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Facies and architecture of a coarse-grained alluvial-dominated incised valley fill: a case study from the Oligocene Gebel Ahmar Formation, Southern Tethyan-shelf (northern Egypt)

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ABSTRACT

Exposures of multistorey, alluvial deposits from the Oligocene Gebel Ahmar Formation in the Cairo-Suez province (north Eastern Desert, Egypt) show the architecture of an up to 35 m thick continuously prograding fluvial/alluvial filling of an incised valley. The Oligocene base level fall resulted in cannibalization of the Eocene bedrock. Subsequent baselevel rise created accommodation space that was filled by deposition of four stacked storeys: lower storeys (1-2) of low sinuosity sandy braid plains and upper storeys (3-4) of gravelly braid plain. These braid plains were sourced from exposed Upper Cretaceous-Eocene and Paleozoic-Lower Cretaceous siliciclastic successions to the south. These successions dominate the Galala-Araba inverted structures. The sandy braid plain channel belts mainly downstream accretion (DA), downstream oblique accretion(DLA), lateral accretion (LA), sandy bedforms (SB), channel (CH), and Hollow (HO) elements, while the gravelly braid plain consists mainly of gravel bars and sheets (GB), gravel-sandstone foresets (GSF), gravel-sand couplets (GSC), and scour pool filling (SPF) architectures. Incised valley incision is potentially linked to a global drop of sea level caused by glaciation, although hinterland tectonism (i.e. Late Cretaceous-Paleogene tectonic inversion and Late Eocene-Oligocene crustal updoming in the source terrains) as well as Late Oligocene-Miocene rifting play a significant role in the subsequent filling. The hinterland tectonism as well as the climate controls the sediment supply. The understanding of the nature of the Oligocene incised valley fill helps in the constrain potential down depositional dip hydrocarbon reservoirs in Nile Delta, East Mediterranean basins, and similar settings in passive continental margins.

1. Introduction

The incised valley systems are of great interest due to their filling reflects changes in response to climate, sea-level, tectonic, and anthropic influences. Incised valleys are being critical in sequence stratigraphy, and wetland management (Dalrymple et al., 1994; Rodriguez et al., 1998; Blum and Aslan, 2006; Mattheus and Rodriguez, 2011; Srivastava et al., 2013; Breda et al., 2016; Main et al., 2016). In addition, incised valleys can be key for hydrocarbon reservoirs (Martin et al., 2011; Mattheus and Rodriguez, 2011). The majority of incised valleys preserved in the stratigraphic record are thought to be cut and filled in response to a fall and subsequent rise of relative sea level (Boyd et al., 2006). Incision and filling of an incised valley can be driven also by factors not related to relative sea-level changes, such as variations in fluvial discharge due to climatic and/or tectonic changes (Schumm et al., 1987; Blum, 1992; Schumm, 1993; Holbrook, 2001; Aldinucci et al., 2007; Rasmussen, 2014). These incised valleys are dominated by fluvial sandstone fill with fine-grained parting, commonly cited in the literature (Wright and Marriot, 1993; Aitken and Flint, 1994; Willis, 1997; Blum and Price, 1998; Arnott et al., 2000; Aldinucci et al., 2007; Wang et al., 2015; Rasmussen, 2014; Bianchi et al., 2015, and references therein) but the documentation of the gravelly type that lacking the fine-grained parting are less common. This case study offers an opportunity to study architecture and evolution of a coarse-grained alluvial incised valley fill from the rock record and possible controlling factors such as tectonics and climate.

This study focuses on the coarse-grained alluvial-dominated, valley fill deposits of the Oligocene Gebel Ahmar Formation that overlies different levels of Eocene carbonate bedrock and underlies Miocene basalt sheets at Cairo-Suez province, northern Egypt (Fig. 1A). Surprisingly, no architectural studies have been carried out for this succession in NE Egypt. The incised valley setting is

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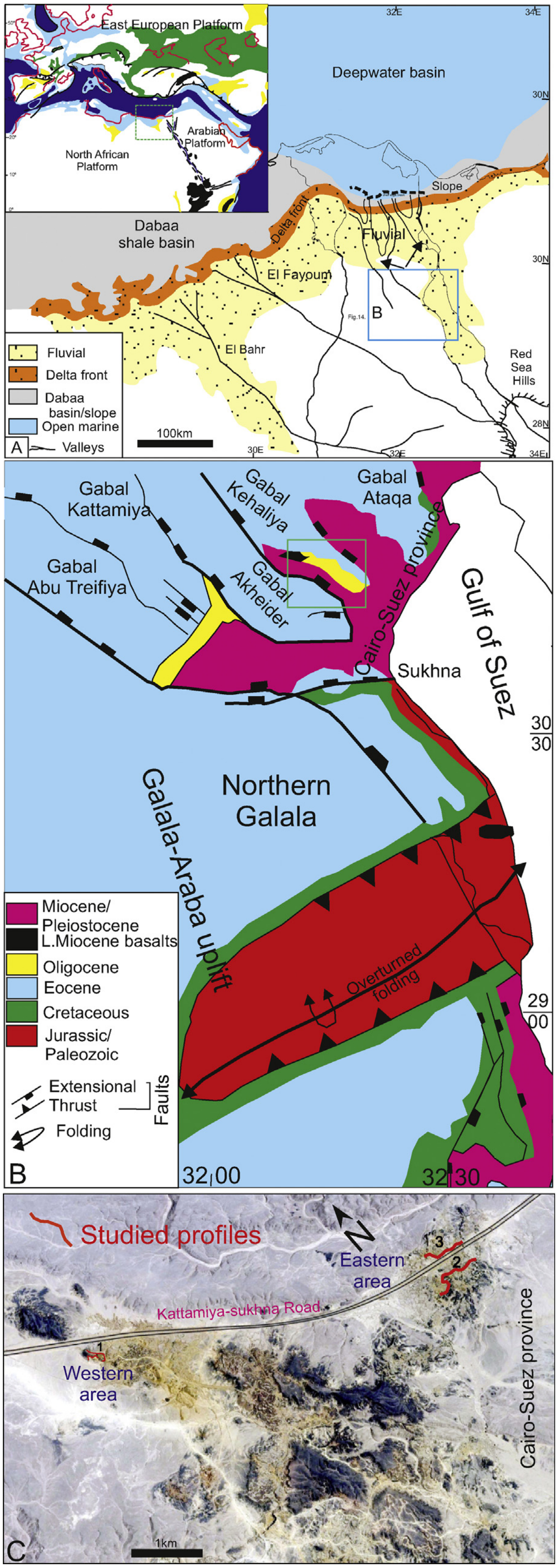

Fig. 1. (A) Paleogeography of the Oligocene strata along the northern rim of the Arabian-African plates, summarized after Rögl (1998), Meulenkamp and Sissingh (2003), Dolson et al. (2005),Issawi and McCauley (1993), Selim (2016). The major Oligocene to Miocene fluvial incisions are highlighted by canyon-drainages. The inset map is Oligocene paleogeographic map (after Meulenkamp and Sissingh, 2003). (B) Geological map of the north Eastern Desert (after Klitzsch et al., 1987). The structure of the Cairo-Suez province after Hussein and Abd-Allah (2001). (C) Satellite image of the study area showing location of the studied profiles.

inferred due to its wedge-shape external cross-sectional geometry, basal unconformity surface, multistorey internal architectures, lithofacies, and stratigraphic relationships of this formation. By the Earliest Oligocene, deep subaerial valleys were incised into the exposed carbonate shelf (Dolson et al., 2005). These valleys incised during general erosional phase that characterized the Oligocene eustatic sea level drop, due to ice volume and cooling event (Miller et al., 2008). Mess et al. (2001) revealed a global climatic change toward cool conditions and development of large Antarctic ice sheets with shifting of vegetation from dominantly tropical to subtropical Eocene forests to more “mixed mesophytic forests”. The aim of this study is to describe and interpret the sedimentary facies, their origin and evolution, and to examine their architectural elements of barform and channel-infill dimensions through detailed field-based examinations of Oligocene Gebel Ahmar Formation. Using the sedimentological interpretations to document spatial and temporal variability in alluvial architecture, and discuss and integrate the implications of these findings as they relate to possible controls on valley incision and filling. The depositional architecture and stacking pattern of such deposits reflect fluctuations in intrinsic parameters such as discharge and sediment supply, and accommodation (interaction between climate and tectonism). It is hoped that by gaining a good understanding of the incised valley fill an insight into the down dip hydrocarbon reservoirs in the nearby east Nile Delta can be gained. The Oligocene reservoirs of East Nile Delta represent one of the most promising and future exploration targets (see El Naggar and El Morshedy, 2013; Selim, 2016).

2. Geological background

Strong tectonic activity and rapid and intense changes in global climate occurred during the Oligocene (see Guiraud et al., 2005). The dramatic drop in the global sea level that occurred in the earliest Oligocene caused by a glacial episode (Miller et al., 2008), resulted in the emergence of most of the continental shelves around the world (Guiraud et al., 2005). By the end of Eocene, the NE Africa continental margin was characterized by a carbonate shelf that has been incised and extensively eroded with many northward-trending incised valleys (Dolson et al., 2014). These valleys were filled mainly with thick non-marine succession across northern Egypt (Dolson et al., 2014). The Oligocene Gebel Ahmar Formation at the Cairo-Suez province represents one of these valley fills. The Cairo-Suez province (Study area) is delimited to the south by Galala-Araba uplifted blocks and to the north by the Nile Delta (Fig. 1B). Galala-Araba uplifted blocks represent a part from the Syrian Arc (Kuss et al., 2000; Hussein and Abd-Allah, 2001), which display large NE-SW oriented folds in northern Egypt and Eastern Mediterranean regions, due to a convergence between Africa and Eurasia and the closure of the Neotethys during the Late Cretaceous-Paleogene (Moustafa and Khalil, 1995; Abd-Allah, 2008). Further south at NE corner of Afro-Arabian plate, mantle plume of Afar uplifted during the Late Eocene-Oligocene (Hofmann et al., 1997). To the west and southwest, NW-oriented faults were formed with the opening of the Gulf of Suez during Late Oligocene-Miocene. The Gulf of Suez rift represents a continuation of the Red Sea rifting with dominant NW-oriented extensional faults, following the divergence of African plate away from Arabian plate (Patton et al., 1994 and Bosworth and McClay, 2001).

Oligocene-aged outcrops in Egypt (Fig. 1) are sparse as a result of wide-scale erosion due to tectonically induced uplift, enhanced by a major and global mid-Oligocene drop in sea-level (Haq et al., 1988; Haq and Al-Qahtani, 2005). In the North Western Desert