PRIMARY SCHOOL PUPILS' PERCEPTIONS OF CONTOUR PATTERNS

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ABSTRACT

The aims of the research are to investigate the ways in which primary school children perceive common contour patterns and to identify some of the problems which they encounter in learning the concept of contours. Research into children's understanding of maps carried out by geographers and psychologists is reviewed. The place of contour maps in the school curriculum is examined and methods of teaching the concept of contours are described. A class of children in their final year of primary education were taught the concept of contours by building a relief model from a contour map. In the first stage of the research the pupils were tested individually on their understanding of heights and slopes, and were asked to match contour patterns with cardboard layer models. In the second stage of the research they were again tested on their understanding of heights and slopes using a new map, and were asked to match contour patterns on the map with painted plywood and plaster relief models. The questions and answers were tape recorded and the transcripts were analysed to provide both quantitative and qualitative data. It is suggested that errors made by the pupils were perceptual as well as conceptual in nature. The implications for teaching contours in the national curriculum are discussed and attention is drawn to the potential benefits of collaborative research between geographers and psychologists.

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INTRODUCTION

A number of years ago I carried out research into some of the problems in reading and interpreting Ordnance Survey maps encountered by pupils in their final year of secondary education (Boardman and Towner, 1979, 1980; Boardman, 1983). I became particularly interested in the errors which pupils made in answering questions on contour patterns. I subsequently undertook further research using a simpler contour map to study the mistakes made by pupils in their first and third years of secondary education (Boardman, 1982, 1989).

When the national curriculum was introduced in 1991, relief maps were included in the geography Order approved by Parliament. The statement of attainment that pupils should be able to 'interpret relief maps' (DES, 1991:4) was categorised at level 5, which placed it at the interface between key stages 2 and 3, and thus at the boundary between the primary and secondary phases of education. This brief statement encompassed some of the most complex ideas relating to maps, but the examples which accompanied the statement indicated a fairly basic level of understanding: pupils should be able to 'read heights and identify slopes, hill tops and valley bottoms from contour maps' (DES, 1991:4).

The research reported in this thesis was largely stimulated by this statement of attainment, not least because the age at which pupils should be taught the concept has always been regarded as problematic. Specifically, the aims of the research are to investigate the ways in which primary school children perceive common contour patterns and to identify some of the problems which they encounter in learning the concept of contours. Whilst the thesis continues my exploration of the ways in which pupils read contour maps, the research differs from my previous studies in several respects.

Firstly, my earlier research was carried out by administering written tests to fairly large numbers of pupils in different schools, scoring their answers to the questions, and analysing the scores. This identified some of the mistakes, but did not explain why they were being made. The present research was undertaken by asking questions individually to a small number of pupils and setting tasks not only on contour maps but also on specially constructed three-dimensional models. It was hoped that this procedure would permit greater insights into the pupils' reasoning, especially as their answers could, where appropriate, be followed up with supplementary questions.

Secondly, my previous studies were undertaken with pupils of secondary school age, but the present research was carried out with children of upper primary school age. The justification for this was that the statutory Order for geography in the national curriculum placed relief maps and contours at the interface between the primary and secondary phases of education. It was considered instructive, therefore, to investigate the feasibility of teaching the concept of contours to children in their final year of primary education.

Thirdly, because my earlier research was carried out by administering written tests to pupils in different schools, it was not possible to take account either of the methods of teaching the concept which the teachers had used, or of the amount of practice which the pupils had experienced in reading contour maps. In the present research, I was responsible for teaching the concept of contours to the children as well as for conducting the subsequent research into their understanding of the concept.

Fourthly, whereas my previous studies were designed from my background as a geographer, the present research draws not only on the geographical literature relating to contour maps but also on the psychological literature relating to children's understanding of spatial representations. By studying the literature and research methods of the second discipline I hoped to obtain greater insights into the ways in which children perceived contour patterns.

The amount of research which has been carried out into children's understanding of maps in general and contours in particular is surprisingly small, bearing in mind that geography has been taught in secondary schools since the beginning of the century. Accordingly the review of the literature in this thesis ranges widely through a variety of studies of children's map drawing and map reading abilities undertaken by geographers, and a number of studies of children's understanding of spatial representations carried out by psychologists. The methods used in the two disciplines have some striking differences.

Apart from research into the cognitive maps drawn by children, studies undertaken by geographers have tended to concentrate on tests of basic map skills taught in the school curriculum, such as those relating to location, direction, scale and symbolism, usually with a view to identifying the ages at which pupils are able to learn these skills. Geographers' research into children's map skills is reviewed in chapter 1, including my own previous research into secondary school pupils' understanding of contour maps.

There is a growing amount of published research into children's understanding of spatial representations carried out by psychologists, mainly because of extensive work done by a small number of researchers. Their research does, however, differ markedly from that undertaken by geographers. Typically it investigates the ability of young children to use a simple map or model to perform a spatial task, such as finding a specific location in a room or following a short route in the playground. Research carried out by psychologists is reviewed in chapter 2.

Reading contours is one of many map skills which children are taught, so in chapter 3 contours are set in the context of mapwork in the school curriculum. The place of relief maps in the geography national curriculum is described, and methods of teaching the concept of contours are outlined. The chapter concludes with an account of the pilot study which was undertaken to investigate the feasibilty of teaching contours to primary school children and to test their understanding of the concept.

The present research was carried out in two stages and the results are reported in chapters 4 and 5. In the first stage, the children were tested using the contour map from which they had built relief models. They were asked to imagine that they were walking along footpaths marked on the map, and to answer questions about height and slope at various points. They were then asked similar questions on an imaginary contour map which they had not previously seen. Their final task was to attempt to match different contour patterns with cardboard layer models.

The children's perceptions of contour patterns were explored further in the second stage of the research. A new contour map was drawn and sets of relief models were constructed from plywood and plaster. The children were asked further questions on height and slope, and they attempted to match specific contour patterns with the corresponding relief models.

The final chapter discusses the results of the research and speculates on possible reasons for the ways in which the pupils interpreted contour patterns. It is suggested that errors made by the pupils may have been perceptual as well as conceptual in nature. The implications of the research for teaching the concept of contours in the national curriculum, which was revised in 1995, are considered. Attention is drawn to the potential benefits of collaborative research between geographers and psychologists.

1. RESEARCH CARRIED OUT BY GEOGRAPHERS

This chapter begins with an outline of the characteristics of maps as spatial representations. There follows a review of research which geographers have carried out into the mapping skills of children at different ages. Studies of the performance of primary, middle and secondary school pupils on written tests of basic map reading skills are summarised. The chapter continues with an account of the evolution of contours as the standard means of depicting topography on maps and concludes with a summary of my previous research into secondary school pupils' understanding of contour maps.

Maps as spatial representations

A map has been defined in a variety of ways but the words 'representation', 'spatial phenomena' and 'earth's surface' commonly appear in definitions. In preparing an article entitled 'What is a map?' Vasiliev *et al* (1990) searched the literature for established definitions in dictionaries, textbooks and journal articles. The authors synthesised them into one general definition of a map: 'a representation of the earth's geographic surface'.

Any definition of a map has to be based on its essential quality of being a representation of objects in space. Yet the concept of space itself is not easy to define. 'Space in a park', 'space between towns', 'territorial space' and 'the space age' illustrate different uses of the word. Space is a concept which permits the structuring of relationships between objects, and between people and objects. Space is subjective and relative, depending on the way it is structured by the mind for a particular purpose. There is no objective or absolute space.

The difficulty of defining space is further complicated as far as a map is concerned because the map itself occupies space. Yet the space represented on a map is a scaled down version of reality. Space shown on a map usually refers to 'place', 'area', 'region' or 'environment'. The word 'place' refers simply to an undefined portion of space. 'Area' is a mathematical concept which is used in geography to refer to space of widely different orders of magnitude. 'Region' in its geographical sense refers to a large amount of space on the earth's surface. The word 'environment' sometimes refers to ecological relationships which are not necessarily spatial. Each of these different notions of space influences the type of map that is drawn.

A map shows information by means of words, numbers and symbols. Words are used to name places and important features. Numbers are used to show distances and heights as well as to identify grid lines. Symbols take the form of *points,* such as those indicating churches or railway stations on Ordnance Survey maps; *lines,* such as roads, rivers and contours; and *areas,* such as the shaded area indicating the land occupied by buildings in a town, or the land covered with woodland in a rural area. It will be apparent that this combination of words, numbers and symbols, often placed in close juxtaposition, makes the map a complex document.

As it is impossible to show all the features of a portion of the earth's surface on a map, certain kinds of transformation take place in making a map. This may be termed map generalisation, a full analysis of which has been provided by Keates (1982). It involves three processes: selection, omission and simplification.

Selection is necessary in the preparation of a map because only a limited number of features can be shown on it. Every map is selective in so far as it shows some features and leaves out others. A small scale physical map of a country in an atlas will show only the main highland areas and largest rivers. A medium scale topographical map, on the other hand, will show all variations in relief and tributaries of rivers. The amount of selection is thus determined by the scale of the map: the smaller the scale, and the more general the nature of the map, the greater is the degree of selection.

Selection of some features implies the *omission* of others. The shorter rivers and lower hills are omitted from a small scale atlas map. The smaller streams in a drainage basin will not be shown on a medium scale topographical map. Whether or not a particular feature is shown will depend on its relative importance, and this is a matter for the judgment of the map maker. Like selection, omission has a subjective element.

Simplification is also largely a function of the scale of the map. The outline of a country or the course of a river will have to be simplified on a small scale atlas map because of the width of the line used to portray it. On a medium scale topographical map, the course of the river will still be simplified by showing only the more prominent meanders.

Whilst selection, omission and simplification together reduce the amount of information communicated by the map, certain features shown on it may be highlighted by the opposite process of *exaggeration*. The width of a main road is nearly always exaggerated even on a medium scale map, thus displacing slightly from their true positions the features shown on each side of the road. Similarly the size of a building may be exaggerated by the use of a point symbol: for example, a church repesented by a circle surmounted by a cross takes up a proportionately larger area on the map than the actual building occupies on the ground. The selectivity of the map is thus reinforced by making some features more prominent than others. The process of exaggeration, by enlarging the apparent dimensions of features which would fall below resolution at map scale, is one of the most powerful elements in map structure (Keates, 1982).

It is important to distinguish clearly between *maps* and *plans*. The difference is essentially one of scale. Vasiliev *et al* (1990) note that in North America the word *plan* seems to be reserved for floor space inside buildings. Once outside, the appropriate word becomes *map*. In Europe, including Britain, on the other hand, the word *plan* is extended to include the street patterns of towns and cities. For areas beyond urban boundaries, the word *map* is used.

The term *large scale* refers to a representation which depicts a small area of the earth's surface, such as a street plan, whereas the term *small scale* refers to a representation which depicts a large area, such as a map of a country. Architects and surveyors always refer to their representations of buildings and floor spaces within them as plans. Representations drawn on scales up to 1:1,000 (1 centimetre to 10 metres) should be called plans, and scales up to 1:10,000 (1 centimetre to 100 metres) are used for street plans. The Ordnance Survey describes its products on the 1:1,250 and 1:2,500 scales (1 centimetre to 12.5 metres and 25 metres respectively) as *plans*, and those on the 1:10,000 and smaller scales as *maps*.

Another distinction between maps and plans is whether they show topography. Plans may contain spot heights but they do not show topography. Maps, on the other hand, show topography, usually by means of contour lines or layer tinting. When a map does not show topography, it is because it has been designed for a specific purpose, such as to show the names of streets in a town or the main roads linking towns. The Ordnance Survey does not show topography on its 1:1,250 and 1:2,500 scale *plans*, but does show contours on its *maps* on the 1:10,000 and all smaller scales.

It is also important to distinguish maps from models. A map is a two-dimensional repesentation of space, whereas a model is a three-dimensional representation. This is true no matter whether the model shows the layout of furniture in a room or the variations in relief in a landcape. Whilst maps and models are equally valid representations of space, they are essentially different because models show the third dimension of an environment.

Maps are used for a variety of purposes. They are probably most often used to find where a place is, i.e. *location,* a task which requires the use of coordinates. Another common purpose is to ascertain where one place is located in relation to another, i.e. *direction,* a task which assumes a knowledge of the points of the compass. The scale of a map is frequently used to determine how far one place is from another, i.e. to measure *distance,* a task which demands an ability to convert a measurement on the scale line of the map to the corresponding distance on the ground. Using a map for any purpose requires a knowledge of its *symbolism*, which involves reading the map key or legend. If information about topography is required, such as the height of the land, steepness of slope or types of landforms, reference is made to contours and spot heights.

Maps use points, lines and areas to indicate locations, directions and distances, and are organised in terms of horizontal and vertical coordinate systems. It should be recognised that mapping is essentially a form of symbolic processing (Millar, 1994). Although this is seldom made explicit, it is important because the map reader has to understand the meaning of the symbols and appreciate what they represent. Some symbols used to depict features on maps are quite arbitrary and their meaning is not necessarily obvious to the inexperienced map reader.

Children's cognitive maps

Maps in the *cartographic* sense outlined above should be distinguished from *cognitive* maps. The different meanings attached to the term 'cognitive map' by geographers and psychologists has led to confusion and ambiguity in its use. For psychologists a cognitive map is a mental construct which an individual uses to understand and know an environment. It is in effect a mental representation of spatial and environmental knowlege and exists only in the mind of an individual. Geographers, on the other hand, regard a cognitive map as one transferred from the mind of an individual to a piece of paper or some other recording medium. It is a freehand sketch map drawn by an individual to show the main features of a familiar environment.

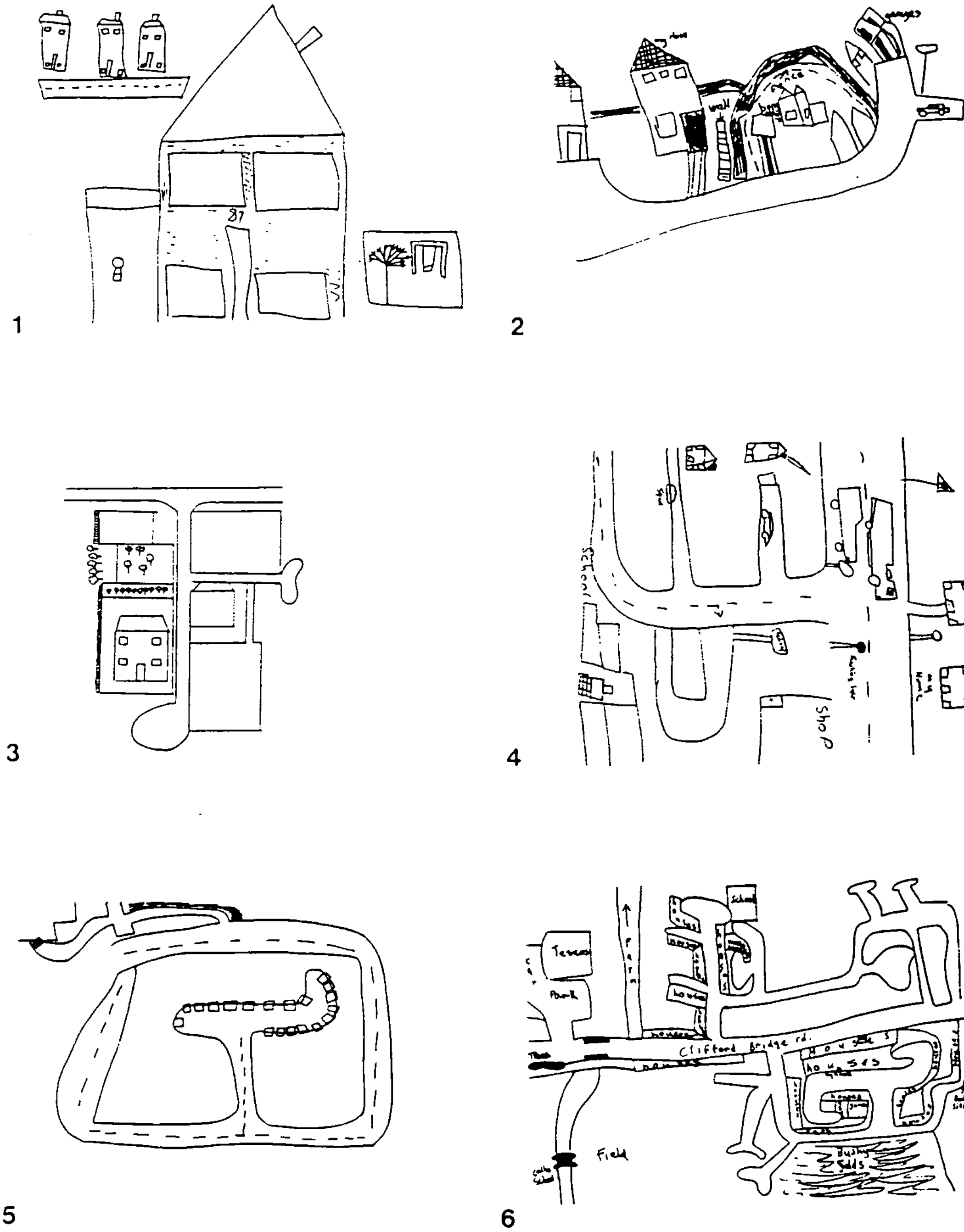
In a review of the literature on cognitive maps Kitchin (1994) draws attention to the inherent definitional problems associated with a concept which is used in different disciplines. He points out that much misunderstanding arises from the use of the word 'map' in the term 'cognitive map'. Kitchin argues that a cognitive map has no real connections with a cartographic map and is an unfortunate choice of term. He regards a cognitive map as just a hypothetical construct or a 'convenient fiction'.

Despite the ambiguity and confusion over the meaning and use of the term, geographers have assumed that the mental construct can be transferred from the mind of an individual to a visible form, usually by drawing it on a piece of paper. In this sense cognitive maps are drawn from memory and depend on the recall and reconstruction of an individual's experience of place. The maps depict a personal view of some part of a spatial environment which is familiar to the individuals who draw them. The resulting maps display considerable variety: some individuals draw quite complex maps which resemble cartographic maps, whilst others draw very simple plans (Gould and White, 1974).

The map drawing abilities of children have been studied by asking them to draw freehand maps of places with which they are familiar. The resulting maps depict a personal view of some part of the children's spatial environment, such as that around their home or school. The nature of these cognitive maps and the detail shown on them indicate the children's ability to represent a familiar environment on a piece of paper (Downs and Stea, 1977; Catling, 1978, 1979).

In one study Matthews (1984) asked all 172 children between the ages of 6 and 11 in a Coventry primary school to draw a map of the area around their home. The objectives of the study were specifically to examine whether gender influences children's awareness of place and their ability to represent space. The maps drawn by the children were classified according to three grades of mapping ability, each associated with a developing skill to produce a complete orthogonal transformation of space.

Grade I, pictorial and pictorial-verbal forms, were the simplest kinds of 'map'. Children simply drew a picture of their environment, sometimes adding labels. These were really embryonic maps, houses being shown in side elevation, as seen from street level. Children who drew these maps lacked the ability to transform a ground level view into an aerial one (Figure 1.1, maps 1,2).



Grades of mapping ability:

1)	Pictorial	Girl age 6
2)	Pictorial-verbal	Boy age 6
3)	Pictorial-plan	Girl age 9
4)	Pictorial-plan-verbal	Boy age 9
5)	Plan	Girl age 11
6)	Plan-verbal	Boy age 11

FIGURE 1.1. CHILDREN'S COGNITIVE MAPS

(Matthews 1984)

Grade II, pictorial-plan and pictorial-plan-verbal maps, represented an intermediate stage in map development, combining ground level and aerial perspectives. These maps displayed some elements of symbolisation, involving the selection of point, line and area signs to depict spatial phenomena, an essential aspect of drawing in plan form (Figure 1.1, maps 3,4).

Grade III, plan and plan-verbal maps, were the most highly developed and showed all features in plan form, sometimes in considerable detail over a large area. Children who drew maps of this kind were able to portray their environment in a manner which demonstrated a broad understanding of Euclidean relationships, symbolisation, scale and orientation (Figure 1.1, maps 5,6).

Matthews (1984) found a general trend, irrespective of age, for children to draw hybrid maps, combining pictorial and plan forms. Most of the younger children (aged 8 years or under) drew simple pictorial maps, whilst nearly all the older children (aged 10 years and over) drew maps in plan form. Boys appeared to acquire more rapidly than girls the ability to depict space in a structured and integrated manner. The maps drawn by boys were more complex in form and displayed a better understanding of spatial relationships. By the age of 11 most of the boys produced grade III maps, whereas most of the girls drew grade II maps combining pictorial and plan characteristics. Older boys frequently managed to produce integrated maps, revealing a good grasp of the relationships between different elements of the environment, whereas older girls rarely achieved this ability. Boys demonstrated a stronger understanding of local routes, enabling them to relate places to one another, and mentioned places further away from home than girls.

In a study of New England children aged 6-11 years Hart (1979) also found that boys' sketch maps of their home area were considerably better in spatial organisation than those of girls. Hart categorised the children's spatial activity according to three ranges of movement from their homes allowed by their parents: places where children were allowed to go without permission, with permission, and when accompanied by older children. In all three ranges of movement the limits of spatial range were larger for boys than for girls, and the difference in the extent of spatial range increased as the children grew older. The evidence from the children's sketch maps clearly showed that boys were less constrained in their movements than girls. Boys not only explored further during play but were also more likely to undertake activities such as running errands which took them further away from home. Girls were more often expected to help their mothers around the home and to look after younger children. Hart's research suggests that the effects of socialisation and gender-role differentiation may exert an influence on children's mapping ability.

Matthews (1986) used the same technique as Hart with children aged 6-11 years in a suburban Coventry primary school. He asked the children to draw a map of their home area and journey to school, and then interviewed them to determine their home range experiences. The home range of the younger boys and girls was similar, but from the age of about 8 years upwards boys enjoyed more freedom than girls, travelling increasingly greater distances as they grew older. Analysis of the children's free-recall maps showed that those drawn by boys were more accurate, richer in detail and more integrated in form than those drawn by girls of a similar age.

In a more recent study of maps drawn by children in a rural village in Kenya, Matthews (1995) found that children who were without formal training and with limited access to maps were able to draw relatively sophisticated place representations. He asked a sample of 40 children between the ages of 7 and 13 years to draw a map of their village and to describe their journey from home to school. All of the children were able to undertake this exercise, and most managed to draw more than lines linking two places. The majority of the children showed space as viewed in plan form, although most incorporated pictorial elements into their maps. Differences were again found in the maps drawn by boys and girls. Boys' maps drew attention to a wider amount of environmental detail and were more likely to show places beyond the bounds of parental sanctions. Girls' maps showed spaces immediately around the home compound, reflecting a well-defined social code which impaired their freedom and mobility.

Although free-recall sketch map drawing provides interesting information about the ability of children to represent their spatial environment on paper, it is important to remember that drawing ability may intervene between knowledge and its depiction. In other words, children may know far more about their spatial environment than they actually draw on paper. Drawing is a complex skill which involves knowledge of procedures as well as knowledge of the objects that are represented (Millar, 1994). The technique of sketch map drawing requires children to translate their spatial knowledge into a different format from that in which they experienced the space. It cannot be assumed that map drawing directly externalises children's spatial knowledge of their environment (Siegel *et al*, 1979).

For this reason Matthews (1985) investigated the way in which children were able to externalise about space when provided with stimuli in the form of a large-scale plan or vertical air photograph. He compared the way in which children aged 6 to 11 in four Coventry primary schools were able to represent their home area and journey to school by means of four different techniques, of a structured and unstructured kind: free-recall mapping (graphic unstructured), map interpretation (graphic structured), air photograph interpretation (iconic structured), and free verbal recall (verbal unstructured). Only one technique was used in each school, the numbers of children being 155, 172, 174 and 192 respectively.

The four techniques produced different results. Children provided much more information about their home area with the aid of a large-scale plan or air photograph than by means of free-recall mapping or free verbal recall. The visual prompts appeared to encourage children to scan randomly over the area around their homes and thus to produce more detail. For the journey to school task on the other hand, children provided more detail in free-recall mapping. The children were also able to note more than twice the amount of detail in the area around their homes than on the journey to school. This may be because children spend more time around their home and actively explore places during play and movement, whilst the journey to school covers a greater distance and is often a more passive and restricted experience.

Successful map drawing involves not only the ability to represent features of the environment symbolically, but also the capacity to arrange the elements spatially (Matthews, 1992). Children's cognitive maps should not be regarded as analogies of the real world but rather as 'metaphors' (Downs, 1981). Comparison of the map drawn by a child with a professionally prepared plan does not necessarily indicate the child's true spatial ability.

Pupils' basic map skills

Most of the research carried out by geographers into children's map skills has investigated their ability to read cartographic maps. Tests of symbolism, scale, direction and location were administered by Charlton (1975) to 105 children aged 8 to 13 in a primary and a middle school in Leeds. She found that whilst the children's understanding of all four concepts increased with age, definite stages could be detected in their understanding of scale and location. Both of these concepts involve Euclidean notions and, once they had been understood, the children seemed to be able to apply a similar level of understanding to most maps. The other two concepts, symbolism and direction, appeared to be much more dependent on instruction.

When the basic map skills of 140 pupils aged 11-12 in the first year of a mixed comprehensive school near Sheffield were tested by Salt (1971), direction and scale were found to be the two skills that were least well developed. Reversals formed one source of error in direction among some children. Most pupils were able to handle scale correctly when it simply involved computation, but when they had to compare scales the majority did not appear to have acquired a true undertanding of the concept. Salt's observations of the difficulties encountered by children in drawing plans is consistent with the conclusion of Piaget and Inhelder (1956) that comprehension of an abstract plan requires formal operational thought, and that a true understanding of maps is not achieved until the spatial concepts needed for abstract plan drawing have been acquired.

The map reading and map using abilities of children aged 5-9 years were tested by Walker (1980). He asked 100 children, consisting of 10 boys and 10 girls from each of the age groups 5 to 9, to attempt three tests which respectively required an understanding of scale, orientation and symbolisation, and a fourth test in which these were combined in a simple map using problem. Walker found that most children showed an understanding of symbols in using a map at the age of 6 years, whilst an understanding of scale and orientation in map use had been acquired by most children by the age of 8 years, when they were also able to complete the map using problem successfully. The performance of the children in these tasks indicates that map understanding emerges in an elementary form at an early age.

A study of young children's understanding of a plan view and the concept of scale was carried out by Gerber (1981) with 80 children aged 6 to 8 years in Brisbane, Australia. He tested their understanding of a plan view by asking them to represent on a piece of paper four separate objects in their classroom. Most children were able to draw plan views of objects which had simple geometrical shapes but not more complex ones. When asked to draw a cluster of objects in the classroom, however, the majority were unable to represent the observed arrangement accurately. In an experiment concerned with the concept of scale, Gerber showed the children a metre rule and asked them to estimate the length and breadth of their classroom. Nearly half of the children were able to do so with reasonable accuracy. Gerber then asked the children to estimate longer distances of over 100 metres but found that they were very poor at judging these. From this result Gerber concludes that such children have only limited understanding of scale and will not be able to estimate distances on a map. This conclusion is difficult to justify, however, because the process of estimating distance in a natural environment is different from that of using scale on a map. In any case older children and even adults would probably experience difficulty in estimating long distances with only a metre rule for reference.

Children's understanding of the concept of scale was tested by Towler and Nelson (1968) using a model of a toy farm on a board. They gave children aged 6-12 years a small board, one quarter of the size of the area of the model, and a set of symbol shapes representing the farm buildings. Each shape was provided in five sizes and the children were asked to choose the appropriate one-quarter scale symbol and place it on the small board. Children of all ages selected the correct quarter size symbols with some shapes, such as circles and ovals, but most children had difficulty in choosing the correct symbols with other shapes, such as rectangles. Only the oldest children selected all the correct symbols and from this Towler and Nelson concluded that children do not develop a concept of scale before the age of 10 or 11 years. This conclusion may not be justified, however, because the younger children did select some symbol shapes correctly. It would appear that the children's performance may have been influenced not only by their ability but also by the materials used in the experiment.

The abilities of children to generalise from a distribution on a map and to compare two separate distributions were investigated by Heamon (1973). He tested in several ways 80 children aged 8-14 in Abingdon. For example, they were shown a 1:10,560 (6 inches to 1 mile) map containing several villages, the houses in which were coloured red, situated in a discontinuous belt. Rivers were coloured blue, land over 200 feet brown, and woods green. The children were given a piece of paper with the shape of the map frame already drawn and asked to draw one shape to show where most of the houses were. Pupils aged 14 were better able to draw the outline of the built-up area than the younger children. In another test using the same map, the pupils were asked what they noticed about the position of nearly all of the woods. Heamon found that by the age of 12 about half of the children were able to perceive a relationship between the two generalised distributions, and that this ability had been acquired by nearly all pupils by the age of 14. Heamon claimed that his tests were devised to examine Piaget's idea of 'centration', the tendency for children to focus their attention on a limited number of stimuli. Piaget observed that this tendency decreased as children grew older and it is illustrated by the way in which younger children tend to look for micro-features rather than macro-features on a map.

An attempt to discover whether map work performance could be associated with certain psychological variables was made by Satterly (1964). He administered a battery of tests to 60 pupils aged 14-15 in a secondary modern school . The psychological tests were conceptual, spatial and perceptual, and the tests of map work performance covered such abilities as map drawing, recognition of conventional signs, and recognition of the contour representation of landforms, both discrete and as part of a complicated contour organisation. The pupils' scores on the two sets of tests showed a statistically significant correlation between the psychological variables measured and performance in map work. In other words, pupils who obtained high scores on the psychological tests tended to obtain high scores on the tests of map work performance. The analysis showed that the best single predictor of map work skill was provided by performance on a test of the perception of embedded shapes. Whilst this finding is interesting, however, it does not appear to have any practical application, nor does it offer an explanation for variations in ability. Satterly noted that many pupils who could recognise the contour representation of landforms when these were discrete had greater difficulty in recognising the same landforms when they were part of another more complex contour organisation. He concluded that many pupils had not acquired the ability to visualise solid reality from contour patterns by the time they left school.

The different methods and materials used in the research studies carried out by geographers means that it is not possible to draw general conclusions about the ages at which most children develop an understanding of various map concepts relating to location, direction, scale and symbolism. The studies have also tended to concentrate on group performance, such as the mean scores obtained by different age groups, and what children appear to be able or unable to do at specific ages. There has been little discussion of the strategies adopted by individual children in attempting to solve particular map tasks. The precise nature of the difficulties experienced by the unsuccessful children and the possible reasons for their errors have also received only limited attention.

Relief depiction on maps

The process of depicting relief on a topographical map involves the transformation of a three-dimensional surface (the land) on to a two-dimensional surface (a piece of paper). The problem which this presents has long been recognised by both geographers and cartographers. 'Delineation of the continuous three-dimensional form of the land has always been one of the most challenging problems in cartography' wrote Thrower (1972:78). 'Because of the relative importance to man of the minor landforms, their representation together with other data has been a great problem in large-scale mapping' observed Robinson and Sale (1984:368). 'The cartographer has had to prove himself pretty clever whenever the facts he had to show upon a flat surface were themselves about flat matters, merely two-dimensional. But in showing three-dimensional facts on a flat surface he displays his true ingenuity' declared Greenhood (1964:74).

The representation of topography on a piece of paper presents several problems which do not occur in the symbolisation of other elements of a map (Castner and Wheate, 1979). Relief varies continuously over the whole of the mapped surface and, except in perfectly flat areas, is not confined to part of it. As a result the depiction of relief may interfere with a map reader's attempts to read other elements of the map. Other map elements are mostly discrete and the reader can recognise and select them for attention. Relief, on the other hand, has to be shown over the whole of the map and thus contributes a considerable amount of 'visual noise' to the map.

Furthermore, topography can be mapped in different ways, for example, to show relative height as well as absolute height, and to the show the slope of the land as well as its shape. The main relief features shown on a map may be interpreted individually over a small area, or collectively over a more extensive area. The depiction of relief usually constitutes a major visual component of the map which enables the experienced map reader to build up an image of the landscape which is retained whilst reading and interpreting the map. The manner in which relief is depicted on a map, therefore, can affect the way in which the reader subsequently visualises the landscape. Less experienced map readers, however, may not be familiar with a method of depicting relief and its limitations, and accordingly may perceive and interpret the relief shown in a way which is quite different from that intended by the map maker.

The various methods of showing topography on maps at different times in history have been traced by Lynam (1953). He notes a gradual change in depicting hills from an elevation or profile view ('rather like cock's combs') in the thirteenth century, through an oblique or bird's eye view ('little rows of shady sugar loaves') in the fifteenth century, to the use of the plan view ('hairy caterpillars found crawling across maps') in the eighteenth century. Lynam observes that, with the development of map making, this shift in perspective was paralleled by the refinement of hill shading, from the arbitrary medieval practice of shading profile views, through the oblique shading of later bird's eye views, to the vertical shading of plan views.

Wood (1993) has made the interesting observation that the development of the way in which hills are shown in children's drawings parallels the sequence in the history of map making. Thus young children draw a picture of a generic 'anyhill' represented in side elevation as seen, egocentrically, by a human being at ground level. Older children draw either a version of 'anyhill' in side elevation or an abstraction based on its shadow-throwing properties. Hills are later shown from an oblique aerial viewpoint and are differentiated into classes, such as rolling or mountainous. Finally hills are drawn in plan form, as if seen from directly overhead and showing their individuality. The development of different viewpoints, from ground level to oblique and then vertical, reflects similar changes in the viewpoints used by children in their cognitive maps described and illustrated earlier in this chapter.

Hachuring developed as a means of showing hills and slopes during the eighteenth century. Hachures are parallel lines drawn in the direction of slope, the steepness being indicated by the thickness of the hachuring and the interval between the hachures. Numbered spot heights showed absolute height, and hachures showed relative height. Thus a hill with steep slopes was represented by a circular group of hachures with a spot height in the centre.

At the same time as hachuring was becoming increasingly refined, it was being gradually supplanted by a still more abstract convention, the contour. The earliest maps on which contours are found date from the middle of the eighteenth century, but it took most of the nineteenth century for the contour to become established as the favoured method of showing topography (Wood, 1993). The contour originated as a means of showing the depth of lakes and offshore waters. Soundings were made at selected points and underwater depths were recorded. The resulting scatter of points was then used to interpolate contour lines which helped the map reader to form a mental image of the undulations on the lake bed or sea floor. The interpretation of a series of point data produced a continuous submarine surface which provided information in a spatially continuous form.

A similar method was subsequently used to show the height of the land above sea level. Surveyors used theodolites to take spot height readings at specific points on the land and then drew contour lines by interpolation from the scatter of points. Contours are thus lines drawn on a map through all points which are at the same height above, or depth below, a chosen datum, usually sea level (Monkhouse and Wilkinson, 1952). This definition suggests that contour lines are drawn after measurements have been made at an infinite number of points, but in practice they are interpolated from selected on-site readings. Nowadays readings taken in the field are supplemented with information obtained from aerial photographs.

Unlike most other linear features on a map, such as rivers and roads, a contour does not represent a feature in the landscape. A contour, like a grid line, is a measured line with a value, but it does not exist in reality. Although contours do not themselves designate real features, however, they provide the means by which variations in topography can be detected. Just as grid lines are the means of locating on a map features in a two-dimensional field, so contours are the means of locating on a map features in a three-dimensional field. But, unlike grid lines, which are arbitrary reference systems, contours relate to real features.

The contour is now the standard method of showing relief on topographical maps. The largest scale Ordnance Survey map on which contours are drawn is the 1:10,000 (1cm to 100 metres). Contours are shown on all Ordnance Survey maps at smaller scales, the best known of which are the Pathfinder maps at the 1:25,000 scale (4cm to 1km) and the Landranger maps at the 1:50,000 scale (2cm to 1km). Contours are drawn at a vertical interval of 5 metres on 1:10,000 and 1:25,000 maps, and at a vertical interval of 10 metres on 1:50,000 maps. On all scales contours are printed as thin brown lines, and every fifth contour, known as an index line, is drawn more thickly to assist reading. A combination of colour layer tinting and hill shading is used to supplement contours on the Travelmaster maps at the smaller 1:250,000 scale (4cm to 10km) which are often used in road atlases. Hill shading and colour layer tinting are also used on the older Tourist maps at the 1:63,360 scale (1 inch to 1 mile) which are still available for selected areas.

There is great variety in the patterns which contours form on maps. In practice, however, these tend to be variations of a fairly small number of basic patterns, the most common of which are the valley, spur, hill and ridge. The re-entrants of contours representing valleys are by far the most pervasive feature of topographical maps and are usually identified by the presence of a river or stream within the re-entrants. Similar re-entrants indicate spurs between valleys, from which they are distinguished by the fact that the highest numbered contour occurs at the centre instead of the outside of the re-entrants. A hill is readily identified by a contour pattern of roughly concentric circles, usually with a spot height in the middle. A ridge is represented by a series of broadly parallel lines, with the contour numbering decreasing from the centre towards the sides. It is the combination of these basic contour patterns into a great variety of more complex patterns which makes the typical topographical map such a confusing document for the inexperienced reader (Sandford, 1972; Graves, 1975; Boardman, 1985).

Pupils' errors with contours

My interest in pupils' understanding of contours began with a map reading test designed to identify some of the problems which pupils encounter in reading and interpreting Ordnance Survey maps. The test covered a range of map skills and was administered to a total of 578 pupils aged 15-16 years in their final year of compulsory education in twelve Birmingham schools (Boardman and Towner, 1979, 1980; Boardman, 1983). The pupils were following geography courses leading to the General Certificate of Education (GCE) at Ordinary level and the Certificate of Secondary Education (CSE), including a course based on the Schools Council Geography for the Young School Leaver (GYSL) project.

The pupils were provided with a sketch map showing contours traced from part of an Ordnance Survey 1:50,000 map of a rural area 8 kilometres by 5 kilometres to the north-east of Birmingham (Figure 1.2). At the time the Ordnance Survey had recently relabelled the contours drawn at intervals of 50 feet on the former 1:63,360 (1 inch to 1 mile) maps with their equivalent metric value on the new 1:50,000 maps, resulting in an irregular and unfamiliar contour interval. The land shown on the sketch map descended gradually in height from a little over 152 metres in the south-west to less than 61 metres in the north-east, and was traversed by a west-east trending river valley.

The pupils were asked to shade in pencil on the sketch map the land which was below 91 metres in height. Whilst 80 per cent of the O-level pupils performed this apparently straightforward task accurately, only 43 per cent of the CSE pupils and 17 per cent of the GYSL pupils did so. The mistakes made, mainly by the latter two groups of pupils, are relevant to the present research.

The correctly shaded map is shown in Figure 1.3a. Some pupils shaded only the land between 91 and 76 metres in height (Figure 1.3c), apparently failing to realise that land below 76 metres is also below 91 metres. Other pupils omitted to shade land below 61 metres as well as that below 76 metres (Figure 1.3b,c,e). Some

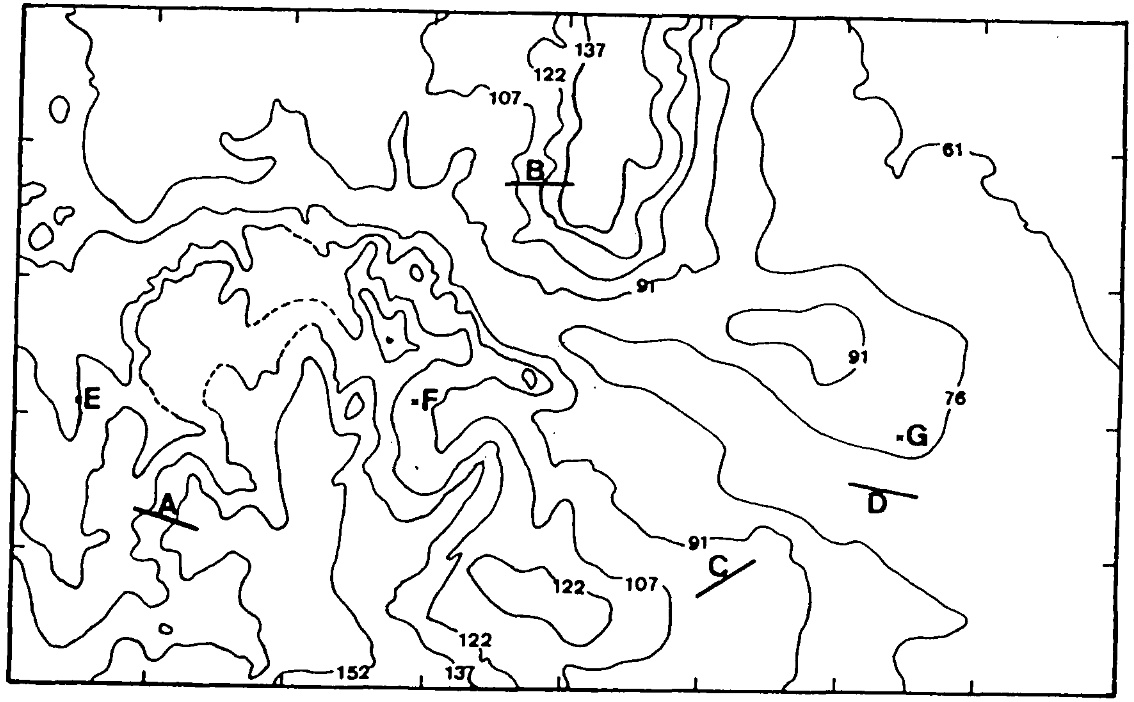


FIGURE 1.2. CONTOUR MAP USED IN WRITTEN TEST (Boardman 1983)

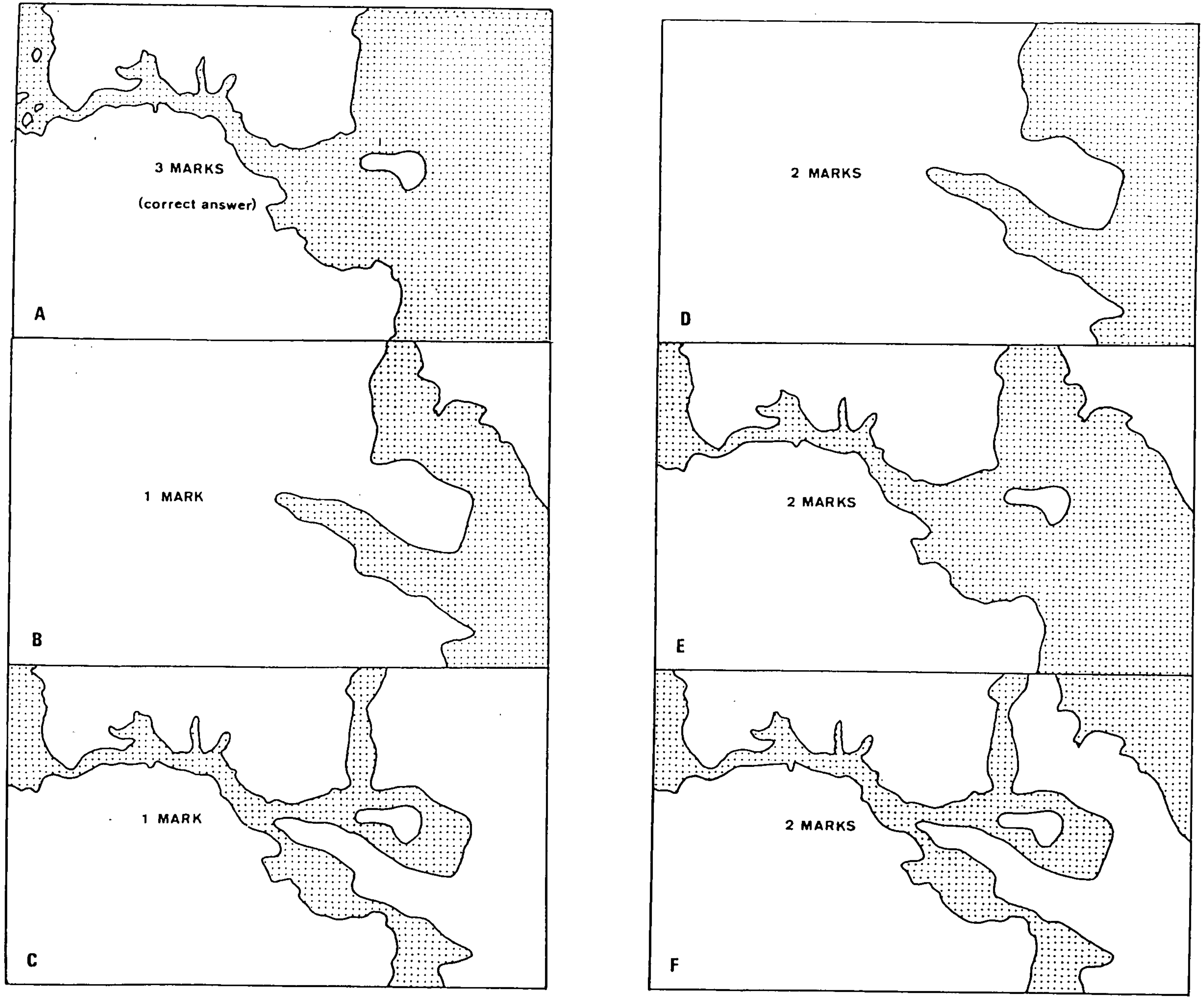


FIGURE 1.3. PUPILS' SHADING OF CONTOUR MAP (Boardman 1983)

left land between 91 and 76 metres blank, shading only land below 76 metres (Figure 1.3b,d). They apparently chose the nearest contour bearing a number less than 91, suggesting that they either interpreted the question literally (below 91), or failed to appreciate the continuous fall in height of the land between one contour and the next. A few pupils shaded land between 91 and 76 metres, left unshaded land between 76 and 61 metres, and then shaded land below 61 metres (Figure 1.3f). All of these errors indicate that the pupils had a partial or incomplete understanding of what a contour map represents.

A further question asked the pupils to look at each of four short lines in turn (A,B,C and D in Figure 1.2), decide which end is higher, and draw a circle round that end. On average 92 per cent of the O-level pupils, 81 per cent of the CSE pupils and 61 per cent of the GYSL pupils circled the correct end of each line. Slightly more pupils circled the wrong end of line D than lines A,B and C, possibly because D is parallel to the contour and pupils had to appreciate the slope of the valley. The next question, which asked the pupils to decide which of the four lines lies on the steepest slope, was answered wrongly by more pupils in all groups. 77 per cent of the O-level pupils correctly selected line B, but only 49 per cent of the CSE pupils and 31 per cent of the GYSL pupils did so. Pupils who gave incorrect answers apparently did not appreciate the relationship between closeness of contours and steepness of slope.

Finally the pupils were asked to estimate the height of the land at three points (E,F and G in Figure 1.2). Point E was the easiest to determine because it lies on a numbered contour. 89 per cent of the O-level pupils, 63 per cent of the CSE pupils and 39 per cent of the GYSL pupils gave the correct height. Point F proved to be much more difficult, however, because it lies midway between two contours. Its height was estimated correctly to within two metres by 68 per cent of the O-level pupils but only 29 per cent of the CSE pupils and 16 per cent of the GYSL pupils. Rather more managed to estimate the height of point G because it lies near a numbered contour: 84 per cent of the O-level pupils, 57 per cent of the CSE pupils and 31 per cent of the GYSL pupils gave the correct height.

The results obtained in this study may reflect either the higher academic ability of O-level pupils, or the greater emphasis given to reading Ordnance Survey maps in O-level courses than in CSE courses. Map reading was assigned a relatively minor role in GYSL courses in particular (Boardman, 1988). The test was administered in twelve schools, so it was not possible to take account of the kind of teaching which the pupils had received, nor the amount of practice they had had in contour map reading.

Another study involved 336 pupils aged 11-14 who had followed map reading courses which included contours in six comprehensive schools in the West Midlands (Boardman, 1982, 1989). 166 of the pupils were aged 11-12 and the other 170 were aged 13-14. They were provided with a much simpler contour sketch map than that used in the previous study. This was traced from part of the same Ordnance Survey 1:50,000 map and showed a smaller area 5 kilometres square (Figure 1.4a). The relief rose gently from the 76 metre contour near the centre of the map to the 122 metre contour near the eastern edge.

The pupils were asked to shade on the sketch map all land above 91 metres in height. Only 36 per cent of the younger pupils completed this shading task with complete accuracy (Figure 1.4b). The older pupils did rather better, 75 per cent shading the map correctly. Errors made by the pupils were similar to those in the previous study. Some did not shade the land inside the unnumbered contours near the northern edge of the map (Figure 1.4c). Others shaded only land above 107 metres (Figure 1.4d), apparently having chosen the nearest contour bearing a number greater than 91, indicating that they did not appreciate the continuous rise in the slope between one contour and the next. A common mistake, particularly among the younger pupils, was to shade only land between 91 and 107 metres (Figure 1.4e); they did not appear to realise that land above 107 metres was also above 91 metres. A few pupils shaded only land between 107 and 122 metres (Figure 1.4f).

The pupils were next asked to look at each of three short lines in turn (A,B and C in Figure 1.4a), decide which end is higher, and draw a circle round that end. 77

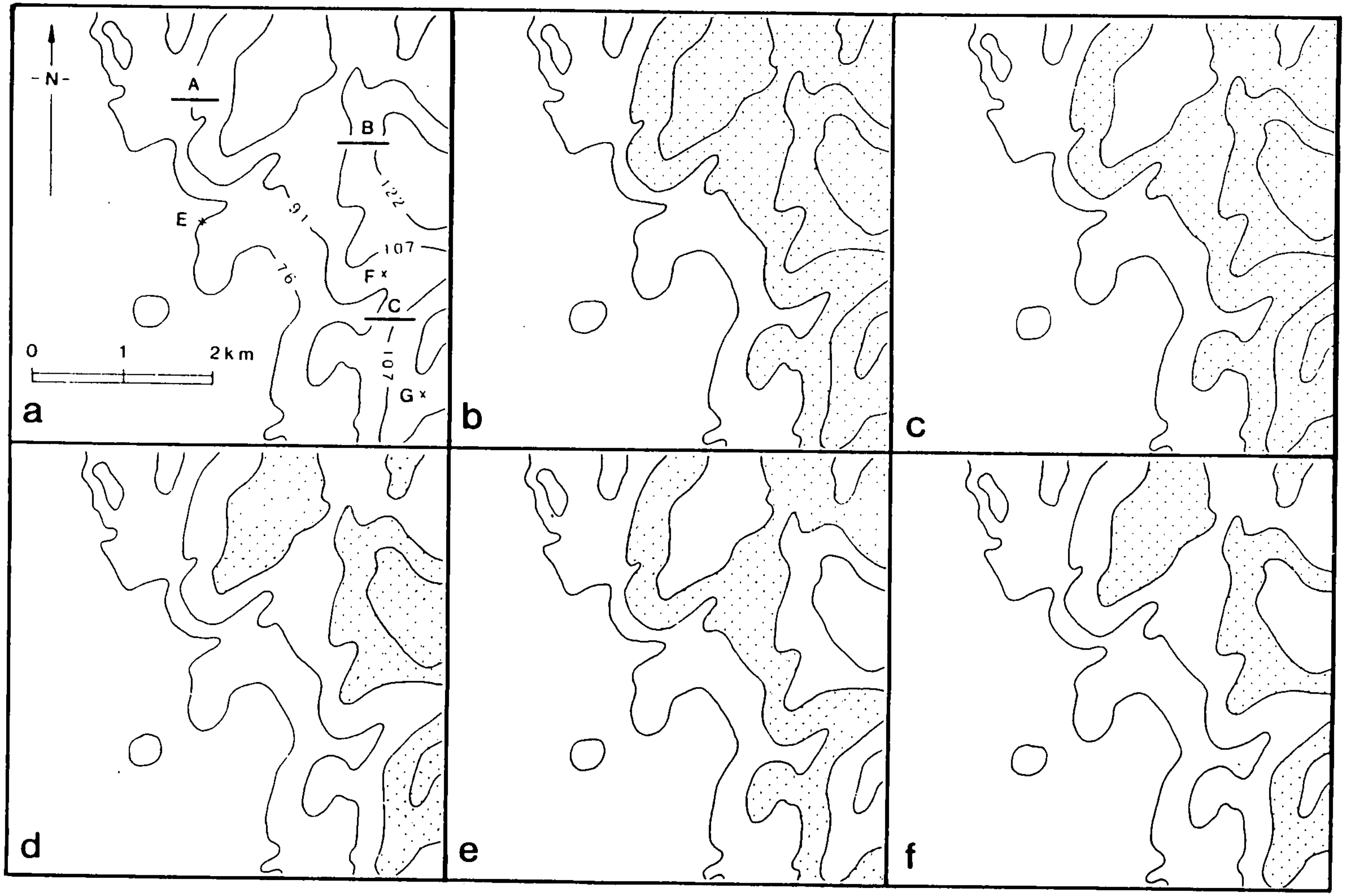


FIGURE 1.4. CONTOUR MAP AND PUPILS' SHADING (Boardman 1989)

per cent of the younger pupils and 89 per cent of the older pupils did this correctly for line B, their attention probably having been drawn to the contours numbered 107 and 122 near that line. Only just over half of the younger pupils and three-quarters of the older pupils, however, identified the higher end of lines A and C correctly. The absence of contour numbering near line A, and the presence of only one numbered contour near line C, may have reduced the pupils' ability to recognise the higher end of these lines. When the pupils were asked to decide which of these lines lies on the steepest slope, less than half in both age groups identified line C correctly. This again indicates that the others did not appreciate the relationship between closeness of contours and steepness of slope.

Lastly the pupils were asked to estimate the height of the land at three points (E,F and G in Figure 1.4a). Most pupils gave the height of point F correctly because it lies on a numbered contour. Only small percentages of pupils in both age groups, however, were able to estimate the height of points F and G, which lie midway between contours. Pupils who gave incorrect answers usually said that F was 91 metres and G 107 metres. They either simply read the number on the nearest contour, or failed to appreciate the continuous rise in the slope between the contours.

The older pupils obtained higher scores than the younger ones on all questions in this test, suggesting that understanding of the concept of contours develops with age. As in the previous study, no account could be taken of the kind of teaching which the pupils had received in the different schools, nor the amount of practice in contour map reading provided in the different courses.

The only other research into pupils' understanding of contour maps carried out in the UK was a study by Underwood (1981), who attempted to ascertain the effect of geographical experience on the interpretation of topographical maps. The subjects for the study were 55 girls aged 15 years and 11 girls aged 17 years, who were divided into three groups on the basis of their experience with topographical maps. Of the younger girls, 22 (group A) had ceased to study geography in the previous year, and 33 (group B) had chosen to continue to study geography for public examinations. The

11 older girls (group C) were studying geography for GCE Advanced level, and thus had more experience with topographical maps than the two younger groups.

The contour map used in the test contained a variety of patterns. The test included a range of questions, such as asking the girls to mark the highest and lowest points on the map, to estimate the height of five points marked on the map, and to locate the steepest and gentlest slopes on the map. Other quite demanding questions included one which asked the girls to imagine that they were standing at a specific point marked on the map and to decide whether or not they would be able to see people standing at eight other points, assuming good visibility. Unfortunately Underwood does not give the results obtained by the girls on the various questions. Instead she just gives the mean scores on the test as a whole: as expected group C, with the most experience of topographical maps, achieved the highest score, and group A, with the least experience, obtained the lowest score.

Underwood also investigated whether there was a relationship between the girls' map reading performance and their visual-spatial ability as measured by a standard test, the AH5 group test of high grade intelligence. She found that visual-spatial ability and map-reading skills were reliably related for group A, the least experienced pupils, but that there was no reliable relationship for the more experienced group B nor for the most experienced group C. She suggests that greater experience of map reading in groups B and C may have compensated for deficiencies in visual-spatial ability by providing cues to aid map interpretation. Like the results obtained by Satterly (1964), however, this finding is interesting but does not appear to have any practical application.

In a study of contour interpretation involving a large sample of Australian students, Griffin and Lock (1979) designed a multiple-choice questionnaire which concentrated upon the students' ability to identify different types of slope on contour diagrams. Each of 14 questions displayed a contour pattern upon which a profile line was drawn. Subjects were given five optional answers in the form of different profiles, from which they were asked to choose the one which they considered most closely represented the profile line on the contour diagram. Seven questions showed contour diagrams in the form of simple patterns of concentric circles representing the kinds of conical hill often used in teaching the contour concept. The other seven showed contour patterns which commonly appear on maps and might be described as realistic, such as nested re-entrants representing valleys, but without any indication of the drainage network. The profile lines on the 14 contour diagrams consisted of four cases of uniform slope, four cases of concave slope, and six cases of convex slope.

The questionnaire was answered by a total of 701 subjects at six levels of education: 484 students in years 10, 11 and 12 (ages 15-17) in geography classes in four Adelaide secondary schools, and 217 first-, second- and third-year undergraduates taking geography courses at the University of Adelaide. The results showed a general improvement in performance on the 14 questions from lower to higher levels in both the secondary and tertiary groups. Comparison of the error rates for the seven circular and seven realistic contour patterns indicated that the latter gave rise to more errors. The questions involving the identification of a convex slope resulted in more errors than those involving a concave slope. The most frequent error was that of slope reversal, that is, perceiving a convex slope as a concave one or *vice versa.* Although the frequency of error declined in moving up the educational sequence, the dominance of slope reversal did not. Indeed slope reversal was the most frequent error among students at all educational levels, including those with the greatest experience. The researchers concluded that failure to judge the relative steepness of slope along convex profiles was the result of perceptual error rather than lack of conceptual competence.

In a recent book on the ways in which children make sense of place, Matthews (1992) devotes only one paragraph to relief. He observes that few studies have looked specifically at children's ability to understand relief maps. He concludes the paragraph: 'I know of no formal experiments assessing how children respond to different forms of relief symbolization' (Matthews, 1992:160). Research to be reported later will show how one group of children responded to contour patterns.

2. RESEARCH CARRIED OUT BY PSYCHOLOGISTS

This chapter begins by considering aspects of Piaget's theory of spatial concept development in so far as it is relevant to children's understanding of spatial representations. There follow reviews of some more recent research undertaken by psychologists into children's abilities in perspective-taking tasks, drawing three-dimensional objects, and using spatial coordinates and spatial representations. The final part of the chapter considers the potential value of research which draws on the traditions of both psychology and geography.

Perspective-taking tasks

Studies of the stages in the development of children's thinking carried out by Jean Piaget and his associates in Geneva, spanning more than half a century, have had a great influence on education. Piaget's research findings and conclusions have stood up well to the test of time and his results have been confirmed by other workers who have replicated some of his experiments, although his theoretical framework has not been universally accepted. His detailed clinical studies were concerned with the development of children's spatial understanding and not directly with their understanding of spatial representations, but some of his findings are relevant to the use of maps.

After conducting numerous experiments, Piaget and Inhelder (1956) and Piaget, Inhelder and Szeminska (1960) observed that children's spatial understanding develops gradually and passes through three stages: topological, projective and Euclidean. The term 'topology' refers to spatial equivalence, the main property of which is proximity. The elementary relationship of proximity and its related one of separation are described in terms of points which are connected to one another by means of lines. Thus if young children aged 4-7 years are asked to draw the area around their home, they will simply show the places they know and remember, together with the connections between them. Their viewpoint is egocentric and shows little understanding of such concepts as direction or distance. Nevertheless their representations have the characteristics of elementary topological maps.

Children's thinking about spatial relationships evolves, according to Piaget, from topological to projective during the stage of concrete operational thought, which is characteristic of children between the ages of 7 and 11 or 12 years. The term 'projective' indicates the representation of three-dimensional objects in two-dimensional form, such as a picture or a map. The development of projective spatial understanding is closely related to the growth of the ability of children to put themselves in the position of other people and view objects in their imagination from viewpoints other than their own.

Children's spatial understanding continues to evolve from projective to Euclidean as they approach Piaget's stage of formal operational thinking at the age of 11 or 12 years. The term 'Euclidean' refers to spatial geometry in which the relationships of objects in space are structured in terms of horizontal and vertical lines, squares, rectangles, triangles and circles. Euclidean geometry is metric in nature and based on a full reference system of coordinates. Direction, scale and orientation are all shown correctly.

The development of children's spatial understanding through the topological, projective and Euclidean stages is reflected in their cognitive maps which were discussed and illustrated in the previous chapter. The three levels of grading applied to cognitive maps by Matthews (1984) broadly correspond to the three stages of spatial understanding identified by Piaget. Thus pictorial and pictorial-verbal maps (grade I) are likely to be drawn by children in the topological stage, pictorial-plan and pictorial-plan-verbal maps (grade II) by those in the projective stage, and plan and plan-verbal maps (grade III) by those who have reached the Euclidean stage.

The growth in children's appreciation of perspective in space was demonstrated by the well-known three mountains experiment carried out by Piaget and Inhelder (1956). They constructed a one-metre square three-dimensional model of three mountains varying in height from 12 to 30 centimetres and placed it on a table in front of the child. The lowest mountain, coloured green and with a small house on the summit, was in the right foreground. To its left and slightly to the rear was a higher mountain, coloured brown and with a red cross on the summit. In the background stood the highest mountain, coloured grey and capped with snow. The child was seated at one side of the table and a small doll was placed at each of the other three sides in succession. The child's task was to decide which perspective the doll would see in each position. In one version of the experiment, the child was asked to reproduce the view seen by the doll by arranging three pieces of cardboard, shaped and coloured the same as the mountains. In another version the child was shown a set of pictures representing the mountains as seen from different viewpoints, and was asked to choose the picture which showed the view seen by the doll.

When asked to indicate what the doll saw, children aged 4 and 5 years invariably responded by giving their own perspective. They simply imagined that the doll's view was the same as their own. Although children aged 6 years appeared to show some awareness that the doll's view was different from their own, they were not able to reproduce it correctly. Children aged 7 and 8 years appeared to be aware of perspectives other than their own but often gave wrong answers. It was not until the age of 9 years that children demonstrated a real understanding of the doll's perspective and usually gave correct answers. The errors made by the younger children were described by Piaget and Inhelder as 'egocentric', and these tended to decrease as the children grew older. They concluded that very young children were incapable of seeing the world in other than egocentric terms and would not be able to understand any perspective that they had not experienced.

It has been suggested by Borke (1975), however, that the task presented to the children for communicating their perceptual role-taking skills was beyond the cognitive capabilities of most children below the age of 9 years. She showed that when the nature of the task is changed, young children may reveal abilities that they were thought to lack. Borke used displays containing small toy figures as well as Piaget's three mountains array. The difference between her studies and Piaget's original one was that her task was introduced and realised in ways appropriate to children aged 3 and 4 years. The children had much greater success with the scenes containing toy figures than with the three mountains. This suggests that one factor affecting role taking ability is the ease with which the child can discriminate cues for visualising the other person's perspective. Discrete, easily differentiated objects provide more cues for young children to identify and remember than essentially similar configurations such as Piaget and Inhelder's three mountains.

Borke also found that asking children to revolve an exact duplicate of the experimental display to indicate the other person's viewpoint resulted in a very low error rate on the two scenes depicting discrete objects. Children appear to communicate their awareness of another person's viewpoint more easily when asked to turn an identical display than when asked to select a picture or model. Although young children can recognise pictures of objects from a fairly early age, they seem to experience considerable difficulty when asked to make the transition from a three-dimensional display to a two-dimensional picture. Borke concludes that the more difficult it is for children to solve a task, the greater is the likelihood that they will give their own perspective in an attempt to perform successfully in the situation.

Hughes and Donaldson (1979) have also shown that young children are far from being invariably egocentric. They studied children's perspective-taking abilities in hide-and-seek games, a context which makes good sense to children. The child was asked to hide a small boy from one or more toy policemen who were 'looking for the boy'. In the first study, the child had to do this by placing a small model wall between one of the policemen and the boy; in the other studies the child had to hide the boy within various configurations of walls. Thus the child was not directly asked to decide what the policeman could see, but the demand was implicit in the task.

The level of performance of children aged 3 and 4 years on these tasks was remarkably high. Very few of the children had any difficulty either with the one-policeman task or with the simpler two-policemen task. It was only with the more difficult two-policemen task that some of the 3-year-olds made a number of errors, and even here most of the 4-year-olds still performed extremely well. Hughes and Donaldson were careful to introduce the tasks in ways which would help the child to understand the situation. The tasks were clear to the children, and they quickly grasped what they were being asked to do. The motives and intentions of the characters (hiding and seeking) were entirely comprehensible to the children.

Donaldson (1978) has argued that young children could not perform the tasks in Piaget's three mountains experiment because their understanding and use of language was still developing. The situation simply did not make sense to them and they did not fully understand what they were expected to do. Her criticism of the three mountains experiment is that it is an artificial task beyond the experience of young children: 'it is abstracted from all basic human purposes and feelings and endeavours. It is totally cold blooded' (Donaldson, 1978:24). She maintains that the three mountains task is particularly difficult because it requires children to perform both front/back and left/right reversals in order to work out the doll's view. She has shown that young children are able to perform a simpler but comparable task if they are introduced to it in such a way that they understand what is being asked of them. This indicates that young children are not nearly so limited in their ability to 'decentre', or appreciate someone else's viewpoint, as Piaget maintained.

In follow-up studies of Piaget's three mountains experiment, research reviewed by Liben (1981) suggests that perspective-taking ability is influenced by the nature of the materials used and the way in which they are presented. Even young children have shown good perspective-taking ability if they are presented with familiar materials, or permitted to rotate the display, or use a display with distinctive features.

In another review of the research, Spencer, Blades and Morsley (1989) conclude from the evidence that tasks involving different perspectives can be tackled successfully by children who are younger than Piaget suggests. Like Liben (1981) they conclude that children's performance in tasks involving the coordination of perspectives is influenced by the kinds of stimuli presented, by the complexity of the relations among the presented stimuli, and by the types of response required. To this list Donaldson (1978) would add the experimenter's motives in asking the child to perform the task and the child's motives in responding.

Children's drawings

In one of their experiments Piaget and Inhelder (1956) asked children to draw a display of three-dimensional objects. A model village containing such features as streets, cottages, a church and some trees, was arranged on a base and placed on a table. They asked the children to draw these objects on a sheet of paper smaller than the model, either as viewed directly from above or as seen in oblique perspective. All of the objects thus had to be placed relative to one another at the same time. The layout presented the children with the twofold task of seeing the village from a particular perspective, and of using Euclidean coordinates to transform the direct visual experience into a plan.

Piaget and Inhelder found that children below the age of 7 years were unable to reconstruct the model village, and most only managed to reproduce small clusters of some of the objects. Although children between the ages of 7 and 9 years were able to replicate the model village, they often distorted distances between the objects. By the age of 9 or 10 years children were able to draw an accurate reconstruction of the model village. During the stage of concrete operational thinking (from 7 to 12 years), children began to arrange objects according to the dimensions of the model and corresponding to a particular viewpoint. After the age of 10 years children began to show more careful and accurate judgement of distances between objects in the model and increasing ability to reduce these distances approximately to scale. Children were now mastering the task of drawing the layout by taking into account not only position and distance, using a system of coordinates, but also perspective and proportion. When children reached the stage of formal operational thinking (at 11 or 12 years), they were able to make a small-scale plan of the arrangement of objects in the model. They established the positions of objects and distances between them by accurate measurement, and were able to draw true maps which were detailed and coordinated.

The task that Piaget and Inhelder asked the children to attempt was, in fact, a quite difficult one. They were faced with the problem of representing a set of three-dimensional objects on a two-dimensional flat surface. In the real world children are used to seeing the three dimensions of space and can describe up-down, near-far, and left-right relationships. But a piece of paper has only two dimensions, and 'three into two won't go'. So children have to decide how to represent the third dimension. In addition they were being asked to draw the scene from a particular viewpoint, which in itself is a demanding task, and to put objects together in various spatial relationships on a piece of paper which was smaller than the model.

An account of the stages through which children's drawing develops has been provided by Cox (1991), although she is mainly interested in how children draw objects at eye level rather than from above. It appears that young children do not, and perhaps cannot, draw visually realistic pictures. They may draw objects or parts of objects which they cannot actually see. Between the ages of about 5 and 9 years children produce drawings which reflect what they know about the objects in a scene. Their drawings are said to exhibit 'intellectual realism'. The children 'draw what they know rather than what they see'. After the age of about 9 years there is a gradual shift so that children draw a scene as it looks, although they may show its structure in different ways. As children grow older they attempt to draw a scene from a particular viewpoint. Their drawings are said to demonstrate 'visual realism'.

Light (1985) regards the intellectual realism of young children as a product of a conscious strategy. Children modify their view of an object in order to show features which they consider to be significant. They are motivated to inform, and so produce a drawing which is intended to convey rather than simply contain information. Crook (1985), however, questions whether children's desire to communicate information can account for their intellectually realistic drawing of objects. He suggests instead that it may be the result of children constructing a mental list of the known properties of an object. He argues that when children are drawing they have difficulty in inhibiting a tendency to run through this list of properties. The way that children describe the scene to themselves also influences how they arrange the objects in their drawings.

There is an interesting parallel between the stages in the development of children's spatial understanding identified by Piaget and the characteristics of their drawings, including their cognitive maps. The stage of intellectual realism, according to Cox (1991), corresponds with Piaget and Inhelder's stage of early projective spatial relationships. Young children are unable to adopt successfully a particular viewpoint, even their own, so there is no overall coordination of perspective for a whole scene. By the time children reach the stage of visual realism, on the other hand, they have developed an understanding of both projective and Euclidean relationships. They can draw a scene from a particular viewpoint, and work out distances, proportions and relationships between objects correctly in relation to that viewpoint. The transition from intellectual realism to visual realism in children's drawings is thus reflected in the evolution of their cognitive maps from projective to Euclidean.

When drawing a scene in which one object is partly hidden by another, older children use the technique of partial occlusion to indicate that part of the more distant object is obscured by the object that is nearer. Studies of children's drawings, however, have shown that young children below the age of about 8 years do not readily use this technique of partial occlusion (Freeman and Cox, 1985; Cox,1992). Instead they tend to separate the two objects and draw the complete outline of both, showing the partly hidden object on the paper above or at the side of the other object. Later they bring the two objects together and show one as partly hidden by the other. This development is again reflected in the cognitive maps drawn by children as they progress from the topological to the projective and Euclidean stages.

It should be noted that the angle from which the child views the scene influences the drawing produced. If the child looks down at a model placed on a table, the further objects are visible by looking over the nearer ones. But if the model is raised up to the child's eye level, the further objects cannot be seen over the nearer ones, unless the child stands up or moves to the left or right of the scene.

The system of linear perspective is the generally accepted method of projecting aspects of a three-dimensional scene on to the two-dimensional surface of a picture. Children only gradually develop the ability to draw a picture in perspective, in which an object near to the artist will be shown larger than the same object placed further away. In this respect Piaget and Inhelder's instruction to draw the model village either as viewed directly from above or as seen in oblique perspective must have been particularly confusing to the children who attempted the task. Although both needed to be drawn from a single viewpoint, the option of the view from above required the production of a plan drawing, whilst a view from any other angle indicated a perspective drawing.

Like drawings, maps and plans represent three-dimensional information in two-dimensional space. The difference in representation is that drawings aim to convey the identity of objects. Maps and plans, on the other hand, represent locations, directions and distances between objects by organising them with reference to vertical and horizontal coordinates. As Millar (1994) puts it, drawings represent the 'what' of objects, whilst maps and plans represent the 'where' of objects.

The difference between drawing objects and mapping objects is not the level of abstraction. Both kinds of drawing use abstractions of essential features in the environment, and both use symbols to represent objects from the real three-dimensional world. The difference lies in what features are of interest, and are therefore 'abstracted' or symbolised. In other words, maps are selective representations of an environment. As Millar (1994) has emphasised, mapping is essentially a form of symbolic processing, and the meaning of the symbols has to be understood by the user.

Using spatial coordinates

Research has been carried out into the age at which children begin to understand how a point or place can be located accurately on a plan by using a system of coordinates. Piaget, Inhelder and Szeminska (1960) showed children two identical rectangular pieces of paper, on one of which a single point was marked. The children, who were given measuring equipment, were asked to plot this point in the same position on the second piece of paper. Piaget *et al* found that children could not locate the point accurately until the age of about 8 years. It should be noted, however, that the children were not provided with a coordinate system but had to work out the position of the point for themselves. Furthermore, younger children may have had little experience of using the measuring equipment they were given.

Different results have been obtained in experiments in which children are provided with a coordinate system. Somerville and Bryant (1985) found that children as young as 4 to 6 years of age were able to carry out simple tasks using coordinates. They showed children an opaque square board that was placed above two rods. One rod protruded from the left or right side of the board (to provide a horizontal coordinate), and the other from the top or bottom of the board (to provide a vertical coordinate). The children had to work out from the visible parts of the rods where they thought the rods crossed under the board by choosing one of four given points marked on the top of the board. Some children aged 4.5 years were able to do this correctly and most children aged 6.5 years successfuly completed a number of variations of the task. Somerville and Bryant's results suggest, therefore, that children are able to understand coordinates from the age of 4 years if they are provided with a coordinate system, whereas Piaget's experiment indicates that they can only do so after the age of 8 years if they have to work out the coordinates for themselves.

Experiments to find out whether young children can use coordinate systems in tasks comparable to using grid references on maps have been carried out by Blades and Spencer (1989). They point out that using a grid reference involves two steps.

First the grid reference has to be read correctly and the reference points on the axes of the map frame have to be found. The second step is to construct vertical and horizontal lines (parallel to the map coordinates) from the reference points until the lines intersect at the required location. The experimenters designed a board which contained 16 sunken squares in a 4 x 4 layout (Figure 2.1). In each square a different picture was hidden under a cardboard cover. Vertical and horizontal coordinate lines drawn across the board intersected at the centre of each covered picture. The vertical coordinates were numbered 1,2,3,4 and the horizontal coordinates were lettered a,b,c,d. The children were given a card bearing a grid reference (such as 2a or 3c) on the front and a copy of the correct hidden picture on the back. They were asked to find the correct square on the board for the grid reference on the card. When they had chosen a square on the board, the children could remove its cover and then turn over the card to see if the pictures matched. Whilst most of the 6-year-olds completed this task successfully, only a few of the younger children were able to do so.

Blades and Spencer wondered whether the performance of the younger children might have been due to their inability to carry out both steps involved in using a grid reference, or alternatively to their unfamiliarity with the letters and numbers on the coordinates. They therefore repeated the experiment after labelling each coordinate with a differently coloured circle. Each card given to the children showed a grid reference by means of two coloured circles, one for the horizontal coordinate and one for the vertical coordinate. Half the 4-year-olds and most of the 5- and 6-year-olds were successful in this task, suggesting that the performance of the younger children in the previous experiment had been hampered because the coordinates were labelled with symbols which were unfamiliar to them. In a further experiment, children showed that they could carry out the reverse procedure: when they were shown one of the pictures on the board, they could choose the correct grid reference for that picture.

The discrepancy between the findings of these more recent experiments and the earlier ones of Piaget, Inhelder and Szeminska (1960) may be due to the different nature of the tasks which were set to test the children's ability to use coordinates.

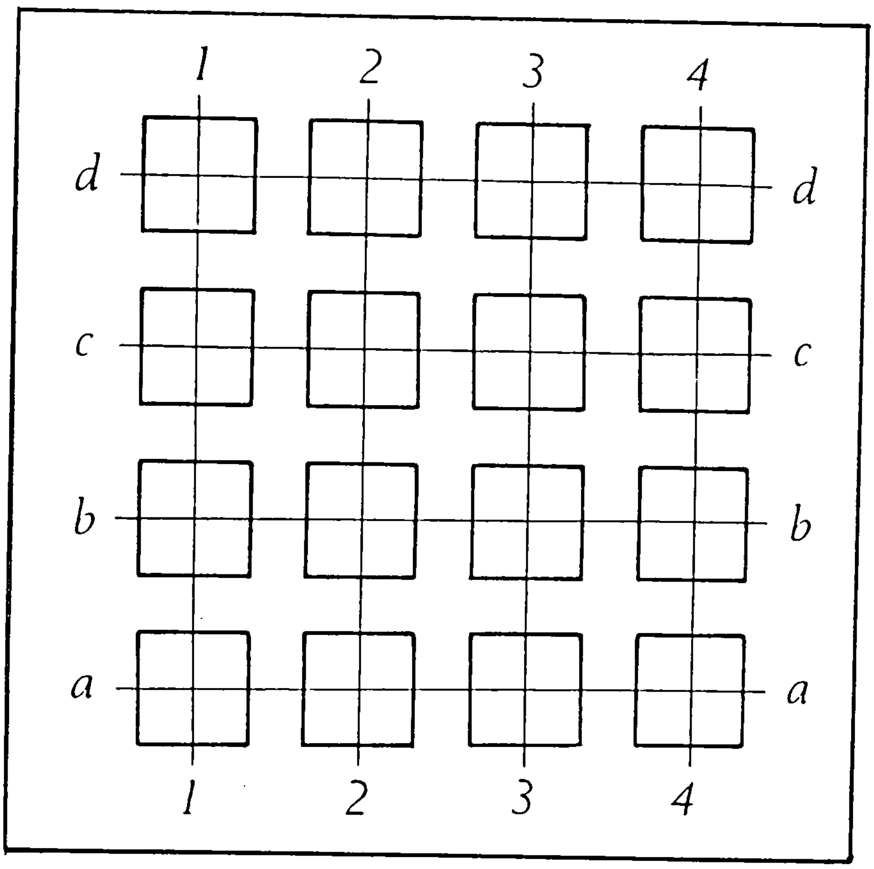


FIGURE 2.1. BOARD FOR COORDINATES TASK

(Blades and Spencer 1989)

Piaget *et al* did not provide a coordinate grid for the children, who had to construct their own grid on an unmarked piece of paper using measuring equipment. In the experiments carried out by Somerville and Bryant (1985) and Blades and Spencer (1989), however, a grid was provided for the children, and even the younger ones showed that they could use a coordinate reference.

Another explanation of the discrepancy between these results and Piaget's conclusions lies in the extent to which the tasks required perceptual or conceptual spatial thought. Piaget described perceptual thought as what a child can understand from direct activity in space, that is, from direct perception of the immediate environment. Conceptual thought, on the other hand, refers to the ability to consider spatial relationships when they cannot be perceived directly. Thus conceptual thought refers to the mental generation and manipulation of spatial information in problem-solving tasks, such as the mental rotation of a three-dimensional object.

Piaget maintained that children use both perceptual and conceptual thought whilst progressing through the topological, projective and Euclidean stages. He also observed that children's perceptual spatial abilities develop well in advance of their conceptual abilities. Unfortunately this part of Piaget's theory is not very well specified and he did not indicate what to expect of a child at, for example, the projective level of perceptual thought, or at what age such a level might be achieved. The distinction between perceptual and conceptual thought has nevertheless to be taken into account when considering children's performance on spatial tasks, because many of the tasks used to assess children's abilities involve both perceptual and conceptual components. Success is more likely to be achieved on a task requiring perceptual thought than on a similar task requiring conceptual reasoning.

Piaget's experiment with the two rectangular pieces of paper was a task of conceptual reasoning because successful performance depended on constructing the coordinates of the given point and transferring that information to the second piece of paper. The children in Somerville and Bryant's (1985) experiment, on the other hand, could solve the task by extrapolating from the visible ends of the rods to work out which of the marked locations indicated the most likely crossing point. This is mainly a perceptual task because the coordinates and possible crossing points were provided and visible to the children. Blades and Spencer's (1989) experiment similarly used a test of perceptual spatial abilities because the coordinate system was again provided. The important difference between Piaget's original experiment and the two more recent studies, therefore, is that Piaget examined conceptual spatial reasoning and the latter two involved perceptual spatial reasoning. Since Piaget maintained that perceptual understanding is well in advance of conceptual spatial thought, the findings of the more recent studies are consistent with Piaget's theory.

One of the consequences of failing to distinguish between perceptual and conceptual tasks is the claim that children can achieve levels of spatial performance well before the ages implied in Piaget's description of spatial abilities. This claim is often based on the results from experimental tasks which differed from Piaget's original tasks by including a greater perceptual component and thus reducing the demands on the children's conceptual reasoning. A further complication is that most experimental tasks are difficult to categorise as solely perceptual or conceptual, and it may be impossible to assess the relative importance of the perceptual and conceptual components in a particular task. This should be recognised in research involving spatial representations, because the use of a map, plan or model obviously introduces a perceptual component into any task. As Blades and Spencer (1994) have emphasised, the distinction between perceptual and conceptual components is important in so far as it focuses attention on the demands of different tasks.

Using spatial representations

The term 'spatial representation' is used to describe any physical representation of space such as a map, plan or model. The use of a representation in an environment implies that an individual selects information from a map, plan or model and applies that information to solve a problem in the environment. In a place location task, for example, a child may look at a plan of a room which indicates where a toy is hidden in the room, and the child has to extract information from the plan in order to locate the toy successfully in the actual room.

Blades and Spencer (1994) point out that the ability to use a spatial representation has two components. Firstly, the child has to recognise that a map or model is a representation. Understanding that one set of spatial information (map or model) has a relationship to another set of spatial information (the environment) may be described as the recognition of correspondence between two spaces, and involves an appreciation of the symbols used in the representation. Secondly, after recognising the correspondence, the child has to select information from the representation and encode it in a form that can be applied to a task in the environment. The child may need, for example, to work out his or her position 'on' the representation as well as identify the location of specific objects. The development of the ability to select and encode information may be described in terms of specific 'spatial strategies' (Blades and Spencer, 1994:172).

Experiments have been designed by psychologists to investigate the ability of young children to use a simple representation to perform a spatial task, such as finding a specific location in a room. Unfortunately the researchers do not always describe their representations accurately and in particular fail to distinguish between maps and plans. This error is illustrated in an experiment reported in a widely cited article by Bluestein and Acredolo (1979) with the title 'Developmental changes in map reading skills'. What the researchers describe as a 'map' is in fact a large-scale representation of a very small area: a 12-foot square collapsible room. A representation of an area as small as this should not be called a 'map' but a 'plan'. Even this word is not strictly correct because the authors admit that their representation showed distinctive features of the room drawn from 'a vertical rather than aerial perspective'. The difference between 'vertical' and 'aerial' perspective is not made clear, but the authors add that 'some pictorially represented three-dimensional information was provided to aid identification of the objects' (Bluestein and Acredolo, 1979:693). Their pictorial representation of the room is reproduced in Figure 2.2. As the authors used the word 'map' throughout their article, it is retained in the summary which follows.

Bluestein and Acredolo studied the ability of children aged 3-5 years to use the map to find an object in the room, which contained a table and four chairs in the centre, distinctively shaped features in each corner, and differently coloured boxes in the middle of each wall. The child was seated at a table on which was placed the map of the room in correct alignment and a sticker showing a toy elephant. The child was asked to use the map to find the elephant. Four conditions were formed by presenting the map inside and outside the room, crossed with having the map aligned and unaligned (rotated 180 degrees) with the room. In a fifth condition, the map was held vertically outside the room. In each condition, the child sat at the table, looked at the map on which the elephant sticker had been placed, and went to retrieve the elephant.

When the children looked at the correctly orientated map inside the room, half the 3-year-olds, three-quarters of the 4-year-olds and all the 5-year-olds were able to use the map to find the hidden elephant. When the map was rotated through 180 degrees, however, only the 5-year-olds could use it correctly. A common error made by children with the rotated map was to select the box directly opposite the correct one. This does not necessarily indicate egocentric thinking because they may simply have assumed that the map was correctly aligned with the room. According to Bluestein and Acredolo, the results suggest that young children can use a simple map of a small area when it is correctly aligned with it, but, as has been pointed out above, their 'map' was in fact a plan with pictorial additions. It should also be noted that the children had an overview of the whole layout of the room. The tasks did not, therefore, resemble the conditions in natural environments which do not normally premit overviews.

Furthermore, the aligned-inside condition served as a pretest, and only those children who passed the pretest were tested under the remaining four conditions. Making the reasonable assumption that children who failed the pretest would also

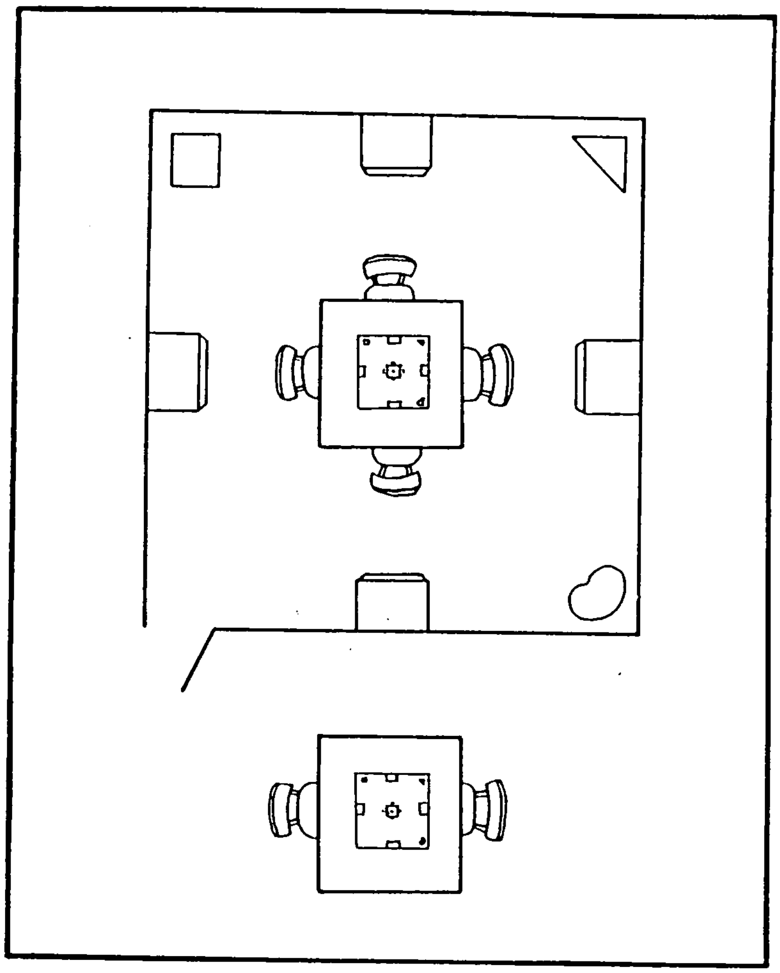


FIGURE 2.2. PLAN OF ROOM FOR LOCATION TASK

(Bluestein and Acredolo 1979)

have failed the other four conditions, Liben and Downs (1989) reworked the data and extrapolated the percentages of children from the full sample who passed the various conditions. The recalculated data show high failure rates for 3- and 4-year-olds in unaligned conditions. Thus Bluestein and Acredolo made exaggerated claims about the ability of young children to use 'maps'.

A similar experiment was carried out with children aged 6-8 years by Presson (1982) and reported in an article with another misleading title, 'The development of map reading skills'. Like Bluestein and Acredolo, Presson throughout the article wrongly describes the representation of a room as a 'map' instead of a 'plan'. In the experiment, a small room again contained four hiding places, one in each corner, but there was otherwise only a single 'landmark', such as a chair placed midway along one wall. The hiding place for the toy was shown on the 'map', which was rotated 90 or 180 degrees relative to the room.

Most of the children's errors reflected a tendency to select a hiding place on the basis of whether it was near to or far from the landmark. The children appeared to identify the hiding place by reference to the landmark rather than by mentally rotating the map. Presson also found that children were likely to make fewer errors when the map was rotated only 90 degrees rather than 180 degrees. This suggests that if children were attempting to rotate the map mentally, then the greater the rotation, the more difficult the task.

Research using similar methods has been carried out by Blades and Spencer (1986). Like the previous researchers, they wrongly use the word 'map' instead of 'plan', add to the confusion by failing to differentiate between maps and models, and report their research in an article with the misleading title, 'Map use by young children'. Thus in one experiment Blades and Spencer asked a group of 16 children aged 3-4 years to use a scale model of a room to locate a small hidden toy. The room contained several items of furniture and six hollow bricks which served as hiding places for the toy (Figure 2.3). A 1:8 scale model of the room showed the furniture, and six Lego bricks represented the hiding places in the actual room. The child stood

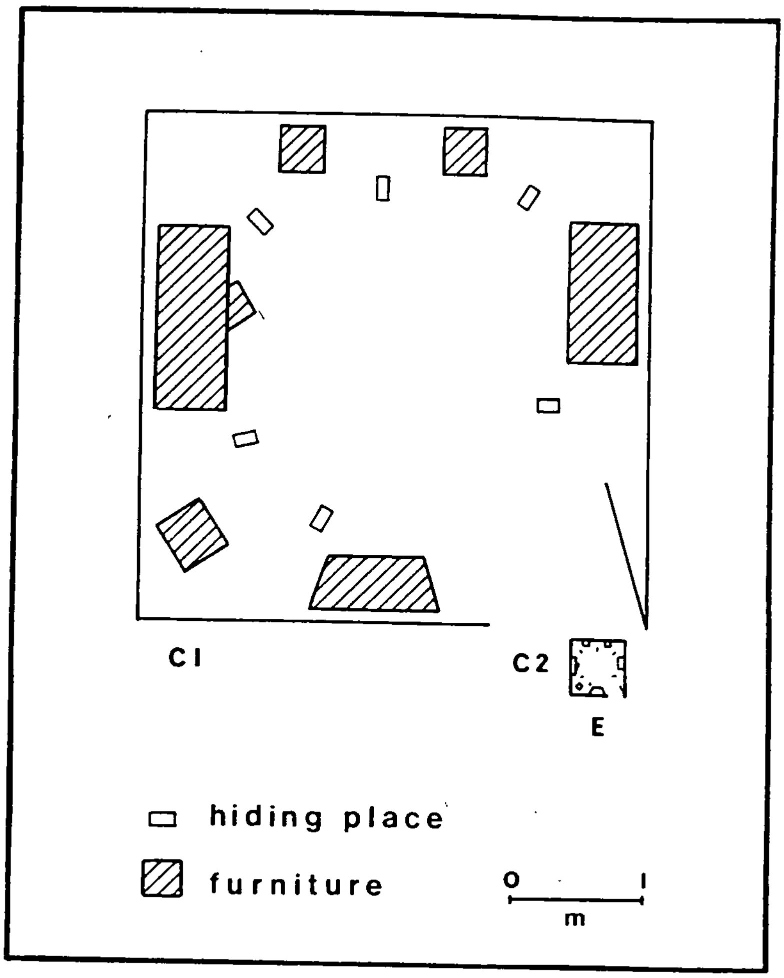


FIGURE 2.3. PLAN OF ROOM FOR LOCATION TASK

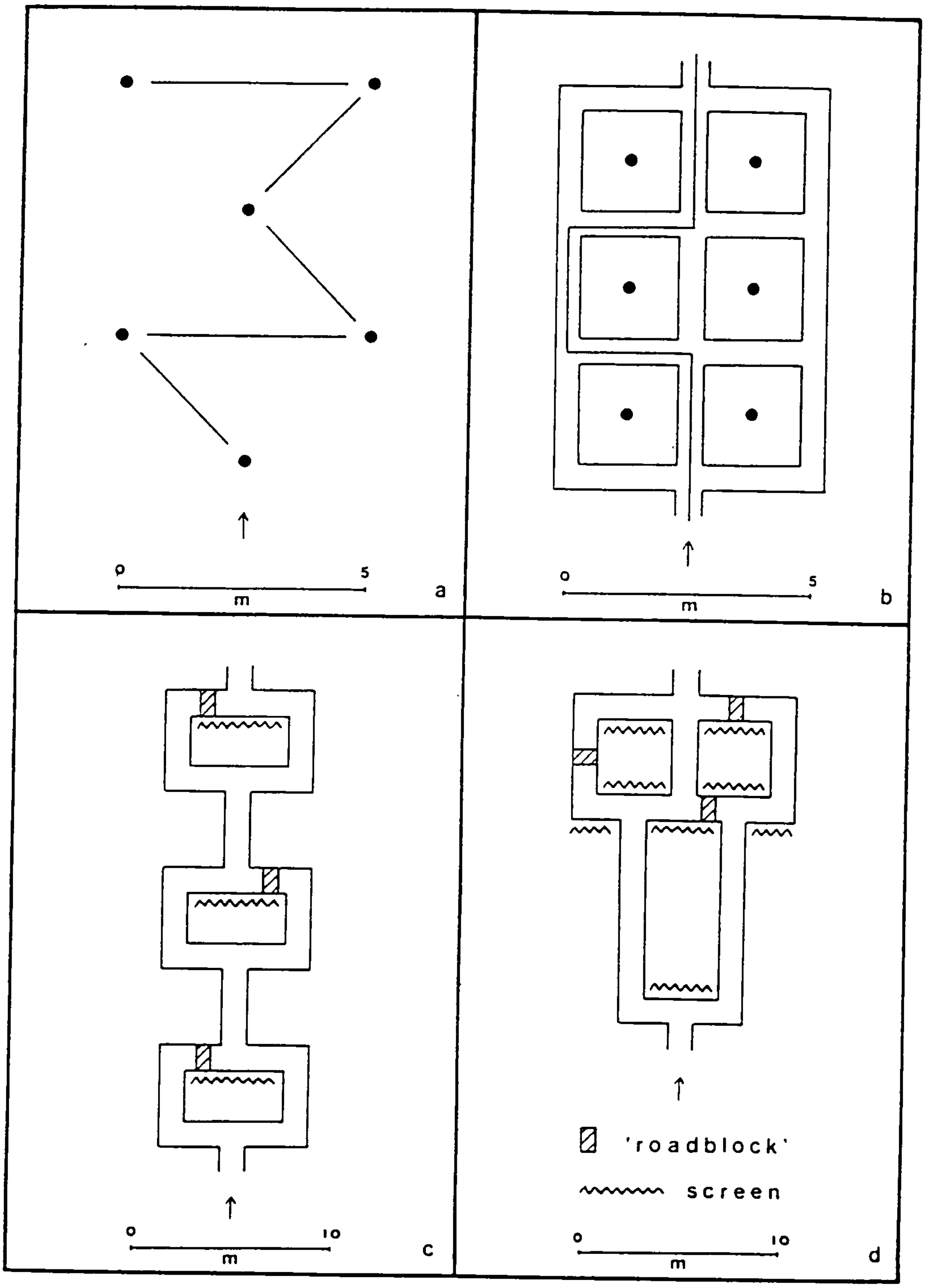
(Blades and Spencer 1986)

at position C1 while the toy was being hidden and moved to position C2 while being shown the toy's location on the model by the experimenter at position E. Each child was asked to go into the room on six occasions, always to a different hiding place. Blades and Spencer report that, out of a total of 96 (16 x 6) trials, the children 'went straight to the correct hiding place on 83 occasions', although they do not say what constituted 'straight'. In the same paragraph the authors conclude that 'young children are able to use maps and models of small environments to locate a particular place in that environment' (Blades and Spencer, 1986:48). The insertion of the word 'maps' into this claim is difficult to justify in view of the fact that the children had used models.

In a variation of this experiment, individual children stood in the room itself, which on this occasion contained only four pieces of furniture, one piece in each corner. Each child was asked to place a small doll in the model to show where he or she was standing in the actual room. Blades and Spencer report that, in a group of 20 children aged 3-4 years, 16 were able to place the doll in the position which corresponded to their own position in the room, often relating it to a nearby piece of furniture. The researchers do not, however, say what margin of error was permitted in this experiment.

Blades and Spencer (1986) then designed further experiments to investigate whether young children could use a simple 'map' to follow a short route. In their illustrations which are reproduced in Figure 2.4 the authors use the words 'map' and 'plan' as if they are interchangeable. Thus in Figures 2.4a and b the scale is 1:50, and in Figures 2.4c and d it is 1:100. Yet in the legend the first two are called maps even though the scale is double that of the second two, which are correctly called plans. The word 'map' is retained in the summaries of the experiments which follow because it is used by the authors throughout their article.

Six differently coloured buckets were placed in a nursery playground. In one layout the buckets were simply positioned at different points in the playground; in another layout the buckets were positioned at different points and paths marked in



(a) Map indicating route between differently coloured buckets (scale refers to dimensions of actual layout). (b) Map indicating route along paths drawn between differently coloured buckets (scale refers to dimensions of actual layout). (c) Plan of maze with three junctions and two choices at each junction. (d) Plan of maze with four possible routes after the first junction.

FIGURE 2.4. LAYOUTS FOR ROUTE FOLLOWING TASKS

(Blades and Spencer 1986)

chalk on the ground were drawn between the buckets. Maps were drawn at a scale of 1:50 and for the first layout showed the buckets by means of appropriately coloured circles; those for the second layout included the paths. The route for the first layout was drawn from bucket to bucket (Figure 2.4a), and the route for the second layout was marked along the paths between the buckets (Figure 2.4b). Children were asked to carry a map and follow the route marked on it.

Two groups of 7 children, with mean ages 4 years 1 month and 4 years 8 months, were asked to use a total of 17 maps showing different routes through the two layouts. The older group successfully followed the routes on most of the maps (mean number correct 13.7), but the younger group were unable to use many of the maps (mean number correct 4.1). The older children were able to follow the routes with few mistakes, but the younger children did not seem to understand the purpose of the maps; for example, they sometimes included all the buckets in a tour of the playground, or followed a route between the buckets which bore no resemblance to the route marked on the map.

In both of these experiments the children could see the whole environment at the same time. In practice maps are normally used to follow a route through an environment which is not completely visible. Accordingly Blades and Spencer (1986, 1987) designed further experiments to investigate whether children could find their way through an area which they could not see from a single viewpoint. They drew a maze 25 metres long in chalk on a school playground and placed screens 1.5 metres high in positions which prevented the children from seeing across the maze or from seeing cardboard boxes placed across the paths as 'road blocks' (Figure 2.4c).

Maps drawn at a scale of 1:100 showed the layout of the maze and the positions of the road blocks. The children carried these maps as they walked through the maze and had to make correct turns at each of three T-junctions in order to complete the task successfully. A total of 60 children were divided into five age groups, their mean ages in years and months being 3.11, 4.6, 5.2, 5.9 and 6.2. The twelve children (six boys and six girls) in each age group were asked to use six variations of the maze. As each maze contained three T-junctions, a child was scored out of a possible 18 correct choices. The performance of the children was compared against chance. All except the youngest age group performed significantly better than chance. The majority of the children in the other four age groups were able in most instances to avoid the paths that were blocked, and the performance of the children improved with age. Similar results were obtained when the experiment was repeated using a slightly more complex maze (Figure 2.4d). The researchers conclude their article by claiming that 'untrained children as young as 3 years old can use maps to locate places in small environments', and that 'after the age of 4.5 years many children can use a map to follow a route' (Blades and Spencer, 1986:52). In view of the misuse of the word 'map' in the article, these are exaggerated claims.

The experiments carried out by psychologists using spatial representations with young children thus have a number of recurring features. First, the spatial representations are described as 'maps' when they are actually large-scale plans. Second, the plans used in the experiments are highly simplified, schematic drawings. Third, the plans depict very small spaces such as a room or part of a playground. Fourth, the plans contain minimal information, such as pieces of furniture in a room or lines on a playground. Fifth, the experiments are conducted in small, enclosed or restricted layouts and not in natural environments. Sixth, the children are asked to attempt fairly simple tasks, such as finding a hidden object in a room or following a short route in a layout.

The experiments have the laudable aim of demonstrating the ability of young children to use simple spatial representations to carry out specific tasks in a restricted environment. Unfortunately psychologists have used the results of these experiments to draw unwarranted inferences about what children might be able to do with cartographic maps in the real environment beyond the enclosed room and playground. They have made exaggerated claims in articles with misleading titles and have failed to appreciate, or chosen to ignore, the complexity of using cartographic maps representing natural environments.

Linking two disciplines

Experiments carried out by psychologists relating to map understanding illustrate the limitations of approaching research from the standpoint of a single discipline. In the same way the research into map understanding carried out by geographers suffers from the absence of a psychological perspective. Collaboration between a psychologist, Lynn Liben, and a geographer, Roger Downs, at Pennsylvania State University, USA, has demonstrated the potential benefits of interdisciplinary research into map understanding. After surveying the literature in psychology and geography, Liben and Downs (1989) conclude that the traditions of both disciplines have strengths and weaknesses in this area of research.

Liben and Downs recognise that investigations reported in the psychological literature are usually carefully designed, described and analysed. The conclusions generally illuminate the effects of controlled variations in the procedures and subject variables such as age. 'Despite these strengths, the studies are often restricted with respect to the questions addressed, particularly insofar as they involve highly restricted kinds of map forms and map tasks' (Liben and Downs, 1989:171). The studies often fail to relate children's mapping to their everyday environment, and many of the assumptions about maps that appear in the psychological literature are faulty.

After reviewing studies reported in the geographical and environmental literature, Liben and Downs note that they are usually addressed to a wider range of children's competencies. They make use of a broader range of stimulus materials and mapping tasks, and rarely make incorrect assumptions about maps. 'Unfortunately, however, this literature is simultaneously characterized by inadequate attention to specific procedures used for collecting, analyzing and reporting data. Investigators have a penchant for presenting sweeping conclusions, not sufficiently qualified either with respect to unevenness in the data ..... or with respect to the limited nature of the data' (Liben and Downs, 1989:171).

Whilst acknowledging that research carried out within the individual disciplines has much to offer, Liben and Downs conclude that the contributions are often limited and misleading when viewed in isolation from one another. In particular they are concerned that the limitations of the current disciplinary approaches to children's map understanding may be giving rise to what they describe as a 'conventional wisdom' that presents a simplistic picture. Liben and Downs criticise the conclusions of such researchers as Bluestein and Acredolo (1979), Presson (1982) and Blades and Spencer (1986) as presenting an oversimplified view of map understanding which suggests that it develops early and easily. They challenge this view on both theoretical and empirical grounds, although they would not wish to replace it with one which suggests that map understanding is something which children acquire late and find difficult.

At the theoretical level Liben and Downs (1989) base their challenge on Piaget's theory of cognitive development. They accept the Piagetian position that children develop topological and later projective and Euclidean concepts gradually during childhood, and highlight some of the limitations in young children's spatial and representational concepts. They point out that projective and Euclidean concepts of space must be understood by children if they are to be able, for example, to align maps with their referents, or to appreciate distance and other information on maps.

At the empirical level Liben and Downs observe that the range of maps, tasks and spaces used in research with young children has been limited. They compare the kind of map presented to young children with the 'See Spot run' type of sentence found in early reading books. Whilst it is true that 'See Spot run' is a sentence, it would be wrong to make inferences about a child's ability to read and understand grammar and syntax because he or she can handle this sentence. Yet this is exactly what researchers who study children's map understanding are in danger of doing by using very simple maps in their experiments and then drawing inferences from their findings which suggest that children can use a map at an early age and find it easy to do so.

An attempt to remedy the deficiencies of the single discipline approach to research was made in the Mapping Project at Penn State (MAPPS) which was jointly directed by Liben and Downs (1989). One experiment in their research is particularly relevant to the research to be reported later because it involved the use of contour maps. Liben and Downs worked with children aged 5-8 years in an elementary school in Pennsylvania. The activities which they organised in the classroom served the dual function of providing a teaching programme in mapping and producing data on children's map understanding. In one task the children were asked to transfer locations from a three-dimensional relief model of the local area to a contour map of the same area. The topography in an area about 12 x 12 miles was represented on a 16 x 16 inch three-dimensional cardboard relief model up to 2 inches in height. The terrain ranged from about 600 to 2100 feet above sea level, and each layer on the model represented a contour increment of 100 feet. Seven coloured flags were placed on the model in locations which varied with respect to how clearly defined they were by landscape features and thus to how readily their locations could be described topologically. A flag on the top of one of the mountains, for example, was considered a highly defined location because it was the only mountain of that shape and was separate from other mountains. In contrast, flags on the large, flat areas of the model were considered at minimally defined locations because of the lack of landmarks near these flags, which meant that their positions had to be determined by estimating distance or direction in relation to surrounding features.

The children had been taught in previous lessons about contour maps in general, and the contour map of the local area in particular. The kind of teaching undertaken is not reported, but an attempt to teach contours to such young children is very interesting, because it would not normally be undertaken until children are older. In the experiment the model was placed on a table in the classroom and each child was given a board containing a 7 x 7 inch contour map of the area shown on the model. The children were given rectangular stickers of similar colour to the seven flags on the model, and were asked to place the stickers in the correct positions on their maps. The children surrounded the model and were allowed to move freely around the table on which it was placed, so that no attempt was made to control alignment between map and model. The researchers did, however, begin with a casual suggestion concerning alignment: the children were told that they might find it helpful to make the map go the same way as the model.

The performance of the children was poor: average scores were 27 per cent correct in the first grade (age 6 years) and 40 per cent correct in the second grade (age 7 years). In the second grade, success was, as predicted, greatest (59 per cent) on a mountain with a distinctive shape, but low (30 per cent) on another mountain which had similarly shaped peaks around it. Success in locations on the open, flat areas, where confusion could most easily occur, dropped to 22 per cent. For a location near the corner of the model, however, where its edges served as a guide, accuracy improved to 58 per cent.

Liben and Downs reported considerable variations within grades, not only with respect to the number of correct responses, but also with respect to individual children's strategies. Some children appeared to be oblivious to the need to find isomorphisms between model and contour map. They arranged stickers in the same spatial dispersion as the flags on the model, but showed no observable concern for the relative alignment between model and map. Many of these children were apparently able to preserve relative metric relationships among the seven stickers, accommodating the scale reduction from the 16 x 16 inch model to the 7 x 7 inch map. The children placed the stickers in completely inaccurate locations, however, because they ignored the projective spatial relationships. In contrast some other children recognised the need to establish isomorphisms, carefully aligned the map with the model, and arranged the stickers correctly.

The interesting feature of this experiment lies in the use of a conventional topographical map instead of the highly simplified line drawings used by Bluestein and Acredolo (1979), Presson (1982) and Blades and Spencer (1986). The fact that the results in the map and model experiment were disappointing is not in itself surprising in view of the young age of the children. Indeed the experiment does not necessarily demonstrate that even the children who were successful actually understood contours. They were simply asked to place stickers on a map in positions corresponding to those occupied by flags on the model. They could have managed to do this by referring to the edges of the map and model as guides rather than to the closeness of the contours or the topography these lines represented.

Liben and Downs' brief discussion of the strategies which some of the children used when attempting to relate model to contour map illustrates a distinctive feature of research carried out by psycholgists into children's mapping skills. Whilst geographers are interested in the results of tests to indicate the ages at which children are able to acquire specific mapping skills, psychologists consider the processes involved in the acquisition of these skills.

After conducting other experiments in the Mapping Project at Penn State (MAPPS), Liben and Downs conclude that the development of map understanding in children is gradual and multifaceted. 'Map understanding indeed begins early, but it progresses through a complex and difficult sequence of developments that are simply not well understood at present' (Liben and Downs, 1989:193). The way in which children learn to handle different aspects of maps is dependent on their cognitive level and experience, and a range of individual differences are likely to occur within any single age group.

Liben and Downs urge that future work should draw on the traditions of psychology and geography. Since most research so far has been carried out with young children, they recommend that studies should be undertaken with older children in order to investigate more advanced aspects of mapping, including the transformation of the three-dimensional terrain on to a two-dimensional plane. It is older children's understanding of the transformation of the terrain into contour patterns that is the focus of the research reported in subsequent chapters.

3. CONTOUR MAPS IN THE SCHOOL CURRICULUM

This chapter provides the background to the present research. An outline of the place of map skills in school geography courses is followed by a summary of the requirements of the national curriculum relating to map skills. Methods of teaching the concept of contours to children with the aid of relief models are then described and the chapter concludes with an account of the pilot study which was undertaken to investigate the feasibility of the present research.

Map skills in school geography

Primary school teachers specialise, not in a subject, but in an age phase. They are class teachers with responsibility for teaching all subjects of the curriculum. Half the present primary teaching force dropped school geography at the age of 14. In most teacher training courses less than 20 hours are devoted to the subject. There are few geography graduates in primary schools and many of the smaller schools do not have anyone on the staff with special expertise in the subject.

In these circumstances it is not surprising that, before the national curriculum was introduced, geography teaching in primary schools was variable in quality. It was frequently combined with history and often formed part of topic work in environmental studies or environmental education. Accordingly there was considerable variation in the teaching of map skills and some schools made little use of maps, even in studies of the local area. A survey of primary education in England carried out by HM Inspectorate between 1975 and 1977 concluded that 'there were substantial numbers of classes where no use was made of atlases, maps or globes. Even where work centred on the neighbourhood of the school, maps of the locality were introduced relatively infrequently' (DES, 1978: para. 5.136). The inspectors recommended that work in geography would benefit from more careful planning to provide some ordering of the content and ensure that children are introduced to essential skills.

Catling (1979) contrasted the active learning organised for infants with the more passive tasks expected of juniors. Thus when children in the 7-11 age range were given maps, little guidance was provided in their use. The result was that children often found map work unattractive and difficult. He recommended that children could begin by drawing cognitive maps, which the teacher could use for both diagnostic and teaching purposes. Used as a diagnostic instrument, cognitive maps provide the teacher with insights into the child's level of spatial understanding and graphic representation. When cognitive maps are used as a teaching technique, children can compare one another's maps for accuracy and orientation, and subsequently place their maps alongside a large scale plan of the neighbourhood for further instructive comparison. The diagnostic function was used by Matthews in his research outlined in chapter 1, whilst the teaching function was supported in books for teachers (for example, Boardman, 1983; Bale, 1987).

Other writers have encouraged the greater use of maps by primary school children, particularly those who have argued that graphicacy should complement literacy, numeracy and oracy in the curriculum. Graphicacy was defined by Balchin (1972) as 'the communication of spatial information that cannot be conveyed adequately by verbal or numerical means'. He recommended that teaching which includes the development of graphicacy should begin early in primary schools, building on children's emerging visual-spatial ability. Graphicacy is concerned especially, but not wholly, with spatial relationships as in maps.

Graphicacy has been claimed by geographers as particularly their concern, although Castner (1990) has argued that it is common to other subjects where spatial relationships are studied, notably mathematics, science, art and design. An influential handbook on geographical work in primary and middle schools (Mills, 1981) disseminated ideas about good practice which included the development of graphicacy, particularly through map skills. The first book to include the word graphicacy in the title (Boardman, 1983) included a list of 100 skills divided into groups considered appropriate for children in different age ranges. In addition to being widely encouraged by geographers, graphicacy has been acknowleged as a useful concept by authors who have discussed children's spatial understanding from a largely psychological perspective. Thus one geographer observes that 'graphicacy is now an accepted part of the primary curriculum' (Matthews, 1992: 214), whilst three psychologists recognise that 'graphicacy should be an explicit focus of the school's curriculum, and take its rightful place alongside the other basic expressive skills' (Spencer, Blades and Morsley, 1989: 253).

The protracted effort necessary to promote graphicacy and the greater use of maps in primary schools contrasts with the position in secondary schools, where geography has occupied a place in the curriculum for more than a hundred years and has largely been taught by graduate specialists in the subject (Balchin, 1993). Even before the introduction of the national curriculum, geography was taught, usually as a separate subject, to all pupils between the ages of 11 and 14. In view of the wide variation in the experiences of children from feeder primary schools, geography teachers have usually taught basic map skills to pupils when they enter secondary schools. The recognition of fieldwork as an important part of geography helped to ensure that pupils acquired at least a basic level of competence in reading and using maps inside and outside the classroom. Two major curriculum development projects concerned with geography for pupils in the 14-16 age range provided a stimulus for the further development of map reading and interpretation skills in courses leading to public examinations (Boardman, 1988; Boardman and McPartland, 1993 a,b,c).

The four basic concepts which pupils have to grasp in order to understand and use maps are *direction, location, scale* and *symbolism* (Boardman, 1983). Map skills frequently involve applications of mathematical concepts to the geography curriculum. Thus the concept of rotation through right angles in mathematics usefully precedes work on the points of the compass. Ideas about *direction* are then extended in geography so that pupils are able to state the direction in which they are moving when they walk, for example, round the school building or along streets in the neighbourhood.

The principle of *location* on a map is taught initially through finding places in squares identified by means of letters and numbers similar to those on A to Z street plans. An understanding of the concept of coordinates is required for reading grid references, and the use of grid lines is introduced when pupils have learnt to draw and read graphs in mathematics lessons. The numbers of the grid lines on an Ordnance Survey map start in the lower left-hand (south-west) corner and increase to the right (east) and upwards (north) in the same way as the numbers along the axes of graphs. Just as the number on the x axis of a graph is given before that on the y axis, so the easting on a map is given before the northing.

Pupils are often introduced to the concept of *scale* in mathematics by drawing simple plans of small objects on a table top and by inserting furniture on a plan of a room. In geography they learn to use a large scale plan of the school building and grounds, and measure, for example, the lengths of walls or perimeter of the playground from the scale line provided. When pupils have been taught the concept of ratio in mathematics they learn the meaning of map scales such as 1:10,000 and use maps for measuring distances and following routes.

Pupils appreciate the need for *symbolism* when they compare maps of the same area on different scales and observe the reduction in the amount of detail that is shown as the scale is reduced. They then note examples of the different kinds of symbols which are used to represent features on smaller scale maps: points (such as churches and stations), lines (such as roads and rivers), and areas (such as lakes and woodland). The contour is a linear symbol and when pupils understand the concept they will learn to associate different contour patterns with particular landforms, such as the set of concentric circles representing a hill. After pupils have been taught to draw line graphs in mathematics, they will learn in geography how to draw a cross-section along a line on the map, thus transforming a contour pattern into a section across the landscape.

After reviewing the educational literature and research evidence available at the time, and drawing on the experience of teachers in the classroom, I suggested the approximate ages by which children of average ability should normally be capable of acquiring various map skills (Boardman, 1983). I emphasised that the skills listed for each age range were tentative, and that the scheme was not intended to be applied rigorously to all children in all circumstances. Some children would be able to master various skills at earlier ages than those suggested, whilst slow learning children would not attain them until later. The sequence of skills was based on the Piagetian interpretation of spatial understanding outlined in the previous chapter and was compiled before psychologists such as Blades and Spencer (1986, 1987, 1989) had published the results of their research involving young children. The scheme may, therefore, underestimate the potential of younger children to use simple spatial representations rather than cartographic maps.

The list of skills considered appropriate for pupils in the 5-13 age range broadly corresponded with those suggested in a handbook on geographical work in primary and middle schools produced by the Geographical Association (Mills, 1981, 1988), and those for pupils in the 11-18 age range were reproduced in the Association's companion volume for teachers in secondary schools (Boardman, 1986). The lists subsequently formed the basis of the map skills section of the national curriculum.

The national curriculum

The introduction of a national curriculum into all primary, middle and secondary schools was a requirement of the 1988 Education Reform Act. The eleven years of compulsory education were divided into key stage 1 (ages 5-7), key stage 2 (ages 7-11), key stage 3 (ages 11-14) and key stage 4 (ages 14-16). Subject working groups were appointed to prepare programmes of study for teaching to pupils in the four key stages. Each subject was divided into a number of attainment targets, which in turn were divided into a series of statements of attainment. These were categorised into ten levels of difficulty for the purposes of assessment. The levels overlapped the key stages; for example, key stage 2 covered levels 2-5, whilst key stage 3 covered levels 3-7. The average 11-year-old pupil was expected to attain level 4 by the end of key stage 2, whilst the more able pupil would reach level 5.

The Government's aim in producing a national curriculum was to raise standards and its immediate effect was to standardise what is taught in schools. For the first time courses in all primary and secondary schools had to be designed within a centrally determined framework. Teachers were required to devise schemes of work round statutory programmes of study and attainment targets divided into large numbers of statement of attainment. This was a challenging task for teachers in primary schools, who had to prepare schemes of work for all subjects of the curriculum. Even in secondary schools, where the planning was undertaken by subject specialists, problems arose because the programmes of study were highly prescriptive and overloaded with content.

The position of geography, particularly in primary schools, was strengthened by its designation as a foundation subject in the national curriculum. 'Everyone needs to be able to read and interpret maps' said Secretary of State Kenneth Baker when he announced the terms of reference for the Geography Working Group in a DES press release on 5 May 1989. The task of the twelve members of the Group was essentially to construct an instrument which would standardise school geography courses and enable performance to be accurately measured. There was to be an emphasis on factual knowledge and basic skills to correct what were perceived to be inadequacies in school geography, particularly in the primary phase. The Group produced its report in May 1990 and a period of consultation with the teaching profession followed. After further revision the statutory Order for geography (DES, 1991) was approved by Parliament in March 1991 and was implemented in all primary, middle and secondary schools from September 1991.

The programmes of study for geography contained five attainment targets: geographical skills, knowledge and understanding of places, physical geography, human geography, and environmental geography. These were divided into 183 statements of attainment, each of which stated what pupils should be able to do at a particular level; for example, 'use four-figure grid references' (level 4); 'use six-figure grid references' (level 5).

The geographical skills attainment target included 29 statements of attainment relating to the use of maps, of which 21 were categorised at levels 3-7 and were thus appropriate for pupils in key stages 2 and 3. The statements broadly corresponded with the lists in the two Geographical Association handbooks (Mills, 1981; Boardman, 1986), although some ambiguity resulted from the overlap between key stages in the national curriculum. In order to draw attention to the element of progression when pupils are learning different kinds of map skills, I suggested that the 21 statements of attainment could be grouped (Boardman, 1991). For example, the first three statements listed at level 5 are 'use six-figure grid references' (5a), 'interpret relief maps' (5b), and 'follow a route on an OS map and describe features' (5c). However, statement 5a is a development of the level 4 statement 'use four-figure grid references' (4a), which in turn is a development of the level 3 statement 'use letter/number coordinates' (3a). These three thus form a group relating to the concept of location on a map.

Statement of attainment 5b, that pupils should be able to 'interpret relief maps' (DES, 1991:4), was the only one to refer directly to relief. This brief statement encompassed some of the most complex ideas relating to maps. Indeed the statement could be applied at increasing levels of difficulty to present a challenge to pupils of all ages up to level 10. The examples which accompanied the statement, however, indicated a fairly basic level of understanding: pupils should be able to 'read heights and identify slopes, hill tops and valley bottoms from contour maps' (DES, 1991:4). As the statement was categorised as level 5, it overlapped key stages 2 and 3 and thus lay at the interface between primary and secondary education. In this respect it differed from my previous recommendation that the interpretation of relief maps is best left until the secondary phase, when most pupils have made the transition from concrete to operational thought (Boardman, 1983). The concept of contours would rarely have been taught in primary schools before the introduction of the national curriculum, but it was now considered appropriate for the more able pupils in key stage 2. This was the main reason for undertaking the present research, the aims of which are to investigate the ways in which primary school children perceive common contour patterns and to identify some of the problems which they encounter in learning the concept of contours.

Learning the concept of contours

The common experience of teachers, supported by research findings, is that most children find the concept of contours difficult to understand. Accordingly the concept is not usually taught until pupils are making the transition from concrete to formal operational thinking. When learning to read contours, pupils have to *perceive* the linear symbol on the map and also have to understand the *concept* for which the symbol stands. The process of reading contours may be analysed by breaking it down into a number of distinct steps. The pupil has to:

1. Perceive the *lines* drawn on the map.
2. Read the *numbers* printed on the lines.
3. Understand that the numbers indicate *height* in metres above sea level.
4. Interpolate heights on unnumbered lines.
5. Estimate heights between numbered and unnumbered lines.
6. Appreciate that the lines and the spaces between them represent *slopes*.
7. Ascertain the *direction* of slope by comparing the numbers on different contours.
8. Recognise the *steepness* of slope from the spacing of the contours.

When the concept of contours has been understood, the pupil then has to learn to recognise the common contour patterns which represent valleys, spurs, hills and ridges. The recognition of these patterns could become a purely mechanical process, however, so it is important that the pupil attempts the final and most difficult stage. This is to try to visualise the landscape by mentally transforming the two-dimensional contour patterns into the three-dimensional landforms found in real environments.

It has been suggested by Sandford (1979) that pupils learn to perceive contours but to imagine slope, and then to put slopes together mentally in order to visualise the terrain. Although his views are speculative and he does not cite any research evidence to support his claims, Sandford suggests that an understanding of contours comes about in three stages. Firstly, pupils are only able to perceive contours as being closely or widely spaced, and as parallel or making nesting circles or re-entrants. Secondly, with experience and practice, pupils learn to see across the contours instead of along them, and to interpolate mentally the space between contours. Thus, when they read off heights, they are able to distinguish between steep and gentle slopes and between hill tops and valley bottoms. Thirdly, pupils develop an ability to see from the contours that the elements which make up the terrain form patterns which constitute landform types. Hills and valleys are then seen as elements in a terrain which may constitute, for example, an escarpment or a dissected plateau.

Since most children experience difficulty in understanding the concept of contours, a didactic method of teaching the concept by defining contours and drawing common patterns on the blackboard is unlikely to be adequate. For a long time, therefore, teachers have sought ways of presenting this abstract concept to pupils with the aid of hardware models of various kinds.

In an early article Davey (1910) said that models were absolutely necessary in teaching contours. He recommended starting with a model of a quite small area which was known to the pupils, then proceeding to others, each model being compared with a map on the same scale. Bradford (1910) advocated making a model of an island and putting into a dish of water, which had previously been marked off to represent heights. She also suggested that the model could subsequently be cut into two, so that the pupils could see a vertical section through the island. In a later article

David (1944) outlined five lessons with a class of top juniors (aged 10-11 years) in a Birmingham primary school. She based these on a model into which were inserted pins joined up with cotton to represent contours.

Several early method books on the teaching of geography included advice on ways in which pupils can construct their own models. Thus Wallis (1915) recommended that pupils who had reached what he described as 'the transition stage' (about 12.5 years) should make a model by tracing the coast and contours from a map at intervals of 100 feet. These were then transferred to strips of lath, cut out and built up into a stepped model, which was smoothed out using plaster. Barnard (1933) also recommended the building of a model from layers of wood to represent successive contour intervals. These layers were not glued together, however, so that they could be taken apart to provide a clear visual illustration of the concept. On the other hand Fairgrieve (1926) advocated the teaching of contours by means of a graded series of exercises without using models.

Long and Roberson (1966) believed that it is easier for pupils to grasp in simple terms how depth of water is measured than it is for them to understand how height of land is measured. They recommended an approach using submarine contours and devised a lesson based on an admiralty chart showing the depth of water in the Solent obtained by soundings at numerous points. The pupils had to show on the map the route which the Queen Elizabeth should follow in order to reach Southampton Docks safely. To do this they had to draw a line joining up points where the depth is 30 feet, interpolating where necessary from nearby soundings. They then shaded the area of deeper water below this submarine contour.

A development of the use of a plasticine island relates contours to sea level (Boardman, 1986). The island is placed in a fish tank, the side of which is marked with a scale graduated at regular intervals. The base of the tank represents the dry shore at low tide and water poured into the tank represents the incoming tide. When the water reaches the first mark on the scale, a line is drawn round the model by making an impression in the plasticine with an old ball point pen. This records the water mark, which represents sea level. More water is then poured into the tank to represent storm conditions which flood the land around the coast. Another line is drawn round the model when the water reaches the second mark on the scale. The process is repeated several times until the island is almost submerged. When the water is poured out of the tank the pupils can see the contours drawn at regular intervals on the model to indicate increasing height. Whilst this method is useful for teaching the concept of contours, it does not relate to a map of a real area.

A more effective method is to build up an accurate model of a small area by tracing contours from a map on to thick cardboard or polystyrene ceiling tiles (Boardman, 1986). As this method was used in the present research, it will be described in detail. The Ordnance Survey map containing the city of Durham on the scale of 1:10,000, the largest scale on which contours are shown, was used as the base map. This was enlarged so that the incised meander of the River Wear, within which lies the centre of the historic city, occupied most of a sheet of A3 size paper. From this enlargement the contours were traced at 5 metre intervals and where necessary interpolated. The bridges over the river were added, together with a scale line and compass point. The map is shown, reduced to A4 size, in Figure 3.1.

Polystyrene ceiling tiles, 500 mm square and 8 mm thick, were used as the building material. The 40 m, 50 m, 60 m and 70 m contours were traced on to separate tiles and the patterns were cut out with scissors. Marks were made on each tile to indicate the position of the next highest contour. The map was mounted on a piece of thick cardboard and the tiles were secured in position with adhesive. The resulting layer model at this stage of construction is shown on the left of Figure 3.2.

Although the edges of the layers at this stage represented the contours, the stepped or terraced appearance of the model did not resemble the real landscape. The spaces between the layers, therefore, were filled in with plaster and smoothed out. When dry the model was sanded down and painted green, apart from the river, which was painted blue. The completed relief model is shown on the right of Figure 3.2. The vertical scale is approximately double the horizontal scale.

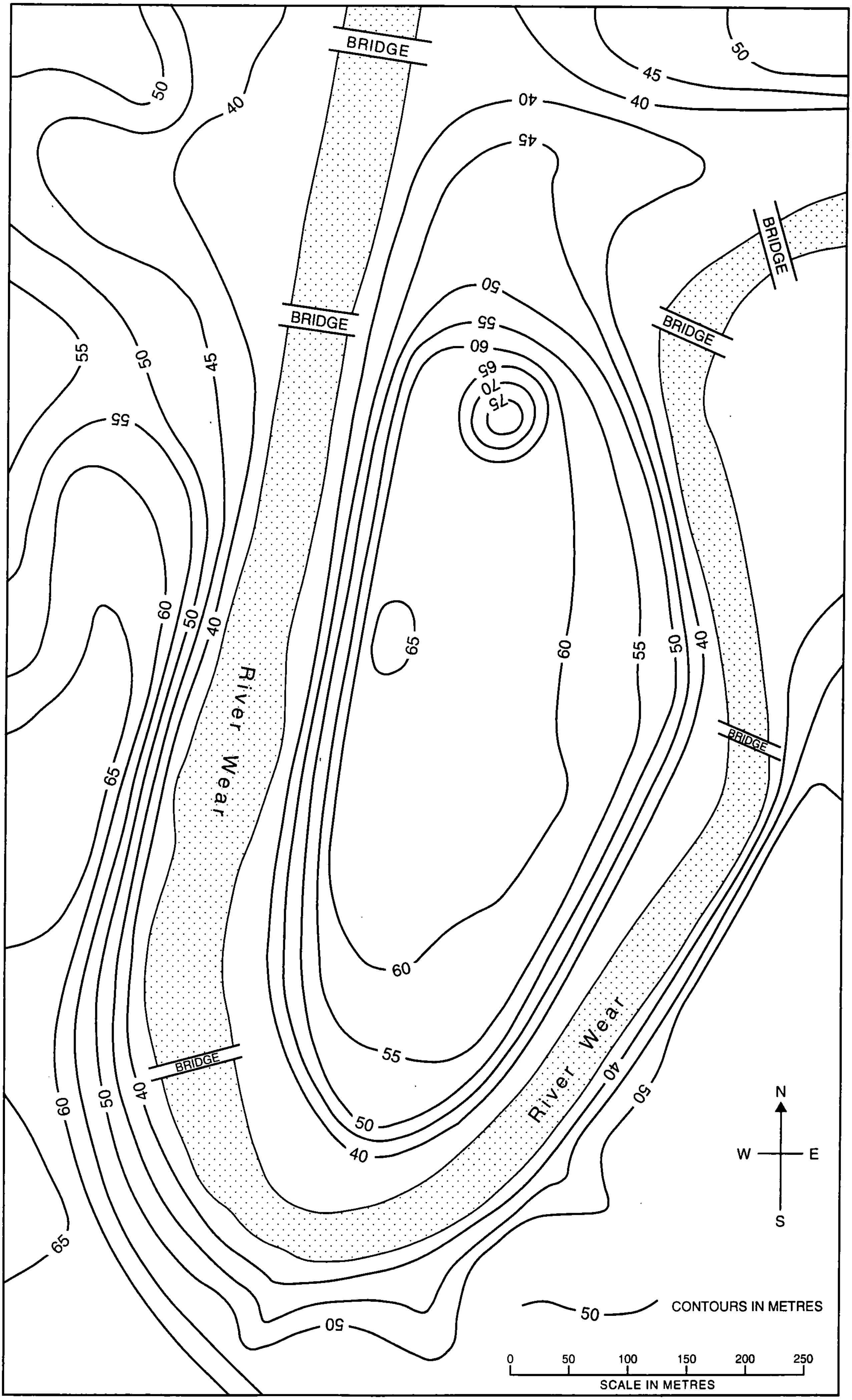


FIGURE 3.1. DURHAM MAP USED FOR MODEL BUILDING

FIGURE 3.2. MODELS BUILT FROM DURHAM MAP

The pilot study

A pilot study was undertaken to investigate the feasibility of teaching contours to older primary school children and to trial test questions designed to explore some of the problems which they encounter in attempting to understand the concept. The study was carried out with a class of children aged 10-11 years in a primary school situated about 10 miles south of Durham. The class contained 33 children, but holidays and absences meant that for most of the time 28 were present. The layout of the school was semi-open-plan, with classes separated by quiet areas enclosed by sliding partitions. A small craft area next to the class teaching area was ideal for practical work, and the adjacent quiet area was used for the subsequent testing of the children.

The children were shown a poster containing a low level oblique aerial photograph of the peninsula inside the meander of the River Wear at Durham, obtained from the Tourist Information Office. The photograph was taken from a point above the south-west corner of the map and could thus be aligned almost exactly with it after minimal rotation. The bridges on the map also appeared on the photograph, although differences in perspective meant that they did not coincide exactly.

The children were then given copies of the A3 size contour map of Durham and, after a brief introduction to contours as lines which show the height of the land, the method of constructing a relief model was explained. Model building materials provided for the children consisted of a pack of polystyrene ceiling tiles, a packet of plaster and a tub of adhesive. Children who did not build models from ceiling tiles used a roll of corrugated cardboard provided by the school, which also supplied tracing paper and paint.

The work with the children was undertaken over a period of eight mornings. In the first week all five mornings were used for teaching and practical work, and in the second week three mornings were used for testing the children.

The class had not done any previous work on contours, although a few children had encountered them in scouts or guides. I arranged with the class teacher to take a group of eight children (four boys and four girls) in the craft area on the first three mornings. After comparing the map with the photograph, the children traced the contours from the map working in pairs. They then transferred the contours on to the polystyrene tiles, using a complete tile showing the river as the base. The children cut out the contour shapes with scissors and used adhesive to secure the layers in position above the base. When plaster had been mixed the children moulded it between the layers with spatulas and smoothed out the steps on their models.

On the fourth morning the class teacher took the group of eight children whilst they painted their models. At the same time I took the rest of the class, showing the other twenty children how to construct models using corrugated cardboard. The procedure was similar, the children working in pairs. They glued the layers of cardboard in position on the fifth morning, but few had time to use plaster or paint before clearing up for the week-end.

The pilot testing was undertaken during the first three mornings of the following week, when the children were tested in pairs in the quiet area. The test with each pair took 10-15 minutes and was tape recorded using a battery-powered cassette recorder with a built-in microphone.

The map which the children had used for constructing their models was placed on the table in front of them. Red lines were marked on it to indicate footpaths. The children were asked to imagine that they were going for a walk along the footpaths, following a route marked by arrows. At each arrow they were asked to say whether they would be going uphill, downhill or on the level, and to say why. Red spots were also marked at intervals along the footpaths. At each one the children were asked to say at what height they would be at that point.

A specially drawn imaginary map, which the children had not previously seen, was then placed on the table. This contained similar red lines, arrows and spots. The children were again asked to imagine that they were following the route indicated, to say whether they would be going uphill, downhill or on the level at each arrow, and to give the height of the land at each spot. The children were asked two additional questions about this map, both of which asked them to choose a route from two alternatives indicated. Finally the children were asked to shade in pencil all land that was over 60 metres in height.

The work carried out by the class showed that it was feasible to teach the concept of contours to top primary school children with the aid of relief models which they constructed themselves, although it has to be acknowledged that the method was time-consuming. The polystyrene tiles formed strong, firm layers with which to build up the relief models, but the corrugated cardboard proved to be too soft and flexible for this purpose. It was subsequently found that the contours could be transferred from the map to the tiles without using tracing paper. By placing the map directly on to the tiles and pressing a sharp pencil point through the paper along the contours at frequent intervals, rows of closely spaced dots were left on the tiles.

The testing procedure also proved satisfactory, but certain modifications were considered necessary to the contour patterns and routes shown on the imaginary map in order to improve clarity and remove ambiguity. The final question which asked the children to shade the land over 60 metres in height took quite a long time and yielded little additional information, so it was decided to discard it, thus removing from the test the only question which required a written response. During the testing it was also found that one child in each pair tended to dominate the responses to the questions, so it was considered better to test each child individually in the main study which is reported in the next two chapters.

4. THE RESEARCH: STAGE 1

The aims of the research were to investigate the ways in which primary school children perceive common contour patterns and to identify some of the problems which they encounter in learning the concept of contours. The research was carried out in two stages with a class of children after they had been taught the concept of contours and had constructed a relief model from a contour map. The testing was designed to meet the requirement of statement of attainment 5b in the geography national curriculum. It will be recalled that this stated that pupils should be able to 'interpret relief maps', and the accompanying examples indicated that they should be able to 'read heights and identify slopes, hill tops and valley bottoms from contour maps'. This chapter reports the first stage of the research, which involved testing the pupils individually on contour maps and asking them to match contour patterns with cardboard layer models.

Teaching and practical work

The study was carried out in a primary school located in a former colliery village about three miles from the centre of Durham. The original school building dated from the early part of the century but it had been extended to the rear. Modifications completed in the 1970s made the interior of the school largely open plan, including the library and reading areas. The spacious layout of the school made it ideal for the purposes of the study, both for the practical work with the class and for the subsequent testing of individual children.

An initial visit was made to obtain the approval of the head teacher, and a second visit followed to discuss the details of the work with the class teacher. The class of year 6 children who participated in the study comprised 14 boys and 14 girls aged 10-11 years. The teaching and practical work took place over a period of four hours in two consecutive weeks. The testing of the children individually was completed in three days during the following week.

The map used for teaching the concept of contours was the same map of the River Wear at Durham as that used in the pilot study. It will be recalled that this map showed the contours on each side of the river at 5 metre intervals and occupied most of a sheet of A3 size paper. The map was complemented by the low level oblique aerial photograph of the peninsula inside the meander of the River Wear, which was taken from a point above the south-west corner of the map and could be aligned with it after minimal rotation.

A pack of large polystyrene ceiling tiles (500 mm square) and a packet of plaster were provided for the children. Sheets of thick cardboard were used for the bases of the models, and the school supplied adhesive and paint.

Earlier in the term the class had done some work on maps relating to the use of symbols and scale. The children had taken part in a paper chase on the school field, using a map of it prepared by their teacher. They had to find code letters hidden at various points by relating the map to the ground.

In the first lesson of this study the class teacher introduced the idea of contours to the children by demonstrating a computer program which transformed a contour map of a hill into a three-dimensional model of the hill. The poster containing the aerial photograph was then displayed and the children were shown how to build a model of the area from a contour map.

Working in five groups, the children transferred the contours from the map to the tiles by pressing a pencil point through the map along the contours, leaving rows of dots on the tiles. The children then cut out the contour shapes and glued them in position as a series of layers on the cardboard base, which contained a tracing of the banks of the river. By the end of the first hour most groups had placed several layers in position on the inside of the river meander.

As the children were actively engaged in this work, the class teacher allowed them to continue for a second hour. With the advice of a special needs teacher, who was also present for this hour, one group transferred only the contours at intervals of 10 metres on to the tiles. The other groups completed the layers on the outside of the river meander and glued them in position.

In the following week, during the third hour, plaster was mixed in a container for each group. The children filled in the spaces between the layers with plaster and smoothed out the steps on their models. All groups completed this work during the hour and the models were left to dry overnight. On the next day the children spent a further hour painting their models blue and green to resemble the river and wooded slopes shown on the aerial photograph. A total of four hours was thus devoted to the model building activity.

Test materials and procedure

The children were tested individually in the reading area of the library during a period of three days in the following week. A total of 27 pupils (14 boys and 13 girls) were tested (one girl was absent). Each test lasted about 15 minutes and was tape recorded. The children were told that the purpose of the tape recording was to save them from writing anything. A battery-powered cassette recorder with a built-in microphone was placed on the table. After it had been switched on the children seemed to ignore it as they were concentrating on the test materials and questions.

The map of the meander of the River Wear at Durham which the pupils had used for constructing their models was placed on the table. Red lines had been added to the map to represent footpaths. The A3 size map, reduced to A4 size, is shown in Figure 4.1. The pupils were asked to imagine that they were going for a walk along the footpaths, following the route indicated by arrows. At each arrow they were asked to say whether they would be going uphill, downhill or on the level. For the first one or two arrows they were asked to say why, until it was clear from their

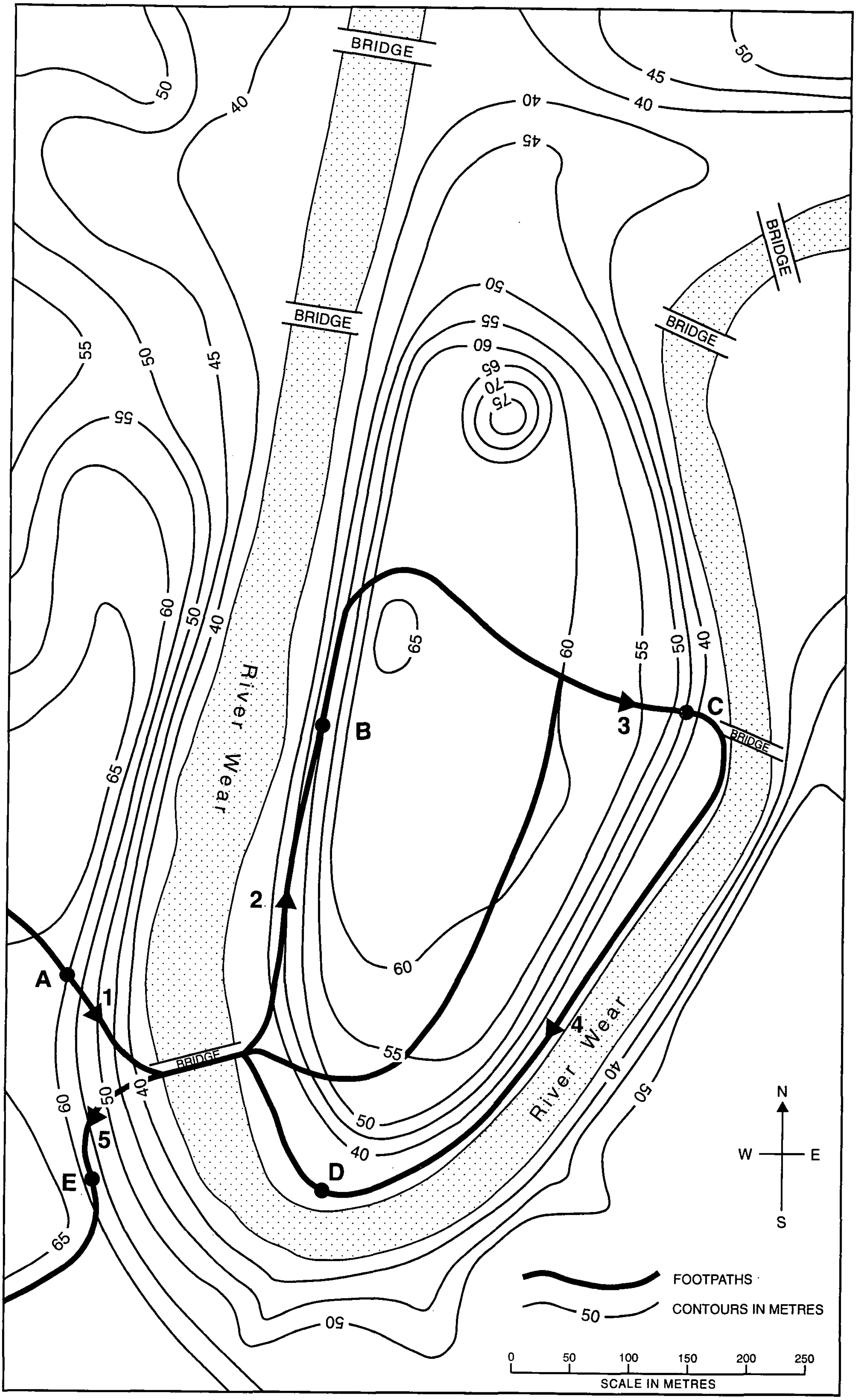


FIGURE 4.1. DURHAM MAP USED IN STAGE 1

answers that they were giving a correct explanation. If they made errors they continued to be asked for the reasons for their answers, but they were at no time told that they were wrong.

Red spots were also marked at intervals along the footpaths. At each spot the pupils were asked to say at what height they would be at that point. Again they were asked how they worked out the height for the first one or two spots, until it was clear that they could work out the height from the contours.

The children were then shown a specially drawn imaginary contour map which they had not previously seen. The contour patterns represented a hilly area with three small valleys occupied by streams, together with footpaths, arrows and spots marked in red. A copy of this A3 size map, reduced to A4 size, is shown in Figure 4.2. Again the pupils were asked to imagine that they were following the route marked on the footpaths, say whether they would be going uphill, downhill or on the level at each arrow, and give the height of the land at each spot. They were asked to give their reasons only at the first one or two arrows and spots if their answers were correct, but they continued to be asked for their reasons if they were making errors.

Two additional questions were asked about this map, both of which required the pupils to choose a route. They were taken back to point A on the map and told that they wanted to get to point C without climbing above 60 metres. They were asked to point to the route that they would take and explain why they had chosen it. The pupils were then told that they wanted to get from point C to point F, remaining on the level all the time. They were again asked to point to the route and say why they had chosen it.

Even if the children were able to read heights and identify slopes from contour maps, this would not necessarily mean that they were able to visualise slopes from contour patterns. For this reason a new element, not used in the pilot study, was introduced into the test. This asked the pupils to match simple contour patterns with cardboard layer models. A 150 mm square card bearing numbered contours was placed on the table alongside four layer models of the same size. Each model was

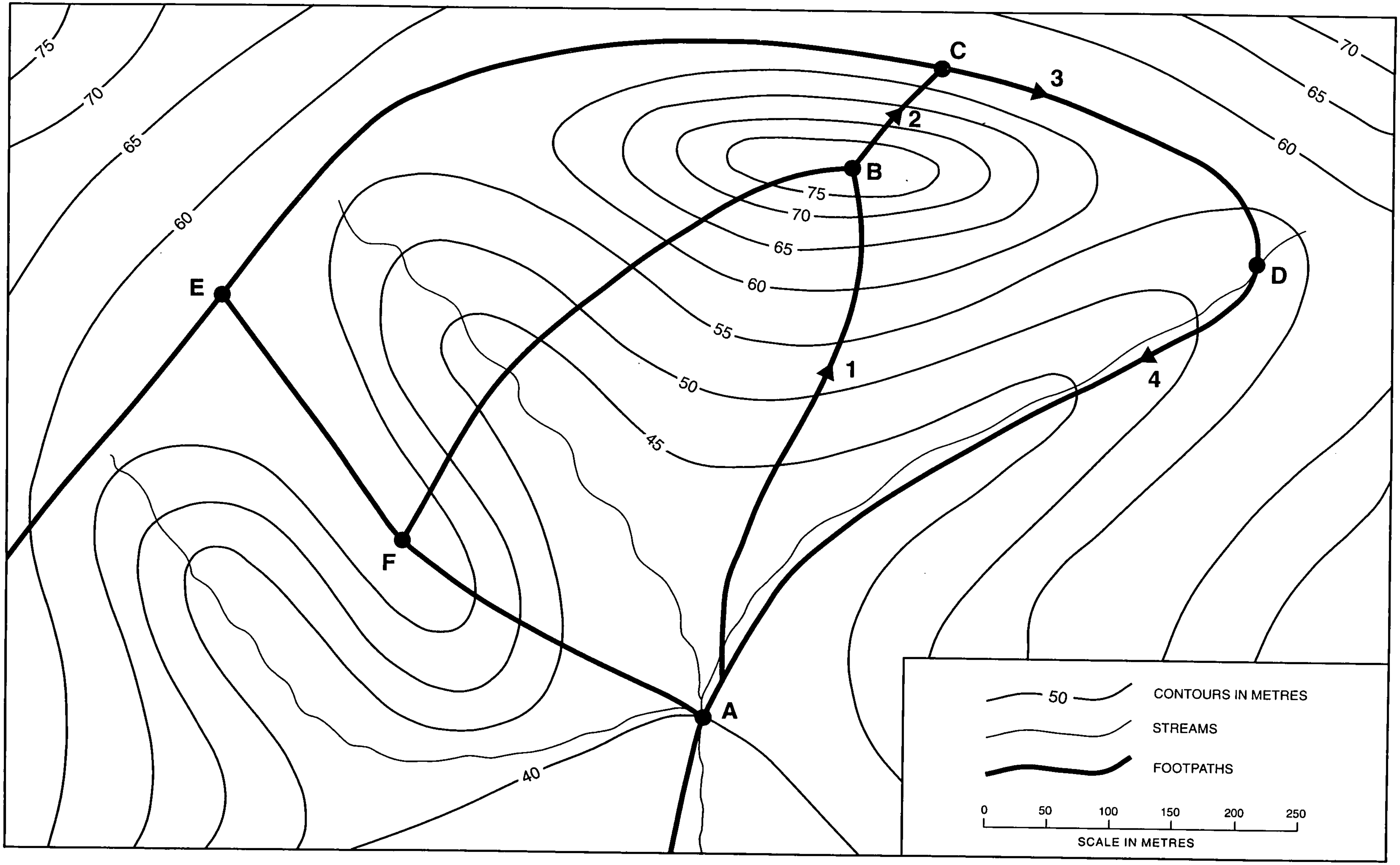


FIGURE 4.2. CONTOUR MAP USED IN STAGE 1

made from the same contour pattern on the card, but the layers were arranged in different ways and the contours on them were not numbered. The pupils were asked to select the model which showed the layers arranged correctly. The procedure was repeated with a further four contour patterns of increasing complexity.

The five contour patterns are shown, reduced in size to 75 mm square, in Figures 4.3-4.7, together with the different ways in which the layers of cardboard were arranged on the models. In each figure the base of the model is left blank, the first layer is stippled, and the second layer is shaded vertically. In Figures 4.4-4.7 the third layer is shaded diagonally and in Figure 4.7 the fourth layer is cross-hatched. For the purposes of the test the steps were not smoothed out as this would have obliterated the edges of the steps which represented the contours.

The pupils' tape-recorded answers to the test questions were transcribed using pro-formas (Appendices 1a,b,c,) on which the correct answers are given in brackets. The scores for each pupil on each question were subsequently entered on to tables showing boys and girls separately to facilitate comparison if differences emerged. The pupils' scores on the questions on reading heights on the two maps are shown together (Tables 4.1 and 4.2), followed by those on identifying slopes (Tables 4.3 and 4.4), and then those on matching contour patterns with layer models (Tables 4.5 and 4.6). Each '1' indicates a correct answer and each '0' an incorrect answer. The total number of pupils answering each question correctly is shown in the final column. Quotations from the transcripts are included in the accompanying text to illustrate the pupils' thinking when they were answering the questions.

Reading heights

The pupils were asked to give the height at each lettered spot on both maps. Every pupil except one gave the height of spot A on the first map (Figure 4.1) correctly as 60 m (Tables 4.1 and 4.2). The numbering of the contour close to the spot made this an easy initial question.

TABLE 4.1. BOYS' SCORES ON HEIGHTS IN STAGE 1
(n=14)

	Wn	Aa	Te	Sv	Ke	Le	St	Nr	Ab	Ar	Dv	Pl	Dn	Ax	Total
Map 1															
A	1	0	1	1	1	1	1	1	1	1	1	1	1	1	13
B	1	0	1	1	1	0	1	1	0	0	0	1	1	1	9
C	1	0	1	1	1	1	0	1	0	1	1	0	1	1	10
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	1	0	1	1	1	1	1	0	1	1	1	1	1	11
Map 2															
A	1	0	1	1	1	0	1	1	1	1	1	1	1	1	12
B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D	0	0	1	1	0	0	1	1	0	1	0	1	1	1	8
Total	4	1	5	6	5	3	5	6	2	5	4	5	6	6	63

Key — 1 Correct answer 0 Incorrect answer

Aa Andrew A — Ax Alex — Ke Keith — Pl Paul — Te Terry
Ab Andrew B — Dn Dean — Le Lee — St Stanley — Wn Wayne
Ar Aaron — Dv David — Nr Norman — Sv Steven

TABLE 4.2. GIRLS' SCORES ON HEIGHTS IN STAGE 1
(n=13)

	Ju	Da	Ka	Cl	Db	An	Dc	Sh	Jo	Li	Ro	Di	Ki	Total
Map 1														
A	1	1	1	1	1	1	1	1	1	1	1	1	1	13
B	0	0	1	0	1	0	0	0	0	1	1	1	0	5
C	0	0	0	0	0	0	1	0	1	1	0	0	0	3
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	1	0	0	0	1	2
Map 2														
A	1	1	1	1	1	1	1	1	1	1	1	1	1	13
B	0	0	0	0	0	0	0	0	0	0	0	0	1	1
C	0	0	0	0	0	0	0	0	0	0	0	0	1	1
D	0	0	0	0	1	0	0	0	1	1	1	0	1	5
Total	2	2	3	2	4	2	3	2	5	5	4	3	6	43

Key — 1 Correct answer 0 Incorrect answer

An Andrea — Da Donna A — Di Diane — Ka Karen — Ro Robyne
Cl Claire — Db Donna B — Jo Joanne — Ki Kimberley — Sh Sharon
Dc Donna C — Ju Julie — Li Linzie

The height of spot B, however, was given correctly as 50 m by only 14 pupils. The difficulty in reading a map with closely spaced contours may explain the misreading of the height of this spot by 5 boys and 8 girls. At this point the 50 m contour is close to the 55 m contour, the most commonly given wrong answer. In following the contour up or down the map to find the number, it was easy for the pupils to transfer from one contour to the next one.

Spot C required pupils to interpolate the height from the nearby numbered contours: 10 boys correctly said 45 m, but only 3 girls did so. The most commonly given incorrect answers were 50 m and 40 m, indicating that the pupils had either misread the contours or failed to calculate the mid-point between them.

For the purposes of scoring answers to the height of spot D, only the strictly geographically and mathematically correct answers 'between 35 and 40 m' or 'below 40 m' were accepted. No pupil gave either of these answers, but in retrospect this was a harsh scoring scheme, as most pupils said either 35 or 40 m. The pupils were probably used to being asked questions which required single numbers for answers, and would not be expecting a question to which there was an imprecise answer, or more than one answer. It is also hardly surprising that the pupils did not refer to the continuous slope down towards the river because they had not been specifically taught this process. However, they had built a model on which they placed the 40 m tile parallel to, but at some distance from, the river bank, and subsequently smoothed out the slope.

Presented with the problem of estimating height from the available information, the pupils engaged in a variety of reasoning. Some simply read off the figure 40 from the nearest contour:

> 'It's nearest to this contour here, the 40' (Donna A).

But others realised that estimation was involved:

> 'Well, I went down that, and I thought it would have been 35. 'Cos it went from 50 to 45 and then 40 to 35' (Keith).
>
> 'Cos it goes 50, 45, 40, 35 and then 30' (Dean).

'Like 30, 20, 10' (Sharon).

'I just drawed another contour downwards' (Norman).

Keith drew in the 35 m contour in his imagination; Dean inserted another two contours; and Sharon worked only in tens.

Spot E, located between two contours, produced the biggest differences between the answers of boys and girls. 11 boys but only 2 girls either said that it was between 55 and 60 m or estimated it at about 57.5 m. Most other pupils said that it was either 55 or 60 m. This was a difficult question because it involved not only interpolating the height of an unnumbered contour (55), but also estimating the height between two contours. Mistakes occurred in the process of computation; for example, Stanley initially said that the spot was 'between 60 and 50', and when asked for the height mid-way between 55 and 60, he replied '53'.

On the second map (Figure 4.2) the height of spot A was given correctly by all of the girls and all except two of the boys, who did not apparently notice the 40 m contour numbering close to the spot.

The only geographically and mathematically correct answers for the height of spot B are 'between 75 and 80 m' or 'above 75 m'. Again in retrospect this was a harsh scoring scheme as only one pupil gave either of these answers, and nearly all of the others said either 75 or 80 m. This is understandable because the pupils had not been specifically taught that the top of a hill is higher than the highest contour, even when they were model building.

Working out the height of spot C is probably the most difficult question on the map. It lies between two 60 m contours, indicating that it is between 55 and 60 m in height. This has to be inferred by following the 60 m circular contour round the hill and noting another 60 m contour near the top corner of the map. The pupils had not been taught this aspect of map reading, so it is hardly surprising that only one pupil worked out the correct height. Although two other pupils said that spot C was 'between 60 and 60' (not a correct answer), most of the others said that it was at 55 or 60 m after counting:

'That contour there is 75, that one's 70, that one's 65, that one's 60, and that one will be 55' (Donna A).

'75, 70, 65, 60, then it will be 55' (David).

A few pupils, however, counted upwards from 75, despite the circular contours:

'80, 85, 90, 95, 100' (Lee).

'80, 85, 90, 95, 100, 105' (Sharon).

The height of spot D was correctly stated as being between 50 and 55 m by 8 boys and 5 girls. Most of the others said that it was 50 or 55, simply reading off the number of one of the contours without making the further deduction that the point was between the two contours.

The pupils' performance on reading heights may be summarised as follows:

(a) Nearly all pupils could read the height of a point on a contour bearing a number close to it (spot A on both maps).

(b) When the contours were closely spaced and had to be followed some distance before a number was reached, some pupils misread the number because they transferred to the next contour above (spot B on map 1).

(c) If the point was on an unnumbered contour, some pupils made errors in interpolating its height from adjacent contours above and below (spot C on map 1).

(d) If the point lay between two contours, some pupils made errors in giving its height even when the contours were numbered close to the point (spot E on map 1, spot D on map 2).

(e) Pupils did not necessarily realise that the top of a hill was higher than the highest contour, suggesting that they saw it as a flat top (spot B on map 2).

(f) Pupils did not necessarily realise that the bottom of a slope was lower than the lowest contour, again suggesting that they saw the slope as flattening out immediately below the contour (spot D on map 1).

(g) Pupils did not necessarily realise that the land between two adjacent contours bearing the same number was lower (or higher) than these two contours (spot C on map 2).

Identifying slopes

The pupils were asked to say whether they would be going uphill, downhill or on the level at each arrow on both maps. On the first map (Figure 4.1) 11 boys correctly said that they would be going downhill at arrow 1, but only 4 girls did so (Tables 4.3 and 4.4). Pupils who said that they would be going uphill gave some interesting reasons; for example:

> 'It's 60, then it goes up to 55, and then up again to 50, so it's going up' (Donna A).
>
> 'Cos you're going up higher metres. The lower the metres, the higher you're up' (Terry).
>
> 'The arrow's pointing up that way' (Andrea).
>
> 'Cos the numbers are going down' (Dean).

What made these pupils think that increasing height is indicated by decreasing numbers of metres is a mystery. They had built a model in which height increased from 40 m near the river to over 60 m at the top of the steep valley sides. When attempting to answer this question the pupils may have been confusing height with area, as reflected in the decreasing size of the layers as they reached the top of their model. Or they may have been using some other cue and referred to the numbers to justify their decision. They might have been thinking, for example, about rank order, when smaller numbers (1,2,3 etc) indicate a higher position than bigger numbers.

11 boys and 6 girls correctly said that they would be going uphill at arrow 2. Some said that they would be on the level and gave apparently good reasons:

> 'Cos the arrow's pointing alongwards' (Stanley).
>
> 'Cos the end of the triangle thing is on the line' (Linzie).
>
> 'It's on the black line' (Robyne).

The close proximity of the contours and the size of the arrow head does indeed make it difficult to decide whether the path is on the level or going uphill at this precise point.

TABLE 4.3. BOYS' SCORES ON SLOPES IN STAGE 1
(n=14)

	Wn	Aa	Te	Sv	Ke	Le	St	Nr	Ab	Ar	Dv	Pl	Dn	Ax	Total
Map 1															
1	1	1	0	1	1	1	1	1	0	1	1	1	0	1	11
2	1	1	1	1	1	1	0	1	1	1	1	0	1	0	11
3	1	1	1	1	1	1	1	0	1	1	1	0	1	1	12
4	1	1	0	1	1	1	1	0	1	1	1	1	1	1	12
5	1	1	0	0	1	1	0	0	0	0	1	1	0	0	6
Map 2															
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
2	1	1	1	0	1	0	0	0	0	1	1	1	1	1	9
3	1	1	0	1	1	0	1	0	0	1	1	1	1	1	10
4	1	1	1	1	1	0	0	1	1	0	1	1	1	0	10
A-C	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
C-F	1	1	1	1	1	1	0	1	1	1	1	1	1	1	13
Total	11	11	7	9	11	8	6	6	7	9	11	9	9	8	122

For Key see Table 4.1

TABLE 4.4. GIRLS' SCORES ON SLOPES IN STAGE 1
(n=13)

	Ju	Da	Ka	Cl	Db	An	Dc	Sh	Jo	Li	Ro	Di	Ki	Total
Map 1														
1	0	0	0	0	0	0	1	0	1	1	0	0	1	4
2	1	1	1	0	1	0	1	1	0	0	0	0	0	6
3	1	0	0	0	0	1	0	1	0	0	1	1	1	6
4	1	1	0	0	0	1	0	1	1	1	1	0	1	8
5	0	1	0	0	0	0	0	0	1	0	0	1	1	4
Map 2														
1	1	1	1	0	1	1	1	0	0	0	1	0	1	8
2	0	1	0	0	0	1	0	0	0	0	0	0	1	3
3	1	1	0	0	0	1	0	1	1	1	1	1	0	8
4	1	0	1	0	1	1	1	1	0	0	1	0	0	7
A-C	1	1	1	1	1	1	1	1	1	1	1	1	1	13
C-F	1	1	1	0	1	1	1	0	0	1	1	1	1	10
Total	8	8	5	1	5	8	6	6	5	5	7	5	8	77

For Key see Table 4.2

At the more widely spaced contours where arrow 3 is located, 12 boys and 6 girls knew that they would be going downhill. Of the pupils who thought that they would be on the level, one remembered the model:

'Cos it's going straight across the top' (Paul).

But another had a more obscure reason:

'Cos the end of the triangle is on the 55' (Linzie).

Arrow 4 is parallel to the contours and 12 boys and 8 girls correctly said that they would be on the level at this point. Those who thought that they would be going downhill had not grasped this idea:

'Cos it's in the middle of the contour line. It's going down' (Donna C).

'It's pointing downwards' (Norman).

It is interesting and puzzling that only 6 boys and 4 girls correctly concluded that they would be going uphill at arrow 5. A few pupils repeated their earlier error in which they associated increasing height with decreasing numbers of metres on the contours:

'We're going from 50, and going down to 60. The higher the metres, the lower it is' (Terry).

Other pupils gave more obscure reasons:

'The arrow's pointing downhill' (Julie).

'It's pointing down' (Norman).

They were clearly associating an arrow pointing towards the bottom of the map with movement downhill.

On the second map (Figure 4.2) all of the boys and 8 of the girls knew that they would be going uphill at arrow 1. This answer could easily be worked out by looking at the series of numbered contours close to the footpath. The girls who said that it was on the level gave some interesting reasons:

'Cos it's a straight line' (Sharon).

'Cos it's going straightish' (Joanne).

'Cos it's between the two lines' (Linzie).

The origin of the association of a straight line with level ground is difficult to ascertain. If the pupils imagined that the land between two contours was level, they were probably imagining it as rising in a series of steps.

Only 9 boys and 3 girls correctly worked out that they would be going downhill at arrow 2. They had noted the circular, enclosed contours indicating the hill and, by following the numbering round the contours, realised that they would be going down the other side. Some pupils thought that they would be on the level:

'Cos it's a straight line' (Sharon).

'Cos it's just like on top of there. You're just going straight along' (Lee).

'Cos the point of the arrow's on the line' (Linzie).

Other pupils thought that they would be going uphill:

'Because the line's going up' (Joanne).

'It's pointing up' (Norman).

'Cos the arrow's pointing up' (Robyne).

When asked how she knew that it was going up and not down, Robyne replied:

'Cos the point's at the top'.

Steven, who had also said that the arrow was pointing up, similarly answered:

'Cos there's a pointer on the top of the arrow'.

These pupils were clearly associating an arrow pointing towards the top of the map with movement uphill.

10 boys and 8 girls said correctly that they would be going on the level at arrow 3, having noted that it lay on the footpath at a point where it was parallel to a contour. Others failed to make this association, saying that they would be going downhill:

'Cos the arrow's pointing down' (Donna C).

'Cos it's just like on the slope again. The lines are wider out' (Lee).

At arrow 4, 10 boys and 7 girls knew that they would be going downhill. The others said that they would be on the level, apparently ignoring the contours:

'Cos it's going straightish' (Joanne).

'Cos it's between the two lines' (Linzie).

All 14 boys and all 13 girls made the correct choice when asked to select the route that would enable them to walk from point A to point C on the map without climbing above 60 m. The pupils apparently found this an easy choice to make because it was clear that the path through point B would take them above 75 m, leaving the route through D as the correct one.

The map showed a choice of three possible routes between point C and point F. 13 boys and 10 girls correctly chose the path through point E as the one that would enable them to stay on the level all the time. Three pupils chose the path through point B, and of these two seemed to be influenced by the directness of the route:

> 'Cos it looks a bit straighter' (Sharon).
>
> 'Cos it's sort of quicker. And it's probably easier than going round the hill' (Stanley).

The third simply repeated the wording of the question:

> 'Cos it's like it's going on the level' (Joanne).

One pupil chose the route that went through point A as well as point B, and gave an obscure reason:

> 'Cos it's easier to get across. There's only short lines' (Claire).

The pupils' performance on identifying slopes may be summarised as follows:

(a) When working out the direction of slope, pupils did not always look across the contours and read the numbers (arrow 1 on both maps, arrow 5 on map 1).

(b) When the contours were closely spaced, and the direction of travel was obliquely across them, pupils sometimes interpreted this as movement on the level, at least locally at the point of the arrow (arrow 2 on map 1).

(c) When the contours were widely spaced, some pupils interpreted the land as being flat, even when the numbering of the contours and the direction of travel indicated a slope (arrow 3 on map 1, arrow 4 on map 2).

(d) Even when the direction of travel was parallel to the contours, some pupils did not necessarily interpret the land as being level (arrow 4 on map 1, arrow 3 on map 2).

(e) When the contours had to be followed for some distance before the numbers were reached, it was even more difficult for some pupils to work out the direction of slope (arrow 2 on map 2).

In addition to the above, a few pupils were for some reason under the misapprehension that the lower the number on a contour, the higher was the land, whilst others associated an arrow pointing towards the top of the map with an uphill slope, and an arrow pointing towards the bottom of the map with a downhill slope.

Matching patterns with models

The final part of the test asked the pupils to match the simple contour patterns with the cardboard layer models. A 150 mm square card bearing numbered contours was placed on the table alongside four layer models of the same size. Each model had the same contour pattern as the card, but the layers were arranged in different ways and the contours on them were not numbered. The pupils were asked to select the model which matched the pattern. The results are shown in Tables 4.5 and 4.6, and the pupils' choices are summarised in Table 4.7.

The pattern on card 1 consisted of two contours increasing in height from right to left (Figure 4.3). This pattern was correctly matched with model B by 5 boys and 8 girls. Of those who did not match the pattern correctly, 7 pupils chose A, 3 chose C and 4 chose D. Since half of the pupils made mistakes in this task, some may have been guessing. Certainly some who matched the pattern with model A did not give a reason and just said:

> 'Cos it matches' (Norman).
>
> 'Cos they look the same' (Robyne).

On the other hand at least one pupil had carefully examined the pattern and models before choosing A:

> 'I measured it like, roughly, where the lines are, how long. It's roughly about the same' (Terry).

TABLE 4.5. BOYS' SCORES ON MODELS IN STAGE 1
(n=14)

Pattern	Wn	Aa	Te	Sv	Ke	Le	St	Nr	Ab	Ar	Dv	Pl	Dn	Ax	Total
1	1	1	0	0	0	0	0	0	1	0	0	0	1	1	5
2	0	0	0	0	1	1	0	1	0	0	0	0	1	1	5
3	1	1	1	1	1	0	1	1	0	1	1	0	1	1	11
4	1	1	0	1	1	0	0	1	0	1	1	0	1	1	9
5	0	0	1	0	1	1	0	0	0	0	0	1	1	1	6
Total	3	3	2	2	4	2	1	3	1	2	2	1	5	5	36

For Key see Table 4.1

TABLE 4.6. GIRLS' SCORES ON MODELS IN STAGE 1
(n=13)

Pattern	Ju	Da	Ka	Cl	Db	An	Dc	Sh	Jo	Li	Ro	Di	Ki	Total
1	1	1	1	1	1	0	1	1	1	0	0	0	0	8
2	0	0	0	0	1	0	1	1	0	1	1	0	0	5
3	1	1	1	0	1	1	1	0	1	1	1	1	1	11
4	0	1	1	1	0	0	1	0	1	1	0	0	1	7
5	1	1	1	1	0	0	1	0	1	1	0	0	1	8
Total	3	4	4	3	3	1	5	2	4	4	2	1	3	39

For Key see Table 4.2

TABLE 4.7. PUPILS' CHOICE OF MODELS IN STAGE 1
(Boys and girls, n=27)

Pattern	Correct		Reverse		Others			
1	(B)	13	(D)	4	(A)	7	(C)	3
2	(G)	10	(F)	17	(E)	0	(H)	0
3	(J)	22	(L)	5	(K)	0	(M)	0
4	(O)	16	(N)	11	(P)	0	(Q)	0
5	(U)	14	(T)	8	(R)	5	(S)	0

Another pupil who matched the pattern with model C had also carefully compared them:

> 'Cos that's going down there about the same width as that. And the same there. And it's about the same going to there round there. And it's about the same in the middle' (Paul).

A pupil who matched the pattern with model C had similarly compared them:

> 'Cos on the first one, on C, that comes in like sharpish. It's not like as fat as that one. D looks about the same as that one' (Stanley).

It would appear from the last two quotations that the pupils were looking for slight variations in the way the layers of the models had been cut from the cardboard, even though they had been told that the patterns on all the models were the same. They were not matching the numbering on the pattern with the layers on the models.

The pattern on card 2 contained three contours increasing in height from left to right (Figure 4.4). This pattern was correctly matched with model G by only 5 boys and 5 girls. Despite the simplicity of the pattern, less than half of the pupils completed the matching task correctly. It is noteworthy that every pupil who made an error said that the pattern matched model F. This is the complete reverse of the contour pattern, the height on model F increasing from right to left. Sometimes the pupils arrived at the model by a process of elimination, models E and H being rejected because they had flat areas, with a contour on the card but no step on the model:

> 'On this one like it's only got three different contours, so it couldn't have been that one, and this one only had three as well, and this one, that looks littler than that bit, and this one looks littler than that, and doesn't look the same on this one here' (Donna A).
>
> 'That and that looked the right size, and they're in the correct places, as it goes down' (Andrew A).

Card 3 contained the easiest contour pattern, a series of three enclosed nesting contours rising in height (Figure 4.5). Most pupils, 11 boys and 11 girls, matched it correctly with model J. They may have remembered the computer program which demonstrated the contour pattern of a hill at the start of the first lesson, as well as the small hill they had built on their models. All pupils who failed to match the pattern with model J chose model L, which had the contour pattern reversed as a small depression. The flat areas with no steps on models K and M were rejected because the pupils saw that a step was missing.

The pattern on card 4 showed three contours representing a small valley near the top and a spur near the bottom (Figure 4.6). Slightly more than half of the pupils, 9 boys and 7 girls, correctly matched it with model O. All those who failed to do so said that it matched model N, which was again the reverse of the contour pattern. The pupils were able to eliminate models P and Q because they contained a flat area with no step where there was a contour on the card.

For card 5, however, the process of elimination could not be used because all models contained the same number of steps as contours on the card. The pattern consisted of four contours representing a valley on the left and a spur on the right (Figure 4.7). This was correctly matched with model U by only half of the pupils, 6 boys and 8 girls. Of those who failed to match it correctly, 8 chose model T, the reverse of the contour pattern, 5 chose model R and none chose model S.

To summarise the pupils' performance in matching contour patterns with layer models, pattern 3 was the only one which was readily matched with the correct model by most pupils, who recognised that the pattern of enclosed nesting contours represented a hill. The remaining four contour patterns were matched with the correct models by an average of only about half of the pupils. All pupils who failed to match patterns 2 and 4 correctly chose the models which represented the reverse of the actual patterns, and most of those who did not match pattern 5 with the correct model again selected the one which was the reverse of the actual pattern. The frequent choice of the models representing the reverse of patterns 2 and 4, and to a lesser extent pattern 5, was the most interesting error to emerge in the series of matching tasks.

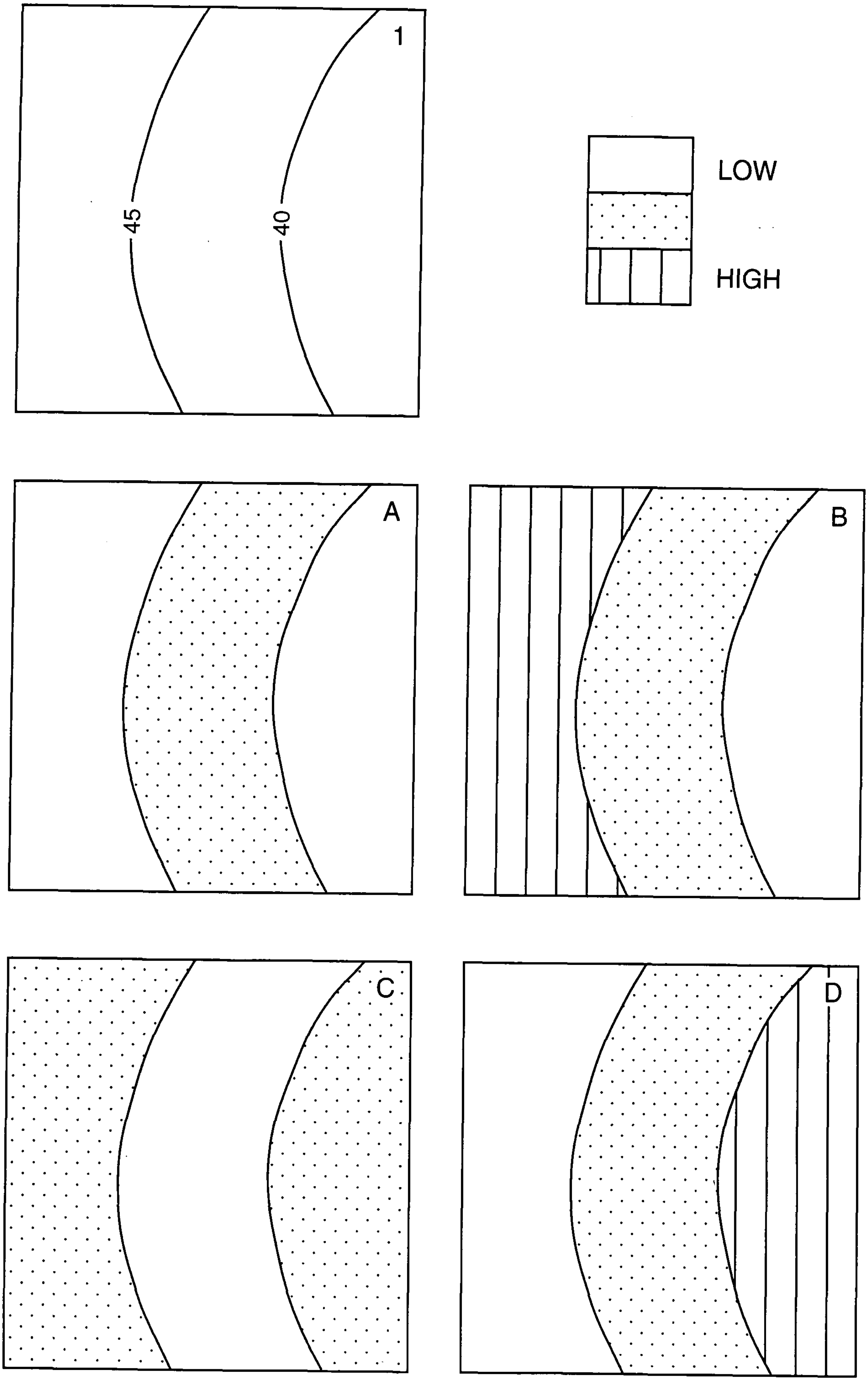


FIGURE 4.3. CONTOUR PATTERN 1 AND LAYER MODELS A-D

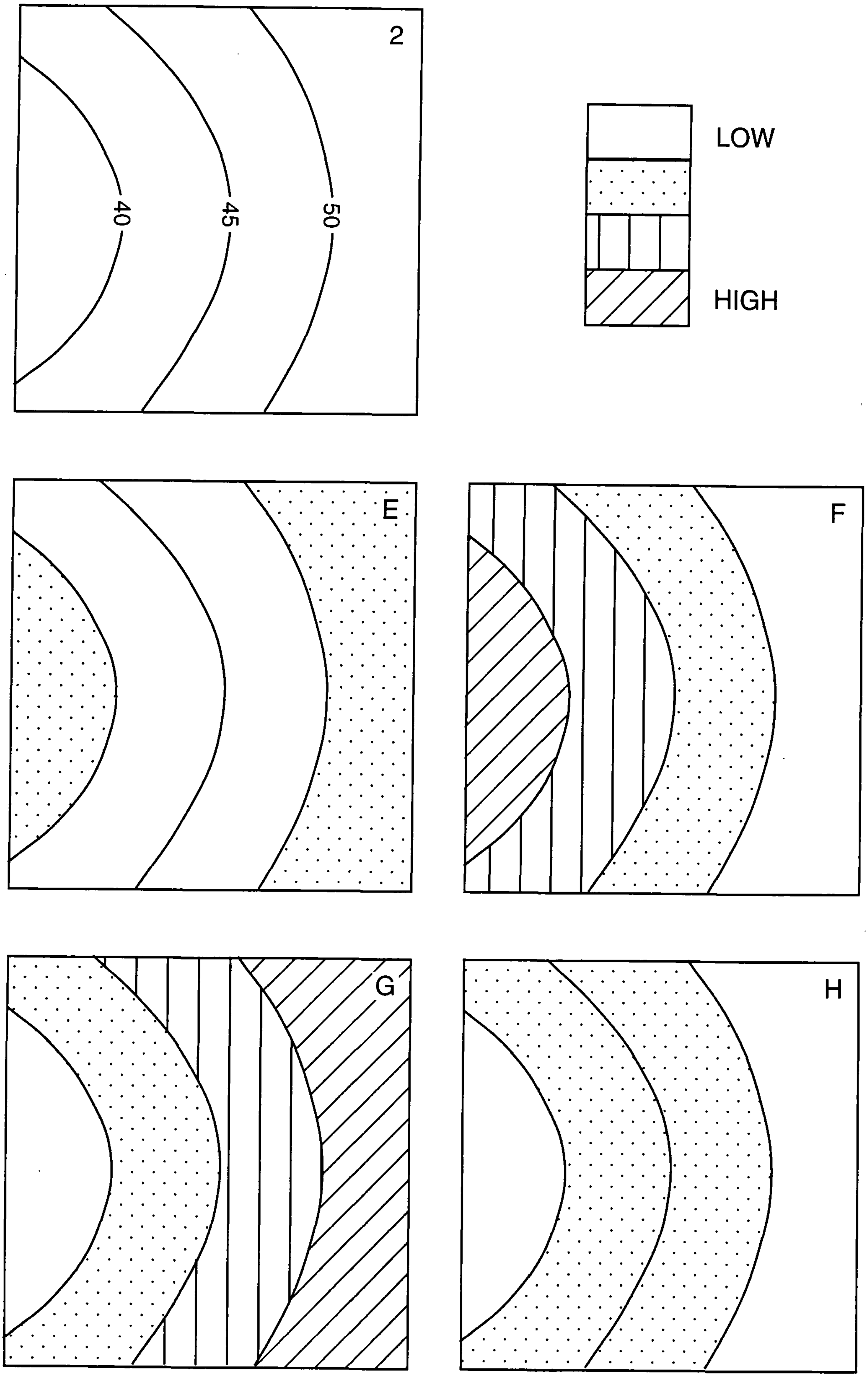


FIGURE 4.4. CONTOUR PATTERN 2 AND LAYER MODELS E-H

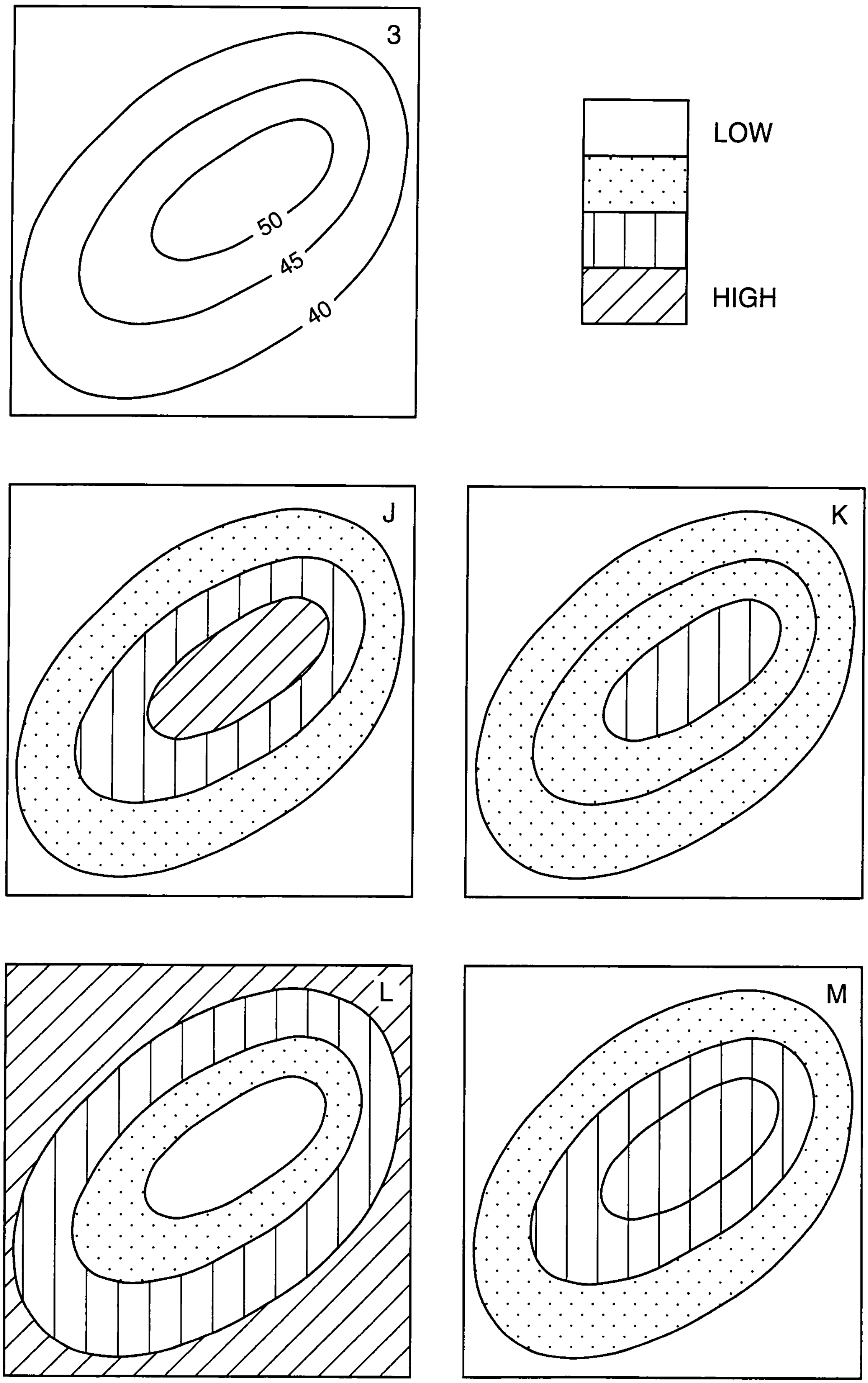


FIGURE 4.5. CONTOUR PATTERN 3 AND LAYER MODELS J-M

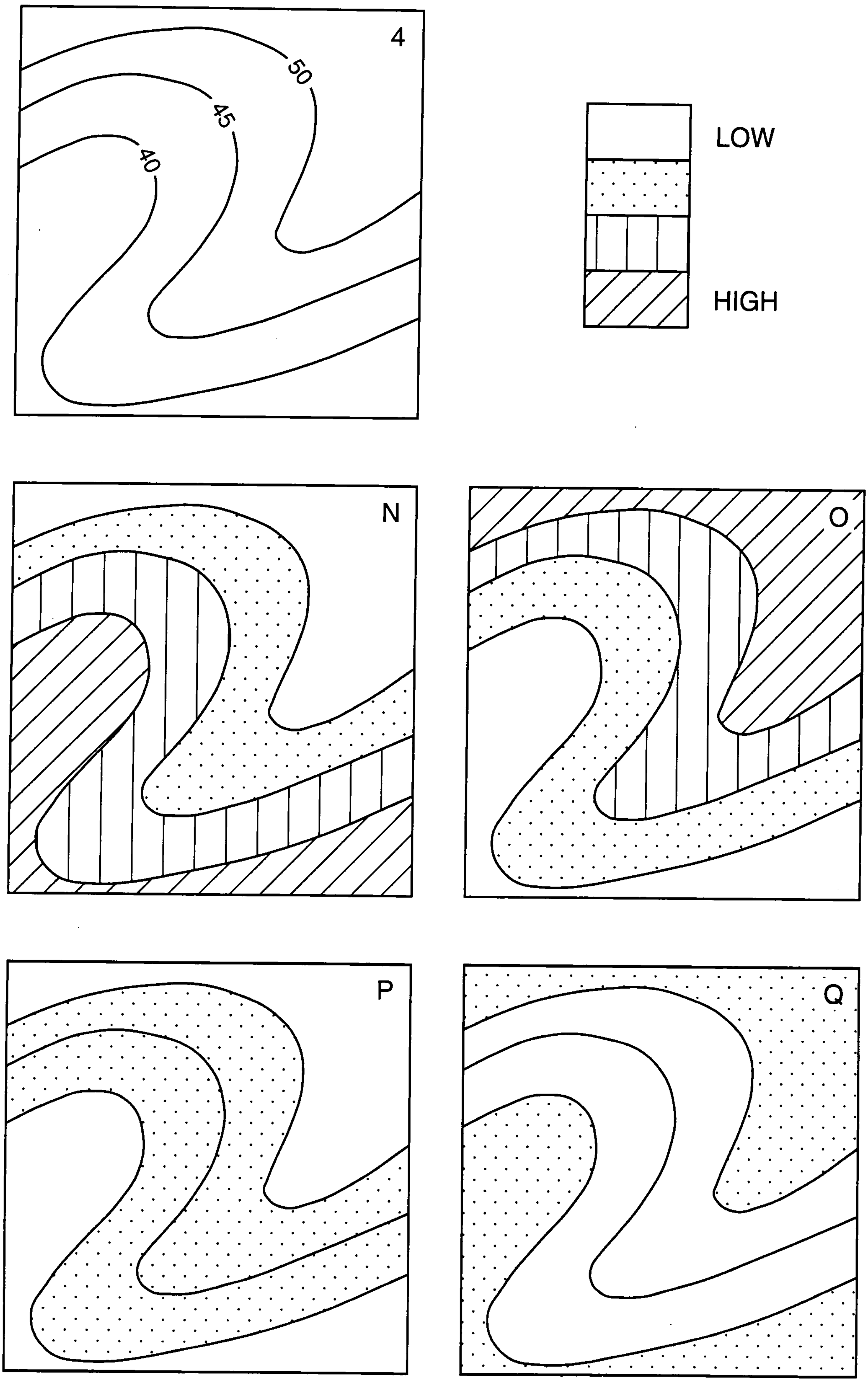


FIGURE 4.6. CONTOUR PATTERN 4 AND LAYER MODELS N-Q

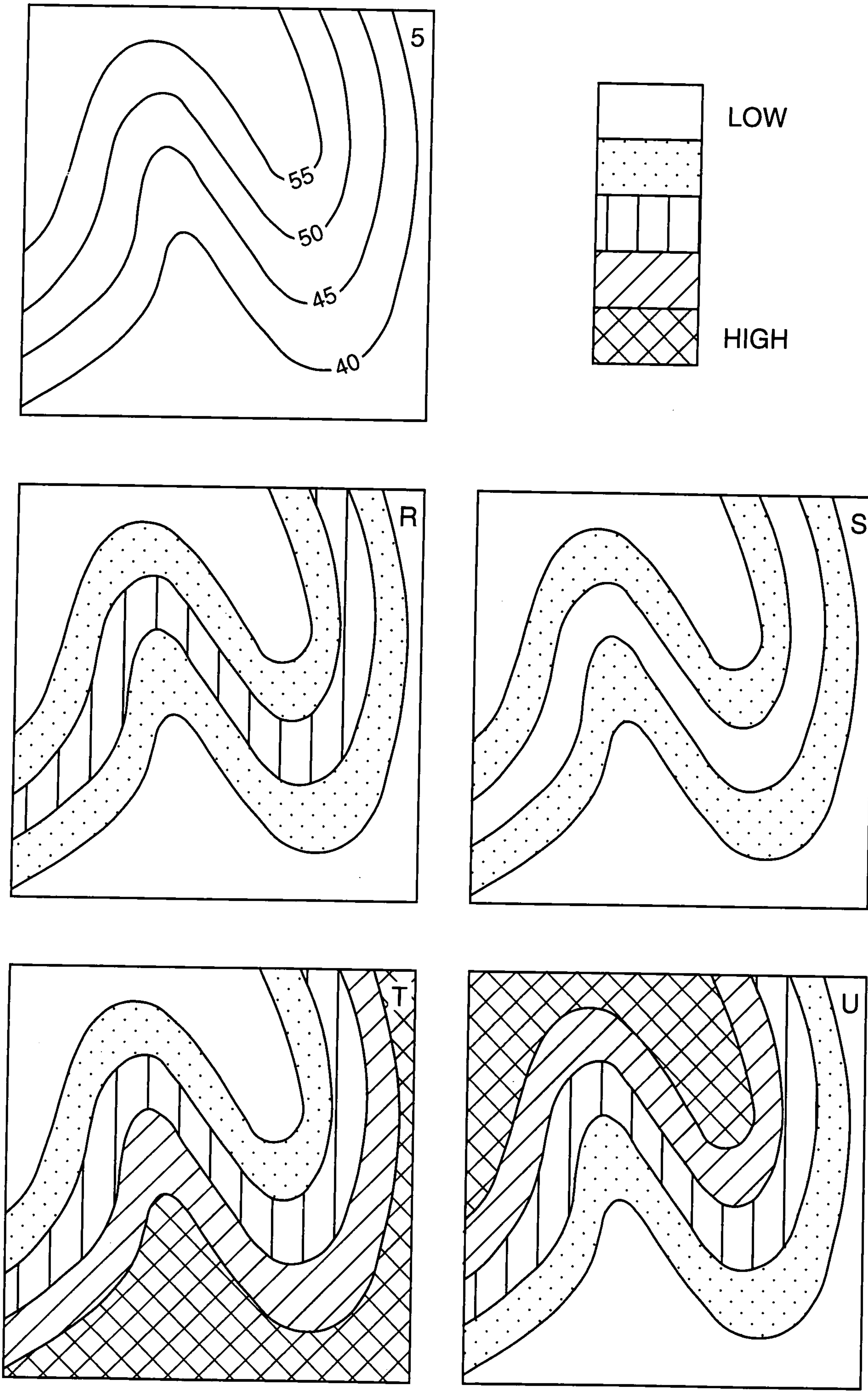


FIGURE 4.7. CONTOUR PATTERN 5 AND LAYER MODELS R-U

Overall performance

The scores obtained by the 14 boys on the three sections of the test and their total scores on the test as a whole are shown in Table 4.8. The scores obtained by the 13 girls are shown in a similar way in Table 4.9. It will be seen that the boys' scores on the test ranged from 10 to 20 out of 25, and the girls' scores ranged from 6 to 17. The mean scores of the 27 pupils on the three sections of the test and on the test as a whole are shown in Table 4.10. It will be seen that the pupils obtained a mean overall score of 14.0 out of 25 (SD=3.3).

Although the number of pupils involved was small, it is interesting to note that the boys achieved a higher overall score (mean=15.8, SD=3.0) than the girls (mean=12.2, SD=2.8). Application of the 't' test showed that the difference between the mean scores of the boys and the girls was significant at the 0.05 confidence level (t=2.8, d.f.=25).

On the height questions, where the overall mean was 3.9 out of 9, the mean for the boys (4.5) was higher than that for the girls (3.3). On the slope questions, where the overall mean was 7.3 out of 11, the mean for the boys (8.7) was again higher than that for the girls (5.9). The section of the test which involved matching contour patterns with layer models was the only one on which the girls achieved a higher mean (3.0) than the boys (2.6).

Summary

The results from the first stage of the research indicate that the pupils understood the basic conventions of a contour map in so far as they recognised that contour lines represent slopes and could translate numbers into heights. The readiness with which the pupils entered into the testing procedure and attempted to answer the questions suggest that they grasped the representational devices of lines and numbers. The results also indicate, however, that the pupils' understanding was

TABLE 4.8. BOYS' SCORES ON TEST SECTIONS IN STAGE 1
(n=14)

	Wn	Aa	Te	Sv	Ke	Le	St	Nr	Ab	Ar	Dv	Pl	Dn	Ax
Heights (9)	4	1	5	6	5	3	5	6	2	5	4	5	6	6
Slopes (11)	11	11	7	9	11	8	6	6	7	9	11	9	9	8
Models (5)	3	3	2	2	4	2	1	3	1	2	2	1	5	5
Total (25)	18	15	14	17	20	13	12	15	10	16	17	15	20	19

For Key see Table 4.1

TABLE 4.9. GIRLS' SCORES ON TEST SECTIONS IN STAGE 1
(n=13)

	Ju	Da	Ka	Cl	Db	An	Dc	Sh	Jo	Li	Ro	Di	Ki
Heights (9)	2	2	3	2	4	2	3	2	5	5	4	3	6
Slopes (11)	8	8	5	1	5	8	6	6	5	5	7	5	8
Models (5)	3	4	4	3	3	1	5	2	4	4	2	1	3
Total (25)	13	14	12	6	12	11	14	10	14	14	13	9	17

For Key see Table 4.2

TABLE 4.10. MEAN SCORES ON TEST SECTIONS IN STAGE 1

Section	Boys (n=14)	Girls (n=13)	Overall (n=27)
Heights (9)	4.5	3.3	3.9
Slopes (11)	8.7	5.9	7.3
Models (5)	2.6	3.0	2.8
Total (25)	15.8	12.2	14.0

often fragile, and the quotations from the transcripts show that they were easily confused by the more probing questions.

Thus nearly all of the pupils were able to give the correct answer about height when there was a number near to the spot, but the incorrect answers that they often gave for subsequent heights show that this basic ability was quickly disturbed. Errors were made in particular when height had to be interpolated or estimated from adjacent contours. Tackling questions of this kind required a deeper conceptual understanding of how contours are used to represent continuous slopes. It should be emphasised, however, that the pupils had not been taught how to carry out these more complicated numerical tasks.

Some of the answers which the pupils gave to the questions on slopes are intriguing and reveal a tension between the device of contour lines to represent slopes and the device of route arrows used for the purposes of testing. It seems likely that the unanticipated distraction arising from the arrows and their placement on footpaths crossing the contours created an intrusion which hindered the pupils' basic understanding of slope representation. Indications of the fragile nature of this understanding is shown by the way in which some pupils equated a straight line on the map with level ground, an arrow pointing towards the top of the map with movement uphill, and an arrow pointing towards the bottom of the map with movement downhill. Misconceptions such as these suggest either that the pupils were influenced by pictorial drawing conventions, or that they had difficulty in finding a reference point for the questions, so that they were only able to equate arrows pointing up or down on the map with movement up or down on slopes. On the other hand, the large number of correct answers to the questions involving a choice of walk indicates that most pupils understood the basic purpose and conventions of the contour map.

The tasks which involved matching contour patterns with layer models presented the pupils with sets of contours and numbers in their least cluttered form. This was the simplest kind of task which could be devised to test whether the pupils were able to relate lines and numbers to actual slopes. Yet the pupils clearly found these tasks difficult and some probably resorted to guessing. The frequency with which pupils chose a model which represented the reverse of a contour pattern, however, suggests that this error was not entirely due to chance.

In the light of the interesting findings from the first stage of the research, it was considered worthwhile to investigate further the pupils' ability to read heights and identify slopes on a contour map, and to match contour patterns with models. For the purposes of the second stage of the research, an attempt was made to improve those features of the maps and models which had emerged as a source of difficulty for the pupils.

5. THE RESEARCH: STAGE 2

The purpose of the second stage of the research was to explore further some of the pupils' perceptions of contour patterns which had emerged during the first stage. New test materials were designed to improve features of the original materials which may have distracted the pupils and contributed to their errors. The amount of superimposed detail shown on the map was reduced and the spaces between the layers on the models were filled in. This chapter reports the results of the second stage of the research, which was carried out with the same class of children three months later. The pupils were tested individually on the contour map and asked to match contour patterns with relief models.

New test materials

A new imaginary contour map was prepared in an attempt to reduce some of the sources of difficulty encountered by the pupils on the previous two maps. It was again drawn on A3 size paper and is shown, reduced to A4 size, in Figure 5.1. The map contained six contours which were well spaced and numbered at 10 metre intervals near the centre of the map. These numbers could be read off from left to right without rotating the map. The contours included straight and curved sections, and were spaced regularly and irregularly in different parts of the map. The overall contour pattern represented a landscape rising gently from the left to the right of the map, and from the centre left to the top and bottom of the map.

The second copy of the map shows diagrammatically how it was used in the test situation (Figure 5.2). In order to ensure clarity in identifying points, three black (B) and two white (W) map pins were inserted into the map at the points marked 1B,

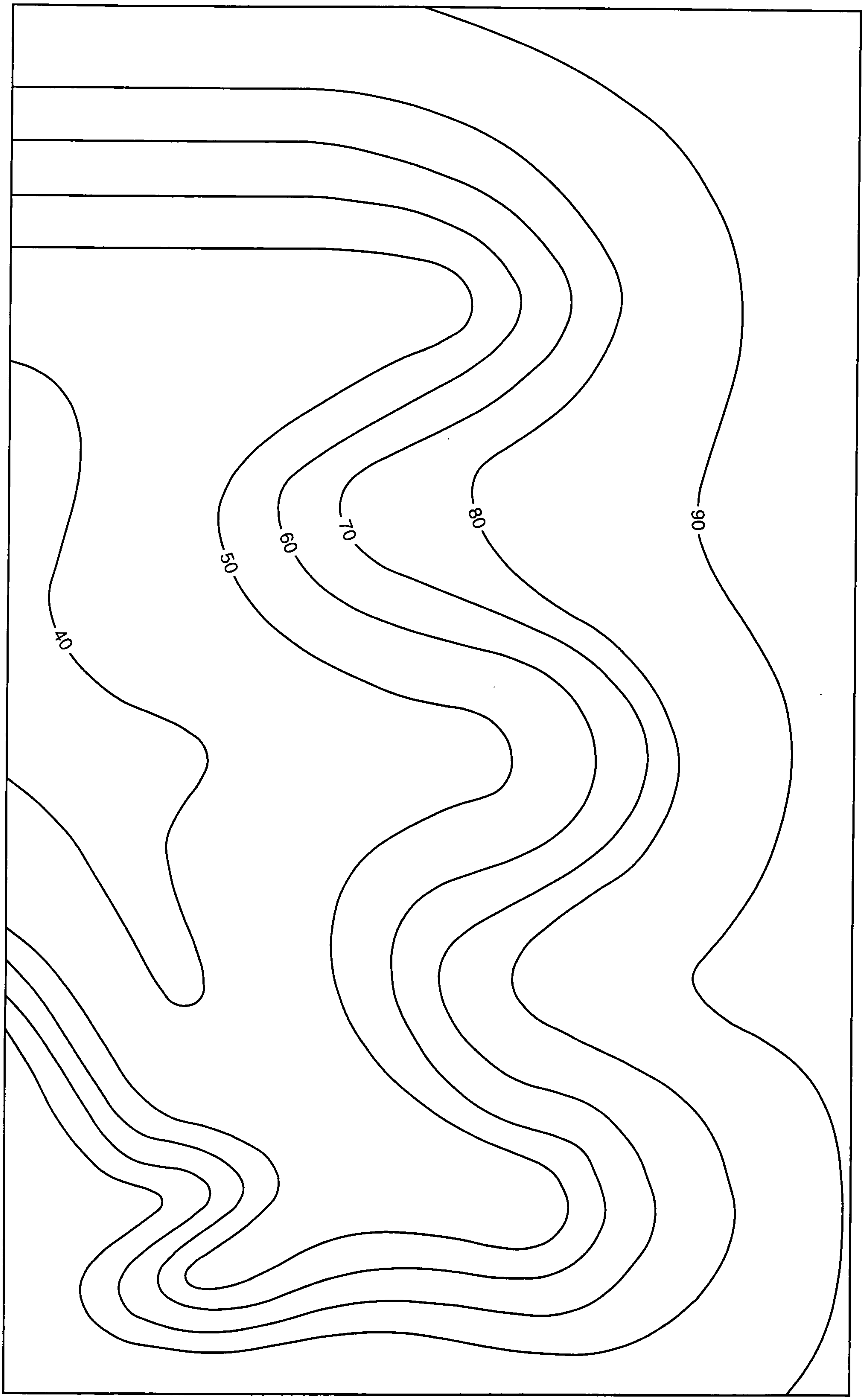


FIGURE 5.1. CONTOUR MAP USED IN STAGE 2

2W, 3B, 4W and 5B. The pupils were asked to give the height of the land at each point. It will be seen that all of the points lay on contours, so that the pupils did not have to answer any questions requiring them to interpolate heights on unnumbered contours, or to estimate heights between contours. There were also no questions which sought answers based purely on convention, for example, that the top of a hill is higher than the highest contour, that the bottom of a slope is lower than the lowest contour, or that the land between two adjacent contours bearing the same number is lower (or higher) than these two contours.

Pairs of coloured map pins were also inserted into the map inside the five squares (the significance of which is explained below). The letters indicate the colours of the map pins: yellow (Y), red (R), light blue (LB), dark blue (DB), light green (LG) and dark green (DG). The pupils were asked to imagine that they were walking from one pin to the other and to say whether they would be going uphill, downhill or on the level, giving the reason for their answer. The direction of travel was always from the lighter pin to the darker pin, ie, from yellow to red, from light blue to dark blue, and from light green to dark green. The use of map pins meant that the pupils did not have to handle lines, arrows, letters and numbers superimposed on the contours, as they had attempted to do on the earlier maps. The pins also removed any possible ambiguity in the exact positions of the points between which movement was taking place, and any reduction in clarity resulting from an arrow being drawn across two contours.

For the final part of the test sets of relief models were constructed by transferring contour patterns derived from the map on to 6 mm thick plywood. These were cut out and the models were built up using the same method that had been used earlier with polystyrene tiles. The spaces between the layers of plywood were filled in with plaster to remove the steps and produce smooth slopes. When dry the models were painted green and the contours were shown on them by means of black lines.

The contour patterns were extracted from the five squares shown on the map (Figure 5.2). Each was drawn on card and enlarged from 75 mm square to 150 mm

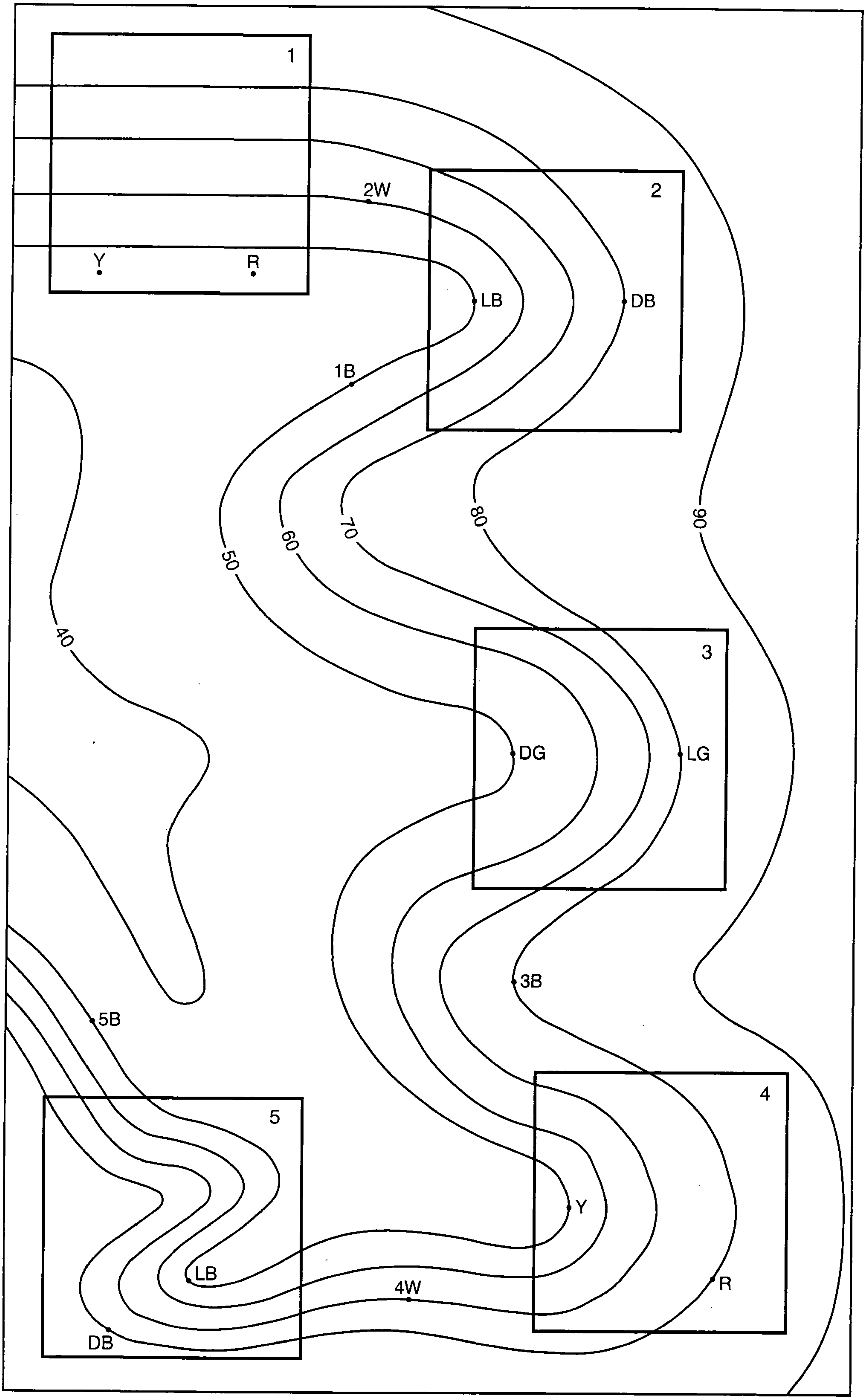


FIGURE 5.2. POSITIONS OF MAP PINS AND TEMPLATE

square in order to permit the construction of models of a reasonable size. It will be seen that each square contained four contours: in square 1 the contours were straight, in square 2 they were curved and regularly spaced, and in squares 3, 4 and 5 they were curved and irregularly spaced. The contours in squares 2, 3 and 4 were three versions of the same pattern: the pattern in square 2 represented an even slope, that in square 3 a concave slope, and that in square 4 a convex slope. The pattern in square 5 contained a double bend representing a convex slope rising to an adjoining spur.

A set of four models was constructed for each contour pattern. In each case the models consisted of (1) the correct version; (2) the reverse of the correct version, ie, with the slope rising in the opposite direction; (3) a version with the slope rising to the space between the second and third contours, and then falling again; (4) a version with the slope rising to the space between the third and fourth contours, and then falling again. None of the models showed the slope rising and then falling to a central depression because in the earlier study nearly all pupils recognised that this could not be the correct version when the pattern showed contours rising or falling steadily.

The four different ways in which the layers on each model were arranged during its construction are shown for each contour pattern in Figures 5.3-5.7. In each figure the base of the model is left blank, the first layer is stippled, the second layer is shaded vertically, the third layer is shaded diagonally, and the fourth layer is cross-hatched. When looking at these figures it should be remembered that the spaces between the layers on the actual models were subsequently filled in, so that the slopes were smooth and continuous.

During the test a hollow 75 mm square template was placed successively in each of the positions marked by the squares in Figure 5.2. An enlarged 150 mm square card bearing the same unnumbered contour pattern was placed alongside the map, together with the four models, all of which were orientated in the same direction as the map. The pupils were asked to select the model which showed the slope correctly.

A total of 26 pupils (14 boys and 12 girls) were tested individually (two girls were absent). Each test lasted about 15 minutes and was tape recorded. As an introduction to the test, the pupils were reminded of the models of the River Wear at Durham which they had constructed during the previous term. They were shown a model which was partially completed (with layers visible) on one side and fully completed (with slopes filled in) on the other side. The pupils were asked whether they remembered what contours showed; if they had forgotten they were reminded that they showed the height of the land above sea level. The new contour map, mounted on strong cardboard and with the map pins inserted into it, was then placed on the table, and the pupils were asked the questions on height and slope. When the questions on each set of models were asked, the card and four models were placed on the table to the right of the map.

The pupils' tape-recorded answers to the test questions were transcribed using pro-formas (Appendices 2a,b,c), on which the correct answers are shown in brackets. Their scores were subsequently entered on to separate tables for boys and girls to facilitate comparison (Tables 5.1-5.6). In these tables each '1' indicates a correct answer and each '0' an incorrect answer. The total number of pupils answering each question correctly is shown in the final column. Quotations from the transcripts are again included in the accompanying text to illustrate the pupils' thinking.

Reading heights

The pupils were asked to give the height at each of the points marked 1B, 2W, 3B, 4W and 5B by black or white map pins. Most pupils found this a straightforward task. All of the girls and most of the boys obtained full marks on the five height questions (Tables 5.1 and 5.2). The pupils were able to follow a contour from the pin to the number, irrespective of the distance involved.

Andrew A and Paul were initially under a misapprehension when they gave the height of pin 1B as 70 instead of 50 m; they may have looked down the map vertically

TABLE 5.1. BOYS' SCORES ON HEIGHTS IN STAGE 2
(n=14)

Height	Wn	Aa	Te	Sv	Ke	Le	St	Nr	Ab	Ar	Dv	Pl	Dn	Ax	Total
1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	12
2	1	1	1	1	1	1	0	1	0	1	1	1	1	1	12
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
5	1	1	1	1	0	1	1	1	1	1	1	1	1	1	13
Total	5	4	5	5	4	5	4	5	4	5	5	4	5	5	65

Key 1 Correct answer 0 Incorrect answer

Aa Andrew A, Ax Alex, Ke Keith, Pl Paul, Te Terry
Ab Andrew B, Dn Dean, Le Lee, St Stanley, Wn Wayne
Ar Aaron, Dv David, Nr Norman, Sv Steven

TABLE 5.2. GIRLS' SCORES ON HEIGHTS IN STAGE 2
(n=12)

Height	Ju	Da	Ka	Cl	Db	An	Dc	Sh	Jo	Li	Ro	Di	Total
1	1	1	1	1	1	1	1	1	1	1	1	1	12
2	1	1	1	1	1	1	1	1	1	1	1	1	12
3	1	1	1	1	1	1	1	1	1	1	1	1	12
4	1	1	1	1	1	1	1	1	1	1	1	1	12
5	1	1	1	1	1	1	1	1	1	1	1	1	12
Total	5	5	5	5	5	5	5	5	5	5	5	5	60

Key 1 Correct answer 0 Incorrect answer

An Andrea, Da Donna A, Di Diane, Ka Karen, Ro Robyne
Cl Claire, Db Donna B, Jo Joanne, Ki Kimberley, Sh Sharon
Dc Donna C, Ju Julie, Li Linzie

from the pin until they came to the number 70. Stanley and Andrew B gave the height of pin 2W as 70 instead of 60 m; their eyes may have slipped from one contour to the next in the process of following it round the bend. All four pupils subsequently gave correct answers to the remaining height questions. Only one pupil misread the height of pin 5B, placed at the furthest point from the numbering of the contours.

The ease with which the pupils read heights on this map was doubtless largely due to the clear presentation of the map and simplicity of the questions. There were no questions requiring the pupils to interpolate heights on unnumbered contours, nor to estimate heights between contours, nor to give answers based on convention, all of which had led to difficulties in the first stage of the research.

Identifying slopes

The pupils were asked to say whether they would be going uphill, downhill or on the level between the pairs of coloured map pins inside the five squares. Most pupils were able to answer correctly the questions on slopes between the first four pairs of coloured pins (Tables 5.3 and 5.4). The sole mistake made by a boy was due to a misconception which had been a mystery in the earlier study: the occasional association of increasing height with decreasing numbers on the contours. When asked why he thought he would be going downhill on the slope from the light blue pin to the dark blue pin in square 2, Terry replied:

> 'I know the lower numbers are the higher peaks, and the higher numbers are the lower peaks'.

Asked where he had learnt this, Terry replied:

> 'In an encyclopaedia at home'.

When this misunderstanding had been pointed out Terry was able to give correct answers to the next two questions on slopes.

Ten girls answered each of the first four slope questions correctly. The errors made by the others indicated incomplete understanding of the concept of contours.

TABLE 5.3. BOYS' SCORES ON SLOPES IN STAGE 2
(n=14)

Slope	Wn	Aa	Te	Sv	Ke	Le	St	Nr	Ab	Ar	Dv	Pl	Dn	Ax	Total
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
2	1	1	0	1	1	1	1	1	1	1	1	1	1	1	13
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
5	1	1	0	1	1	1	0	1	1	0	1	1	1	1	11
Total	5	5	3	5	5	5	4	5	5	4	5	5	5	5	66

For Key see Table 5.1

TABLE 5.4. GIRLS' SCORES ON SLOPES IN STAGE 2
(n=12)

Slope	Ju	Da	Ka	Cl	Db	An	Dc	Sh	Jo	Li	Ro	Di	Total
1	0	1	1	1	1	1	0	1	1	1	1	1	10
2	0	1	1	1	1	1	1	0	1	1	1	1	10
3	1	1	1	0	1	1	1	1	1	1	1	0	10
4	1	1	1	1	1	1	1	0	1	1	1	0	10
5	0	0	0	1	0	0	1	0	1	1	1	1	6
Total	2	4	4	4	4	4	4	2	5	5	5	3	46

For Key see Table 5.2

For example, Julie, when asked why she thought she would be going uphill between the yellow and red pins in square 1, explained:

'It goes straight up'.

The subsequent conversation between the researcher (R) and Julie (J) went as follows:

'What is the height of the yellow pin?' (R).

'50' (J).

'What is the height of the red pin?' (R).

'50' (J).

'Now if you start at 50 m, you go along that line, and you finish at 50 m, have you gone uphill, downhill or on the level?' (R).

'On the level' (J).

Julie's correct answer did not necessarily mean that she understood contours, however, as she thought she would be on the level between the light blue and dark blue pins in square 2:

'Cos it goes straight up to the other pin'.

The conversation continued in a similar manner:

'What is the height of the light blue pin?' (R).

'50' (J).

'What is the height of the dark blue pin? (R).

'80' (J).

'Now if you are walking from 50 m to 80 m, are you going uphill, downhill or on the level? (R).

'Uphill' (J).

The fifth slope question produced a larger number of mistakes, 3 boys and 4 girls making errors. This slope was in the lower left-hand corner of the map, at some distance from the numbering of the contours. Furthermore the contour pattern here was the reverse of that of the previous three slopes in so far as the land rose to the left instead of to the right of the map. This combination of factors may have confused some of the pupils, who were still reading the sequence of numbers 50-80 from left to right and thought they would be going downhill:

'Cos the light blue is uphill and the dark blue is downhill' (Karen).

'Cos the numbers are still going down, right the way round' (Donna A).

Terry explained his working in full:

'I followed the lines round from the blue pin, and I come to 80. Then I followed the blue pin round and I come to 50. And then from the 80 to the 50, I knew we were going downhill' (Terry).

The conversation with Stanley revealed a strange association between the words 'smaller' and 'closer':

'How do you know it's downhill?' (R).

'Cos the contours get smaller as you go down' (S).

'Can you tell me what you mean by they get smaller?' (R).

'They get like closer together' (S).

'They get closer together. I see. In fact they sometimes are close, and sometimes they are far apart. The best way to check is to look at the numbers. Can you tell me what the height of the light blue pin is?' (R).

'50' (S).

'And what is the height of the dark blue pin?' (R).

'80' (S).

'That's right. Now if we walk from the light blue pin to the dark blue pin, are we going uphill, downhill or on the level?' (R).

'Uphill' (S).

To summarise, the use of pairs of coloured map pins inserted into the map for the questions on slopes appeared to help the pupils to handle the idea of movement without having to grapple with arrows and numbers superimposed on the contours, as in the first stage of the research. Most pupils were able to look across the contours and state the slope correctly for the first four pairs of pins. Some pupils appear to have been confused by the fifth pair of pins, however, because of the different alignment of the slope in the lower left-hand corner of the map and its distance from the numbering on the contours near the centre of the map.

Matching patterns with models

The final part of the test, which asked the pupils to match the contour patterns in the squares with the relief models, produced by far the largest number of errors. The results are shown in Tables 5.5 and 5.6, and the pupils' choices are summarised in Table 5.7. The pattern in square 1 consisted of four straight contours increasing in height from bottom to top. This apparently simple pattern (Figure 5.3) was correctly matched with model C by just over half of the pupils, 7 boys and 7 girls, for whom the task was straightforward:

> 'Cos the numbers are going up' (Andrea).
>
> 'Cos the four lines are going up. And it's going up in numbers' (Dean).

Sometimes pupils explained why, in selecting model C, they rejected the others:

> 'That one, it's going up and then it's going down. That one, it's going up and then it's going down a bit. And that one is just going down' (Steven).
>
> 'Cos like that one's going down, that one's going over, and that one's going over and down' (Lee).

Of the 12 pupils who selected the wrong model, 6 chose model B. This was the reverse of model C, the contours increasing in height from top to bottom. Pupils gave their reasons:

> 'Because the lines are sloping down, with the numbers' (Donna B).
>
> 'Cos it looks like it's going upwards. If you put that side there, it'll be going up as a slope' (Norman).
>
> 'Cos these four are on a sort of slant. And that's going downwards' (Paul).

Another 5 pupils wrongly selected model A, which rose to a central ridge and then fell. Sharon selected it:

TABLE 5.5. BOYS' SCORES ON MODELS IN STAGE 2
(n=14)

Pattern	Wn	Aa	Te	Sv	Ke	Le	St	Nr	Ab	Ar	Dv	Pl	Dn	Ax	Total
1	1	0	0	1	1	1	0	0	0	1	0	0	1	1	7
2	1	0	1	1	1	1	1	0	1	1	0	1	1	1	11
3	1	0	1	1	1	1	1	0	1	1	0	1	1	1	11
4	1	0	1	1	1	1	1	1	1	1	1	1	1	1	13
5	1	0	0	1	0	0	0	0	0	0	0	0	0	1	3
Total	5	0	3	5	4	4	3	1	3	4	1	3	4	5	45

For Key see Table 5.1

TABLE 5.6. GIRLS' SCORES ON MODELS IN STAGE 2
(n=12)

Pattern	Ju	Da	Ka	Cl	Db	An	Dc	Sh	Jo	Li	Ro	Di	Total
1	1	1	0	0	0	1	0	0	1	1	1	1	7
2	0	0	1	0	1	0	0	1	0	1	0	0	4
3	0	1	1	0	1	0	1	0	0	1	0	0	5
4	1	1	1	1	1	1	1	0	0	1	0	0	8
5	0	0	0	0	0	1	0	0	0	1	1	0	3
Total	2	3	3	1	3	3	2	1	1	5	2	1	27

For Key see Table 5.2

TABLE 5.7. PUPILS' CHOICE OF MODELS IN STAGE 2
(Boys and girls, n=26)

Pattern	Correct		Reverse		Others			
1	(C)	14	(B)	6	(A)	5	(D)	1
2	(H)	15	(E)	8	(G)	1	(F)	2
3	(K)	16	(L)	6	(J)	2	(M)	2
4	(P)	21	(N)	3	(O)	1	(Q)	1
5	(U)	6	(T)	9	(S)	5	(R)	6

'Cos it has a bump, and they're just like straight' (Sharon).

Andrew A explained why, in selecting model A, he rejected models B and C:

'Cos like that's just going up the angle of slope. If you step off the end of there, it's a straight fall down. And it's the same with C. But on that one you go up and go down' (Andrew A).

Asked why it had to go up and down, he replied:

'Cos like you go up and can't get down. You'll kill yourself or something if you drop off' (Andrew A).

Andrew A's answer revealed an unexpected perceptual distraction. He had apparently been looking at the abrupt, vertical edge of the model. He may also have been looking at the card bearing the contours in isolation from the complete map. Square 1 was, however, near the top left-hand corner of the map. It is interesting to speculate on how many pupils viewed the edge of the model or map as the edge of an abyss.

The pattern in square 2 consisted of four curved, evenly spaced contours increasing in height from left to right and representing a small valley (Figure 5.4). This pattern was correctly matched with model H by 11 boys but only 4 girls:

'Because this part here's got a circle and that's got a flat bit, like round, and that's flat. It's got three contours, and that one has as well. They go up in a hill' (Wayne).

'Cos it's going upwards' (Karen).

'Because it hasn't got any bumps on like those' (Sharon).

'Cos the lines are going up there, and they're going up there' (Linzie).

Of the 11 pupils who made the wrong choice, 8 selected model E. This was the reverse of model H, the contours decreasing in height from right to left. It was plausible to mistake the contour pattern for that of part of a hill if no reference was made to the numbering:

'Because it slopes upwards. The hill goes up' (Donna A).

'Cos it's going uphill, and that one's going up' (Andrea).

The pattern in square 3 was similar to that in square 2 except that, instead of being evenly spaced, the contours were more closely spaced with increasing height, giving a concave slope (Figure 5.5). All 11 boys who had correctly matched square 2 with model H also matched square 3 correctly with model K:

> 'Because that's the flat bit here. And that's got a big contour here. And it goes uphill from that contour' (Wayne).
>
> 'It's just the same as the other one' (Paul).

Only 5 girls, however, matched pattern with model correctly. Another 5 girls and 1 boy chose model L, which was the reverse of model K, the contours decreasing in height from left to right. Again pupils who did not refer to the numbering of the contours could mistake this pattern for part of a hill.

The pattern in square 4 differed from the preceding one in that the contours were more widely spaced with increasing height, giving a convex slope (Figure 5.6). All of the boys except one correctly matched the pattern with model P, and 8 girls also did so. Indeed more pupils were successful with this pattern than any other. It is only possible to speculate why this was apparently easier than the previous three patterns. It may have been the gradually wider spacing of the contours with height, which continued beyond the square towards the edge of the map. Of the 5 pupils who selected the wrong model, 3 chose model N. This was the reverse of model P, the contours decreasing in height from left to right. As in the previous two reversals, the pupils apparently saw the pattern as part of a hill.

Square 5 contained the pattern which proved to be by far the most difficult one for the pupils to match correctly (Figure 5.7). The contours in this square were more closely spaced than in the previous four squares, and together formed a valley near the bottom and a spur near the top. The pattern was matched correctly with model U by only 6 pupils. These included 3 boys who obtained full marks in the test and the only girl who did so. For them the matching task was straightforward:

> 'It's going high to low, and high to low there' (Alex).
>
> 'Cos that's the littlest line, and it goes upwards' (Linzie).

Of the 20 pupils who failed to match the contour pattern correctly with model U, 6 chose model R, 5 chose model S and 9 chose model T. These results could have been obtained by chance and suggest that the pupils were guessing. Certainly they found the task difficult and often needed more than two attempts and the help of the researcher before they arrived at the correct model. Lee, for example, who had answered all questions in the test correctly until he attempted the final task, first chose model R, then model T, and lastly model U. The conversation between Lee (L) and the researcher (R) went as follows:

> 'Cos it looks like going the same like there. It's got the same contour lines' (L).
>
> 'Yes, and can you tell me about the slope?' (R).
>
> 'It's going down and then up, and then it goes round, and it goes down, and goes like upwards' (L).
>
> 'Let's have a look at it a bit more closely. Let's look at the map first of all. Can you tell me the number of that contour?' (R).
>
> '50' (L).
>
> 'And what's the number of that one?' (R).
>
> '80' (L).
>
> 'So let's have a look at model R. That's the 50, that's the 60, and that's the 70. It gets up to this hill, and then it drops again. So it doesn't actually get up to 80. So it's not the same one as on the map. Have another look at the four models' (R).
>
> 'This one' (L).
>
> 'T. Can you tell me why you chose T?' (R).
>
> 'The contour lines are going down and like that is as well there' (L).
>
> 'They're going down. Right, so shall we have another look at the map now? You said a moment ago that's the 50 and that's the 80. It means you're going up from 50 to 80. Let's see if that's right. This one's the first one and it's right at the top, isn't it? That can't be the 50. The lowest one

is 50. On this model the 50 is there, the 60 there, the 70 there, up to 80. So it's not the same. Have another look at the other models' (R).

'This one' (L).

'U. And why did you choose U?' (R).

'I wasn't choosing that one cos it was going up and then down, like that' (L).

'So it can't be S. Why do you think U is the right one then? I know you've ruled out all these now. What is there about U that's right?' (R).

'Cos it's like everything's the same on there and that. That's going down and that's going down. And that's going round like that. And it's the same curve' (L).

'So on this one that's the 50 and then it's 60, 70, 80. It's going upwards towards the corner. And on this one it's 50, 60, 70, 80. It takes quite a time. It's a difficult one because it's got two bends in it' (R).

Lee did not initially give a reason for choosing model R beyond saying that it looked the same as the pattern. When asked about the slope he described the model without reference to the contour pattern. He was referred to the map and asked to look at the numbers on the contours, when he saw that the 80 m contour did not appear on model R.

Lee then chose model T apparently on the grounds of its continuous slope but without relating this to the numbering on the contours. He was shown that on the map the slope rose towards the left, whereas on model T the slope rose towards the right.

Finally Lee chose model U, but only after ruling out model S because it contained a central ridge. He arrived at model U by a process of elimination rather than by a process of matching the contour pattern to the relief models. It is worth emphasising that Lee had shown a better understanding of contours than most pupils, having answered correctly all of the preceding questions in the test. The final task was the only one that he could not manage on his own.

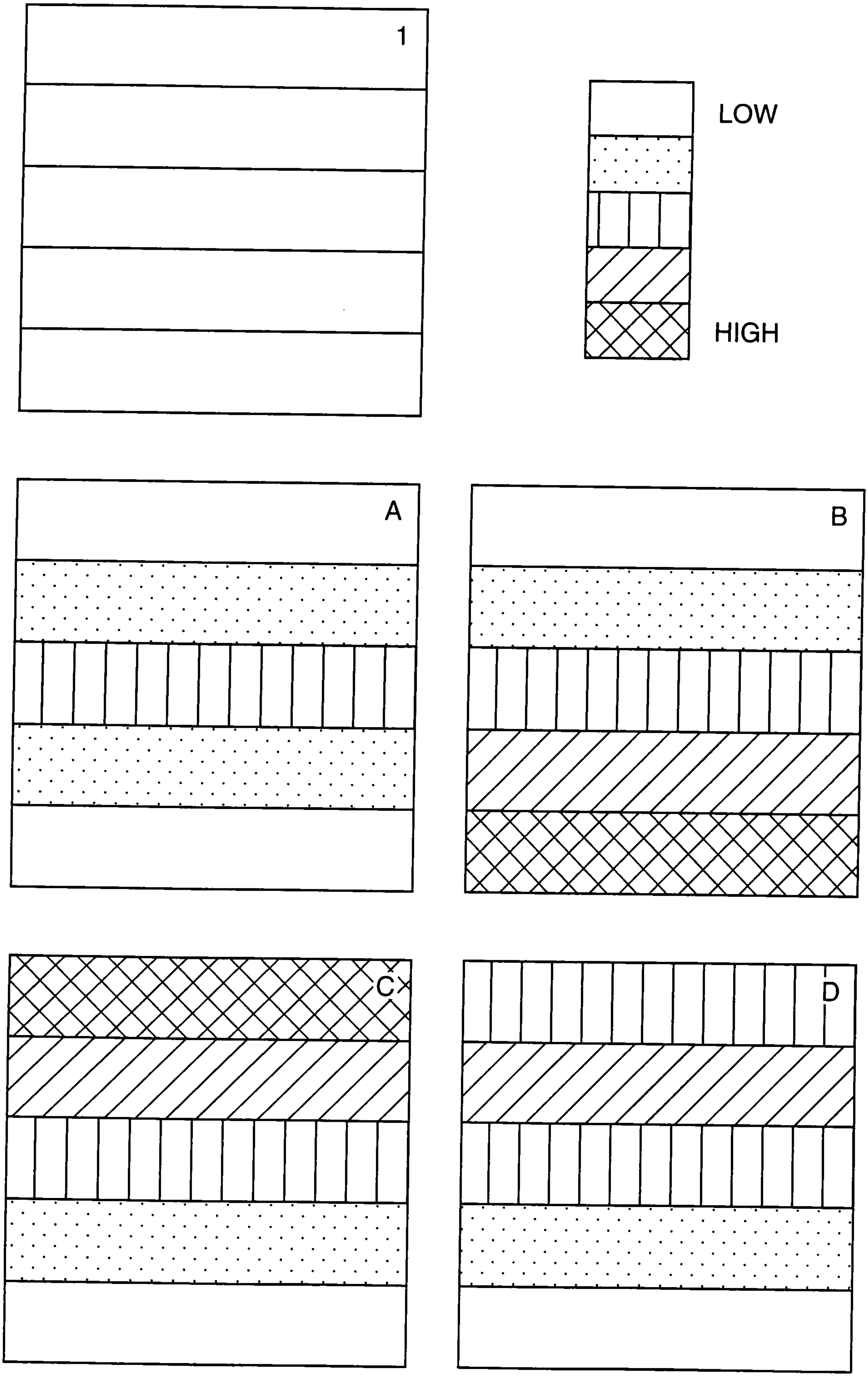


FIGURE 5.3. CONTOUR PATTERN 1 AND RELIEF MODELS A-D

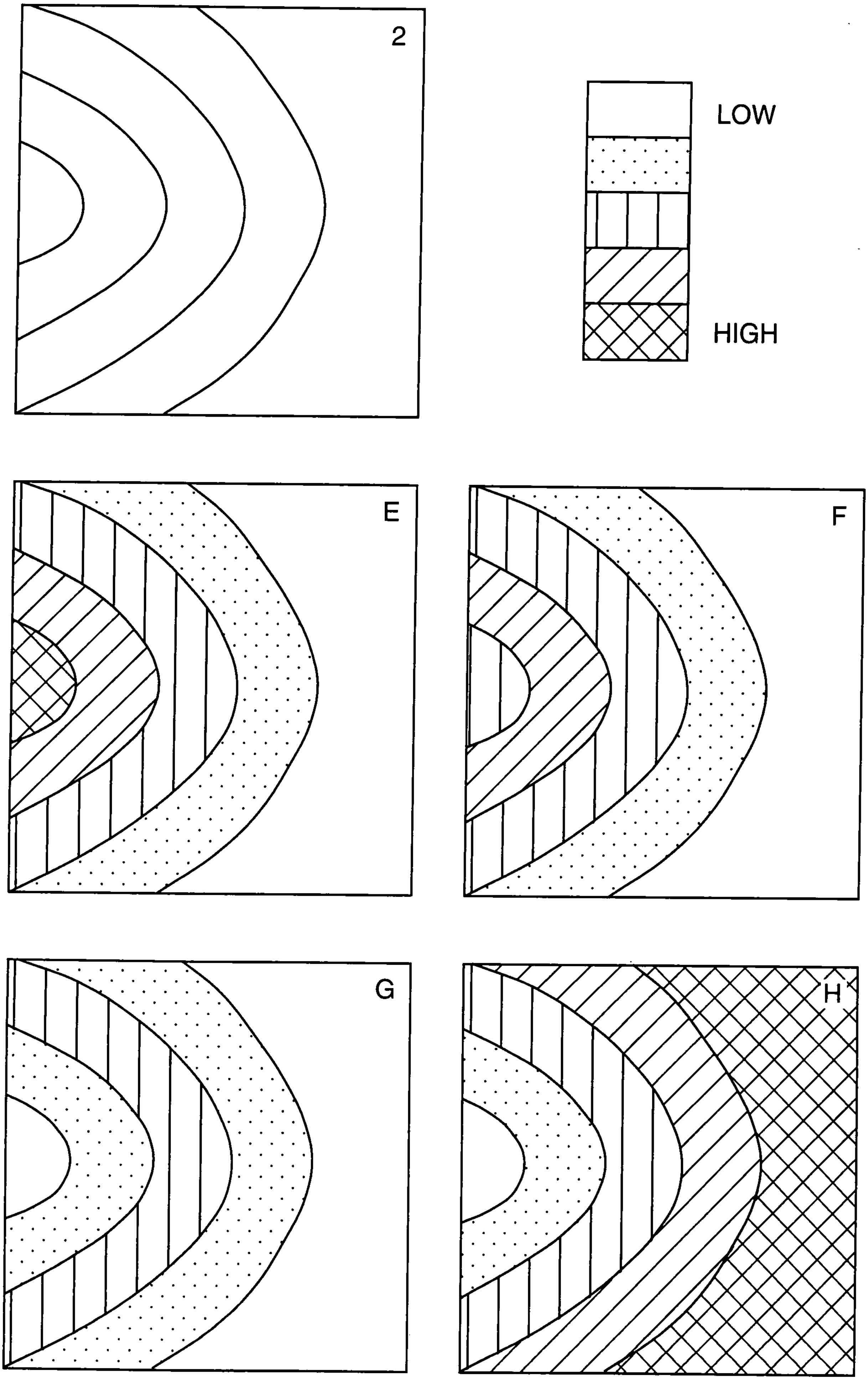


FIGURE 5.4. CONTOUR PATTERN 2 AND RELIEF MODELS E-H

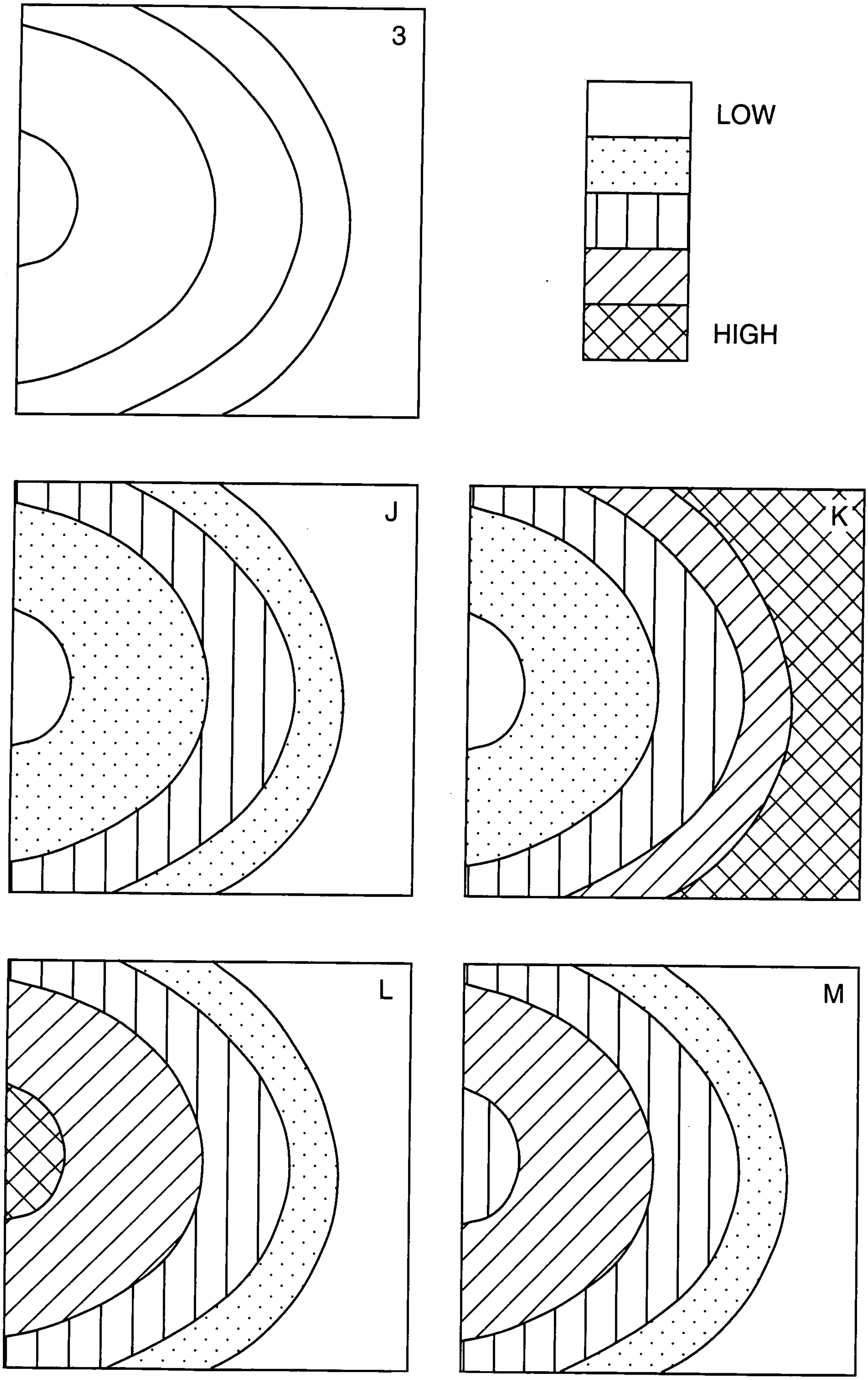


FIGURE 5.5. CONTOUR PATTERN 3 AND RELIEF MODELS J-M

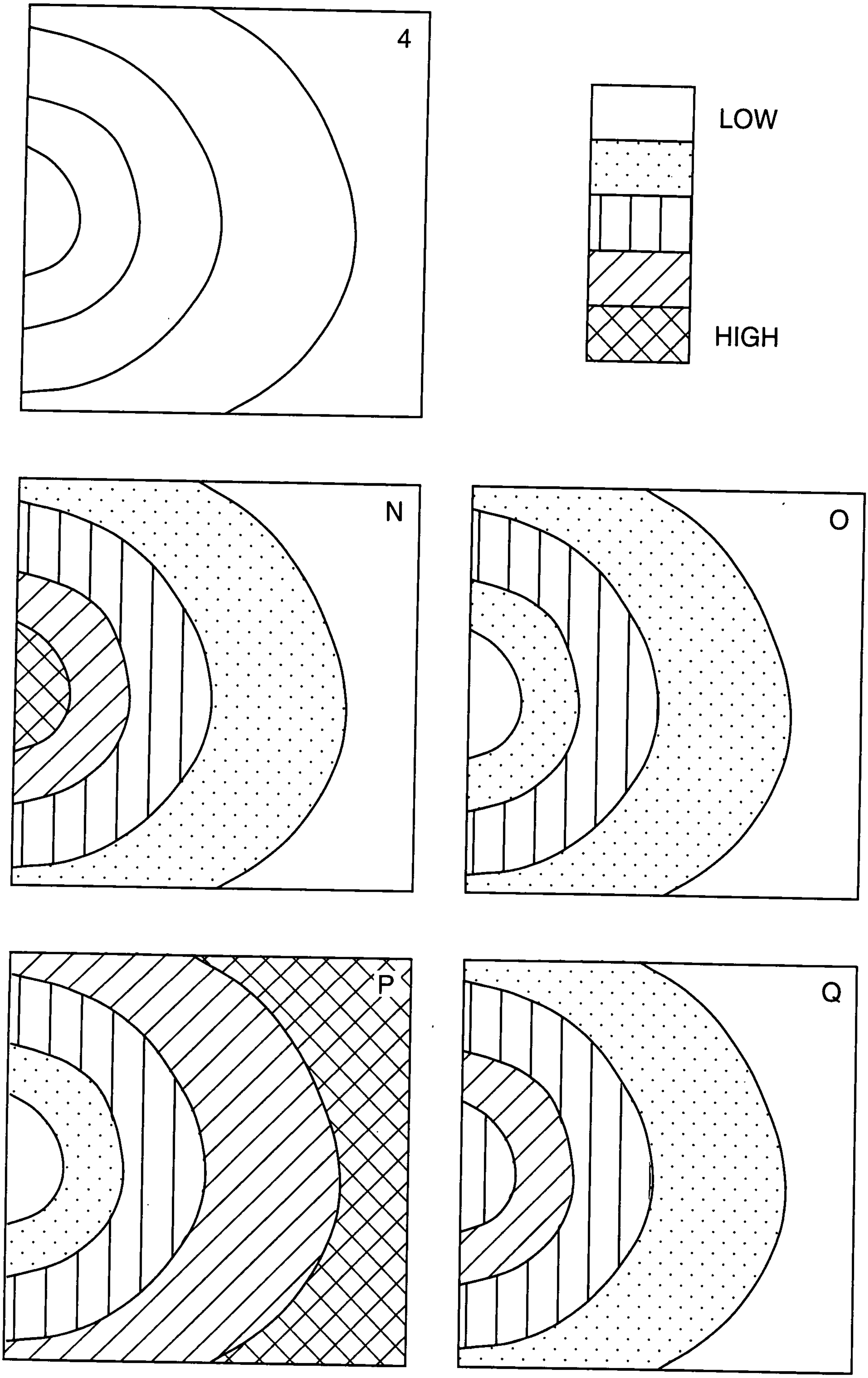


FIGURE 5.6. CONTOUR PATTERN 4 AND RELIEF MODELS N-Q

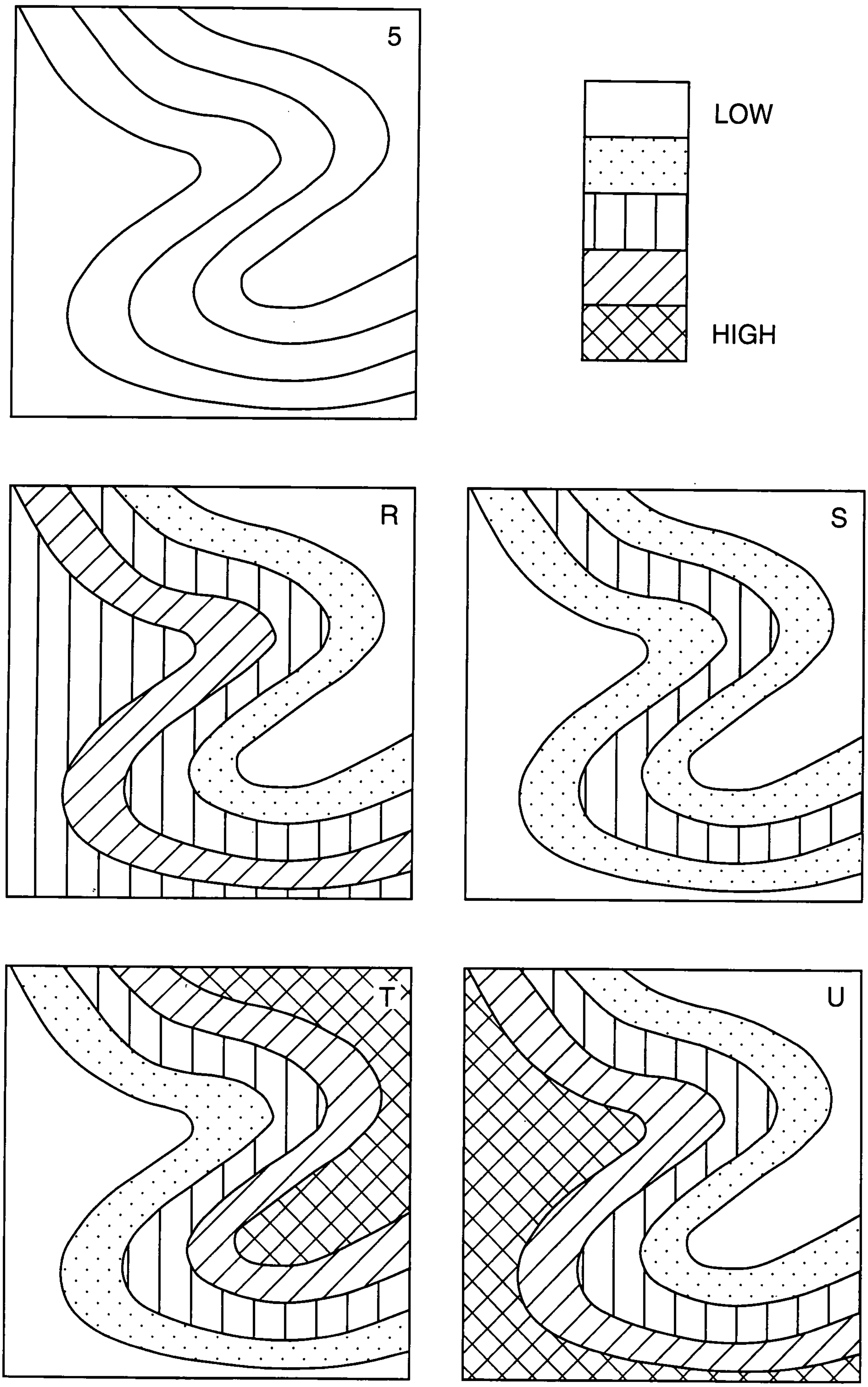


FIGURE 5.7. CONTOUR PATTERN 5 AND RELIEF MODELS R-U

The pupils certainly experienced considerable difficulty in attempting to match the contour pattern in square 5 with the correct relief model. They were confused by the alignment of the contours, which was different from that in the previous three squares. Furthermore the slope indicated by the contour pattern rose from right to left instead of from left to right. The numbering on the contours was also at a greater distance from the fifth square, and so errors could occur when following the contours from the centre of the map round to the lower left-hand corner. The inclusion of a contour pattern containing a double bend within the same square doubtless increased the pupils' difficulties.

Overall performance

The scores obtained by the 14 boys on the three sections of the test and their total scores on the test as a whole are shown in Table 5.8. The scores obtained by the 12 girls are shown in a similar way in Table 5.9. It will be seen that there was little difference between the range of scores for the boys (from 9 to 15) and the range for the girls (from 8 to 15). The mean scores obtained by the 26 pupils on the different sections of the test and on the test as a whole are shown in Table 5.10. The mean overall total score of 11.9 out of 15 (SD=2.0) suggests that the redesigned map used in the second stage of the research was generally suitable for older primary school pupils.

As in the first stage of the research, the boys achieved a higher overall score (mean=12.6, SD=1.9) than the girls (mean=11.1, SD=1.9). Application of the 't' test, however, showed that the difference between the mean scores of the boys and the girls was not significant at the 0.05 confidence level (t=1.7, d.f.=24).

The section of the test which involved reading heights, where the overall mean was 4.8, was the only one on which the girls obtained a higher mean (5.0) than the boys (4.6). On the slope questions, where the overall mean was 4.3, the boys achieved a higher mean (4.7) than the girls (3.8). On the section of the test which

TABLE 5.8. BOYS' SCORES ON TEST SECTIONS IN STAGE 2
(n=14)

	Wn	Aa	Te	Sv	Ke	Le	St	Nr	Ab	Ar	Dv	Pl	Dn	Ax
Heights (5)	5	4	5	5	4	5	4	5	4	5	5	4	5	5
Slopes (5)	5	5	3	5	5	5	4	5	5	4	5	5	5	5
Models (5)	5	0	3	5	4	4	3	1	3	4	1	3	4	5
Total (25)	15	9	11	15	13	14	11	11	12	13	11	12	14	15

For Key see Table 5.1

TABLE 5.9. GIRLS' SCORES ON TEST SECTIONS IN STAGE 2
(n=12)

	Ju	Da	Ka	Cl	Db	An	Dc	Sh	Jo	Li	Ro	Di
Heights (5)	5	5	5	5	5	5	5	5	5	5	5	5
Slopes (5)	2	4	4	4	4	4	4	2	5	5	5	3
Models (5)	2	3	3	1	3	3	2	1	1	5	2	1
Total (25)	9	12	12	10	12	12	11	8	11	15	12	9

For Key see Table 5.2

TABLE 5.10. MEAN SCORES ON TEST SECTIONS IN STAGE 2

Section	Boys (n=14)	Girls (n=12)	Overall (n=26)
Heights (5)	4.6	5.0	4.8
Slopes (5)	4.7	3.8	4.3
Models (5)	3.2	2.3	2.8
Total (15)	12.6	11.1	11.9

involved matching contour patterns with relief models, where the overall mean was 2.8, the boys again achieved a higher mean (3.2) than the girls (2.3).

The boys' scores on the tests in stages 1 and 2 are shown together in Table 5.11, and the girls' scores are shown in a similar way in Table 5.12. It will be seen that the boys' total scores ranged from 22 to 34 out of 40, whilst the girls' total scores ranged from 16 to 29. Five of the 14 boys (Wayne, Steven, Keith, Dean and Alex) performed well in both stages, obtaining total scores of more than 30. None of the 12 girls obtained a total score of more than 30 in the two stages. Indeed only two girls (Donna A and Linzie) obtained scores of 26 or more, whereas ten boys did so.

Summary

In the second stage of the research the improvements to the map and simplification of the questions undoubtedly helped the pupils to read heights accurately. They were able to read the figures on the well spaced contours and did not have to interpolate heights on unnumbered contours or estimate heights between contours.

The insertion of pairs of map pins into the map also helped the pupils to focus on movement along or across slopes without being distracted by arrows and further numbers superimposed on the contours. Although most pupils could state the slope correctly for the first four pairs of pins, some made errors with the fifth pair, probably because of the different alignment of the slope and its position in relation to the numbering of the contours.

The continuous smooth, painted slopes of the plywood and plaster relief models constructed for the second stage of the research resembled reality more closely than the cardboard layer models used in the first stage. The task of matching the models with contour patterns, however, remained the most difficult section of the test, requiring as it did the visualisation of the three-dimensional equivalent of the two-dimensional plan.

TABLE 5.11. BOYS' SCORES ON TESTS IN STAGES 1 AND 2
(n=14)

	Wn	Aa	Te	Sv	Ke	Le	St	Nr	Ab	Ar	Dv	Pl	Dn	Ax
Stage 1 (25)	18	15	14	17	20	13	12	15	10	16	17	15	20	19
Stage 2 (15)	15	9	11	15	13	14	11	11	12	13	11	12	14	15
Total (40)	33	24	25	32	33	27	23	26	22	29	28	27	34	34

For Key see Table 5.1

TABLE 5.12. GIRLS' SCORES ON TESTS IN STAGES 1 AND 2
(n=12)

	Ju	Da	Ka	Cl	Db	An	Dc	Sh	Jo	Li	Ro	Di
Stage 1 (25)	13	14	12	6	12	11	14	10	14	14	13	9
Stage 2 (15)	9	12	12	10	12	12	11	8	11	15	12	9
Total (40)	22	26	24	16	24	23	25	18	25	29	25	18

For Key see Table 5.2

When the pupils attempted to match the curved contour patterns representing parts of small valleys with the equivalent relief models, there was little difference in their ability to discern the regularly and irregularly spaced contours of even, concave and convex slopes, although more pupils were successful with the convex slope than the other two. The most common error with these curved patterns was to reverse the slopes as if the contours represented part of a hill instead of a valley.

The final task in which the pupils were asked to match a combined valley and spur contour pattern with the appropriate model proved to be particularly difficult. Very few pupils were able to do this without help because of the greater complexity of the contour pattern, the different alignment of the slope from the other curved patterns, and the distance of the contour numbering from the centre of the map.

6. CONCLUDING DISCUSSION

This concluding discussion begins with some reflections on the methods used in the research and is followed by speculation on possible reasons for some of the errors made by the pupils in their perceptions of contour patterns. The implications for teaching the concept of contours are then considered, and lessons to be learnt from the introduction of the national curriculum during the past few years are outlined. It is argued that there are limitations in attempting to conduct research into children's map reading abilities from the perspective of a single discipline. The conclusion is drawn that collaboration between geographers and psychologists will lead to potentially more productive research.

Reflections on research methods

My previous research into pupils' understanding of contour maps was carried out from a geographical perspective using written tests on contour patterns derived from Ordnance Survey maps. The test results were useful in so far as they provided quantitative data and revealed some of the mistakes which pupils made when asked, for example, to shade all land above a certain height. The results did not, however, reveal anything about the reasons *why* pupils made these errors. Neither did they show whether the pupils were able to visualise the reality of the slopes or landforms represented by contours on a map.

In the present research, an attempt was made to introduce a psychological perspective by exploring the strategies which pupils adopted in trying to make sense of contour patterns. This was made possible by replacing written tests with individually administered tests in which questions were asked and answered verbally on specially drawn maps containing a range of contour patterns. Quantitative data were obtained by scoring the pupils' answers to the questions on heights, slopes and models. These were supplemented by qualitative data obtained by asking the pupils why they gave certain answers. An attempt was thus made to show not only *how* the pupils answered the questions but also *why* they responded in the ways they did, a procedure which is a potentially richer source of data (Boardman, 1993).

The research enabled maps and models to be used to explore the processes involved in understanding contours as representations. The novel feature of the research was the use of three-dimensional models as a means of ascertaining the extent to which pupils were able to relate contour patterns to the relief they represent. The use of cardboard layer models in stage 1 of the research is open to criticism because they showed relief as a series of steps, although this kind of model did have the advantage that the contours, as edges of the layers, remained visible. The use of plywood and plaster models in stage 2 of the research rectified this defect by smoothing out the slopes and painting the contours as black lines on green slopes. This procedure, too, is open to criticism because the lines drawn on the models do not appear in the landscape.

A further problem with a three-dimensional model is that it is a representation of a representation. The contour pattern consisting of lines on a piece of paper is a representation of a landform, and the model is a representation of the contour pattern. The model is thus an artificial device constructed, in the case of the present research, for the purposes of exploring the pupils' perceptions of the contour pattern.

Numerous extraneous factors probably influenced the results obtained in both stages of the research. The pupils had previously done some work on maps in geography lessons involving the use of symbols and scale. No enquiries were made, however, about the children's experience of using maps outside school. Some may have used maps in scouts or guides, for example, or simply by accompanying their parents on walks. These children may have obtained higher scores on some of the test items, especially if their previous map reading experience included contours.

No attempt was made to compare the children's test scores with their performance on a standardised test of spatial ability. Any correlation that might have emerged would have yielded data of purely academic interest. It would not have provided further information about the ways in which pupils' perceive common contour patterns, nor about the problems which they encounter in learning the concept of contours.

As I had taught the concept of contours to the class, I was at least known to the children before the testing took place. In circumstances in which tests are individually administered, however, it is never possible to avoid the inhibiting influence which an adult interviewer has on a child interviewee. This is likely to be greater when the interviewer is a researcher who is a visitor to the school. A visiting adult male interviewer may have a more inhibiting effect on a girl than on a boy, thus depressing the girls' scores and limiting their responses.

All children in the class (except absentees) were tested, so the question of sampling error did not arise. It is not possible to say, however, whether the children in this class were typical of those of similar age in other schools. No generalisations can be made, therefore, from the findings of this research.

The use of set questions and tasks ensured uniformity in testing the pupils. Although care was taken in framing the questions to make them clear and unambiguous, it is always possible that some children misunderstood them, or interpreted them in a different way from that intended. Another possibility is that when children were uncertain of the answer to a question, they may have guessed or invented a reply rather than admit that they did not know.

There is sometimes a gap between questions as adults present them (intended questions) and questions as children respond to them (received questions). It has been shown by Hughes and Grieve (1980) that when children are presented with a question by an adult, they will provide an answer even if that question is conceptually ill-formed. The researchers presented groups of children aged 5 and 7 years with questions intended to be bizarre, for example, 'Is milk bigger than water?', 'Is red heavier than yellow?'. Although questions such as these were unanswerable as they stood, the children almost invariably provided answers. They were apparently actively trying to make sense of the situations presented to them. Some children in the present research may well have been adopting a similar procedure when they were attempting to match contour patterns with three-dimensional models.

The questions and tasks could also be criticised because they were divorced from reality and beyond the children's experience. The children were presented with sets of black lines drawn on white paper and were asked to match them with the corresponding three-dimensional models. This is an abstract task in the same psychologically important sense as Piaget's three mountains task. Some pupils found the matching task too difficult and looked for different ways of making sense of the contour patterns and relating them to the models. Other pupils may have given up the attempt and resorted to guessing or inventing answers.

All normal children, according to Donaldson (1978), can show skill as thinkers and language users so long as they are dealing with 'real-life' meaningful situations. She maintains that in such situations children have purposes and intentions, and through them they can recognise and respond to similar purposes and intentions in others. Children's thinking is embedded in these human intentions. They sustain and direct their thoughts and speech.

In contrast, many of the problems which are presented to children in school require them to keep strictly to what is given. Their thinking has to be what Donaldson terms 'disembedded'. Much of education involves using disembedded modes of thought, thus creating difficulties in children's minds. These include problems which are presented in abrupt isolation by some other person whose purposes are obscure. Such were the tasks that the children were asked to attempt on the maps and models in this research. 'Let's imagine we're going for a walk' was the nearest they came to a real-life situation which was familiar to them. Otherwise the tasks were beyond their experience. The research revealed many examples of the pupils making reasonable but erroneous inferences about what was likely to be meant.

Interpreting the results

The difficulties which pupils experience in learning the concept of contours and subsequently in reading contour maps, as discussed in chapter 1, have generally been explained in terms of conceptual problems. Difficulties of a conceptual nature occur in all kinds of learning and are to be expected in the early stages of learning to read contours and interpret contour patterns. It could be argued that the pupils' cognitive development, supported by further tuition and practice, should eliminate most conceptual errors in due course. My previous research, together with that reported by Underwood (1981), however, showed that older school pupils were still making errors with basic contour patterns, whilst Griffin and Lock (1979) found that similar errors were being made by undergraduates. In view of the persistence of these errors into adulthood, it is worth enquiring whether they are purely conceptual in nature.

Although the evidence has previously been assumed to indicate that pupils are making conceptual errors in reading contours, it is also possible that they are making *perceptual* errors. The manner in which map readers perceive contour patterns may influence the way in which they interpret the patterns. In certain circumstances the graphic message presented by the map may be modified and possibly distorted. The findings of the present research, particularly the tendency for slope reversal, suggest that perceptual errors may occur when pupils attempt to visualise a three-dimensional surface represented by a two-dimensional contour pattern.

In order to examine the possibility that some of the errors may be perceptual in nature, it is necessary to compare the visual characteristics of contour patterns with some of the phenomena discussed in the psychological literature on visual perception. A search of this literature (for example, Bruce and Green, 1985; Gordon, 1989; Humphreys and Bruce, 1989; Roth and Bruce, 1995) suggests that the way in which sets of variably spaced lines are perceived may conflict with the mapping convention which relates slope to contour spacing.

It is possible that a phenomenon known as the texture gradient effect may be responsible for this apparent conflict. This was originally identified by Gibson (1950) and is a part of what he later termed 'ecological optics' (Gibson, 1966,1979). It is said to occur as a result of the human perceptual organisation of the information drawn from the everyday environment - an environment which consists mainly of surfaces. During this process it appears that 'the physical world gets visually denser as it recedes' (Gibson, 1950:94). For example, the paving stones on a path or the sleepers on a railway line appear to get thinner and closer together as they recede into the distance. This gradient of density and texture is composed of elements and gaps, and is said to produce the appearance of a continuous third dimension.

In defining the term gradient of texture as an increase or decrease in something along a given axis or dimension, Gibson uses the analogy of the gradient of a road, which is its change in altitude with distance. This change may be positive (uphill), negative (downhill) or zero (level). It may also be rapid (steep) or slow (gentle), and when the change is abrupt, as at the edge of a cliff, the gradient becomes a discontinuity (Gibson, 1950:73).

These ideas may be illustrated by the ways in which lines drawn on a sheet of paper may create distinct impressions. If a series of parallel straight lines, equidistant from one another, are drawn from the bottom to the top of the sheet, the impression is that of a *frontal* surface, perpendicular to the line of sight. If the series of lines are drawn so that they converge towards the top of the sheet, however, the impression is that of a *longitudinal* surface, parallel to the line of sight.

In the same way, if parallel lines, equidistant from one another, are drawn across the sheet, the impression is that of a *frontal* surface. But if the lines are drawn closer together towards the top of the sheet, the impression is that of a *longitudinal* surface. In the latter case, the increase in density up the picture plane gives the perspective of a curved surface which slants upwards and then away from the observer. Gibson argues that the impression of a surface is the basic factor which underlies people's experience of space and objects (Gibson, 1950:91).

The visual evidence provided by certain kinds of contour patterns may be similar to that which tends to promote the texture gradient effect. This might lead the map user to yield unconsciously to cues of depth during the perceptual activity involved in reading and interpreting the pattern. In stage 2 of the present research, the pupils were looking at a series of lines drawn on a sheet of paper when they were asked to match the contour patterns with the relief models. The lines in square 1 were straight, parallel and equidistant from one another (Figure 5.2), giving the impression of what Gibson terms a frontal surface. The lines in squares 2, 3 and 4, however, were curved, making it more difficult to apply Gibson's theory. In square 2 the curved lines were equidistant, indicating an even slope; in square 3 the lines became closer together towards the right, indicating a concave slope; and in square 4 they became more widely spaced towards the right, indicating a convex slope. Square 3 might be said to be a curved version of a longitudinal surface giving the impression that it slants away from the observer.

Those pupils who selected the reverse of the correct model may have seen the small semi-circle in square 3 as the top of a hill, and the widening curved lines to the right as the lower slopes of the hill. They may have gained the impression that the contour pattern was a picture of the relief rather than a representation of it. During the testing each pupil was seated in front of the map and the models were placed to the right of it. When selecting a model the pupil was thus looking from left to right and this may have increased the impression of a longitudinal surface.

Whether the contour pattern showed an even, concave or convex slope appeared to make little difference to the frequency of errors. It is interesting, however, that the number of pupils who chose the reverse model decreased from square 2 to square 3, and again from square 3 to square 4. This may have been simply the result of practice rather than the patterns formed by the contours. Whatever the explanation for the choice of the reverse slope, the pupils who made this error saw a positive gradient as a negative one. Clearly they did not refer to the numbering of the contours, so they were seeking some other way of interpreting each pattern.

Other factors almost certainly contributed to the difficulties which the majority of pupils experienced when they tried to match the contour pattern in square 5 with the corresponding relief model. They had to handle a combination of positive and negative gradients in the same square. The direction of slope in the valley was the opposite of that of the valleys in the preceding three squares. The pupils who made errors may have transferred the sequence of numbers from 50 to 80 reading from left to right near the centre of the map directly to the square in the corner without following the contours round the bend to the square. Confusion between the similar contour patterns representing valleys and spurs, distinguished only by their numbering, is one of the common errors in map reading.

There is at least the possibility that the pupils perceived a set of contours as a texture gradient rather than as a representation of slope. This possibility is not inconsistent with Gibson's (1950) classification of form. He differentiates between the 'realities' of solid three-dimensional forms, the 'representations' of outline, pictorial and perspective drawings, and the 'abstractions' which are symbolic renditions of geometric forms. These three classes require an increasing level of concept formation, attained at progressively later stages of childhood development. The implication is that visualisation of a contour pattern as a texture gradient is a more direct and elementary act of perception (the second stage), whereas an attempt to visualise it as a sloping surface involves more advanced concept formation resulting from learning and practice (the third stage). There is no reason to suppose that the addition of contour numbering will be sufficient to eliminate the influence of the texture gradient effect in cases where it is particularly intrusive.

In their study of Australian students' interpretation of contour diagrams summarised in chapter 1, Griffin and Lock (1979) found that the identification of a convex slope gave rise to more errors than that of a concave slope. Their finding that slope reversal was the most common error is similar to that in the present study, although in their case it indicated mistaking a convex slope for a concave one or *vice versa*. As this error occurred at all educational levels, the researchers concluded that it was less likely to be caused by lack of conceptual competence than by perceptual error associated with the texture gradient effect. Other researchers have drawn attention to the way in which map reading and interpretation may be influenced by the perceptual activity of the map user (Robinson and Petchenik, 1976; Board and Taylor, 1977).

In considering problems of visual perception, it is interesting to speculate whether there is any relationship between the intellectual realism in children's drawings, discussed in chapter 2, and the way they respond to contour patterns. Although most children progress to visual realism in the drawings they produce after the age of about 9 years, it is possible that some older children may resort to a form of intellectual realism when they try to make sense of an unfamiliar pattern representing a three-dimensional configuration. In the present research, when attempting to match a contour pattern inside a square on the map with a relief model, some children may have mentally extended the contours beyond the square and visualised a broader pattern such as a set of concentric circles representing a hill. A generous interpretation of perceived contour patterns is not inconsistent with the volatile nature of representational activity in children's drawings.

One of the main attributes of people with high spatial ability is held to be a good spatial memory (MacFarlane Smith, 1964; NFER, 1991). People who possess a good spatial memory probably recognise component shapes from past experience, and then register how these components are interrelated spatially. In this way such people build a firm base upon which they can carry out mental transformations. Their spatial thinking relies on spatial memory, and the power of that memory increases with attention to shapes. This is supplemented and reinforced by knowledge of the rules for recognising shapes, repeated exposure to them, and frequent practice in interpreting them.

Support for the importance of memory, exposure and practice in interpreting contour patterns comes from a study of the map reading abilities of undergraduates by Gilhooly *et al* (1988). They compared the performance of first-year psychology and geography students, dividing them on the basis of their geographical education at school and their extra-curricular use of contour maps, as in hill walking and orienteering. They found that subjects skilled in contour map reading showed advantages in the recall of contour maps, both in answering questions from memory about the maps, and in drawing the contour aspects of the maps from memory. On the other hand these skilled readers showed no advantage with planimetric maps which do not show topography, such as street plans of towns.

The results are interpreted by Gilhooly *et al* as showing that skilled readers of contour maps have formed a rich repertoire of contour patterns or schemata which enables them efficiently to encode and retrieve contour information. They argue that such individuals, who will either have studied geography formally for several years, or will have made extensive use of contour maps in real-life settings, would not be expected to have advantages with planimetric maps. In other words the special features of contour patterns require a good spatial memory for their interpretation, reinforced by repeated exposure and plenty of practice.

Although the number of pupils in the present research was small, the difference between the performance of the boys and the girls helps to confirm the findings of earlier research, both into mental abilities in general and into map reading in particular. Gender differences, showing that males perform better than females in spatial tasks and in tests of spatial ability, are found consistently in the literature on mental abilities (Maccoby and Jacklin, 1974; Harris, 1981; Newcombe, 1982). Differences in the spatial abilities of boys and girls seldom occur below the age of 8 or 9 years. Although some studies have found no gender differences after this age, when differences do occur the scores for boys are usually higher than those for girls. These become more pronounced during adolescence, when boys demonstrate a clear superiority in spatial skills.

In his study of the cognitive maps of children aged 6-11 years reviewed in chapter 1, Matthews (1984) found that the free-recall sketch maps drawn by boys from about the age of 8 years onwards showed a broader understanding of space, and mentioned places much further away from their homes, than those drawn by girls. The maps drawn by boys were more accurate and complex in form, showing a good understanding of spatial relationships. By the age of 11 years strong differences were apparent, boys demonstrating a higher level of spatial competence in their mapping.

In both stages of the present research involving pupils aged 10-11 years, the boys obtained higher mean overall scores than the girls, although the boys did not score more highly in all sections of the tests and the difference was not significant in stage 2. Boys consistently performed better than girls on the contour sketch map tasks in my previous research, also summarised in chapter 1. Higher scores were obtained by boys not only in the relief shading task but also in the subsequent questions on identifying the higher ends of the short lines, deciding which one lay on the steepest slope, and estimating height at given points. The differences were small among pupils aged 11-12 years but became more pronounced among the pupils aged 13-14 and 15-16 years (Boardman, 1990).

Implications for teaching

It seems logical to conclude that the pupils' limited conceptual understanding explains at least some of their difficulties in reading contours and interpreting contour patterns. The suggestion in the previous section, however, is that the pupils may have been experiencing perceptual as well as conceptual problems. If this is the case, it becomes all the more important to structure teaching and learning so that these problems are minimised.

There were limitations to the teaching undertaken in the present study. I was a visitor to the school and so was not familiar with the children's abilities. The teaching had to be completed within a limited amount of time. The practical work which the pupils carried out in constructing their relief models was a time consuming and largely mechanical activity. The pupils participated in the group work to varying degrees. As with much small group work, there were enthusiastic leaders and disinterested passengers. The former probably strengthened their grasp of the contour concept during the process of model building, whilst the latter may have learnt little.

After they had completed their models, the pupils were not subsequently taught that the spacing of contours on a map indicates the steepness of the slope. They were also not specifically taught that certain contour patterns represent hill tops or valley bottoms, or that the top of a spur can be distinguished from the bottom of a valley by looking at the numbering of the contours. The pupils were not given any practice in applying their newly acquired knowledge of contours to another map which they had not previously seen. The questions and tasks that were set in the tests for the purposes of the research followed soon after the lessons in which the pupils encountered a new concept for the first time.

Despite these limitations, it is possible to suggest from the findings some procedures which teachers could follow when children are being taught the concept of contours. These might help pupils to understand and learn the concept more readily, and at the same time reduce the perceptual errors which may occur in reading and interpreting contour maps.

1. Great care should be taken in drawing the first contour map to be used by children. The contours should be spaced fairly widely and clearly numbered. The numbering should be prominent and observe the convention that the top of the number is on the higher ground. Interpolation of unnumbered contours should be straightforward from adjacent contours above and below. The vertical interval of the contours should be apparent by looking at the key or inspecting the map. Contours should not be partly obscured by unnecessary detail or symbols showing other features.

2. The pupils should use a contour map with the above characteristics as the basis for constructing a relief model to convert the two-dimensional map into a three-dimensional representation of the landscape. Polystyrene tiles form a suitable building material as they are thicker than card, yet can be cut with scissors. Care should be taken to avoid too great a vertical exaggeration, so that slopes do not appear

to be considerably steeper than they are in reality. The resulting stepped slopes should be smoothed out with plaster or filler, and the finished model can then be painted. It is useful to display a model under construction alongside a completed model, as recommended by Rhodes (1994).

3. When completed the model should be used for teaching purposes in order to demonstrate and reinforce the contour concept. The pupils should compare their model with the map from which they constructed it and answer appropriate questions on map and model. Thus they should relate the closeness of the contours on the map to the steepness of the slopes on the model, and relate heights which they read or interpolate from the map to the corresponding points on the model. The contour patterns representing hill tops and valley bottoms should be compared with these features on the model.

4. The pupils should apply their newly acquired knowledge and skills to reading and interpreting contour patterns on maps which they have not previously seen. Questions should initially be fairly simple, such as reading heights, recognising slopes, and identifying hill tops and valley bottoms. More difficult questions can then be attempted, such as interpolating heights on unnumbered contours, estimating heights between contours, and identifying spurs between valleys. Plenty of practice is clearly necessary when pupils are learning to read and interpret contour maps.

5. Pupils should be taught to identify some of the common patterns of contours coloured brown on Ordnance Survey maps at the scales of 1:10,000, 1:25,000 and 1:50,000, and should relate these patterns to the landforms they represent. Particular attention needs to be given to the V-shaped re-entrants of contours representing valleys and the parallel contours indicating the sides of flat-bottomed valleys. Having learnt to distinguish valley contour patterns from those of the intervening spurs, in which the highest land is at the centre of the re-entrants, pupils should be taught to identify hills and ridges from their characteristic contour patterns. They should then learn how to recognise some of the larger landscape features such as escarpments and plateaus.

In practice other information shown on Ordnance Survey maps can often be used in conjunction with contours to assist perception of contour patterns. Rivers, streams, lakes and other water features marked in blue on the Pathfinder and Landranger maps at the scales of 1:25,000 and 1:50,000 provide clues to the direction of slope of the land and the identification of landforms. More use could be made of the Travelmaster maps at the 1:250,000 scale and the former Tourist maps at the 1:63,360 scale, both of which employ colour layer tinting. Different shades of green, yellow and brown are printed between successive contours at ascending altitude. Although each layer of colour suggests a uniform level between contours instead of a progressive change in height, the overall distribution of high and low land is easier to see at a glance. A realistic visual impression of height and slope is also created on these maps by the use of hill shading, in which it is imagined that a relief model is brightly illuminated obliquely from the north-west corner, so that slopes facing east and south-east are in shadow. Research into cartographic design carried out by Phillips (1979) suggests that adults read and interpret layer tint maps with greater speed and accuracy than contour maps.

Whilst the role of the teacher is crucial when pupils are *learning* the concept of contours and interpreting the patterns they form, the development of computer software now provides opportunities for pupils to *practise* their newly acquired skills. Several programs have been developed to provide drill and practice routines in various forms of map reading involving direction, location, scale and symbolism, and some also convert common contour patterns into three-dimensional representations of relief features. The storage of Ordnance Survey map data in digital form on computers has permitted the development of sophisticated software which raises the contours from a digital 1:50,000 map and produces a three-dimensional representation of the relief over the whole of the map shown on the screen. Digital terrain modelling is certainly a very striking development in mapping software, but the extent to which it helps pupils to recognise and interpret contour patterns awaits evaluation.

The national curriculum lesson

The statutory Order for geography in the national curriculum was, from the start, controversial. Many of the problems with the Order have been blamed on the composition of the Geography Working Group appointed by the Secretary of State for Education. Membership of the Group, which was chaired by a university vice-chancellor, was dominated by academic geographers and included only one practising secondary school teacher and one primary specialist. The problems predicted by teachers were confirmed as they attempted to translate the statutory requirements into curricula, and testing agencies tried to determine how pupils' achievements could be assessed. The main difficulties were associated with the overloaded and overprescriptive content of the geography curriculum, the large number of content-specific statements of attainment, the interpretation of the statements, the application of the 10-level scale to the subject, and the overlap of levels between key stages (Boardman and McPartland, 1993d; Bennetts, 1994).

Some of the problems with the geography Order were specific to the subject, but difficulties in implementing the national curriculum were encountered to a greater or lesser extent in other subjects. Although the majority of teachers supported the principle of a national curriculum, most objected to the overloaded and overprescriptive Orders which were approved by Parliament against the advice of teachers, and to the national tests which the Government insisted should be administered by teachers to measure pupils' attainment. There followed a period of considerable tension between the Government and the teaching profession, particularly in relation to national tests. Matters came to a head in 1993 when the Secretary of State for Education, John Patten, adopted an unyielding and confrontational style in his dealings with teachers, described parents who objected to national tests as 'neanderthal' and was sued for libel by the Chief Education Officer for Birmingham whom he had called a 'nutter'. In the summer of that year teachers refused to administer national tests in English, mathematics and science even though they were legally required to do so. This act of civil disobedience, which the Government was powerless to stop, brought the national curriculum and testing arrangements close to the point of collapse.

The beleaguered Secretary of State asked Sir Ron Dearing to carry out a review of the national curriculum and assessment arrangements. Adopting a conciliatory approach and listening to teachers, Sir Ron Dearing engaged in a process of review which entailed an extensive programme of consultation with the profession. His interim report, completed in July 1993, proposed a substantial reduction in the content of the subject Orders and the scale of national testing. After further consultation he completed his final report in December (Dearing, 1993) and his main recommendations were accepted in full by the Government. Sir Ron Dearing had successfully negotiated the ceasefire and ultimate peace accord which brought to an end the war over the national curriculum and testing arrangements.

The Dearing Report recommended that there should be a substantial slimming down of the subject content required to be taught by law. This slimming down should be achieved by identifying in each subject those elements which were to be made compulsory and those elements which were to be optional. The number of statements of attainment in each subject should be greatly reduced and the number of attainment targets reviewed. The national curriculum in general, and the subject Orders in particular, should be made less prescriptive in order to give more scope for professional judgement. The arrangements for assessment should be simplified: national tests should focus sharply on summative purposes, while moderated teacher assessment should be the prime means of formative assessment.

The School Curriculum and Assessment Authority (SCAA) set up advisory groups to reduce content and simplify assessment in each subject. Membership of the subject advisory groups consisted largely of practising primary and secondary school teachers, many of whom had been nominated by their subject associations. The proposals for all subjects were published in May 1994 with the general recommendation that programmes of study 'should guide the planning, teaching and day-to-day assessment of pupils' work'. It was also proposed that statements of attainment should be replaced by level descriptions, the essential function of which is 'to assist in the making of summary judgements about pupils' achievement as a basis for reporting at the end of a key stage' (SCAA, 1994:1). A clear rationale for the distinction between programmes of study and attainment targets was thus established. Discussion of content now relates to the programmes of study, whilst measurement of attainment is linked to criteria in level descriptions.

After a period of consultation with the teaching profession, the proposals were subsequently confirmed in new Orders for all national curriculum subjects approved by Parliament in January 1995 for implementation in the following September. In the Order for geography, the programme of study for pupils aged 7-11 in key stage 2 includes a brief list of map skills. It states that pupils should be taught to 'use and interpret globes, and maps and plans at a variety of scales; the work should include using co-ordinates and four-figure grid references, measuring direction and distance, following routes' (DFE, 1995:4). There is no reference to contours or relief maps.

The programme of study for pupils aged 11-14 in key stage 3 similarly includes a short statement on map skills. Pupils should be taught to 'use and interpret maps and plans at a variety of scales, including Ordnance Survey 1:25,000 and 1:50,000 maps; the work should include using six-figure grid references, following routes, identifying relief and landscape features, drawing cross-sections, and using maps in decision-making exercises' (DFE, 1995:10). This is the only reference to identifying relief features on maps in the new geography Order. By implication it means learning the concept of contours, although the word is not used anywhere in the Order.

The number of attainment targets in geography has been reduced from five to one and 183 statements of attainment have been replaced by 8 level descriptions and a further one for exceptional performance. All of the level descriptions are phrased in very general terms; for example, the level 5 description includes the statement that pupils 'select and use appropriate skills' from the key stage 2 or key stage 3 programme of study (DFE, 1995:19).

The consequence of the changes to the national curriculum is that primary schools will not be expected to teach the concept of contours to children. The understanding of contours is confirmed as more appropriate for teaching to pupils aged 11-14, as I recommended before the national curriculum was introduced (Boardman, 1983, 1986). The evidence which has been presented in this thesis provides further support for the inclusion of contour patterns in the secondary rather than the primary school curriculum. Accordingly the recommendations for teaching the concept of contours and the use of contour maps, outlined in the previous section, are addressed to teachers in secondary schools rather than those in primary schools. I have used the contour map of Durham (Figure 3.1) and relief models built from it (Figure 3.2) to illustrate the method of teaching the concept of contours in a chapter on learning from Ordnance Survey maps (Boardman, 1996) in a new handbook for geography teachers in secondary schools (Bailey and Fox, 1996).

Towards collaborative research

It was shown in chapters 1 and 2 that research carried out by geographers and psychologists has taken different paths. Geographers have investigated pupils' understanding of map concepts and mastery of map skills in the classroom, and have administered written tests to measure pupils' performance. The maps used in the tests are cartographic maps such as those published by the Ordnance Survey, or maps which have been redrawn from published sources to show selected detail relevant to the research. The results of the tests have highlighted the kinds of errors made by pupils and drawn attention to the difficulties which they appear to experience in attempting certain tasks. Discussion of the results, however, has rarely provided insights into the reasons *why* pupils perform well or badly on specific tasks.

Research into map understanding carried out by psychologists, on the other hand, has mainly concentrated on the use of simple representations by young children. Experiments have been undertaken in rooms, laboratories or other small areas such as part of a playground. The children have attempted practical tasks individually and the strategies they employ have been carefully observed and reported. The maps used by psychologists in their research, however, are not cartographic maps. They are highly simplified representations of small areas which should be called *plans*, the term used by architects, surveyors, cartographers and geographers to denote such large-scale representations. For this reason the titles of articles which include such phrases as 'map reading skills' (Bluestein and Acredolo, 1979; Presson, 1982), and 'map use' or 'the use of maps' (Blades and Spencer, 1986, 1987) are misleading because they do not relate to maps in the cartographic sense.

As was pointed out in chapter 2, psychologists have sometimes used the words 'map' and 'plan' as if they are interchangeable. The confusion was illustrated in Figure 2.4, in the legend of which the first two drawings are called maps even though the scale is double that in the second two drawings which are correctly called plans. Elsewhere the words 'map' and 'model' are used without making any distinction between two-dimensional and three-dimensional representations of space. Findings obtained from children's use of a *model* to undertake the task illustrated in Figure 2.3 are generalised as being applicable to the use of a *map*. Thus the researchers claim that children as young as 3 years old can use maps to locate places in small environments and that after the age of 4.5 years many children can use a map to follow a route (Blades and Spencer, 1986). These are bold claims to make about children's use of maps from the limited evidence provided by their success with other kinds of representation.

The experiments carried out by psychologists have yielded some valuable information about the ways in which young children use simple plans to attempt specific tasks. The findings from these experiments suggest that children's spatial understanding develops earlier than the ages postulated by Piaget and that young children possess some of the basic skills necessary for using spatial representations. Unfortunately psychologists have tended to assume that results obtained using highly simplified large-scale representations also apply to the use of small-scale cartographic maps. For example, in discussing the educational implications of the success of young children in using a coordinate system on the board with sunken squares and pictures shown in Figure 2.1, the researchers conclude: 'If children are given tasks in which a coordinate system is provided (e.g. on a graph or on a map), there is no reason why children cannot start to learn the skills associated with using coordinate grids from a very early age' (Blades and Spencer, 1989: 18).

Elsewhere the same authors imply that I ought to revise my list of skills in which grid references are not considered appropriate until the 7-9 years age group because they have shown that '4-year-olds can use them with apparent full understanding and satisfaction' (Spencer, Blades and Morsley, 1989:247). All they have really shown, however, is that young children can use coordinates on a board with sunken squares and pictures. This is a completely different matter from using grid references on a map, which involves reading vertical and horizontal axes superimposed on a complex array of other information. The recommendations of psychologists were ignored by geographers during the revision of the national curriculum. In the new statutory Order for geography, produced after extensive consultation with teachers, four-figure grid references are included in the programme of study for pupils aged 7-11 years in key stage 2, and six-figure grid references are included in the programme of study for pupils aged 11-14 years in key stage 3 (DFE, 1995). There are sound reasons for this arrangement in view of the need to reduce the prescribed content of the geography curriculum and teach grid references only after coordinates have been taught in mathematics.

It is difficult to determine with any degree of accuracy the most suitable age at which to teach children a particular concept, and the contour concept is no exception. The great diversity in the research studies carried out by geographers and psychologists, and the different methods and materials used in testing children of a wide age range, has not helped the process of identifying the mapping concepts and skills which are most likely to be appropriate for pupils at specific ages. Psychologists have a contribution to make to mapping research because of their expertise in cognition, perception and child development, but it is a contribution which needs to take account of the realities of teaching and learning.

The laboratory conditions in which psychologists conduct their experiments bear little resemblance to the busy classrooms in which teachers work and children learn. Teachers have to make daily decisions about what to teach, and there is a limit to what children can be taught in the time available during any one year. With younger children priority has to be given to ensuring basic standards of literacy and numeracy, as infant school teachers repeatedly told Sir Ron Dearing when he consulted them during his review of the national curriculum. There are more important things for young children to learn than how to read or use maps or plans.

The exaggerated claims and unwarranted inferences made by psychologists in articles with misleading titles illustrate the limitations of pursuing research into map understanding from within a single discipline. There needs to be a dialogue between geographers, psychologists and teachers about the kinds of research which are likely to be most productive. This should help to ensure that the results of experiments carried out in laboratories are not used to justify recommendations which make unrealistic demands on scarce curricular time in classrooms.

The potential benefits of interdisciplinary collaboration have been demonstrated by Liben and Downs (1989), psychologist and geographer directing the Mapping Project at Penn State (MAPPS). They use cartographic maps in their research and avoid the faulty assumptions about maps that appear in the psychological literature. They also organise activities for children in the classroom to provide a teaching programme in mapping as well as research data on pupils' map understanding. The need to strengthen the link betwen teaching and research was an important consideration in the research reported in this thesis.

Future research into pupils' perceptions of contour patterns should clearly be undertaken within the framework of the revised national curriculum. This means that the pupils should be aged 11-14 years in the secondary phase of education, where they will learn to read and interpret relief maps as required by the programme of study for key stage 3 in the new geography Order. The research should be carried out in conjunction with a teaching programme in which pupils study the essential features of relief maps and the representation of landforms by means of contour patterns.

The teaching programme outlined earlier in this chapter could form the context for the research. When pupils have completed the five stages of the programme, they could be tested individually on reading heights, recognising slopes, and identifying hill tops and valley bottoms from contour patterns on a simplified map. This could be followed by more difficult questions, such as interpolating heights on unnumbered contours, estimating heights between contours and identifying slopes with varying degrees of steepness. Similar questions could subsequently be asked about contour patterns on actual Ordnance Survey maps, starting with simple patterns in areas of gently rolling relief and proceeding to more complex patterns in areas with greater contrasts in topography.

The research should attempt to identify the strategies which pupils use in answering the questions, particularly when they make errors. If they reverse the direction of slope, for example, it would be useful to know whether their errors arise in reading the numbering on the contours, or in recalling the contour patterns which represent particular landforms, or in visualising the relief depicted by different contour patterns. Clarification of the sources of errors might indicate whether the pupils' difficulties are conceptual or perceptual in nature.

Collaboration between psychologists and geographers in future research into pupils' understanding of contour patterns would help to ensure that the processes involved in reading contours are investigated in addition to performance as measured by test scores. The research would also focus not only on how pupils perceive common contour patterns in isolation but also on how they attempt to make sense of the infinite variations embedded in the complexity of the typical topographical map.

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Appendix 1a. Test questions on Durham map in stage 1

This is the map you used to build the model last week.
This time I've marked some footpaths on it in red.
Let's imagine we're going for a walk along this path.
We'll follow the direction of the arrows.

At spot A what height are we? (60)

At arrow 1 are we going uphill, downhill or on the level? (D)

At arrow 2 are we going uphill, downhill or on the level? (U)

At spot B what height are we? (50)

At arrow 3 are we going uphill, downhill or on the level? (D)

At spot C what height are we? (45)

At arrow 4 are we going uphill, downhill or on the level? (L)

At spot D what height are we? (Below 40, or between 35 and 40)

At arrow 5 are we going uphill, downhill or on the level? (U)

At spot E what height are we? (Between 55 and 60, or a number)

Appendix 1b. Test questions on contour map in stage 1

This is a map you haven't seen before.
The contours are shown on it in the same way.
The blue lines are streams and the red lines are footpaths.
Let's imagine we're going for a walk along this path.
We'll follow the direction of the arrows.

At spot A what height are we? (40)

At arrow 1 are we going uphill, downhill or on the level? (U)

At spot B what height are we? (Above 75, or between 75 and 80)

At arrow 2 are we going uphill, downhill or on the level? (D)

At spot C what height are we? (Below 60, or between 55 and 60)

At arrow 3 are we going uphill, downhill or on the level? (L)

At spot D what height are we? (Between 50 and 55, or a number)

At arrow 4 are we going uphill, downhill or on the level? (D)

Now here is a choice of path for you to make.
Let's imagine we're at spot A and we want to walk to spot C.
But we don't want to go above 60 metres.
Which path will you choose - this one or this one? (Via D)

Here's another choice of path for you to make.
Let's imagine we're at spot C and we want to walk to spot F.
But we want to stay on the level all the time.
Which path will you choose - this one, or this one, or this one? (Via E)

Appendix 1c. Test questions on models in stage 1

1. Here is a contour pattern with numbers on it.
   The pattern was used to make these four models.
   The layers of card are arranged in different ways.
   Which model matches the pattern? (B)

2. Here is another contour pattern with numbers on it.
   The pattern was used to make these four models.
   The layers of card are arranged in different ways.
   Which model matches the pattern? (G)

3. Here is another contour pattern with numbers on it.
   The pattern was used to make these four models.
   The layers of card are arranged in different ways.
   Which model matches the pattern? (J)

4. Here is another contour pattern with numbers on it.
   The pattern was used to make these four models.
   The layers of card are arranged in different ways.
   Which model matches the pattern? (O)

5. Here is another contour pattern with numbers on it.
   The pattern was used to make these four models.
   The layers of card are arranged in different ways.
   Which model matches the pattern? (U)

Appendix 2a. Test questions on heights in stage 2

1. What is the height at this black pin? (50)

2. What is the height at this white pin? (60)

3. What is the height at this black pin? (80)

4. What is the height at this white pin? (70)

5. What is the height at this black pin? (50)

Appendix 2b. Test questions on slopes in stage 2

1. If we walk from the yellow pin to the red pin, are we going uphill, downhill or on the level? (L)

2. If we walk from the light blue pin to the dark blue pin, are we going uphill, downhill or on the level? (U)

3. If we walk from the light green pin to the dark green pin, are we going uphill, downhill or on the level? (D)

4. If we walk from the yellow pin to the red pin, are we going uphill, downhill or on the level? (U)

5. If we walk from the light blue pin to the dark blue pin, are we going uphill, downhill or on the level? (U)

Appendix 2c. Test questions on models in stage 2

1. Let's look at the contour pattern in this square.
   This card shows the contour pattern enlarged.
   The pattern was used to make these four models.
   Only one model shows the slope correctly.
   Which one is it? (C)

2. Let's look at the contour pattern in this square.
   This card shows the contour pattern enlarged.
   The pattern was used to make these four models.
   Only one model shows the slope correctly.
   Which one is it? (H)

3. Let's look at the contour pattern in this square.
   This card shows the contour pattern enlarged.
   The pattern was used to make these four models.
   Only one model shows the slope correctly.
   Which one is it? (K)

4. Let's look at the contour pattern in this square.
   This card shows the contour pattern enlarged.
   The pattern was used to make these four models.
   Only one model shows the slope correctly.
   Which one is it? (P)

5. Let's look at the contour pattern in this square.
   This card shows the contour pattern enlarged.
   The pattern was used to make these four models.
   Only one model shows the slope correctly.
   Which one is it? (U)