Classification of artificial (man-made) ground

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ABSTRACT: The legacy inherited from anthropogenic processes needs to be addressed in order to provide reliable and up-to-date ground information relevant to the urban environment. The legacy includes holes as well as materials. Their characteristics derive from former quarrying and mining activities, industrial processes creating derelict ground, variably consolidated made ground, and contaminated groundwater and soils. All need to be systematically assessed to inform the planning process and provide the basis for engineering solutions. Site-specific investigation needs to be conducted on the back of good quality geoscientific data. This comes from 'field' survey, remotely sensed data interpretation, soil geochemical sampling, and geotechnical investigation. Three-dimensional characterization of superficial deposits is required to reach an understanding of the potential spatial lithological variability of artificial ground and the geometry of importance surfaces, i.e. the boundary conditions.

1. Introduction

The provision of reliable and up-to-date ground information for the urban environment has assumed increasing importance in recent years as towns and cities have become the focus for regeneration and development, and demands the best available geoscientific advice. Clearly the properties of naturally occurring superficial deposits and solid rocks need to be defined and understood. But, in addition, the legacy inherited from anthropogenic processes needs to be addressed.

The legacy includes holes as well as materials. Their characteristics derive from former quarrying and mining activities (leading to subsidence and a disturbed groundwater regime), industrial processes creating derelict ground (leading to unexpected site characteristics – geohazards), earthworks (characterised by variably consolidated made ground), and polluted (even contaminated) groundwater and soils. Some might have been treated to one or more ground improvement techniques. All need to be systematically assessed to inform the planning process and provide the basis for engineering solutions (McMillan et al., 2001).

Thus, as major initiatives are taken to encourage greater usage of 'brownfield', 'inner city greenfield' and 'urban ring greenfield' sites for industrial redevelopment and for modern housing (DETR, 2000) so the demand grows for up-to-date information on ground conditions, geomorphology and topography together with base-line data against which polluted land and derelict land may be assessed.

The Digital Map Production Implementation project initiated a review of the BGS Rock Classification Scheme in order to set up hierarchical schemes and master dictionaries of terms for the geological map digital database. A classification scheme needs to be designed specifically for applications to geological maps and datasets in the UK and as such consider only deposits which are commonly mapped at 1:10 000 scale. The schemes have been based with modification upon the specifications for 1:10 000 and 1:50 000 maps, and field mapping procedures (BGS, 1995). They are designed to be used and interpreted by both geologists and non-geologists to allow thematic material comprising identified classes of superficial deposits to be extracted from geological maps and other datasets. The schemes can be developed further to cover other classes of materials.

2. Genetic Basis of the Classification Scheme

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Mapping of artificial ground in the field requires recognition by geologists and geomorphologists of the diagnostic landform (morphology) and, where possible, record the physical, sedimentological and lithological (compositional) characteristics of the surface materials. During the process of map compilation these characteristics are interpreted to deduce the origin (genesis) of the deposits. Usually the map shows the origin, qualified by the lithology of the top metre of deposit. Sequences may be deduced from temporary cuttings, natural sections and subsurface datasets including boreholes and trial pits. Where good subsurface datasets exist, maps of resources, geotechnical and lithological profiles may be constructed.

A single criterion may be sufficient to determine the origin of a deposit, but this is rare. In general a combination of characteristics is required, but these may not always be available. For example, a landform may be mapped both on the ground and from remote datasets including air photographs and satellite imagery, but only limited information may be available on the nature of surface sediments in terms of their composition, lithology and texture. Conversely, subsurface information from boreholes and trial pits will consist of lithological (or compositional) and other physical characteristics, but surface morphological information may be absent or insufficient to interpret the genesis of some sediments. Thus, in theory it is possible to systematically subdivide any one deposit into its textural, morphological and genetic components, but in practice it is seldom possible to do this.

The genetic approach applies both to artificial (man-made) ground and natural superficial deposits. For artificial deposits, the man-made origin constitutes the primary criterion for classification, and if known, the nature of the ground and the composition of the man-made material can also be included. A hierarchical scheme is developed linking the principal genetic class (Level 1) with basic (Level 2) and more detailed mapping categories (Levels 3 and 4). The scheme incorporates the necessary cross-references, synonyms and obsolete terms for digital retrieval purposes. The definition of each genetic category and its subdivisions may include textural and other physical information, which may be common to more than one genetic class.

3. Classification of Artificial (Man-Made) Ground

The major categories for artificial (man-made) ground mapped by BGS comprise: worked ground, made ground, infilled ground, landscaped ground and disturbed ground. A glossary of commonly used terms associated with these categories is provided (Appendix 1).

These categories include both man-made deposits and voids, that is, areas that have been worked or excavated such as pits, quarries and cuttings. The categories have been used widely in recent BGS mapping projects, particularly in urban, applied (thematic) geological mapping studies supported by the former Department of the Environment (DoE), and are now routinely delineated on current BGS 1:10 000 geological maps (BGS, 1995). They will appear to an increasing extent on newly published BGS 1:50 000 series maps, a number of which incorporate urban areas surveyed during recent applied geological mapping projects.

The classification of artificial ground (modified from BGS, 1995) is shown in Table 1 and illustrated in Figure 1. The basic mapping categories (Level 2 of Table 1) are defined thus:

Made ground Areas where the ground is known to have been deposited by man on the former, natural ground surface: road, rail, reservoir and screening embankments; flood defences; spoil (waste) heaps; coastal reclamation fill; offshore dumping grounds; constructional fill (landraise).

Worked ground Areas where the ground is known to have been cut away (excavated) by man: quarries, pits, rail and road cuttings, cut away landscaping, dredged channels

Infilled ground Areas where the ground has been cut (formerly termed away (excavated) and then had ‘Worked Ground artificial ground (fill) deposited: and Made Ground’) partly or wholly back-filled workings such as pits, quarries, opencast sites; landfill sites (except sites where material is dumped or spread over the natural ground surface; see landraise).

Landscaped Areas where the original surface has ground been extensively remodelled, but where it is impractical or impossible to separately delineate areas of worked (excavated) ground and made ground

Disturbed ground Areas of surface and near-surface mineral workings where ill-defined excavations, areas of man-induced subsidence caused by the workings and spoil are complexly associated with each other, for example collapsed bell pits and shallow mine workings

4. Classification of Fill, Made Ground and Waste

There have been a considerable number of attempts to classify types of fill and waste material (for example: DoE, 1993; DETR/EA, 1998). However, fill materials at any one site are commonly an admixture

of organic, chemical and inert materials. The nature of the fill can vary, both vertically and horizontally, over a short distance, and at sites where there is no record of the fill, or at poorly monitored landfill sites, the nature of the fill can only be determined by a densely spaced, borehole site investigation. The UK Waste Classification Scheme (Draft for discussion, 1998), jointly produced by the Department of the Environment, Transport and the Regions (DETR) and the Environment Agency (EA) considered the classification of waste, and recommended that waste material should be classified in a consistent manner nationally. The index to the first level categories of waste composition the DETR/EA Scheme is listed in Table 2a.

Due to the possible contentious problems in classifying fill types, it is considered best practice to record only the proven types of fill at a site, or where there is uncertainty concerning the nature of the fill it should be recorded as 'undifferentiated'. Since there is much disagreement and uncertainty concerning the classification of waste material, it is recommend that for mapping purposes, the material type (deposit), where known, is classified using the list of common terms used in the UK for waste/fill - shown at Level 4 of Table 1, and defined in Appendix 1. The categories are cross-referenced, by number, to the probable first level categories of the UK Waste Classification Scheme shown on Table 2a.

In some urban areas with extensive man-made deposits it is not always possible to determine whether a 'landfill' site registered by a local authority represents made ground (for example, spreads on the pre-existing ground surface, also known as 'Landraise') or infilled ground (for example quarries). It may be necessary to show such sites on thematic maps as 'Landfill site, undifferentiated', denoted by a unique line-type.

A European Community (EC) directive (OJ No. C 212/33, 1993) classifies landfill sites according to their origin:

- municipal waste
- industrial waste

and also according to their characteristics

- hazardous waste
- non-hazardous waste
- inert waste

However, since 'non-hazardous' may include some organic materials that could, under certain conditions, give rise to hazardous methane or carbon dioxide, this classification is considered as too ambiguous to be of use in classifying the material type. The EC classification of Landfill Sites is shown as an example of landfill subdivision (Table 2b), but it is not recommended for wider use.

5. Graphical Portrayal - Maps and Digital Images

The mapping categories are shown on BGS 1:10 000 and 1:50 000 series geological maps by various styles of hatching over the underlying drift deposit or bedrock; colour fill or colour hatching may be used on digitally generated maps. The boundaries are shown by a fine, dashed line on geologists' 1:10 000 scale standards, although digital 'versatec' prints have in the past shown the boundary as a continuous fine line.

The hierarchical scheme (Table 1) for the artificial (man-made) ground classification scheme is as follows:

Level 1 This shows artificial (man-made) ground undivided.

Level 2 Users wishing to retrieve information on the map-face will generally select the major (Level 2) categories defined in Section 3.1 (such as made ground, worked ground subdivisions shown on the 1:10 000 map), or perhaps a combination of one or more of these with a particular type of underlying natural superficial deposit or bedrock. For example, an enquirer studying aquifer pollution from landfill sites may wish to show the incidence of infilled ground overlying sand and gravel deposits and/or sandstone bedrock. The mapping categories (Level 2) are rarely sub-divided on BGS 1:10 000 scale maps. Where good records exist, types of made ground and fill have been categorised. For instance the BGS Stoke-on -Trent Project for the DoE (Wilson et al., 1992) showed subdivisions of the made ground on a thematic map, including: colliery waste, ironworks slag and ceramic waste. Borehole logs received from outside sources, particularly site investigation records, commonly describe the nature of the made ground (fill) deposit, and this information may be required from the database.

Level 3 Below this major category comes the geographical/topographical category. This is not systematically recorded or presented on standard 1:10 000 maps, although individual sites such as sand and

gravel quarry (worked ground), infilled opencast coal site (infilled ground), railway embankment (made ground), bell pits (disturbed ground) may be denoted on the map face. The majority of borehole logs received by BGS do not record the topographical category, and the record will 'step' from the major category (Level 2) (for example made ground, infilled ground) to details of the deposit or material type (Level 4) (for example ash, colliery waste, blast furnace slag).

Level 4 Level 4 in the hierarchy is the material type (deposit). Common terms used for waste/fill material in the UK are shown in Table 1, and are defined in Appendix 1. The material may be denoted on the map face either on its own (for example colliery spoil), or together with the topographical category (for example disused pit infilled with blast furnace slag). The deposit is not systematically recorded by BGS during mapping surveys, chiefly because it is commonly not visible, and because of the variable nature of the material, both horizontally and vertically, at many sites. As noted in the Stoke-on-Trent example (Wilson et al., 1992), above, some thematic maps may show subdivisions of infilled ground (worked and made ground) based on material type or a combination of material type and topographical category (Level 3)(opencast coal site, colliery waste). Borehole logs may record the nature of the made ground or fill material; in BGS logs this is usually recorded as a comment or qualifier.

6. Conclusions

The legacy inherited from anthropogenic processes needs to be addressed in order to provide reliable and up-to-date ground information relevant to the urban environment. The legacy includes holes as well as materials. Their characteristics derive from former quarrying and mining activities, industrial processes creating derelict ground, variably consolidated made ground, and contaminated groundwater and soils. All need to be systematically assessed to inform the planning process and provide the basis for engineering solutions.

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APPENDIX 1. Glossary of commonly used terms for artificial (man-made) ground

Most of the categories at Level 4 of the artificial (man-made) ground classification scheme are self explanatory, others less so. The listings comprise the categories most commonly encountered, at this 'material' level, in site investigation records and during field survey; it is not exhaustive, and it is assumed that further categories will be added. Categories of waste are listed in the UK Waste Classification Scheme (DETR/EA, Draft for Consultation, 1998). Natural materials are commonly a component of artificial deposits.

Definitions are based on:

*The Concise Oxford dictionary of earth science*s. 1990. Allaby, A. and Allaby, M. (editors). (Oxford: Oxford University Press.)

Penguin dictionary of geology. 1972. Whitten, D.G.A., and Brooks, J.R.V. (Harmondsworth: Penguin Books.)

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aggregate in the building industry: a range of mineral sub-stances, for example sand, gravel, crushed rock, stone, slag and other minerals which, when cemented, forms concrete, mortar, mastic, plaster. Uncemented, it can be used to as a bulk material in road-making and ballast

asbestos waste waste material derived from of asbestos products or their manufacture

ash general term for powdery residue left after combustion of any substance (also used geologically for volcanic particles less than 2mm in size; (see Gillespie and Styles, 1999)

ballast coarse stone mixed with sand etc. Used to form bed of railway or substratum of road

bell pit in mining, a bell-shaped excavation in which the extracted material was dragged to a central shaft; an obsolete method for extracting mineral deposits from shallow depths. Disused bell pits are usually collapsed and/or partly backfilled with rock waste

building rubble waste material derived from construction, usually consisting of brick, concrete, stone and plasterboard with minor amounts of wood and metal. May be partly organic in content

blast-furnace slag semi-fused or fused waste material produced in the metal industry

brick clay kneaded, moulded and baked (fired) or sun-dried; usually a small, rectangular block

cardboard thick paper or paste board

ceramic waste (undifferentiated) waste material from the pottery and ceramic industries, commonly comprising partly fired and fired clay products

chemical waste (undifferentiated) waste material, and by-products derived from the chemical industry and chemical processes

china clay waste kaolin and waste materials derived from the extraction of kaolin from granitic rocks

clay waste generally clayey material usually containing at least 20% by weight of clay particles (less than 1 /16 mm in size according to the scale of Wentworth, 1922)

clinker semi-fused or fused, hard foundry slag; stony residue from burnt coal

coal shale colliery waste, generally of a fissile shaly nature.

colliery waste also known as *spoil; tip and bing* (Scotland) heterolithic waste material produced from the mining of coal or associated ironstone and fireclay; commonly a mixture of mudstone, siltstone, sandstone, carbonaceous 'shale' and coal, with minor amounts of ironstone. May contain secondary minerals such as pyrite and sulphur

domestic/garden refuse undifferentiated organic and inorganic waste

effluent waste liquid flowing from a sewage tank or industrial process

fill general term for material used to infill a void or cavity in the earth's surface or sub-surface; constructional fill (made ground) is material placed above the natural earth surface

foundry sand or sand waste, may be impregnated with organic materials produced in the metal and glass industries

foundry slag semi-fused or fused waste material produced in the metal and glass industries

furnace ash residue left after the combustion of any substance, but commonly coal in metallic blast furnaces

garden waste predominantly organic waste including woody materials, grass and soil

herbicide substance toxic to plants and used to kill unwanted vegetation

industrial waste (undifferentiated) waste products from industrial processes

landfill site waste disposal site used for the controlled deposit of the waste onto or into land

landraise site a specific type of landfill site (see above) where the waste is deposited on the pre-existing natural ground surface; the deposit is classified as made ground in the BGS Rock Classification Scheme

mine dumps (tailings) inferior part of ore or mineral or surrounding rock, usually deposited close to the mine (see mineral waste)

mineral waste (undifferentiated) general term for the waste products of mining and surface mineral workings

mine stone (synonym: **spoil;** see also **colliery waste**) generally the inorganic material commonly used for ballast or aggregate. May be partly organic in content

oil shale waste waste products from the mining of dark grey or black shale containing organic substances that yield liquid hydrocarbons on distillation
organic waste (undifferentiated) waste materials containing carbon compounds, such as wood, plant materials, coal
paper substance made from compacted interlaced fibres of rags, wood, straw
pesticide substance used for killing pests, especially insects
plasterboard board with a core of plaster for walls
pulverised fuel ash (pfa) pulverised (fine grade) ash waste from the burning of coal, usually in coal-fired power stations; commonly used as an inert fill material, or for the production of breeze blocks
quarry waste general term for waste materials consisting mostly of rock with overburden drift deposits, derived from quarrying (see rock waste, slate waste, shale waste)
radioactive waste general term for waste materials derived from nuclear processes that are contaminated with radionuclides; may be classified as low-level, intermediate or high-level waste
rock waste general term for waste materials consisting mostly of rock, derived from quarrying or excavation
sewage sludge solid waste material from sewage treatment
wor**kshale waste** waste material derived from quarrying or mining of fissile mudstone (for example alum shale, bituminous shale)
slate waste waste material derived from quarrying or mining of slate (cleaved, fissile, low-grade metamorphosed mudstone)
spoil earth material (rock or unconsolidated sediment) thrown up or brought up in mining, excavating or dredging (synonym **mine ston**e, which consists predominantly of **colliery wast**e)
toxic waste poisonous waste
waste general term for superfluous material (refuse) and by-products of manufacturing, mineral extraction, or physiological process, no longer serving a purpose, and which the holder discards or intends or is required to discard. Some categories of waste, however, may constitute a re-useable resource, for example **colliery waste (spoil)** which is re-used (and re-classified as **mine ston**e) as a fill material, or **pfa** (mixed with cement) re-used as a grouting material

Figures

Add from McMillan, A.A. and Powell, J.H., 1999:
Table1 (p.24)
Table2 (p.25)
Figure 1 (p.51)