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Provenance of Miocene sandstones in northern Iraq: constraints from framework petrography, bulk-rock geochemistry and mineral chemistry

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Abstract

Modal analysis, bulk-rock geochemistry and phase chemistry of sandstones of the Miocene Fat'ha and Injana formations, northern Iraq, show that the clastics were derived from heterogeneous sources that include basic igneous and metamorphic rocks as well as older sedimentary rocks. The sandstones are generally carbonate-rich lithic arenites. Their geochemistry supports the petrographic results and indicates that they are all Fe-rich, lithic or quartz arkosic sandstones. According to geochemical data, garnets are derived from metamorphic sources, hornblende is of igneous origin, and clinopyroxenes, are produced by basic igneous rocks. Epidote is most probably to be a product of disintegration of metamorphic rocks, essentially, metamorphosed igneous rocks. Rutile geochemistry implies low-grade metamorphic and basic to ultrabasic igneous sources. Chemical composition of chromian spinels indicates that they are derived from Alpine-type peridotite. The ophiolitic-radiolarite belts of Taurus-Zagros as well as the uplifted Cretaceous and Paleocene strata of north and northeastern Iraq are likely to be the major source of clastics to the Fat'ha–Injana basin, a foreland basin formed as a result of the continental Arabian and Turkish/Iranian plates collision.

Keywords: provenance; heavy minerals; mineral chemistry; modal analysis; Miocene; Iraq

Introduction

The study integrates provenance approaches (modal analysis, bulk-rock geochemistry, phase chemistry of selected heavy mineral grains) to reconstruct the provenance of Middle and Late Miocene clastics from northern Iraq.

Provenance analysis serves to reconstruct the pre-depositional history of sediments or sedimentary rocks. This includes the distance and direction of transport, size and setting of the source region, climate and relief in the source area, and the specific types of source rocks (Pettijohn et al., 1987).

The paleogeographic setting of northern Iraq was highly affected by the collision between the Arabian and Iranian plates, which also had an effect on the accumulation and disturbance of the sedimentary cover (Al-Sharhan and Nairn, 1997; Buday and Jassim, 1987).

The Miocene sedimentation of northern Iraq is generally of marine nature. It started with the deposition of Early Miocene carbonates and evaporites of Serikagni, Euphrates, Dhiban and Jeribe formations within shallow epicontinental seas and lagoons in marginal basins. The marine conditions became progressively more restricted, with many small seas and lagoons sporadically replenished with normal sea water. It gave rise to the shallowing-upward cyclic deposition of evaporites in Middle Miocene Fat'ha (Lower Fars) Formation. The marginal parts of the Fat'ha basin are dominated by clastics represented by fine sandstones and silty claystones occupying the upper two-thirds of the sequence of the upper unit of the formation. These clastics were deposited in fluvially-dominated delta (Al-Juboury and McCann, 2008; Al-Juboury et al., 2001; Al-Naqib and Aghwan, 1993).

The deposition of fluviatile Injana (Upper Fars) Formation in the foreland basin of Iraq in the Late Miocene marked the end of marine conditions in northern Iraq. This formation is a clastic sequence of medium to coarse sandstones, siltstones and claystones and was deposited in a fluvial-tidal environment (Al-Banna, 1982; Al-Juboury, 1994).

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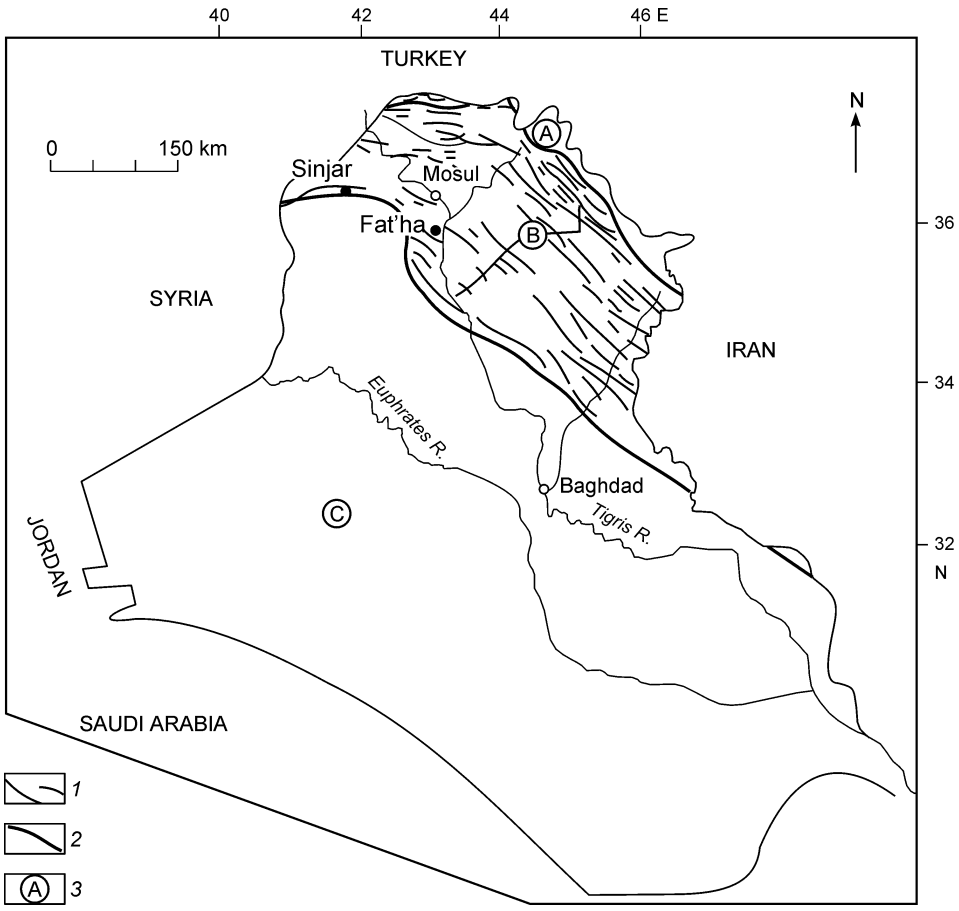

Fig. 1. Tripartite tectonic division of Iraq (modified after Bolton 1958). *1*, anticlinal axes; *2*, boundary between zones of stability and instability; *3*, zone: A, thrusts; B, folded (instability); C, unfolded (stability).

Geologic setting and stratigraphy

The regional features of northern Iraq are the Zagros Mountain Range with an NW-SE structural trend in the northeast and E-W trending Taurus Range in the north and northwest. The structural framework of Iraq was divided by Bolton (1958) into Thrust Zone, Folded Zone, and Unfolded Zone (Fig. 1).

The Nappe Zone (thrust and folded) includes the area of northern and northeastern Iraq and forms the high Zagros Mountains. This zone has undergone intense igneous activity including the intrusions of dolerites and gabbros and the extrusions of andesites and basalts as well as explosive pyroclastics and tuffs. Rocks of this zone such as phyllites, schists and metabasalts (spilites) show a low grade of metamorphism (Abdul-Wahab, 1983).

The folded zone (unstable shelf) contains three tectonic zones which are, from west to east: the Mesopotamian Zone (Quaternary molasses and buried structures), the Foothill Zone (Neogene molasses and long anticlinal structures separated by broad synclines), and High Folded Zone (Paleogene molasses and harmonic folded structures). These longitudinal tectonic zones are segmented into blocks bounded by ENE-WSW (shifting to NE-SW) transverse faults with both vertical and horizontal displacement (Jassim et al., 1999). The transverse blocks have been active at least since the Late Cretaceous and strongly affected the sedimentary facies of the Cretaceous and Tertiary sequences (Numan, 1997). According to the tectonic division of Iraq (Numan, 2001), the area under study covers the Foothill and Mesopotamian zones of the quasiplatform foreland of Iraq (Fig. 2). The main axis of the basin is NW-SE in which the sandy and clayey facies of the Late Miocene Injana Formation envelope the contemporaneous evaporatic facies of the Middle Miocene Fat'ha Formation (Al-Mashadani, 1984)).

The Fat'ha Formation (Middle Miocene, Langhian?) (Al-Juboury and McCann, 2008; van Bellen et al., 1959) consists of numerous shallowing-upward cycles of alternating mudrocks, limestones, gypsum and/or anhydrite and halite in the center of the basin. The clastics found only in the upper member of the Fat'ha Formation form the dominant lithology in the marginal part of the basin. The unit comprises sandstone, silty claystone and claystones characterized by red color and represents two main coarsening-upward cycles. These cycles have been interpreted as formed within a fluvially-dominated deltaic depositional system, where the delta aggraded at the expense of lagoonal cycles (Fig. 3, *A*).

Injana Formation (Late Miocene) (van Bellen et al., 1959) is basically a clastic sequence, which consists of upwards fining cyclothems of carbonate-rich sandstones, siltstones and