MassFLOW-3D Simulation of Sediment Flow and Distribution of the Ty Sandstone Reservoir in the Nini Field, Central Graben*

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Search and Discovery Article #20140 (2012)
Posted March 31, 2012

*Adapted from extended abstract prepared for poster presentation at AAPG Annual Convention and Exhibition, April 22-25, 2012. Please refer to companion article, entitled "3-D Forward Modeling and Simulation of Sediment Flow: Distribution and Deposition, Ormen Lange Gas Field," by Riccardo Basini et al., Search and Discovery Article #20141 (2012).

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Background

The aim of the present study is to analyze the sediment flow behavior and distribution of the Ty sandstone reservoir in the Nini field, which is located in the Siri Fairway just east of the Central Graben along the Norwegian-Danish border (Figure 1). In general hydrocarbon generation is taking place in the Central Graben area, which is also the source of the hydrocarbons migrating laterally (up to 75 km) into the Siri Fairway. The Central Graben shows a very steep slope towards the southwestern part of the graben. Major interest is to evaluate the possibility of the sediments to create some depo-structures before plunging in the deeper part of the graben. Particular attention is given to the behavior of palaeo-flows around a geological structure, a salt diapir, located in the southwestern part of the Siri Fairway.

Methods and Analysis

Computational fluid dynamics (CFD) is a tool for numerical solution of the physical equations describing fluid flow and sediment transport. The method has been widely applied in the engineering branches of fluid mechanics, but it has thus far been little used in sedimentological research and reservoir studies. Nowadays CFD analysis realized as numerical simulations is being developed to fill the gap between small laboratory experimental scale and large field scale, integrating data from theory, nature, and experiments. It can also shed light on flow parameters which are so far impossible to deduce from experimental and field studies. MassFLOW-3D™, a deterministic process modeling software, has been developed and successfully used to construct a process-based, 3-dimensional model for the simulation of sediment gravity flows. All principal hydraulic properties of the flow (e.g., velocity, density, sediment concentration, turbulence intensity, bottom shear stress) and its responses to topography can be continuously monitored in 3 dimensions.

The present project passed through different phases aimed to test and obtain the most realistic palaeo- bathymetry (Figure 2) and characteristics of the palaeo-flows reproducing the distribution of turbidite deposits. In order to run process-based, forward fully 3D numerical simulations, the palaeo-bathymetry prior to the turbidity currents had to be reconstructed. This started from the available seismic data, stepwise back-stripping (removing one after the other the sediments layer present on top of the desired surface as well as possible tectonic effects) the available data to the horizon of interest.

For each palaeo-bathymetry, realistic flow conditions (position of the flow inlet, flow size and velocity, grain distribution) were evaluated and analyzed, observing different possible scenarios in the palaeo-system. In the various simulations, the number of turbidity-current surges was changed as well, in order to verify deposition when the different flows were reducing their speed and to evaluate transport, deposition, and erosion. Particular attention was given to the depositional thickness in the two well logs marked as Nini-2, located nearby the salt diapir, and Nini-3 located upstream of the diapir along the flow pattern (Figure 3).

Results

One significant achievement is the verification of the most realistic palaeo-bathymetry: our model confirmed that one palaeo-bathymetry provided by Noreco allowed our model to reproduce the depocenters as mapped in the available well cores, whereas other possible surfaces analyzed were not suitable to give reliable sand deposition.

The significant achievement was the fact that the sediments thickness obtained from the modeling and the numerical simulations in the two locations “Nini-2” and “Nini-3” match very well that which is observed in the cores (Figure 4). Nevertheless, several different scenarios could lead to similar depositional patterns in the two previously mentioned areas. Only detailed analysis of facies and finer depositional structures observed in the cores could give more indications to narrow the possibilities from several plausible to one specific flow depositing the layers estimated from the well logs. Therefore, more information from the cores could give more indication about the nature of the flows (i.e., if they are erosional or depositional, showing the mean grain size and the flow direction, detecting if the deposit is due to one single turbidity surge or to multiple ones, etc.). This may be performed in a further phase of this study, so that our analysis could target more accurately the best scenario leading to the desired stratigraphy detected in the field, matching the finer strata observed in the cores.

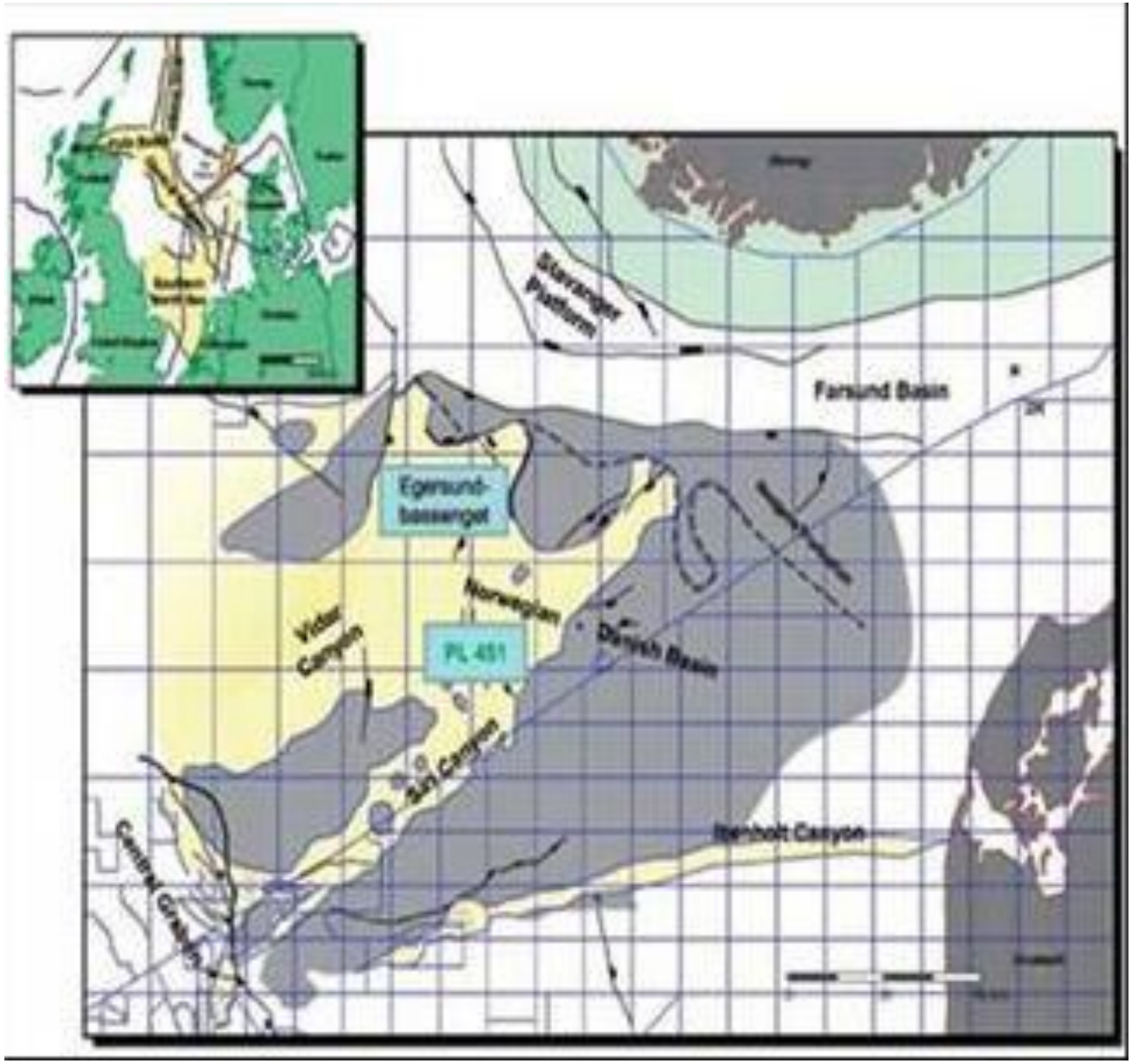

Figure 1. Location of the Central Graben and the Siri Fairway.

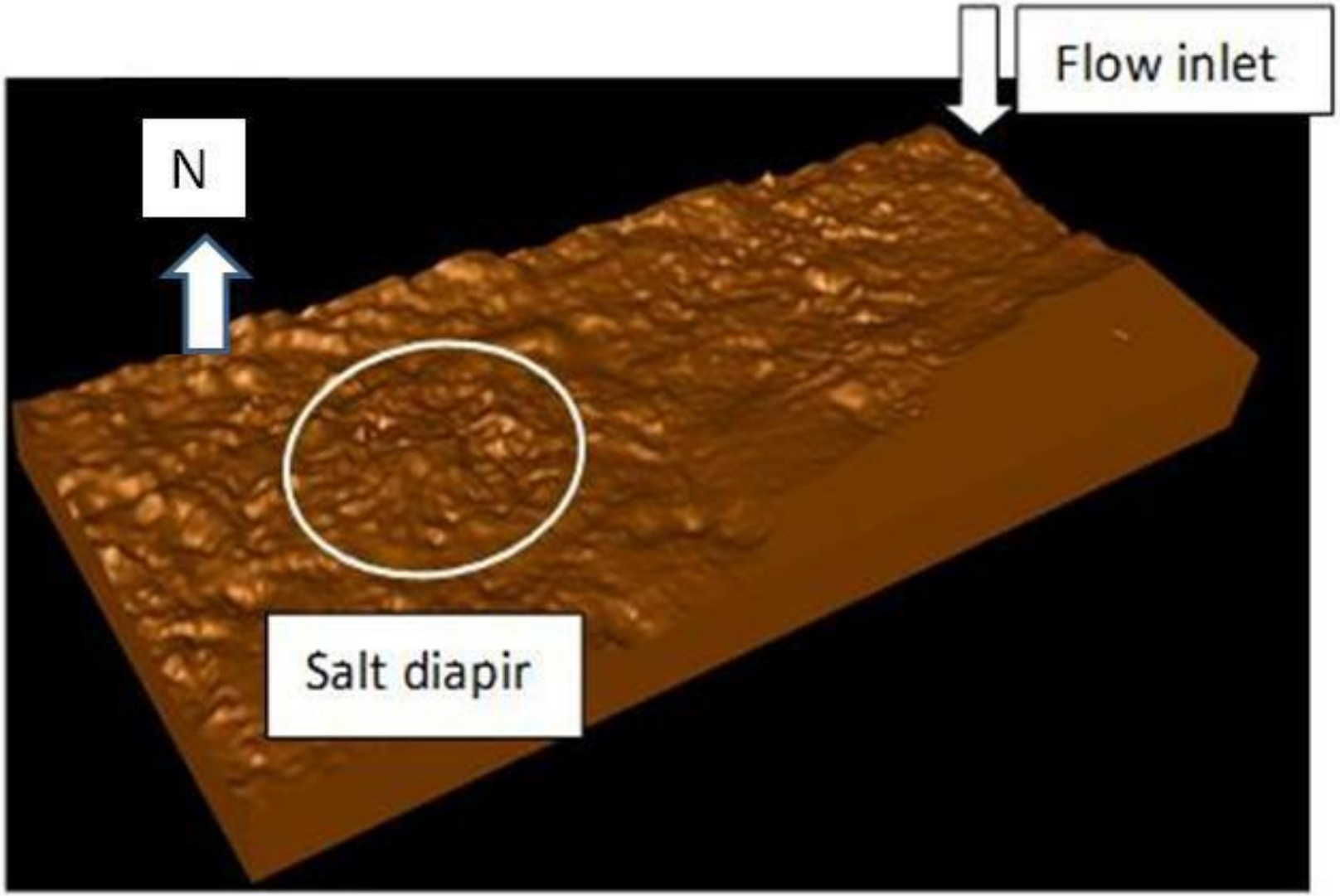

Figure 2. Final backstripped TY reservoir bathymetry.

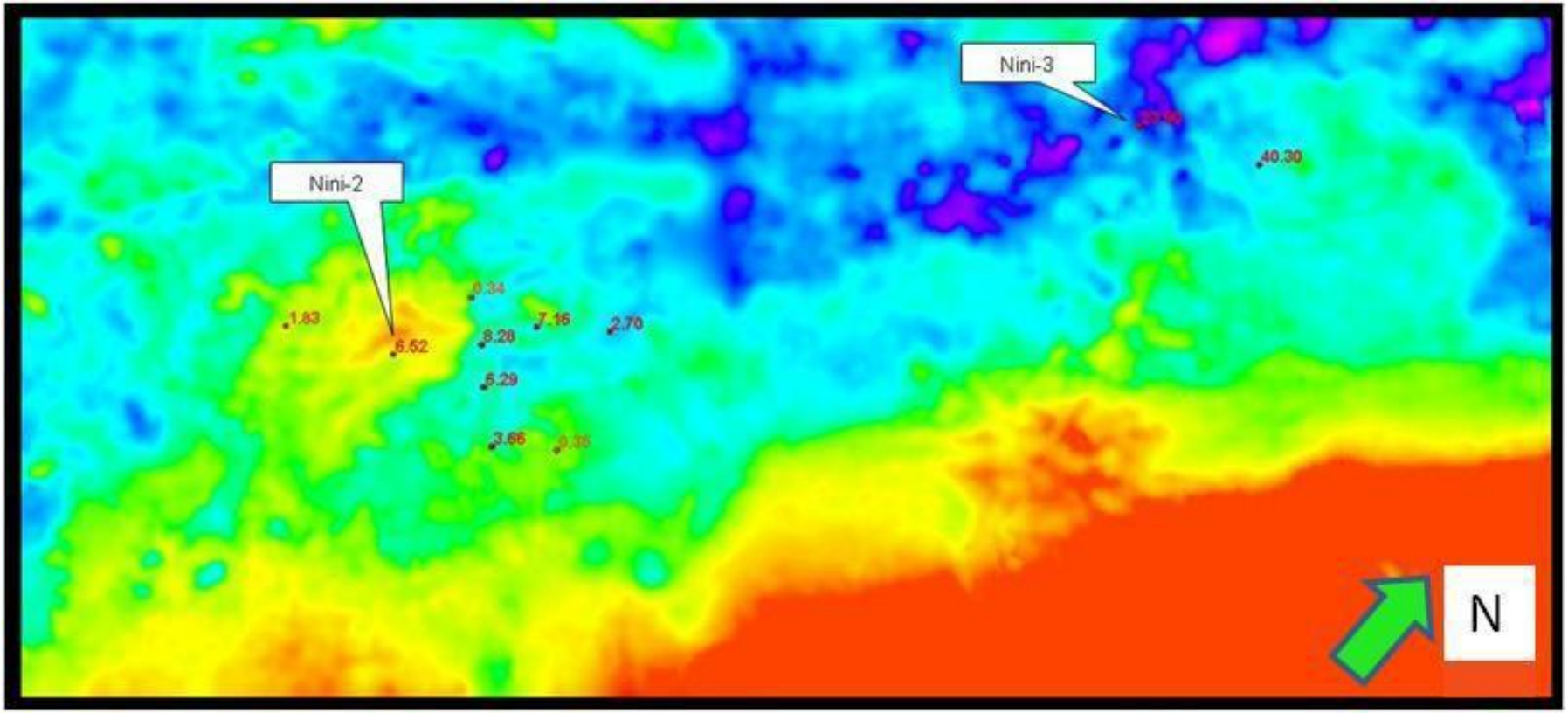

Figure 3. Map of sediment distribution and thickness in the core logs provided by the Norwegian Energy Company. The locations of Nini-2 and Nini-3 cores are tagged, and the sediment thicknesses in these two sites (6.52 m and 23.40 m, respectively) are specified.

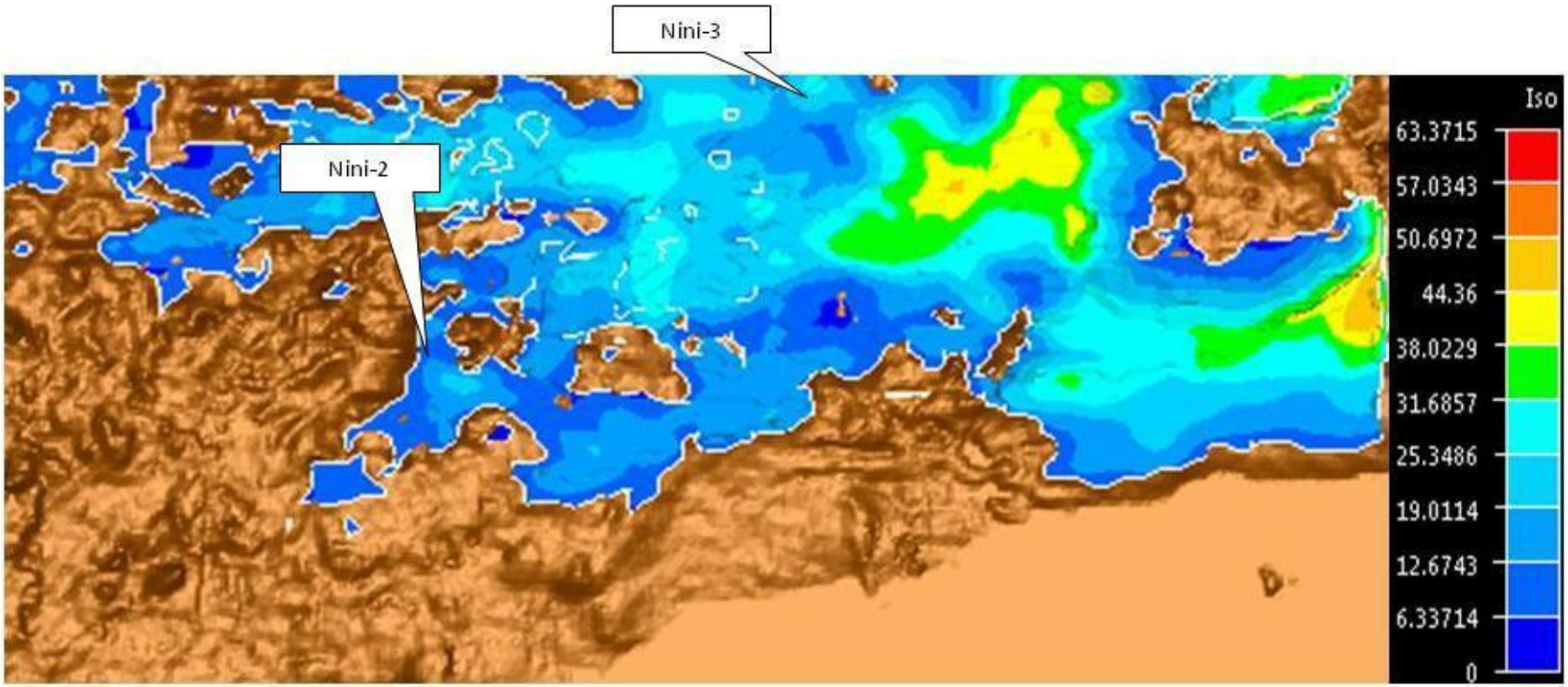

Figure 4. Sediment distribution and thickness obtained from the numerical simulations. The color bar shows scheme for the total packed sediment thickness, expressed in meters, in the area of interest. The sediment thickness in the two locations, Nini-2 (around 6 m) and Nini-3 (around 25 m), is indicated by the colors, matching quite well what is provided by the core observations.