THE HASHEMITE UNIVERSITY
Faculty of Natural Resources and Environment
Department of Earth Sciences and Environment
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Geological Field Techniques 111201391

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Making a geological map

10.1 Principles and aims

A geological map is one of the most important tools of geologist's trade. It shows how geological features (rock units, faults, etc.) are distributed across a region. It is a two dimensional representation of part of the Earth ' s surface, scaled down to a size that is convenient for displaying on a sheet of paper or a computer screen. Information on the third dimension is incorporated by means of strike and dip symbols and other structural labels. Different rock units are usually shown as different colours (and/or ornaments) and are overlain on a topographic base map for easy location. Additional information on features such as structure, lithology and stratigraphy is also included, allowing interpretation of the subsurface. Increasingly, geological mapping data are stored with subsurface information in computer models that allow more sophisticated visualization and manipulation in three dimensions than is possible with traditional paper maps.

10.2.1 Base maps and other aids **Topographic maps**

Good geological mapping depends on good base maps. You should find out what is available for the mapping area well before you start, so that you can assess which maps to use (and at what scale). Many governments produce good quality topographic maps based on a ' National Grid ' designed specifically for that country; increasingly these are available digitally (e.g. for the UK, OS 1:10,000 Land plan maps; for the USA, 1:24,000 quadrangle maps). Digital topographic maps can be downloaded free, for instance from the U.S. Geological Survey website, for much of the USA. However, for some countries or regions good maps may be costly or impossible to obtain.

Figure 10.1 b, a 1:25,000 Ordnance Survey map, includes several features that could be particularly useful for mapping (note that the 1 km eastings and northings are labelled in blue on the map extract):

- topographic contours that define landforms in the landscape and give elevations;
- point features on which to take bearings (e.g. cairn on Meikle Crag at NX 342572, corner of coniferous plantation at NX 348579, corner of wall on top of Pauples Hill at NX 361583);
- linear features to check compass declination angle (e.g. wall running NE from minor road at NX 342580);
- spot heights to calibrate altimeter (e.g. road junction at NX 357580);
- location of specifi c exposures (e.g. on Craigdow Moor at NX 339572);
- indications of vegetation (e.g. marshland at NX 351575; scrub at NX 338575; rough grassland at NX 343574).

Aerial photographs

Aerial photographs may be used for mapping, either using a transparent overlay (e.g. acetate, Mylar ®), or mapping directly onto photographs enlarged to a suitable scale (e.g. 1:7000). Many are high enough resolution to be used at large scales (e.g. 25 cm resolution photographs are appropriate for 1:2500 scale mapping) (Table 10.1).

Satellite i mages

Some low - resolution imagery (e.g. Landsat) is freely available online, but this is of limited use for detailed mapping, although it may help provide a regional. Context However, a range of data (maps, high - resolution satellite imagery, aerial photographs) is increasingly being displayed online, both in bird ' s eye view and three – dimensional perspective, via interfaces such as GoogleMaps ™ , Google Earth ™ , Microsoft Bing Maps ™ . These systems make available some of the visualization capabilities of a GIS to any internet user, and represent an invaluable resource when planning a mapping season, especially to remote and poorly mapped areas.

Additional d ata

Geophysical or geochemical data may be available for some areas, and maps of gravity or magnetic anomalies can provide valuable insights into large - scale subsurface structures that may influence the surface geology.

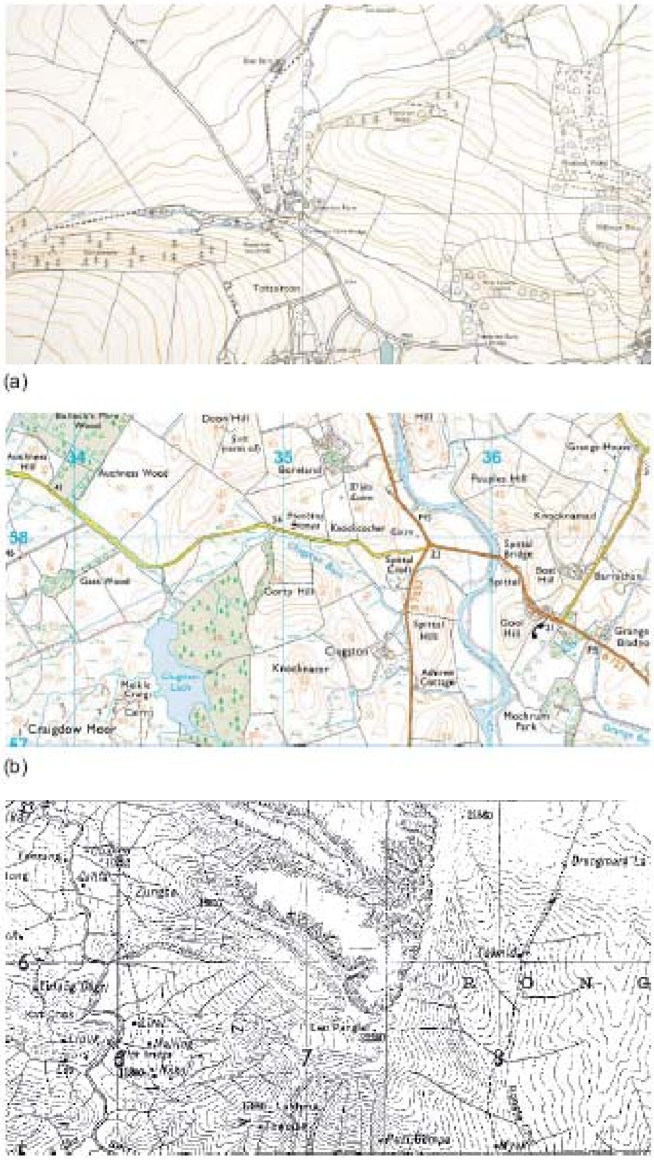


Figure 10.1 Examples of topographic maps. (a) Extract of a 1:10,000 British Ordnance Survey map of part of Shropshire, UK showing field boundaries, tracks and buildings in detail. (b) Extract from 1:25,000 topographic map of part of southern Scotland, UK, from the British Ordnance Survey (within 10km grid square NX(25)35). Grid squares are 1km across, and contour intervals are in metres. (c) Photocopy of part of a much smaller scale map of northern India, dating from the 1940s. Grid squares are 10,000 yards across, and contour intervals are in feet. Details are sparse for this large area and out of date, but such maps may be the best available in remote regions. (a: Ordnance Survey 1:10,000 Sheet SO38NE © Crown Copyright. b: Ordnance Survey 1:25,000 Scale Colour Raster © Crown Copyright 2009. An Ordnance Survey/EDINA supplied service.)

Table 10.1 Advantages and disadvantages of aerial photographs and satellite images for geological mapping.

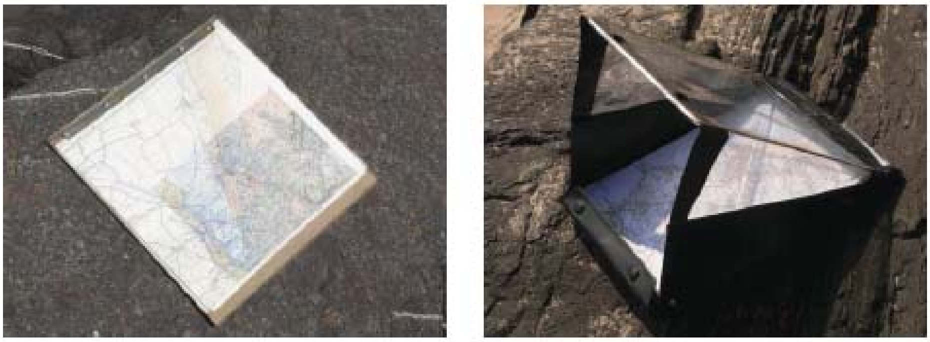
Method	Advantage	Disadvantage
Aerial photograph	Clear depiction of landscape features May show more detail than map Landforms may be interpreted before mapping Clear features in photographs make it easy to confirm your location	Limited global coverage Costly; rarely available for free May be old: landscape may have changed May be difficult to obtain for some areas Distortions must be corrected by processing No contours; slopes may not be obvious
Satellite image	Tend to show larger areas More readily available (e.g. Landsat) More sources of free images More information in different spectral bands: allows interpretation before mapping Newer images constantly being acquired	Most are lower resolution than photographs Limited coverage of high-resolution images High-resolution images are costly Relief often less clear than in an aerial photograph May be old: landscape may have changed Distortions must be corrected by processing Clouds may obscure area

10.2.2 Equipment for maping

The use of tools for geological fieldwork has been covered in the beginning lecturers , and only a few further remarks with regard to equipment needed for geological mapping are made here (Table 10.2). A long surveyor ' s type of tape measure (*c.* 30 m) is useful for some surveying distances accurately. A map case (Figure 10.4) is essential to protect field maps from the elements (rain, sun, dust). A good map case has a see - through cover so you can check your position and your data quickly. The case should also allow easy addition of data to the map, with a rigid base on which to write and plot. A supply of strong rubber bands or clips is invaluable for holding fi eld maps and other sheets in place. Some geologists favour the discipline of mapping directly onto a base map; others prefer using a rainproof, plastic overlay.

Table 10.2 Summary of the equipment required for mapping (see also Tables 2.1–2.3).

Mapping equipment
Ruler
Protractor
Map case
Base maps
Clips/rubber bands
Mapping pens
Full selection of coloured pencils



(a) (b)

Figure 10.4 (a) A home-made map case (c. 30 cm across) incorporating a rigid board for drafting, and a hinged Perspex sheet to protect map sheets without obscuring them. (b) A second map case, which has a clipboard base for A4-sized sheets. The hinge on the plastic cover is sprung so that it holds the position in the photograph unless secured; the side panels help protect the sheets from the elements, while allowing access to the field map.

Some equipment is easily lost when dropped, or left on the ground by an exposure. Use brightly coloured equipment, bright labels, paint or sticky tape to make your tools more conspicuous.

10.3 Location, location, location

Locating yourself accurately in the field while mapping is of paramount importance. Many of the basic skills involved have been covered. Eg. GPS, base map, triangulations method.

10.4 Making a field map

Mapping aims to *record* as much relevant information as possible on the geology of an area using field maps and a notebook, and then *present* an interpretation of those observations in the form of a final fair copy map, which may include interpretative cross - sections. This section summarizes how to record information on the topographic base maps you take into the field.

10.4.1 Information to record on field maps

Field maps are valuable records of observations and data gathered in the field, from which later geological interpretations will be drawn. Your field maps (and notebook) should be comprehensible to any geologist wishing to make later interpretations; they should not simply be personal records.

Make sure each field map sheet has the information in Table 10.4 (on the reverse if there is not enough space, as in Figure 10.6). Table 10.5 provides a summary of the other types of information that could be included on the field map;

Table 10.4 Checklist of information to be included on each field map.

Additions to a field map
Scale and N arrow
Explanation of colours used
Stratigraphic column (if appropriate)
List of non-standard symbols used
Cross reference to notebook(s) used
Name and contact details of author
Date of mapping
Reference direction for structural data (e.g. grid N)

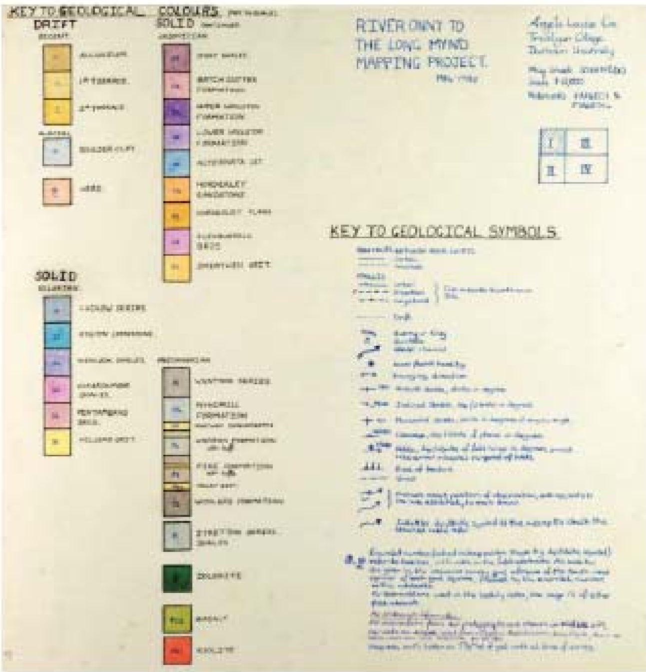


Figure 10.6 A well-structured layout for additional information on a field map that contains most of the elements mentioned in Table 10.4, including a small graphic showing how this field map sheet relates to three adjacent sheets produced for the project. (Reverse side of field map of Angela L. Coe, The Open University, UK.)

Table 10.5 Information to record on a field map. Level of detail is determined by time allocated and scale of mapping. Conventional symbols used for plotting these data are given in Appendix A10 (Figure A10.3).

Information	Comments
Rock exposures	Location: extent if appropriate, nature (e.g. man-made). Brief notes of rock types or facies, and other important information (e.g. fossils, index minerals, structures)
Structural data	Symbols *and* measurements (dip/strike, plunge/trend) for bedding, foliations, lineations, fold axes, joint orientations, etc.
Notebook localities	Clearly label those localities where you have made detailed notes in your book
Specimen localities	Label the locations where samples were taken (rock, fossil, sediment, water, etc.); it is best to link these directly to notebook localities
Photographs, sketches	Label where photographs were taken or field sketches made if not at a notebook locality
Major contacts	Lithological and tectonic: solid where observed, dashed where inferred.
Additional evidence	For example topographic features, drainage, soils, float, vegetation (Figure 10.7a)
Superficial deposits	For example alluvium, glacial/fluvioglacial material, sand, peat, river terraces, etc.
Degree of exposure	Comments on quality and quantity of exposure, weathering, soil cover, etc.
Hazards	Note of hazards not obvious from base map

10.4.2 The evolving map

Major lithological divisions

There may be an existing stratigraphic scheme that you can adopt or adapt to define units of the various rock types within the mapped area, in which case the criteria for the unit definitions should be already documented. However, you may need to apply your own unit definitions, either because you are engaged in pioneering fieldwork, or because the existing scheme is inappropriate (e.g. not detailed enough).

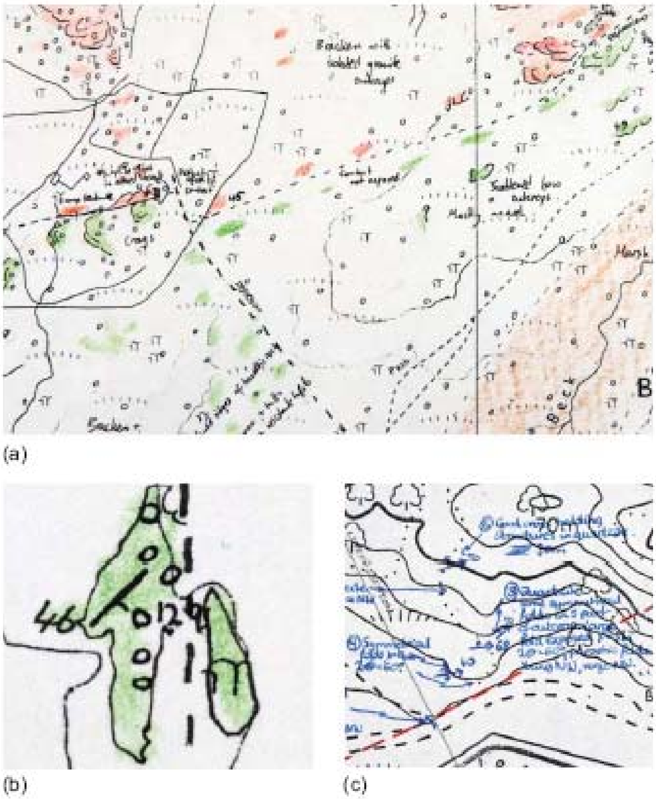


Figure 10.7 (a) A field map of an area in the English Lake District. Exposures are coloured, but not outlined or labelled with a unit code. Annotation is sparse, but includes some comments on vegetation and landscape features relevant to the underlying geology (depressions, scarps, marshy ground). (b) Magnified portion of an adjacent field map, showing a strike line symbol plotted at locality number 46. The strike line is accurately plotted, with a short tick indicating dip of the stratum to the southeast at 12°, and the exposure has been outlined using a thin black pen line. This map could be improved by using colour to distinguish mapping lines better from the base map, and by ringing the locality number for clarity. (c) A field map from a brief mapping exercise in Scotland. Locality numbers are ringed, and their location given by arrows. Detailed notes compete with structural symbols for space, and the map is rather congested. Such notes could be reserved for the field notebook alone in most mapping situations. (a and b: Extracts from field maps of Tom W. Argles, The Open University, UK. c: Extract from field map of Angela L. Coe, The Open University, UK.)

Lithological subdivisions and marker layers

The type and scale of mapping control how detailed a scheme has to be to classify lithological units. A large area may have a wide range of rock types that are easy to categorize. Mapping smaller areas, or those with little variation in rock type, demands discrimination on subtler criteria. The basic mappable unit is the formation. Formations may contain one or more subdivisions known as members, which are units with characteristics that distinguish them from the adjacent parts of the formation. In monotonous sections of strata, the widespread occurrence of a distinctive single member or even layer can be critical to interpreting the geology of the area.

10.5 Mapping techniques

You should always aim to record as much relevant detail as practical in your notebook to help construction of the final geological map. Some features (e.g. uniformly dipping strata) can be adequately recorded with a few measurements. Others, such as complex brittle fault zones, may require numerous measurements and observations to constrain their orientation and kinematics satisfactorily. Mapping may be focused on different aspects of the geology (e.g. bedrock, superficial deposits, artificial deposits, mineral deposits, glacial geomorphology, soils), which will impose different constraints
on the mapping techniques used. In addition, other constraints such as time, terrain, vegetation, weather, etc., mean that you must develop an appropriate mapping strategy for the conditions. Three common mapping methods are described in the following sections, although in some areas a combination of these different techniques may be appropriate.

10.5.1 Traverse mapping

This method is often adopted for reconnaissance mapping of a large region, at relatively small scales (1:250,000 to 1:50,000). It may also be the only approach possible where rock exposures are restricted to stream sections or roads, or where access is limited to streams, roads, ridge crests, etc. (Figure 10.9). River sections in mountainous regions are commonly sub parallel and quite evenly spaced, presenting the opportunity for multiple traverses. The geology can be interpolated between them if the structure is broadly simple, especially if aerial photographs or satellite images can be used to help trace units or boundaries across sparsely vegetated areas.

Figure 10.9 River gorge at Wangtu, northwest India, illustrating the point that in very mountainous regions, the only practical mapping approach may be traverses along river sections or roads. In this view, the road is cut into the cliff on the left-hand side of the photograph, about half way up the image. (Tom W. Argles, The Open University, UK.)

Linear traverse

Ideally, a traverse runs perpendicular to the strike of stratigraphy or structure, yielding the most information on the regional geology. If the traverse is along a well - defined linear feature (e.g. road or stream).

Closed compass traverse

Another way to create a traverse is by pacing out a polygon on a set of compass bearings; some correction for minor bearing errors may be required when you finally reach the end point (Figure 10.10 b).

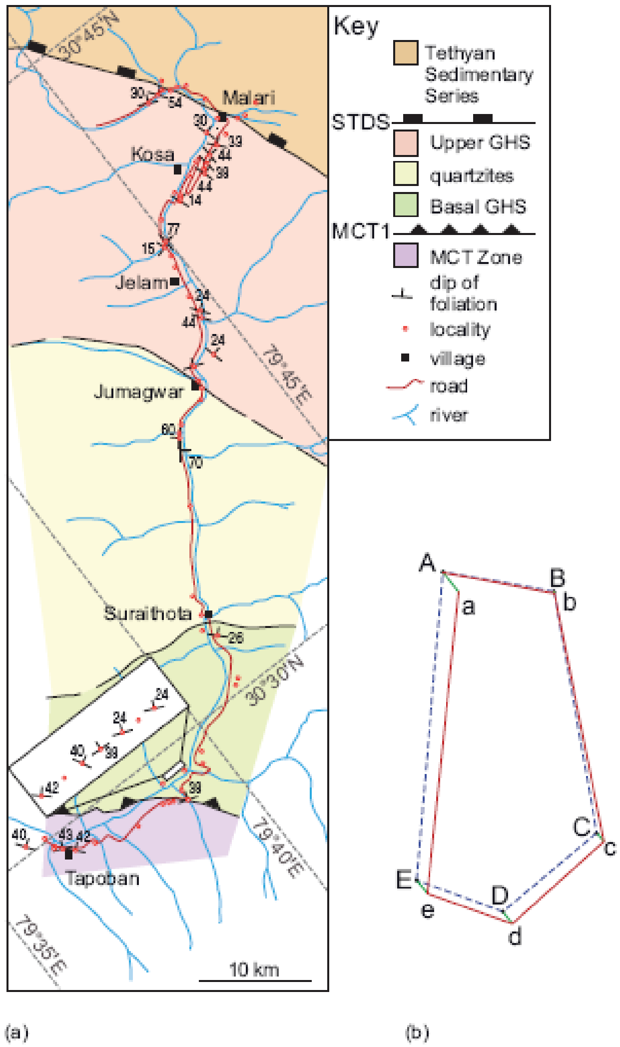


Figure 10.10 (a) A linear traverse mapped in the Alaknanda valley, northwest India. In this complex orogenic zone, the focus of this project was on gathering structural data and collecting samples for metamorphic and geochemical analysis. (b) Correcting a closed compass traverse for minor bearing errors. When the traverse was plotted using the bearings and distances in the notebook (red lines), the last leg (e to a) did not join up exactly to the origin (Point A), by a closure error of 43 m. The traverse was corrected by adjusting each plotted point (a to e) parallel to the closure error (green lines) by an amount proportional to the cumulative distance travelled to reach that point. So, for point d, correction = 43 × (780/1435) = 23.4 m. The result is the corrected closed traverse ABCDE (dashed blue lines).

10.5.2 Contact mapping

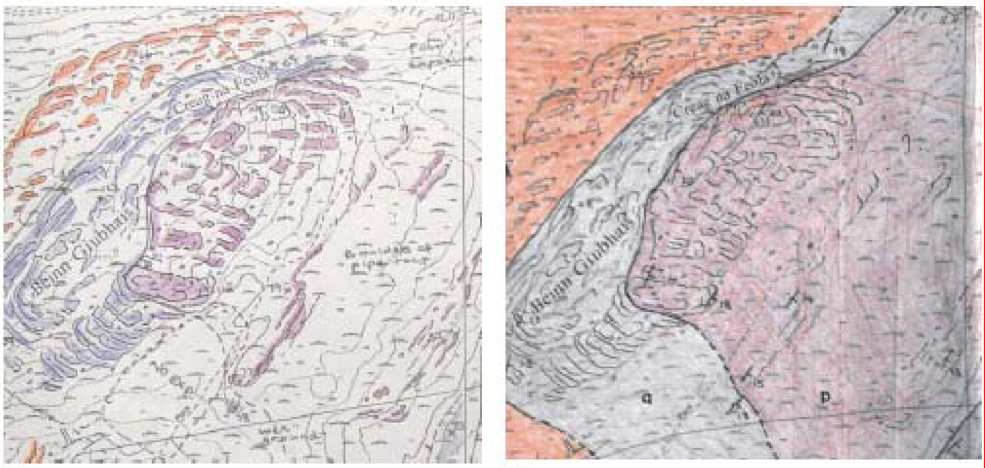
One important objective of geological mapping is to trace out the contacts between different geological units. In many cases, careful examination of aerial photographs or satellite images (including online sources) prior to (or during) mapping may pay rich dividends, since these may pick up subtler differences in soil type and vegetation than can be seen while on the ground. Contacts may be rapidly traceable across rugged terrain, and even under superficial deposits, in this way. Because contacts typically juxtapose rock units that have different properties (hardness, permeability, composition), there are often landscape clues to their presence.

This technique is generally suited to mapping at scales of between 1:50,000 and 1:15,000, but it can also be used for very detailed mapping of small areas. In areas of good exposure, this method can build up a geological map quickly, especially if the structure is reasonably simple. The technique can be compromised by difficult terrain, poor exposure or complex geology. However, in poorly exposed terrain, contacts may still be traced by combining information from the few exposures with other information :landscape features, drainage and mapping of the drift deposits that obscure the contact. Obvious contacts may be traced further using binoculars, especially in rugged landscapes with extensive exposure.

Figure 10.11 Contacts like this one in southern Tibet may be conspicuous enough to be traced across difficult terrain using binoculars. (Tom W. Argles, The Open University, UK.)

10.5.3 Exposure mapping

This technique is typically more detailed than either contact or traverse mapping, and is used to produce maps at a scale of between 1:15,000 and 1:1000. Many landscapes are composed of more - or - less scattered exposures of rock separated by areas where the rock is obscured, by superficial deposits, vegetation, ice, water and so on. In this environment, the geologist aims to examine as many exposures as possible, outlining the extent of exposed rock in pencil and filling in each outlined exposure with the colour assigned to each rock unit that occurs there (Figure 10.12). The pencil outlines should be traced over in ink at the end of the day, because pencil will smudge or fade over a long field season. It is also a good opportunity to review the day’s work. However, exposure mapping is not simply a ‘colour by numbers’ exercise! Do not be tempted to leave important contacts or boundaries to be drawn between different units later. You should investigate and confirm the suspected presence of a boundary in the field where possible, and dash boundaries where inferred. This constant re - evaluation of the structure will help you pick up offsets and anomalies more quickly.



(a) (b)

Figure 10.12 (a) An example of a field map produced by exposure mapping, with exposures outlined in pen; note that unit boundaries are also shown as dashed or solid lines. (b) A portion of the final fair copy map from the field map in (a), showing how the inferred outcrops of the mapped units are shown as solid blocks of colour. (Field map and final fair copy map of Susie Clarke, Oxford, UK.)

10.5.4 Using other evidence

Topographic features: Feature mapping

In any area of poor exposure, gathering clues to the underlying geology from the landscape is a useful skill. The topography itself is heavily influenced by the bedrock underneath, so that, for example, many breaks in slope mark the location of a

lithological boundary (Figure 10.13 a). Gently dipping strata can be mapped out by the succession of scarp and dip slopes (Figure 10.14 b), even where rock is not exposed. Systematic offsets of scarp features may indicate faults, especially where the offsets coincide with linear depressions. Curved ridges may indicate folding that can be traced out, either on the ground or by reference to aerial photographs. Where scarps or ridges die out gradually, you might suspect that the resistant bed forming the feature has pinched out. Table 10.6 lists how some common topographic features might reflect the bedrock geology, with some examples shown in Figure 10.14.

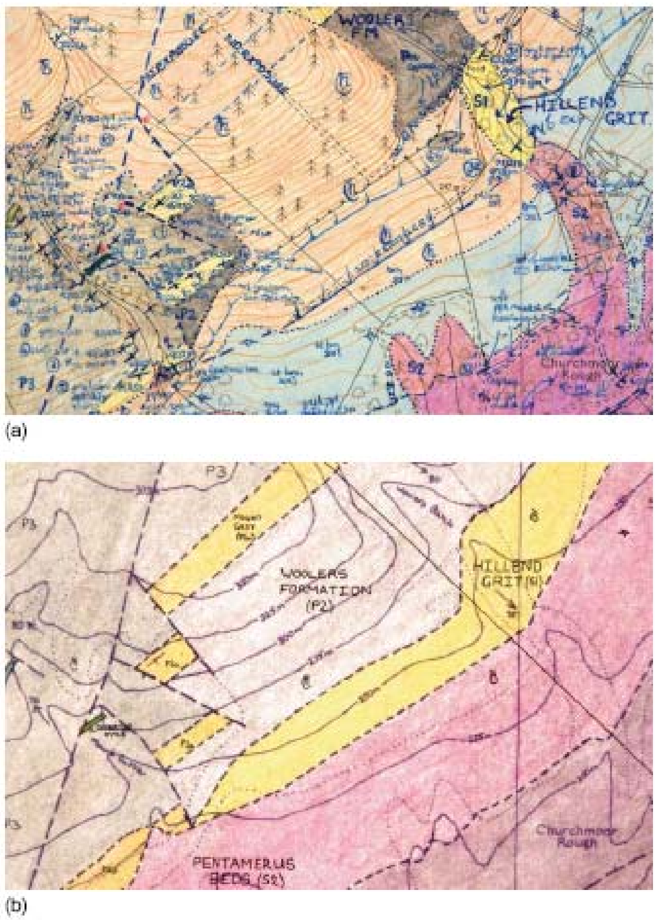
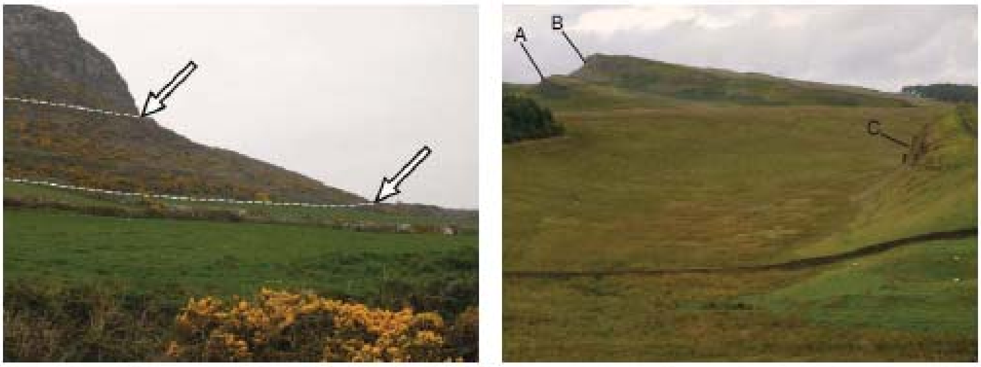


Figure 10.13 (a) Part of a field map of the Long Mynd area, Shropshire, UK, incorporating landscape features (e.g. breaks in slope) as evidence of stratigraphic boundaries. Each break in slope is marked as a line with a series of arrows pointing at it; two occur in the centre of this extract, with another at top right. Superficial deposits that obscure the bedrock geology are also mapped. (b) The corresponding portion of the final fair copy map from the field map in (a), showing how the inferred outcrop of the bedrock units is depicted; the two central breaks in slope mark the boundaries of the Hillend Grit. (Field map and final fair copy map of Angela L. Coe, Open University, UK.)



(a) (b)

Figure 10.14 Some landscape clues to bedrock geology. (a) Two breaks in slope (arrowed) mark the boundaries between massive gabbro (crags on left) and cleaved mudstones (underlying fields on right) at Carn Llidi, southwest Wales, UK. The intermediate slopes are underlain by contact metamorphosed mudstones and gabbro debris. (b) Steep scarp slopes mark resistant strata, near Haltwhistle, UK: a sandstone at A and the Whin Sill (dolerite sill) at B and C. The horizon dipping to the right (south) follows the dip of the sill. Depressions between the scarps are underlain by softer siltstones and limestones. (a and b: Tom W. Argles, The Open University, UK.)

Table 10.6 Topographic clues to bedrock geology.

Topographic feature	Possible cause(s)
Break in slope	Stratigraphic boundary, fault, unconformity, limit of metamorphic aureole
Depression, ravine	Fault, shear zone, layer of softer material, synformal fold
Ridge	Dipping resistant rock layer, dyke, mineralized fault zone, antiformal fold
Escarpment	Edge of gently dipping strata, fault

Drainage

Many conspicuous drainage features owe their existence to the underlying bedrock or superficial geology (e.g. Figure 10.15). Table 10.7 summarizes some common examples. Care is needed in interpretation, as both bedrock and superficial deposits may influence drainage.

(a)

(b)

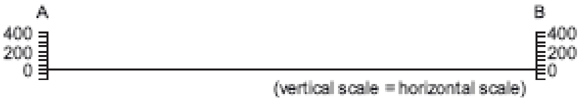
Figure 10.15 Examples of drainage and vegetation contrasts.
(a) Marshy ground with rushes (foreground) marks the outcrop of impermeable Silurian mudstones, while most of the sheep are grazing on the well-drained pasture underlain by permeable Carboniferous Limestone (exposed in the crags behind). The contact between the two rock types is marked by a distinct break in slope, conspicuous against the woodland near the left-hand side of the photograph. Witherslack, Cumbria, UK.
(b) The green verdant vegetation and flatter foreground is underlain by interbedded limestones and mudstones. The steeper slopes with vegetation typical of acidic soils (heather, bracken) are underlain by sandstone. The contact is marked by the vegetation change, running from just left of the group of trees on the horizon obliquely left behind the plantation on the left-hand side. This locality is near Alnwick, Northumberland, UK. (a: Tom W. Argles, The Open University, UK; b: Angela L. Coe, The Open University, UK.)

Table 10.7 Drainage characteristics of the underlying geology.

Drainage feature	Possible cause(s)
Wet, boggy ground, marsh	Impermeable substrate (e.g. mudstone, granite, gneiss, glacial till)
Dry, well-drained ground	Permeable substrate (e.g. limestone, chalk, some sandstones, gravel, blown sand)
Ephemeral streams	Permeable bedrock (e.g. limestone, chalk), or low rainfall (arid areas)
Spring lines, seeps	Boundary between permeable (up-slope) and impermeable (down-slope) substrates (e.g. fault, unconformity, or stratigraphic boundary)
Sinkholes	Boundary between impermeable (up-slope) and permeable (down-slope) substrates (e.g. fault, unconformity, igneous or stratigraphic boundary); typical of limestone areas
Potholes, caves, karst features	Typical of limestone areas, rare in regions underlain by other rocks
Dendritic drainage	Area underlain by similar substrates (or even a single rock type)
Rectangular drainage	Exploiting regular lines of weakness in bedrock, such as joints in granite
Radial drainage	Water drains outward from a raised feature (e.g. structural dome, granite intrusion, volcanic centre)
Linear drainage	Lines of relative weakness in bedrock (e.g. faults, fold axes, soft strata, dykes)

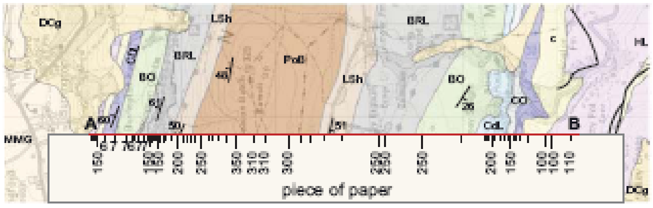
10.6.2 Cross – sections

Constructing or sketching cross - sections while mapping an area is an important step in understanding the geology, and may provide critical insights into the developing map. Sections are generally drawn along a line perpendicular to the dominant strike of strata and structures (e.g. faults, fold axes), so that they show the subsurface structure most clearly. Accurate sections typically have a horizontal scale equal to that of the map on which they are based, but the vertical scale may be exaggerated to emphasize the structures (in which case, strata dip more on the section than in reality).



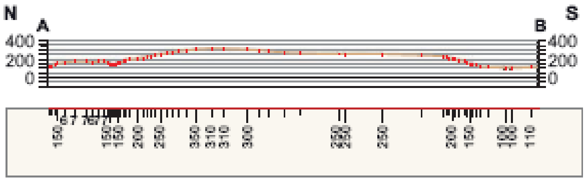
(a)

Decide on an appropriate vertical scale for the cross-section. Mark the line of section on the map with a faint line, or mark the end points. On a separate sheet of graph paper, draw a straight horizontal line of the same length, to represent mean sea level (the usual reference datum). Add vertical axes at each end, labelling them with an appropriate scale for the height relative to sea level.



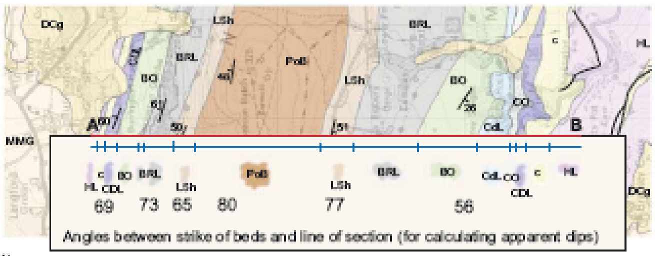
(b)

Lay the straight edge of a second sheet of paper along the section line on the map. Mark the end points of the section line on the edge of the paper, and wherever topographic contours cross the section line mark ticks, labelled with the contour height, on the second sheet of paper. (It may help to mark rivers and ridge crests too.)



(c)

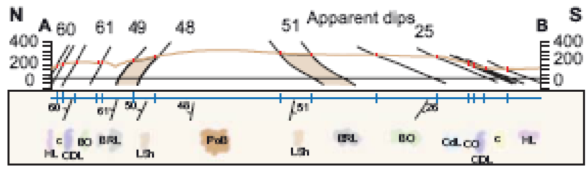
Transfer the contour heights to the graph paper by laying the edge of the paper along the horizontal axis, and marking dots projected up to the correct height all along the cross-section. Join these dots with a smooth curve interpolated between them to produce a topographic profile as a base for your cross-section. Label the end points with a grid or GPS reference, or a compass bearing.



(d)

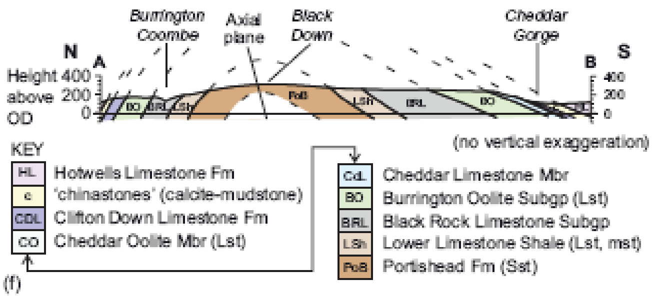
Using a third sheet of paper, transfer geological information such as stratigraphic boundaries, faults and igneous contacts along the line of section from the map to the cross-section in the same way as you did for the contour heights (stage (b)).

Figure 10.19



(e)

Transfer the position of these features directly onto the topographic profile on the graph paper. Dip measurements can also be transferred onto the section. If there are none on the line of section, data lying short distances away from the section line can be projected at right angles onto the line. However, only where strata strike at exactly 90° to the section line can their dip angles be drawn directly onto the cross-section. Dips of strata striking at more oblique angles to the line of section must be corrected to lower values, because in effect the cross-section cuts these strata obliquely, and their dips will hence be apparent dips on the cross-section. The more oblique the strike to the section line, the lower the apparent dip will be. (Appendix 10, Figure A10.1 shows a graph you can use to determine apparent dips.) Draw short lines for the dip data at the correct angle just above the profile initially, as a guide.



(f)

Choose an important marker horizon or stratigraphic boundary, and draw this across the section, matching its dip to the dip measurements where possible, and interpolating between the different points on intersection with the topography. With this guide to the overall structure, add other unit boundaries in the same way; unless you have evidence for varying strata thickness, draw these parallel to the first horizon. In some cases, you may know or be able to determine the throw on faults, and their attitude; you may also be able to define fold structures. Generally, you will be able to extend your section further below the surface in folded areas; indicate uncertainty with question marks. Finally, add a key to unit colours and other symbols.

Table 10.9 Additional elements of a final fair copy map.

Element	Comments
Title	Include the name of the area mapped, and indicate any special theme (e.g. ore mineralization)
Scale	As a ratio (e.g. 1:10,000) and in graphical form (e.g. a graduated bar)
N arrow	Indicate true north, and also show relative deviations of grid and magnetic north
Author, date	Include both the date of mapping and of map publication
Sources	Cite the sources of topographic base maps and any additional data used (e.g. previous maps)
Explanation	A detailed legend showing colours, ornaments and letters for units, all symbols, lines, etc., similar to that in Figure 10.6
Stratigraphic column	A vertical section, showing the stratigraphic order and relative thickness of strata
Cross-section(s)	Include one or more horizontal cross-sections, generally along the base, to illustrate the structure of the area

10.6.4 Digital maps and GIS

Many final geological maps are drafted electronically, using Geographic Information System (GIS) technology to plot the geological data in a geospatial framework. However, in some cases the actual mapping is also conducted using portable computers (laptops or ‘ tablet ’ PCs), which allow data to be directly entered into databases, and maps to be drafted on - screen on an electronic base map. Professional surveys and other companies increasingly use this technology, but it has limitations as well as advantages. Such methods are beyond the scope of this introduction, as each system is likely to require specific training in the software and mapping styles adopted by the organization. However, the general principles of mapping outlined in this chapter should still be followed while mapping in this way; it is only the tools that have changed.

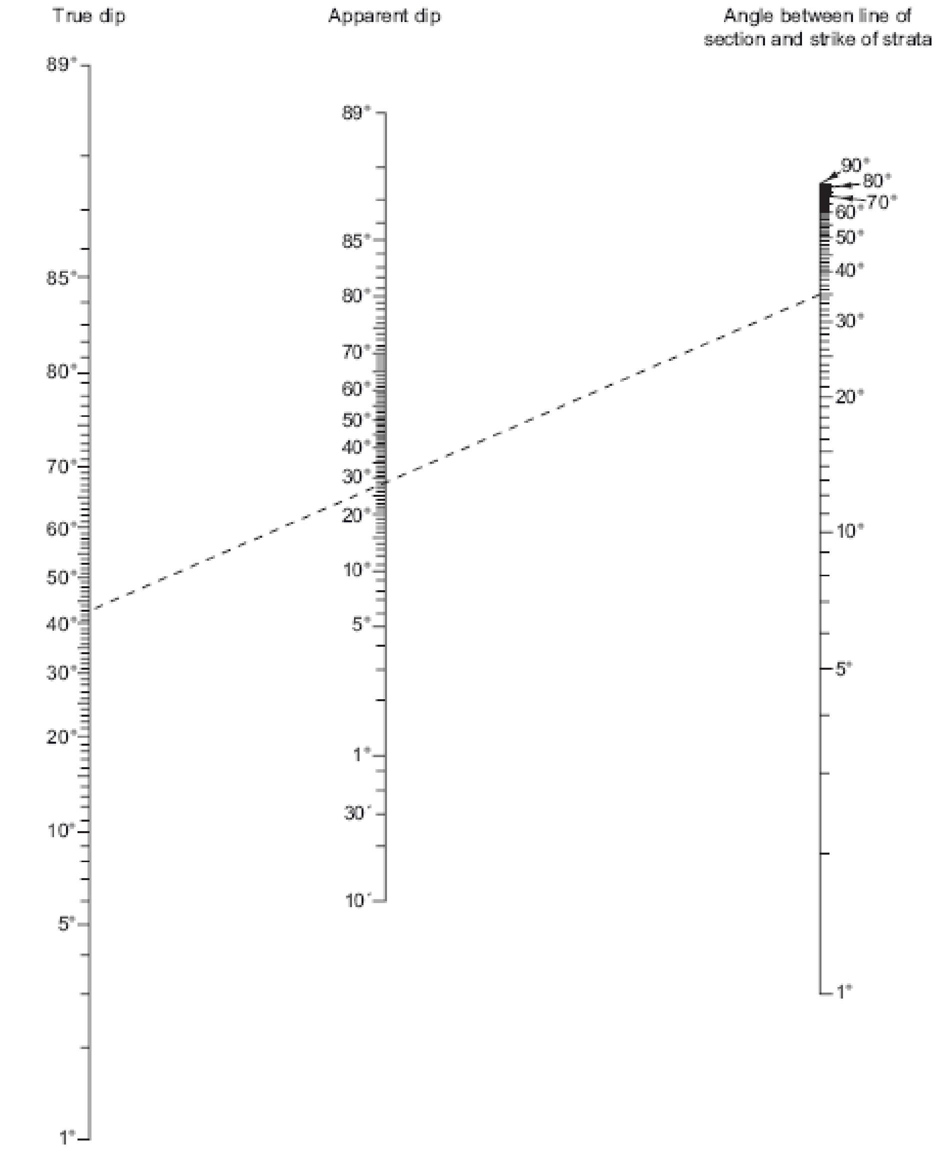


Figure A10.1 Nomogram to determine the apparent dip given the true dip and the angle between the strike and the line of section. The dashed line illustrates an example: for a true dip of 43° on a cross-section oriented at 35° to the strike of the bedding, the apparent dip on the cross-section would be 28°. (Based on Billings 1972.)

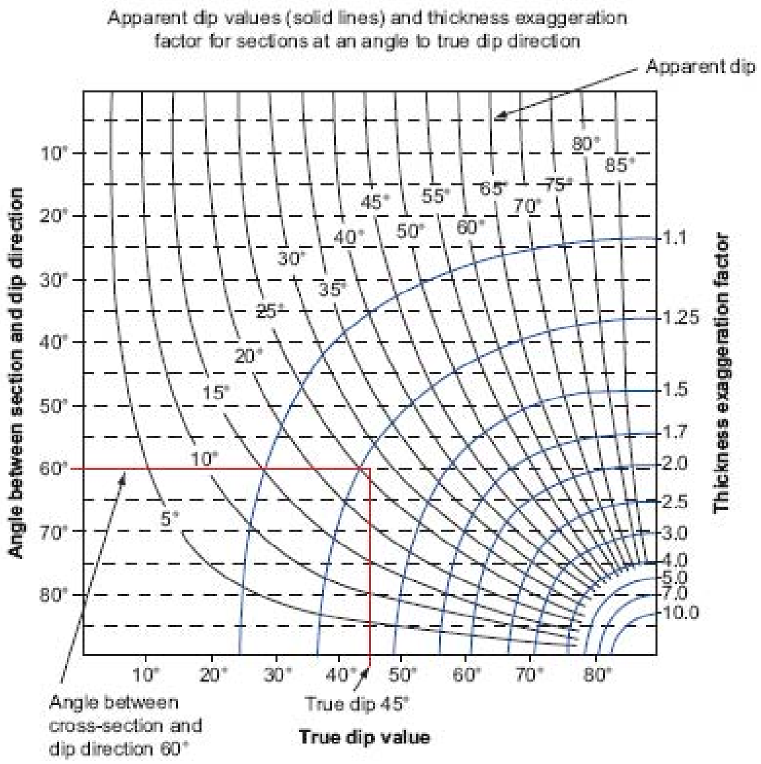


Figure A10.2 A graph to determine the apparent dip angles (solid, curved lines) and the thickness exaggeration (curved blue lines) for bedding in cross-sections that are not parallel to the true dip direction (i.e. where the strike of bedding is not perpendicular to the line of section). An example is given on the diagram (red lines) for bedding with a true dip of 45° on a cross-section orientated at 60° to the dip direction. In this case, the apparent dip of 27° can be read off the graph, and the thickness of bedding will be 1.275 times the actual thickness. (Modified from McClay 1991.)

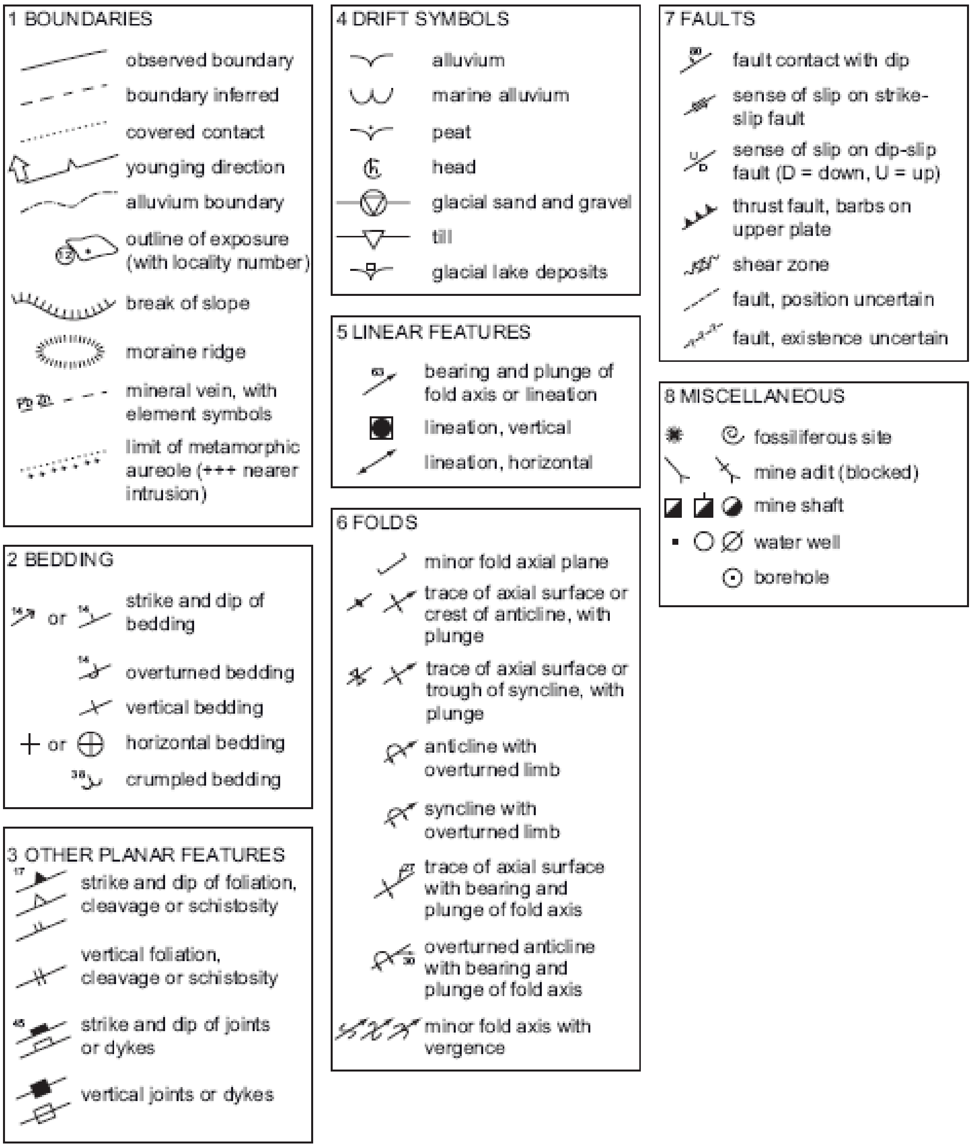


Figure A10.3 A selection of symbols for use in preparing geological maps. Alternatives are given for some of the symbols.