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# Modelling approaches in sedimentology: Introduction to the thematic issue

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ABSTRACT

As an introduction to this thematic issue on "Modelling approaches in sedimentology", this paper gives an overview of the workshop held in Paris on 7 November 2013 during the 14th Congress of the French Association of Sedimentologists. A synthesis of the workshop in terms of concepts, spatial and temporal scales, constraining data, and scientific challenges is first presented, then a discussion on the possibility of coupling different models, the industrial needs, and the new potential domains of research is exposed.


## 1. Introduction

Whether numerical or experimental, modelling is now widely used in sedimentology, but it covers a large range of domains both in time and space: experimental analogical models (notably used for geomorphological evolution of reliefs) enable us to characterize at a small scale erosion, transport, and deposition processes, to infer quantitative evolution laws, and to calibrate their relevant parameters. Hydro-sedimentary modelling is mainly used to understand the evolution of present environments using a detailed numerical modelling of these erosion–transport–deposition processes (solving the Navier–Stokes equations, for example). Process-based simplified approaches are applied to geological time scales: they are based either on solving deterministic laws describing main processes (genetic models, de Marsily et al., 2005), or with additional introduction of stochastic parameters into the laws (the so-called random-genetic methods). Reservoir architecture modelling is based on geostatistical approaches or mixed geometric/stochastic methods mentioned here as hybrid models: they enable us to quantify the uncertainty of the resulting geomodels, which are linked either to the data, or to the conceptual model (depositional environment, correlation scheme...). At the basin scale, stratigraphic modelling uses averaged transport and deposition laws (diffusion equation, for example) in order to reproduce large-scale depositional architectures and to test the impact of control parameters (accommodation, climate, clastic sedimentary input or carbonate production...).

Some of these approaches are coupled: process-based models are often calibrated on analogical experiments, and

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then applied to recent systems, before being used on outcrops or subsurface data. Process-based, random-genetic or hybrid models produce reservoir architectures that may be used as training images for geostatistical methods. At the basin scale, stratigraphic modelling may be coupled with thermo-mechanical models in order to get the timing of the deformation of the basin, through the evolution of the lithosphere, and analyze its impact on surface processes. Stratigraphic models may also be used as an input of large-scale fluid circulation models, which may be coupled with reactive transport simulation for environmental purposes (geothermal energy, $CO_2$ storage, wastes), or diagenesis-related problems.

During the 14th Congress of the French Association of Sedimentologists held in Paris from 5 to 7 November 2013, a workshop on "Modelling approaches in sedimentology" has been organized between researchers of these different communities in order to:

- exchange on the different concepts and approaches developed to model and solve problems in sedimentology;
- discuss the methodologies adopted to honour data, through parameter calibration, and in relation with uncertainty quantification;
- identify the limits and key issues of these approaches;
- evaluate the possibility and needs for coupling between models, in order to initiate new collaborations and research domains in relation with industrial needs.

## 2. Organization of the workshop

The workshop was organized in three stages.

First, a poster session, with 27 contributions, gathered the participants and illustrated their different modelling approaches and their latest results. The electronic version of some of these posters is available on the website of the French Association of Sedimentologists (ASF) at the address: http://www.sedimentologie.fr/.

Following the poster session, two discussions were held in parallel between modellers divided according to the scale of their models:

- **theme 1:** large-scale modelling of the history and sedimentary architecture of basins: geodynamical control, data synthesis, fluid palaeo-circulations (coordinators: P. Joseph, G. Caumon, D. Rouby);
- **theme 2:** modelling of sedimentary and diagenetic heterogeneities: processes, reservoir architecture and properties, fluid-flow behaviour (coordinators: V. Teles, R. Labourdette, P. Le Hir, S. Lopez, P. Weill).

These discussions were structured around three key-points and are summarized in the next section:

- presentation of the spatial and temporal scales, and main concepts of each model;
- use and availability of constraining data;
- identified scientific challenges in modelling approaches and coupling between models.

Finally, a round table with all the participants enabled to share and summarize the conclusions of the two thematic previous discussions and initiated a debate on academic and industrial needs and potential new research domains.

## 3. Synthesis of the workshop

### 3.1. Theme 1

This first theme gathered researchers working at a large geological scale with different approaches such as stratigraphic, thermo-mechanical, geological and/or fluid-flow modelling at the basin scale. Consequently, the considered space and time scales are quite homogeneous between these models. Spatial dimensions span from a few to thousands of kilometres, simulated time span from 100 ka to several (tens to even hundreds) million years. The modelling concepts presented during this workshop covered different aspects of basin-scale processes:

- *stratigraphic* and *geomorphological* models represent large-scale sedimentary processes either with diffusion-like or hydrodynamic equations;
- *geological* models can borrow different techniques from machine learning (e.g., neural networks), geostatistical methods or deterministic maps;
- *thermo-mechanical* models use rheological laws of solid behaviour;
- *basin-scale flow* models may couple fluid-flow laws in porous media, geochemical reactive laws and geomechanical laws.

In terms of input data, a wide range of data has been listed by stratigraphic and geological modellers: seismic data, fault geometry, climate data, dating, outcrop sedimentological sections, well logs and core data and their geological interpretation in terms of facies and depositional environments, hydrodynamic data (pressure and flow rates). Palaeogeographic, palaeo-bathymetry/palaeo-relief constructed by the geological modellers, as well as palaeoclimatic maps are interpreted data used by stratigraphic and basin-scale groundwater modellers. Thermo-mechanical models need information on the lithosphere structure and thermicity, and on mantle convective processes.

Simulation results of these models are calibrated mostly through a trial-and-error process, although some inversion techniques are also developed. Validation is done by comparison against well and seismic data, or interpreted palaeogeographic maps in the case of thermo-mechanical models.

It has been highlighted that the coupling of these different models would be a very interesting step forward. For example, stratigraphic models need a better estimate of subsidence and uplift rates through time that could be modelled by lithosphere thermo-mechanical models acting as providers of "boundary conditions". Basin-scale fluid-flow models are dependent on the timing and duration of the diagenetic events and on the geochemical

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