3 The three-dimensional aspect: structure contours

3.1 Introduction

The problem of representing three-dimensional things on a flat piece of paper has exercised minds for many years, nowhere more so than with regard to maps. Many atlases begin by discussing the question of how to represent the spherical earth in a book. A similar problem is the portrayal of the undulations – the relief – of the earth's surface. Early map-makers attempted to depict relief by drawing humpy little hills, often wildly exaggerated in height and steepness. Better pictorial methods gradually evolved, such as shading and hachuring, but in general these are unsuited to geological maps. By far the most successful means yet devised are topographic contour lines. These are now common on larger scale geological maps, say 1:100 000 or larger. Figures 1.4 and 1.5 illustrated the concept of topographic contours, and Fig. 1.6 showed how to construct topographic profiles from them. It is important that you are completely familiar with topographic contours.

This chapter is concerned with applying all these principles to *underground* surfaces. It begins by emphasising the similarity between topographic contours and those drawn for underground surfaces, called structure contours. The chapter explains how structure contours are derived, and illustrates their use. Although these days the routine construction and manipulation of structure contours are increasingly being carried out by computer methods, the understanding of the three-dimensional principles behind them remains fundamental.

3.2 The nature of structure contours

Contour lines can be used to represent on a piece of paper any three-dimensional surface, not necessarily the relief of the land. The contours drawn in Fig. 3.1a could equally represent the shape of the earth's surface or, say, the surface* of a rock formation. Although the formation may be underground, it still has an altitude, and the contour lines simply join the points on either its top or bottom surface that have equal height.

It is possible, therefore, to draw on a map contour lines which portray not the land surface but the position and undulations of some underground surface. Such contour lines are called **structure contours**. Without labels, the lines on Fig. 3.1a could be topographic contours representing a hill, but they could equally well be structure contours depicting a map unit that has been upwarped into a dome. The structure contours sketched in Fig. 3.1b are of a surface which has the form of a basin, and in Fig. 3.1c they depict a dome. Note that because the dome in Fig. 3.1c is deeply buried, the altitudes are negative with respect to sea-level.

If the structure contours of a surface are known, a cross-section can readily be constructed, in an exactly analogous way to a topographic profile (Fig. 1.6). Instead of marking on a strip of paper where the *topographic* contours meet the line of the section, the position and altitude of the *structure* contours are marked and transferred to the section grid. This has been done to produce the cross-sections shown in Figs 3.1b and 3.1c. Some published maps include structure contours, normally of a surface that is considered representative of the structure of the area, but it usually falls to the map reader to construct them. Structure contours can be drawn for any geological surface, for example, a fault or the boundaries of an igneous intrusion.

3.3 Examples of structure contours on maps

Figure 3.2a is a structure contour map of the Ekofisk oilfield, the first of the giant oilfields to be discovered in the North Sea. The surface for which the structure contours are drawn is the top of the rock unit which contains most of the oil. The contours show this formation to be in the form of a deeply buried dome, slightly elongate in a

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* Note that the word 'surface' has two slightly different meanings in the map context. In addition to meaning *land* surface – the outer surface of the earth – the term also applies to the boundary of *any* geological body or curving geological plane, and these can be underground. Thus geologists talk both about 'the beds outcropping *at* the land surface', the ground on which we live, and 'the outcrop *of* a surface', such as the boundary of a map unit or a fault.

A. Maltman, *Geological maps: An Introduction*

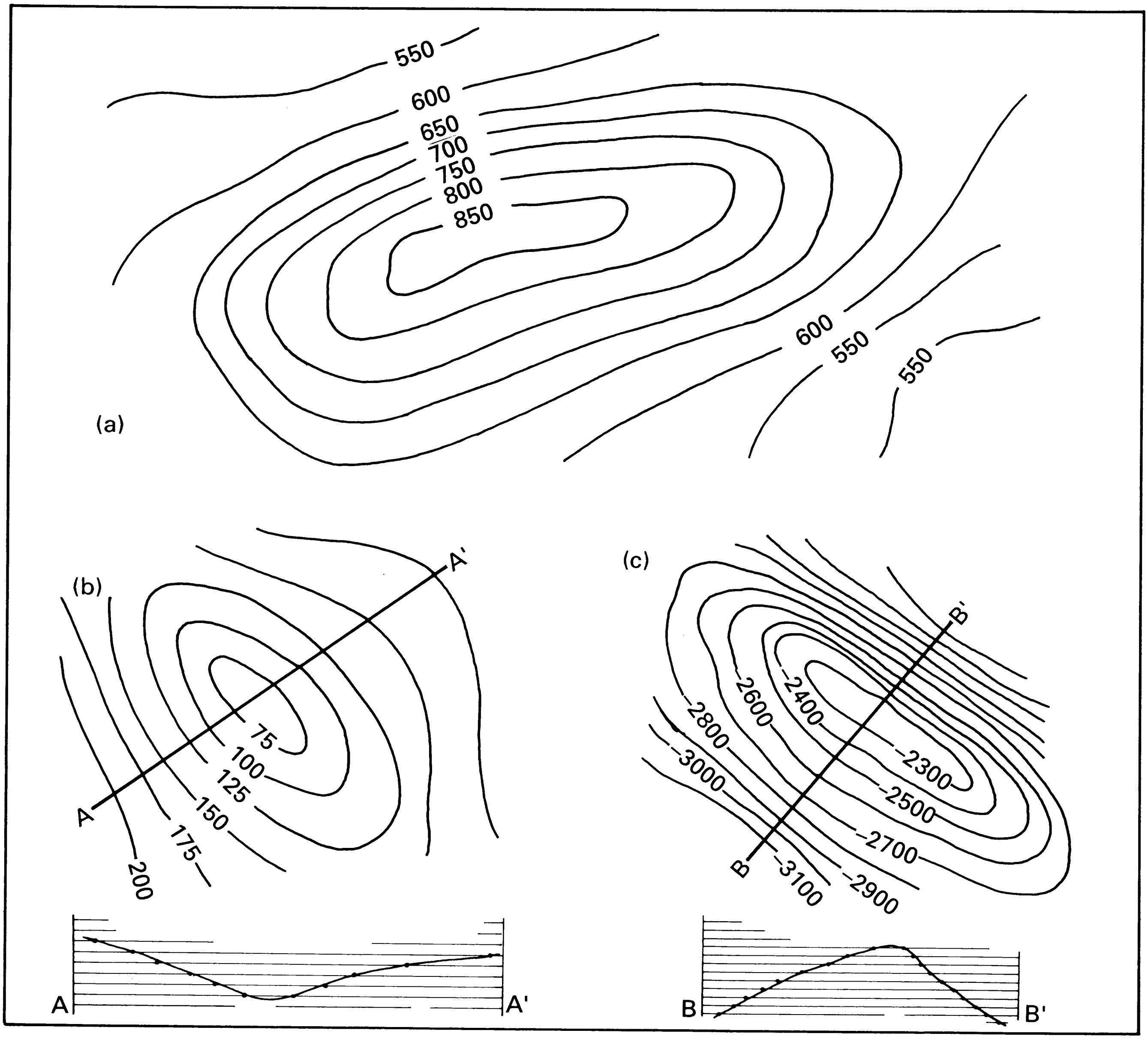


Fig. 3.1 The similarity between topographic and structure contours. The lines in (a), if they are regarded as topographic contours, represent a hill. Equally they could be regarded as structure contours representing a dome-shaped geological surface, buried beneath some higher land surface. The lines in (b), without information on whether they are topographic or structure contours, could represent either a depression in the land surface or a buried structure of basinal form. The lines in (c), although similar in form to topographic contours representing a hill, are likely in view of their negative altitudes, to be structure contours representing a subsurface dome. In practice, different line symbolisms are used on maps to differentiate the two kinds of contours.

N–S direction. It is in the upper part of this dome that the oil is trapped.

Figure 3.2b is an inclined view of the structure which may help you see how the structure contours are representing the dome. It is vital that you become used to visualising structure contours in three dimensions. Map 1 provides an exercise. Figure 3.2b also shows the location of the main oil wells, positioned to penetrate the oil in the crest of the dome. Perhaps it is becoming apparent to you why structure contours are of such value in applied geology. In fact, it was for practical reasons that the device was originated in the anthracite fields of Pennsylvania.

Figure 3.3 illustrates an unusual practical use of structure contours, as well as a very irregular contour pattern

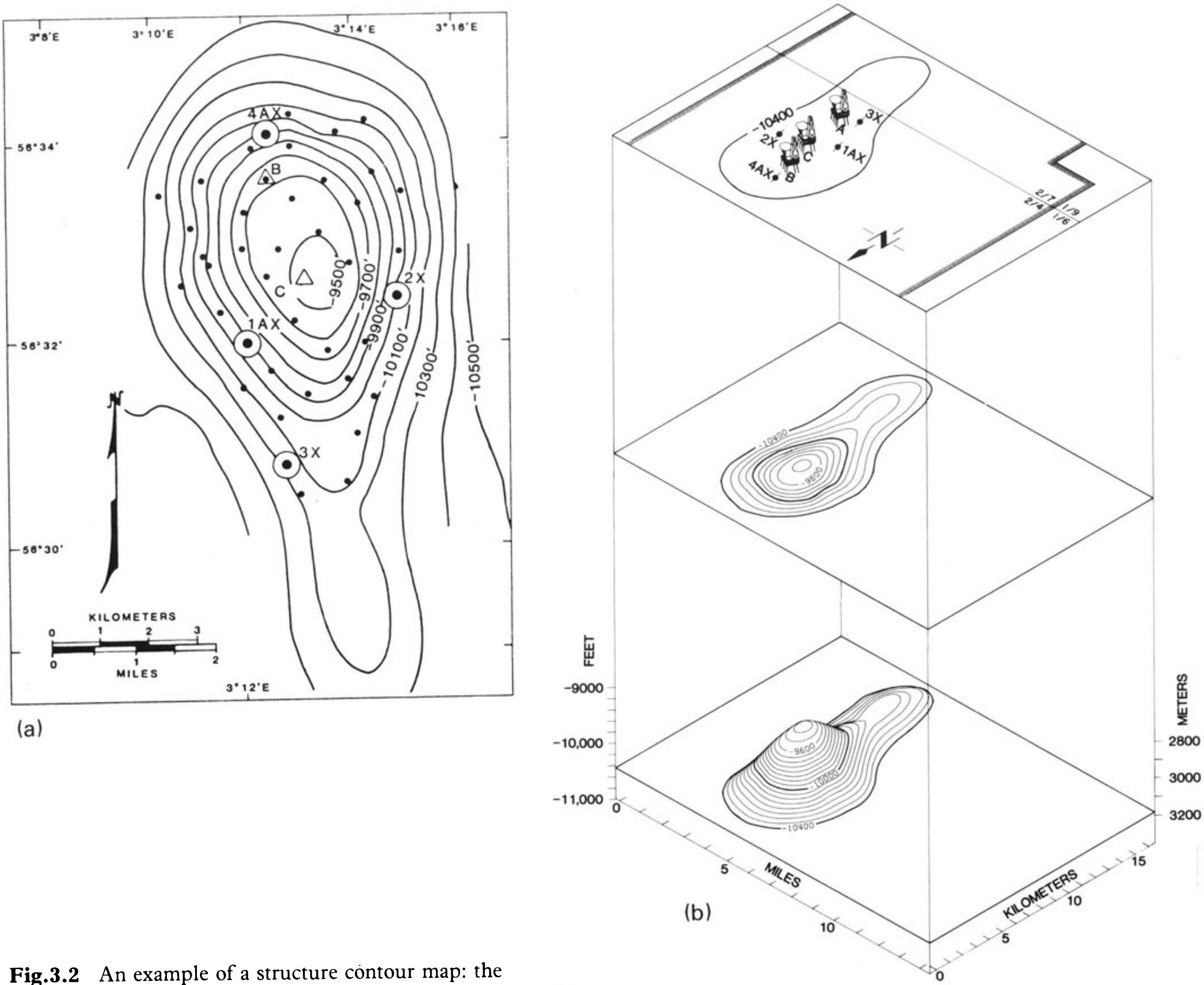


Fig.3.2 An example of a structure contour map: the Ekofisk oilfield, North Sea. (a) Structure contour map of the top of the oil-bearing formation. (b) Oblique view of the form of the contoured surface (bottom level of drawing), in comparison with the structure contours (drawn at some arbitrary middle level) and the sea-bed (top level). Reproduced with modification from van der Bark and Thomas (1980), by permission of the American Association of Petroleum Geologists.

(see section 4.2 for the reasons for the irregularities). In the area south of Bordeaux, France, the quality of the grapes depends upon the soil, which in turn depends upon the depth to a particular limestone, known as the Calcaire à Astéries. Better wine is likely to be made where the limestone is buried by no more than a few metres. The structure contours for the top surface of the limestone allow, by comparison with a map showing topographic altitudes, determination of the depth to the limestone at any locality of interest. This provides an initial guide to the likely value of a specific locality for wine-making.

3.4 Structure contours derived from borehole/well information

But how are structure contours known if the surface they represent is out of sight underground? The most common method of deriving them, especially in industry, is to use information obtained by drilling (e.g. Bishop, 1960). If the elevation of the land surface where the drilling starts is known, the depth at which the bedding surface of interest is encountered can be measured, and, by subtraction, its elevation derived. Such boreholes, usually called wells in

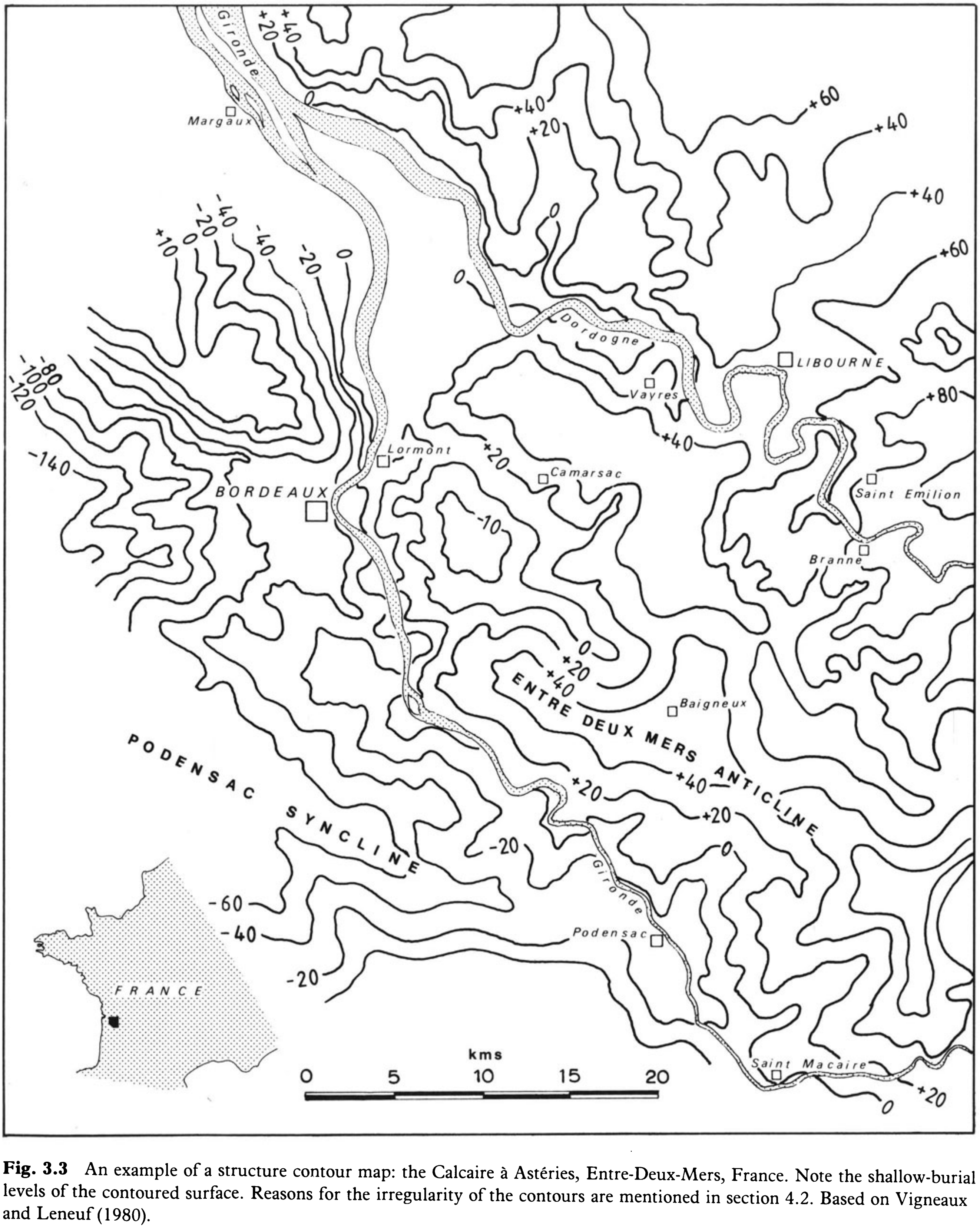


Fig. 3.3 An example of a structure contour map: the Calcaire à Astéries, Entre-Deux-Mers, France. Note the shallow-burial levels of the contoured surface. Reasons for the irregularity of the contours are mentioned in section 4.2. Based on Vigneaux and Leneuf (1980).

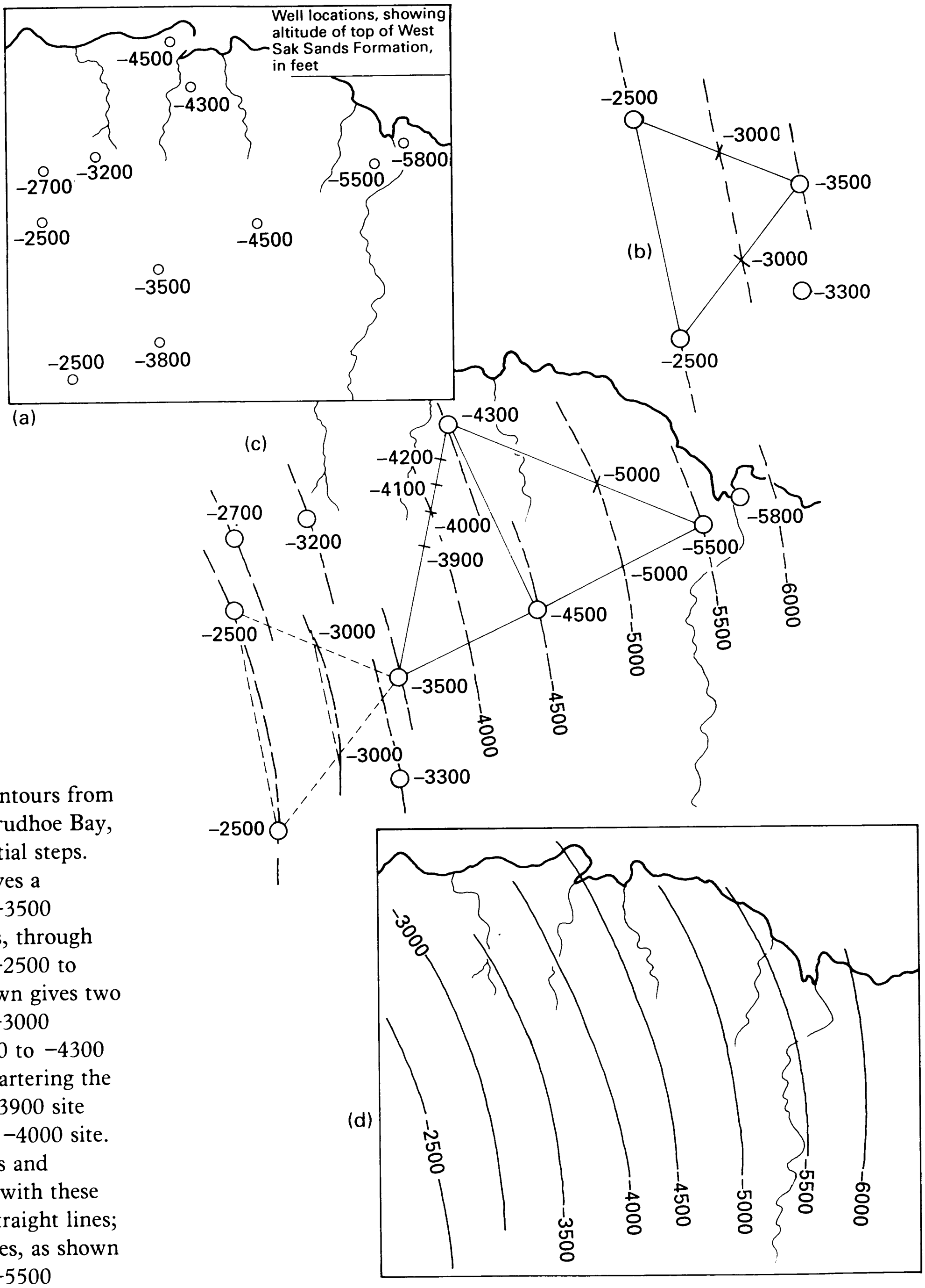


Fig. 3.4 Drawing structure contours from well data: a worked example, Prudhoe Bay, Alaska. (a) Starting data. (b) Initial steps. Joining the two −2500 wells gives a tentative −2500 contour. The −3500 contour may run parallel to this, through the −3500 well. Bisecting the −2500 to −3500 sides of the triangle shown gives two −3000 points, and a tentative −3000 contour. (c) Bisecting the −3500 to −4300 distance gives a −3900 site. Quartering the distance between the derived −3900 site and the −4300 well locates the −4000 site. However, the tentative contours and spacings derived in (b) conflict with these new sites if they are added as straight lines; a solution is to curve all the lines, as shown in (c). Bisecting the −4500 to −5500 distance gives a −5000 site; a further −5000 point is derived by dividing the −4300 to −5500 distance into twelfths, and hence the −5000 contour. Parallel to this, presumably, is the −5500 contour and, beyond the −5800 well, the −6000 contour. (d) Completed map, omitting well data but showing structure contours at 500 ft intervals. Base data highly simplified from Jamieson *et al.* (1980), by permission of the American Association of Petroleum Geologists.

the oil industry, are important sources of much subsurface information. Of course, to assess a buried undulating surface with any accuracy, many holes would be needed with interpolation between the known values. Figure 3.4 is a worked example, and Map 2 provides an exercise. Any other available information will be added in to help control the accuracy of the structure contours. In oil exploration, especially, the data from seismic sections will be included.

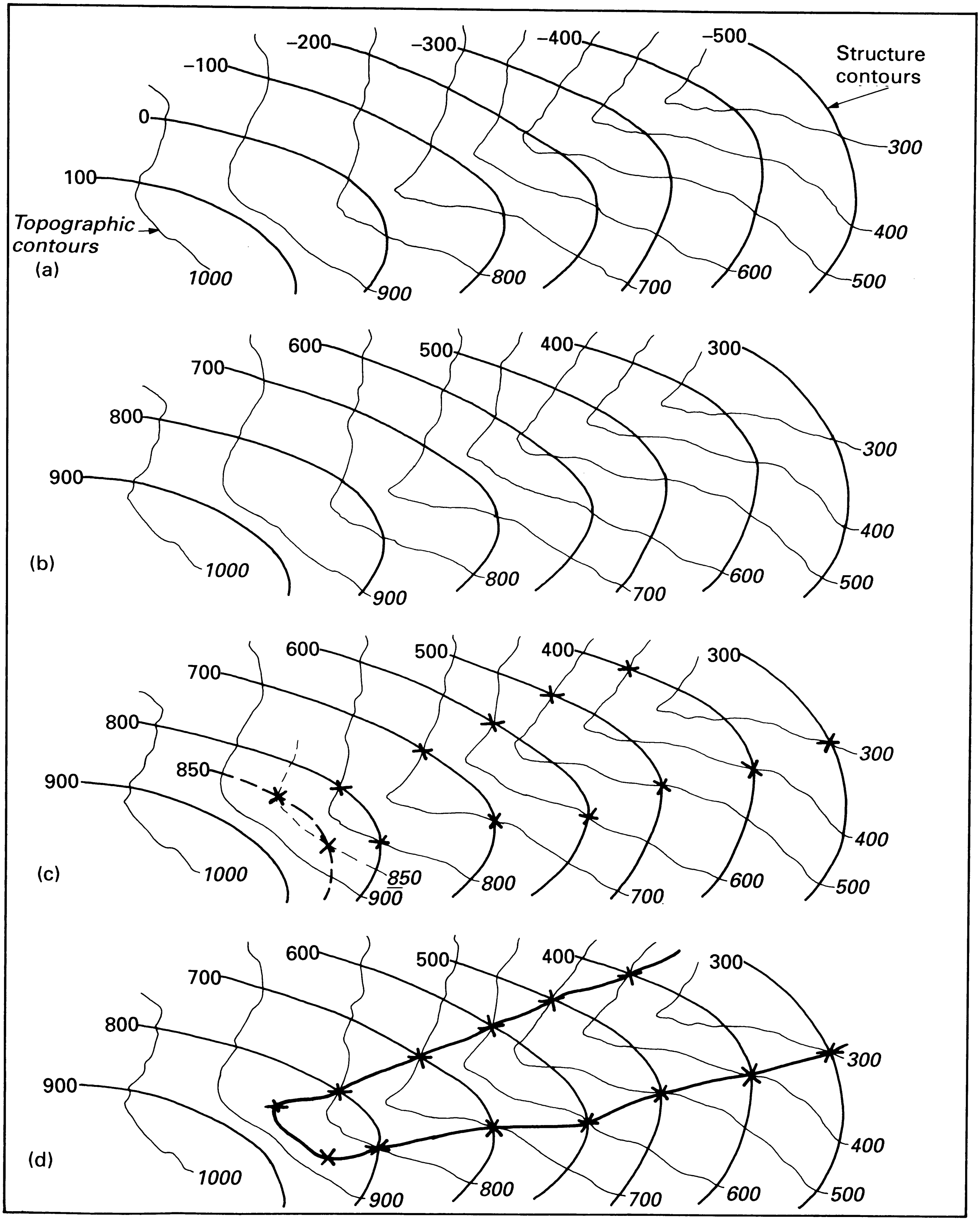


Fig. 3.5 The relationship between topographic contours (narrow lines), structure contours (medium lines) and outcrop (broad lines). Section 3.5 explains this figure in detail.

3.5 Structure contours derived from topography: the theory

It is possible to construct contours for near-surface rocks without borehole information, if the formation outcrops. For this, it is necessary to know the various topographic altitudes at which the unit reaches the land surface. This, of course, is exactly what is shown on a geological map. Therefore, this technique is much used, both in academic research and commercial work. In fact, the three-dimensional thinking that the method involves is relevant to many kinds of subsurface work. However, beginners can find the concepts difficult. Therefore, the following explanation starts with a broader consideration of the problem and develops the method step-by-step.

Topographic contours and structure contours both work on the principle of connecting points of equal elevation, differing merely in the particular surfaces they represent. They can be shown together on a single map. In Fig. 3.5a the topographic contours are depicting a land surface ranging between 300 and 1000 m in elevation, whereas the structure contours are showing a curved formation boundary at an altitude of between −500 and 100 m. The formation surface is therefore underground. You should look at Fig. 3.5a and make sure you can see in your mind's eye the two separate surfaces represented: the land surface and the formation at depth.

Figure 3.5b shows a rather similar situation – exactly the same land surface, and structure contours for a curved formation surface – but there is an important difference from Fig. 3.5a. The particular formation boundary shown, although of the same shape as before, is at a higher altitude and so is less deeply buried. In fact, in some places the topographic contours and the structure contours intersect at precisely the same value of altitude. Where this is the case, the formation surface cannot be buried at all. The formation will actually outcrop at the earth's surface. Figure 3.5c is exactly the same as Fig. 3.5b except that it includes the points where the contours are showing that the formation boundary must outcrop.

The values of the contours given on the map depend on the contour interval; there may well be intermediate elevations where the bed also reaches the surface. Figure 3.5c shows in addition the interpolated 850 m contours, and hence further points where the bed would be expected to outcrop. Figure 3.5d shows the logical extension of this – *all* the points where the bedding surface should reach the land surface. These merge together to form a linear trace. This line is the trace of where the bedding intersects with the land surface: it is the *outcrop* of that bedding surface. Thus, by knowing the structure contours for a geological surface and the topographic contours we have predicted what should be the outcrop of that surface. This is a procedure which finds some use in field surveying (section 13.2), but it is a variation on this approach that allows us to make the more valuable construction of deriving structure contours from topography.

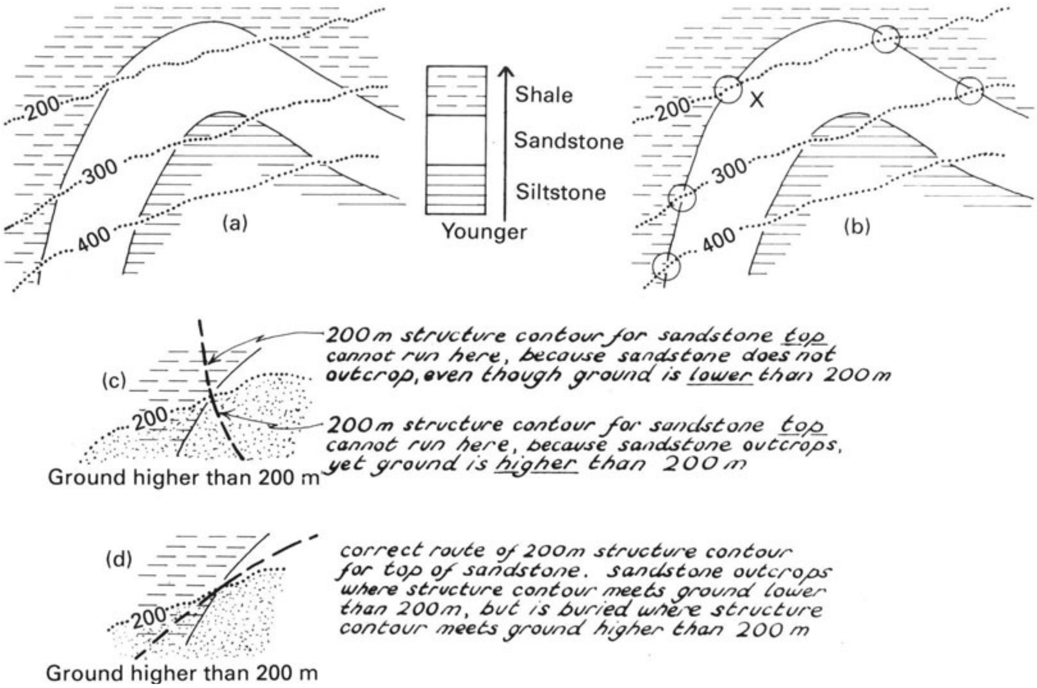
For most purposes it is much more useful to construct not the outcrop from known structure contours and topography, but structure contours from known outcrop and topography, for these last two factors are available at the land surface. It is possible for just the same reasons as developed above. Figure 3.6a shows a small part of the outcrop of a geological surface and it shows topographic contours. Figure 3.6b shows locations through which the 200, 300, and 400 m structure contours must pass, and Fig. 3.6c represents the only way in which the structure contours can be drawn satisfactorily in this example. Section 3.6 discusses further why this is the only possible path. (An alternative interpretation involving all the boundaries being wholly vertical is also possible here, but would normally be identifiable if more of the map were seen.)

A large-scale geological map will usually supply the information on topography and outcrop, and so in principle we can construct on it structure contours for surfaces of interest. We are therefore in a position to predict *from a map*, the three-dimensional arrangement of an outcropping formation. Imagine the practical applications of this: a hydrogeologist can derive the location and form of an aquifer; a mining geologist can estimate the length of tunnel or drill-hole necessary to reach the material of value; an engineering geologist can assess the nature of the rocks he is considering excavating for a building foundation. If we derive structure contours for the top and bottom of a formation of commercial value, we will be able to calculate its volume, that is, we can estimate reserves. We have arrived at one of the great practical uses of geological maps.

3.6 Structure contours derived from topography: the practice

Begin by locating on the map the outcrop of the surface that is to be contoured. If you are interested in the top of a formation, make sure you are dealing with the top surface and not the base! The top will be adjacent to the next youngest formation, and the dip direction of the unit, if it is known, will be towards it (section 2.3.1).

Look for places where the outcrop of the surface crosses topographic contours, and start your construction in an area where there are plenty of intersections. Leave until last those areas where there are few intersections and therefore least control on the route of the structure contours. Where the outcrop crosses or meets a topographic contour, you know the surface must be at the same altitude as that topographic contour. If you can locate two or more reasonably close intersections with the same altitude, you can tentatively connect them to produce the structure contour for that altitude.



200 m structure contour for sandstone top cannot run here, because sandstone does not outcrop, even though ground is lower than 200 m

200 m structure contour for sandstone top cannot run here, because sandstone outcrops, yet ground is higher than 200 m

correct route of 200 m structure contour for top of sandstone. sandstone outcrops where structure contour meets ground lower than 200 m, but is buried where structure contour meets ground higher than 200 m

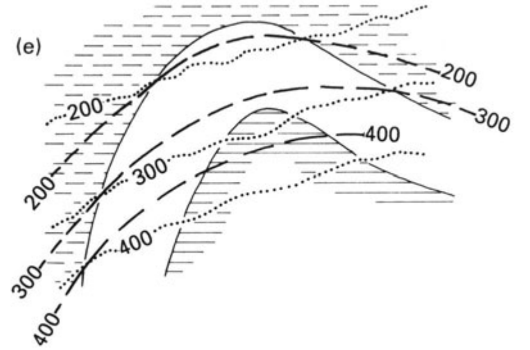


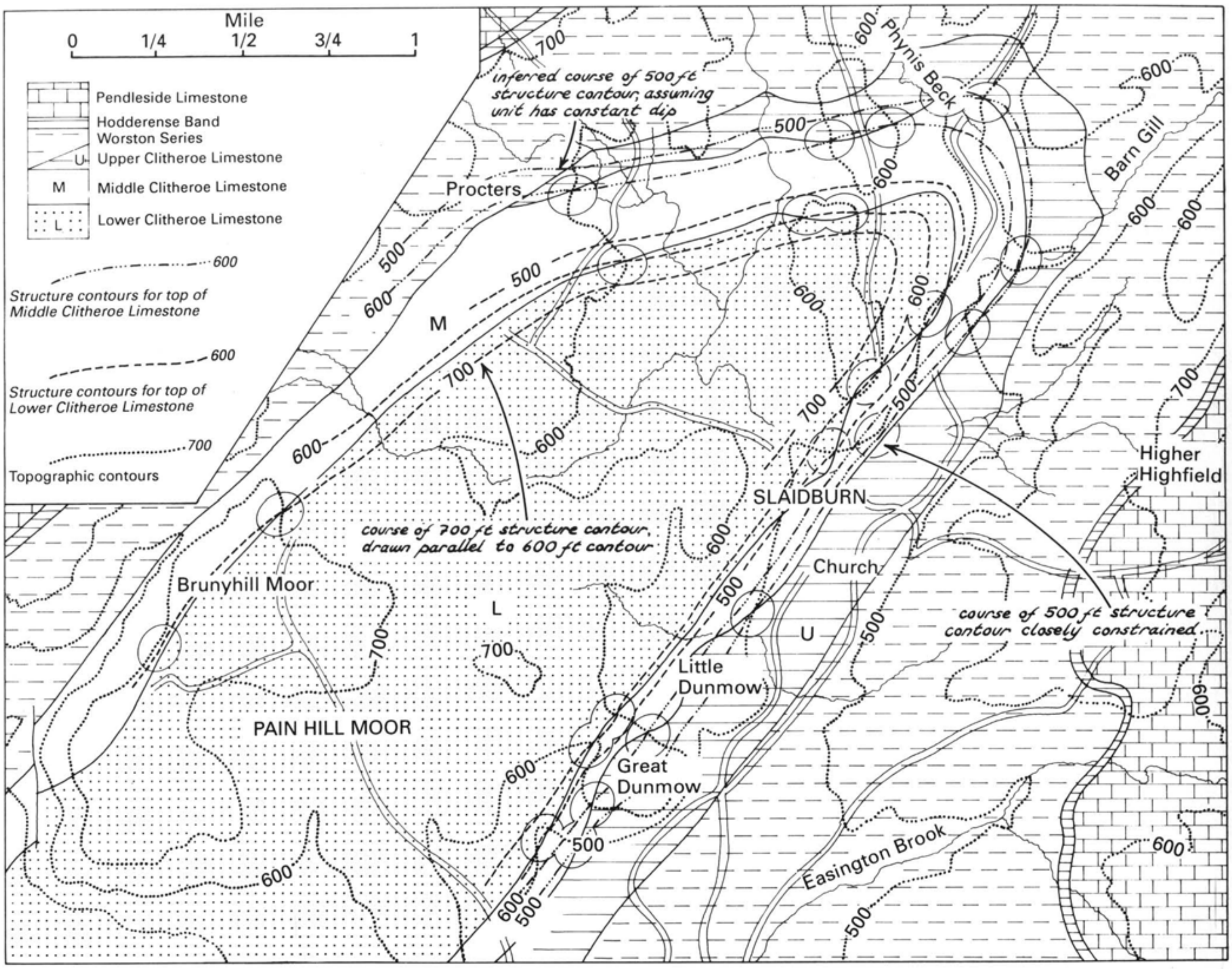
Fig. 3.6 Constructing structure contours from topography and outcrop. (a) Portion of a hypothetical geological map, showing topographic contours (dotted) and the outcrop of a sandstone unit. The top of the sandstone is to be contoured. (b) Preliminary steps. Reference to the stratigraphic sequence shown in the key enables the *top* of the sandstone to be located on the map. Circles indicate where the altitude of the top of unit is known, from intersections with topographic contours: the structure contours will pass through these circles. Consider the circle at X. At first it may seem that there are two possible routes for the 200 m structure contour to pass through the outcrop/200 m topographic contour intersection, as illustrated in (c) and (d). However, the route shown in (c) is not compatible with the map information, and only the route shown in (d) can be correct. (e) shows the 200, 300 and 400 m structure contours completed from the map information.

It may seem at first that there are several courses the structure contour could take through the point of known altitude (e.g. see Fig. 3.6b). However, only one of them will correspond with the actual outcrop that is shown on the map (Fig. 3.6d). For example, if the structure contour (drawn for the *top* of a unit) of a certain altitude crosses an intersection into ground of a lower altitude, then the formation that is being contoured will be outcropping there. On the other hand, if the same structure contour enters ground of higher altitude, then the outcrop there will be of material stratigraphically above the contoured formation.

The structure contour of a surface can cross a topographic contour of the same altitude only at a point where that surface outcrops. There is nothing wrong with it crossing topographic contours of higher altitudes, provided the surface at those places is buried. Conversely, it can cross topographic contours of lower altitudes, provided the map shows the surface being contoured to have been eroded away at those points.

Another help in drawing the course of a structure contour is to sketch in lightly some interpolated intermediate altitudes to obtain more control points. In most cases the structure contour will curve smoothly; if it makes violent twists it is likely to be wrong, or there has been faulting of the rocks. Experience counts a lot in drawing satisfactory structure contours and there is usually a fair amount of trial and error involved.

When the tentative structure contour seems to be obeying all the topographic and outcrop information in the starting area, it can be firmed up. Further structure contours in that vicinity can then be added, using the same



inferred course of 500 ft structure contour, assuming unit has constant dip

course of 700 ft structure contour, drawn parallel to 600 ft contour

course of 500 ft structure contour closely constrained

Fig. 3.7 Deriving structure contours from outcrop and topographic contours: a worked example, Slaidburn, Yorkshire. The ellipses enclose areas of information particularly useful in drawing the structure contours. With the contour patterns established, additional subsurface contours, say 400, 300 and 200 ft, could be added to allow subsurface predictions. Geological map based on Parkinson by permission of the Geological Society, on 'The Carboniferous succession in the Slaidburn district, Yorkshire', D. P. Parkinson, *Quart. J. Geol. Soc. London*, **92**, p. 294–331.

methods. Adjacent structure contours tend to be parallel, so that once one is drawn with confidence, it serves as a guide for the nearby ones. They are likely to be evenly spaced. Structure contours can touch each other only where the surface is vertical. These latter guides take priority over any interpolated points, which, after all, are only hypothetical. Developing several adjacent contours together usually gives better results than completing each line in turn. There is normally little point in adding structure contours of *higher* altitude than the present-day land surface, that is, representing where the contoured surface used to be before erosion. On the other hand, adding *subsurface* contours is of immense practical use, as mentioned earlier, in predicting the underground location of materials.

It is usually easiest to work progessively outwards from the starting area, but with some maps it is necessary to sketch the structure contours for several separated areas where there is good topographic control, and then to extrapolate between them. A look at the outcrop patterns on the map should give you some idea of the form of the rocks (section 2.3) and therefore the kind of overall shape the structure contours are likely to have. With practice you will develop your own way of tackling these constructions.

Figure 3.7 shows a worked example of structure contours derived from the intersection of outcrops and topography on a real geological map. Some explanatory comments are added. The important thing when drawing stucture contours is not to try and apply a series of memorised rules, but to *understand* the procedure. Always

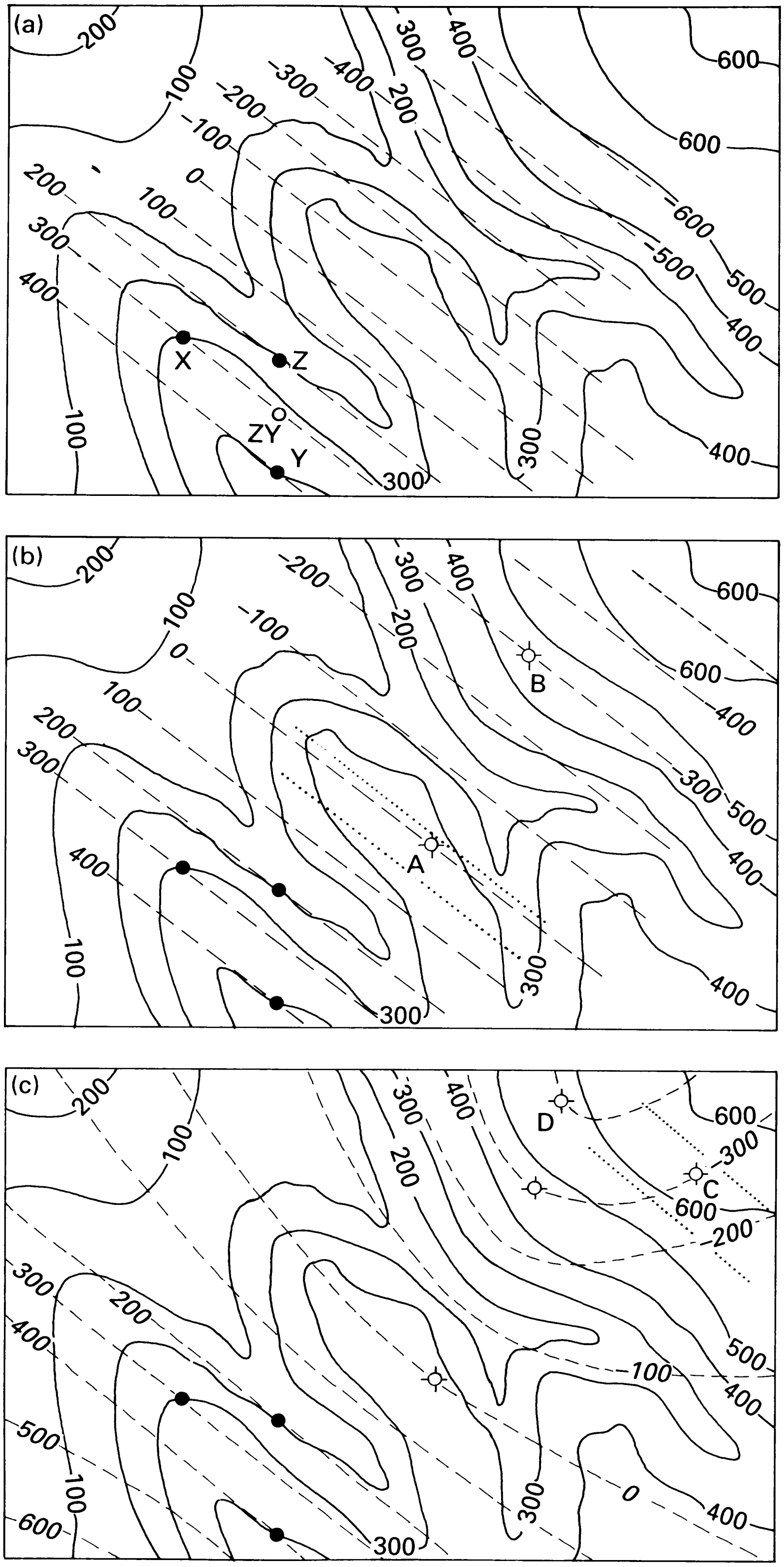


Fig. 3.8 An example of the use of borehole/well information to constrain the routes of structure contours drawn from topography. (a) Topographic contours (solid lines) and known outcrops of coal seam at X, Y and Z (solid black circles). At location ZY, halfway between Z (200 m) and Y (400 m), altitude of seam is presumably 300 m, enabling 300 m structure contour to be drawn through ZY and X. Parallel to this, 400 m structure contour is drawn through Y and 200 m structure contour through Z. Additional structure contours are equidistant, assuming uniform dip of the seam. (b) Borehole at A encounters coal seam not at the 80 m predicted from (a) (0 and −100 m structure contours of (a) shown as dotted lines), but at 0 m. This suggests dip increases north-eastwards; structure contours in (b), with increased spacing, reflect this new information. Borehole at B confirms seam at −300 m, as predicted. Structure contours of (b) are best interpretation of information from three outcrops and two boreholes. (c) Further borehole at C fails to encounter seam at −460 m as predicted from (b). (−400 and −500 m structure contours of (b) shown in dotted lines), but at −300 m. This could indicate a reversal of dip direction in the north-east of the area (i.e. seam dips south-west), in which case borehold D should encounter seam at about −320 m. However, seam at D is met at −400 m, suggesting that structure contours are not parallel, leading to the refined interpretation shown in (c).

try to visualise in three dimensions what you are doing. Working geologists do not spend vast amounts of time carrying out these constructions, especially in these days of assistance from computers, but an understanding of how the methods work is paramount.

3.7 Structure contours from topography and boreholes

Deriving structure contours from outcrop and topography is useful in near-surface operations, but the reliability of

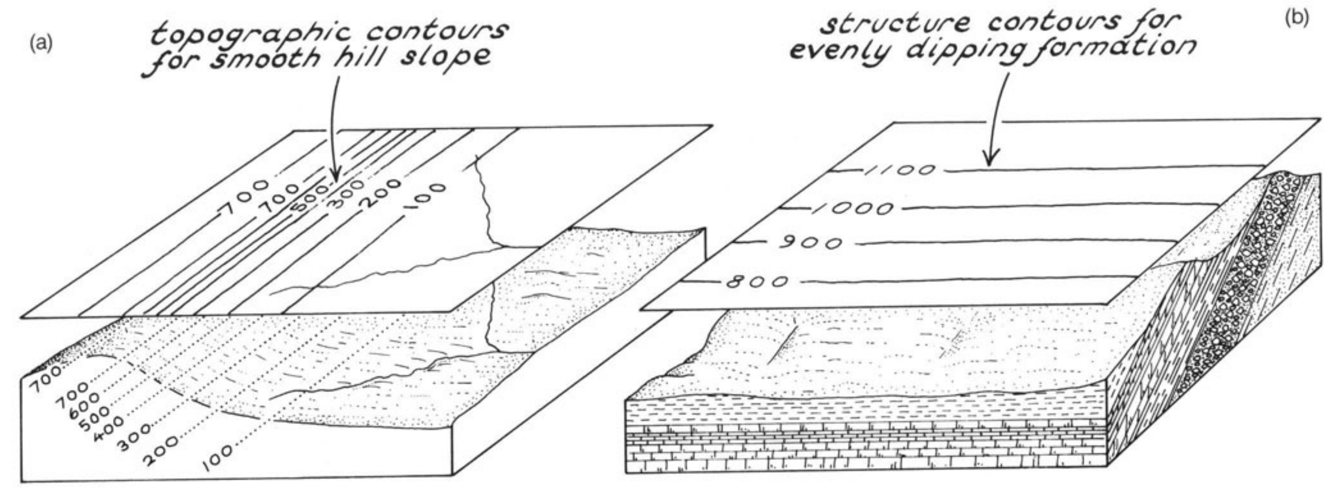


Fig. 3.9 The significance of straight structure contours (strike lines). (a) Straight topographic contours resulting from smooth hillslope with consistent direction. The varying gradient is represented by the spacing of the contours. (b) Straight structure contours representing a smooth geological surface; the even spacing reflects a uniform angle of dip.

underground predictions falls off as increasing extrapolation becomes necessary. It may become too approximate for commercial work on more deeply buried rocks. Then it becomes necessary to supplement the map information with some direct underground data. Drilling is expensive, but a carefully sited borehole or two can greatly constrain where the structure contours can be drawn. Figure 3.8 gives an example. Map 5 provides an exercise using outcrop and borehole information in conjunction.

3.8 Straight structure contours

Structure contours are exactly the same as topographic contours except that they represent some underground surface. They can, however, look a bit different. Figure 3.9a shows the topographic contours for some hypothetical smooth hill slope of fairly even gradient. The topographic contours are straight and evenly spaced, merely becoming closer where the gradient is steeper. Rarely are topographic contours actually like this on maps because natural hill slopes usually have various irregularities due to erosion. Bedding surfaces, however, can have this appearance on large-scale maps if the inclined plane is smooth and non-undulating (Fig. 3.9b). Here, the structure contours will appear as straight lines. They are, however, unlikely to be dead straight. You should not construct contours with a ruler; natural planes are not that smooth!

Straight structure contours are sometimes referred to as *strike lines*. This is because structure contours everywhere parallel the strike of the surface they are representing, which is conspicuously constant in direction if the lines are straight. The strike direction is therefore readily visualised and measured from them. Knowledge of the strike direction is essential in assessing the orientation of geological surfaces. The idea of strike and dip was introduced in section 2.3.1. but we now need to look more closely at this much used geological concept.

3.9 Summary of chapter

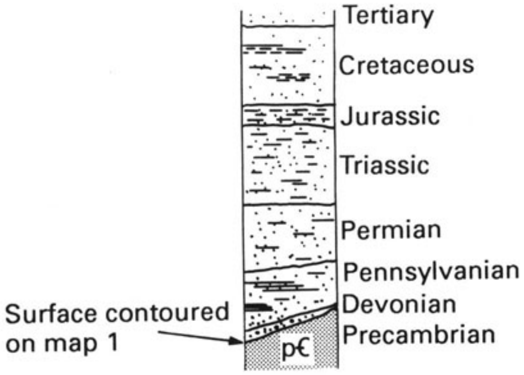
1. Structure contours are similar to topographic contours, but represent some underground surface such as the boundary of a rock unit rather than the land surface.
2. They depict in map view the position and form of the underground surface, and are therefore a highly useful construction.
3. They can be constructed from borehole/well information by interpolating the elevations of the surface between the holes.
4. Structure contours for outcropping surfaces can be constructed from the topographic elevations at which they outcrop.
5. The drawing of structure contours from outcrop elevations is more closely controlled if there is borehole information in addition.
6. Structure contours for smooth, uniformly-inclined surfaces are straight, and are also called strike-lines.

3.10 Selected further reading

Badgley, P. C. (1959). *Structural Methods for the Exploration Geologist*, New York, Harper and Brothers.
(Chapter 4 of this excellent, advanced book is about structure contour maps. It includes a list of properties of structure contours and constructing hints.)

Ragan, D. M. (1985). *Structural Geology. An introduction to geometrical techniques*, 3rd edn, New York, Wiley.
(Chapter 18 is a brief treatment of structure contours.)

MAP 1 Raton, New Mexico, USA



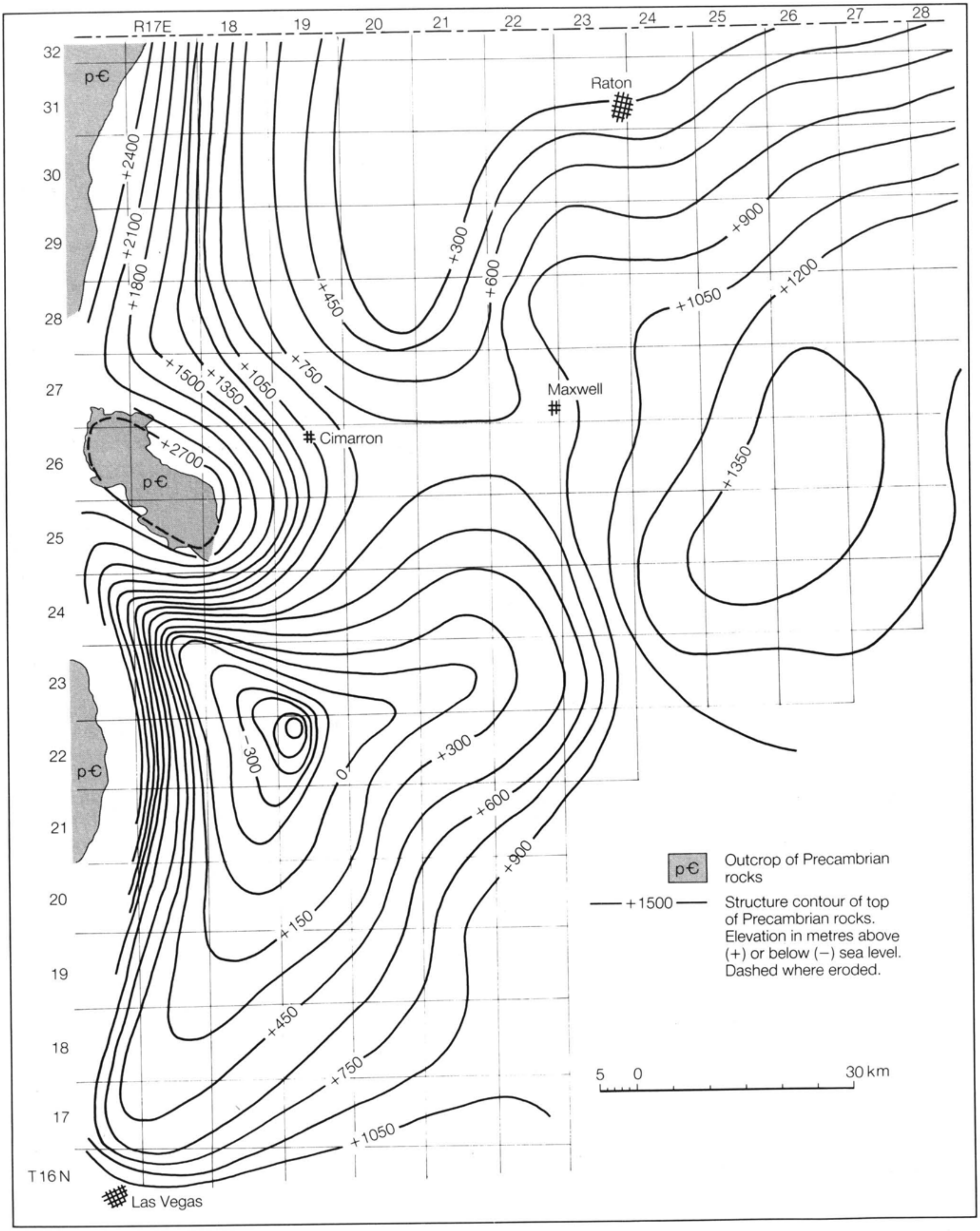
In northeastern New Mexico, between the towns of Las Vegas and Raton, is a thick sequence of Palaeozoic and Mesozoic clastic sedimentary rocks. Gas has been extracted from some of the Cretaceous rocks. In fact, there are signs that hydrocarbons have been widely generated in the area, but suitable traps have proved elusive. In the search for oil and gas traps, numerous structure contour maps have been constructed for various stratigraphic horizons.

It turns out that the overall control on the form of the sedimentary basin is the Precambrian basement. On its surface the sedimentary pile accumulated. The form of this surface is depicted in the structure contour map opposite, reproduced with slight modification from Woodward (1984), by permission of the American Association of Petroleum Geologists.

Where in the area is the thickest accumulation of sediments likely to be? If the present-day land surface at that site is 2000 m above sea-level, how thick are the sediments there? Describe in words the form of the Precambrian basement in the vicinity of that site.

Away from the structure just discussed, where is the next thickest sedimentary accumulation likely to be? How does the structure here differ from that described above? What kind of structure separates the two areas? Describe its orientation.

Where in the map area is the highest point on the Precambrian surface? Where does it show the steepest gradient? Where is it least steep?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+1050
+1200
+1350
+2700
−300
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+300
+600
+900
+150
+450
+750
+1050
p€
Outcrop of Precambrian rocks
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Structure contour of top of Precambrian rocks. Elevation in metres above (+) or below (−) sea level. Dashed where eroded.
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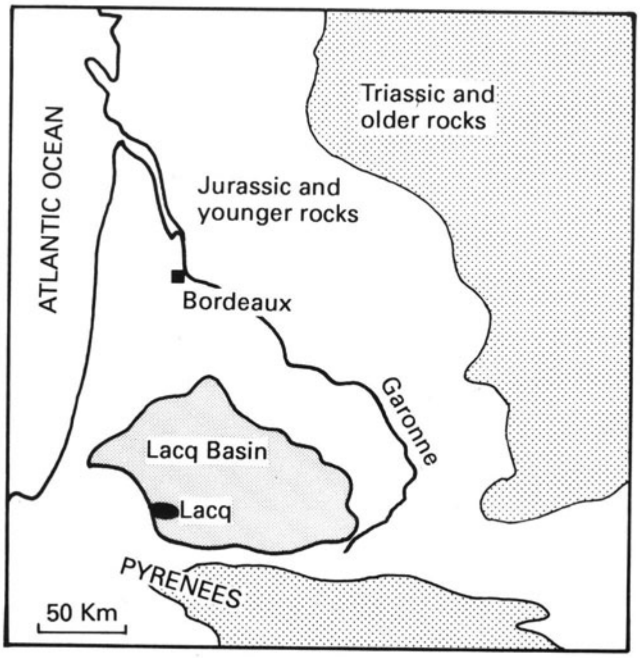
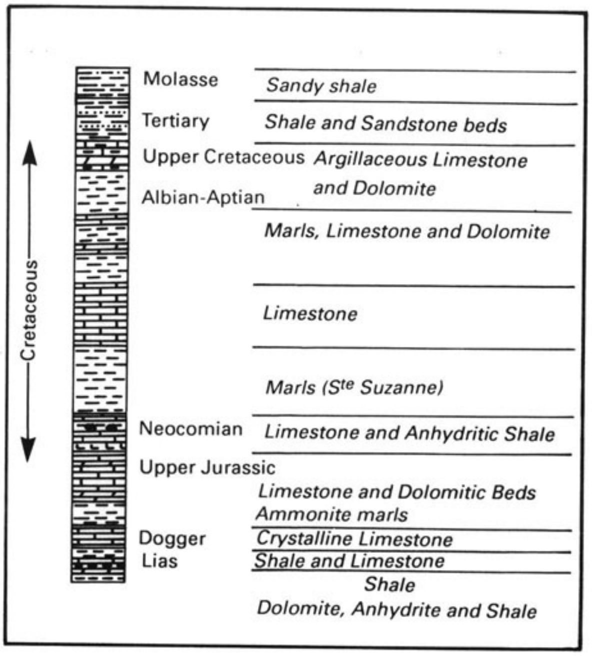
30 km

MAP 2 Lacq gas field, Aquitaine, France





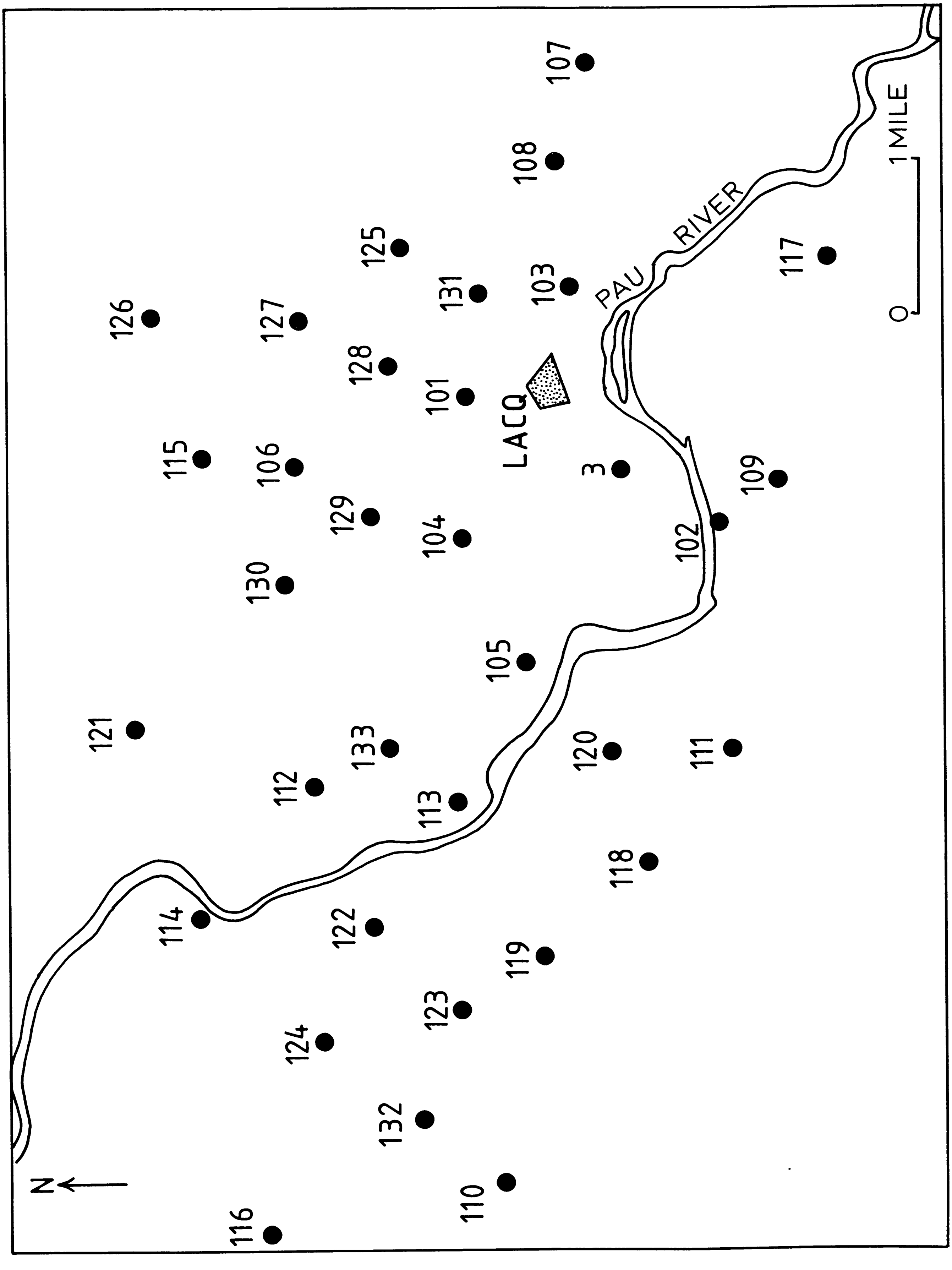
During the decade 1950–60, extensive drilling defined what was to become France's largest gas field. On the map opposite, slightly modified from Winnock and Pontalier (1970), by permission of the American Association of Petroleum Geologists, the locations of some of the wells are shown. The table opposite gives the depth at which each well encountered the top of the Neocomian rocks (a division in the lower Cretaceous), within which gas is trapped.

From these data draw a structure contour map of the upper surface of the Neocomian. Describe in words the form of the Lacq structure. Sketch a NE–SW cross-section, say through wells 118 and 126, to illustrate the structure.

Lacq gas field, Aquitaine: well depths.

Well number	*Depth**	*Well number*	*Depth**
3	11 070	117	14 420
101	11 250	118	11 960
102	12 300	119	11 790
103	11 390	120	11 040
104	10 730	121	13 150
105	10 300	122	11 590
106	12 070	123	12 200
107	13 010	124	12 640
108	12 360	125	12 490
109	14 300	126	14 000
110	13 880	127	12 740
111	12 950	128	11 810
112	11 540	129	11 370
113	10 500	130	11 790
114	12 850	131	11 690
115	12 950	132	12 940
116	13 460	133	10 680

* Depth quoted is to top Neocomian, in feet below sea-level.


LACQ
PAU RIVER
0
1 MILE
N
3
101
102
103
104
105
106
107
108
109
110
111
112
113
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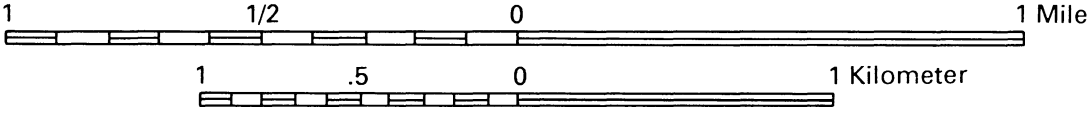
128
129
130
131
132
133

MAP 3 Bear Hole, Montana, USA

Ql		Quaternary
Mmt Mml	Lower Mississippian	Mississippian
Dtj		Devonian
Ob	Upper Ordovician	Ordovician
€g	Middle and Upper Cambrian	Cambrian
p€		Precambrian

Strike and dip of beds based on photogrammetric methods

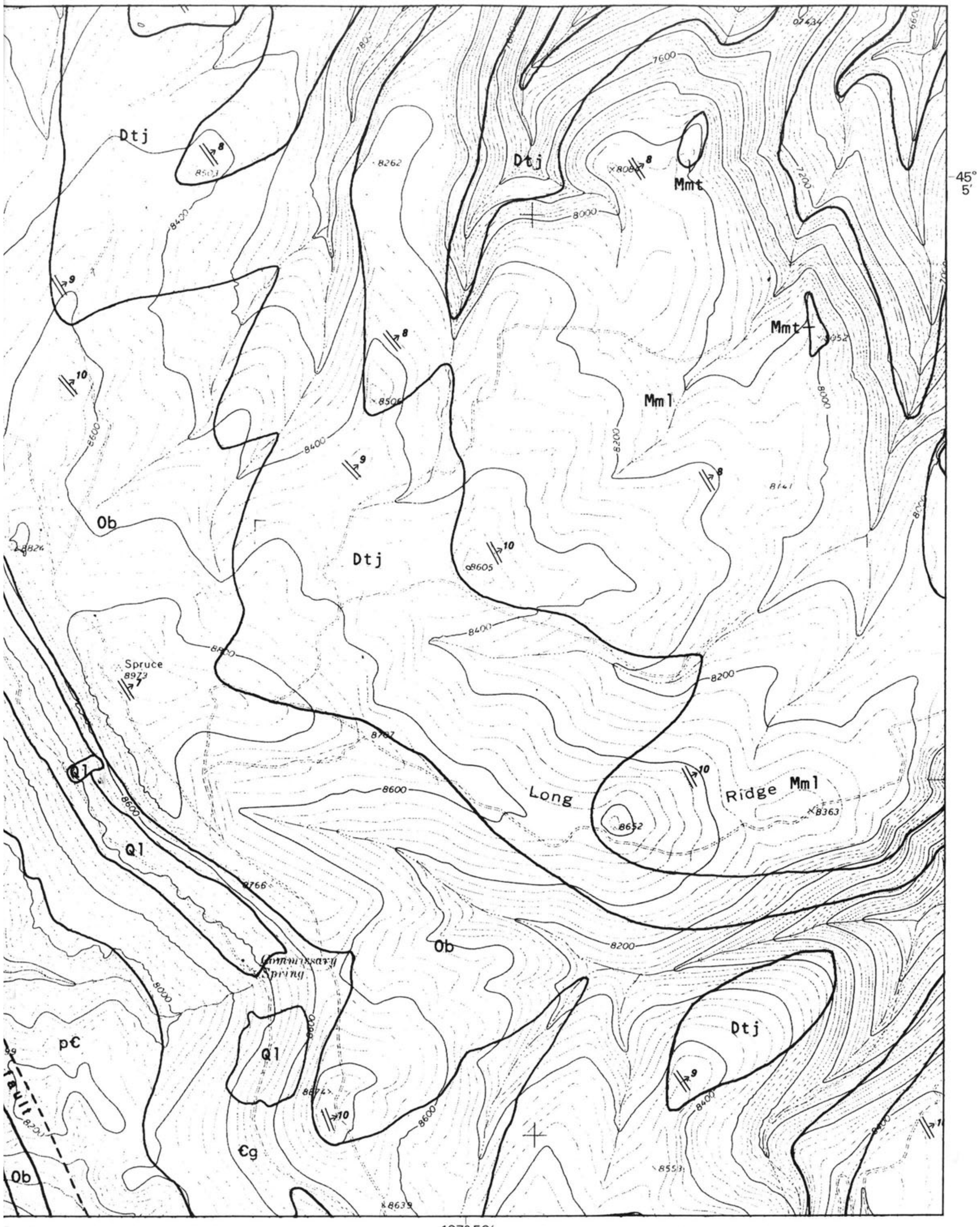
Scale 1:24 000



The map opposite is of an area in south-central Montana, in the Big Horn Mountains. The land is part of the Crow Indian Reservation. The geology also appears, in very simplified form, on Plate 2 (note the values of latitude and longitude). The map is part of the USGS 1:24 000 Preliminary Geological Map of the Bear Hole Quadrangle, Map MF-1885, reproduced by permission of the USGS. It was produced using a combination of field reconnaissance and air photo interpretation, together with a computer-assisted method of determining the strike and dip of units from the air photos. The technique was feasible because the units are uniformly dipping and of reasonably consistent thickness. The formations in the area range in age from Precambrian to Mississippian (Lower Carboniferous), as indicated on the above key.

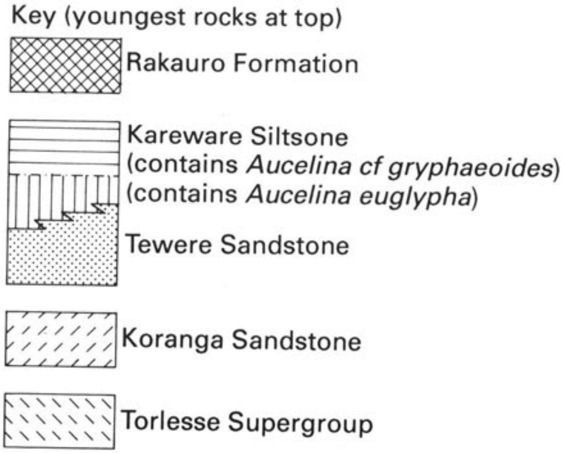
Identify the Upper Devonian by adding colour to its outcrop. Locate its top and its base. Draw structure contours, say the 8200, 8400, and 8600 ft values, for the top and bottom surfaces of the Upper Devonian. Comment on the form and spacing of the structure contours, and hence the form of the Upper Devonian.

The formations appearing in the northeast corner of the area are unlabelled. Deduce what they should be.



Dtj
8503
8
8262
Dtj
8
8088
Mmt
7600
7434
7200
8000
8400
9
Mmt
8952
8
8506
10
Mml
8200
8000
8400
9
8
8141
Ob
8826
Dtj
10
8605
8400
8800
Spruce
8973
7
8200
8707
Ql
8600
Long
Ridge
Mml
10
8652
8363
8600
Ql
8766
Ob
8200
Commissary Spring
8000
pЄ
Ql
8200
Dtj
9
8400
8674
10
8600
Fault
Єg
8553
8400
Ob
8639
45°
5′
107° 50′

MAP 4 Maccoyella Ridge, Koranga, New Zealand



The facing map is based on part of the New Zealand Geological Survey PTS Sheet N87/9, N88/7: Geology of Koranga, Raukumara Peninsula, by permission of the New Zealand Geological Survey. It is enlarged here from the 1 : 15 840 (four inches to a mile) of the original to approximately 1 : 10 000. The grid reference numbers can be used in an analogous way to the UK National Grid.

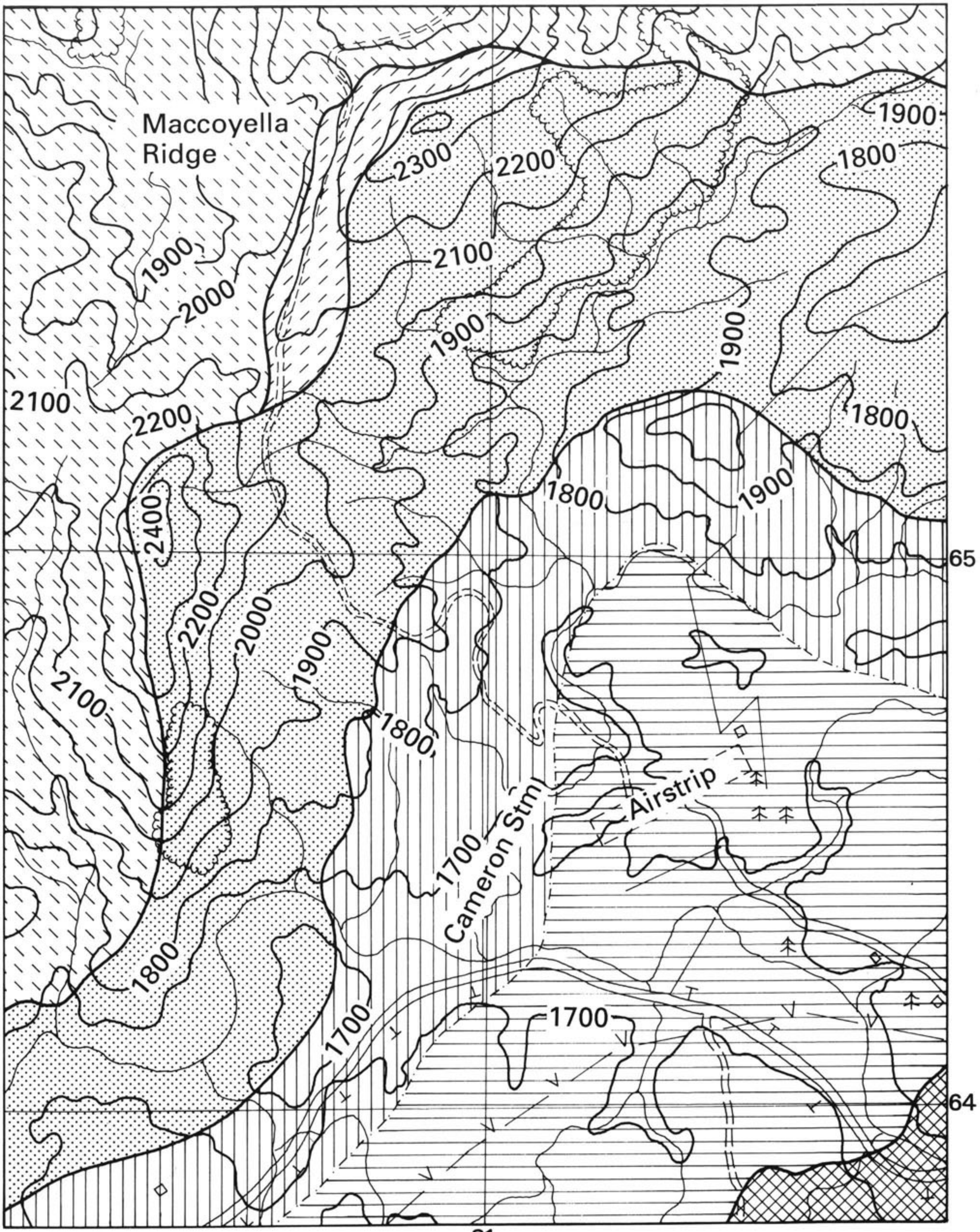
The map shows a sequence of sedimentary rocks of Jurassic–Cretaceous age. There is some variation in thickness, shown particularly by the Koranga sandstone, which in some places is absent altogether. Also, the units are slightly folded, so that structure contours will tend to curve, and their spacing may vary, reflecting differing amounts of inclination.

From the age relations given in the key, in what overall direction are the units dipping?

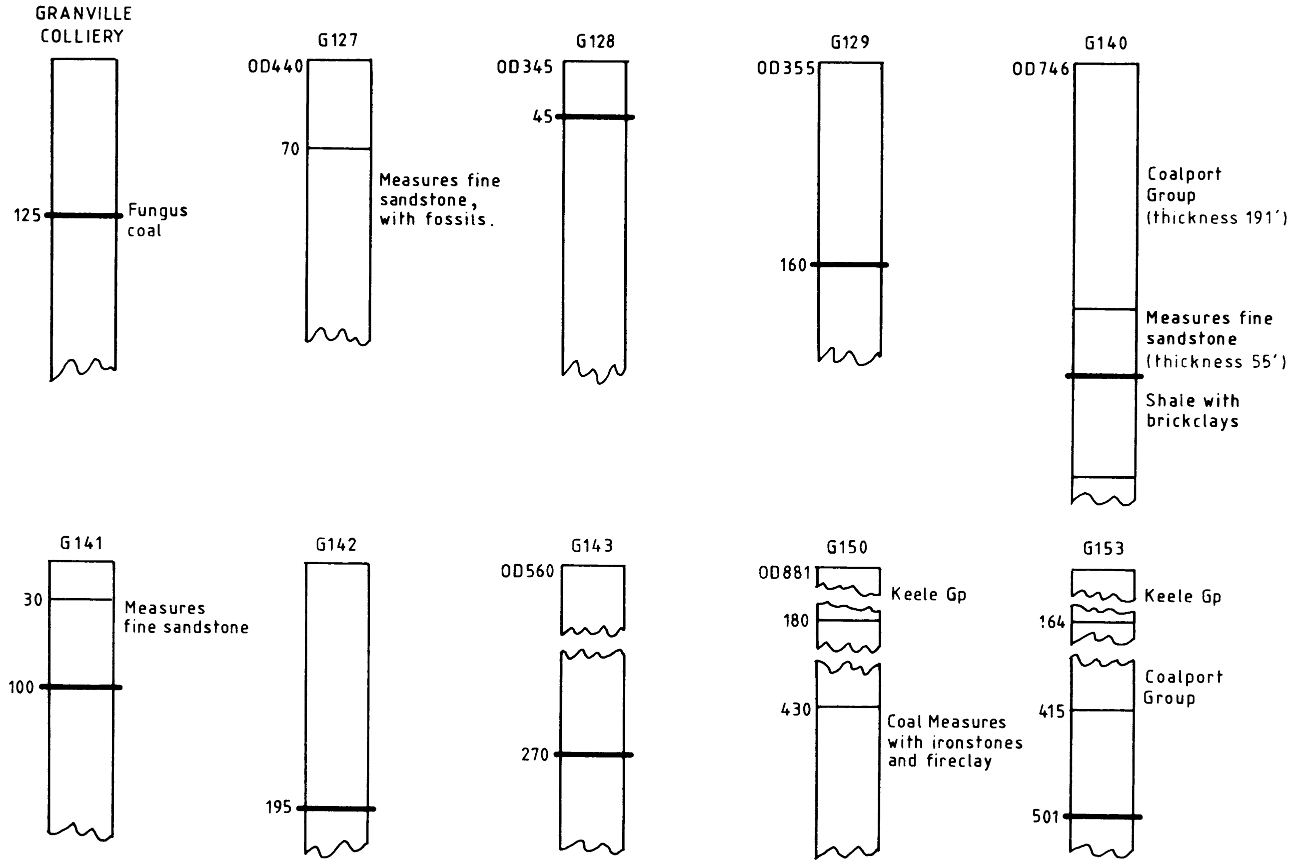
On the map, is the top surface or the base of the Te Were sandstone further towards the southeast? Carefully draw structure contours for the base of the Te Were sandstone.

Describe in words the form of this surface.

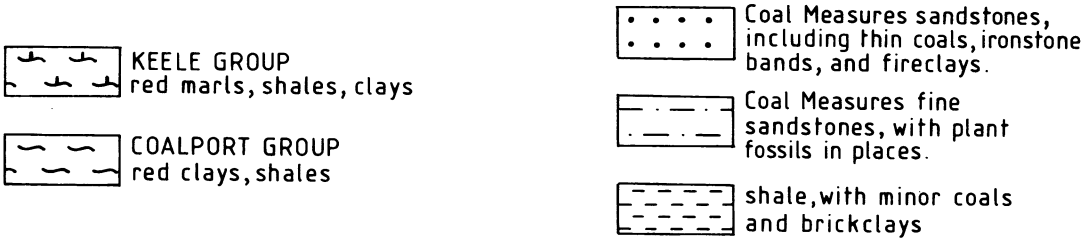
Assuming all the other units dip by the same amount as the Te Were base, sketch a cross-section across the area to show the overall geological structure.


Maccoyella Ridge
1900
1800
2300
2200
2100
1900
2000
2100
1900
1900
1800
2200
1800
1900
2400
65
2200
2000
1900
2100
1800
Airstrip
Cameron Stm
1700
1800
1700
1700
64
81

MAP 5 Coalbrookdale Coalfield, Shropshire, England



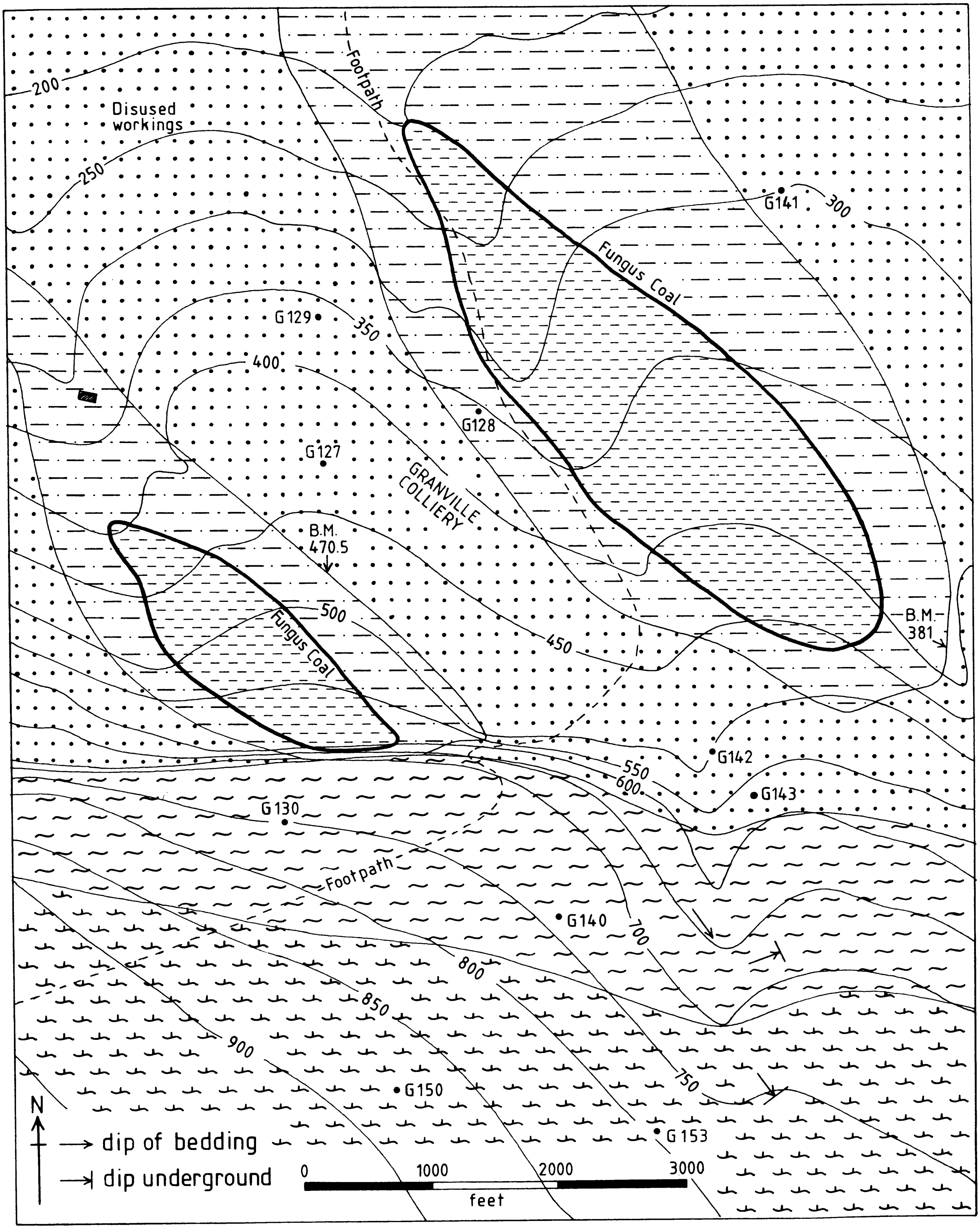
depths from surface given in feet



The Coalbrookdale Coalfield lies between Shrewsbury and Wolverhampton. It is small, but because of the nearby ironstone, is one of the places where the Industrial Revolution began. Like almost all other UK coalfields, the rocks are of Carboniferous age. Locate it on the part of the Ten Mile map reproduced here as Plate 1. What is the oldest unit that the coal-bearing rocks (Lower Westphalian) are in contact with?

Opposite is a map of the kind of geology found in the Granville Colliery area. What is the overall structure of the Fungus Coal in this area?

A new mine-shaft is being constructed in the area where borehole G130 has been sunk. Make a vertical column (like those in the key) of what you predict this borehole should contain. In particular, state the depth at which you predict the Fungus Coal will be reached. (Note that all these problems are best tackled by first drawing structure contours for the Fungus Coal. This is done most accurately by combining the topographic and the borehole information on its elevations.)


200
Disused workings
250
Footpath
G141
300
Fungus Coal
G129
350
400
G128
G127
GRANVILLE COLLIERY
B.M. 470.5
500
Fungus Coal
450
B.M. 381
G142
550
600
G143
G130
Footpath
G140
700
800
850
900
750
G150
G153
N
→ dip of bedding
→| dip underground
0
1000
2000
3000
feet