3D digital soil-geology models of the near surface environment

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Introduction:

Research in the top few metres of the ground beneath our feet has traditionally been split between soil science, geology and several sub-disciplines. This has led to different working practices, classifications and boundaries as well as inconsistent approaches to databasing and modelling (Figure 1). A significant uncertainty lies within the 'transition zone' between the pedosphere and geosphere. The BGS sets out to investigate this zone through a muldisciplinary field survey, combining spatial soil and geoscientific findings in a 3D model at site specific and catchment scale in representative soil-geoscapes across the UK. In undertaking these studies we were particularly interested in investigating whether technologies developed to map geology in 3D can be used to routinely develop shallow spatial models of the soil-geology environment and if technologies used in digital soil mapping can assist in reducing uncertainties associated with such models at a variety of scales.

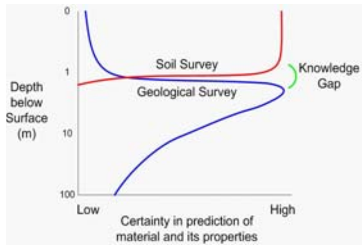

Figure 1: Knowledge gap

Methods and site study:

The project comprised of two main stages. Firstly a site survey (Figure 2) and secondly data processing and assembly and the construction of a 3D spatial soil-geology model. The site study was carried out on an area of agricultural land approximately 2km² near Shelford, Nottinghamshire, UK. The site is located adjacent to the River Trent leading up to a gentle slope of Triassic mudstone. The majority of the site is underlain by up to 5m thick Pleistocene river terrace deposits as well as younger Holocene alluvial and colluvial deposits. Soils found in the study area vary from deep and permeable (gleyic) brown earths and slowly permeable stagnogley soils to groundwater gley soils. Fieldwork was orientated along several parallel traverses/catenas running from the hilltop, downslope towards the River Trent.

Type of survey	Methods
Remote sensing/terrain analysis	25 cm air photos, digital terrain model (DTM) 5m cell size
Geological survey	Walk-over survey and drilling of 18 boreholes using the BGS Dando drilling rig
Soil survey	Detailed walk-over survey with 95 augerholes and 2 trial pits
Geophysical survey	2D electrical resistivity tomography (ERT), Rapid electrical soil mapping (Geocarta™), ground penetrating radar (GPR)
Gamma spectrometry	Walk-over survey, detection and interpretation of K, Th and U
Hydrogeological survey	Piezometer installations, groundwater monitoring, infiltration tests
Differential GPS survey	Accurate levelling of borehole/piezometer location using differential GPS

Figure 2: Images of field survey activities

Construction of 3D models

Developing a spatial 3D soil-geology model in GSI3D® utilises a Digital Terrain Model, geological (and in this case soil) mapped line-work, downhole borehole and augerhole data and geophysical data (Figures 3 and 4). Once this data is digitised and assembled in the software, it enables the geoscientists to construct regularly spaced intersecting cross-sections by correlating boreholes and the outcrops-subcrops of units to produce a fence diagram of the area (Figures 5 and 6). Mathematical interpolation between the nodes along the sections and the limits of the units or horizons produces a solid model comprised of a series of stacked triangulated volume objects (Figure 7). Below shows the workflow from data acquisition to the construction of a spatial 3D model.

Data gathering and assembly

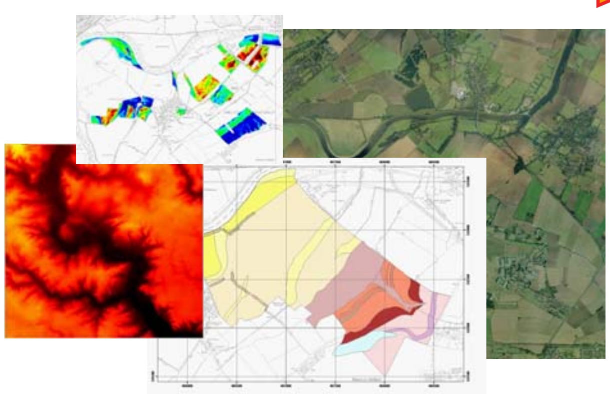

Figure 3: Images of DTM, geological and soil maps, aerial photo and geophysical images.

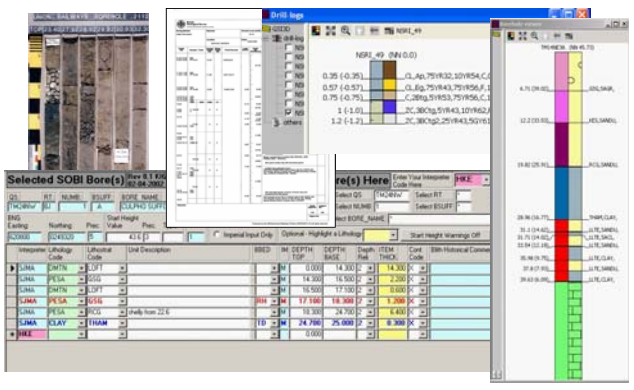

Figure 4: Images of different borehole and augerhole data sets.

Model construction (in GSI3D®)

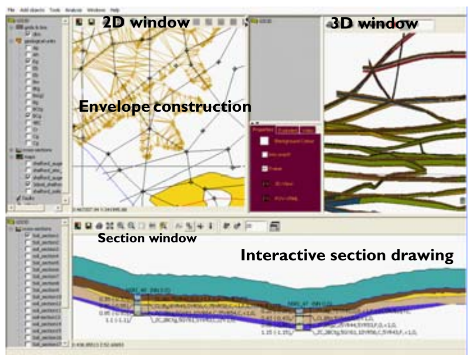

Figure 5: Screenshot of soil model construction.

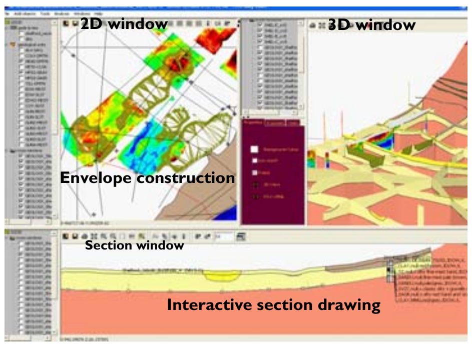

Figure 6: Screenshot of geological model construction.

The model construction comprises of four main stages

1. Interactive section drawing between individual boreholes in 2D window. For this model 23 geological and 33 soil sections have been drawn resulting in a fence diagram.
2. Construction of envelopes for each soil type/horizon and geological formation.
3. Calculation of sections and envelopes via triangulation to a 3D volume model.
4. Export of model data in XML format for model storage and viewing.

Calculated 3D Soil Geology model

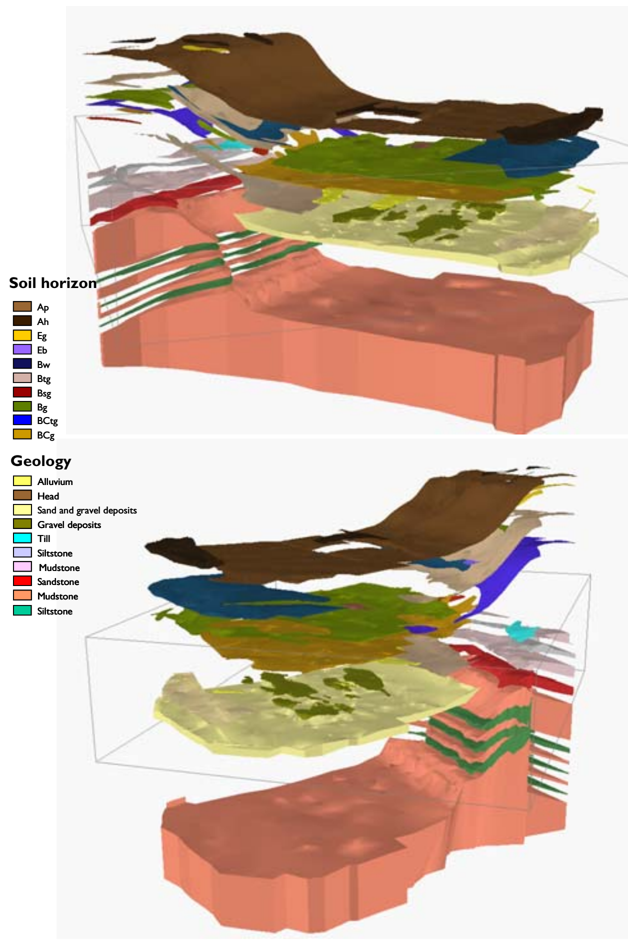

Figure 7: 3D soil geology model (size approx 2kmx1kmx40m) of Shelford, UK and exaggerated ten times.

Result

The 3D soil geology model (Figure 7) shows calculated volumes for 10 top and subsoil horizons in conjunction with underlying Holocene and Pleistocene superficial deposits and solid bedrock of Triassic mud, silt and sandstone. The total volume of the 3D model is approx. 0.08 km³. In the BGS, the modelling software has so far only been used in geological modelling correlating layers of usually > 1m. Soil horizons therefore appear as only thin veneers/blankets.

Conclusions: Further software development to improve the correlation and combination of soil and geological information in GSI3D® is on the way. A model as this can aid better understanding of the transition zone and helps to visualise, understand and interpret processes like movement of water, nutrients and soil particles. Given sufficient geological and soil information in xy and z a soil geology model can be built in any size and for any location.

Science and research outlook

- Connection and integration of spatial subsurface models with numerical hydraulic models
- Pathways and behaviour of nutrients and contaminants in 3 and 4D

Model application

- Ground and surface water management (GW flow vulnerability and storage assessment)
- Wetland and catchment management
- Geotechnical and engineering assessments
- Geoarcheology, historical geology

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