

## Geological resource management of the future: Drilling down the possibilities

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**Abstract:** Management of geological resources is based, ideally, on information on the quality and quantity of surface and subsurface litho-stratigraphical properties. Increasingly, these data become available for the offshore realm, though the integration into manageable and user-friendly applications is still at its infancy. Building on expertise from on-land data mining, we are now in the phase of creating 3D voxel models allowing for multi-criteria resource volume calculations. The underlying data will be subdued to uncertainty modelling, a necessary step to produce data products with confidence limits. Anticipating on the dynamic nature of the marine environment, we aim at coupling the voxel model to environmental impact models to calculate resource depletion and regeneration, based on geological boundary conditions. In combination with anticipated impacts on fauna and flora, mining thresholds will be defined. All of the information is integrated into a decision support system for easy querying and on-line visualizations. The main aim is to provide long-term predictions on resource quantities to ensure future developments for the benefit of society and our future generations.

**Key words:** Sustainable Exploitation, Mining thresholds, 3D Geological Models, 4D Decision Support System, Uncertainty modelling.

### INTRODUCTION

Mineral and geological resources can be considered to be non-renewable on time scales relevant for decision makers. Once exhausted by humans, they are not replenished rapidly enough by nature, meaning that truly sustainable resource management is not possible. Comprehensive knowledge on the distribution, composition and dynamics of geological resources therefore is critical for developing long-term strategies for resource use (e.g., Van Lancker et al., 2010). For the marine realm, resource management is often hampered by sparse data availability, though increasing exploitation demands call for innovative approaches that include uncertainty as a primary asset. This is the scope of the TILES project (2013-2017), set-up for managing marine aggregate exploitation in the southern North Sea, but generically designed for a broader range of resources and environments.

The ambition of TILES is to:

(1) Develop a decision support system (DSS), containing tools that link 3D geological models, knowledge and concepts, providing information on present-day resource quantities and distribution, to numerical models of extraction-related environmental impact through time. Together they quantify natural and man-made boundary conditions and changes to define exploitation thresholds that safeguard sustainability on a multi-decadal time scale.

(2) Provide long-term adaptive management strategies that have generic value and can be used for all

non-hydrocarbon geological resources in the marine environment.

(3) Propose legally binding measures to optimize and maximize long-term exploitation of aggregate resources within sustainable environmental limits. These proposed measures feed into policy and associated monitoring plans that are periodically evaluated and adapted.

### WORKFLOW

The project objectives will be achieved through interdisciplinary and transnational research on the nature and dynamics of geological resources and on the environmental impact of extraction (FIGURE 1). State-of-the-art 3D geological models will be developed by transforming a layer model, defining stratigraphic unit boundaries, into a so-called voxel model (consisting of 'tiles' or volume blocks) and assigning to each voxel lithological or other characteristics (e.g., Stafleu et al. 2011). The primary voxel information will be based on a combination of point and line data, respectively from coring and seismic investigations. These data, and additional environmental datasets, that are added to the voxels will be subjected to uncertainty analyses, a necessary step to produce data products with confidence limits. Uncertainties relate to data- and interpolation issues (van Heteren and Van Lancker, in press); their propagation will be assessed through the data products. The geological models will feed into 4D numerical impact models that quantify the environmental impact of extraction. Here, there is scope to define mining thresholds, based on the nature and dynamics of

geological resources and on the impact of their removal. The 3 and 4D model results will be incorporated into scenario analyses and forecasts, using a newly developed multi-criteria decision support system (DSS) (e.g., De Tré et al., 2010). The DSS, based on an object-oriented database structure and resource suitability modelling, will allow specifying flexible criteria for geological, environmental and socio-economical parameters. Information will be visualized in series of tailor-made suitability maps that assist in resource assessments.

Using a dedicated subsurface viewer, a suite of data products will be viewable online. They can be extracted on demand from the underlying voxel (3D pixel) model. The flexible 3D interaction and querying will be invaluable for professionals, but also for the public at large and for students in particular.

## CONCLUSIONS

To anticipate on actual and future resource supplies and needs, long-term adaptive management strategies for the exploitation of geological resources are urgent requests (e.g., marine spatial planning, EU's Marine Strategy Framework Directive). They comply ideally with EU recommendations on 'Efficient use of resources' (EC COM2011\_571) and ICES Guidelines for the management of Marine Sediment Extraction (ICES, 2003). The scope of the latter corresponds well with the recommendations provided by the International Seabed Authority (ISA) regarding deep-sea mining.

It needs emphasis that setting-up transnational, harmonized geological knowledge bases can function as a critical platform for the exchange of data, information

and knowledge. It will herald a new age in resource management, locally and transnationally.

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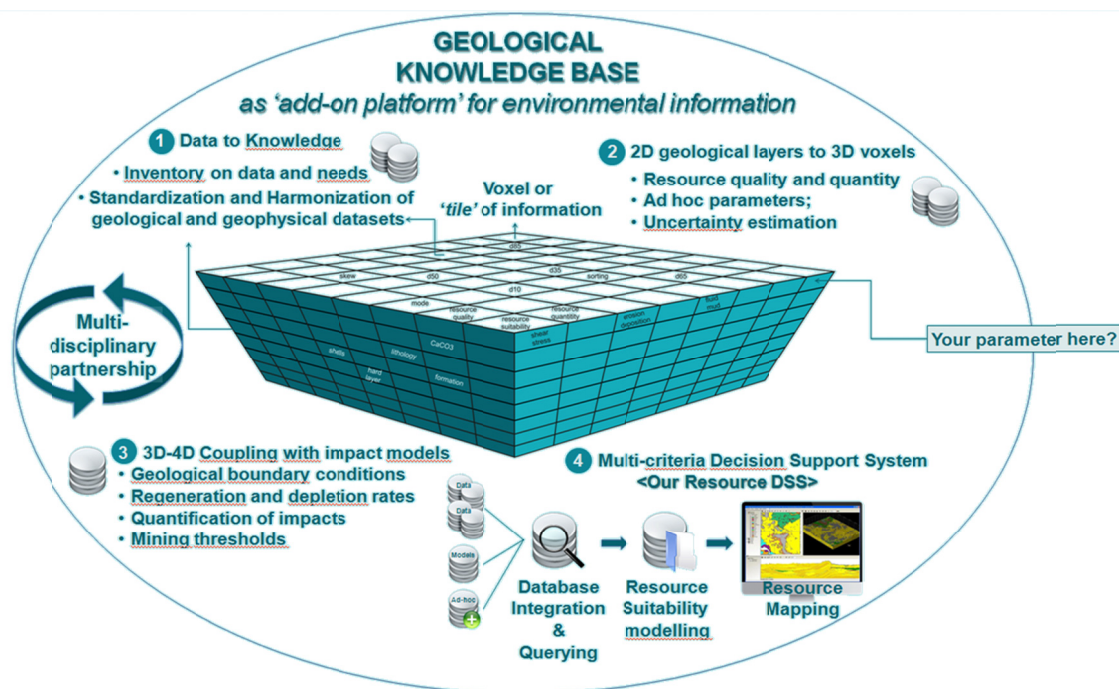


FIGURE 1. TILES workflow. The set-up of a Geological Knowledge Base is promoted to advance and innovate, structurally, on collaborative research and management related to resources, in casu non-living, but with ample opportunities to link with the living environment.