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Environmental geology mapping for land use planning purposes in the Torbay area

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In 1986 Geomorphological Services Ltd (GSL), in association with Engineering Geology Ltd (EGL), commenced an environmental geology study of the Torbay area for the Department of the Environment. The objectives of this study were to produce new geology maps and to provide a compilation and interpretation of geological, geotechnical and earth science data as a basis for safe, cost-effective planning for development and urban renewal. The study involved both fieldwork and the collation of existing records and published material. This paper describes the nature and scope of the work and includes a presentation of certain aspects of the study. The importance of this technique of presenting thematic data for land use planning is discussed.

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Introduction

Increasing pressure for infra-structural development in Great Britain heightens the conflict between the different land use demands placed on an area. Options are often constrained by the need to safeguard the environment, poor ground conditions, economics, existing development and the demands for urban renewal. Within this framework geology, geotechnics, geomorphology and related subjects can provide essential information on constraints to development (such as land instability and poor foundation conditions) and resources for development (such as mineral and water resources, and high grade agricultural land).

However, one of the main problems facing land use planning is that few planners have a geological background and few geologists have a planning background, and hence there is often a communication gap between the two groups. In this context environmental geology or thematic geology mapping provides an important means of presenting the detailed, often very technical, geological and geomorphological information to the planning community.

In Great Britain the Department of the Environment (DOE), together with the Welsh Office and the Scottish Development Department, have commissioned a number of environmental geology maps (EGM's) to identify the best form of presentation of the results to overcome the communication problems between geology and planning (e.g. Nickless 1982; see also Brown et al. 1986; Forster et al. 1987). This paper describes the nature and scope of the environmental geology mapping study of the Torbay area carried out by Geomorphological Services Ltd (GSL) and Engineering Geology Ltd (EGL), for the DOE.

The Torbay EGM

In May 1986 GSL and EGL commenced an environmental geology study of the Torbay area for the DOE. The objectives of this study were:
(i) to produce new geological base maps of the study area, with the available geology maps still largely based on the original mapping carried out by Ussher between 1888 and 1892. However, between 1966-1977 the northern part of the area was resurveyed at 1:10,000 scale by research assistants at Exeter University under the direction of Dr Selwood who produced a revised memoir of the Newton Abbot area (Selwood et al. 1984);
(ii) to provide a compilation and interpretation of geological, geotechnical and earth science data as a basis for cost-effective planning for development and urban renewal. The results of this study have been published as a short report accompanied by a suite of 10, 1:25,000 scale thematic maps. The full list of published maps is as follows:

(1) bedrock geology;
(2) superficial geology;
(3) geomorphology;
(4) slope steepness;
(5) soils;
(6) geotechnical conditions;
(7) sites of geotechnical investigations;
(8) sites of mineral workings;
(9) land use planning provisions;
(10) ground characteristics for planning and development.

The report and maps should be treated as an every-day work of reference by all those concerned with land development, planning and environmental management in the Torbay area, with the narrative taking the form of an extended explanation of the legends found on the maps. The information contained in the maps and report provide the framework within which planning and development decisions may be taken. They provide clear guidelines as to the limitations and constraints likely to be met at particular locations, indicating problem areas where development may be costly in comparison with other areas less disadvantaged by the physical characterisitcs of the ground.

The suite of maps are not restricted to the physical characteristics of the area, but also include information on the location of previous site investigations and former mineral workings, and the nature of land use planning provisions (as at the end of 1987). The last of the maps can be viewed as a summary map which draws selected aspects of the physical environment from each of the other maps, highlighting those ground conditions which are likely to pose significant problems for the planner and developer.

The range of subjects addressed by the study, from geotechnics to agriculture and conservation issues has been much broader than in previous EGM studies, and as a result, the map series title "Applied Earth Science Background to Planning and Development" is considered more applicable.

It is important to recognise that the maps and accompanying reports provide only a general indication of ground conditions and must not be relied upon as a source of detailed information about specific areas, or as a substitute for site investigations. Users of any of the maps and report must satisfy themselves, by seeking appropriate advice and carrying out ground surveys and site investigations if necessary, that ground conditions are suitable for any particular land use or development.

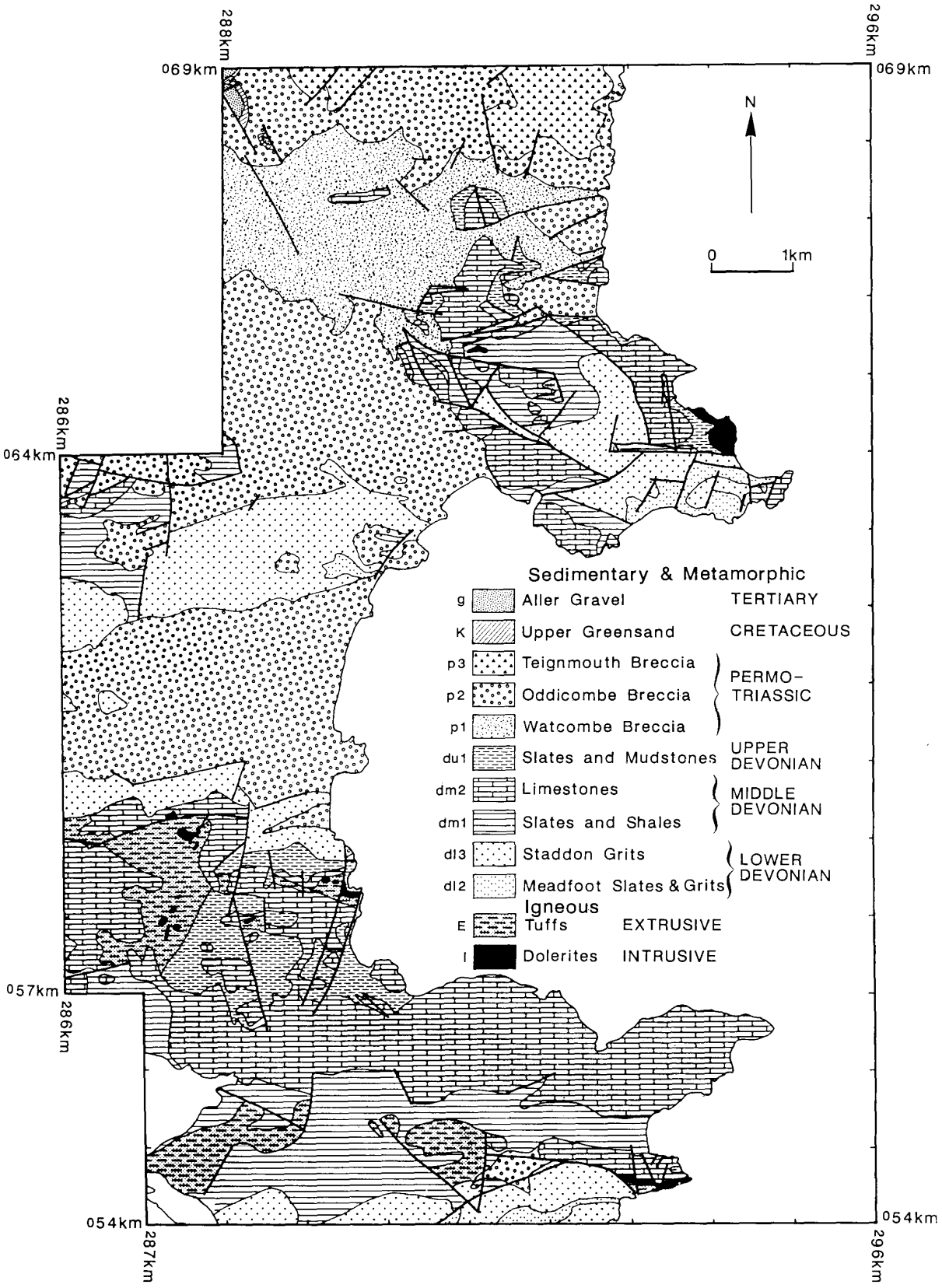

Figure I. Bedrock geology map.

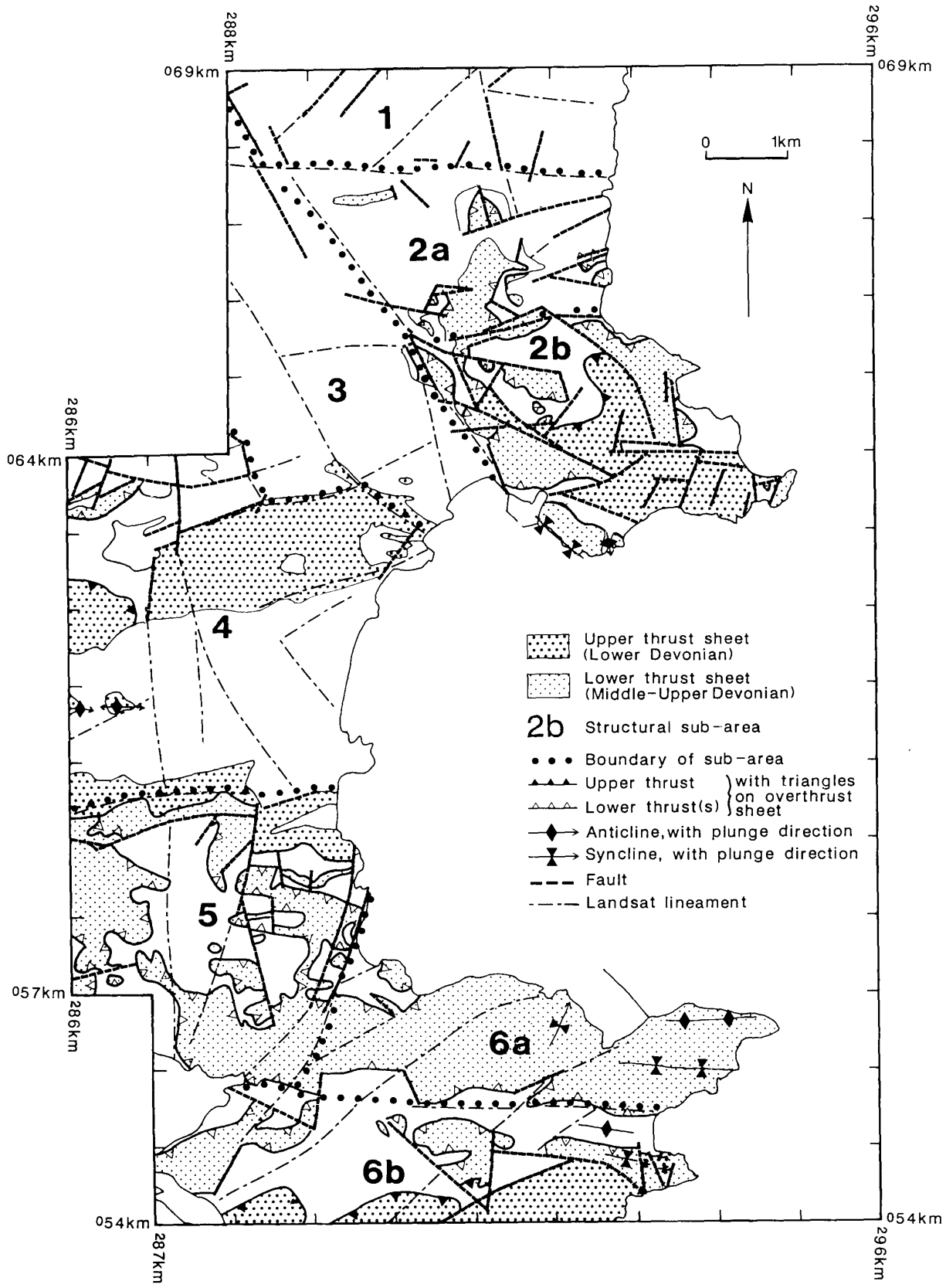

Figure 2. Summary structural geology map.

Work programme

The work undertaken for the study was carried out between April 1986 and March 1988, and includes:

(i) geological mapping;

(ii) 1:25,000 scale thematic mapping;

(iii) computer modelling;

(iv) establishing a geotechnical data base;

(v) identification of sites of former mineral workings; (vi) a review of land use planning provisions.

Geological mapping

Geological field mapping was undertaken at 1:10,000 scale with particular attention paid to checking the lithological boundaries shown on the original 1:10,560 scale geological maps of the area produced by Ussher between 1888-1892, clarifying structural relationships between units and assessing geological structures in a regional context.

The field mapping was supplemented by the interpretation of Landsat Thematic Mapper (TM) imagery, together with the use of additional information from borehole records and previous research. The use of TM imagery allowed the identification and subsequent integration of lineaments of structural significance, providing a continuity of structure not apparent on the previous geological maps.

The area is characterised by complex lateral sedimentary facies changes and structural complexity resulting from recumbent folding, thrusting and faulting. A generalised map of bedrock lithology and a summary structural map are presented on Figs. I and 2 respectively. Together these figures indicate how the distribution of lithological units is controlled primarily by an early (Variscan) phase of thrusting which has resulted in the complicated relationship between Devonian rocks of different ages. At least two main levels of thrusting can be recognised:

(i) a lower thrust of Middle-Upper Devonian limestone over Upper Devonian slates and tuffs or, in places, Middle Devonian slates;

(ii) an upper thrust of Lower Devonian over Middle and Upper Devonian rocks.

These thrusts have been subsequently folded and faulted to form basins in which younger rocks were deposited e.g. the Newton Abbot, Chelston and Paignton cuvettes and the Decoy Basin to the north west. Erosion of the Permian and younger rocks has exposed the underlying thrust sheets in places, resulting in a complex pattern of outcrops, with Permian breccias often occurring in close association with Devonian rocks of different ages.

1:25,000 scale thematic mapping

Aerial photograph interpretation, with additional field verification was carried out for the mapping, at 1:25,000 scale of:

(1) **Superficial geology;** identifying the spatial distribution of the following superficial materials: mixed estuarine salt marsh and lagoonal deposits, contemporary estuarine deposits, contemporary beach material, raised beach deposits, river alluvium, colluvial valley infill, head (periglacial slope deposits), landslide debris and landfill sites.

(2) **Geomorphology and hydrology;** identifying a range of geomorphological features including solifluction lobes, areas susceptible to soil erosion, solution hollows and caverns in the Devonian limestone. The presence of solution features can cause geotechnical problems, for example Brunsden et al. (1976) recorded large sediment-filled solution pipes in a road cutting along the Kingsteignton-Newton Abbot By-pass which caused severe problems during construction (Fookes and Hawkins 1988).

In the light of such potential problems, an electromagnetic survey using a Geonics EM-31 was carried out to establish the extent of karst development within the Middle Devonian limestone of the Torbay area. The instrument provides a continuous reading of ground conductivity (inverse of resistivity) and buried cavities may be identified by the occurrence of conductivity anomalies. The use of electro-magnetic surveying methods has recently been reviewed by McCann et al. (1987).

Two sites were chosen for the geophysical survey, at Wall's Hill, Torquay and on the plateau between Churston Ferrers and Brixham. Electrical conductivity contour plans were produced for both sites, with a sample area shown on Fig. 3. In both areas the limestones had a background conductivity value of less than 0.1mmho/m. Higher values tend to indicate an increase in overburden thickness or the degree of fracturing of the rock mass. Conductivity anomalies were recorded, particularly on the Churston Ferrets plateau where both linear, north-south trending features, and large, circular features appear to be present. In contrast, large areas of the Wall's Hill area had very low conductivity values, below 0.1mmho/m.

The electromagnetic survey was carried out in conjunction with a detailed ground investigation involving both drilling and trial pitting over part of the Churston Ferrers plateau. The results of this investigation confirmed that conductivity anomalies did represent sites of greater overburden thickness than the surrounding areas (Fig. 3).

The results from these sites suggest that there may be considerable spatial variability in the nature and degree of solution weathering within the Torquay limestones. Where solution features are present there will be wide variations in strength and soil thickness even over short distances, resulting in clear problem for foundation design.

As part of the geomorphological mapping the nature and extent of coastal landsliding was recorded. A total of 290 coastal landslides were identified, emphasising the problems encountered in establishing the distribution of landslides in south-west England (Jones et al. 1988). These failures range from large rockfalls on the Permian breccias to small, very rare, falls on the Devonian limestones. The frequency of activity increases on more exposed sections of coast or where the rocks have been shattered by faulting.

Rock and debris slides vary from massive features, such as those in the Redgate Beach area or Daddyhole Cove, to smaller failures on the slates and shales in Saltern Cove, Goodrington. Another characteristic form of slope failure is that of large mudslides developed in the Permian breccias, such as the Valley of the Rocks mudslide at Watcombe.

(3) **Soils;** a wide range of soil units have been identified in the study area, on the basis of both pedological and engineering characteristics. This information has been used to produce an assessment of both agricultural land quality and geotechnical conditions.

Computer modelling

A computer-based digital terrain modelling suite of programmes has been used to produce a three-dimensional representation of the land surface based on the contour information presented on the published 1:25,000 scale Ordnance Survey maps. Slope steepness over the whole of this model was calculated on a 25m x 25m grid, and the resulting map was used to define areas of land steeper than 1:5, the local guideline for building development (Fig. 4).

The slope steepness map indicates both the large range of slope values which occur within the area and the presence of some very steep slopes in absolute terms. These characteristics produce problems for those concerned with planning and development. The steeper slopes provide well-drained conditions, in most cases, climatic advantages when associated with southerly aspects and elevation that provides panoramic views of Tor Bay and the sea. On the other hand these steeper slopes may

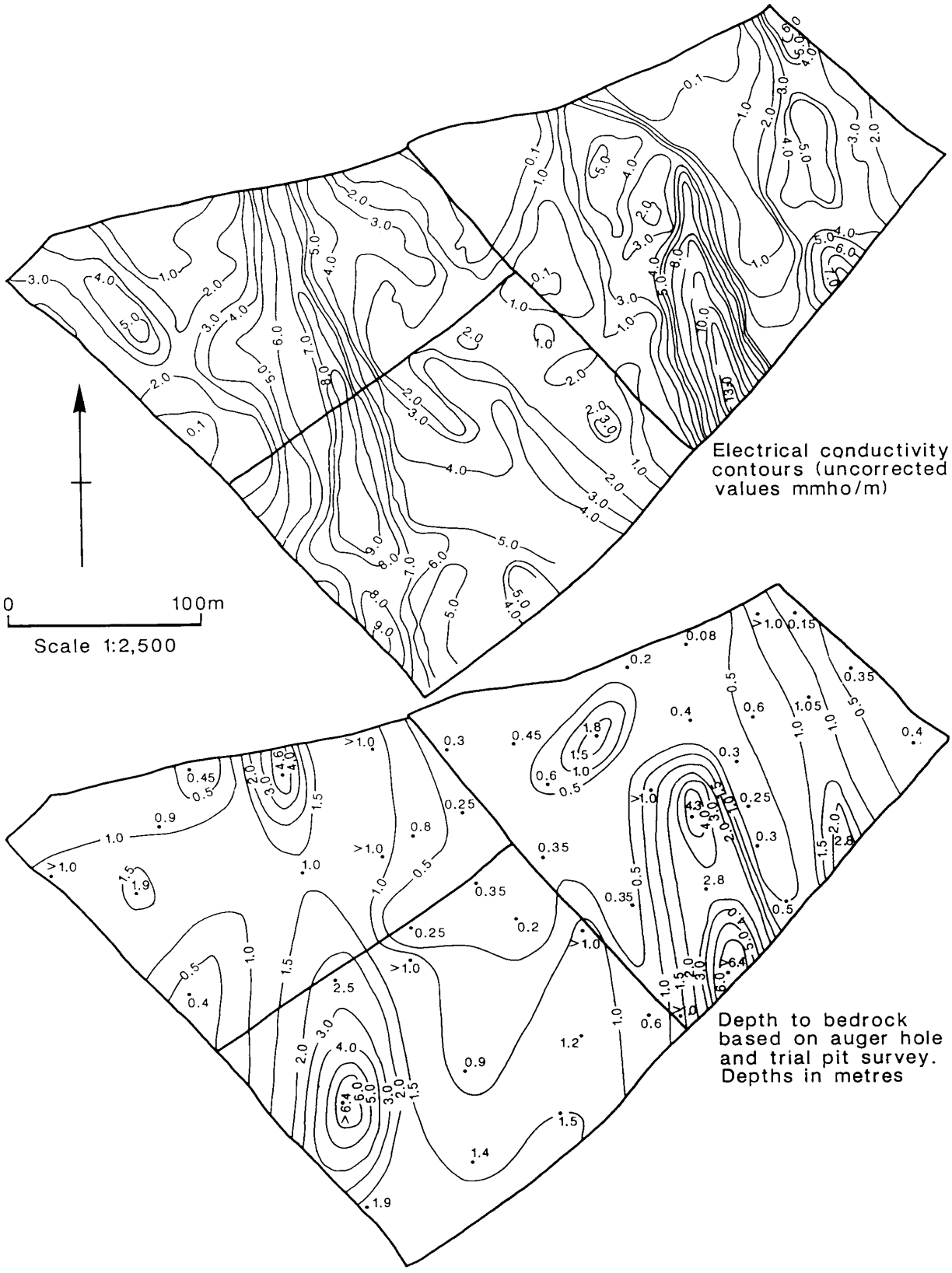

Figure 3. Comparison between electrical conductivity values and depths to bedrock over an area of the Devonian limestone plateau, Brixham.

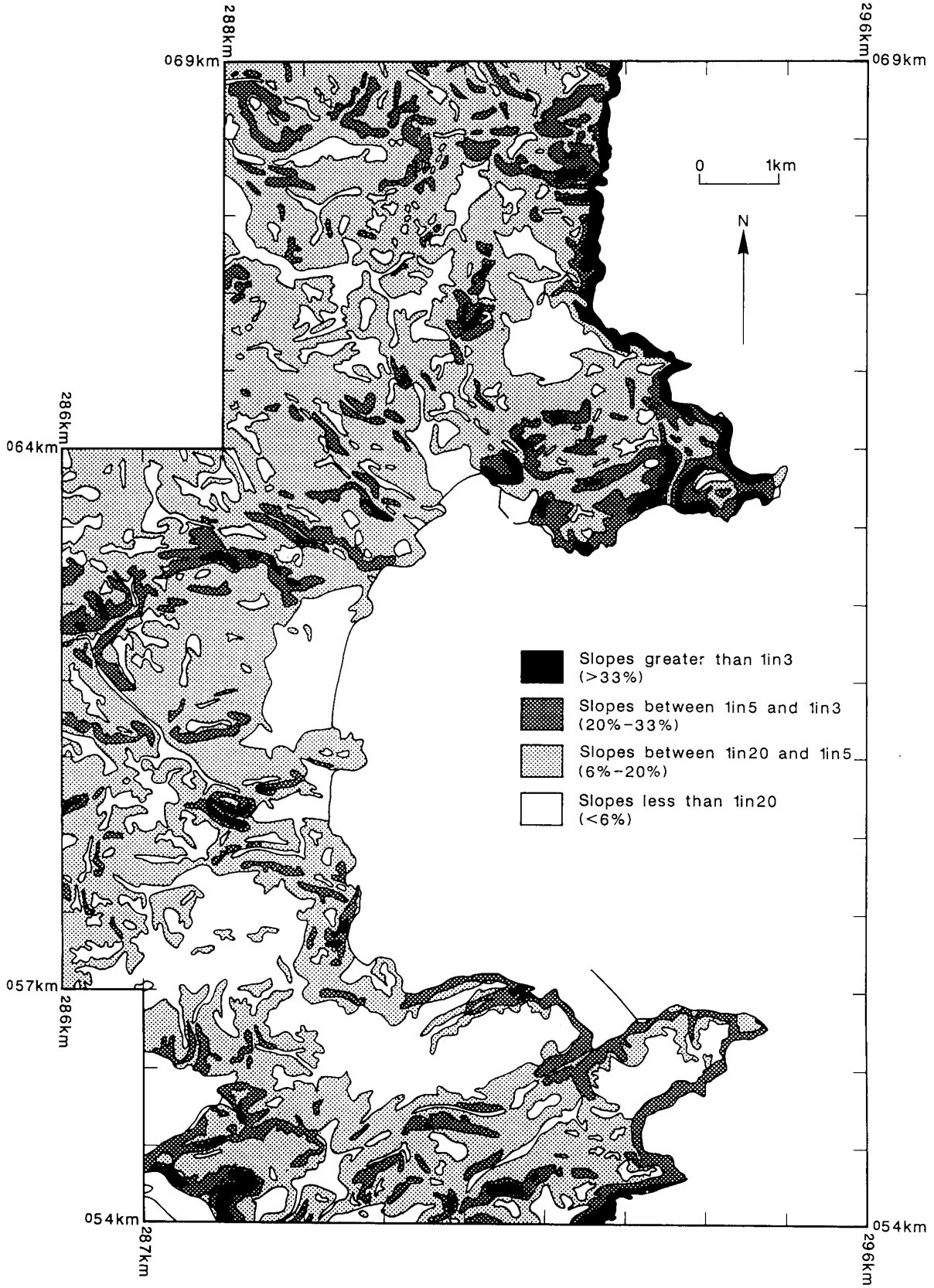

Figure 4. Simplified slope steepness map.

experience stability problems, especially where slopes have been modified during construction.

Establishing a geotechnical database

Part of the study has been directed towards the collection, collation and synthesis of all existing published and archival material relevant to the development of a computerised geotechnical database for the Torbay area. Archival sources have included field notes, borehole logs, site testing reports from central and local government, statutory undertakers, research and academic institutions and private sector mineral operators, consultants and developers. The resultant database provides a means of accessing the material but does not provide specific technical information. It is up to the user to assimilate this information, assess its usefulness and negotiate with the holder of the data for its release and use.

Identification of sites of former mineral workings

The locations of former mineral workings have been identified from a search through historical maps of the area, particularly the lst and 2nd editions of the Ordnance Survey 6 inch to 1 mile map series. These mineral workings are of particular significance for the following reasons:

(i) many sites have been backfilled with various types of waste material with unknown degrees of compaction or consolidation;

(ii) unfilled quarries have been left with bare rock faces which may be prone to rock falls or other forms of instability.

Review of land use planning provisions

Land use planning comprises a complex system of decision making processes which aims to secure the best possible balance of development and conservation of the land in the public interest. This normally requires of the local planning authority a positive approach to development, the need to reconcile conflicting claims for alternative land uses, and a concern for the environmental quality of the area under its jurisdiction.

In practice these responsibilities are expressed both through planning policy, in the form of development plans, and through decisions regarding specific planning applications. In so far as the first of these have appeared in publications issued by the relevant authorities and organisations, they can be brought together on one map. This has been done for the study area as a whole, giving a map of land use planning provisions as they stood at the end of 1987. Each of the provisions is briefly outlined in Table 1.

Ground characteristics for planning and development

During the course of this study it has become apparent that there are a range of ground characteristics which could be of major concern to planners and developers. These aspects have been abstracted from the systematic maps 1-8 and have been recompiled on to a single map so as to identify those locations where difficulties may reasonably be expected to occur. This does not mean that other specific problems will not occur elsewhere. The regional characteristics which have been included on this map are shown in Table 2.

Discussion

A common criticism of Environmental Geology Mapping (EGM) studies is that the final maps are too generalised and could be misinterpreted by non-specialist users who may assume that where no limitations are depicted a development can proceed without further investigation. However, it should be reemphasised that the purpose of such studies is to make planners and developers aware of relevant ground conditions so that they can seek professional advice where necessary.

EGM'S can heighten the awareness of the physical conditions prevailing within an area and should, if used correctly, enable further detailed investigations to focus on certain factors which may otherwise have been overlooked, such as the presence of cavernous limestone. In other instances awareness of the geological conditions may prevent the implementation of planning permission in cases which could lead, as a result of the development being proposed, to considerable effects on surrounding properties.

Table 1. Land use planning provisions.

CATEGORY OR DESIGNATION	DEVELOPMENT CONTROL/CONSERVATION STRATEGY
Grade 1, 2 and 3a agricultural land	High quality agricultural land. Local planning authority required to consult MAFF during preparation of development plans or when considering planning applications where the proposal would involve the loss of 20 ha or more of Grades 1, 2 or 3a land. *
Local Nature Reserves	Declared by Torbay Borough Council in consultation with the Nature Conservancy Council, under the National Parks and Access to the Countryside Act, 1949.
Sites of Special Scientific Interest	Notified under the Wildlife and Countryside Act, 1981 by the Nature Conservancy Council, which has a commitment to preserve the integrity of the sites.
Areas of Outstanding Natural Beauty	Designated by the Countryside Commission under the National Parks and Access to the Countryside Act, 1949. There is a presumption against major development within an AONB.
Scheduled Ancient Monuments	Scheduled under the Ancient Monuments and Archaeological Areas Act, 1979 and protected by the Historic Buildings and Monuments Commission.
Heritage Coastline	Non-statutory designation declared jointly by the Countryside Commission, Devon County Council, The National Trust and South Hams District Council. Areas along the coast of broad conservation value.
Coastal Preservation	Designation declared by Devon County Council to prevent new development along the unspoiled coastline. Areas
Areas of Great Landscape Value	Designation declared by Devon County Council to ensure that the landscape quality is conserved and enhanced.
Nature Conservation Zones	Designation declared by Devon County Council to protect important and valuable wildlife habitats by providing protection from development that may have an adverse effect on the site.
Mineral Consultation Areas	Designation declared by Devon County Council to prevent sterilisation of mineral resources.

* Note: Detailed Agricultural Land Classification information is only available for Torbay Borough.

Table 2. Ground characteristics for planning and development.

GROUND CHARACTERISTICS	DESCRIPTION
Cavernous limestone	Extent of Middle Devonian limestone affected by solution weathering to a variable degree. Possible presence of extensive soil filled solution pipes, caverns and swallow holes in bedrock. Infill may contain large voids. Extent of solution weathering cannot be determined without investigation.
Upper Devonian slates and mudstones with interbedded tuffs	Outcrop of interbedded and interdigitated mudrocks and tuffs. Problems due to extreme local variation in foundation strata and depths of weathering causing associated difficulties in excavation and foundation design.
Soft ground	Alluvial, colluvial, estuarine and marine deposits. Low bearing capacities due to low shear strengths, high compressibility soft silts and clays, with sand and gravel layers and bands of peat. Possibility of high groundwater tables and flooding.
Actively eroding coastlines	Areas of active coastal landsliding ranging from rockfalls to translational failures.
Ancient coastline landslides	Sites of long-term instability. Problems may result from periodic movements.
Active inland landslides	Areas of presently unstable ground.
Ancient inland landslides	Ancient landslides, presently stable but could be reactivated.
Steep slopes	Slopes steeper than 1:5.
Sites of former mineral workings	Problems associated with steep rock faces or infill material of variable bearing capacity.
Undermined ground	Sites of former iron and tin workings.
Landfill sites	Waste disposal sites.

The authors of this paper agree with the conclusions of Brook and Marker (1987) that EGM's are a valuable means of communication between planners and earth scientists by providing:

(a) detailed information for Local Plan formulation;

(b) the foundation for sound Structure Plan policies and a means of evaluating them;

(c) a context for consideration of development proposals;

(d) a readily accessible database for consulting engineers and other professional earth scientists.

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