time without penalty. The test will be approximately 50 to 60 minutes in length.

5. I understand that my participation in the study will be treated with strict confidence and that I will remain anonymous. Within these limits, the results of this study will be made available to me at my request.

6. I understand that this test is on a voluntary basis. Furthermore, I understand that my participation in the study does not guarantee results beneficial to me.

7. I understand that at the completion of the test a more thorough explanation of the study will be made available at my request.

Signature_____Date_____

APPENDIX D:

Script for Test Administration

APPENDIX B

SCRIPT FOR TEST ADMINISTRATION

The purpose of this test is to increase understanding of historical battlefield map reading and map design. The types of maps you will find in this test are similar to those you might find in a military history or military geography text or atlas. Conduct of this test is under the supervision of the Department of Geography, Michigan State University.

Are there any subjects who are "color-blind?"

(Release color-deficient subjects from participation)

I will now pass out the test booklets; when I call out your pay grade category, please raise your hand.

(Pass out test booklets to officers/cadets, then to non-commissioned officers, and finally to enlisted personnel)

Please do not open your test booklet until instructed to do so. The test will consist of four parts:

Part I will require that you study a battlefield map and its accompanying legend. In Section A, you will first be required to construct a military unit symbol. Subsequently, in Section B you will be required to match ten map symbols with their associated descriptions.

Part II will require that you view a series of maps of a fictional battle, "The Arrakeen Crossing," read an accompanying narrative, and then answer fifteen questions pertaining to the battle.

Part III is similar to part II, except that you will study another fictional battle, entitled "The Defense of the Logone Plateau."

Part IV is a questionnaire designed to assess your military experience.

You will have 15 minutes to complete each part, I though IV. If you finish a part early, please do not advance to the next part or answer any questions on any previous part. You may, however, reexamine the legend viewed in Part I, and you may work on the questionnaire.

In your test booklet you will find a yellow consent form, a pink answer sheet, and a blue questionnaire. Please pull them out. I will ask you now to read the consent form, and will answer any questions you have.

(Answer questions)

APPENDIX B (continued)

If you have consented to participate in this test, please sign and date the form. Today's date is *(provide date)*. In order to maintain your anonymity, consent forms will now be collected; please pass them forward.

(Collect consent forms)

Now please look at your answer sheet. Insure that the number at the top of your answer sheet matches the test booklet number on the front page of your test booklet. If both numbers do not match, raise your hand and I will correct the problem for you; do not correct the problem yourself.

(Make necessary corrections)

Please make no marks in the test booklet; make all your marks on the answer sheet. This is a timed test. Try to answer all questions to the best of your ability. If you find yourself "stuck" on a question, proceed to the next and return to unanswered questions if time permits. If you cannot answer a question, you should circle the "cannot tell" response on your answer sheet.

Are there any questions before we begin the test?

(Answer Questions)

Turn to the first page and begin part I. You have 15 minutes to complete this part.

(Provide elapsed time at 5 minute intervals, and at 2 minutes remaining)

(After time expires) This concludes the time allotted for Part I. Make no further marks on your answer sheet.

Turn to the next page and begin Part II. You have 15 minutes to complete this part.

(Provide elapsed time at 5 minute intervals, and at 2 minutes remaining)

(After time expires) This concludes the time allotted for Part II. Make no further marks on your answer sheet.

Turn to the next page and begin Part III. You have 15 minutes to complete this part.

(Provide elapsed time at 5 minute intervals, and at 2 minutes remaining)

(After time expires) This concludes the time allotted for Part III. Make no further marks on your answer sheet.

APPENDIX B (continued)

Please take a few minutes to fill out both sides of the questionnaire. I would appreciate any further comments you may have about the test or its administration.

Please place your answer sheet and questionnaire in your test booklet and pass them in.

(Collect test booklets)

I would like to thank you for your participation.

I will now gladly answer any additional questions you have about the test.

APPENDIX E:

Statistical and Numeric Summaries

APPENDIX E

STATISTICAL AND NUMERIC SUMMARIES

Table 13. Effects of Varying Method of Terrain Representation while Natural Legend Type is held Constant. *Mean percentage of correct responses are compared.*

Results From: Part II, The Arrakeen Crossing (Simple Map Series)
Groups Compared: Group 4 (Non-Interpreted) vs. Group 3 (Interpreted)

Category/ Questions	Group 4 Mean *(Non-Interpreted)*		Group 3 Mean *(Interpreted)*	Student's T * *Significant at α=.05*
Category I *(Quest. 1-2)*	75.0%	vs.	82.2%	1.099 NS
Category II *(Quest. 3-4)*	59.1%	vs.	51.1%	1.177 NS
Category III *(Quest. 5-7)*	87.9%	vs.	83.7%	1.053 NS
Total Symbol Understanding & Overall Integration Tasks	**75.9%**	**vs.**	**73.9%**	**0.604 NS**
Category IV *(Quest. 8-11)*	53.4%	vs.	68.3%	3.222 *
Category VI *(Quest. 12-15)*	52.3%	vs.	68.9%	2.783 *
Total Terrain Analysis Tasks	**52.8%**	**vs.**	**68.6%**	**3.522 ***
PART II OVERALL	**63.6%**	**vs.**	**71.1%**	**2.390 ***

Results From: Part III, The Defense of the Logone Plateau (Complex Map Series)
Groups Compared: Group 3 (Non-Interpreted) vs. Group 4 (Interpreted)

Category/ Questions	Group 3 Mean *(Non-Interpreted)*		Group 4 Mean *(Interpreted)*	Student's T * *Significant at α=.05*
Category I *(Quest. 1-2)*	70.0%	vs.	69.3%	0.093 NS
Category II *(Quest. 3-4)*	72.2%	vs.	75.0%	0.461 NS
Category III *(Quest. 5-6)*	72.2%	vs.	72.8%	0.078 NS
Total Symbol Understanding & Overall Integration Tasks	**71.4%**	**vs.**	**72.4%**	**0.223 NS**
Category IV *(Quest. 7-10)*	45.6%	vs.	59.7%	2.830 *
Category V *(Quest. 11-12)*	48.9%	vs.	59.1%	1.462 NS
Category VI *(Quest. 13-15)*	33.6%	vs.	53.8%	3.737 *
Total Terrain Analysis Tasks	**42.6%**	**vs.**	**57.8%**	**4.632 ***
PART III OVERALL	**53.9%**	**vs.**	**63.5%**	**3.389 ***

APPENDIX E (Continued)

Table 14. Effects of Varying Method of Terrain Representation while Conventional Legend Type is held Constant. *Mean percentage of correct responses are compared.*

Results From: Part II, The Arrakeen Crossing (Simple Map Series)
Groups Compared: Group 2 (Non-Interpreted) vs. Group 1 (Interpreted)

Category/ Questions	Group 2 Mean *(Non-Interpreted)*		Group 1 Mean *(Interpreted)*	Student's T * *Significant at α=.05*
Category I *(Quest. 1-2)*	75.0%	vs.	77.2%	0.324 NS
Category II *(Quest. 3-4)*	36.9%	vs.	40.2%	0.473 NS
Category III *(Quest. 5-7)*	73.8%	vs.	75.4%	0.253 NS
Total Symbol Understanding & Overall Integration Tasks	**63.6%**	**vs.**	**64.3%**	**0.505 NS**
Category IV *(Quest. 8-11)*	48.5%	vs.	56.5%	1.809 *
Category VI *(Quest. 12-15)*	37.5%	vs.	60.3%	3.492 *
Total Terrain Analysis Tasks	**42.9%**	**vs.**	**58.4%**	**3.533 ***
PART II OVERALL	**52.5%**	**vs.**	**61.9%**	**2.798 ***

Results From: Part III, The Defense of the Logone Plateau (Complex Map Series)
Groups Compared: Group 1 (Non-Interpreted) vs. Group 2 (Interpreted)

Category/ Questions	Group 1 Mean *(Non-Interpreted)*		Group 2 Mean *(Interpreted)*	Student's T * *Significant at α=.05*
Category I *(Quest. 1-2)*	66.3%	vs.	69.1%	0.376 NS
Category II *(Quest. 3-4)*	69.6%	vs.	57.2%	1.689 *
Category III *(Quest. 5-6)*	59.8%	vs.	57.2%	0.350 NS
Total Symbol Understanding & Overall Integration Tasks	**65.2%**	**vs.**	**61.1%**	**0.903 NS**
Category IV *(Quest. 7-10)*	53.8%	vs.	58.9%	0.960 NS
Category V *(Quest. 11-12)*	40.2%	vs.	58.4%	2.265 *
Category VI *(Quest. 13-15)*	33.3%	vs.	53.2%	3.901 *
Total Terrain Analysis Tasks	**42.4%**	**vs.**	**56.9%**	**3.358 ***
PART III OVERALL	**52.5%**	**vs.**	**58.6%**	**1.901 ***

APPENDIX E (Continued)

Table 15. Effects of Varying Legend Type while Non-Interpreted Terrain Information is held Constant. *Mean percentage of correct responses are compared.*

Results From: Part II, The Arrakeen Crossing (Simple Map Series)
Groups Compared: Group 2 (Conventional Legend) vs. Group 4 (Natural Legend)

Category/ Questions	Group 2 Mean *(Conventional)*		Group 4 Mean *(Natural)*	Student's T * *Significant at α=.05*
Category I *(Quest. 1-2)*	75.0%	vs.	75.0%	0.000 NS
Category II *(Quest. 3-4)*	36.9%	vs.	59.1%	3.205 *
Category III *(Quest. 5-7)*	73.8%	vs.	87.9%	2.227 *
Total Symbol Understanding & Overall Integration Tasks	**63.6%**	**vs.**	**75.9%**	**3.359 ***
Category IV *(Quest. 8-11)*	48.5%	vs.	53.4%	1.030 NS
Category VI *(Quest. 12-15)*	37.5%	vs.	52.3%	2.292 *
Total Terrain Analysis Tasks	**42.9%**	**vs.**	**52.8%**	**2.063 ***
PART II OVERALL	**52.5%**	**vs.**	**63.6%**	**3.298 ***

Results From: Part III, The Defense of the Logone Plateau (Complex Map Series)
Groups Compared: Group 1 (Conventional Legend) vs. Group 3 (Natural Legend)

Category/ Questions	Group 1 Mean *(Conventional)*		Group 3 Mean *(Natural)*	Student's T * *Significant at α=.05*
Category I *(Quest. 1-2)*	66.3%	vs.	70.0%	0.548 NS
Category II *(Quest. 3-4)*	69.6%	vs.	72.2%	0.422 NS
Category III *(Quest. 5-6)*	59.8%	vs.	72.2%	1.972 *
Total Symbol Understanding & Overall Integration Tasks	**65.2%**	**vs.**	**71.4%**	**1.757 ***
Category IV *(Quest. 7-10)*	53.8%	vs.	45.6%	1.529 NS
Category V *(Quest. 11-12)*	40.2%	vs.	48.9%	1.376 NS
Category VI *(Quest. 13-15)*	33.3%	vs.	33.6%	0.000 NS
Total Terrain Analysis Tasks	**42.4%**	**vs.**	**42.6%**	**0.484 NS**
PART III OVERALL	**52.5%**	**vs.**	**53.9%**	**0.539 NS**

APPENDIX E (Continued)

Table 16. Effects of Varying Legend Type while Interpreted Terrain Information is held Constant. *Mean percentage of correct responses are compared.*

Results From: Part II, The Arrakeen Crossing (Simple Map Series)
Groups Compared: Group 1 (Conventional Legend) vs. Group 3 (Natural Legend)

Category/ Questions	Group 1 Mean *(Conventional)*		Group 3 Mean *(Natural)*	Student's T * *Significant at α=.05*
Category I *(Quest. 1-2)*	77.2%	vs.	82.2%	0.807 NS
Category II *(Quest. 3-4)*	40.2%	vs.	51.1%	1.588 NS
Category III *(Quest. 5-7)*	75.4%	vs.	83.7%	1.623 NS
Total Symbol Understanding & Overall Integration Tasks	**64.3%**	**vs.**	**73.9%**	**2.177 ***
Category IV *(Quest. 8-11)*	56.5%	vs.	68.3%	2.855 *
Category VI *(Quest. 12-15)*	60.3%	vs.	68.9%	1.629 NS
Total Terrain Analysis Tasks	**58.4%**	**vs.**	**68.6%**	**2.561 ***
PART II OVERALL	**61.9%**	**vs.**	**71.1%**	**2.982 ***

Results From: Part III, The Defense of the Logone Plateau (Complex Map Series)
Groups Compared: Group 2 (Conventional Legend) vs. Group 4 (Natural Legend)

Category/ Questions	Group 2 Mean *(Conventional)*		Group 4 Mean *(Natural)*	Student's T * *Significant at α=.05*
Category I *(Quest. 1-2)*	69.1%	vs.	69.3%	0.035 NS
Category II *(Quest. 3-4)*	57.2%	vs.	75.0%	2.506 *
Category III *(Quest. 5-6)*	57.2%	vs.	72.8%	2.036 *
Total Symbol Understanding & Overall Integration Tasks	**61.1%**	**vs.**	**72.4%**	**2.336 ***
Category IV *(Quest. 7-10)*	58.9%	vs.	59.7%	0.148 NS
Category V *(Quest. 11-12)*	58.4%	vs.	59.1%	0.102 NS
Category VI *(Quest. 13-15)*	53.2%	vs.	53.8%	0.123 NS
Total Terrain Analysis Tasks	**56.9%**	**vs.**	**57.8%**	**0.196 NS**
PART III OVERALL	**58.6%**	**vs.**	**63.5%**	**1.487 NS**

APPENDIX E (Continued)

Table 17. Effects of Varying Both Legend Type and Method of Terrain Representaion.
Mean percentage of correct responses are compared.

Results From: Part II, The Arrakeen Crossing (Simple Map Series)
Groups Compared: Group 2 (Conv. Legend/Non-Inter. Terrain) vs. Group 3 (Nat. Legend/Inter. Terrain)

Category/ Questions	Group 2 Mean *(Conv./Non-Inter.)*		Group 3 Mean *(Natural/Inter.)*	Student's T * *Significant at α=.05*
Category I *(Quest. 1-2)*	75.0%	vs.	82.2%	1.114 NS
Category II *(Quest. 3-4)*	36.9%	vs.	51.1%	2.122 *
Category III *(Quest. 5-7)*	73.8%	vs.	83.7%	1.874 *
Total Symbol Understanding & Overall Integration Tasks	**63.6%**	**vs.**	**73.9%**	**3.081 ***
Category IV *(Quest. 8-11)*	48.5%	vs.	68.3%	4.694 *
Category VI *(Quest. 12-15)*	37.5%	vs.	68.9%	5.296 *
Total Terrain Analysis Tasks	**42.9%**	**vs.**	**68.6%**	**6.055 ***
PART II OVERALL	**52.5%**	**vs.**	**71.1%**	**6.548 ***

Results From: Part III, The Defense of the Logone Plateau (Complex Map Series)
Groups Compared: Group 1 (Conv. Legend/Non-Inter. Terrain) vs. Group 4 (Nat. Legend/Inter. Terrain)

Category/ Questions	Group 1 Mean *(Conv./Non-Inter.)*		Group 4 Mean *(Natural/Inter.)*	Student's T * *Significant at α=.05*
Category I *(Quest. 1-2)*	66.3%	vs.	69.3%	0.401 NS
Category II *(Quest. 3-4)*	69.6%	vs.	75.0%	0.886 NS
Category III *(Quest. 5-6)*	59.8%	vs.	72.8%	1.864 *
Total Symbol Understanding & Overall Integration Tasks	**65.2%**	**vs.**	**72.4%**	**1.766 ***
Category IV *(Quest. 7-10)*	53.8%	vs.	59.7%	1.100 NS
Category V *(Quest. 11-12)*	40.2%	vs.	59.1%	2.653 *
Category VI *(Quest. 13-15)*	33.3%	vs.	53.8%	4.101 *
Total Terrain Analysis Tasks	**42.4%**	**vs.**	**57.8%**	**3.572 ***
PART III OVERALL	**52.5%**	**vs.**	**63.5%**	**3.610 ***

APPENDIX E (Continued)

Table 17 (Cont.). Effects of Varying Both Legend Type and Method of Terrain Representation. *Mean percentage of correct responses are compared.*

Results From: Part II, The Arrakeen Crossing (Simple Map Series)
Groups Compared: Group 1 (Conv. Legend/Inter. Terrain) vs. Group 4 (Nat. Legend/Non-Inter. Terrain)

Category/ Questions	Group 1 Mean *(Conv./Inter.)*		Group 4 Mean *(Natural/Non-Inter.)*	Student's T * *Significant at α=.05*
Category I *(Quest. 1-2)*	77.2%	vs.	75.0%	0.320 NS
Category II *(Quest. 3-4)*	40.2%	vs.	59.1%	2.665 *
Category III *(Quest. 5-7)*	75.4%	vs.	87.9%	2.514 *
Total Symbol Understanding & Overall Integration Tasks	**64.3%**	**vs.**	**75.9%**	**2.518 ***
Category IV *(Quest. 8-11)*	56.5%	vs.	53.4%	0.633 NS
Category VI *(Quest. 12-15)*	60.3%	vs.	52.3%	1.380 NS
Total Terrain Analysis Tasks	**58.4%**	**vs.**	**52.8%**	**1.214 NS**
PART II OVERALL	**61.9%**	**vs.**	**63.6%**	**0.488 NS**

Results From: Part III, The Defense of the Logone Plateau (Complex Map Series)
Groups Compared: Group 2 (Conv. Legend/Non-Inter. Terrain) vs. Group 3 (Nat. Legend/Inter. Terrain)

Category/ Questions	Group 2 Mean *(Conv./Inter.)*		Group 3 Mean *(Natural/Non-Inter.)*	Student's T * *Significant at α=.05*
Category I *(Quest. 1-2)*	69.1%	vs.	70.0%	0.135 NS
Category II *(Quest. 3-4)*	57.2%	vs.	72.2%	2.078 *
Category III *(Quest. 5-6)*	57.2%	vs.	72.2%	2.129 *
Total Symbol Understanding & Overall Integration Tasks	**61.1%**	**vs.**	**71.4%**	**2.345 ***
Category IV *(Quest. 7-10)*	58.9%	vs.	45.6%	2.674 *
Category V *(Quest. 11-12)*	58.4%	vs.	48.9%	1.411 NS
Category VI *(Quest. 13-15)*	53.2%	vs.	33.6%	3.567 *
Total Terrain Analysis Tasks	**56.9%**	**vs.**	**42.6%**	**4.414 ***
PART III OVERALL	**58.6%**	**vs.**	**53.9%**	**1.522 NS**

APPENDIX E (Continued)

Table 18. Communication Failure Ratios. *Ratios are compared by group; the test statistic is the One-Way Analysis of Variance (ANOVA) F-Test at α=.05.*

Results From: Part II, The Arrakeen Crossing (Simple Map Series)

	Conventional Legend		*Natural Legend*		
Category/ Questions.	**GROUP 1** *(Interpreted Terrain)*	**GROUP 2** *(Non-Interpret. Terrain)*	**GROUP 3** *(Interpreted Terrain)*	**GROUP 4** *(Non-Interpret. Terrain)*	**ANOVA F** * *Significant at α=.05*
Category I *(Quest. 1-2)*	4.5	14.4	6.2	12.9	2.883 *
Category II *(Quest. 3-4)*	10.8	21.0	6.7	11.7	4.300 *
Category III *(Quest. 5-7)*	14.6	24.0	22.6	14.1	3.373 *
Total Symbol Understanding & Integration Tasks	**10.4**	**21.2**	**10.3**	**13.0**	**5.217** *
Category IV *(Quest. 8-11)*	12.0	26.6	15.8	28.7	6.286 *
Category VI *(Quest. 12-15)*	12.1	53.4	28.9	72.9	10.201 *
Total Terrain Analysis Tasks	**11.1**	**41.2**	**21.9**	**50.6**	**1.690** *
PART II OVERALL	**11.0**	**32.8**	**16.6**	**33.6**	**10.868** *

Results From: Part III, The Defense of the Logone Plateau (Complex Map Series)

	Conventional Legend		*Natural Legend*		
Category/ Questions.	**GROUP 2** *(Interpreted Terrain)*	**GROUP 1** *(Non-Interpret. Terrain)*	**GROUP 4** *(Interpreted Terrain)*	**GROUP 3** *(Non-Interpret. Terrain)*	**ANOVA F** * *significant at α=.05*
Category I *(Quest. 1-2)*	11.6	12.8	18.6	3.7	2.710 *
Category II *(Quest. 3-4)*	16.5	32.2	18.0	15.8	2.688 *
Category III *(Quest. 5-6)*	22.2	21.6	16.5	3.9	2.718 *
Total Symbol Understanding & Integration Tasks	**17.2**	**21.8**	**17.8**	**7.7**	**3.172** *
Category IV *(Quest. 7-10)*	26.0	29.4	16.9	32.8	3.148 *
Category V *(Quest. 11-12)*	11.5	36.3	13.9	30.5	3.386 *
Category VI *(Quest. 13-15)*	16.9	31.4	17.9	43.5	9.569 *
Total Terrain Analysis Tasks	**18.1**	**32.6**	**16.4**	**36.2**	**10.547** *
PART III OVERALL	**17.6**	**27.8**	**16.2**	**24.5**	**5.540** *

APPENDIX E (Continued)

Table 19. Effects of Varying Legend Type and Method of Terrain Representation on Test Subject Uncertainty. *Mean percentage of total "Cannot Tell" responses are compared by test part and group.*

Results of Varying Legend Type While Method of Terrain Representation is Held Constant

Groups Compared	Test Part	*Type of Legend / Method of Terrain Representation*		Student's T * *Significant at α=.05*
1 vs. 3	Part II	*Conventional/Interpreted* 4.2%	*vs. Natural/Interpreted* 4.8%	0.735 NS
2 vs. 4	Part II	*Conventional/Non-Interpreted* 15.6%	*vs. Natural/Non-Interpreted* 9.7%	3.062 *
2 vs. 4	Part III	*Conventional/Interpreted* 9.7%	*vs. Natural/Interpreted* 5.9%	1.170 NS
1 vs. 3	Part III	*Conventional/Non-Interpreted* 13.2%	*vs. Natural/Non-Interpreted* 11.5%	2.115 *

Results of Varying Method of Terrain Representation While Type of Legend is Held Constant

Groups Compared	Test Part	*Method of Terrain Representation / Type of Legend*		Student's T * *Significant at α=.05*
2 vs. 1	Part II	*Non-Interpreted/Conventional* 15.6%	*vs. Interpreted/Conventional* 4.2%	3.513 *
4 vs. 3	Part II	*Non-Interpreted/Natural* 9.7%	*vs. Interpreted/Natural* 4.8%	2.929 *
1 vs. 2	Part III	*Non-Interpreted/Conventional* 13.2%	*vs. Interpreted/Conventional* 7.3%	3.018 *
3 vs. 4	Part III	*Non-Interpreted/Natural* 11.5%	*vs. Interpreted/Natural* 5.9%	2.658 *

Results of Varying Both Type of Legend and Method of Terrain Representation

Groups Compared	Test Part	*Type of Legend / Method of Terrain Representation*		Student's T * *Significant at α=.05*
2 vs. 3	Part II	*Conventional/Non-Interpreted* 15.6%	*vs. Natural/Interpreted* 4.8%	3.896 *
4 vs. 1	Part II	*Natural/Non-Interpreted* 9.7%	*vs. Conventional/Interpreted* 4.2%	2.579 *
1 vs. 4	Part III	*Conventional/Non-Interpreted* 13.2%	*vs. Natural/Interpreted* 5.9%	4.118 *
3 vs. 2	Part III	*Natural/Non-Interpreted* 11.5%	*vs. Conventional/Interpreted* 7.3%	2.115 *

APPENDIX E (Continued)

Table 20. Effect of the Number of Task-Related Duty Positions held on Test Performance. *Test performance is compared between groups of varied duty positions; the test statistic is the One-Way Analysis of Variance (ANOVA) at α=.05. Mean percentage of correct test responses are shown.*

Category/ Questions	No Positions *(n=114)*	One Position *(n=36)*	Two Positions *(n=15)*	Three Positions *(n=12)*	ANOVA F * *Significant at α=.05*
PART I: Military Symbol Identification					
Part IA: *(Construction)*	61.7	80.4	86.7	86.7	8.370 *
Part IB *(Matching)*	67.2	85.6	70.0	85.0	5.629 *
PART I OVERALL	**65.4**	**83.9**	**75.6**	**85.6**	**7.197 ***
PART II: The Arrakeen Crossing (Simple Map Series)					
CATEGORIES I-III *(Quest. 1-7)*	63.8	79.4	66.7	78.6	6.276 *
CATEGORIES IV&VI *(Quest. 8-15)*	54.5	60.4	58.3	53.1	0.742 NS
PART II OVERALL	**60.1**	**69.3**	**62.2**	**65.0**	**3.050 ***
PART III: The Defense of the Logone Plateau (Complex Map Series)					
CATEGORIES I-III *(Quest. 1-6)*	64.2	76.4	70.0	70.8	3.743 *
CATEGORIES IV-VI *(Quest. 7-15)*	48.6	76.4	53.3	46.9	1.137 NS
PART III OVERALL	**54.9**	**62.9**	**60.0**	**56.1**	**3.123 ***
PARTS I-III TOTAL	**60.1**	**72.1**	**65.9**	**68.9**	**7.168**

APPENDIX E (Continued)

Table 21. Effect of Proclaimed Level of Familiarity on Test Performance.
Test performance is compared between groups of varied familiarity levels; the test statistic is the One-Way Analysis of Variance (ANOVA) at α=.05. Mean percentage of correct test responses are shown.

Category/ Questions	Unfamiliar *(n=45)*	Somewhat Familiar *(n=51)*	Familiar *(n=74)*	Very Familiar *(n=7)*	ANOVA F * *Significant at α=.05*
PART I: Military Symbol Identification					
Part IA: *(Construction)*	60.9	63.1	76.4	95.7	5.506
Part IB *(Matching)*	62.3	70.4	77.6	94.3	4.812
PART I OVERALL	**62.1**	**67.9**	**77.6**	**94.8**	**6.090**
PART II: The Arrakeen Crossing (Simple Map Series)					
CATEGORIES I-III *(Quest. 1-7)*	67.6	65.2	73.9	75.5	2.890
CATEGORIES IV&VI *(Quest. 8-15)*	54.7	54.1	56.1	66.7	1.838 NS
PART II OVERALL	**60.7**	**59.3**	**64.4**	**75.2**	**2.589 NS**
PART III: The Defense of the Logone Plateau (Complex Map Series)					
CATEGORIES I-III *(Quest. 1-6)*	63.3	66.3	69.8	80.9	2.117 NS
CATEGORIES IV-VI *(Quest. 7-15)*	46.7	52.3	50.2	52.4	0.814 NS
PART III OVERALL	**53.3**	**57.9**	**58.2**	**65.0**	**1.638 NS**
PARTS I-III TOTAL	**58.7**	**61.7**	**66.5**	**77.9**	**5.249**

APPENDIX E (Continued)

Table 22. Effects of Formal Education in Military History or Military Geography on Test Performance. *Mean percentage of correct test responses are compared between groups; the test statistic is the One-Tail Student's T Test at α=.05.*

Category/ Questions	No Formal Education *(n=139)*	Some Formal Education *(n=38)*	Student's T * *Significant at α=.05*
PART I: Military Symbol Identification			
Part IA: *(Construction)*	66.2	80.7	2.794 *
Part IB *(Matching)*	68.9	85.0	3.613 *
PART I OVERALL	**68.0**	**83.7**	**3.485 ***
PART II: The Arrakeen Crossing (Simple Map Series)			
CATEGORIES I-III *(Quest. 1-7)*	67.9	77.1	2.808 *
CATEGORIES IV&VI *(Quest. 8-15)*	54.7	60.5	1.420 NS
PART II OVERALL	**60.9**	**68.2**	**2.483 ***
PART III: The Defense of the Logone Plateau (Complex Map Series)			
CATEGORIES I-III *(Quest. 1-6)*	66.4	71.9	1.558 NS
CATEGORIES IV-VI *(Quest. 7-15)*	48.7	54.7	1.425 NS
PART III OVERALL	**55.8**	**62.2**	**1.503 NS**
PARTS I-III TOTAL	**61.6**	**71.2**	**3.610 ***

APPENDIX E (Continued)

Table 23. Effect of Proclaimed Level of Interest on Test Performance.
Test performance is compared between groups of varied interest levels; the test statistic is the One-Way Analysis of Variance (ANOVA) at α=.05. Mean percentage of correct test responses are shown.

Category/ Questions	No Interest *(n=18)*	Little Interest *(n=42)*	Somewhat Interested *(n=55)*	Interested *(n=44)*	Very Interested *(n=18)*	ANOVA F * *Significant at α=05*
PART I: Military Symbol Identification						
Part IA: *(Construction)*	52.2	64.8	69.1	75.9	82.2	3.312
Part IB *(Matching)*	43.3	68.1	77.6	75.2	91.1	8.345
PART I OVERALL	**46.3**	**66.9**	**74.2**	**75.5**	**88.1**	**8.345**
PART II: The Arrakeen Crossing (Simple Map Series)						
CATEGORIES I-III *(Quest. 1-7)*	58.7	62.2	72.9	75.6	75.4	6.154
CATEGORIES IV&VI *(Quest. 8-15)*	50.0	51.2	56.4	58.2	65.9	1.817 **NS**
PART II OVERALL	**54.1**	**56.3**	**64.1**	**66.4**	**70.3**	**4.783**
PART III: The Defense of the Logone Plateau (Complex Map Series)						
CATEGORIES I-III *(Quest. 1-6)*	54.6	66.3	68.8	70.8	72.2	2.586
CATEGORIES IV-VI *(Quest. 7-15)*	43.8	49.5	50.5	51.3	52.5	0.617 **NS**
PART III OVERALL	**48.1**	**54.9**	**57.8**	**59.1**	**60.4**	**2.231 NS**
PARTS I-III TOTAL	**49.5**	**59.8**	**65.4**	**66.9**	**72.9**	**8.260**

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