Introduction

Recent studies have been able to pin point the timing of the Nile's initiation as a major river from a more proximal catchment area (Fielding et al., 2018). Knowledge of the evolution of the Nile brings with it potential insights into the predicted reservoir quality of the offshore Oligocene to recent Nile Delta sediments. This paper will focus on an investigation into multi-disciplinary studies and how they are key in correctly interpreting the detrital provenance signatures of ancient clastic sediment wedges and their implications for reservoir quality whilst overcoming bias from effects such as diageneses and hydraulic sorting.

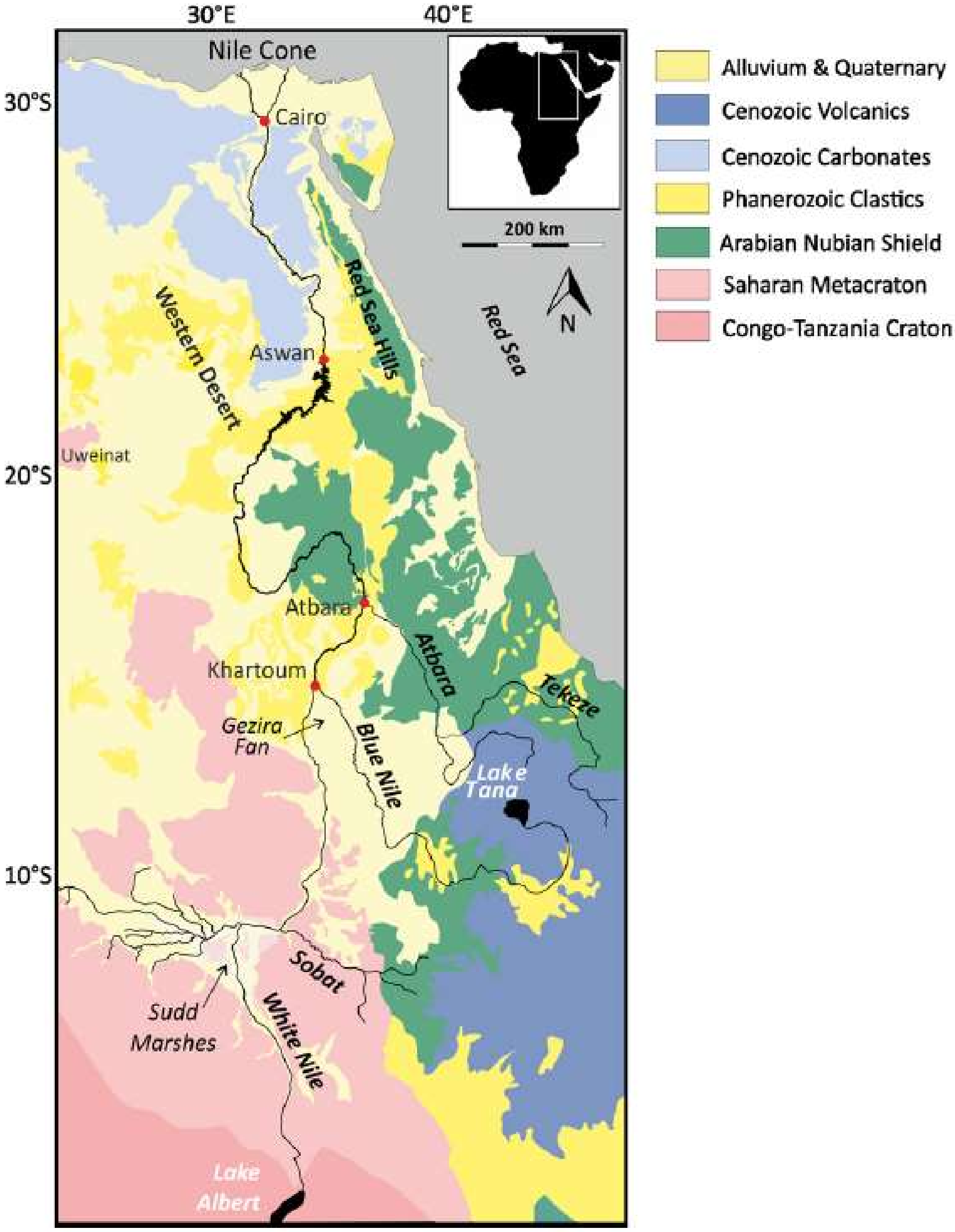


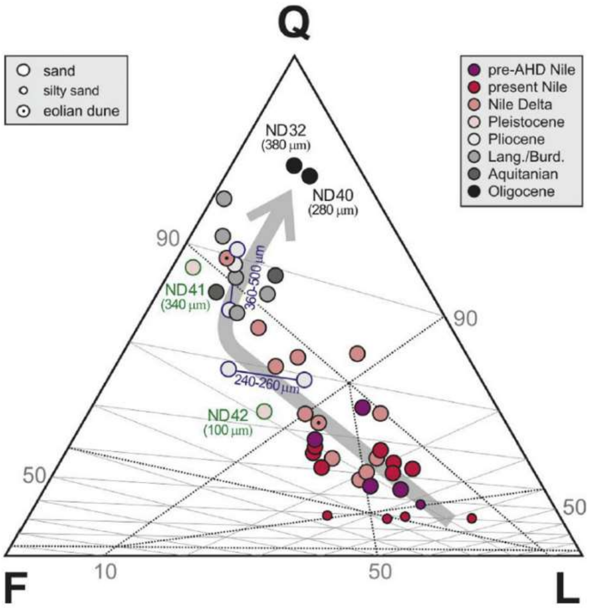
***Figure 1** Geological map and present-day Nile catchment area (from Fielding et al., 2018).*

Method and/or Theory

One place exceptionally well suited to carry out such an investigation is the thick Oligocene to recent sedimentary succession in the offshore Nile delta (Craig et al., 2011). In this article, we compare the compositional signatures of Nile River and Nile delta sediments – using two provenance techniques: 1) Heavy mineral analysis and petrography and; 2) U/Pb zircon geochronology. Petrographic analysis was carried out on samples from before and after the construction of the Aswan High Dam in 1964 and transported as bedload and suspended load (Garzanti et al., 2006, 2015; Fielding et al., 2017) - with those of partly lithified Oligocene to Pleistocene Nile delta sands, silts, and muds cored offshore by BP Egypt (Fig. 1; Fielding et al., 2018). Fielding et al., (2018) focuses principally on provenance, whereas Garzanti et al., 2018 illustrates the stratigraphic trends shown by petrographic modes and heavy-mineral suites and thoroughly discusses their potential controlling factors. Particular focus was given to comparing heavy mineral assemblages in samples with grain sizes from cohesive mud to upper-medium sand, to evaluate differences in the intensity of diagenetic effects in strata characterized by different porosity and permeability to intrastratal fluids.

Petrography and heavy mineral analyses

The Nile delta sands range from feldspatho-quartzose to quartzose, containing sparse granitoid lithic fragments and micas, sedimentary lithic fragments, low-grade metamorphic lithic fragments, and extremely sparse carbonates. Altered volcanic rock fragments are present from the base of the Oligocene studied core and upwards but are only common in the Upper Pliocene and Pleistocene samples. Volcanic detritus is present in most samples in higher proportions than in the Red Sea Hills wadi sands, or in any Saharan samples (Garzanti et al., 2015).



Analysis of heavy mineral assemblages shows that diagenesis has strongly affected the composition of samples with increasing depth, demonstrated by progressively decreasing transparent heavy mineral concentration index (Garzanti and Andò, 2007), and progressively increasing Zircon-Tourmaline-Rutile index (ZTR; Hubert, 1962).

Figure 2 *Petrography of Nile Delta sands from Garzanti et al., 2018. (Q=quartz; F=feldspar; L=lithic grains, predominantly volcanic`\\).*

U/Pb zircon geochronology

Fielding et al., (2018) showed all Nile delta cone sand samples from Oligocene to Pleistocene to be dominated by a c.600 Ma Pan-African peak in zircon age distribution. In addition, there sparse Archaean and Paleoproterozoic grains are also present in each sample in different proportions, and sparse Cenozoic (c.30 Ma) grains are present in many Oligocene to Pleistocene samples. It is these Cenozoic grains that are key to determining the evolution of the paleodrainage of the Nile. Fielding et al., (2018) demonstrate that the only potential source area for these grains is the Ethiopian Highlands and therefore invoke a connection between the Blue Nile and the Main Nile from the Oligocene onwards; coincident with the onset of uplift in the region (Pik et al., 2003).

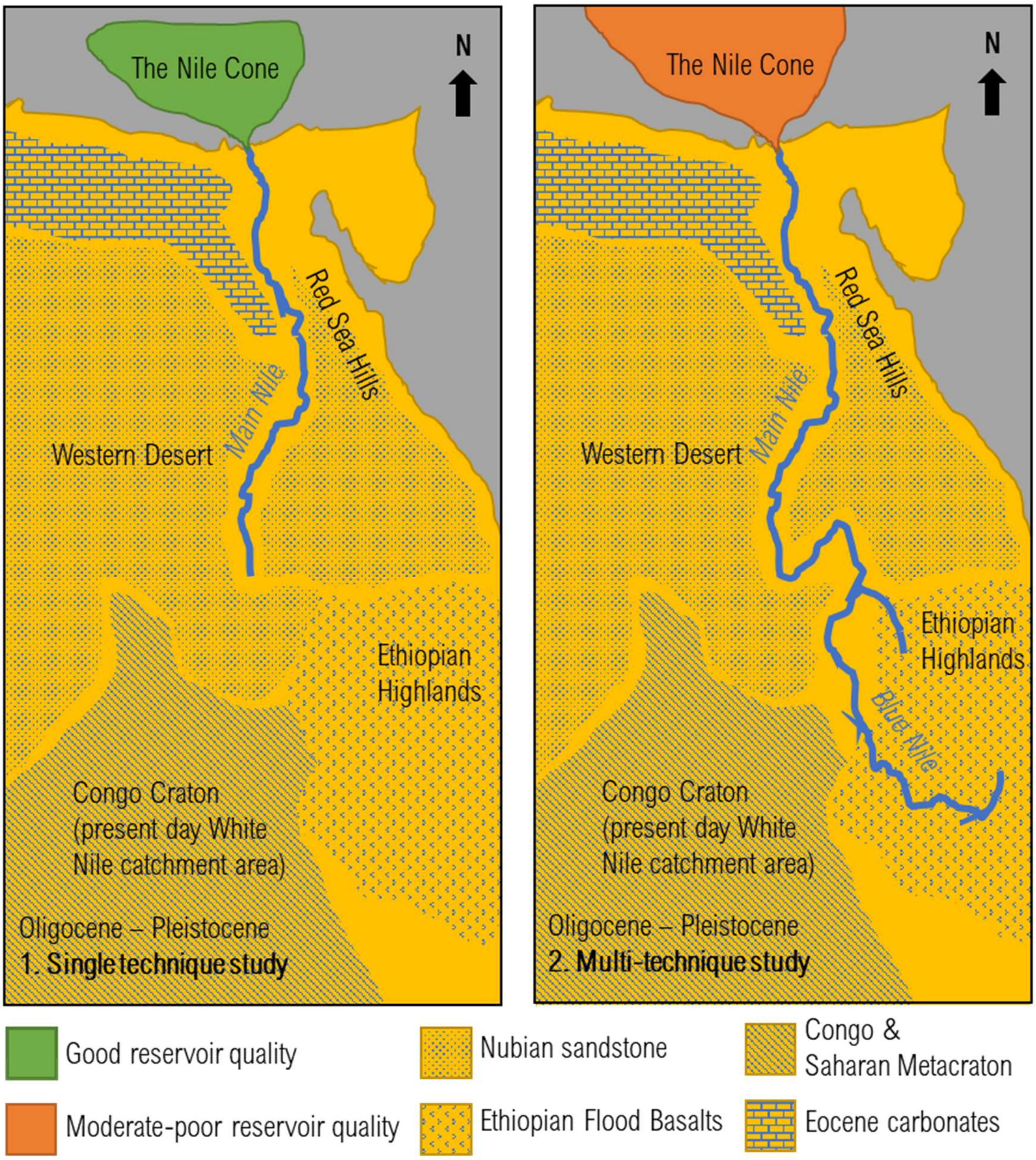


Figure 3. *Schematic paleogeographic reconstructions illustrating the extent of the Nile drainage catchment area during the Oligocene to the Pleistocene. The left-hand map shows a paleogeographic reconstruction depicting good reservoir quality sands in the delta when only heavy minerals and petrography are used to determine provenance. The right-hand map shows a paleogeographic reconstruction depicting poor reservoir quality sands in the delta as a result of a different catchment interpretation based on a multi-technique provenance study. Note the volume of sediment reaching the delta also varies.*

Discussion & reservoir quality implications

Interpreting the petrographic dataset alone leads to a very different paleodrainage reconstruction and therefore, a different reservoir quality prediction, compared to that seen when also incorporating other techniques such as U/Pb zircon geochronology (Figure 3). Basing interpretations on the petrographic data alone would suggest that the Blue Nile did not contribute sediment to the Nile Delta until at least the Pleistocene (Figure 3. Map 1). If this was the case then sediment must have been derived from the Red Sea Hills and the reworked Nubian sands that once covered much of the region as this is the only area with any significant uplift (Bosworth, 2015). Reservoir quality could therefore be inferred to be of moderate-good quality from the Oligocene until the Pleistocene. However, when a second provenance technique is introduced (U/Pb zircon), the presence of the Cenozoic (c.30 Ma) zircons in the Oligocene-Pleistocene delta samples requires a connection with the Blue Nile since at least the Oligocene in order to account for these relatively young grains (Fielding et al., 2018). Conway et al. (1993) show that the present-day Blue Nile contributes by far the highest amount of sediment to the delta. The volcanic nature of the sediment will have a severe impact on reservoir quality of delta sediments not only since the Pleistocene but also from as early as the Oligocene. The main reason that the two techniques vary so drastically is due to mineral stability under burial. Zircon is a relatively robust and ubiquitous mineral whereas other heavy minerals are much less resistant to weathering and diagenesis. Garzanti et al. (2018) go into significant detail to untangle the provenance signature from the diagenetic signature of the heavy mineral and petrographic assemblages in the Nile delta. They conclude that any stratigraphic compositional trends in the offshore delta sediments serve only to document a selective exponential decay of non-durable species through the cored succession. Failure to recognize such a fundamental diagenetic bias can lead to incorrect paleogeographic reconstructions, as shown in Figure 3. This in turn has significant implications for sediment volume and mass balance calculations.

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