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Investigating fault propagation and segment linkage using throw distribution analysis within the Agbada formation of Ewan and Oloye fields, northwestern Niger delta

Abimbola Adewole Durogbitan

Petrofac IES, UK

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ABSTRACT

Throw distribution analysis of the key stratigraphic surfaces (sequence boundaries and maximum flooding surfaces) across faults has allowed detailed investigation of the tectonic history within the Ewan and Oloye fields, northwestern Niger delta. The structure in the studied area is dominated by growth fault systems which are listric in cross section and concave to the basin in plan-view. Generally, the faults are active down to 2000 m depth before they die out or sole into the underlying shale. The hanging-wall blocks of growth faults are deformed into broad rollover anticlines, with some synthetic and antithetic faults initiated from the anticline crests, and fault splays off major faults, further complicating these structures. Stratigraphic key surfaces within the syn-faulting succession range in age from 16.7 to 10.35 Ma.

Periods of maximum and minimum throw are established from 2-Dimensional throw distribution on the growth fault plane. Throw distribution allows analysis of growth fault nucleation, propagation and linkage. Each fault nucleated at different and a distinct interval within the stratigraphic section, as a result of the paleo-stress distribution between the interacting faults. Nucleation and linkage positions can be identified at points of maximum and minimum throw respectively. Following nucleation, faults propagated radially and linked to form the present geometry. Within the study area, fault propagation and segment linkage (lateral and vertical) are important features of the fault system. Understanding of growth fault evolution and linkage has greatly improved prediction of seal potential, trap geometry and migration. The accurate timing of the segment linkage has helped to evaluate the seal risk.

1. Introduction

Early models for normal fault systems were based on the interpretation of 2-dimensional seismic data (Gibbs, 1984; Hardman and Booth, 1991; Robert and Moores, 1992) where they were considered to be relatively simple, single plane structures with no segmentation. Recent studies on normal fault growth systems have shown that single/larger fault systems often evolve by a process of fault segment interaction and linkage (Mansfield and Cartwright, 1996; Pivnik et al., 2003; Hus et al., 2005, 2006; Baudon and Cartwright, 2008). Segmentation of normal faults has been documented by numerous authors (e.g. Peacock and Sanderson, 1991; Trudgill and Cartwright, 1994; Cartwright et al., 1996; Walsh et al., 2003b). Segments may initially nucleate as discrete faults (Cowie et al., 2000), but with increasing displacement and lateral growth they begin to interact and eventually link (Peacock and Sanderson, 1991; Cartwright et al., 1995). Fault linkage throw distribution patterns are schematically illustrated in Fig. 1. The location of the study area is shown in Fig. 1b.

The Niger Delta is characterized by a sedimentation rate that exceeds the subsidence rate (Doust and Omatsola, 1990), a condition that preserved the displacement histories of faults as stratal thickness changes across syn-depositional faults. Understanding the style of the displacement accumulation (continuous or stepwise) and the rate of movement of growth faults is important for the prediction of stratigraphic architecture of oil and gas accumulations and also gives insight into how fault systems develop through time. Several works on the interaction between fault displacement and sedimentary processes have been carried out which show the relationship between tectonics and sedimentation (Weber and Daukoru, 1975; Doust and Omatsola, 1989; Mansfield

E-mail address: adewoledurogbitan@yahoo.co.uk.

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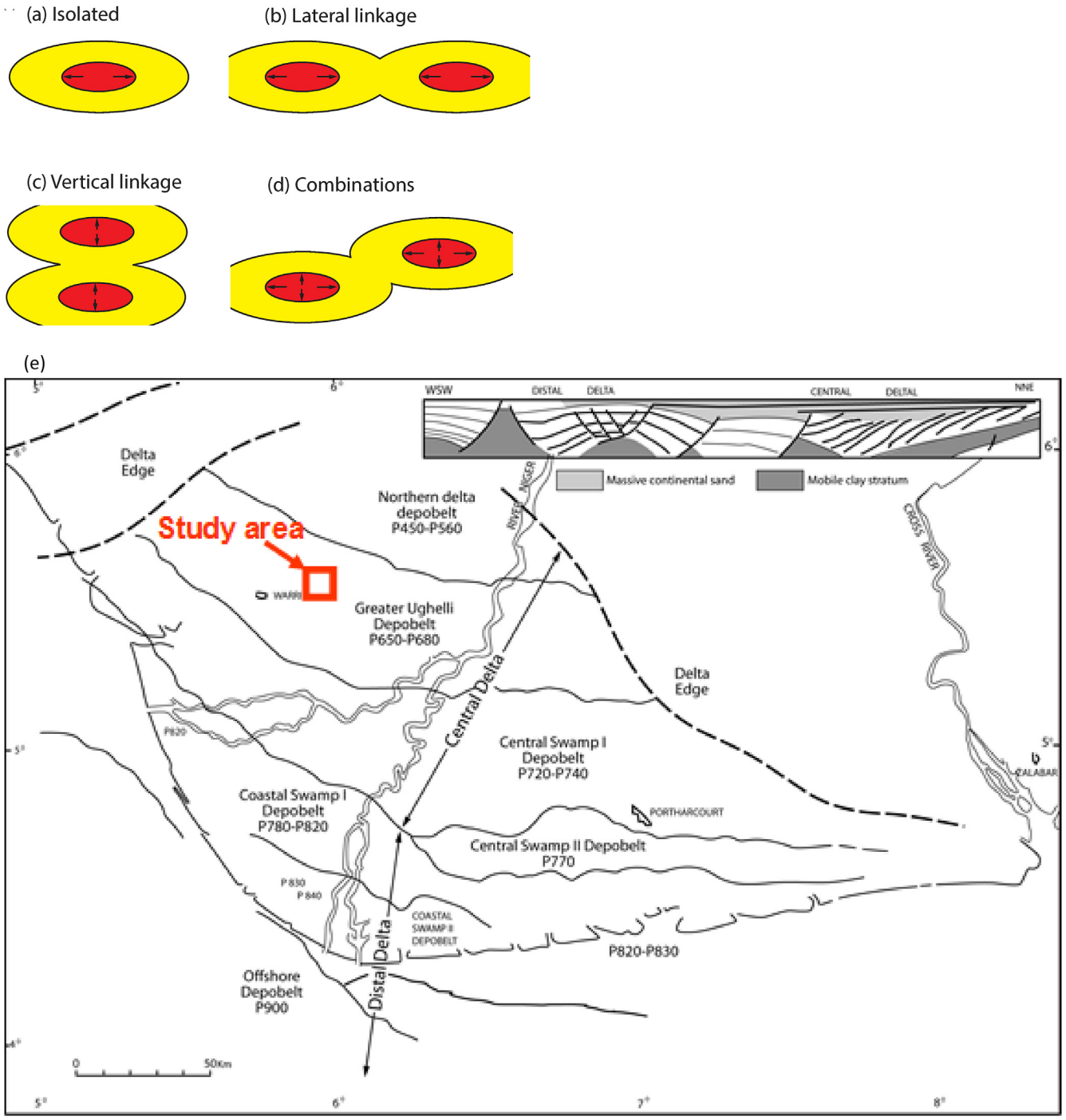

Fig. 1. a-d). End members of fault evolution. Arrows indicate the fault tips. e) Showing the location of the study area and age of deltaic sequences in depobelt and relationship to the broad changes in tectonic style (Doust and Omatsola, 1990).

and Cartwright, 1996; Cartwright et al., 1998; Hodgetts et al., 2001; Hooper et al., 2002; Imber et al., 2003; Pochat et al., 2004 and Back et al., 2006). The characteristics of some growth faults in the Niger Delta interpreted to be active are poorly understood. A better understanding of these faults will increase our understanding of previously and presently active geological processes in the Niger Delta, especially the characteristic growth, interaction and linkage of faults. In this study, growth fault evolution and associated deltaic sedimentation in the shallow marine deposits of Ewan and Oloye fields, northwestern Niger Delta has been investigated using throw distribution analysis. The main factors determining the throw distribution within the syn-faulting sequences along isolated syn-sedimentary faults are the rate of sedimentation and the displacement rate. Throw distribution analysis for eight growth fault tips have been analyzed using TrapTester™ software with the aim of providing quantitative constraints on fault growth models and the growth fault evolution history. To obtain a detailed record of normal/growth fault development it must be possible to correlate horizons across the fault from footwall to hanging wall, and the growth strata must contain key surfaces, the ages of which are