PropBase abstract

Modelling of 3D Physical Property intra-unit heterogeneity of the UK East Midlands for the BGS PropBase project

Kingdon, A, Williams, JDO and Williamson JP

3D geological models have replaced maps as BGS's primary output. They show the intersection of geology and the surface plus subsurface geometry constrained by wells and geophysics. They give a simplified view of defined lithostratigraphic units attributed only with names and enveloped by surfaces. Properties are implicit through descriptions; internal variability is largely ignored.

PropBase populates 3D models by extracting physical properties from BGS databanks and mapping their variation through 3D volumes with no seismic framework. We present a populated grid of the Triassic Sherwood Sandstone Group (SSG) near Nottingham, the principal UK carbon storage reservoir candidate.

A 45 X 65 km test model, built in GOCAD® from surface linework and stratigraphy from 578 wells, was selected because of its relatively simple geology; Carboniferous, Permian and Triassic rocks outcrop progressively eastwards and dip ~1° east. Wireline logs are the sole pervasive property data-but, as they target the underlying Coal Measures, few sample the entire SSG. 58 logs were used to calculate porosity proxies from both sonic (Raymer-Hunt-Gardner method) and density data. A proportional 3D stratigraphic grid (Sgrid) was generated with 200 x 200 x 2 m cells. Log-derived porosities were upscaled as points into the Sgrid; all cells cut by a log were attributed with the mean porosity. Data outliers (spikes; high clay content) were omitted as artefacts before interpolation, preventing distorted results in areas of poor data control. Values from both density and sonic data were initialised across separate Sgrids using Discrete Smooth Interpolation, so each cell contained a porosity attribute.

Two main features emerged:

- a high porosity zone close to the SSG outcrop caused by surface water flushing
- porosity decreasing eastward with depth, due to compaction

A zone of higher porosity between two faults in the model's east is less clear, especially on the sonic grid, and poorly constrained, but may indicate fault-induced fractures.

Ever greater environmental and resource pressure on the geosphere requires ever more realistic subsurface simulation. Limited 2D and scarce 3D seismic data and a lack of suitable property data hinders upscaling across much of the UK. Though imperfect, the SSG grid makes best use of available data in Nottinghamshire.

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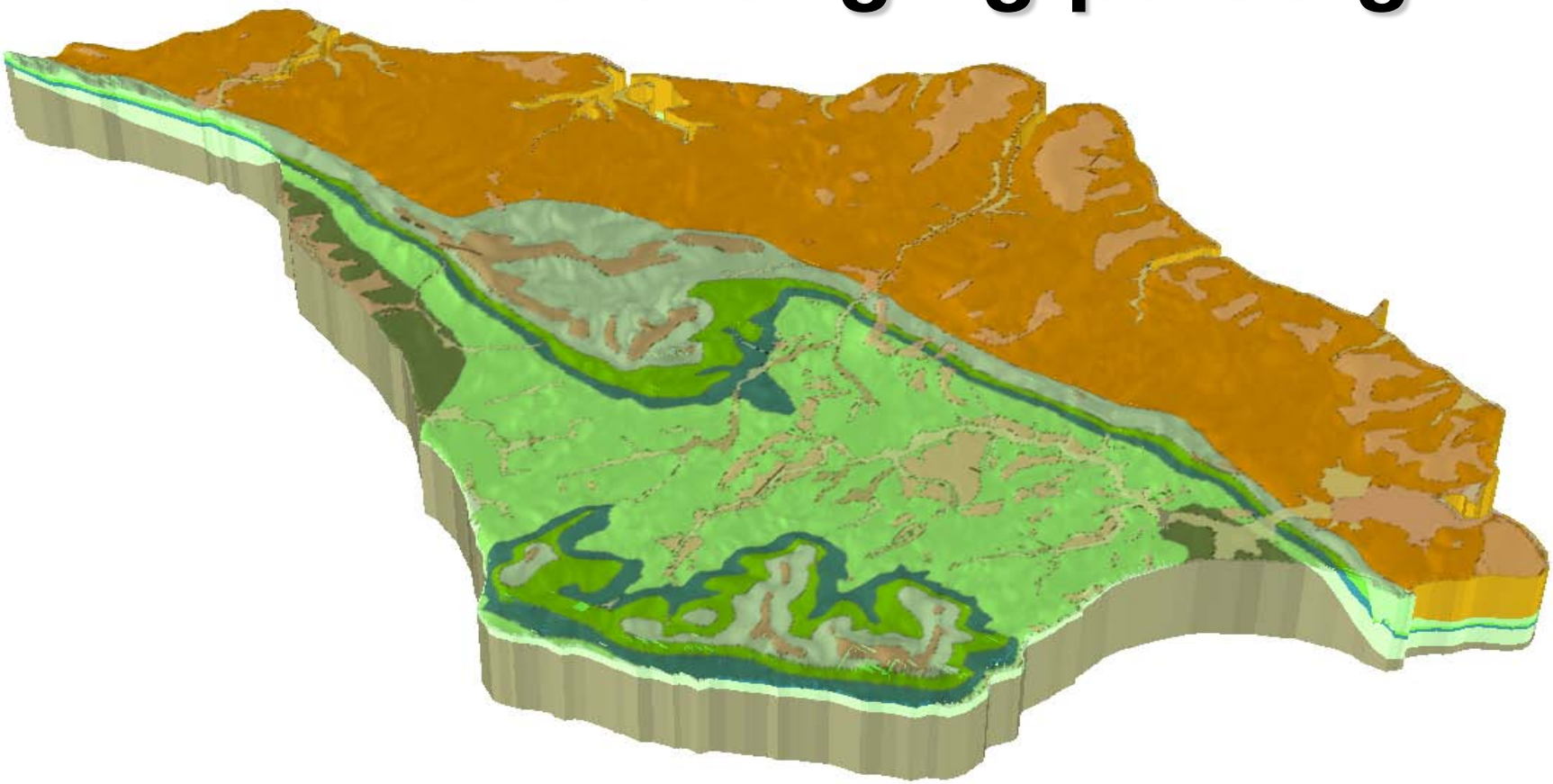
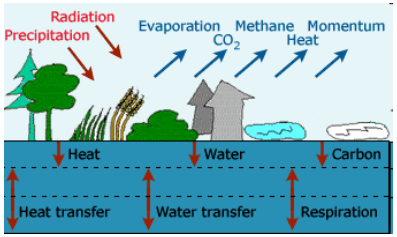
Mapping to modelling the changing paradigm



3D framework model of the Isle of Wight

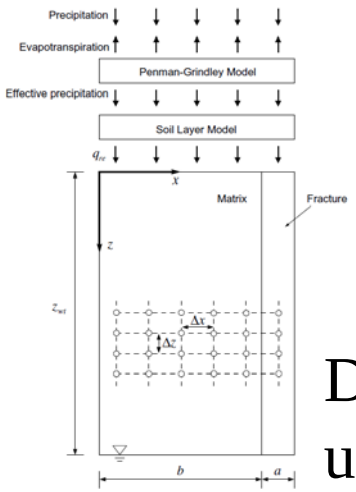
Developed using BGS GSI$^{3D\ (TM)}$ software and methodologies

Process modelling in BGS

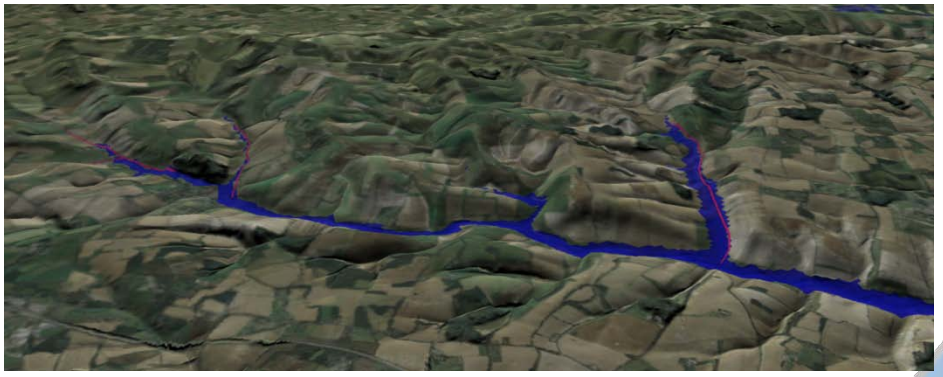


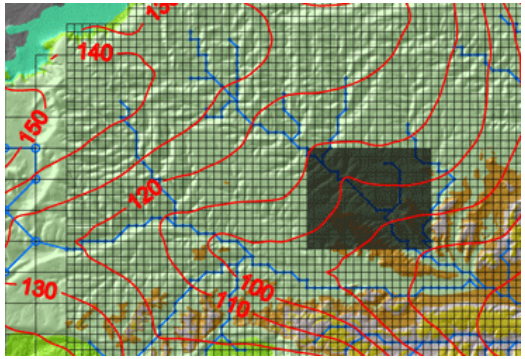
Soil Moisture

Overland Flow



Dual permeability unsaturated zones





ZOOMQ3D: Groundwater Flow

Integrated simulation of surface water - groundwater flooding

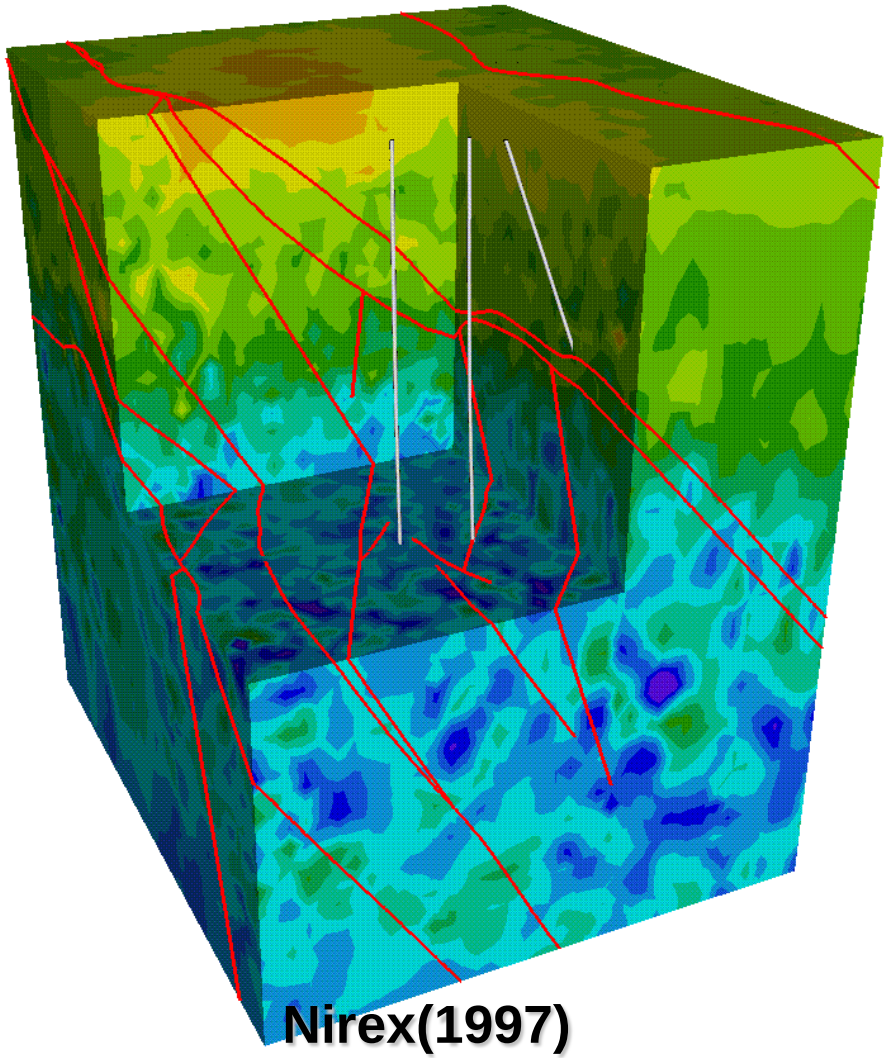
Destination: 4D geological models

- Time dependent process models of natural systems increasingly required to understanding the response of natural environmental to climate change
- Now: Geology in process models has to heavily simplified
  - Flat and layered
  - Each layer homogeneous
- Future: accurate 4D models demonstrating time dependent dynamic systems including:
  - Topography and structure from 3D framework models
  - Intra-unit variability described by inclusion of properties
  - How close are we to this destination in regions of UK?

Importance of porosity

- UK‘s populated areas are mostly underlain by porous clastic sedimentary rocks
- This porosity is being used in more ways
  - Extraction of drinking water and hydrocarbons
  - Storage of natural gas and CO_2
  - Fluid flow regimes are affected by other processes in the geosphere like mining, open casting and waste disposal
- Understanding variation of porosity is fundamental to understanding the nature of these rocks.
- Porosity data has been measured in a variety of ways, for a variety of end-users over a long period of time.
- There has never been a program to map porosity across the UK
- 3D regional mapping properties like porosity is a major priority

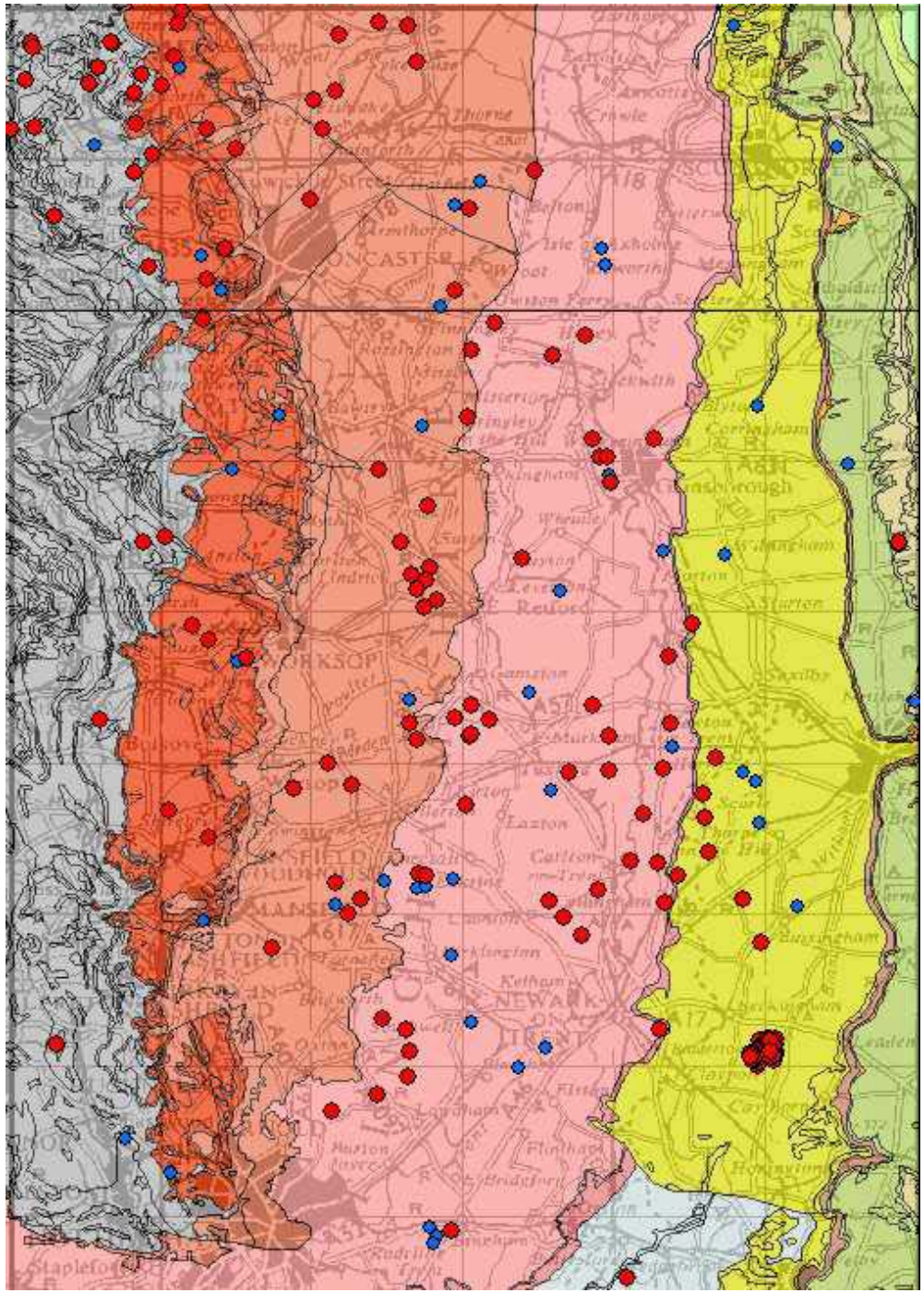
3D physical properties model population



Nirex(1997)

Sellafield acoustic impedance inverted seismic cube populated with upscaled rock strength

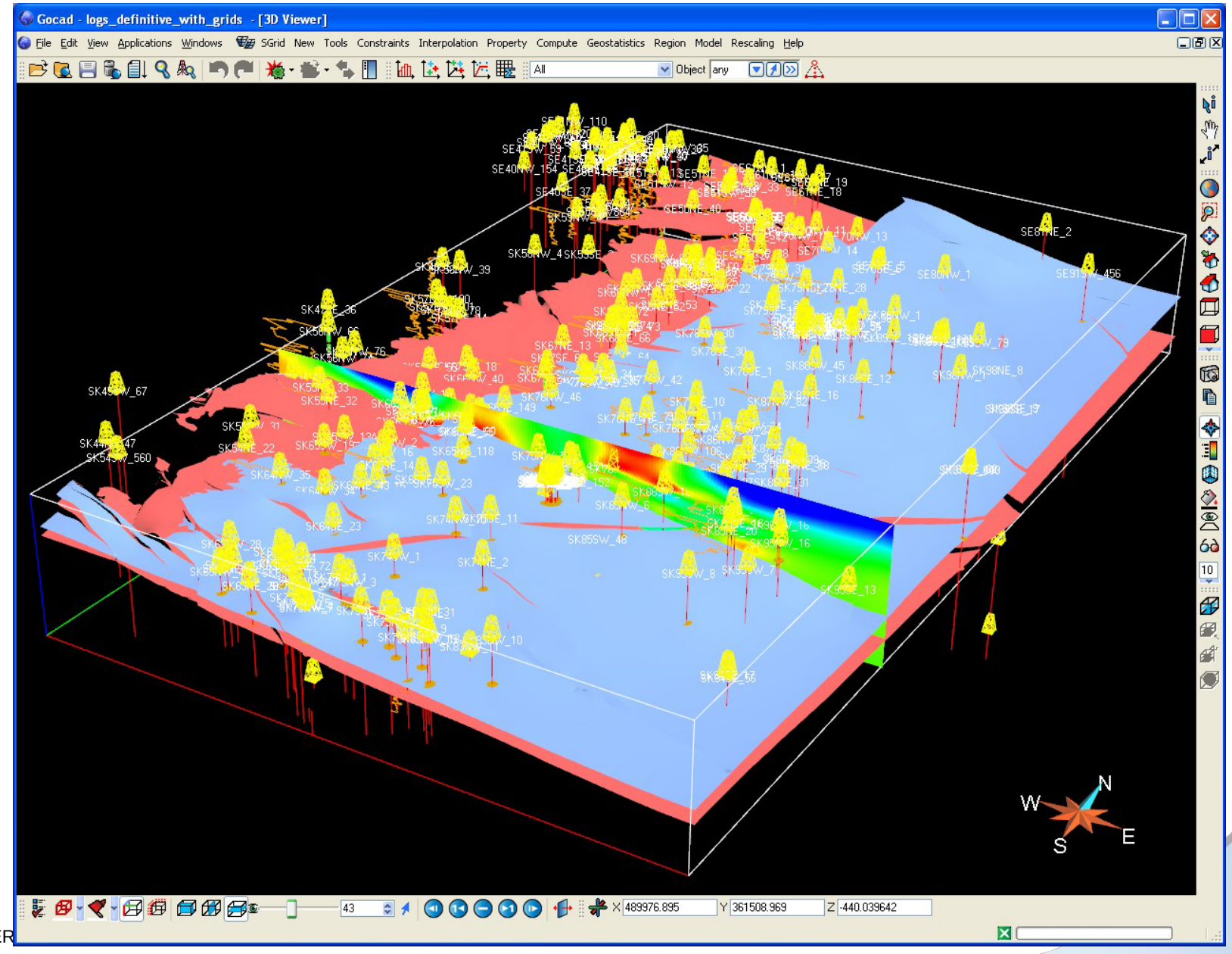
- Ideal would be whole UK landmass described like this
- Model shows one of very few UK landmass 3D seismic models (>1% coverage)
- Available 2D seismic data is sporadic and largely of 1970-80s vintage
- Therefore creating large scale porosity maps of the UK will require a different approach
- PropBase aims to populate 3D models by extracting physical properties from BGS databanks and mapping their variation through 3D volumes with no seismic framework



PropBase 3D

- UK East Midlands chosen due to simple geology
- Triassic Sherwood Sandstone Group (SSG)
- Carboniferous, Permian &Triassic outcrop eastwards and dip ~1° E
- 100s of trial pits but no geotech samples cut SSG
- Wireline logs from 70-90 coal exploration the sole pervasive property data-
- Target the underlying Coal Measures, so few sample the entire SSG

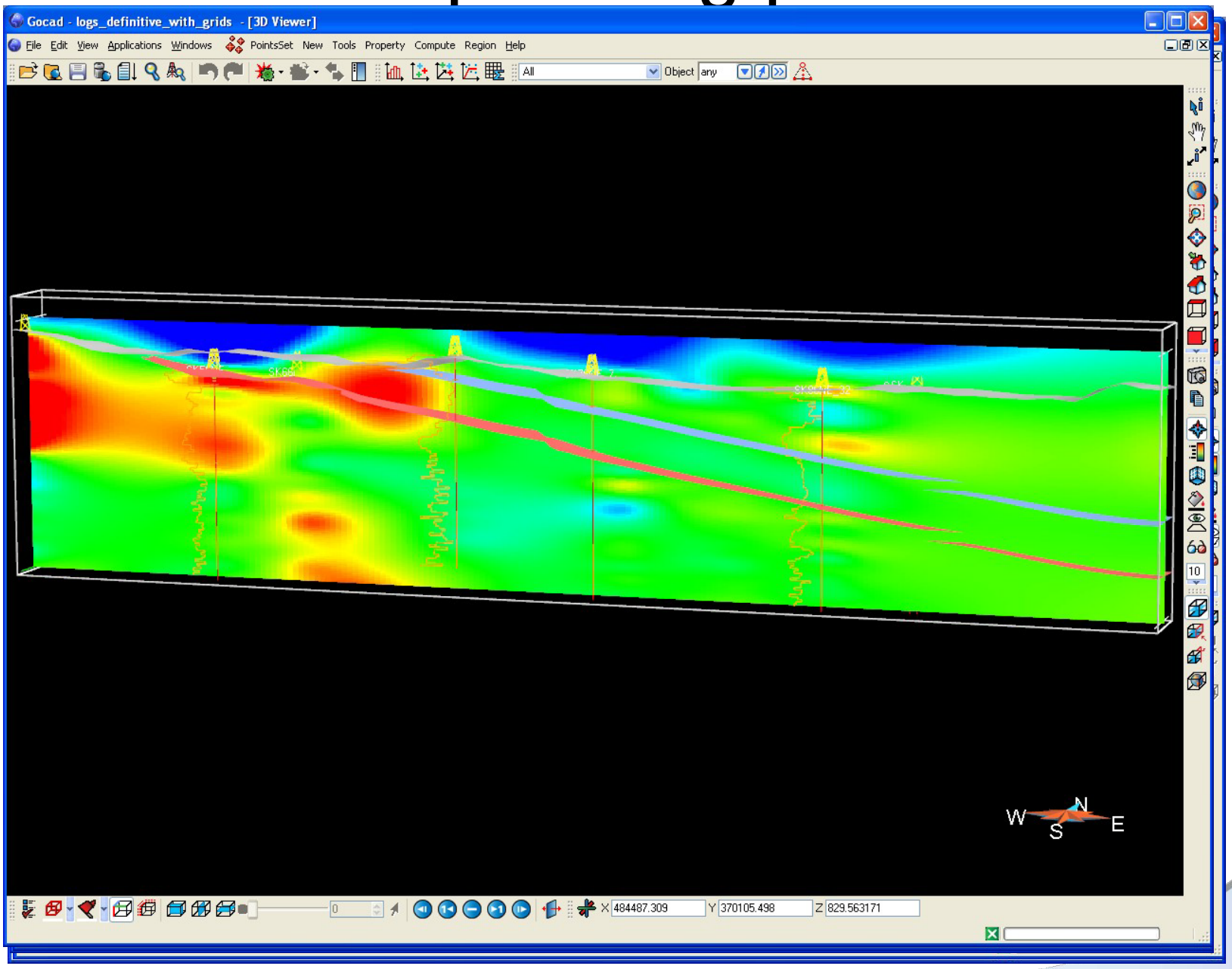
East Midlands model



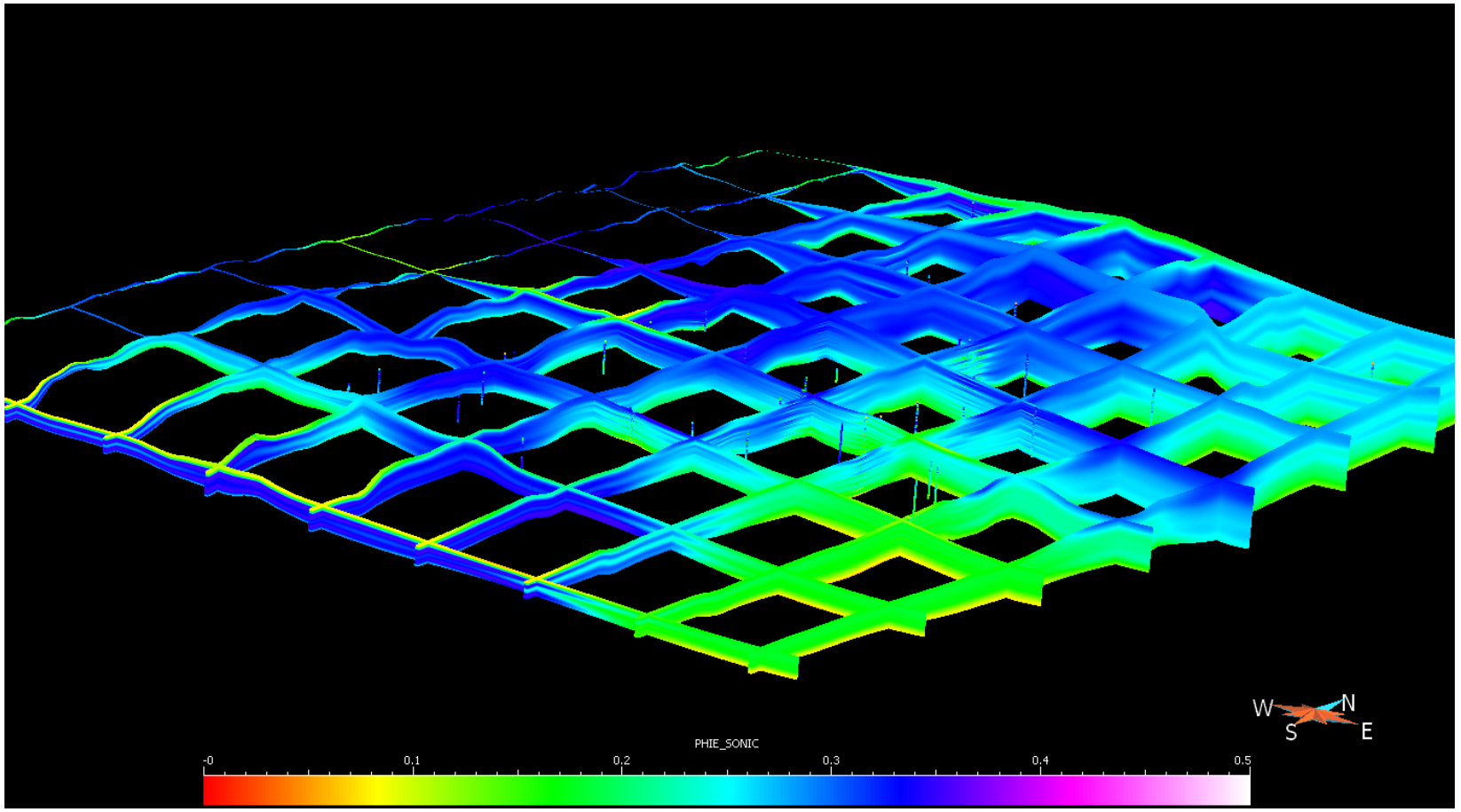
Sherwood Sandstone Voxelation

- Proportional stratigraphic grid (Sgrid) from top to base SSG
  - Generated with 200 x 200 x 2 m cells (20293750 cells)
  - Log-derived porosities upscaled as points into the Sgrid;
  - Porosity curves calculated from density and sonic logs
  - Porosity logs upscaled as points (mean of values intersecting each grid cell)
  - All cells cut by logs attributed with the mean porosity.
  - Upscaled point values used to constrain grid, and are ‘initialised’ throughout grid using Discrete Smooth Interpolation, so each cell contains porosity attribute.
  - Data outliers (spikes, high clay) omitted as artefacts before interpolation, preventing distorted results in areas of poor data control.

Upscaling process



Sonic Porosity populated Sgrid



Conclusions

- Need to quantify what errors are within matrix
  - Need to test additional algorithms for more accurate extrapolation of properties
  - Comparisons of sonic and density datasets to eliminate error
- BGS needs direct sampling of representative SSG in in-situ conditions to accurately ground truth modelling
- Ever greater environmental and resource pressure on the geosphere requires ever more realistic subsurface simulation.
- Limited 2D and scarce 3D seismic data and a lack of suitable property data hinders upscaling across much of the UK.
- Though imperfect, the SSG grid makes best use of available data in Nottinghamshire.
- Presents a test case for better understanding of the subsurface of the UK

Conclusions

- Current work allows property data to be provided seamlessly into 3D models using GSI3D and GOCAD
- PropBase studies have enabled BGS to:
  - display and interpret more datasets with greater ease
  - simplify the process of populating 3D framework models volumes with physical properties
  - study the heterogeneity of geological units
  - compare different datasets to be easily compared improving the data verification process
- 3D modelling has enabled understanding geological structure to be communicated to non-geoscientists
- Populated geological models allow heterogeneity to be communicated