6 MAPS, NAVIGATION AND GPS

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All expeditions, no matter what their aim, require maps and some form of navigation. Irrespective of the type of terrain, mode of transport or the season of travel, navigation will play a dominant part in the preparation, planning and execution of any form of journey or fieldwork. Expeditions will have designated roles with perhaps a science coordinator, safety officer or medics and it is strongly recommended that you also include of a chief navigator. The navigator should be responsible for the provision of all expedition mapping, ensuring that all participants have good map-reading skills and are equipped with the tools by which to navigate.

MAP PROCUREMENT

Maps will be needed from the very outset of planning to determine how to get to your expedition area and to determine the extent of the area within which the expedition is to operate.

Try to obtain your maps as soon as possible. To do this you will need to identify what you need the mapping for, what scales of map are best suited to the various objectives of your expedition, from where you can source the maps, what the availability is like for your area and how much money is available to purchase maps and what quantity.

Sources for obtaining maps

There are many sources from which mapping is available, but enquiries and research are often needed to establish the best source. Any expedition in the UK will have access to national mapping from almost any walking shop, which can be purchased easily and without dilemma. Expeditions taking place away from our shores, especially in wilderness areas, face greater challenges. It must also be appreciated that the time needed to acquire this mapping could be weeks, or even months, so plan early to avoid disappointment.

Published maps for topography, geology, vegetation cover and soils will probably exist at national and regional levels – whether they are still in stock in the host country is another thing. Try to purchase regional and local maps from a UK map supplier, such as Stanfords or GeoPubs, before going. Tactical Pilotage Charts show elevation, topography and basic vegetation cover, at 1:500,000 scale, and are available for most parts of the world. Regional surveys of soils and vegetation cover have been carried out for many countries by the Food and Agriculture Organization of the United Nations (FAO, Rome): enquire at the HMSO to see if the region of interest has been mapped. You may be able to view maps in the map collection of the Royal Geographical Society (RGS), or review the coverage of a region using the CARTONET database of the British Library. A worldwide directory of national earth-science agencies and related international organisations is published by the US Geological Survey (USGS); it gives details of overseas agencies that might hold maps or sets of air photographs. It may also be worthwhile to enquire at the National Cartographic Information Service (NCIS) of the US Geological Survey, or the Cartographic Section of the US National Archive. More detailed maps, at 1:50,000 or 1:25,000, often cover only a small percentage of less developed countries and may date from colonial times. If you can obtain detailed maps, think yourself lucky, but bear in mind that the map data may be over 20 years' old and accuracy may not be as high as UK Ordnance Survey maps.

If your fieldwork is overseas, you should be aiming to carry it out jointly with a team from the host country: this will facilitate access to data. Furthermore, this facilitates the transfer of skills to places where they are most needed, and helps to reduce bureaucratic and logistical problems.

More and more data summarising the features of the world are being digitised and are available over the Internet, from word-processed documents and spreadsheet tables, to scanned air photos and satellite images of entire continents. At the expedition planning stage, the websites of the RGS–IBG Expedition Mapping Unit (www.rgs.org/mapping), the US National Geographic Society and the USGS are particularly useful. Digital maps are now easily obtainable at broad continental and national levels, usually on CDs. These digital maps of developing countries are unlikely to be more detailed than 1:1,000,000, and are therefore of use only where regional studies are important.

Map scales

In the UK we are fortunate to have the world's best quality mapping at a scale that can suit almost all eventualities. Once you depart from the UK, life becomes harder and the quality of mapping can decrease measurably. Choosing the right scale of map to suit your various expedition requirements can be hard, but try to list the preferred options. Maps are generally described as being either "large scale" or "small scale". A large-scale map will normally imply a scale from 1:2500 to 1:100,000 and a small-scale map from there upwards. Small-scale maps are normally used for planning. They are ideal for journeys into and out of an expedition area and are very good for long distance journeys, especially when in vehicles or on animals because on one map the distance represented could as large as 150 km. Large-scale maps are usually used for specific locations and are of better use when travelling on foot, but the distance represented by one map might not exceed 40 km. So more maps will be needed for large areas.

Map costs

Always be prepared to pay for mapping. You might not always get value for money, but that is a risk you may have to take. To overcome this you may wish to see the mapping before you purchase it. When buying your maps take into consideration the exact quantities that you need. Despite the importance placed upon expedition members to keep their maps safe, you can guarantee that the first item misplaced will be a map, so buy enough to cover all eventualities.

Map reliability/accuracy

The Ordnance Survey maps of the UK are arguably the best in the world, of the highest accuracy and contain all the information that you could wish for. The same cannot be said for other countries and you must be able to appreciate the currency and accuracy of the information.

When viewing the maps have a look for the “Print Note” or “Compilation Note” in the map margin. Most maps will tell you when the map was compiled, the age of the information used to create the map and when it was printed. Do not be misled by a print date of 2002 when in fact the map was compiled in 1955! Compare detail between different scale maps, especially for road information because these may still be depicted as a track in some areas when in fact a major road has been built through the area.

The other factor to take into consideration will be the language; since the dissolution of the Warsaw Pact there are many more excellent quality large-scale maps available but annotated in Cyrillic.

Finally, note the date and rate of change of the magnetic variation or magnetic declination because these will change with time and must be recalculated by you.

Satellite imagery

Satellite imagery can also be used to complement maps that you have acquired for your expedition. In today’s modern world it could be said that acquiring satellite imagery will be easier than acquiring some aerial photography or even mapping.

The main use for satellite imagery is in a geographic information system (GIS). That is another subject all by itself and is not covered here.

There are many satellites collecting imagery of the world. The types of images that they produce are endless. From a purely navigational point of view it will be easier and cheaper to acquire panchromatic images. This will give you a picture of the world below and will augment your maps extremely well. Colour images may sound nice, but the cost will rise and some detail can be confusing in colour. The more familiar types are LANDSAT 7 and SPOT.

The list of sources for satellite imagery is huge. It is so widely available that it is hard to know where to start. Contacting one of the commercial vendors, such as Info Terra or Space Imaging Europe, will aid you in identifying exactly what is available and the costs involved. They might well be able to offer slightly older imagery at a reduced price. Sources of satellite imagery are given on the RGS–IBG Expedition Mapping Unit website (www.rgs.org/mapping).

The accuracy of a satellite image is based on its ground resolution, i.e. the size of a pixel at ground level. Most satellites these days are producing images to resolutions of 50 metres and better. This is ideal for navigation, because most maps may not have an accuracy of greater than 50 metres.

As there are so many satellites acquiring imagery, the reliability of those images is likely to be better than maps. An image could be taken on a Monday and by the Wednesday you could have a copy of it for use.

Satellite imagery is available in either a hard or a soft copy. It is always wise to procure a soft copy because you can then make multiple copies at your leisure, as long as you have the ability to view it and print it. Free viewers are available and can be sourced through a commercial vendor.

Different types of images cover different sized areas, e.g. LANDSAT 7 comes in a scene 170 km × 185 km. The size will depend on the company supplying the data. A LANDSAT 7, panchromatic 170 km × 185 km scene might cost you around £500. However, there is also free imagery. A joint US/Japanese project called Aster has free imagery for users. It is of a good enough quality for a navigator. The National Imagery and Mapping Agency (NIMA) also has free imagery available on its homepage. Look for its Geo Engine and search from there.

Aerial photography

Another product that can augment your mapping is aerial photography. Aerial photography comes in either monochrome or colour. Again, monochrome is both cheaper and more suited to navigation.

As with satellite imagery there are many sources for aerial photography. Getting it for any western European country will not prove to be too difficult. Further away from that things will get harder; this is mainly the result of security restrictions.

The big problem with aerial photography is that all images are captured using an aeroplane, and are always subject to tilt as a result of side, head or tail winds. Therefore all aerial photographs are distorted, and the image that you see will not represent the ground perfectly. Not all aerial photographs come with a grid annotated on them and objects can often be hidden in shade. New buildings, roads, etc. might have been built since the sortie was flown.

It is easier to get aerial photography as hard copy. Normally this will have a glossy finish. If possible try to obtain the index plot for the sortie which, if available, will show the relationship between individual photos and the ground. This may be vital in wilderness areas because it can be very hard to pinpoint features on the air photo and the corresponding features on the map.

Each aerial photo should come with a strip of information located on one or more edges. The most important information to identify is the photo or print number, the date when the photo was taken, the focal length of the lens used in the camera and the flying height. Examples of those are given below.

Print number	056
Date Time Group	061245ZMAY91
Camera focal length	152.4 mm
Flying height	6000 feet

Determining air photo scale

The easiest method of scaling an air photo is to use the following:

F (camera focal length)/H (flying height [AMSL])

Example, based on the above information:

$$F = 6 \text{ inches}, H = 6000 \text{ feet}$$
$$F/H = 6/6000 \times 12 \text{ (to make the same units)} = 1/12{,}000$$
$$F/H = 1{:}12{,}000$$

Note that 152.4 mm = 6 inches (approximately).

Putting the map grid on to an air photo

With care the map grid can be transposed on to a photo by inspection. Care must be taken, because the grid will not plot as a regular shape.

To plot the map grid on to the aerial photograph, start by plotting the four corners of the photograph on to the map. Be as precise as possible. The map grid may then be transposed on to the photograph. Remember to add grid numbers and other information as required.

AIDS TO NAVIGATION

Once the maps have been procured and the detail scrutinised to build a mental

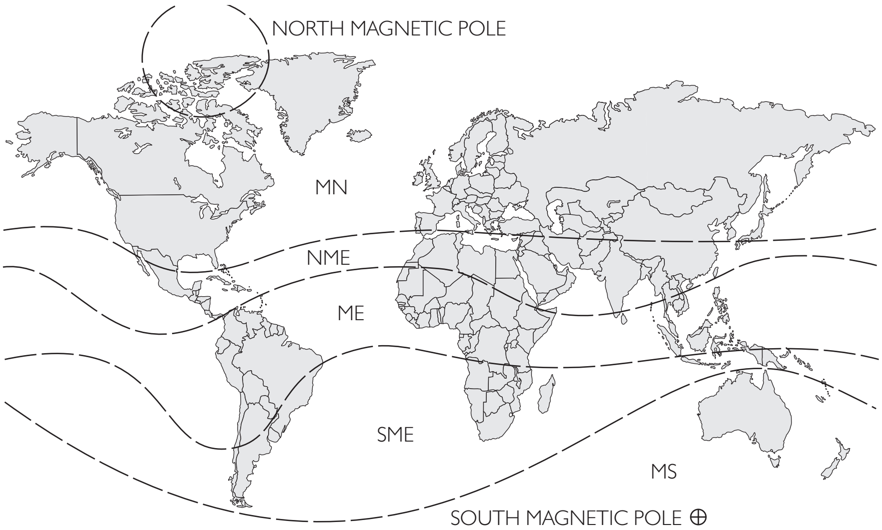

Figure 6.1 *Silva compass magnetic bands*

picture of the terrain, the time has come to consider the navigational tools to recommend to each expedition member.

The compass

Every expedition member must have a compass. The best type is the plastic or lightweight compass, which is cheap and very reliable. It should, however, have the following basic features:

- Oil-filled housing to allow for proper floatation and movement of the compass needle.
- Luminescent stripes for night use.
- Lanyard for keeping it on your body.
- The needle in the plastic compass should be weighted to suit the magnetic attraction in a particular part of the world. A rough guide can be seen in Figure 6.1.
- The two- to three-letter combinations can be found on the rear of plastic compasses. Some companies can provide a “Global” compass that ensures a free-moving needle no matter your location.

Compass bearings

Navigators will use a combination of true, grid and magnetic bearings:

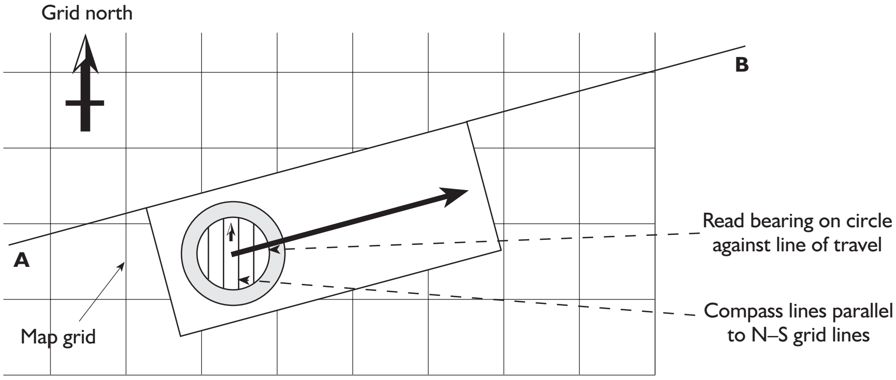

Figure 6.2 *Grid bearings*

- True bearings are measured clockwise from meridians of longitude (graticule) to the desired location on the map.
- Grid bearings (Figure 6.2) are measured from grid north clockwise to the feature on the map.
- Magnetic angles (Figure 6.3) are measured from magnetic north clockwise to the feature as identified on the ground.

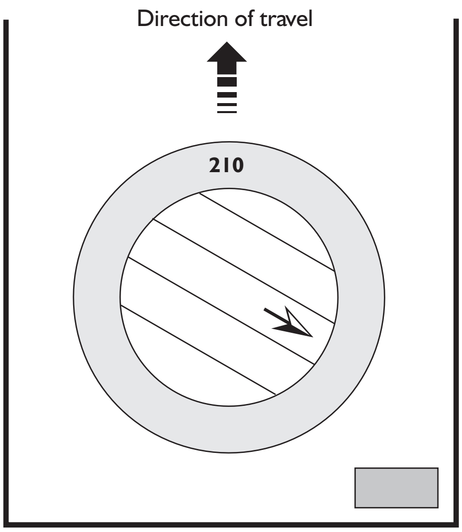

Figure 6.3 *Magnetic angles*

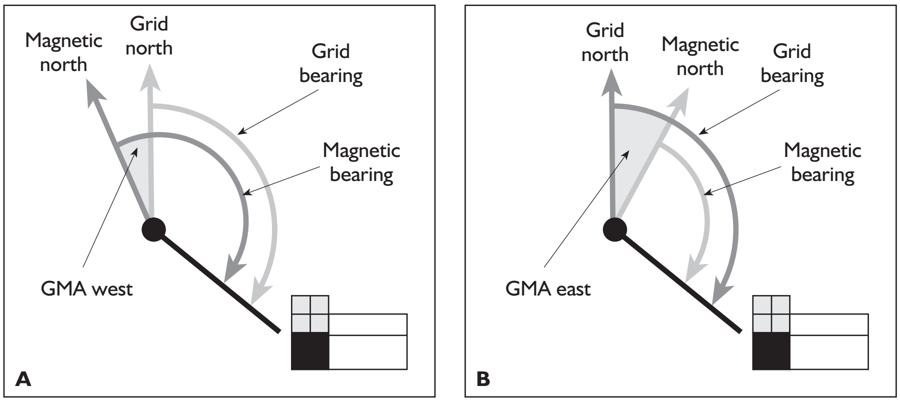

Figure 6.4 *Grid magnetic angle (GMA): (a) magnetic bearing = grid bearing + GMA; (b) magnetic bearing = grid bearing − GMA*

Grid magnetic angle

Grid magnetic angle (GMA) is the difference between grid north and magnetic north (Figure 6.4). It is defined as being east or west of grid north. Incorrectly applied it will lead to incorrect bearings:

- If the GMA is **WEST** then you will need to **add** it to a grid bearing to obtain a magnetic bearing.
- If the GMA is **EAST** then you will need to **subtract** it from a grid bearing to obtain a magnetic bearing.

Magnetic variation

Magnetic variation (MVAR) or magnetic declination is the difference between true north and magnetic north. It can be defined as being east or west of true north (Figure 6.5).

Remember, if you are using the longitude lines on your map, you will be measuring the true bearing and not the grid.

- If MVAR is **WEST** you will have to **add** it to a true bearing to obtain a magnetic bearing.
- If MVAR is **EAST** you will have to **subtract** it from a true bearing to obtain a magnetic bearing.

Watch

This is another basic, but vital, tool for navigation. Knowing your time accurately is important, so ensure that you have a good reliable timepiece in each party. They also

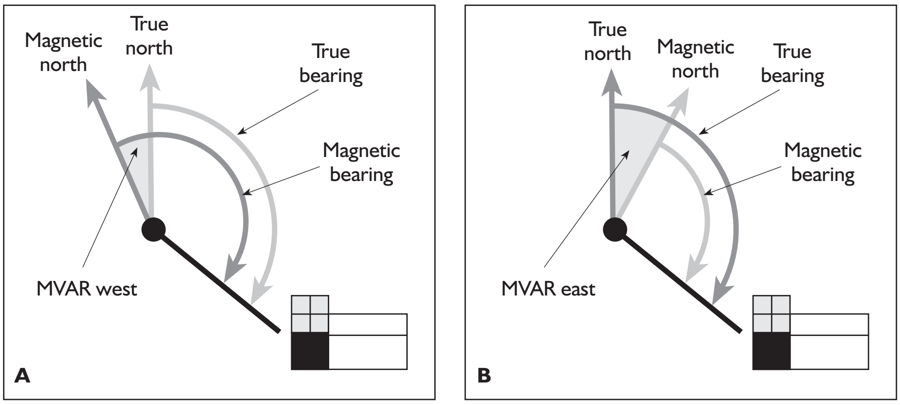

Figure 6.5 *Magnetic variation (MVAR): (a) magnetic bearing = true bearing + MVAR; (b) magnetic bearing = grid bearing − MVAR*

become vitally important if faced with a survival scenario. The preferred type is an analogue watch with both hour and minute hands. See "Survival navigation" (below) for use in a survival scenario.

Altimeter

A good altimeter is the most effective guide to telling you your height/altitude. This becomes of prime importance if in extremely mountainous or jungle terrain. All altimeters require calibration and this must be done at a known height. This could be a known spot height from a map, a local airfield, a known survey point or if none of the aforementioned is available then from a global positioning system (GPS) receiver. If you do use a GPS receiver your height accuracy will degrade. Currently the global height accuracy for GPS is about 20 m.

Pacing

If you are on foot and are travelling in terrain with minimal features, then knowing how many paces you take to walk 100 m is ideal.

A single pace is a double stride and is normally counted on the heel of your right boot hitting the ground. A local athletics track with a 100 m bay is ideal for this. Walk the 100 m at least twice and walk normally. Try doing this carrying different loads, because your strides to 100 m will differ depending upon the weight in your rucksack. Once you are happy with your pacing, plot all the variables on a small piece of graph paper and cover it with Fablon. It can then be kept with you at all times. Due consideration is then taken for hilly terrain or muddy ground, but nevertheless it is a tool that is always with you.

Another tool to aid in pacing is a pedometer. These devices can judge the distance that you have travelled on foot.

Plot sheets

When navigating in a featureless terrain such as the desert or the Arctic, the mapping will be plain and potentially out of date because sand dunes/snow drifts move continuously.

To help you in these environments it is very useful to plot every move that you make on a piece of graph paper.

This "plot sheet" needs to be scaled and all bearings, distances, spotted features and new tracks can be plotted to update your own mapping. All notes taken should be annotated on a dead reckoning log (explained below).

Global positioning system

This has been intentionally left to last. Do not become totally dependent on it. GPS is a very good aid to navigation, but that is all it is. Batteries will run out, the receiver could get damaged in a small fall and in some terrains you might not even be able to track any of the satellites. Becoming over-reliant on GPS is bad practice, and you should never forget how to use the more classic navigation tools.

The basics

GPS is an American satellite-based positioning system first developed in the mid-1970s. At its core is a constellation of 24 satellites that orbit the earth and transmit information that can be processed by a GPS receiver. This system is capable of providing very accurate positions in a very short time frame. As this goes to print the global accuracy for a standard hand-held GPS receiver is 13 m or less (position only). You may get better or worse than this. The location of the satellites in the sky and the number of satellites being tracked will help to determine this.

However, this accuracy and its relationship to your maps will all depend upon your ability to set your receiver to specific parameters as defined on your maps. Remember that maps came first and that mapping theory is used on GPS receivers.

GPS set-up

The two most important parameters are the map datum and the coordinate format that you wish to use.

If you select the wrong datum on your receiver you can expect to get a position error of up to 1000 m. All modern mapping will specify its datum in the map margin.

The choice of a coordinate format will depend upon your mapping. Be aware that certain countries have their own position format – this could be a bit of an unknown. Whatever format is chosen, remember that GPS can give you only a unique position on the world, so you must conform to the format exactly. All errors are user errors!

Other set-ups that you may wish to consider are:

- Bearing style and bearing units: it is worth setting your receiver to magnetic bearings. Any bearing displayed can then be set on your compass as well!

- Time: all receivers have the ability to be set for local time.
- Navigation units: how you wish distances and speeds to be displayed.

Initialising a GPS receiver

Once you have arrived in your expedition area you will need to initialise your receiver. Nearly all GPS receivers have the option to select the continent, country and sometimes the nearest city. Choose this and then wait for the receiver to display a new position, but be patient as it may take 12–15 minutes to initialise.

Waypoints

A big advantage with GPS is the ability to load a waypoint (map feature) in coordinate format into the receiver and then let the receiver guide you to it. Try to choose features of the map and not just any old grid reference.

Routes

If you are in vehicles or on animals then you can create a route to follow. Individual waypoints are needed for this and, once loaded, these can be imported into a route. Once activated, the receiver will guide you from point to point and usually will inform you on arrival at a point.

This feature should not be used when travelling on foot.

Navigating with GPS

GOTO is a function that when chosen will display a list of all stored waypoints on the GPS. All receivers have a GOTO function. This will prompt you to select a loaded waypoint and then guide you to it. Remember that the information displayed to aid you will be "as the crow flies". GPS cannot predict obstacles such as cliffs, rivers, etc., so be careful. Do not get into the habit of looking at your receiver permanently and thereby becoming blinkered to your surroundings.

Nearly all receivers will have either a compass screen or a highway screen. The easiest to use for foot navigation is the compass screen. If in vehicles or on animals the highway screen may be easier.

Background mapping on a GPS receiver

Many companies now offer the ability to load, from a CD, mapping into specific receivers. This digital mapping should be treated carefully. Outside the UK no digital mapping is available that shows true topographic information, i.e. footpaths, contours, etc. The best use of a package like this is the opportunity to create waypoints via a PC keyboard rather than the keypad of your receiver. These can then be "burned" into the memory of the receiver for use.

Other navigational tools

Other navigational tools that can be easily forgotten but are still vitally important are:

- graph paper: for plot sheets
- pencils: for plotting bearings, completing fixes, completing logs
- protractor: a more precise way for plotting bearings than a compass
- conversion tables: kilometres, miles, mph, kph, etc.
- notebook: recording information
- dictaphone: especially good when using vehicles or animals; saves trying to rewrite notes at the end of a day
- parallel rulers (small): exceedingly good value
- ruler: metric and metal.

Jungle navigation

Jungle navigation can be extremely difficult and frustrating because known prominent features are often very hard to find, let alone identify, on the map.

Primary tropical forest is normally easy to walk through, fallen trees being the only obstacle. Route selection should be based on the contours and drainage pattern. In steep terrain keep to ridges (even though they lack water), otherwise the going will be extremely slow. Planning of the route is essential, because visibility is very restricted.

Secondary tropical forest occurs around the edges of primary jungle or in patches where the primary jungle has fallen down or been cleared. The growth can be extremely dense and should be avoided. Your visibility will be severely restricted and routes should be related to the shape of the ground.

Swamp areas should also be avoided. If unavoidable a straight-line route should be planned from a well-defined starting point and ending at some identifiable point. Aim off from this point so that you know that, on reaching the far side, you have to turn left or right to locate it.

Sketches should be made of features that could be used for navigating – river crossings, clearings, etc., including the direction you were facing when doing the sketch.

Clearings should always be sought after, especially if on high ground.

Remember, in the jungle the shadow will point away from the sun.

Survival navigation

Using the sun

The sun can be used to determine the four major points of the compass. Remember the sun rises in the east and sets in the west.

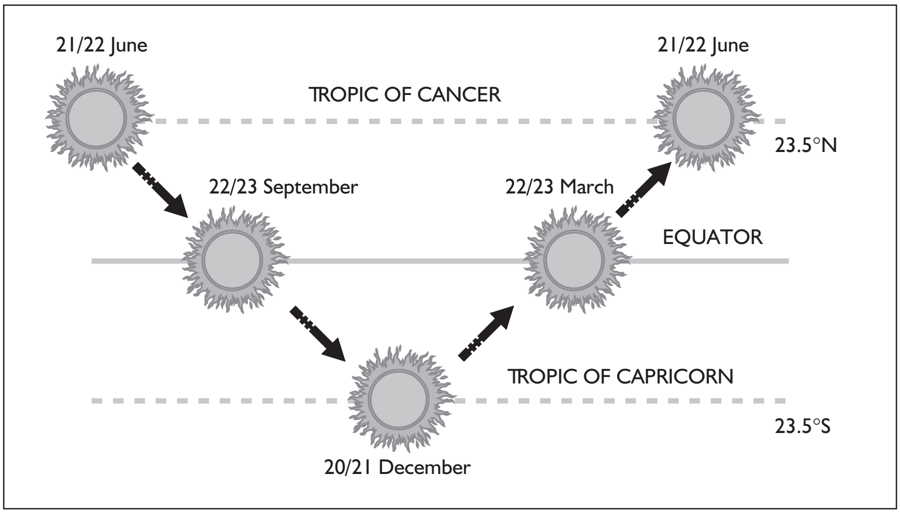

Figure 6.6 *North or south and the sun at midday*

If you are north of the Tropic of Cancer, at midday the sun will give you south. If you are south of the Tropic of Capricorn, at midday the sun will give you north.

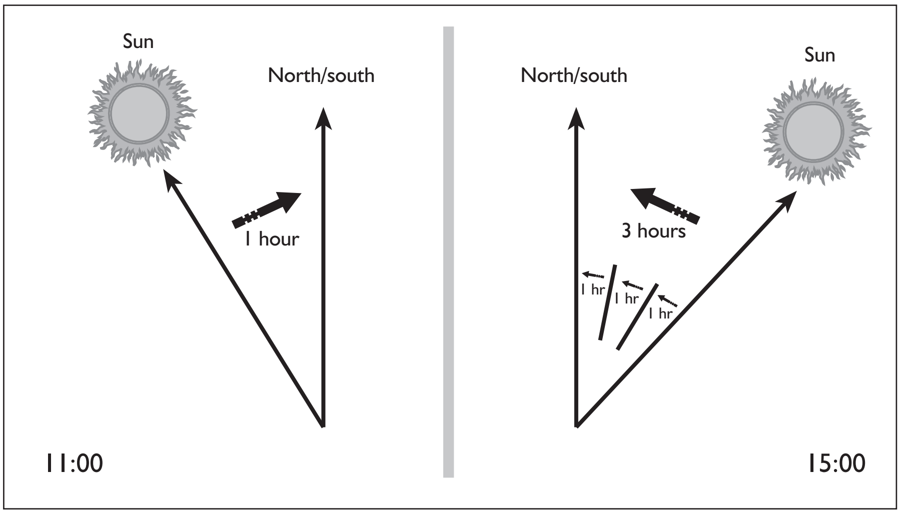

Figure 6.7 *Finding north and south*

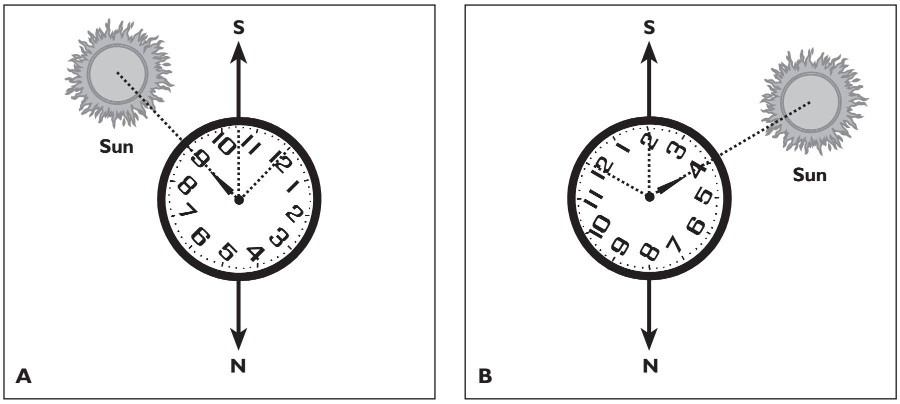

Figure 6.8 *Using an analogue watch in the Northern Hemisphere: (a) morning, (b) afternoon*

North or south (Figure 6.6)
Depending on your latitude and if you are in between the Tropics, the sun at midday could give you either north or south.

If you are going to a country within the two Tropics contact the RGS–IBG Map Room with dates and latitudes (email: info@rgs.org). A definite answer can then be calculated for you.

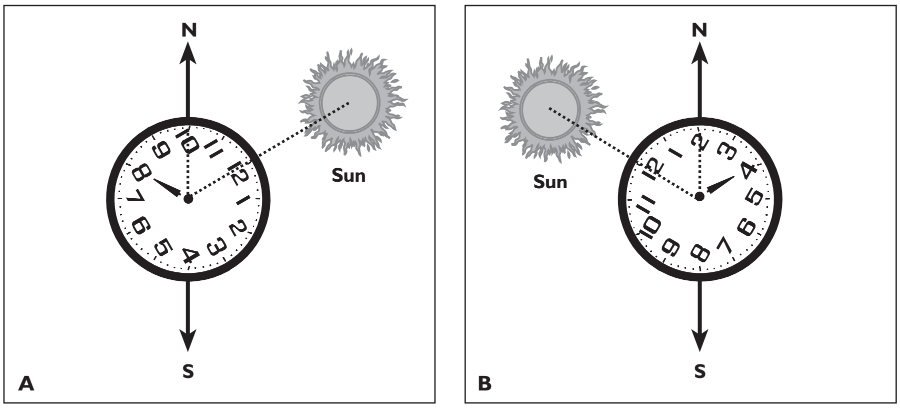

Figure 6.9 *Using an analogue watch in the Southern Hemisphere: (a) morning, (b) afternoon*

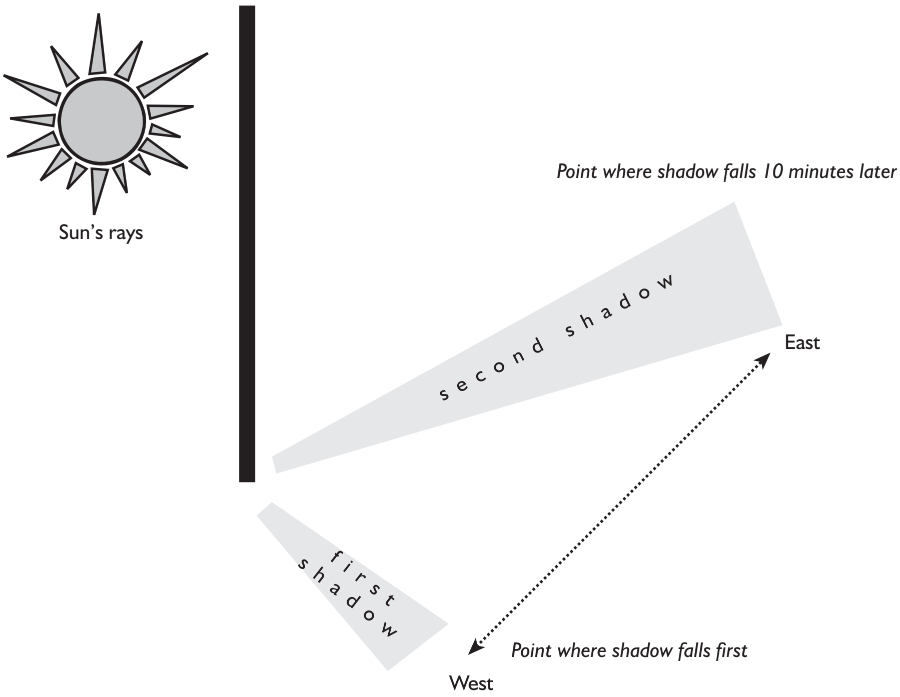

Figure 6.10 *Finding east and west*

Finding north or south (Figure 6.7)
By stating that one outstretched hand at arm's length is equal to one hour, you can determine north or south from the sun using your hands.

To save you from staring at the sun, try this technique with your back to it. Remember, however, that this will also give you the opposite heading.

Using an analogue watch
In the Northern Hemisphere, north of the Tropic of Cancer, lay your watch flat with the hour hand pointing to the sun; south will be midway between the hour hand and 12 o'clock on your watch (Figure 6.8).

In the Southern Hemisphere lay your watch flat with the 12 o'clock pointing to the sun; north will be midway between the hour hand and 12 o'clock (Figure 6.9).

Finding east and west (Figure 6.10)
Place a stick in the ground, which should be flat and clear of debris. Mark the tip of the shadow, e.g. with a stone. A minimum of ten minutes later, mark the tip of the

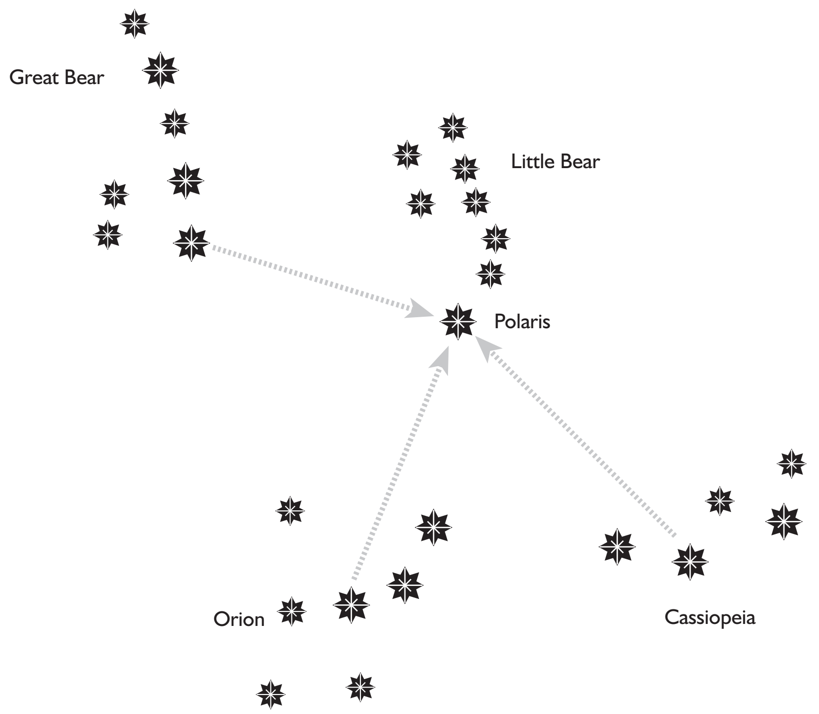

Figure 6.11 *The stars: Northern Hemisphere. Note that Polaris is shown brighter than it is in reality*

shadow. The line joining the two points is the east/west line, no matter what the latitude or time of day is. This, however, is not a very accurate method.

The stars

The star that best denotes the direction of north at night in the Northern Hemisphere is Polaris (in the Southern Hemisphere Polaris is not visible). There are three main star constellations that can be used to locate it: Cassiopeia, the Great Bear and Orion (Figure 6.11).

The vertical angle of Polaris also gives you your latitude. So the further south your location, the lower in the sky will Polaris be found. The more remote your location, the more stars you will be able to see. Finding specific stars in this environment can be harder.

In the Southern Hemisphere life is less easy because there is no bright star to use as a south indicator. The best way of estimating the location of south is to use the Southern Cross and the brightest star in the Hydrus constellation as your reference.

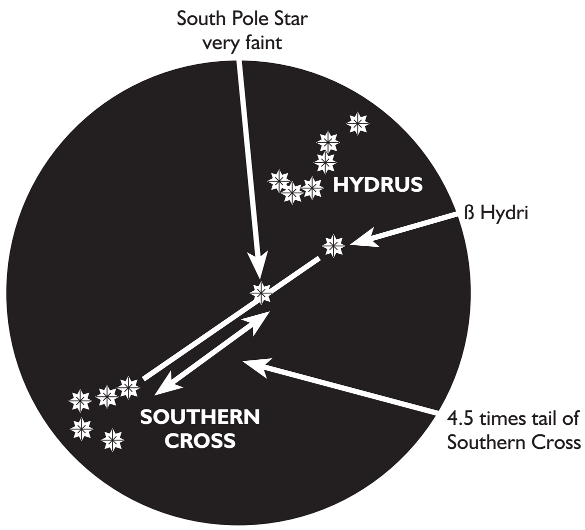

Figure 6.12 *Southern Cross in the Southern Hemisphere*

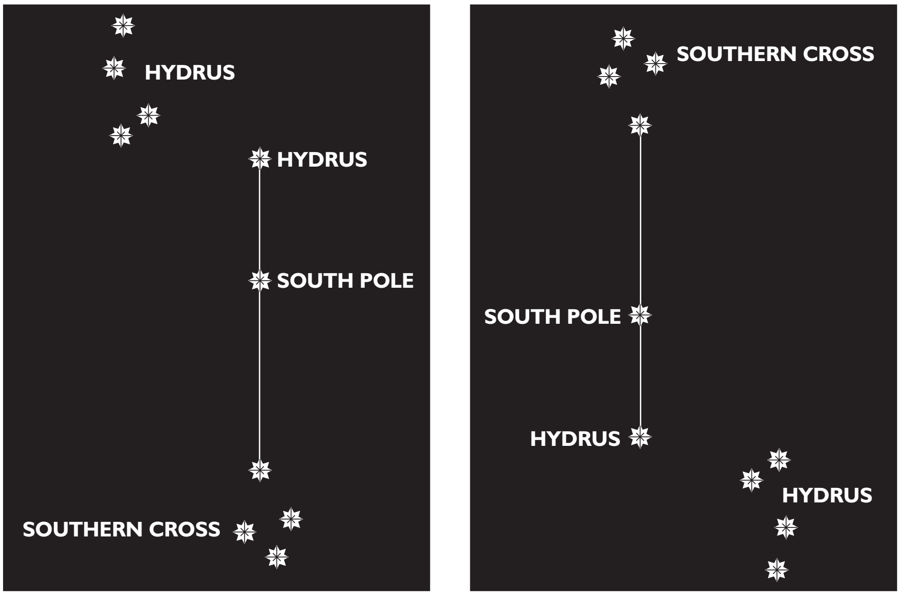

Figure 6.13 *North–south line – how to find in the Southern Hemisphere*

Draw a line from ß Hydrus to the Southern Cross. Imagine that the Southern Cross is a kite; extend the longer axis 4.5 times and that point will be south (Figure 6.12).

When the line joining the tail of the Southern Cross to Hydrus appears to be vertical it is a good indication of the north–south line (Figure 6.13).

Other tools

Another tool you can use in a survival situation is the wind. If you know the direction of the prevailing wind you will be able to see this in features on the ground.

ROUTE PLANNING

Planning a route is critical. The selection of the route must be methodical and follow the following basic guidelines.

Creating a route planner

When creating a route to follow you should always complete a route planner. Never try to memorise the route in your head. A route planner should consist of the following minimum headings:

Leg no. Start position End position Distance Bearing Estimated time Remarks

The following are points to note:

- State clearly the distance units, i.e. kilometres, miles or nautical miles.
- State clearly the bearing type, i.e. magnetic, true or grid.
- The remarks column should specify features to look for or features that you may well cross, i.e. rivers, wadis, saddles, cols, etc.

The start and finish positions of the route

These positions must be in a coordinate format and not just relate to a map feature.

Understanding the contents of the maps you will be using

A simple mnemonic to remember is VAGS:

V – **vertical interval**, or contour spacing: being able to recognise the relief patterns on the map and where necessary the steepness of the terrain.

A – **age of the map**: understanding that the detail on the map might well not represent the features on the ground. The map could be so old that a lot has changed in the intervening years, i.e. track direction.

G – **grid magnetic angle** or **magnetic variation**: understanding the corrections that you will have to apply to compass magnetic bearings to be able to draw/plot those bearings on the map.

S – **scale**: as already mentioned, different scale maps will represent the land in different ways.

Once you have fully digested all of the map information, you can start your route planning. Again you can go about this by using another mnemonic – TRECH:

T – **time and distance**: take into consideration the terrain you are crossing, the effect it will have on the distance that you are realistically likely to cover by your mode of travel in a set time scale. Do not attempt too much in one single leg. Many legs will make navigation easier.

R – **relief and going**: take into consideration the relief and how badly it will affect movement. The well-established Naismith's Rule, based on hillwalking experience, suggests that you should allow, for movement on foot with pack:
5 km per hour
+ 0.5 hour per 300m of ascent
− 0.5 hour per 300m of descent
+ 0.5 hour per 300m of steep/difficult descent.
This provides a reasonable guide when tempered with experience.

E – **ease of navigation**: try to plan the legs of your route that coincide with prominent terrain features. It is worth considering the following:
Direct and non-direct routes: the fastest route may not be a straight line.
Handrailing: you may wish to handrail features to aid in your navigation by the use of obvious features such as power lines, pipelines or cliffs.
Height: do not lose height, especially if on foot and in the jungle.
Aiming off: if point is on a linear feature, aim to hit it to one side and work towards it.
Attack points: pick an easier feature and use it as a base to find the end of a leg.
Catching features: bounce off larger, obvious features to find the end of a leg or route.

C – **cover**: the use of terrain or land features that can provide cover from the elements, i.e. the leeward side of hills if the prevailing wind direction is known.

H – **hazards and safety**: recognition of areas where problems might arise if no alternative is available. We are, after all, explorers! Are there possible escape routes?

ROUTE FOLLOWING

With a route finalised it is now time physically to go and follow it. Do not dive in feet first without first of all setting your map. This can be done by various techniques. You can use your compass to set the map to north. You can set your map by equating features visible on the ground with those same features on the map. And lastly mark on your map your known position.

To complement this it is always worth checking to your rear for back sights. Note start time of each leg. Continue to check your position by carrying out fixes (techniques on this subject are covered later) and keep your wits about you.

If you are in a vehicle, ignore wheel slippage, because it will be minimal. You should concentrate on the extra distance entailed in avoiding obstacles or the drift of the vehicle caused by the driver and side of the steering wheel. A right-hand drive vehicle has been proven to drift off to the right while driving on desert-type terrain.

If you are in any doubt, then stop. Do not guess! Your colleagues might be thankful for a stop for a hot drink or some food while you confirm your position.

Above all, concentrate!

Finding your end of leg

The best method of locating your destination is the square search. This is a proven technique. However, you must always leave someone where you finished before starting the search, because this will be your last known location!

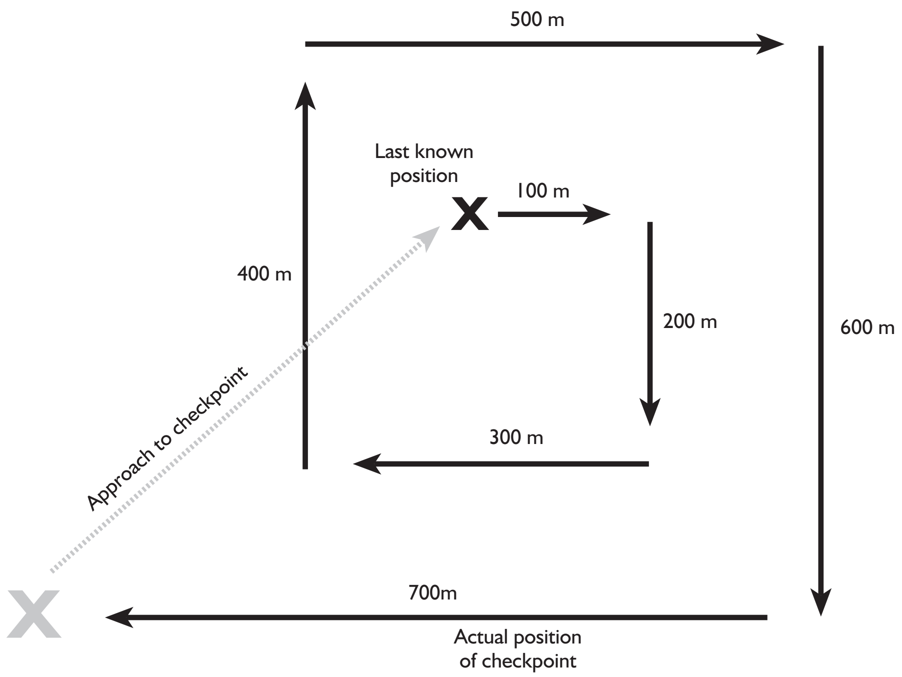

Figure 6.14 *The square search*

On nearing the end of the leg, you should be searching for it. Get a feel for how far you can see to your sides and to your front, e.g. this could be only 100 m.

At the end of the route, stop and leave at least one person there. You then proceed east, no matter the final direction, for the distance that you can search to your front and to your sides. In this example it would be 100 m.

At the end of the 100 m turn 90 degrees and search for 200 m, but keeping your search distance to 100 m.

Continue in this fashion until you locate your checkpoint, target, etc. (Figure 6.14).

Dead reckoning

The principle of navigation by dead reckoning (DR) is simple. From a defined position you travel in a defined direction, for a defined distance after which a new position can be determined.

This sounds good and easy in theory but in practice many errors can occur which will seriously affect your final DR position. The two main errors are in the measurement of distance (e.g. odometer error, poor pacing) and maintenance of your direction (e.g. obstacles, hazards). In order to counteract these errors the navigator must update his or her position regularly by using features that are on both the map and the ground.

There are two main methods available and they are either a multiple fix or a single fix. A modern term for the multiple fix is a resection and if done properly it will define your position very accurately. A single fix does as it describes. It uses only one bearing to obtain a position fix. This makes it less accurate than a multiple fix, but in some terrains you may have only one object that is both visible on the ground and appears on the map.

Multiple fix (Figure 6.15)

1. The size of triangle will depend upon the following:
   (a) compass and pointing errors (poor compass operation, not converting magnetic bearing to suit the map)
   (b) incorrect plotting of detail on map or chart.
2. Your true position will be within the plotted triangle.

Single fix (Figure 6.16)

If you only have one identifiable feature to use, then a single bearing fix should be used:

1. DR position plotted on map from course, speed and distance.
2. True position must be along bearing line from positively identified landmark or feature.
3. Assuming DR log to be correct, most probable estimated position (EP) is shortest distance (perpendicular) from bearing line to DR position.

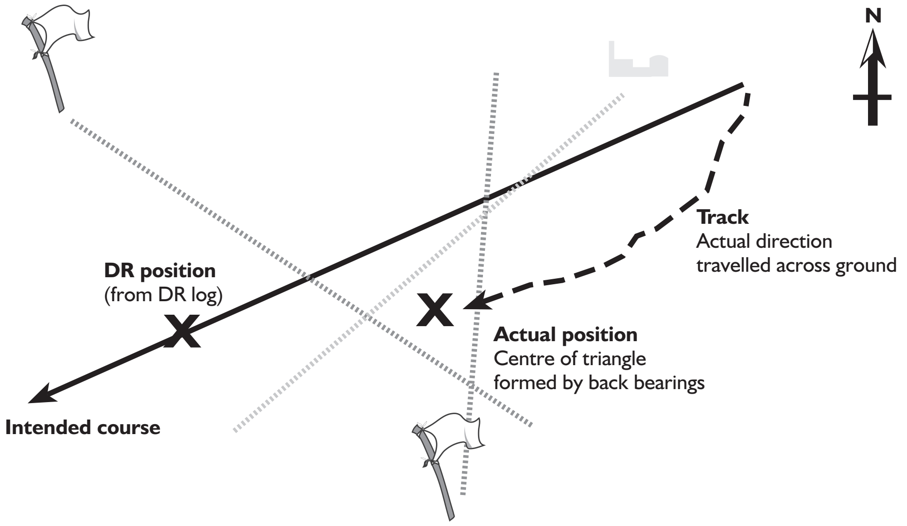

Figure 6.15 *Multiple fix. DR, dead reckoning*

Alternate running fix (Figure 6.17)

Where only one feature is identifiable you can use it more than once to determine your position:

1. Start as you would for a single bearing fix. Mark DR position on map. Take bearing to feature and plot it on map.
2. Travel a fixed distance D on a fixed direction.

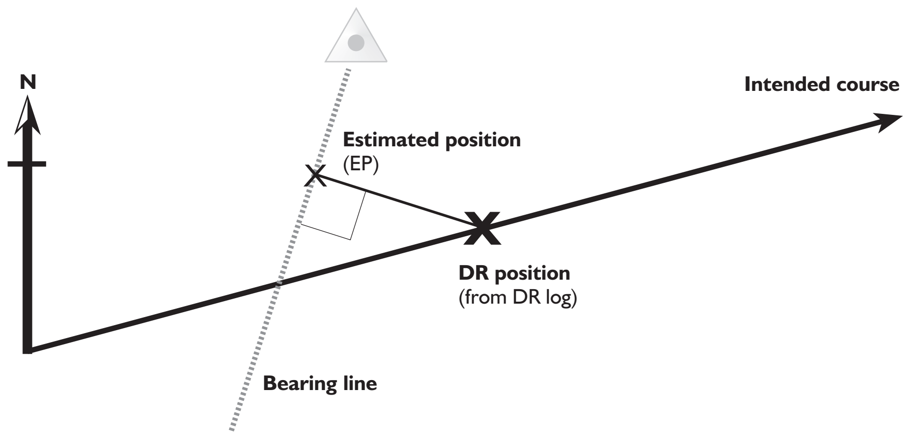

Figure 6.16 *Single fix. DR, dead reckoning*

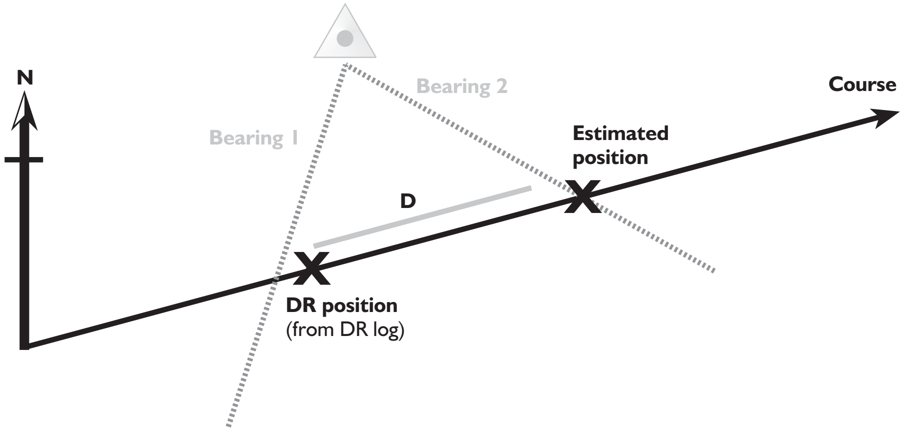

Figure 6.17 *Alternate running fix. DR, dead reckoning*

3. Plot second bearing to feature.
4. First and second positions must lie on bearing lines.
5. Distance D and course travelled can only fit in one unique position and a new EP can be plotted.

DR log

The DR log is filled out by the navigator during the navigation of a route and is a continuous update of the route planner.

The remarks box is where bearings for resections and single bearing fixes are logged (Figure 6.18). DR logs can be designed with your mode of transport in mind.

Leg	Time		Time	Bearing	Speedo		Dist	Remarks
	Start	Finish			Start	Finish		

Figure 6.18 *Dead reckoning log*

How far can I see in a flat featureless environment?

In flat featureless terrain, it is useful to know the distance to the visible horizon and the following formula can be used:

$$\sqrt{(\text{Height of the person in feet} \times 3/2)} = \text{Distance in nautical miles (nm)}$$

For example, for a 6-foot observer:

$$\sqrt{(6 \times 3/2)}$$
$$\sqrt{18/2} = 3 \text{ nm}$$
$$1 \text{ nm} = 1.852 \text{ km}$$

Which implies that the average person can see out to approximately 5.5 km. Standing on a vehicle can increase visibility to 8–10 km.

EQUIPMENT MANAGEMENT

Maps

The best thing to do with any map is to place it in a proper map case. Try not to cut up your maps, there is so much information in the margins. Get used to handling a few maps in a single case. You may decide that you want to cover your maps with laminate or Fablon. This is all well and good for waterproofing, but not for carrying out any position fixes (the author can testify to this!). The only accurate way of drawing bearings on to a map is by pencil!

Compasses

Remember to keep a lanyard on your compass and hang it safely somewhere. Around the neck is ideal and it is easy to access from there. If you use a prismatic compass, then get a padded case to keep it in until it is required. Keep away from metal objects when taking bearings and do not store your compass by a metallic object. After a period of time this will affect the correct direction of magnetic north. If you do happen to get a bubble in the compass housing, the best way to disperse it is gently to heat it (not over a fire!) and hope that that does the trick. If it persists and affects the movement of the compass needle, then put a small hole into the housing to drain the fluid.

Electrical items

Remember that the life span of a battery will change depending upon the environment that you are in. If you are using lithium batteries the life span can be extended, but the fall-off in power is sharper and quicker. Remember, however, that all batteries should be disposed of properly.

The environment will also affect the way electrical bits work. Placing an equipment item on the dashboard of a vehicle while in a hot climate is just asking for trouble.

Always have proper cases for all electrical items. They can keep heat at bay, keep heat in and also provide protection against falls, etc.

CONCLUSION

So now you should have the basics to enable you to put your mapping, navigation and GPS together for your expedition. Acquiring your expedition maps will probably be one of your hardest procurement jobs. Plan early and you should not be disappointed. You will, no doubt, run training sessions before departure; use these to practise navigation techniques and to introduce the tools that you will be using.

FURTHER INFORMATION

Further reading

Burns, B. (1999) *Wilderness Navigation: Finding your way using map, compass, altimeter and GPS*. Seattle: The Mountaineers Books.

Clark, M. (1993) *Expedition Use of Maps, Air Photographs and Satellite Imagery from Expeditions Planners Handbook and Directory, 1993–1994*. London: RGS–IBG Expedition Advisory Centre.

Ferguson, M. (1997) *GPS Land Navigation: A complete guidebook for backcountry users of the NAVSTAR satellite system*. Boise, Idaho: Glassford Publishing.

HMSO (1989) *Manual of Map Reading and Land Navigation*. London: HMSO.

Kals, W.S. (2002) *The Complete Land Navigation Handbook*. San Francisco: Sierra Club.

Keay, W. (1994) *Land Navigation*. Windsor: Duke of Edinburgh Award Scheme.

McWilliam, N. (ed.) (2003) *Expedition Field Techniques: Geographical information sciences*. London: RGS–IBG Expedition Advisory Centre, in press.

Royal Institute of Navigation (2003) *Guide to GPS for Navigators in Foot*. London: Royal Institute of Navigation.

Sources of information

RGS–IBG Map Collection, 1 Kensington Gore, London SW7 2AR. Tel: +44 207 591 3000, email: info@rgs.org, website: www.rgs.org
The Map Room of the Royal Geographical Society (with the Institute of British Geographers) contains one of the largest private collections of maps and related material in the world. The one million sheets of maps and charts, 2600 atlases, 40 globes (as gores or mounted on stands) and 700 gazetteers comprise the core of the Map Room's material. It includes printed items (on paper, vellum, and cotton or silk) dating as far back as AD 1482, manuscript items from 1716 onwards, aerial photography from 1919, satellite imagery maps and CD-ROMs.

RGS–IBG Expedition Mapping Unit. Website: www.rgs.org/mapping
Fieldworkers use many conventional survey and recording techniques. They can also benefit from new technologies: the global positioning system (GPS) to record positions and to navigate; remote sensing (RS) to provide environmental information; and geographic information systems (GIS) to record, process and display all kinds of spatial data. The Expedition Mapping Unit exists to share expertise in these techniques. The emphasis is on low-cost, reliable, relatively simple approaches – ones appropriate to most non-profit research and conservation endeavours. This website compiled by a volunteer network of fieldworkers has a useful list of web links on a wide range of geographic information resources including printed maps, satellite imagery, GPS and data sets for GIS.

British Cartographic Society. Website: www.cartography.org.uk
The Map Curators' Group of the British Cartographic Society has compiled the 4th edition (2000) of *A Directory of UK Map Collections* on-line only and can be found at:
www.cartography.org.uk/Pages/Publicat/Ukdir/UKDirect.html

British Library. Website: www.bl.uk
Bodleian Map Library, Oxford. Website: http://www.bodley.ox.ac.uk

British Orienteering Federation. Website: www.britishorienteering.org.uk

British Schools Orienteering Federation. Website: www.bsoa.org

International Map Trade Association (IMTA). Website: www.maptrade.org

Land Info International. Website: www.landinfo.com
Maintains the world's largest commercial database of digital GIS data products. Covering more than 75 per cent of the Earth's surface, Land Info has an expanding archive of over 250,000 maps.

The Map Shop, Upton-on-Severn, Worcs. UK. Website: www.themapshop.co.uk

National Library of Scotland. Website: www.nls.uk

National Library of Wales. Website: www.llgc.org.uk

National Navigation Award. Website: www.nnas.org.uk

National Remote Sensing Centre Ltd. Website: www.nrsc.co.uk
Satellite images.

Public Record Office, Kew. Website: www.pro.gov.uk

Oddens's bookmarks. Website: http://oddens.geog.uu.nl/index.html
Comprehensive and up-to-date list of map and map-related sites.

Ordnance Survey. Website: www.ordsvy.gov.uk/

Nigel Press Associates Ltd. Website: www.npagroup.co.uk

Royal Institute of Navigation. Website: www.rin.org.uk

Stanfords. Website: www.stanfords.co.uk
International map and guidebook retailers.

United Kingdom Hydrographic Office. Website: www.ukho.gov.uk