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High-resolution Reservoir Architecture Modelling of Crevasse Splay Deposits in Low-net-to-gross Fluvial Stratigraphy

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SUMMARY

Thin-bedded crevasse splays in low-net-to-gross fluvial stratigraphy were previously not considered as potential reservoir targets. This paper focuses on the construction of a high-resolution static reservoir-architecture model of crevasse splay deposits associated with meandering rivers on the low-gradient coastal plain of endorheic basins. Outcrops of the Miocene Huesca fluvial fan (Ebro Basin, Spain) display low-net-to-gross fluvial stratigraphy, bounded by two large sand-prone channel belts. A static model of the study area is constructed following a sequential macro-to-micro approach. The model shows connectivity between the channel belts through crevasse splays. Connections between separate crevasse splays are present through incisions of younger crevasse splays and channels. Without the connectivity between the channel belts, connectivity would still be present in vertical wells through the extensive crevasse splays originating from the channel belts. This makes the model suitable for reservoirs with less connections as well. Ongoing research on process-based modelling of crevasse splays will yield an improved understanding of the grain-size distribution and can be used to populate the static model. The model will be upscaled to allow for fluid flow simulations in which several production mechanisms will be evaluated in order to assess the economic potential of these secondary tough gas reservoirs.

Introduction

Thin-bedded crevasse splays in a low net-to-gross fluvial stratigraphy were previously not considered as potential reservoir target. Limited research has been published on the reservoir aspects of crevasse splay sandstone (e.g. Mjøs et al., 1993; Pranter et al., 2009). Recent studies by Li et al. (2014) and Van Toorenenburg et al. (2015) indicate that crevasse splays attain large connected volumes by lateral amalgamation and by intersection with associated fluvial channel sandstone. The Northwest European gas province contains extensive Permo-Triassic fluvial successions with tough gas reservoir potential which could be unlocked through infrastructure-led exploration.

This paper focuses on the construction of a high-resolution static reservoir-architecture model of crevasse splay deposits associated with meandering rivers on the low-gradient coastal plain of endorheic basins. Outcrops of the Miocene Huesca fluvial fan (Ebro Basin, Spain) will serve as a basis for the model.

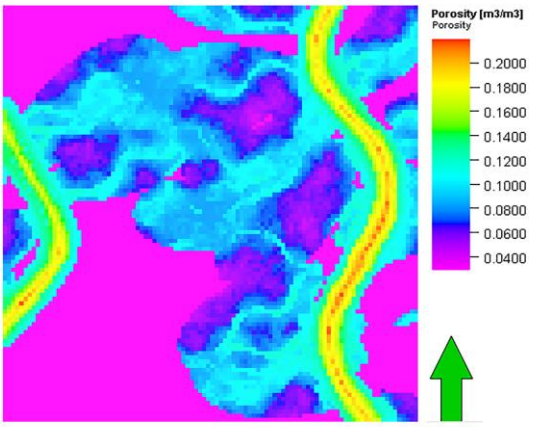
Data and methods

Outcrops in the Huesca fluvial fan consist of a low net-to-gross, mud-prone fluvial stratigraphy, bounded by two large sand-prone channel belts. Data on stacking patterns and the connectivity between different sandstone bodies were acquired from: (a) geo-referenced 3D-photopanels with stereographic projection software, and (b) detailed lithological outcrop logs supported by cm-accurate dGPS measurements.

A static model of the reservoir architecture in the study area was constructed with industry-standard modelling software following a sequential macro-to-micro approach. The lithological logs and the interpretations of the 3D-photopanels were used as hard constraints. Paleo-flow directions and spatial correlations served to populate trend volumes and probability distributions, and were used as input for object-based and multi-point statistics modelling of the reservoir facies.

Results

The fieldwork area compromises two N-S oriented channel belts spaced approximately one kilometre apart and enclosing low-net-to-gross floodplain stratigraphy with a thickness of 40m. The dominant facies in the floodplain interval is structureless, mottled silt and clay intercalated with thin layers of fine-grained crevasse splay sandstone. The grain size and thickness of the crevasse splay deposits is decreasing away from channel belts. Intervals of stacked crevasse splays frequently occur, displaying sand-on-sand contact through incision. These intervals are traced in outcrop to the fluvial channel sandstone in the bordering channel belts through high resolution dGPS correlation.



The data from the photo panels, dGPS measurements and lithological logs are correlated into a 3D reservoir architecture model. The channel belts are connected through crevasse splays. Connectivity between separate crevasse splays is present through incisions of younger crevasse splays and channels. The volume represented by the crevasse splays is larger than the volume of the channel belts. Figure 1 shows a single horizontal slice of the model displaying porosity distribution.

Figure 1 *A horizontal layer of the reservoir architecture model, displaying the porosity distribution of the floodplain environment between two channel belts. The crevasse splays connect the two channel belts.*

Discussion

The two channel belts are connected in the model via the amalgamated crevasse splay sandstone deposits that protrude from both channel belts. If that connectivity would not be present, the channel belts would still be connected in vertical wells through the extensive crevasse splays originating from the channel belts. This makes the model suitable for reservoirs with less connections as well.

Ongoing research in the onshore Dutch gas fields Pernis West and Gaag, and offshore field K2b, show that detection of these low net-to-gross fluvial environments is possible in Permo-Triassic stratigraphy. Layers are correlatable on meter-scale over distances of over 5 km where trends in net-to-gross can be identified in the horizontal direction. This indicates that the positions of the channel belts can be traced back by the increasing N/G. A verification of the study will be performed in a field with small well spacing.

Ongoing research on process-based modelling of crevasse splays will yield an improved understanding of the grain-size distribution within crevasse splays and will be used to populate the static model. A realistic grain-size distribution is important as it constitutes a major control on petrophysical properties such as porosity and permeability. The resulting static reservoir model will be upscaled to allow for dynamic flow simulations. Various production mechanisms will be evaluated in order to assess the economic potential of secondary tough gas reservoirs in low-net-to-gross fluvial stratigraphy.

Conclusions

A static model of a low-net-to-gross fluvial environment of 40m thickness based on input data from outcrops in the Huesca fluvial fan is constructed. The reservoir architecture model shows connectivity between two channel belts on a distance of approximately 1 km. Large connected reservoir volumes are present through connections of crevasse splays between each other, the channel belts channels and through incisions. More research is needed to improve the model, and to construct flow simulations to point out if these secondary reservoirs can be developed and produced economically.

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