Quantitative Stratigraphic Architecture, Depositional History and Progradation Rates of an Ancient Sand-prone Subaqueous Delta (Sognefjord Formation, Troll Field, Norwegian North Sea)*

Stefano Patruno[1], Christopher A-L. Jackson[1], Gary J. Hampson[1], and Paul Whipp[2]

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[1] Department of Earth Science and Engineering, Imperial College London, South Kensington Campus, London, UK (s.patruno09@imperial.ac.uk)
[2] Statoil ASA Bergen, Norway

Abstract

In this study, we develop a new method to extract progradation rates from ancient shallow-marine clinoforms, and we use it to refine the depositional model of the Upper Jurassic Sognefjord Formation, which forms the main reservoir in the giant Troll Field (Norwegian North Sea). This provides a tool to improve reservoir characterisation and near-field exploration by enhancing prediction of reservoir distribution and character.

Introduction

The stratigraphic architecture of the studied succession is constrained by integrating 3D seismic data with a dense core and wireline-log dataset. The Sognefjord Formation is a 10-200 m thick clastic wedge, deposited in ca. 6 Myr, by a fully marine, westward-prograding deltaic system that was sourced from the Norwegian mainland. A series of 10-60 m thick, westerly-dipping subaqueous clinoform sets are developed within the Sognefjord Formation and these can be mapped for several tens of kilometres along strike. Within each clinoform set, clinothems are formed by regressively stacked sandstone-rich bedsets, devoid of subaerial facies and separated by thin mudstone intervals (Figure 1). Horizontal to descending trajectories are observed in each clinoform set, and the sets are stacked vertically. Coarse-grained subaqueous deltas provide a new interpretative template that may be applicable to other ancient clinoform-bearing shallow-marine sandstones with reservoir potential.

Discussion

Quantification of clinoform age and progradation rates is constrained by 20 regionally correlatable bioevents. This analysis requires the availability of a dense stratigraphic and sedimentological dataset, and involves three steps (Figure 2): (1) sediment decompaction; (2)

calculation of estimated clinoform ages; and (4) extraction of progradation, sediment accumulation and net sediment flux rates. Since sediment accumulation rate decreases steeply from the foreset to the toeset and topset of a clinoform, an exponential age-depth model is used in the third step of this method, to derive an equation for the age of the facies break that mirrors the foreset to bottomset transition, which represents storm wave base, is dated, and progradation rates are measured along transects tied to well correlations and seismic interpretations.

$$t_P = [h_P \bullet (\ln h_P - \ln h_1) \bullet (S_P)^{-1}] + t_1$$

This equation is a function of four parameters: (1) age (t_1) and (2) height above the basal flooding surface (h_1) of a dated biostratigraphic event within the clinoform set; (3) height of the clinoform-trajectory reference point above the basal flooding surface (h_P); and (4) instantaneous sediment accumulation rate (S_P). Progradation, sediment accumulation and net sediment supply rates are constrained along transects aligned parallel to clinoform dip, and may be interpolated between transects. This chronostratigraphic method improves the predictive potential of sequence stratigraphic and clinoform trajectory analyses.

Results and Conclusions

Our results indicate a fall in progradation rate (from 500 to 30 km/Myr), net sediment flux (from 90 to 10 km^2/Myr) and simultaneous rise in sedimentation rate (from 15 to 70 m/Myr) towards the basin (Figure 3). We attribute these variations to the progradation of the subaqueous delta into progressively deeper waters associated with increased interaction with along-shore currents that provide net sediment transport out of the study area, as well as sculpting the linear, elongated clinoforms. Because of this interaction of seabed bathymetry and oceanographic processes, the emplacement of deep-marine reservoirs on the basin floor is potentially hindered, even during periods of relative sea level fall. Localised spatial and temporal anomalies from the trends described above are interpreted to reflect phases of rift-related normal faulting. This is further credited by backstripping analysis and seismic isochron mapping.

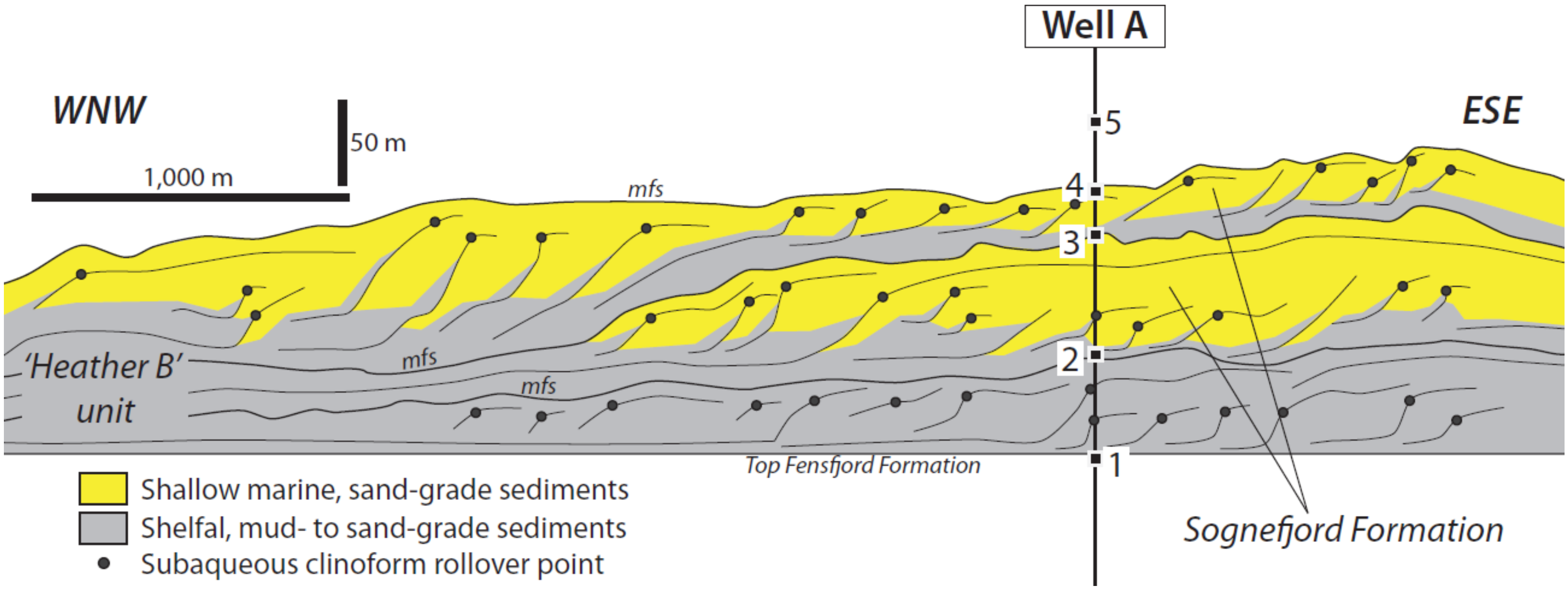

Figure 1. Interpretative seismic cross-section through the western part of the Troll Field, showing typical relationship between clinoform sets and enveloping maximum flooding surfaces (mfs).

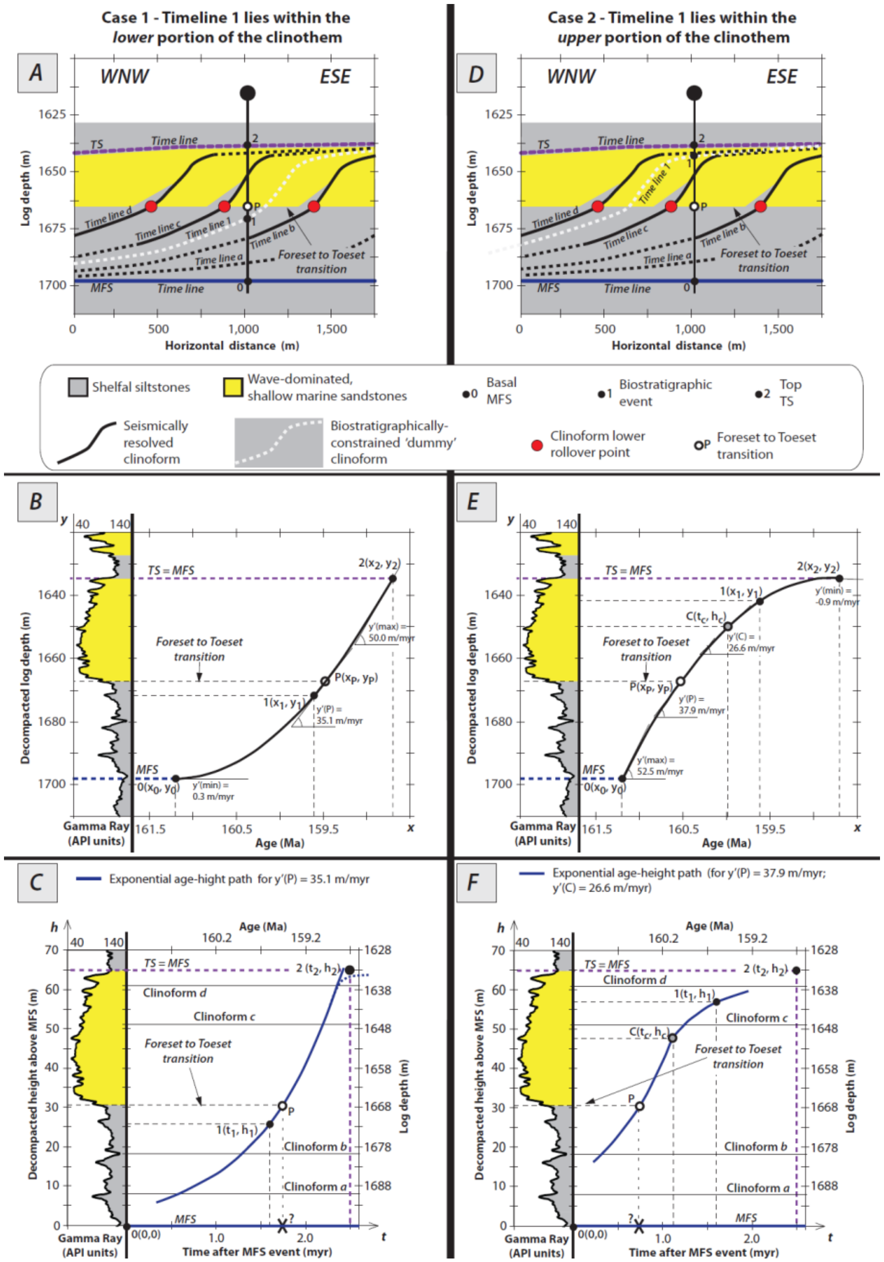

Figure 2. The workflow used to estimate the clinoform age in cases where a biostratigraphic event (point 1) lies within the lower (**A-C**) and upper (**D-F**) parts of a clinoform set.

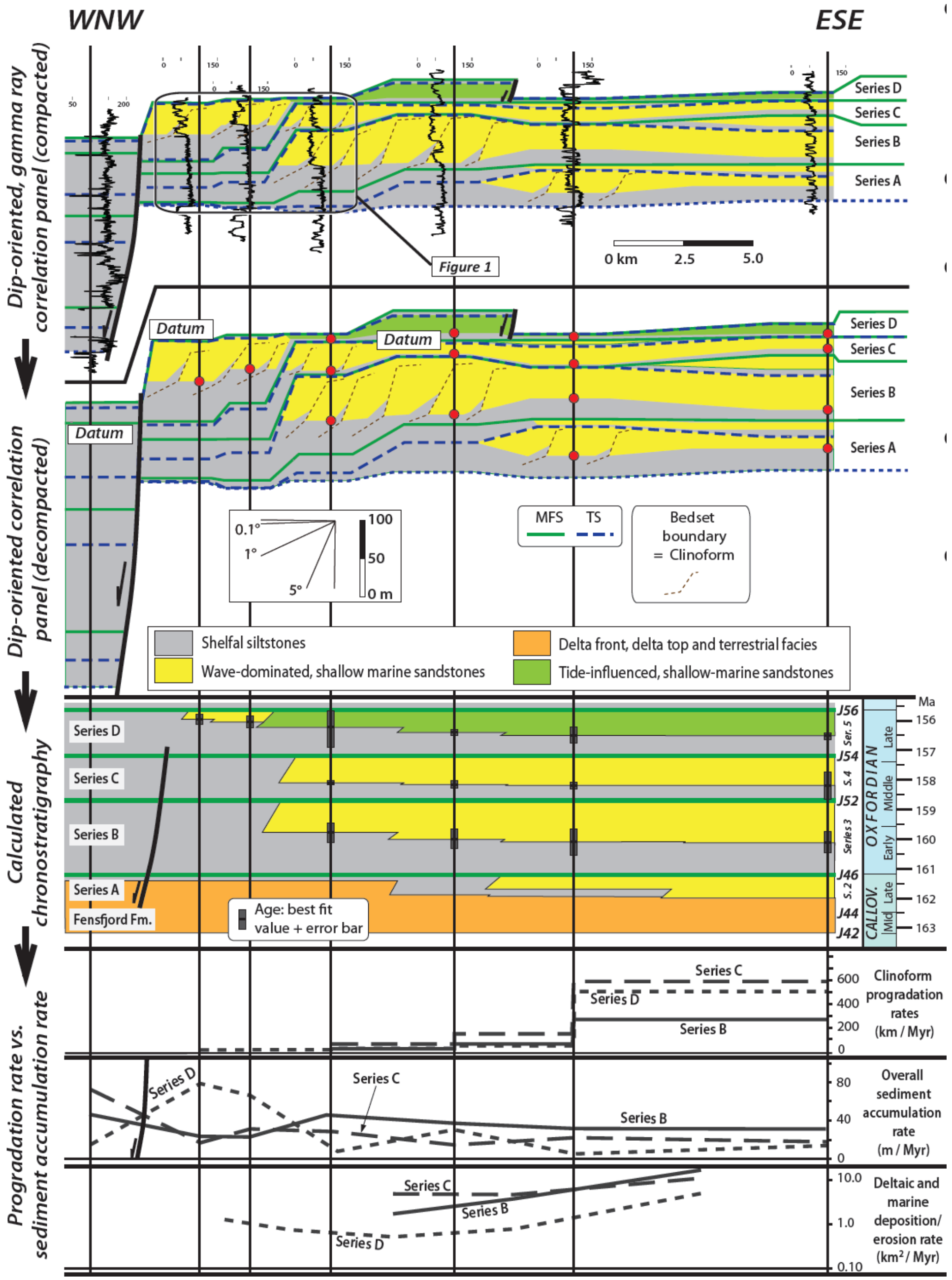

Figure 3. The workflow followed consists of: (1) decompaction; (2) clinoform age calculation; (3) extraction of chronostratigraphic rates.