Marine and Petroleum Geology 67 (2015) 583–603

Contents lists available at ScienceDirect

Marine and Petroleum Geology

journal homepage: www.elsevier.com/locate/marpetgeo

Research paper

Short length-scale variability of hybrid event beds and its applied significance

Marco Fonnesu [a,*], Peter Haughton [a], Fabrizio Felletti [b], William McCaffrey [c]

[a] UCD School of Geological Sciences, University College of Dublin, Belfield, Dublin 4, Ireland
[b] Dipartimento di Scienze della Terra, Università degli Studi di Milano, Via Mangiagalli 34, 20034 Milano, Italy
[c] Institute of Applied Geoscience, School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK

ARTICLE INFO

Article history:
Received 15 September 2014
Received in revised form
14 March 2015
Accepted 21 March 2015
Available online 29 May 2015

Keywords:
Sediment gravity flow
Turbidites
Hybrid event beds
Lateral variability
Linked-debrites
Reservoir quality

ABSTRACT

Hybrid event beds (HEBs) are a type of deep-water sediment gravity flow deposit that generally comprise a basal clean sandstone overlain by a variety of muddier and less-permeable sandy facies. They are thought to be emplaced by combinations of turbidity currents, transitional flows and debris flows, all as part of the same transport event. To date, a number of studies have highlighted the common presence of HEBs mainly in the outer and marginal parts of deep-water systems where they replace beds composed dominantly of clean sand up-dip and/or axially over scales of km to 10 s km. In addition to these broad patterns, important yet poorly understood short-length facies changes (over metres to 100 s m) occur, modifying the overall texture and reservoir characteristics at or beneath typical spacing of production wells. The nature and origin of the short length-scale transitions is here addressed in four well-exposed HEB-prone outcrops: the Cretaceous-Paleocene Gottero Sandstone and the Miocene Cilento Flysch, both in Italy, the Carboniferous Mam Tor Sandstone in northern England, and the Carboniferous basal Ross Sandstone Formation, Western Ireland. A series of detailed correlation panels show marked lateral variations in internal bed make-up for most of the hybrid event beds studied. This variability typically involves lateral changes in the proportions of the cleaner basal sandstone and the overlying muddy sandstone division that occur without substantial change in the overall event bed thickness. The variability is inferred to reflect the complex fingering between the up-dip sandstone-dominated part of the event bed and the down-dip linked debrite due to internal erosion (ploughing) of the debrite into the basal clean sand. Where the upper part of the bed is dominated by large mudstone rafts, these may have foundered into liquefied sand and been injected and partly fragmented by the sand intrusions. The variable thickness and continuity of the basal clean sandstones have important implications for reservoir characterisation; significant variability in bed character at interwell scale can be anticipated. Rugose contacts between the intra-bed facies divisions may impact on drainage and sweep efficiency during hydrocarbon production.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Sandstones deposited by turbidity currents are an important component of many hydrocarbon reservoirs (Nilsen et al., 2007). These largely turbulent flows can progressively fractionate their sediment load, leaving graded deposits that are at least moderately well sorted with most of the clay segregated to form mudstone units (the T_e division; Bouma, 1962) capping relatively porous and permeable sandstone beds. However, many reservoirs also include, or in some cases are dominated by, stacked event beds comprising a basal clean (i.e. clay-poor) sandstone division overlain by a variety of muddier and less permeable sandy facies. These hybrid event beds (*sensu* Haughton et al., 2009) are thought to form from flows that were at least partly turbulent, but that also had zones of damped turbulence beneath or from which clay and sand were emplaced together by linked debris flows and/or transitional flows (*sensu* Baas et al., 2009, 2011). Consequently the reservoir properties of much of the sandy part of the event bed are compromised by high matrix-clay concentrations (Fugelli and Olsen, 2007). In addition, the significant lateral extent of the muddy sand component means that the cleaner and better quality sandstones in the

* Corresponding author.
E-mail address: marco.fonnesu@ucdconnect.ie (M. Fonnesu).

http://dx.doi.org/10.1016/j.marpetgeo.2015.03.028
0264-8172/© 2015 Elsevier Ltd. All rights reserved.

basal part of stacked event beds are poorly connected, particularly vertically. Amy et al. (2009) have used sector models to show that once the muddy sand component of a hybrid event bed exceeds c. 20%, the facies make-up has a significant impact on production efficiency in terms of volumes of oil produced and more rapid water breakthrough.

The term hybrid event bed (HEB) was introduced (Haughton et al., 2009) to describe a common bed motif in deep-water successions occurring alongside more familiar turbidity current deposits (turbidites). The designation builds on the earlier concept of linked debrites (Haughton et al., 2003) and incorporates the slurry flow ideas developed by Lowe and Guy (2000). An ideal five-part structure was identified (Fig. 1A) comprising (from base to top) a basal, generally graded, structureless sandstone (termed H1) in some cases with scattered mudclasts (H1b), a unit of banded sandstone comprising alternating cleaner/paler sands loaded into darker argillaceous sandstone bands (H2), a chaotic division of argillaceous sandstone with variable concentrations of mudstone clasts and sheared sand patches (H3), a fine/very fine grained, parallel- and ripple-laminated sandstone (H4) and a silty mudstone capping division (H5). All divisions are not always present in the one bed (Haughton et al., 2010; Talling, 2013). H1 thins at the expense of H3 and pinches out distally and laterally. The H2 division may be absent, or subtle and easily overlooked; in other cases it is greatly expanded and can dominate the deposit such as in the margins of the Lower Cretaceous Britannia sandstone beds (Barker et al., 2008). H4 may be absent or may wholly or partly have collapsed into the underlying H3 division. Event beds broadly conforming to the hybrid model have been widely documented in cores from hydrocarbon wells (Haughton et al., 2003, 2009; Barker et al., 2008; Davis et al., 2009; Kane and Ponten, 2012), shallow sea floor cores (Zeng et al.,1991; Talling et al., 2007b; Georgiopoulou et al., 2009; Lee et al., 2013) and outcrops (Wood and Smith, 1959; Mutti et al., 1978; Van Vliet, 1978; Ricci Lucchi and Valmori, 1980; Sylvester and Lowe, 2004; Talling et al., 2004, 2007a; 2012; Amy and Talling, 2006; Ito, 2008; Hodgson, 2009; Jackson et al., 2009; Muzzi Magalhaes and Tinterri, 2010; Tinterri and Muzzi Magalhaes, 2011).

A number of mechanisms have been proposed to explain the development of hybrid event beds and the emplacement of the argillaceous sands/sandstones they contain. The variable structure and range of contexts in which they occur suggest they can form in more than one way. Key to most of the mechanisms is an active role for clay in damping turbulence and modulating the flow behaviour (Baas and Best, 2002). Where the models differ is in the emphasis put on vertical as opposed to lateral changes in flow structure and rheology. Baas et al. (2009, 2011) characterised the structure of transitional clay-rich flows in open channels showing progressive turbulence modulation and emphasising top-down onset of plug-flow with modified (enhanced and then damped) turbulent flow beneath before it is eventually extinguished. Sumner et al. (2008) used experimental data to show progressive turbulence damping in rapidly decelerating clay-rich flows with sand initially settling from a turbulence-modified suspension to form the H1 division before the suspension stiffens to leave an overlying poorly graded argillaceous sand or sandy mud (a fluid mud emplacing H3). Kane and Ponten (2012) applied a similar model to deep-water sandstones in the Gulf of Mexico, stressing the role of vertical rheological heterogeneity in what were inferred to be transitional flows with turbulent basal layers and overlying quasi-laminar layers. The common presence of micas, clay chips and carbonaceous fragments in many H3 divisions, indicating prior hydraulic fractionation of components, is important. In these cases, efficient longitudinal and transverse segregation of components with lower settling velocities (see Pyles et al., 2013) into slower moving sectors of the flow may then force transformations, triggering the onset of transitional and then quasi-laminar flow conditions. The character of the aggrading deposit can therefore sample different sectors of the flow as it passes, with clean sand (H1) deposited from the still turbulent flow front and increasingly argillaceous sand (H2 and H3) from further back in the flow. Large and far-travelled flows may have significant sectors with transitional characteristics, explaining instances of very thick banded (H2) divisions such as those in the Britannia Sandstone Formation (Lowe and Guy, 2000; Barker et al., 2008). Many H3 divisions include volumetrically significant mudstone clasts and this suggests a link between the onset of HEB

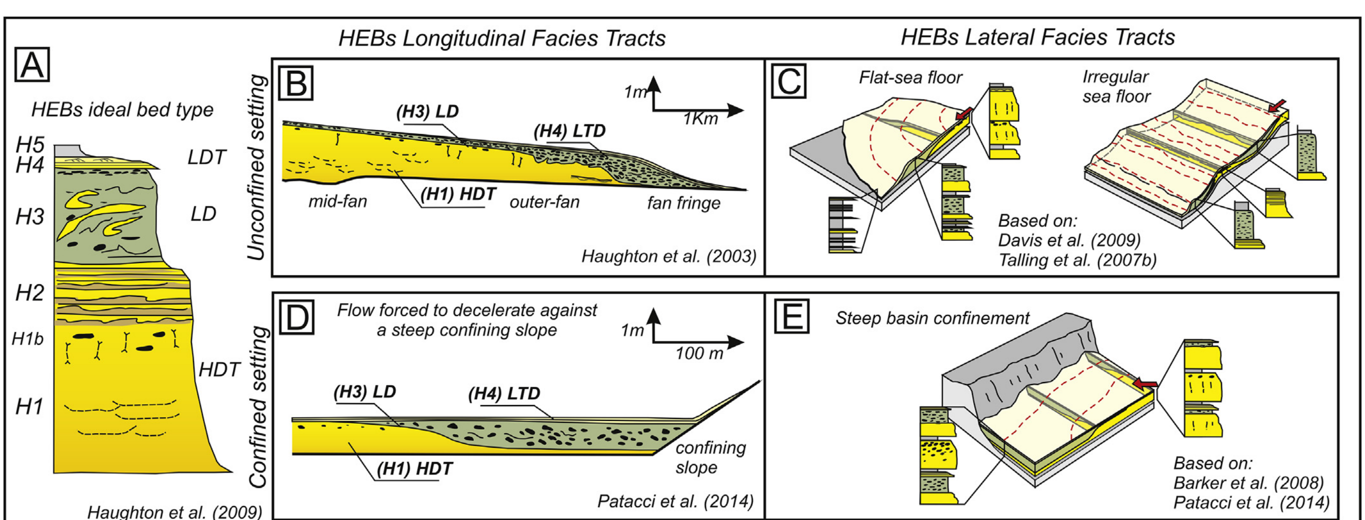

Fig. 1. Hybrid event bed type model and hybrid gravity flow facies tract expression. (A) Idealised organisation of a typical hybrid event bed (H1–H5 sequence) as suggested by Haughton et al. (2009). (B) Longitudinal facies tract expression of an hybrid flow deposit in unconfined setting: the mudclast-rich debritic H3 division progressively thickens down-dip in the outer fan and fan fringe fan sectors before finally pinching out (Haughton et al., 2003); facies transitions occur over several kilometres; (C) hybrid event beds are preferentially distributed in the marginal sectors of unconfined lobes (Davis et al., 2009) and influenced by local changes of gradient which make flatter areas prone to debris flow development and deposition (Talling et al., 2007b). (D) In obliquely confined settings the slope forces the flow to decelerate, rapidly damping turbulence and producing a transformation to cohesive flow which deposits close to the margin. (E) In laterally confined settings, thinner, slope-adjacent flows become less turbulent, becoming hybrid, and depositing hybrid event beds adjacent to the margin (HDT: high-density turbidite; LD: linked-debrite; LTD: low-density turbidite).

Download English Version:

https://daneshyari.com/en/article/6434962

Download Persian Version:

https://daneshyari.com/article/6434962

Daneshyari.com