

FM 21-26

DEPARTMENT OF THE ARMY FIELD MANUAL

MAP READING

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No. 21-26

HEADQUARTERS
DEPARTMENT OF THE ARMY
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MAP READING

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***This manual supersedes FM 21-26, 25 March 1965, including all changes.**

CHAPTER 1

INTRODUCTION

1-1. Purpose

This manual provides information and guidance for personnel who are engaged in the use of maps, aerial photographs, and related materials.

1-2. Scope

a. This manual contains information relating to the purpose and use of various types of maps, aerial photographs, photomosaics, photomaps, and pictomaps. Included are such subjects as marginal data, grids, map scales, land navigation, terrain forms and contours, field sketching, special purpose overlays, and standards of map accuracy. Appended to the manual is a list of related reference texts and tables of measure with conversion factors. The preparation of maps is not within the scope of this manual. The material contained herein is applicable without modification to both nuclear and nonnuclear warfare.

b. Users of this manual are encouraged to submit changes or comments to improve the manual. Comments should be keyed to the specific page, paragraph, and line of the text for which a change is recommended. Reasons should be provided for each comment to insure understanding and complete evaluation. Comments should be forwarded direct to the Commandant, U. S. Army Engineer School, Fort Belvoir, Va., 22060.

1-3. Related Publications

Reference is made in particular to FM 21-30 and FM 21-31 for a more complete knowledge of the symbols used on and with maps and overlays. Attention is also called to other references listed in Appendix A.

1-4. What Is a Map?

A topographic map is a mathematically determined presentation of a portion of the earth's surface systematically plotted to scale upon a plane surface. Manmade and natural features are depicted by sym-

bols, lines, colors, and forms. The ideal situation in compilation would be realized if every feature on the portion of the earth being mapped could be shown in true shape, orientation and proportion, with legibility retained. Obviously, such representation is impossible. This is evident when one considers that on a graphic at the scale of 1:250,000 all appropriate information contained within a square mile of the earth's surface must be condensed into a small area approximately .25 by .25 inch. An attempt to plot each feature true to scale would result in a product difficult, if not impossible, to read, for many items would be delineated so minutely as to defy recognition even with the aid of a magnifying glass. To be understandable, features must be indicated by conventional signs and symbols. For legibility many of these necessarily must be exaggerated in size, often far beyond the actual ground limits of the features represented. On a 1:250,000 scale map, the prescribed symbol for a landmark building covers an area equivalent to approximately 500 feet square on the ground; a road symbol is equivalent to a road approximately 520 feet wide on the ground; the symbol for a single track railroad (the width of a cross-tie) is equivalent to a railroad cross-tie approximately 1000 feet wide on the ground. The portrayal of many other features requires similar exaggeration, making it impossible to show every existing item. Therefore, both the selection of features to be shown as well as their portrayal are in accord with the guidance established by the Department of Defense.

1-5. Why Are Maps Important?

A map provides comprehensive information on the existence and location of, and the distances between, ground features such as populated places, routes of travel and communication, and extent of vegetation cover. It also indicates variations in land forms and heights of natural features. With our military forces dispersed throughout the world, it

has become increasingly necessary to rely on maps to supply information to our combat elements and to resolve logistical supply problems caused by operations far from our own shores. Troops and vast amounts of materials must be transported, stored, and phased into an operation at the proper time and place. By necessity, much of this planning must be done with maps. It is readily apparent that a major requirement for any operation is an adequate supply of maps. Equally apparent is the fact that the finest maps made are worthless unless the map user knows how to read them.

1-6. Care of Maps

a. One of the first considerations in the care of maps is the proper folding of the map. Figures 1-1 and 1-2 show ways of folding maps to make them small enough to be carried easily and still be available for use without having to unfold them entirely. After a map has been folded it should be pasted in a folder for protection. Apply adhesive to the back of the segments corresponding to A, F, L, and Q (fig. 1-2). It is suggested that before attempting to cut and fold a map in the manner illustrated in figure 1-2, a practice cut and fold be made with a piece of practice paper.

b. Most maps are printed on paper and require protection from water, mud, and tearing. Whenever possible, a map should be carried in a waterproof packet, in a pocket, under an outer garment, or other places where it is handy for use but still protected.

c. Care must also be exercised when using the map as it may have to last a long time. If it becomes

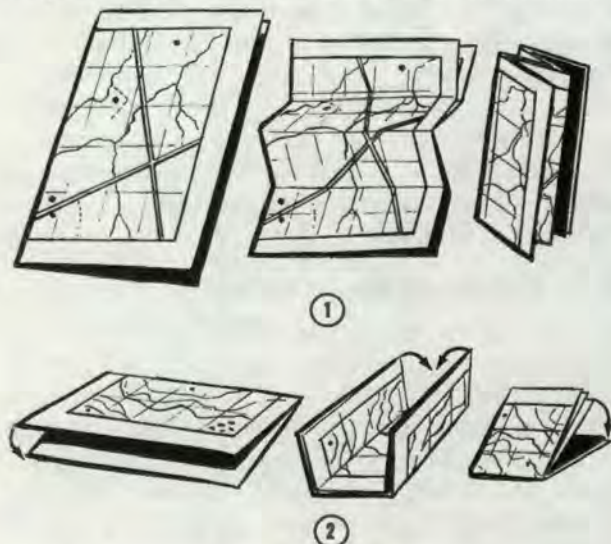


Figure 1-1. Two methods of folding a map.

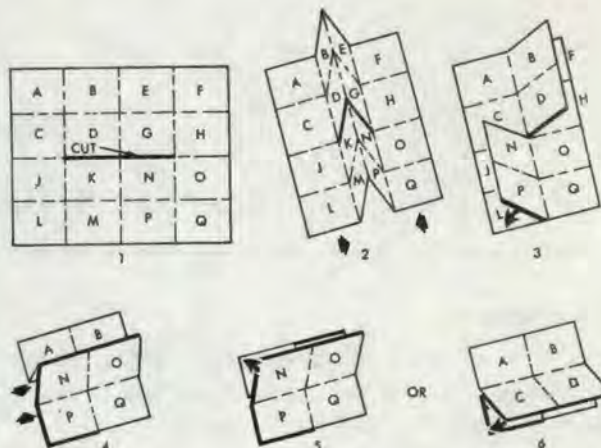


Figure 1-2. How to slit and fold a map for special uses.

necessary to mark a map, use light lines so that they may be erased easily without smearing or smudging, or leaving marks that may later cause confusion. If the margins of the map must be trimmed for any reason, it is essential to note carefully any marginal information which may be needed later, such as grid data, magnetic declination data or overlapping grid values and ticks.

1-7. Procurement of Maps

a. All military units are authorized an allowance of maps. FM 101-10-1 provides tables of initial allowance; however, local conditions may change some of these allowances. Map requisitions and distribution follow Engineer Intelligence channels through corps. In the division, however, maps are a responsibility of the division support command. Figure 1-3 shows the normal flow of map requisition and shipment.

b. To order a map, it is necessary to use only the stock number, which identifies each individual map. See paragraph 2-1b(21) for a discussion of the composition of the stock number.

c. The stock number of each map is indicated in its lower margin. Stock numbers are also listed in map catalogs that are available at division and higher levels and occasionally in smaller units. The U.S. Army Map Supply Systems Catalogs, which cover maps of the world, are produced by Army Map Service, but within a theater of operations, a catalog of theater maps may be prescribed for use. A map catalog consists of small scale maps upon which the outlines of the individual map sheets of a series have been delineated.

d. Another document that is an aid to the map

user is the gazetteer. A gazetteer lists all the names appearing on a map series of a geographical area, a designation that identifies what is located at that place name, a grid reference, a sheet number of the

map upon which the name appeared, and the latitude and longitude of the named feature. Gazetteers are prepared for maps of foreign areas only. Figure 1-4 shows a page from a gazetteer.

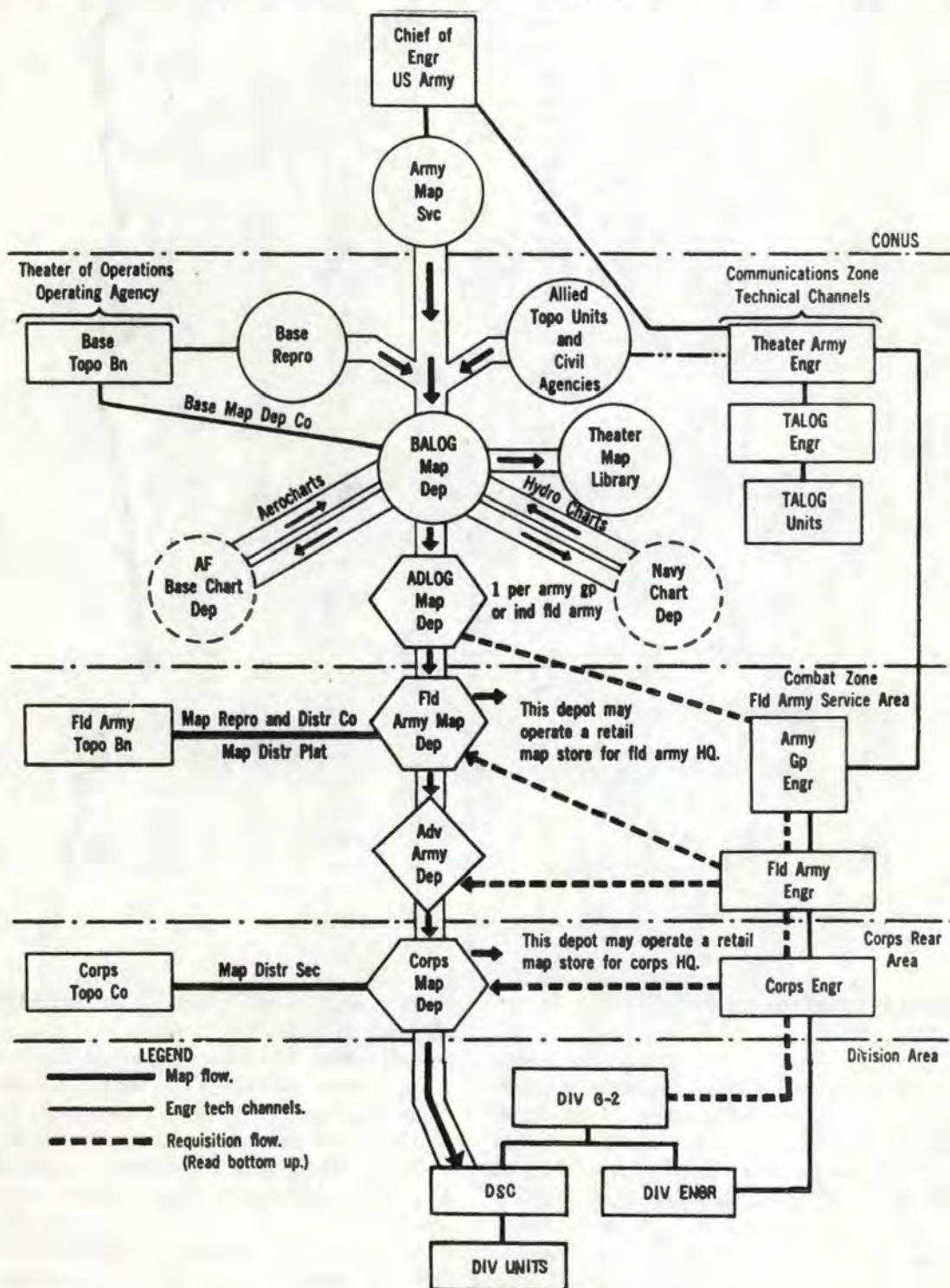


Figure 1-3. Normal map distribution flow chart.

NAME	DESIGNATION	GRID REF.	SHEET NO.	LAT.	LONG.	
WASSERSTEIG	AN	NUA804	7523	48°26'	9°39'	WASSERWIESEN
WASSERSTEIGE	AN	NUB032	7818	48°08'	8°40'	WASSERWIESEN
WASSERSTEIN	AN	NUA475	7424	48°32'	9°00'	WASSERWIESEN
WASSERSTEIN	HILL	T08786	8739	49°13'	12°13'	WASSERWIESEN
WASSERSTEIN	ROCK	NCA476	3823	52°08'	9°38'	WASSERWIESEN
WASSERSTEIN	NT	WV0269	6611	49°22'	7°39'	WASSERZELL
WASSERSTEIN	NT	PT6470	8433	47°34'	11°11'	WASSERZELL
WASSERSTEIN	FRST	HU3270	7522	48°20'	9°26'	WASSERZELL
WASSERSTEIN	CHCH	PV9069	8655	49°21'	11°57'	WASSERZELL
WASSERSTEIN	ROCK	UD0942	0840	49°00'	12°20'	WASSERZELLERHOF
WASSERSTEIN	HILL	NU7094	7621	48°20'	9°18'	WASSERZELL
WASSERSTEIN	AN	HV8809	7127	48°50'	10°12'	WASSERZELL
WASSERSTEIN	AN	PA7407	8334	49°11'	11°25'	WASSERZELL
WASSERSTEIN	NT	PA7308	8334	49°11'	11°24'	WASSERZELL
WASSERSTEIN	NT	HV2747	8613	49°21'	8°00'	WASSERZELL
WASSERSTEINBERG	RIDGE	HV2747	8614	49°21'	8°00'	WASSERZELL
WASSERSTEINCHEN	AN	NA4208	6223	49°43'	9°35'	WASSERZELL
WASSERSTEINER BERG	NT	HV2374	0513	49°25'	7°50'	WASSERZELL
WASSERSTEINHOHE	CAVE	HU3170	7522	48°20'	9°25'	WASSERZELL
WASSERSTETTEN	POPL	HU3287	7622	48°22'	9°20'	WASSERZELL
WASSERSTICH-GR	DTCH	PT7261	8533	47°20'	11°17'	WASSERZELL
WASSERSTICHWEG	ROAD	NUA190	7315	48°40'	8°12'	WASSERZELL
WASSERSTOCK	ROAD	NUA289	7315	48°50'	8°13'	WASSERZELL
WASSERSTRAND	SO	HU4051	7623	48°10'	9°32'	WASSERZELL
WASSERSTRASSE	POPL	HCT082	4118	51°05'	8°02'	WASSERZELL
WASSERSTUBE	POPL	LC7703	4509	51°28'	7°14'	WASSERZELL
WASSERSTUBE	FRST	NUA574	7419	48°31'	9°18'	WASSERZELL
WASSERSTUBE	AN	HV2209	7121	48°50'	9°18'	WASSERZELL
WASSERSTÜCKER	NDW	MB4107	5315	50°37'	8°10'	WASSERZELL
WASSERSTUPPEN	POPL	UD3478	6542	49°26'	12°43'	WASSERZELL
WASSERTAL	AN	HU5674	7118	48°40'	9°17'	WASSERZELL
WASSERTAL	VAL	PV6626	7033	48°58'	11°16'	WASSERZELL
WASSERTAL	AN	HU7573	7417	48°31'	8°40'	WASSERZELL
WASSERTAL	VAL	NU5074	7424	48°31'	9°41'	WASSERZELL
WASSERTAL	VAL	PA6922	6134	49°05'	11°21'	WASSERZELL
WASSERTAL	VAL	HV2272	8613	49°21'	7°46'	WASSERZELL
WASSERTAL	VAL	PT5867	8432	47°32'	11°06'	WASSERZELL
WASSERTAL	VAL	PT6247	8633	47°21'	11°09'	WASSERZELL
WASSERTAL	VAL	PC3880	3892	52°00'	11°01'	WASSERZELL
WASSERTAL	AN	NT2598	8122	47°50'	9°20'	WASSERZELL
WASSERTAL-GR	SPRG	HV2371	6613	49°21'	7°59'	WASSERZELL
WASSERTAL-GR	DTCH	PT3070	8430	47°35'	10°44'	WASSERZELL
WASSERTAL-GR	DTCH	UN3373	8442	47°35'	12°47'	WASSERZELL
WASSERTALER HANG	SLP	HV2271	8613	49°23'	7°50'	WASSERZELL
WASSERTEICH	FRST	HU4877	7415	48°33'	8°18'	WASSERZELL
WASSERTEICH	STRM	HU4877	7415	48°33'	8°18'	WASSERZELL
WASSERTEICH	VAL	HU1564	7521	48°26'	9°12'	WASSERZELL
WASSERTEICH	FRST	HV2055	6713	49°15'	7°34'	WASSERZELL
WASSERTEIL	AN	HV2273	8621	49°25'	9°18'	WASSERZELL
WASSERTHAL	FARM	TN9992	8230	47°45'	12°19'	WASSERZELL
WASSERTHAL	VAL	PV7022	7034	48°55'	11°26'	WASSERZELL
WASSERTHAL GRABEN	DTCH	UN0092	8240	47°45'	12°20'	WASSERZELL
WASSERTHÖL	SO	UN3881	8343	47°40'	12°50'	WASSERZELL
WASSERTHÜNGEN	POPL	PV1633	6920	49°02'	10°35'	WASSERZELL
WASSERTURM	AN	NU7080	7825	48°07'	9°56'	WASSERZELL
WASSERUNG	FRST	NU1616	5231	50°42'	9°14'	WASSERZELL
WASSERUNG	NDW	HV3335	5916	49°03'	8°22'	WASSERZELL
WASSERUNG	NDW	HV0935	6920	49°04'	9°07'	WASSERZELL
WASSERWALZEY	HILL	NA3009	6214	49°44'	8°02'	WASSERZELL
WASSERWALGENSEN	HILL	LC7693	4209	51°46'	7°12'	WASSERZELL
WASSERWALGENSEN	HILL	NC2118	4321	51°37'	9°18'	WASSERZELL
WASSERWAND	CLIF	TN8900	8730	47°44'	12°11'	WASSERZELL
WASSERWAND	SLP	PA3824	6131	49°51'	10°55'	WASSERZELL
WASSERWAND-K	PEAK	UN3471	8443	47°34'	12°52'	WASSERZELL
WASSERWEG	ROAD	PC2623	4330	51°39'	10°49'	WASSERZELL
WASSERWEG	ROAD	NA2135	8013	48°58'	7°54'	WASSERZELL
WASSERWEG	ROAD	NA5947	8917	50°04'	8°34'	WASSERZELL
WASSERWEG	ROAD	HV8801	7227	48°45'	10°12'	WASSERZELL
WASSERWEH	DAM	HU1925	7013	48°04'	7°45'	WASSERZELL
WASSERWERK PENZBERG	HILL	PT7789	8284	47°46'	11°22'	WASSERZELL
WASSERWERK ANEINE	HILL	LC9085	3710	52°12'	7°23'	WASSERZELL
WASSERWERK SIEGLAR	HILL	MB6833	5108	50°50'	7°08'	WASSERZELL
WASSERWERK STORTEL	HILL	MB0881	4712	51°10'	7°41'	WASSERZELL
WASSERWERK WORMS	HILL	HV6397	6316	49°37'	8°20'	WASSERZELL
WASSERWERKSKANAL	CHAL	HU0832	7812	48°08'	7°46'	WASSERZELL
WASSERWIESE	NDW	H89231	5127	50°49'	10°19'	WASSERZELL
WASSERWIESE	NDW	NA8726	6118	49°53'	8°40'	WASSERZELL
WASSERWIESE	NDW	PV6687	6435	49°51'	11°17'	WASSERZELL
WASSERWIESEN	NDW	HU1277	7421	48°33'	9°10'	WASSERZELL
WASSERWIESEN	NDW	HU2274	7421	48°31'	9°18'	WASSERZELL
WASSERWIESEN	NDW	HU2273	7421	48°31'	9°18'	WASSERZELL
WASSERWIESEN	NDW	HU0074	7420	48°31'	9°00'	WASSERZELL
WASSERWIESEN	NDW	HU8945	7719	48°13'	8°50'	WASSERZELL
WASSERWIESEN	AN	HV4389	6415	49°33'	8°14'	WASSERZELL

Figure 1-4. Page from a gazetteer.

1-8. Security of Maps

a. All maps, classified or unclassified, require special handling. If a map falls into unauthorized hands, it could easily endanger a military operation by furnishing an indication of our plans or areas of interest to the enemy. Even more important would be a map upon which the movements or positions of our troops had been marked. It is possible even though the markings on a map have been erased to determine some of the information that had been

marked upon it. **MAPS MUST NOT FALL INTO UNAUTHORIZED HANDS!**

b. If a map is no longer needed, it must be turned in to proper authority. If a map is in danger of being captured, it must be destroyed. The best method of destruction is by burning and scattering the ashes. If burning is impracticable, the map can be torn into small pieces and scattered over a wide area.

c. Maps of some areas of the world are subject to **THIRD PARTY LIMITATIONS** and require spe-

cial handling. These are agreements which permit the United States to make and use maps of another country provided that these maps are not released to any third party without prior consent of the country concerned.

d. Some maps may be classified and must be handled and cared for in accordance with AR 380-5 and, if applicable, other local security directives.

1-9. Categories and Uses of Military Maps

The term "military maps" as used in this manual refers to maps prepared by the Department of the Army for use by the Department of Defense. Military maps are categorized by scale and type.

a. *Scale.* The scale is expressed as a fraction and gives the ratio of map distance to ground distance. The terms "small scale," "medium scale," and "large scale" may be confusing when read in conjunction with the numbers. However, if the number is viewed as a fraction, it quickly becomes apparent that 1:600,000 of something is smaller than 1:75,000 of the same thing. Hence, the larger the number after 1:, the smaller the scale of the map. Appendix D illustrates the differences in the extent of coverage and the detail shown on maps of different scales and types covering the same area.

(1) *Small scale.* Maps at scales of 1:600,000 and smaller are used for general planning and for strategical studies at the high echelons. The standard small scale is 1:1,000,000.

(2) *Medium scale.* Maps at scales larger than 1:600,000 but smaller than 1:75,000 are used for planning operations, including the movement and concentration of troops and supplies. The standard medium scale is 1:250,000.

(3) *Large scale.* Maps at scales of 1:75,000 and larger are used to meet the tactical, technical, and administrative needs of field units. The standard large scale is 1:50,000.

b. *Types (Refer to Appendixes D and E for examples).*

(1) *Planimetric map.* A map which presents only the horizontal positions for the features represented. It is distinguished from a topographic map by the omission of relief in a measurable form.

(2) *Topographic map (fig. E-3).* A map which portrays terrain and landforms in a measurable form, as well as the horizontal positions of the features represented. The vertical positions, or relief, are normally represented by contours. On maps showing relief, the elevations and contours are measured from

a specified vertical datum plane, usually mean sea level.

(3) *Plastic relief map (fig. E-1).* A topographic map preprinted on plastic material and formed by heat and vacuum over a reproductive positive mold, thus giving the same information as contained on a topographic map in a three dimensional form so that the user can readily see variation in elevation.

(4) *Photomap (fig. E-4).* A reproduction of an aerial photograph or a photomosaic made from a series of aerial photographs upon which grid lines, marginal data, place names, route numbers, important elevations, boundaries, approximate scale and approximate direction have been added (para 9-2).

(5) *Jointoperations graphics (figs. E-5 and E-6).* A series of 1:250,000 scale military maps designed for joint ground and air operations. The maps are published in a ground and an air edition. The topographic information is identical on both the ground and air version of the same map sheet. The ground series shows elevations and contours in meters while the air series shows the same elevations and contours in feet. Both series emphasize the air landing facilities but the air series has additional symbols to identify aids and obstructions to air navigation. (See appendix C for additional information.)

(6) *Pictomap (fig. E-2).* PICTOMAP is the acronym for Photographic Image Conversion by Tonal Masking Procedures. It is a map on which the photographic imagery of a standard photomap has been converted into interpretable colors and symbols (para 9-3).

(7) *Plastic relief photomap.* A photomap made on plastic in the same manner as a topographic plastic relief map.

(8) *Photomosaic.* An assembly of aerial photographs which is commonly called a mosaic in topographic usage. Mosaics are useful when time does not permit the compilation of a more accurate map. The accuracy of a mosaic depends on the method employed in its preparation and may vary from simply a good pictorial effect of the ground to that of a planimetric map.

(9) *Military city map (fig. D-1).* A topographic map, usually 1:12,500 scale, of a city, delineating streets and showing street names, important buildings, and other urban elements of military importance which are compatible with the scale of the map. The scales of military city maps can vary from 1:25,000 to 1:5,000, depending on the im-

portance and size of the city, density of detail, and available intelligence information.

(10) *Special maps.* Maps for special purposes such as trafficability, communications and assault maps. These are usually overprinted maps of scales smaller than 1:100,000 but larger than 1:1,000,000 (para 1-11). Other types of special maps are those made from organosol or materials other than paper, to meet the requirements of special climatic conditions.

(11) *Terrain model.* A scale model of the terrain showing land-forms, and in large scale models, industrial and cultural shapes. It is designed to provide a means for visualizing the terrain for planning or indoctrination purposes, and for briefing on assault landings.

1-10. Foreign Maps

It may be necessary to use maps that have been compiled by nations other than our own. When this happens, and when time permits, the marginal information and grids are changed to conform to our standards. The scales may differ from U.S. maps, but they do express the ratio of map distance to ground distance and can be used in the same way. The legend must be used since the map symbols almost always differ from ours. Because the accuracy of foreign maps varies considerably, they are usually evaluated in regard to established accuracy standards before they are issued to our troops. TM 5-248 gives detailed information pertaining to foreign made maps.

1-11. Special Purpose Maps

A special purpose map is one that has been designed or modified to give information not covered on a standard map or to elaborate on the standard map data. Special purpose maps are usually in the form of an overprint. An overprint is a map or chart upon which, in addition to the usual information, data of special importance and use have been printed or stamped. The wide range of subjects that could be covered under the heading of special purpose maps prohibits, within the scope of this manual, more than a brief mention of a few of the more important ones. The special purpose maps or overprints may be in the form of individual sheets or many of them may be combined and bound into a study of an area. A few of the subjects covered

are—

- a. Land forms.
- b. Drainage characteristics.
- c. Vegetation.
- d. Climate.
- e. Coast and landing beaches.
- f. Roads and bridges.
- g. Railroads.
- h. Airfields.
- i. Urban areas.
- j. Electric power.
- k. Fuels.
- l. Surface water resources.
- m. Ground water resources.
- n. Natural construction materials.
- o. Crosscountry movement.
- p. Suitability for airfield construction.
- q. Airborne operations.

1-12. Map Standards of Accuracy

a. *General.* Military maps normally are prepared in accordance with National Standard Map Accuracy requirements and a note indicating this is included in the credit note. However, when source materials or other factors do not permit the meeting of these standards, maps of less accuracy may be prepared. The following is extracted from AR 117-5.

b. *National Standard Map Accuracy Requirements.*

(1) *Horizontal accuracy.* For maps at publication scales smaller than 1:20,000, 90 percent of all well-defined features, with the exception of those unavoidably displaced by exaggerated symbolization, are located within two one-hundredths of an inch (.02 in.), at publication scale, of their geographic positions as referred to the map projection.

(2) *Vertical accuracy.* Ninety percent of all contours and elevations interpolated from contours are accurate within one-half of the basic contour interval. Discrepancies in the accuracy of contours and elevations beyond this tolerance may be decreased by assuming a horizontal displacement within the tolerance specified above.

c. *Military City Maps.*

(1) Horizontal and vertical accuracies are commensurate with those required for 1:50,000 scale topographic maps.

(2) The horizontal tolerance for well-defined features is 83 feet (25.3 meters) ground distance for Class A maps and 166 feet (50.6 meters) ground distance for Class B maps (e below). At the scales used for city maps, these ground distances are

equivalent to the following map distances:

	Class A	Class B
1:5,000	.20 inch (5.0 mm)	.40 inch (10.0 mm)
1:10,000	.10 inch (2.5 mm)	.20 inch (5.0 mm)
1:12,500	.08 inch (2.0 mm)	.16 inch (4.0 mm)

d. *Photomaps.* The detail match between adjoining photographs is not in error by more than two one-hundredths of an inch (.02 in.) at publication scale where the variation in ground elevation does not exceed 1/25 of the flight altitude. Position errors do not exceed seventy-five one-thousandths of an inch (0.075 in.) at publication scale. Tie-in between sheets has the same tolerance as the match between adjoining photographs. These standards are a guide and generally cannot be met under wartime conditions. Accuracy requirements are determined specifically for each project.

e. *Map Evaluation Criteria.* The general criteria used in the evaluation of topographic maps are based upon accuracy of position, and the currency and presentation of map content, and are expressed

either by letter-numeral categories or by adjectives. These are as follows:

(1) *Class A-1 (excellent, adequate).* Maps which meet National Map Accuracy Standards, with up-to-date content, standard grid and military scale, and romanized names.

(2) *Class A-2 (good, adequate).* Maps which meet the same standards of accuracy as Class A-1, but which do not meet one or more of the standards for currency or presentation.

(3) *Class B-1 (good, usable).* Maps which do not meet accuracy requirements for Class A-1, but which meet a horizontal accuracy tolerance of .04 inch and a vertical accuracy tolerance of one contour interval, and which do meet the standards for currency and presentation.

(4) *Class B-2 (fair, usable).* Maps which meet the same standards of accuracy as Class B-1, but do not meet the standards for currency and presentation.

(5) *Class C (poor, inadequate).* Maps which fail to meet the standards of accuracy, currency, or presentation for either Class A or B.

CHAPTER 2

MARGINAL INFORMATION AND SYMBOLS

2-1. Marginal Information

a. Before placing into use any piece of equipment, an intelligent operator always reads the manufacturer's book of instruction. This is also true with maps. The instructions are placed around the outer edges of the map and are known as marginal information. All maps are not the same so it becomes necessary, every time a different map is used, to examine the marginal information carefully.

b. Figure E-3 is a folded, large scale (1:50,000), topographic map. The circled numbers indicate the items of marginal information with which the map user must be familiar. These circled numbers correspond to the item numbers listed and described below.

(1) *Sheet name.* The sheet name is found in two places; the center of the upper margin and the right side of the lower margin. Generally, a map is named after its outstanding cultural or geographic feature. Whenever possible the name of the largest city on the map is used.

(2) *Sheet number.* The sheet number is found in the upper right margin and is used as a reference number for that map sheet. For maps at 1:100,000 scale and larger, sheet numbers are based on an arbitrary system which makes possible the ready orientation of maps at scales of 1:100,000, 1:50,000 and 1:25,000 (fig. 2-1 and 2-2).

(3) *Series name and scale.* The map series name is found in the upper left margin. A map series usually comprises a group of similar maps at the same scale and on the same sheet lines or format designed to cover a particular geographic area. It may also be a group of maps to serve a common purpose, such as the military city maps. The name given a series is that of the most prominent area. The scale note is a representative fraction which gives the ratio of a map distance to the corresponding distance on the earth's surface. For example, the scale note 1:50,000 indicates that one unit of measure

64		7064	7164	7264
63	6963	7063	7163	7263
62	6962	7062	7162	7262
	69	70	71	72

Figure 2-1. Basic development of the sheet number for 1:100,000 scale maps.

on the map equals 50,000 units of the same measure on the ground.

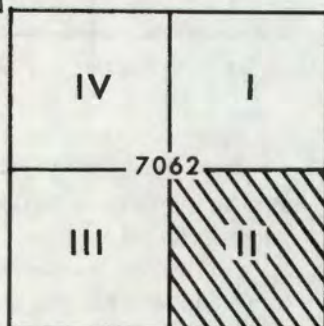
(4) *Series number.* The series number appears in the upper right margin and the lower left margin. It is a comprehensive reference expressed either as a four digit numeral (e.g., 1125), or as a letter, followed by a three or four digit numeral (e.g., M661; T7110).

(5) *Edition number.* The edition number is found in the upper margin and in the lower left margin. It represents the age of the map in relation to other editions of the same map and the agency responsible for its production. The latest edition will have the highest number. EDITION 3-AMS indicates the third edition prepared by Army Map Service. Edition numbers run consecutively; a map bearing a higher edition number is assumed to contain more recent information than the same map bearing a lower edition number. Advancement of the edition number constitutes authority to rescind or supersede the previous edition.

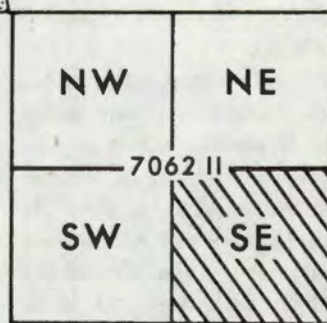
(6) *Bar scales.* The bar scales are located in the center of the lower margin. They are rulers used to convert map distance to ground distance. Maps

86°30'	86°00'	85°30'	85°00'	84°30'
6964	7064	7164	7264	38°00'
6963	7063	7163	7263	37°30'
6962	7062	7162	7262	37°00'
				36°30'

A Sheet Numbers at 1:100,000 Scale (7062)



B Sheet Numbers at 1:50,000 Scale (7062 II)



C Sheet Numbers at 1:25,000 Scale (7062 II SE)

Figure 2-2. Systems for numbering 1:100,000, 1:50,000 and 1:25,000 scale maps.

have three or more bar scales, each in a different unit of measure.

(7) *Credit note.* The credit note is in the lower left margin. It lists the producer, dates, and general methods of preparation or revision. This information is important to the map user in evaluating the reliability of the map as it indicates when and how the map information was obtained. On some recent 1:50,000 scale maps, the map credits are shown in tabular form in the lower margin, with reliability information presented in a coverage diagram.

(8) *Adjoining sheets diagram.* Maps at all standard scales contain a diagram which illustrates the adjoining sheets.

(a) On maps at 1:100,000 and larger scales and at 1:1,000,000 scale, the diagram is called the Index to Adjoining Sheets, and consists of as many rectangles, representing adjoining sheets, as are necessary to surround the rectangle which represents the sheet under consideration. The diagram usually contains nine rectangles, but the number may vary depending on the locations of the adjoining sheets. All represented sheets are identified by their sheet numbers. Sheets of an adjoining series, whether published or planned, that are at the same scale are represented by dashed lines. The series number of the adjoining series is indicated along the appropriate side of the division line between the series (fig. 2-3).

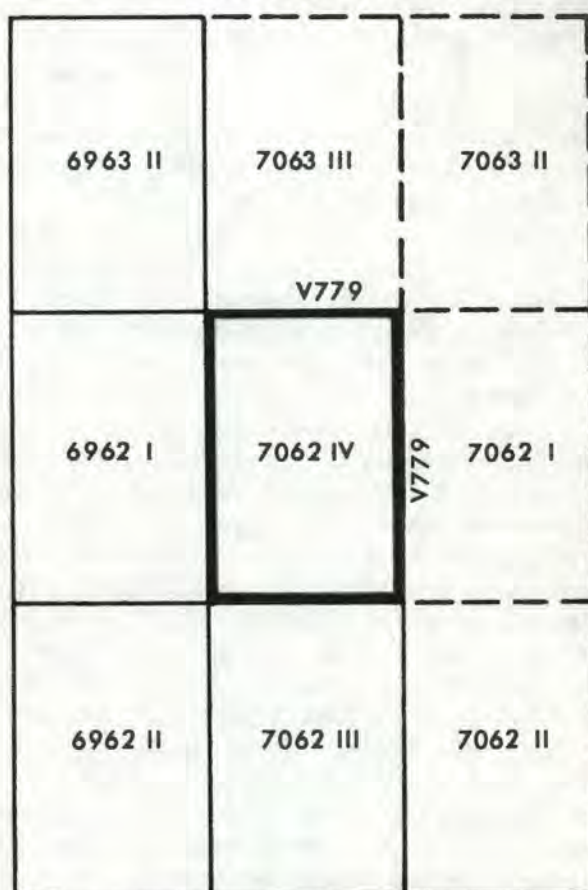
(b) On 1:50,000 scale maps, the sheet number and series number of the 1:250,000 scale map of the area are shown below the Index to Adjoining Sheets.

(c) On maps at 1:250,000 scale, the adjoining sheets are shown in the Location Diagram. Usually, the diagram consists of 25 rectangles, but the number may vary with the locations of the adjoining sheets.

(9) *Index to boundaries.* The Index to Boundaries diagram appears in the lower or right margin of all sheets 1:100,000 scale or larger, and 1:1,000,000 scale. This diagram, which is a miniature of the map, shows the boundaries which occur within the map area, such as county lines and state boundaries. On 1:250,000 scale maps, the boundary information is included in the Location Diagram.

(10) *Projection note.* The projection system is the framework of the map. For military maps, this framework is of the conformal type, i.e., small areas of the surface of the earth retain their true shapes on the projection; measured angles closely approximate true values; and the scale factor is the same in all directions from a point. The projection is identi-

INDEX TO ADJOINING SHEETS



Sheet 7062 IV falls within NJ 15-1, V502, 1:250,000

Figure 2-3. Index to adjoining sheets.

fied on the map by a note in the lower margin. Refer to TM 5-241-1 for the development characteristics of the conformal type projection systems.

(a) Between 80° South and 84° North, maps at scales larger than 1:500,000 are based on the Transverse Mercator Projection. The note reads—

TRANSVERSE MERCATOR PROJECTION

(b) Between 80° South and 84° North, maps at 1:500,000 scale and smaller are based on standard parallels of the Lambert Conformal Conic Projection. The note reads, for example—

LAMBERT CONFORMAL CONIC
PROJECTION

STANDARD PARALLELS 36°40'N AND 39°20'N

(c) Maps of the polar regions (south of 80° South and north of 84° North) at 1:1,000,000 and

larger scales are based on the Polar Stereographic Projection. The note reads—

POLAR STEREOGRAPHIC PROJECTION

(d) General and special purpose maps, regardless of scale, are based on projection systems individually selected to conform with the intended use of the map. The selected projection is identified on the map by a note in the lower margin.

(11) *Grid note.* The grid note is located in the center of the lower margin. It gives information pertaining to the grid system used, the interval of grid lines, and the number of digits omitted from the grid values. Notes pertaining to overlapping or secondary grids are also included when appropriate.

(12) *Grid reference box.* The grid reference box contains instructions for composing a grid reference.

(13) *Vertical datum note.* This note is located in the center of the lower margin. It designates the basis for all vertical control stations, contours and elevations appearing on the map. On Joint Operations Graphics at 1:250,000 scale, the vertical datum note may appear in the Reliability Diagram.

(14) *Horizontal datum note.* This note is located in the center of the lower margin. It indicates the basis for all horizontal control stations appearing on the map. The network of these stations controls the horizontal positions of all mapped features. On Joint Operations Graphics at 1:250,000 scale, the horizontal datum note may appear in the Reliability Diagram.

(15) *Legend.* The legend is located in the lower left margin. It illustrates and identifies the topographic symbols used to depict some of the more prominent features on the map. The symbols are not always the same on every map. To avoid error in the interpretation of symbols the legend must always be referred to when a map is read.

(16) *Declination diagram.* The declination diagram is located in the lower margin of large-scale maps and indicates the angular relationships of true north, grid north, and magnetic north. On maps at 1:250,000 scale, this information is expressed as a note in the lower margin.

(17) *User's note.* A user's note is located in the center of the lower margin. It requests cooperation in correcting errors or omissions on the map. Errors should be marked and the map forwarded to the agency identified in the note.

(18) *Unit imprint.* The unit imprint, located in the lower right margin, identifies the agency which printed the map and the printing date. The printing

date should not be used to determine when the map information was obtained.

(19) *Contour interval.* The contour interval note appears in the center of the lower margin. It states the vertical distance between adjacent contour lines on the map. When supplementary contours are used, the interval is indicated.

(20) *Special notes and scales.* (not included on the Leavenworth map). Under certain conditions special notes or scales may be added to the marginal information to aid the map user. The following are examples:

(a) *Glossary.* A glossary is an explanation of technical terms or a translation of terms on maps of foreign areas where the native language is other than English.

(b) *Classification.* Certain maps require a note indicating the security classification. This is shown in the upper and lower margins.

(c) *Protractor scale.* A protractor scale may appear in the upper margin on some maps. It is used to lay out the magnetic-grid declination for the map which, in turn, is used to orient the map sheet with the aid of a magnetic compass.

(d) *Coverage diagram.* On maps at scales of 1:100,000 and larger, a coverage diagram may be used. It is normally in the lower or right margin and indicates the methods by which the map was made, dates of photography, and reliability of the sources. On maps at 1:250,000 scale, the coverage diagram is replaced by a reliability diagram.

(e) *Elevation guide.* On some maps at scales of 1:100,000 and larger, a miniature characterization of the terrain is shown by a diagram in the lower right margin of the map. The terrain is represented by bands of elevation, spot elevations, and major drainage features. The elevation guide provides the map reader with a means of rapid recognition of major land forms.

(f) *Special notes.* A special note is any statement of general information that relates specifically to the mapped area. For example: Ricefields are generally subject to inundation; however, they may be seasonally dry.

(21) *Stock number identification.* All maps published by or for the Corps of Engineers which are in the Department of the Army map supply system, contain stock number identifications, which are used in requisitioning map supplies. The identification consists of the words "STOCK NO." followed by a unique designation which is composed of the series



Figure 2-4. An area as viewed from a ground position.

number, the sheet number of the individual map and on recently printed sheets, the edition number. The designation is limited to 15 units (letter and numbers). The first 5 units are allotted to the series number; when the series number is less than 5 units, the letter "X" is substituted as the 5th unit. The sheet number is the next component, except that Roman numerals which are part of the sheet number are converted to Arabic numerals in the stock number. The last two units are the edition number; the edition number is preceded by an "0" if the number is less than 10. If the current edition number is unknown, the number 01 is used. The latest available edition, however, will be furnished. Asterisks are used for any intervening units between the sheet number and the edition number to make a total of fifteen units. For example: Series E 823, sheet number 3884 IV NE, Edition 1, Stock No. E 823 X 38844NE*01.

2-2. Topographic Map Symbols and Colors

a. The purpose of a map is to permit one to visualize an area of the earth's surface with pertinent features properly positioned. Ideally, all the features within an area would appear on the map in their true proportion, position, and shape. This, however, is not practicable because many of the features would be unimportant and others would be unrecognizable because of their reduction in size. The mapmaker has been forced to use symbols to represent the natural and manmade features of the earth's surface.

These symbols resemble, as closely as possible, the actual features themselves but as though viewed from above (fig. 2-4 and 2-5).

b. To facilitate the identification of features on the map by providing a more natural appearance and a contrast, the topographic symbols are usually printed in different colors, with each color identifying a class of features. The colors vary with different types of maps, but on a standard large-scale topographic map, the colors used and the features each represents are—

- (1) *Black*—the majority of cultural or manmade features.
- (2) *Blue*—water features such as lakes, rivers, and swamps.
- (3) *Green*—vegetation such as woods, orchards, and vineyards.

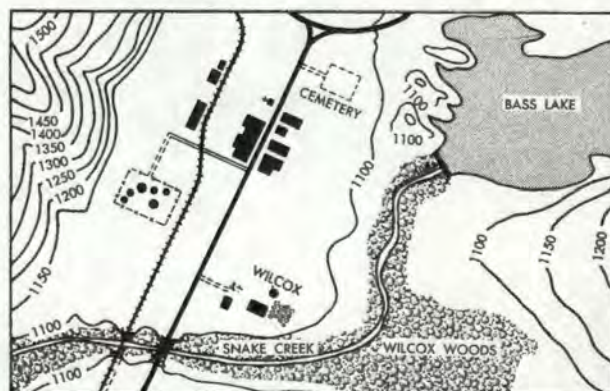


Figure 2-5. Map of the same area as in figure 2-4.

- (4) *Brown*—all relief features such as contours.
- (5) *Red*—main roads, built-up areas, and special features.

(6) Occasionally other colors may be used to show special information. These, as a rule, are indicated in the marginal information. For example, aeronautical symbols and related information for air-ground operations are shown in purple on Joint Operations Graphics.

c. In the process of making a map, everything must be reduced from its actual size on the ground to the size at which it appears on the map. This requires, for purposes of clarity, that some of the symbols be exaggerated. They are positioned, however, in such a manner that the center of the symbol remains in its true location. An exception to this would be the position of a feature adjacent to a major road. If the width of the road has been exaggerated, then the feature is moved from its true position to preserve its relation to the road.

d. FM 21-31 gives a description of topographic symbols and abbreviations authorized for use on U.S. military maps.

2-3. Military Symbols

In addition to the topographic symbols used on maps to represent the natural and manmade features of the earth, military personnel require some method for showing the identity, size, location, and movements of troops and military activities and installations. The symbols used to represent these military features are known as military symbols. Normally, military symbols are not printed on maps because the features and units that they represent are constantly moving or changing; military security is also a consideration. They do appear on special maps and overlays (para 7-1). The map user draws them in, in accordance with proper security precautions. Refer to FM 21-30 for complete information on military symbols and abbreviations.

CHAPTER 3

GRIDS

3-1. Identifying Locations

Meet me at 21st Street and 56th Avenue. This is a simple method of giving a location most of us have used at some time. It works well in cities that have identified streets or in areas with well-known features, but presents problems in undeveloped areas or in unfamiliar parts of the world. To cope with the problem of location, a uniform and precise system of referencing is required. Some of these systems are discussed in this chapter. To satisfy military requirements, the system used must meet the following conditions:

- It does not require a knowledge of the geographic area involved.
- It is applicable to large geographic areas.
- It does not require landmarks.
- It is applicable at all map scales.
- It is easy to understand and use by all military personnel.

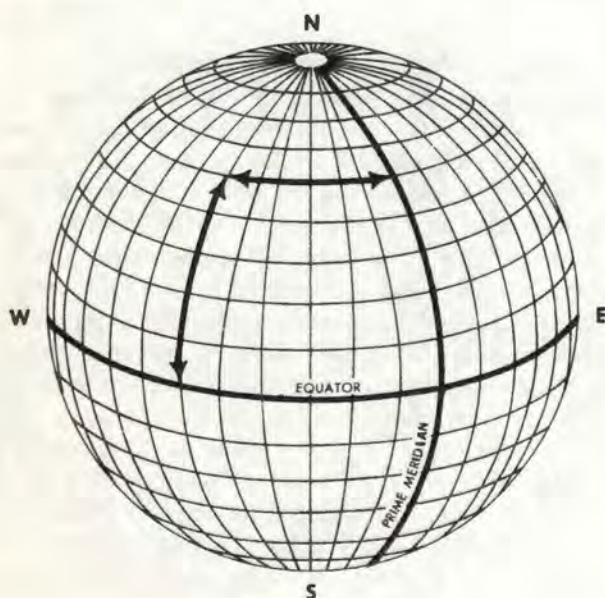


Figure 3-1. Reference lines.

3-2. Geographic Coordinates

a. One of the oldest systematic methods of location is based upon the geographic coordinate system. By drawing a set of east-west rings around the globe (parallel to the equator), and a set of north-south rings crossing the equator at right angles and converging at the poles, a network of reference lines is formed from which any point on the earth's surface can be located. The distance of a point north or south of the equator is known as its *latitude*. The rings around the earth parallel to the equator are called parallels of latitude or simply parallels. Lines of latitude run east-west but north-south distances are measured between them (fig. 3-1 and 3-2). A second set of rings around the globe at right angles to lines of latitude and passing through the poles are known as meridians of longitude or simply meridians. One meridian is designated as the

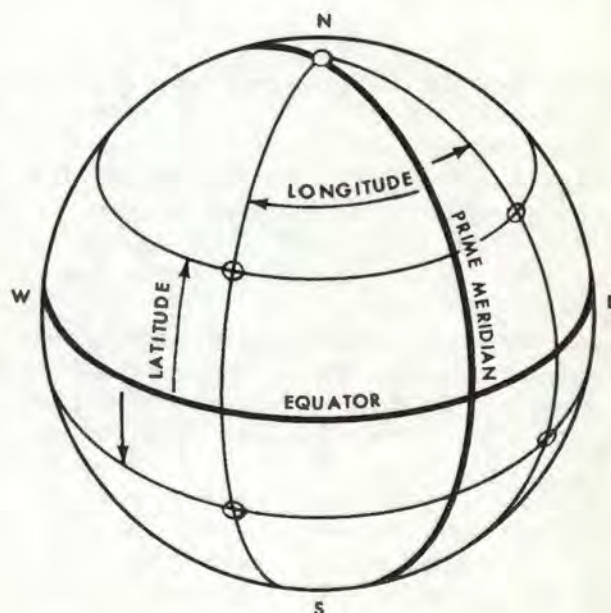


Figure 3-2. Position location.

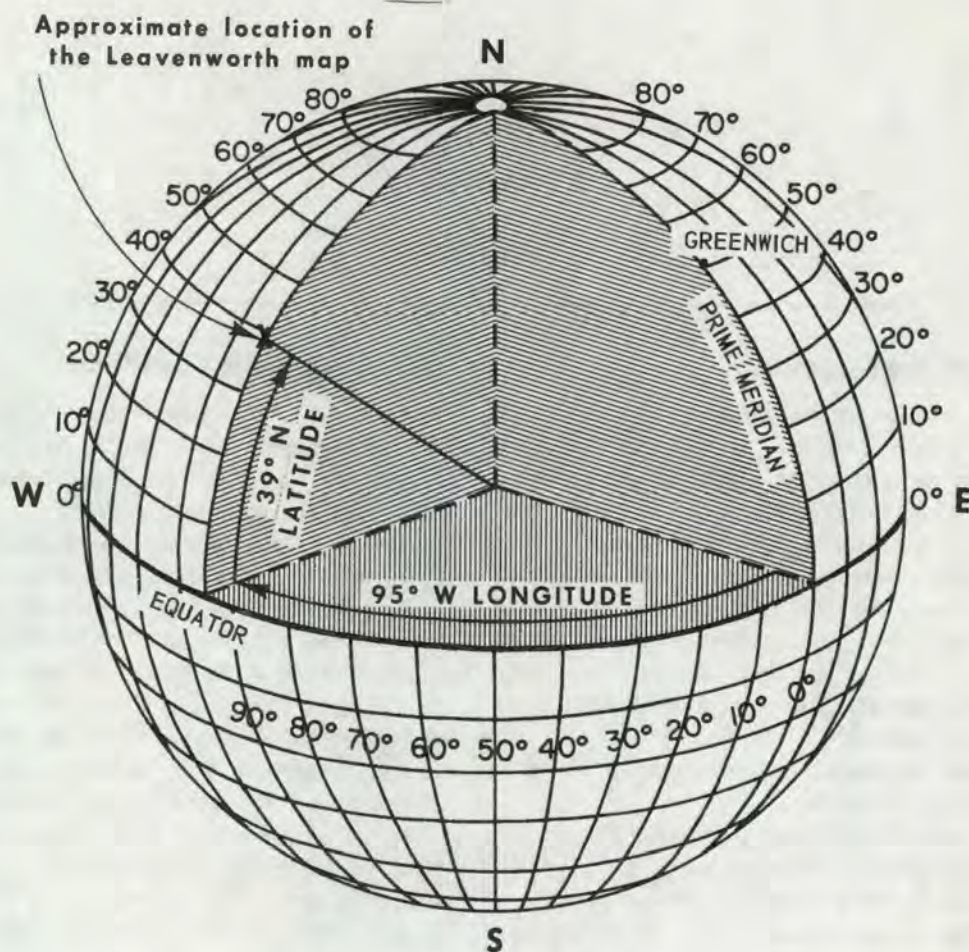


Figure 3-3. Latitude and longitude.

prime meridian. The prime meridian of the system we use runs through Greenwich, England, and is known as the Greenwich meridian (see fig. 3-7 for other prime meridians). The distance east or west of a prime meridian to a point is known as its *longitude*. Lines of longitude (meridians) run north-south but east-west distances are measured between them (fig. 3-1 and 3-2).

b. Geographic coordinates are expressed in angular measurement. Each circle is divided into 360°, each degree into 60 minutes, and each minute into 60 seconds. The degree is symbolized by °, the minute by ', and the second by ". Starting with 0° at the equator, the parallels of latitude are numbered to 90° both north and south. The extremities are the north pole at 90° north latitude and the south pole at 90° south latitude. Latitude can have the same numerical value north or south of the equator, so the direction N or S must always be given. Starting

with 0° at the prime meridian, longitude is measured both east and west around the world. Lines east of the prime meridian are numbered to 180° and identified as east longitude; lines west of the prime meridian are numbered to 180° and identified as west longitude. The direction E or W must always be given. The line directly opposite the prime meridian, 180°, may be referred to as either east or west longitude. The values of geographic coordinates, being in units of angular measure, will mean more if they are compared with units of measure with which we are more familiar. At any point on the earth the ground distance covered by 1° of latitude is approximately 111 kilometers (69 miles); 1 second is equal to approximately 30 meters (100 feet). The ground distance covered by 1 degree of longitude at the equator is also approximately 111 kilometers (69 miles), but decreases as one moves north or south, until it becomes zero at the poles. For ex-

ample, one second of longitude represents about 30 meters (100 feet) at the equator but at the latitude of Washington, D.C., 1 second of longitude is approximately 24 meters (78 feet). Latitude and longitude are illustrated in figure 3-3.

c. Geographic coordinates appear on all standard military maps and on some they may be the only method of locating or referencing the location of a point. The four lines that inclose the body of the map (neatlines) are lines of latitude and longitude. Their values are given in degrees and minutes at each of the four corners. On the Leavenworth map (fig. E-3), the figures $39^{\circ}15'$ and $94^{\circ}45'$ appear at the lower right corner. The bottom line of this map is latitude $39^{\circ}15'00''$ N, and the line running up the right side is longitude $94^{\circ}45'00''$ W. In addition to the latitude and longitude given for the four corners there are, at regularly spaced intervals along the sides of the map, small tick marks extending into the body of the map. Each of these tick marks is identified by its latitude or longitude value. One-third of the way up the right side of the map is a tick mark and the number 20'. The full value for this tick is $39^{\circ}20'00''$ of latitude. At one-third and two-thirds of the distance across the map from the 20' tick will be found a cross tick (grid squares 4155 and 3455) and at the far side another 20' tick. By connecting the ticks and crosses with straight lines, a $39^{\circ}20'00''$ line of latitude can be added to the map. This procedure is also used to locate the $39^{\circ}25'00''$ line of latitude. For lines of longitude the same procedure is followed using the ticks along the top and bottom edges of the map.

d. After the parallels and meridians have been drawn, the geographic interval (angular distance between two adjacent lines) must be determined. Examination of the values given at the tick marks gives the interval. For most maps of scale 1:25,000, the interval is $2'30''$. For the Leavenworth map and most maps of scale 1:50,000, it is $5'00''$. The geographic coordinates of a point are found by dividing the sides of the geographic square in which the point is located into the required number of equal parts. If the geographic interval is $5'00''$ and the location of a point is required to the nearest second, each side of the geographic square must be divided into 300 equal parts ($5'00'' = 300''$), each of which would have the value of 1 second. Any scale or ruler that has 300 equal divisions and is as long or longer than the spacing between the lines may be used. For example, on the Leavenworth map, the following

steps will determine the geographic coordinate of the horizontal control point on top of PILOT KNOB (southwest of the city of Leavenworth).

(1) Draw the parallels and meridians which enclose the area around the control point on the map.

(2) Determine the values of the parallels and meridians within which the point falls.

Latitude $39^{\circ}15'00''$ and $39^{\circ}20'00''$

Longitude $94^{\circ}55'00''$ and $95^{\circ}00'00''$

(3) Determine the geographic interval ($5'00'' = 300''$).

(4) Select a scale that has 300 small divisions or multiples thereof (300 divisions, 1 second each; 150 divisions, 2 seconds each; 75 divisions, 4 seconds each, etc.).

(5) To determine the latitude—

(a) Place the scale with the 0 (zero) of the scale on the latitude of the lowest number value ($39^{\circ}15'00''$) and the 300 of the scale on the highest numbered line ($39^{\circ}20'00''$) (1, fig. 3-4).

(b) Keeping the 0 and 300 on the two lines, slide the scale (2, fig. 3-4) along the parallels until the PILOT KNOB horizontal control point symbol is along the edge of the numbered scale.

(c) Read the number of seconds from the scale (3, fig. 3-4), approximately 170.

(d) Convert the number of seconds to minutes and seconds ($170'' = 2'50''$) and add to the value of the lower numbered line ($39^{\circ}15'00'' + 2'50'' = 39^{\circ}17'50''$) (4, fig. 3-4).

(e) The latitude is $39^{\circ}17'50''$, but this is not enough.

(f) The latitude $39^{\circ}17'50''$ could be either north or south of the equator, so the letter N or S must be added to the latitude. To determine whether it is N or S, look at the latitude values at the edge of the map and find the direction in which they become larger. If they are larger going north, use N; if they are larger going south, use S (fig. 3-5).

(g) The latitude for the point is $39^{\circ}17'50''$ N.

(6) To determine the longitude, repeat the same steps but measure between lines of longitude and use E and W. The geographic coordinates of the horizontal control point on top of PILOT KNOB should be approximately $39^{\circ}17'50''$ N and $94^{\circ}56'09''$ W (fig. 3-6).

e. To locate a point on the Leavenworth map knowing the geographic coordinates, many of the same steps are followed. For example, to locate $39^{\circ}27'40''$ N and $94^{\circ}50'40''$ W:

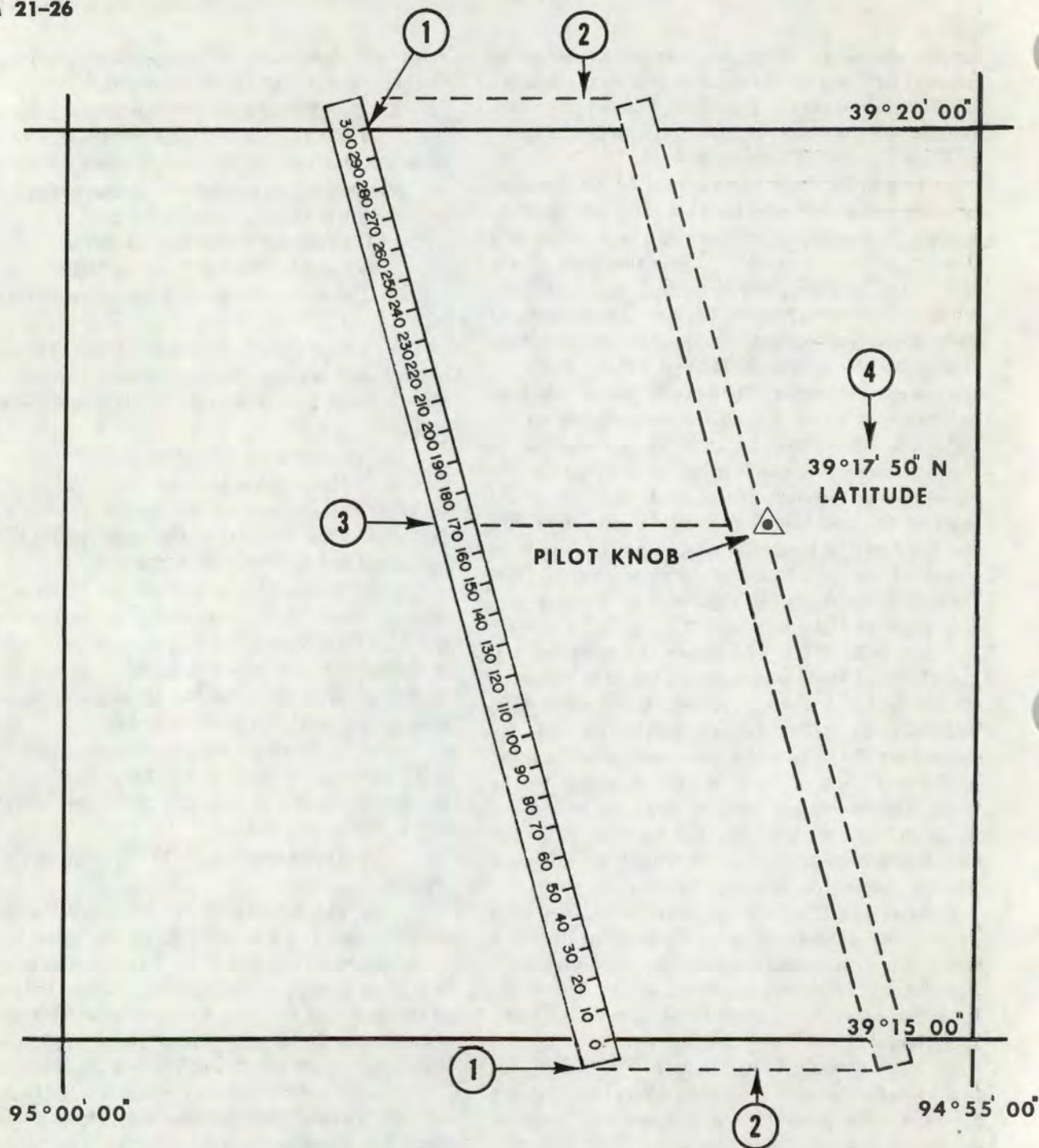


Figure 3-4. Dividing a geographic square with a scale to determine latitude.

- (1) Find the geographic lines within which the point falls: latitude $39^{\circ}25'00''$ and $39^{\circ}30'00''$, longitude $94^{\circ}50'00''$ and $94^{\circ}55'00''$.

- (2) Draw these lines.

- (3) For latitude—

- (a) Subtract from the latitude of $39^{\circ}27'40''$ the value for the lower numbered latitude line $39^{\circ}25'00''$.

- (b) Change the difference of $2'40''$ to seconds (160'').

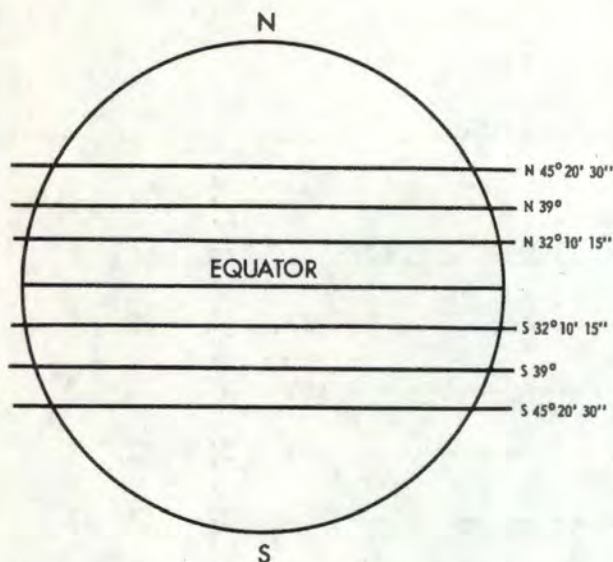


Figure 3-5. The necessity of indicating N or S.

(c) Place the 0 of the scale on the $39^{\circ}25'00''$ line and the 300 on the $39^{\circ}30'00''$ line.

(d) At the number 160 on the scale, make a mark on the map.

(e) Staying on these same two lines, move the scale several centimeters to the left or right and repeat (d) above.

(f) Draw an extended straight line through the two points located.

(4) For longitude, follow the same steps as for latitude.

(5) The location of the point is at the intersection of the two lines. The feature is SWAMP SCHOOL, northeast of Weston, Missouri.

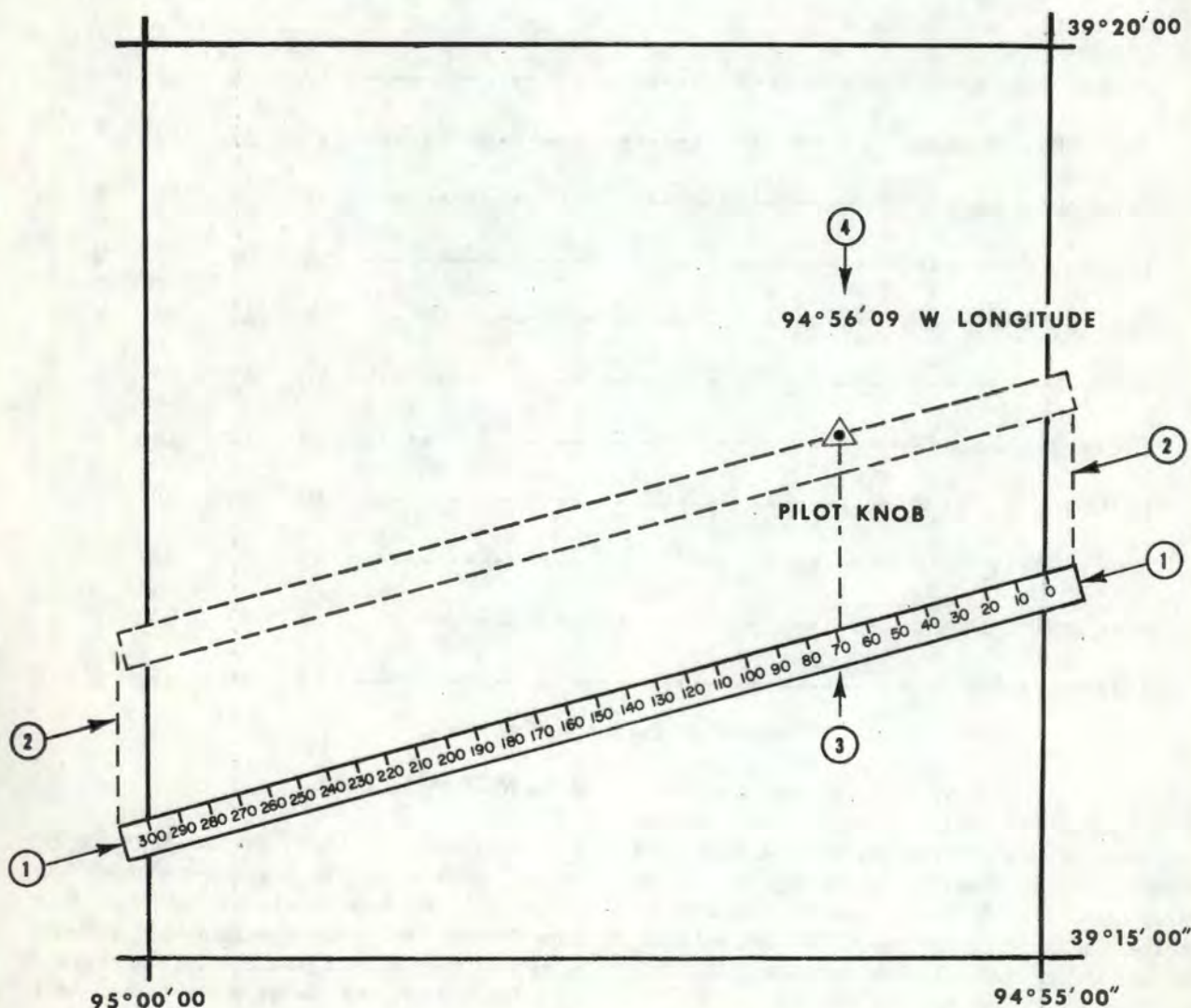


Figure 3-6. Dividing a geographic square with a scale to determine longitude.

Foreign Prime Meridians

(Based on Greenwich longitude)

	0	'	"	
Amsterdam, Netherlands -----	4	53	01	E
Athens, Greece -----	23	42	59	E
Batavia (Djakarta), Indonesia -----	106	48	28	E
Bern, Switzerland -----	7	26	22	E
Brussels, Belgium -----	4	22	06	E
Copenhagen, Denmark -----	12	34	40	E
Djakarta, see Batavia				
Ferro, Canary Islands -----	17	39	46	W
Helsinki, Finland -----	24	57	17	E
Istanbul, Turkey -----	28	58	50	E
Lisbon, Portugal -----	9	07	55	W
Madrid, Spain -----	3	41	15	W
Oslo, Norway -----	10	43	23	E
Paris, France -----	2	20	14	E
Pulkovo, U. S. S. R. -----	30	19	39	E
Rome, Italy -----	12	27	08	E
Stockholm, Sweden -----	18	03	30	E
Tirane, Albania -----	19	46	45	E

Figure 3-7. Table of prime meridians.

f. The maps made by some nations do not have their longitude values based on the prime meridian that passes through Greenwich, England. Figure 3-7 shows the prime meridians which may be used by other nations. When these maps are issued to our soldiers a note usually appears in the marginal information giving the difference between our prime meridian and the one used on the map.

3-3. Military Grids

An examination of the Transverse Mercator Projection which is used for large-scale military maps, shows that most lines of latitude and longitude are curved lines. The quadrangles formed by the intersection of these curved parallels and meridians are of different sizes and shapes, complicating the lo-

cation of points and the measurement of directions. To facilitate these essential operations, a rectangular grid is superimposed upon the projection. This grid (a series of straight lines intersecting at right angles), furnishes the map reader with a system of squares similar to the block system of most city streets. The dimensions and orientation of different types of grids vary, but these three properties are common to all military grid systems:

They are true rectangular grids;

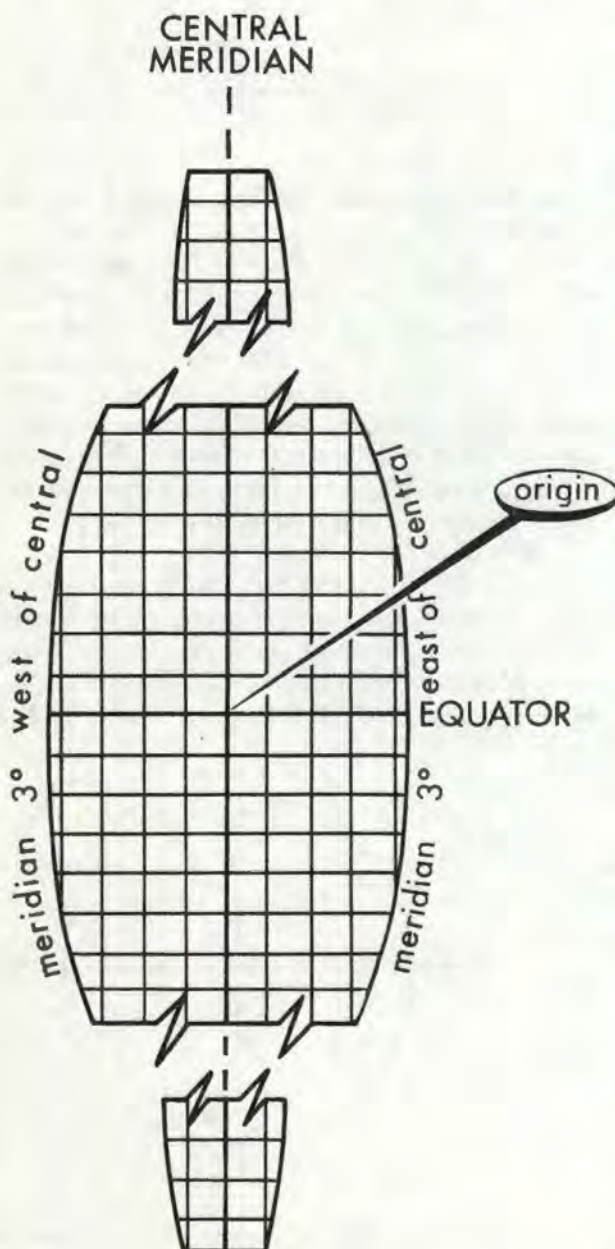


Figure 3-8. A UTM grid zone.

They are superimposed on the geographic projection;

They permit linear and angular measurements.

a. *Universal Transverse Mercator Grid.* The Universal Transverse Mercator Grid (hereinafter referred to as the UTM Grid) has been designed to cover that part of the world between Lat 84° N and Lat 80° S, and as its name implies, is imposed on the Transverse Mercator Projection. Each of the 60 zones (6° wide) into which the globe is divided for the grid has its own origin at the intersection of its central meridian and the equator (fig. 3-8). The grid is identical in all 60 zones. Base values (in meters) are assigned to the central meridian and the equator and the grid lines are drawn at regular intervals parallel to these two base lines. With each grid line assigned a value denoting its distance from the origin, the problem of locating any point becomes progressively easier. Normally it would seem logical to assign a value of zero to the two base lines and measure outward from them. This, however, would require either that directions—N, S, E, or W—be always given with distances, or that all points south of the equator or west of the central meridian have negative values. This inconvenience is eliminated by assigned "false values" to the base lines, resulting in positive values for all points within each zone. Distances are always measured *RIGHT and UP* (east and north as the reader faces the map) and the assigned values are called "false easting" and "false northing". The false easting value for each central meridian is 500,000 meters, and the false northing value for the equator is 0 meters when measuring in the Northern Hemisphere and 10,000,000 meters when measuring in the Southern Hemisphere (fig. 3-9). The use of the UTM Grid for point designation will be discussed in detail in paragraph 3-4, The U. S. Army Military Grid Reference System.

b. *Universal Polar Stereographic Grid.* The rectangular grid imposed on the areas represented by the Polar Stereographic Projection is called the Universal Polar Stereographic (UPS) Grid.

(1) *North polar area.* The origin of the UPS Grid applied to the north polar area is the North Pole. The "north-south" base line is the line formed by the 0° and 180° meridians; the "east-west" base line is the line formed by the two 90° meridians. The false coordinates of the origin are 2,000,000 meters east and 2,000,000 meters north (fig. 3-10).

(2) *South polar area.* The origin of the UPS Grid in the south polar area is the South Pole;

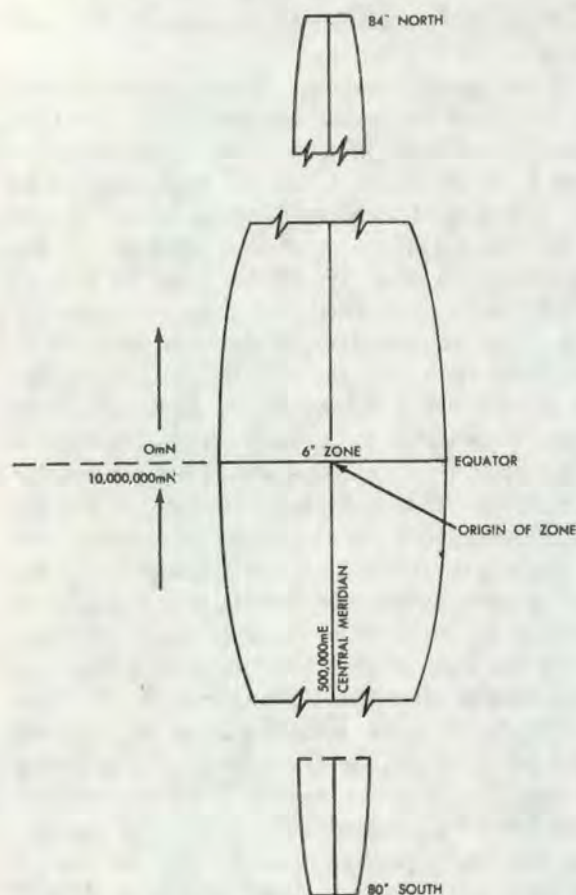


Figure 3-9. False easting and northing for a grid zone.

the base lines and false coordinates of the origin are similar to those of the north polar area (fig. 3-11).

3-4. The U.S. Military Grid Reference System

The U.S. Army Military Grid Reference System is designated for use with the UTM and UPS Grids. The coordinate values of points in these grids could contain as many as 15 digits, if numerals alone were used. The U.S. Army Military Grid Reference System reduces the length of written coordinates by substituting single letters for several numbers. Using the UTM and the UPS grids, it is possible for the location of a point (identified by numbers alone) to be in many different places on the surface of the earth. With the use of the U.S. Army Military Grid Reference System there is no possible chance for a point to be identified as being at more than one place on the surface of the earth. This becomes very important in this age of possible global warfare. In this system the world is divided into 60 grid

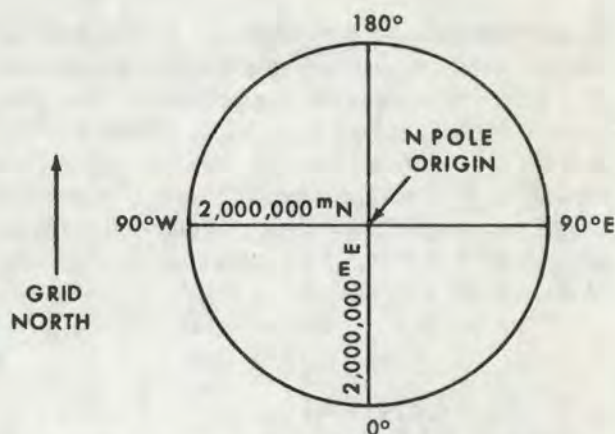


Figure 3-10. False easting and northing for the UPS Grid (North Pole).

zones, which are large, regularly-shaped geographic areas, each of which is given a unique identification, called the *grid zone designation*. These are covered by a pattern of 100,000-meter squares, based on the grid covering the area. Each square is identified by two letters called the 100,000-meter square identification, and this identification is unique within the area covered by the grid zone designation. Numerical references within the 100,000-meter square are given to the desired accuracy in terms of the easting (E) and northing (N) grid coordinates for the point.

a. Grid Zone Designation.

(1) *UTM Grid*. The first major breakdown is the division of each zone into areas $6^\circ \times 8^\circ$ and $6^\circ \times 12^\circ$. It will be remembered that for the Transverse Mercator Projection the earth's surface between 80° S and 84° N was divided into 60 N-S

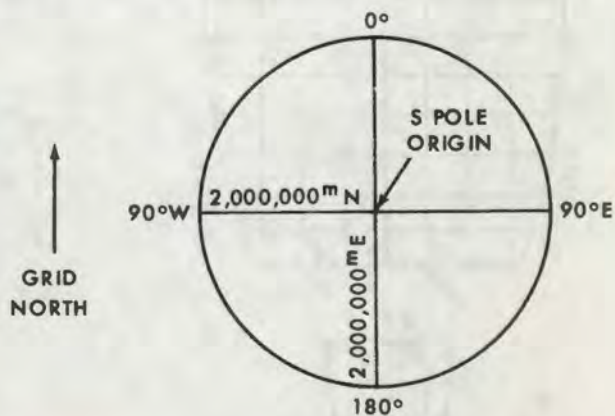


Figure 3-11. False easting and northing for the UPS Grid (South Pole).

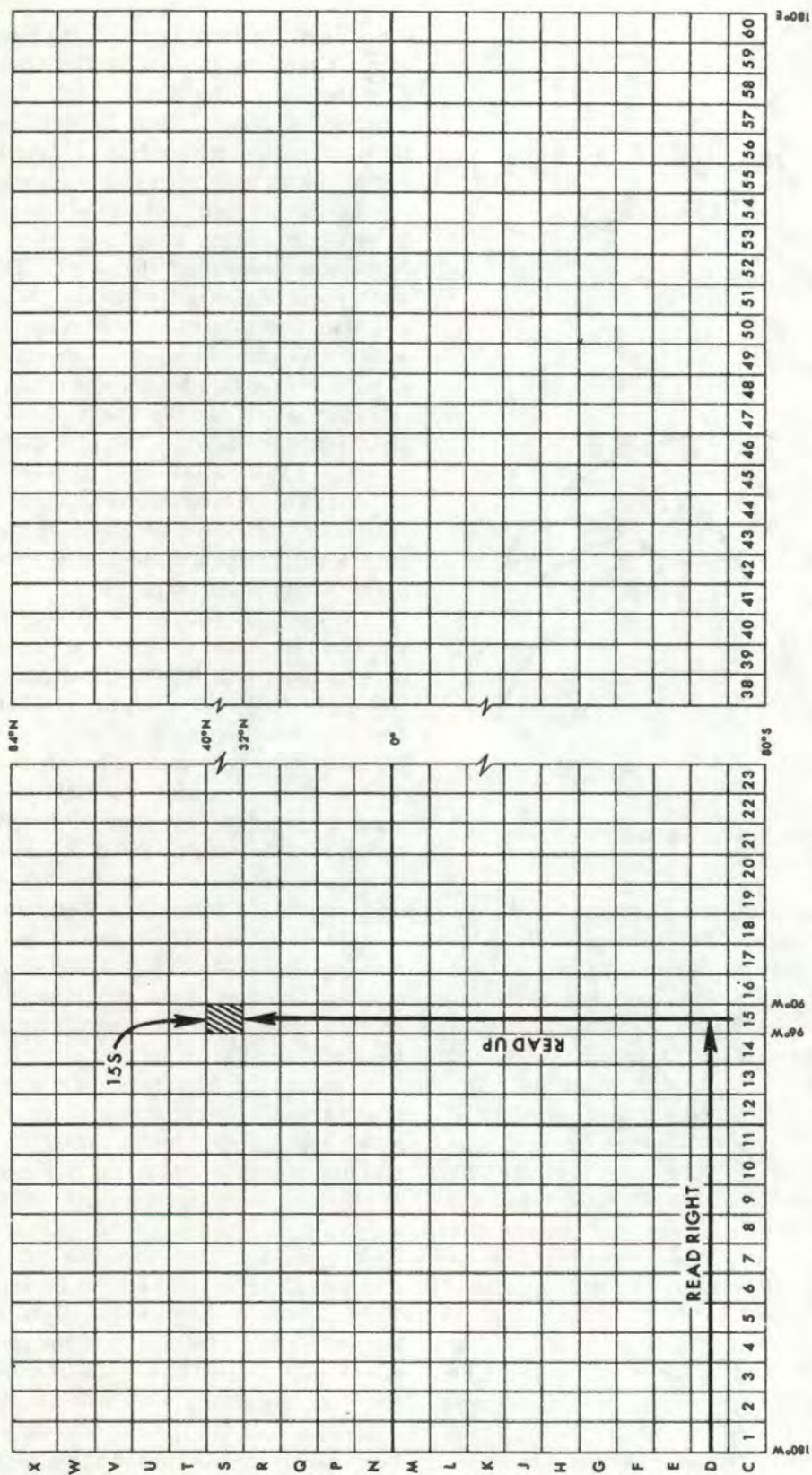


Figure 3-12. Grid zone designation for UTM.

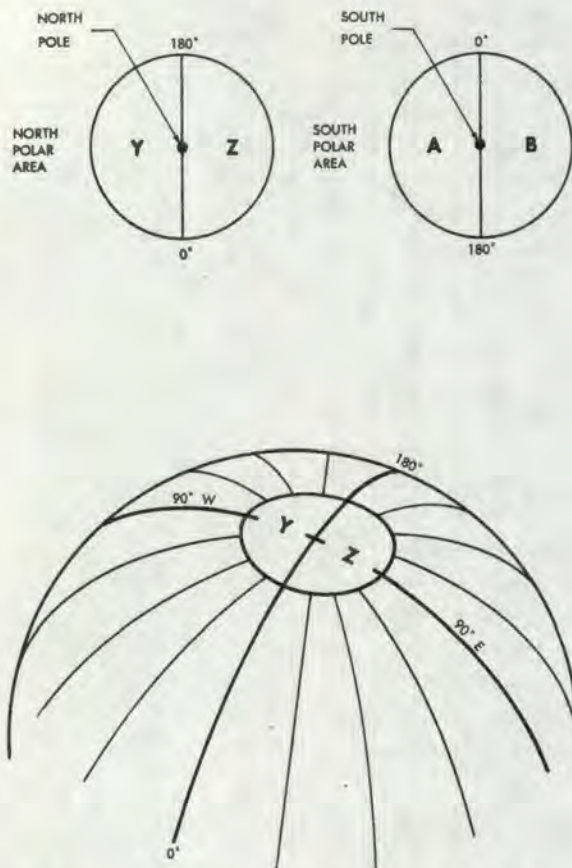


Figure 3-13. Grid zone designation for UPS Grid.

zones each 6° wide. These zones are numbered from west to east, 1 through 60, starting at the 180° meridian. This surface is divided into 19 east-west rows each 8° high and 1 additional row at the extreme north which is 12° high. These rows are then lettered, from south to north, C through X (I and O omitted to avoid confusion with numerals). Any $6^\circ \times 8^\circ$ zone or $6^\circ \times 12^\circ$ zone can then be identified by giving the number and letter of the grid zone and row in which it lies. These are read RIGHT and UP, so the number is always written before the letter. This combination of zone number and row letter constitutes the grid zone designation. Leavenworth lies in zone 15 and row S, or in grid zone designation 15S (fig. 3-12).

(2) *UPS Grid.* The remaining letters of the alphabet, A, B, Y, and Z, are used for the UPS Grids. Each polar area is divided into two zones, separated by the 0° - 180° meridian. In the south polar area, the letter A is the grid zone designation for the area west of the 0° - 180° meridian, and B for

the area to the east. In the north polar area, Y is the grid zone designation for the western area and Z for the eastern (fig. 3-13).

b. *100,000-Meter Square.* Between 84° north and 80° south each $6^\circ \times 8^\circ$ or $6^\circ \times 12^\circ$ zone is covered by 100,000-meter squares, which are identified by the combination of two alphabetical letters. The first letter is the column designation; the second letter is the row designation (fig. 3-14). The north and south polar areas are also divided into the 100,000-meter squares by columns and rows. The system is designed to place like-lettered squares as far apart as possible. A detailed discussion of the arrangement of letters which identify the columns and rows of 100,000-meter squares is beyond the scope of this manual; TM 5-241-1 gives a description of the system. The 100,000-meter square identification letters for each sheet are shown in the sheet miniature which is a part of the grid reference box in the lower margin of the map.

c. *Military Grid Reference.* We have now divided the earth's surface into $6^\circ \times 8^\circ$ quadrangles, and covered these with 100,000-meter squares. The military grid reference of a point consists of the numbers and letters indicating in which of these areas the point lies, plus coordinates locating the point to the desired precision within the 100,000-meter square. Having learned the essentials of the grid zone designation and the 100,000-meter square identification, it remains but to see how the coordinates of the point are tied in which these larger areas.

(1) *Grid lines.* The regularly spaced lines that make up the UTM and UPS Grids on any large-scale map are divisions of the 100,000-meter square; the lines are spaced at 10,000- or 1,000-meter intervals. Each of these lines is labeled at both ends with its false easting or false northing value (showing its relation to the origin of the zone). For the 1,000-meter grid, except for the values labeling the first grid line in each direction from the southwest corner of the sheet, the last three digits (000) of the value are omitted. Two digits of the values are printed in large type, and these same two digits appear at intervals along the grid line on the face of the map. They are called the principal digits, and represent the 10,000 and 1,000 digits of the grid value; they are of major importance to the map reader because they are the numbers he will use most often for referencing points. The smaller digits complete the full false coordinates of the grid lines, but they are rarely used for point designation (fig. 3-15). On

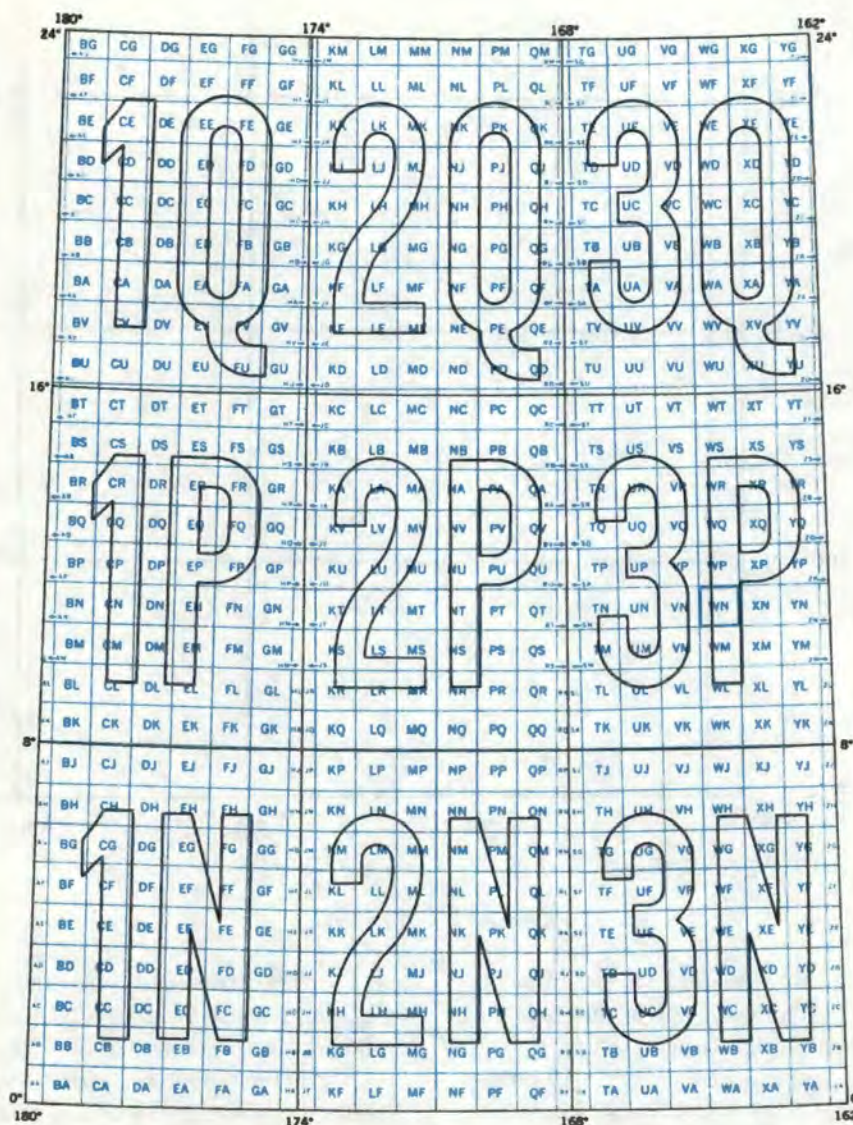


Figure 3-14. 100,000-meter square identifications.

sheets whose grid line spacing is 10,000-meters, only one principal digit is shown, representing the 10,000 digit of the grid value.

Example:

The first grid line north of the southwest corner of the Leavenworth map is labeled 4347000 m.N. This means its false northing (distance north of the Equator) is 4,347,000 meters. The principal digits, 47, identify the line for referencing points in the northerly direction. Likewise, the first grid line east of the southwest corner is labeled 328,000 m.E. This is because the Central Meridian has a value of 500,000 m.E, and this grid line is 172,000 meters west of the central meridian, or 328,000 meters east.

The principal digits, 28, identify the line for referencing points in the easterly direction.

(2) *Grid coordinate scale.* A grid coordinate scale (fig. 3-16) divides a grid square more accurately than can be done by estimation, and the results are more consistent. Also this scale has been designed for the express purpose of plotting grid coordinates; it is much faster than using an engineer scale and presents less chance of making an error.

(a) The 1:25,000 scale (lower right in figure) subdivides the 1,000 meter grid block into 10 major subdivisions, each equal to 100 meters. Each 100 meter block has five graduations, each equal to 20 meters. Points falling between the two graduations

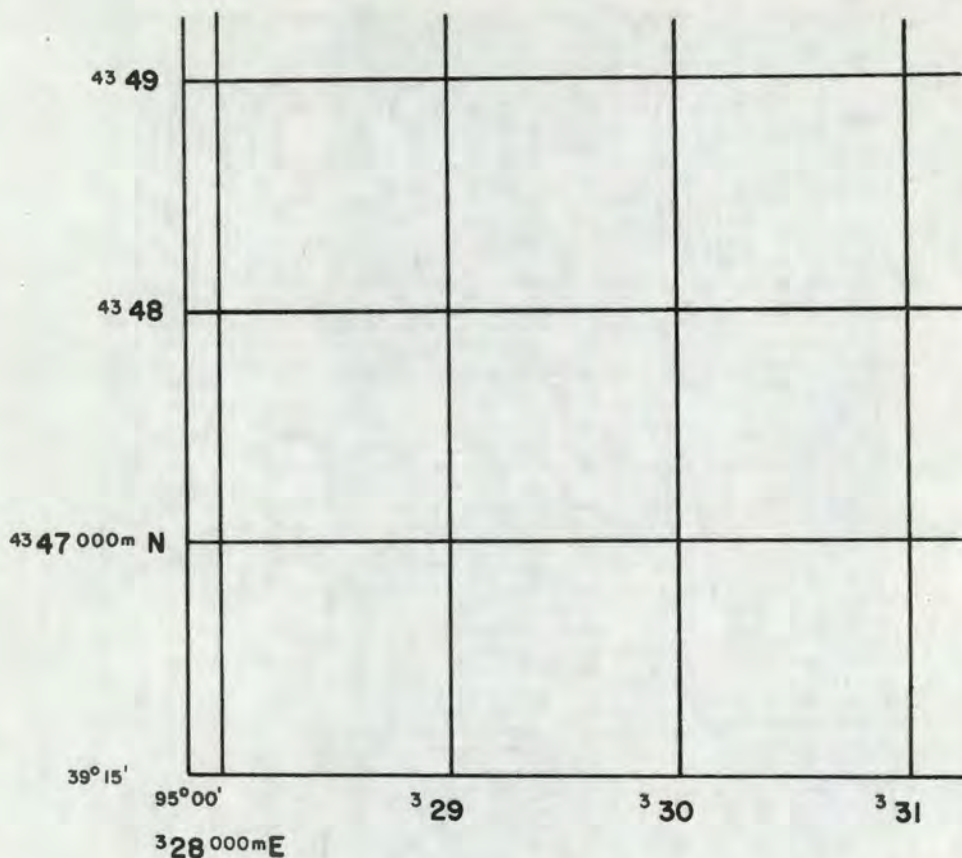


Figure 3-15. Grid lines.

can be read accurately to 10 meters, this value being the fourth and eighth digits of the coordinates.

(b) The 1:50,000 scale (upper left in figure) subdivides the 1,000 meter grid block into 10 major subdivisions each equal to 100 meters. Each 100 meter block is then divided in half. Points falling between these graduations must be estimated to the nearest 10 meters for the fourth and eighth digits of the coordinates.

(c) To use a coordinate scale for determination of coordinates, place the scale with the zeros of the scale at the lower left corner of the grid square. Keeping the scale on the lower horizontal grid line, slide it to the right until the point for which coordinates are desired touches the edge of the scale. When reading coordinates, examine the two sides of the coordinate scale to insure that the horizontal scale is aligned with the east-west grid line, and the vertical scale is parallel with the north-south grid line (fig. 3-17).

(3) *Point designation.* The designation of a point is based on the military principle: Read RIGHT

then UP. The precision desired determines the number of digits to be read beyond the principal digits. It should be impressed upon the reader that the term "grid coordinate" often includes both the 100,000 meter square identification and the desired number of digits. In many instances, it is a *tactical requirement* that the 100,000 meter square identification be included in any point designation.

(a) Reading RIGHT-UP (fig. 3-17), coordinates 1484 locate the 1000-meter grid square in which point X is located. The next square to the right would be 1584; the next square up would be 1485; etc.

(b) To locate the point to the nearest 100 meters, estimate the tenths of the grid square from grid line to point, in the same order (RIGHT-UP). Give complete coordinate RIGHT, then complete coordinate UP. This point is about 2 tenths of a grid square right and about 1 tenth up; coordinates to the nearest 100 meters are 142841.

(c) Artillery requirements usually call for location of the target within at least 10 meters (about

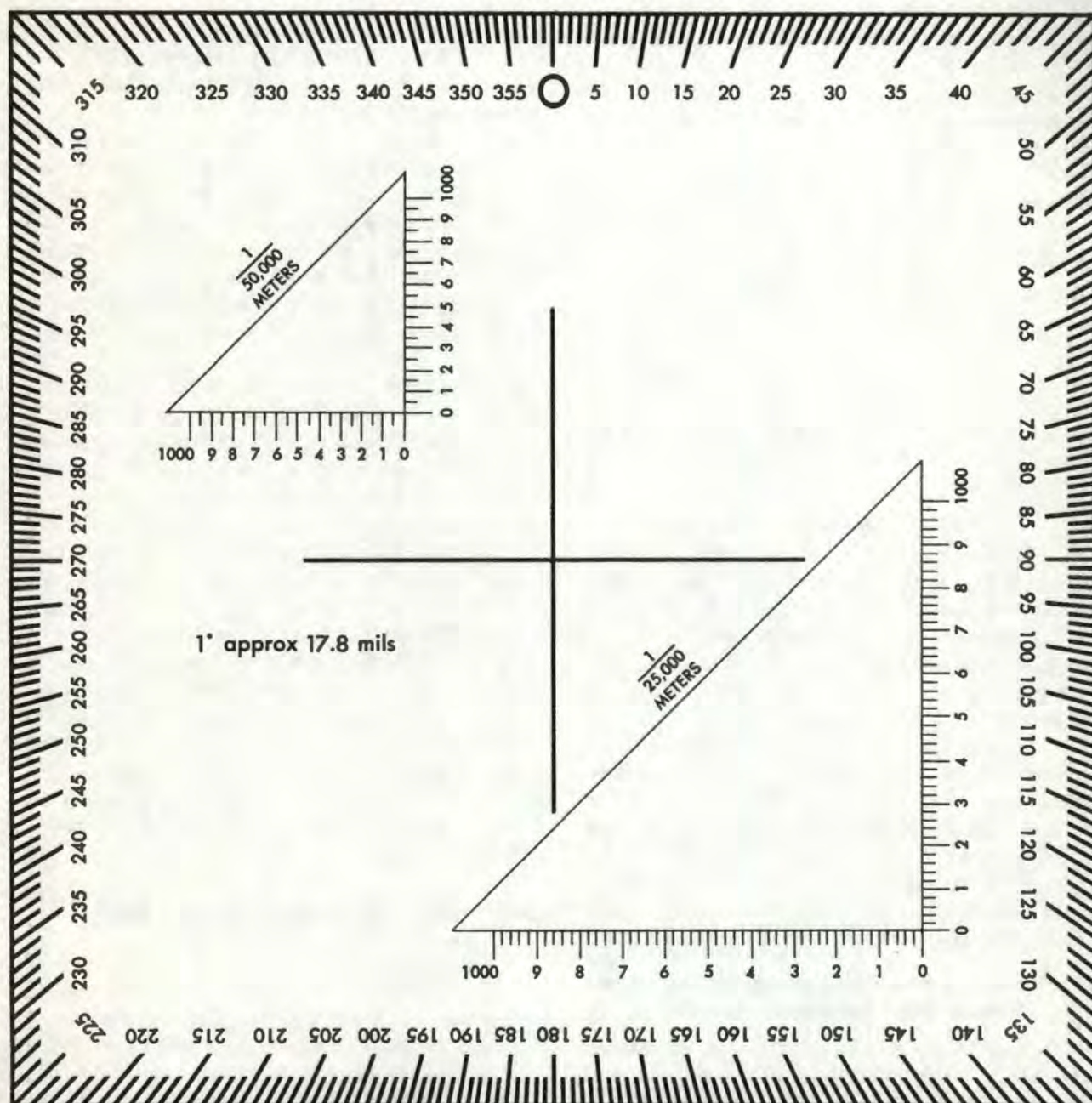


Figure S-16. Coordinate scales

30 feet). To locate the point to the nearest 10 meters, use a scale to measure the hundredths of a grid square RIGHT and UP from grid line to point. This point is 17 hundredths right and 9 hundredths up; coordinates to the nearest 10 meters are 14178409 (always prefix a zero if the hundredths reading is less than 10).

(d) On maps of very large scales, and under

special conditions, it may be desirable to locate a point within one meter. This is done by measuring the thousandths of a grid interval from line to point.

(e) The precision of a point reference is shown by the number of digits in the coordinates—the more digits, the more precise the location.

1484—a 1,000-meter grid square
142841—to the nearest 100 meters

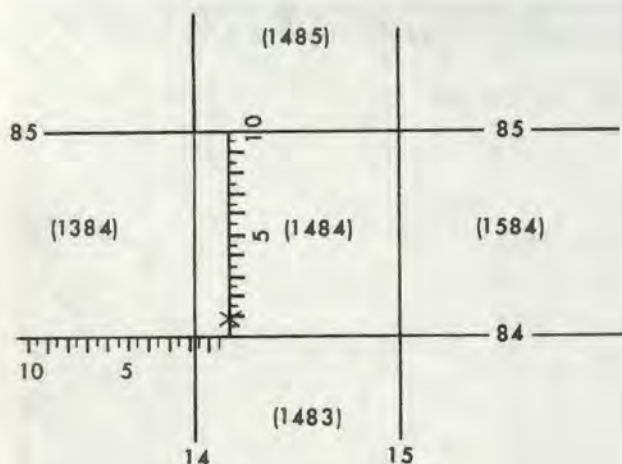


Figure 3-17. Proper placement of a coordinate scale on a grid to read coordinates of a point.

14178409—to the nearest 10 meters

1416884087—to the nearest meter

(f) If a scale is not available that exactly divides the side of the grid square in tenths or hundredths, these divisions may be made by slanting the scale until it fits the interval between grid lines, as explained under measurement of geographic coordinates (para 3-2d).

(g) Coordinates are written as one continuous number without spaces, parentheses, dashes, or decimal points. From this it should be obvious that whoever is to use the written coordinates must know where to make the split between the RIGHT reading and the UP reading; for this reason, the coordinates of the point within the 100,000-meter square must always contain an even number of digits.

3-5. Location of a Point Using the U.S. Army Military Grid Reference System

a. *Grid Zone.* As shown in figure 3-18, the number 15 locates a point within zone 15, which is an area 6° wide and extends between 80° S latitude and 84° N latitude.

b. *Grid Zone Designation.* The number and letter combination 15S as shown in figure 3-19 further locates a point within grid zone designation 15S which is a quadrangle 6° wide by 8° high. There are 19 of these quads in zone 15. Quad X, which is located between 72° N latitude and 84° N latitude, is 12° high.

c. *100,000 Meter Square Identification.* The addition of two more letters further locates a point within a 100,000 meter grid square. Thus, 15S UP

(fig. 3-20) locates a point within the 100,000 meter square UP, in the grid zone designation 15S. For information on the lettering system of 100,000 meter squares, see TM 5-241-1.

d. *10,000 Meter Square.* The breakdown of the U. S. Army Military Grid Reference System continues as each side of the 100,000 meter square is divided into ten equal parts. This division produces lines which are 10,000 meters apart. Thus, the coordinates 15S UP 46 would locate a point as shown in figure 3-21. The 10,000 meter grid lines appear as index (heavier) grid lines on maps at 1:100,000 and larger.

e. *1,000 Meter Square.* To obtain 1,000 meter squares, each side of the 10,000 meter square is divided into 10 equal parts. This division appears on large scale maps as the actual grid lines, which are 1,000 meters apart. On the Leavenworth map, using coordinates 15SUP4062, the easting 40 and the northing 62 gives the location of the southwest corner of grid square 4062 or to the nearest 1,000 meters of a point on the map. To locate to the nearest 100 meters, the grid coordinate scale can be used to divide the 1,000 meter grid square into 10 equal parts. *Example:* 15SUP403622. The grid coordinate scale has divisions every 50 meters on the 1:50,000 scale and every 20 meters on the 1:25,000 scale. These can be used to interpolate to the nearest 10 meters and give the location of one point on the earth's surface to the nearest 10 meters. *Example:* 15SUP40356225.

3-6. Maps with More Than One Grid

a. *Grid Zone Junctions.*

(1) In certain instances a sheet may contain more than one grid. This condition results from a junction between two grid zones within the UTM grid system. On large scale maps the occurrence of a junction within the neatlines of a sheet is rare since the sheet lines are usually laid out to coincide with junctions. On medium and small scale sheets, junctions are more prevalent than on larger scale maps owing to the greater area covered.

(2) Where a junction appears on the map, the junction line is accentuated in lineweight and each zone is identified by labeling parallel to and on each side of the junction line. On large scale maps only, grid ticks and grid values are shown along the neatlines to provide full sheet coverage for each grid represented (fig. 3-22).

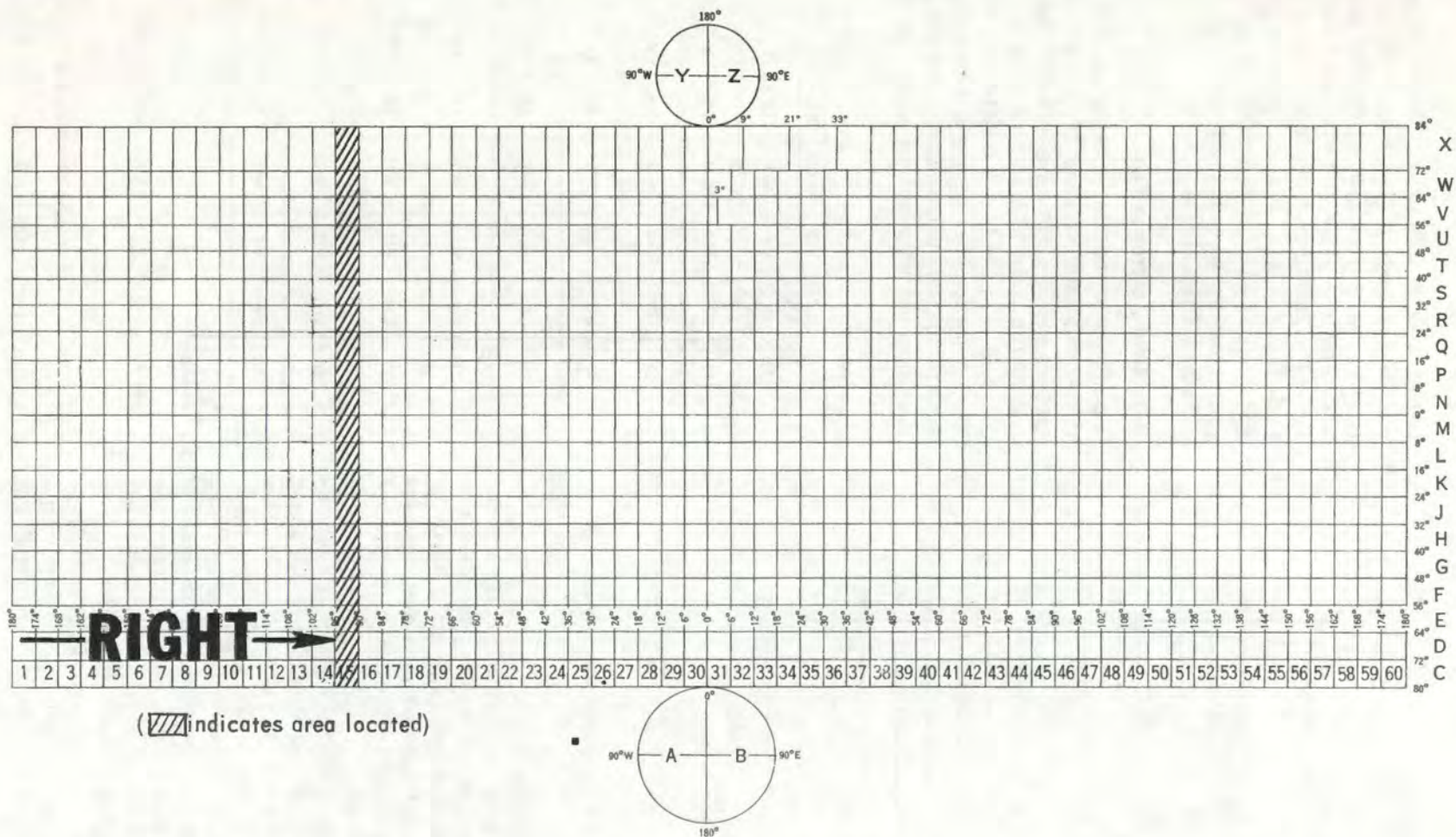


Figure 3-18. Grid zone.

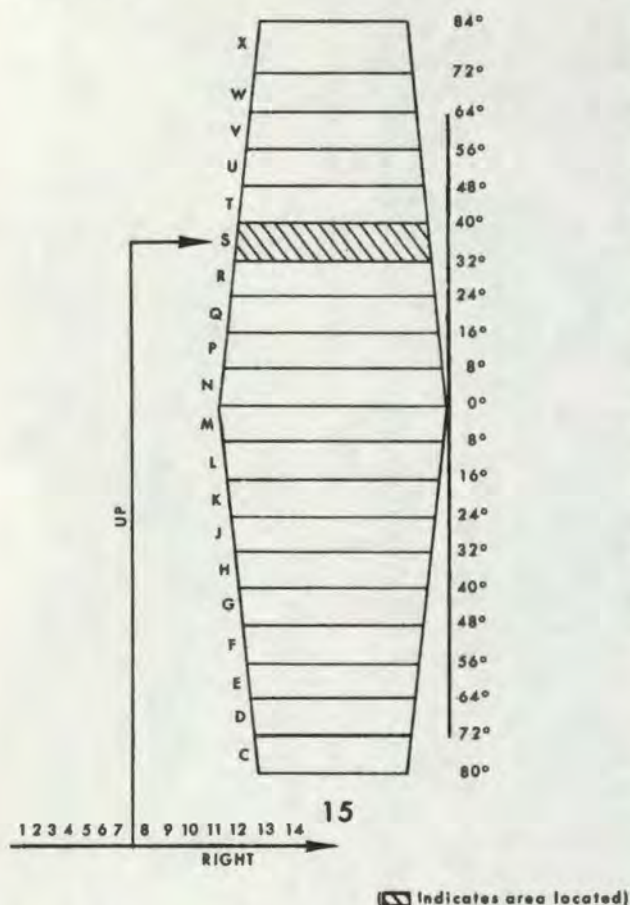


Figure 3-19. Grid zone designation.

b. Overlapping Grids.

(1) When a large scale map falls within approximately 25 miles of a grid junction, the sheet also shows the neighboring grid. This grid, called the *overlapping grid*, is important for extending operations across junctions, particularly in fire-control and survey operations.

(2) The overlapping grid is shown by ticks outside the neatline on all four sides of the map. Every fifth tick is labeled with its value in a color other than that used for the major grid on the sheet. The grid can be easily constructed when necessary by connecting the corresponding ticks on opposite neatlines with straight lines, and completing the labeling. This provides an extension of the grid lines of an adjoining UTM grid zone (fig. 3-23).

(3) It should be noted that on large-scale sheets, a grid zone junction line, when it coincides with a north-south neatline, is neither symbolized nor

labeled as a grid junction. However, since every grid zone extends 6° east-west, every grid zone junction line is a meridian whose geographic value is divisible by 6. If the grid ticks and marginal data for an overlapping grid appear on a sheet, the map reader can determine if a neatline coincides with a grid junction line if it is divisible by six. He then knows that the adjoining map sheet falls within a different UTM grid zone.

3-7. Grid Reference Box

A grid reference box (fig. 3-24 and fig. E-3) appears in the marginal information of each map sheet. It contains step-by-step instructions for using the grid and the U.S. Army Military Grid Reference System. The grid reference box is divided into two parts. The left portion identifies the grid zone designation and the 100,000 meter square; if the sheet falls in more than one 100,000 meter square, the grid lines

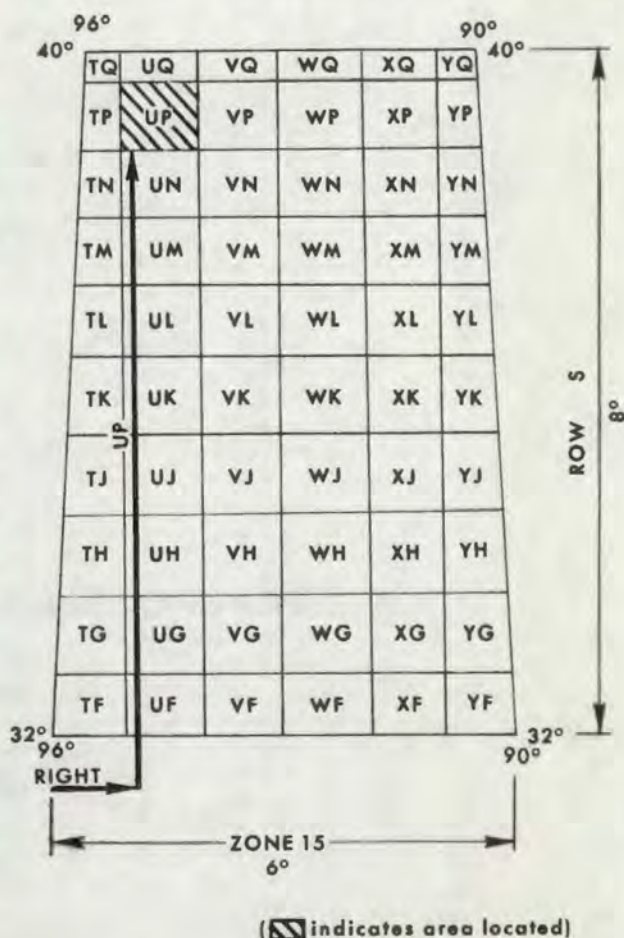


Figure 3-20. 100,000 meter square identification.

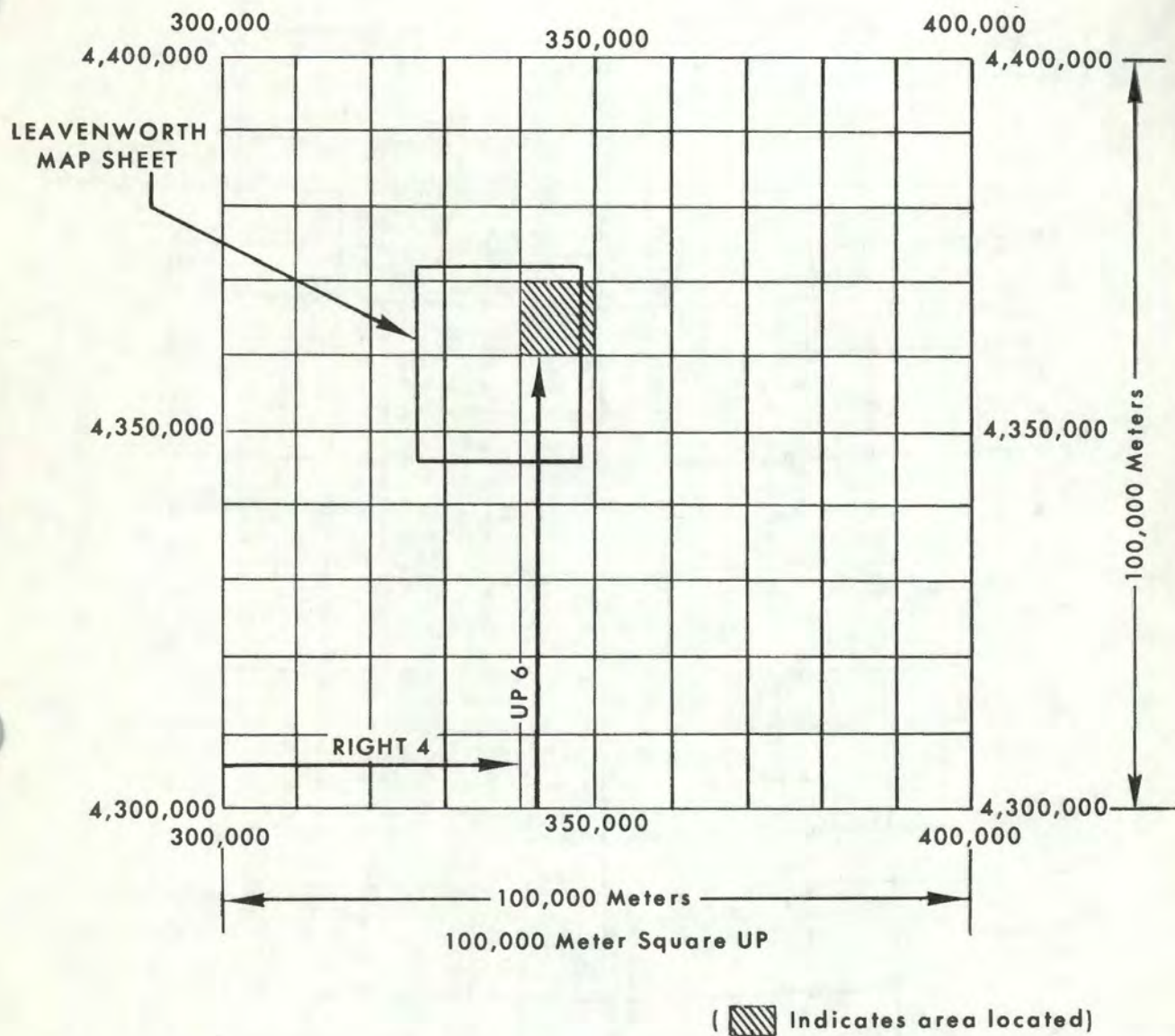
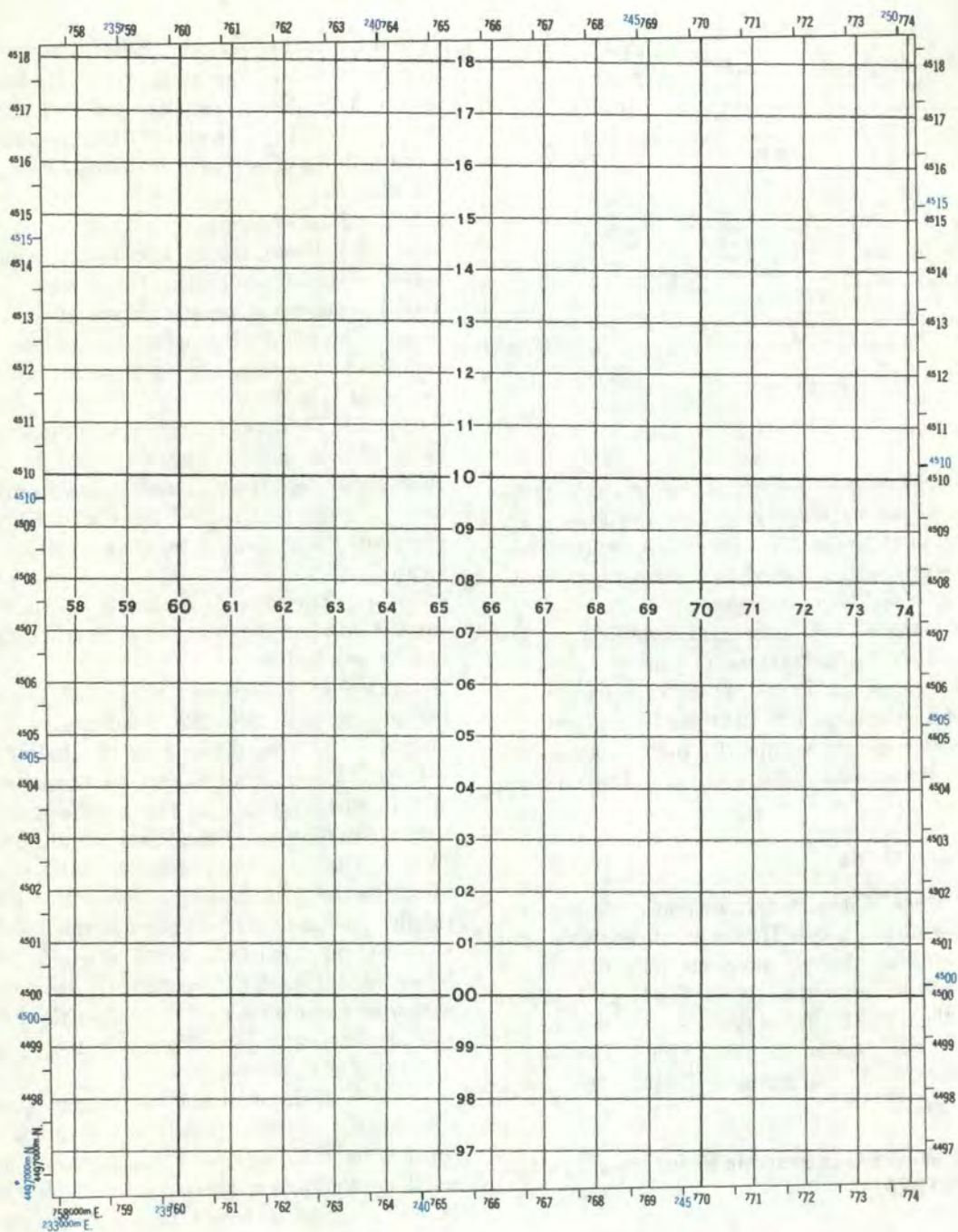


Figure 3-21. 10,000 meter square.

Scale 1:50,000 (in miniature)

3-18



BLACK NUMBERED LINES INDICATE THE 1,000 METER UNIVERSAL TRANSVERSE
MERCATOR GRID, ZONE 47, INTERNATIONAL SPHEROID

BLUE NUMBERED TICKS OUTSIDE THE NEATLINE INDICATE THE 1,000 METER UNIVERSAL TRANSVERSE
MERCATOR GRID, ZONE 48, INTERNATIONAL SPHEROID

Scale 1:50,000 (in miniature)

Figure 3-23. A major and overlapping grid as shown on a large scale map.

GRID ZONE DESIGNATION: 15S 100,000 M. SQUARE IDENTIFICATION UP IGNORE the SMALLER figures of any grid number; these are for finding the full coordinates. Use ONLY the LARGER figures of the grid number; example: 4347000	TO GIVE A STANDARD REFERENCE ON THIS SHEET TO NEAREST 100 METERS						
	<table border="1" style="width: 100%;"> <tr> <td colspan="2">SAMPLE POINT: HAZELWOOD SCHOOL</td> </tr> <tr> <td style="width: 60%;"> 1. Read letters identifying 100,000 meter square in which the point lies: 2. Locate first VERTICAL grid line to LEFT of point and read LARGE figures labeling the line either in the top or bottom margin, or on the line itself: Estimate tenths from grid line to point: 3. Locate first HORIZONTAL grid line BELOW point and read LARGE figures labeling the line either in the left or right margin, or on the line itself: Estimate tenths from grid line to point: </td> <td style="width: 40%; text-align: center; vertical-align: middle;"> UP 40 62 3 2 </td> </tr> <tr> <td colspan="2"> SAMPLE REFERENCE: UP403622 If reporting beyond 9°N-S or 18°E-W, prefix Grid Zone Designation, as: 15SUP403622 </td> </tr> </table>		SAMPLE POINT: HAZELWOOD SCHOOL		1. Read letters identifying 100,000 meter square in which the point lies: 2. Locate first VERTICAL grid line to LEFT of point and read LARGE figures labeling the line either in the top or bottom margin, or on the line itself: Estimate tenths from grid line to point: 3. Locate first HORIZONTAL grid line BELOW point and read LARGE figures labeling the line either in the left or right margin, or on the line itself: Estimate tenths from grid line to point:	UP 40 62 3 2	SAMPLE REFERENCE: UP403622 If reporting beyond 9°N-S or 18°E-W, prefix Grid Zone Designation, as: 15SUP403622
SAMPLE POINT: HAZELWOOD SCHOOL							
1. Read letters identifying 100,000 meter square in which the point lies: 2. Locate first VERTICAL grid line to LEFT of point and read LARGE figures labeling the line either in the top or bottom margin, or on the line itself: Estimate tenths from grid line to point: 3. Locate first HORIZONTAL grid line BELOW point and read LARGE figures labeling the line either in the left or right margin, or on the line itself: Estimate tenths from grid line to point:	UP 40 62 3 2						
SAMPLE REFERENCE: UP403622 If reporting beyond 9°N-S or 18°E-W, prefix Grid Zone Designation, as: 15SUP403622							

Figure 3-24. Grid reference box.

that separate the squares are shown in the diagram and the values for these grid lines are given. The right portion of the grid reference box explains how to use the grid and is keyed to a point on the map.

Example of a military grid reference:

15S locates the 6° x 8° area (grid zone designation)

15SUP locates the 100,000 meter square

15SUP46 locates within 10,000 meter square

15SUP4062 locates within 1,000 meter square

15SUP403622 locates within 100 meter square

Location: Hazelwood School on the Leavenworth map.

3-8. British Grids

In a few areas of the world, British grids are still shown on military maps. However, the British grid systems are being phased out. Eventually all military mapping will be converted to the UTM grid. When required, the British grid may be shown as a major grid, or by ticks around the neatline as a secondary grid. Figure 3-25 illustrates a British grid as a secondary grid.

3-9. The World Geographic Reference System (GEOREF)

a. This is a worldwide position reference system used primarily by the USAF. It may be used with any map or chart that has latitude and longitude printed on it. Instructions for using GEOREF data are printed in blue and are found in the margin of aeronautical charts (fig. 3-26 and 3-27).

b. This system is based upon a division of the earth's surface into quadrangles of latitude and longitude having a systematic identification code.

It is a method of expressing latitude and longitude in a form suitable for rapid reporting and plotting. Figure 3-26 illustrates a sample grid reference box using GEOREF. The GEOREF system uses an identification code which is divided into three main divisions.

(1) First division.

(a) There are 24 north-south (longitudinal) zones, each 15° in width. These zones, starting at 180° and progressing eastward are lettered A through Z (omitting I and O). The first letter of any GEOREF coordinate identifies the north-south zone in which the point is located.

(b) There are 12 east-west (latitudinal) bands, each 15° in width. These bands are lettered A through M (omitting I) northward from the south pole. The second letter of any GEOREF coordinate identifies the east-west band in which the point is located.

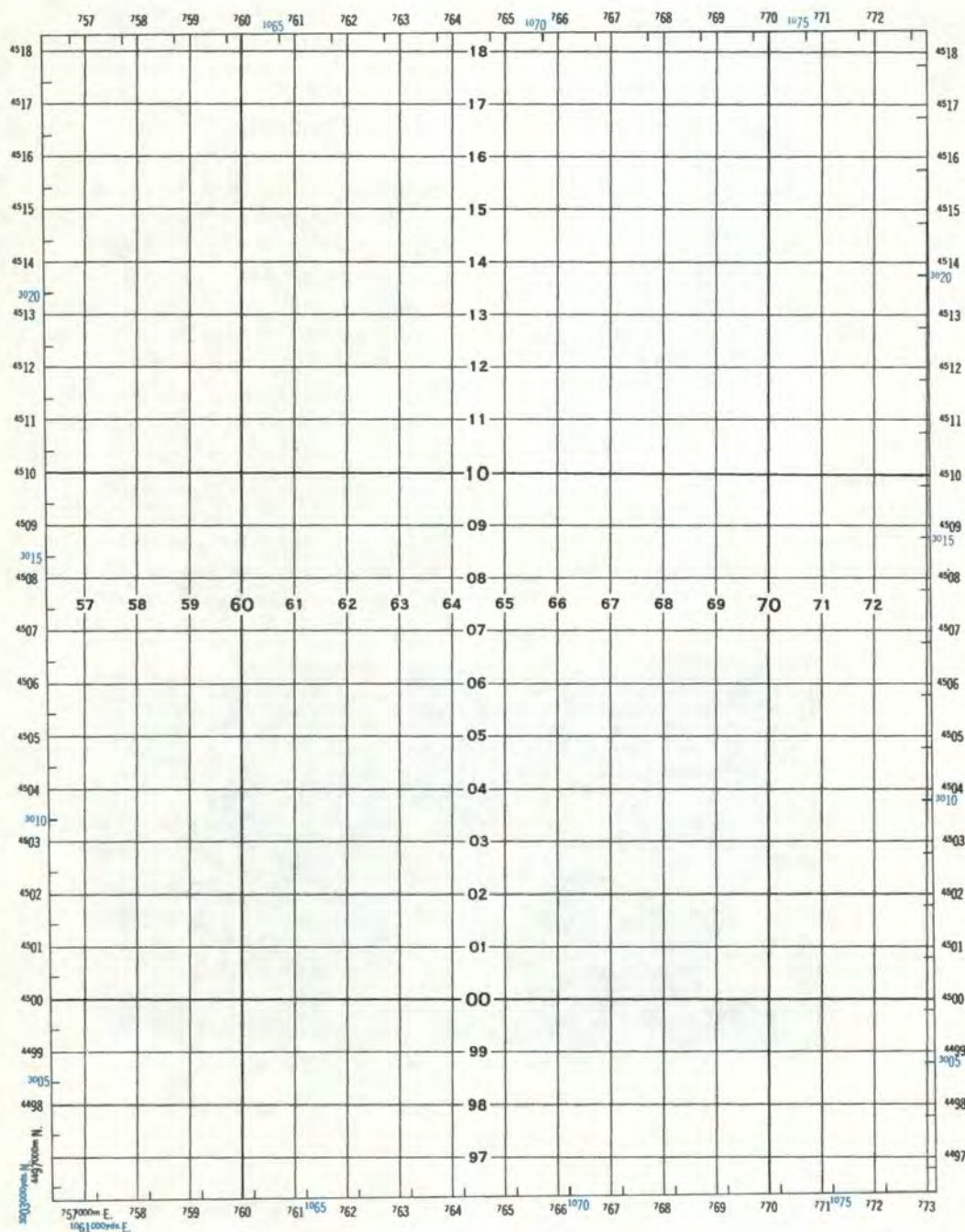
(c) The zones and bands divide the earth's surface into 288 quadrangles each of which is identified by two letters.

(2) *Second division.* Each 15° quadrangle is further divided into 225 quadrangles of 1° each (15° x 15°). This division is effected by dividing a basic 15° quadrangle into 15 north-south zones and 15 east-west bands. The north-south zones are lettered A through Q (omitting I and O) from west to east. The third letter of any GEOREF coordinate identifies the 1° north-south zone within a 15° quadrangle. The east-west bands are lettered A through Q (I and O omitted) from south to north. The fourth letter of a GEOREF coordinate identifies the 1° east-west band within a 15° quadrangle. Four letters will identify any 1° quadrangle in the world.

(3) Third division.

(a) Each of the 1° quadrangles is divided into 3,600 1' quadrangles. These 1' quadrangles are formed by dividing the 1° quadrangles into 60 1' north-south zones numbered 0 through 59 from west to east and 60 east-west bands numbered 0 to 59 from south to north. To designate any one of the 3,600 1' quadrangles requires 4 letters and 4 numbers. The rule READ RIGHT-UP is always followed. Numbers 1 through 9 are written as 01, 02, etc.

(b) Each of the 1' quadrangles may be further divided into 10 smaller divisions both north-south and east-west, permitting the identification of 0.1' quadrangles. The GEOREF coordinate for any 0.1' quadrangle consists of 4 letters and 6 numbers.



BLACK NUMBERED LINES INDICATE THE 1,000 METER UNIVERSAL TRANSVERSE
MERCATOR GRID, ZONE 47, INTERNATIONAL SPHEROID

BLUE NUMBERED TICKS INSIDE THE NEATLINE INDICATE
THE 1,000 YARD INDIA ZONE IVB GRID, EVEREST SPHEROID

Scale 1:50,000 (in miniature)

Figure 3-25. The UTM as a major grid with a British grid as a secondary grid as shown on a large-scale map.

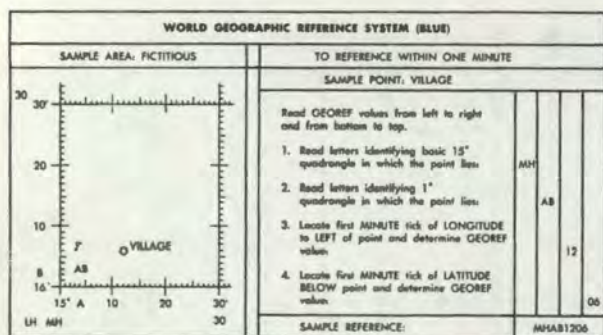


Figure 3-26. Illustration of instructions for determining a reference by the GEOREF (printed in blue).

3-10. Protection of Map Coordinate/ Locations

a. A disadvantage of any standard system of location is that the enemy, if he intercepts one of our messages using that system, can interpret the message and find our location. This possibility

can be eliminated by using an authorized low-level numeral code to express locations. AR 380-52 outlines the procedures for obtaining authorized codes.

b. The authorized numeral code provides a capability for encrypting map references and other numerical information which requires short term security protection when, for operational reasons, the remainder of the message is transmitted in plain language. The system is published in an easy to use booklet format with sufficient material in one booklet to provide the holder enough material for 1 month's operations. Sample training editions of this type system are available from Commanding General, U.S. Army Strategic Communications Command, ATTN: COMSEC NICP-B, Fort Huachuca, Arizona 85613.

c. The use of any other method, other than authorized codes, for the encryption, or "hiding", coordinates from the enemy is, by regulation, unauthorized and shall not be used.

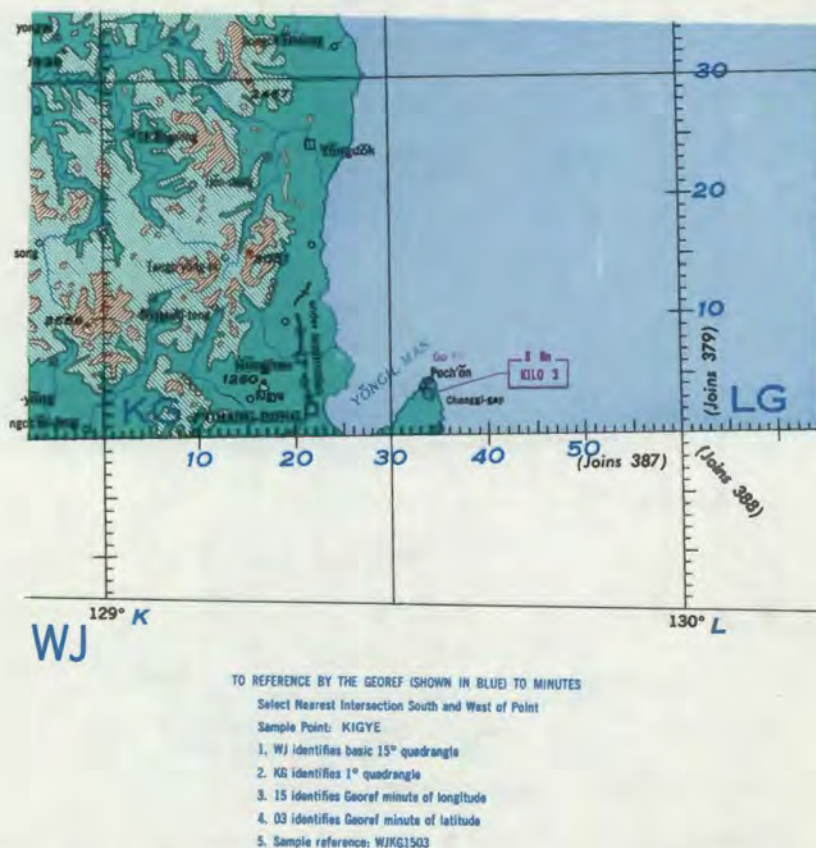


Figure 3-27. Sample reference using the GEOREF.

toward the direction opposite from the forward direction of the thrust line ((2), fig. 3-28).

(3) Right (R) means to the right of the thrust line at a 90° angle ((2), fig. 3-28).

(4) Left (L) means to the left of the thrust line at a 90° angle ((2), fig. 3-28).

(5) Distances are stated in units of horizontal measurement expressed in hundreds of meters.

Example: 800 meters would be expressed as 8; 1250 meters would be expressed as 12.50; etc.

(6) It should be noted that the right (R) and left (L) directions refer to the thrust line as measured from the base point forward. They *do not change* when a back measurement is given.

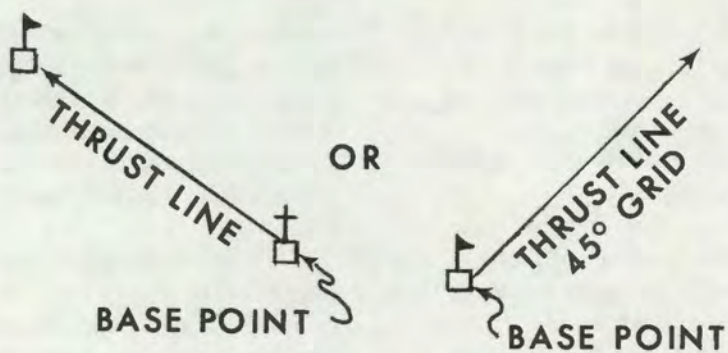
d. To express the location of an object using the thrust line system:

(1) First, by use of a sheet of paper with a square corner and the map's graphic scale, determine the distance along the thrust line from the base point to a point at right angles to the object. The

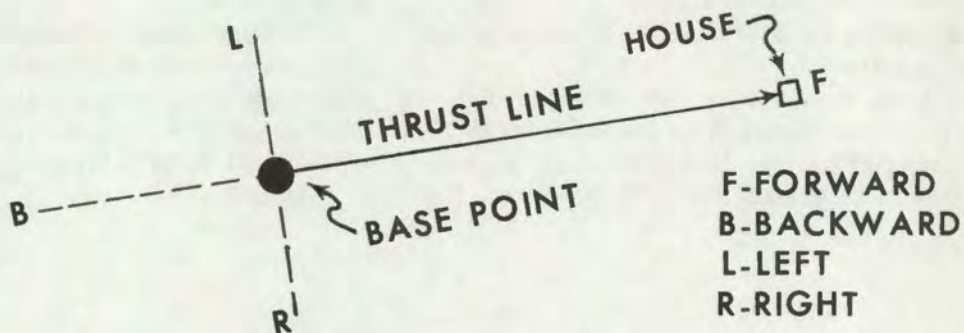
corner of the paper allows easy determination of the right angle. Express this distance in hundreds of meters and prefix it with the letter that indicates forward or backward from the base point. *Example:* F10.00; this means that our first measurement is forward from the base point 1000 meters (10.00 x 100).

(2) Next, the distance from this point on the thrust line to the object is determined and expressed in hundreds of meters prefixed by an indication of whether it is to the left or right of the thrust line. *Example:* R2.50; this means that the object concerned is 250 meters (2.50 x 100) to the right of the thrust line.

(3) Combining these readings would give a complete thrust line coordinate of F10.00R2.50. Persons familiar with the thrust line system, and **ONLY** those persons who know the base point and direction of the thrust line will be able to locate the building in ((3), fig. 3-28).



1. Two types of thrust lines.



2. Thrust line directions.

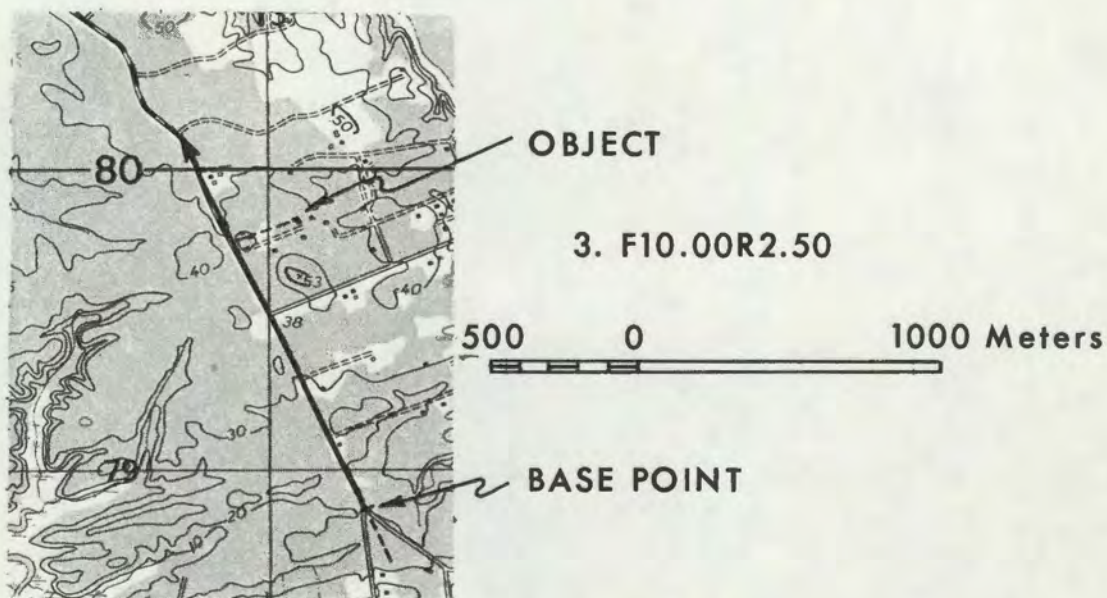


Figure 3-28. Thrust line coordinate system.

CHAPTER 4

SCALE AND DISTANCE

4-1. Importance

A map is a graphic representation of a portion of the earth's surface in a uniform and proportional relationship. This relationship is known as the map scale. The scale of the map permits the determination of ground distance from the map. The determination of distance is an important factor in the planning and execution of a military mission.

4-2. Representative Fraction (RF)

a. The numerical scale of a map expresses the ratio of horizontal distance on the map to the corresponding horizontal distance on the ground. It usually is written as a fraction and is called the representative fraction (RF). The representative fraction is always written with the map distance as one (1). It is independent of any unit of measure. An RF of 1/50,000 or 1:50,000 means that one (1) unit of measure on the map is equal to 50,000 of the *same units* of measure on the ground.

b. The ground distance between two points is determined by measuring between the points on the map and multiplying the map measurement by the denominator of the RF.

Example:

$$RF = 1:50,000 \text{ or } \frac{1}{50,000}$$

Map distance = 5 units

$5 \times 50,000 = 250,000$ units of ground distance (fig. 4-1).

c. The situation may arise where a map or sketch has no RF. To be able to determine ground distance on such a map, the RF must be determined. There are two ways to do this—

(1) *Comparison with ground distance.*

(a) Measure the distance between two points on the map (MD).

(b) Determine the horizontal distance between the corresponding points on the ground (GD).

(c) Utilizing the RF formula and remembering that RF must be in the general form

$$\frac{1}{x}, RF = \frac{1}{x} = \frac{MD}{GD}$$

(d) Both the MD and the GD must be in the *same unit of measure* and the MD must be reduced to 1.

MD = 4.32 centimeters

GD = 2.16 kilometers (216,000 centimeters)

$$RF = \frac{1}{X} = \frac{4.32}{216,000} \text{ or } 4.32X = 216,000$$

X = 50,000;

therefore $RF = \frac{1}{50,000}$ or 1:50,000

(2) *Comparison with another map of the same area that has an RF.*

(a) Select two points on the map with the unknown RF. Measure the distance (MD) between them.

(b) Locate those same two points on the map that has the known RF. Measure the distance (MD) between them. Using the RF for this map, determine GD, which is the same for both maps.

(c) Using this GD and the MD from the first map, determine the RF using the formula:

$$RF = \frac{1}{X} = \frac{MD}{GD}$$

d. Occasionally it may be necessary to determine

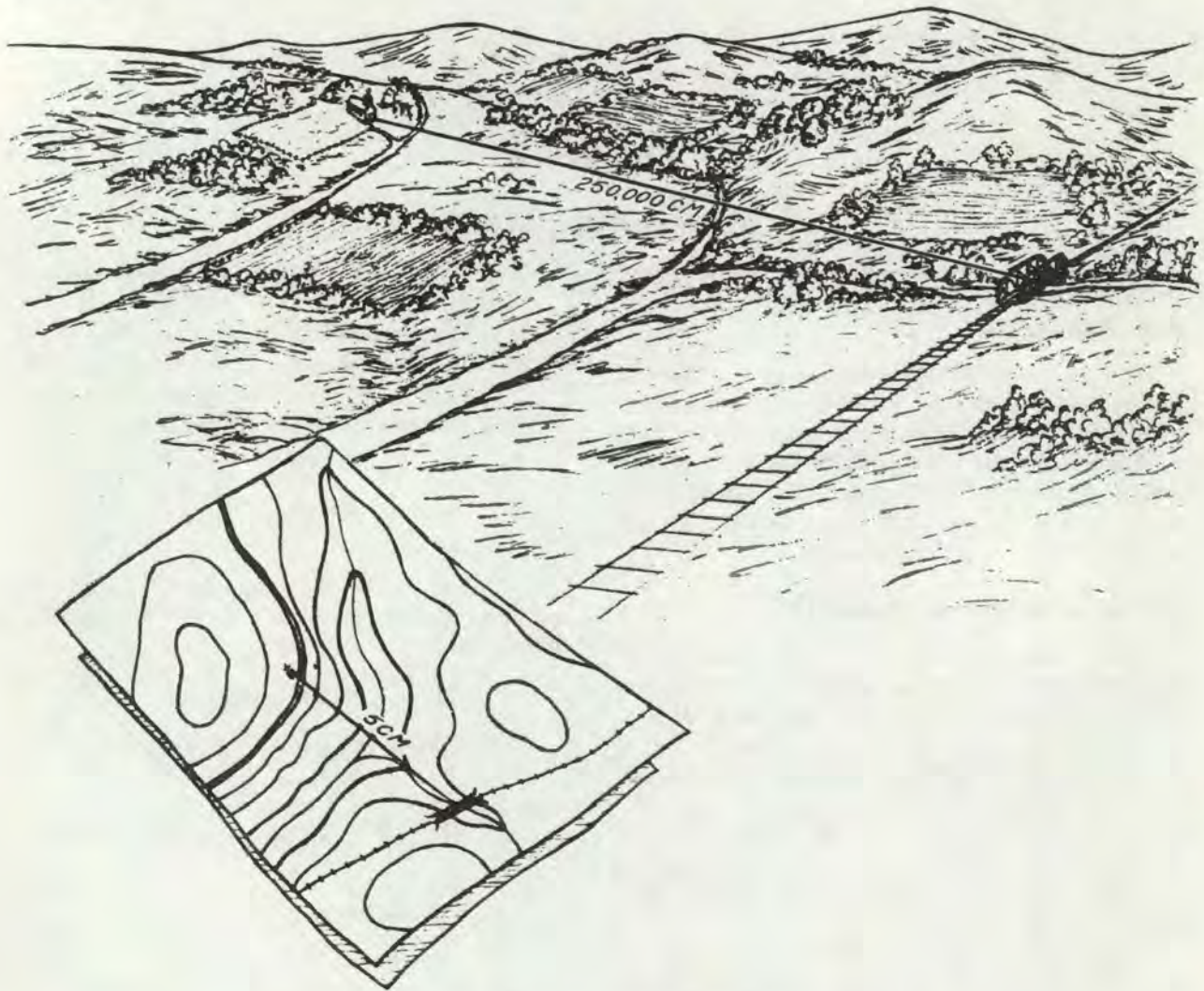


Figure 4-1. Map distance to ground distance.

map distance from a known ground distance and the RF:

$$MD = \frac{GD}{\text{Denominator of RF}}$$

Ground distance = 2,200 meters

RF = 1:50,000

$$\begin{aligned} MD &= 0.044 \text{ meter} \times 100 \text{ (centimeters in a meter)} \\ &= 4.4 \text{ centimeters on the map.} \end{aligned}$$

e. When determining ground distance from a map, the scale of the map affects the accuracy. As the scale becomes smaller, the accuracy of measurement decreases because some of the features on the map

must be exaggerated so that they may be readily identified.

4-3. Graphic (Bar) Scales

a. On most military maps there is another method of determining ground distance. It is by means of the graphic (bar) scales. A graphic scale is a ruler printed on the map on which distances on the map may be measured as actual ground distances. To the right of the zero (0) the scale is marked in full units of measure and is called the primary scale. The part to the left of zero (0) is divided into tenths of a unit and is called the extension scale. Most maps have three or more graphic scales, each of which measures distance in a different unit of measure (fig. 4-2).

EXTENSION SCALE

PRIMARY SCALE

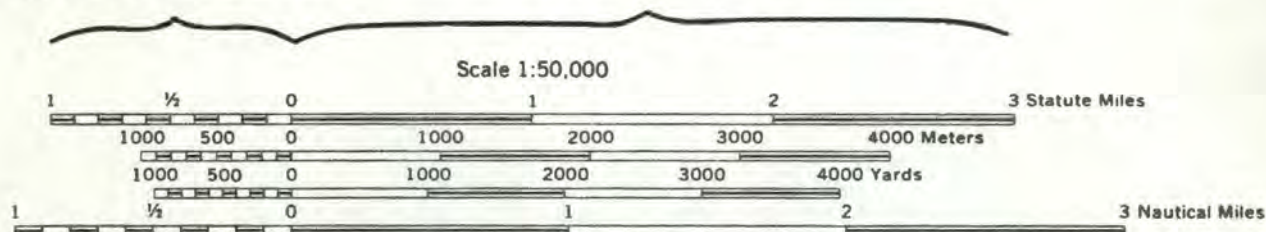


Figure 4-2. Graphic (bar) scale.

b. To determine a straight-line ground distance between two points on a map, lay a straight-edged piece of paper on the map so that the edge of the paper touches both points. Make a tick mark on the edge of the paper at each point. Move the paper down to the graphic scale and read the ground distance between the points. Be sure to use the scale that measures in the unit of measure desired (fig. 4-3).

c. To measure distance along a winding road, stream or any other curved line, the straight-edge of a piece of paper is used again. Make a tick mark at or near one end of the paper and place it at the point from which the curved line is to be measured. Aline the edge of the paper along a straight portion, and make a tick mark on both map and paper at the end of the alined portion. Keeping both tick marks together, place the point of the pencil on the

paper's tick mark to hold it in place. Pivot the paper until another approximately straight portion is alined and again make a tick mark on both map and paper. Continue in this manner until the measurement is complete. Then place the paper on the graphic scale and read the ground distance (fig. 4-4).

(1) Often, marginal notes give the road distance from the edge of the map to a town, highway, or junction off the map. If the road distance is desired from a point on the map to such a point off the map, measure the distance to the edge of the map and add to that measurement the distance specified in the marginal note. Be sure the unit of measure is the same.

(2) It may be desired to measure road distances in kilometers rather than in miles. Large scale maps do not have kilometer graphic scales. However, the meters graphic scale can be very simply converted to kilometers by moving the decimal point in each figure three places to the left.

d. The amount of time required to travel a certain

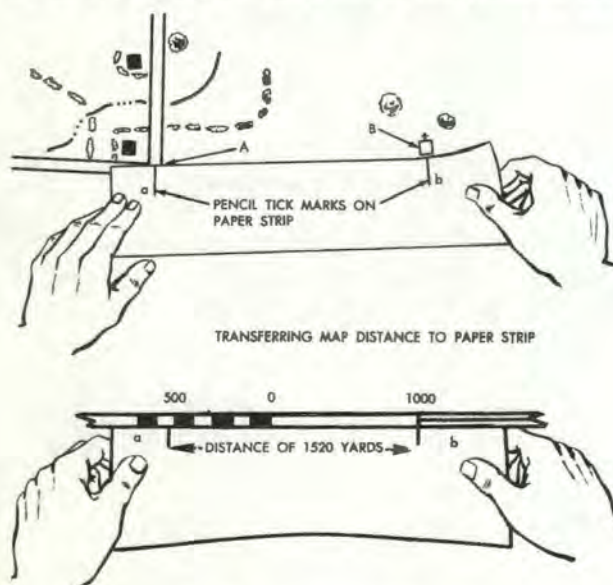


Figure 4-3. Measuring straight line map distances.

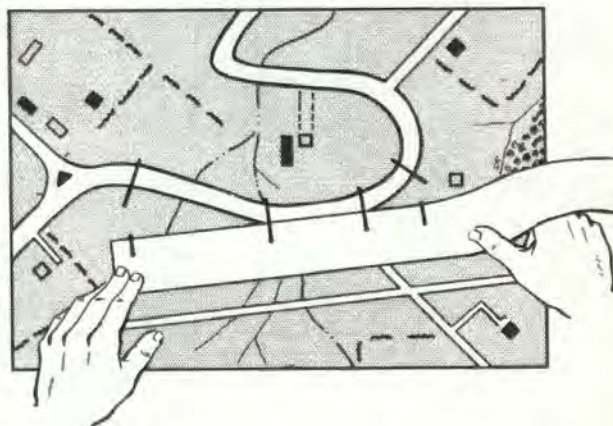


Figure 4-4. Measuring curved line distances on a map.

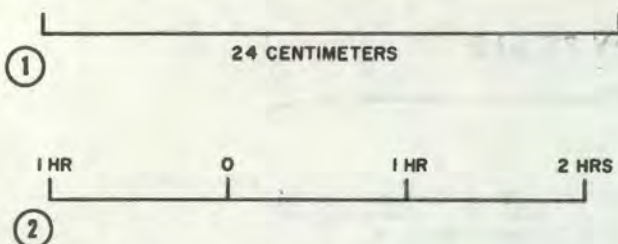


Figure 4-5. Construction of a time-distance scale (lengths of lines are illustrative only and not at 1:50,000 scale).

distance on the ground is an important factor in most military operations. This can be determined if a map of the area is available and a graphic time distance scale is constructed for use with the map as follows:

R = Rate of travel (speed)

D = Distance (ground distance)

T = Time

$$T = \frac{D}{R}$$

For example, if an infantry unit is marching at an average rate (R) of 4 kilometers per hour, it will take approximately 3 hours (T) to travel 12 kilometers

$$\frac{12(D)}{4(R)} = 3(T).$$

e. To construct a time-distance scale, knowing your length of march, rate of speed, and map scale, e.g., 12 kilometers at three kms per hour on a 1:50,000 scale map, use the following process:

(1) Mark off the total distance on a line by referring to the graphic scale of the map or, if this is impracticable, compute the length of the line as follows:

(a) Convert the ground distance to centimeters: 12 kms x 100,000 (cms in km) = 1,200,000 cms.

(b) Find the length of the line to represent

the distance at map scale—

$$MD = \frac{1}{50,000} \times 1,200,000 = 24 \text{ cms.}$$

(c) Construct a line 24 cms. in length.

(2) Divide the line by the rate of march into three parts (2, fig. 4-5), each part representing the distance traveled in one hour and label.

(3) Divide the scale extension (left portion) into the desired number of lesser time divisions—

1-minute divisions—60

5-minute divisions—12

10-minute divisions—6

Figure 4-6 shows a 5-minute interval scale. Make these divisions in the same manner as for a graphic scale. The completed scale makes it possible to determine where the unit will be at any given time. However, it must be remembered that this scale is for one specific rate of march only, 4 km per hour.

4-4. Conversion Factors

a. It is sometimes necessary to convert units of the English system of linear measurement to units of metric system without the use of a conversion chart. A method of converting 19,685 inches to meters and kilometers follows:

(1) Inches to meters:

$$\frac{19,685}{39.37 \text{ (inches in a meter)}} = 500 \text{ meters}$$

(2) Inches to kilometers:

$$\frac{19,685}{39.37 \times 1000 \text{ (meters in a kilometer)}} = .5 \text{ kilometer}$$

b. Appendix B contains additional conversion factors which may be used as an aid in converting the English system of linear measurement to the metric system.

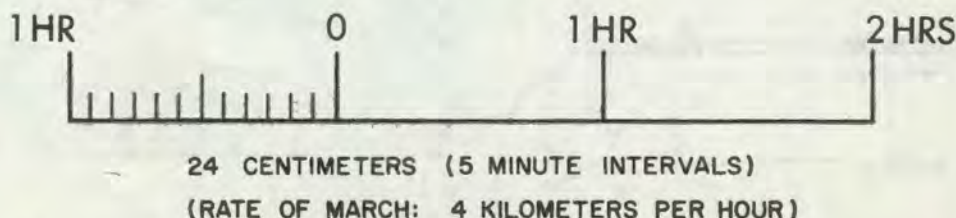


Figure 4-6. Time-distance scale (length of line is illustrative only and not at 1:50,000 scale).

CHAPTER 5

DIRECTIONS

5-1. Methods of Expressing Direction

a. Directions are expressed in everyday life, as right, left, straight ahead, etc.; but the question arises, "to the right of what?" Military personnel require a method of expressing a direction that is accurate, adaptable for use in any area of the world, and has a common unit of measure.

b. Directions are expressed as units of angular measure and there are several systems used.

(1) The most commonly used unit of angular measure is the degree with its subdivisions of minutes and seconds.

(2) Another unit, less frequently used, is the mil (abbreviated *m*). For U.S. military purposes, a complete circle is divided into 6,400 mils. The mil is commonly used in artillery, tank and mortar gunnery. It is convenient for many practical uses because it subtends approximately one unit of length at a distance (range) of one thousand units. For further information, refer to FM 6-40.

(3) The grad is a unit of measure found on some foreign maps. There are 400 grads in a complete circle (a 90° right angle equals 100 grads). The grad is divided into 100 centesimal minutes (centigrads) and the minute into 100 centesimal seconds (milligrads). This unit of measure is used with the metric system.

5-2. Base Lines

In order to measure anything there must always be a starting point or zero measurement. To express a direction as a unit of angular measure there must be a starting point or zero measure and a point of reference. These two points designate the base or reference line. There are three base lines, true north, magnetic north, and grid north. Those most commonly used are magnetic and grid; the magnetic when working with a compass, and the grid when working with a military map.

a. True north—a line from any position on the

earth's surface to the north pole. All lines of longitude are true north lines. True north is usually symbolized by a star (fig. 5-1).

b. Magnetic north—the direction to the North Magnetic Pole, as indicated by the north-seeking needle of a magnetic instrument. Magnetic north is usually symbolized by a half arrowhead (fig. 5-1).

c. Grid north—the north that is established by the vertical grid lines on the map. Grid north may be symbolized by the letters GN or the letter *y*.

5-3. Azimuth and Back Azimuth

a. The most common military method of expressing a direction is by using azimuths. An azimuth is defined as a horizontal angle, measured in a clockwise manner from a north base line. When the azimuth between two points on a map is desired, the points are joined by a straight line and a protractor is used to measure the angle between grid north and the drawn line. This measured angle is the grid azimuth of the drawn line (fig. 5-2). When using an azimuth, the point from which the azimuth originates is imagined to be the center of the azimuth circle (fig. 5-3). Azimuths take their name from the

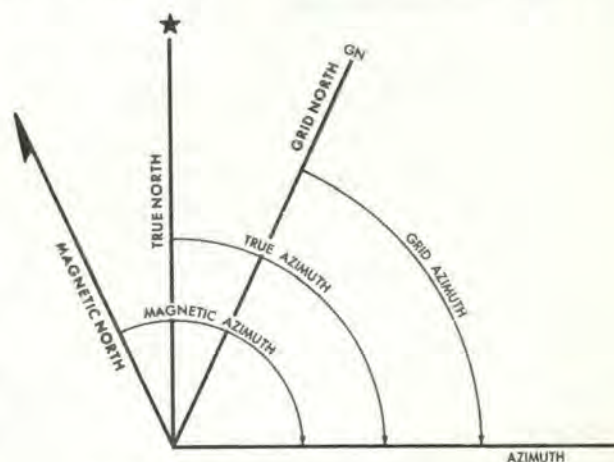


Figure 5-1. True, grid, and magnetic azimuths.

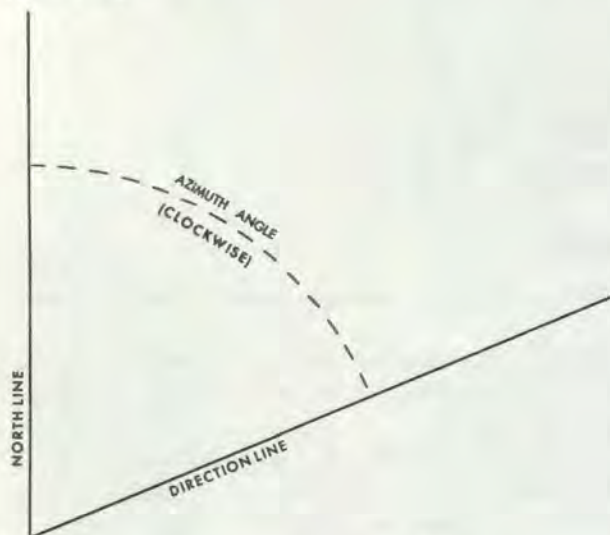


Figure 5-2. Azimuth angle.

base line from which they have been measured; true azimuths from true north, magnetic azimuths from magnetic north, and grid azimuths from grid north (fig. 5-1). Therefore, any one given direction can be expressed in three different ways: a grid azimuth if measured on a military map, a magnetic azimuth if measured by a compass, or a true azimuth if measured from a meridian of longitude.

b. A back azimuth is the reverse direction of an azimuth. It is comparable to doing an "about face." To obtain a back azimuth from an azimuth, add 180° if the azimuth is 180° or less, or subtract 180° if the azimuth is 180° or more (fig. 5-4). The back azimuth of 180° may be stated as either 0° or 360° .

5-4. Declination Diagram

a. A declination diagram is placed on most large-scale maps to enable the user to orient the map properly. The diagram shows the interrelationship of magnetic north, grid north, and true north (fig. E-3). On medium-scale maps declination information is shown by a note in the map margin (fig. E-6).

b. Declination is the angular difference between true north and either magnetic or grid north. There are two declinations, a *magnetic declination* and a *grid declination*.

c. The declination diagram contains three prongs representing magnetic north, grid north, and true north (fig. 5-5).

(1) *G-M Angle*. An arc, indicated by a dashed line, connects the grid north and the magnetic north

prongs. The value of this arc—the grid-magnetic angle (G-M ANGLE)—states the size of the angle between grid north and magnetic north and the year it was prepared. This value is expressed to the nearest $1/2^\circ$, with mil equivalents shown to the nearest 10 mils.

(2) *Grid Convergence*. An arc, indicated by a dashed line, connects the prongs for true north and grid north. The value of the angle for the center of the sheet is given to the nearest full minute with its equivalent to the nearest mil. These data are shown in the form of a grid convergence note.

(3) *Conversion Notes*. Notes may also appear in conjunction with the diagram explaining the use of the G-M angle. One note provides instructions for converting magnetic azimuth to grid azimuth and the other note, for converting grid azimuth to magnetic azimuth. The conversion (add or subtract) is governed by the direction of the magnetic north prong relative to that of the grid north prong.

d. The grid north prong is always aligned with the easting grid lines on the map, and on most maps is formed by an extension of an easting grid line into the margin. The angles between the prongs, however, are seldom plotted exactly. The relative position of the directions is obtained from the diagram, but the numerical value should not be measured from it. For example, if the amount of declination from grid north to magnetic north is 1° , the arc shown in the diagram may be exaggerated; if meas-

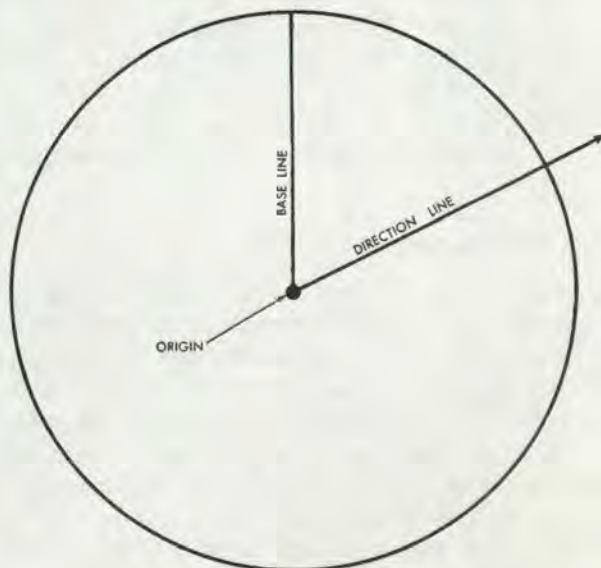
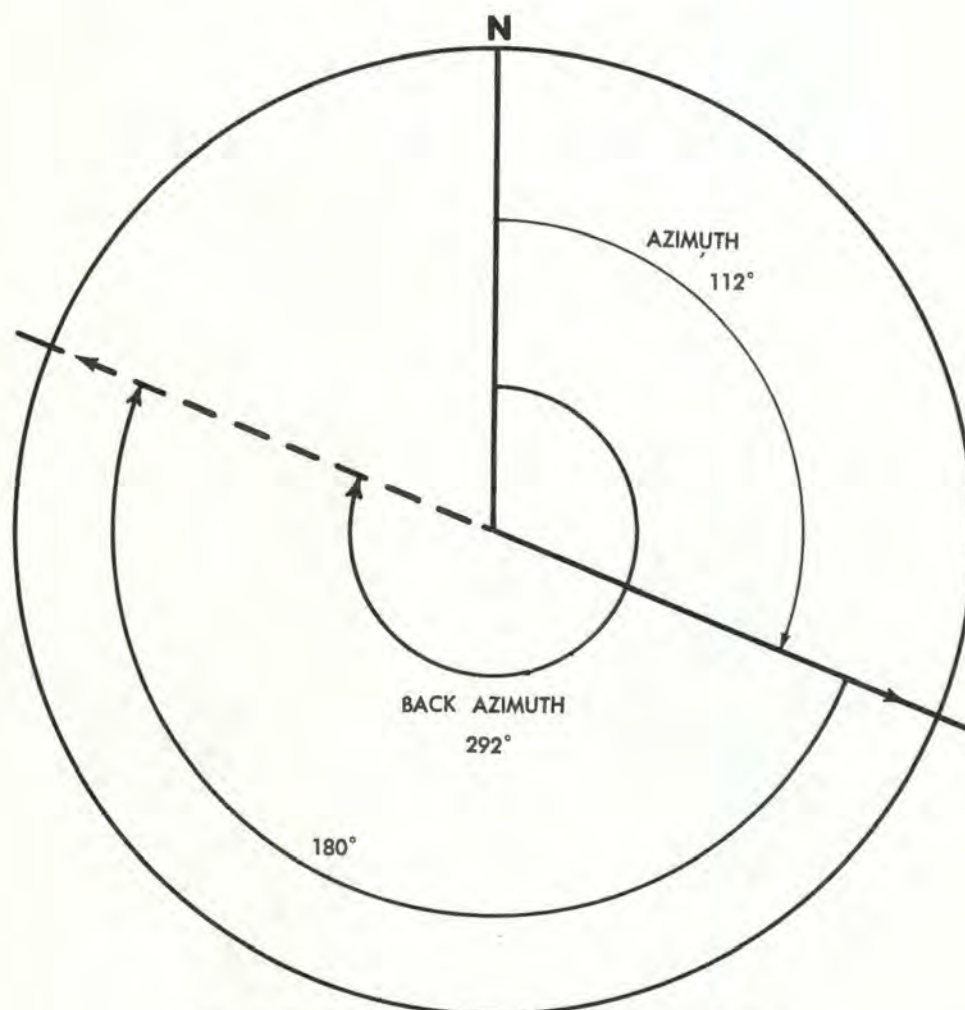


Figure 5-3. Origin of azimuth circle.



AZIMUTH = CLOCKWISE ANGLE FROM BASE DIRECTION

BACK AZIMUTH = AZIMUTH $\pm 180^\circ$ OR 3200 MILS.

Figure 5-4. Azimuth and back azimuth.

ured, it may have an actual value of 5° . The position of the three prongs in relation to each other varies according to the declination data for each map.

e. It is often necessary to convert from one type of direction to another. A magnetic compass reading gives a magnetic azimuth, but to plot this line on a gridded map, the magnetic azimuth value must be changed to a grid azimuth. The reverse is true when orientation is taken from the map; the grid azimuth measured from the map must be converted to a magnetic azimuth for use with the magnetic compass. The declination diagram is used for these conversions. Most maps include with the diagram the

grid-magnetic (G-M) angle and notes explaining its use to convert from one azimuth to another. On older sheets which do not show this information, it is necessary to determine whether to add or subtract the difference to the given azimuth to obtain the desired one. A rule to remember when solving such problems is this: *no matter where the azimuth line points, the angle to it is always measured clockwise from the reference direction (base line)*. With this in mind, the problem is solved in three easy steps:

(1) Examine the declination diagram on the map (fig. 5-6).

(2) From the apex of the declination diagram,

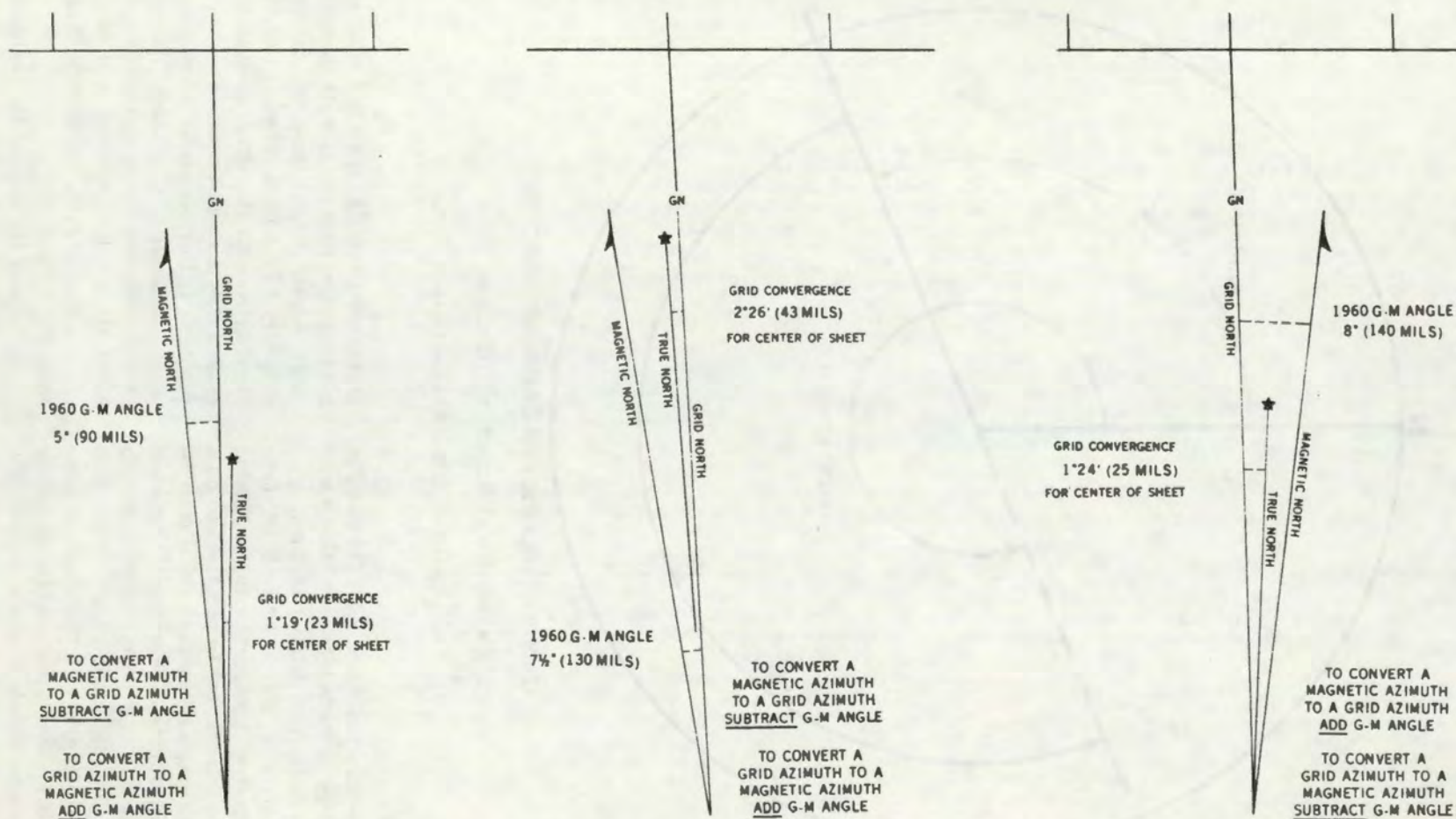


Figure 5-5. Declination diagrams.

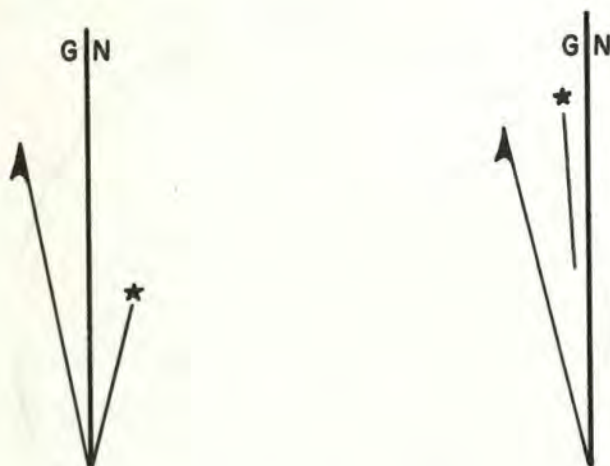


Figure 5-6. Declination diagrams (old treatment).

draw an arbitrary line at roughly right angles to the general direction of north, regardless of the actual value of the azimuth in degrees (fig. 5-7). The position of the arbitrary line in relationship to the declination diagram is of little importance. Figure 5-8 shows an arbitrary line drawn at a different angle. It is both simple and correct to use such an arbitrary line to represent the azimuth line. Remember that the line itself does not change position, but its angular value is changed because of measurement from different reference directions.

(3) Complete the diagram by drawing an arc from each reference line to the arbitrary azimuth line. A glance at the completed diagram shows whether the given azimuth or the desired azimuth is greater, and thus whether the known difference between the two must be added or subtracted (fig. 5-9).

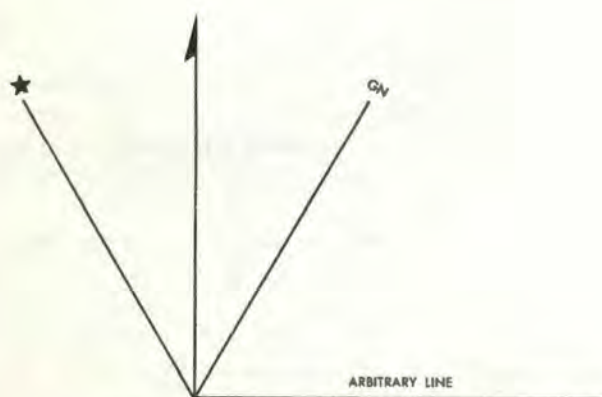


Figure 5-7. Declination diagram with arbitrary line.

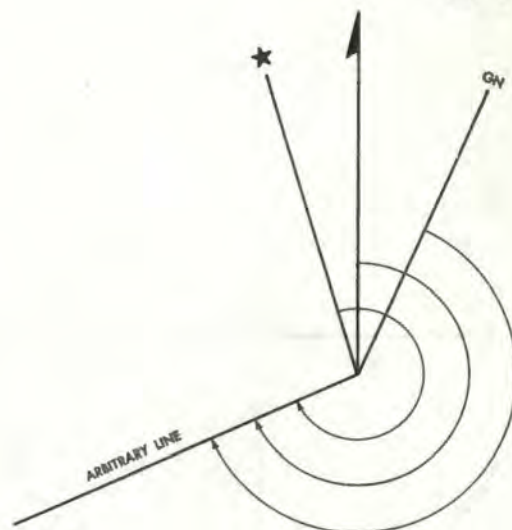


Figure 5-8. Declination diagram with arbitrary line in different position.

(4) After the correct conversion rules have been determined, they should be noted in the map margin adjacent to the declination diagram for future reference.

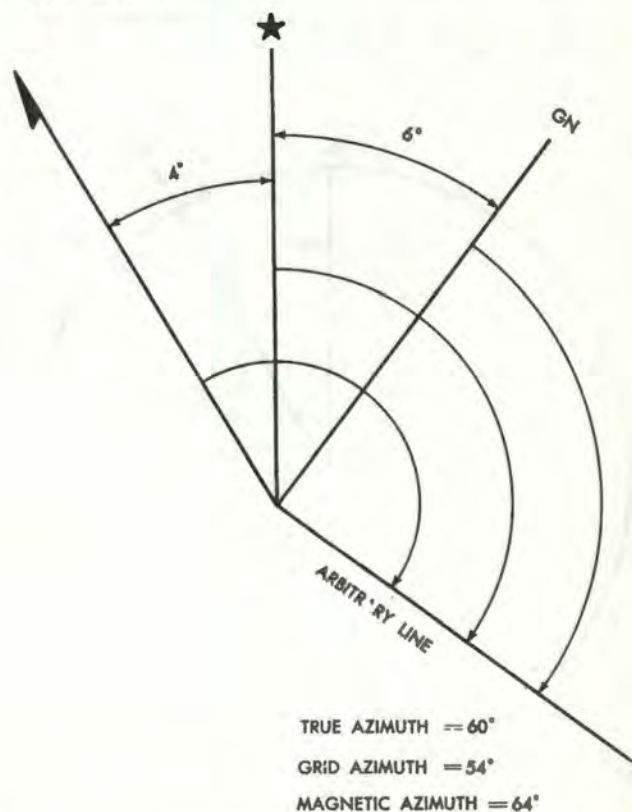


Figure 5-9. Azimuth-angle relationship.

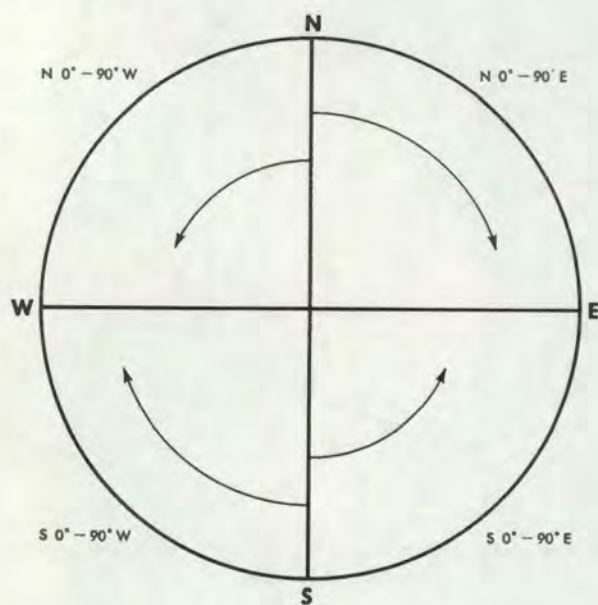


Figure 5-10. Bearings.

f. Some older maps have a note under the declination diagram which gives the magnetic declination for a certain year and the amount of annual change. The annual change is so small, when compared to

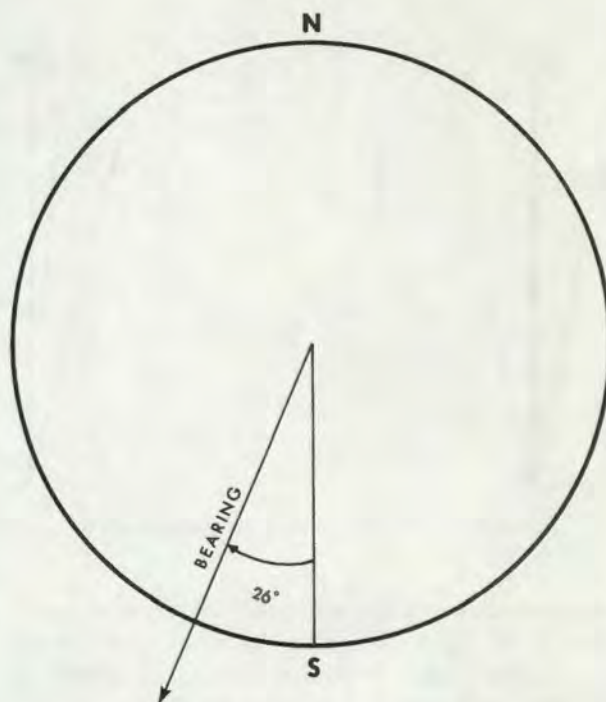


Figure 5-12. Bearing of S 26° W.

the $\frac{1}{2}^\circ$ values of the G-M angle, that it is no longer shown on standard large scale maps.

5-5. Bearings

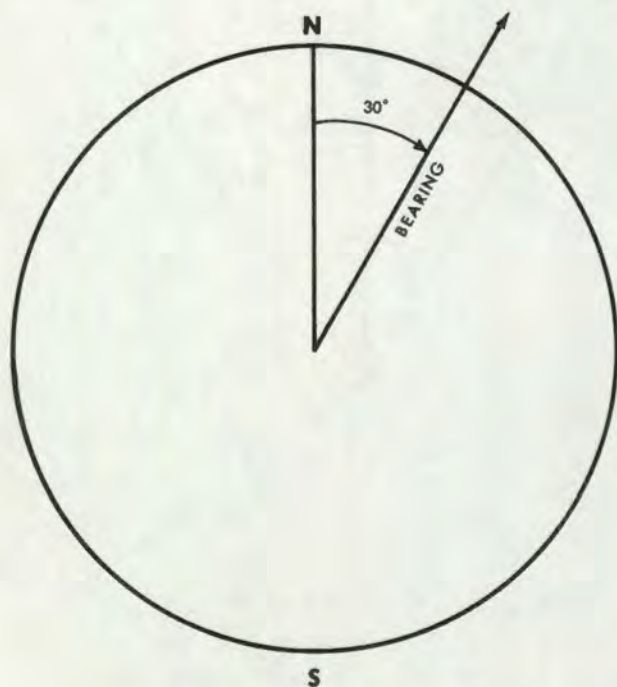
a. A bearing expresses a direction as an angle measured east or west from a north or south reference line (fig. 5-10). Bearing cannot exceed 90° or one-quarter of a circle. One-quarter of a circle is known as a quadrant.

b. To give a bearing, the following information is necessary:

- (1) The reference line from which measured (north or south).
- (2) The amount of angle.
- (3) The direction in which the angle was measured (east or west). A bearing of N 30° E means from a north line an angle of 30° measured in an eastward direction (fig. 5-11). A bearing of S 26° W is shown in figure 5-12.

(4) The four cardinal directions are expressed simply as north, east, south and west.

c. Having more than one way to state a direction at times requires a conversion from one to another. Regardless of the method used to state a direction, the direction line does not change position, only the reference line from which it was measured is different.

Figure 5-11. Bearing of N 30° E.

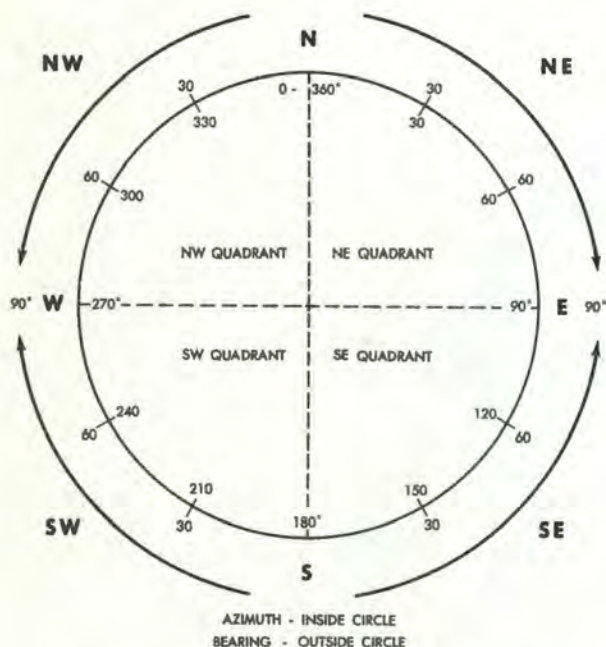


Figure 5-13. Azimuth and bearing relationship.

Bearings can be converted to azimuths or azimuths to bearings using figure 5-13, which shows their relationship. It should be remembered that the direction letters used for the bearing are always the same as those that name the quadrant in which the direction line lies: that is, the bearing of a line in the

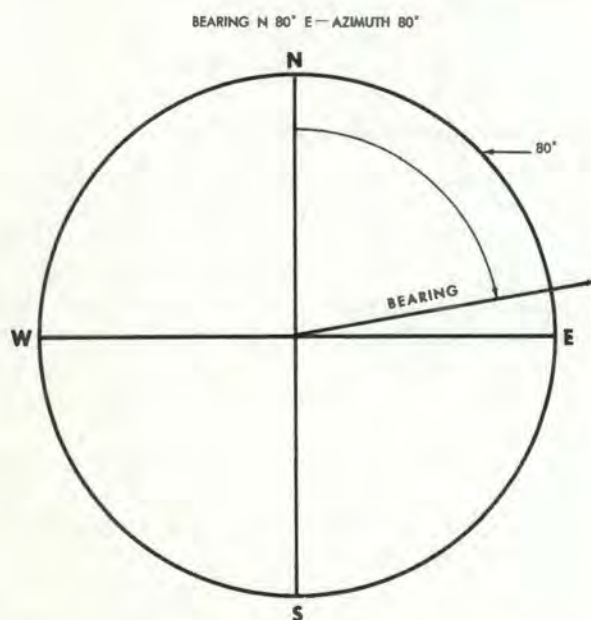


Figure 5-14. Northeast quadrant.

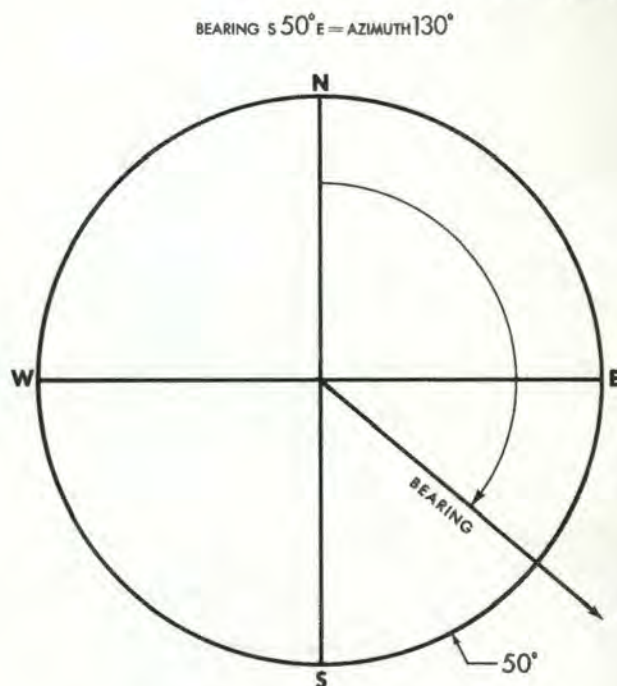


Figure 5-15. Southeast quadrant.

northeast quadrant will always be N (so many degrees) E, and so on around the compass. The following are examples of converting bearings to azimuths and vice versa:

(1) *Northeast quadrant.* In the northeast quadrant the bearing is equal to the azimuth plus the letters N and E (fig. 5-14).

(2) *Southeast quadrant.* In this quadrant the bearing is equal to 180° minus the azimuth, with the letters S and E added (fig. 5-15). To determine an azimuth from a bearing in this quadrant, omit direction letters and subtract the bearing from 180°.

(3) *Southwest quadrant.* The bearing of an azimuth in this quadrant is equal to the azimuth minus 180° with the direction letters S and W added (fig. 5-16). To determine the azimuth from a bearing in this quadrant, omit the direction letters and add 180° to the bearing.

(4) *Northwest quadrant.* In the northwest quadrant the bearing is equal to 360° minus the azimuth, with the direction letters N and W added (fig. 5-17). To determine the azimuth from a bearing in this quadrant, omit the letters and subtract the bearing from 360°.

d. Bearings, as well as azimuths, may be measured from magnetic, grid or true north lines and as a result may require conversion. The direct conversion

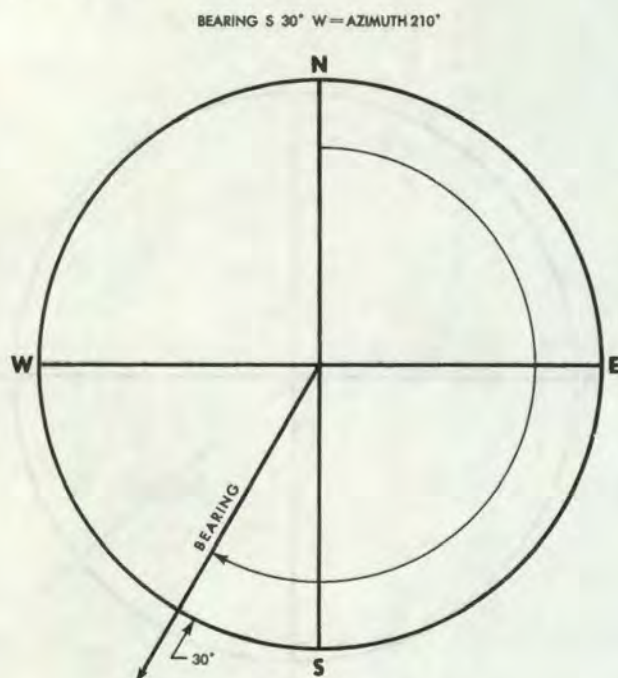


Figure 5-16. Southwest quadrant.

of bearings from one reference line to another is not recommended. First convert the bearing to an azimuth and then convert to an azimuth measured from the new reference line. Finally the azimuth may

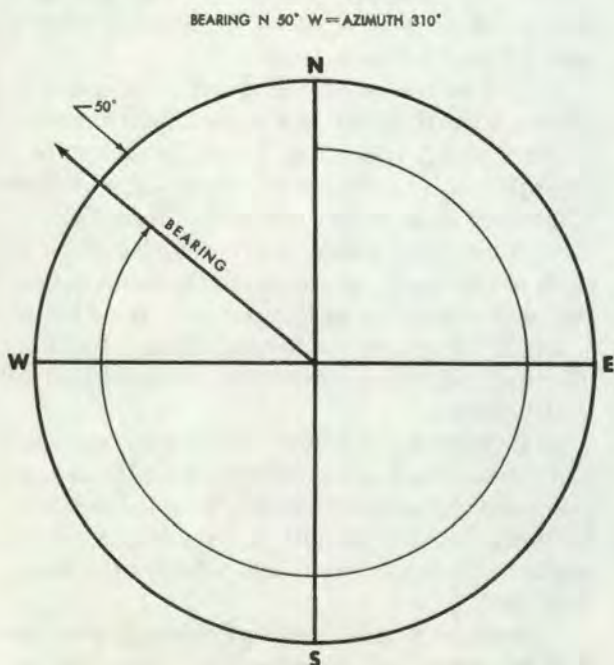


Figure 5-17. Northwest quadrant.

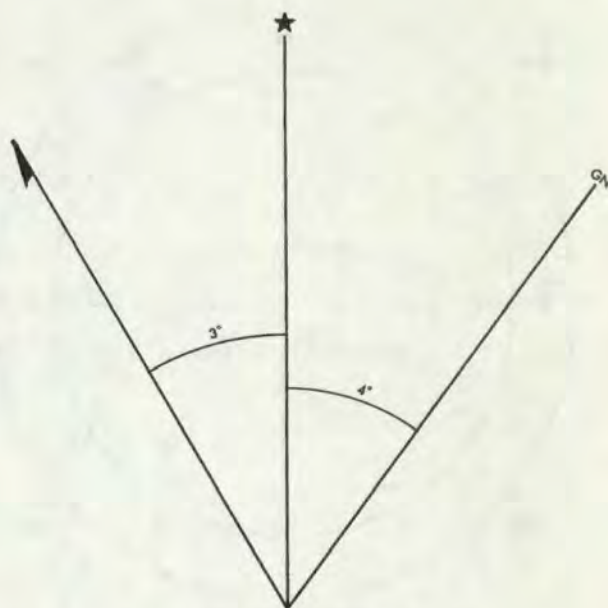


Figure 5-18. Declination diagram.

be converted back to a bearing if necessary. This is advisable because a bearing may be measured clockwise or counterclockwise from either north or south. For example, using the declination diagram in figure 5-18—

A magnetic bearing of S 13° E equals—
 Magnetic azimuth of 167°
 True azimuth of 164°
 Grid azimuth of 160°
 True bearing of S 16° E
 Grid bearing of S 20° E

5-6. The Compass and Its Uses

a. The magnetic compass is the most commonly used and simplest instrument for measuring directions and angles in the field. Two varieties of magnetic compasses are standard for military use today, the *lensatic compass* (fig. 5-19) and the *artillery (M2) compass*. Since the latter is a special purpose compass, it will not be discussed in this manual. For information on the artillery (M2) compass see TM 9-1290-333-15.

b. The lensatic compass must always be held level and firm when sighting on an objective and reading an azimuth. There are several techniques for holding the compass and sighting.

(1) With one method, the slit in the eyepiece, the hairline front sight in the cover, and the target are alined. The azimuth can then be read by glancing

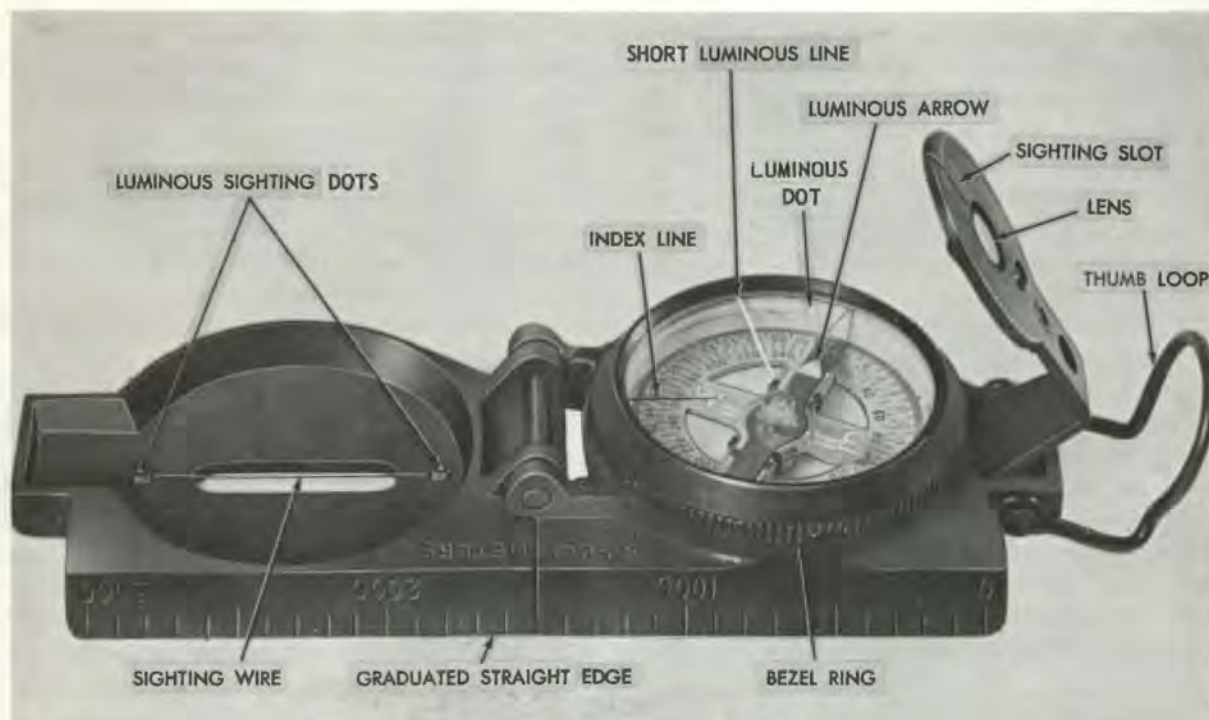


Figure 5-19. Lonsatic compass.

down at the dial through the eyepiece. This technique provides a reading precise enough to use for resection and intersection (para 5-9 and 5-10).

(2) A second method has an advantage in that it keeps the compass lower and farther away from the steel helmet, although it is less precise than the system described in (1) above. To use this method, open the cover until it forms a straight edge with the base; pull the eyepiece to the rear-most position. Next, place your thumb through the thumb loop, form a steady base with your third and fourth fingers and extend your index finger along the side of the compass. Place the thumb of the other hand between the eyepiece and the lens; extend the index finger along the remaining side of the compass and the remaining fingers around the fingers of the other hand, pull your elbows firmly into your sides. This will place the compass between your chin and your belt. To measure an azimuth, simply turn your entire body toward the object, pointing the compass cover directly at the object. Once you are pointing at the object, just look down and read the azimuth from beneath the fixed black index line.

c. For night use, special features of the compass are the luminous markings and the 3° bezel serration

and clicking device. Turning the bezel ring to the left causes an increase in azimuth while turning it to the right causes a decrease. The bezel has a stop and spring which allows clockwise and counterclockwise turns at 3° intervals per click and holds the bezel ring in any desired position. One method for determining compass directions at night follows:

(1) Rotate the bezel until the luminous line is over the black index line.

(2) Hold the compass with the left hand and rotate the bezel ring with the right hand, in a counterclockwise direction, to the number of clicks required. The number of clicks is determined by dividing the value of the required azimuth by 3. For example, for an azimuth of 51°, the bezel ring would be rotated 17 clicks counterclockwise.

(3) Turn the compass until the north arrow is directly under the luminous line on the bezel.

(4) Hold the compass open and level in the palm of the left hand with the thumb along the flat side of the compass. In this manner, the compass can be held consistently in the same position. Position the compass approximately halfway between the chin and the belt, pointing to your direct front. A little practice in daylight will make you proficient

in pointing the compass the same way every time. Looking directly down into the compass, turn your body until the north arrow is under the luminous line. Then proceed forward in the direction of the front cover luminous sighting dots (fig. 5-19).

d. Certain precautions regarding the care and use of a magnetic compass are important because they assure, within reason, that a compass will work when and where it is needed.

(1) Handle the compass with care. The dial is set at a delicate balance which a shock could damage.

(2) Close and return the compass to its special container when not in use. In this way it is not only protected from possible damage but is readily available for use when needed.

(3) When the compass is to be used in darkness, an initial azimuth should be set, if possible, while light is still available. With this initial azimuth as a base, any other azimuth which is a multiple of 3° can be established through use of the clicking feature of the bezel.

(4) Compass readings should never be taken near visible masses of iron or electrical circuits. The following are suggested as approximate safe distances to insure proper functioning of the compass:

High tension power lines.....	55	meters
Field gun, truck or tank.....	18	meters
Telegraph and telephone wires and barbed wire	10	meters
Machinegun.....	2	meters
Helmet or rifle.....	0.5	meter
Nonmagnetic metals and alloys do not affect compass readings.		

(5) Practice using the compass at regular intervals to assure competent technique in an emergency.

5-7. Orientation of a Map

a. Before a map can be used it must be oriented. A map is oriented when it is in a horizontal position with its north and south corresponding to north and south on the ground.

b. A simple way to orient a map is with a compass.

(1) With the map in a horizontal position, the compass is placed parallel to a north-south grid line with the cover side of the compass pointing toward the top of the map. This will place the black index line on the dial of the compass parallel to grid north. Since the needle on the compass points to magnetic north, we have a declination diagram on the face of the compass formed by the index line and the compass needle.

(2) Rotate map and compass until the directions of the declination diagram formed by the black index line and the compass needle match the directions shown on the declination diagram printed on the margin of the map. The map is then oriented.

(3) If the magnetic north arrow on the map is to the left of grid north, the compass reading will equal the G-M angle (given in the declination diagram). If the magnetic north is to the right of grid north, the compass reading will equal 360° minus the G-M angle.

(4) In figure 5-5 the declination diagram on the right illustrates a magnetic north to the right of grid north and the compass reading will be 360° minus 8° or 352° . The two examples on the left show the magnetic north to the left of grid north where the compass reading will equal the G-M angle.

(5) Remember to point the compass north arrow in the same direction as the magnetic north arrow ((2) above), and the compass reading (equal to the G-M angle or the 360° minus G-M angle) will be quite apparent.

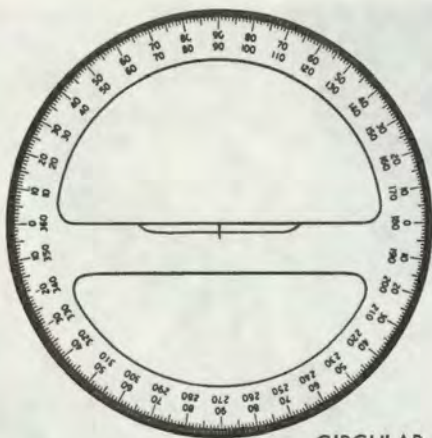
(6) Some maps have a built-in protractor consisting of a pivot point "P" on the south neatline of the map and several degrees of arc along the north neatline of the map. The grid-magnetic line is obtained by connecting pivot point "P" with the appropriate value of the grid-magnetic angle (taken from the declination diagram) on the arc. The map may then be oriented by placing the compass parallel to this line and rotating the map and compass until the needle point is aligned with the continuous line formed by the index line and the sighting wire. The map is then oriented.

c. When a compass is not available, map orientation requires a careful examination of the map and the ground to find linear features common to both, such as roads, railroads, fence lines, power lines, etc. By aligning the feature on the map with the same feature on the ground (fig. 5-20) the map is oriented. Orientation by this method must be checked to prevent the reversal of directions which may occur if only one linear feature is used. This reversal may be prevented by aligning two or more of these features. If no second linear feature is visible, but the map user's position is known, a prominent object may be used. With the prominent object and the user's position connected with a straight line on the map, the map is rotated until the line points toward the feature.

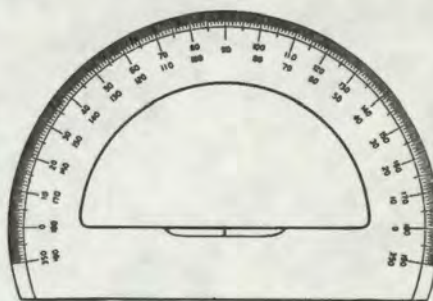
d. If two prominent objects are visible and plotted



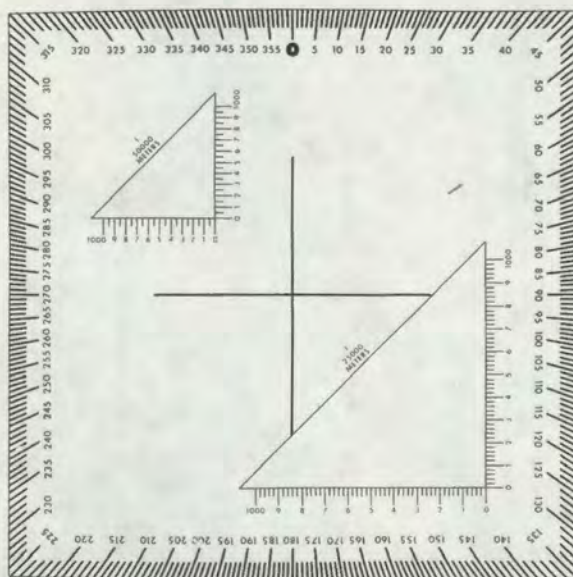
Figure 5-20. Map orientation by inspection.



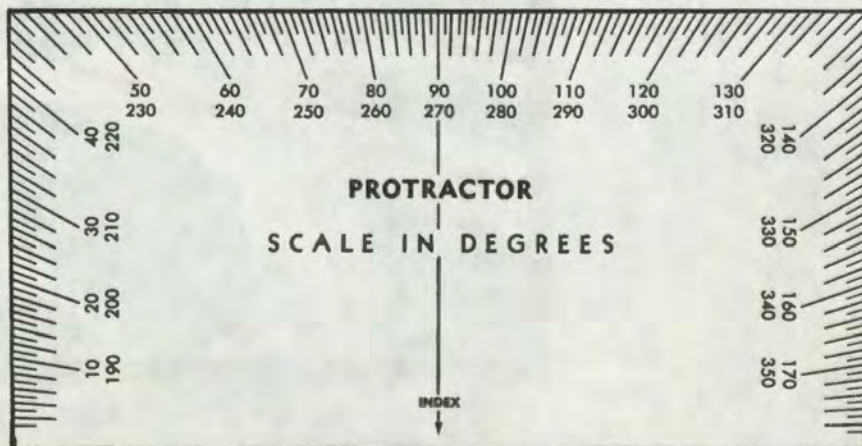
CIRCULAR



SEMICIRCULAR



SQUARE



RECTANGULAR

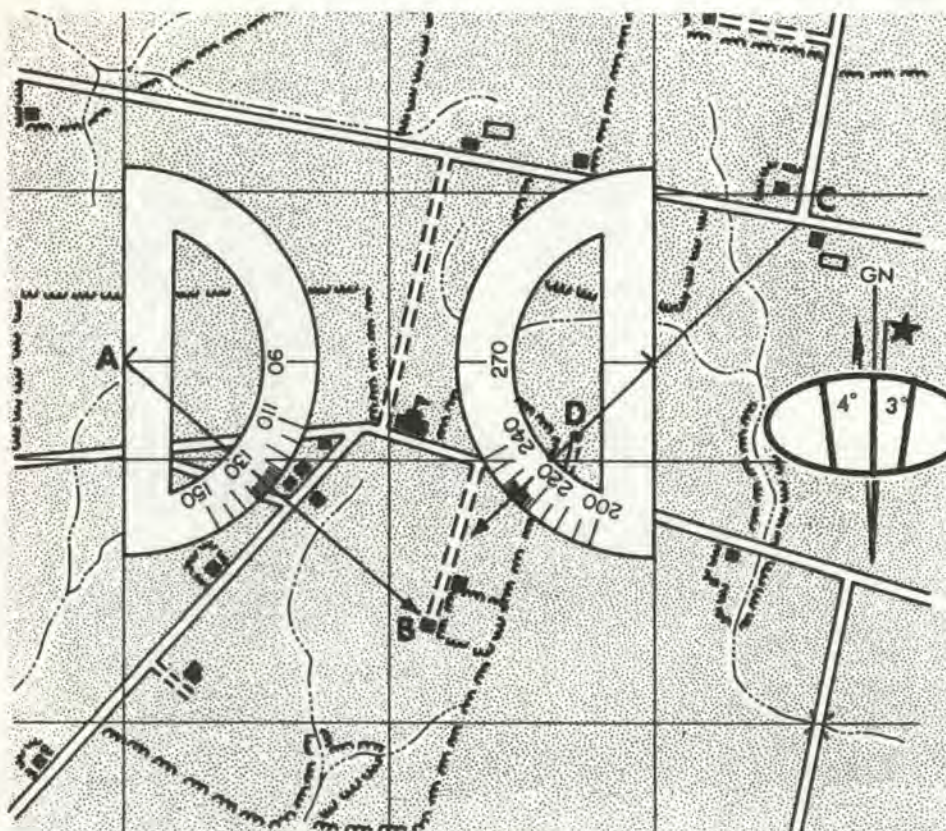


Figure 5-22. Measuring an azimuth on a map.

on the map, and your position is not known, move to one of the plotted and known positions, place your straightedge or protractor on the line between the plotted positions, turn the protractor and the map until you can sight along the edge to the other plotted and visible point. The map is then oriented.

e. When a compass is not available and there are no recognizable prominent landforms or other features, a map may be oriented by any of the field expedient methods mentioned in paragraph 5-12.

5-8. Protractor

a. Protractors come in several forms—full circle, half circle, square, and rectangular (fig. 5-21). All of them divide a circle into units of angular measure, and regardless of their shape, consist of a scale around the outer edge and an index mark. The index mark is the center of the protractor circle from which all the direction lines radiate.

b. To determine the grid azimuth of a line from one point to another on the map (from A to B or C

to D) (fig. 5-22):

- (1) Draw a line connecting the two points.
- (2) Place the index of the protractor at the point where the line crosses a vertical (north-south) grid line.
- (3) Keeping the index at this point, align the 0°-180° line of the protractor on the vertical grid line.
- (4) Read the value of the angle from the scale; this is the grid azimuth of the point.

c. To plot a direction line from a known point on a map (fig. 5-23):

- (1) Convert, if necessary, the direction to a grid azimuth.
- (2) Construct a north-south grid line through the known point:
 - (a) Approximately align the 0°-180° line of the protractor in a north-south direction through the known point.
 - (b) Holding the 0°-180° line of the protractor on the known point, slide the protractor in the north-south direction until the horizontal line of the pro-

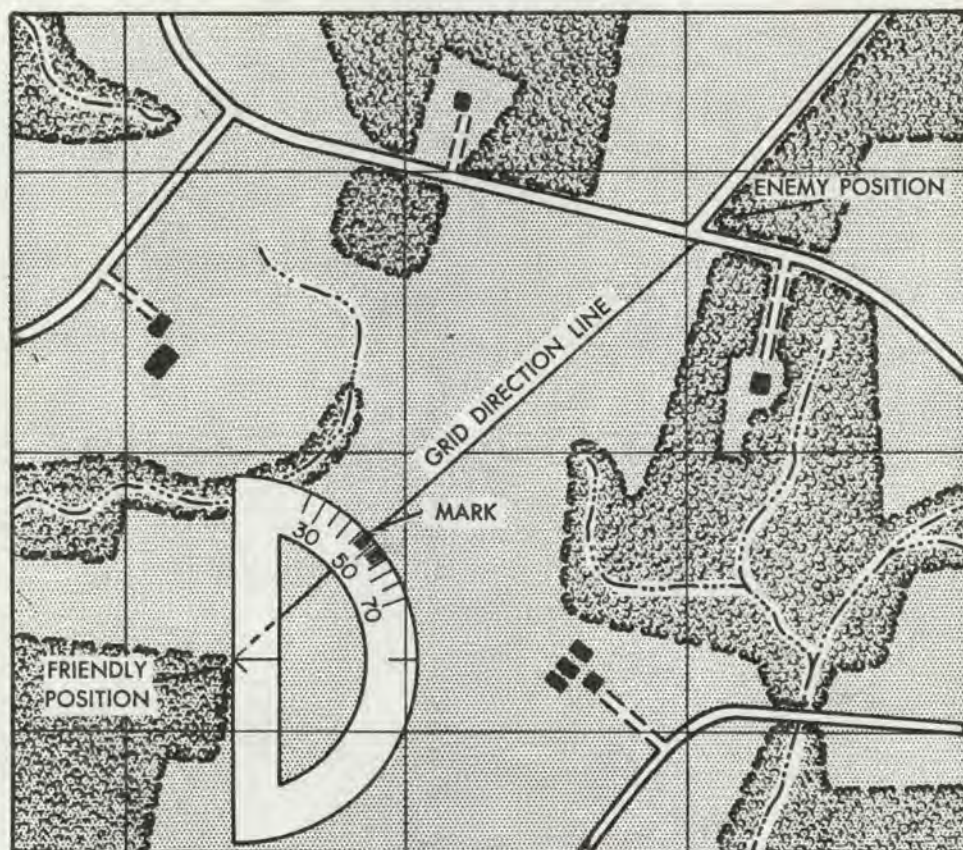


Figure 5-23. Plotting an azimuth on a map.

tractor (connecting the protractor index and the 90° tick mark) is aligned on an east-west grid line.

(c) Draw a line connecting 0°, the known point, and 180°.

(3) Holding the 0°–180° line coincident with this line, slide the protractor index to the known point.

(4) Make a mark on the map at the required angle.

(5) Draw a line from the known point through the mark made on the map. This is the grid direction line.

5-9. Intersection

The location of an unknown point by successively occupying at least two but preferably three known positions and sighting on the unknown point is called intersection. It is used to locate features that are not defined on the map or which are not readily identifiable. The two methods of intersection are the map and compass method and the straightedge method.

a. *Map and Compass Method* (fig. 5-24).

(1) Orient the map using the compass (para 5-7b).

(2) Locate and mark your position on the map.

(3) Measure the magnetic azimuth to the unknown position; convert to grid azimuth.

(4) Draw a line on the map from your position on this grid azimuth.

(5) Move to a second known position from which unknown point is visible. Locate this position on the map and again orient the map using the compass.

(6) Repeat (3) and (4) above.

(7) As a check on accuracy, move to a third position and repeat (1) through (4) above.

(8) Where the lines cross is the location of the unknown position. Using three lines a triangle is sometimes formed instead of an intersection. This is called the triangle of error. If the triangle is large, recheck your work to find the error. Do not assume that the position is at the center of the triangle.

b. *Straightedge Method (When No Compass Is Available)* (fig. 5-25).



Figure 5-25. Intersection without compass.

(1) Orient the map using the compass (para 5-7b).

(2) Locate two or three known positions on the ground and mark them on the map.

(3) Measure the magnetic azimuth to a known position; convert to grid azimuth.

(4) Change the grid azimuth to a back azimuth (para 5-3b) and draw a line on the map from the known position back toward your unknown position.

(5) Repeat (3) and (4) above for a second known position.

(6) For a check on your accuracy, repeat (3) and (4) above for a third known position.

(7) The intersection of the lines is your location. Using three lines, a triangle of error may be formed. If the triangle is large, recheck your work.

b. Straightedge Method (When No Compass Is Available).

(1) Orient the map on a flat surface by the inspection method (para 5-7c).

(2) Locate two or three known positions on the ground and mark them on the map.

(3) Lay a straightedge on the map with the center of the straightedge at a known position as a pivot point and rotate the straightedge until the known position on the map is aligned with the known position on the ground.

(4) Draw a line along the straightedge away from the known position on the ground toward your position.

(5) Repeat (3) above using a second known

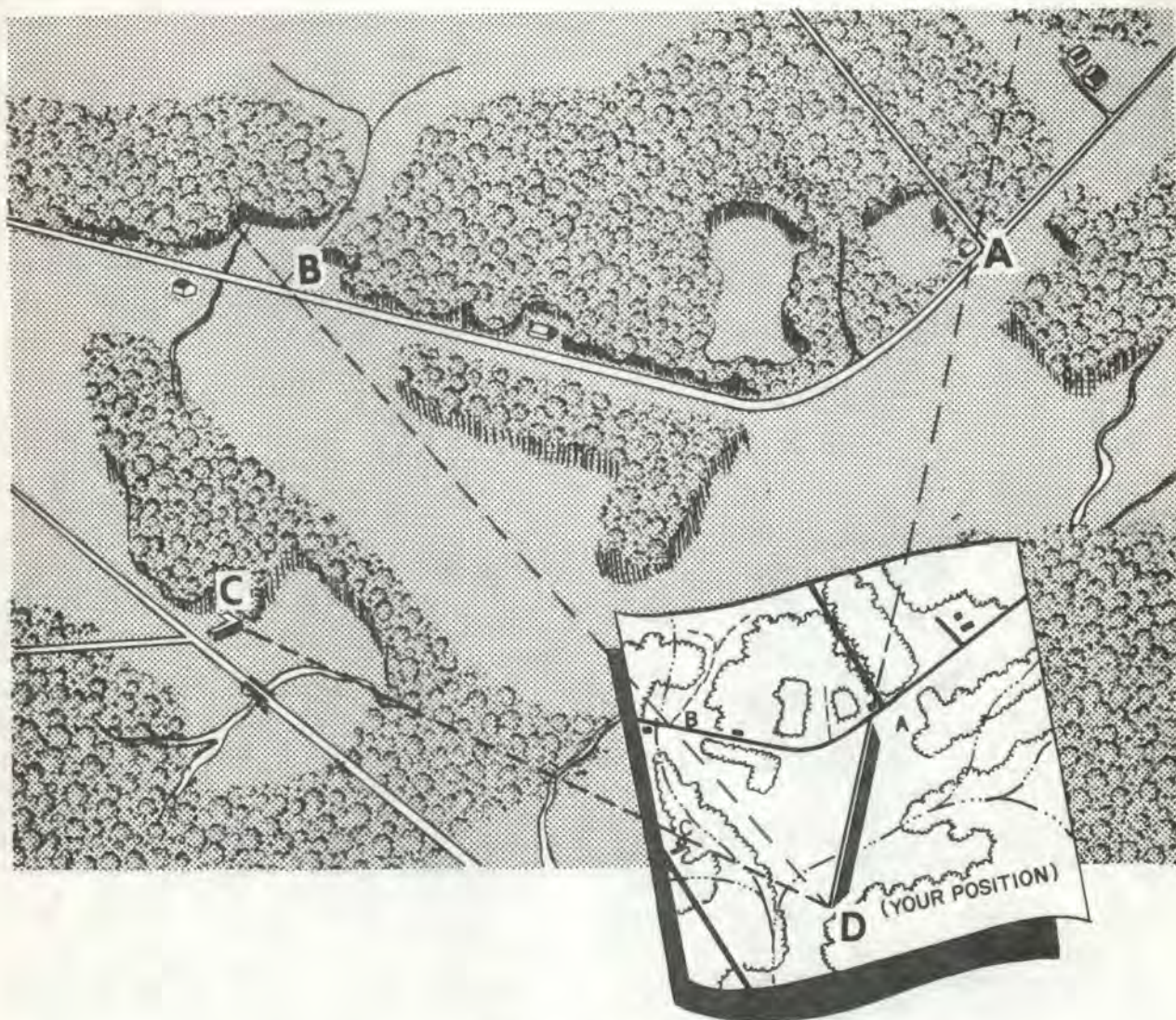


Figure 5-26. Resection.

position and as a check on your accuracy repeat (3) above using a third known position.

(6) The intersection of the lines is your location.

5-11. Position Location by One Line

a. Location of Distant Point by One Line. Often it is not possible or practicable to occupy two positions to perform intersection. Direction can be used to assist in location from one position only.

(1) Determine the one line of direction from your position to the distant point.

(2) Draw that line of direction on the map.

(3) Inspect the terrain in the vicinity of the distant point for distinctive terrain features.

(4) Inspect the map along the line of direction to find those same terrain features. Estimation of range should assist in such ground-map comparison.

(5) Plot the map position of the point on the line of direction according to the pattern of terrain features you have observed.

(6) Although sometimes not practical, this technique often results in a reasonably accurate determination of direction.

b. Location of User's Position by One Line. The same

A DIRECTION



B TIME

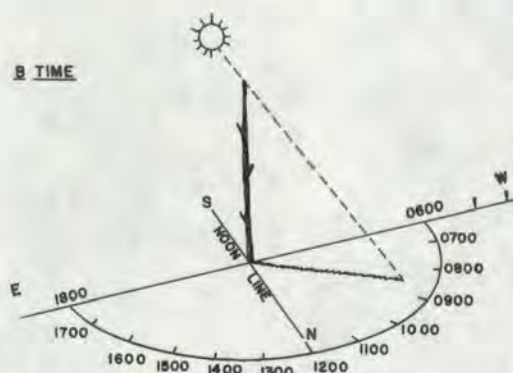


Figure 5-27. Determining a direction and time by shadow.

technique described in *a* above can often be used to locate your own position. The principal difference is that you must change the azimuth to back azimuth, since you are drawing the line on the map from the distant point back through your own position.

5-12. Determining Directions Using Field Expedients

*a. Shadow-tip Method of Determining Direction and Time.**

(1) This simple and accurate method of finding direction by the sun consists of only three basic steps (A, fig. 5-27):

(a) *Step 1.* Place a stick or branch into the ground at a fairly level spot where a distinct shadow

* The material in paragraph 5-12a, d(3), and figures 5-27 and 5-28 was adapted from the book *Better Ways of Pathfinding*, published by Stackpole Company, Harrisburg, Pa., copyrighted © 1964 by Robert S. Owendoff, 153 Gundry Drive, Falls Church, Virginia 22046. All rights reserved by copyright owner (author).

will be cast. Mark the shadow tip with a stone, twig, or other means.

(b) *Step 2.* Wait until the shadow tip moves a few inches. If you are using a 4-foot (1.22 meters) stick, about 10 minutes should be sufficient. Mark the new position of the shadow tip in the same way as the first.

(c) *Step 3.* Draw a straight line through the two marks to obtain an approximate east-west line. If you are uncertain which direction is east and which is west, observe this simple rule—

The sun "rises in the east and sets in the west" (but rarely DUE east and DUE west). The shadow tip moves in just the opposite direction. Therefore, the first shadow tip mark is always in the west direction, and the second mark in the east direction, EVERYWHERE on earth.

(2) A line drawn at right angles to the east-west line at any point is the approximate north-south line, which will help orient you to any desired direction of travel.

(3) Inclining the stick to obtain a more convenient shadow, in size or direction, does not impair the accuracy of the shadow-tip method. Thus, a traveler on sloping ground or in highly vegetated terrain need not waste valuable time looking for a sizable level area. A flat dirt spot the size of your hand is all that is necessary for shadow-tip markings, and the base of the stick can either be above, below, or to one side of it. Also, any stationary object (the end of a tree limb or the notch where branches are jointed) serves just as well as an implanted stick, because only the shadow tip is marked.

(4) The shadow-tip method can also be used to find the approximate time of day (B, fig. 5-27).

(a) To find the time of day, move the stick to the intersection of the east-west line and the north-south line, and set it vertically in the ground. The west part of the east-west line indicates 0600 hours, and the east part is 1800 hours, ANYWHERE on earth, because the basic rule always applies.

(b) The north-south line now becomes the noon line. The shadow of the stick is an hour hand in the shadow-clock and with it you can estimate the time using the noon line and the 6 o'clock line as your guides. Depending on your location and the season, the shadow may move either *clockwise* or *counterclockwise*, but this does not alter your manner of reading the shadow-clock.

(5) The shadow-clock is not a timepiece in the ordinary sense. It makes every day 12 unequal "hours" long, and always reads 0600 hours at sunrise and 1800 hours at sunset. However, it does provide a satisfactory means of telling time in the absence of properly set watches. Being able to establish time of day is important for such purposes as keeping a rendezvous, pre-arranged concerted action by separated persons or groups, estimating the remaining duration of daylight, and so forth. Shadow-clock time is closest to conventional clock time at mid-day, but the spacing of the other hours, compared to conventional time, varies somewhat with the locality and the date.

(6) If you have a watch, the shadow-clock can be used to "store up" the direction you obtained by using the shadow-tip method. Merely set your watch to shadow-clock time and then use the WATCH METHOD described in *d* below. This avoids the 10-minute wait required to complete a shadow-tip reading for true direction and thereby permits you to take as many instantaneous readings as necessary to avoid "circling." After traveling for an hour or so, take a check shadow-clock reading and reset your watch if necessary.

(7) The direction obtained by this modified watch method is the same as that of the regular shadow-tip method using a stick. That is, the degree of accuracy of both methods is identical.

(8) The shadow-tip system is not intended for use in polar regions, which the Department of Defense defines as being above 60° latitude in either hemisphere. Distressed persons in these areas are advised to stay in one place so that search-rescue teams may more readily find them. The presence and location of all aircraft and ground parties in polar regions are reported to and regularly checked by governmental or other agencies, and any need for help becomes quickly known.

b. Equal Shadow Method of Determining Direction (fig. 5-28).

(1) This variation of the shadow-tip method is more accurate and may be used at all latitudes less than 66° at all times of the year.

(a) *Step 1.* Place a stick or branch into the ground *vertically* at a fairly level spot where a distinct shadow at least 12 inches long will be cast. Mark the shadow tip with a stone, twig, or other means. This must be done 5 to 10 minutes before noon (sun time).

(b) *Step 2.* Trace an arc using the shadow as the radius and the base of the stick as the center. A

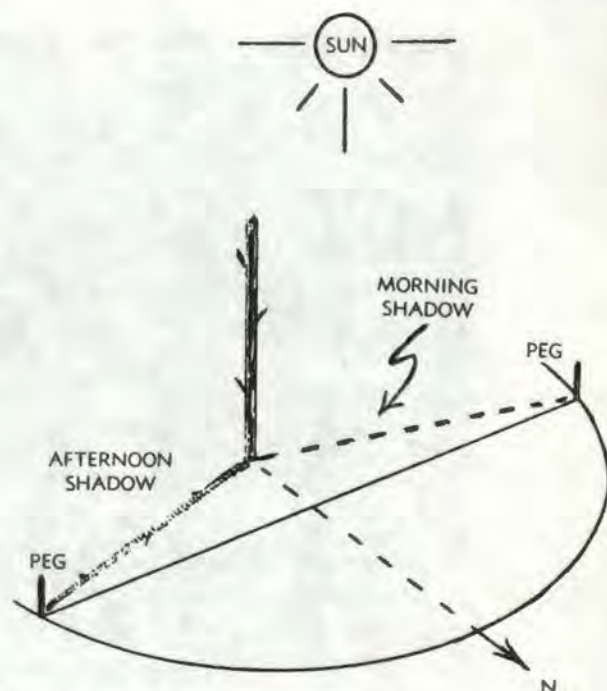


Figure 5-28. Equal shadow method of determining direction.

piece of string, shoelace, or a second stick may be used to do this.

(c) *Step 3.* As noon is approached the shadow becomes shorter. After noon the shadow lengthens until it crosses the arc. Mark the spot as soon as the shadow tip touches the arc a second time.

(d) *Step 4.* Draw a straight line through the two marks to obtain an east-west line.

(2) Although this is the most accurate version of the shadow tip method—

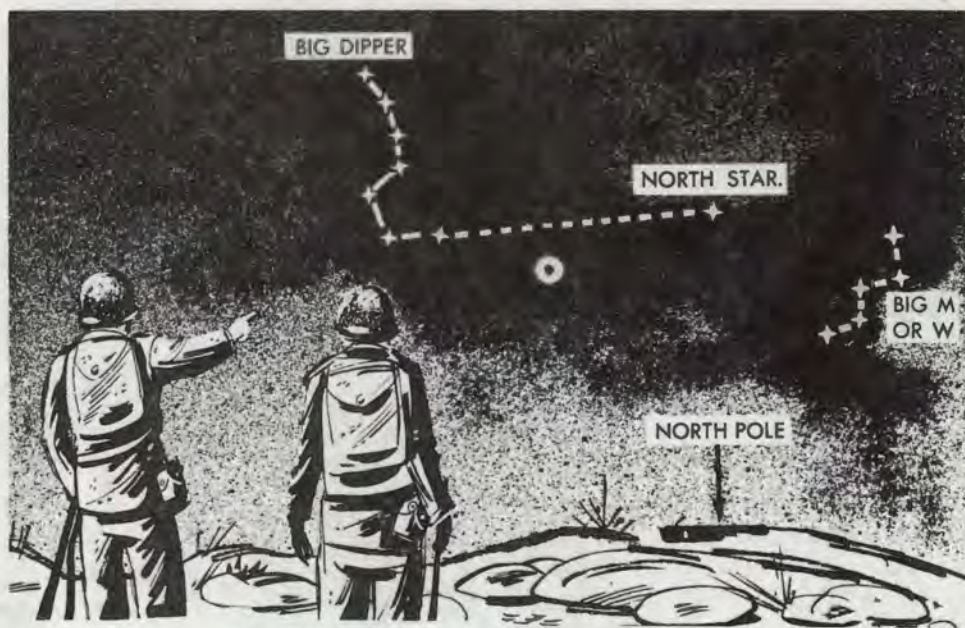
(a) *It must be performed around noon.*

(b) In order to complete the procedure, the observer must watch the shadow and complete step 3 at the exact time the shadow tip touches the arc.

c. Direction at Night. At night the stars may be used to determine the north line in the northern hemisphere or the south line in the southern hemisphere. Figure 5-29 shows how this is accomplished.

d. Direction, Using a Watch (fig. 5-30).

(1) A watch can be used to determine the approximate true north or south. In the north temperate zone only, the hour hand is pointed toward the sun. A south line can be found midway between the hour hand and 1200 hours, standard time. If on daylight saving time, the north-south line is found midway between the hour hand and 1300 hours. If there is any doubt as to which end of the line is



FINDING DIRECTION BY THE NORTH STAR

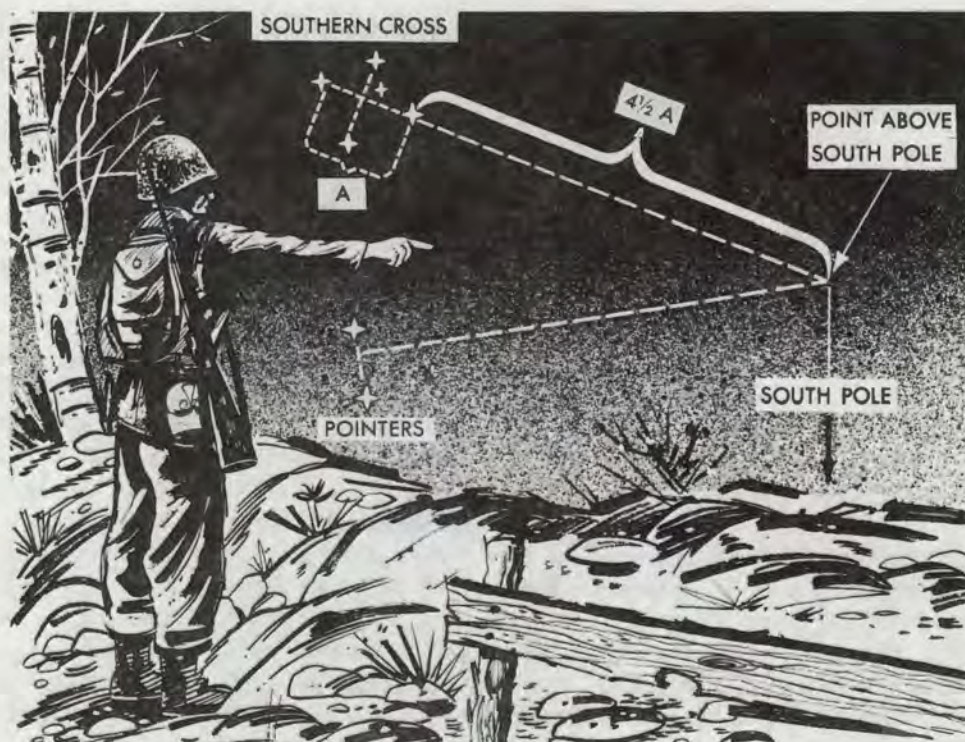


Figure 5-29. Determination of direction by using the stars.

north, remember that the sun is in the east before noon and in the west in the afternoon.

(2) The watch may also be used to determine direction in the south temperate zone; however, the method is different. The 1200 hour dial is pointed toward the sun, and halfway between 1200 hours and the hour hand will be a north line. If on daylight saving time, the north line lies midway between the hour hand and 1300 hours. The temperate zones extend from latitude $23\frac{1}{2}^{\circ}$ to $66\frac{1}{2}^{\circ}$ in both hemispheres.

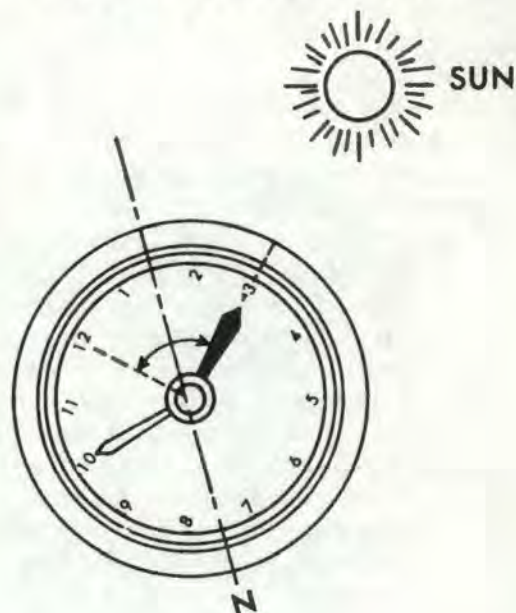
(3) The watch method can be in error, especially in the lower latitudes, and may cause "circling". To avoid this, make a shadow-clock and set your watch to the time indicated. After traveling for an hour take another shadow-clock reading. Reset your watch if necessary.

5-13. Dead Reckoning

a. Dead reckoning is the process by which one's present location is determined by plotting the course and distance from the last known location. In areas where maps exist, even poor ones, travel is guided by them to a great extent. It is a matter of knowing one's position at all times through association of map features with the ground features. But a great portion of the globe is unmapped; hence the possibility that military forces may have to move overland without a map or the time to make one. Although these areas could be anywhere, they are more likely to be found in frozen wastelands and deserts.

b. For many centuries, mariners have used dead reckoning to navigate their ships when they are out of sight of land or during bad weather, and it is just as applicable to navigation on land. Movement on land must be carefully planned. In military movement, one's starting location and destination are known and if a map is available, are carefully plotted, along with any known intermediate features along the route. These intermediate features, if clearly recognizable on the ground, serve as invaluable checkpoints. If a map is not available, the plotting is done on a blank sheet of paper. A scale is selected such that the entire route will fit on one sheet. A north direction is clearly established. The starting point and destination are then plotted in accurate relationship to each other. If the terrain and enemy situation permit, the ideal course is a straight line from starting point to destination. This is seldom possible or practicable. The route of travel usually

NORTH TEMPERATE ZONE



SOUTH TEMPERATE ZONE

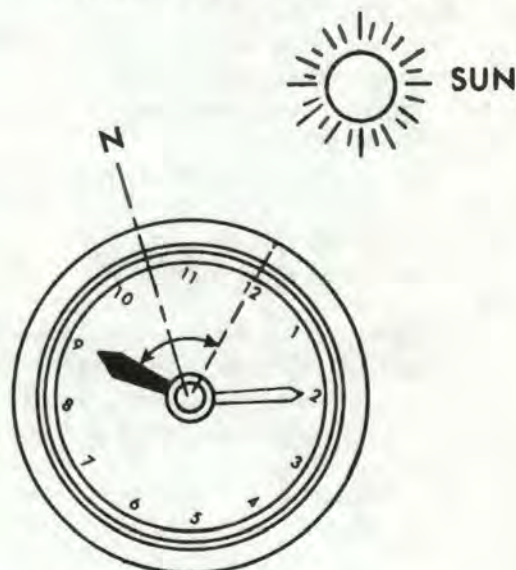


Figure 5-30. Directions using a watch.

consists of several courses, with an azimuth established at the starting point for the first course to be followed. Distance measurement begins with the

departure and continues through the first course until a change in direction is made. A new azimuth is established for the second course and the distance is measured until a second change of direction is made, and so on. Records of all data are kept and all positions are plotted. In general, this same procedure is followed regardless of whether the navigator is walking (pacing) or riding in a vehicle.

(1) A pace is equal to one natural step, approximately 30 inches. To measure distance, you count the number of paces in a given course and convert to the map unit. Usually, paces are counted in hundreds, and hundreds can be kept track of in many ways: make notes in a record book; count on your fingers; place small objects such as pebbles into an empty pocket; tie knots in a string; or use a mechanical hand counter. Distances measured this way are only approximate, but with practice can become very accurate. It is important that each person who uses dead reckoning navigation establish the length of his average pace. This is done by pacing a measured course many times and computing the mean. In the field, an average pace must often be adjusted because of the following conditions:

(a) *Slopes.* The pace lengthens on a downgrade and shortens on the upgrade.

(b) *Winds.* A headwind shortens the pace while a tailwind increases it.

(c) *Surfaces.* Sand, gravel, mud, and similar surface materials tend to shorten the pace.

(d) *Elements.* Snow, rain, or ice cause the pace to be reduced in length.

(e) *Clothing.* Excess weight of clothing shortens the pace while the type of shoes affects traction and therefore the pace length.

(f) *Stamina.* Fatigue affects the length of the pace.

(2) Distances can be measured by an odometer which is standard equipment on most vehicles. Readings are recorded at the start and end of a course, and their difference is the length of the course.

c. The duties of a navigator are so important and exacting that he should not be burdened with any others. This is especially true in regard to vehicular movement. The march commander should not attempt to do the navigating himself, since his normal responsibilities would suffer as a result. The commander selects one person to be navigator and makes him responsible for all the details involved. These include—

(1) Assembling necessary equipment.

(2) Keeping equipment serviceable.

(3) Performing the detailed duties of taking and recording necessary data for precise location at all times.

(4) Maintaining liaison with the commander.

(5) Supplying data to keep the column on course.

d. A steering mark is any well-defined object on the ground in the direction of travel toward which a navigator may steer. It is easier to follow these than to steer continuously by compass.

(1) *Steering marks by day.* Naturally, steering marks are easier to find during daytime marches. Such objects as lone trees or buildings, timber corners, and shapes on the horizon are good examples. Even a cloud formation or wind direction may be used if checked periodically by compass.

(2) *Steering marks by night.* By night, the stars are usually the single source of steering marks. Because of the rotation of the earth, the positions of the stars are continually changing and compass checks on azimuth are necessary. The length of the safe period between checks depends on the star selected. A star near the north horizon serves for about a half hour. The pole star is an ideal steering mark since it is less than 1° off true north, but above latitude 70° it is too high in the sky to be useful. When moving south, azimuth checks should be made every 15 minutes to be safe. When traveling east or west, the difficulty of staying on azimuth is caused more by the likelihood of the star climbing too high in the sky or losing itself behind the western horizon than it is by the star changing direction angle. In all the above cases, it is necessary to change to another guide star when one becomes useless. South of the equator, the above general directions for using north and south stars are reversed.

e. On foot, the hand compass is standard for navigation by dead reckoning. The starting point is known on the map, if a map is available; if not, an assumed starting point is indicated on some sort of a plotting sheet. At this point on the ground, an azimuth is set on the compass for the first course, and the journey is started. At the first turn, a new azimuth is established and followed, and the process is repeated to the goal. A log of all values, azimuths, and distances is kept and the journey is plotted. Figure 5-31 is a pictorial illustration of the use of the compass in navigating on foot.

f. In vehicular movement, the process of measuring angles and distances for plotting purposes is

the same as for movements on foot. The difference lies in the methods employed to make the measurements. More often than not, the hand compass is the only compass available. This means much care must be taken to compensate for deviation caused by using the compass inside the vehicle. It also means dismounting periodically with the compass to eliminate disturbing magnetic attractions. The process of leaving the vehicle to establish a true azimuth can be somewhat confusing, and for this reason a procedure is outlined.

(1) *Vehicular navigation without steering marks.* In wide open country, where no steering marks are available, the vehicle is positioned in the direction of travel. The navigator dismounts and walks 50 meters forward. An azimuth on the vehicle is then read and, by addition or subtraction of 180° , the forward azimuth is obtained. This azimuth is used to plot the course. The driver drives forward to join the navigator. Instructions are given to the driver to stay on as straight a course as possible. The navigator gets into the vehicle and determines the deviation from the correct magnetic azimuth just obtained. The compass is read while the navigator is seated in the vehicle holding the compass in the same position as it is to be held while advancing. Further, it is read with the motor running and the ammeter showing normal charge, and with the brake and gear levers in running position. This azimuth is used to direct the movement only. The march is then started and held to the azimuth by the navigator who continually watches the compass. If the course changes more than 10° , the procedure should be repeated. It should

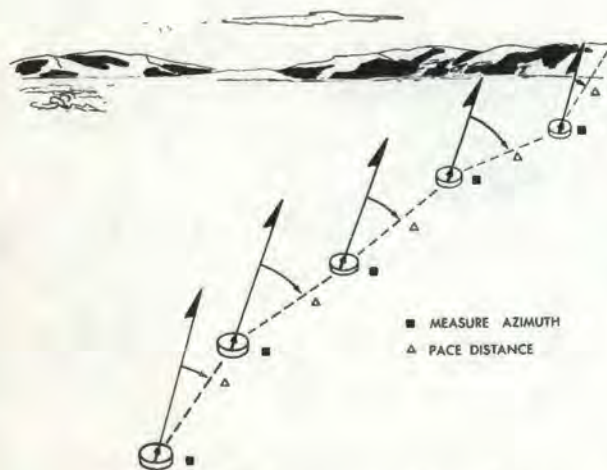


Figure 5-31. Compass navigation on foot.

take only a few minutes to establish each new reading.

(2) *Vehicular navigation using steering marks.* Vehicular navigation is much simpler when steering marks are available. The steering mark is selected and no azimuth is needed during the movement. However, an azimuth is needed for plotting the course. This is obtained at each turn in the march by moving away from the magnetic influence of the vehicle to take the compass azimuth, as described above.

g. The log (fig. 5-32) is essential for navigation by dead reckoning. It is a form on which all the distances and azimuth of a march are recorded. A series of columns are labeled in such a manner that the data are complete. The distances are in miles and the azimuths are true azimuths for direct plotting purposes. If the means of measurement does not record in miles, another column is set up for the conversion. For example, a measuring wheel records the number of revolutions it makes, and the number then has to be converted to miles for each course. Also, it might be preferable to plot grid azimuths rather than true azimuths, which would mean a different conversion factor after declination and deviation corrections are made. The last column is reserved for notes related to any particular course or courses. Such notes clarify the log at a later date. Often, relatively short stretches of a march cannot be traversed in a straight course because of some natural feature such as a river, or a steep and rugged slope. The break in the normal navigation procedure is shown on the log in order to assure a proper plotting. The sample log in figure 5-32 shows that the Wahoo River caused 4 extra miles to be recorded on the odometer, 2 miles of which were lost in a false attempt to cross. These were noted for deduction from the course length by writing, "Cut 2 miles". The last course of the march, K-L, was continued after the river crossing. This might not be the case, and a new course would be desirable once the crossing has been made. If so, a separate odometer reading should be logged, both before and after the crossing. Also, if the crossing entails considerable linear distance, it should be entered as a separate course, with distance and azimuth to permit a more accurate plot. It may be necessary to estimate the distance and read an azimuth from the far side of the crossing area. In such a case, notes are made to clarify the operation and to account for the odometer mileage lost in its execution.

1	2	3	4	5	6	7
ODOMETER READING AT START OF EACH COURSE	DISTANCE IN MILES	FORWARD AZIMUTH (MAGNETIC)	DECLINATION CORRECTION	DEVIATION CORRECTION	TRUE AZIMUTH	NOTES
A 4750						
B 4756	6	17°	+13°	+3°	33°	
C 4765	9	358°	"	+2°	13°	
D 4773	8	341°	"	+1°	355°	
E 4774	1	314°	"	0°	327°	
F 4775	1.5	341°	"	+1°	355°	
G 4777	1.5	322°	"	0°	335°	
H 4778	1	312°	"	0°	325°	
I 4790	12	300°	12°	-1°	311°	
J 4796	6	341°	"	+1°	354°	
K 4802	6	302°	"	-1°	313°	
4810	20	319°	"	0°	331°	Wahoo River Crossing
4814						Cut 2 mi
L 4824			Base Camp (data)			

Figure 5-32. Sample log.

h. The march may be plotted directly on the face of the map, or on a separate piece of paper at the same scale as the map. If the latter method is chosen, the complete plot can be transferred to the map sheet, provided that at least one point of the plot is also shown on the map. The actual plotting is done by protractor and scale. The degree of accuracy obtained depends upon the quality of draftsmanship, the physical conditions, and the care taken in obtaining the data while en route. Figure 5-33 illustrates a separate paper plot of the data obtained for the log sample in figure 5-32. It should be noted that four of the courses from D to H are short and have been plotted as a single course, equal to the sum of the four distances and using a mean azimuth of the four. This is recommended because it saves time, without a loss of accuracy.

i. If at all possible, a plot should be tied into at least one known intermediate point along the route of march. This is done by directing the route to pass near or over such a point. If the plotted position of the intermediate point differs from its true known location, discard the previous plot and start anew from the known location. The previous plot may be inspected to see if there is a detectable constant error applicable to future plots; otherwise, it is of no further use.

j. Deliberate Offset.

(1) An offset is a planned magnetic deviation to the right or left of an azimuth to an objective. It is used when approaching a linear feature from the side, and a point along the linear feature (such as a road junction) is the objective. Because of errors in the compass, or in mapreading, one may reach the linear feature and not know whether the objective lies to the right or left. A deliberate offset by a known number of degrees in a known direction compensates for possible errors and insures that upon reaching the linear feature, the user knows whether to go right or left to reach the objective.

(2) Figure 5-34 shows an example of the use of offset to approach an objective. It should be remembered that the distance from "x" to the objective will vary directly with the distance to be traveled and the number of degrees offset. Each degree offset will move the course about 17 meters to the right or left

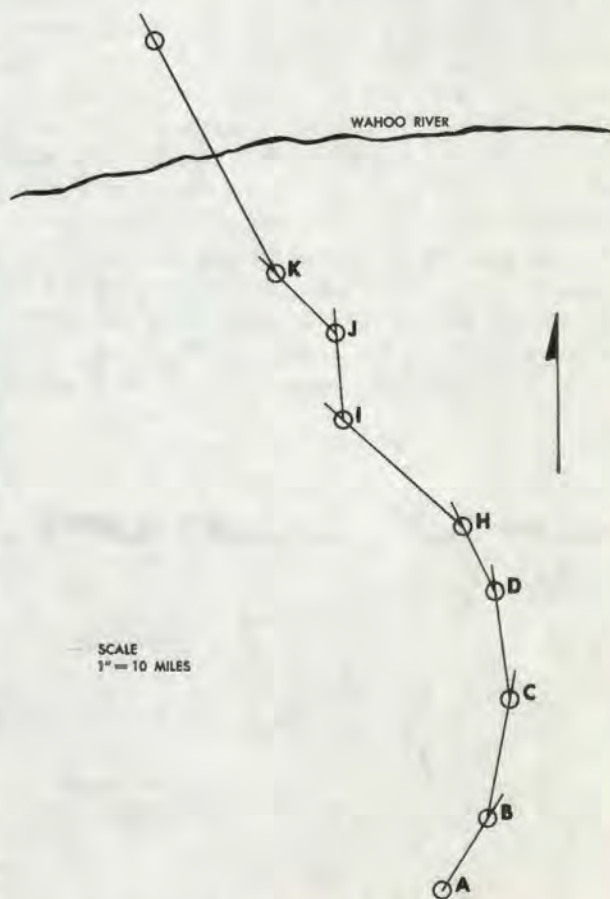


Figure 5-33. Sample plot.

for each 1000 meters traveled. For example: in fig. 5-34 the number of degrees offset is ten. If the distance traveled to "x" is 1000 meters then "x" is located about 170 meters to the right of the objective.

k. Figure 5-35 shows an example of how to bypass enemy positions or obstacles by detouring around them and still stay oriented by moving at right angles for specified distances. For example, you are moving on an azimuth of 360° and wish to bypass an obstacle or position. Change direction to 90° and travel for 100 meters, change direction back to 360° and travel for 100 meters, change direction to 270° and travel for 100 meters, then change direction to 360° and you are back on your original azimuth.

l. Bypassing an unexpected obstacle at night is a fairly simple matter. To make a 90° turn to the right, hold the compass as described in paragraph 5-6c; turn until the center of the luminous letter E is under the luminous line (do not change the setting of the luminous line). To make a 90° turn to the left, turn until the center of the luminous letter W is under the luminous line. This does not require changing the compass setting (bezel ring), and it insures accurate 90° turns. For example, you decide to detour to the right. You turn until E is under the luminous line and proceed in that direction until you have out-

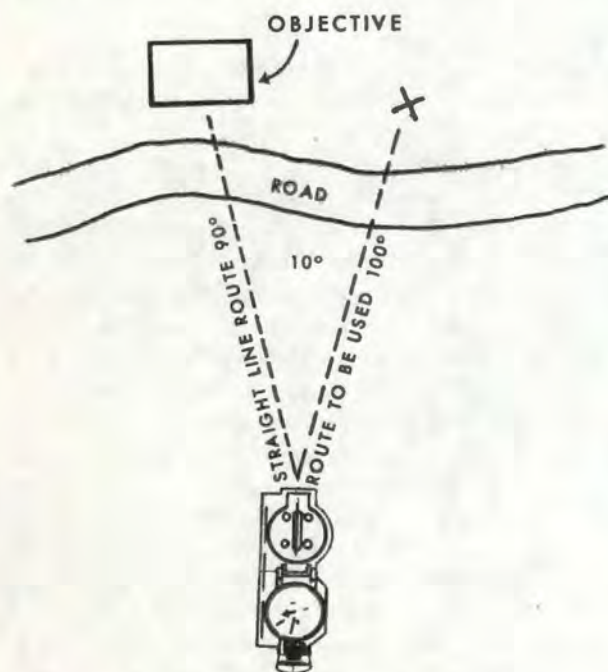


Figure 5-34. Deliberate offset to objective.

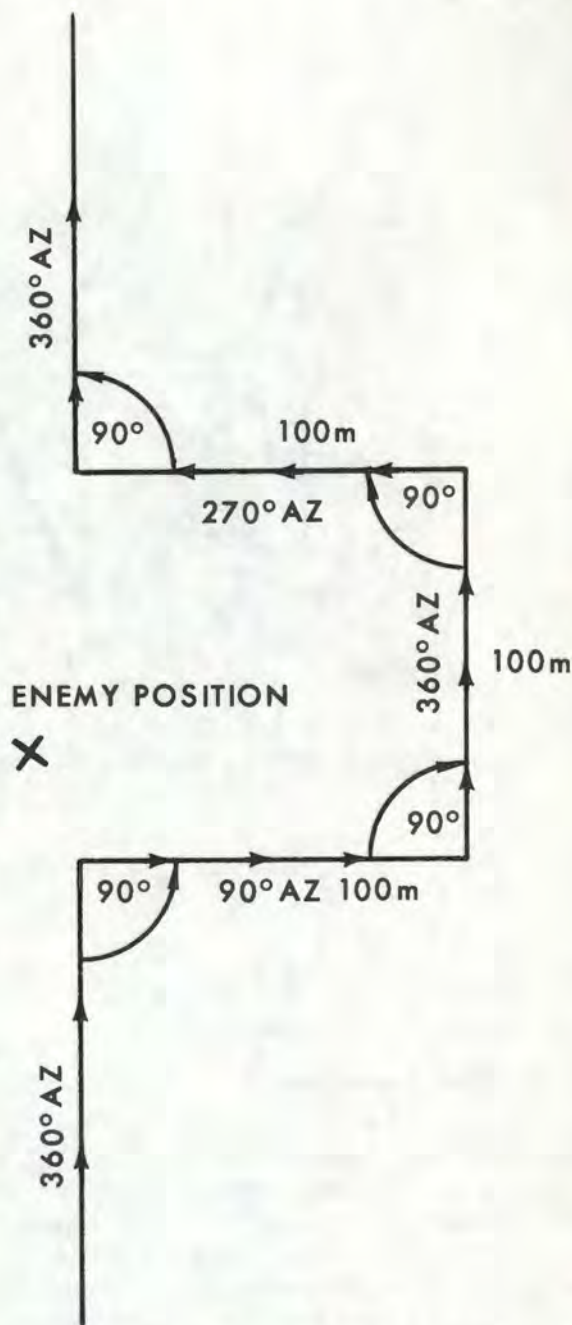


Figure 5-35. Detour around enemy positions or obstacles.

flanked the obstacle. You then turn until the north arrow is under the luminous line and proceed parallel to your original course until you have bypassed the obstacle. You then turn until the W is under the luminous line and move back the same distance you originally moved out. Finally, you turn until the

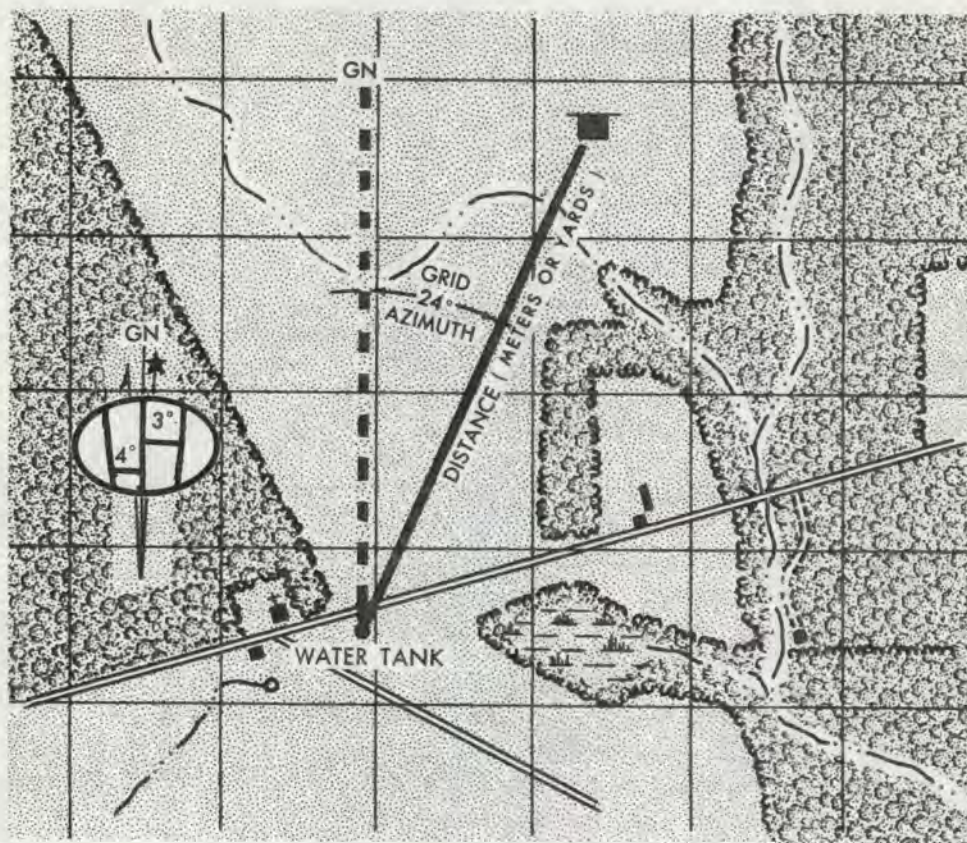


Figure 5-36. Polar coordinates used to designate position on a map.

north arrow is under the luminous line and proceed on your original course. This method works regardless of what your initial azimuth may be.

5-14. Polar Coordinates

Straight Line Azimuth. A point on the map may be determined or plotted from a known point by giving a direction and a distance along that direction line. This method of point location uses polar coordinates (fig. 5-36). The reference direction is normally expressed as an azimuth and the distance in any convenient unit of measurement such as meters or yards. Polar coordinates are especially useful in the field because magnetic azimuth can be determined from the compass and the distance can be estimated.

5-15. Mapreading Aboard Aircraft

a. Today where aircraft are used extensively in military operations, more and more personnel must be able to read maps and navigate from the air. The methods used are similar to those used in land navigation, except that when in the air, the mapreader

must remain constantly oriented, both in position and direction, and must adjust his thinking to the faster rate of travel.

b. Mapreading from an aircraft is easier than from the ground because the terrain features, when viewed from the air, more closely resemble the scale of those shown on the map, and because the reader views a much larger area and can therefore identify more landmark features to aid in orientation. On the other hand, however, the large amount of terrain detail visible may in itself be confusing unless the reader limits himself to specific features for orientation. The following steps should be followed in aerial missions which require mapreading:

(1) Study the maps before the mission. Always consult with the pilot prior to departure. Make sure you can locate yourself on the map and are familiar with the route or routes to be followed and the mission to be accomplished. In making a map study, select those terrain features you think will be most obvious from the air. Mark them on the map, and then study the map carefully so that you will be

familiar with the sequence and general locations in which you will see the feature later.

(2) In an aircraft the pilot always knows his general position and the direction of travel. If there is an intercom system available, make use of it to consult with the crew whenever necessary.

(3) Always sit facing the direction of travel and make sure you have a clear view of the terrain ahead.

(4) Keep the map oriented in the direction of travel. On cross-country flights, it is often best to use

an air chart or the air version of the Joint Operations Graphic if available. A large-scale topographic map can then be used when in the area where reconnaissance or other mission is to be performed.

(5) Follow the route on the map and know your location at all times. Where possible, use prominent terrain or topographic features for reference points and steering marks.

(6) If you do become lost, consult immediately with the pilot or the crew to relocate yourself on the map.

CHAPTER 6

ELEVATION AND RELIEF

6-1. Introduction

a. A knowledge of map symbols, grids, scale, and distance gives enough information to identify two points, locate them, measure between them, and determine how long it would take to travel between them. But what happens if there should be a 300-foot cliff between the two points? The map user must also become proficient in recognizing the various landforms and irregularities of the earth's surface and be able to determine the elevation and differences in height of all terrain features.

(1) *Datum plane.* This is a reference from which vertical measurements are taken. The datum plane for most maps is mean or average sea level.

(2) *Elevation.* This is defined as the height (vertical distance) of an object above or below a datum plane.

(3) *Relief.* Relief is the representation of the shape and height of landforms and the characterization of the earth's surface.

b. The elevation of points and the relief of an area affect the movement and deployment of units by limiting the route along which they may travel, their speed of movement, and the ease or difficulty of attacking or defending an area. Also affected are observation, fields of fire, cover, concealment, and the selection of key terrain features.

6-2. Contour Lines

a. There are several ways of indicating elevation and relief on maps. The most common way is by contour lines. A contour line is a line representing an imaginary line on the ground along which all points are at the same elevation. See paragraph 6-5 for a discussion of shaded relief, layer tinting, form lines and hachures.

b. Contour lines indicate a vertical distance above or below a datum plane. Starting at sea level, normally the zero contour, each contour line represents an elevation above sea level. The vertical distance between adjacent contour lines is known

as the contour interval and the amount of the contour interval is given in the marginal information. On most maps the contour lines are printed in brown. Starting at zero elevation, every fifth contour line is drawn with a heavier line. These are known as index contours and someplace along each index contour the line is broken and its elevation is given. The contour lines falling between index contours are called intermediate contours. They are drawn with a finer line than the index contours and usually do not have their elevations given.

c. Using the contour lines on a map, the elevation of any point may be determined by—

(1) Finding the contour interval of the map from the marginal information, and noting both the amount and the unit of measure.

(2) Finding the numbered contour line (or other given elevation) nearest the point for which the elevation is being sought.

(3) Determining the direction of slope from the numbered contour line to the desired point.

(4) Counting the number of contour lines that must be crossed to go from the numbered line to the desired point and noting the direction—up or down. The number of lines crossed multiplied by the contour interval is the distance above or below the starting value.

(a) If the desired point is on a contour line, its elevation is that of the contour.

(b) For a point between contours, most military needs are satisfied by estimating the elevation to an accuracy of one half the contour interval. All points less than one-fourth the distance between the lines are considered to be at the same elevation as the line. All points one-fourth to three-fourths the distance from the lower line are considered to be at an elevation one-half the contour interval above the lower line (fig. 6-1). If a more precise determination of elevation is needed, or if the contours are very widely spaced, the elevation of the point may be interpolated to the accuracy desired.

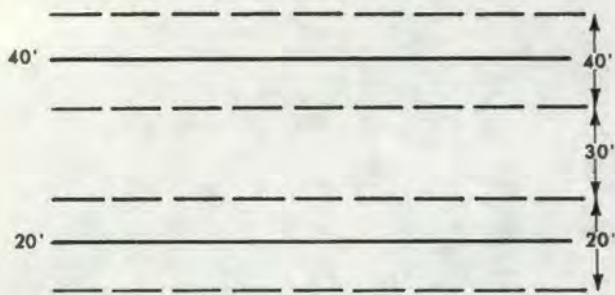


Figure 6-1. Estimating elevations between contour lines

(c) To estimate the elevation of the top of an unmarked hill, add half the contour interval to the elevation of the highest contour line around the hill.

(d) To estimate the elevation of the bottom of a depression, subtract half the contour interval from the value of the lowest contour around the depression.

d. On maps where the index and intermediate contour lines do not show the elevation and relief in as much detail as may be needed, supplementary contours may be used. These contour lines are dashed brown lines, usually at one-half the contour interval for the map. A note in the marginal information indicates the interval used. They are used exactly as are the solid contour lines.

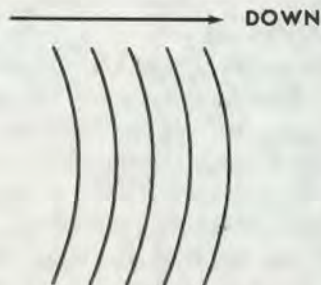
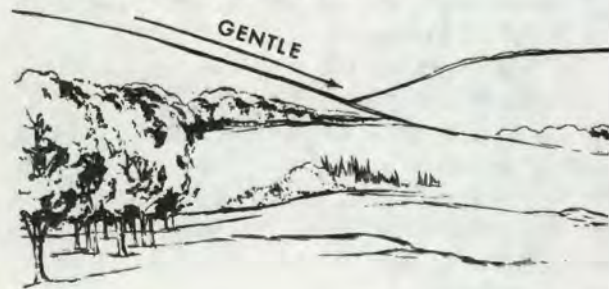


Figure 6-2. Uniform gentle slope.

e. On some maps the contour lines may not meet the standards of accuracy as specified in paragraph 1-12, but are sufficiently accurate in both value and interval to be shown as contours rather than as form lines (para 6-5b). In such cases, the contours are considered as approximate and are shown with a dashed symbol; elevation values are given at intervals along the heavier (index contour) dashed lines. The contour note in the map margin identifies them as approximate contours.

f. In addition to the contour lines, bench marks and spot elevations are used to indicate points of known elevation on the map. Bench marks, the more accurate of the two, are symbolized by a black X, as X BM 124. The elevation value shown in black refers to the center of the X. Spot elevations shown in brown generally are located at road junctions, on



Figure 6-3. Uniform steep slope.

hilltops and other prominent landforms. The symbol Δ designates an accurate horizontal control point. When a bench mark and a horizontal control point are located at the same point, the symbol BM Δ is used.

g. The spacing of the contour lines indicates the nature of the slope.

(1) Contour lines evenly spaced and wide apart indicate a uniform, gentle slope (fig. 6-2).

(2) Contour lines evenly spaced and close together indicate a uniform, steep slope. The closer the contour lines to each other, the steeper the slope (fig. 6-3).

(3) Contour lines closely spaced at the top and widely spaced at the bottom indicate a concave slope (fig. 6-4). Considering relief only, an observer at the top of a concave slope can observe the entire slope and the terrain at the bottom. Conversely, a unit attacking up such a slope would have no cover or concealment from observers or weapons at or near the top; also, the farther up the slope, the more difficult is the climb.



Figure 6-4. Concave slope.

(4) Contour lines widely spaced at the top and closely spaced at the bottom indicate a convex slope (fig. 6-5). An observer at the top of a convex slope has no observation of most of the slope or of the terrain at the bottom. Conversely, a unit attacking up such a slope has a much greater degree of cover and concealment than on a concave slope; also, the farther up the slope, the easier is the climb.

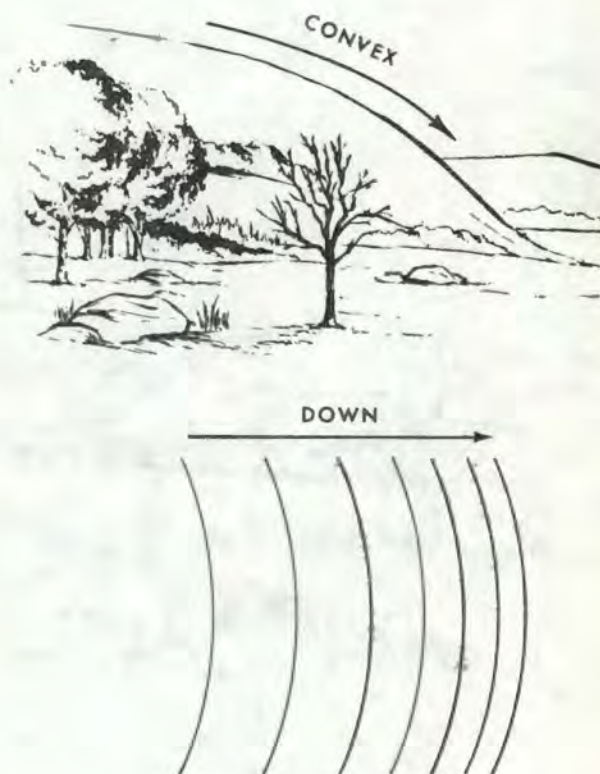


Figure 6-5. Convex slope.

h. In order to show the relationship of land formations to each other and how they would be symbolized on a contour map, stylized panoramic sketches of the major relief formations were drawn and a contour map of each sketch developed. Each of figures 6-6 through 6-12 shows a sketch and map with a different relief feature and its characteristic contour pattern.

(1) *Hill*: A point or small area of high ground (fig. 6-6). When you are located on a hilltop, the ground slopes down in all directions.

(2) *Valley*: A stream course which has at least a limited extent of reasonably level ground bordered on the sides by higher ground (a, fig. 6-7). The valley generally has maneuver room within its confines. Contours indicating a valley are U-shaped and tend to parallel a major stream before crossing it. The more gradual the fall of a stream, the farther each contour parallels it. The curve of the contour crossing always points up-stream.

(3) *Draw*: A less-developed stream course in which there is essentially no level ground and therefore, little or no maneuver room within its confines (b, fig. 6-7). The ground slopes upward on each side and towards the head of the draw. Draws occur frequently along the sides of ridges, at right angles to the valleys between them. Contours indicating a draw are V-shaped, with the point of the "V" toward the head of the draw.

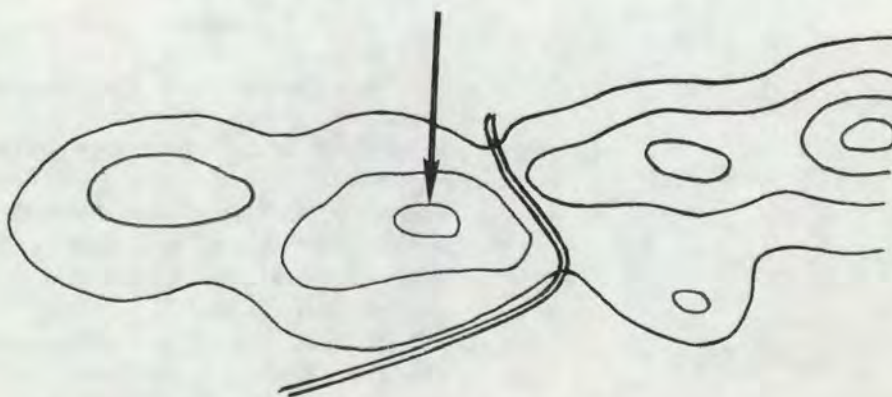
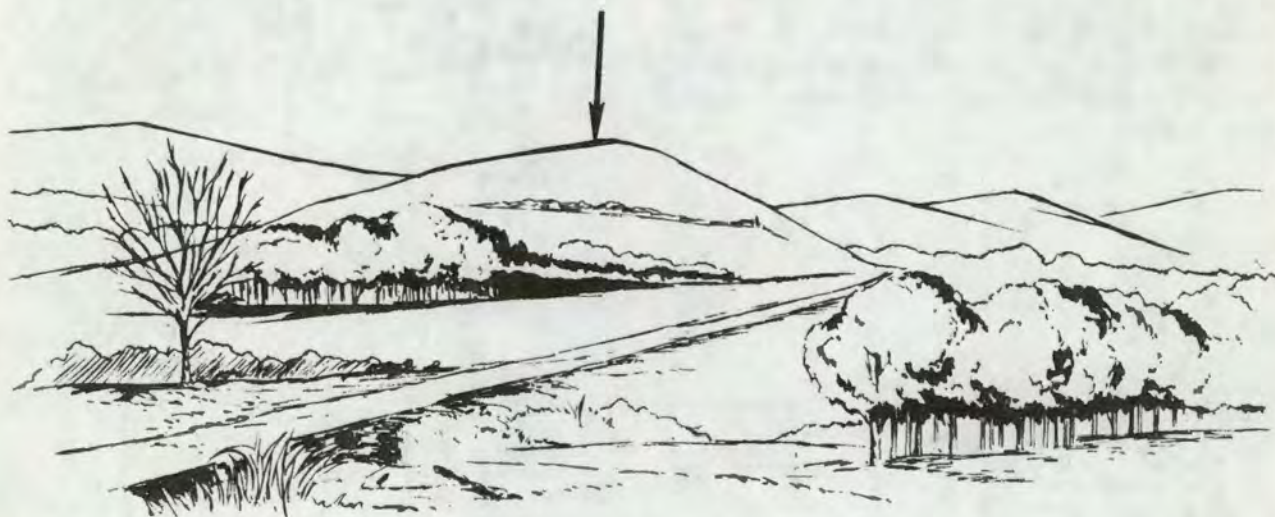


Figure 6-6. Hill.

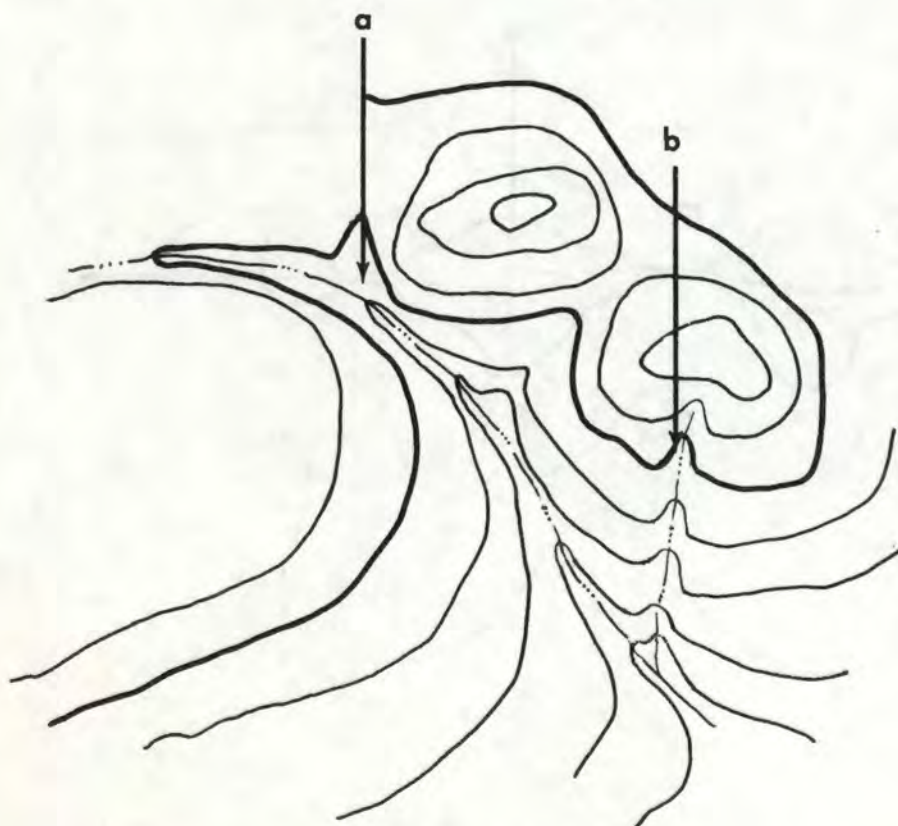
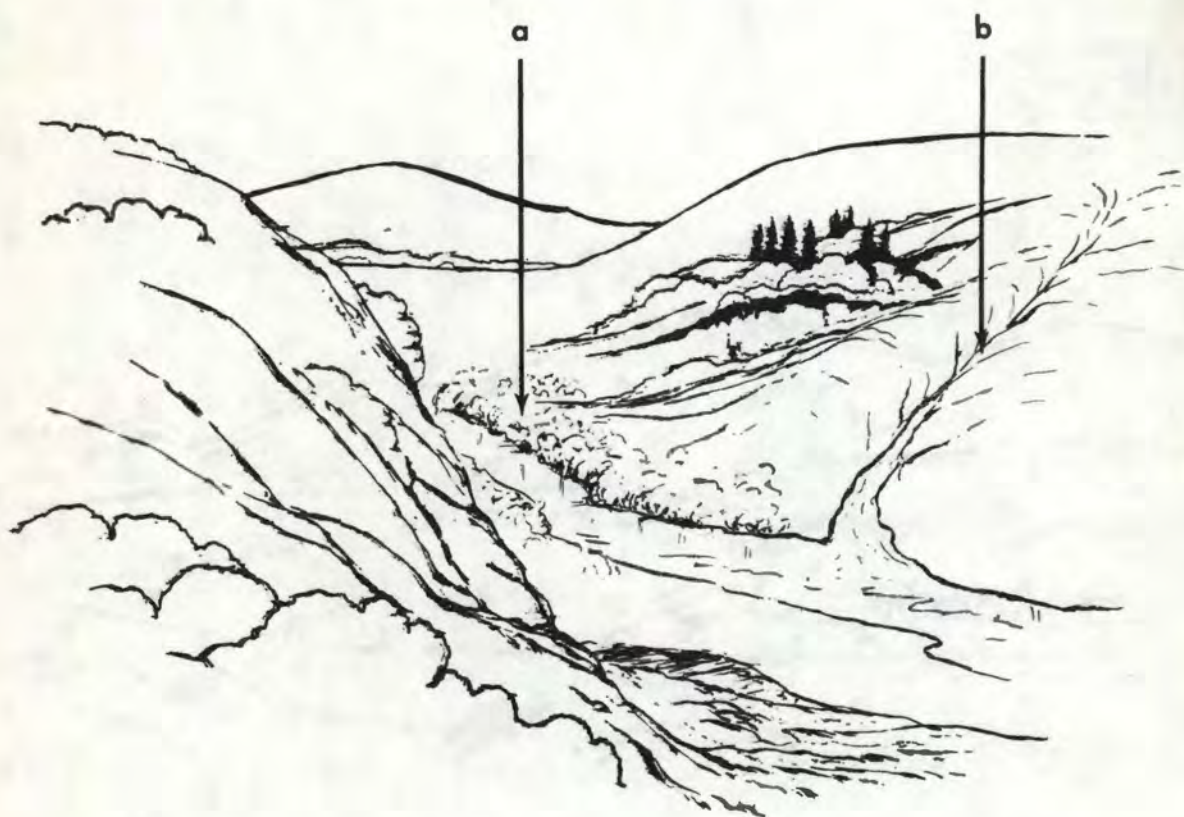


Figure 6-7. a. Valley; b. Draw.

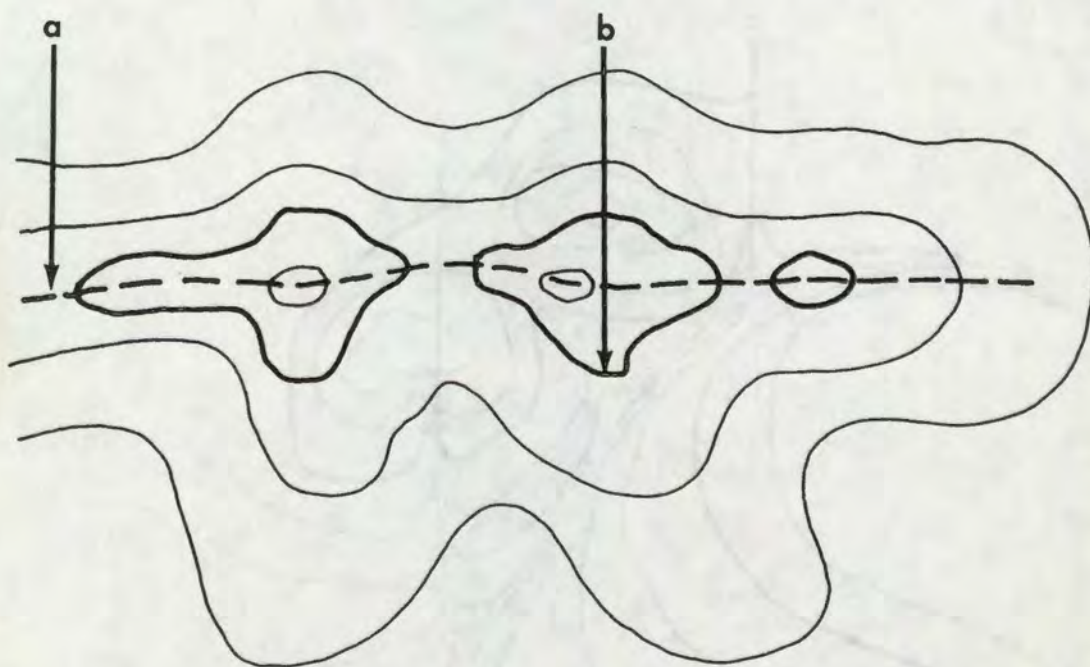
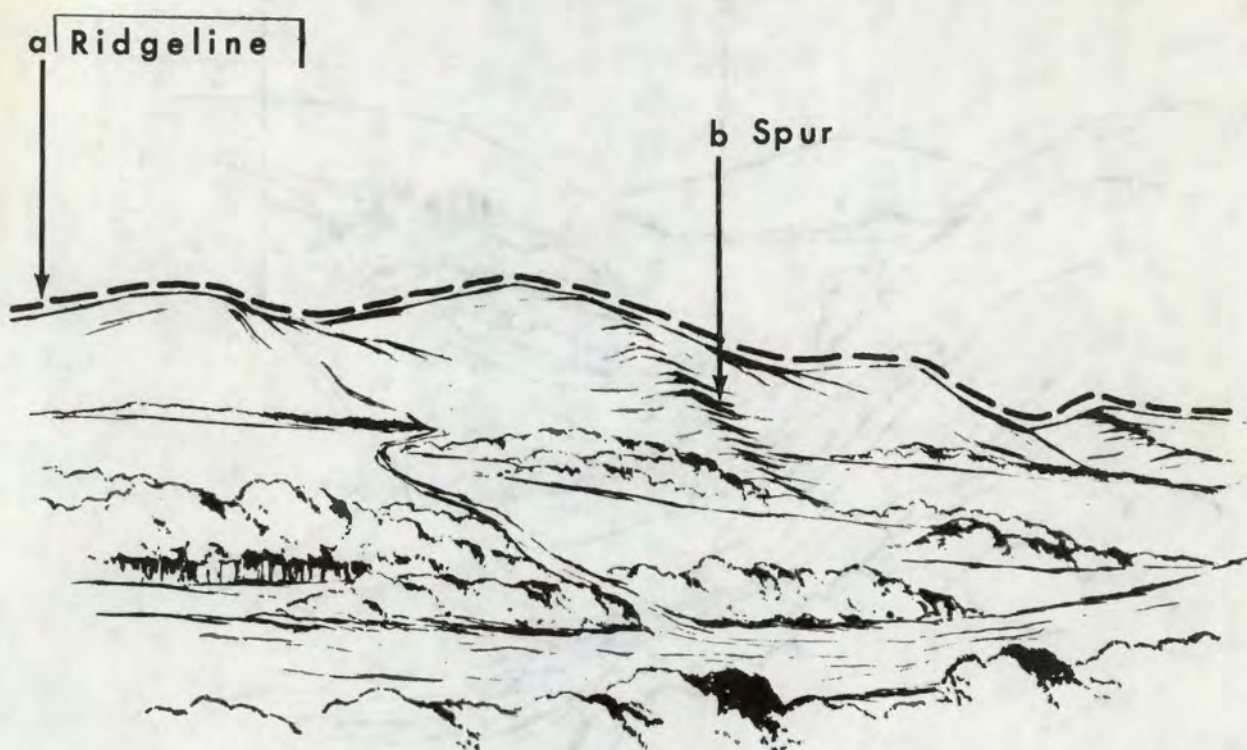


Figure 6-8. a. Ridge. b. Spur.

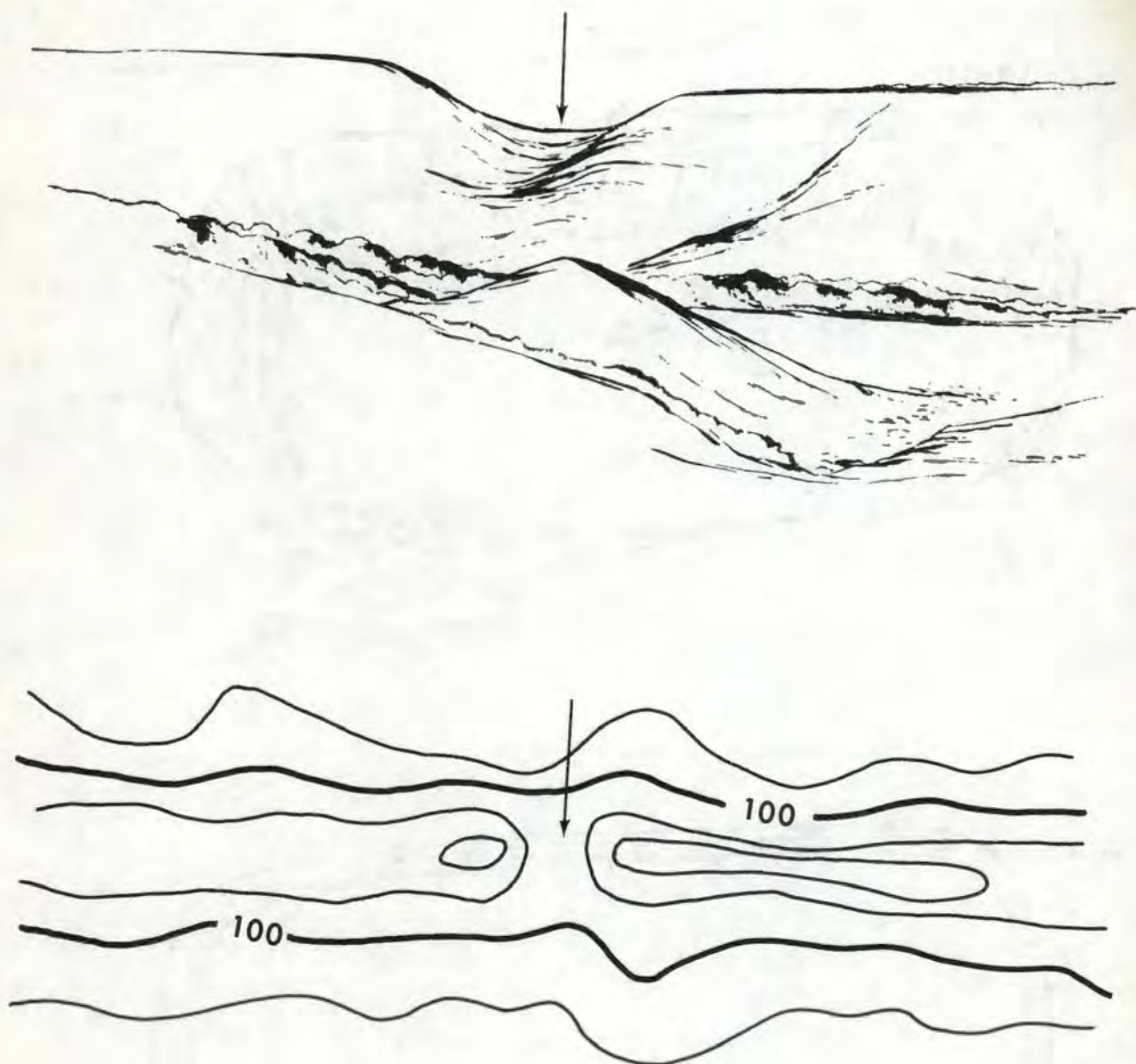


Figure 6-9. Saddle.

(4) *Ridge*: A line of high ground, with normally minor variations along its crest (a, fig. 6-8). The ridge is not simply a line of hills; all points of the ridge crest are appreciably higher than the ground on both sides of the ridge.

(5) *Spur*: A usually short, continuously sloping line of higher ground normally jutting out from the side of a ridge (b, fig. 6-8). A spur is often formed by two roughly parallel streams cutting draws down the side of a ridge.

(6) *Saddle*: A dip or low point along the crest

of a ridge. A saddle is not necessarily the lower ground between two hilltops; it may be simply a dip or break along an otherwise level ridge crest (fig. 6-9).

(7) *Depression*: A low point or sinkhole, surrounded on all sides by higher ground (fig. 6-10).

(8) *Cuts and fills*: Man-made features by which the bed of a road or railroad is graded or leveled off by cutting through high areas (a, fig. 6-11) and filling in low areas (b, fig. 6-11) along the right-of-way.

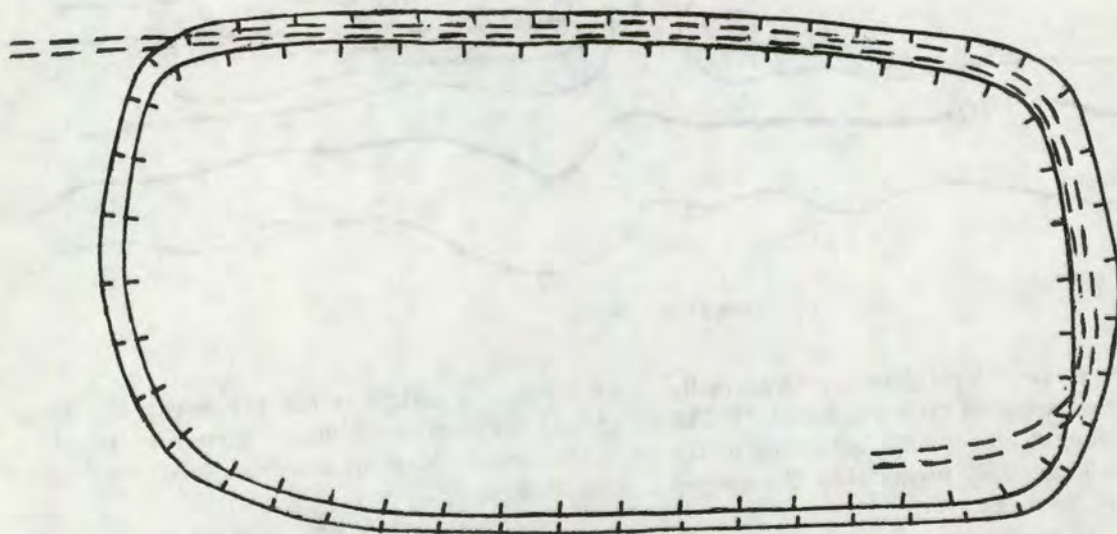
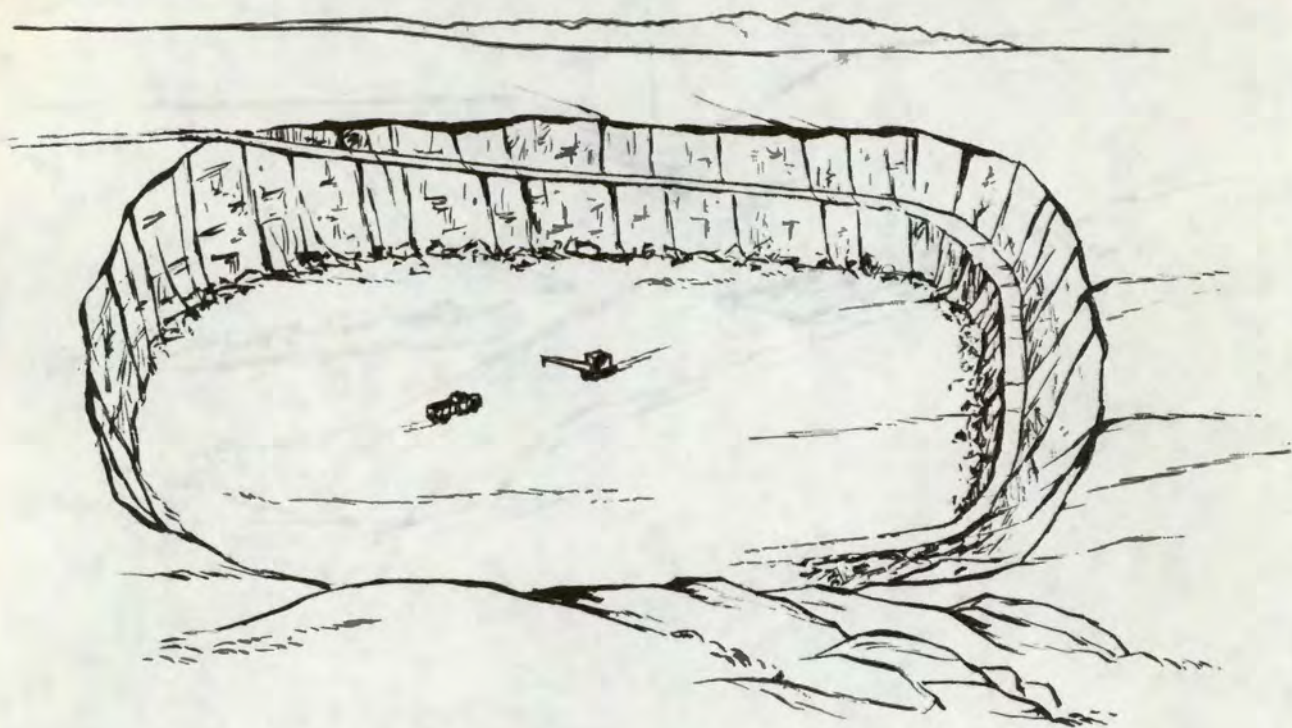


Figure 6-10. Depression.

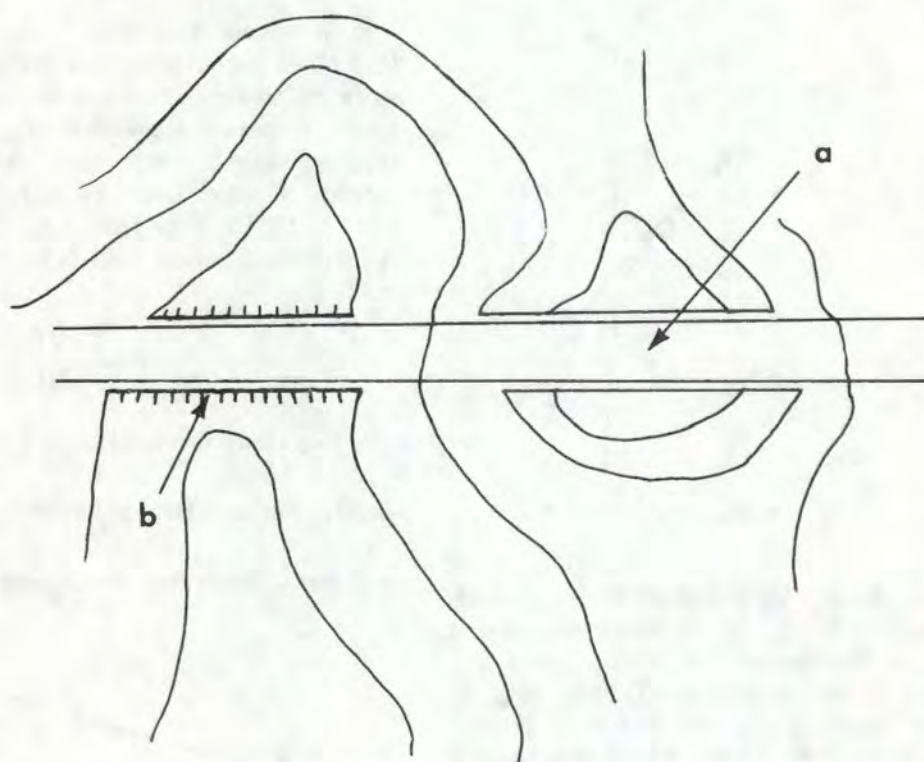


Figure 6-11. a. Cut. b. Fill.

(9) *Cliff*: A vertical or near vertical slope (fig. 6-12). When a slope is so steep that it cannot be shown at the contour interval without the contours coalescing, it is shown by a ticked "carrying" contour or contours. The ticks always point toward lower ground.

6-3. Slope

The rate of rise or fall of a ground form is known as its slope, and may be described as being steep or gentle. The question arises as to how steep or how gentle? The speed at which equipment or personnel



Figure 6-12. Cliff

can move is affected by the slope of the ground. (Most equipment has a limit as to the steepness it can negotiate.) Because of this, a more exact way of describing a slope is demanded. Slope may be expressed in several ways, but all depend upon a comparison of vertical distance (VD) to horizontal distance (HD) (fig. 6-13). VD is the difference between the highest and lowest elevations of the slope and is determined from the contour lines. HD is the horizontal ground distance between the highest and the lowest elevations of the slope and is measured according to paragraph 4-3. The VD and HD must be expressed in the same units. Both measurements must be made with extreme accuracy in order to have a valid determination of steepness. In

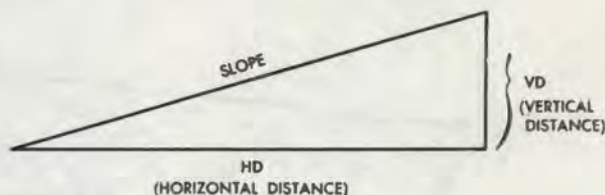


Figure 6-13. Slope diagram.

addition, the computations normally are made for only the steepest part of a slope.

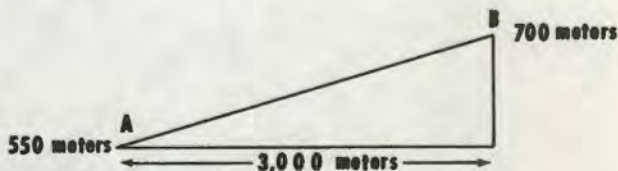
a. One form of expression slope is as a gradient. The relationship between the horizontal and vertical distance is expressed as a fraction with a numerator of one (fig. 6-14).

$$\text{Gradient} = \frac{\text{VD}}{\text{HD}} = \frac{150}{3000} = \frac{1}{20}$$

b. A common expression of slope is as a percent (%) which indicates the number of vertical units of elevation to every hundred units of horizontal distance. Whenever a gradient or percent is used to express a slope, a plus or minus sign must be given to indicate whether the slope is rising or falling. In figure 6-15, the slope from A to B is approximately +5%, and the slope from B to A is approximately -5%.

$$\% \text{ Slope} = \frac{\text{VD}}{\text{HD}} \times 100$$

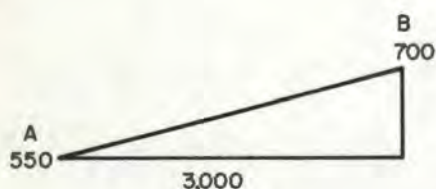
c. Slope may also be expressed in degrees, a unit of angular measure. Determine the value of $\frac{\text{VD}}{\text{HD}}$ in decimal form. This will be the tangent of the slope angle.



$$\text{VD} = \text{B} - \text{A} = 150 \text{ METERS}$$

$$\frac{150}{3,000} = \frac{1}{20} \text{ OR 1 METER OF RISE FOR EVERY 20 METERS OF HORIZONTAL DISTANCE}$$

Figure 6-14. Slope gradient.



$$VD = B - A = 150 \text{ METERS}$$

$$HD = 3,000 \text{ METERS}$$

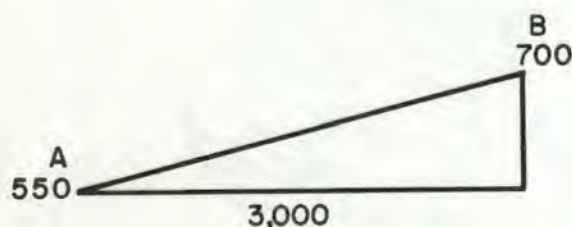
$$\% \text{ OF SLOPE} = \frac{150 \times 100}{3,000} = \frac{15,000}{3,000} = 5 \text{ PERCENT}$$

Figure 6-15. Slope expressed in percent (%).

The slope angle can then be found in a table of trigonometric tangent functions. The approximate slope angle may be calculated by multiplying the gradient by 57.3. This method is reasonably accurate for slope angles under 20° (fig. 6-16).

6-4. Profiles

a. The study of land forms from an examination of the contour lines is adequate for many purposes,



$$VD = B - A = 150$$

$$HD = 3,000$$

$$\text{DEGREE OF SLOPE} = \frac{150 \times 57.3}{3,000}$$

$$\frac{8,595}{3,000} = \text{APPROXIMATELY } 3^\circ \text{ OF SLOPE}$$

Figure 6-16. Slope expressed in degrees.

but when precision is demanded, a profile usually is required. A profile, within the scope and purpose of this manual, is an exaggerated side view of a portion of the earth's surface along a line between two points.

b. A profile can be constructed from any contoured map as shown in figure 6-17. The construction of a profile requires the following steps:

(1) Draw a line (profile line) on the map along the line for which a profile is desired.

(2) Find the value of the highest and lowest contour lines that cross or touch the profile line. Add one contour value above the highest and one below the lowest to take care of hills and valleys.

(3) On a blank sheet of paper draw equally spaced horizontal lines. Draw enough lines so that there will be one line representing each contour value as determined in (2) above.

(4) Place the lined paper on the map with the lines adjacent and parallel to the profile line.

(5) Number the line on the lined paper, closest to the profile line with the highest value determined in (2) above.

(6) Number the rest of the lines in sequence down to the lowest value on the line farthest from the profile line.

(7) From every point on the profile line where a contour line crosses or touches, drop a perpendicular to the line having the same value as the contour line. Place a tick mark where the perpendicular line crosses the line.

(8) The highest point of hills and the lowest point of valleys will have to be determined by interpolation and then a perpendicular dropped to their interpolated value.

(9) After all perpendiculars have been dropped to the lined paper, connect all tick marks with a smooth, natural curve. Remember that hills and valleys are usually rounded. Streams, however, tend to form a sharp V-shape or a U-shape.

(10) The profile just drawn may be exaggerated. The spacing between the lines drawn in (3) above will determine the amount of exaggeration and may be varied to suit any purpose.

c. When time is short, or when a complete profile is unnecessary, one may be constructed showing only the hill and ridge tops and, if desired, the valleys. This is called a hasty profile (fig. 6-18). It is constructed in the same manner as a full profile.

d. Some practical uses of profiles:

- (1) Determining visibility (defilade) (fig. 6-19).
- (2) Plotting mask (hidden) areas (fig. 6-20).

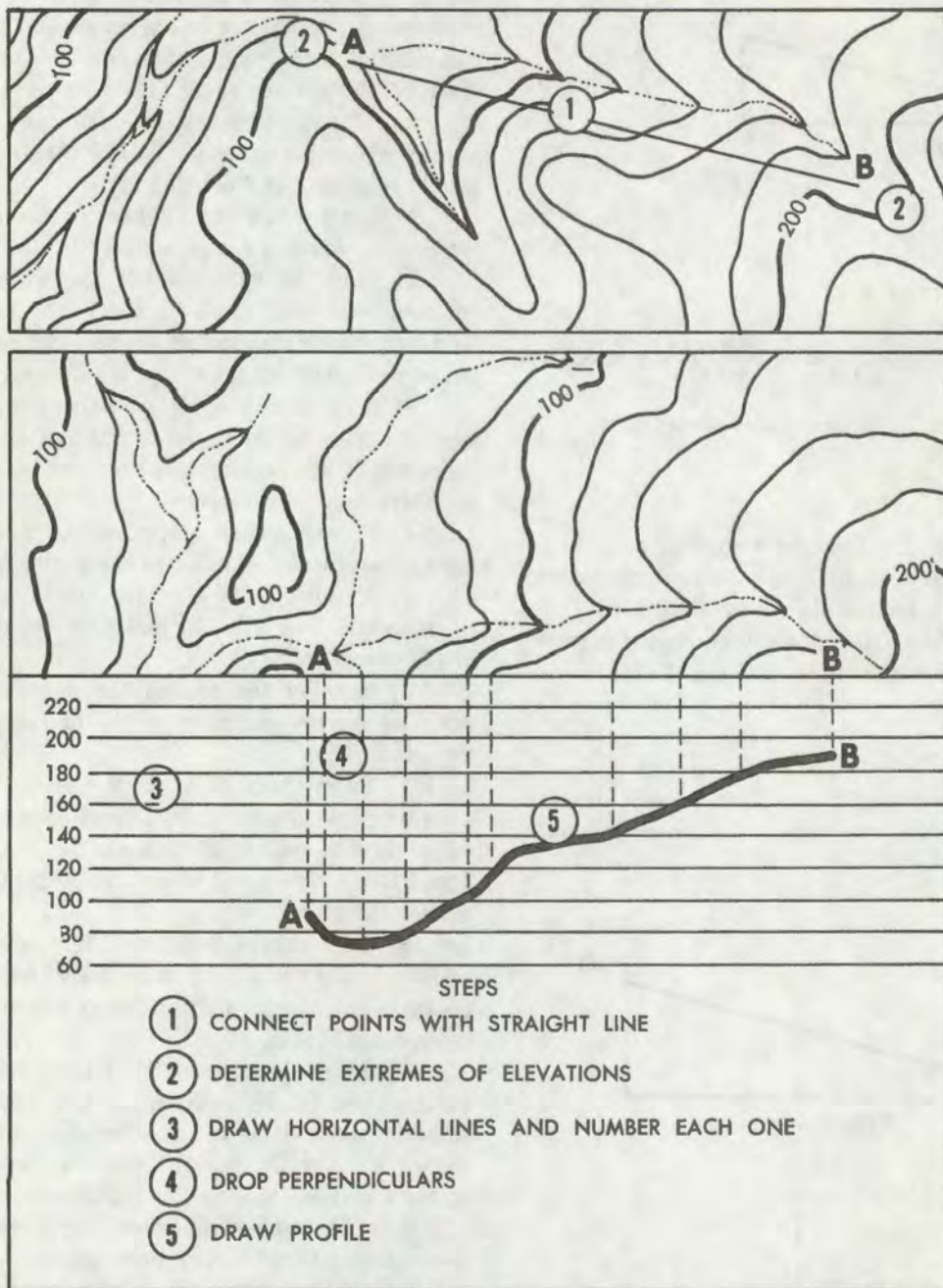


Figure 6-17. Drawing a profile.

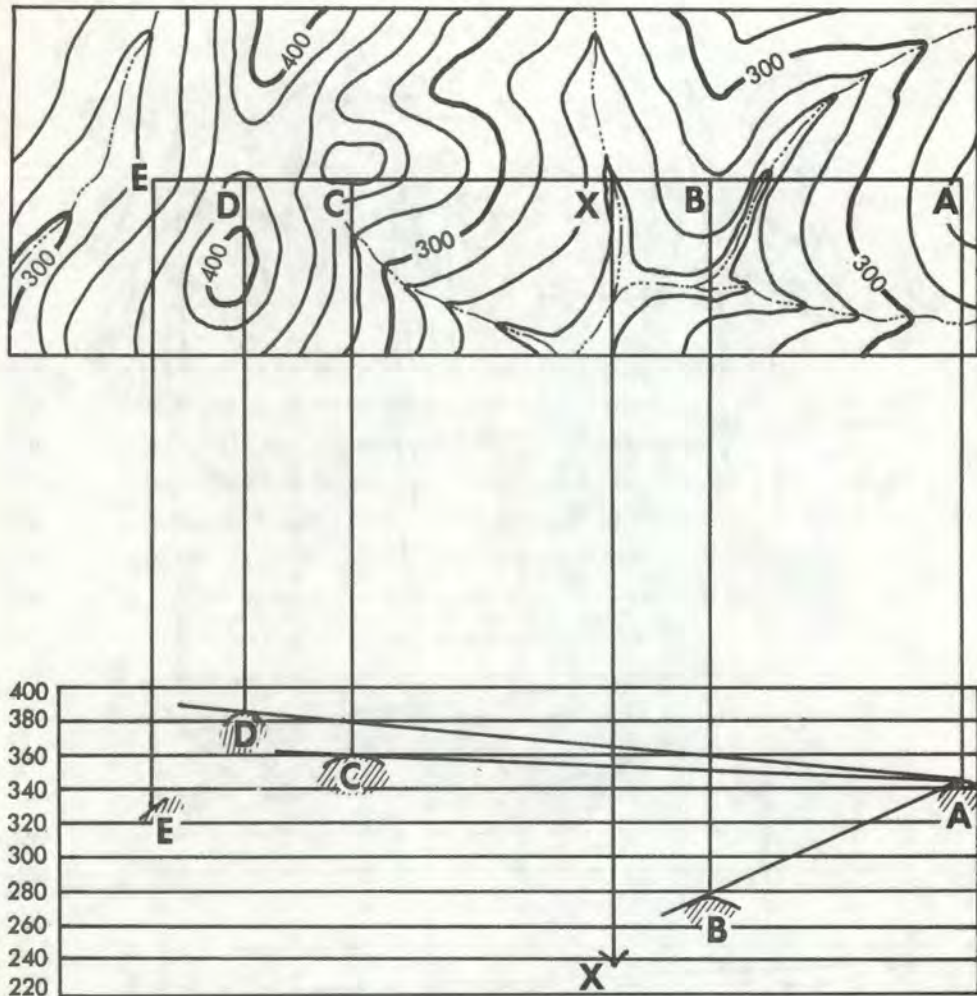


Figure 6-18. Drawing a hasty profile.

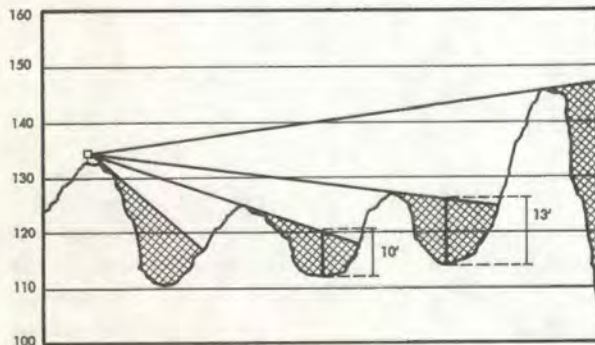


Figure 6-19. Defilade from profile.

- (3) Planning for road and railroad construction.
- (4) Planning for pipeline construction.
- (5) Planning for earthmoving.

6-5. Other Methods of Depicting Relief

a. Layer Tinting. Layer tinting is a method of representing relief by color. A different color is used for each equal band of elevation. Each shade of color, or band, represents a definite elevation range. This system does not show exact elevations but simply indicates that the elevations are within the

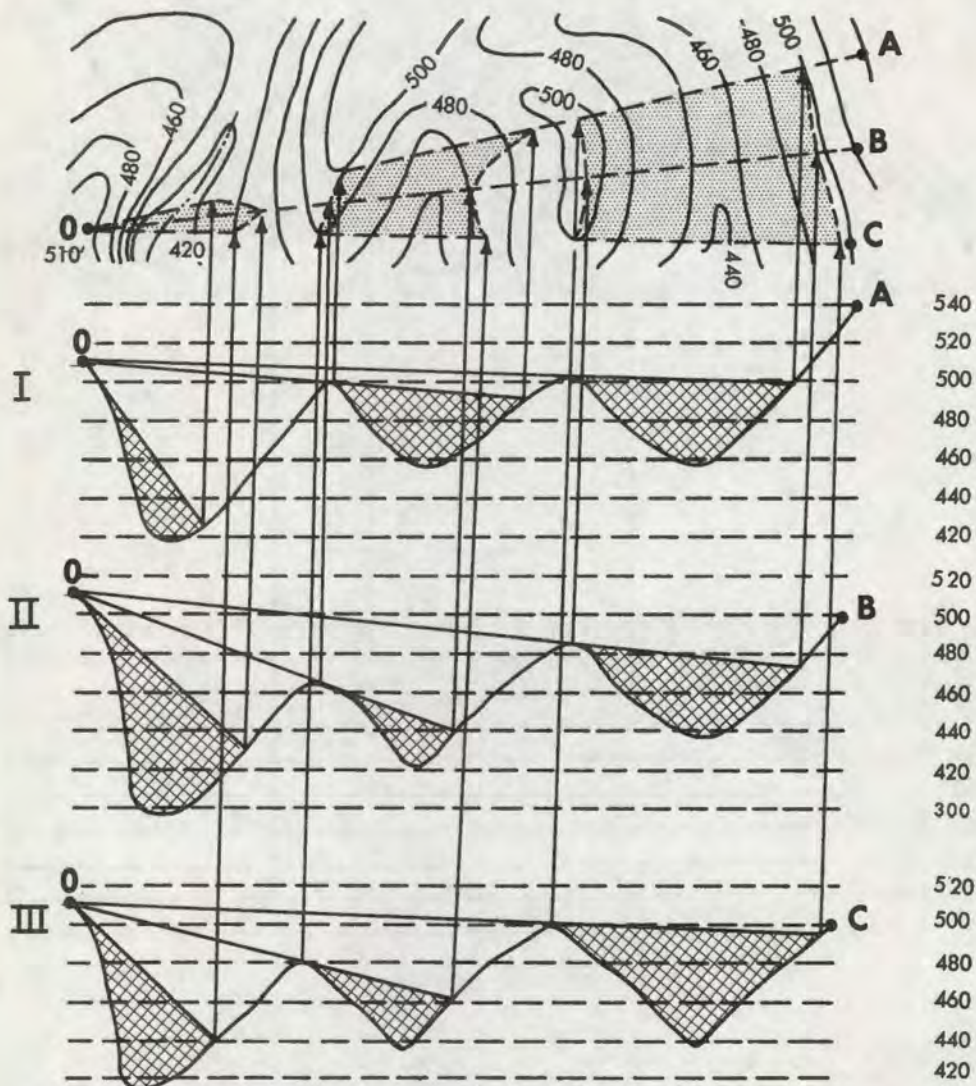


Figure 6-20. Plotting mask areas.

elevation range which that color represents. Blue usually represents the sea. A legend is printed in the margin of the map to indicate the elevation range represented by each color.

b. Form Lines. The form line is another means of portraying relief on a map. It is not a contour line

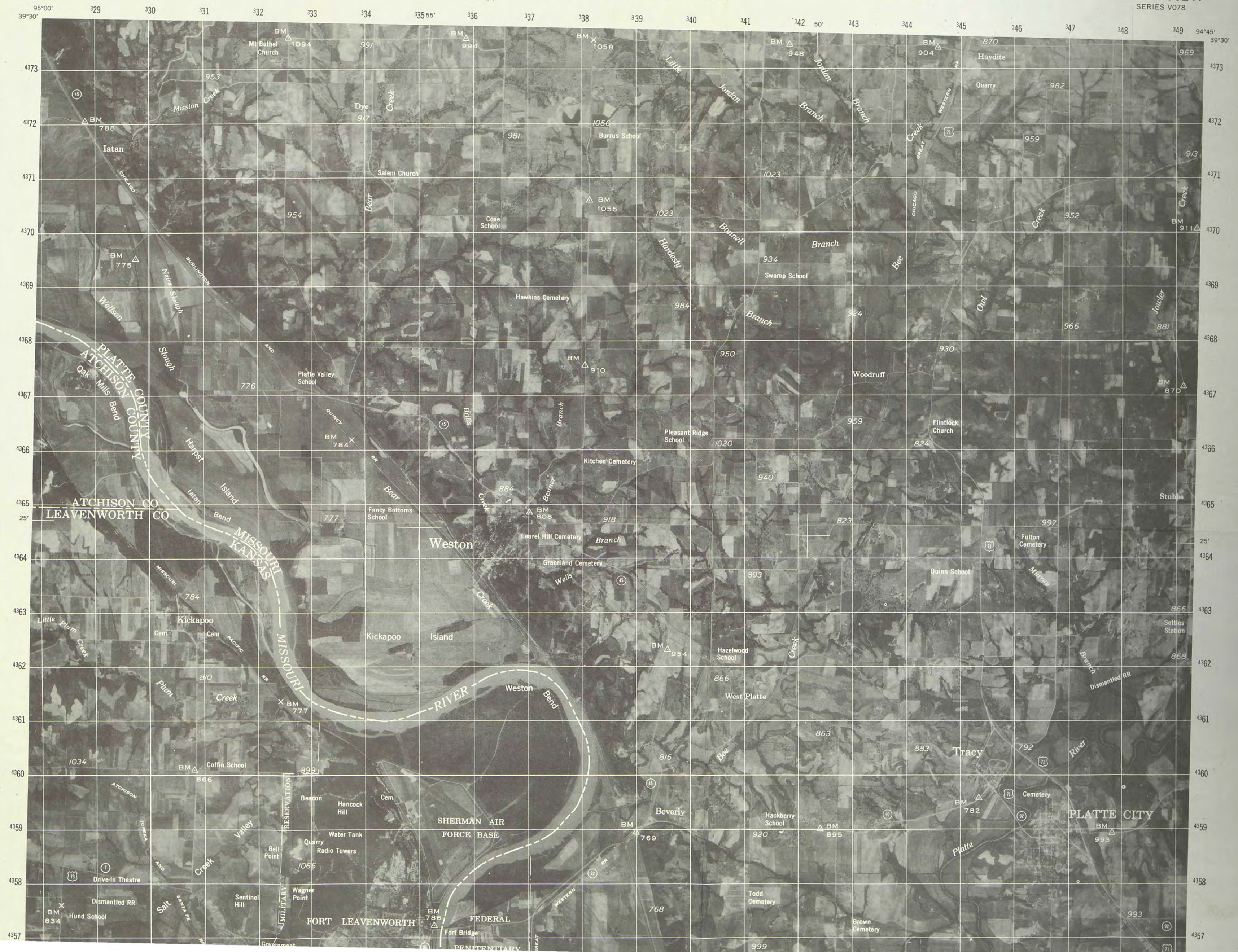
because it does not necessarily connect points of equal elevation and it is not measured from any base plane or datum. It gives only a general idea of relief and may be employed when accurate data are not obtainable. Form lines have no standard elevation, although an attempt is made to draw them parallel

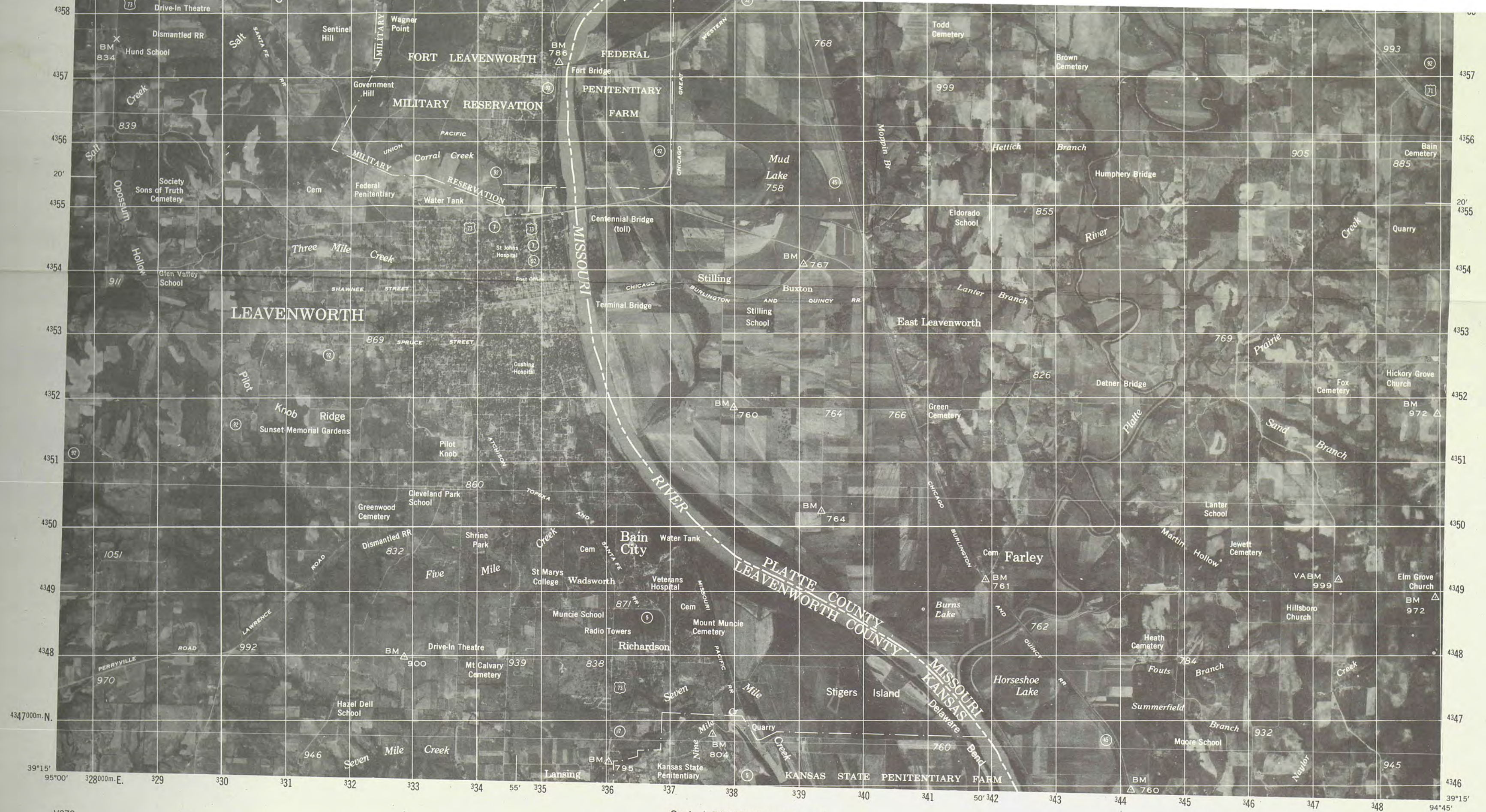


LEAVENWORTH

EDITION 1-AMS

REFER TO THIS MAP AS:
SHEET 7062 IV
SERIES V078

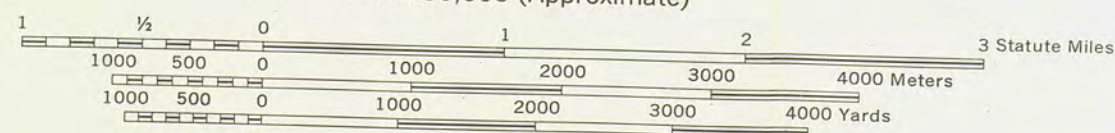




V078
Edition 1-AMS

Prepared by the Army Map Service (AM), Corps of Engineers, U.S. Army, Washington, D.C., 1963. Mosaic controlled by best average fit to Kansas 1:50,000, AMS Series V778, Second Edition-AMS, Sheet 7062 IV, 1958. Aerial photography September 1957. Additional names taken from Kansas-Missouri, 1:24,000, U.S.G.S., Leavenworth, 1961; Missouri-Kansas, 1:24,000, U.S.G.S., Platte City, Tracy, Weston, 1961.

Scale 1:50,000 (Approximate)



HORIZONTAL DATUM: 1927 NORTH AMERICAN DATUM
TRANSVERSE MERCATOR PROJECTION
VERTICAL DATUM: 1929 MEAN SEA LEVEL

ONE THOUSAND METER UNIVERSAL TRANSVERSE MERCATOR GRID, ZONE 15
THE LAST THREE DIGITS OF THE GRID NUMBERS ARE OMITTED

USERS NOTING ERRORS OR OMISSIONS ON THIS MAP ARE URGED TO MARK HEREON AND FORWARD DIRECTLY TO COMMANDING OFFICER, ARMY MAP SERVICE, WASHINGTON, D.C. MAPS SO FORWARDED WILL BE RETURNED OR REPLACED IF DESIRED.

GRID ZONE DESIGNATION: 15S		TO GIVE A STANDARD REFERENCE ON THIS SHEET TO NEAREST 100 METERS	
100,000 M. SQUARE IDENTIFICATION		SAMPLE POINT: HAZELWOOD SCHOOL	
UP	1. Read letters identifying 100,000 meter square in which the point lies: 2. Locate first VERTICAL grid line to LEFT of point and read LARGE figures labeling the line either in the top or bottom margin, or on the line itself: Estimate tenths from grid line to point: 3. Locate first HORIZONTAL grid line BELOW point and read LARGE figures labeling the line either in the left or right margin, or on the line itself: Estimate tenths from grid line to point:	UP	
		40	3
		62	2
		IGNORE the SMALLER figures of any grid number; these are for finding the full coordinates. Use ONLY the LARGER figures of the grid number; example: 4347000	
		SAMPLE REFERENCE: UP403622	
		If reporting beyond 18" in any direction, prefix Grid Zone Designation, as: 15SUP403622	

PRINTED BY ARMY MAP SERVICE, CORPS OF ENGINEERS

GRID CONVERGENCE
1° 11' (21 MILS)
FOR CENTER OF SHEET



INDEX TO ADJOINING SHEETS

6963 II	7063 III	7063 II
6962 I	7062 IV	7062 I
6962 II	7062 III	7062 II

HEIGHTS IN FEET 20

LEAVENWORTH, KANS.; MO.

Figure E-4. Leavenworth photomap.



PICTOMAP
1:25,000
Figure E-2.

Printed by the U.S. Army Topographic Command

1:250,000 - EDITION 1
LAS VEGAS, NEVADA; ARIZONA; CALIFORNIA
JOG (G) 1501 NJ 11-12
UNITED STATES

POPULATED PLACES

LEGEND

LOS ANGELES
OMAHA
GALVESTON
LOROMIE
Grand Coulee
Sun Valley
Landmark feature

ROADS
Dual highways, interstate route marker
Hwy surface, heavy duty
Hwy surface, medium duty
Hwy surface, light duty
More than two lanes wide
Two lanes wide, state route marker
Improved light duty
Unimproved dirt
Trail

RAILROADS
Normal gauge
Narrow gauge
Intermodal

BOUNDARIES
State
County, parish
Park or reservation
Terrain elevations
HIGHEST elevation is a
Spot elevation, normal, critical
Horizontal control point

HIDROGRAPHY
Depth curve in fathoms
Shoal, barometer
Swamp or marsh
Mangrove
Reef, limit of danger
Rocks, Sunken, Avoch
Fountain, flat
Lava

VEGETATION
Wood - breakdown
AERODROMES (Military or Civil)
EDNA - None
EDNA - Elevation
221 - Elevation
Field limits, with runway pattern unknown
Field limits unknown, with runway pattern
Field limits and runway pattern unknown
SEAPLANE BASE
SEAPLANE (EMERGENCY)
HIDROPORT

VISUAL AIDS AND OBSTRUCTIONS
Obstruction
338 - Elevation of obstruction top, above sea level
(79) - Elevation of obstruction top, above ground level
Group obstruction
Radio facility obstruction
Power transmission line

1

3 LANES 14 LANES

15

3 LANES 14 LANES

10

Other

Single rock

Double rock

Normal gauge

Narrow gauge

Intermodal

State

County, parish

Park or reservation

Terrain elevations

HIGHEST elevation is a

Spot elevation, normal, critical

Horizontal control point

Depth curve in fathoms

Shoal, barometer

Swamp or marsh

Mangrove

Reef, limit of danger

Rocks, Sunken, Avoch

Fountain, flat

Lava

Wood - breakdown

AERODROMES (Military or Civil)

EDNA - None

EDNA - Elevation

221 - Elevation

Field limits, with runway pattern unknown

Field limits unknown, with runway pattern

Field limits and runway pattern unknown

SEAPLANE BASE

SEAPLANE (EMERGENCY)

HIDROPORT

Obstruction

338 - Elevation of obstruction top, above sea level

(79) - Elevation of obstruction top, above ground level

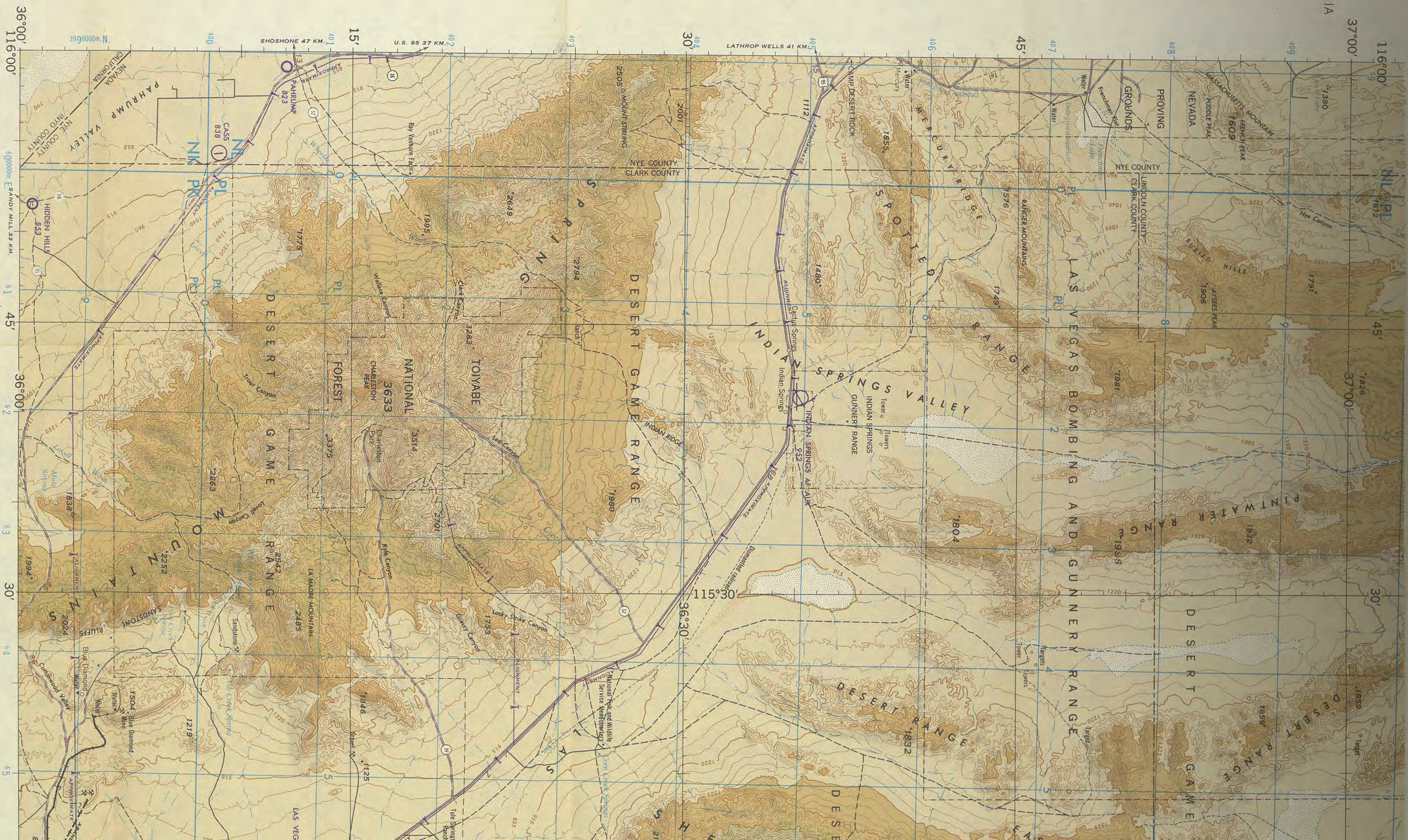
Group obstruction

Radio facility obstruction

Power transmission line

NOTES
MAGNETIC VARIATION FOR 1965 IS APPROXIMATELY 15°W OVER THE ENTIRE AREA
Figures along roads indicate approximate distances in kilometers

1:250,000 - EDITION 1
LAS VEGAS, NEVADA
JOG (G) 1501 NJ 11-12



Prepared under the direction of the Defense Intelligence Agency and published by the Aeronautical Chart and Information Center, U.S. Air Force, St. Louis, Missouri, 63118.
Compiled in 1966 from best available source materials.



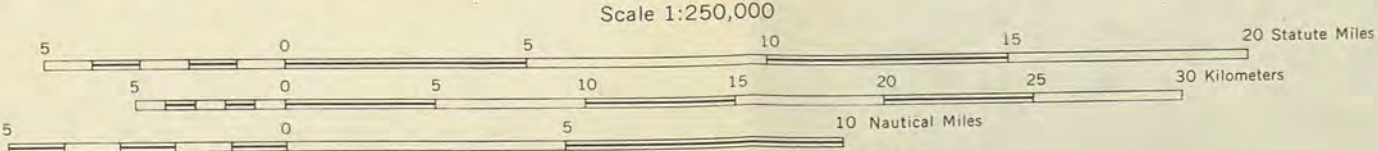
GRID COORDINATE		TO FIND A GRID COORDINATE	
115		115	
3990000		3990000	
N. PL. Q.		N. PL. Q.	
PK. Q.		PK. Q.	
0		0	
3990000		3990000	
115		115	
3990000		3990000	



BLUE NUMBERED LINES



JOINT OPERATIONS GRAPHIC (GROUND)



CONTOUR INTERVAL 60 METERS
WITH SUPPLEMENTARY CONTOURS AT 30 METERS

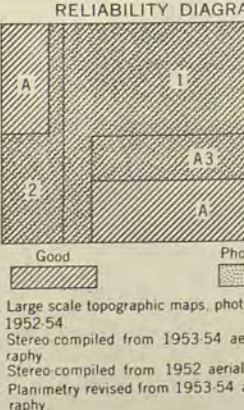
VERTICAL DATUM: MEAN SEA LEVEL
HORIZONTAL DATUM: NORTH AMERICAN 1927

TRANSVERSE MERCATOR PROJECTION

BLUE NUMBERED LINES INDICATE THE 10,000 METER UNIVERSAL TRANSVERSE MERCATOR GRID. ZONES 11S AND 12S, CLARK 1818, SPHEROID.

Figure E-6. Joint operations graphic (ground).

GRID ZONE DESIGNATION		TO GIVE A STANDARD REFERENCE ON THIS SHEET TO NEAREST 100 METERS	
11S		SAMPLE POINT, HIDDEN FOREST CAMP	
100,000 M SQUARE IDENTIFICATION		1. Read letters identifying 100,000 meter square in which this point lies.	
NL	PL	QL	PL
NK	PK	QK	
60		70	
390000		PL5955	
11SPL5955		11SPL5955	



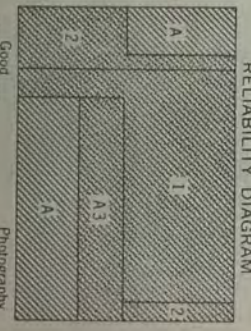
A Large scale topographic maps, photo 1952-54
1 Stereo compiled from 1953-54 aerial photography
2 Stereo compiled from 1952 aerial photography
3 Planimetry revised from 1953-54 aerial photography



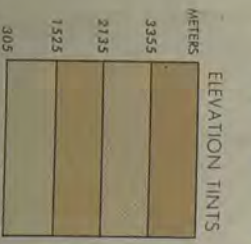
20 Statute Miles
30 Kilometers

ROUND)

ELEVATIONS IN METERS



- A. Large scale topographic maps, photogrammetric.
- 1. Stereo compiled from 1953-54 aerial photos.
- 2. Aerial photography.
- 3. Photomicrofilm from 1953-54 aerial photos.



LOCATION DIAGRAM FOR NJ 11-12
(MAC INDEX SHOWN IN BLUE)

NJ 11-4	NJ 11-5	NJ 11-6	NJ 12-4	NJ 12-5
NJ 11-7	NJ 11-8	NJ 11-9	NJ 12-7	NJ 12-8
NJ 11-10	NJ 11-11	NJ 11-12	NJ 12-10	NJ 12-11
NJ 11-1	NJ 11-2	NJ 11-3	NJ 12-1	NJ 12-2
NJ 11-4	NJ 11-5	NJ 11-6	NJ 12-4	NJ 12-5

STOCK NO. 1501GNJ1112

1:250,000 - EDITION 1
LAS VEGAS, NEVADA; ARIZONA; CALIFORNIA
JOG (A) 1501 NJ 11-12
UNITED STATES

LEGEND

POPULATED PLACES

1st LOS ANGELES
2nd OMAHA
3rd GALVESTON
4th Laramie
5th Grand Coulee
6th Sun Valley
Landmark feature

ROADS

Dual Highways; Interstate route marker
Hard surface, heavy duty
More than two lanes wide
Two lanes wide; Federal route marker
Hard surface, medium duty
More than two lanes wide
Two lanes wide; State route marker
Improved light duty
Dirt
Unimproved dirt
Trail

RAILROADS

Normal gauge
Narrow gauge

BOUNDARIES

International
State
County; Parish
Park or reservation

TERRAIN ELEVATIONS

HIGHEST elevation is 11918 feet located at 36°16'N, 115°42'W
Spot elevation, normal, critical
Horizontal control point

HYDROGRAPHY

Depth curves in fathom
Falls, Rapids
Salt evaporator
Swamp or marsh
Mangrove
Reef; Limit of danger
Rocks, Sunken, Awash
Foreshore flat
Levee

VEGETATION

Woods - brushwoods

AERODROMES (Military or Civil)

Field limits with runway pattern
EDNA - Name
50 - length of longest runway to nearest hundreds of feet
s - Soft or unimproved surface
725 - Elevation
Field limits, with runway pattern unknown
Field limits unknown, with runway pattern
Field limits and runway pattern unknown

SEAPLANE BASE
SEAPLANE (EMERGENCY)
HELIPORT

RADIO FACILITIES

RADIO RANGE LF/MF
MULTIPLE RADIO FACILITIES

CONTROLLED AIRSPACE

ADIZ ATLANTIC ADIZ

VISUAL AIDS AND OBSTRUCTIONS

Obstruction
1108 - Elevation of obstruction top, above sea level.
(259) - Elevation of obstruction top, above ground level.
Group obstruction
Radio facility obstruction
Power transmission line
Ocean station vessel (Normal position)
Visual ground sign
Aero Light Marine Light

CAUTION
AIR INFORMATION CURRENT THROUGH
3 MAY 1966
Consult NOTAMS and USAF/USN Flight Information Publications for the latest air information; the Chart Updating Manual for other chart revision information.

HIGHEST TERRAIN elevation for each 15 MINUTE QUADRANGLE is represented in THOUSANDS and HUNDREDS of feet. They are omitted where relief information is inadequate. A minus sign (-) following the figure indicates that the figure is based on an estimated elevation.
EXAMPLES: 51 81-

LINES OF EQUAL MAGNETIC VARIATION FOR 1965
(Annual rate of change - 2' decrease)



Prepared under the direction of the Defense Intelligence Agency and published by the Aeronautical Chart and Information Center, U.S. Air Force, St. Louis, Missouri, 63118. Compiled in 1966 from best available source materials.

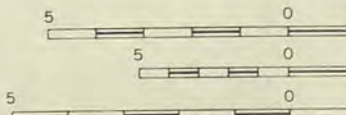
ELEVATIONS IN FEET

JOINT O



1:250,000 - EDITION 1
LAS VEGAS, NEVADA
JOG (A) 1501 NJ 11-12

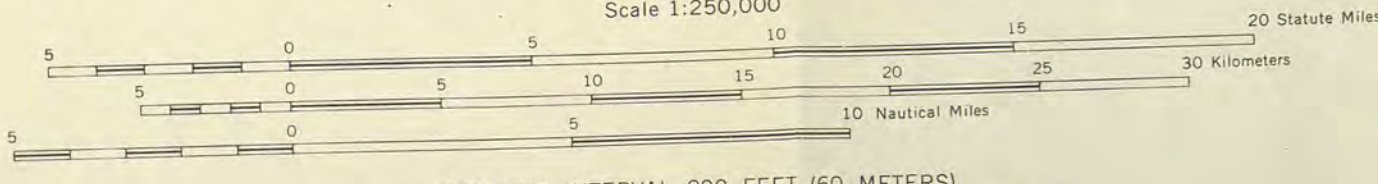
GRID ZONE DESIGNATION		TO GIVE A STANDARD REFERENCE ON THIS SHEET TO NEAREST 1000 METERS	
11S		SAMPLE POINT: HIDDEN FOREST CAMP	
100,000 M. SQUARE IDENTIFICATION		1. Read letters identifying 100,000 meter square in which the point lies.	
NL PL QL		2. Locate first VERTICAL grid line to LEFT of point and read LARGE figure labeling the line, either in the bottom margin or on the line itself.	
NK PK OK		Estimate tenths from grid line to point.	
3. Locate first HORIZONTAL grid line BELOW point and read LARGE figure labeling the line, either in the left margin or on the line itself.		Estimate tenths from grid line to point.	
4. Combine the smaller figures of step 3 and the larger figures of step 2 to give the full coordinates. Use ONLY the larger figures of the grid numbers.		SAMPLE REFERENCE: PL5955	
example: 3990000		If reporting beyond 10' in any direction, prefix Grid Zone Designation 11SPL5955	



BLUE NUMBERED LINE



JOINT OPERATIONS GRAPHIC (AIR)



CONTOUR INTERVAL 200 FEET (60 METERS)
WITH SUPPLEMENTARY CONTOURS AT 100 FEET (30 METERS)

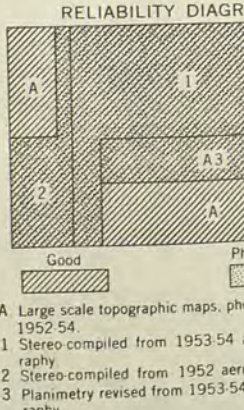
VERTICAL DATUM: MEAN SEA LEVEL
HORIZONTAL DATUM: NORTH AMERICAN 1927

TRANSVERSE MERCATOR PROJECTION

BLUE NUMBERED LINES INDICATE THE JOINT OPERATIONS GRAPHIC (AIR) GRID, ZONE 11S AND 12S. CLARKE 1866 SPHEROID.
THE LAST FOUR DIGITS OF THE GRID NUMBERS ARE OMITTED.

Figure E-5. Joint operations graphic (air).

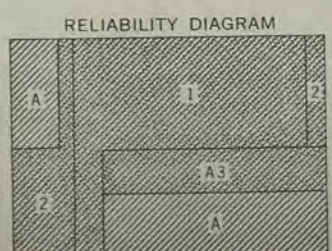
GRID ZONE DESIGNATION			
11S			
100,000 M. SQUARE IDENTIFICATION			
PL	QL	PK	QK
5	9	5	9
SAMPLE POINT: HIDDEN FOREST CAMP			
1. Read bottom identifying 100,000 meter square in which the point lies.			
2. Locate first vertical grid line to left of point and read RANGE figure labeling the line either in the bottom margin, or on the line itself.			
3. Estimate tenths from grid line to point.			
4. Locate first horizontal grid line below point and read RANGE figure labeling the line either in the left margin, or on the line itself.			
5. Estimate tenths from grid line to point.			
SAMPLE REFERENCE: PL5955			
If recording beyond 12° in any direction, prefix Grid Zone Designation, as: 11SP1955			



A Large scale topographic maps, published 1952-54.
1 Stereo compiled from 1953-54 photography.
2 Stereo compiled from 1952 aerial photography.
3 Planimetry revised from 1953-54 photography.



ELEVATIONS IN FEET



A Large scale topographic maps, photogrammetric, 1952-54
1 Stereo compiled from 1953-54 aerial photography
2 Stereo compiled from 1952 aerial photography
3 Planimetry revised from 1953-54 aerial photography

GEOREF BASIC 15' QUADRANGLE

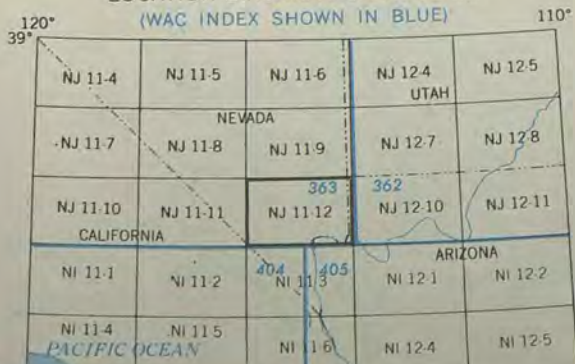


ELEVATION TINTS



472 Printed by the U.S. Army Topographic Command

LOCATION DIAGRAM FOR NJ 11-12



JOG (A) 1501 NJ 11-12

to sea level and to space them according to the purpose of the map or sketch being prepared. Form lines are shown as dashed lines and are never labeled with representative elevations.

c. Shaded Relief. Relief shading indicates relief by a shadow effect achieved by tone and color which results in darkening one side of hills, ridges, or mountains. The degree of slope is indicated by the density of shading. Shaded relief is sometimes used in conjunction with contours to emphasize landforms.

d. Hachures. Hachures are short brown lines used to depict relief, both in conjunction with and independent of contour lines. They do not represent exact elevations, but are used to show the general form and relative slopes of the land. They are primarily used to show large rocky outcrop areas or heavily dissected terrain. This method of depicting relief is used extensively on small scale maps to show mountain ranges, plateaus, and individual peaks. A typical hachure map is illustrated in figure 6-21.



Figure 6-21. Hachure map.

CHAPTER 7

OVERLAYS

7-1. Description

An overlay is a transparent or translucent medium upon which special military information has been plotted at the same scale of a map, photograph or other graphic. This information is used with the map, aerial photograph, or other graphic as a base of reference. When the overlay is superimposed over the base, the details on the overlay appear in their true position with respect to that base.

7-2. Uses

Overlays are used as displays of military operations; displays of enemy and friendly troop disposition; supplements to orders sent to the field to show detail that will aid in interpreting and understanding the orders; displays of communications network, etc. They are also used as annexes to reports made in the field to clarify matters that are difficult to explain clearly in writing.

7-3. Preparation

a. Map Overlay. There are three steps in the preparation of a map overlay: orientation of the overlay material, plotting and symbolization of the detail, and addition of the required marginal information.

(1) Orientation.

(a) Orient the overlay material over the map area to be annotated and, if possible, attach it to the map temporarily with tape.

(b) Trace the grid intersections nearest the two opposite corners of the overlay and label each with the proper grid coordinates. These register marks show the receiver of your overlay exactly where it fits on his map; without them the overlay is difficult to orient (fig. 7-1).

(2) Plotting of new detail.

(a) Colored pencils or markers in standard

colors are used when available to plot any detail (para 3-2, FM 21-30). Otherwise, plot the positions of the activities or other information you wish to show with a pen or pencil that makes a lasting mark without cutting the overlay. Use standard topographic or military symbols where possible. Non-standard symbols invented by the author must be identified in a legend on the overlay. Depending on the conditions under which the overlay is made, it may be advisable to plot the positions first on the map, then to trace them onto the overlay. Since the overlay is to be used as a supplement to orders or reports and the recipient will have an identical map, show only that detail with which the report is directly concerned.

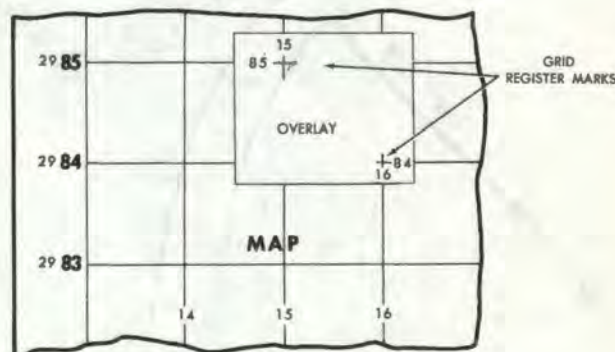
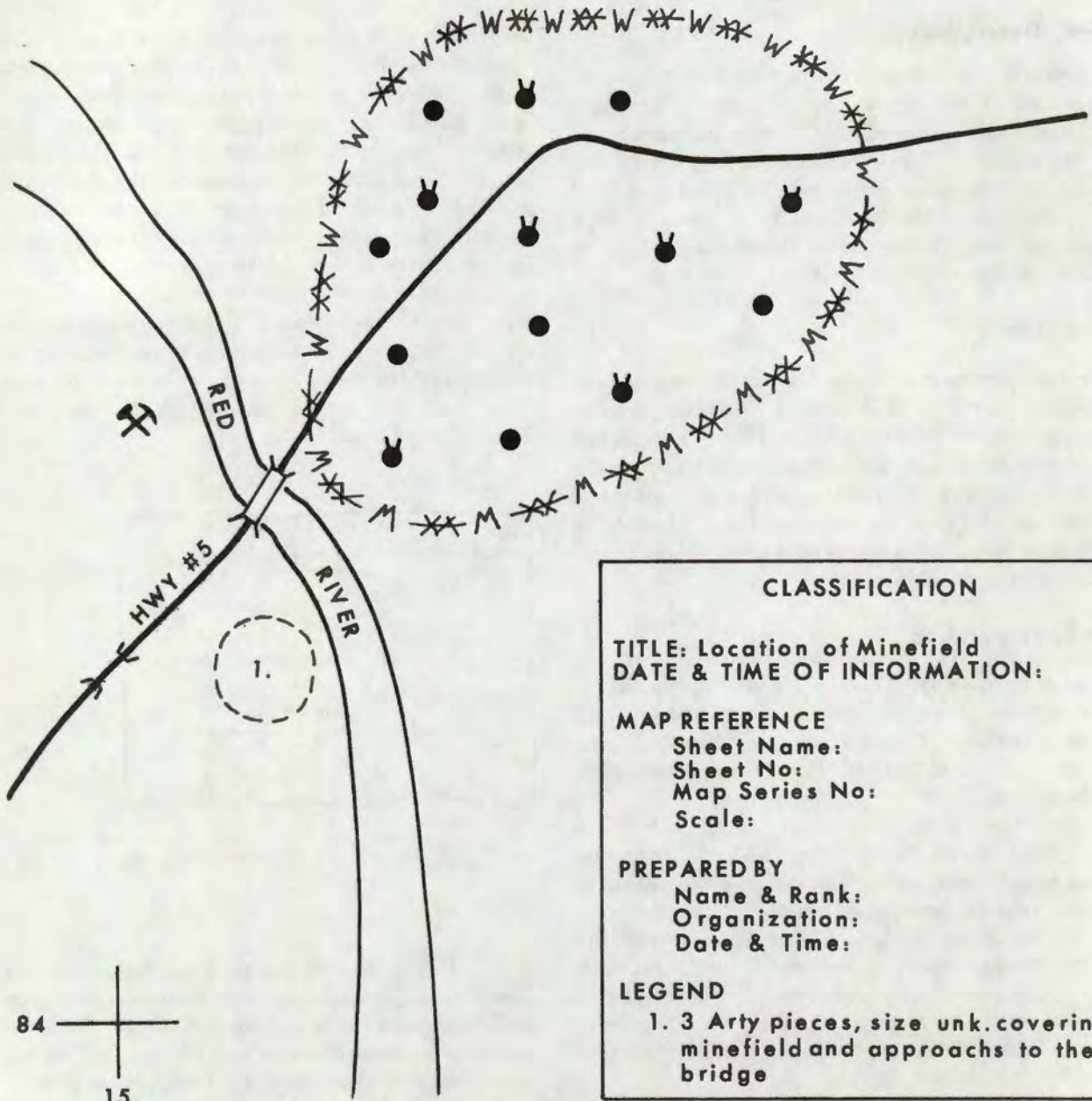
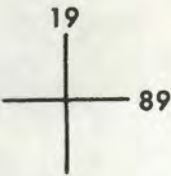


Figure 7-1. Registering the overlay.

(b) If you have observed any topographic or cultural features that are not shown on the map, such as a new road or a destroyed bridge, plot their positions as accurately as possible on the overlay and mark with the standard topographic symbol.

(c) If difficulty in seeing through the overlay material is encountered while plotting or tracing

CLASSIFICATION



CLASSIFICATION

TITLE: Location of Minefield
DATE & TIME OF INFORMATION:

MAP REFERENCE

Sheet Name:
Sheet No:
Map Series No:
Scale:

PREPARED BY

Name & Rank:
Organization:
Date & Time:

LEGEND

1. 3 Arty pieces, size unk. covering
minefield and approaches to the
bridge

CLASSIFICATION

Figure 7-2. Map overlay with marginal information.

detail, lift the overlay from time to time to check orientation of information being added in reference to the base.

(3) *Marginal information* (fig. 7-2). When all required detail has been plotted or traced on the overlay, the following information is printed as close to the lower right hand corner as detail permits:

(a) *Title and objective*. This tells the reader *why* the overlay was made and may also give the actual location. For example, "Road Reconnaissance" is not as specific as "Route 146 Road Reconnaissance."

(b) *Time and date*. Any overlay should contain the latest possible information. An overlay received in time is very valuable to the planning staff and may affect the entire situation; an overlay that has been delayed for any reason may be of little use. Therefore, the exact *time the information was obtained* aids the receivers in determining its reliability and usefulness.

(c) *Map reference*. The sheet name, sheet number, map series number, and scale must be included. If the reader does not have the map used for the overlay, this provides the information necessary to obtain it.

(d) *Author*. The name, rank and organization of the author, supplemented with a date and *time of preparation* of the overlay tells the reader if there was a time difference between when the information was obtained and when it was reported.

(e) *Legend*. This is only necessary when nonstandard symbols are used. If it is necessary to invent nonstandard symbols to show the required information, the legend must clarify what these symbols mean.

(f) *Security classification*. This must correspond to the highest classification of either the map or the information placed on the overlay. If the information and map are unclassified, this shall be so stated. The location of the classification notes is shown in figure 7-2 and shall appear in all three locations as shown.

(g) *Additional information*. Any other information that amplifies the overlay shall also be included, as briefly as possible.

b. *Aerial Photograph Overlay*. Overlays of single aerial photographs are constructed and used in the same way as map overlays. The steps followed are essentially the same, with the following exceptions:

(1) *Orientation of overlay*. The photograph nor-

mally does not have grid lines to be used as register marks. The borders of the photograph limit the area of the overlay, so the fiducial marks or linear features are traced in place of grid register marks. Finally, to insure proper rotation of the overlay with respect to the photograph, indicate on the overlay the position of the marginal data on the photo as seen through the overlay.

(2) *Marginal information*. The marginal information shown on photographs varies somewhat from that shown on maps. Overlays of photographs (fig. 7-3) should show the following information:

(a) *North arrow*. This may be obtained in two ways: (1) by comparison with a map of the area or (2) by orientation of the photograph by inspection. In the latter case a compass or expedient direction finder must be used to place the direction arrow on the overlay. Use the standard symbol to represent the actual north arrow used—grid, magnetic, or true north.

(b) *Title and objective*. This tells the reader *why* the photo overlay was made and may also give the actual location.

(c) *Time and date*. The exact *time the information was obtained* is shown on a photo overlay just as on a map overlay.

(d) *Photo reference*. The photo number, mission number, date of flight, and scale appears here or the information is traced in its actual location on the photograph.

(e) *Scale*. The scale must be computed since it is not part of the marginal data.

(f) *Map reference*. Reference is made to the sheet name, sheet number, series number, and scale of a map of the area, if one is available.

(g) *Author*. The name, rank, and organization of the author are shown, supplemented with a date and *time of preparation* of the overlay.

(h) *Legend*. As with map overlays, this is only necessary when nonstandard symbols are used.

(i) *Security classification*. This must correspond to the highest classification of either the photograph or the information placed on the overlay. If the information and photograph are unclassified, this shall be so stated. The location of the classification notes is shown in figure 7-3 and appears in all three places as shown.

(j) *Additional information*. Any other information that amplifies the overlay shall also be included, as briefly as possible.

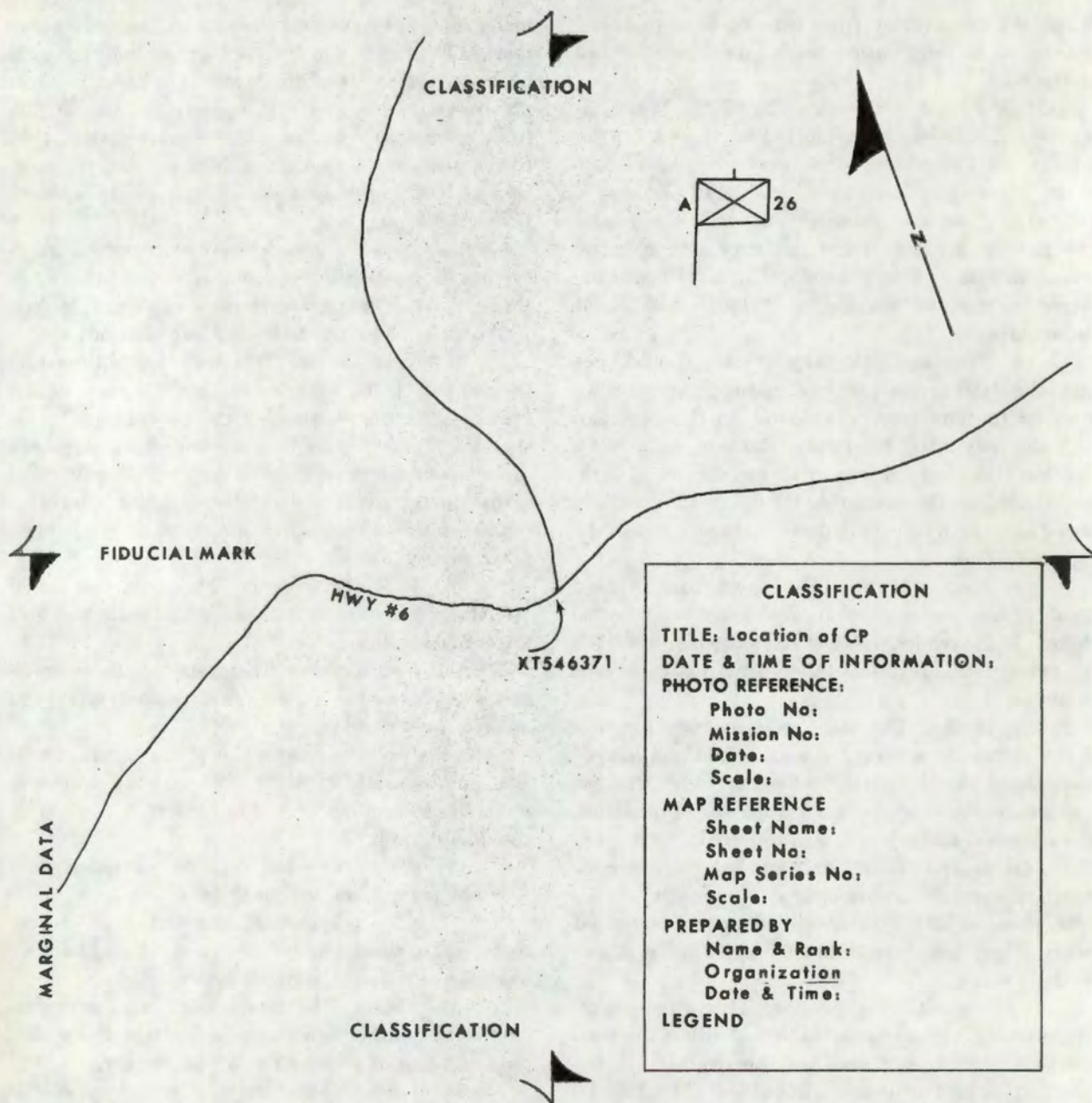


Figure 7-3. Photographic overlay with marginal information.

CHAPTER 8

AERIAL PHOTOGRAPHS

8-1. Description and Use

An aerial photograph is any photograph taken from an airborne vehicle (aircraft, drones, balloons, satellites, etc.). The aerial photograph has a wide range of uses in military operations; however, for the purpose of this manual it will be considered primarily as a map supplement or map substitute. A topographic map may be obsolete because it was compiled many years ago. A recent aerial photograph shows any changes that have taken place since the map was compiled. For this reason, maps and aerial photographs supplement each other. The amount of information that can be gained by using the two together is greater than by using either alone.

8-2. Comparison with Maps

a. An aerial photograph has the following advantages over a map:

- (1) It provides a pictorial representation of the ground that no map can equal.
- (2) It is more readily obtained. The photograph may be in the hands of the user within a few hours after it is taken while a map may take months to prepare.
- (3) It may be made of areas that are inaccessible to ground troops for political or military reasons.
- (4) It shows military features that do not appear on maps.
- (5) It can provide a day-to-day comparison of selected areas permitting evaluations to be made of enemy activity.
- (6) It provides a permanent and objective record of the day-to-day changes within the area.

b. The aerial photograph has the following disadvantages as compared to a map:

- (1) Ground features are difficult to identify or categorize without symbols and are often obscured by other ground detail as, for example, buildings in wooded areas.

(2) Position location and scale are only approximate.

(3) Detailed variations in the landforms are not readily apparent without overlapping photography and a stereoscopic viewing instrument.

(4) Because of a lack of contrasting colors and tone, a photograph is difficult to use in poor light.

(5) It lacks marginal data.

(6) It requires more training to use.

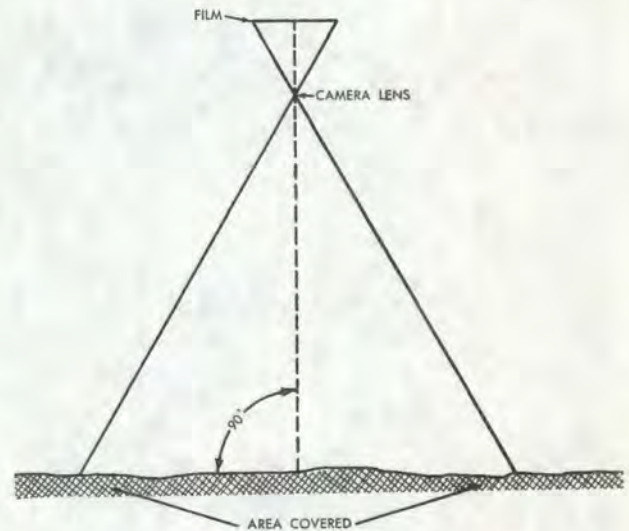


Figure 8-1. Relationship of the vertical aerial photograph to the ground.

8-3. Types of Photographs

Aerial photography most commonly used by military personnel may be divided into two major types, the vertical and the oblique. Each type depends upon the altitude of the camera with respect to the earth's surface when the photograph is taken.

a. *Vertical.* A vertical photograph is taken with the camera pointed straight down (fig. 8-1 and 8-2). Its primary uses are as a map supplement or map substitute, the making of new maps or the revision

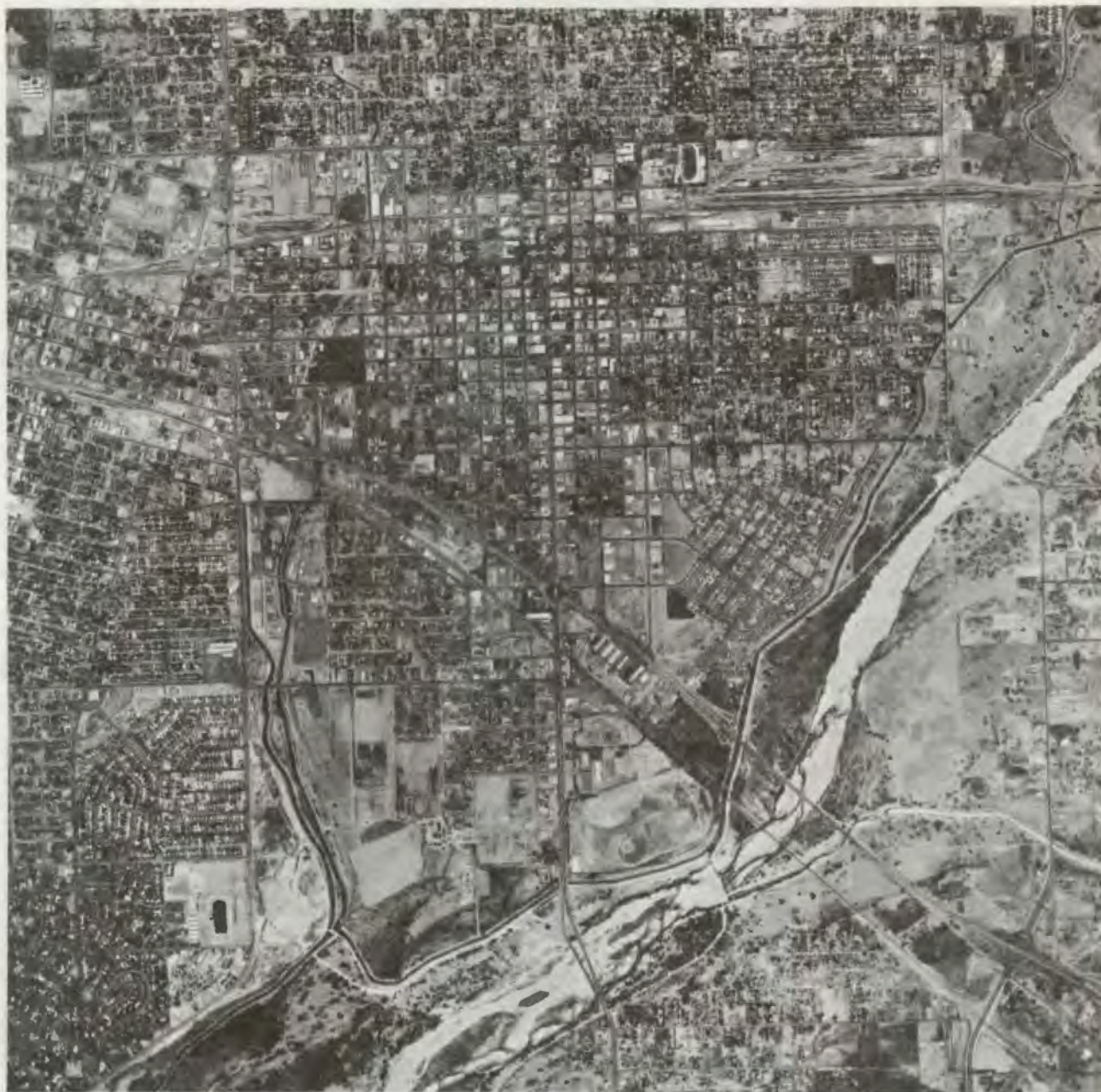


Figure 8-2. Vertical photograph.

of existing maps, and for intelligence. A vertical photograph has the following characteristics:

- (1) The lens axis is perpendicular to the surface of the earth.
- (2) It covers a relatively small area.
- (3) The shape of the ground area covered on a single vertical photo closely approximates a square or rectangle.

(4) Being a view from above it gives an unfamiliar view of the ground.

(5) Distance and directions may approach the accuracy of maps if taken over flat terrain.

(6) Relief is not readily apparent.

b. Low Oblique. The low oblique is a photograph taken with the camera inclined approximately 30° from the vertical (fig. 8-3 and 8-4). It is used to

study an area prior to attack, to substitute for a reconnaissance, to substitute for a map, or to supplement a map. A low oblique has the following characteristics:

- (1) It covers a relatively small area.
- (2) The ground area covered is a trapezoid, although the photo is square or rectangular.
- (3) The objects have a more familiar view, comparable to viewing from the top of a high hill or tall building.
- (4) No scale is applicable to the entire photograph and distance cannot be measured. Parallel lines on the ground are not parallel on this photograph, therefore direction (azimuth) cannot be measured.

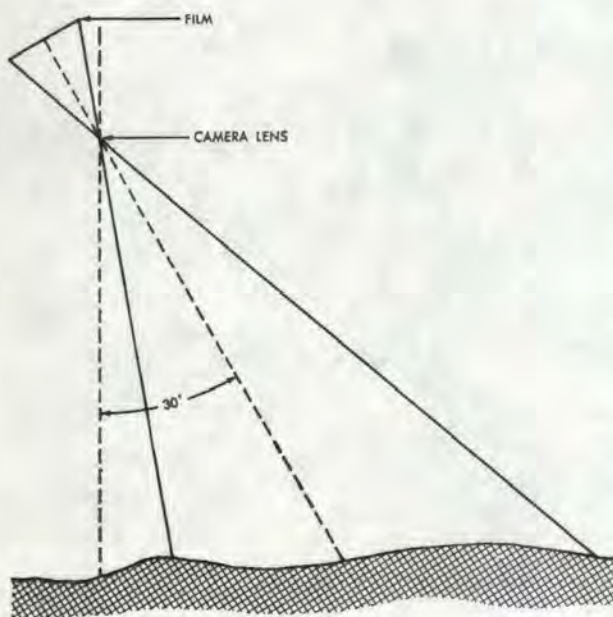


Figure 8-3. Relationship of low oblique photograph to ground.

- (5) Relief is discernible but distorted.
- (6) It does not show the horizon.

c. High Oblique. The high oblique is a photograph taken with the camera inclined approximately 60° from the vertical (fig. 8-5 and 8-6). It has a limited military application, being used primarily in the making of aeronautical charts; however, it may be the only photography available. A high oblique has the following characteristics:

- (1) It covers a very large area (not all usable).
- (2) The ground area covered is a trapezoid but the photograph is square or rectangular.

(3) The view varies from the very familiar to unfamiliar, depending on the height at which the photograph is taken.

(4) Distances and directions are not measured on this photograph for the same reasons that they are not measured on the low oblique.

(5) Relief may be quite discernible, but distorted as in any oblique view. Only in a high altitude high oblique is the relief not apparent.

(6) The horizon is always visible.

d. Trimetrogon (fig. 8-7). An assemblage of three photographs taken simultaneously, one vertical and two high obliques, in a direction at right angle to the line of flight. The obliques, taken at an angle of 60° from the vertical, sidelay the vertical photography, producing composites from horizon to horizon.

e. Multiple Lens. Multiple lens photography consists of composite photographs taken with a camera having two or more lenses, or by an assembly of two or more cameras. The photographs are combinations of two, four, or eight obliques around a vertical. The obliques are rectified to permit assembly as verticals on a common plane.

f. Convergent. Convergent photography is obtained with a single twin-lens wide-angle camera, or with two single-lens wide-angle cameras coupled together rigidly in the same mount so that each camera axis converges when intentionally tilted a prescribed amount (usually 15° or 20°) from the vertical. Again the cameras are exposed simultaneously. For precision mapping the optical axes of the cameras are parallel to the line of flight, and for reconnaissance photography, the camera axes are at high angles to the line of flight.

g. Panoramic.

(1) The development and increasing use of panoramic photography in aerial reconnaissance has resulted from the need to cover in greater detail more and more areas of the world. In order to cover the large areas involved, and to resolve the desired ground detail, present-day reconnaissance systems must operate at extremely high resolution levels. Unfortunately, high-resolution levels and wide angular coverage are basically counteracting requirements.

(2) A panoramic camera is a scanning type of camera which sweeps the terrain of interest from side to side across the direction of flight (fig. 8-8). This permits the panoramic camera to record a much wider area of ground than either frame or strip cameras. As in the case of the frame cameras,



Figure 8-4. Low oblique photograph.

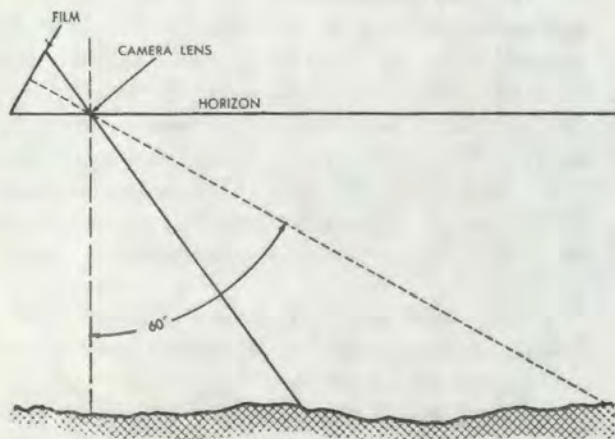


Figure 8-5. Relationship of high oblique photograph to ground.

continuous cover is obtained by properly spaced exposures, timed to give sufficient overlap between frames. Panoramic cameras are most advantageous for applications requiring the resolution of small ground detail from high altitudes.

8-4. Types of Film

a. Panchromatic. This is the same type of film that is used in the average hand-held small camera. It records the amount of light reflected from objects in tones of gray running from white to black. Most aerial photography is taken with panchromatic film.

b. Infrared. This is a black and white film that is sensitive to infrared waves. It can be used to detect



Figure 8-6. High oblique photograph.

artificial camouflage materials and can be used to take photographs at night if there is a source of infrared radiation.

c. *Color*. This film is the same as that used in the average hand-held camera. It is limited in its use because of the time required to process it and its need for bright, clear, sunny weather.

d. *Camouflage Detection*. This film is a special

type that records natural vegetation in a reddish color. When artificial camouflage materials are photographed they appear bluish or purplish. The name of this film indicates its primary use.

8-5. Numbering and Titling Information

a. Each aerial photograph contains in its margin valuable and important information for the photo

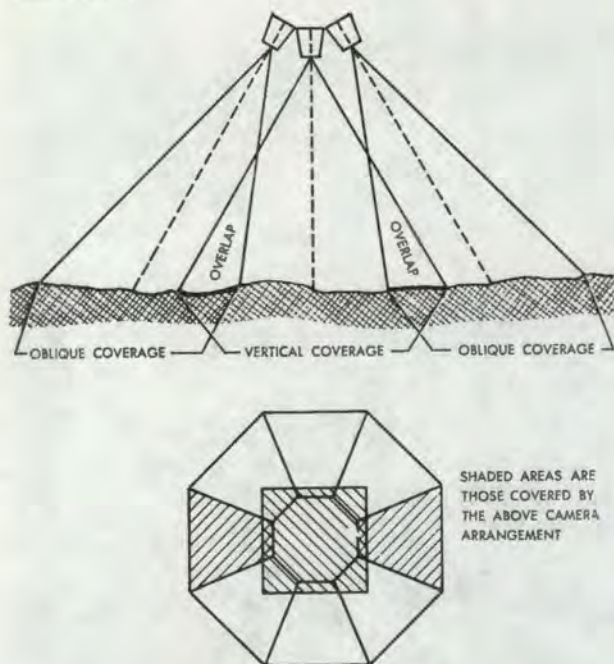


Figure 8-7. Relationship of cameras to ground for trimetrogon photography (3 cameras).

user. The arrangement, type, and amount of this information is standardized; however, the rapid development of camera, film, and aeronautical technology since World War II has caused numerous changes in the numbering and titling of aerial photographs. As a result, the photo user may find that the marginal information on older photography varies somewhat from the standard current practice. With certain camera systems, some of the data is automatically recorded on each exposure, while other systems require that all titling data be added to the film after processing.

b. Standard titling data for aerial photography prepared for the use of the Department of Defense are listed in c below.

(1) For reconnaissance and charting photography, items 2 through 14 and item 19 are lettered on the beginning and end of each roll of film. Items 1 through 9 and item 19 are lettered on each exposure.

(2) For surveying and mapping photography, items 2 through 19 are lettered on the beginning and end of each roll of film, and items 1, 2, 3, 5, 6, 7, 8, 9, 13, and 19 are lettered on each exposure.

c. Titling items and sequence:

- (1) Negative number
- (2) Camera position

- (3) Taking unit
- (4) Service
- (5) Sortie/mission number
- (6) Date (followed by a double hyphen (=))
- (7) Time group and zone letter (GMT)
- (8) Focal length
- (9) Altitude
- (10) Kind of photography or imagery
- (11) Geographic coordinates
- (12) Descriptive title
- (13) Project number and/or name
- (14) Camera type and serial number
- (15) Cone serial number (if any)
- (16) Lens type and serial number
- (17) Magazine type and serial number
- (18) Type of photographic filter used
- (19) Security classification

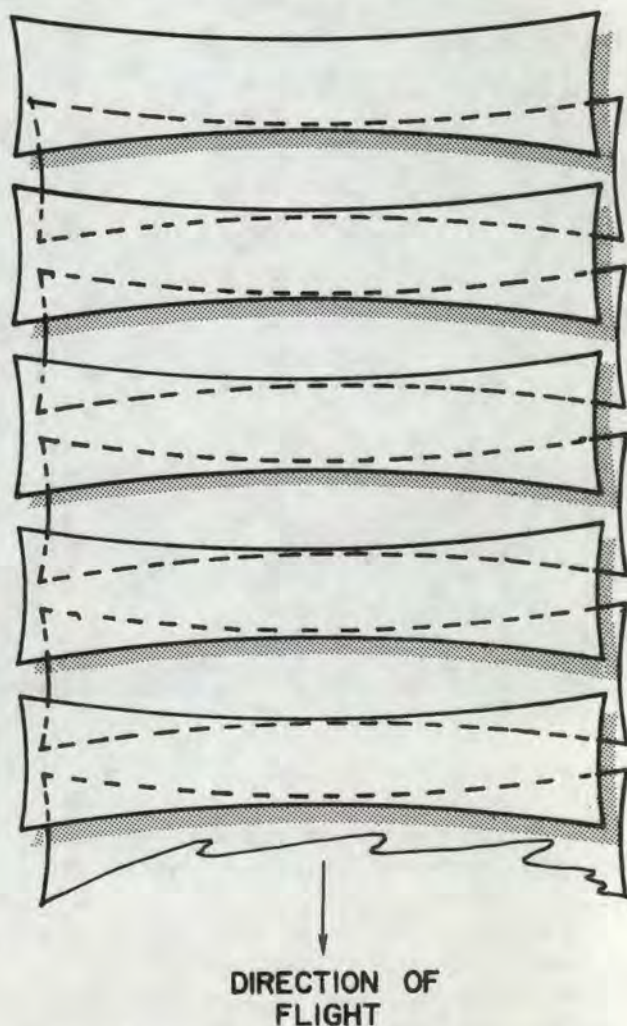


Figure 8-8. Ground coverage obtained with panoramic camera.



Figure 8-9. Selection of points for scale determination.

d. Automatically recorded data may differ somewhat in arrangement from the sequence listed above, but the same information is available to the photo user. A detailed explanation of the titling items and the codes used to indicate them may be found in TM 5-243.

8-6. Scale Determination

Before a photograph can be used as a map supplement or substitute, it is necessary to know its scale. On a map, the scale is printed as a representative fraction (*RF*) which expresses the ratio of map dis-

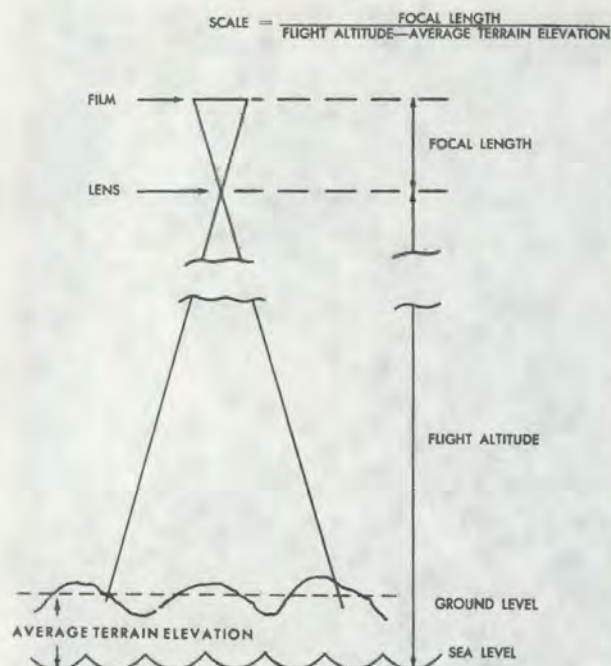


Figure 8-10. Computation of scale from terrain level.

tance (MD) to ground distance (GD), $RF = \frac{MD}{GD}$. On a

photograph, the scale is also expressed as a ratio, but it is the ratio of the photo distance (PD) to ground

distance, $RF = \frac{PD}{GD}$. The approximate or average

scale (RF) of a vertical aerial photograph is determined by either of two methods, the *comparison method* or the *focal length—flight altitude method*.

a. Comparison Method. The scale of a vertical aerial photograph is determined by a comparison of a measured distance between two points on the photograph with the measured ground distance between the same two points.

$$\text{Scale (RF)} = \frac{\text{Photo Distance}}{\text{Ground Distance}}$$

The ground distance is determined by actual measurement on the ground or by the use of the scale on a map of the same area (para 4-2). The points selected on the photograph must be identifiable on the ground or map of the same area and should be

spaced in such a manner that a line connecting them will pass through or nearly through the center of the photograph (fig. 8-9).

Example:

Photo distance = 8 centimeters

Ground distance = 2 kilometers

$$\frac{8 \text{ cm}}{2 \text{ km} \times 100,000 \text{ (cm in 1 km)}} = \frac{8}{200,000}$$

$$\text{or } RF = 1:25,000$$

b. Focal Length—Flight Altitude Method. When the marginal information of a photograph includes the focal length and the flight altitude, the scale of the photo is determined using the formula (fig. 8-10):

Scale (RF)

$$= \frac{f \text{ (focal length)}}{H \text{ (flight altitude)} - h \text{ (average ground elevation)}}$$

Example:

$$f = 6'' \text{ (inches)} \quad \text{or} \quad 15.2 \text{ (centimeters)}$$

$$H = 10,000' \text{ (feet)} \quad \text{or} \quad 3,048 \text{ (meters)}$$

$$h = 850' \text{ (feet)} \quad \text{or} \quad 259.08 \text{ (meters)}$$

With metric measurements:

$$\frac{15.2}{(3,048 - 259.08) \times 100} = \frac{15.2}{278,900} = \frac{1}{18,300} \text{ (approx)}$$

$$\text{or } 1:18,300$$

With English measurements:

$$\frac{.5'}{10,000' - 850'} = \frac{.5}{9150} = \frac{1}{18,300}$$

When the ground elevation is at sea level, (fig. 8-11) h becomes zero, and the formula becomes:

$$\text{Scale (RF)} = \frac{f \text{ (focal length)}}{H \text{ (flight altitude)}}$$

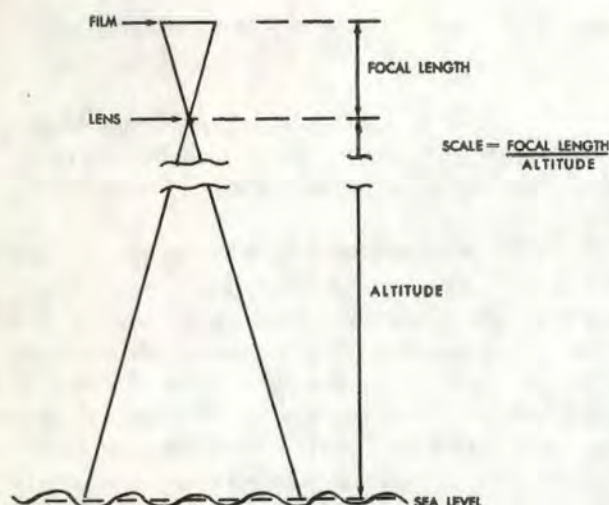


Figure 8-11. Basic computation of scale from sea level.

8-7. Indexing

a. When aerial photos are taken of an area, it is convenient to have a record of the extent of coverage of each photo. A map on which the area covered by each photo is outlined and numbered or indexed to correspond to the photo, is called an *index map*. There are two methods of preparing index maps.

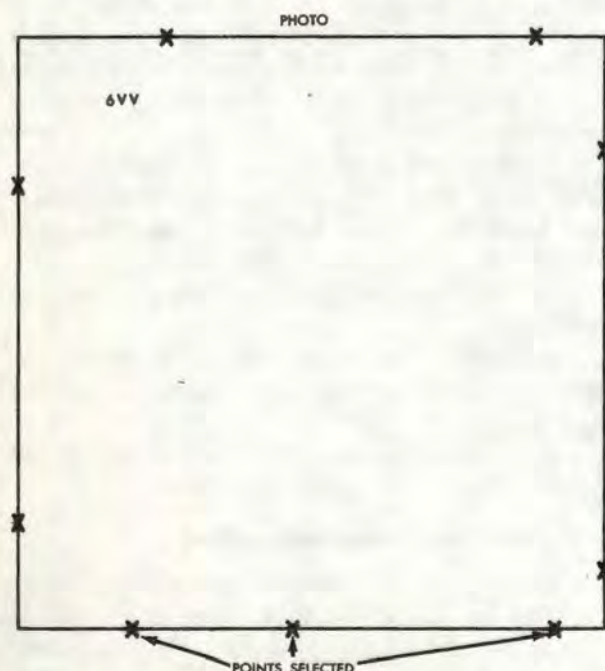


Figure 8-12. Four corner method (selection of points).

(1) *Four corner method.* This method (fig. 8-12 and 8-13) requires location on the map of the exact point corresponding to each corner of the photo. If a recognizable object such as a house or road junction can be found exactly at one of the corners, this point may be used on the map as the corner of the photo. If recognizable objects cannot be located at the corners, then the edges of the photo should be outlined on the map by lining up two or more identifiable objects along each edge; the points where the edges intersect should be the exact corners of the photo. If the photo is not a perfect vertical, the area outlined on the map will not be a perfect square or rectangle. After the four sides are drawn on the map, the number of the photograph is written in the inclosed area for identification. This number should be placed in the same corner as it is on the photo.

(2) *Template method.* The template method is used when a large number of photos are to be indexed, and the exact area covered by each is not as important as approximate area and location. In this case a template—cardboard pattern or guide—is cut to fit the average area the photos cover on the index map, and is used to outline the individual area covered by each photo. To construct a template, find the average map dimensions covered by the photos to be indexed as follows: Multiply the aver-

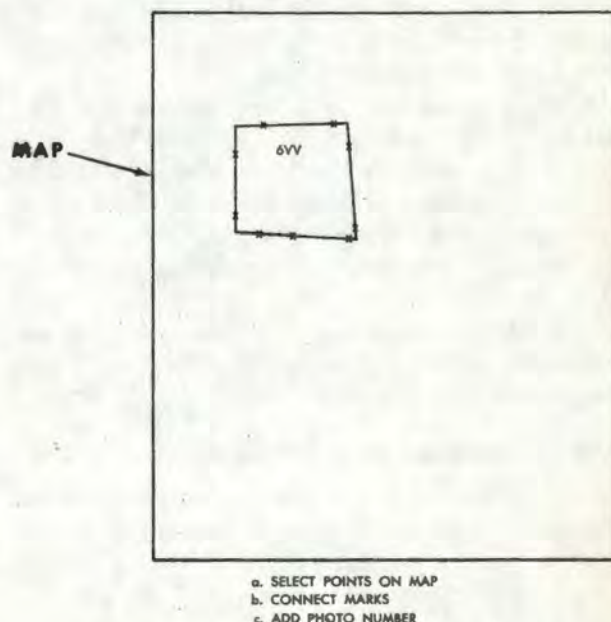


Figure 8-13. Plotting, using the four corner method.

age length of the photos by the denominator of the average scale of the photos, and multiply this by the scale of the map. Do the same for the width of the photos. This gives the average length and width of the area each photo covers on the map—or the size to which the template should be cut.

Example:

Size of photo = 17.8×22.9 centimeters

Scale of photo = 1:20,000

Scale of map = 1:50,000

$$\text{Length} = 22.9 \times 20,000 \times \frac{1}{50,000}$$

$$= \frac{45.8}{5} = 9.1 \text{ centimeters}$$

$$\text{Width} = 17.8 \times 20,000 \times \frac{1}{50,000}$$

$$= \frac{35.6}{5} = 7.12 \text{ centimeters}$$

To index the map: Select the general area covered by the first photo, and orient the photo to the map. Place the template over the area on the map and adjust it until it covers the area as completely and accurately as possible. Draw lines around the edges of the template. Remove the rectangle, and proceed to the next photo (fig. 8-14).

b. After all photos have been plotted, write on the map sufficient information to identify the mission or sortie. If more than one sortie is plotted on one map or overlay, it is recommended that a different color for each sortie be used.

c. In most cases when a unit orders aerial photography, an index is included to give the basic information outlined in *a* above. Instead of being annotated on a map of the area, it appears on an overlay and is keyed to a map.

8-8. Orientation of Photograph

The orientation of the photograph is important because it is of very little value as a map supplement or substitute if its location and direction are not known by the user.

a. If a map of the same area as the photograph is available, the photograph is oriented to the map by

comparing features common to both and then transferring a direction line from the map to the photograph.

b. If no map is available, the shadows on a photograph may be used to get an approximate true-north line. This method is not recommended in the torrid zone.

(1) *North temperate zone.* The sun moves from the east in the morning through south at noon to west in the afternoon. Conversely, shadow fall varies from west through north to east. Before noon, therefore, north is to the right of the direction of shadow fall; at noon, north is the direction of shadow fall; and after noon, north is to the left of shadow fall. On an average, the amount of variation in shadow fall per hour is 15° . From marginal information, determine the number of hours from noon that the photo was taken, and multiply that number by 15° . With a protractor, measure an angle of that amount in the proper direction (right to left) from a clear, distinct shadow, and north is obtained. For photographs taken within 3 hours of noon, a reasonably accurate north direction can be obtained. Beyond these limits, the 15° must be corrected, depending on time of year and latitude.

(2) *South temperate zone.* The sun moves from east through north at noon, to west. Shadows then vary from west through south to east. Before noon, south is to the left of shadow fall; at noon, south is shadow fall; and after noon, south is to the right of shadow fall. Proceed as in (1) above to determine the direction of south.

c. On a photograph that can be oriented to the surrounding ground features by inspection, a magnetic north line can be established using a compass.

(1) Orient the photograph by inspection.

(2) Open the compass and place it on the photograph.

(3) Without moving the photograph, rotate the compass until the north arrow is under the stationary black line.

(4) Draw a line along the straight edge of the compass. This is a magnetic north line.

8-9. The Point Designation Grid

a. Since aerial photographs are seldom exactly the same scale as a map of the same area, it is not feasible to print military grids upon them. A special grid is used for the designation of points on photographs (fig. 8-15). This grid, known as the *point*

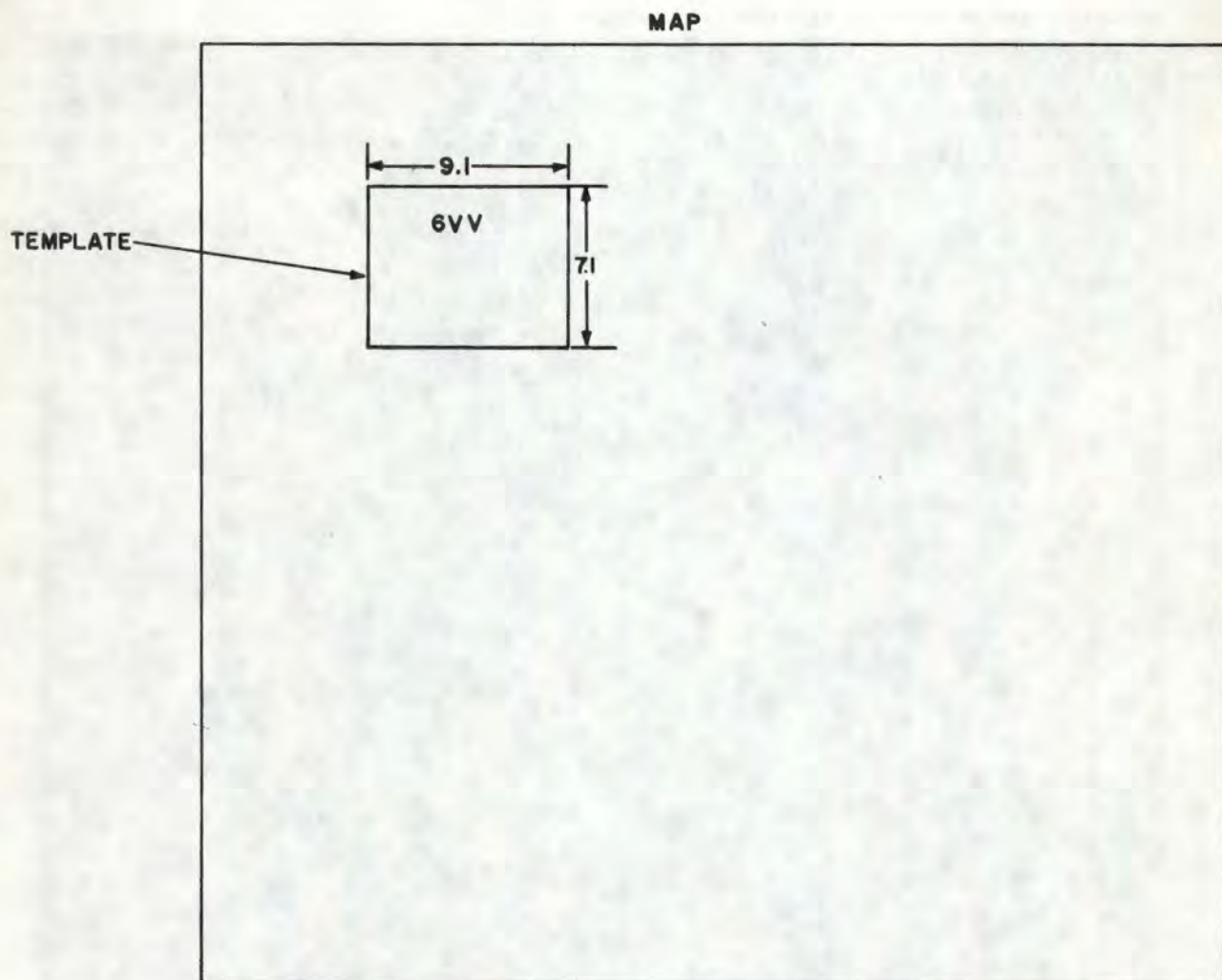


Figure 8-14. Indexing with a template.

designation grid, has no relation to the scale of the photo, to any direction, or to the grid used on any other photograph or map. It has only one purpose, to designate points on photographs.

b. The point designation grid is rarely printed on photographs; therefore, it becomes the responsibility of each user to construct the grid on the photograph. All users *must* construct the grid in exactly the same way. Before the grid can be constructed or used, the photograph must be held so that the marginal information, regardless of where it is located, is in the normal reading position (step (1), fig. 8-16).

(1) Draw lines across the photograph joining opposite reference marks at the center of each

photograph (fiducial marks). If there are no fiducial marks, the center of each side of the photograph is assumed to be the location of the marks (step (2), fig. 8-16).

(2) Space grid lines, starting with the center-line, 4 cm. or 1.575 inches apart (a distance equal to 1,000 meters at a scale of 1:25,000). The 1:25,000 map coordinate scale can be used for this dimension and to accurately designate points on the photograph, but this does not mean that distance can be scaled from the photograph. Extend the grid past the margins of the photograph so that a horizontal and vertical grid line fall outside the picture area (step (3), fig. 8-16).

MARGINAL INFORMATION IN THE NORMAL READING POSITION

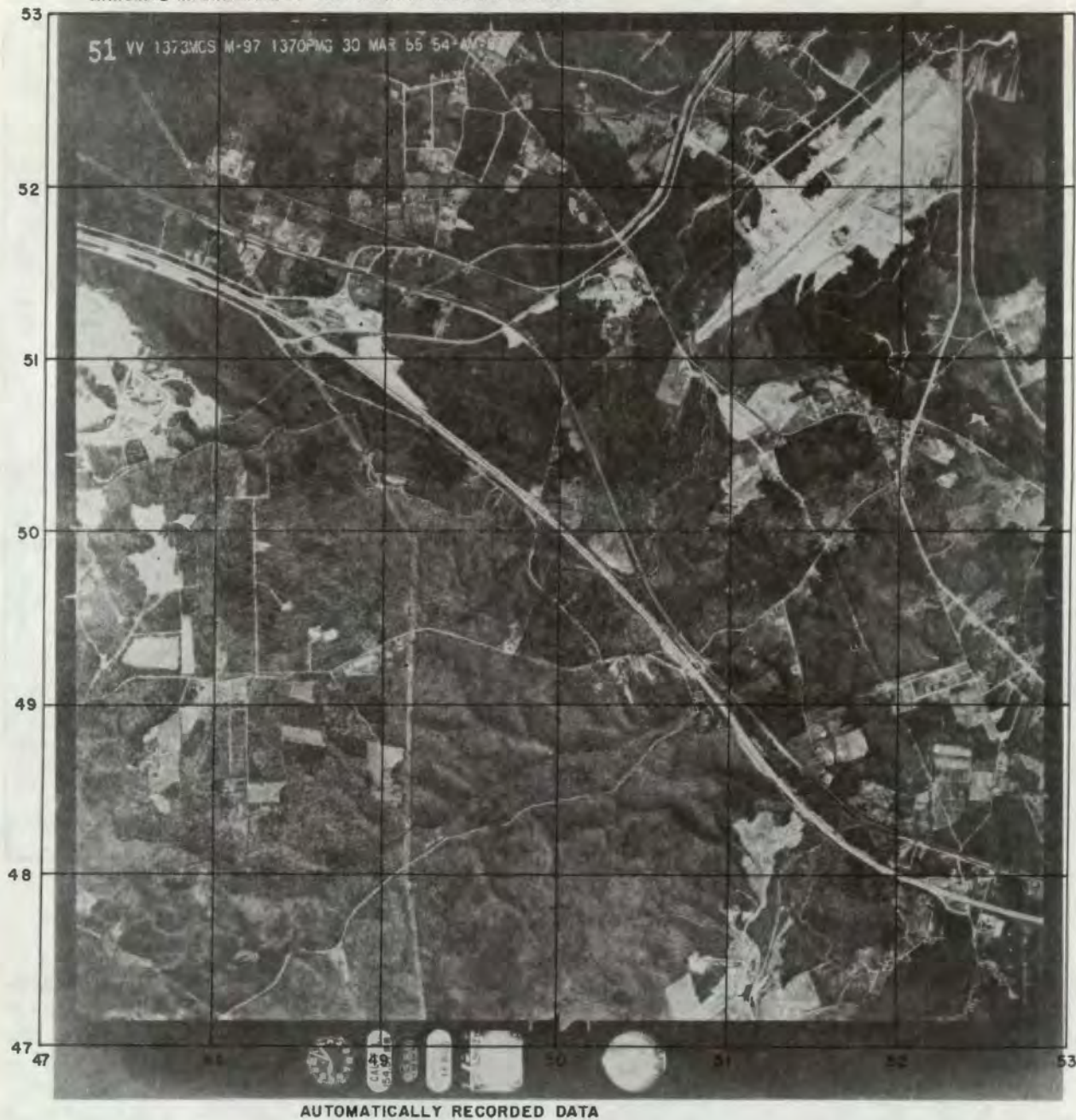


Figure 8-15. Point designation grid.

(3) Number each centerline "50" and give numerical values to the remaining horizontal and vertical lines so that they increase to the right and up (step (4), fig. 8-16).

c. The point designation grid is used, once the photograph is oriented, in the same manner as the

grid on a map (fig. 8-17), READ RIGHT-UP. The coordinate scale used with the UTM grid on maps at the scale of 1:25,000 may be used to subdivide the grid square in the same manner as on a map. However, because the same point designation grid is used on all photographs, the coordinates of a

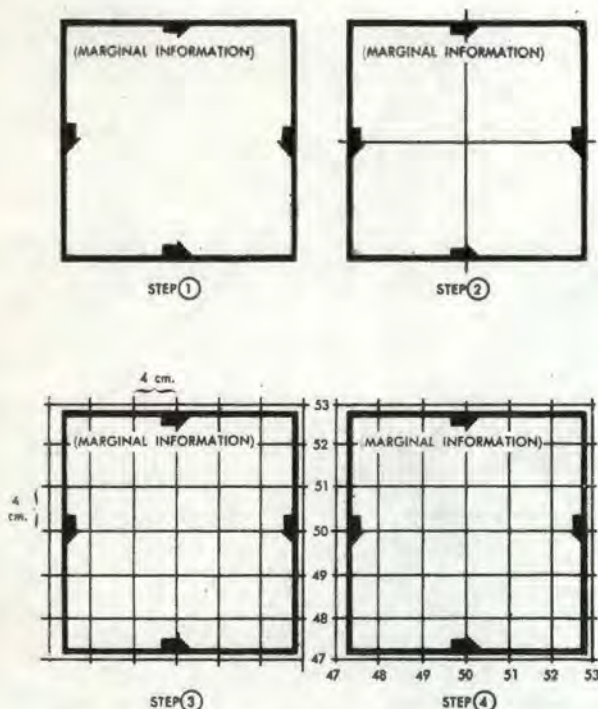


Figure 8-16. Construction of point designation grid.

point on the photograph must be prefixed by the identifying marginal information of the photograph.

d. A grid coordinate using the point designation grid consists of three parts—

(1) The letters "PDG" to indicate an aerial photograph rather than a map grid coordinate.

(2) The mission and photo negative number to identify which photograph is being used.

(3) The six numerical digits to locate the actual point on the photograph.

Example: (fig. 8-15).

(1) PDG (2) 1373MCS-M97-51 (3) 485511

8-10. Identification of Features on a Photograph

a. The identification of features on a photograph is not difficult if certain facts are remembered. These are—

(1) *Unfamiliar view.* The view that is presented by the aerial photograph is from above and as a result objects do not look familiar.

(2) *Reduction in size.* Objects greatly reduced in size appear distorted.

(3) *Lack of color.* Most aerial photography is black and white and all colors appear on the photograph in shades of gray. Generally speaking, the darker the natural color, the darker it will appear on the photograph.

b. The identification of features on aerial photographs depends upon a careful application of five factors of recognition. No one factor by itself will give a positive identification. It requires the use of all five.

(1) *Size.* The size of unknown objects on a photograph as determined from the scale of the photograph or a comparison with known objects of known size gives a clue to their identity. For example, in a built-up area the smaller buildings are usually dwellings and the larger buildings, commercial or community buildings.

(2) *Shape (pattern).* Many features possess characteristic shapes which readily identify the features. Manmade features appear as straight or smooth curved lines, while natural features usually appear to be irregular. Some of the most prominent manmade features are highways, railroads, bridges, canals, and buildings. Compare the regular shapes of these to the irregular shapes of such natural features as streams and timber lines.

(3) *Shadows.* Shadows are very helpful in identifying features since they show the familiar side view of the object. Some excellent examples are the shadows of water towers or smoke stacks. As viewed directly from above, only a round circle or dot is seen, whereas the shadow shows the profile and helps to identify the object. Relative lengths of

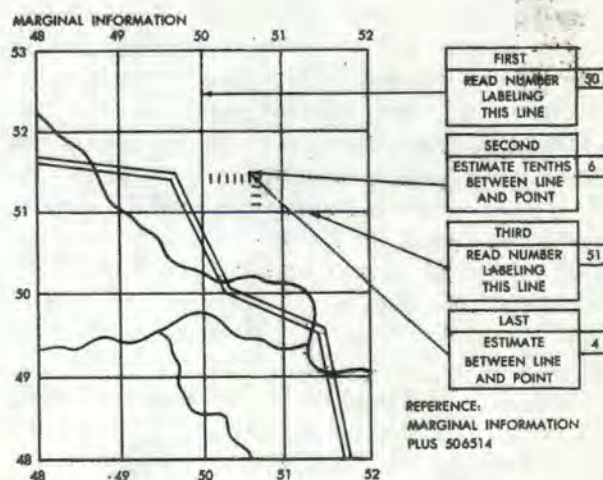


Figure 8-17. Reading point designation grid coordinates.

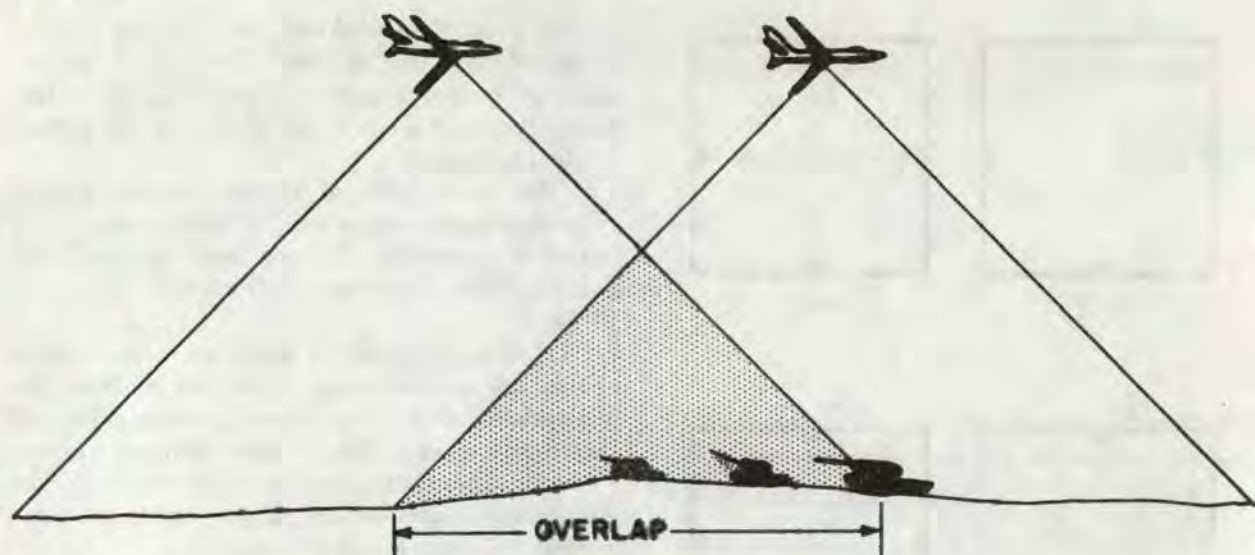


Figure 8-18. Photographic overlap.

shadows also usually give a good indication of relative heights of objects.

(4) *Shade (tone or texture)*. Of the many different types of photographic film in use today, the film used for most aerial photography, except for special purposes, is panchromatic film. Panchromatic film is sensitive to all the colors of the spectrum; it registers them as shades of gray, ranging from white to black. This lighter or darker shade of features on aerial photographs is known as the tone. The tone is also dependent on the roughness, or texture, of the features; a paved highway has a smooth texture and produces an even tone on the photograph, while a recently plowed field or a marsh has a rough, choppy texture and results in a rough or grainy tone. It is also important to remember that similar features may have different tones on different photographs, depending on the reflection of sunlight. For example, a river or body of water appears light if it is reflecting sunlight directly toward the camera, but appears dark otherwise. Its texture may be smooth or rough depending on the surface of the water itself. As long as the variables are kept in mind, tone and texture may be used to great advantage.

(5) *Surrounding objects*. Quite often an object not easily recognized by itself may be identified by its relative position to surrounding objects. Large buildings located beside railroads or railroad sidings

are usually factories or warehouses. Schools may be identified by the baseball or football fields. It would be hard to tell the difference between a water tower next to a railroad station and a silo next to a barn, unless the surrounding objects such as the railroad tracks or cultivated fields were considered.

c. Before a vertical photograph can be studied or used for identification of features, it must be oriented. This orientation is different from the orientation required for the construction or use of the point designation grid. The orientation for study consists of rotating the photograph so that the shadows on the photograph point toward yourself. You then face a source of light. This orientation has placed the source of light, an object, and its shadow in a natural relationship. Failure to orient a photograph properly may cause the height or depth of an object to appear reversed. For example, a mine or quarry may appear to be a hill instead of a depression.

8-11. Stereovision

a. One of the limitations of the vertical aerial photograph is the lack of apparent relief. Stereoscopic vision, or as it is more commonly known, stereovision or depth perception, is the ability to see three-dimensionally or to see length, width, and depth (distance) at the same time. This requires two views of a single object from two slightly different positions. Most individuals have the ability to see three-dimensionally.

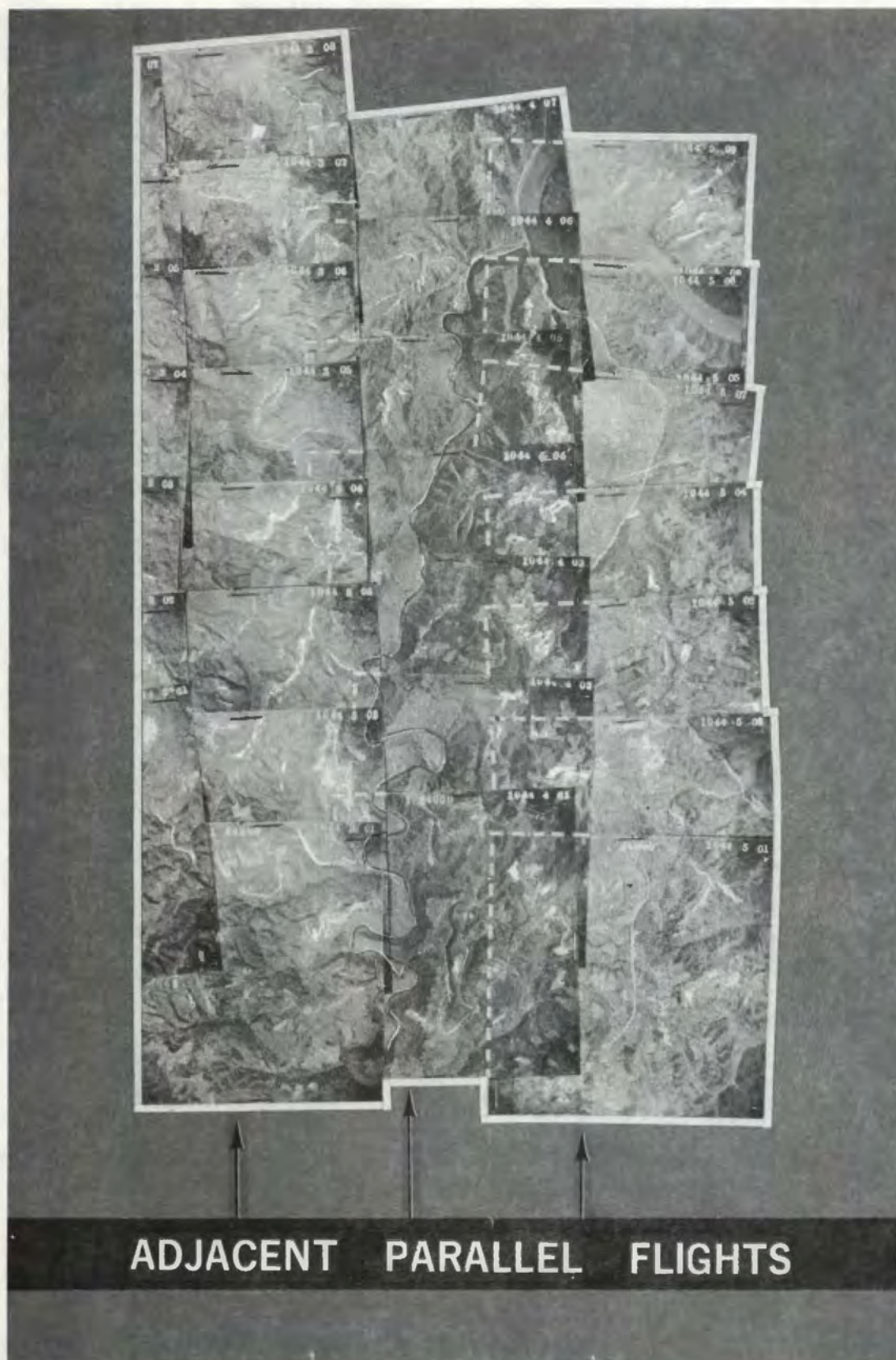


Figure 8-19. Side lap.

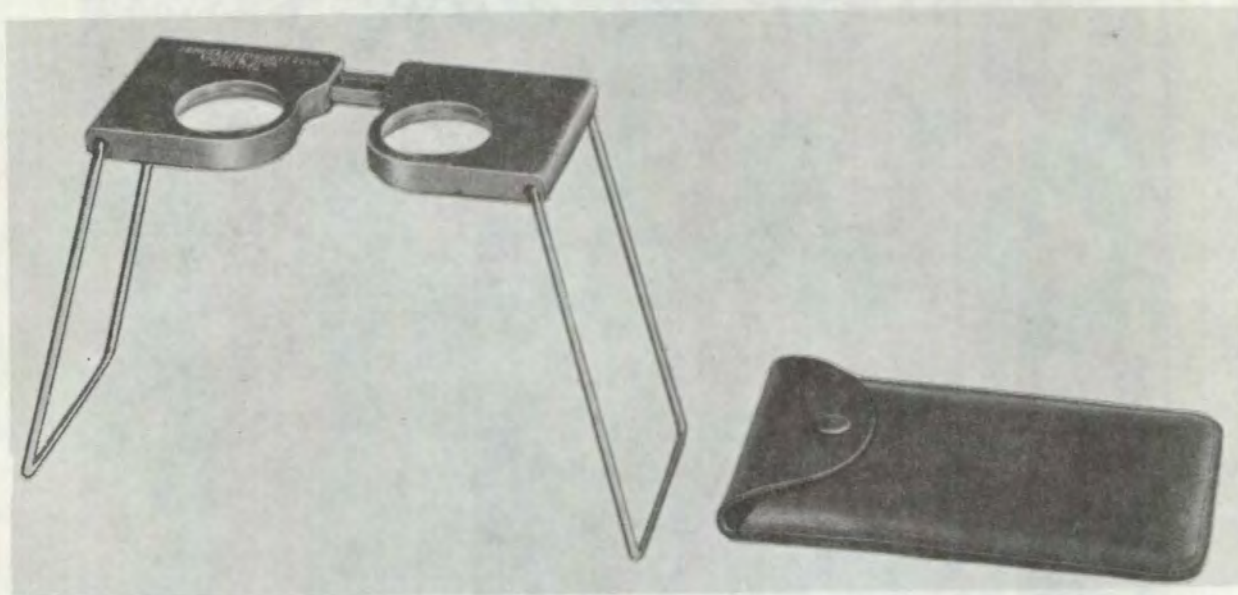


Figure 8-20. Pocket stereoscope.

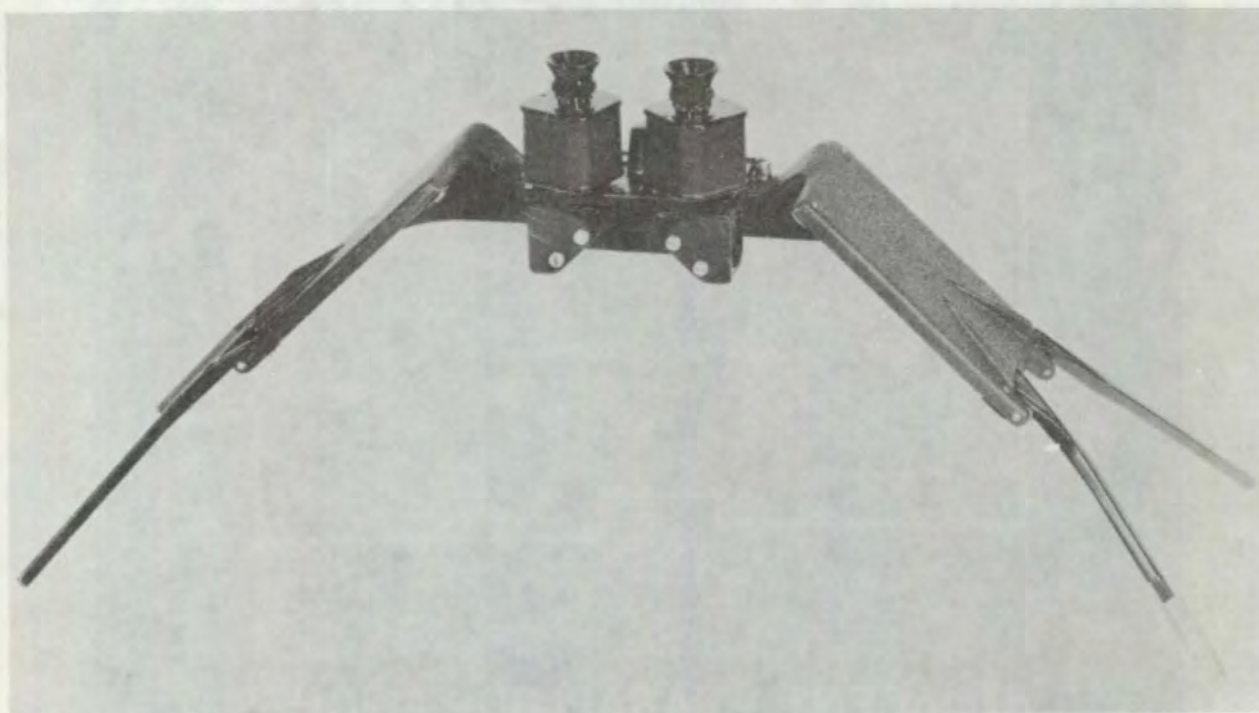


Figure 8-21. Mirror stereoscope.

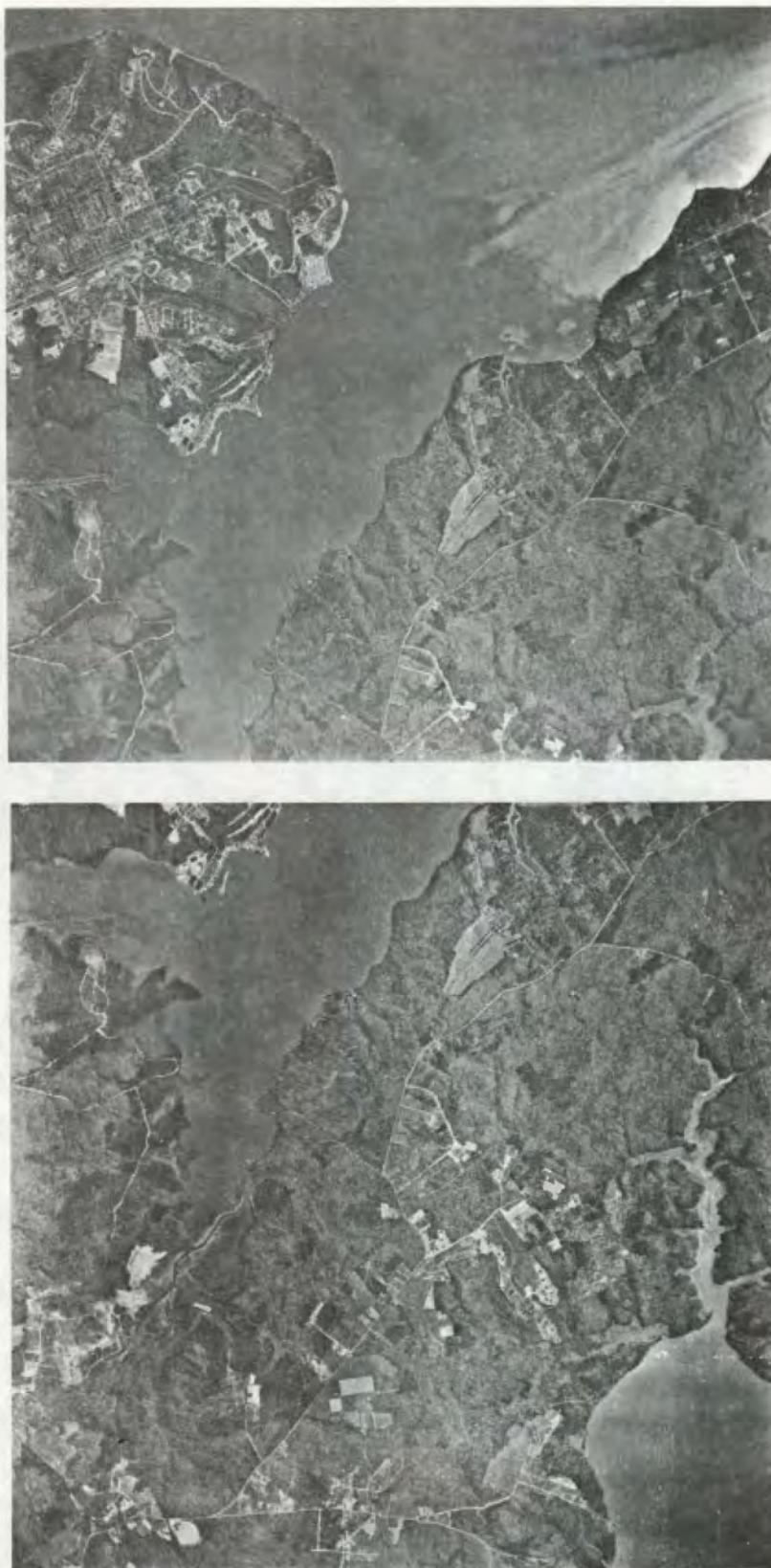


Figure 8-22. Stereopair.



Figure 8-23. Photographs overlapped.

Whenever an object is viewed, it is seen twice—once with the left eye and once with the right eye. The fusion or blending together of these two images in the brain permits the judgment of depth or distance.

b. In taking aerial photographs, it is rare for only a single picture to be taken. Generally, the aircraft flies over the area to be photographed taking a series of pictures, each of which overlaps the photograph preceding it and the photograph following it so that an unbroken coverage of the area is obtained (fig. 8-18). The amount of overlap is usually 56 percent which means that 56 percent of the ground detail appearing on one photo also appears on the next photograph. When a single flight does not give the necessary coverage of an area, additional flights must be made. These additional flights are parallel to the first and must have an overlap between them. This overlap between flights is known as side lap and usually is between 15 and 20 percent (fig. 8-19).

c. The requirement for stereovision, i.e., seeing two views of an object from two slightly different places, can be satisfied by overlapping photographs if one eye sees the object on one photograph and the other eye sees the same object on another photograph. While this can be done after practice with the eyes alone, it is much easier if an optical aid is used. These optical aids are known as stereoscopes. There are many types of stereoscopes, but only the two most commonly used are discussed in this manual.

(1) *Pocket stereoscope.* The pocket stereoscope (fig. 8-20), sometimes known as a lens stereoscope, consists of two magnifying lenses mounted in a metal frame. Because of its simplicity and ease of carrying, it is the type used most frequently by military personnel.

(2) *Mirror stereoscope.* The mirror stereoscope (fig. 8-21) is larger, heavier, and more subject to

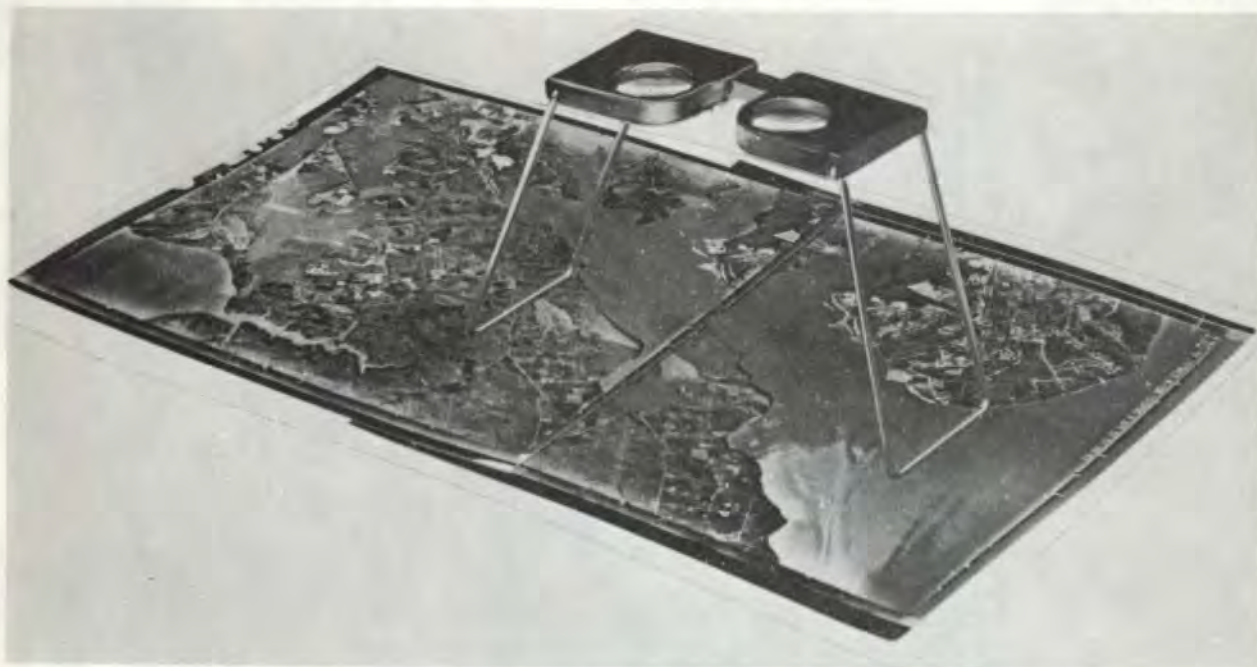


Figure 8-24. Placement of stereoscope.

damage than the pocket stereoscope. It consists of four mirrors mounted in a metal frame.

d. A method to orient a pair of aerial photographs for best three-dimensional viewing is outlined below:

(1) Arrange the selected pair of photos in such a way that the shadows on them generally appear to fall toward the viewer. It is also desirable that the light source during the study of the photography enters the side away from the observer (fig. 8-22).

(2) Place the pair of photographs on a flat surface so that the detail on one photograph is directly over the same detail on the other photograph (fig. 8-23).

(3) Place the stereoscope over the photographs so that the left lens is over the left photograph and the right lens over the right photograph (fig. 8-24).

(4) Separate the photographs, along the line of flight, until a piece of detail appearing in the over-

lap area of the left photograph is directly under the left lens and the same piece of detail on the right photo is directly under the right lens.

(5) With the photograph and stereoscope in this position, a three-dimensional image should be seen. A few minor adjustments may be necessary, such as adjusting the aerial photographs or the stereoscope to obtain the correct position for your eyes. The hills appear to rise and the valleys sink so that there is the impression of being in an aircraft looking down at the ground.

e. The identification of features on photographs is much easier and more accurate with this three-dimensional view. The same five factors of recognition, *size, shape, shadow, tone, and surrounding objects*, must still be applied, but now, with the addition of relief, a more natural view is seen.

CHAPTER 9

MOSAICS AND PHOTOMAPS

9-1. Mosaics

a. Characteristics. A mosaic of aerial photographs is an assemblage of as many aerial photographs as may be required to cover the area concerned. Mosaics are usually assembled to form a pictorial representation of the planimetry of an area only. Elevations are usually not represented although mosaics may be contoured or formlined if desired.

b. Types. Aerial mosaics are of three general types.

(1) *Uncontrolled mosaic.* An assembly of two or more overlapping vertical photographs assembled only by matching photographic detail without the aid of ground control. Such a mosaic gives a good pictorial effect of the ground but may contain serious errors of scale and azimuth inherent in the photographs themselves. A strip mosaic is formed by a series of vertical photographs taken in a single flight.

(2) *Semiconrolled mosaic.* This is a mosaic which is laid to limited ground control, augmented by radial line or slotted templet positions. In both uncontrolled and semiconrolled mosaics, contact prints of the aerial negatives are used.

(3) *Controlled mosaic.* A controlled mosaic is one which is laid to ground control, augmented by radial line or slotted templet positions. It differs from semiconrolled mosaics in that the photographs used are rectified; that is, corrected in projection to bring them to the same scale and to restore them to the vertical view by restitution printing. This operation insures a degree of accuracy comparable to a planimetric line map compiled by radial line methods. Although the inherent distortions in the aerial photograph cannot be entirely eliminated even in the most precisely assembled controlled mosaic, they may be lessened by proper procedures and techniques. However, errors in image position caused by relief of terrain are not removed in a controlled mosaic.

(4) *Orthophotomosaic.* An assembly of ortho-

photographs forming a uniform-scale mosaic. An orthophotograph is a photographic copy, prepared from a perspective photograph, in which displacements of images because of tilt and relief have been removed.

9-2. Photomaps

a. A photomap is a reproduction of a photograph or mosaic upon which grid lines, marginal data, place names and other overprint information have been added. A single vertical photograph with a point-designation grid could be considered a photomap. Normally, however, the military photomap is a map-size reproduction of a controlled mosaic. As a map substitute, it is reproduced in quantity and is printed on a press using standard map paper. The addition of a grid transforms a mosaic into a photomap and this gives it the same properties of point designation contained in a gridded map. The grid used on the photomap is the UTM map grid. A photomap made from an uncontrolled mosaic gives a good picture of the terrain and can be prepared quickly, although it will have errors in scale and direction. A photomap made from a controlled mosaic takes much longer to prepare, but it can be scaled approximately. The actual preparation of a mosaic and photomap is detailed in TM 5-240. On the back of the Leavenworth map in this manual is a photomap (fig. E-4). Photomaps are *not* usually printed on the back of maps but for convenience within the purpose of this manual it has been done.

b. On a standard photomap, the grid, scale, and directions are used in the same manner as on a map. However, the identification of features is the same as on a single photograph.

c. Some photomaps, in addition to the names and grid data, have the major cultural and drainage features added in color. These color-intensified photomaps show the manmade features in red, and the drainage features in blue as on a standard topographic map.

d. The photomap has two uses, as a map substitute and as a map supplement.

(1) *Map substitute.* For those areas of the world where no map coverage exists, a photomap may be the sole source of information and as such is used as a map. If the photomap is to be used for the location of positions or the determination of distance and directions, it must be examined to find whether it is controlled or uncontrolled to determine its accuracy.

(2) *Map supplement.* When a photomap is used as a map supplement, it adds to the information of the map; the map and photomap must be used together. Usually the map is used for accurate measurements and the photomap for up-to-date detail.

9-3. Pictomap

A pictomap (fig. E-2) is a refinement of the photomap on which the tones and imagery of a photomosaic are converted into colors and symbols.

Three tones are extracted from the mosaic photographically, and printed in color. Drafted symbols and names data are also added in color.

a. The pictomap is processed photographically and yields three tones—

(1) Landtone (buff) for uncovered land.

(2) Vegetone (green) for vegetation of one form or another.

(3) Shadowtone (black-green) for darker shades and shadows.

b. Many roads and buildings may appear in white, buff, or red, depending on the size and importance of the building and the scale of the pictomap.

c. Main roads, some buildings, certain linear features, and control information are overprinted in red.

d. Names, grids, boundaries, marginal data, railroads, contour lines, and hydrographic data are overprinted in black.

e. Drainage symbols are overprinted in blue.

CHAPTER 10

FIELD SKETCHING

10-1. Introduction

a. A sketch is a large-scale, free-hand drawn map or picture of an area or route of travel, showing enough detail and having enough accuracy to satisfy special tactical or administrative requirements. Sketches are useful when maps are not available or the existing maps are not adequate, or to illustrate a reconnaissance or patrol report.

b. Sketches may vary from hasty to complete and detailed, depending upon the time element, the accuracy required, the situation, climate conditions, skill of the sketcher, and the area. In addition, the degree of accuracy will vary with the purpose of the sketch. For example, a sketch of a large minefield must be related as closely as possible to points of ground control. On the other hand, a small unit commander who wishes to draw a quick sketch of his defensive positions to check their placement and coverage is not concerned with control networks and datums. He has solved his control problem if he has shown on his sketch at least one well-defined feature on the ground.

c. There are two types of sketches—the military and the panoramic. The former is the vertical view of the ground; the latter an oblique view of the ground.

10-2. Military Sketches

Military sketches include road and area sketches.

a. *Road Sketches.* Road sketches show the natural and military features on and in the immediate vicinity of the road. In general, the width of the terrain sketches will not exceed 365 meters on each side of the road, though in special cases it may be as great as 550 meters (fig. 10-1).

b. *Area Sketches.*

(1) A *position sketch* is one of a military position, camp site, or other area of ground, made by a sketcher who has access to all parts of the area sketched (fig. 10-2).

(2) An *outpost sketch*, as its name indicates, shows the military features of ground along a friendly outpost line and as far toward the hostile position as may be sketched from the rear of and along the line of observation.

(3) A *place sketch* is one of an area made by a sketcher from a single point of observation. Such a sketch may cover ground in front of an outpost line, or it may serve to extend a position or road sketch toward the enemy from the farthest point which can be reached by the sketcher.

(4) An *individual sketch* is a sketch of an area mapped by one party; that is, by one sketcher and his assistants.

(5) A *combined sketch* is a sketch formed by joining sketches which are the work of several parties.

c. *Scale of Sketches.* The scale of a sketch is determined by the object in view and the amount of detail required to be shown. The latter is often governed by the size of the unit concerned. Thus, a sketch of a defensive position or a camp site for a platoon or a company will, in general, call for a sketch of larger scale than a sketch for the same purpose for a division. The standard scales of military sketches, together with the usual contour intervals and the general uses to which they are applied, are shown in table 10-1.

d. *Sketching Equipment* (fig. 10-3).

(1) The equipment provided for sketching is packed in a case and contains the following items:

(a) *Alidade, triangular.* The sketching alidade is a triangular scale with white faces, $8\frac{1}{2}$ inches long and $\frac{7}{8}$ inch wide. It furnishes a well-defined sighting line, normally used in determining the direction lines of points to be plotted during the construction of a sketch. On one face it carries, for use on sketches of 1:5,000, 1:10,000 and 1:20,000 scale, a scale of yards and a scale which indicates differences in elevation in feet for a 1 percent slope. (A new alidade having metric measurements is entering the system.

ELEVATION	PACES	CLINOMETER		DIFFERENCE OF ELEVATION
		FORE	BACK	
34				
34	72	0	0	
34	140	0	0	
33	20	-1/2	-1/2	-1
33	84	0	0	
37.1	41	+1	-1	+4.1
37.1	69	0	0	
27.2	99	-1	+1	-9.9
20.9	42	-1 1/2	+1 1/2	-6.3
27.8	69	+1	-1	+6.9
39.2	57	+2	-2	+11.4
50.9	78	+1 1/2	-1 1/2	+11.7
81.1	67	+4 1/2	-4 1/2	+30.2
99.1	30	+6	-6	+18
78.1	60	-3 1/2	+3 1/2	-21
75.5	26	-1	+1	-2.6
52.3	93	-2 1/2	+2 1/2	-23.2
59.2	46	+1 1/2	-1 1/2	+6.9
65.2	30	+2	-2	+6
70.2	50	+1	-1	+5
70.2	93	0	0	
90.9	138	+1 1/2	-1 1/2	+20.7
103.4	62	+2	-2	+12.5
126.0	75	+3	-3	+22.6
144.4	61	+3	-3	+18.4
121.5	28	-8	+8	-22.9
72.2	76	-6 1/2	+6 1/2	-49.4

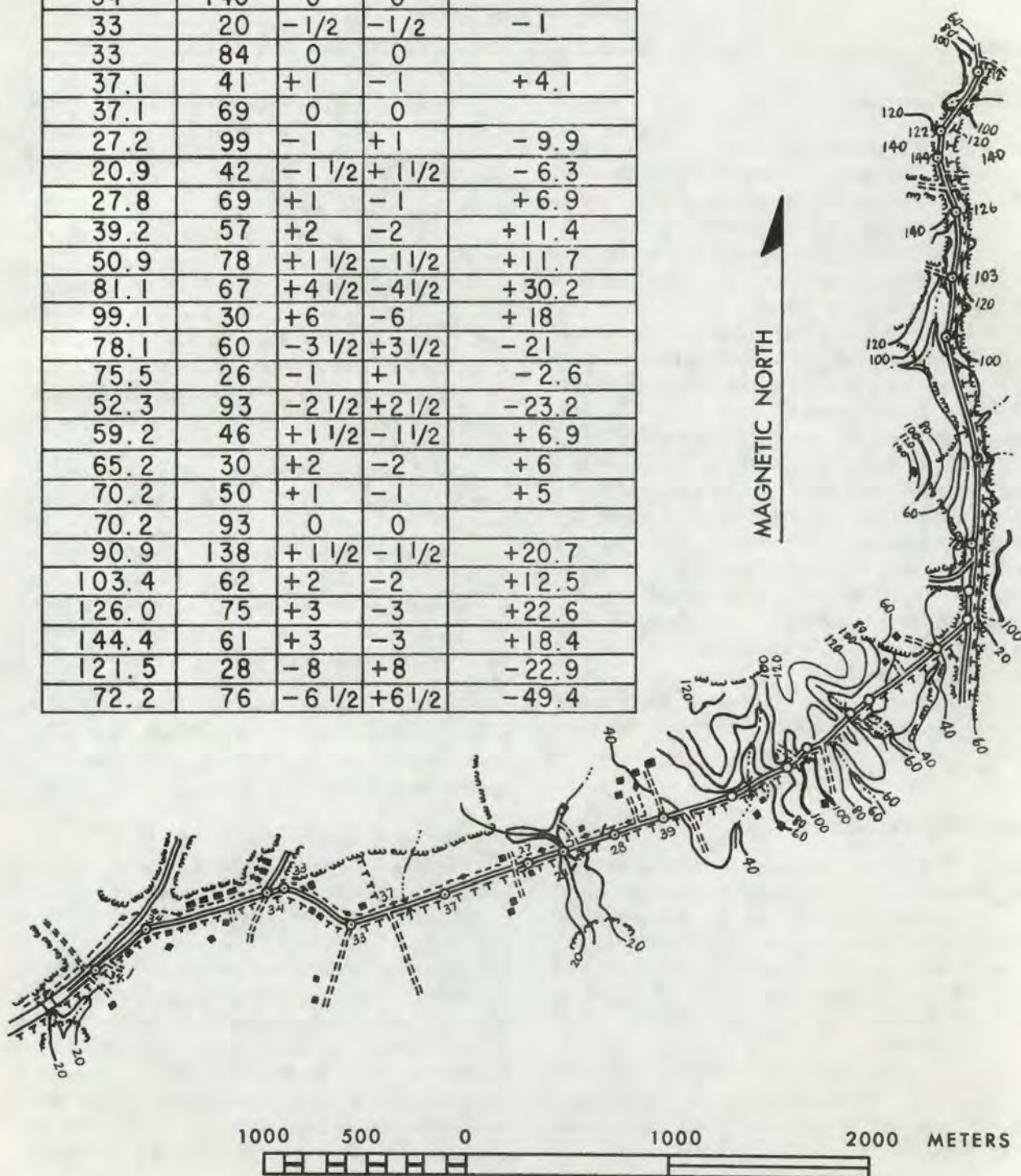


Figure 10-1. Road sketch, including field notes.

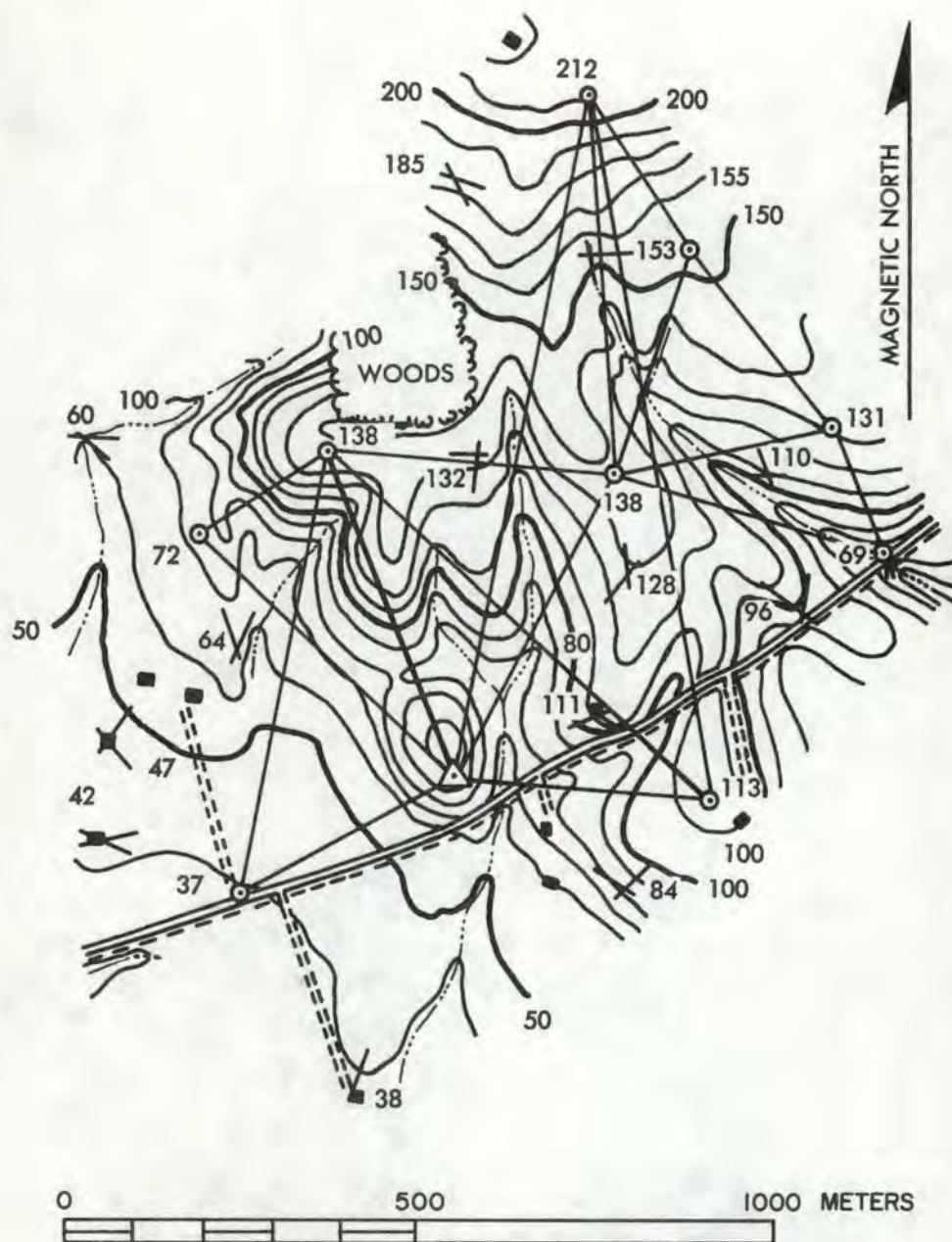


Figure 10-2. Position sketch.

Alidades having English measurements will be issued until depletion of stock, at which time the new alidades will be issued on a replacement basis.) When this scale is applied between points on the sketch, the scale of elevation differences reads directly in feet the difference in elevation between the points if the slope is 1 percent. For other slopes the difference in elevation is obtained by multiplying the elevation difference for 1 percent by the percent

of slope. By addition of the proper number of ciphers to the scale of differences, this scale may be used as a distance scale graduated in feet. The second face has scales of inches divided into tenths. The third face is blank. To this face the sketcher will find it convenient to fasten a scale of paces which corresponds to the length of his pace. The construction of a pace scale is covered below in (4) below.

(b) Board, sketching, w/waterproof cover. The

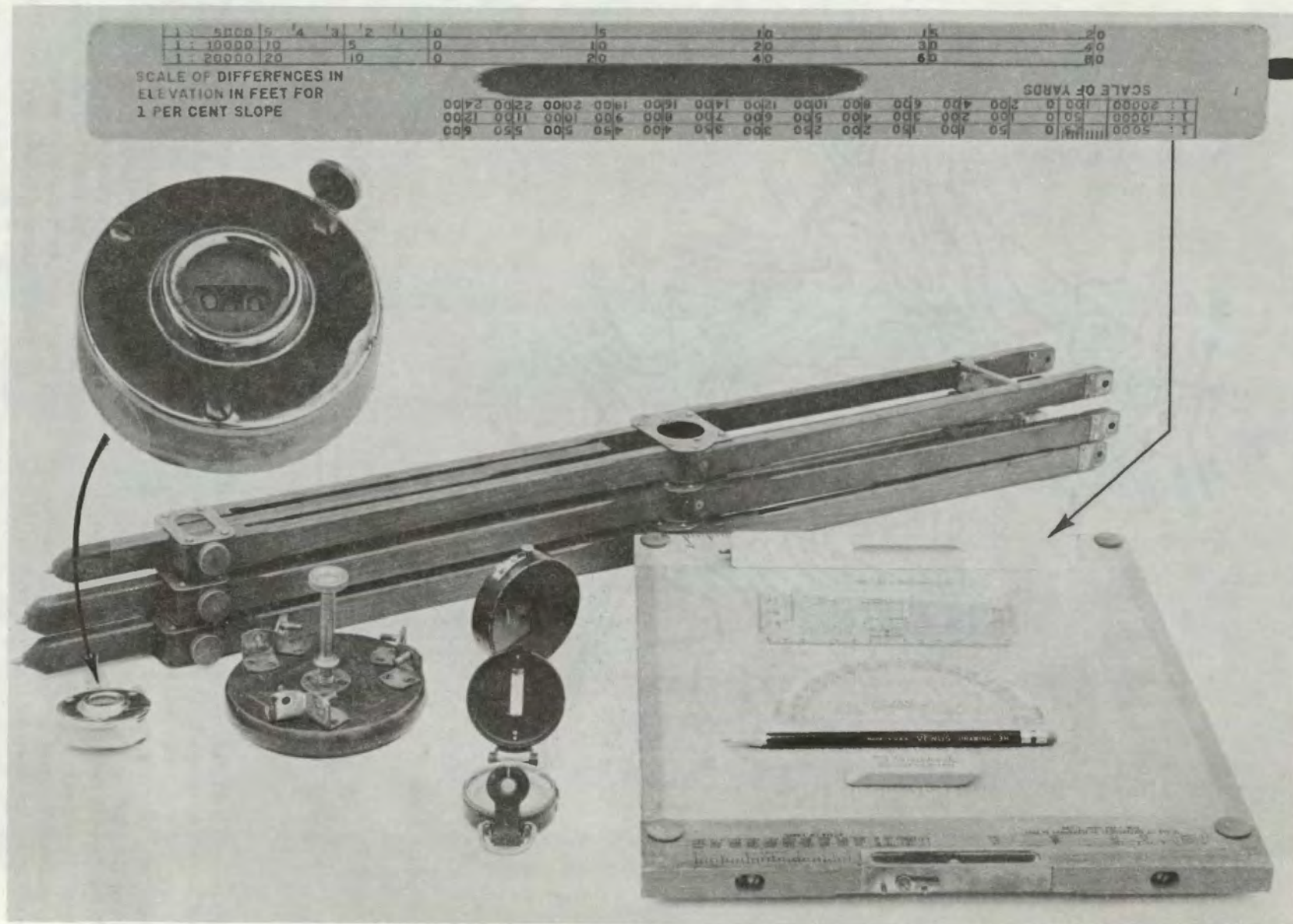


Figure 10-3. Military sketching set.

Table 10-1. Scales of Sketches

R.F.	Approximate number of inches equal to 1 mile	Contour interval (feet*)	Use
1:5,000----	12	5	For engineering construction or for exceptional purposes when great detail is desired.
1:10,000---	6	10	For position and outpost sketches.
1:20,000---	3	20	For road sketches and for amplification of the topographic detail shown on tactical maps.

* For metric measurements the same procedure is followed using rounded figures such as 10 or 1000 meters or centimeters.

sketching board is a small planetable consisting of a drawing board fastened to an adjustable tripod by means of a brass hand screw. There is a waterproof cover to protect the drawing board from dirt and moisture. The drawing board (12½ by 15 inches face, 5⁄8-inch thick) is made of white pine, grooved and fastened with screws and slotted washers to allow for expansion. A brass trough with a 3-inch steel magnetic needle covered by a glass window set flush with the upper edge of the board is inlaid in the center of the outer edge of one of the end pieces. A small lever raises or releases the needle which cannot oscillate over ½ of an inch. At each corner is a ¾-inch brass paper clip with spring and nut adjustment for fastening drawing paper to the board. Centered on the back of the board is a brass tripod plate with a 3⁄8-inch hole threaded with female threads, 16 to an inch. Graphic scales similar to those on the face of the alidade and an inch scale

are stamped on the same end piece of the sketching board as that bearing the magnetic needle. On the opposite end piece is a scale graduated to read the slope in percent when the sketching board is used as a slope board.

(c) *Tripod, sketching board.* The legs and the screw for attaching the sketching board to the head of the tripod are detachable from the head for convenience in packing. Each leg folds in three sections down to 15 inches from a maximum of 40¾ inches. The head is a solid circular piece 4½ inches in diameter and 5⁄8 inch thick with a felt pad and a threaded brass screw plate. The brass hand screw for attaching the board to the tripod is 3 inches long with a milled head at one end. A shoulder is provided 1 inch from the threaded end. The threads are stripped for a quarter of an inch from the shoulder, making a simple arrangement to hold the hand screw to the tripod when the board is removed, and to permit the board to rotate on the tripod when in place.

(d) *Clinometer, elevation and depression, surveying.* The service clinometer is an instrument for the direct measurement of percent of slopes. The observer sights through the peepholes at a distant point, at the same time reading the scale of percent on a mirror inside the instrument. Graduations are in red for ascending and in black for descending slopes. (The instrument pendulum is allowed to swing freely by first sliding the bar and then pressing the stop button.) Readings must be taken with the pendulum at rest but free to move, i.e., with the stop button depressed. By holding the clinometer so that the reading is zero, a good hand level is obtained. Since the clinometer is held at eye level to measure the average slope of the ground the sketcher must sight on a spot equal to his eye height above the observed point.

(e) *Compass magnetic.* For information on the magnetic compass, see paragraph 5-6.

(f) *Counter, reciprocating, hand-held.* This is a mechanical registering device for counting. It is built on the odometer principle with a trigger or lever to move the figures on the dial. A spring causes the trigger to rise as soon as the pressure is removed. In counting paces, press the trigger each time the foot hits the ground.

(g) *Protractor, rectangular.* A rectangular protractor is included in the sketching equipment. It is graduated from 0° to 180° and from 180° to 360°, clockwise, to read azimuth. It is also provided with one or more scales and can be used as a ruler, scale, and parallel ruler.

(2) To assemble the sketching board in the form of a planetable, proceed as follows:

(a) Remove the tripod legs, supply envelope, and the sketching board from the chest.

(b) Raise the lid under the sketching board, remove the tripod head from the left rear pocket, and the brass hand screw from the right rear pocket.

(c) Unfold and extend each leg, tightening the lower extensions in place by means of the mill-headed screws. Grasp the folding portion of the leg in one hand and insert the pins in the legs under tripod head into the corresponding holes at the top of the legs by pressing the parts of the leg together so that they may slide into place. Drop the small level near the top of the leg into place so that the leg is fixed to the tripod head.

(d) Remove the waterproof cover from the sketching board and place the center of the board over the hole in the tripod head.

(e) Fasten the board to the tripod head by inserting the brass hand screw. Clamp the screw to fix the board in relation to the tripod. Release the screw a quarter turn when it is desired to rotate the board in relation to the tripod.

(f) Fasten the paper to the board by means of the four flatheaded screws provided.

(g) Special care should be taken to prevent the top of the board from becoming marred. Place it face down when packing it in the chest.

(h) Special care should also be taken in setting up the tripod to avoid damage to the legs. When seating each leg into the ground, grasp it just above ground level and press at the same angle it is pointing.

(3) Preparing military sketches requires the determination of distance. This is done by pacing, which requires a knowledge of the sketcher's pace length. * For example:

1,000 feet = measured distances

383 = number of paces

$\frac{1,000 \times 12}{383} = 31.3 \text{ inches—pace length}$

(4) In order to use the pace length easily to plot distances on the sketch, it is necessary to construct a pace scale (fig. 10-4). To construct a scale that will represent 1,000 paces at a scale of 1:10,000 for use by a sketcher with a 31-inch pace length, the following steps are given:

(a) Determine the length of the scale.

$\frac{1,000 \text{ paces} \times 31}{10,000 \text{ (denominator of RF)}} = 3.1 \text{ inches}$

(b) Lay out a line 3.1 inches long. The length of this line equals 1,000 paces.

(c) Divide the line into 10 parts. Each part equals 100 paces.

(d) Divide the left-hand division into 10 parts. Each part equals 10 paces.

(e) Label the scale. The scale may now be used on the sketch to plot distances. For convenience, the scale may be pasted to the alidade.

e. *Control.* Control is a system of relatively accurate measurements to determine the distances, directions, or differences in elevation between points on the earth's surface. It is always desirable to have one point of control for each sketch. Control, as used here, is both horizontal and vertical, since the

* For metric measurements the same procedure is followed using rounded figures such as 100 or 300 meters or centimeters.

$$\textcircled{1} \frac{1,000 \text{ PACES} \times 31}{10,000 (\text{DENOMINATOR OF RF})} = 3.1 \text{ INCHES}$$

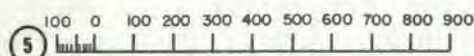
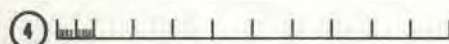
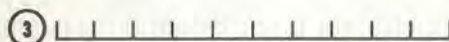
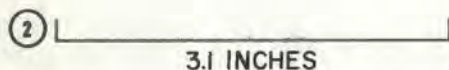


Figure 10-4. Construction of a pace scale.

sketch portrays both the horizontal and vertical position of features.

(1) A network of control covers the United States. It is based on common origins known as datums, one for horizontal control and one for vertical control. Stations in the network are identified on the ground, usually by concrete monuments with brass nameplates affixed on top. If the sketches are based on these stations they are on the same datum as standard maps, which means that sketching data can be applied to or used in conjunction with standard maps.

(2) If there is no control within the area to be covered by the sketch, a prominent and well-defined feature is selected to be an arbitrary control point.

f. Traversing.

(1) A traverse is a series of straight lines running from point to point, the distance and direction between each point having been measured. A traverse provides a network of control upon which the detail of the sketch is based. There are two types of traverses, the closed and the open.

(a) A closed traverse starts and ends at the same point, or at points whose relative horizontal positions are known (fig. 10-5).

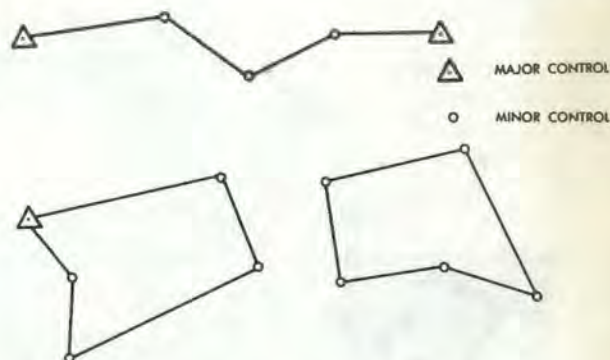


Figure 10-5. Closed traverse.

(b) An open traverse ends at a station whose relative position is not previously known, and unlike a closed traverse, provides no check against errors.

(2) The route for a traverse is selected after considering the size of the area, visibility, and ease of travel. Unless the area is very large, the traverse should follow the border of the area to be sketched. An exception to this is a road sketch where the traverse must follow the road (fig. 10-6).

(3) The running of a traverse requires strict observance of logical steps in sequence. These steps are—

- (a) Assemble sketching board and tripod.
- (b) Fasten drawing paper to sketching board.
- (c) Proceed to point where traverse is to begin.
- (d) Spread the legs of the tripod so that the points are about 2 feet apart and place them solidly



Figure 10-6. Execution of foresight for a traverse.

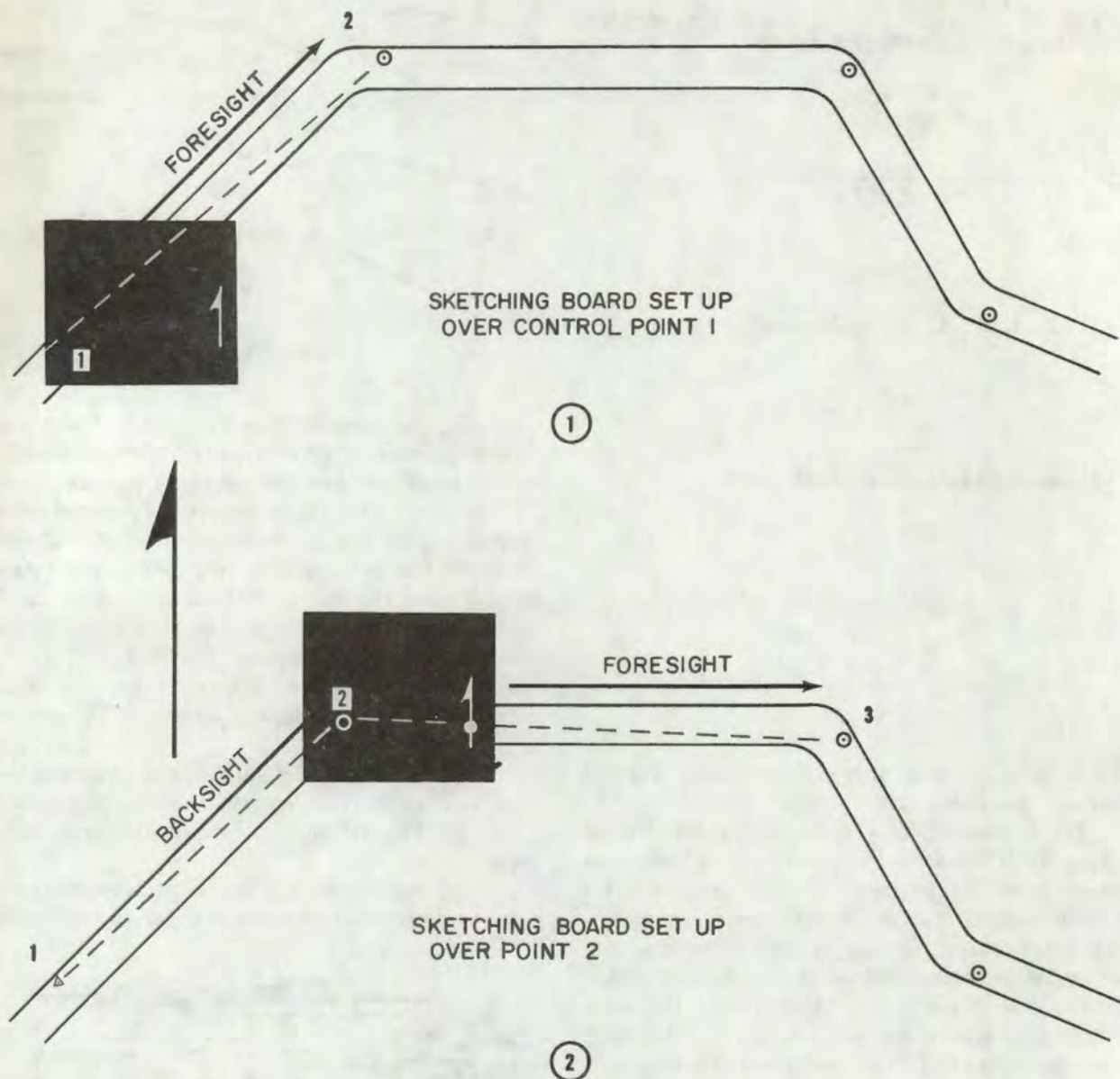


Figure 10-7. Diagram of a traverse showing foresight and backsight.

on the ground with the starting point centered within them.

(e) Level the board by eye. This is done by shifting the position of the legs.

(f) Orient the board to magnetic north, using the compass built into the sketching board and clamp it into place, using the hand screw.

(g) Draw a magnetic north arrow on the sketching paper.

(h) Place a pin into the paper to represent the starting point and identify it.

(i) Select a sighting edge and a ruling edge on the alidade and always use these same edges.

(j) Place the alidade on the sketching board with the ruling edge against the pin.

(k) Sight along the upper edge of the alidade to the second station of the traverse (called a foresight) (1, fig. 10-7). Move the alidade if necessary, using the pin as a pivot.

(l) Draw a line along the edge of the alidade from the pin toward the second station.

(m) Using the clinometer, read the vertical

angle, in percent, to a point about 5 feet (the height of the observer's eye) above the ground at the second station.

(n) Record the clinometer reading at the end of the direction line. Do not forget plus or minus.

(o) Pick up the sketching board and pace to the second station, counting the paces as you go.

(p) Set up the sketching board at the second station and, using the pace scale, lay off the distance paced along the direction line and mark this second point.

(q) With the clinometer, read the vertical angle, in percent, back to the first station. Remember to sight about 5 feet above the ground.

(r) Compare this with the reading taken from the first station to the second. Numerically they should be the same but one should be plus and the other minus.

(s) Average the numerical values of the two clinometer readings and use the sign (+ or -) of the first reading. This is the average percent of slope.

(t) To determine the difference in elevation for a 1-percent slope, use the scale of differences on the alidade. Measure with the correct scale the plotted distance between station 1 and station 2.

(u) Multiply the reading from the scale of difference by the average percent of slope and add or subtract, as indicated by the sign, from the elevation of station 1.

(v) Place another pin in the plotted position of the second point, level the sketching board, and orient by sighting on the first station while the alidade is held against the two pins (called a back-sight) ((2) fig. 10-7). The orientation may be checked with the magnetic compass of the sketching board.

(w) Without moving the position of the sketching board, pivot the alidade around the pin at station 2 and sight on station 3.

(x) Repeat (k) through (w) above for each station of the traverse.

g. Closing a Traverse.

(1) A closed traverse, carefully and properly run, should close on the original starting point or on another point of known position and elevation. When the traverse does not close, there is an error of closure (fig. 10-8).

(2) Any error in excess of 3 percent of the total traverse length should cause the traverse to be rerun from start to finish.

(a) Errors of less than 3 percent may be ad-

justed by drawing a straight line equal to the length of the total traverse (1, fig. 10-9).

(b) On this line lay out each distance of the traverse and number (2, fig. 10-9).

(c) At the end of this line and perpendicular to it, lay out the error of closure (3, fig. 10-9).

(d) Draw a line connecting the starting point with the error of closure (4, fig. 10-9).

(e) Draw perpendiculars at each of the station points (5, fig. 10-9).

(f) On the traverse, draw a line connecting start and finish (6, fig. 10-9).

(g) At each station draw a line parallel to that connecting the start and finish (7, fig. 10-9).

(h) On each of these parallel lines lay off the amount of error for each station as indicated in (e) above and connect them (8, fig. 10-9).

(i) This is the corrected traverse. It has been corrected by assuming a uniform error at each station (9, fig. 10-9).

(3) When running a traverse, errors can occur in the vertical as well as the horizontal. These errors can be adjusted by assuming the error to be proportionate to the number of stations. The adjustment is a matter of dividing the total error of vertical closure by the number of stations and applying an equal amount to the elevation of each point. For example, using the traverse in figure 10-9, if the starting elevation had been 500 feet and the computed elevation of the same point at the end of the traverse 480 feet, the error would be minus 20 feet. The correction would be plus because it must be added. In the above traverse there are 5 stations; so 20 divided by 5 equals 4 feet. At station 1, 4 feet would be added; at station 2, 8 feet; station 3, 12 feet; station 4, 16 feet; and at the end (station 5), 20 feet.

h. Detail Compilation.

(1) Certain features are usually of military im-

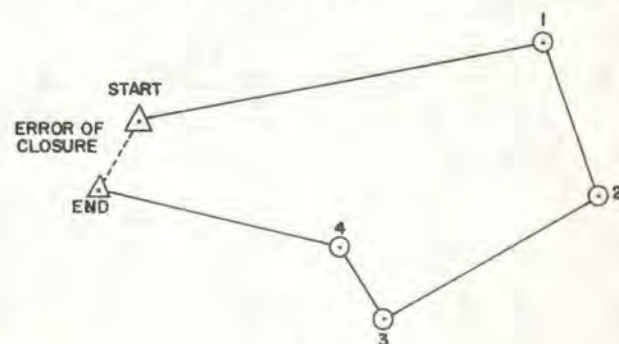


Figure 10-8. Error of closure.

portance and are shown on a sketch. The degree of detail to which each feature is drawn, or of which notes are made, as well as the number of features included, must be in accordance with the purpose of the sketch. This detail could be any or all of the following items:

(a) *Trails, roads, highways, railroads.* Surfacing, number of lanes or tracks, width of surface, width and depth of ditches, cuts, fills, seasonal passability, bordering features, bridges, culverts, junctions, elevations at critical points, grades, length.

(b) *Bridges, causeways, fords, ferries.* Size, clearance, condition, safe loading, normal water depth and velocity, type, elevation.

(c) *Streams, bodies of water, springs, glaciers, swamps, marshes, tidelands.* Width, depth, velocity, quantity, quality, endurance, bottom, junctions, elevations, drainage system, tide influence, bank details, obstructions, surface details, unusual value.

(d) *Hills, valleys, ravines, peaks, cliffs, ridges, mountain passes.* Type and density of cover, outline,

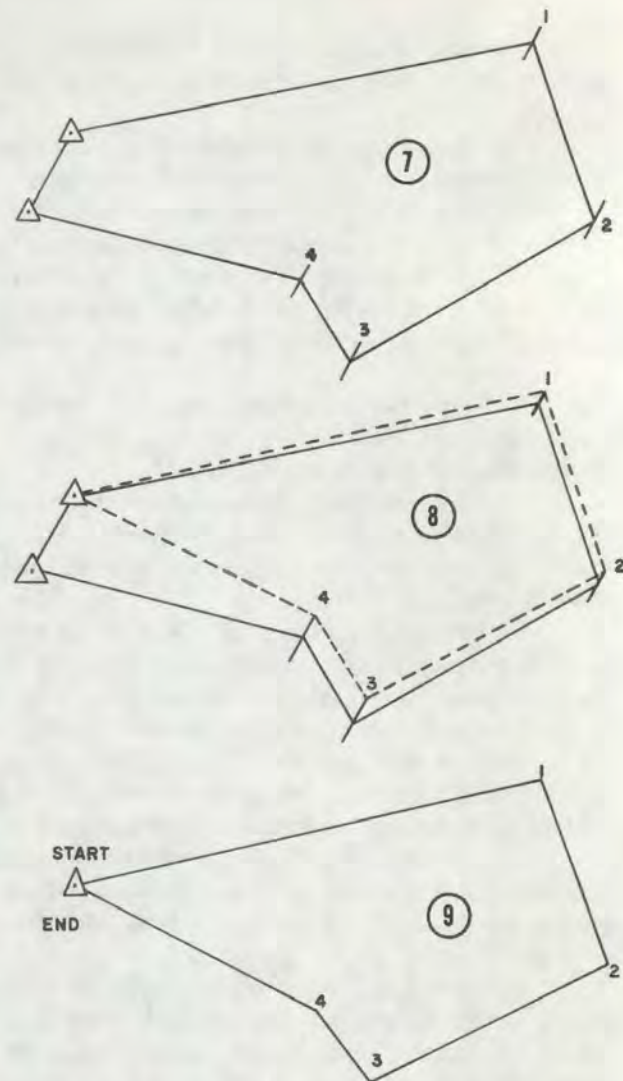


Figure 10-9—Continued.

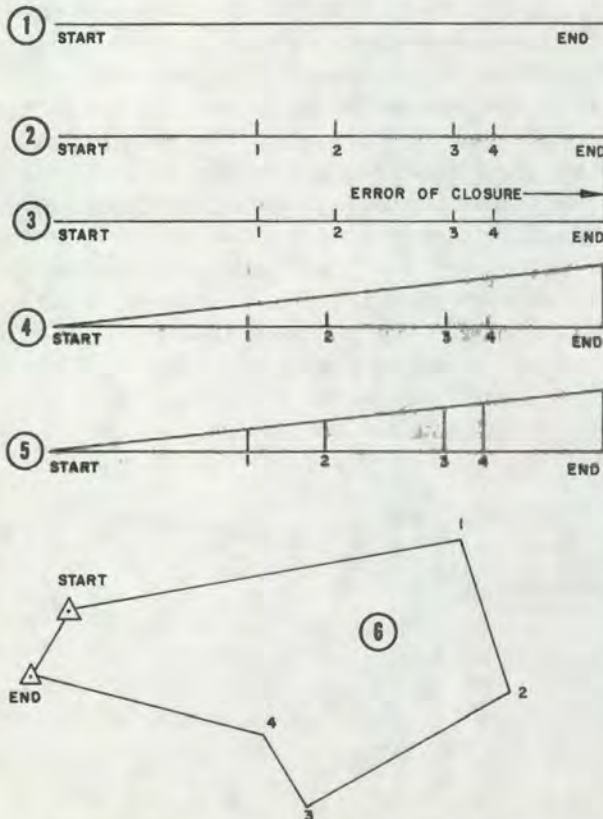


Figure 10-9. Adjusting an error of closure.

elevations, slope, height, depth, length, distinguishing characteristics.

(e) *Towns, villages, camps, campsites, powerlines, communication lines, radio and television stations and towers, beacons, radio ranges, airfields, airports, post offices, railroad stations, schools, churches, townhalls, bus stations, Federal centers, industrial buildings.* Name, size, outline, capacity, serviceability, category, surroundings.

(f) *Heavy fortifications, light fortifications, tank traps, obstacles, wire, minefields, weapon emplacements, outposts.* Size, degree of camouflage, approach terrain, armor.

(2) After the traverse has been run and adjusted, the detail within the area is compiled. At each

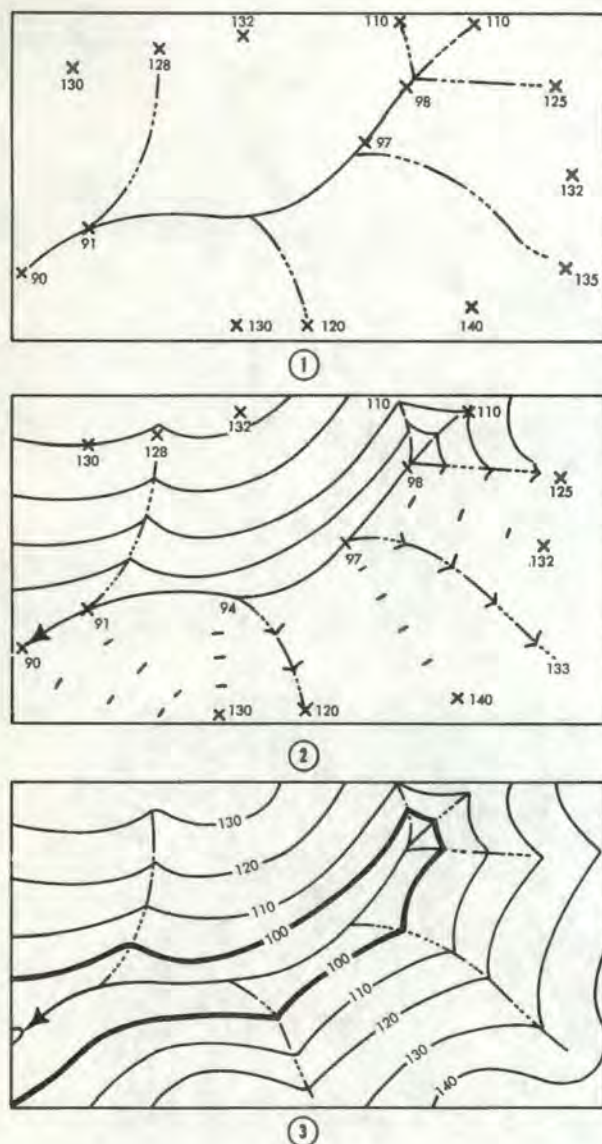


Figure 10-10. Logical contouring.

of the stations of the traverse, the sketching board is oriented, the details in the vicinity located, and their elevations determined. This is done by sighting on the object, drawing the line of sight, pacing and laying out the distance, and computing the elevation. After the point is located and marked, the line of sight is erased. This procedure is followed at each of the stations of the traverse until all of the required items of detail have been located. If the sketch is to be contoured, all critical points must be located and their elevations determined. Critical points are streams and gullies, ridges, and all other places where the ground slope changes. After these critical

points are located and their elevations determined, the area is logically contoured. Figure 10-10 shows the contouring of the area. The theory of logical contouring depends upon the assumption that the slope between two critical points is constant; that is, the ground surface from one point to the other is assumed to be an inclined plane along which contours logically drawn appear equally spaced. The mechanics of the process are illustrated in figure 10-10. The drainage skeleton and critical points on which 10-foot contours are to be interpolated is shown in (1), figure 10-10. The procedure is as follows:*

(a) Along the main stream line interpolate the elevations of all stream junctions not shown, such as the stream junction between 91 and 97. The stream rises 6 feet from 91 to 97, and this rise is assumed to be evenly distributed along the stream. Therefore, the rise above 91 at any intermediate point, such as the stream junction under consideration, is the proportional part of 6 feet which the distance from 91 to this stream junction bears to the distance from 91 to 97. The rise, therefore, is 3 feet above 91 and the elevation sought is 94, which is written down.

(b) It is now possible to interpolate contour intervals along each tributary stream from its source to its confluence with the main stream. This is done on the same theory that the slope of the stream is uniform between confluence and source, the two points whose elevations in each case are known. The contours cross the stream at equidistant intervals at points whose elevations are multiples of 10. The crossings are indicated lightly by V-shaped marks pointing upstream. This is illustrated in figure 10-10.

(c) Next determine, by interpolation between the critical points of the hill and opposite points on the stream, where 10-foot contours fall, and indicate by lightly drawn dashes ((2), fig. 10-10).

(d) Finally, sketch in the contours joining these V's and dashes by carefully drawn lines, crossing the ridges or spurs in broad curves and crossing the stream in sharp V's gradually changing to curves toward the mouth. In sketching in the contour, one ground form should be built up at a time. In the illustration, each spur between two streams should be taken up and completed in turn, preferably working progressively upstream.

* For metric measurements the same procedure is followed using rounded figures such as 100 or 300 meters or centimeters.

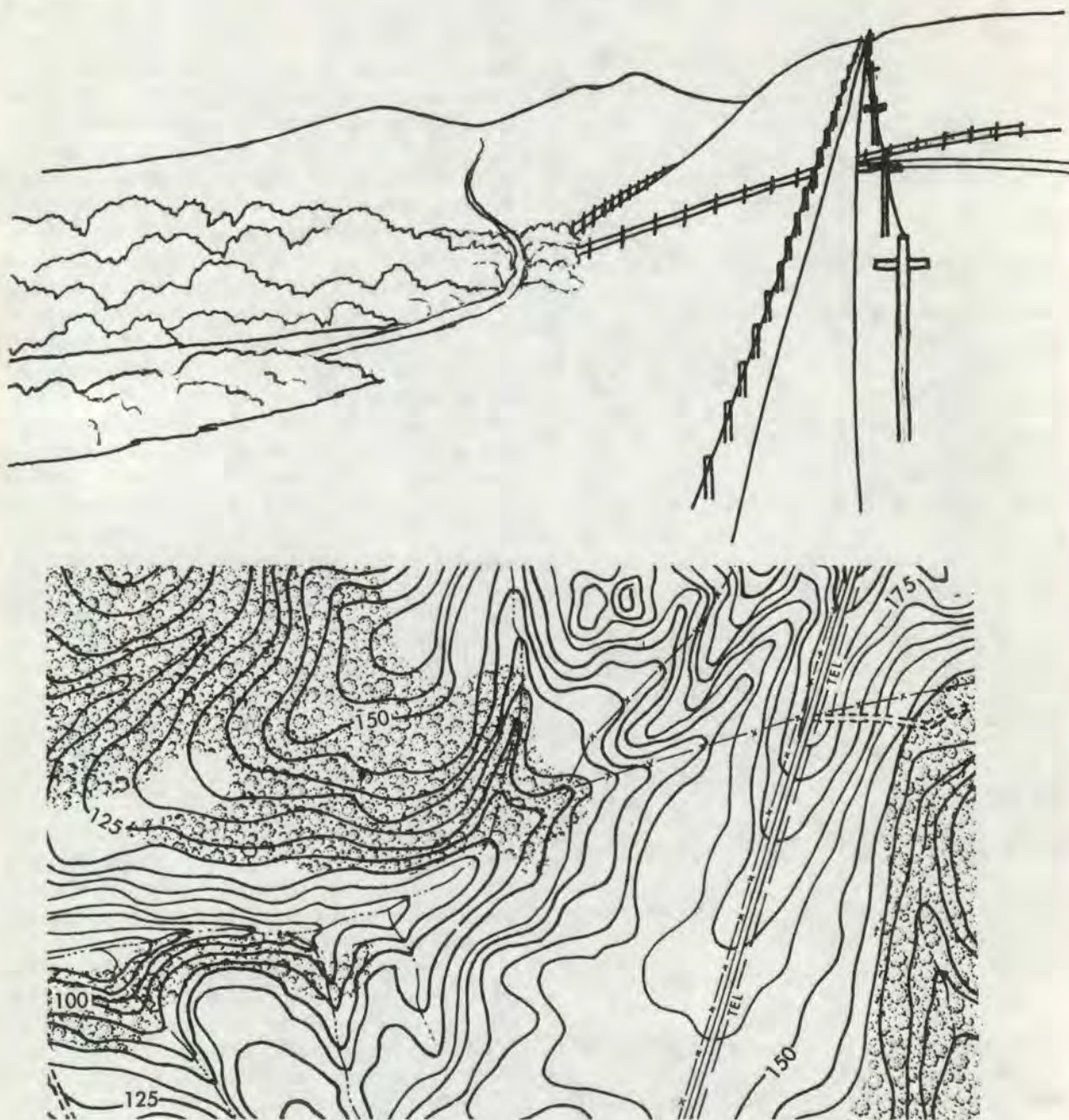


Figure 10-11. Comparison of panoramic and military sketches.

(e) The completed form, (3), figure 10-10, should have all guide elevations and lines carefully removed and the contours numbered or indicated across the sheet. Every fifth contour beginning with zero should be emphasized by a heavy line. In the illustration only contour 100 is in this category.

(3) After the sketch is completed and when

time permits, the sketch should be checked and any errors or omissions corrected. Great care must be exercised in the use of symbols and any deviation from the standard symbols must be explained by the inclusion of a legend. A title box must always be included in any sketch in order that the user may evaluate the sketch. The items that must be in-



Figure 10-12. A perspective drawing.

cluded are—

- (a) Descriptive title (location).
- (b) Date.
- (c) Name, grade, and organization of sketcher.
- (d) Scale and contour interval.
- (e) Graphic scale.

10-3. Panoramic Sketching

a. Description. A panoramic sketch is a pictorial representation of the terrain in elevation and perspective as seen from one point of observation. It shows the horizon which is always of military importance, and intervening features such as crests, woods, structures, roads, fences, and so on. It is an excellent means for target designation and may be effectively used for illustrating a reconnaissance, supplementing and clarifying written reports, and assigning objectives and sectors. Its great value lies in the rapidity with which it can be made and read. A trained panoramic sketcher can quickly prepare a sketch which conveys information of military value

that is easily read and understood. A comparison of a panoramic sketch and a military sketch or map is shown in figure 10-11.

b. Principles. An understanding of the principles of perspective drawing may assist the sketcher, but it is not a prerequisite to the drawing of a panoramic sketch. If a sketch were made, as in figure 10-12 looking through a window, keeping the eye stationary, and tracing on the window glass the outline of the objects exactly as they appear through it, the result would be a perspective drawing.

(1) The horizon line is the line formed by the intersection with the ground of a horizontal plane at the height of the sketcher's eye (fig. 10-13). In level country and over water, the horizon line is coincident with the skyline. In rolling country the horizon line is a little below the lowest point in the skyline, or where the skyline would be if the country were flat. In figure 10-13 the horizon line is approximately on line with the floor of the back of the building which appears, to the observer, to be the highest point of the floor.

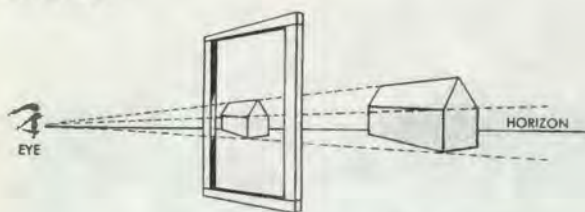


Figure 10-13. Horizon line.

(2) Lines which actually are parallel on the ground appear to converge as they recede and, if produced, appear to meet or vanish at a point called the vanishing point of that system of parallel lines. The correct effects of distance, direction, and slopes which are commonly attributed to the artist's inspiration are in reality at the command of anyone who will study and apply the following rules:

(a) Parallel lines, which on the ground are horizontal, vanish at a point on the horizon (fig. 10-14).

(b) Parallel lines, which on the ground slope downward away from the observer, vanish at a point below the horizon (1, fig. 10-15).

(c) Parallel lines, which on the ground slope upward away from the observer, vanish at a point above the horizon (2, fig. 10-15).

(d) Parallel lines receding to the right vanish to the right; those receding to the left vanish to the left (3, fig. 10-15).

(e) The degree of convergence in perspective varies with the angle made by the parallel lines with the observer's line of sight. Parallel lines nearly in the prolongation of the lines of sight appear to remain parallel. Vertical lines on the terrain remain vertical in perspective.

(f) The apparent size of any object varies with its distance from the observer. The farther away the object, the smaller it appears to the observer.

(g) The apparent distances between regu-



Figure 10-14. Vanishing point.

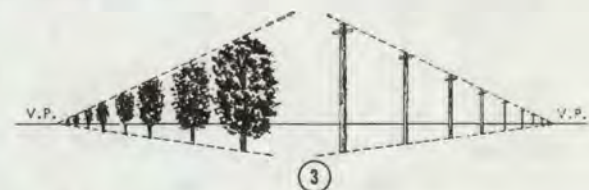
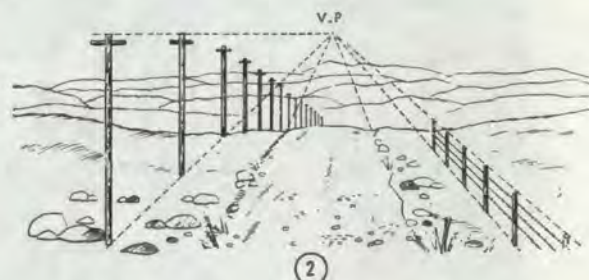
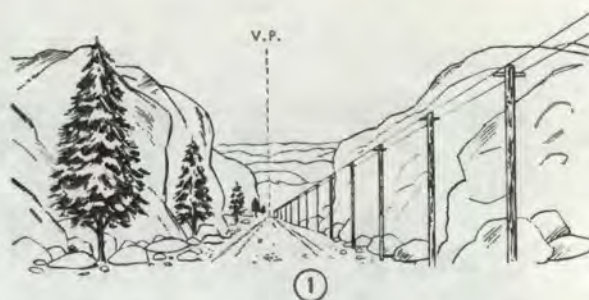


Figure 10-15. Various types of vanishing points.

larly spaced objects vary with their distances from the observer (E, fig. 10-17) in the same way the apparent size varies.

c. Steps in Perspective Drawing.

(1) Figure 10-16 shows the successive steps in the perspective drawing of a house. It is not intended that this detailed method of drawing be used in hasty sketching. Practice in this method, however, is the best means of learning to apply the rules of perspective. It makes possible the correction of errors in hasty sketches.

(2) The successive steps in the perspective drawing of a section of terrain are illustrated in figure 10-17. This figure represents a topographic map of a road first extending due north, then east, and then due north again as far as the eye can see, over level ground. A row of trees of approximately

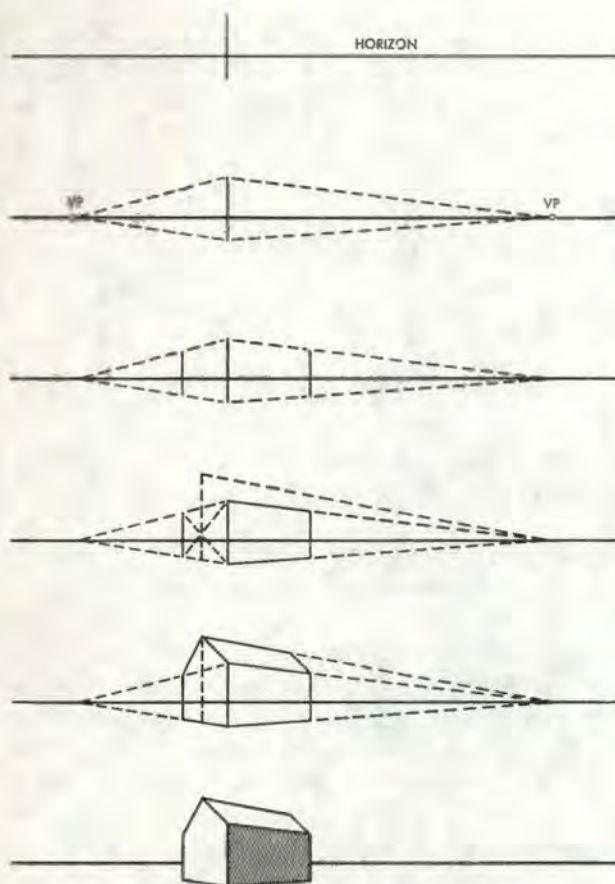


Figure 10-16. Steps in the perspective drawing of a house.

uniform height borders on the left side of the road and the sketcher is assumed to be standing at the right side of the road. Figure 10-17 shows how the sketch is built up in the correct perspective. The two road sections extending north have a common vanishing point in the horizon and their sides converge very rapidly. The sides of the road extending east remain parallel in perspective and the heights of the trees along this section are uniform.

d. Delineation.

(1) Delineation is the portrayal of objects or features of the landscape as they appear to the observer. Absolute simplicity is essential in a panoramic sketch. No line is drawn without a definite idea of what it represents and its valid necessity.

(2) The skyline, crests, and roads are the main control lines of the sketch and are drawn in first to form a framework within which the details are properly placed.

(3) Refer to figure 10-18. Features are represented with a few, rather than many, lines. Pref-

erably a conventional outline is employed. This increases both speed and clarity and leaves room for the addition of important details without overcrowding the sketch. The effect of distance is created by making the lines in the foreground heavy, and distant hills very light. Full lines are better than broken ones. Important details in the distance can be drawn heavily or enlarged for emphasis.

(4) A light hatch may be used to distinguish wooded areas from open fields when necessary. When consecutive tree groups are partially superimposed, alternate groups should be hatched. Hatching (fig. 10-19) should follow the natural lines of an object, such as the courses of masonry in a wall. A firm, continuous line should be used throughout, and feathered and undecided lines avoided.

e. *Shade and Shadow.* Shade and shadow should be used only for improving the readability of the sketch. It is almost always possible to give all the information needed by the use of outline drawing in perspective. When time permits, some features may be made to stand out more clearly by the proper use of shade and shadow. Because of its limited application to field sketching, the theory of shade and shadow will not be discussed in detail; however, sketchers are cautioned that a single direction of

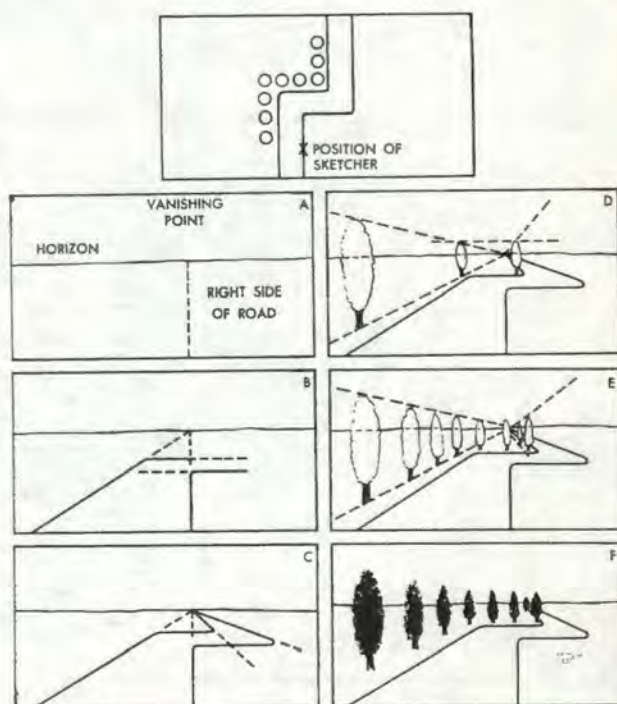


Figure 10-17. Steps in preparing a panoramic sketch of a road.

light rays must be assumed for the entire sketch, with the result that all objects will be shaded on the same side.

f. Equipment.

(1) Panoramic sketches can be made with no other equipment than paper and pencil. The following articles, however, are valuable aids to the sketcher:

- (a) Compass.
- (b) Field glasses.
- (c) Knife.
- (d) Eraser.
- (e) Sketching pad or notebook.
- (f) Several pencils.
- (g) Mil rule.

(2) A medium hard and medium soft pencil are desirable. A map of the terrain is useful if available. From it the names of towns, rivers, and mountains may be determined and ranges to prominent objects obtained. A mil rule may be used to measure deflec-

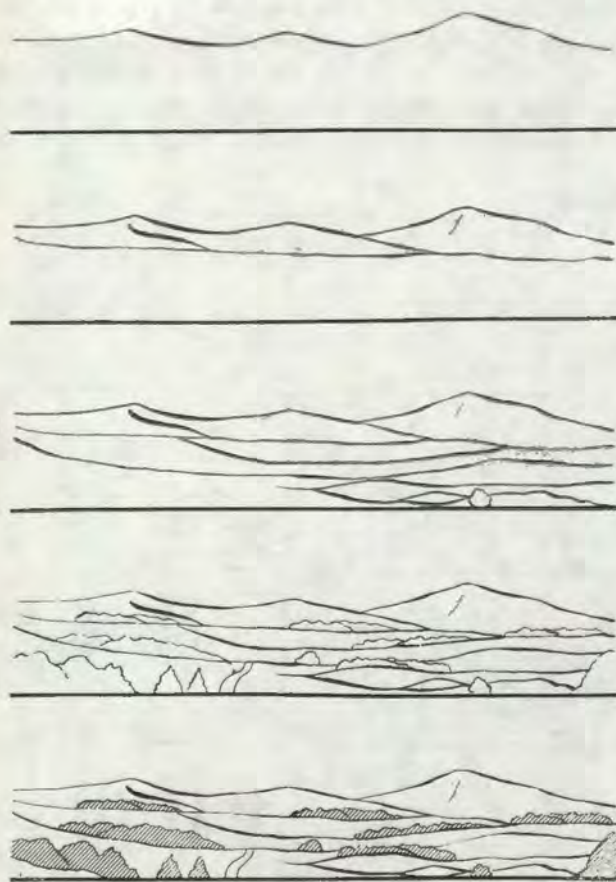


Figure 10-18. Delineation showing the order in which a sketch is built up.

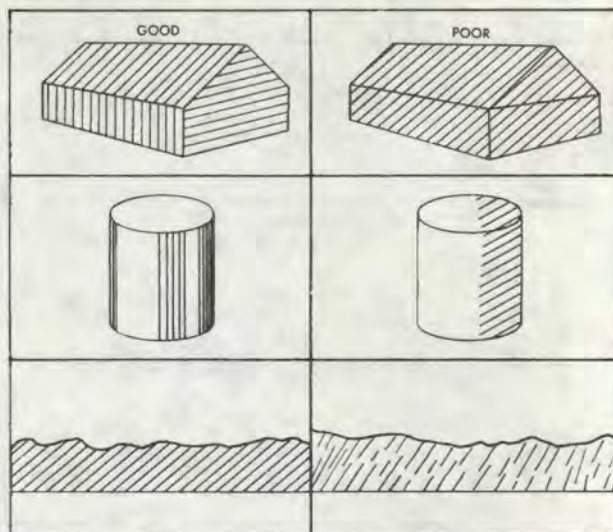


Figure 10-19. Good and poor hatching.

tions. One can be improvised by laying off on a strip of cardboard a series of marks $\frac{3}{4}$ -inch apart, attaching a string to the center of the strip, and making a knot in the string 15 inches from the scale. Hold the knot between the teeth and look over the extended scale. At that 15-inch distance, each of the $\frac{3}{4}$ -inch spaces measures 50 mils.

g. Sketching Sheet.

(1) Figure 10-20 shows a reduced copy of a sheet from the sketching pad, with explanatory notes. The sketching pad provides space for recording necessary data in a systematic and uniform manner, and provides vertical guidelines spaced $\frac{3}{4}$ -inch apart for horizontal measurement. Since there are nine of these $\frac{3}{4}$ -inch spaces, each of which covers 50 mils at the scale most frequently used, it follows that a sector 450 mils in width can be covered in a single sketch.

(2) The sketching pad is a useful and convenient aid to the sketcher, and in the discussion which follows it is assumed that it will be used. However, it should be kept in mind that it is not an indispensable item of equipment and that if correct principles are followed, a perfectly satisfactory sketch can be made on a message blank or any other sheet of paper.

h. Preliminary Study of Terrain. Before beginning to sketch, the sketcher should carefully study the landscape so that he may distinguish the various crest lines in their proper relationship. If a map of the area is available, it should be studied in conjunction with the terrain. Field glasses are valuable

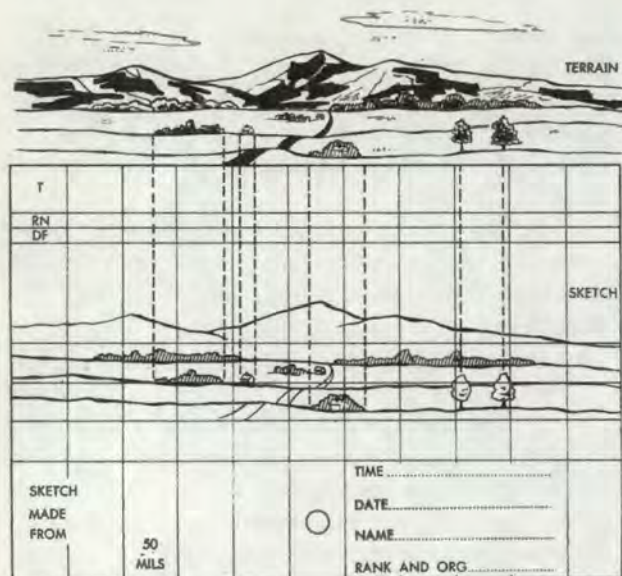


Figure 10-21. Location of features (methods 1 and 2).

will serve to locate the corresponding features on the sketch.

(3) *Method 3.* Measure deflections from the reference point by holding the pencil 15 inches from the eye (fig. 10-22). The distances measured may then be transferred directly to the sketch.

(4) *Method 4.* Measure deflections with the mil rule (fig. 10-23). If the mil rule is of the same scale as the sketch, it may be used to lay off the measurements directly. If not, deflections may be indicated by means of the 50-mil guidelines.



Figure 10-22. Location of features (method 3).

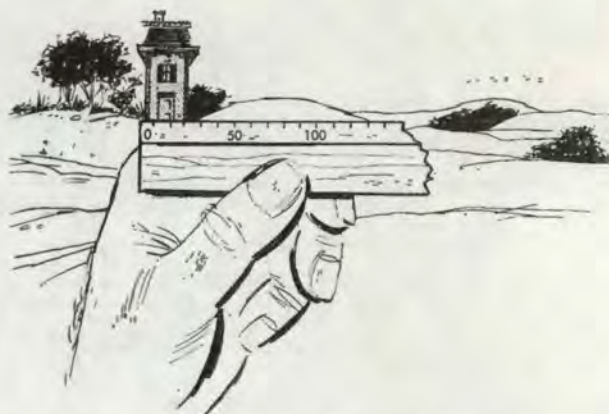


Figure 10-23. Location of features (method 4).

n. Choice of Methods.

(1) No one method is best suited for all kinds of work. A combination of methods should be used in most sketches. Method 1 is rapid and simple, and especially valuable at the beginning of the sketch to fix the skyline and the deflection to a few prominent features. It should not be used for filling in small details. Method 2 is similar to the first and may be used to begin the sketch. Its most appropriate use is for the location of a number of details at one time. Methods 3 and 4 are of value principally for checking deflections and measuring the width and height of objects and their distance from the skyline.

(2) Figure 10-24 shows a variation of method 2, using the pencil as a guide in extending the vertical lines downward, while the pad is held up against the landscape.

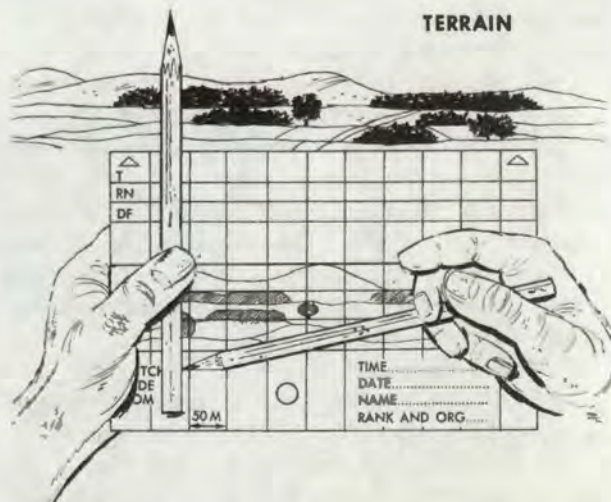


Figure 10-24. Location of features (variation of method 2).

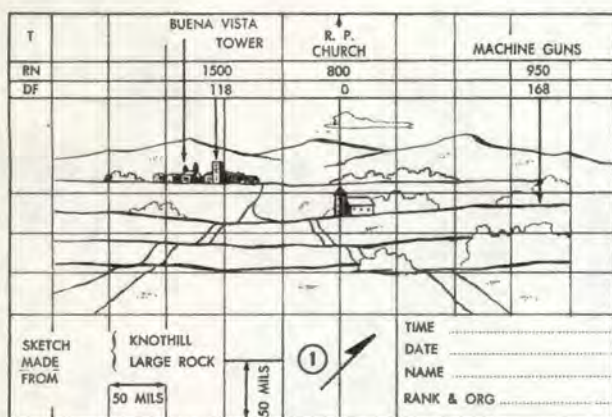


Figure 10-25. Completed panoramic sketch.

o. Details.

(1) Only the following classes of details should be drawn in the sketch.

(a) Those details which are of military importance in themselves. Examples are possible targets, objectives, natural obstacles, sector limits, or positions of troops.

(b) Those details which aid in the location of details or positions of military importance.

(2) Details should not be added simply to fill up space or improve the appearance of the sketch.

The addition of detail will depend largely upon the purpose for which the sketch is made. A sketch drawn for the purpose of portraying the terrain in general naturally will contain more detail than one whose purpose is showing the location of a single target. The latter, however, probably will show more detail in the vicinity of the target than does a general sketch of the same terrain. When the sketch supplements a map, particular attention should be given to important details not shown on the map. When it supplements a report or message, it should show clearly the features or positions mentioned in the communication.

(3) As in other military tasks, the sketcher must keep his mission constantly in mind and make the type of sketch which will be of the greatest possible value to those for whom it is intended, and yet not consume so much time in preparation that it will be of less value than a simpler sketch which reaches its destination correspondingly sooner.

(4) After completing the actual sketching, data regarding targets or other important features should be shown by extending vertical lines through the spaces at the top of the sheet and noting the information as shown in figure 10-25. Any additional data required should be added to the sketch as soon as completed.

APPENDIX A

REFERENCES

A-1. Army Regulations

AR 117-5	Military Mapping and Geodesy
AR 320-5	Dictionary of United States Army Terms
AR 320-50	Authorized Abbreviations and Brevity Codes

A-2. Pamphlets

DA Pam 108-1	Index of Army Films, Transparencies, GTA Charts, and Recordings
DA Pam 310-series	Military Publications Indexes

A-3. Field Manuals

FM 5-1	Engineer Troop Organizations and Operations
FM 5-30	Engineer Intelligence
FM 5-34	Engineer Field Data
FM 5-35	Engineers' Reference and Logistic Data
FM 5-36	Route Reconnaissance and Classification
FM 5-146	Engineer Topographic Units
FM 6-40	Field Artillery Cannon Gunnery
FM 21-5	Military Training Management
FM 21-6	Techniques of Military Instruction
FM 21-30	Military Symbols
FM 21-31	Topographic Symbols
FM 30-5	Combat Intelligence
FM 30-10	Terrain Intelligence
FM 101-10-1	Staff Officer Field Manual

A-4. Technical Manuals

TM 5-230	General Drafting
TM 5-231	Mapping Functions of the Corps of Engineers
TM 5-232	Elements of Surveying
TM 5-233	Construction Surveying
TM 5-239	High Precision Military Stereoplotter
TM 5-240	Map Compilation, Color Separation, and Revision
TM 5-241-series	The UTM Grid Systems
TM 5-243	Cartographic Aerial Photography
TM 5-244	Multiplex Mapping
TM 5-245	Map Reproduction
TM 5-248	Foreign Maps
TM 5-249	Terrain Models and Relief Map Making
TM 5-441	Topographic Surveying
TM 30-245	Photographic Interpretation Handbook
TM 30-246	Tactical Interpretation of Air Photos

APPENDIX B

UNITS OF MEASURE AND CONVERSION FACTORS

B-1. English System of Linear Measure

12 inches	= 1 foot
36 inches	= 1 yard
3 feet	= 1 yard
1,760 yards	= 1 mile statute
2,026.8 yards	= 1 mile nautical
5,280 feet	= 1 mile statute
6,080.4 feet	= 1 mile nautical
63,360 inches	= 1 mile statute
72,963 inches	= 1 mile nautical

B-2. Metric System of Linear Measure

1 millimeter	= 0.1 centimeter	= 0.0393 inch
10 millimeters	= 1.0 centimeter	= 0.3937 inch
10 centimeters	= 1.0 decimeter	= 3.937 inches
10 decimeters	= 1.0 meter	= 39.37 inches
10 meters	= 1.0 decameter	= 32.81 feet
10 decameters	= 1.0 hectometer	= 328.1 feet
10 hectometers	= 1.0 kilometer	= 0.62 mile
10 kilometers	= 1.0 myriameter	= 6.21 miles

B-3. Equivalent Units of Angular Measure

1 mil ()	= 1/6400 circle	= 0.05625°	= 0.0625 grad
1 grad	= 1/400 circle	= 16.0 mils	= 0°54' = 0.9°
1 degree	= 1/360 circle	= approx 17.8 mils	= approx 1.1 grad

B-4. Ground Distance at Map Scale

<i>Scale</i>	<i>1 inch equals</i>	<i>1 cm equals</i>
1:5,000	416.67 ft 127.00 meters	164.0 ft 50 meters
1:10,000	833.33 ft 254.00 meters	328.1 ft 100 meters
1:12,500	1,041.66 ft 317.0 meters	410.1 ft 125 meters
1:20,000	1,666.7 ft 508.00 meters	656.2 ft 200 meters
1:25,000	2,083.3 ft 635.00 meters	820.2 ft 250 meters
1:50,000	4,166.7 ft 1,270.0 meters	1,640.4 ft 500 meters
1:63,360	5,280.0 ft (1 mile) 1,609.3 meters	2,078.7 ft 633.6 meters
1:100,000	8,333.3 ft 2,540.0 meters	3,280.8 ft 1,000 meters
1:250,000	20,833 ft 6,350.0 meters	8,202.0 ft 2,500 meters
1:500,000	41,667 ft 12,700 meters	16,404.0 ft 5,000 meters

B-5. Conversion Factors

One	Inches	Feet	Yards	Statute miles	Nautical miles	mm
Inch.....	1	0.0833	0.0277	-----	-----	25.40
Foot.....	12	1	0.333	-----	-----	304.8
Yard.....	36	3	1	0.00056	-----	914.4
Statute Mile.....	63,360	5,280	1,760	1	0.8684	-----
Nautical Mile.....	72,963	6,080	2,026	1.1516	1	-----
Millimeter.....	0.0394	0.0033	0.0011	-----	-----	1
Centimeter.....	0.3937	0.0328	0.0109	-----	-----	10
Decimeter.....	3.937	0.328	0.1093	-----	-----	100
Meter.....	39.37	3.2808	1.0936	0.0006	0.0005	1,000
Decameter.....	393.7	32.81	10.94	0.0062	0.0054	10,000
Hectometer.....	3,937	328.1	109.4	0.0621	0.0539	100,000
Kilometer.....	39,370	3,281	1,094	0.6214	0.5396	1,000,000
Myriameter.....	393,700	32,808	10,936	6.2137	5.3959	10,000,000

One	cm	dm	m	dkm	hm	km	mym
Inch.....	2.540	0.2540	0.0254	0.0025	0.0003	-----	-----
Foot.....	30.48	3.048	0.3048	0.0305	0.0030	0.0003	-----
Yard.....	91.44	9.144	0.9144	0.0914	0.0091	0.0009	-----
Statute Mile.....	160,930	16,093	1,609	160.9	16.09	1.6093	0.1609
Nautical Mile.....	185,325	18,532	1,853	185.3	18.53	1.8532	0.1853
Millimeter.....	0.1	0.01	0.001	0.0001	-----	-----	-----
Centimeter.....	1	0.1	0.01	0.001	0.0001	-----	-----
Decimeter.....	10	1	0.1	0.01	0.001	0.0001	-----
Meter.....	100	10	1	0.1	0.01	0.001	0.0001
Decameter.....	1,000	100	10	1	0.1	0.01	0.001
Hectometer.....	10,000	1,000	100	10	1	0.1	0.01
Kilometer.....	100,000	10,000	1,000	100	10	1	0.1
Myriameter.....	1,000,000	100,000	10,000	1,000	100	10	1

Example I

Problem: Reduce 76 centimeters to (?) inches

$$76 \text{ cm} \times 0.3937 = 29 \text{ inches.}$$

Answer: There are 29 inches in 76 centimeters.

Example II

Problem: How many feet are there in 2.74 meters?

$$\frac{2.74}{.3048} = 9 \text{ feet}$$

Answer: There are approximately 9 feet in 2.74 meters.

APPENDIX C

JOINT OPERATIONS GRAPHICS (JOG)

C-1. Introduction

Joint Operations Graphics (JOG) (para 1-9b(5)) are based on the format of the standard 1:250,000 scale military topographic maps and contain additional information needed in present-day joint air-ground operations.

C-2. Types

Each graphic is prepared in two types; one is designed for air operations and the other for ground operations. Each version is identified in the lower margin as JOINT OPERATIONS GRAPHIC (AIR) or JOINT OPERATIONS GRAPHIC (GROUND).

C-3. Contents

a. The basic topographic information is the same on both JOG versions.

b. Power transmission lines are symbolized as a series of purple pylons connected by a solid purple line.

c. Airports, landing facilities, and related air information are shown in purple. The top of each obstruction to air navigation is identified by its elevation above sea level and its elevation above ground level.

d. The purple symbols which may be unfamiliar

to the user are shown in the legend in the margin (fig. E-5 and E-6).

e. Along the north and east edges of the graphic, detail is extended beyond the standard sheet lines to create an overlap with the graphics to the north and to the east.

f. Layer tinting (para 6-5a) and relief shading (para 6-5c) are added as an aid to interpreting the relief.

g. The incidence of the graphic in the World Geographic Reference System (GEOREF) (para 3-9) is shown by a diagram in the margin.

C-4. Joint Operations Graphic (Air)

The JOG (AIR) series, prepared for air use, contains detailed information on air facilities such as radio ranges, runway lengths, and landing surfaces (fig. E-5). The highest terrain elevation in each 15 minute quadrangle is identified by the large open-faced figures shown in the legend. Elevations and contours on JOG (AIR) sheets are given in FEET.

C-5. Joint Operations Graphic (Ground)

The JOG (GROUND) series is prepared for use by ground units, and only stable or permanent air facilities are identified (fig. E-6). Elevations and contours are located in the same positions as on the air version, but are given in METERS.



Figure D-2. Pictomap at 1:25,000 scale. This map is produced as a photo base from recent photography. The photo base is given an image enhancement treatment and key features are cartographically delineated. The black outline shows the area covered by the city map (fig. D-1).



Figure D-4. Topographic map at 1:250,000 scale. This is the standard tactical planning map of the U.S. Army and is called a Joint Operations Graphic, Ground, Series 1501. There is a companion map modified for use by aviators, called Series 1501 Air. The black outline shows the area covered by the topographic map (fig. D-3).

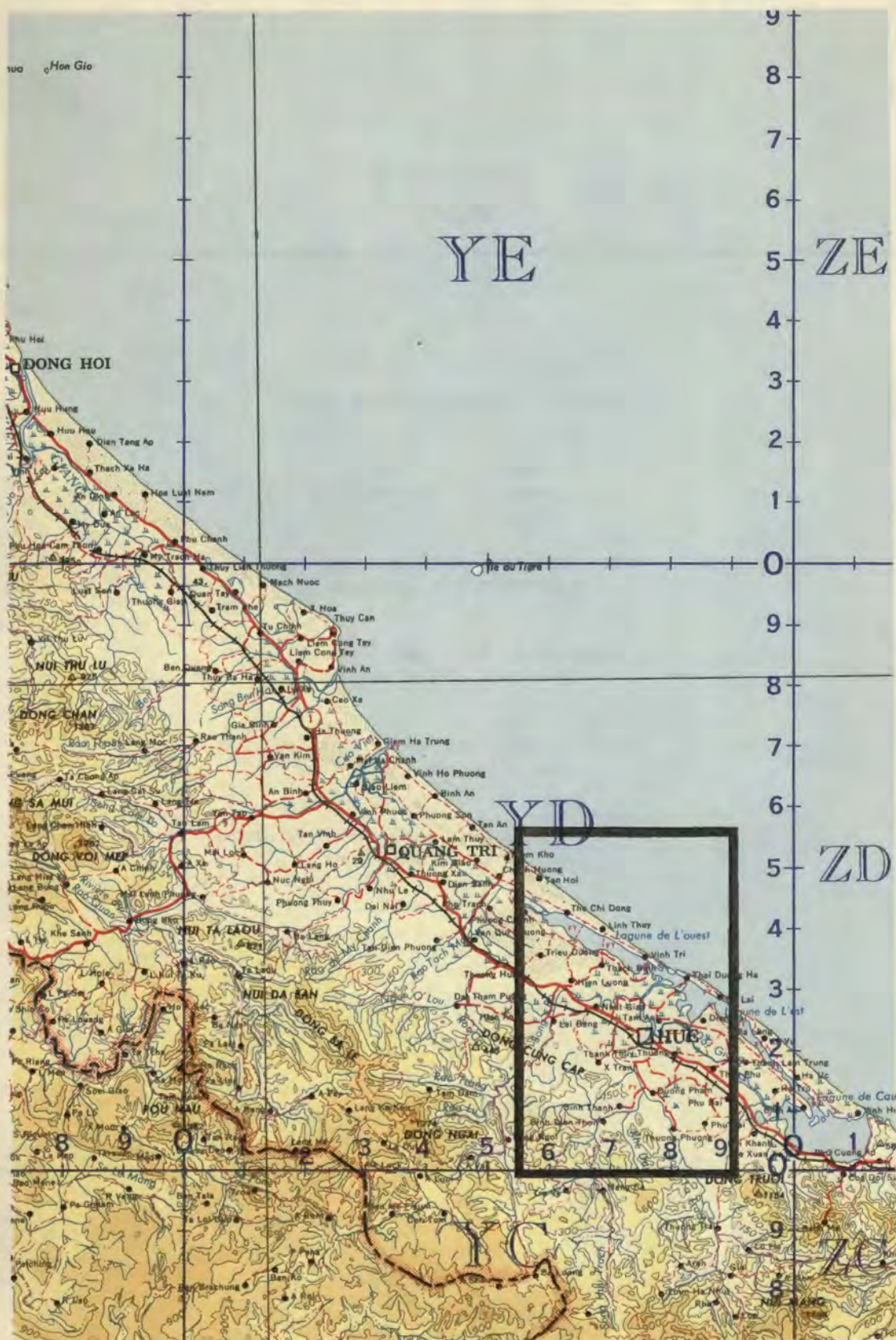


Figure D-5. Topographic map at 1:1,000,000 scale. This is the standard strategic planning map of the U.S. Army. Other small scale maps are available and are listed in the USAMSS Small Scale Catalogs. The black outline shows the area covered by the 1:250,000 scale map (fig. D-4).

APPENDIX E

MAPS

Figure E-1. Plastic relief map (photo).

Figure E-2. Pictomap.
(Located in back of manual)

Figure E-3. Leavenworth topographic map.
(Located in back of manual)

Figure E-4. Leavenworth photomap.
(Located in back of manual)

Figure E-5. Joint operations graphic (air).
(Located in back of manual)

Figure E-6. Joint operations graphic (ground).
(Located in back of manual)



Figure E-1. Plastic relief map (photo).

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