

air
cadets



the next generation

air cadet publication
ACP 32

navigation
volume 1 - map reading



Amendment List		Amended by	Date Incorporated
No	Date		
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ACP 32

NAVIGATION

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Map Reading

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CHAPTER 1

WHAT IS A MAP?

Introduction

Why do we need maps?

1. Even from the earliest days the urge for man to explore has been great. The early travellers used natural features to help them find their way from place to place. By noting the position of the stars, the moon and the sun, man devised a method of finding out where he was. This meant exploration past known boundaries was now possible. As the explorer ventured further and further from home and recognisable features disappeared, he would often sketch his surroundings so that the way home could be found more easily. These early “maps” were often drawn on animal hide, stone or reed paper.



Fig 1-1 13th Century Britain (courtesy of the British Library)

Finding your position on the earth

2. If we think of the earth as a sphere, we can imagine how it could be covered with imaginary lines to help pinpoint a position on the surface. First of all the earth has an axis, running from the True North pole to the True South pole - the only 2 points on earth that do not rotate. Next, imagine a line that runs around the middle of the earth half way between the North and South poles- this circular line is called the equator.

3. If we add more lines running parallel to the equator, they will also be circular, though smaller than the equator; they are called lines of latitude. Lines on the Earth's surface drawn from pole to pole are called lines of longitude.

Longitude

Prime Meridian

4. Longitude lines, also called meridians, are circular. They are numbered and have a starting point at Greenwich in England. This line is numbered zero and called the prime meridian- all other lines are either east or west of it. Every meridian - from one pole to the other - is a semi-circle, and has an anti-meridian on the opposite side of the earth. A meridian and its anti-meridian together make a full circle round the earth.

Lines of Longitude

5. By numbering the lines, it means that the whole of the earth can be covered. The position of each line is expressed in degrees away from the prime meridian. For example in the diagram point "A" is about 20° (degrees) west of the prime meridian. Point "B" is about 40° east of the prime meridian. Although this system can give reasonably accurate positioning it is not accurate enough for everyday use, so each degree is further broken down into 60 minutes. This now gives us a system of describing a point's location in terms of degrees and minutes either east or west of the prime meridian (Greenwich).

Degrees and minutes

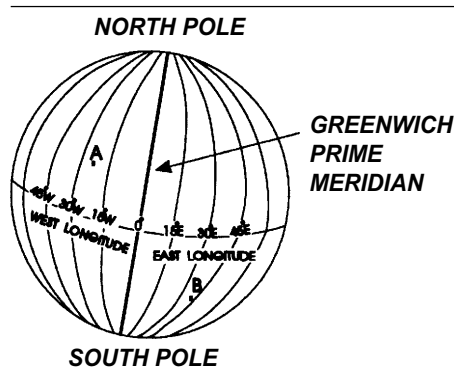


Fig 1-2 Lines of Longitude

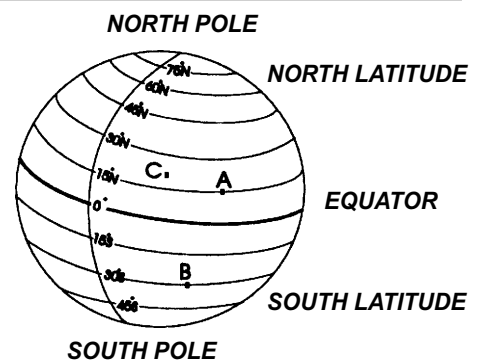


Fig 1-3 Lines of Latitude

Latitude

Lines of Latitude

6. Lines of latitude are circles drawn around the earth, parallel to the equator. The equator, at zero degrees, splits the earth into two halves, the northern hemisphere and southern hemisphere. Using the lines of latitude you can describe any point's location in degrees and minutes either north or south of the equator.

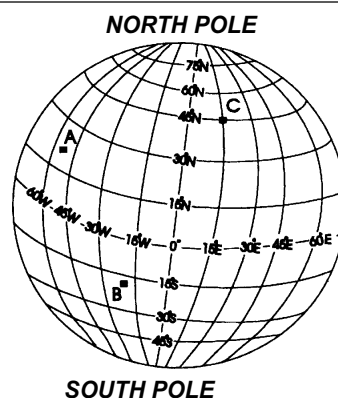
7. The parallels of latitude are often drawn at 15° intervals covering the globe, although other intervals may be chosen. The examples in Fig 1-3 show point "A" to be 15° north, point "B" to be 30° south and point "C" to be 20° north.

Recording a Position

Recording your position

8. If you put the latitude and longitude lines together on the same globe you will get a matrix. With this system you can give a point's exact position by stating its latitude, followed by its longitude in degrees and minutes. For example point "A" would be at $20^\circ\text{N } 56^\circ\text{W}$, point "B" at $17^\circ\text{S } 17^\circ\text{W}$ and point "C" at $45^\circ\text{N } 15^\circ\text{E}$. Note that Latitude must always be given first.

Fig 1-4 Latitude and Longitude matrix



Curved or Flat

The curved surface of the earth is flattened to fit on paper

9. Since the world is curved a truly representative map would also need to be curved. This would be too difficult for normal use so the curved surface of the earth is flattened out to fit on to a sheet of paper. This means that there are some differences between a map and the actual ground it represents. If however, only small areas of ground are considered when map making, these errors are reduced to a negligible amount. The need for accurately drawn maps gave rise to the art of cartography (map making).

Maps are made using satellites

10. This art has now become a science where today, every area of ground is covered either by survey or by satellite to give up-to-date maps of the world.

Ordnance Survey

M726 series map

11. The UK is fortunate because it is served by possibly the best cartographers anywhere. The Ordnance Survey (OS) is a Government department based in

Southampton and produced its first map in 1791 for the Army (hence Ordnance). These maps were initially 1 inch to 1 mile (M722 series) and it took 190 sheets to cover the UK. OS are constantly up-dating the information and map availability. At this time there are 204 sheets in the Metric 726 Series 1:50,000 covering the whole of the UK. OS have done a very good job producing this series and you should find them easy to use. It is this map series that the Air Training Corps use most and will be the main reference in this publication.

What Do You Want From A Map?

12. If you need to get from A to B it is important that you find the best route so that you can avoid rivers, lakes, motorways and other such obstacles. By the end of this publication you should be able to interpret (read) a map, that will include:

Symbols

Grid references

Distances

Most of the basic work can be carried out in the classroom but getting familiar with the map and what it tells you is the first priority.

Topographical maps

13. The M726 Series is classed as a topographical map which means that it particularly shows the shape and surface detail of the land, including natural and man-made features. A typical map would show:

Rivers	Valleys	Hills
Streams	Woods	
Mountains	Marshes	

14. Man-made features would include:

Roads	Canals
Railways	Towns
Villages	Power lines

15. The M726 Series is not the only type of map available, there are maps for several other user groups, including:

- a. Administrative maps (eg. for population surveys or council boundaries)
- b. Historical maps (giving details on layout of monuments and buildings).
- c. Marine maps (estuaries, sandbanks or wrecks).
- d. Road maps (motorist route planning).
- e. Outline maps (giving very brief description of specific area).

Map Selection

Which map to use?

Types of maps

16. The map you will require will depend on your activity. Here are some of the choices available:

<u>SCALE</u>		<u>POSSIBLE USES</u>
1: 10,000	(1cm = 100m)	Orienteering, town planning
1: 25,000	(1cm = 250m)	Walking (you may need more than one)
1: 50,000	(1cm = 500m)	Walking (most popular)
1: 63,360	(1inch = 1 mile)	Walking (replaced by 1: 50,000)
1: 100,000	(1cm = 1,000m)	Cycling, hostelling, route planning
1: 250,000	(1cm = 2,500m)	Cycling , motoring, flying
1: 1,000,000	(1cm = 10km)	Long distance air navigation

Remember - the larger the number on the right hand side of the scale ratio, the larger the area covered and so less detail.

17. The most popular maps that are used by walkers are:

- a. Landranger series (OS) 1: 50,000
- b. Outdoor Leisure (OS) 1: 25,000
- c. Tourist (OS) 1: 63,360 or 2.5 cm :1 Mile

18. The detail required on a map will depend on the area being covered. An area which is small is best served with a very detailed map but if touring in a car a less detailed map is more useful.

Revision (the latest edition)

Use the latest revision

19. A map is most accurate on the day that it is produced and will continue to be accurate until the features on it are changed. If you had planned an expedition in the classroom then went to the start point to find the valley had been dammed and the river is now a reservoir, this could prove to be a heavy dampener on the walk and your enjoyment. Some maps may stay fairly constant - for example, those of mountainous areas, as it takes many years to erode mountains and the area is not likely to be developed. You must be aware of urban areas like towns and villages because they can grow or have road bypasses built. Maps covering these areas may therefore change frequently. Before you start check the revision date of the map you are about to use.

Looking After Your Map

NEVER mark maps

20. Some maps are now produced laminated (plastic covered) and you can also treat maps with a waterproof coating. You may decide to protect your map by using a map case, clear map holder or even a plastic bag. Whatever method you choose you must always take care of your map. Always keep your map folded because in high winds you may lose control of it (flapping around) or lose it altogether. NEVER mark a map surface with ink as this will damage the surface when you try to remove the mark. If you need to mark a map use a soft pencil and use it very lightly so the marks can be removed easily with a soft clean eraser. Try to avoid getting your map wet but if it does then allow the map to dry naturally at the earliest possible chance. Remember maps are expensive - treat them with care.

Folding your map

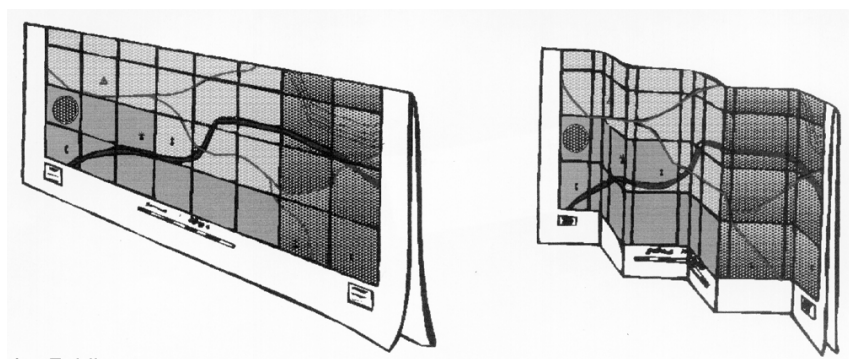


Fig 1-5 Folding your map

Sample Questions

Do not mark the paper in any way - write your answers on a separate piece of paper, in the form of a sentence.

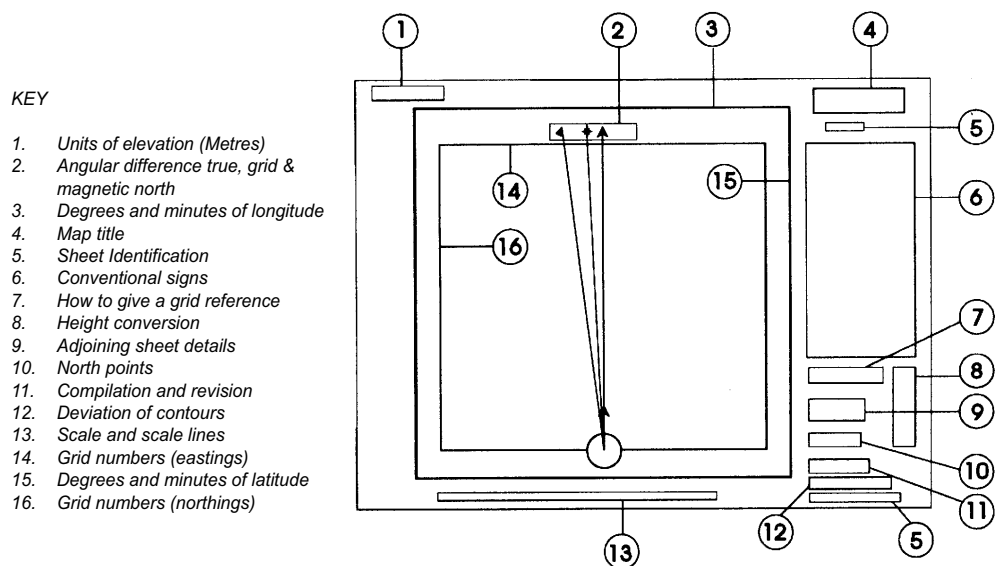
1. Which of these best describes a topographical map? It shows:
 - a. The shape and surface detail of the land
 - b. Underlying geological features
 - c. The distribution of climates
 - d. The distribution of minerals
2. The Series M726, 1:50,000 maps are:
 - a. Geological
 - b. Synoptic
 - c. Topographical
 - d. Demographical
3. Which one of these maps shows the greatest detail:
 - a. 1:25,000
 - b. 1:250,000
 - c. 1:500,000
 - d. 1:1,000,000
4. How should a map be folded so that it does not suffer too much damage in use and yet ensures the maximum area of map is accessible for reference?
 - a. Fold back each of the four edges until the piece required is exposed
 - b. Fold into four equal quarters
 - c. Fold up from the bottom “concertinawise”
 - d. Fold in half length wise with the outwards, then “concertinawise”

CHAPTER 2

MAP LANGUAGE

Introduction

1. The first time you look at a map it will probably be very confusing. It will no doubt take you a while to understand what is on the sheet and how it gives you information. Make sure you have a Series M726, 1:50,000 map to look at while you are working through this chapter. Outside of the main grid, in the margins, there is a host of useful information and in this chapter you will find a breakdown of what's what. Whether you are in the classroom or out in the field, if in doubt look in the margin.



Elevation

Check the units of height

2. When you are using a map you must first check the units of height or elevation. They will either be in feet or metres. In older maps the units of elevation are normally in feet, so to avoid confusion, check. The units of elevation are displayed on the map in the top left hand corner, key position 1 in the diagram. It is essential when you are calculating timings that you know the correct units of height.

Latitude/Longitude

Information on Latitude and Longitude

3. The lines of latitude are expressed in degrees and minutes and are marked along the right and left (east and west) hand side of the map in key position 15. The lines of longitude are marked along the top and bottom (north and south) of the map in key position 3. The lines of latitude and longitude are not actually drawn on the map itself- it would be too confusing.

3 Norths

4. In map reading there are always references to north. There are in fact 3 norths:

- a. True north
- b. Grid north
- c. Magnetic north

True North

5. This is the geographical north pole of the earth - the point where the earth's axis meet the surface.

Grid North

6. This north takes its name from the National Grid system, a system of imaginary lines drawn vertically and horizontally which divide your map into a series of squares. Because grid lines are drawn on a flat map and not on the curved surface of the earth as are the lines of latitude and longitude, the two systems are different. This difference is shown on the map, key position 10, as a difference between true north and grid north.

Magnetic North

7. Magnetic north is the point where a magnetic needle will align itself if freely suspended. The earth has its own magnetic field, similar to that produced by a giant bar magnet running along the earth's axis. Unfortunately, the earth's north and south magnetic poles do not coincide with the geographical poles - in fact they are about 1200 miles apart!

Map Identification

How to identify your map

8. On the M726 Series of maps the identification box is found at key position 5, at both the top and bottom of the right hand column. This gives details such as:

- a. SERIES M726 (type and scaling of map)
- b. SHEET 139 (particular area covered by map)
- c. EDITION 6-GSGS (Geographical Section General Staff, Authority in UK)

What does GSGS stand for?

9. There will be times when the information in this box will change. The most noticeable change will be the edition number. You may also find the adjoining sheet information useful if you are not quite sure of the sheet number you require.

Title

10. In the top right hand area of the column you will find the title of the sheet at key position 4. This will be a rough guide to the area covered by the map. For example: Birmingham, Grantham, East Kent and Black Mountains.

Scale and Scale Lines

Where are scale lines on your map?

11. The scales are situated along the bottom of the sheet at key position 13 and they give you: distances in nautical miles, statute miles and kilometres.

A nautical mile = 6080 feet = 1.85km

A statute mile = 1760 yds = 1,6093 km

A kilometre = 0.6214 mile or 5/8 of a mile

12. These scales can be used to obtain measurements for calculations of distances when route planning in the field.

Revision

Which revision is best?

13. The revision date is an important feature on a map because it gives the user an idea how up-to-date it is. The revision date can be found under the heading “COMPILATION AND REVISION” which is in the lower quarter of the right hand column at key position 11. The date will tell when the last set of changes to effect the map were added. Changes include such things as: new motorways, major industrial developments or new housing estates.

The Map

14. Having checked all the information and ensured that you have chosen the correct map, you are now ready to take a closer look at the main grid to see what it tells you.

15. When a map maker compiles information to put on to a map the aim is to give an accurate representation of what is on the ground. An aerial photograph of an area the same size as your map, would not give you all the information you require and would not be very clear. A map improves on an aerial photograph by using a set of convenient signs and symbols (a kind of shorthand depicting features on the ground). After a little practice using these signs and symbols you will soon find it quite easy to read a map and interpret what you see.

General Features

16. You must be able to “SEE” what is on a map and know what the features would actually look like if you were standing in front of them. To help you in this, some of these features are graded to signify the degree of importance they hold. Sometimes the same symbol is shown in different colours to signify a difference; for example, red National Trust symbols show the area is open all year, whilst the same symbol in blue indicates it has a restricted opening period. It is worth noting that if a feature is fenced-in then it will have a solid line on the map but if it is a natural boundary it will have a broken line around it.

Triangulation Points













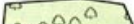











Trig points

17. Surveyors build up a map from a large number of triangles. The angles that are calculated from field work go into giving an accurate measurement on the ground.


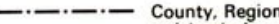

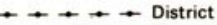


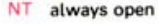

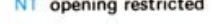
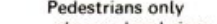
The points from where this information is taken are called triangulation points (trig points). Trig points are actually small concrete pillars with a 3 channelled plate on top. On the map they are shown as a small blue triangle with a dot in the middle with its height printed next to it (to the nearest metre).

Conventional signs

GENERAL FEATURES

	Electricity transmission line (with pylons spaced conventionally)		Quarry	
	Pipe line (arrow indicates direction of flow)		Spoil heap, refuse tip or dump	
	Buildings		Radio or TV mast	
	Public buildings (selected)		Church or Chapel	
	Bus or coach station			with tower
	Coniferous wood			with spire
	Non-coniferous wood		without tower or spire	
	Mixed wood		Chimney or tower	
	Orchard		Glasshouse	
	Park or ornamental grounds		Graticule intersection at 5' intervals	
			Heliport	
			Triangulation pillar	
			Windmill with or without sails	
			Windpump	

BOUNDARIES

	National		County, Region or Islands Area
	London Borough		District
	National Park or Forest Park		
	National Trust		NT always open
	Forestry Commission		NT opening restricted
			Pedestrians only -observe local signs

Roads and Paths

18. There are some signs and symbols that will be more important to you when you are planning an expedition on foot - they will be roads, paths and tracks. Note the different colours representing different types of road.

Conventional signs



PUBLIC RIGHTS OF WAY
(Not applicable to Scotland)

- Footpath
- Bridleway
- Road used as a public path
- Byway open to all traffic

Public rights of way indicated by these symbols have been derived from Definitive Maps as amended by later enactments or instruments held by Ordnance Survey on 1st February 1986 and are shown subject to the limitations imposed by the scale of mapping. Later information may be obtained from the appropriate County or London Borough Council

The representation on this map of any other road, track or path is no evidence of the existence of a right of way

Danger Area MOD Ranges in the area. Danger! Observe warning notices



Extent of available information

Spot Heights

19. Spot heights appear on maps as an added guide and are used to back up triangulation points. They are represented by a dot with the height next to it (to the nearest metre).

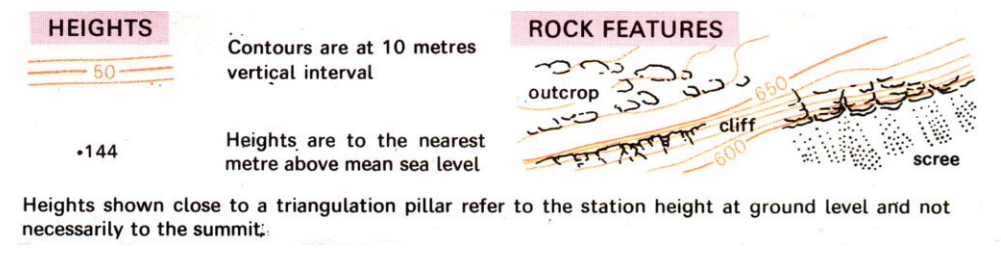
Contour Lines

Contour lines

20. A contour line is a reddish brown line drawn on the map joining all points of equal height above mean sea level (MSL). Mean sea level is a fixed height approximately half way between high and low tides calculated at Newlyn in Cornwall over many years. This MSL gives a common baseline so that anywhere in the UK can be measured to give an accurate height. By joining all the points at the same height you can achieve a picture and shape of the land. These contour lines will wander all over the map and eventually rejoin at the starting point to show an area of equal height. There is an exception to this rule and that is where a contour line meets a cliff face. If you look at a contour line and cannot find the height try following it round until you come across the figure. These heights are shown in small breaks in the contour line itself and every fifth line is shown slightly thicker to make them easier to read. These contour lines are situated at 10 metre intervals on the M726 Series and the rise or fall between contours is called the vertical interval (VI).

Vertical Interval

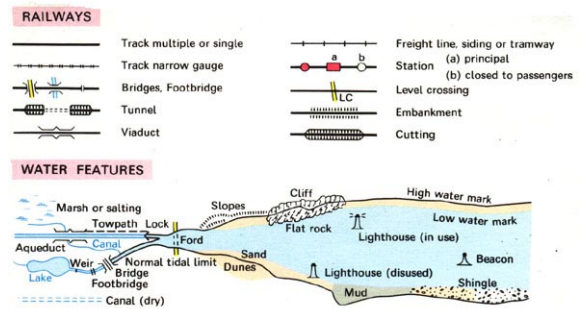
Conventional signs



Railways and Waterways

21. Railway conventional signs are used to indicate either double or single track. Special features include tunnels, cuttings, sidings and embankments. Stations that are open to the public are shown in red, whereas a station that is closed is shown in white. Bridges, viaducts and tunnels especially those connected with roads, railways and waterways are shown as solid objects when above ground and as dotted or broken lines when below ground.

Conventional signs



Tourist Information

22. This information is often very useful. The long distance path information shown at the bottom simply indicates the route of the path across the sheet.

Conventional signs

TOURIST INFORMATION

- Information centre
- Parking
- Picnic site
- Viewpoint
- Camp site
- Caravan site
- Youth hostel
- Selected places of tourist interest
- Telephone, public/motoring organisation
- Golf course or links
- Public convenience (in rural areas)

ROUTE OF NORTH DOWNS WAY

Long Distance Path (LDP)

ABBREVIATIONS

- P Post office
- PH Public house
- MS Milestone
- MP Milepost
- CH Clubhouse
- PC Public convenience (in rural areas)
- TH Town Hall, Guildhall or equivalent
- CG Coastguard

ANTIQUITIES

- VILLA Roman
- Castle Non-Roman
- Battlefield (with date)
- Tumulus
- Position of antiquity which cannot be drawn to scale

Ancient Monuments, and Historic Buildings in the care of the Secretaries of State for the Environment, for Scotland and for Wales and that are open to the public

The revision date of archaeological information varies over the sheet

Conclusion

23. Remember - conventional signs are appropriate ONLY to the map that you are using. They may be different on a different version of the same map. These signs and symbols are easy to learn and the best way to improve your understanding is to get as much practice using them as possible, then follow it up by groundwork. There may be one or two signs that you come across that you don't recognise - if in doubt look in the margin.

Sample Questions

Do not mark the paper in any way - write your answers on a separate piece of paper, in the form of a sentence.

1. On an M726 series map the letters "PC" represent:
 - a. Public convenience
 - b. Police communications centre
 - c. Private chapel
 - d. Picnic site

2. Contour lines are continuous (ie wherever they run they eventually return to their starting point), with one exception. The exception is:
 - a. At a cliff edge
 - b. At the North or South Pole
 - c. At a river
 - d. When the land is very flat

3. To help in reading and counting contours to determine heights, some contours are drawn using thicker lines than the rest. The thicker ones occur:
 - a. Every 2nd contour
 - b. Every 3rd contour
 - c. Every 5th contour
 - d. Every 10th contour

4. On the M726 series map, spot heights are shown in:
 - a. Kilometres
 - b. Metres
 - c. Feet
 - d. Yards

CHAPTER 3

SCALES

Why use a scale?

Introduction

1. If your map is to cover a reasonable area then everything on the map has to be reduced considerably from its real size. The choice of scale would be determined by the user or the task required.

How do you express scale?

Different ways to express a scale

2. There are 3 ways to express scale

a. In words- by saying “so many centimetres to the kilometre”. For example a scale of “2cm to 1km” means that for every 2cm on the map you would travel 1km on the ground. Measuring the distance from the Squadron Headquarters to the local Police Headquarters as 12cm on this scale would be equal to 6 km on the ground.

b. As a Representative Fraction (RF)- in this method the scale is expressed in the form of a fraction, for example $\frac{1}{50,000}$ Using this method you are saying that any distances measured on the map are one-fiftythousandth of the real distance on the ground.

c. As a ratio: very similar to b. but is written as:

1:50,000 The meaning is also the same as b.

Calculation

Understanding scale

3. In the case of RF and ratio the expression of the distance, whether it is in inches, centimetres or metres, is the measurement on the ground. So a 1:50,000 ratio would be equally valid for

1 inch on the map ≡ 50,000 inches on the ground

1 cm on the map ≡ 50,000 cm on the ground

1 m on the map ≡ 50,000 m on the ground

4. If the scale is expressed in words it may be necessary to convert it into either a RF or a ratio. For example, to convert a scale of 1 inch to 1 mile, you have to calculate the number of inches in a mile:

There are 1,760 yards in a mile

There are 5,280 feet in a mile (1760 x 3)

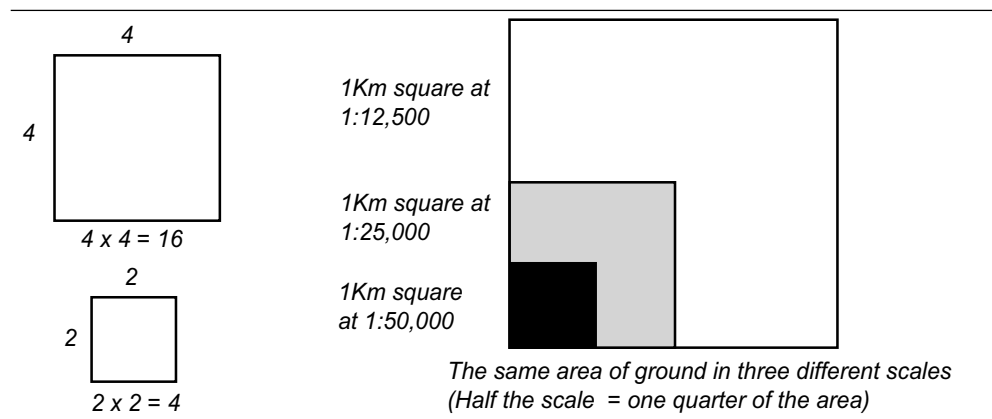
There are 63,360 inches in a mile (5280 x 12)

5. So the scale of 1 inch to 1 mile can be expressed as a ratio of 1:63,360. This type of calculation is made easier using the metric system, but it will still require careful thought.

Area

Reducing areas

6. When using scales, areas of ground will also be proportionately reduced but remember that areas contract rapidly on small scale maps. For example if you take a map that is half the scale of another then the area is reduced by a quarter (not a half). This is because the area of a rectangular figure is length multiplied by breadth. If you therefore halved the scale you will quarter the area of the map.



7. From this you can see that a large scale map is very detailed in area. As a rough guide:

Different types of map use different scales

- Large scale - city or town maps (defined buildings)
- Medium scale - Larger areas (buildings as symbols)
- Small scale - atlas (large towns in name only)

Visualisation

8. If you can get into the habit of checking your scale when you use your map you will soon become familiar with distances and areas covered by that scale. This will also make your task of route planning easier to achieve.

Air Photography

9. Photographs from the air can provide an almost instant representation of what is on the ground. Air photographs, like maps, can become out of date very quickly. The examples below show the differences between maps and photographs (both black and white and colour). By using a special lens you can obtain a 3-D picture of the ground which will show relief. The scale of the photograph is fairly small and therefore to give adequate detail for use on the ground a very large photograph would be needed. Which would you prefer to use, a photograph or a map?

Fig 3-1 Blackpool Airport





Fig 3-2 Telford in Shropshire

Sample Questions

Do not mark the paper in any way - write your answers on a separate piece of paper, in the form of a sentence.

1. If you measured the distance between two places on a 1:50,000 map and it came to 26 centimetres, what would be the real distance over the ground in Kilometres?
 - a. 52
 - b. 26
 - c. 13
 - d. 7.5

2. On a 1:50,000 M726 series map, what distance on the ground is represented by 2cm on the map?
 - a. 4Km
 - b. 2Km
 - c. 1Km
 - d. 0.5Km

3. On a 1:50,000 M726 series map, what distance on the ground is represented by one side of a 2cm grid square?
 - a. 1Km
 - b. 10Km
 - c. 0.5Km
 - d. 5Km

4. For which of the following uses would a map with a scale of 1:1,000,000 be suitable?
 - a. Showing street and houses in great detail
 - b. Motoring in the UK
 - c. Navigating on foot, as in an expedition
 - d. Long distance aeronautical navigation

CHAPTER 4

GRID REFERENCES

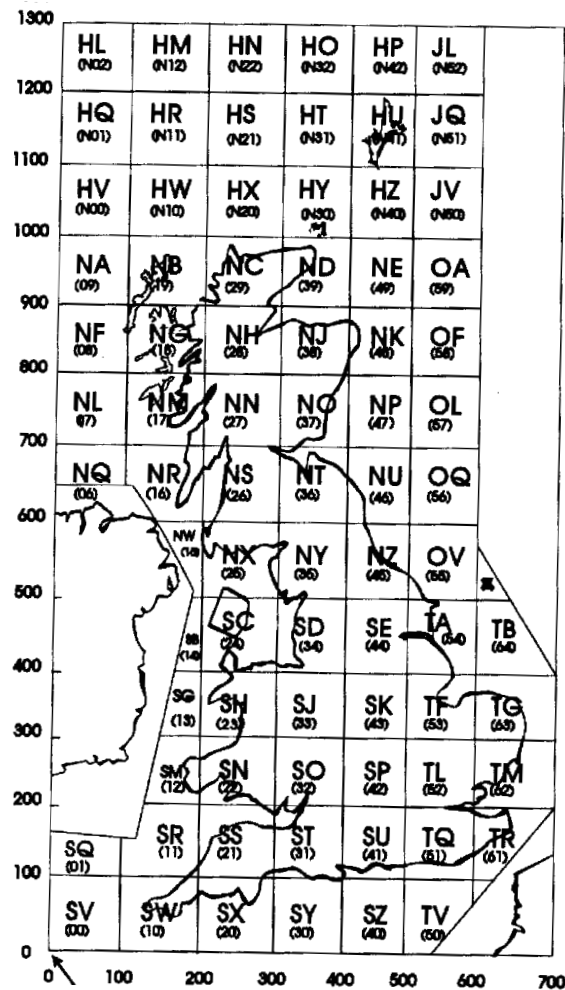
Grid Lines

1. If you look at a M726 Series map you will notice that it is covered in squares. These squares make up a grid that covers the whole area of the map. The lines are better known as “grid lines” and allow you accurately to locate points on the map. This system also allows you to route plan using “grid references” (GR). For ease, the numbers are printed around the grid and inside at every 10th grid line in both directions across the map.

UTM

2. These grid lines belong to a much bigger system that covers the UK and is known as the National Grid (there is no connection with the electricity supply!).

Kilometres Northings



FALSE ORIGIN OF NATIONAL GRID

Kilometres Eastings

The UK's National Grid is not the only one of its kind as nearly every country will have its own National Grid. There is a world wide grid called Universal Transverse Mercator Grid (known as UTM Grid), which is used on aviation and maritime charts because of the much larger distances involved.

The National Grid

3. Every grid system must have a starting point so that the grid can be built up from it. From the diagram at the previous paragraph you can see that the UK's starting point is off Lands End. To cover the UK there is a need for seven 100 kilometre lines of eastings (vertical lines) and thirteen 100 kilometre lines of northings (horizontal lines) from the starting point. These squares of 100 kilometres (Km) are further identified by two letters.

Grid References (GR)

4. You will understand that a map drawn on the scale to fit a 100km square will have very little detail at all. A map that will be useful to you has to be based on a much smaller area. The M726 Series covers an area of about 40km² which is less than a quarter of the 100km² area. The M726 Series map has squares of 1km in size giving an accurate scale map for most types of use. The number printed against each vertical line indicates the number of kilometres that line is east of the starting point for the 100km square to which your map belongs. The number printed against the horizontal grid line indicates the number of kilometres the line is north of the same starting point. There is on a M726 Series map a "British National Grid" legend that tells you where your map is in relation to the 100km square. The need for these grid lines will now become obvious and can be referred to as eastings and northings lines.

***GRs point to the South
West corners***

5. It is fairly easy to locate an object within a 1km square as long as you know what square it is in. This can be done using Easting and Northing to indicate the south west (SW) corner of the square you wish to identify. By using the SW corner of the square, the grid reference is standardised so everyone knows what it means.

6. As shown by the examples you end up with two sets of figures. If you put them together they form a 4-figure reference. You always quote the eastings first followed by the northings. There is a saying that might help you remember this sequence:

Across the hall (eastings) and up the stairs (northings)

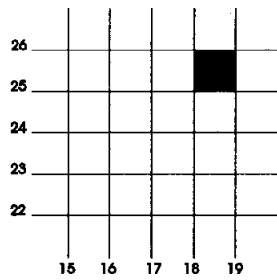


Fig 4-1 GR 1825

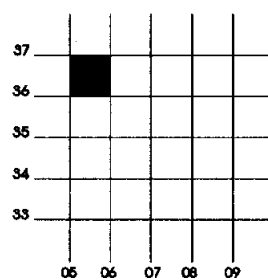


Fig 4-2 GR 0536

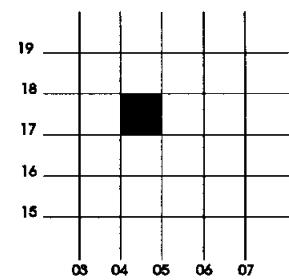


Fig 4-3 GR 0417

7. This 4-figure reference system is a good method of pinpointing objects on the ground like a church or a farm but if there are more than one of the same object in that particular square it may get confusing. To overcome this problem you need to increase your accuracy. There is a system of 6-figure referencing you can use.

6 Figure GR

8. In the following examples each 1km square has been subdivided into 10 equal parts (1/10ths). Each of the small squares now represents 100m² on the ground. So to give a 6-figure reference you start in the SW corner and get your 1km grid number (say 33) as before, then mentally divide the grid into ten parts and estimate how far into the square the object is (say 4). Once this is done add the figure to the first (giving 334)- now you have your easting. Repeat the process for the northing and you will end up with a 6-figure reference number. Judging tenths across the square (both up and down) may be difficult to begin with but with practice it soon becomes an easy system to use.

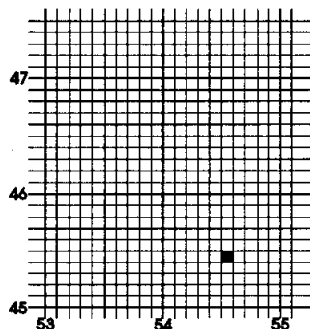


Fig 4-4 GR 545 454

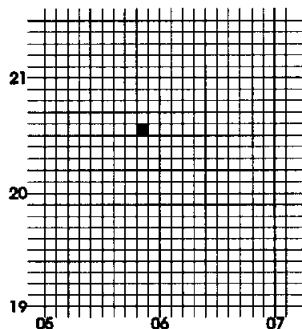


Fig 4-5 GR 058 205

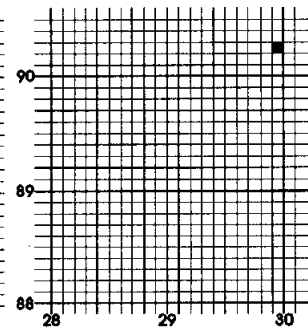


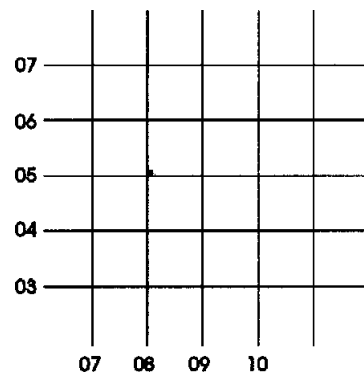
Fig 4-6 GR 299 902

Noughts

9. When you are compiling your GR you may find it contains noughts. You must remember to include them. If the object you seek is on the easting or northing lines then the third number in your grid reference will be a nought, you must include it. In this example the GR would be:

080 050

Fig 4-7 GR080 050



Letters

The full GR

10. In the diagram at paragraph 2 showing the National Grid, the 100Km squares are identified by the use of letters. You would not normally refer to these but there are some cases where you would need to (in the completion of a long trek, crossing into another 100Km square). To provide clarity and to avoid uncertainty the letters would also be added to the grid reference, for example:

SO 080 050

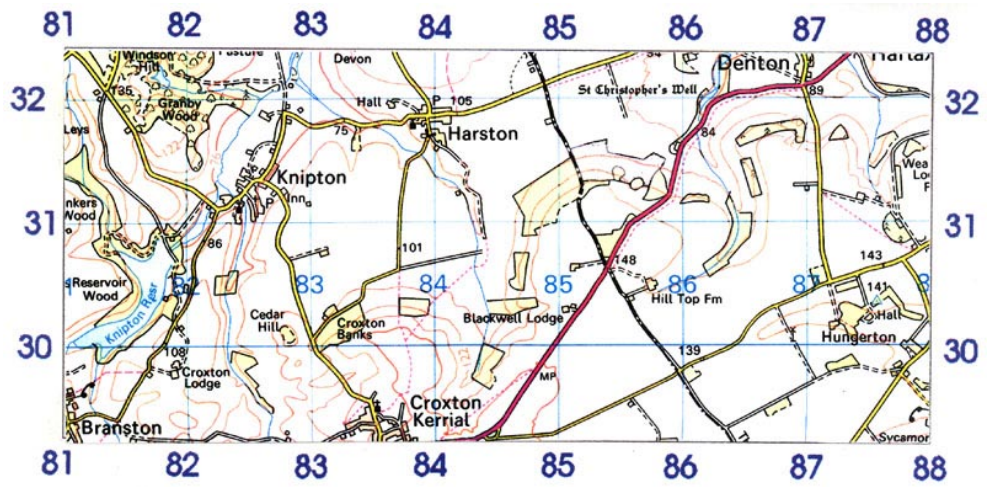
Plotting A Grid Reference

11. If you had been tasked to locate an object at a given reference 875 303 on Sheet 130 on a M726 Series 1:50,000 map, this is how you might go about it:

- a. Mentally divide the number into two segments.
- b. This gives you 875 and 303.
- c. Use the 87 from the first set (easting).
- d. Locate that number across the sheet.
- e. Use the 30 from the second set (northing).
- f. Locate that number up or down the sheet.
- g. You will now be able to locate the SW corner of the square where the object lies - 87 30.
- h. Now use third number from the first set (5).
- i. Move half way across the easting line.
- j. Use the third number of the second set (3).
- k. Move up the grid 3 tenths.
- l. At this point you will find a trig point at 141m.

12. This may seem a long process but once you have gained some experience you will no doubt develop your own method and increase your speed.

13. So far you have been estimating the 10 divisions required for a 6 figure reference. There are more accurate methods of taking this measurement. One such method is a useful device called a "Roamer". This device has tenths marked out in several different scales along various edges. You can find these scales on most compasses designed for navigation on foot.



Sample Questions

Do not mark the paper in any way - write your answers on a separate piece of paper, in the form of a sentence.

1. A "Roamer" would be used in finding:
 - a. The direction of a track
 - b. The grid reference point
 - c. The average gradient
 - d. A relative bearing

2. When using an M726 1:50,000 map, a 4-figure grid reference will define a 1 Kilometre square on the map. The 4-figure reference refers to a particular corner of the square: which corner?
 - a. NE
 - b. SE
 - c. NW
 - d. SW

3. Each side of each Grid square on a 1:50,000 map represents on the ground:
 - a. 1/2 Kilometre
 - b. 1.5 Kilometre
 - c. 1 Kilometre
 - d. 2 Kilometre

4. What is the meaning of the two letters in a Grid Reference using the UK National Grid e.g. a GR of TL307624?
 - a. The point is located in one of the Grid squares with sides of 500Km
 - b. The point is located in one of the Grid squares with sides of 1Km
 - c. The point is located in one of the Grid squares with sides of 100Km
 - d. The point is located 30Km East and 62Km North of origins of the grid

CHAPTER 5

RELIEF

Introduction

What is relief?

1. The word “relief” means the rise and fall of the ground or, in other words such features as hills and valleys. This involves both the height and the shape of the land. As a map is drawn on a flat sheet of paper the representation of height and shape is difficult. Map makers have various ways of doing this, but whatever method, it is left to the reader (you!) to interpret the information. This chapter introduces you to relief on a map.

Height

Methods of showing height

2. Methods of showing height on a map include:

a. Spot heights and triangulation points, which are used to give an accurate height above sea level at given points. They give an indication of height but not shape.

b. Layer tinting, which uses colours that may vary depending on the type of map you are using. For example, land up to 60 metres may be coloured green, rising higher ground may be light brown and higher ground still may be in dark brown. If this system is in use on a map you will find a key legend for the colours in the margin. Layer tinting gives you some idea of the shape as well as height and its main advantage is that it gives a quick impression of the highest and lowest ground. However, because of its general nature it is best to use it only as a rough guide.

Unit Of Measurement

CHECK the units of height

3. Units of height are important. In particular you must appreciate the difference between feet and metres, a foot being about the size of your shoe whereas a metre is a full stride. You can imagine your group’s reaction if you were planning to climb a hill of a 1,000 feet which was going to take two hours, only to find that it was actually 1,000 metres taking six or seven hours to climb. Hence it is vital to know the units of height from the planning stage right through to the execution of an exercise.

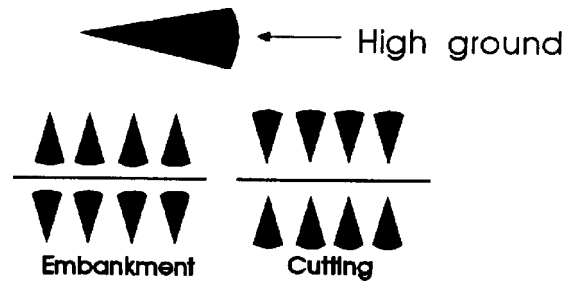
Shape

Showing steep ground

4. Methods of showing shape include:

a. Hachures. These are short tadpole-shaped strokes, the thicker end of the stroke being in the direction of the higher ground. When depicting steep ground they are drawn thickly and close together. On areas where the ground is a gentle slope, the hachures are drawn thinly and wider apart. This method gives no definite height indication and is seldom used except to show cuttings, embankments and steep slopes.

Fig 5-1 Hachures



b. Hill Shading. Hill shading is similar to hachures, but using an oblique stroke to achieve a depth of shading. This means that the darkest shading is the steepest ground. Another form of shading is based on a convention that light is shed from the NW corner and the hills are shaded accordingly. This method does not in itself give any indication of height.

Contour Lines

Contour lines

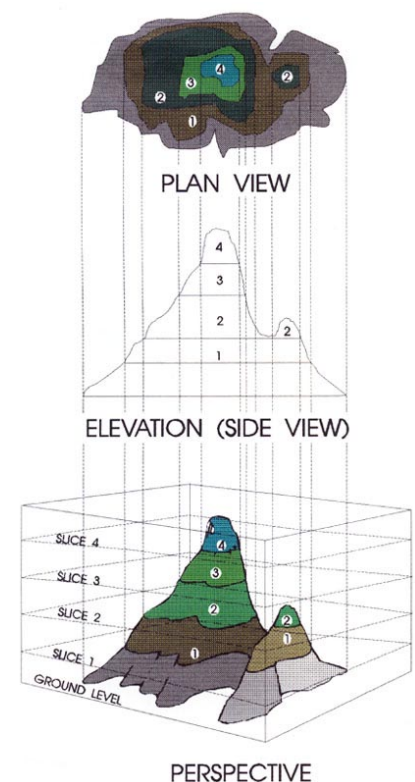
5. Contour lines on a map join all the points of the same height together and, with a little practice you can get from them a very good idea of the shape of the ground. So much so, they are the standard way in which height is depicted. There are some points to bear in mind before you start interpreting information from contour lines:

- a. Between any two contour lines there must be a slope either up or down.
- b. Contour lines are continuous and only stop abruptly at a cliff edge.
- c. Heights on contour lines are printed so that when you read them the right way up, you are facing uphill.

Contour Plans

6. Contour lines represent an area on the ground and can be thought of as a plan of that ground. If you take a map and look at the contour lines you will see something like the plan view shown below. From this representation you can build up a picture in your minds eye as to what it will look like on the ground (side view). The perspective is the combination of plan and side views and gives both the shape and height of the object.

Fig 5-2 Visualising the shape of the land



Slopes

Steepness and direction

Steep or gentle slopes?

Contour markings face uphill

7. If two contour lines are far apart it would suggest there is a greater distance to travel from one to the other to gain the height. This is better described as a gentle slope. If you see two contour lines very close together you would expect to see a very steep slope. The next few figures demonstrate these points well and with practice you too will be able to “see” when a climb will be hard (steep) or easy (gentle). It is not always easy to tell in the classroom whether a set of contours represents a steep upward or a steep downward slope. Remembering that contour

values are always printed facing uphill this should give you a good guide in telling which way the slope is going. Other clues may be available to you, like rivers or lakes as these tend to be at the bottom of a slope.

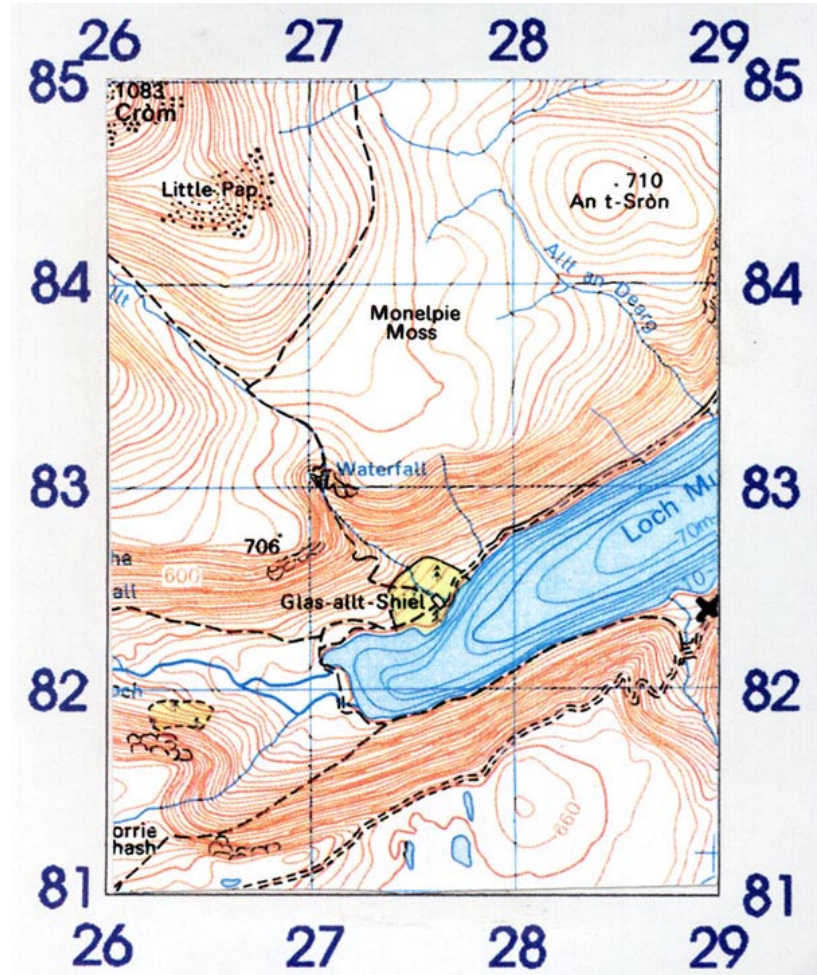


Fig 5-3 Photograph from GR 289 824



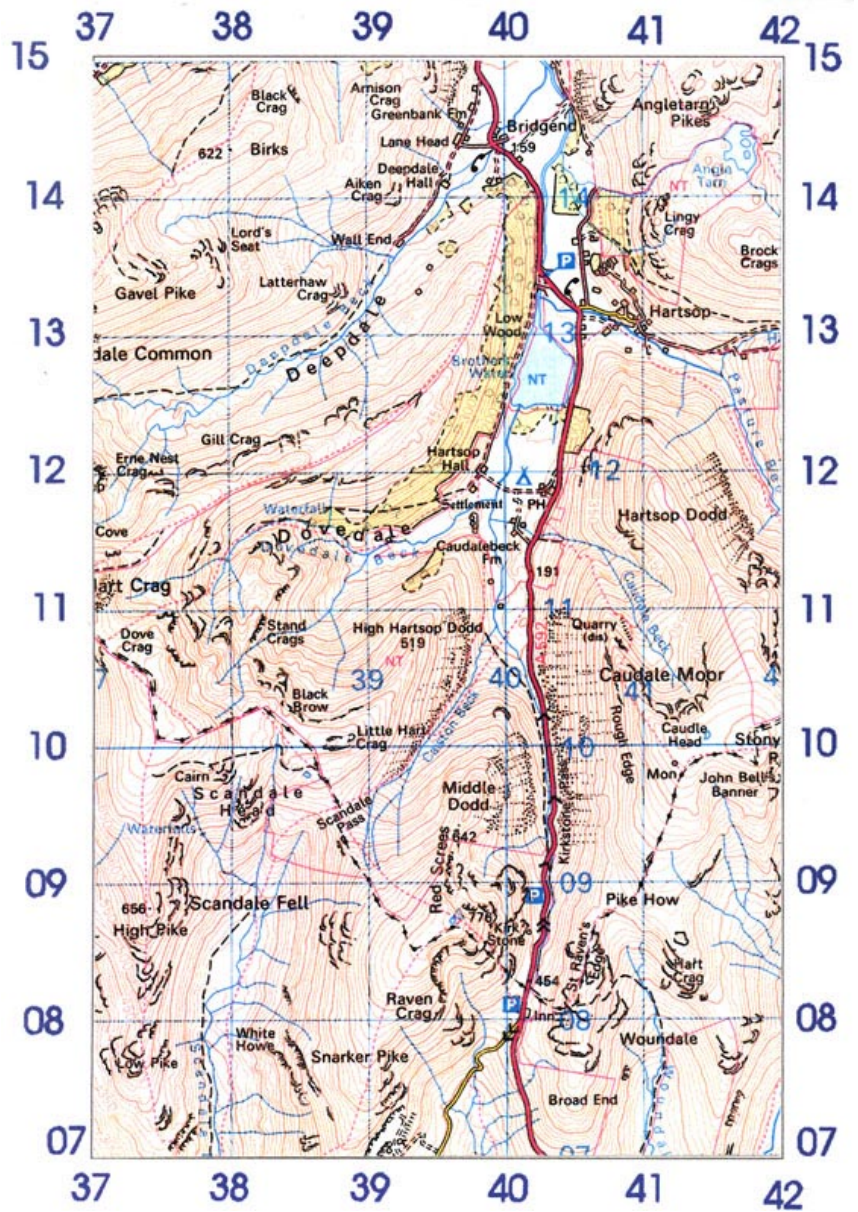
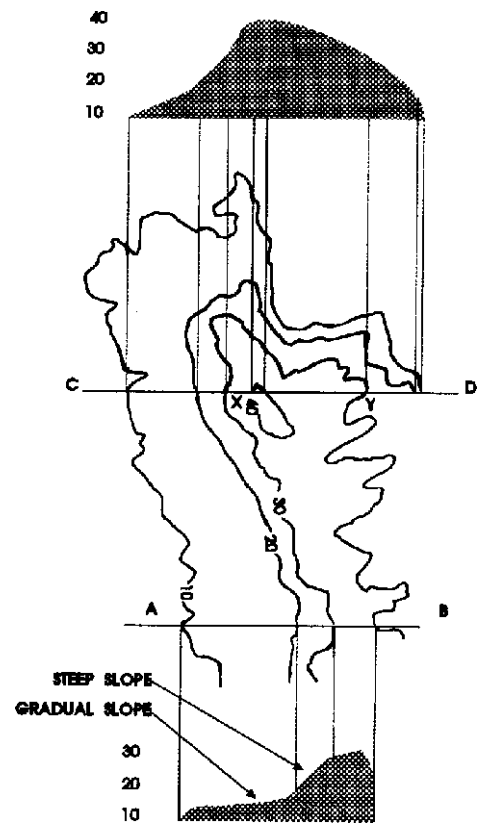


Fig 5-4 Photograph from GR 402 083

Convex/Concave

8. As well as being gradual or steep, slopes may be convex or concave. The diagram shows in line CXYD that the slope is convex (YD) because the contours are closer together at the bottom. If the contours are further apart at the bottom as in (CX) the slope is concave. It follows that if the contour lines are more evenly spaced, then the slope will be relatively uniform or straight.

Fig 5-5 Convex and Concave slopes



Lie of the land

9. Where contours meander and are varying distances apart, but never very close, the ground is undulating and relatively flat. You can only gain a little knowledge of the ground from the sparse detail, but the land will fall gentle from the higher contour to the lower one.

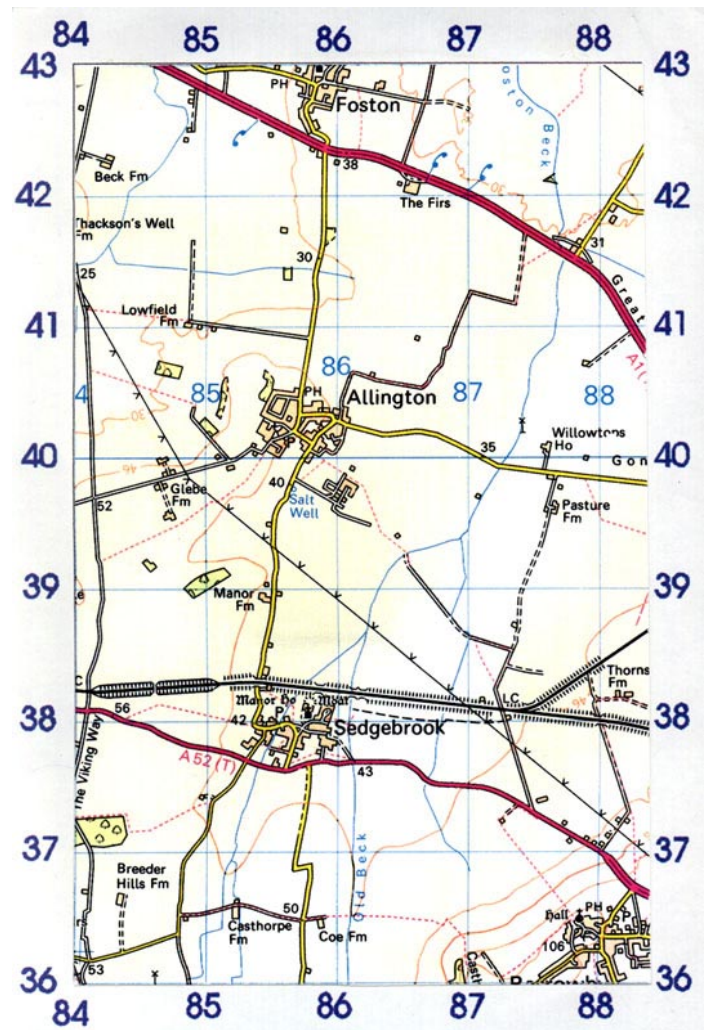


Fig 5-6 Photograph from
GR 878 365

Ridges Saddles and Cols

A ridge is a long narrow stretch of elevated ground; it is also known as a saddle. Where a ridge has a peak at each end, the lower part of the ridge between the summits is called a col.

Fig 5-7 Ridge and Col

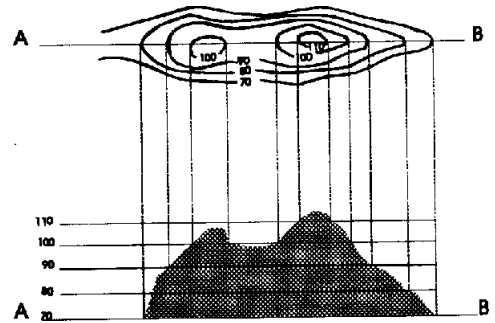
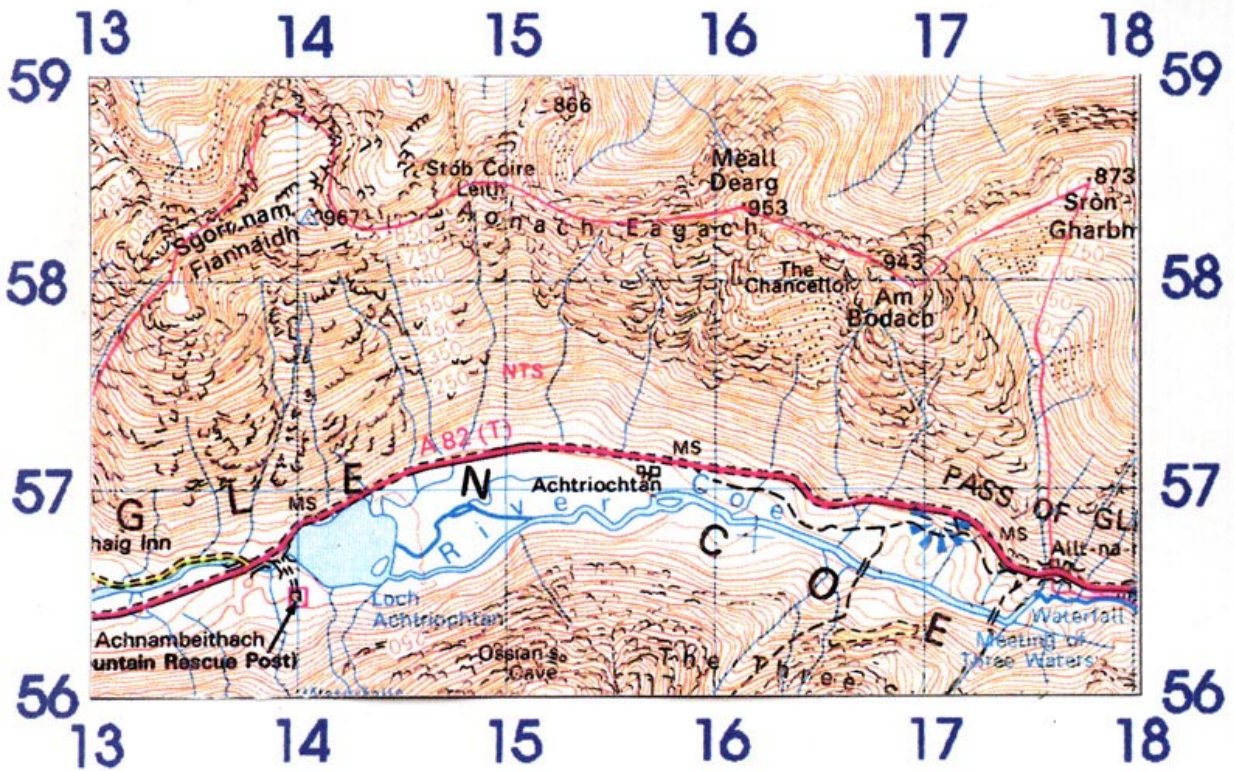


Fig 5-8 Photograph from GR 176 567



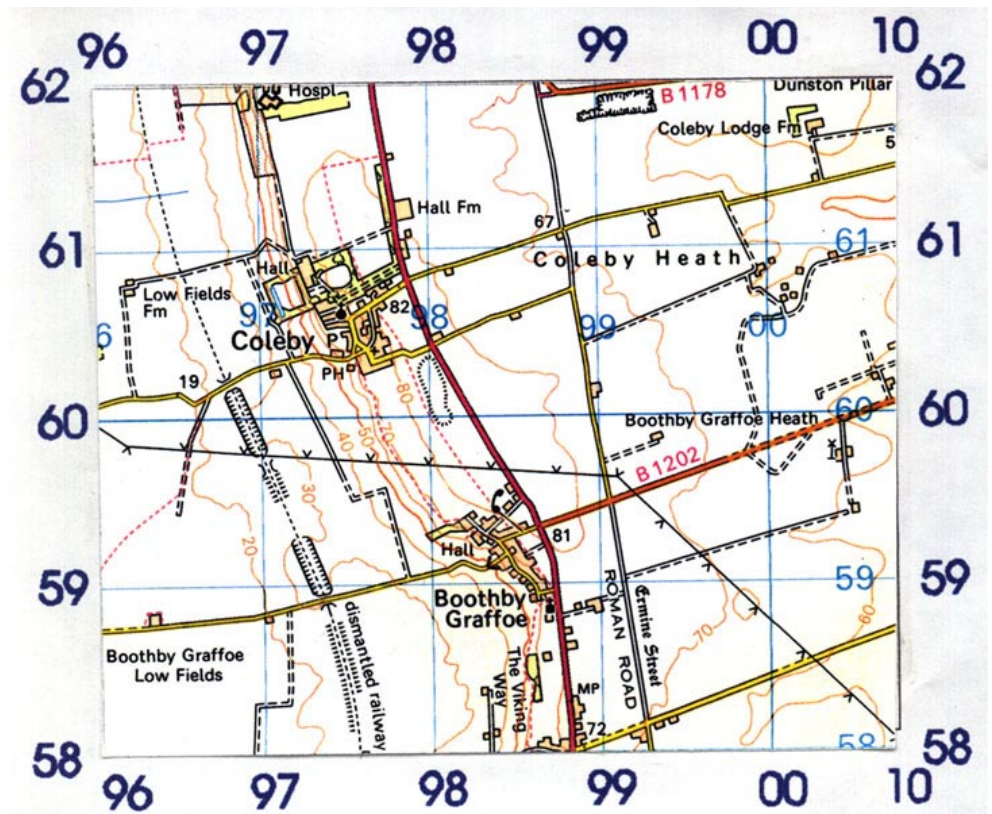


Fig 5-9 Photograph from
GR 973 589



Spurs And Re-entrants

Difference between Spurs and Re-entrants

11. A spur is a piece of high ground jutting from a range of hills into lower ground. A re-entrant is a narrow valley closed at one end, separating two spurs. They are very similar on the map because the contours for both will have a hairpin shape. You will need to study the contour heights and decide whether the closed part of the hairpin points to the high or low ground. If the closed part points in the direction of the lower ground it is a spur - shown in the diagram. If the closed part points towards the higher ground it is a re-entrant.

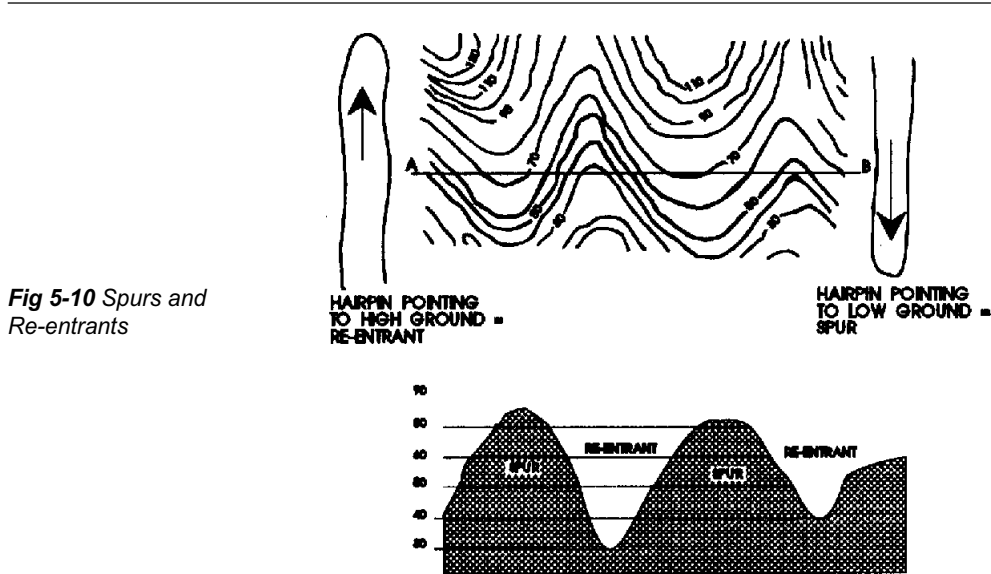


Fig 5-10 Spurs and Re-entrants

Escarpment and Knoll

An escarpment is a landform with sides sloping in opposite directions consisting of a steep scarp slope and a more gentle dip or back slope. A knoll is a small isolated hill.

Fig 5-11 Escarpment

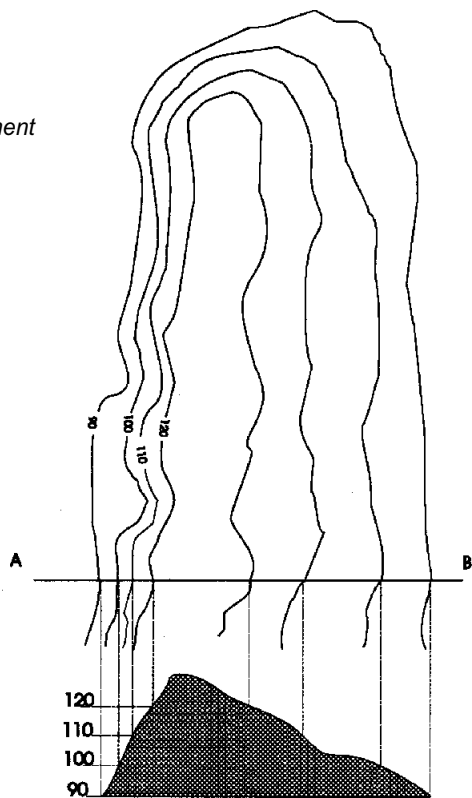


Fig 5-12 An Escarpment



For examples of Knolls and peaks at different grid references see over.

Conclusion

If you use the information that is provided by a contour map the lie of the land will become easy to interpret with experience and practice. Once gained, this experience will allow you to build a mental picture of the ground when reading the map in the planning stage.

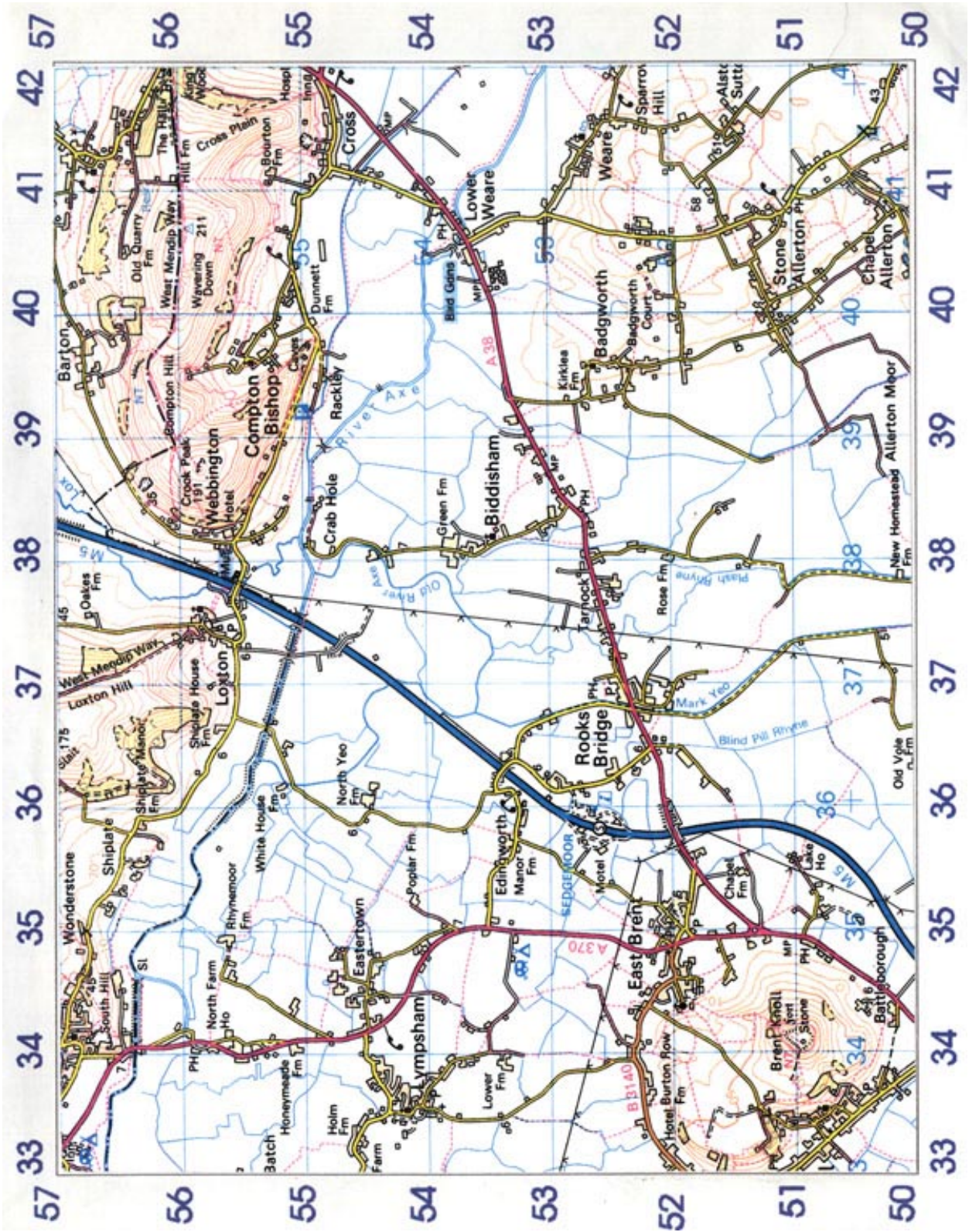




Fig 5-14 Crook Peak from GR 378 555



Fig 5-16 Crook Peak from GR 371 525

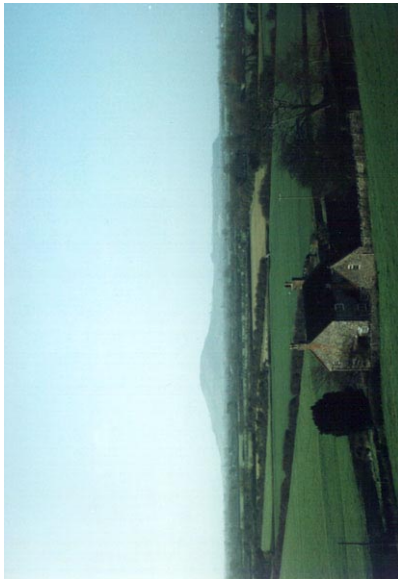


Fig 5-13 Brent Knoll from GR 389 552

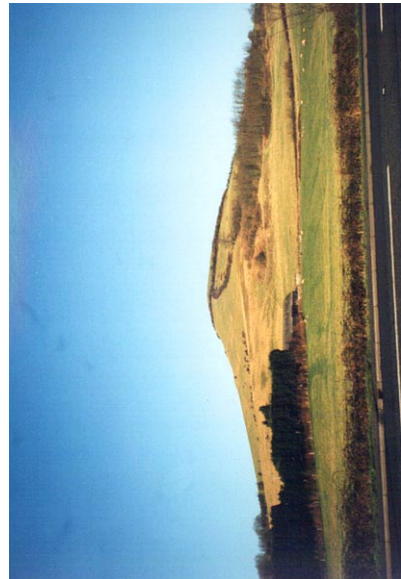


Fig 5-15 Brent Knoll from GR 349 509

Sample Questions

Do not mark the paper in any way - write your answers on a separate piece of paper, in the form of a sentence.

1. In map reading, what does the word “relief” mean?
 - a. Hill shading
 - b. Layer tinting
 - c. The rise and fall of the land
 - d. Hachuring
2. What shape would the contours be for a spur?
 - a. Round
 - b. Elliptical
 - c. Hairpin
 - d. Straight
3. If you were to rotate the map so that the figures on the contour lines were the right way up, which way would you be looking?
 - a. Down the slope depicted by the contours
 - b. Up the slope depicted by the contours
 - c. Grid North
 - d. True North
4. What must there be between any two adjacent contour lines (on a map) which have different values?
 - a. Flat land
 - b. A slope
 - c. A ridge
 - d. A spur

CHAPTER 6

GRADIENTS AND INTERVISIBILITY

1. In this chapter you will learn more about slopes. You will see how the steepness of a slope is expressed and how to work out what you should be able to see from a given point.

Gradients

Gradients expressed as a ratio

2. The angle or degree of a slope is called a gradient and is expressed as a ratio. Imagine a slope with a gradient of 1:5. This would mean that for every 5 units along the ground (horizontally) the slope will rise or fall by 1 unit. If this ratio is small the slope will be very steep and if the ratio is large the slope will be gentle. Very steep roads in the UK are specially marked on maps so that you may avoid them if you wish.

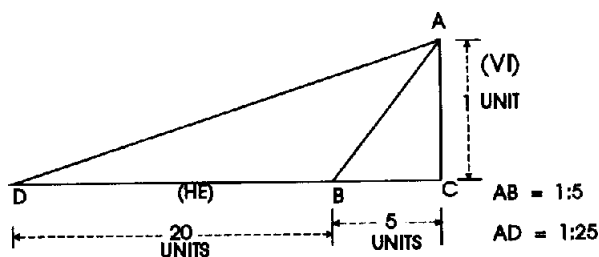


Fig 6-1 Slopes - gentle or steep

AC = VERTICAL INTERVAL (VI)

CB and CD = HORIZONTAL EQUIVALENT (HE)

Measurement Of A Gradient From A Map

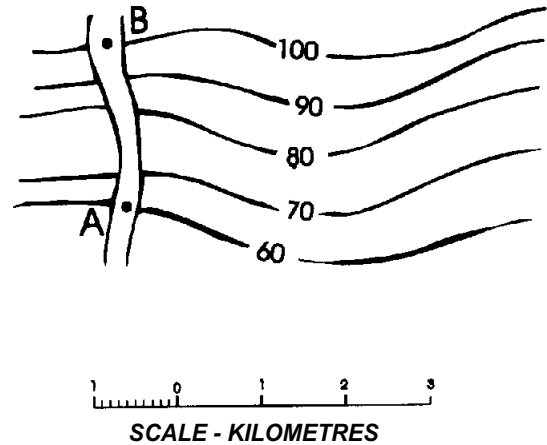
VI and HE

3. To work out a gradient from a map you need to know both the vertical interval (VI) and the horizontal equivalent (HE). Given 2 points A and B, it is possible to calculate the VI by measuring the distance between the contour lines. In the example this measurement would be 40 metres. To obtain the HE use the map's scale and measure the distance between the 2 points. In the example the HE is measured out to be 2000 metres. IT IS IMPORTANT THAT YOU USE THE SAME UNITS OF MEASUREMENT IN BOTH THE HE AND THE VI. You now have two figures and you must reduce these to a ratio in which the VI is "1".

$$VI = 40$$

$$HE = 2000$$

Fig 6-2 Calculating a gradient



4. The ratio is 40:2000 which (if 2000 is divided by 40) gives 1: 50. The ratio of 1:50 for this slope means that for every 1 unit you ascend you have moved forward 50 units. If you are looking at a map and your planned route takes you across some steep ground (where the contours are so close together that short measurements are difficult), measure the HE over several contours.

Visualising Gradients

5. The eye tends to exaggerate slopes and so in order to visualise an area of ground accurately from a map a great deal of practice is required. To find gradients you must measure the distances between contours, which may be small and difficult to measure accurately on a M726 Series 1:50,000 map. However, it is quite easy to construct a table that will assist you in visualising gradients.
6. Begin with contours that are as close as 1mm to each other. From the scale you know that 1mm on the map equals 50,000mm on the ground, which is 5000cm or 50 metres. Thus you have an HE of 50m. On the M726 map the VI between contours is 10m. A VI of 10 with an HE of 50 gives a gradient of 10:50 or 1:5. Similar calculations for contour lines that are 2mm apart give a gradient of 10:100 or 1:10. For a 3mm spacing the gradient is 10:150 or 1:15, and so on. In this way you can build up your own copy of the table on the next page. The table also shows a column for expressing gradients as a percentage; you may wish to complete this column if you are familiar with percentages - your instructor will help if you need it.

Do not mark the table below but use it as a guide. You may like to draw it or use a photocopy.

GRADIENTS

DISTANCE BETWEEN ADJACENT CONTOURS (IN MILLIMETRES)	GRADIENT AS %	APPROX GRADIENT
1	20	1:5
2	10	1:10
3	6.66	1:15
4	5	1:20
5	4	1:25
6	3.33	1:30
7	2.85	1:35
8	2.5	1:40
9	2.22	1:45
10 (1cm)	2	1:50
11	1.8	1:55
12	1.66	1:60
13	1.54	1:65
14	1.43	1:70
15	1.33	1:75
16	1.25	1:80
17	1.18	1:85
18	1.11	1:90
19	1.05	1:95

Intervisibility

What is Intervisibility?

7. When you are map reading it may be necessary to know whether you can pick out a feature or point to help in the next stage of your route. Be very careful because as these examples show interpreting the lie of the ground can be tricky.

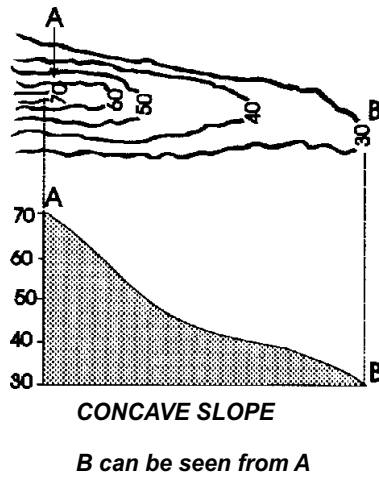


Fig 6-3 Concave slope

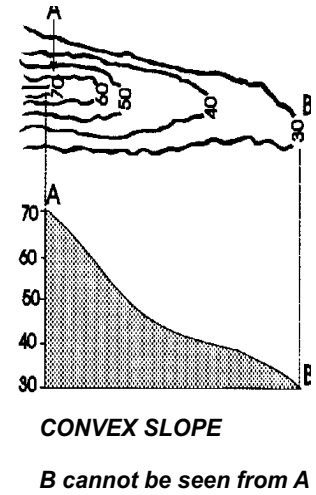


Fig 6-4 Convex slope

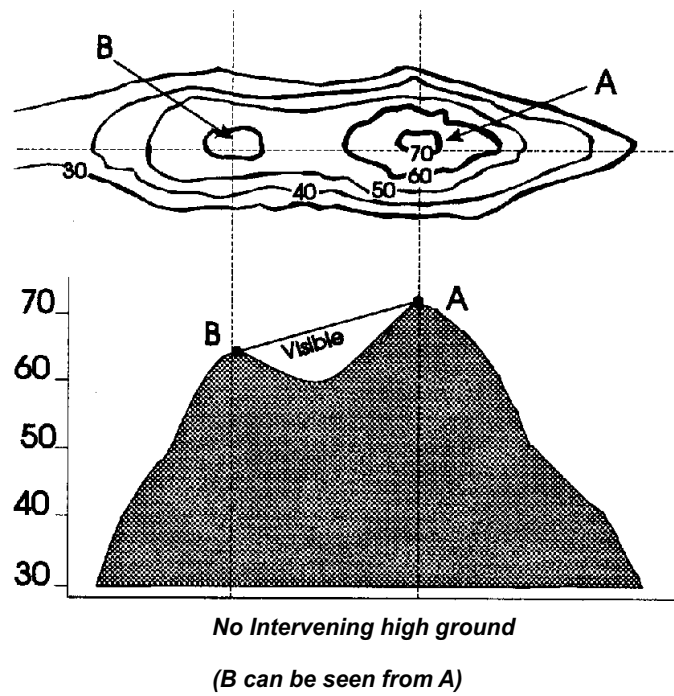
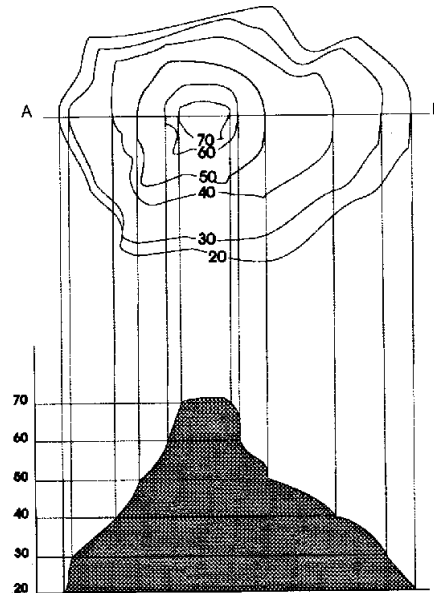


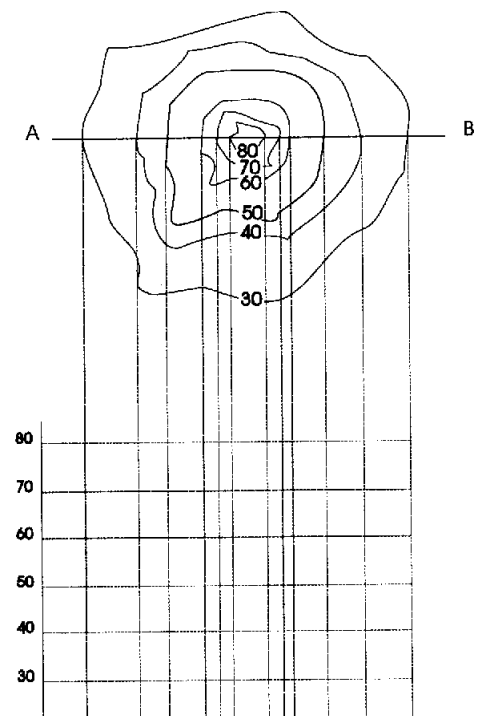
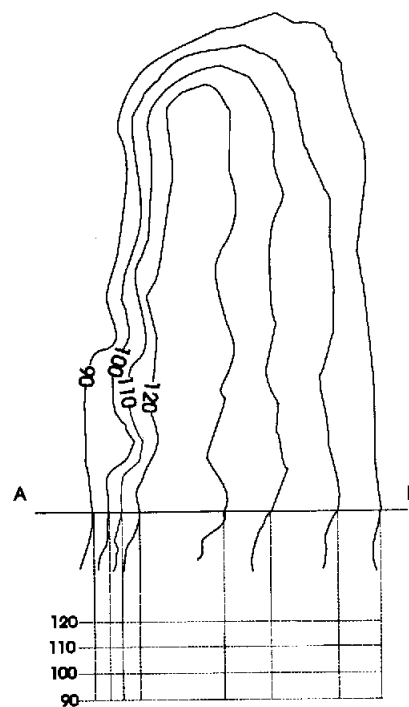
Fig 6-5 Visible ground

When to draw a section

8. If the ground between you and your goal is not clear you may have to draw a section. Your instructor will help you if have any problems understanding how it is done.



9. Cover the diagrams with tracing paper and using a pencil, lightly mark the shape of the land in the following examples.



10. Intervisibility problems cannot always be solved accurately from a map. Buildings and trees are not always shown on maps, especially if they have been added since the map was drawn. If visibility is critical for what you are doing then a reconnaissance visit must be made.

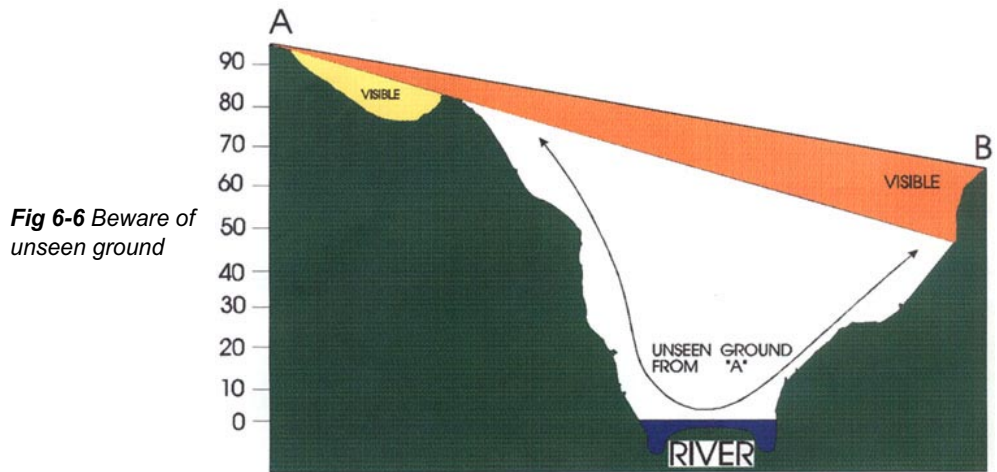
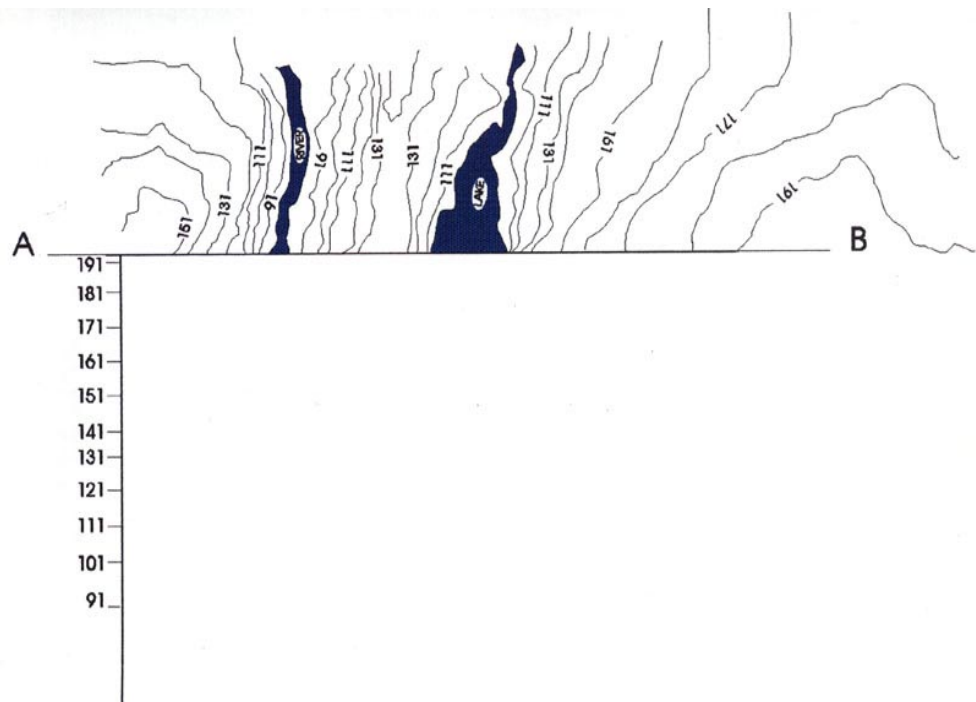


Fig 6-6 Beware of unseen ground

11. Now that you have had some practice drawing sections, try this example. Remember to use tracing paper and pencil ONLY.



Sample Questions

Do not mark the paper in any way - write your answers on a separate piece of paper, in the form of a sentence.

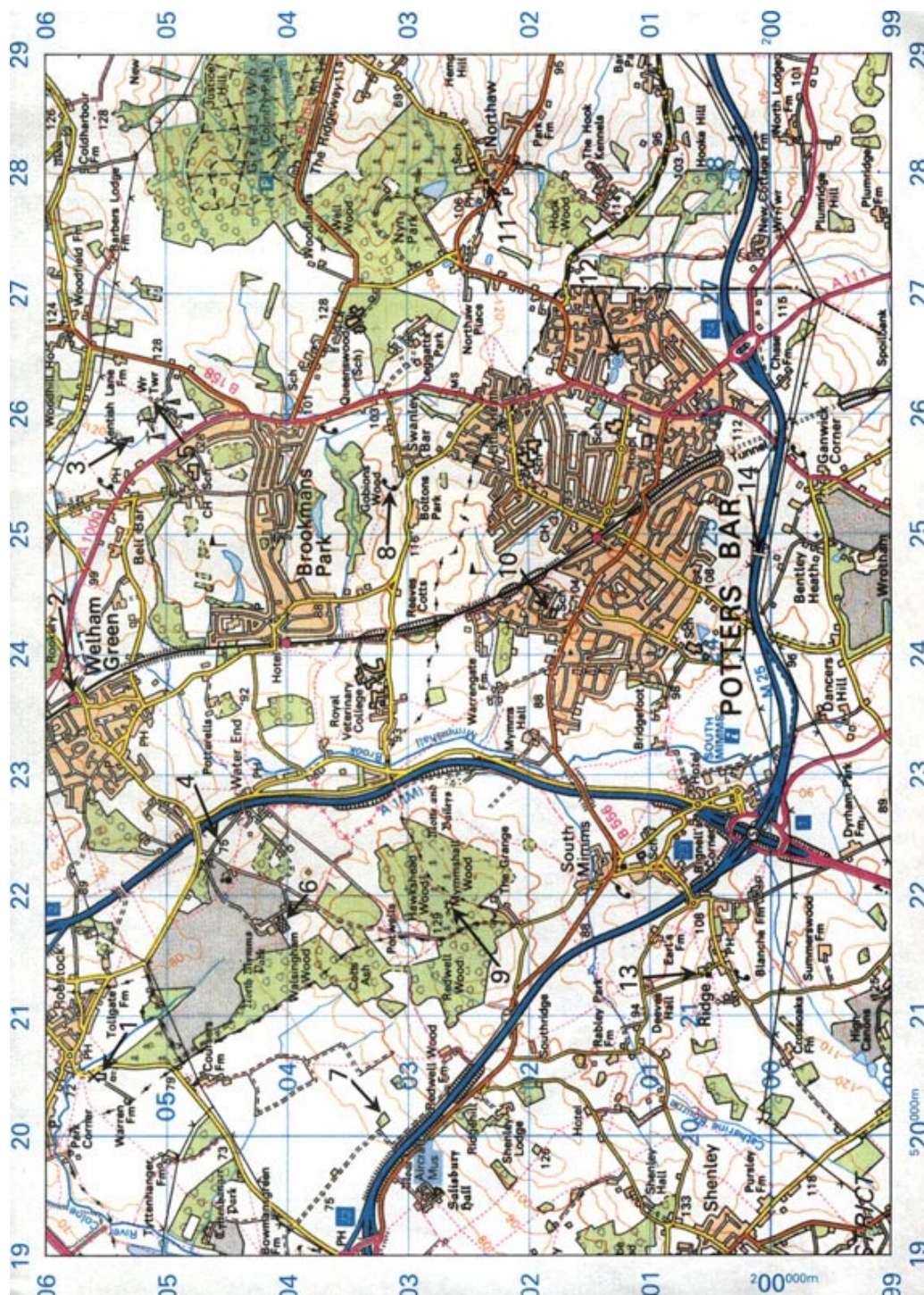
1. If the Vertical Interval between two places is 90 metres and the Horizontal Equivalent is 2 kilometres, what is the gradient (to the nearest whole figure)?
 - a. 1:11
 - b. 1:22
 - c. 1:33
 - d. 1:44

2. Which of these gradients is the steepest?
 - a. 1:7
 - b. 1:11
 - c. 1:14
 - d. 1:17

3. If, by studying a map, you cannot be sure whether one place can be seen from another, what can you do to decide?
 - a. Draw a cross-section of the land between them
 - b. Calculate the gradient between them
 - c. Calculate the mean contour line
 - d. Calculate the height of the land by reference to the spot heights in the area

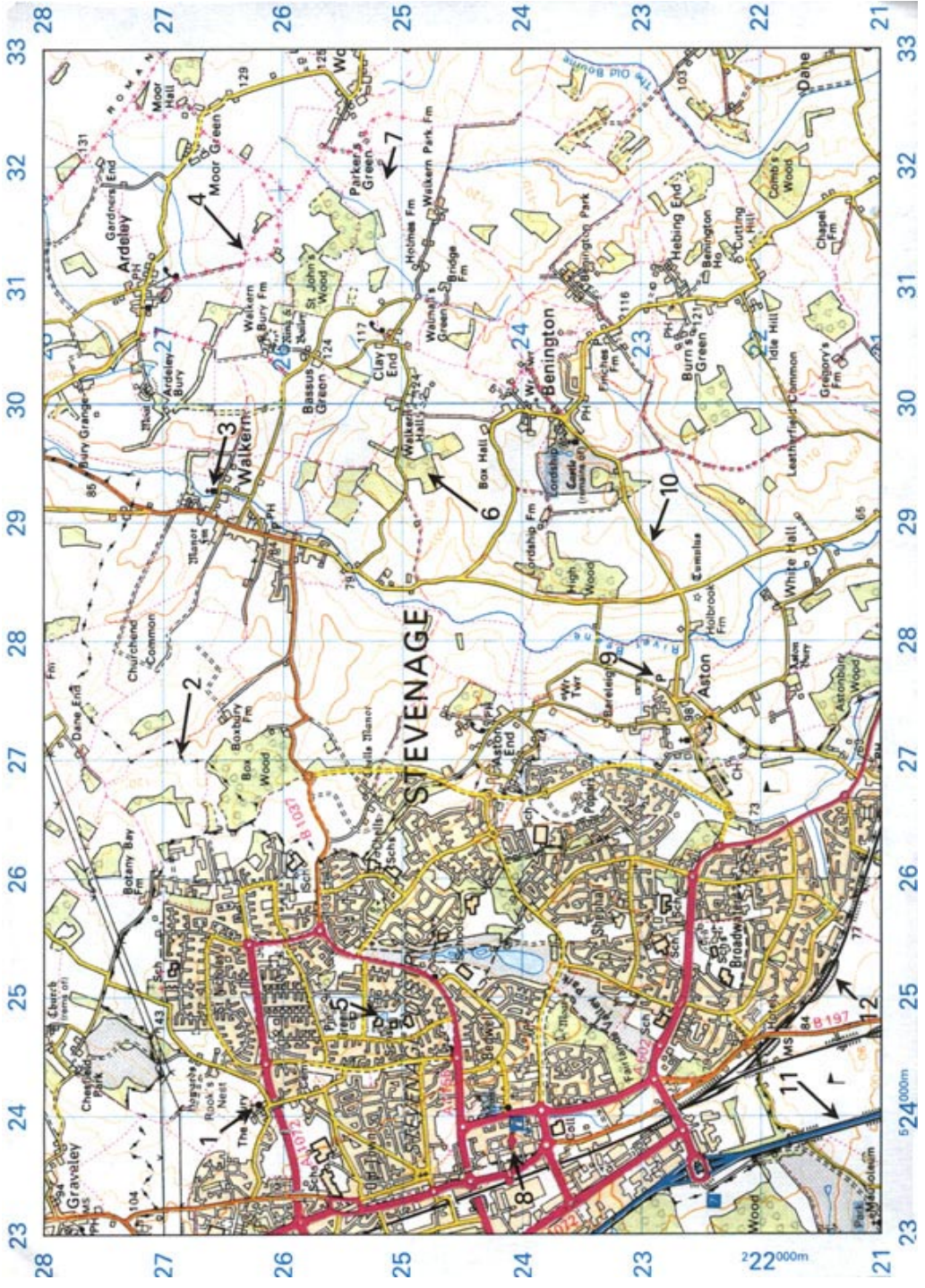
GENERAL EXERCISE

Give the 6 figure Grid Reference of the points of detail indicated by the arrows



GENERAL EXERCISE 2

Identify the conventional signs by the numbered arrows without reference to a legend




GENERAL EXERCISE 3

Identify the relief features indicated below



1. Name the relief features numbered 1-5
2. What are the types of slopes under the lines numbered 6 and 7?
3. What is the approximate height, above sea level of Long Loch?
4. What is the difference in height between the Kinloch Mountain Rescue Post and Hallival (395 963)?
5. What is the name of the feature numbered 8, and what is its highest point

CHAPTER 1



INSTRUCTORS GUIDE

MAP READING

WHAT IS A MAP?

Page 32.1.1-4 Para 12

1. Once you have selected your map - HOW do you use it?

It is necessary that the cadets know the following points in connection with the subject.

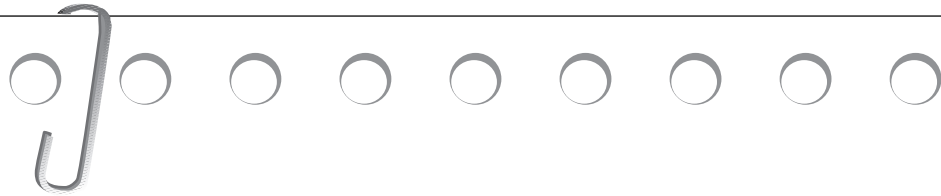
Planning is a very important part of any activity and time should be spent on getting to know the area you intend to go. The sort of things to look out for are those features which stand out on the map and would be easily recognisable on the ground. This is particularly useful if you or your party run into problems - remember your reaction will be quicker if you familiar with the map. Once you are happy with your map and feel confident to use it you need to go out and gain some experience of comparing the map to the ground area. This may be achieved in towns, cities or local country side. Any map may be used even a street map as long as it gives the cadets practice in moving from one point to another.

2. If you look at any atlas of the world, you will get a good idea of how continental landmasses lie compared to oceans. When the surface of the earth is shown on a flat piece of paper some distortion takes place. You can spot errors of distortion if you look closely. For example Greenland is shown to be larger than India but in fact India is approximately four times the size of Greenland. This happens because the surface of the earth is stretched at the poles and squeezed at the equator to make it lie flat.

Maps tend to be accurate in shape and position (bearing) - they are inaccurate as far as distance and area are concerned.

To allow more detail to be shown the world map can be broken down into many single sheet maps. You might think of it as using a microscope with the world under the lens. The more you zoom in the clearer the picture becomes and the more accurate the image you get.

3. To make map reading more enjoyable and to make cadets think, you may like to try some of the following ideas.
 - a. Blindfold a cadet and then pace out a set distance in a straight line. Make a note of how much drift there is and in what direction it was.
 - b. Have one cadet blindfolded and have another direct the first through a small obstacle course (using paces and direction only).
 - c. Have the cadets draw a map of the town/village or city centre (from memory) then compare the results to an actual map.
 - d. Try comparing old maps to new ones to see what changes have taken place in your area.
 - e. Mark out a route on an aerial photograph and have the cadets follow it.
 - f. Use different types of ground to find out different pace numbers and times i.e. 100m on - paths, road, tracks, bracken, heather, sand, uphill and downhill.
4. Map reading can be fun but it also has a serious side. If you decide to go out for a walk locally it is possible to get lost. A map can be a good friend to you when you are out walking - don't leave home without one!



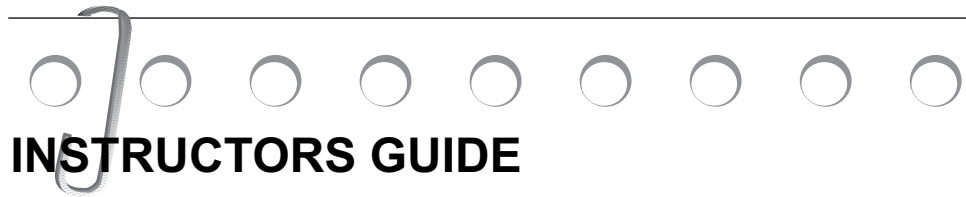
Page 32.1.1-5 Para 16

There are many types of maps in general use. Different types of map depict different types of information. Although maps tend to suit a specific user, different types of map can sometimes be used by different groups. For map reading in the Corps the important factor is scale. The many types of map available on the market reflect the wide range of activities for which maps are needed.

Motoring atlas of the UK	1 inch to 3 mile scale
Cycle tours	1:50,000 or 1.25 inches to 1 mile
Explorer maps	4 cm to 1 Km or 2.5 inches to 1 mile
Pathfinders maps	4 cm to 1 Km or 2.5 inches to 1 mile
Coast to Coast maps	
Travelmaster map	1 inch to 4 miles
Waterway guides	
Outdoor Leisure maps	4 cm to 1 Km or 2.5 inches to 1 mile
National Trail guide	1:25,000
Historical maps and guides	1 cm to 25 cm or 25 inches to 1 mile
World Atlas	
Local authority maps	
Air maps	
Agricultural maps	
Marine maps	
Political maps	

There are now available CD-ROMS that contain information that you can interrogate, zoom in or “walk” through in detail.

CHAPTER 2



INSTRUCTORS GUIDE

MAP LANGUAGE

Page 32.1.2-6 Para 18

ROADS

Roads in the UK are categorised into classes. All roads except motorways are classed according to the width, surface and ease of driving (no really sharp bends). There are 3 main classes and they are:

- a. Trunk Roads - Motorways and A(T) Roads. These are maintained by Central Government
- b. Classified Roads - A and B Roads. Maintained by the County Council through which they run.
- c. Unclassified Roads - Footpath, bridleways and urban roads. These are maintained by the local District Council concerned.

TRUNK ROADS

A trunk road has been so classed by the Trunk Roads Act 1936 or 1946, or has been made a trunk road (either by upgrading or construction) by order of the Government. Trunk Roads form part of the road system for through traffic. The roads are numbered and carry either a prefix, a suffix or both. For example:

M25 where the M is for Motorway

A1 where A is for All purpose

A1(M) where an A road has been upgraded or constructed to motorway standard.

MOTORWAYS

Motorways are the only type of road that is constructed to a specific standard and has restrictions placed on their use. Motorways are built to at least dual carriageway standard, with hard shoulders. Motorways have limited joining points and NO intersections.

A ROADS

A roads are all purpose and prefixed with the letter A. They are deemed as important to the road system, whether they are feeders to the trunk roads or as part of the urban infrastructure.

B ROADS

B roads are classed to be not as important as A roads but have a value to the communities through which they pass.

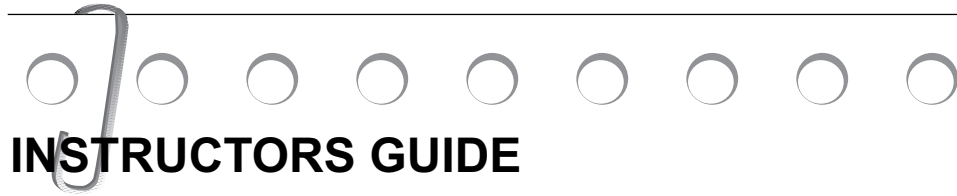
UNCLASSIFIED ROADS

Unclassified roads carry no numbers or letters and serve the area in which they are built.

THE HIGHWAY CODE

The Highway Code contains a wealth of information regarding road types, description and uses. Also contained within the Highway Code is rules for safety of pedestrians. This would prove useful information that can be studied and observed by those planning or executing expeditions on foot.

CHAPTER 3



INSTRUCTORS GUIDE

SCALES

Page 32.1.3-1 Para 2

Map Scales

It may be hard for the cadets to understand that as the Representative Fraction (RF) increases the smaller the scale becomes. The following table will allow you to ask the cadets their ideas on the RF's of the following:

	<u>RF</u>	<u>Cm to Km</u>	<u>Use</u>
Large scale	1:1250	80	Town plans
	1: 25,000	4	Tactical/leisure
	1: 50,000	2	Tactical/leisure
Medium scale	1: 250,000	0.4	Strategical/tactical
Small	1: 625,000	0.151	Planning

Page 32.1.3-3 Para 9

A good exercise for cross referencing map symbols to the air photograph is select a few points on the map and have the cadets pick them out from the map. It is a good comparison exercise coupled with improving map symbol skills.

CHAPTER 4



INSTRUCTORS GUIDE

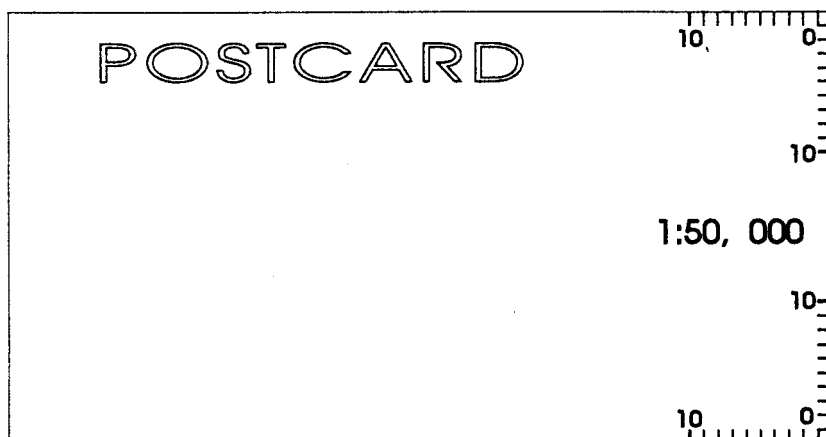
GRID REFERENCES

Page 32.1.4-5 Para 11

Making a Roamer

A Roamer is an aid to measuring the tenths on a map. Although these scales are included on most compasses, a roamer is a very easy guide to make. By using a postcard you can achieve quite an accurate measuring tool for grid reference work. You could give it two different scales if so desired. Place the edge of the postcard onto a 1:50,000 scaled map. Locate the corner of the postcard near the bottom centre of the map by the scaling bars. The top one of these is the kilometres scale and the first part of that scale is marked off in tenths. Carefully align the postcard along this edge and mark off the scale. Rotate the postcard through 90 degrees and repeat. Once you have finished the 1:50,000 scale you could possibly use another scale map for the other corners.

You should end up with something like this:



Place the corner of the postcard on the map feature that you want to record as a GR - make sure the edges of the postcard are parallel to the grid lines. Count the number of tenths, both horizontally (eastings) and vertically (northings) to the lower numbered grid line - when added to the 4 figure GR, you now have the GR in 6 figures.

CHAPTER 5

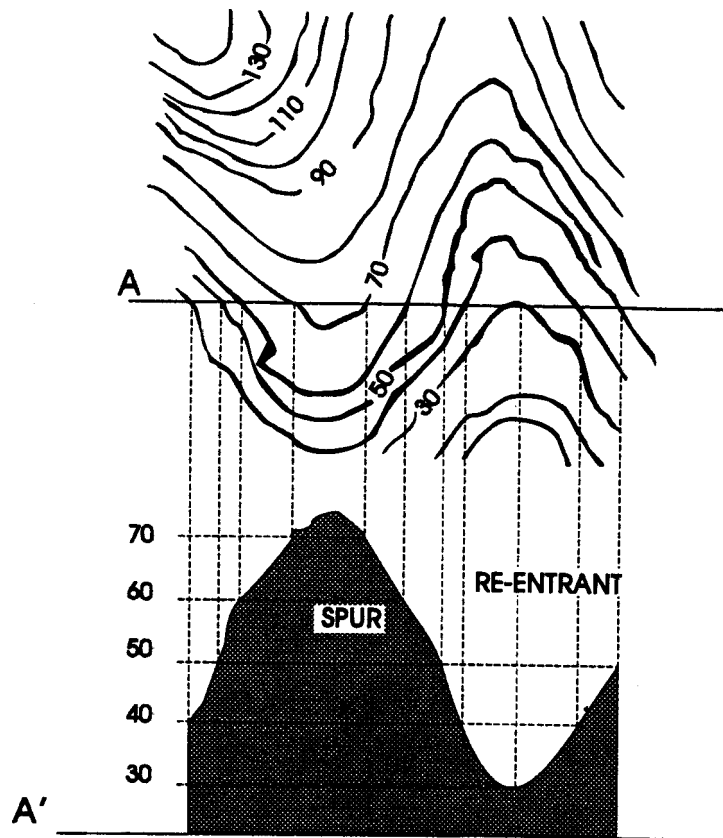
INSTRUCTORS GUIDE

RELIEF

Page 32.1.5-12 Para 11

Drawing a section

To encourage the understanding of contour lines there are ways to build up a picture. In the diagram a line AB is drawn across the contours (You may use either plain or squared paper). Every time a contour line cuts AB draw a dotted line down to line A'B' (this is at mean sea level). Draw horizontal lines to match the contour line height above line A'B'. Once this is completed you can draw the section by joining the dots.



Self Assessment Questions - Answer Sheet

Chapter 1 Page 32.1.1-8

1. a
2. c
3. a
4. d

Chapter 2 Page 32.1.2-10

1. a
2. a
3. c
4. b

Chapter 3 Page 32.1.3-5

1. a
2. c
3. a
4. d

Self Assessment Questions - Answer Sheet cont...

Chapter 4 Page 32.1.4-7

1. b
2. d
3. c
4. c

Chapter 5 Page 32.1.5-14

1. c
2. c
3. b
4. b

Chapter 6 Page 32.1.6-7

1. b
2. a
3. a