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Shenandoah Mountain Rescue Group BASIC MEMBER TRAINING COURSE
Keith Conover, Editor

MODULE TWO: LAND NAVIGATION
by Keith Conover

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INTRODUCTION

Contents

1. Pretest.....2
2. Land Navigation Standards.....9
3. Supplementary Readings:
A. "Land Navigation".....12
B. "The ASRC Grid System".....37
C. "Aeronautical Navigation for Groundpounders".....41
4. Answers to pretest.....45
5. Posttest.....46

Primary Reading

Topographic Maps, U.S. Geological Survey pamphlet (Washington, DC: Government Printing Office, 1977). A small format 28 page introduction to topographic maps. Available free or at minimal charge from the Group or from the USGS.

Acknowledgements

Section 3A is excerpted from the Virginia Wing, Civil Air Patrol Ground Search and Rescue Manual, Copyright 1978 by Keith Conover. and reproduced with permission.

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Note: this Version contains a few minor corrections and improvements from the previous Version 1.1; the corrections are also available as an errata sheet for Version 1.1.

## LAND NAVIGATION PRETEST

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Shenandoah Mountain Rescue Group  
LAND NAVIGATION PRETEST  
Version 1.2 April 1983

BASIC MEMBER TRAINING COURSE  
Keith Conover, Editor  
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### Notes

1. After taking this pretest, check your answers against the key in the back of this Module. This pretest is representative of the type of written questions that may be asked about land navigation on a certification test, but is not comprehensive.
  2. You will need the following to take this test:
    - \* a protractor
    - \* a ruler or other straightedge
- =====

FOR QUESTIONS 1-15, REFER TO FIGURE 1, AN ASRC-GRIDDED SECTION OF A 7.5' TOPOGRAPHIC MAP QUADRANGLE. (USE OF AN ORIGINAL USGS QUAD OF THIS AREA IS PERMITTED: IT IS THE PETERSBURG WEST, WV QUAD.) MATCH THE LETTER OF THE SELECTION (E.G.: a. church) WITH THE FEATURE FOUND AT THE ASRC COORDINATES GIVEN FOR EACH NUMBER. A GIVEN SELECTION MAY BE USED ONCE, MORE THAN ONCE, OR NOT AT ALL.

- |           |                               |
|-----------|-------------------------------|
| 1) A0205  | a. church                     |
| 2) A0440  | b. benchmark                  |
| 3) A1211  | c. highway or road bridge     |
| 4) A1322  | d. footbridge                 |
| 5) A1405  | e. ford                       |
| 6) A1632  | f. perennial stream           |
| 7) A1503  | g. intermittent stream        |
| 8) A2316  | h. cliff                      |
| 9) A2642  | i. saddle (sag, col)          |
| 10) A2703 | j. knob                       |
| 11) A3640 | k. depression (e.g. sinkhole) |
| 12) A3717 | l. ridge                      |
| 13) A3744 | m. ravine                     |
| 14) A3757 | n. fence line                 |
| 15) A3858 | o. cow                        |

FOR QUESTIONS 16 and 17, REFER TO FIGURE 2.

16) What is the 7.5 minute quad directly south of this one? (Petersburg West quad)

- a. Upper Tract
- b. Mozer
- c. Milam
- d. 164

LAND NAVIGATION PRETEST

17) What is the magnetic declination in the area shown on this map (as of 1969, in the center of the quad)?

- a. 7 degrees 8 minutes West
- b. 7 degrees 8 minutes East
- c. 4 degrees 52 minutes West
- d. 4 degrees 52 minutes East
- e. 6 degrees West
- f. 6 degrees East
- g. 1 degree 8 minutes West
- h. 1 degree 8 minutes East
- i. just a tad over that-a-way

FOR QUESTIONS 18-22, AT EACH SPECIFIED LOCATION ON THE MAP (FIGURE 1), YOU WILL FIND AN X-MARK LABELED "A" AND ONE LABELED "B", BOTH CONNECTED WITH A STRAIGHT LINE. DECIDE WHETHER "A" IS HIGHER, "B" IS HIGHER, OR BOTH ARE AT APPROXIMATELY THE SAME ELEVATION. ANSWER ACCORDING TO THE KEY PROVIDED BELOW:

- 18) A2731
- 19) A0723            a. A is higher
- 20) A3312            b. B is higher
- 21) A1713            c. A and B are at about the same elevation
- 22) A2742

23) Which of the following is false?

- a. magnetic declination varies over time, albeit very slowly
- b. magnetic declination varies across a map, though this is almost insignificant across a 7.5 minute quad
- c. the angle depicted by the declination arrows (e.g. top right of Figure 2) is illustrative, rather than exact; the numbers (e.g. 6 degrees, 1 degree 8 minutes) themselves must be used to set an accurate declination adjustment.
- d. ferromagnetic objects held near a compass may cause error.
- e. if no ferromagnetic objects are held near a compass, the compass needle accurately points at the magnetic North (or South, depending on which end of the needle) Pole.

24) What are the approximate latitude and longitude of Dayton Knob? (A1525 on Figure 1)

- a. 38 degrees 58 minutes North, 79 degrees 13 minutes 30 seconds West
- b. 79 degrees 13 minutes 30 seconds North, 38 degrees 58 minutes West
- c. 38 degrees 58 minutes North, 79 degrees 13 minutes 30 seconds East
- d. somewhere between the North Pole and the equator, but a long way from Greenwich Observatory

## LAND NAVIGATION PRETEST

25) Refer to Figure 1 and Figure 3. In which UMS grid is the intersection of the two forks of the Potomac (upper right corner of Figure 1) found?

- a. 136 A
- b. 136 B
- c. 136 C
- d. 136 D

26) What is the (magnetic) bearing off the Elkins VOR to the river junction specified in #22?

- a. 88 degrees
- b. 82 degrees
- c. 220 degrees
- d. 8 degrees

27) Refer to Figure 1. What is the Military Grid Reference for the point designated, in the ASRC Grid Reference, A1420?

- a. 653 kilometers East, 4314 kilometers North
- b. 740000 feet South, 2500100 feet South
- c. 136 Alfa 1.0, 2.5
- d. none of the above

28) The track of the sun across the Northern Hemisphere Sky is as follows: it rises in the \_\_\_\_\_, crosses to its zenith when it is in the \_\_\_\_\_, and then sets in the \_\_\_\_\_.

- a. East, North, West
- b. East, South, West
- c. West, North, East
- d. West, South, East
- e. left, top, right

29) Refer to Figure 1. Field Team Charlie was checking out the shack along the river (A2921) when they were told that Field Team Foxtrot had made a find at A3206 and that they were to proceed there with all haste. The route the Field Team followed is plotted. Why didn't the team simply cut straight up to Foxtrot from the stream?

- a. The team found a cache of Jack Daniels at the shack by the river and was unable to navigate a straight line.
- b. The team used the intermittent stream as a "handrail", until they could cut up to the jeep trail and make better time; they went to the point where the trail cut away from the stream so they could use that as an attack point.
- c. They knew it is easier to find something coming sidehill rather than from below.
- d. They wanted to sneak up on Team Foxtrot; they were mad because Foxtrot had made the find instead of Charlie.

LAND NAVIGATION PRETEST

30) You are standing at A3040 (on Figure 1). The true bearing to the top of Dayton Knob is:

- a. 225 degrees
- b. 219 degrees
- c. 141 degrees
- d. 39 degrees

31) Given the answer for the above question and the declination off Figure 2, what is the magnetic bearing from A2030 to the summit of Dayton Knob?

- a. 213 degrees
- b. 231 degrees
- c. 225 degrees
- d. 232 degrees 8 minutes
- e. 51 degrees
- f. 185 degrees

32) You are somewhere along Fork Ridge (A2033-A3049) where you and your Field Team were dropped by a helicopter. You need a quick fix on your location because the Base Camp Radio Operator is saying something about the MC needing a position report right now. After making suitable comments about the MC to the rest of the team, you look across the river and get a fix on the cemetery next to Route 28; you read off a magnetic bearing of 342 degrees. What is the true bearing to the cemetery?

- a. 162 degrees
- b. 348 degrees
- c. 336 degrees
- d. 349 degrees 8 minutes
- e. 334 degrees 52 minutes
- f. 168 degrees

33) Given your answer for the above question, which of the following best describes your Field Team's position along Fork Ridge?

- a. A2033
- b. A2236
- c. A2439
- d. A2743
- e. A3048

Figure 1: ASRC-gridded section of Petersburg West, WV 7.5' topographic quadrangle map.

730 000 FEET (SOUTH) 5 4317

MOUTH OF SENECA 15 MI. HOPEVILLE 2.5 MI. 4 4315

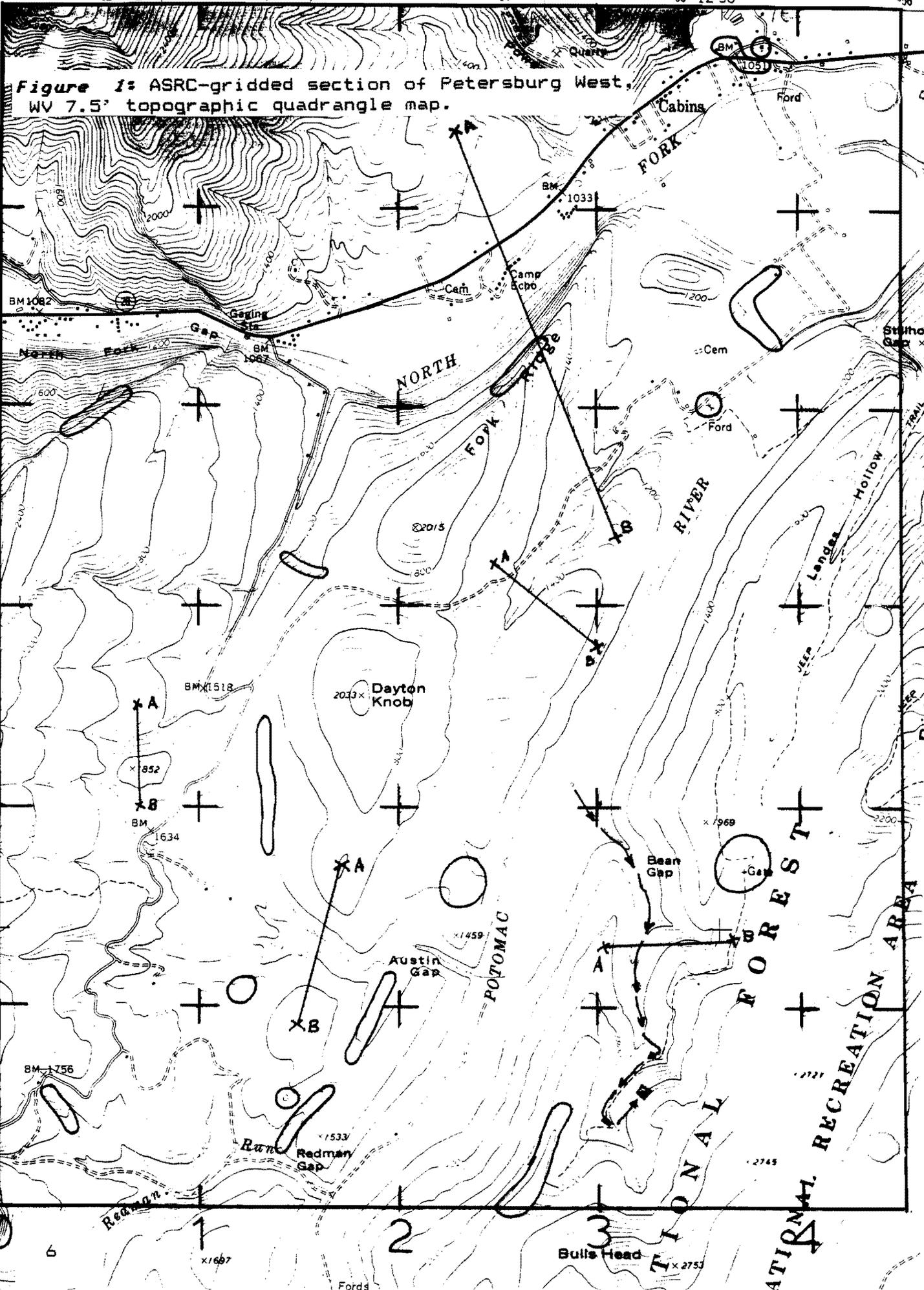
3 4315

2 4314

57' 30"

1 4313

0 4312



6

2

3 Bulls Head x 2753

TONAL FOREST

ATIPNAL RECREATION AREA

38°52'30" 79°15' 652 653 2 080 000 FEET (NORTH) UPPER TRACT 7 MI. 12'30"

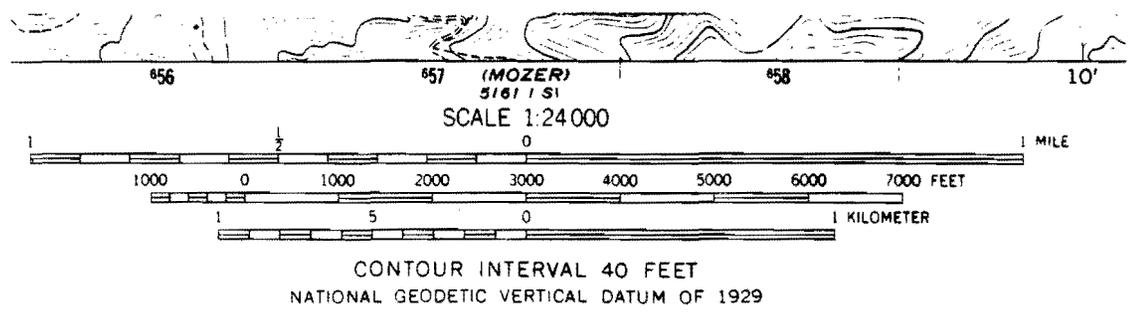
(UPPER TRACT) 5161 NW SE

Mapped, edited, and published by the Geological Survey  
 Control by USGS and USC&GS  
 Topography by photogrammetric methods from aerial photographs taken 1966. Field checked 1969  
 Polyconic projection. 1927 North American datum  
 10,000-foot grids based on West Virginia coordinate system, north and south zones  
 1000-meter Universal Transverse Mercator grid ticks, zone 17, shown in blue

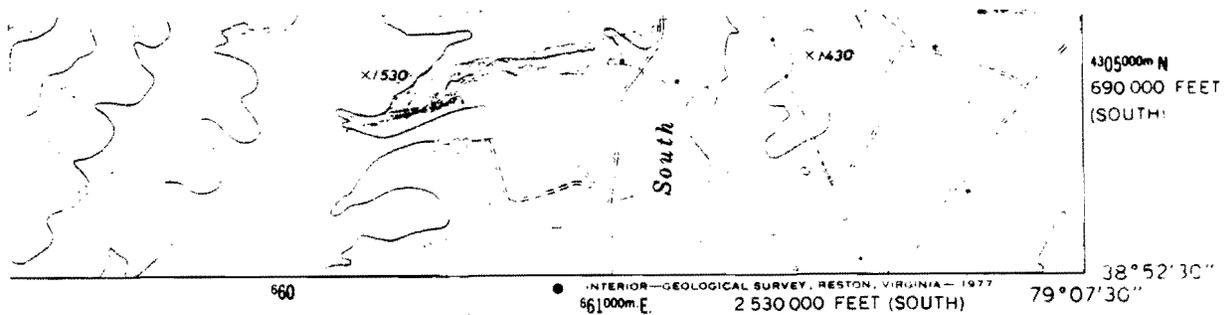
Fine red dashed lines indicate selected fence and field lines where generally visible on aerial photographs. This information is unchecked

6° 107 MILS 1°08' 20 MILS

UTM GRID AND 1969 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET



THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS FOR SALE BY U. S. GEOLOGICAL SURVEY, RESTON, VIRGINIA 22092  
 A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST



ROAD CLASSIFICATION

Primary highway, hard surface	—————	Light-duty road, hard or improved surface	—————
Secondary highway, hard surface	—————	Unimproved road	=====
Interstate Route	—————	U. S. Route	—————
		State Route	—————



PETERSBURG WEST, W. VA.  
 NW/4 PETERSBURG 15' QUADRANGLE  
 N3852.5—W7907.5/7.5

1969

AMS 5161 NW—SERIES V854

Figure 2: Information from bottom of Petersburg West quadrangle.

f) boundaries and fence lines;



Figure 3: Section of UMG-gridded Virginia Aeronautical Chart.

## LAND NAVIGATION STANDARDS

Shenandoah Mountain Rescue Group  
LAND NAVIGATION STANDARDS  
Version 1.2 April 1983

BASIC MEMBER TRAINING COURSE  
Keith Conover, Editor  
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### Notes

1. Standards 1, 1.5, 2, 6a, 6b, and 7 are, strictly speaking, skills standards, but since they lend themselves well to indoor written testing, will be included on written rather than practical tests.
2. The following standards are excerpted from the ASRC Training Guide, Second Edition. These are the basis for all certification tests by the Shenandoah Mountain Rescue Group. Additions by SMRG, indicated by italics, are items the SMRG Training Committee believes important to the education of a well-rounded Basic Member; these will be covered in SMRG training and the tests for this Module, but will not appear on any SMRG Basic Certification Test.

The candidate must be able to demonstrate his ability to do the tasks listed in the following items:

- 1) Given a standard 7.5 minute U.S. Geological Survey (USGS) topographic quadrangle map, correctly identify the following:
  - a) grades of highways, roads, trails, and bridges;
  - b) power and other landmark lines;
  - c) buildings, schools, churches, and cemeteries;
  - d) storage tanks, wells, mines, caves, picnic areas, and campsites;
  - e) benchmarks (control stations) and spot elevations;
  - f) boundaries and fence lines;
  - g) contour lines, depressions, cuts, and fills;
  - h) perennial and intermittent streams, falls, springs, and marshes;
  - i) valleys, ridges, peaks, sags (saddles, cols); and
  - j) elevations and general land contours.

## LAND NAVIGATION STANDARDS

1.5) Given a topographic 7.5 minute quadrangle map, or a copy of the edges of the map, interpret information printed on the map, including:

- a) dates of field checking and photorevision;
- b) scales and contour intervals;
- c) magnetic and grid declination information;
- d) grid ticks for latitude/longitude, the Virginia Grid System, and the Universal Transverse Mercator (UTM) - Military Grid Reference System (MGRS); and
- e) names of adjacent maps.

2) Given a photocopy 7.5 minute series topographic map section with an ASRC grid overprint, the original 7.5 minute quadrangle map, and a Uniform Map System (UMS) gridded aeronautical chart of the area, identify points via:

- a) latitude and longitude;
- b) the ASRC grid system;
- c) the Uniform Map System; and
- d) an azimuth and distance off a VOR (an aeronautical radio-navigation beacon).
- e) the Military Grid Reference System.

2.5) Distinguish the meanings of true north, magnetic north, and grid north; describe the way a magnetic compass functions relative to these, and possible sources of error in using a magnetic compass.

3) Point out the North Star, and describe the way the moon and stars may be used to roughly determine direction.

4) Explain briefly and completely the sun's track across the northern hemisphere sky and the use of the sun's shadow to determine direction.

## LAND NAVIGATION STANDARDS

5) Briefly explain and give examples of the use of the following land navigation concepts:

- a) catching features;
- b) "collecting" features;
- c) attack points;
- d) aiming off; and
- e) coarse and fine orienteering.

6) Given only a 7.5 minute topographic quadrangle or an orienteering map with an attack point and a target plotted on it, and a standard orienteering compass (or a protractor and straight-edge), demonstrate the ability to reliably and accurately:

- a) calculate the true bearing from the attack point to the target;
- b) calculate and set on the compass the magnetic bearing to the target; and
- c) follow the bearing accurately, including triangulating and boxing around obstacles.

7) Correctly locate on a topographic map a position, given:

- a) the bearings to two landmarks indicated on the map (resection); or
- b) the bearing to one landmark indicated on the map, and the information that the position is on a specified linear feature (modified resection).

8) Correctly locate on a topographic map a target, given bearings from two locations to the target (triangulation).

9) Demonstrate the ability to consistently complete basic-level point-to-point orienteering courses.

LAND NAVIGATION

## 8.0 GENERAL

Any GSAR task will employ at least some of the land navigation techniques described in this chapter. Land navigation skills may well be the key to survival in some outdoor emergencies; therefore, every GSAR team member should take care to learn and maintain his or her personal land navigation skills, for personal survival value, if for no other reason.

Land navigation is an art requiring knowledge of the proper use of map and compass. However, this alone is not sufficient; good land navigation also requires the ability to apply navigation concepts in the field. No amount of practice with map or compass alone will guarantee proficiency in land navigation. Cross country travel with map and compass is perhaps the best way to become proficient, and Orienteering (described below) is an ideal way to get this experience.

This chapter will discuss maps and grid systems, compasses, Orienteering, and several specific navigation techniques. The chapter is designed for a reader having studied the U. S. Geological Survey pamphlet "Topographic Maps", or having equivalent knowledge.

## 8.1 TOPOGRAPHIC MAPS AND GRID SYSTEMS

## 8.1.0 General

Maps are necessary for any land navigation. A map is defined as a symbolic representation of the terrain features of a given area, and it may take one of many forms. A mental map derived from past experiences, a pencil sketch and verbal description, or an aerial photograph, all could be used for navigation. However, the best map for general land navigation on foot is one of the topographic maps put out by the U. S. Geological Survey (USGS). Such maps are available for all of Virginia.

A common problem in ground search and rescue is the accurate transmission of geographic position information using voice communications (e.g. radio). To facilitate this process, various systems have been developed for reporting position, most of which are grid systems. Although there are a great many such systems in use, only those of major importance to GSAR personnel will be presented here. These are:

1. The Latitude and Longitude System. Although this is the oldest and most widespread method of indicating position, it is not useful for GSAR, as accuracy of a hundred meters may be vital to GSAR teams. An understanding of it is essential to most other grid systems used for SAR, and it may be used as a reliable but slow last resort.
2. The "Second G in George Washington" System. This system works only when the same map is available at both ends of a communications link. The position is specified by referring to details printed on the map. For example: "We are at a point on the 1580 foot contour line where an intermittent stream crosses it, which is about 2 1/4 inches northeast of the second G in the words George Washington National Forest where they are printed in the top left corner of the map." This system, if it can be called a system, is cumbersome, subject to error, and useful only when a large supply of identical maps are available.
3. The Uniform Map System (UMS). This system is the "official" SAR grid system, such that there can be an official system, and it incorporates the grid system long used by the CAP. It requires the use of pregridded maps, but is quick and easy to use. It is primarily used for downed aircraft search, and is described in section 8.1.2.

4. Lost Person Search Gridding. Lost person search operations are usually confined to a relatively small area. For position reporting during such missions, accuracy is essential, and none of the systems described above can provide such accuracy without becoming complex and confusing. Field Team Leaders are usually provided with a photocopy of a portion of a  $7\frac{1}{2}$  quad, and it is common practice to put a 100 meter grid on the photocopy map, by means of a gridded overlay. Every Field Team Leader, and Base Camp, then has a common large-scale grid system for accurate position reporting.

5. Position and Azimuth (Bearing). Pilots may give GSAR teams position coordinates in terms of an azimuth (a compass direction, or bearing) and distances; or in the form of several azimuths to be used for resection (see section 8.7.2). Such azimuths are usually given from navigational aids called VORs, which are named and identified on aeronautical charts (sectional charts), but not shown on most other types of maps.

### 8.1.1 Topographic Maps

Topographic maps ("topo maps") provide information as to the actual shape of the land surface by means of brown contour lines. At first glance, these lines will probably seem meaningless or confusing to the untrained map reader. However, to one used to such maps, the contour lines provide a wealth of information, and make the terrain "leap out" as if he were looking at a scale model of the area. Rapid interpretation of contour lines takes practice, but the skill is easily retained.

The USGS publishes a folder entitled "Topographic Maps" which serves as an excellent introduction and reference to topographic maps, and which is available from the USGS at little or no cost. The reader is urged to refer to it at this point, as the remainder of this chapter will assume familiarity with its contents.

Every  $7'30"$  x  $7'30"$  quadrangle ( $7\frac{1}{2}$  quad) has certain border information which is of great importance. As an example, we will consider the Waynesboro East  $7\frac{1}{2}$  quad, shown in Figure 8-1. Explanation of the relevant border information is given below.

1. Name. Each map is designated by a unique place-name, a series, (e.g.  $7\frac{1}{2}$  minute topographic series), and by the state(s) which have land shown on the map. This information is found in the upper right corner.

2. Date. In the lower right corner, the map name is reproduced, along with some index numbers. A map date is given, which represents the completion date of the map. (See also number 7).

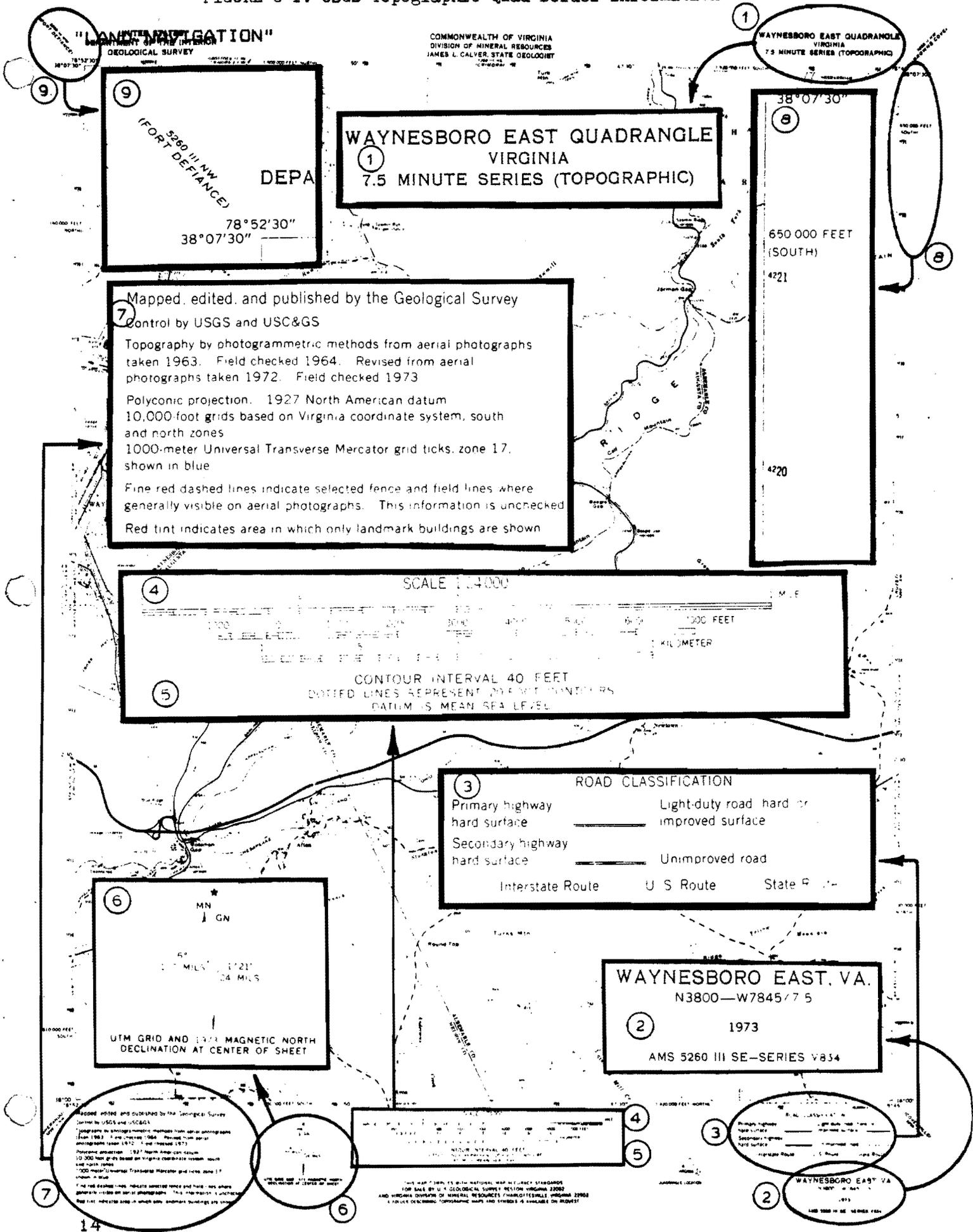
3. Road Classification. Directly above the name and date (number 2), a key to the road symbols is given. This is not the complete topographic map legend; the legend is issued separately, and is shown also on pages 20-21 of "Topographic Maps."

4. Scale. At the bottom center of the sheet, the map scale is indicated in two ways. First, the ratio of map distance to actual distance is given, 1:24,000 being standard for  $7\frac{1}{2}$  quads. Second, a graphic scale of miles, feet, and kilometers is displayed. Directly under the scale is notation of the contour interval used.

5. Contour Interval. The contour interval is the elevation difference between adjacent contour lines. If additional supplemental (dotted) contour lines are used, their use is usually shown here.

6. Declination. A set of three arrows is shown, which indicate the directions of grid north (GN), magnetic north (MN), and map ("true") north (star). These arrows indicate a general direction only and should not be used for orienting a map. The measure of each declination angle (true-magnetic and true-grid) is provided in de-

FIGURE 8-1: USGS Topographic Quad Border Information



degrees and in mils. (There are 6400 mils to  $360^\circ$ .) For this map, the magnetic declination is  $6^\circ$  West, meaning that magnetic north is six degrees west (counterclockwise) of true or map north. Note that grid north and map north are not the same; map north is "true" north, and the edges of the map are lined up map north-south and map east-west. Grid north refers to north in the Universal Transverse Mercator (UTM) grid system, which is no importance for routine land navigation. Also, the phrase "at center of sheet" under the arrows serves to remind us that declination may vary from one part of a map to another. In Virginia, this variation across a map is usually a small fraction of a degree, and may be ignored for our purposes. However, large changes in declination may be brought about by the presence of a ferromagnetic body, such as an outcrop of iron ore, a scrap of metal on the ground, or a belt buckle brought near the compass.

7. Mapping Information. This information expands on the bare fact of the map date, providing information as to when and how the mapping was carried out. Additional information concerning the map is often given here.

8. Edge Information. Around the edge of the map are blue and black "ticks" which key the map to the UTM and Virginia grid systems, respectively. These are of little importance for GSAR. Shown also are markings and ticks indicating latitude and longitude; care should be taken not to confuse the latitude/longitude ticks with those for the two grid systems.

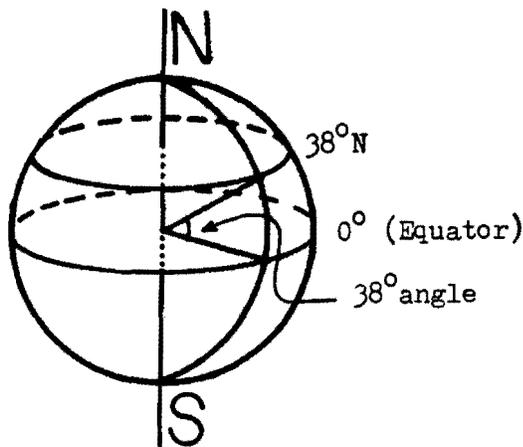
9. Key to Adjacent Maps. In the center of each side of the map, and at each corner, a map name is printed in parentheses and italics. This provides the map user with the names of all surrounding quadrangles.

### 8.1.2 Latitude and Longitude

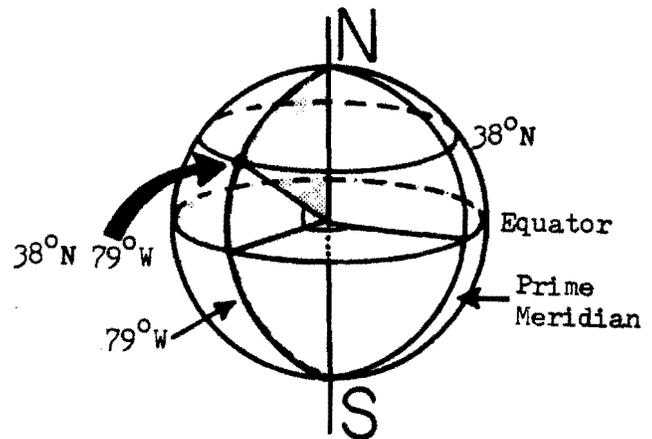
The coordinate system for the earth's surface known as latitude and longitude has international acceptance. The words are Latin: Romans referred to the direction along the axis of the Mediterranean Sea as longitude, and the direction across it as latitude. Latitude now refers to a point's north-south position on an arc (actually, close to a half-circle) drawn from the north pole to the south pole. All such arcs may be divided into degrees, as can any part of a circle, and there are therefore 180 degrees ( $180^\circ$ ) in each such arc. (There are  $360^\circ$  in a full circle.) The latitude of  $0^\circ$  is arbitrarily set at the equator, and latitude is described as being north or south of the equator. Thus  $90^\circ$  north is at the north pole, and  $90^\circ$  south is at the south pole. If all points of equal latitude were to be connected by a line, a circle would result which is referred to as a parallel. An example of this is shown in figure 8-2a.

If any line of latitude describes a circle, then we may again use degree measure to refer to points on this circle. For reference, all points along a north-south arc through Greenwich, England are referred to as being at a longitude of  $0^\circ$ . This north-south line of  $0^\circ$  longitude is referred to as the Prime Meridian, and all other north-south lines are referred to as meridians, as shown in figure 8-2b. Longitude is measured in degrees east or west of Greenwich; therefore,  $180^\circ$  east and  $180^\circ$  west both describe the same meridian, which is at the exact opposite side of the world from the Prime Meridian going through the Royal Observatory at Greenwich.

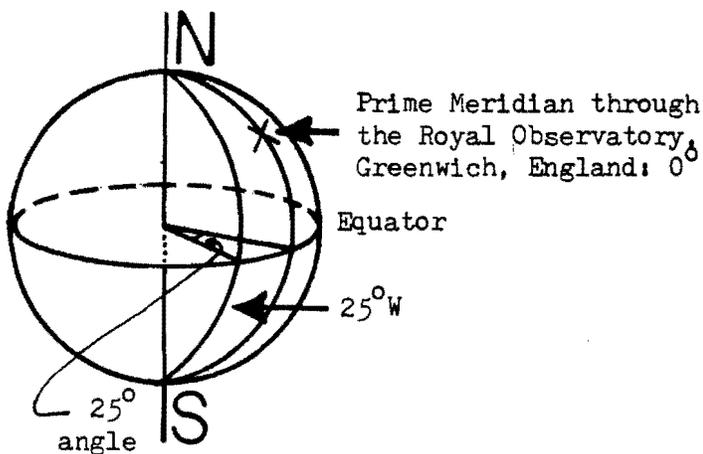
A location may then be totally and precisely located by its latitude and longitude, as illustrated in figure 8-2c. When locations must be specified to greater accuracy than one degree, divisions of degree measure called minutes and seconds of latitude and longitude may be used. One degree may be divided into 60 minutes, and one minute may be divided into 60 seconds, or  $1^\circ = 60' = 3600''$ .



a. Latitude 38° North



c. Latitude and longitude 38°N 79°W



b. Longitude: Prime Meridian (0°) and 25° West meridian

FIGURE 8-2:  
Latitude and longitude

### 8.1.3 The U. S. Geological Survey Topographic Map Series

The United States Geological Survey (USGS) publishes maps, including the topographic series. Topographic maps are published at three primary scales which may be encountered by GSAR personnel.

**1:250,000 Series.** These maps cover an area 1° x 2°, at a scale of approximately one inch to about four miles. Most such maps for Virginia are not up to date as far as road and culture information are concerned, and are not very useful for localized search operations due to the small scale. As a supplement to a state highway map, they are very useful in downed aircraft search operations.

15' Quadrangle Series ("15 minute quads") are published at a scale of 1:62,500, or approximately one inch to a mile. Each quad covers an area 15' by 15', as may be inferred by the name. These maps are quite useful for many types of search operations, as the scale is large enough to be of use in small area operations such as lost person search, but small enough in scale to be useful for search operations covering a larger area. Unfortunately for GSAR teams, the USGS is gradually replacing all 15' quads with 7½' quads, and few 15' quads are still available for Virginia.

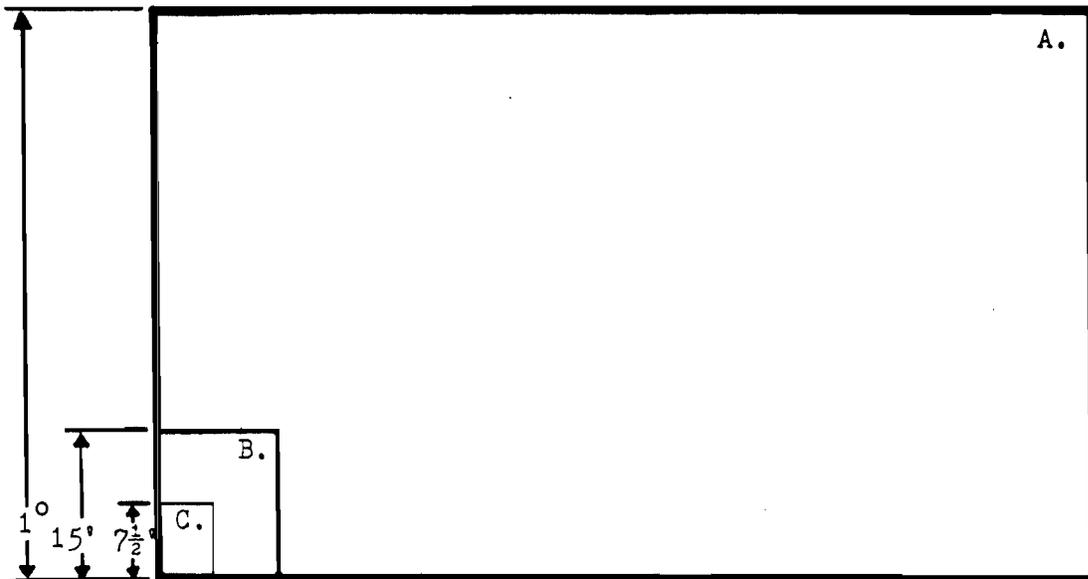


FIGURE 8-3: Relative Coverage of 3 USGS Topographic Map Series Sizes. A: 1:250,000 Series (1° x 2°) B: 15' x 15' Quadrangle Series (1:62500) C: 7'30" x 7'30" Quadrangle Series (1:24000)

7½' Quadrangle Series ("7½' quads") are published at a scale of 1:24,000, or about 2½ inches to the mile, and are available for most of Virginia. These maps are quite detailed, and are ideal for lost person search or close-in downed aircraft search. One problem with 7½' quads is that they are somewhat unwieldy when more than one is required, as it is often difficult to find space to spread them out in the field. Another problem is that although it takes four 7½' quads to cover the same area covered by a 15' quad, the cost of an individual map is the same. Acquiring enough 7½' quads to cover an area can be quite a financial burden to a GSAR team.

The relative coverage and shapes of each of these series is illustrated in figure 8-3.

#### 8.1.4 The Uniform Map System (UMS)

The Uniform Map System (UMS) is the official SAR grid system. CAP members are fortunate in that this system incorporates the standard grid system used by the CAP for years.

The UMS is based on the standard Sectional Aeronautical Chart (scale 1:500,000). Each chart is gridded into 15' x 15' quadrangles, and each quadrangle is assigned a number, from left to right and top to bottom, across the chart. Each quadrangle, or "grid" as it is usually called, may be further subdivided into four quadrants, although this is not usually done on sectional charts. Each quadrant is assigned a

letter as shown in figure 8-4a. Thus, any individual  $7\frac{1}{2}$ ' quad in the country may be specified by (1) a sectional chart name or abbreviation, (2) a number up to three digits, and (3) a letter. Thus the X in figure 8-4a may be referred to as being in grid Washington 314B. Further specification of position is provided by specifying the distance in miles from the nearest 15' (as opposed to  $7\frac{1}{2}$ ') quadrangle corner, giving the horizontal (east-west) distance first, then the vertical (north-south) distance next. This is illustrated in figure 8-4b, where the position of the X may be given as Washington 314B 2.5-3.6. Note that the horizontal distance is always given first, and that the horizontal distance may be east or west, depending on the quadrant (A,B,C, or D) of the grid. Similarly, the vertical distance is always last, and may be north or south from the 15' quad corner. The reason for this seemingly bizarre choice of reference is that most gridded maps have lines only at 15' intervals, and it is difficult to measure distances from the center of a grid's side, or worse, the center of a grid, when these are not marked accurately in advance. Specific instructions for the assignment of grid numbers are given in Attachment 10 to the CAP Emergency Services Manual (CAPM 50-15).

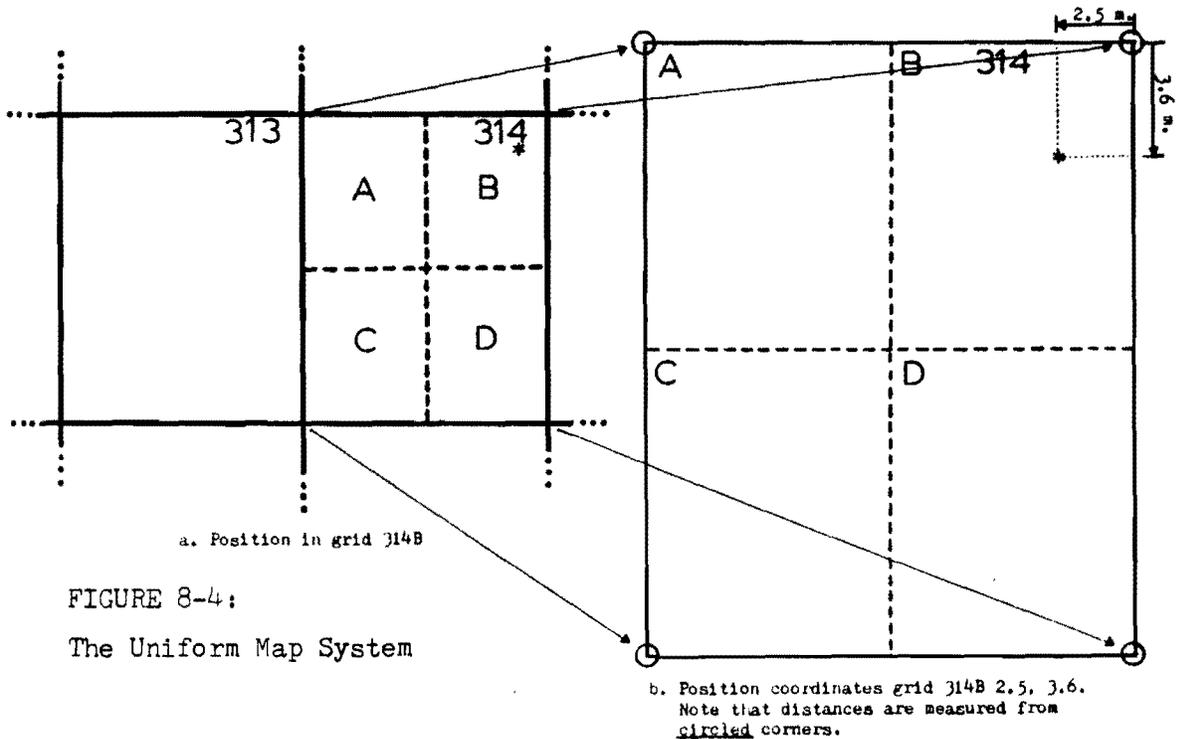


FIGURE 8-4:  
The Uniform Map System

## 8.2 COMPASSES

### 8.2.0 General

A compass is a device used to determine direction. There are many types of compasses, but the only type of compass to be considered here is the magnetic compass. A magnetic compass has two primary parts: (1) a magnetic needle, and (2) a suspension of some sort, to allow the needle to turn freely. A simple and workable compass could consist simply of a magnetized needle suspended on the surface of a cup of water. Many additional features may be added, depending on the purpose of the compass.

The earth has a magnetic field, with north and south poles, as does any magnet. The north magnetic pole, however, is not at the same location as the "true" rota-

tional north pole; magnetic north is located in northern Canada. The magnetic poles are the origins of magnetic "lines of force" which extend from one pole to the other. A compass needle will line up along these lines. The direction of the lines is seldom that of the north-south on a map. The displacement of magnetic and "true" poles contributes to this, as do local effects such as large iron ore bodies. One may measure the angle between these lines and the "true" north-south direction; this is the magnetic declination (see figure 8-5). In Virginia, this declination is approximately  $5\frac{1}{2}^{\circ}$  west. (Each map gives a declination for that particular map.) The declination may be affected by ferromagnetic materials held near the compass.

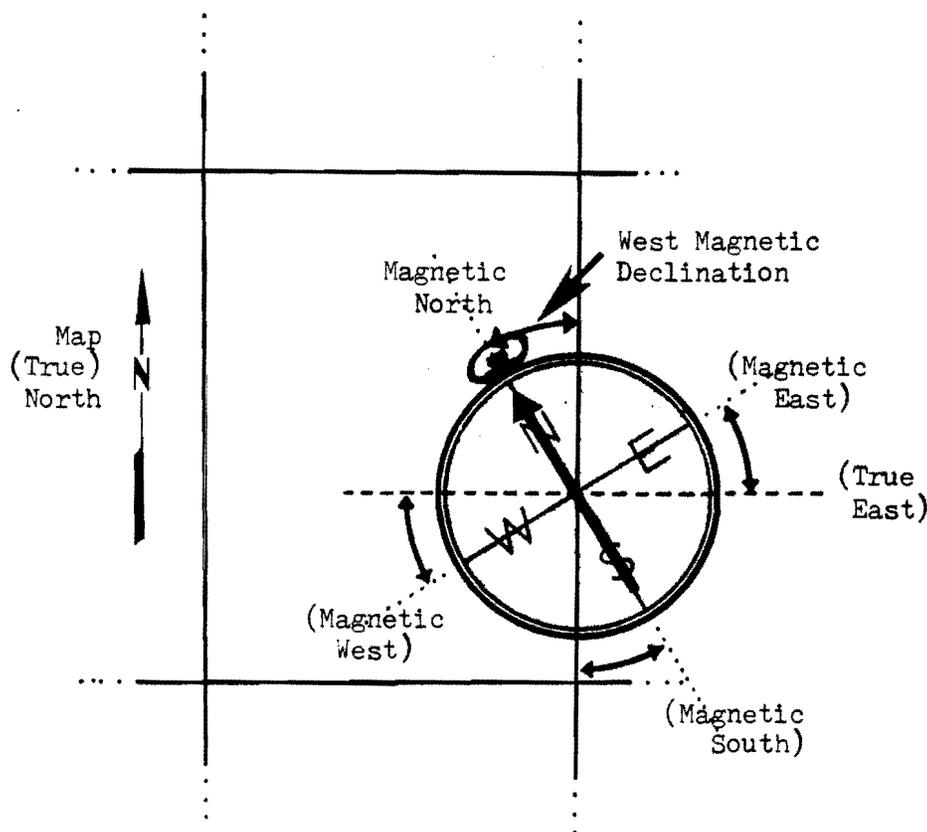


FIGURE 8-5: Magnetic Declination

### 8.2.1 ORIENTEERING COMPASSES

Orienteering type compasses are well suited for the land navigation tasks required of GSAR personnel. An orienteering compass (see figure 8-6) has three major parts: (1) a magnetic needle on a bearing, (2) a central transparent needle housing with parallel lines on it, and degrees marked around the edge, and (3) a rectangular transparent base with a direction of travel arrow on it. There are three arrows on this type of compass: (1) the magnetic needle, (2) an arrow parallel to the lines in the needle housing, and (3) the direction of travel arrow on the rectangular base.

### 8.2.2 LENSATIC COMPASSES

The lensatic compass is widely used by the military, and may be used for orienteering and land navigation in general; however, the orienteering type is easier to use for most land navigation tasks. The lensatic compass (see figure 8-7) has the following main parts: (1) a magnetic needle, which is actually a disc with degrees marked on it, (2) a compass housing in two parts, the top of which has a hairline, and provides a straight edge parallel to the hairline, and (3) a moveable luminous

line. Thus, as with the orienteering compass, there are three arrows: (1) the magnetic needle, (2) the compass housing hairline, and (3) the moveable luminous line. A lensatic compass may be used in a manner similar to that of an orienteering compass; specific instructions are given in subsequent sections. However, some lensatic compasses do not have a straightedge along the side of the case, which makes their use for navigation (as explained herein) extremely difficult.

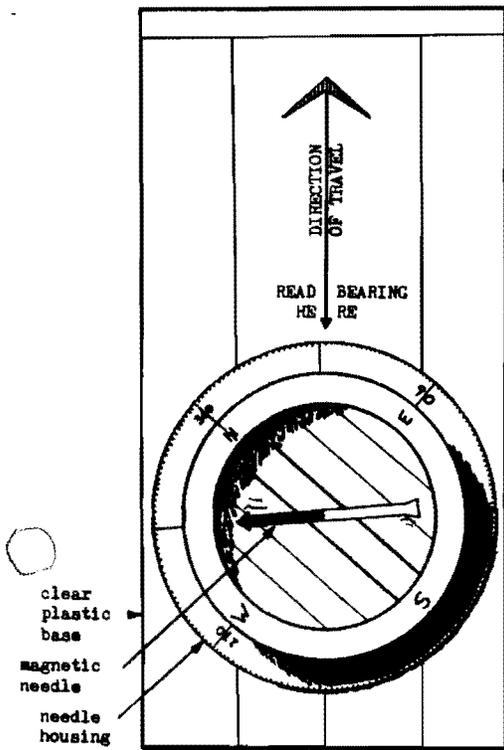


FIGURE 8-6: The Orienteering Compass

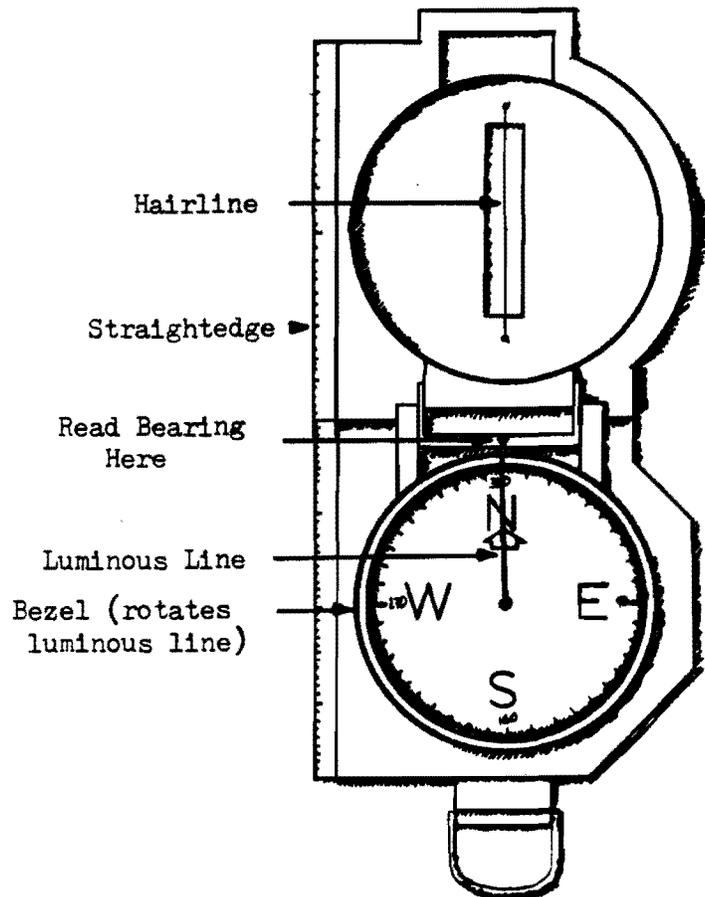


FIGURE 8-7: The Lensatic Compass

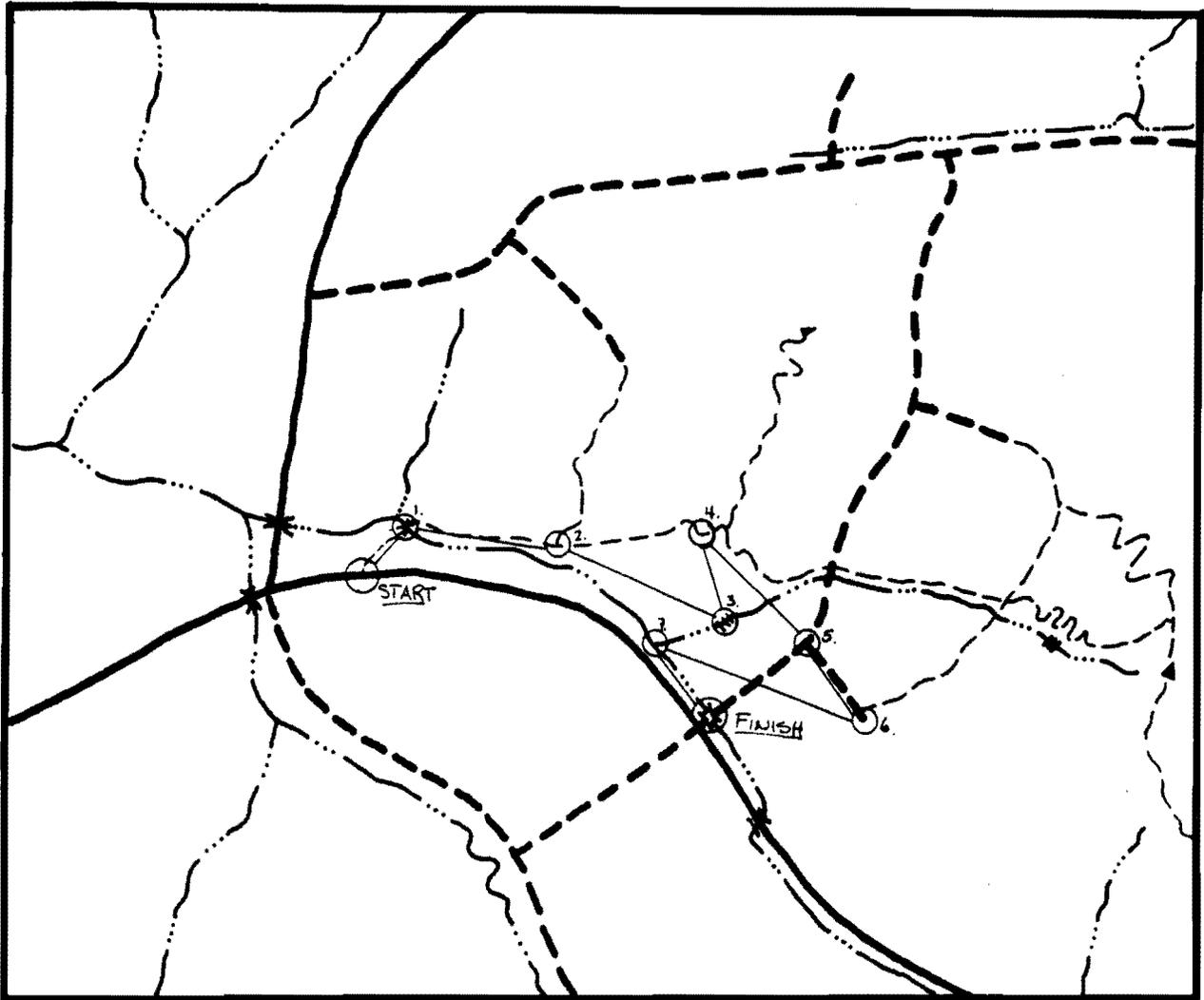
### 8.3 ORIENTEERING

#### 8.3.0 General

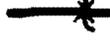
Orienteering is an outdoor sport, originally from Scandinavia, which has gained a large following in the U.S. It involves a timed map and compass course, which requires of contestants good physical condition, map reading and compass skills, and the ability to make optimum route choices. Orienteering offers an opportunity to practice the majority of land navigation skills required for GSAR tasks. In addition, the concepts and techniques developed by and for orienteering are useful in almost any kind of land navigation problem.

The U.S. military services use orienteering as a vehicle for teaching land navigation skills, and the Army and Marine Corps orienteering teams are among the world's best. Much of the material in this section is adapted from military orienteering teaching materials.

The simplest type of orienteering course is a point-to-point course, as illustrated in figure 8-8. Contestants copy points from a master map onto their own, and are to go to each point in the order given. At each point, the contestant will find



KEY

-  Streams; falls
-  Trail; peak
-  1st class road; bridge
-  2nd class road

- 1. The footbridge
- 2. The trail junction
- 3. The waterfall
- 4. The trail switchback
- 5. The road junction
- 6. The road end
- 7. The stream junction

FIGURE 8-8: Point-to-point Orienteering Course

a marker, usually with a special paper punch, and is expected to document finding the marker by punching his ticket. The person completing the course (i.e. showing up at the end with a ticket with punchmarks for all markers) in the least time is the winner. There are many other types of orienteering courses, and the interested reader is referred to Kjellstrom's book Be Expert with Map and Compass for a discussion of them.

## 8.3.1 Orienteering Concepts

The concepts discussed in this subsection are central to the sport of orienteering, and will be of use in any type of land navigation task. Since some concepts are difficult to explain in prose, the reader is urged to make use of the illustrations in figure 8-9. Numbers refer to examples shown in figure 8-9.

Bearing. Also known as an azimuth, a bearing is simply a direction specified from true north (a true bearing) or from magnetic north (a magnetic bearing). For example, a true bearing of  $90^{\circ}$  is due East.

Northing Lines. (1) Many maps designed primarily for orienteering are often published with magnetic north-south grid lines across them. These lines, put there to simplify obtaining magnetic bearings from the map, are called northing lines.

Catching Features. (2,3) The bigger an object is, the easier it is to find. This principle applies to orienteering as well. Rather than trying to navigate a compass course directly to a small target, it is often easier to navigate first to a large linear catching feature, then to navigate further to the target.

In orienteering, it is customary to divide navigation into different types, based on the difficulty involved. The first stage of navigation from one point to another is known as rough orienteering or the "green segment", where often the only route description would be a rough direction, such as "east". Once the selected catching feature is reached, standard orienteering or the "yellow segment" is used. Often this may consist of nothing more than following along a catching feature such as a trail or stream for a while. Such catching features that lie roughly parallel to the intended route of travel are called "handrails". Sometimes, a catching feature on the far side of a target is selected, to "catch" oneself if the target is missed. Also, it may be easier to go to a catching feature on the far side of the target, then navigate back to the target, rather than to aim directly for the target.

Attack Points. (4,5) The final part of navigation to a target, known as precision orienteering or the "red segment", involves careful use of compass and pacing. Since following a compass course precisely is difficult, and errors increase with increasing distance, the distance to be precisely navigated must be minimized by the use of catching features. When selecting catching features, and planning a route in general, you must look for attack points, points that may be precisely located both on the map and in the field. In general, the attack point closest to the target should be chosen, even if it is on the far side of the target, in order to minimize the distance of the "red segment".

Aiming Off. (6) A "T" intersection of one sort or another is occasionally selected as an intermediate target or attack point. If one is approaching the intersection from "above" the T, one will probably come out somewhere along the "top" of the T, with no clue as to whether the intersection is to the left or right. To avoid this problem, it is simple to aim off to one side or the other. In this way, the way to turn once one hits the top of the T is known. For example, if one were deliberately to steer a course  $5^{\circ}$  to the left ( $5^{\circ}$  less than the bearing directly to the intersection), one would immediately turn right upon reaching the top of the T, and soon reach the intersection.

Collecting Features. It is not advisable to strike off on foot along a bearing towards a target, without having some idea of the distance involved. It is possible to be on the right track to reach the target, only to turn back too soon for fear of having overshot it. To avoid this type of problem, one must maintain a constant knowledge of one's position. There are two primary methods for doing so, pacing,

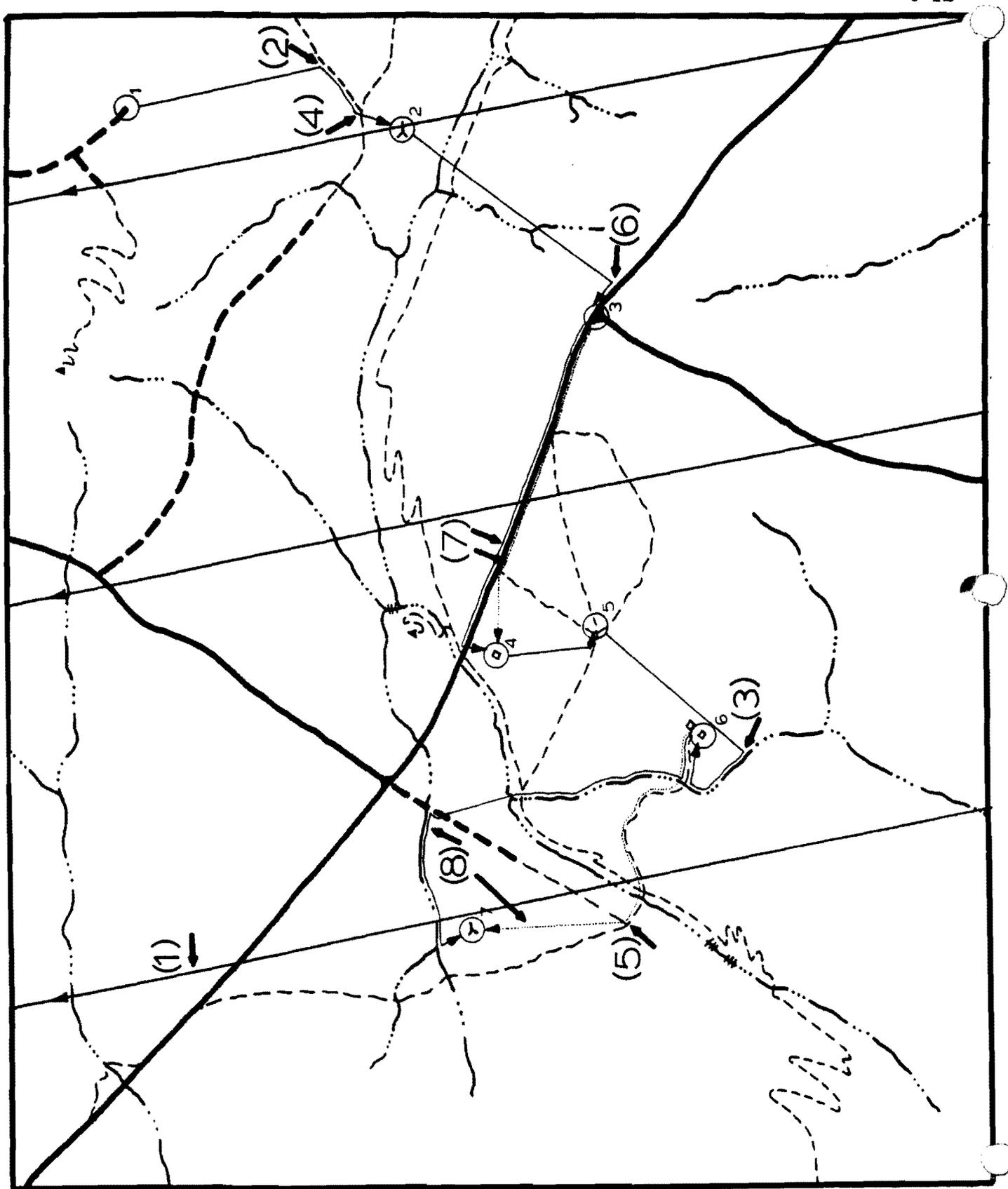


FIGURE 8-9: Orienteering Concepts

Small numbers are target point numbers; large numbers in parentheses are keys to explanations in the text.

which is discussed in a subsequent section, and collecting features, which will now be described. Collecting features refers to the act of preparing a mental list of landmarks along a planned route. As each is passed, it is checked off the mental list. Thus, a close check is kept on one's position. If a major feature is apparently out of place on the list, or missing, it is time to stop and reassess one's position and route.

Backwards Route Planning. (7,8) In general, one should plan a route from target to starting point, rather than from starting point to target. This is due to the ease of selecting good attack points when planning "backwards". Examples of four routes, two planned forwards and two planned backwards, are given in figure 8-9 (7,8). The dotted lines (from station 3 to 4 and 6 to 7) represent the forwards-planned routes which contain longer red segments (precision navigation) to the target.

### 8.3.2 Route Selection

Proficiency in the art of route selection is necessary for GSAR personnel. The ability to evaluate routes for speed, distance, and difficulty is not only required for GSAR navigation tasks, but is an important survival skill as well. Route selection skills may easily mean the difference between a half-hour hike and a half-day bushwhack.

A good route between two points will usually minimize the use of the compass. An experienced orienteerer will run a basic level orienteering course with little or no use of the compass. (However, even the most experienced GSAR team member will find occasions requiring the use of a compass.) One of the major considerations in route selection is that of elevation gain. As a general rule of thumb, twenty-five feet climbed is the equivalent of 100 meters (approximately 300 feet) of level foot travel, in terms of energy expended. Another consideration is that of vegetation. If one is confronted with a patch of brush, a choice must be made between pushing on through the brush, or going around it. Although it is difficult to provide a quantitative expression for difficulty due to brush, the following table will provide a rough indication of travel times for two and one half miles of level foot travel:

path or road:	one hour
light vegetation:	two hours
open woods:	three hours
dense forest:	five hours
laurel/rhododendron:	ten hours.

Specific terrain features such as cliff bands, rivers, and marshes may influence difficulty and travel time.

Route selection is perhaps the one most important skill for GSAR land navigation, and is one of the most difficult to learn. One of the best methods to develop a facility for route selection is to participate often in orienteering meets. Many areas have orienteering clubs sponsoring regular meets; GSAR team members are encouraged to seek out these activities.

## 8.4 DETERMINING A BEARING

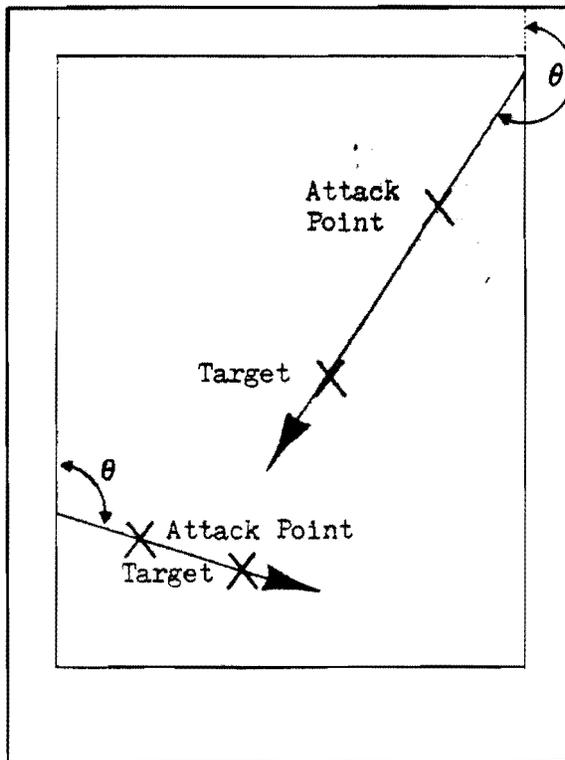
### 8.4.0 General

Given a starting point and a target on a map, one must select a route between the two, using the concepts provided in the last two sections. Sometimes it will be necessary to plot and follow a direct bearing from an attack point to a target point or catching feature. This section will discuss how to arrive at a proper bearing between two points plotted on a map.

### 8.4.1 Map, Protractor, and Straightedge Method

One may derive a true bearing from a map with a protractor and straightedge, as follows: (this procedure is illustrated in figure 8-10)

1. Draw a line from attack point to target, and extend it until it meets a north-south line on the map (e.g. the map edge).
2. Using the protractor, measure the angle formed between map north and the desired line of travel, measuring clockwise. Take care not to measure the angle from north to the line of travel backwards from target to attack point.
3. This angle is a true bearing from attack point to target; a declination correction must be added or subtracted to obtain a magnetic bearing for use in the field.



1. Using straightedge, extend line connecting starting point (attack point) and target to a map north-south line.

2. Using protractor, measure angle from map north to intended travel direction (two examples shown).

3. The angle measured is a true bearing; add or subtract the proper magnetic declination correction to obtain a magnetic bearing for use in the field with a magnetic compass.

FIGURE 8-10: Protractor/Straightedge Method for Determining Bearings

### 8.4.2 Magnetic Declination

Since true bearings and magnetic bearings are not equivalent, except in a very few locations, one must be able to convert from true bearings (as from a topographic map) to magnetic bearings (as taken or used in the field with a magnetic compass) and vice versa.

Declination is the difference between true north and magnetic north, or for that matter the difference between any two corresponding true and magnetic bearings (a point worth several minutes of thought, if it is not immediately clear). Declination is specified as being east or west. West declination, as in Virginia, means that a magnetic needle will point slightly to the west of true north. In terms of degrees, (where  $0^\circ = 360^\circ =$  north,  $90^\circ =$  east,  $180^\circ =$  south,  $270^\circ =$  west), true north is a few degrees more (i.e. clockwise) than magnetic north, and magnetic north is of course a few degrees less (i.e. counterclockwise) than true north. Similarly, mag-

netic east is a few degrees less than true east, and true west is a few degrees more than magnetic west. Thus when converting from a magnetic bearing (e.g. one obtained from triangulation in the field) to a true one (e.g. to be plotted on a map), one must subtract the declination. Similarly, when converting from a true bearing to a magnetic one (as when taking a bearing off a topographic map for use in the field), one must add the declination.

A final example will be given to give a better intuitive understanding of declination. Let us say that we are considering a bearing from point A to point B, as shown in figure 8-11. We may then assign to this actual line of travel a true bearing, which is the number of degrees from true north to the line of travel, measured clockwise from true north. Similarly, we may assign to the line of travel a magnetic bearing, which is the number of degrees from magnetic north, again measured in a clockwise direction. We see that the magnetic bearing is a larger angle than the true bearing, and since this is so, it is intuitively obvious that we must add declination to correct from true to magnetic bearings, and subtract the declination to go from magnetic to true bearings. Rather than to continue attempting to explain declination adjustment in this section, it is recommended that readers obtain a map and compass and practice with them to increase their understanding of declination.

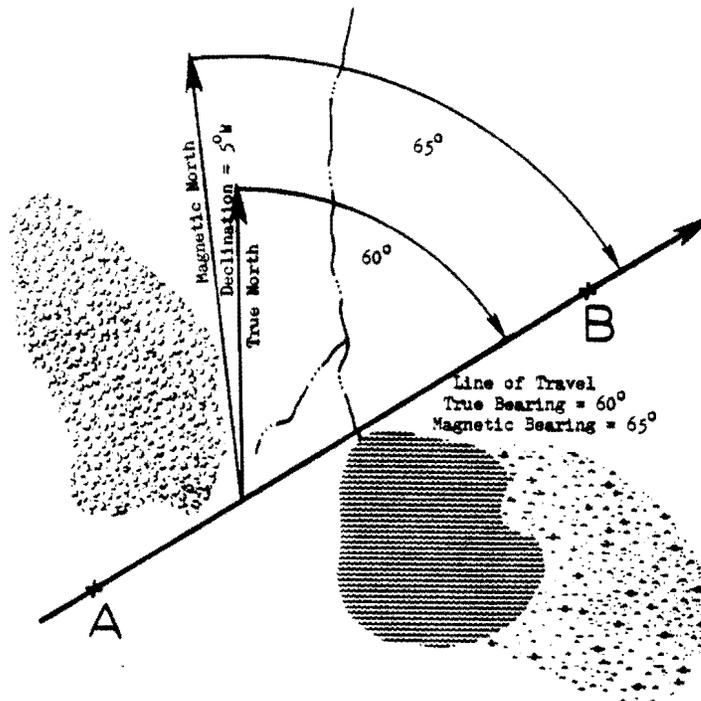


FIGURE 8-11: Declination correction

### 8.4.3 Map and Compass Method

Since protractor and straightedge are not always available in the field, an alternate method using map and compass is described below. Although the description assumes the use of an orienteering compass, the procedure may be used with lensatic or other compasses with some minor changes.

1. Orient the map precisely to true north. (An oriented map is one that is turned so that map and actual directions coincide; that is, the top of the map points due north.) This may be done by inspection of the surrounding terrain, or by use of the compass as follows:

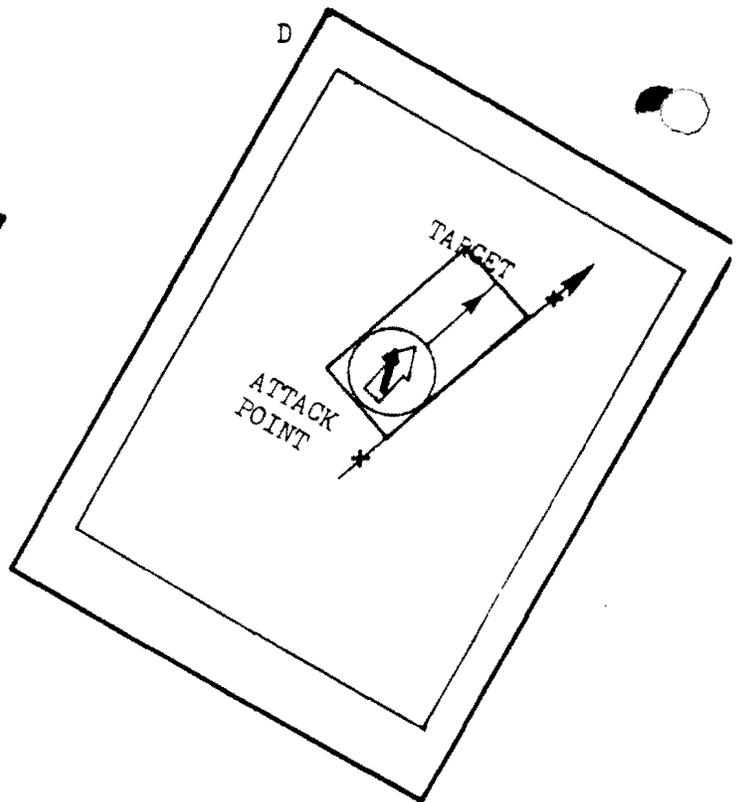
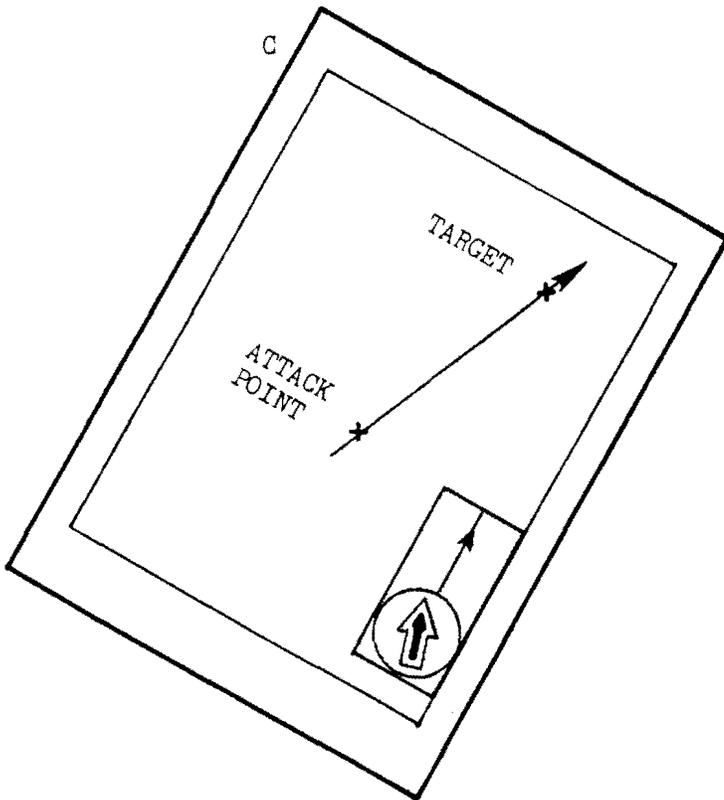
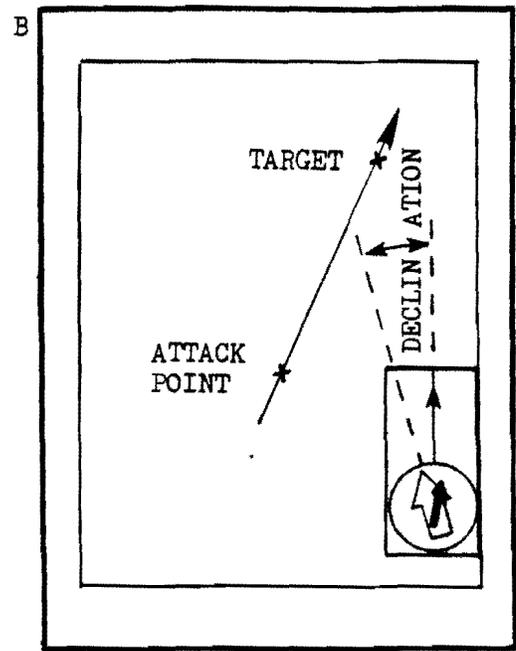
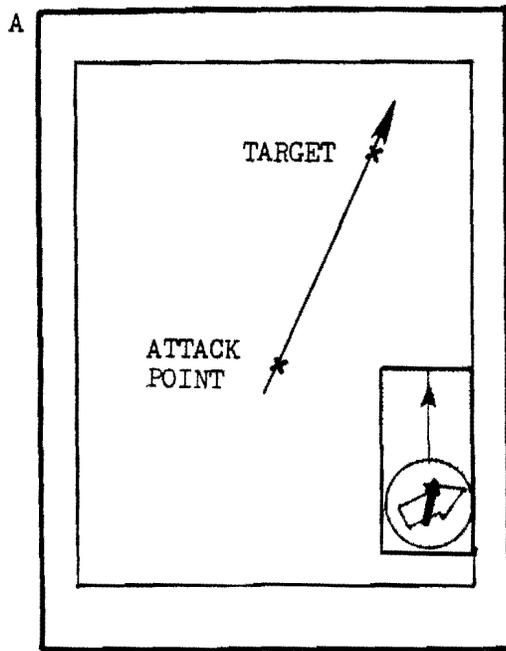
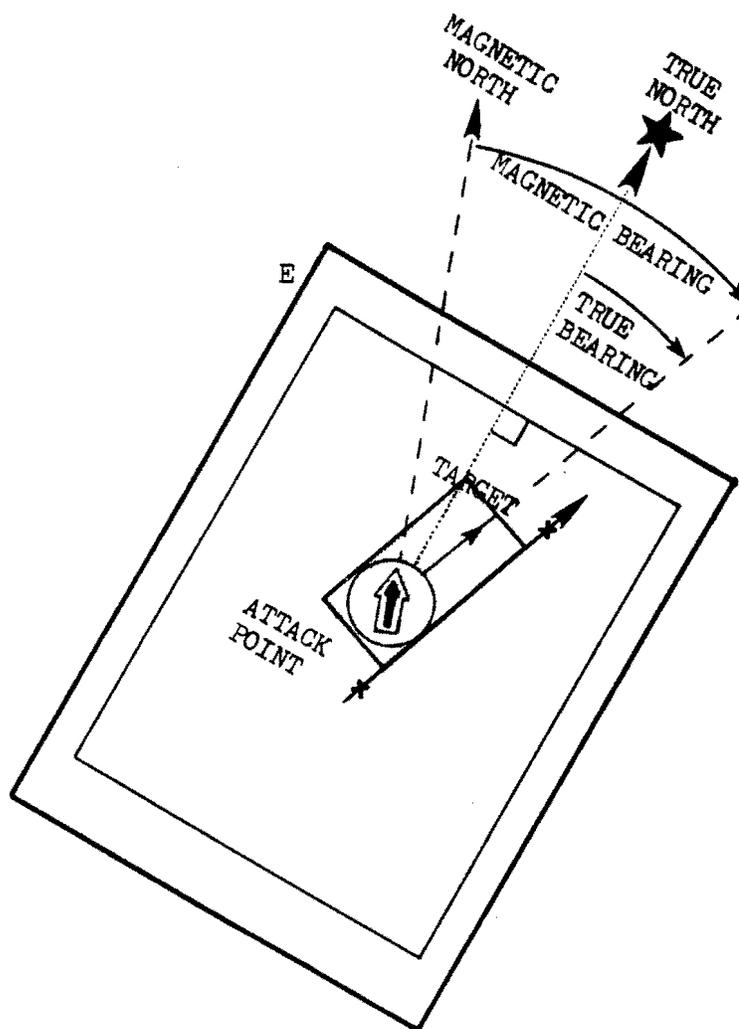


FIGURE 8-12: Map and compass method for determining bearings  
(continues on next page)



(figure 8-12 continued)

- a. Place the compass on the map with the edge of the compass base along the edge of the map and the direction of travel arrow pointing to map north (see figure 8-12a).
- b. Turn the needle housing to the indicated magnetic declination:  $0^{\circ}$  plus the declination for west declination,  $360^{\circ}$  minus the declination for east declination for east declination (see figure 8-12b).
- c. Turn the map and compass as a unit until the magnetic needle is centered properly in the needle housing arrow (see figure 8-12c).

2. Without moving the map, place the side of the compass base along the line from attack point to target with the direction of travel arrow pointing towards the target (see figure 8-12d).

3. Turn the needle housing until the needle housing arrow and the magnetic needle coincide. A magnetic bearing is now shown by the compass (see figure 8-12e).

It is also possible to orient the map to magnetic north initially, then to correct later for magnetic declination. Also, if one were to turn the needle housing arrow to map (true) north instead of magnetic north in step three, above, a true bearing would result.

Using the Lensatic Compass

18 Orient the map precisely to true north:

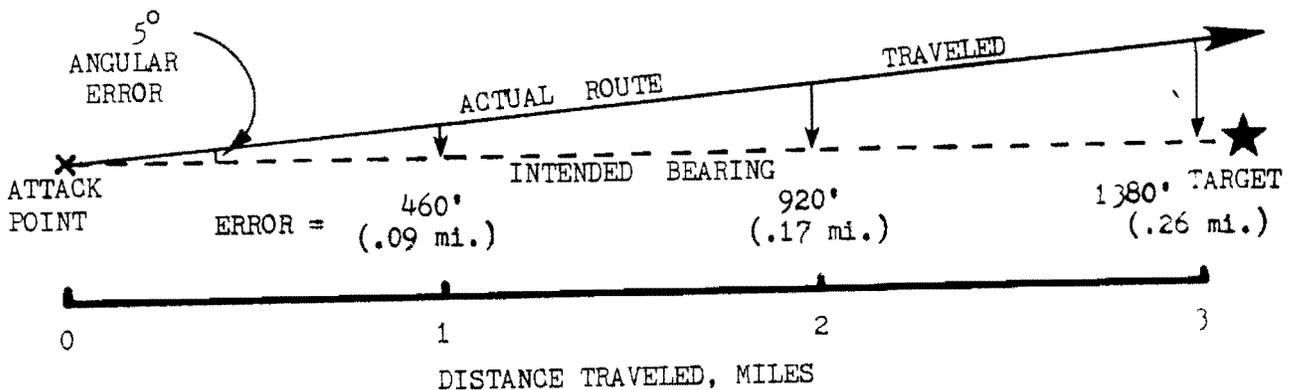
- a. Place edge of opened compass along the map edge, with hairline pointing to map north.
  - b. Turn map and compass as a unit until the compass reads the specified magnetic declination (e.g. reads  $6^{\circ}$  for  $6^{\circ}$  west declination).
2. Place the edge of the opened compass along the line from attack point to target, with the hairline pointing in the direction of intended travel (towards target).
  3. Move the luminous line over the north arrow.
  4. Read off the magnetic bearing under the hairline.

8.5 FOLLOWING A BEARING

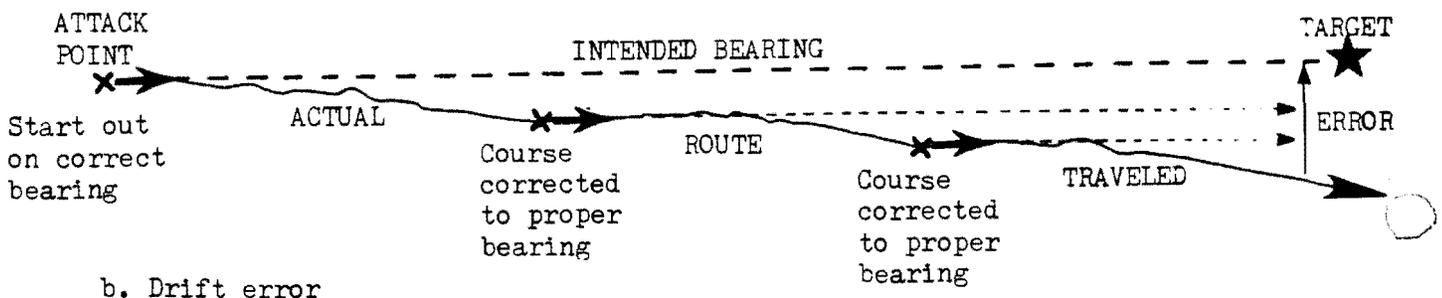
Once the compass is set for a given magnetic bearing, commit the bearing to memory, as it is possible to inadvertently change the compass setting, especially when traveling through brush or rough terrain. For this same reason, one should check the compass setting frequently.

The compass is held in the hand (palm up), directly in front of the body, at elbow height. One then rotates, keeping the compass in front, until the needle is lined up in the needle housing arrow. (For a lensatic compass, rotate until "north" on the needle is under the luminous adjustable line.) To follow this bearing, one merely travels in the direction one is facing.

Staying on a bearing may be difficult. A small error in the bearing will result in an error at the target, with the magnitude of the error increasing as the distance the bearing is followed increases (see figure 8-13a). Even if there is no error in the bearing, continued "drift" may result in error, even though one's course is corrected back to the proper azimuth at regular intervals (see figure 8-13b).



a. Error from bearing error



b. Drift error

FIGURE 8-13: Errors in following a bearing

There are several methods for following a bearing accurately. Perhaps the simplest is to choose an intermediate "target" (e.g. a tree), directly on the bearing. Once this is reached, the compass is used to select another target.

A refinement on this is to sight past the first target and immediately pick out a second target in line with the first. As the first target is reached, a third is chosen, and so on. This may seem more complex and time consuming than the method described above, but is actually much quicker, as fewer compass readings are required.

When traveling in a team, and when extreme accuracy is required, it is possible to send a member on ahead. Verbal instructions to this member will suffice to keep him or her on the proper heading. With practice, this may be done with a minimum of delay and very accurately.

Sometimes a detour may be necessary when following a bearing. If a target can be sighted on the other side, there is little problem. However, if such is not the case, techniques known as "triangulation around an obstacle" (distinct from triangulation as discussed in 8.7.3) and "boxing" may be employed. Triangulation refers to the interposition of a triangle into the route bearing (see figure 8-14a). As the obstacle is reached along one's bearing  $\theta$ , a new bearing of  $\theta$  plus or minus  $\alpha$  is set (in figure 8-14a it is  $\theta$  minus  $\alpha$ );  $\alpha$  is picked so as to "triangulate" around the obstacle with a minimum of extra walking. A distance,  $x$ , is traveled along the new bearing, then a third bearing of  $\theta$  minus or plus  $\alpha$  is set along this third bearing, bringing one back into line with the original bearing  $\theta$ . If the angle  $\alpha$  is chosen to be  $45^\circ$  (which is often possible) then the equivalent distance along the bearing  $\theta$  ( $AC$  in figure 8-13a) is equal to about  $1.4x$ . An example is given in figure 8-13b.

Boxing is somewhat longer in terms of distance, but simpler in terms of calculations. As the obstacle is reached along bearing  $\theta$ , a new bearing of  $\theta$  plus or minus  $90^\circ$  ( $\theta$  minus  $90^\circ$  in figure 8-14c) is traveled a distance  $y$  until one is clear of the obstacle. The bearing  $\theta$  is again followed until past the obstacle, then the bearing  $\theta$  minus or plus  $90^\circ$  ( $\theta$  plus  $90^\circ$  in figure 8-14c) is followed the same distance  $y$  back to the original bearing.

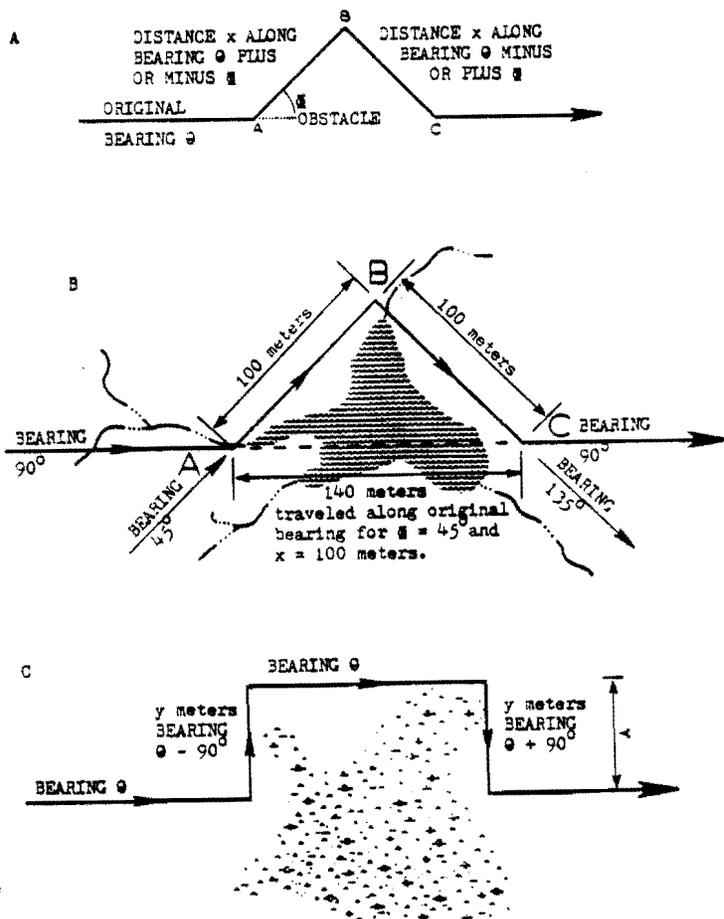


FIGURE 8-14: Navigating a bearing around obstacles

## 8.6 DETERMINING DISTANCE

There are two primary methods for estimating the distance one has traveled. The first is by the use of collecting features as described in a previous section (8.3.1). Often it is necessary to estimate distance without the use of collecting features, or in between such features. This is done by counting the number of paces taken, a pace being counted each time the left foot touches ground. Every person has a unique stride, and strides vary under different conditions of terrain, brush, and steepness, and when running, trotting, or walking. Every GSAR team member should learn his pace length under various conditions. The following chart may be of use for new GSAR personnel:

	Number of paces in 100 meters (for a fresh person, in daylight, on level ground)		
	Small (< 5'8")	Medium	Tall (> 6')
Road/Trail	42	40	37
Light Vegetation	45	43	40
Open Forest	50	46	43
Dense Forest	55	50	46

## 8.7 DETERMINING POSITION

### 8.7.0 General

Determining a position in the field may be difficult and trying to even the most experienced GSAR team member. Keeping track of position constantly is simple with the use of a map and collecting features. A useful hint is to hold the map in one hand, with a thumb on the map marking the present position. As each collecting feature is passed, the thumb may be moved up. Another good idea is to count paces regularly, so the distance back to the last "collecting" feature is known. Some orienteering compasses even have a built-in register for keeping track of paces.

Mission tasks will occasionally require the GSAR team member to be able to determine position with little information to guide him, and the ability to determine position is an important survival skill.

### 8.7.1 Position by Inspection

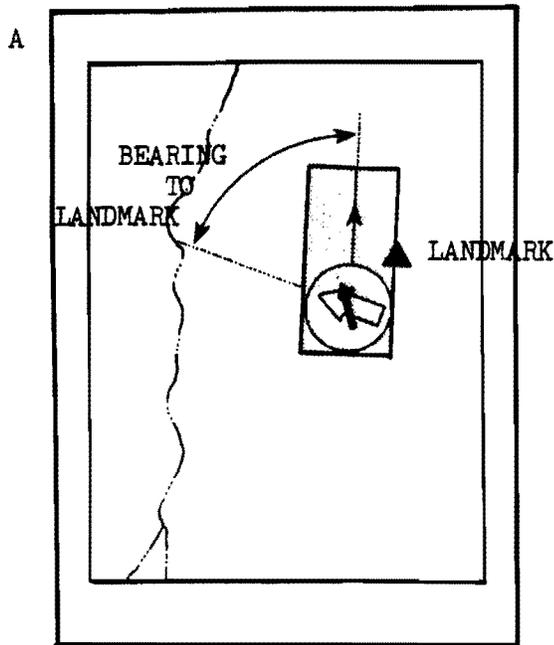
Sometimes it will be possible to determine one's position by simply orienting the map and inspecting the surrounding terrain. Since this method may produce several map locations possibly corresponding to one's actual position, the following procedure is suggested:

1. List the map locations possibly corresponding to the team's location.
2. Determine a route for the team (e.g. proceed north, or go downstream) which will provide different clues if followed from each of the possible locations on the map.
3. Once one of these clues is located, the team's position is known.

### 8.7.2 Position by Resection

If one is along a known linear feature (road, stream, trail, ridgeline) and a prominent landmark is sighted, one's position may be determined. The magnetic bearing to the landmark is determined and recorded. This is done as follows:

1. Sight (point) the compass at the landmark.
2. Turn the needle housing until the needle housing arrow and the magnetic needle coincide.
3. Read the magnetic bearing under the direction of travel arrow (leave this setting on the compass).



(map oriented to true north)

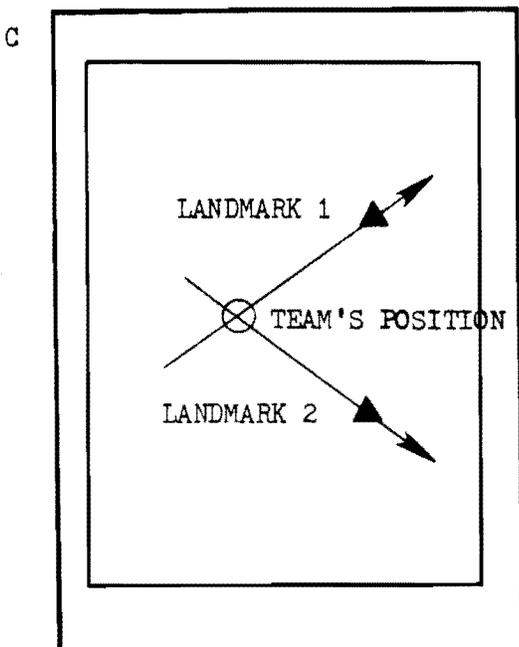
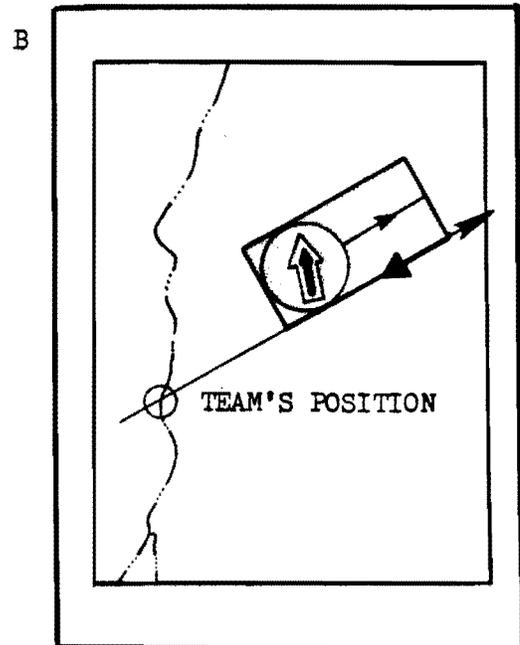


FIGURE 8-15:

Resection

The map is now oriented to true north as described in section 8.4. The edge of the compass may be placed so as to cross through the landmark on the map (see figure 8-15a). The compass base edge is then pivoted around the landmark until the magnetic arrow and needle housing arrow coincide (see figure 8-15b). The intersection of the compass edge line with the linear feature then marks one's position.

If the team is not on a linear feature it is still possible to use bearings from two or more landmarks to determine the team's position, as shown in figure 8-15c. Lines are plotted from each landmark as described above, with the intersection of the bearing lines marking the team's position. This process is known as resection.

### 8.7.3 Position by Triangulation

It may occasionally be necessary to specify the location of a position distant from one's own, for instance a possible crash site on a mountain-side. The process of triangulation used for this purpose is essentially the reverse of resection. The team takes magnetic bearings on the possible crash site from two or more known locations. These bearings are plotted as shown in figure 8-16 and their intersection marks the possible crash site location. It is also possible to use bearings from an ELT locator and to triangulate to derive an estimated ELT position. When plotting bearings, pivot the compass base edge around one's location (A, B, or C in figure 8-16).

### 8.7.4 Making Positions Easily Found

One of the tasks of the first team to a crash site or to a lost person is to guide in additional teams. Although the site location may be reported to the incoming teams via radio, this is not always sufficient to avoid delays in the team's arrival.

It is possible to leave a trail marked by plastic surveyor's tape to the site, but often this is not feasible. An alternative is to provide a bearing from an attack point which is easily located. In order to make the site a larger target, surveyor's tape markers may be placed to either side of the site, as shown in figure 8-17a. Use of single flags to the "left" of the site and double flags to the "right" of the site will also aid teams in finding the site more quickly. If teams may arrive from multiple directions, a three-arm array may be set out, as in figure 8-17b.

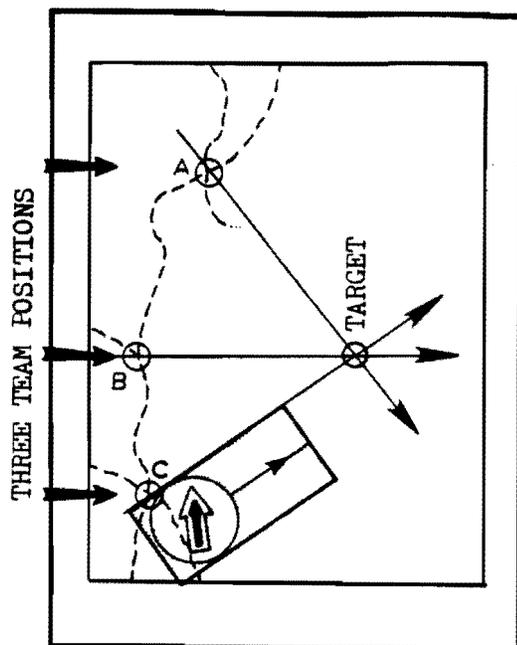
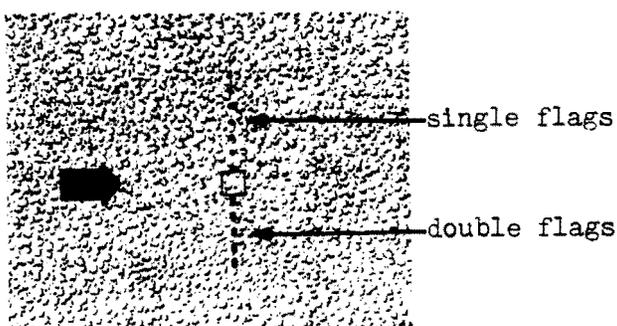
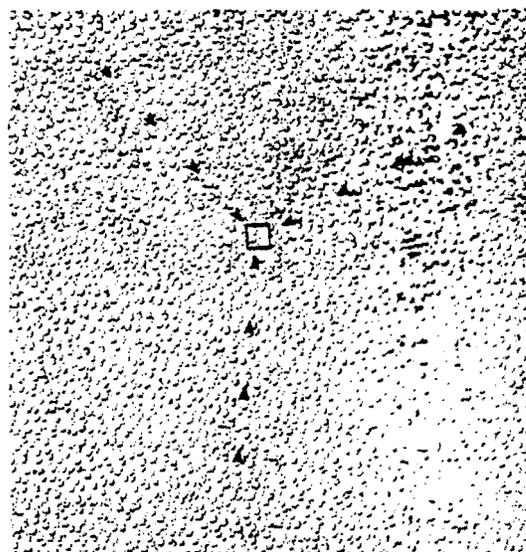


FIGURE 8-16: Triangulation (bearings from three team positions to target plotted as shown in fig. 8-15)



A. Team approaching from known direction



B. Team(s) approaching from unknown or multiple directions

FIGURE 8-17: Site marking

## 8.8 EMERGENCY DETERMINATION OF DIRECTION

## 8.8.0 General

The possibility of becoming stranded without a compass may be small. Even so, this small chance is enough to make knowledge of emergency direction determining methods worthwhile for GSAR personnel. This section will provide brief descriptions of four possible methods.

## 8.8.1 Sun Method

Virginia, which is at a latitude of approximately  $38^{\circ}$ , is north of the Tropic of Cancer and south of the Arctic Circle. Therefore, the sun rises in the east, describes an arc to its noon position in the south, and continues down to set in the west. The sun's noon height above the southern horizon varies from  $75^{\circ}$  at midsummer noon to  $52^{\circ}$  at midwinter noon. Thus a glance at the sun's position and a knowledge of the season and time of day may provide a rough indication of direction.

## 8.8.2 Sun and Stick Method

If accuracy is important, and time is available, the relative motion of the sun across the sky may provide an accurate direction indication by the following method:

1. Place a tall stick upright in the ground.
2. Mark the tip of the stick's shadow at several intervals (timing is not of major importance).
3. Draw a perpendicular from the stick's base to the line drawn in step two. The "T" thus formed has its arms pointing east and west, and the base pointing south, as shown in figure 8-18. (When used south of the equator, the direction indicated by the base of the "T" is north, not south.) This method has limited usefulness in Virginia survival situations, since this kind of accuracy is usually not necessary--the sun method will do just as well and take less time.

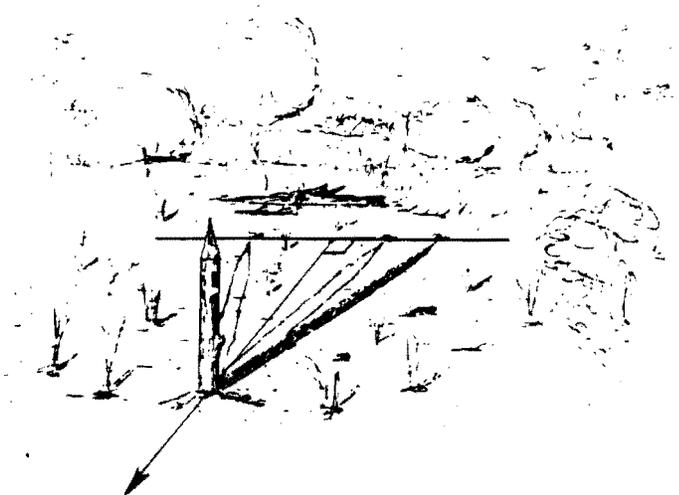


FIGURE 8-18: Stick and sun method of determining direction

8.8.3 Sun and Watch Method

This method is not as accurate as the sun and stick method, but is much quicker. It requires a watch or clock that is running properly. If the hour hand of the watch is pointed towards the sun, the midway between 12 on the watch and the hour hand points south (see figure 8-19a). If after 6 pm or before 6 am, the larger angle between 12 and the hour hand should be used. Error is reduced if the watch is held horizontally tangent to the earth's surface at the equator (figure 8-19b). At 38° north, the watch would thus be tilted down 38° from horizontal towards the south.

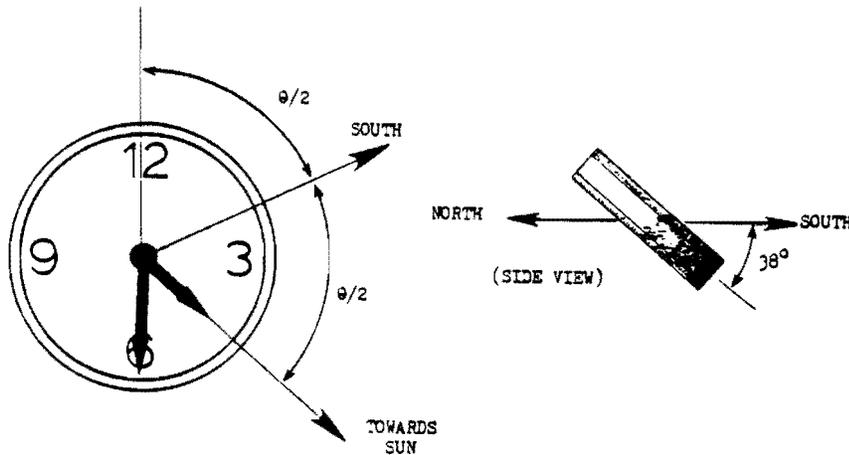
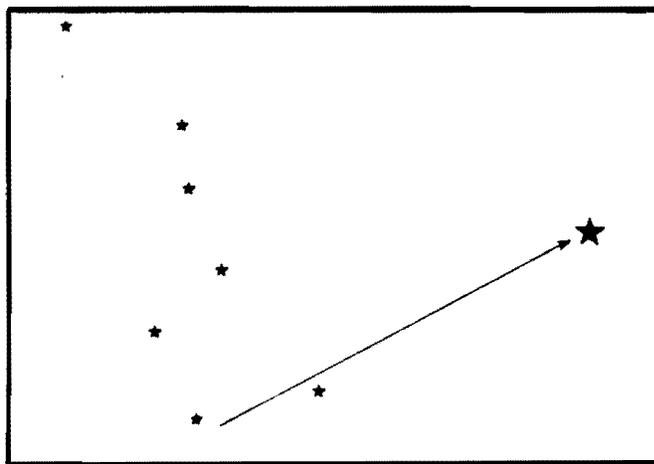
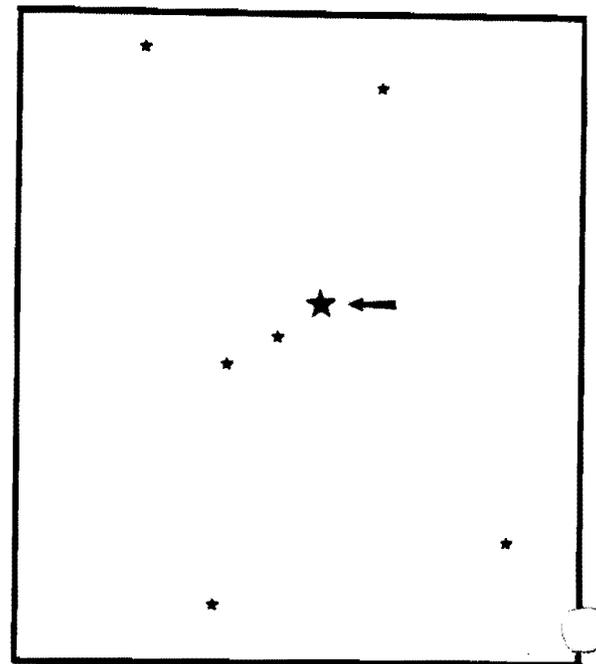


FIGURE 8-19: Watch and sun method of determining direction



a. The Big Dipper indicates the North Star



b. The right-hand star in the "belt" of the constellation Orion always rises directly in the east and sets directly in the west

FIGURE 8-20: The use of the stars to determine direction

8.8.4 Star Observation Method

In the northern hemisphere Polaris (the North Star) provides a quick reference to north. The North Star is located in the night sky as shown in figure 8-20a. It is always within about  $1^{\circ}$  of true north. The striking constellation Orion (The Hunter) spans the celestial equator, with the right star in the "belt" being precisely on the equator. This star always rises precisely in the east and sets precisely in the west. Orion is illustrated in figure 8-20b.

8.9 REFERENCES

- Civil Air Patrol. Emergency Services; CAP Manual 50-15. Maxwell Air Force Base, 1972.
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Shenandoah Mountain Rescue Group  
ASRC GRID SYSTEM EXPLANATION  
Version 1.2 April 1983

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BASIC MEMBER TRAINING COURSE  
Keith Conover, Editor  
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### THE ASRC GRID SYSTEM

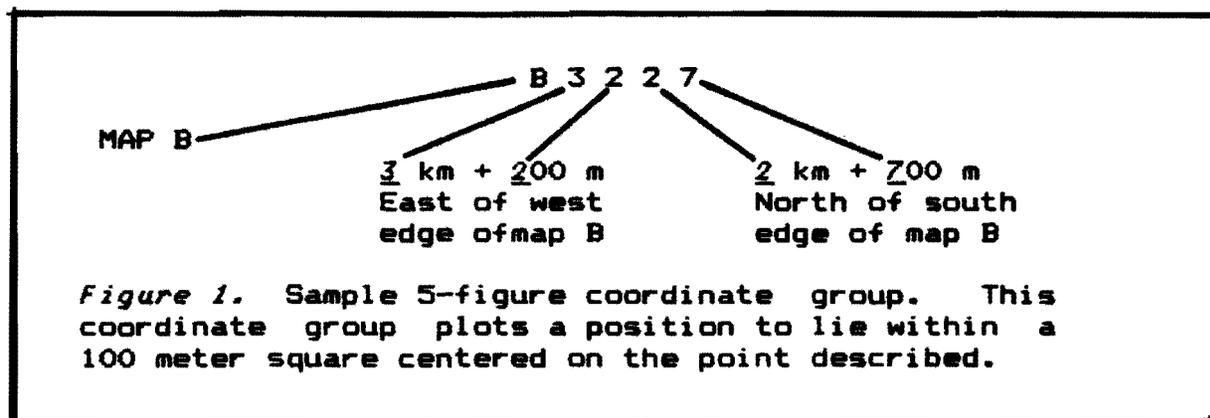
In order to assure accurate, unambiguous, and efficient reporting of positions in the field, the ASRC uses a grid coordinate system similar to that employed by the U.S. Army. Since gridded maps are unavailable in large quantities to the ASRC, gridded photocopies of a single original map are used. An 8-1/2"x11" acetate overlay with a coordinate grid drawn or photographed on it is placed on the original during photocopying so that all the copies carry identical grids. Since the use of photocopy maps is the norm, this step poses little inconvenience to the person procuring maps. Using the grid system, a position report accurate to within 70 meters may unambiguously be made with only five figures, and a position report accurate to seven meters may be made using seven figures. Although the system is designed for use with maps at a scale of 1:24000 (e.g. the USGS 7.5' topographic quadrangles), it may be used effectively with any kind of map.

A sample gridded map is attached. The hachures on the borders are spaced 500 meters apart and labeled every kilometer. The hachures on the map itself are spaced one kilometer apart. Note that the origin of the grid is always in the southwest corner of the map. The overlay is reversible to get the long axis of the sheet north-south or east-west, whichever is more appropriate. On the left margin is a box containing the name of the map, which is a letter designating which run of photocopying from which the map was taken. All maps with the same letter designator are thereby assured of having the same grid. The declination is given in the box below the letter designator. When the copies are made, the overlay is best placed so that grid north and true north are identical, but this is not absolutely essential. In any event, the deviation between grid north and magnetic north must be checked for each run of photocopying and noted on each sheet.

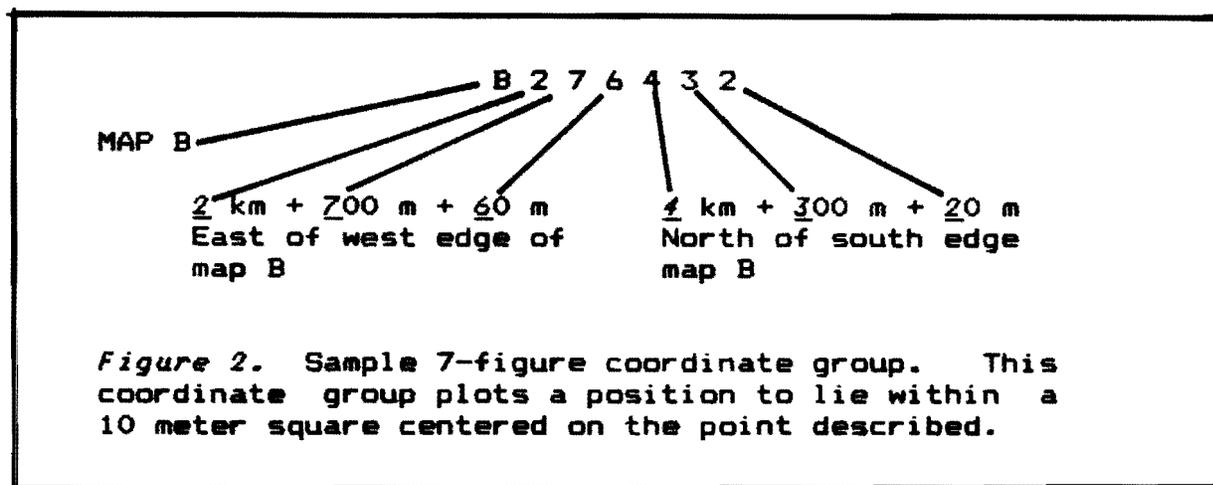
Above the name block is a conversion table from meters on the ground to millimeters on the map. This table is calculated for a map with a scale of 1:24000. Photocopy machines generally enlarge slightly (usually less than 1%), so the table will not precisely match the photocopy map, but it will be close enough for all practical work. No attempt is made to correct for this enlargement because different machines may enlarge to a different degree, and the correction is negligible over 500 meters anyway. The purpose of the scale is to allow more precise plotting than can be done by eye, although the grid can be interpolated by eye to within 100 meters quite accurately.

## GRID SYSTEM

A position report has three parts comprising a total of either five or seven figures. A five figure coordinate group plots a position to lie within a 100 meter square and a seven figure group plots the position to lie inside a 10 meter square. Figure 1 illustrates an example plotted on the attached map.



It should be noted that any position within the 100 meter square will be described by the coordinate group B3227. Consequently the maximum error will be 70 meters. To specify the position to within a 10 meter square (which is only 0.42 x 0.42 mm on the map!), the coordinates can be taken to seven figures as shown in figure 2.



To keep the order of the figures correct, remember the mnemonic "read right up"; alternatively, one may view the coordinates as Cartesian X-Y coordinates, where the X coordinate customarily comes first: (X,Y). Five figure coordinates are accurate enough for almost all field work.

A typical radio position report might go like this:

**TEAM CHARLIE, THIS IS BASE.**

**"BASE, THIS IS TEAM CHARLIE. GO AHEAD."**

**WHAT IS YOUR LOCATION? OVER.**

**"STAND BY." (FTL Charlie consults his map and compass.)**

**"BASE, THIS IS TEAM CHARLIE. OUR LOCATION IS, FIGURES, BRAVO, THREE, TWO, TWO, SEVEN. OVER."**

**ROGER. BASE CLEAR.**

**"TEAM CHARLIE CLEAR."**

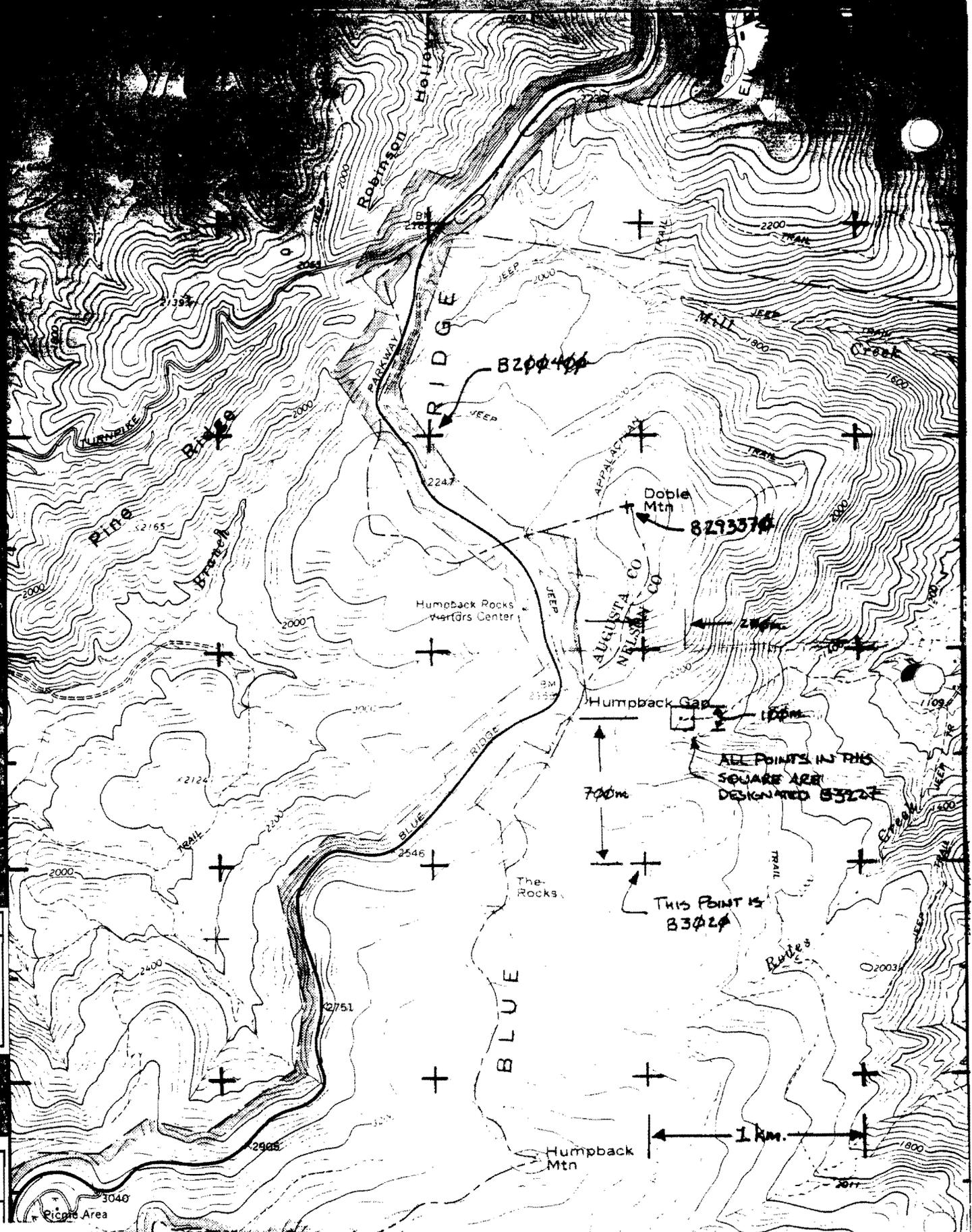
When 7.5' quads are not available, the grid may still be superimposed on any map and used to plot and report positions, but the grid squares will not be one kilometer wide.

Some search and rescue agencies, particularly military ones, use the Military Grid Reference System (MGRS), which employs the metric Universal Transverse Mercator (UTM) grid. Most local quads do not have a UTM/MGRS overprint, but their borders do have blue UTM tick marks each kilometer (1000 meters), with the MGRS coordinate: meters north of the equator or east of the MGRS reference. It is possible to align an ASRC grid overlay on a 7.5 minute quad so that the ASRC grid is in register with the UTM grid, using these blue UTM ticks. It is important to note, however, that the UTM/MGRS north coincides neither with the true north of the map edge grid ("neat lines") nor with magnetic north. If a map is photocopied with the ASRC grid in register with the UTM grid, the declination specified on the photocopied map should be that from UTM grid north to magnetic north. This is easily calculated (in the ASRC geographic area) by adding the UTM declination and the magnetic declination, since they are of opposite direction. Both UTM and magnetic declination are specified at the bottom of each USGS quadrangle map.

APPALACHIAN SEARCH AND RESCUE  
CONFERENCE GRID OVERLAY

m	mm
100	4.2
200	8.3
300	12.5
400	16.7
500	20.8

MAP  
BRAYO  
DECL  
5°W



40 Figure 3. Sample topographic map section with ASRC grid overprint.

Aeronautical Navigation for Groundpounders

-Keith Conover

It was a still, warm fall afternoon in the ridge and valley province of western Virginia. In the dusty intersection of two country roads, three cars were clustered. ASRC members were moving around, checking their packs, grabbing a quick bite of food, and otherwise preparing themselves to head up the mountain to an aircraft crash site. A small plane could be heard somewhere nearby. The Field Team Leader and a few others were clustered around a  $7\frac{1}{2}$ ' topographic quadrangle map spread out on the warm hood of a jeep, and the FTL was talking to the pilot of the search aircraft on his radio. The CAP search aircraft had spotted the crash site, and the pilot was trying to give the ASRC team directions to it. The ASRC team members were ready and impatient to be off at this point, but the FTL still hadn't pinpointed the site on his own topo map from the pilot's description and the latitude and longitude he had given for the sighting. About a half-hour of progressively more confused radio communications ensued with still no target for the field team; several ASRC team members went to sleep, and one of the others found a frisbee in the bottom of his quick response pack. Finally, the FTL realized that the pilot was circling directly above the crash site, and that the team could hardly hear the aircraft, much less see it nearby. The team had to pack up and drive a half-hour east, two ridges over, before it neared the crash site.

In this particular case (you can look up the mission report in the ASRC files if you would like some more details), the pilot had misread the latitude and longitude off his map, but certainly the length of the confusion would have been shortened by a great deal if the FTL had been able to appreciate the problems of flying and mapreading at the same time, and could have talked to the pilot in terms of features he could see on his aeronautical chart. The point of the story is that ASRC members need to be able to talk to pilots in terms they understand, and must be able to translate from aeronautical navigation to land navigation and vice versa. This is not as trivial as it at first glance might appear: a FTL wants to get a fairly accurate fix on a sighting, within half an inch or so on his topo map, before he leads his team off into the woods. However, the entire  $7\frac{1}{2}$ ' quad he is using corresponds to an area the size of a thumbprint on an aeronautical chart. The roads on which the Field Team is driving are not given route numbers on the aero map, and indeed many smaller roads aren't shown at all; on the other hand, the VOR's, Victor Airways, and other such aeronautical landmarks don't show up on topo maps. Essentially, we have a language problem, and it behooves us groundpounders to speak a little of the pilot's language so we aren't dependent on the (rare) bilingual pilots; also, it's a lot easier for us to carry a single gridded aeronautical chart for the whole state than for each pilot to carry a complete set of topographic maps for the state.

The first obstacle to overcome is scale; it's easy to be translating from topo map to aero chart mistakenly equating a mile-long ridge on the topo map with a ten-mile long ridge on the aero chart. On a topo map,

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one mile is represented by two and one-half inches; on an aeronautical chart, one mile is equivalent to only one-eighth of an inch. Check the scale often, and remember that, with 500 foot contours, a lot of terrain doesn't show on an aero chart.

Once you have a feeling for the difference in scale and detail, the most obvious way to start correlating topo maps and aero charts is to hope that you both have the UMS grid on all your maps, and to identify your 7½' topo map with a particular grid on the UMS-gridded aero chart. For the sample problems here, use the attached photocopy of part of a Virginia aeronautical chart and the photocopy of the NE part of the Sherando, VA 7½' USGS Topographic Quadrangle map attached to the ASRC Grid System article. The Sherando Quad is grid 249 Alpha; locate the NE part of this grid on the aeronautical chart. Find Humpback Gap on the topo map; now, using just the topography on the aero chart (remember scale differences) find it on that map as well. Let's say you've got a pilot on the other end of your radio as you're standing in the parking lot at Humpback Gap; you want him to fly to the Gap, then to scan Humpback Rocks and Mountain for a missing hiker. Right now he's leaving Richmond, and you want to direct him to the gap where you're standing. How do you do it? One possibility is to use latitude and longitude (which you should be able to do), but your photocopy maps don't show latitude and longitude, so scratch that. Besides, pilots may be even worse than you at using latitude and longitude, so let's try to give the pilot directions in aeronautical navigation terms; we will digress for a moment to consider these aeronautical navigation methods, then return to the problem.

Pilots navigate by radio beacons known as Very High Frequency Omnidirectional Radio Ranges, known also as VHF OmniRanges or more commonly just VOR's. On the aero chart, these are identified by a small hexagon with a thin 3-inch diameter compass rosette around it; the rosette is marked off in degrees which represents the magnetic bearings from that VOR. Look in the SW corner of grid 248 Bravo for the Montebello VOR; note the box with its frequency (112.6 MHz) and its broadcast identification (MOL) in letters and Morse code. The VOR is continuously broadcasting on its assigned frequency, either with its identifier, or with messages from an associated airport. Pilots may use a special combination of directional radio receiver and compass to align the aircraft along a radial or straight line out from a VOR, and to note the compass bearing. Thus it is possible for a pilot to fly a particular radial to or from a VOR with great accuracy. It is also possible for a pilot to obtain fixes on two different VORs and to use resection to determine his position.

You will also note many symbols on an aero chart; most of these have no relevance for our problem. The one landmark that may be used by pilots to describe a position to you is the standard Victor airways, the established commercial flight routes. These are indicated by a 1/16"-wide halftone line, along with the letter V and its airway number. The compass heading off a VOR is given at the beginning and end of each section, and certain checkpoints are marked with a name and arrows indicating the direction to the VOR's that establish it.

Going back to our problem as we are standing in Humpback Gap; you could say "Find Humpback Gap, which is on the crest of the Blue Ridge in the NE corner of grid 249 Alpha. It's on the 730 radial off the Montebello VOR." Can you confirm this? Try a problem yourself: describe to a pilot

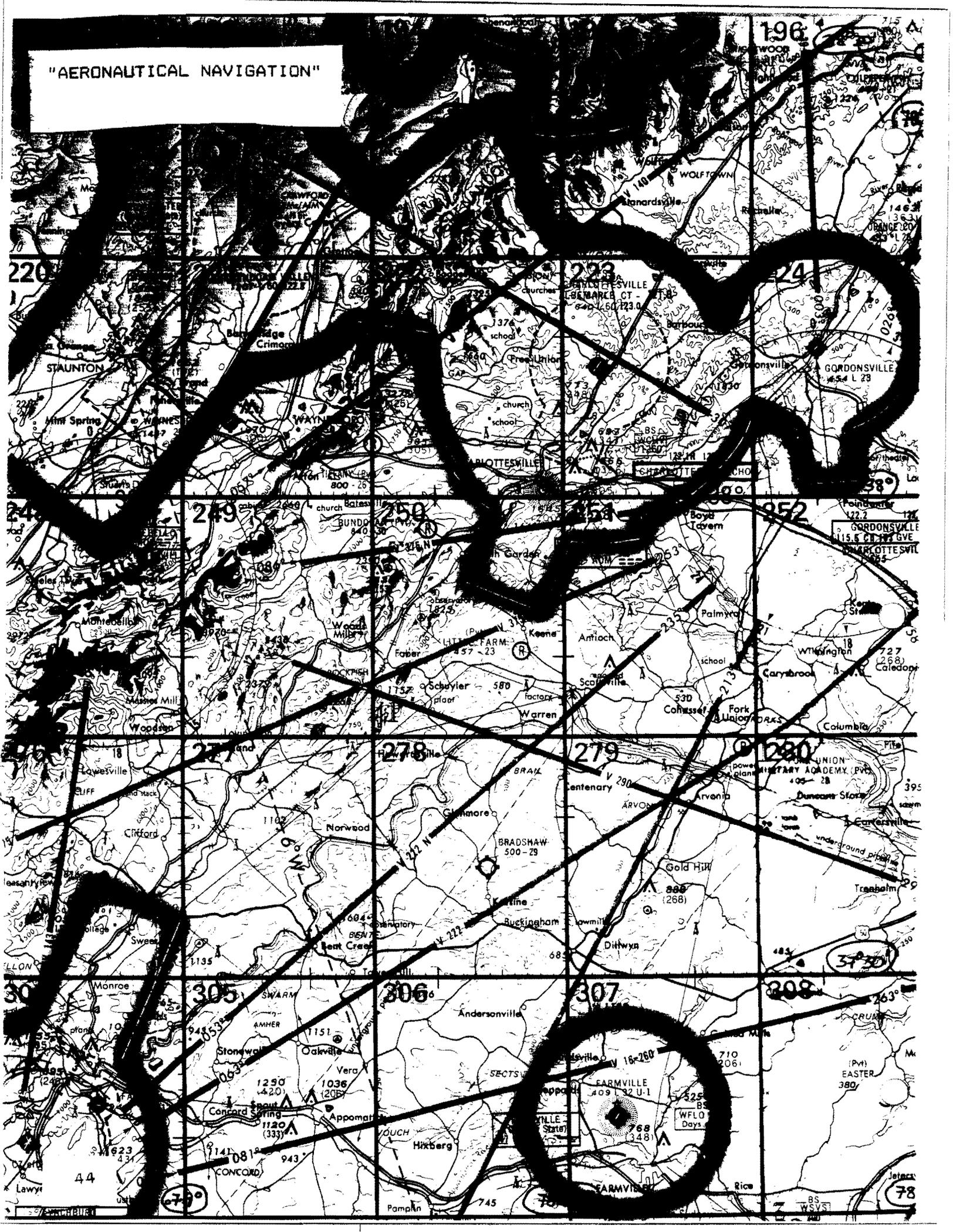
how to find the south end of Pine Ridge. (Answer at the bottom of the page.)

Some pilots have DME equipment which can give the distance from certain VOR's, so you might get a fix in terms of a radial off a VOR and the distance along that radial. Here's problem #2: the pilot radios you and says: "I've got a possible sighting of the two lost people, and they're in the bottom of a big ravine, or maybe it's a small valley, anyway there's a stream and woods in it but no obvious roads or fields; it's on the east side of the ridgeline, 14 miles out the 68° radial off Montebello VOR. Got that?" Where is this on the topo map?

Having gone through these little exercises, you can see the problems involved. With a little practice, translation should present few problems, so practice. Try giving someone directions over the phone to make things realistic; you can use the maps in this handout, or better yet, borrow a real aeronautical chart and some real topos and work some problems. I hope this little article helpful in your studies, and that you find this information useful on missions.

Answer to first problem: "Find the S end of the more southerly of two ridges W of the Blue Ridge Parkway at about 68° off the Montebello VOR. Answer to second problem: The crossing of the Appalachian Trail over Mill Creek in Mill Creek valley. Note: maps are often out of date. The AT now follows closely along the Parkway and doesn't go into the valley at all any more.

"AERONAUTICAL NAVIGATION"



196

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CONCORD

PAMPAN

FARMVILLE

RICE

78

LAND NAVIGATION PRETEST ANSWERS

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Shenandoah Mountain Rescue Group  
LAND NAVIGATION PRETEST ANSWERS  
Version 1.2 April 1983

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BASIC MEMBER TRAINING COURSE  
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1. l
2. h
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5. j
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8. i
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10. l
11. d
12. i
13. n
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16. b
17. e
18. a
19. c
20. b
21. a
22. c
23. e
24. a
25. a
26. a
27. a
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29. b
30. b
31. c
32. c
33. c

LAND NAVIGATION POSTTEST

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<u>LAND NAVIGATION POSTTEST</u>	Keith Conover, Editor
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Notes

1. You will need a protractor and a ruler or other straightedge for this test.
  2. In addition to the figures included with this test, you will need to refer to the figures from the pretest.
  3. Although this is designed as a closed-book test, you can take it as an open-book one if you feel you will learn better that way. You will grade the test yourself, and you will be the only one who sees your score.
- =====

FOR QUESTIONS 1-9, IDENTIFY THE FEATURE; REFER TO FIGURE 4.

Q#	Reference	Coordinates	Feature
1)	ASRC	B1901	_____
2)	ASRC	B2553	_____
3)	ASRC	B4518	_____
4)	MGRS	652E, 4309N	_____
HINT: use Figure 1 from the Pretest			
5)	MGRS	655.5E, 4306N	_____
6)	MGRS	654.5E, 4306.7N	_____
7)	Latitude/Long.	38°55' 50"N, 79°13' W	_____
(marks in river)			
8)	Lat./Long.	38°53' 50"N, 79°14' 30"W	_____
9)	ASRC	B2700-B4528	_____

FOR QUESTIONS 10-12, DRAW A ROUGH PROFILE OF THE LINE BETWEEN "A" AND "B."

- 10) (B1414)
  
- 11) (B0540)



12) (B2515)

13) What USGS quadrangle name applies to UMS grid 136C?

14) If an ASRC grid overlay is superimposed on the Petersburg West quad so that it is in precise register with the "neat lines" (edges of the map), what is the magnetic declination to be marked on map thus photocopied?

15) If the ASRC grid overlay is photocopied so it is exactly in register with the UTM grid ticks, what declination should be noted on the photocopy map?

16) What is the magnetic bearing off the Elkins VOR to Shook Gap?

17) The plane of the ecliptic is the plane of the solar system; its intersection with the earth draws an imaginary line across the sky which is "followed" by the sun, the constellation Orion, and the moon (within 6 degrees) across the night sky. The ecliptic line across the northern hemisphere sky crosses not at the zenith, but somewhat to the \_\_\_\_\_ (cardinal compass direction).

18) On Figure 4, plot a course from point B3512 to Shook Gap (B1033). Use the following techniques and indicate their use:

- "handrails"
- coarse orienteering
- catching feature(s)
- "aiming off"
- attack point(s)
- precision orienteering

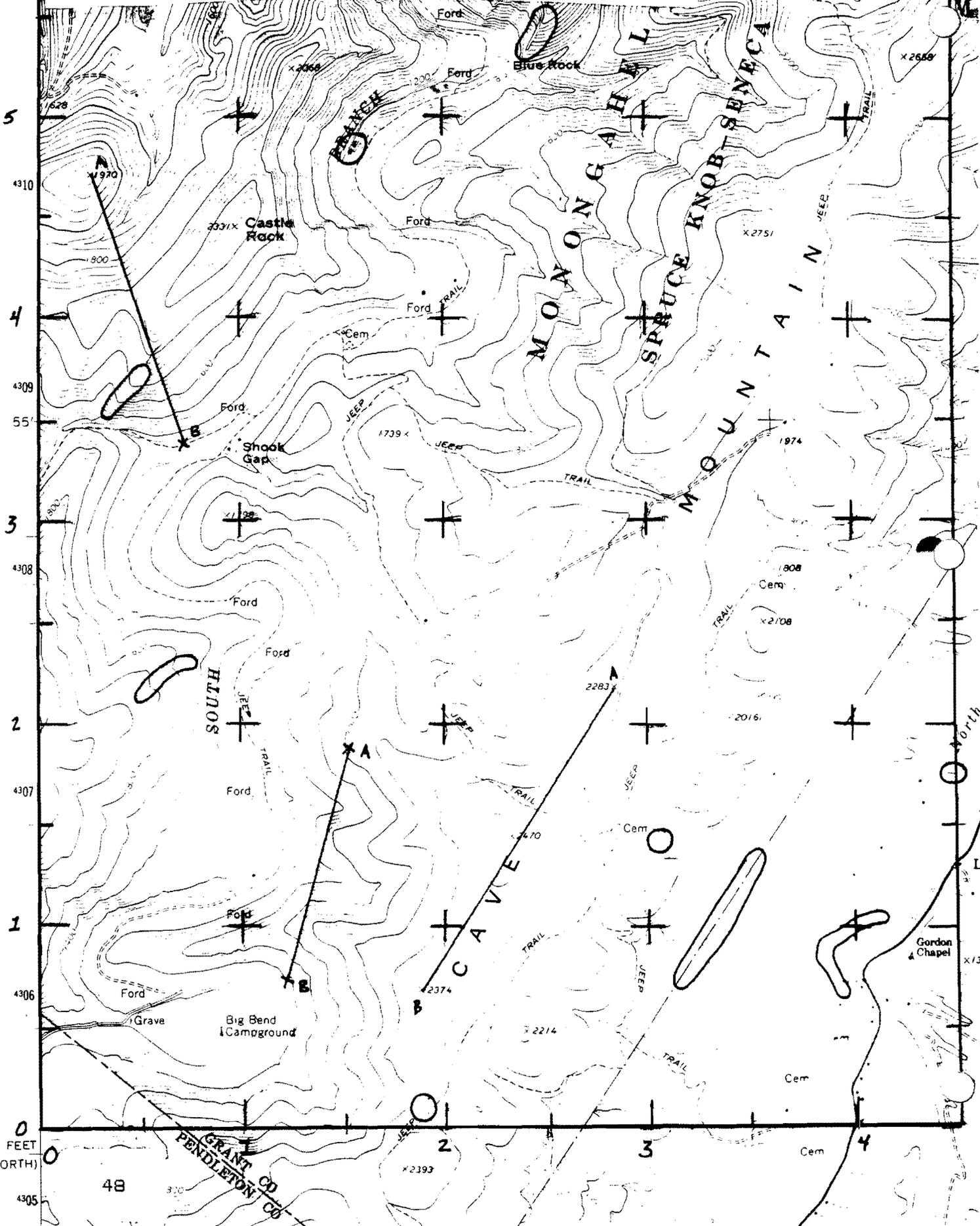
19) Calculate the following:

From	To	True Bearing	Magnetic Bearing
B2314 (peak 2740)	Shook Gap		
Castle Rock	Blue Rock		

20) You are on a downed aircraft search. You are with an ASRC Field Team at Petersburg. You are told by the Civil Air Patrol Mission Coordinator to get an ELT (Emergency Locator Transmitter) radio bearing from Petersburg, and to get the bearing a CAP team got from the town of Landes (they are now en route to Petersburg) and to proceed to the intersection. Your bearing from Petersburg is 235 degrees magnetic, and the CAP team got 330 magnetic from Landes (just SW of Petersburg). Where is the intersection?

5161 IV NE  
(HOREVILLE)

Figure 4: Photocopy section of Petersburg W. Quad



10 000 FEET  
(NORTH)

48

GRANT CO  
PENDLETON CO

x2393

x2214

x2374

x470

x2283

x2708

x2016

1974

x2751

x2668

x13

North

L

L

L

L