Sand Body Dimensions and Infill Sequences of Stable, Humid-Climate Delta Plain Channels

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Sediments deposited in delta plain settings are common in the Jurassic sequences of the Norwegian continental shelf (e.g. the Ness Formation). The most prominent reservoir units in this type of deposit are distributary channel sand bodies. These mainly appear to be laterally discontinuous in a direction normal to the palaeoslope, and probably reflect cut-and-fill processes in stable distributaries. Based on well-data alone, it is difficult to determine vital reservoir parameters such as the geometry and interconnectedness of these channel sand bodies. Studies of well-exposed possible analogues like the Saltwick Formation of Yorkshire (England) and the Aspelintoppen Formation of Spitsbergen were therefore undertaken. This study indicates that single-storey sand bodies deposited in stable cut-and-fill channels have ribbon-like geometries, whereas multistorey channel bodies of the same type tend to display more sheet-like dimensions. A curve relating the width and thickness of these sand bodies has been constructed. Humid climate cut-and-fill sand bodies deposited in stabilized distributaries can be recognized by an infill sequence that, when complete, reflects three stages of infilling (active, partly active and passive phase fills). Active phase infills frequently have the best reservoir quality at the top, owing to high-discharge events prior to (partial) abandonment. In addition to palaeo-river morphology, sandbody dimensions and the degree of interconnectedness are governed by the pattern of differential subsidence along depositional strike, and by the ratio between sediment supply and accommodation.

INTRODUCTION

In recent years, much attention has been focused on studies concerned with increasing recovery from proven hydrocarbon accumulations. Within the field of geology, this interest in reservoir optimization has led to a growing need for quantified geological models where the architecture of the reservoir can be specified according to geostatistical methods (e.g. Lake and Carroll, 1986; Gundesø and Egeland, this volume). One of the key elements in geological quantification is the concept of reservoir “building blocks” (Fig. 1). Briefly, a reservoir building block is a body of rock distinct from other bodies of rock on the basis of specific petrophysical and geometrical properties. The first step towards defining building blocks is the breakdown of the reservoir into large-scale permeability classes (Dreyer et al., in press). The next steps involve dimensional analyses of the various building blocks (fieldwork studies of analogues), coupled with studies of their interrelationships.

The quantification of geological parameters is especially important in reservoirs with a high degree of heterogeneity. The Jurassic Ness Formation, which consists of delta plain deposits (e.g. Ryseth, in press), is one of the most heterogeneous reservoir types on the Norwegian shelf. The present study is concerned with the main reservoir building block of such delta plain sequences; the distributary channel sand bodies. These usually represent high-permeability “pipelines” running through sequences that tend to be dominated by fine-grained material. The main aim of this study is to present data concerning the geometry and infill sequences of these delta plain channel sand bodies. Detailed comparative studies between exposed and subsurface delta plain deposits are outside the scope of this contribution. The dimensional data given here can be used in geological simulations of delta plain reservoirs (Gundesø and Egeland, this volume), or as a basis for detailed correlations in delta plain sequences (e.g. Ryseth, in press).
COMMENTS ON DELTA PLAIN CHANNEL DEPOSITS IN THE NESS FORMATION, NORTHERN NORTH SEA

The Middle Jurassic Brent Group has long been the primary reservoir target in North Sea hydrocarbon exploration. Until recently, it has been customary to produce only from the sandy delta front/shallow marine intervals (Rannoch, Etive, and Tarbert Formations) of this reservoir sequence. The reservoir potential of the heterogeneous delta plain sediments of the Ness Formation has largely been neglected. However, the growing need for reservoir optimization has lately caused a re-evaluation of the production strategy for the Brent Group. In several North Sea fields, a significant amount of the reserves in the Ness Formation is presently changing status from "in place" to "recoverable".

Quantification of sand body geometries in the Ness Formation requires an understanding of the fundamental processes which controlled deposition in the Viking Graben during the Middle Jurassic. It is firmly established that the Ness Formation represents the delta/coastal plain part of the Brent deltaic system (e.g. Graue et al., 1987). At maximum progradation (Fig. 2), the fluvial/wave-dominated delta covered an extensive area, and upper delta plain conditions were present up to 61° 30' N. Sedimentation was influenced by synsedimentary tectonics, especially in the form of increased rates of subsidence on the downthrown side of fault segments, and a relatively humid climate prevailed (Ryseth, in press).

Detailed investigations of core material from the Ness Formation channel sandstones have been carried out by Dreyer (unpublished Norsk Hydro data) and Ryseth (in press). Interpreted vertical core sequences from the Ness Formation are shown in Fig. 3. Although no definite conclusions regarding channel type and sand body extents can be drawn from studies of borehole data (e.g. Bridge, 1985), there are some indications that Ness channel bodies for the most part are laterally restricted sand units that formed in stabilized (non-migrating) rivers. These indications can be summarized as follows.

1. A compilation of Ness Formation channel sand vs. floodplain fines ratios from northern North Sea wells gives an average ratio of 0.34. This suggests that the delta plain was dominated by interchannel sedimentation. It is thus unlikely that sheet-like sand bodies produced by highly mobile channels or channel-belts (e.g. braided streams) are common in the Ness Formation (Allen, 1978; Bridge and Leeder, 1979).

2. Lateral accretion is the primary sandbody-formation mechanism in high-sinuosity meandering streams. In cores, this process can be recognized by a more or less well-developed fining-upwards sequence, accompanied by a structural assemblage corresponding to point-bar migration (e.g. Allen, 1970; Jackson, 1978). The infill sequences in Ness channels rarely conform to these meandering stream characteristics, but tend to reflect vertical accretion and a stepwise decrease in flow-energy. This will be discussed in detail in a separate section.

3. With the closer well spacing obtained in the production phase of North Sea fields, correlations normal to the main channel flow direction may give considerable insight into the geometry of the channel sand bodies. In the Oseberg field, channel bodies can usually not be correlated even between well-pairs a few hundred metres apart in sections normal to palaeocurrent (e.g. Fig. 4). This suggests a dominance of laterally restricted sand bodies (usually less than a few hundred metres wide) in the Ness Formation. However, as discussed below, vertical stacking together with splitting and joining of channel bodies in the horizontal plane may prevent the laterally restricted channel bodies from becoming isolated.

4. Ryseth (in press) shows that Ness channels seem to be characterized by strong incision into the surrounding...