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AN APPROACH TO ASSESSMENT OF RELIEF FORMATS FOR HARDCOPY TOPOGRAPHIC MAPS

Lawrence M. Potash, John P. Farrell, Thomas E. Jeffrey

HUMAN FACTORS TECHNICAL AREA

U. S. Army

Research Institute for the Behavioral and Social Sciences

April 1979

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The relief assessment test described in this report is designed to assess the effect of supplementing contour lines with other relief formats. It contains eight types of problems and a review of relevant aspects of map reading. It has been produced in three relief formats: contour lines, contour lines plus layer tints, and contour lines plus shading. Initial work indicates that addition of layer tints to contour lines can increase speed of reading some types or relief information; whereas, addition of shaded relief does not increase map reading speed more than use of layer tints and can cause a decrease in accuracy.

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20. Map designers will be interested in this report.

Technical Paper 356

AN APPROACH TO ASSESSMENT OF RELIEF FORMATS FOR HARDCOPY TOPOGRAPHIC MAPS

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Topographic Products and
Procedures

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FOREWORD

The Human Factors Technical Area of the Army Research Institute (ARI) is concerned with the demands of the future battlefield for increased man-machine complexity to acquire, transmit, process, disseminate, and utilize information. The research is focused on the interface problems and interactions within command and control centers and is concerned with such areas as topographic products and procedures, tactical symbology, information management, user-oriented systems, staff operations and procedures, and sensor systems integration and utilization.

One area of special interest is that of human factors problems in the design of topographic products and procedures. Maps are an essential part of a large number of military tasks at all staff levels. Many map users report, and have, difficulty in visualizing terrain features from current maps which use contour lines to portray relief. Methods for supplementing contour lines with other relief formats have been developed but assessing the value of supplementing contour lines with other modes of relief portrayal remains a problem. In order to make a decision regarding the cost-benefits tradeoff of supplementing contour lines, the map designer must have some idea of how different supplementary relief formats will affect user performance. This publication presents a technique for assessing map relief legibility and reports initial findings from employing this technique to evaluate use of shading and layer tints as supplementary relief formats. The results of this initial work indicate that adding layer tints to contour lines is beneficial for some types of map reading tests. However, addition of shaded relief to contour line maps offers no advantages over the addition of layer tints, and can decrease performance for some tasks.

This research effort is responsive to requirements of Army Project 2Q162717A721 and to special requirements of the USA Engineering Topographic Laboratory. Special requirements are contained in Human Research Need 76-183, "Topographic Product Design and Test Methodology."

This research effort was made possible through the assistance of Alex Pearson and John Griffin of the USA Engineering Topographic Laboratory and through the cooperation of the 2nd Armoured Division, Fort Hood, Tex.

JOSEPH ZEIDNER
Technical Director

AN APPROACH TO ASSESSMENT OF RELIEF FORMATS FOR TOPOGRAPHIC MAPS

BRIEF

Requirement:

To develop an appropriate methodology and carry out an assessment of the legibility of different relief formats.

Procedure and Findings:

The types of relief information that must be extracted by representative users of hardcopy maps were analyzed. Using the results of this analysis, a Relief Assessment Test was designed to determine the merits of supplementing contour lines with other relief formats. The Relief Assessment Test contains eight types of problems: landform identification, ridge-valley identification, slope identification, identification of high-low areas on the map, spot elevation problems, vertical profile identification, terrain visualization, and defilade. Use of the Relief Assessment Test assumes previous experience and training in the use of contour line maps, but the test does contain a review of relevant aspects of map reading. When this test is administered as a self-paced test, subjects typically take 3 to 5 hours.

The Relief Assessment Test was produced in three formats; contour lines, contour lines plus layer tints, and contour lines plus shading. Initial research was undertaken to assess these three map formats empirically. Subjects were 48 Army officers and NCOs experienced in reading contour maps and using them for land navigation. Subjects were tested in small groups, each subject being told to work at his own rate of speed. Each subject was assigned to one of the three map formats. The results of this initial research indicate that addition of layer tints to contour lines can increase speed of extracting some types of relief information. On the other hand, addition of shaded relief does not increase map reading speed more than use of layer tints, and can cause a decrease in accuracy.

Utilization of Findings:

The Relief Assessment Test can be produced in a number of relief formats to compare their relative merits. It could be used as an assessment test of relief-related map reading skills or, with feedback to the user, as part of a course to teach reading of relief information presented on hardcopy topographic maps. The assessment of the relative merits of the three map formats undertaken in this study provides the map designer with valuable information concerning how adding different supplementary relief formats to contour lines will affect user performance. This information is essential if the map designer is to make an informed decision regarding the cost-benefits tradeoff of supplementing contour lines to increase map relief legibility.

AN APPROACH TO ASSESSMENT OF RELIEF FORMATS FOR TOPOGRAPHIC MAPS

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AN APPROACH TO ASSESSMENT OF RELIEF FORMATS FOR HARDCOPY TOPOGRAPHIC MAPS

INTRODUCTION

Two techniques have been used extensively for assessing the effectiveness of maps as visual displays: (1) opinion surveys of user preferences; and (2) performance testing in field exercises. The survey of user preference is inexpensive and it provides information on the degree of user acceptance but user preference surveys have questionable predictive validity for performance with maps (Wheaton, Zavala and Van Cott, 1967). In one study, preference judgments were found to be useless as predictors of performance under daylight conditions and only on the night task were there any significant correlations between preference and performance (Hill, 1974). Field tests of performance with maps present other difficulties: (1) many of the operational tasks used in the field testing are complex and require a number of skills other than those involved in reading maps; (2) field testing of maps is expensive; and (3) a very large number of variables, such as terrain, seasonal changes in vegetation, etc., are present and must be controlled.

Due to these difficulties with existing techniques for the assessment of maps, the test described in this paper was developed utilizing a class-room approach to the evaluation of map products. The test is used to obtain measures of how well alternative map products provide information to the user. A similar approach for assessing the relative legibility of different relief formats has been developed with imaginary terrain based on sections of the Atlantic sea floor (Phillips, DeLucia and Skelton, 1975). Currently most maps, including U.S. Army maps, portray terrain by the use of contour lines because they provide more precise quantitative information than other techniques. However, a large percentage of map users report difficulty visualizing terrain when contour lines are the only guide (Skop, 1958). Supplementary modes of relief portrayal have been added to contour lines to alleviate this problem. The test described in this paper is designed to assess quantitatively the value of adding supplementary relief to contour lines. Although the approach used by Phillips, et al. (1975) was innovative, there was not adequate control for information content of the map stimuli. In our test, information content was controlled by comparing different map formats on the same terrain and the problem of terrain-specific results was avoided by using 52 map segments representing a wide range of different terrain-contour interval combinations. Another important feature in our test is that hydrography and cultural features were present in the map segments. Since water flows downhill, hydrographic features may convey a considerable amount of terrain relief information. Due to the artificial nature of the terrain in the test of Phillips, et al., hydrography and cultural features are not present. This paper describes our test for relief assessment and presents initial results obtained using the test.

DESCRIPTION OF THE TEST

In order to determine what types of relief information must be extracted from maps by representative users, we studied and analyzed Army Field Manual FM 21-16, "Map Reading," literature on relief portrayal and land navigation and discussed relief portrayal with personnel at the Infantry School at Fort Benning and the Topographic Products Design Branch, USAETL. Although this test is responsive to the needs of military designers, it should be useful in other contexts in which assessment of different relief formats or user ability to extract information from those formats is desired. The following problem types are used in the Relief Format Assessment Test (map segments described below are 4000 m grid squares except for the high-low area problem which uses 8000 m grid squares):

Landform Identification

The subject is asked to identify landforms beneath the tips of arrows overprinted on map segments. The landforms to be identified (hill, valley, spur, depression, and saddle) are illustrated by pencil sketches (representative map segments and landform illustrations are shown in Figure 1). Note that the map segment shown in Figure 1 is a somewhat reduced black and white photograph of the original colored contour line map segment and is representative of other 4000 m map segments described below.

Ridge-Valley Identification

The subject is asked to decide whether each of the lines overprinted on map segments runs along: (a) a valley; (b) a ridge-spur; or, (c) terrain that does not fall exclusively into categories a or b (representative map segment is shown in Figure 2).

Slope Identification

The subject is asked to decide whether each of the lines overprinted on map segments runs along: (a) a uniform up slope; (b) a uniform down slope; (c) a convex up slope; (d) a convex down slope; (e) a concave up slope; and, (f) a concave down slope. Each of the slopes is illustrated by a simple line drawing (representative map segment and slope illustrations are shown in Figure 3).

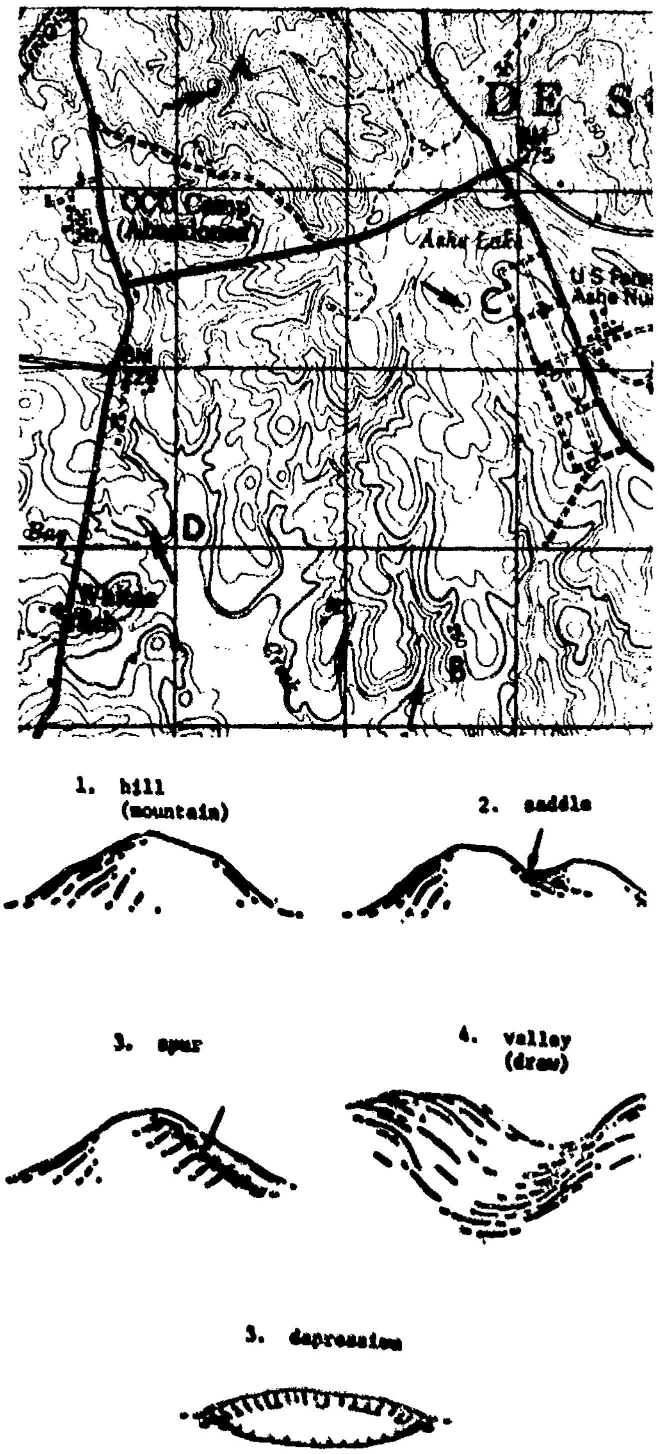


Figure 1. Photograph of a sample overprinted map segment and sample landform sketches used in landform identification problems.

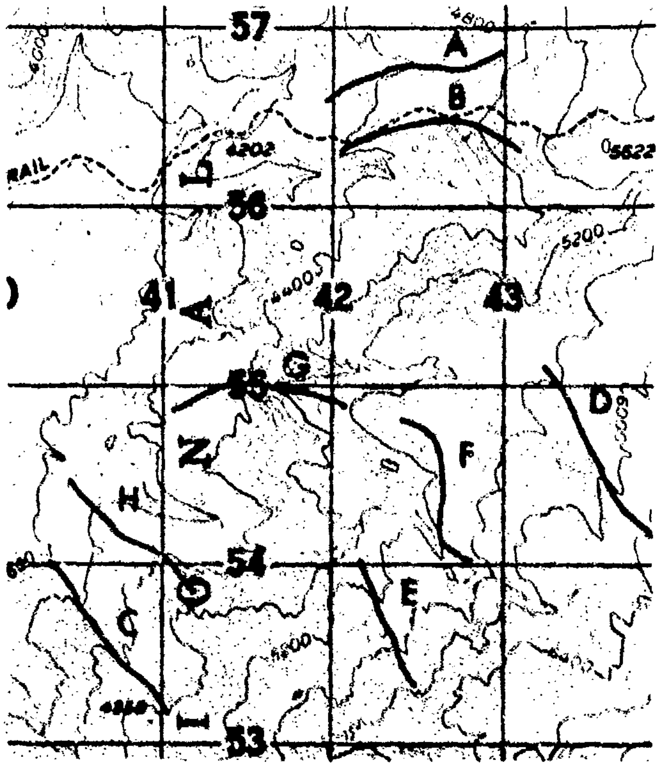


Figure 2. Photograph of a sample overprinted map segment used in ridge-valley identification problems.

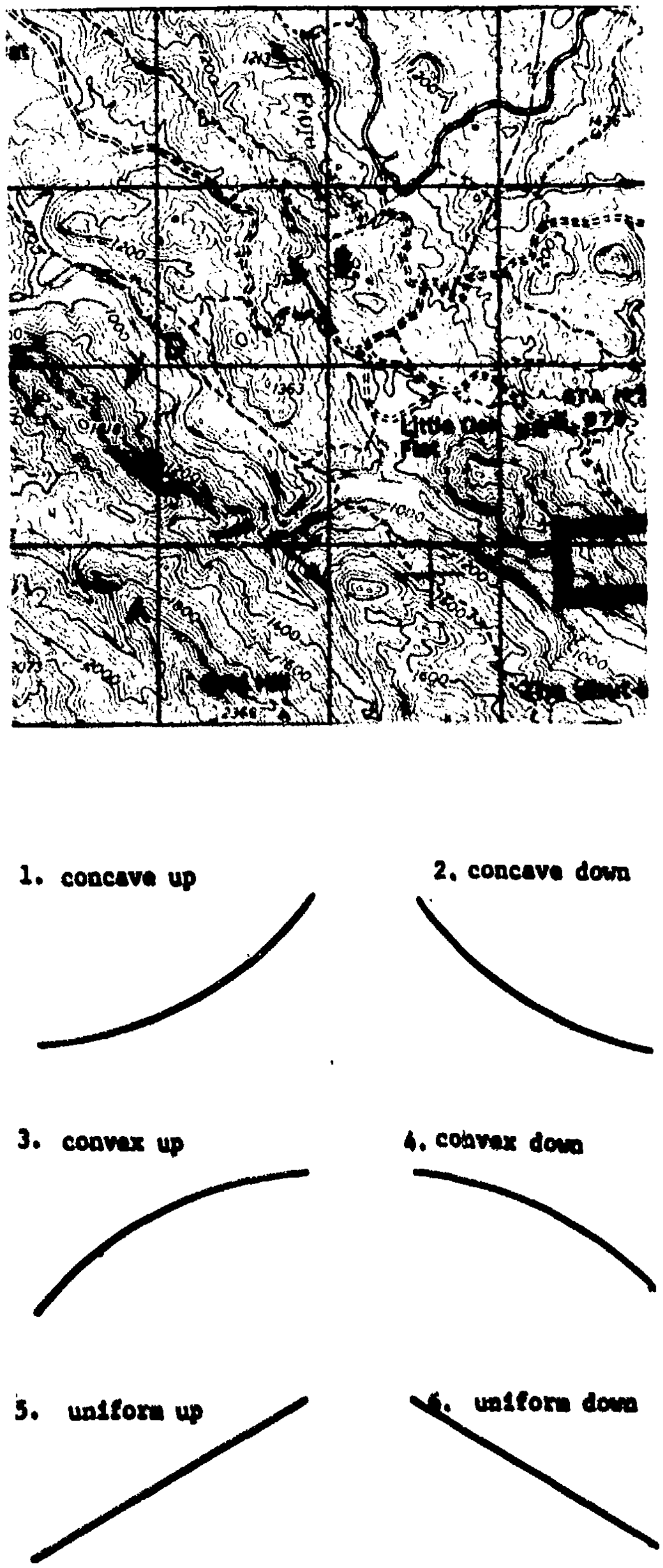
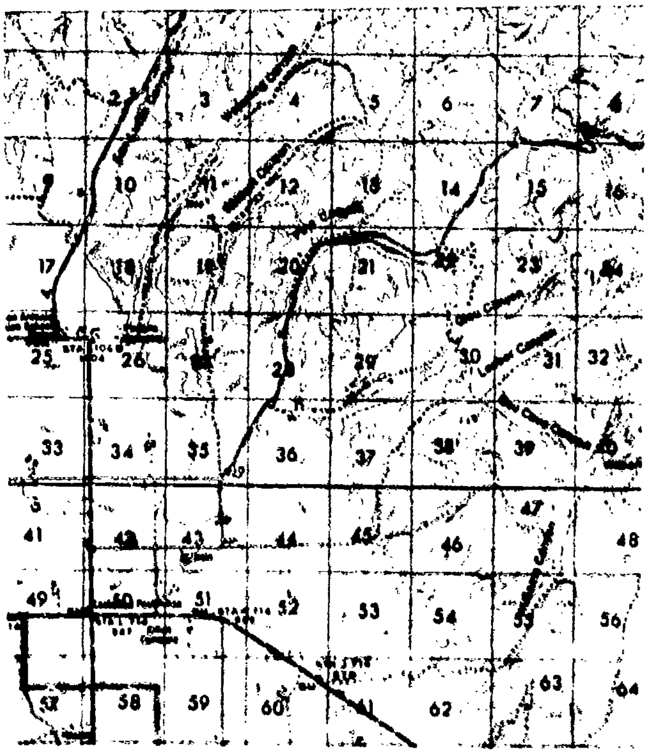


Figure 3. Photograph of a sample overprinted map segment and line drawings illustrating slopes used in slope identification problems.

Identification of High-Low Areas on the Map

The subject is asked to identify the four 1000 metre x 1000 metre grid squares (referred to as 1000 metre grid squares) containing the highest elevations and the four 1000 metre grid squares containing the lowest elevations on a map segment containing sixty-four 1000 metre grid squares. Numbers are overprinted on each of the grid squares for ease of identification. Contour interval is provided (representative map segments are shown in Figure 4).

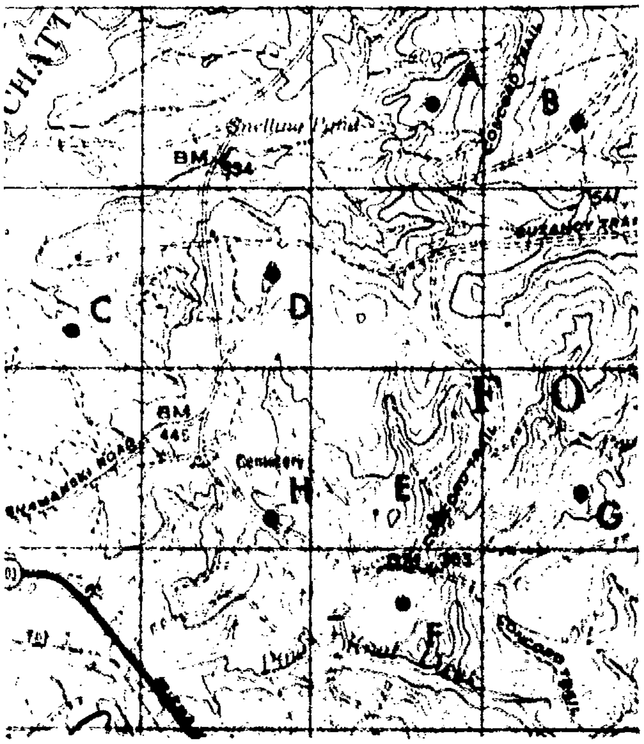


contour interval 40 ft.

Figure 4. Photograph of a sample overprinted map segment used in identification of high-low areas on the map problems.

Spot Elevation Problems

The subject is asked to identify the elevation at different points overprinted on map segments. Contour interval is provided (representative map segment is shown in Figure 5).



contour interval 20 ft.

Figure 5. Photograph of a sample overprinted map segment with accompanying contour interval information used in spot elevation problems.

Vertical Profile Identification

The subject is asked to decide which of three alternative profiles best matches the vertical profile of terrain beneath each of two lines overprinted on the map segments. The subject must utilize available scale and contour interval information. Contour interval and scale are provided (representative map segment and accompanying profiles are shown in Figure 6).

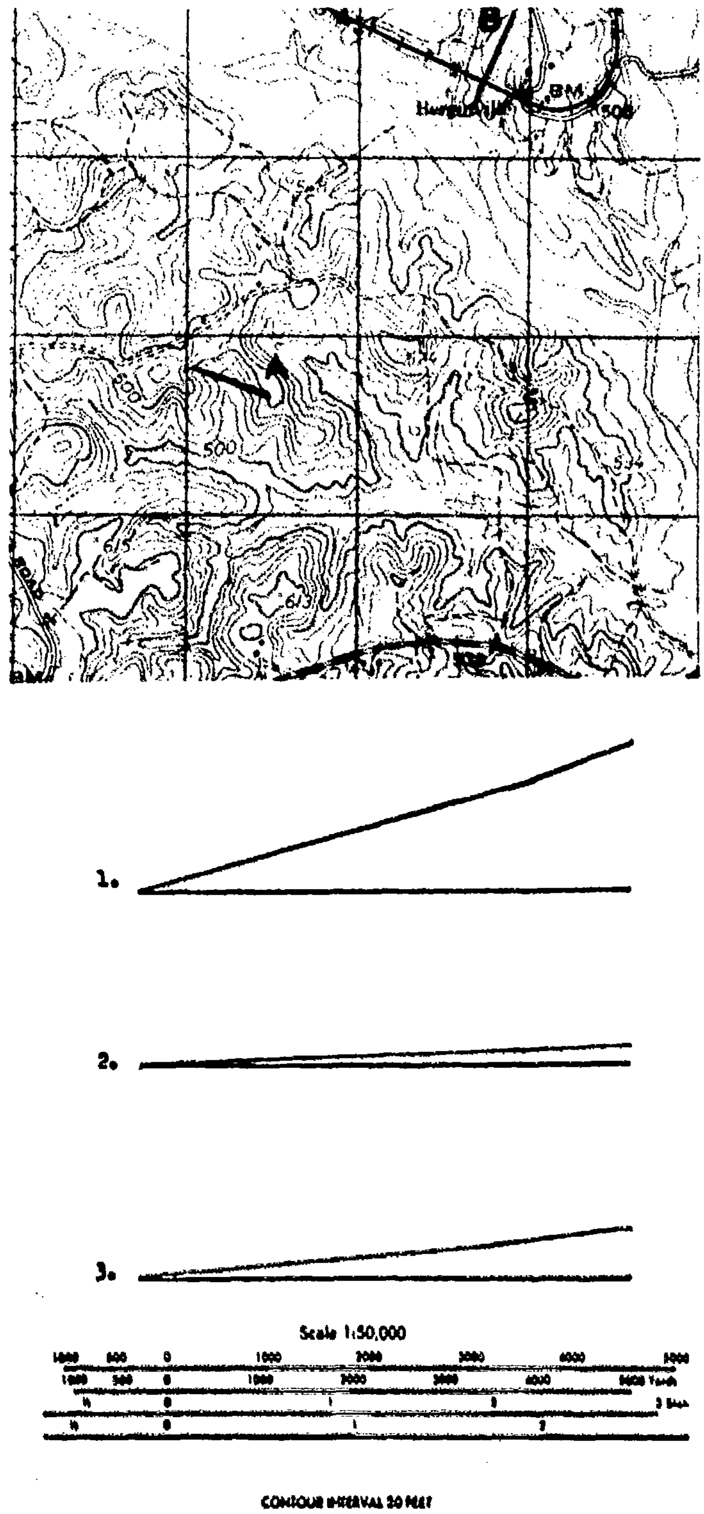


Figure 6. Photograph of a sample overprinted map segment, line drawings illustrating vertical profiles, and accompanying scale and contour interval information used in vertical profile identification problems.

Terrain Visualization

Four arrows are overprinted on each of the map segments. The subject attempts to visualize the scene he would see if he were standing at the arrowtip looking in the direction shown by the arrow. The subject must decide which scene best matches the drawings shown on the opposite page. Contour interval, scale, angle of vision, and maximum range are provided (representative map segment and accompanying scene are shown in Figure 7).

Defilade

The subject is asked to determine intervisibility between various points overprinted on map segments. Contour interval and scale are provided (representative map segment and accompanying scene shown in Figure 8).

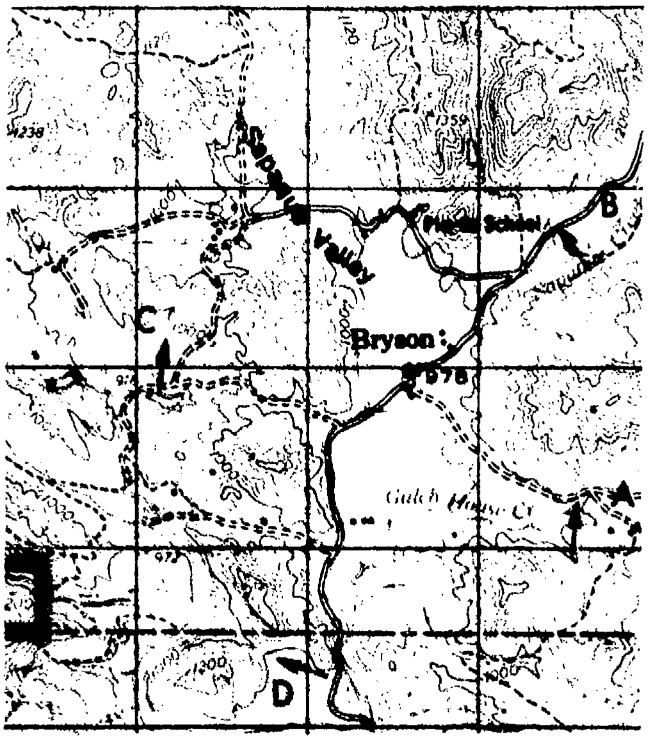
The test provides separate scores for each problem type so that the relative merits of the relief forms can be assessed as a function of the type of information extracted from the map.

A breakdown showing the number of questions devoted to each problem type is shown in Table 1.

Table 1

Number of Map Segments, Questions per Map Segment, and Total Number of Questions Used for Each Problem Type

Problem types (listed in order in which they are presented in test)	Number of map segments	Number of questions per map segment	Total number questions
Landform identification	4	4	16
Ridge-valley identification	4	8	32
Slope identification	4	4	16
Identification of high-low areas on map	8	8	64
Spot elevation problems	4	8	32
Vertical profile identification	8	2	16
Terrain visualization	16	1	16
Defilade	4	6	24



Your approximate angle of vision is enclosed by the dashed lines touching the arrow tip. The length of the thick solid line touching the arrow tip represents the maximum range for your vision.

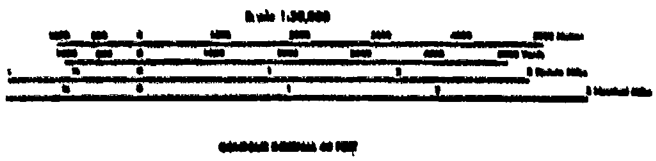


Figure 7. Photograph of a sample overprinted map segment, drawing of scene viewed by the observer, and accompanying contour interval, scale, angle of vision and maximum range information used in terrain visualization problems.

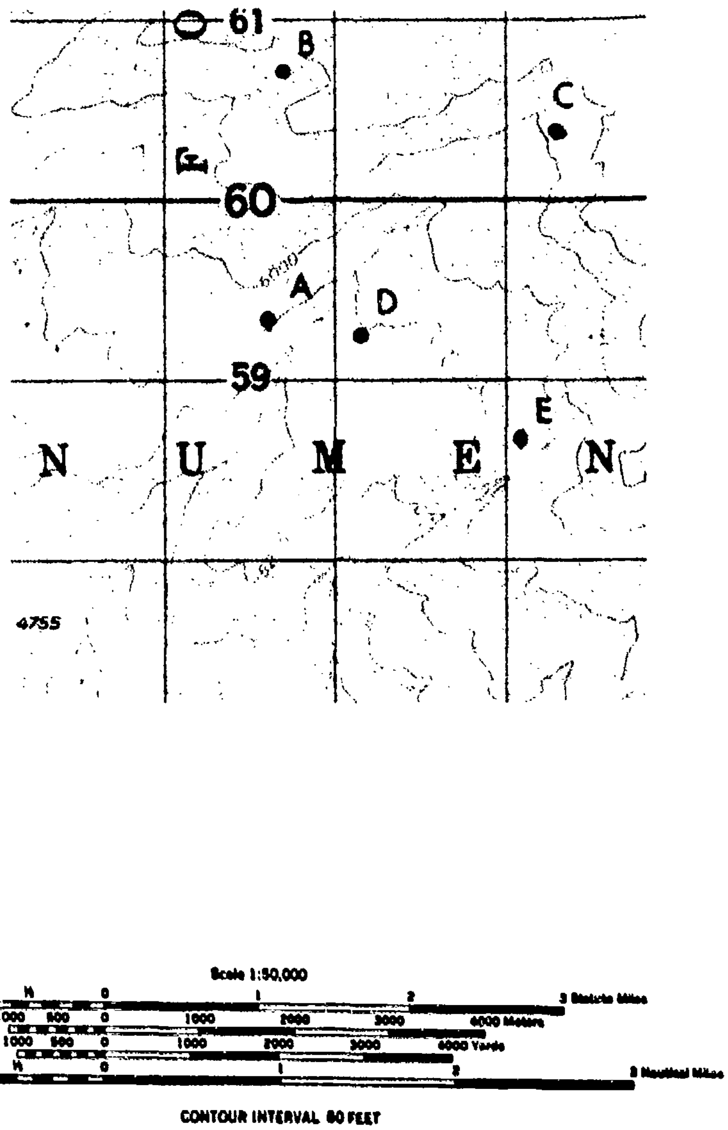


Figure 8. Photograph of a sample overprinted map segment and accompanying scale and contour interval information used in defilade problems.

The Relief Assessment Test has been administered by us as a power test, i.e., progress through the test is self-paced by subjects. When administered in this fashion, the test typically takes from 3 to 5 hours. Performance is measured in terms of how accurately and quickly relief information is extracted from a given relief format. This test has been produced in three relief formats: contour lines, contour lines supplemented with layer tints, and contour lines supplemented with shading. Layer tints are colors used to separate the terrain into distinct elevation bands. The contour line plus layer tint maps use 3-4 colors (white, yellow, tan, brown) to indicate different ranges of elevation; the exact number of colors used depends on the range of elevation portrayed in the map segment. The 4000 m contour line plus layer tint map segment contains 2-3 layer tints whereas the 8000 m map segments used in the high-low problem contain 3-4 layer tints.

For the maps portraying relief with contour line plus shading, the light is assumed to originate in the Northwest so that northwestern and western slopes are unshaded while the eastern and southeastern slopes are in the shade. The degree of slope is indicated by the degree of shading with the eastern slope being darker. Shading was done in grey using the airbrush technique.

DESCRIPTION OF TEST CONSTRUCTION

Four terrain-contour interval combinations were used in order to insure that map test would not be biased toward a given terrain-contour interval combination. The contour intervals represented on the maps range from 3 to 24 m. The elevation ranges (high elevation minus low elevation) represented on the maps ran from 85 to 1830 m. When scale is constant, map designers increase contour interval with increasing elevation range so that the contour lines can adequately portray the terrain without merging. The contour intervals were typical for the elevation ranges portrayed on the four maps. With the exception of vegetation features which were removed, the map stimuli used in the contour line version of the test are portions of "off the shelf" 1:50 000 scale maps since any deviations from a "map-like" appearance may affect the subjects' ability to perceive relief.

In order to minimize the influence of possible experimenter bias upon development of the test questions, randomization was used whenever possible. The maps were divided into 4000 m grid squares (at 1:50 000 scale, 4000 m is 8 cm). For each question, a random number table was used to select a 4000 m grid square to serve as the map stimulus. For the high-low areas on the map problem, 8000 m grid squares were randomly selected from the remaining portions of the map sheets. In the high-low areas on the map problem, the influence of possible experimenter bias in development of map stimuli was minimal. Once the map areas had been chosen, no further selection of landforms, slopes, etc., within the map area was required to construct the question. For the vertical profile identification problem and spot elevation problems, the areas within the 4000 m segment that would be used for the actual question were selected by choosing appropriate 1000 m grid squares using a random number table although positioning of the overprinted stimuli within areas was done using expert judgment. For the other question types, both the area within the 4000 m grid square used in the question and the position of overprinted stimuli were selected by the experimenter.

In the landform and slope recognition questions, the particular landforms (or slopes) that were to be illustrated on a given 4000 m grid square were randomly assigned. Some adjustment was made so that each type of landform was not represented too many times on a given map segment. We feel that the extensive sample of map segments and random assignment of these segments to the given problems in order to avoid experimenter-bias further separates our assessment technique from other experimental techniques reported in the literature. The scoring and adjustments are described in more detail in the results and conclusion section.

The test was developed in contour line format. After development was completed, parallel versions of the test were produced in the other relief formats by adding the appropriate supplementary relief to the contour line maps.

Registration of the arrows, lines, etc., on the map background proved to be a minor problem requiring adjustments in scoring in some instances.

DESCRIPTION OF MANNER IN WHICH TEST IS DESIGNED FOR USE

Each problem type is scored separately. An overall or total score across problem types would be meaningless since the importance of a particular advantage or disadvantage of a relief format depends on the function of the map. Implicit in a total score is an arbitrary weighting for the different problem types. The test is administered so that each subject works with only one format for the following reasons: (a) exposing the subject to different relief formats might prove confusing to those who would have to go from one map format to another throughout the test; (b) it would require more extensive review material; (c) study of one map format might facilitate (or hinder) use of another map format.

TRAINING NECESSARY FOR TEST USE

This test assumes previous experience and training in the use of standard line maps. A map reading review for extracting terrain information required by a problem set is given to the subject prior to presenting the particular type of problem. For relief formats concerning contour plus supplementary portrayal of relief, additional information is included in the review relevant to the supplementary relief format. Problem types are presented in an order that allows successive presentation of review material with problems requiring the entire review material being placed in the later portion of the test. Order of problem presentation is also structured to give subjects practice on skills that may be needed to work more difficult problems. For example, simple landform identification and ridge-valley identification problems provide practice in the kinds of recognition that will be required in the visualization of terrain problems. Order of problem presentation was the same for all relief formats.

INITIAL RESEARCH

This experiment was undertaken to assess the effects of the three relief formats (contour line, contour lines plus layer tints, and contour lines plus shading) on speed and accuracy with which relief information can be extracted from hardcopy maps by subjects who were relatively experienced in map reading.

Subjects

Forty-eight male Army officers and NCOs who had had experience in reading contour maps and using them for land navigation were used as subjects. Approximately two-thirds of the subjects were "ranger-qualified" and had therefore received advanced Army navigation training.

Procedure

Subjects were tested in small groups of up to eight subjects in a group, each subject participating in one session. They were tested in a large room with widely spaced tables--one subject per table. Subjects were assigned to particular map formats by altering the map format placed at each seat and assigning seats randomly each day. Subjects were told to work at their own rate of speed with intructions stating: "Work each problem as quickly and accurately as you can. If you get tired, please take a break or have a cup of coffee after you have finished the problem. Tired students won't give us a valid assessment of the different types of relief portrayal." Subjects used stopwatches to determine the amount of time required to solve each problem and recorded both time and their answers on the answer sheet. As indicated previously, each subject worked with only one format.

Results

The median times (min) required to solve the different types of problems are summarized in Table 2. Note that the times reported in Table 2 are for the blocks of questions contained on each of the map segments. For example, in the landform identification problem, each subject had four time scores, one for each of the four map segments used for this problem (each map segment contained four questions). Using the four time scores, the median was calculated for each subject. The 1.0 min shown in Table 1 for the contour version of the landform identification problem represents the mean of the median times for all subjects who took the contour version of the map test. Analysis of these results using a one-way analysis of variance showed significant differences for time required to solve the identification of high-low areas on the map problem ($p < .01$). The time required to solve the Ridge-Valley Identification problem approached significance. Analysis of the median times required to solve the high-low problem using a Newman-Keuls procedure showed that the solution times for maps supplemented with either layer tints or shading were significantly less than those for unsupplemented contour line maps ($p < .01$ and $p < .05$) but were not significantly different from each other. Layer tints as a supplement to contour lines produced the fastest solution times on seven of the eight problem types although the differences were not statistically significant.

Table 2

Mean of Median Times Required to Answer Questions (min)

	Contour	Shaded relief	Layer tints
Landform identification	1.0	1.0	0.8
Ridge-valley identification	2.4	2.4	1.7
Slope identification	1.3	1.4	1.2
Identification of high-low areas	4.2	3.1	2.5*
Spot elevation problems	4.5	4.1	3.4
Vertical profile identification	1.9	1.7	1.6
Terrain visualization	0.9	0.8	1.0
Defilade	2.7	2.5	1.9

* Sig. at 0.01 level using 1-way ANOVA.

Analysis of the mean accuracy scores using a one-way analysis of variance showed significant differences in accuracy ($p < .01$) for the spot elevation problem (see Table 3).

Analysis of these mean accuracy scores for the spot elevation problems using the Newman-Keuls procedure indicated that accuracy scores were significantly higher for contour line maps and contour line maps supplemented with layer tints than for contour line maps supplemented with shading ($p < .01$), but were not significantly different from each other.

Table 3

Mean Number of Correct Answers

	Contour	Shaded relief	Layer tints
Landform identification	13.6	12.4	13.1
Ridge-valley identification	23.8	20.6	25.2
Slope identification	12.1	10.3	11.7
Identification of high-low areas	47.6	46.8	48.4
Spot elevation problems	23.1	16.6	22.6*
Vertical profile identification	8.5	6.8	7.7
Terrain visualization	9.5	8.4	9.1
Defilade	20.8	19.4	19.7

* Sig. at 0.01 level using 1-way ANOVA.

As indicated in the Description of the Test Construction section, there were minor variations in placement of overprinted lines, points and arrows due to slight differences in registration for the three relief formats. The accuracy scores were corrected for possible effects of differences in registration for the three relief formats. The accuracy scores were corrected for possible effects of differences in registration. Questions in which differences in registration might have affected the answers were eliminated to produce corrected accuracy scores. This alternate scoring procedure produced the same results for accuracy scores as the original scoring procedure ($p < 0.05$).

It is also interesting to note that performance with shading was the poorest (although not significantly so) on all of the eight subtests for both corrected and uncorrected accuracy scores. If the scores for the eight subtests were independent of each other, the probability of this happening by chance would be $(1/3)^8$ or 0.0002.

Taken together, the speed and accuracy scores indicate that for experienced individuals with at least a moderate amount of map reading and land navigation experience, addition of layer tints to the contour lines may enhance speed with which some types of relief information can be extracted from the hardcopy map. Addition of shaded relief to contour line maps, at least for the relatively high skill group that we tested, does not decrease time necessary for extracting relief information from hardcopy maps more than does addition of layer tints and actually may cause a decrement in performance where accuracy is concerned.

Discussion and Conclusions

In a study similar to ours (Phillips et al., 1975) the authors compared contour line maps, contour line maps supplemented with shading, layer tint maps and digital maps. They used questions concerning relative height, absolute height, base legibility (effect of relief portrayal on extraction of non-relief information) and "visualization" (locate steepest slope, defilade, matching portions of the maps to a plastic model). As indicated previously, there are a number of differences between their test and our test including use of actual map stimuli; keeping the basic relief information constant in all map formats, and use of a systematic map sampling procedure for assigning map stimuli to the different problems. In addition to these basic differences, their test was run as a speed test and therefore scores reflect both speed and accuracy. The digital maps proved to be superior for absolute height problems; but differed radically from the other maps in terms of information content and consequently will not be considered further. Layer tints proved best for two of the types of tasks, judging relative height and "visualizing" the landscape. Contour line maps supplemented with shading and contour line maps proved to be about the same for all problems. For judging absolute height, both contour line maps and contour line maps supplemented with shading proved to be significantly better than layer tint maps for one of the two map segments used in their study. The results from our study are in agreement with those of Phillips et al. in that gradient tints produced the best performance in ridge valley and high-low problems which appear to correspond to some of Phillips et als. visualisation and relative height problems. Our results differ from those of Phillips, et al. in that we found that both contour lines and contour lines plus layer tints produced equivalent performance for judging absolute height (spot elevation problems); while adding shaded relief to contour lines produced significantly <u>less</u> accurate performance.

Phillips et al. believe that this difficulty in use of layer tints was due to errors made in matching tints on the maps with tints in the key. Their layer tint maps differed from the ones used in our study in that: (a) their tint boundaries were not numerically labelled for elevation; and, (b) they used seven gradations of a single hue rather than different colors which might be more easily discriminated.

Using 12-layer tints on their maps with colors ranging from green through yellow and brown to white for the highest elevation, Kempf and Poock (1969) found that addition of layer tints to contour lines significantly decreases time necessary to determine spot elevations from that required when contour line maps are used. The different number of layer tints used (3-4 by ourselves and 12 by Kempf and Poock, 1969) may be responsible for the difference in results.

Phillips et al. (1975) did not find any significant effect on extraction of non-relief information due to addition of shading or layer tints to contour lines. Kempf and Poock (1960) found that adding layer tints to contour lines significantly increased time to find specific grid coordinates. In another study Delucia (1972) found that adding shading to contour lines significantly increased the time required for subjects to perform a location task.

In our test, use of four maps differing in elevation range and contour interval should decrease the possibility that the map stimuli used in the test are unrepresentative of topographic maps currently in use. This may not be true of the maps used by Phillips et al. (1975) which were taken from a 1:2.4 million scale map of a portion of the Atlantic Ocean bed. A significant question is "are there terrain related conditions (such as density of contour lines, types of landform, extent of hydrographic features, variation in vegetation, etc.) which play a significant role in determining effectiveness of the supplementary relief used?" Investigation of this question might help to provide a stronger rationale for choosing between alternative possibilities of relief portrayal. A more parametric assessment of each type of relief format might produce interesting results. However, the layer tints and shading techniques used in our study are representative of those currently in use and were chosen by map designers at the Engineering Topographic Laboratory as being most appropriate.

The effects of subject population are easily overlooked when the focus is on the topographic map. The information transmission characteristics vary with the subject population. Highly trained subjects with high ability in pattern analysis might be able to see landforms emerge from the pattern of the contour lines portraying terrain features; whereas, the contour lines may represent only clutter for moderately trained subjects with low ability in pattern analysis (Potash and Jeffrey, 1978). The results of our experiment suggest that, for subjects that have had training in reading contour lines and are at least moderately experienced in the use of contour line maps, addition of layer tints can facilitate extraction of some types of basic relief information. For this type of subject, the addition of shading does not facilitate performance above that produced by addition of layer tints and may result in a decrement in some type of tasks.

This test also may be used in more parametric studies than the present one to assess the effectivenss of different versions of the same relief format and the effects of different environmental conditions such as illumination upon map legibility. The conflicting results on spot elevation-related problems suggests that parametric work might produce interesting results.

This technique can be used for assessment of performance with alternative relief formats which do not have a common basis. However, that is a somewhat more difficult problem, (for example, relief formats such as shading plus spot elevation v. contour lines). If one wants to assess the effect of different formats on perceptual accessibility of information, then care must be taken to make sure that information content of the maps is constant. In the previous example, a sufficient number of spot elevation points must be included so that the available quantitative relief information approximates that provided by the contour lines. If information content "typically" associated with different relief formats is to be assessed, then one may want to contrast "representative" examples of the relief formats. In this case, differences in information content in the map stimuli used in testing may be valid.

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