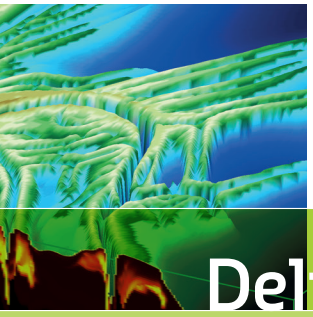
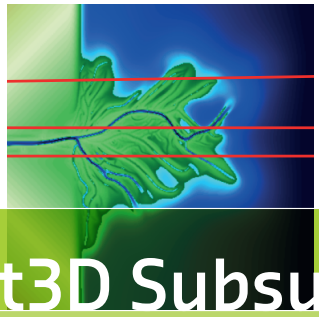
Deltares

Enabling Delta Life





Delft3D Subsurface Characterization

Characterizing the subsurface at depth involves dealing with large uncertainties, as the data available, such as seismics and boreholes, are costly and hence limited. Forward numerical modelling with Delft3D allows simulating high-resolution morphological and stratigraphic patterns in a fluvio-deltaic setting, which can be used to improve building geologically realistic hydrocarbon reservoir models and quantify uncertainty. Delft3D Subsurface Characterization is a product of Deltares and Delft University of Technology consisting of scientific research, software development, scientific and software support for the application of Delft3D numerical analogues for the understanding and the characterization of the subsurface.

Delft3D numerical analogues

Outcrop analogues are an extremely valuable data source when populating 3D-Earth models in the Hydrocarbon industry. They provide information on lateral and vertical distribution of rock properties and 3D geometries of geobodies. So far, analogue data has been restricted to outcrops and modern-day sedimentary systems. New developments in numerical forward modelling presently also allows for implementation of numerical analogues in the existing workflow. These numerical analogues are fully consistent as they are based on physical laws. They provide a three dimensional stratigraphy and morphology, and detailed information on the temporal development of the system, the formation and characteristics of bounding surfaces and palaeo flow velocities.

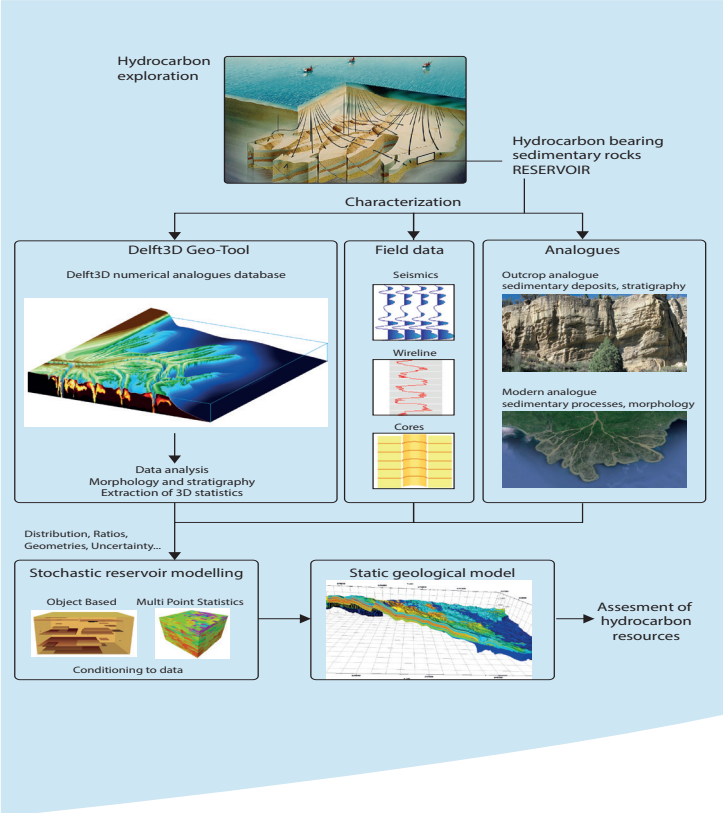


Fig. 1 – Numerical analogues simulated with Delft3D provide geologically realistic stratigraphic and morphological patterns, which can be used to populate Earth models. Thereby, they can be integrated in the existing workflow for reservoir characterization. The figures 'hydrocarbon exploration, 'field data', ' stochastic reservoir modelling', and 'static geological model' are taken from the course 'Reservoir Characterization' and 'Field development', given at the Delft University of Technology.

In the last decade, Deltares and the TU Delft have worked jointly to develop and apply the software tool Delft3D quantify the evolution of fluvio-deltaic systems. Different types of river deltas have been simulated with Delft3D, resulting in a range of stratigraphic architectures. These models can be used as three dimensional, numerical analogues for river delta geo-bodies in the subsurface. By integrating these numerical analogues in the traditional industry workflow geologist can quantify and limit the geological uncertainty around important properties of reservoirs, e.g., porosity, permeability, heterogeneity and connectivity.

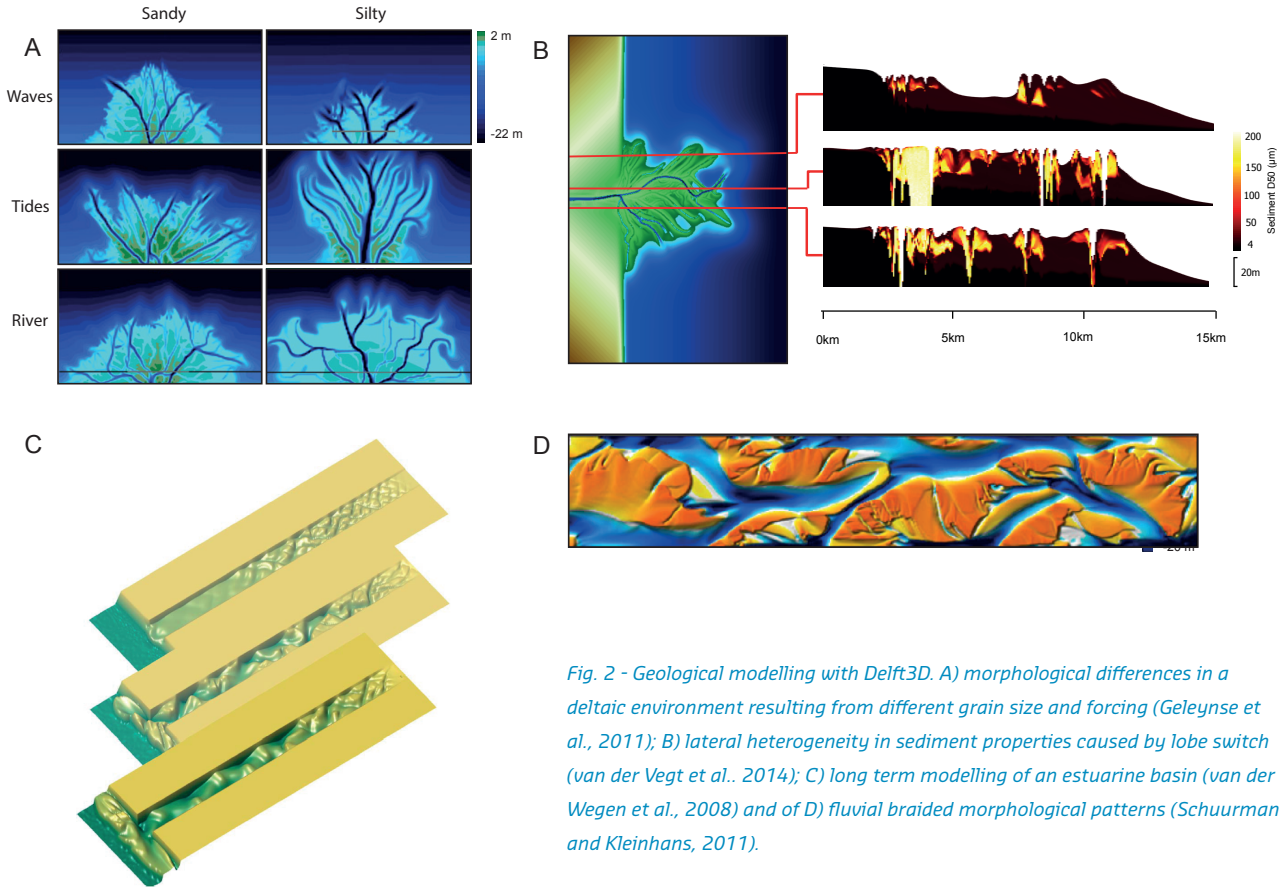


Fig. 2 - Geological modelling with Delft3D. A) morphological differences in a deltaic environment resulting from different grain size and forcing (Geleynse et al., 2011); B) lateral heterogeneity in sediment properties caused by lobe switch (van der Vegt et al.. 2014); C) long term modelling of an estuarine basin (van der Wegen et al., 2008) and of D) fluvial braided morphological patterns (Schuurman and Kleinhans, 2011).

Delft3D

Delft3D is a high-resolution, process-based software, simulating hydrodynamics, sediment transport and morphological changes in a fluvio-deltaic setting. Its spatial resolution is typically 50 m and the vertical resolution 0.3 m. Delft3D has been applied in a wide variety of disciplines, such as coastal engineering, water quality, floods and storms forecasting. Thanks to the growth in computational power and to the development of upscaling techniques in the last decade, Delft3D is presently used to simulate the evolution of deltaic (Geleynse et al., 2011), fluvial (Schuurman and Kleinhans, 2011), and estuarine sedimentary systems (van der Wegen et al., 2008) (Fig. 2).

Numerical simulations show the capability of Delft3D to accurately resolve the morphology and stratigraphy of developing river delta distributary networks under different hydraulic and sedimentary forcing, for example in river-, wave-, or tide-dominated setting. The model is applied to investigate the impact of water and sediment supply, grain size, and substrate composition on deltaic development, showing how allogenic and autogenic processes affect channel properties, grain-size trends, facies distribution and the connectivity of sand bodies.

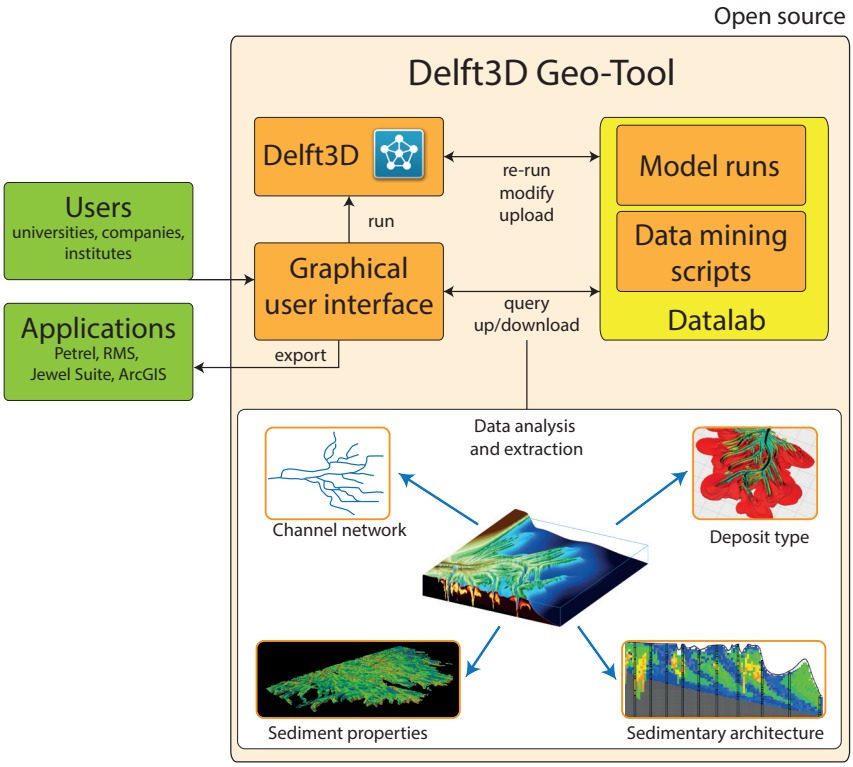


Fig. 3 – Delft3D Geo-Tool components and data mining. A database of numerical analogues built with different boundary conditions, the DATALAB, provides a range of training sets and 3D statistics that can be used as input for stochastic modelling to populate reservoir models. The DATALAB also contains data mining scripts to analyse and extract data from the numerical analogues. A new, simple, graphic-user interface (GUI) allows the asset team to use Delft3D with schematic model set-ups based on a small number of input and parameters, intuitively visualize, extract, and analyse the simulated output, and export it to other software and applications.

Scientific research

Subsurface Characterization is the product of the collaboration between Deltares, Universities, research institutes, and companies. In the past ten years Statoil, Conoco-Philips and Shell have been supporting 3 PhD students, 1 Post-Doc and three MSc projects at the TU Delft. The focus of their research is to develop long term modelling of fluvio-deltaic systems with Delft3D, develop scalable analysis, extraction and the visualisation codes of numerical deltas, comparing modelling data with modern and ancient deltaic systems, and improve upscaling techniques for faster and longer model realizations.

Delft3D Geo-Tool and support

Deltares, TU Delft, and Statoil have been collaborating to develop the Delft3D Geo-Tool, a software shell around the model engine Delft3D, which combines the advanced morphodynamic and hydrodynamic modules of Delft3D with a unique open-source database, DATALAB, a user-friendly web-interface GUI, online data management and analysis tools. Delft3D Geo-Tool offers geologist and engineers the opportunity to intuitively simulate, analyse and export 3D numerical reservoir analogues to existing reservoir model such as RMS, Jewel Suite, and Petrel. Delft3D Geo-Tool has a user-friendly tool to set up scenarios that allows for a systematic evaluation of the effects of variable boundary conditions, such as water and sediment discharge, basin geometry, sediment type and marine forcing (tide and wave) on stratigraphy. For example, the user can test how the channel network changes as a result of increasing fluvial discharge, which importantly affects N/G and connectivity values. Data extracted from Delft3D Geo-Tool can therefore be valuable as input for stochastic property modelling while constructing a geological reservoir model. The Delft3D Geo-Tool will be open source for all Delft3D users uploading results on the database.

The first version will be available in the spring of 2017. After that, Deltares will offer a support service for companies to apply it to their specific projects. The technical support involves system set-up and helpdesk service. Scientific and operational support will be offered to companies for either working or collaborating on specific assets.

The advantages of subsurface characterization with the Delft3D-GeoTool are:

- OPEN-SOURCE: extraction of subsurface properties and geometries from a large and variegate dataset of fluvio-deltaic, high-resolution, 3D numerical analogues, will lead to better prediction of heterogeneity and connectivity in reservoirs.
- EXPERIMENTAL: the control on the boundary conditions, such as hydrodynamic processes and grain size, will allow testing of hypothesis and quantifying uncertainty on deltaic development by generating and analyzing different scenarios.
- INTEGRATION: the connection with existing reservoir software enables an optimal integration of numerical analogues in the reservoir characterization workflow.
- EASY: an intuitive interface, and predefined model setup will enable non-expert to prepare model input and analyze model output.
- SUPPORT: technical and operational support will be provided for setup and application of the Delft3D GEO-TOOL to specific assets.

References

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This brochure is a joint publication of the institutions involved in the development of Delft3D Geo-Tool. For more information, please contact one of the institutions listed below.

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