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Research paper

Outcrop architecture of a fluvio-lacustrine succession: Upper Triassic Yanchang Formation, Ordos Basin, China

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ABSTRACT

Although several studies have considered the sedimentary facies of the Upper Triassic Yanchang Formation in terms of their hydrocarbon potential in the petroliferous Ordos Basin, such studies have mostly interpreted subsurface data and few have systematically examined the detailed outcrop-based anatomy of this succession. This study characterizes a series of well-exposed outcrop sections along an 80-km-long E–W oriented series of road cuttings in the southeast Ordos Basin to reconstruct the sedimentary architecture of a fluvio-lacustrine succession and determine the principal controls that governed the style of accumulation and preservation. The Yanchang Formation is divided into 10 depositional units – Chang 10 (base) to Chang 1 (top) – that record the sedimentary evolution of a series of large-scale fluvial systems that constructed delta-front and pro-delta bodies as they entered a large, interior-draining lake. Detailed analysis of the internal architectures of the delta-front bodies records the mechanism of growth of a large-scale, shallow-water delta succession. Lacustrine subaqueous distributary channels are composed of 3–15 m-thick sandstone fills; such channelized bodies are highly elongate and many can be traced several kilometres. Such bodies can be shown to be commonly associated with thin-bedded mouth-bar and subaqueous interdistributary-bay deposition. The progradational architecture of the delta-front elements is difficult to recognize on outcrop scale.

Deposits of the Chang 10 to 1 units record 4 major lacustrine transgressive-regressive cycles during the Late Triassic: transgressive events are signified by the widespread occurrence of 10–20 m-thick oil-shale-prone intervals; regressive events are signified by the progradational stacking towards the basin centre of sandstone-prone facies associations mainly accumulated in fluvial channel, delta–plain and upper delta-front environments. The uppermost Chang 1 interval records late-stage filling of the lacustrine basin. The transgressive-regressive cycles equate to sequences that can be correlated across the region, development of which was controlled by a combination of changes in the rate of tectonic subsidence, the rate of sediment delivery from the basin margin hinterland, and climate – factors that were themselves influenced by intracontinental growth of the neighbouring Qinling Orogen.

1. Introduction

Fluvio-lacustrine depositional systems are commonly recognized palaeoenvironments that have been interpreted from a wide variety of ancient preserved successions. Several aspects of the sedimentology of fluvio-lacustrine depositional systems have been the focus of considerable attention: (i) the establishment of criteria for the recognition of the preserved expression of different types of river systems at their point of terminus into lakes (e.g. Jiao et al., 2005; Eric, 2007; Dill et al., 2006; Nichols and Fisher, 2007; Ghinassi et al., 2009; Weissmann et al., 2010); (ii) the impact of terrestrial vegetation on fluvio-lacustrine sedimentation (Davies and Gibling, 2010a,b); (iii) the role of gravity-current and sandy debris-flow processes in governing sediment distribution to deep or off-shore lake areas (Shanmugam, 2000; Bouma, 2000); (iv) the development of objective criteria for the identification of lacustrine deltas (Morris et al., 1991; Olsen, 1995; Carroll and Bohacs, 1999; Tanner and Lucas, 2010; Olariu et al., 2010); (v) the development

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of sequence stratigraphic models for fluvio-lacustrine successions (Keighley et al., 2003; Keighley and Flint, 2008); (vi) quantitative studies of the sedimentary architecture of fluvio-lacustrine successions (Morris and Richmond, 1992; Taylor and Ritts, 2004; Colombera et al., 2012, 2013).

Fluvio-lacustrine successions are widely developed in numerous Meso-Cenozoic sedimentary basins in China, from which more than 90% of domestic Chinese liquid hydrocarbon production originates (Xu et al., 1998; Zhao et al., 2010; Yu and Li, 2009). Thus, gaining an improved understanding of the internal anatomy and the external controls on the style of stacking of larger scale bodies in such successions has applied importance. Furthermore, demonstrating how and why the preserved sedimentary architectures of fluvio-lacustrine deltaic successions differ from those of more commonly recognized marine-influenced deltaic successions is important for establishing criteria for the recognition of such bodies and for wider palaeogeographic reconstruction. Previous studies of fluvio-lacustrine successions from Chinese sedimentary basins have been based primarily on analysis of subsurface borehole, well-log and seismic data sets (e.g. Zou et al., 2012; Yu et al., 2010); relatively few studies have focused on detailed outcrop-based sedimentary anatomy (Jiao et al., 1995, 2005; Qi et al., 2009; Xin et al., 1997; Wang, 2001; Yu et al., 2013; Zou et al., 2010, 2012).

The Ordos Basin is the second largest petroliferous basin in China; both the rate of hydrocarbon production and the estimate of ultimate recoverable reserves have increased in recent years (Yang et al., 2005; Xiao et al., 2005; Liu et al., 2008; Yang et al., 2008, Fig. 1). Petroleum resources of the basin are mainly accumulated in fluvio-lacustrine deposits of the Upper Triassic Yanchang Formation (Deng et al., 2011). Although a small number of previous outcrop-based studies of the Yanchang Formation have focused on the characterization of the sedimentology and the recognition of architectural elements (Jiao et al., 1995; Zou et al., 2010; Wang et al., 2004; Zhang et al., 2006; Zhao et al., 2014), these have primarily focused on reservoir property surveys, geological modelling and the establishment of a regional sequence stratigraphic framework to assist in hydrocarbon exploration and field development at a regional scale.

The aim of this study is to document the detailed internal

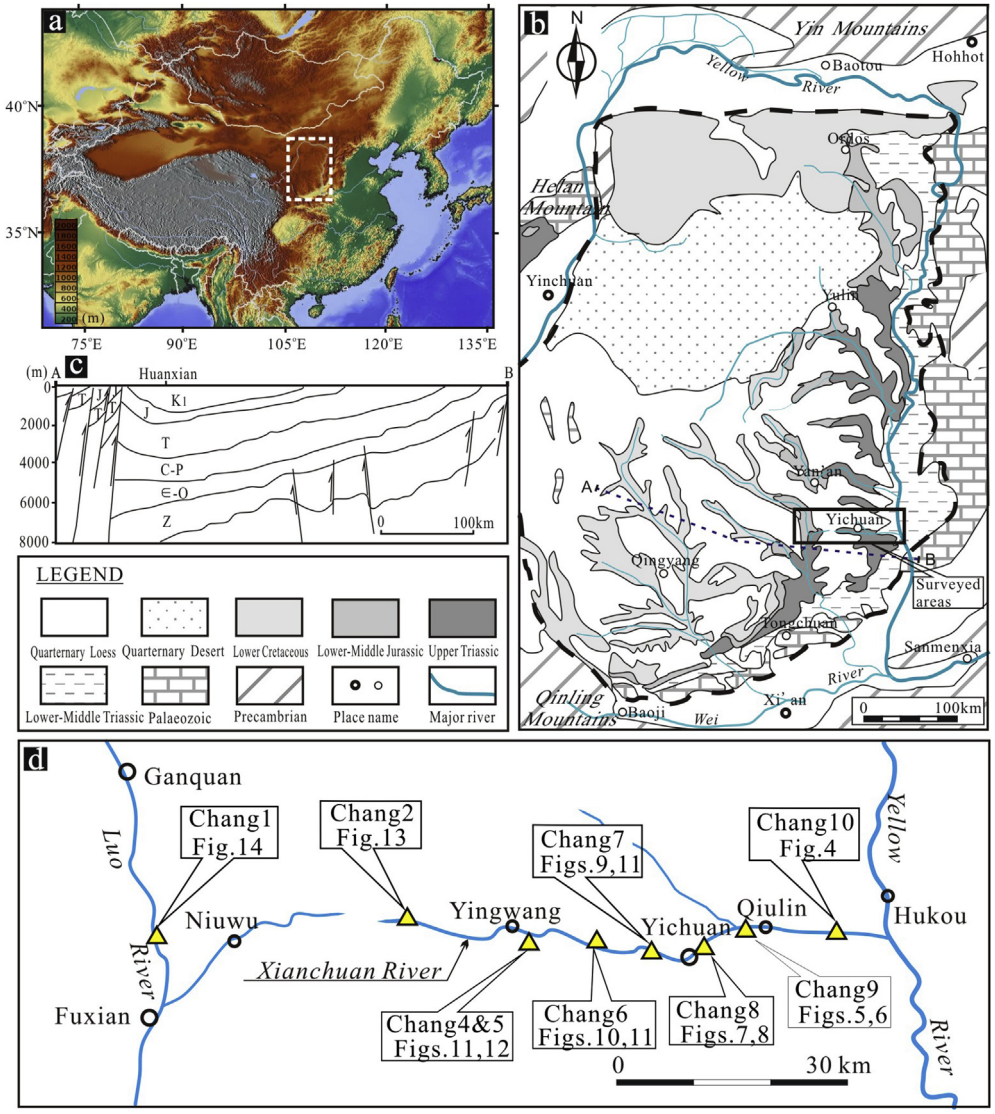

Fig. 1. Map showing the location of the study area. a) Digital elevation map of China and the location of the Ordos Basin. b) Geological map of the Ordos Basin with the location of the basin cross-section and study area shown. c) Geological profile of the southern Ordos Basin along an east–west orientation. d) Location of the studied sites where the principal surveyed sections discussed in this paper are located.