Systematic Geomodeling: What Does It Actually Imply?

Michiel J. van der Meulen, Patrick Kiden, Denise Maljers, Jan Stafleu, Ronald W. Vernes, Jan L. Gunnink, Wim E. Westerhoff and Tirza M. van Daalen

TNO – Geological Survey of the Netherlands, P.O. Box 80115, 3508 TA Utrecht, the Netherlands, michiel.vandermeulen@tno.nl

Abstract

The Geological Survey of the Netherlands maps its country systematically in 3D, putting out four models that each correspond with a particular application domain. Rather than the models themselves, we discuss the implication and implementation of working systematically, focusing on quality assurance and model versioning and maintenance. Our aims for quality assurance are to put a system in place that arranges for independent and documented checks of all model output, according to well-defined quality standards, finding a balance between rigorousness on the one hand, and user demands for faster information delivery on the other. Regarding model versioning and maintenance, we aim to significantly shorten our release cycles, publishing models after making specific improvements rather than full updates. These two aspects of working systematically are particularly important to establish our accountability in terms of the value and quality of our modeling work, which in its turn is vital to the continuity of our Survey.

Introduction

All publications on 3D modeling by the Geological Survey of the Netherlands have introductory statements saying that we work systematically (e.g. Stafleu & Busschers, this volume). While each such publication then typically proceeds with specific modeling outcomes, the present contribution focusses entirely on the meaning and implications of the word ‘systematically’ (for a full account of our activities we refer to Van der Meulen et al., 2013). We focus on versioning and quality control, as well as on the strategy and organization behind these, addressing the general question: how do we put out reliable, up-to-date, national-scale subsurface information for the management of Dutch natural resources and hazards?

Key Concepts

The very subject of this paper requires us to be specific on a number of key concepts. We define, for a start, geomodelling (also referred to as 3D mapping or subsurface modelling) as predicting the structure and properties of the subsurface down to economically relevant depths. ‘Properties’, in the case of the models of our Survey, include stratigraphic unit, lithological class, and a selection of hydraulic parameters. ‘Structure’ refers to the fact that we account for geological features and architectural elements such as basins, fault units, sedimentary systems and facies units. Our current 3D portfolio includes three layer / framework models and a voxel model:

- GeoTOP: a 100 × 100 × 0.5 m voxel grid with lithological and stratigraphic attributes, maximum depth 50 m
- REGIS-II: 133 parameterized hydrostratigraphic units, maximum depth ~1000 m
- DGM: 34 Neogene and Quaternary lithostratigraphic units, maximum depth ~1500 m
- DGM-deep: 13 Carboniferous to Neogene seismostratigraphic units, maximum depth ~7000 m

‘Systematic geomodeling’ indicates an ongoing activity, which we have organized as a process of information production. A very important trend is moving towards working primarily with third-party data; legal mechanisms for compulsory subsurface data delivery to the Survey are either in place or in
development. As a result, we are starting to tap into a body of data that is many times larger than what we could ever hope to acquire on our own resources. The rate and costs of geological mapping in the previous century were determined largely by the actual field surveying and data acquisition. Working with pre-existing and third-party data, digitization and automated data handling made mapping a much more efficient process, time and cost-wise, but it is still by no means a push-button operation. National-scale geological information delivery can still only be the result of a sustained, systematic effort: it is delivered by a process, not a project.

We aim for **consistency** in space, as we work nationwide and cover large areas, and we aim for consistency in time, because we release our models in (regional) parts and versions. Consistency implies that our subsurface models need to be well-defined, not only in terms of their characteristics and properties (scale, resolution, parameters), but also in the sense that their quality needs to be quantified and controlled.

In manufacturing, **quality** is defined as a “measure of excellence, or a state of being free from defects, deficiencies and significant variations”. ISO, the international Organization for Standardization, connects quality with a standard: “the totality of features and characteristics of a product or service that bears its ability to satisfy stated or implied needs” (ISO 8402:1986), reformulated as “degree to which a set of inherent characteristics fulfils requirement” (ISO 9000:2000). All such definitions are as bold as they are difficult to apply to geomodeling. What, in fact, makes a good model? What about requirements of a product made in anticipation of, rather than responding to a specific application or request, or one that is used for other purposes than it was conceived for altogether?

![Diagram of a quality system for geomodeling at the Geological Survey of the Netherlands](image)

**Figure 1. Outlines of a quality system for geomodeling at the Geological Survey of the Netherlands, showing flows of data and information, processes, documents and products.**
Probably for that reason, geomodel quality appears not to be very well constrained: if assessed it is often reduced to inverse uncertainty (high quality = low uncertainty and vice versa), and in other cases it seems to be implicitly taken as closeness to geological perfection – which is not actually helpful. We are currently defining model quality as we go along devising a quality system, starting from the following basic definition: **model quality is a measure for the predictive value of a model.** ‘Measure’ bears to quality preferably being quantifiable and objective, and ‘predictive value’ connects model result with model specifications as well as with new (field) observations.

**Quality Assurance**

**Challenge.** 3D modelling differs from 2D mapping in the fact that it uses and produces more information than one can wholly oversee by visual inspection or traditional reviewing. In addition, whilst a geological map can relatively easily be corrected if a feature is disputed, a misconceived model may set you back to the start of the whole exercise. As our direct investments in systematic modelization add up to about 3 M€/yr, we consider such risk significant. Quality assurance of 3D model needs to address the information overload aspect, find ways to capture errors as early as possible in the production chain, and make use of clever visualization techniques for a full appreciation of the product under scrutiny.

**Status quo.** Our former 1:50,000 geological maps and explanatory notes were subjected to a rigorous, scientific-type editorial review procedure, which addressed the consistency and geological plausibility of the interpretation, with particular attention for cartographic representation (Van der Meulen et al., 2013). This procedure and the responsible board were dismantled when 2D mapping was discontinued in the late 1990s, so a quality system for geomodeling has to be designed and implemented basically from scratch. We currently have a system in development, which arranges for independent checks, and documents (perceived) errors, preparing for a triage that precedes the final model release (as well as certain intermediate modeling stages): (1) residual small errors will be corrected, (2) ‘medium’ errors will be published in the model documentation and fixed in the next release, (3) large errors will block a release. Furthermore, we produce uncertainty information for all geomodels, but not yet for all of their attributes. Finally, we research novel ways for quality assessors to process large amounts of information efficiently (e.g. Van Maanen et al., 2015).

**Desired situation.** We aim for a quality checking process that performs independent and documented checks of all our model output. Quality standards need to be distilled from developing practices and published. A sensible balance between production and quality control needs to be established, being rigorous while satisfying users (and legal requirements) to deliver information faster. The system as currently envisaged is shown in Figure 1.

**Model Versioning And Maintenance**

**Challenge.** An upcoming law on subsurface information will declare our models officially authentic and attaches obligations to their use by government. The same law will arrange for a faster influx of data to our Survey. Among the many responsibilities and obligations this law will bring, shortening the release cycles of models is particularly important to geomodeling: it will be expected that our modeling will keep up with the influx as much as reasonably possible.

**Status quo.** Our 20th century geological maps were published with the perspective of a life of many decades (Figure 2). Current production cycles of 3D subsurface models, the successor products of these maps, are expressed in years rather than decades. DGM and Regis have had multiple releases in the 15 to 20 years that their respective programs have been running. GeoTOP will achieve national coverage in about 20 years, but individual model blocks are already updated according to the insights gained while proceeding with new areas.
Desired situation. Even without considering the abovementioned legal context to geomodeling, withholding improvements from users while we are striving for an unreachable state of perfection will arguably become less and less acceptable to our modern information users. We envisage model maintenance resulting in frequent releases of model versions, e.g. annual or biennial, with fixes of issues that were either identified in our own quality assurance process, or are reported by users. In this way, maintenance and versioning are closely related to the quality system described above. Just as with common software, it is up to the users whether or not they will adopt a particular version, but we want the models we release online to be as up-to-date as reasonably achievable.

Vision And Outlook

We addressed two aspects of systematic geomodeling that we consider important to achieving our vision of a 21st century geological survey organization. The focus is shifting towards data management and information production, and away from surveying and data acquisition that underpinned mapping in the past. Existing and pending legal arrangements will make for an excellent data position, the associated challenge is be to be able to manage and interpret a rapidly growing body of data. Working systematically and improving ourselves in this respect are key.

- The primary processes serving these purpose, and by which we have organized ourselves and our work, are, data ingestion, data management, information production (geomodeling), and the delivery of data and information. Our main secondary processes include quality management, the development and maintenance standards, and research, by which we underpin and advance our activities and products.
We consider our core assets to be our data, information (models), standards and staff (for its knowledge and skill base). As their joint value is and can only be contextual, equally important assets are our communities of users and stakeholders, our credibility and reputation, and our independence.

Our core capacities include, geosciences, data and information analysis, data management, IT, stakeholder management and – given the long planning horizons that apply to geological surveying – strategizing.

The license to operate of a geological survey is ultimately determined by the value it adds, referring its expanding collection of data, and particularly to the value-adding processes of producing geomodels using this collection. Quality assurance helps determining how much value is added at which costs; versioning determines in what portions value is returned to the taxpayers. We consider our awareness of this, and being open about it vital to the continuity of our business to be the provider of subsurface information for the Netherlands.

References


