Earth-Science Reviews 162 (2016) 107–128

Contents lists available at ScienceDirect

Earth-Science Reviews

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

Invited review

The Euphrates-Tigris-Karun river system: Provenance, recycling and dispersal of quartz-poor foreland-basin sediments in arid climate

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ARTICLE INFO

Article history:
Received 9 February 2016
Received in revised form 12 September 2016
Accepted 19 September 2016
Available online 24 September 2016

Keywords:
Sedimentary petrology
Heavy minerals
U–Pb zircon geochronology
Anatolia-Zagros orogen
Undissected collision orogen provenance
Long-distance sediment transport

ABSTRACT

We present a detailed sediment-provenance study on the modern Euphrates-Tigris-Karun fluvial system and Mesopotamian foreland basin, one of the cradles of humanity. Our rich petrographic and heavy-mineral dataset, integrated by sand geochemistry and U–Pb age spectra of detrital zircons, highlights the several peculiarities of this large source-to-sink sediment-routing system and widens the spectrum of compositions generally assumed as paradigmatic for orogenic settings. Comparison of classical static versus upgraded dynamic petrologic models enhances the power of provenance analysis, and allows us to derive a more refined conceptual model of reference and to verify the limitations of the approach.

Sand derived from the Anatolia-Zagros orogen contains abundant lithic grains eroded from carbonates, cherts, mudrocks, arc volcanics, obducted ophiolites and ophiolitic mélanges representing the exposed shallow structural level of the orogen, with relative scarcity of quartz, K-feldspar and mica. This quartz-poor petrographic signature, characterizing the undissected composite tectonic domain of the entire Anatolia-Iranian plateau, is markedly distinct from that of sand shed by more elevated and faster-eroding collision orogens such as the Himalaya. Arid climate in the region allows preservation of chemically unstable grains including carbonate rock fragments and locally even gypsum, and reduces transport capacity of fluvial systems, which dump most of their load in Mesopotamian marshlands upstream of the Arabian/Persian Gulf allochemical carbonate factory. Quartz-poor sediment from the Anatolia-Zagros orogen mixes with quartz-rich recycled sands from Arabia along the western side of the foreland basin, and is traced all along the Gulf shores as far as the Rub' al-Khali sand sea up to 4000 km from Euphrates headwaters.

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http://dx.doi.org/10.1016/j.earscirev.2016.09.009

A river watering the garden flowed from Eden; from there it was separated into four headwaters. The name of the first is the Pishon; it winds through the entire land of Havilah, where there is gold. The name of the second river is the Gihon; it winds through the entire land of Cush. The name of the third river is the Tigris; it runs along the east side of Ashur. And the fourth river is the Euphrates. Genesis 2:10–14

"*Their reward from their Lord will be the gardens of Eden, wherein streams flow and wherein they will live forever. God will be pleased with them and they will be pleased with Him.*"

[Al-Quran 98:8]

1. Introduction

Mesopotamia is the cradle of civilization. Bringing water and fertile sediments to an otherwise desert region, the Euphrates and Tigris Rivers allowed humans to settle, develop agricultural practices 10,000 years ago, learn how to domesticate animals, and produce the first book recorded in history, the Epic of Gilgamesh. Mesopotamia, a garden of Eden wounded by decades of war and unending atrocities committed in the name of God, is geologically speaking part of a subsiding foreland basin including the Arabian/Persian Gulf (Evans, 2011). The transition between the fluvial floodplain and the distal marine basin is - or was before the ecosystem collapsed under the impact of extensive drainage works and construction of large dams in Turkish headwaters (Partow, 2001) - the vast marshland well described by the British explorer Wilfred Thesiger in his book *Marsh Arabs*. Other streams join the trunk-river system, called here the Shatt al-Arab. These are the Karun, identified traditionally with the Gihon of the Genesis and draining the Zagros fold-thrust belt in Iran, and Wadi Rimah/al Batin, held by some to be the Pishon of the Genesis, draining in ancient more humid times presently desert Arabia (Fig. 1).

Sediments of the Mesopotamian foreland basin are derived almost entirely from erosion of the Anatolia-Zagros composite orogen, grown during collision between Arabia and Eurasia preceded by ophiolite obduction in the Late Cretaceous (Alavi, 2004; Okay, 2008). The mountain belt runs along the southern front of the Anatolia-Iranian plateau, connecting the Alps and the Himalayas as part of the garland of ranges issued from Paleogene closure of the Neotethys Ocean (Dercourt et al., 2000). From the Taurus in the south to the Caucasus in the north, the region of distributed tectonic deformation is ≤1000 km in width and has elevations over 1500 m a.s.l. punctuated by volcanic peaks reaching above 5000 m a.s.l. (Yılmaz et al., 1998; Allen et al., 2013). Exposed in this wide tectonic domain are sedimentary strata, volcanic rocks and ophiolitic mélanges, with virtual absence of paleometamorphic crystalline basements and scarcity of high-pressure neometamorphic rocks (Şengör et al., 2003). Because sediments reflect the lithology of source terranes, those shed by the Anatolia-Zagros collision orogen are expected to be distinct compositionally from those generated in the Alps or the Himalayas, and characterized by abundant lithic grains from sedimentary and volcanic rocks of the widely exposed supracrustal level. Characteristic of the Mesopotamian and Gulf regions is the arid climate, resulting in negligible chemical weathering and almost complete preservation of unstable detrital components. Because of the consequently limited erosion rates and fluvial-transport capacity, the Gulf represents today a rare case of partially underfilled marine foreland basin associated with a large collision orogen. Eolian sediment transport plays a major role in such an arid region. In the Pleistocene, during periods of low global sea-level, sand was deflated by reinforced northerly winds along the exposed floors of the Gulf and blown south and southwest up the Rub' al-Khali (Teller et al., 2000; Garzanti et al., 2003, 2013a).