Marine and Petroleum Geology 91 (2018) 1–18

Contents lists available at ScienceDirect

Marine and Petroleum Geology

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

Research paper

Reconstruction of linear dunes from ancient aeolian successions using subsurface data: Permian Auk Formation, Central North Sea, UK

Bernard Besly[a,b], Hollie G. Romain[c], Nigel P. Mountney[c,*]

[a] School of Physical and Geographical Sciences, Keele University, Keele, Staffordshire, ST5 5BG, UK
[b] Besly Earth Science Ltd, 5 the Village, Keele, Newcastle-Under-Lyme, Staffordshire, ST5 5AD, UK
[c] Fluvial & Eolian Research Group, School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, UK

ARTICLE INFO

Keywords:
Aeolian
North Sea
Sedimentology
Auk
Rotliegend
Linear dune

ABSTRACT

A series of well logs and cores penetrating the predominantly aeolian Auk Formation, Permian Rotliegend Group, Central North Sea, UK, have been evaluated to determine the morphology and style of migratory behaviour of the original dune bedforms, the overall depositional environment, and to assess implications for reservoir heterogeneity. This has been achieved by detailed facies analysis of subsurface datasets and by comparison of the observed sedimentary styles of accumulation to analogous modern aeolian dune fields. Aeolian bedform type, morphology, detailed migratory behaviour, and the nature of the accumulation surface have been interpreted. Analysis of the facies architecture of preserved cross-bedded sets and cosets indicates accumulation on a dry substrate via the migration and climb of large linear bedforms that possessed low-angle inclined lower plinths, up to 15 m thick. Dune plinth elements are dominated by wind-ripple and reworked wind-ripple strata, and were preferentially preserved as successive bedforms migrated over one another at low angles. Packages of grainflow-dominated strata representative of accumulation on the higher part of the bedform lee slope are less common and tend to be preserved mostly in the upper parts of large cosets of strata (~30 m thick). Large linear bedforms were separated by dry interdune areas. Although the primary direction of sand transport was along the elongated crests of the bedforms, a secondary component of transverse motion enabled the lateral migration and preferential preservation of lee-slope deposits that arose from a minor oblique component of bedform migration. In places, the architecture records the preservation of small barchanoid dune deposits, either within interdune depressions or superimposed on the lower flanks of the large linear bedforms. The preserved aeolian facies types exert a primary control on reservoir quality. Few previous studies have documented linear dunes in ancient successions; these findings represent a valuable case example.

1. Introduction

An integrated well-log and core interpretation case study is presented to demonstrate how observations from a subsurface dataset can be used to reconstruct dune type, morphology and temporal migratory behaviour of large bedforms within an aeolian dune and interdune succession known only from the subsurface. The method employed outlines objective criteria for interpreting changes in the style, rate and direction of aeolian bedform migration through recognition of stratigraphic evidence for temporal changes in bedform migration behaviour, lee-slope steepness and asymmetry, and by comparison to analogous outcropping successions and currently active aeolian dune fields.

Determination of original aeolian bedform type and migratory behaviour from ancient aeolian successions known only from subsurface intervals is problematic because such successions exhibit lithological heterogeneity at a number of scales. Such heterogeneity develops in response to both the varied arrangement of lithofacies arising from complex autogenic bedform behaviour (e.g. Heward, 1991), and potentially also from allogenic controls on stratigraphic accumulation and preservation (e.g. Howell and Mountney, 1997). As such, the deposits of such accumulations may be highly variable over short lateral distances; elucidating the three-dimensional architecture of the deposits and interpreting their significance in terms of original formative processes are not straightforward.

Aeolian dune successions of the Permian Rotliegend Group of the southern and central North Sea, and surrounding area have previously mostly been interpreted as the accumulated deposits of transverse bedforms (e.g. Glennie et al., 1978, 1998a; Heward, 1991), including barchanoid forms. However, linear aeolian bedforms have been also reconstructed from some parts of this succession (e.g. Steele, 1983).

* Corresponding author.
E-mail address: n.p.mountney@leeds.ac.uk (N.P. Mountney).

https://doi.org/10.1016/j.marpetgeo.2017.12.021
Received 23 February 2017; Received in revised form 13 July 2017; Accepted 13 December 2017
Available online 16 December 2017
0264-8172/

Although spatial variations in bedform type across large aeolian dune fields are widely documented such that transverse and linear forms are known to commonly co-exist (e.g. Namib Desert, Lancaster, 1983; Rub' Al-Khali, Al-Masrahy and Mountney, 2013), there remain few documented examples of such variability from ancient preserved aeolian successions.

Despite linear bedforms accounting for > 50% of dunes present in modern active dune fields, the deposits of such bedforms are rarely interpreted from the ancient record (Rubin and Hunter, 1985; Rodríguez-López et al., 2014). This is, in part, because linear bedforms tend to develop where sand is being transported over deflation surfaces and the potential for long-term aeolian accumulation is therefore limited (Mainguet and Chemin, 1983). As such, there are very few published descriptions relating to the internal facies and bounding-surface distributions of ancient linear dune successions, though one such example is the Permian Yellow Sands of Coutny Durham, England (Steele, 1983). However, more generally, qualitative and quantitative data sets relating to the stratigraphy of successions generated by the accumulation of linear bedforms – which might serve as valuable analogues for the Auk Formation – are few. The modest number of accounts that have been published are from successions that are either not especially close in terms of their analogy, or are not sufficiently well exposed to yield useful dimensional data.

Fig. 1 depicts a schematic representation of a simple (*sensu* McKee, 1979) linear draa (large scale aeolian bedform) that has undertaken migration and aggradation at a low angle-of-climb. Vertical successions located at various positions along an accumulated stratigraphic section depict typical vertical lithofacies profiles. This schematic illustration demonstrates the expected presence of a marked lateral variability in facies arrangements that is typically encountered over lateral distances of 100–300 m within aeolian dune deposits accumulated by the same migrating bedform. Individual vertical profiles within the same set (or coset) can be composed solely of wind-ripple and wind-ripple-dominated facies, whereas only a relatively short distance away, the same stratigraphic section might be represented by a suite of different aeolian dune facies types, including grainflow and grainflow-dominated units. Fig. 1 demonstrates how core and log data are dependent on the exact position of a well, and illustrates the difficulty of attempting to correlate laterally between even closely spaced wells in aeolian successions represented by these types of deposits. For effective reconstruction of aeolian paaleoenvironments from subsurface core and well-log data, an underlying assumption is that, given a number of wells, the unit as a whole is represented by the available data, and an interpretative model can be developed to account for the expected three-dimensional facies arrangements.

The complexity in facies arrangements in aeolian successions is dependent on a number of autogenic factors including, for example, how far down the lee slope of the migrating bedform grainflow avalanches extended before terminating. Given this intrinsic complexity in facies arrangements, care must be taken when interpreting individual one-dimensional graphic logs, especially those recorded from cores taken from subsurface aeolian successions; this is especially important for aeolian successions where the ability to reliably correlate between neighbouring logs – even those spaced only a few hundred metres apart – is severely hindered by the absence of beds or bounding surfaces that can demonstrably be shown to serve as reliable markers for correlation purposes (Mountney, 2006). In many cases, the inability to even establish the presence of features regarded to be reliable indicators of palaeo-horizontal in subsurface aeolian successions is highly problematic (Kocurek, 1988, 1991).

Despite these problems, reconstruction of aeolian dune type from subsurface data remains important because many aeolian successions are known wholly or principally only from the subsurface, yet understanding these systems is important for improving palaeoenvironmental understanding. Examples include the Pennsylvanian-Permian Weber Sandstone of the Rangely Field, Colorado, USA (Fryberger, 1979b; Bowker and Jackson, 1989), the Permian Leman Sandstone of the UK Southern North Sea (Glennie et al., 1978; Weber, 1987), the Permian

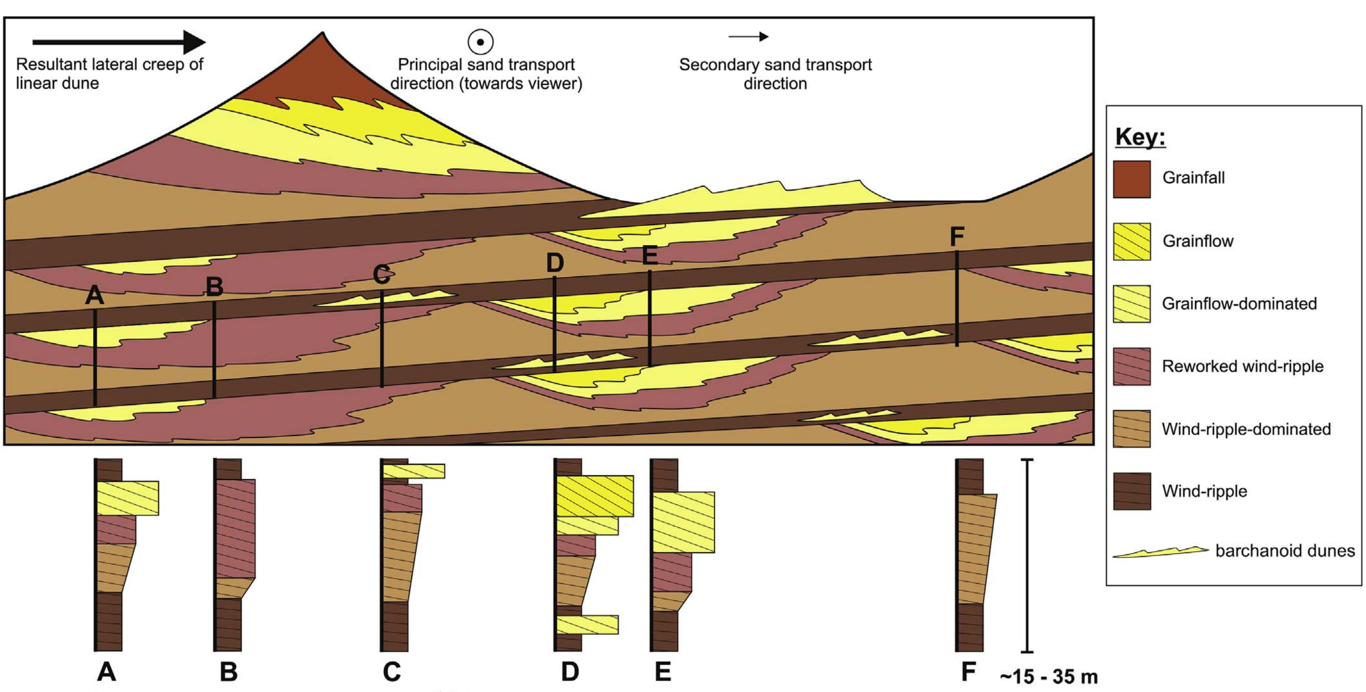

Fig. 1. Schematic vertical successions deposited by a single episode of migration and aggradation of a 'simple' linear dune under conditions of moderate climb. Schematic lines on facies show dip-angle relationships. Note: a) the marked lateral variability over comparatively short distances of vertical successions deposited by the same migrating bedform; b) the persistence of the cleaning and steepening-upward cycle as seen in the typical vertical section (e.g. sections A, B and C); c) the uncertainty introduced in the recognition of this cyclicity where barchanoid dunes are present in interdune corridors (e.g. sections C, D and E); and d) the entire cycle deposited by a single dune migration episode may be represented by non-reworked wind-rippled facies (section F). The relationships depicted are conceptual and do not necessarily record any specific documented natural system.