Anthropogenic deposits in a nationwide 3D geological subsurface model

7th European meeting on 3D geological modelling

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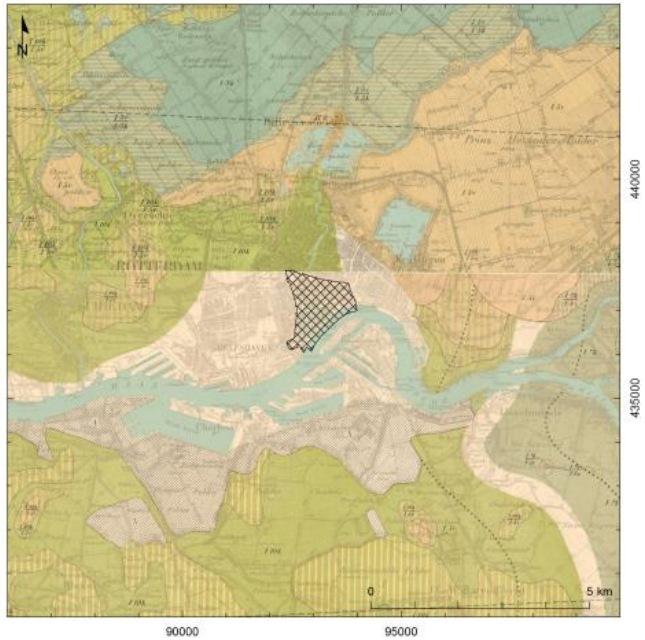
TNO – Geological Survey of the Netherlands

Photo: Amsterdam, Dirk van Hasseltsteeg, 1994 (Het Parool)

Challenges to map the urban subsurface

- Mapping geologists traditionally focused on the natural environment
- Extent and thickness of anthropogenic deposits not well constrained
- Characteristics of anthropogenic deposits differ from natural deposits:
  - Presence of non-natural (or: novel, secondary) materials
  - Lithological properties may show small-scale heterogeneity
  - Stratigraphic principles of natural deposits not applicable
- Presence of man-made objects
- Subsurface buildup and properties change rapidly over time
- Data collected before human interventions do not reflect current subsurface conditions

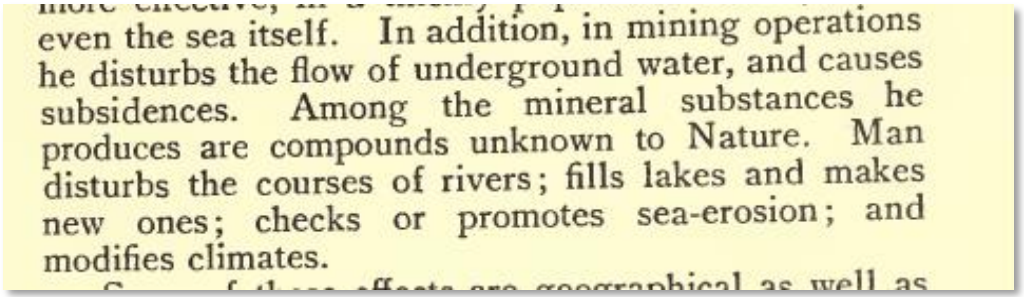


Tesch (1935-1940)

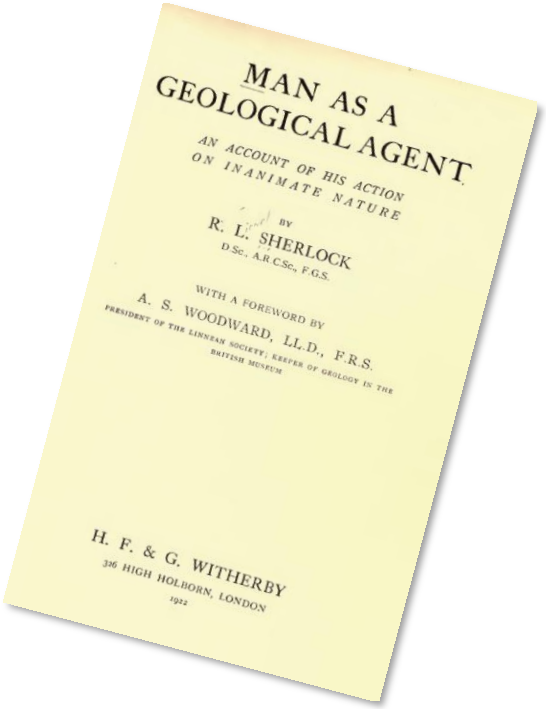
What are anthropogenic deposits?

- Anthropogenic deposits have been created by human activity rather than natural processes
- Anthropogenic deposits consist of:
  - Displaced or reworked natural rock fragments and sediments
  - Non-natural (or: novel, secondary) materials, e.g. bottom ash, slag, crushed concrete
  - A mixture of both
- We only discuss deposits that have been moved from elsewhere (′made ground′)

- This is not a new concept:



even the sea itself. In addition, in mining operations he disturbs the flow of underground water, and causes subsidences. Among the mineral substances he produces are compounds unknown to Nature. Man disturbs the courses of rivers; fills lakes and makes new ones; checks or promotes sea-erosion; and modifies climates.



MAN AS A GEOLOGICAL AGENT

AN ACCOUNT OF HIS ACTION ON INANIMATE NATURE

BY

R. L. SHERLOCK

D.Sc., A.R.C.Sc., F.G.S.

WITH A FOREWORD BY

A. S. WOODWARD, LL.D., F.R.S.

PRESIDENT OF THE LINNEAN SOCIETY; KEEPER OF GEOLOGY IN THE BRITISH MUSEUM

H. F. & G. WITHERBY

326 HIGH HOLBORN, LONDON

1922

Sherlock, R.L. (1922)

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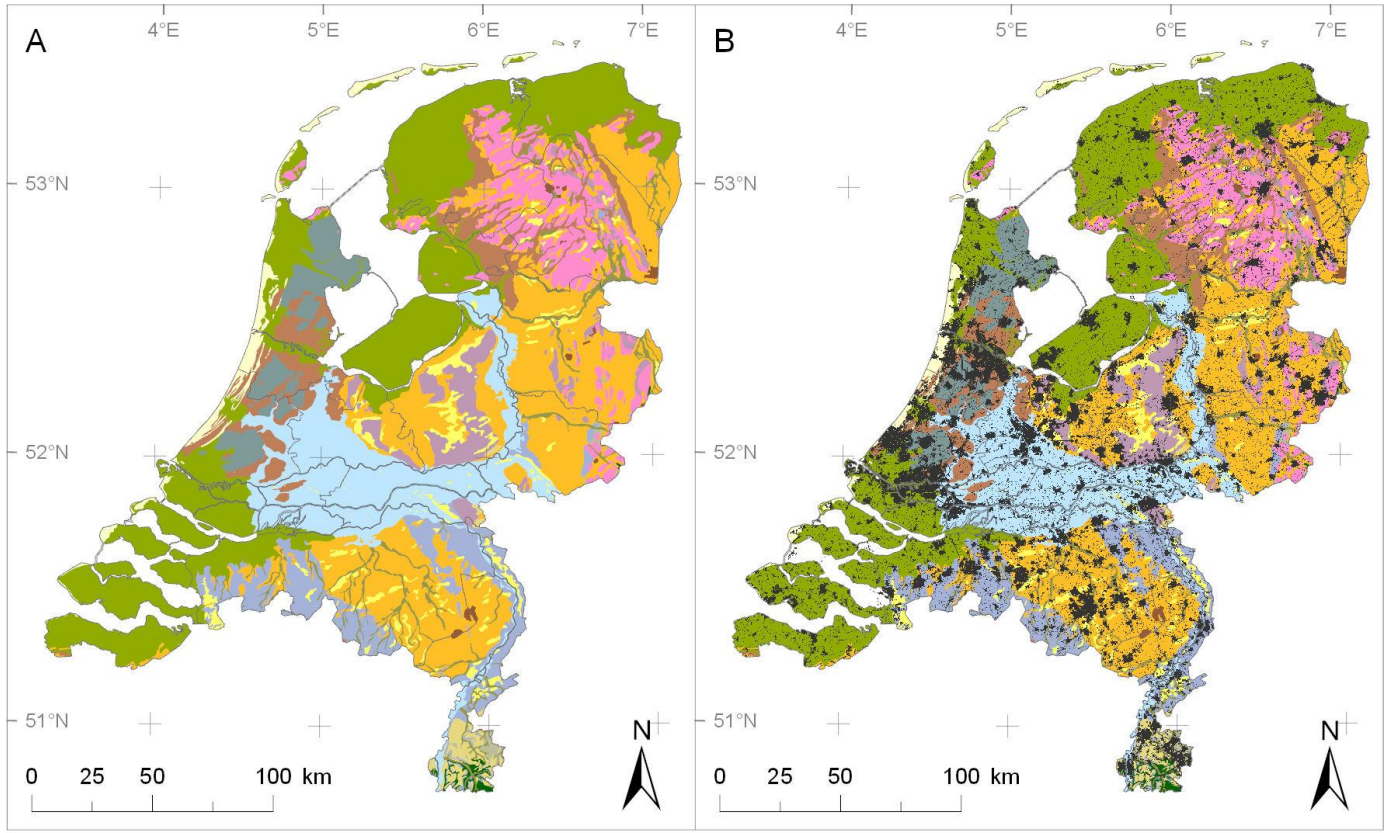
Anthropogenic deposits are widespread …



Dijkstra et al. (2019)

- City centres with underground archives of historic urban development
- Modern residential and industrial areas built on extensive sheets of filling sand and novel anthropogenic materials
- Major roads and railways founded on natural aggregates and novel anthropogenic materials
- Coastal reinforcements and dikes
- Landscaped areas
- Landfill sites

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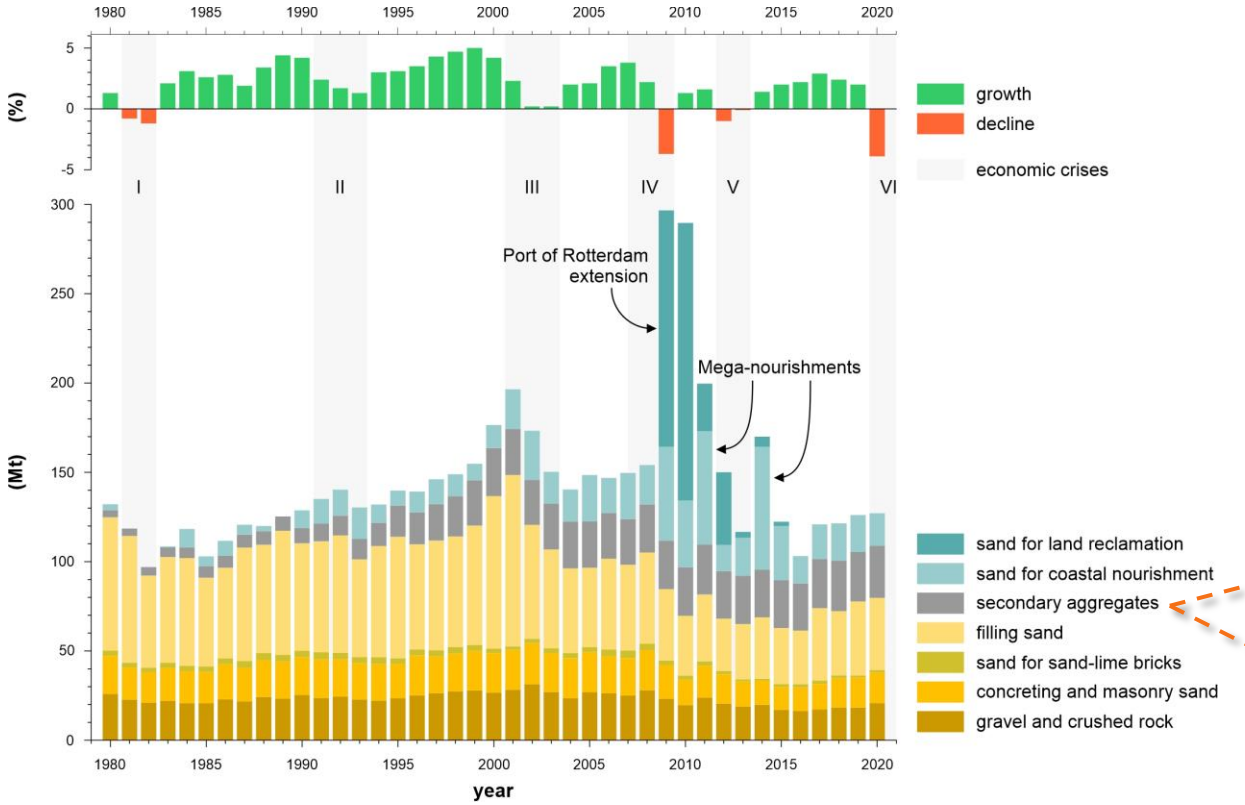
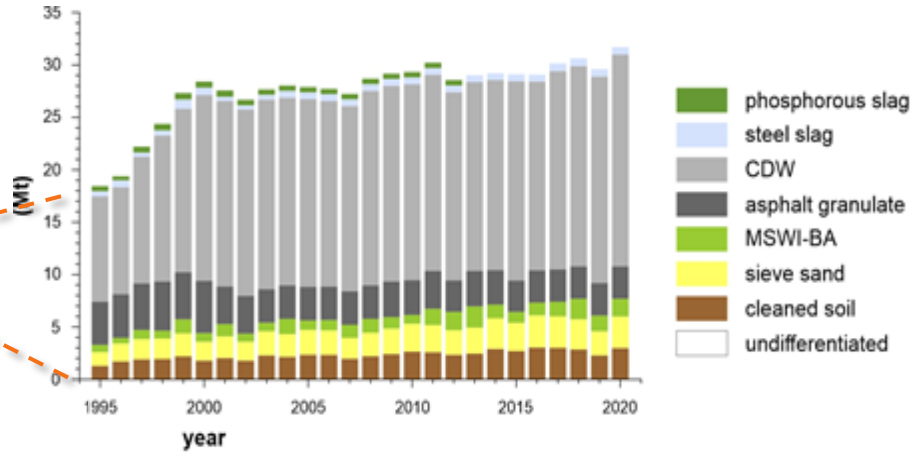
… and volumetrically important





Van der Meulen et al. (2025) Surface Mineral Resources. In: Geology of The Netherlands, 2nd ed..

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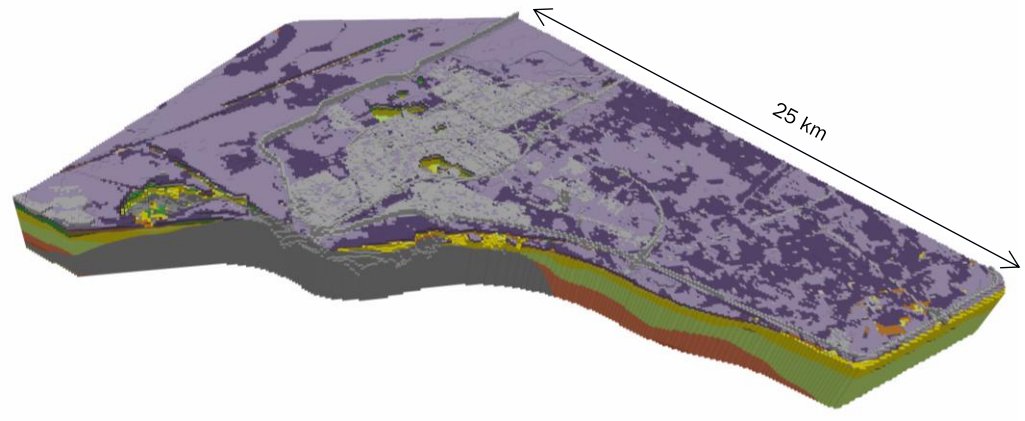
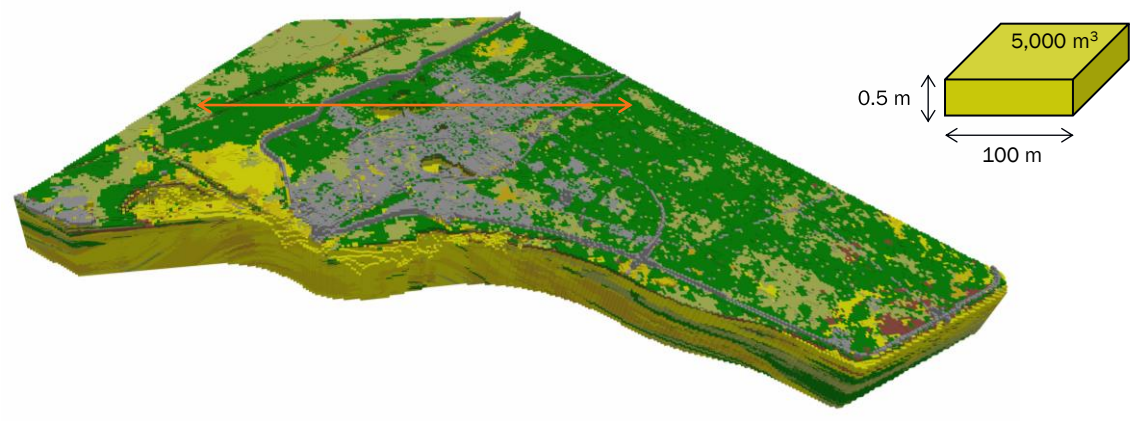
3D GeoTOP modelling

Stratigraphic units (layer-based model)



Lithoclasses (voxel model)



- Anthropogenic deposits
- Clay
- Sandy clay
- Peat
- Fine sand
- Medium sand
- Coarse sand
- Gravel

Representation of anthropogenic deposits:

- Stratigraphic model: single unit
- Lithoclass model: no lithological properties

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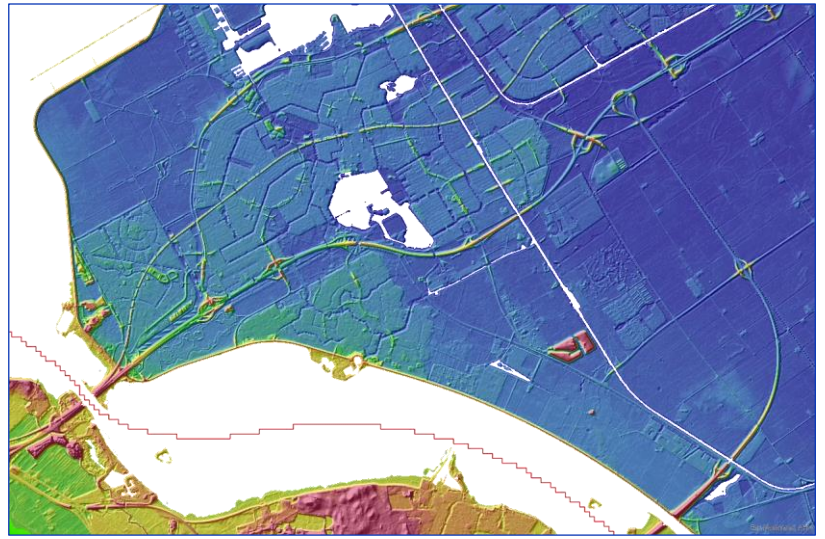
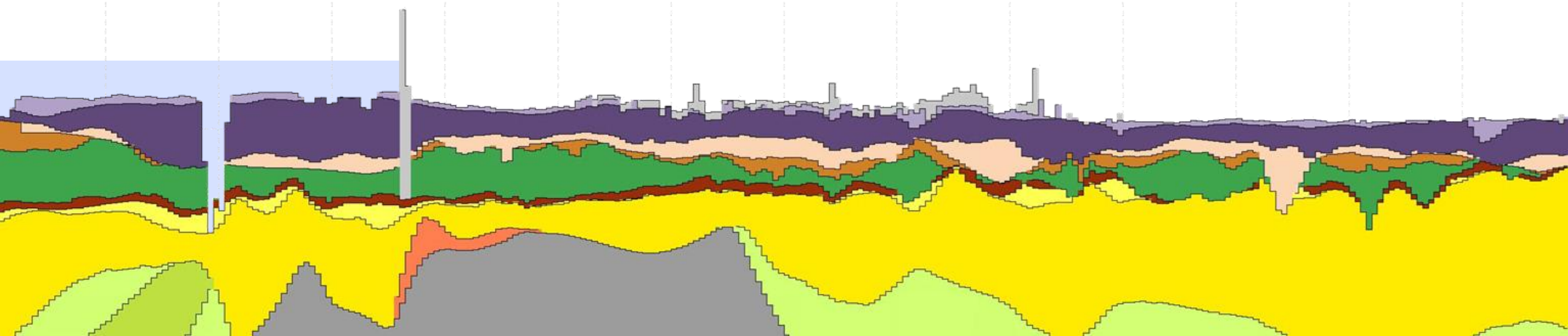
1. Use non-traditional data sources

- Comparison of LIDAR images from successive years:
  - Extensive sheets of filling sand
  - Road and rail embankments, landfill sites
- Use of additional information sources:
  - Nationwide, up-to-date topographic and building registers
  - Geotechnical and archaeological data
  - Historical information (e.g. dike construction method)

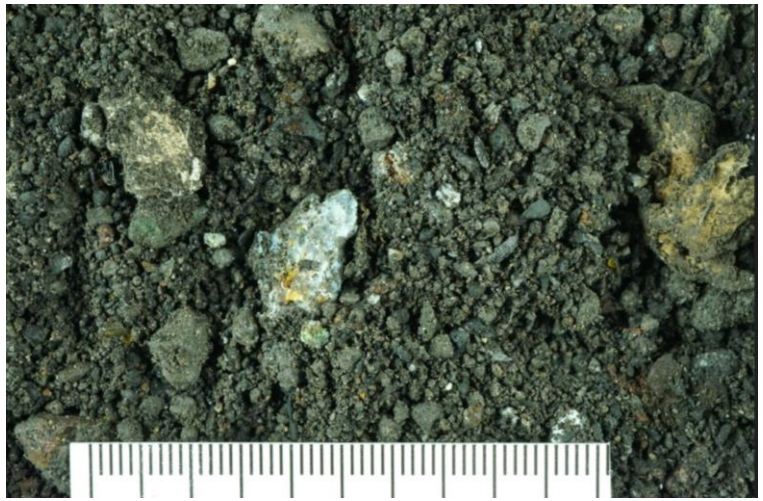


AHN3



2. Enrich lithological nomenclature

- Terminology to describe non-natural deposits in a core or outcrop is lacking or incomplete
- Extend lithological code lists to include terminology for non-natural materials:
  - National level (NL: Key register for the subsurface)
  - European level (GSEU WP6 Subtask on Anthropogenic terminology)



Pictures: TNO; Horckmans & Swennen (2008)

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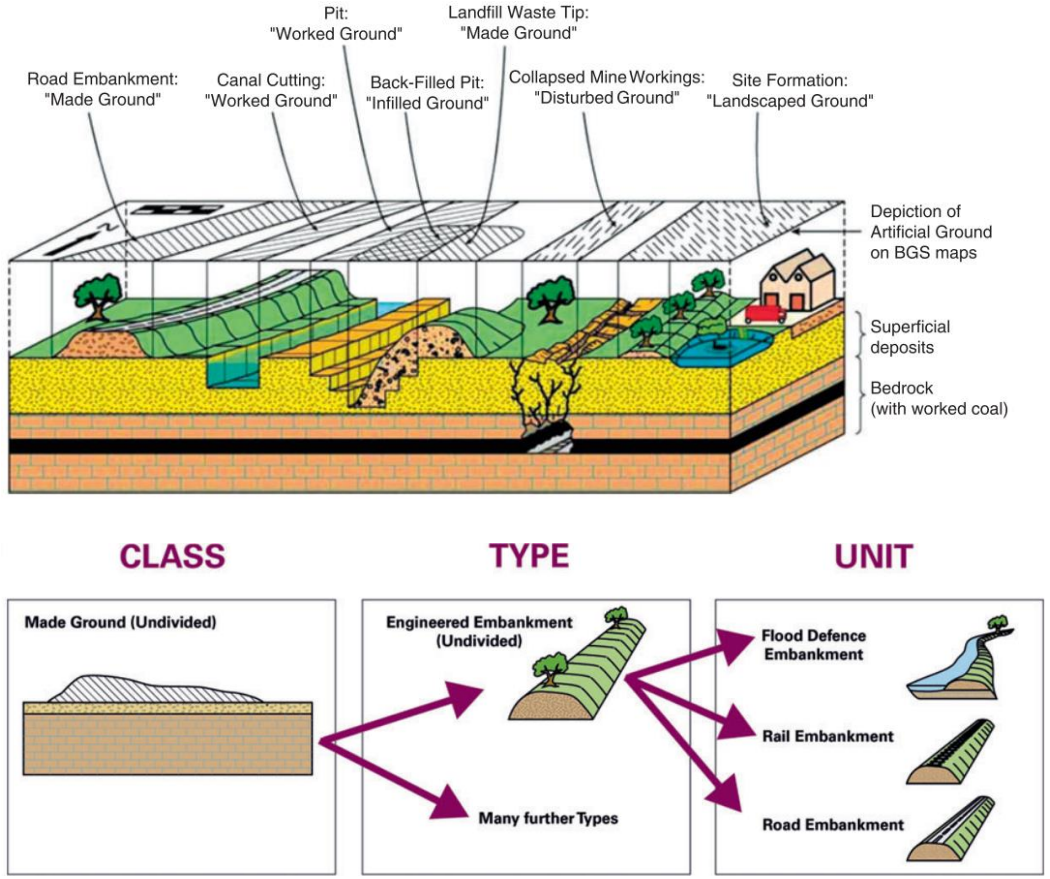
3. Improve stratigraphic classification

Enhanced classification scheme of artificial ground (BGS)

- 5 classes:
  - Made ground
  - Worked ground
  - Landscaped ground
  - Infilled ground
  - Disturbed ground
- Hierarchical (class-type-unit)
- Mainly based on morphology and function
- No information on lithology



Adapted from: Ford et al. (2010)

3. Improve stratigraphic classification

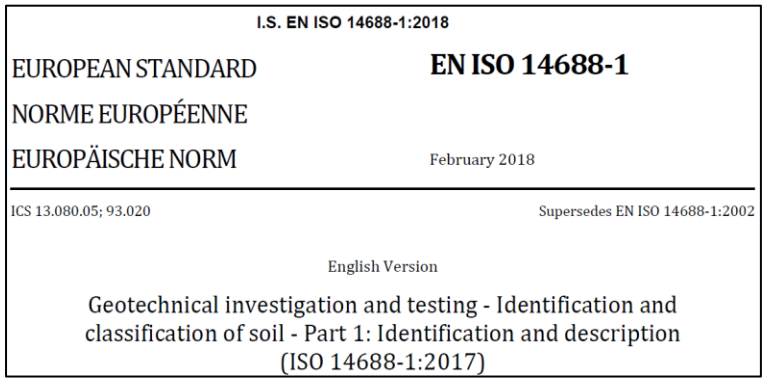
Soil classifications, e.g.:

- US System Soil Classification:
  - “Anthropogenic Soils”: Human Altered and Human Transported Material
- World Reference Base (IUSS, 2022):
  - Anthrosols, Technosols

But: Soil develops in parent material!

Various other approaches:

- Peloggia (BR, 2018): morphological
- Nirei (JP, 2012): chronostratigraphical
- Le Guern et al. (F, 2018): geochemical
- EN-ISO 14688-1: geotechnical



I.S. EN ISO 14688-1:2018

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN ISO 14688-1

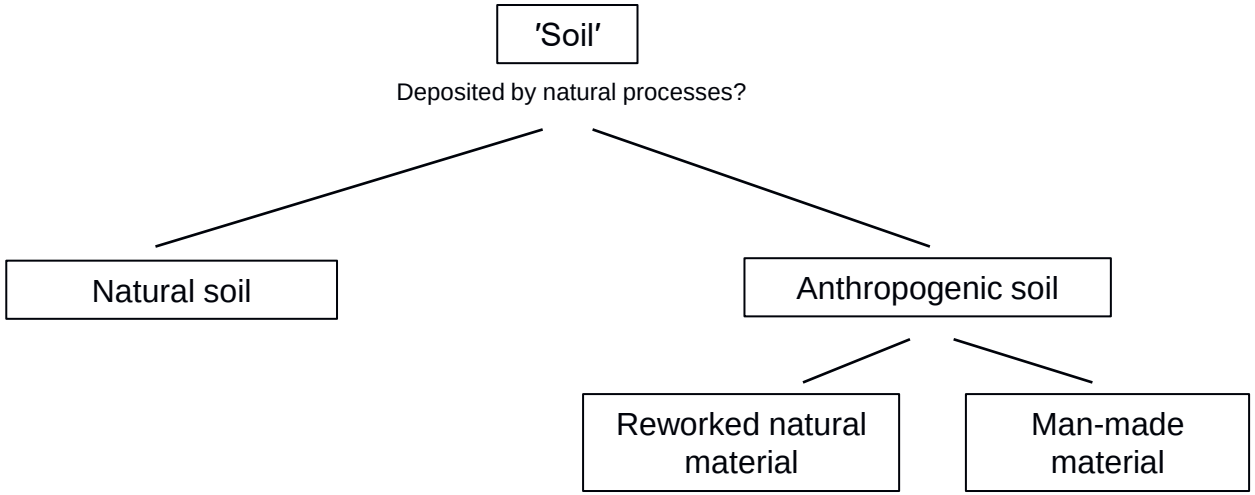
February 2018

ICS 13.080.05; 93.020

Supersedes EN ISO 14688-1:2002

English Version

Geotechnical investigation and testing - Identification and classification of soil - Part 1: Identification and description (ISO 14688-1:2017)



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Stratigraphic classification proposal

Anthropogenic deposits		Holland Fm
Made ground	≥5% ex-situ material	Amsterdam Mb
Natural deposits	‘Clean sediments’, homogeneous	Leidsche Rijn Bed
Non-natural deposits	Novel anthropogenic materials, homogeneous	Omval Bed
Mixture	‘Dirty sediments’, non-homogeneous	Rotterdam Bed
Reworked ground	<5% ex-situ material	Schermer Mb
Agricultural soils	e.g. plaggen soils	Rolde Mb

Discussion:

- Objects (impermeable): Landfills (3D), Large subsurface constructions (3D), Sheet pilings (2D)
- Voids (permeable): Caverns, Mines

Concluding remarks

- To effectively use the urban subsurface and manage the associated risks and opportunities, the extent, thickness and physical properties of anthropogenic deposits need to be better represented on maps and in 3D models

- Extent and thickness of anthropogenic deposits is successfully being inferred from nationwide, up-to-date non-geological information sources, e.g. lidar data, national topographic and building registers

- Lithological nomenclature is being extended to include terminology and properties for non-natural materials

- Stratigraphic classification is based on physical properties. This allows a differentiation between homogeneous and heterogeneous anthropogenic deposits and is of direct value to users


Thanks for your attention
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