Cretaceous Research 30 (2009) 1146–1156

Contents lists available at ScienceDirect

Cretaceous Research

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

Mechanism of calcrete formation in the Lower Cretaceous (Neocomian) fluvial deposits, northeastern Iran based on petrographic, geochemical data

R. Moussavi-Harami [a,*], A. Mahboubi [a], M. Nadjafi [a], R.L. Brenner [b,1], M. Mortazavi [a]

[a] *Department of Geology, Faculty of Science, Ferdowsi University of Mashhad, Mashhad, Khorason Rezavi 91775-1436, Iran*
[b] *Department of Geosciences, University of Iowa, Iowa City, IA 52242, USA*

ARTICLE INFO

Article history:
Received 4 December 2007
Accepted in revised form 28 April 2009
Available online 7 May 2009

Keywords:
Kopet-Dagh
Iran
Siliciclastic
Calcrete
Vadose phase
Phreatic phase

ABSTRACT

The Kopet-Dagh basin of northeastern Iran was formed during the Middle Triassic orogeny. From Jurassic through Miocene time, sedimentation was relatively continuous in this basin. The Shurijeh Formation (Neocomian), which consists of red bed siliciclastic sediments that were deposited in fluvial depositional settings, crops out in the southeastern part of the Kopet-Dagh basin. In addition to clastic lithofacies, non-clastic facies in the form of calcrete paleosols, were identified in this formation. The calcrete host rocks are mainly sandstone, pebbly sandstone. The calcrete in middle unit in the Shurijeh Formation consists of, from bottom to top: incipient calcrete, nodular calcrete, massive calcrete horizons. The maturity pattern of these calcrete gradationally increases from bottom to top in this unit. Lack of organo-sedimentary structure (mainly plant roots), diversity of calcite fabric, suggest that the studied calcretes have a multi-phase development: a short vadose phase followed by a long phreatic phase. These calcretes are neither pedogenic nor groundwater calcretes. Petrographic studies show that they are composed of micritic textures with a variety of calcite fabrics, microsparitic/sparitic veins, displacive, replacive fabrics, quartz, hematite grains. Cathodoluminescence images, trace elemental analysis (Fe, Mn increased, Na, Sr decreased) of calcrete samples show the effects of meteoric waters during the calcrete formation when water tables were variable. In this study, we conclude that evaporation, degassing of carbon dioxide are the two main factors in the formation of non-pedogenic or groundwater calcrete. The sources of carbonate were probably parent materials, surface waters, ground waters, eolian dusts, numerous outcrops of limestones that have been exposed in the source area during Neocomian time.

1. Introduction

Paleosols can provide information about climate, sedimentation rate, evolution patterns of flood plains in fluvial systems, have been considered by geologists, geochemists for a long time (Miall, 1996; De La Horra et al., 2008). Paleosols have been identified on the basis of color, texture, mineralogy (Duchaufour, 1982; Wright and Tucker, 1991; Miall, 1996; Wright and Marriott, 1996; Khadkikar, 2005; Therrien, 2005; De La Horra et al., 2008). Calcrete, calcic soil are common features of arid, semi-arid, sub-humid landscapes wherein they form either within the soil profile or through evaporative precipitation from groundwater in phreatic, capillary-fringe zones (Alonso-Zarza, 2003; Huerta and Armenteros, 2005; Khadkikar, 2005; Schmid et al., 2006; Durand et al., 2007; Khalaf, 2007). These materials are also referred to caliche, nari, kunkar, etc. (Goudie, 1983). Calcrete development is mainly controlled by three factors: the nature of host sediment, availability of carbonate-rich solution, climatic conditions. The suitable climate for calcrete formation is enough precipitation for translocation of carbonate, temperatures that facilitate a high evaporation rate (Khalaf, 2007). However, calcrete usually develops during arid to semi-arid intervals that follow humid climatic intervals. Calcrete is commonly developed within the vadose zone; however, its formation within the phreatic zone is not uncommon. Vadose or pedogenic calcrete is predominantly rhizoconcretionary (Khalaf, 2007). While phreatic or groundwater calcrete occurs as thin sheets formed by precipitation of carbonate from the laterally moving solution within the zone of capillary rise just above the water table (Miall, 1996; Pimentel et al., 1996). However, most calcrete profiles are polygenetic, where different processes may act during their evolution leading to fabric transformation, facies superimposition (Durand et al., 2007; Khalaf, 2007).

Accumulations of calcium carbonate in soils, weathering profiles are particularly widespread in arid, semi-arid regions receiving rainfall between 400, 600 mm/yr, both on calcareous, non-

* Corresponding author.
E-mail address: harami2004@yahoo.com (R. Moussavi-Harami).
[1] Current address: 225 Linden Court, Iowa City, IA 52245-4809, USA.

0195-6671/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cretres.2009.04.003

calcareous rocks (Goudie, 1983; Wright and Tucker, 1991). Given that calcium carbonate accumulation requires sufficiently wet conditions for the release of calcium from primary minerals but also sufficiently dry conditions to ensure subsequent precipitation of CaCO3 one would expect that the conditions leading to the weathering of rocks, those leading to the precipitation of CaCO3 are best fulfilled by semi-arid conditions as these involve seasonal alternations of rainfall, drought (Wang et al., 1994; Durand et al., 2007).

This study investigated the mode of occurrence, textural, mineralogical characteristics of calcretes hosted within the Lower Cretaceous fluviatile sequence in northeastern Iran. The role of movements, characteristics of groundwaters in the formation of these paleosols, influence of meteoric waters in calcrete occurrence are discussed.

2. Geological setting

The Kopet-Dagh is an intracontinental basin located in northeastern Iran. This basin formed after the closure of the Hercynian Ocean following the Middle Triassic Orogeny (Berberian and King, 1981; Ruttner, 1993; Alavi et al., 1997). From the Jurassic through the Miocene time, relatively continuous sedimentation recorded by five major transgressive-regressive sequences that took place in the eastern Kopet-Dagh basin (Moussavi-Harami and Brenner, 1992). The study area is located in the southeastern part of this basin between 35° 44′, 36° 48′ N, 60°13′, 60° 17′ E. In this part of the Kopet-Dagh basin, climate varies from arid to semi-arid conditions, means annual precipitation is 39 mm/yr. The Lower Cretaceous red beds of the Shurijeh Formation crop out within a northwest-southeast plunging syncline (Fig. 1). These siliciclastic rocks have been deposited in a variety of fluvial depositional systems through most part of the Neocomian Time (Moussavi-Harami, 1986; Moussavi-Harami and Brenner, 1990; Moussavi-Harami and Brenner, 1993).

2.1. Shurijeh Formation

In this study, three sections of Shurijeh Formation were measured at Senjedak, Razmgah-e-Paein, Gargesh (Fig. 1). Thicknesses of formation in these sections are 165, 166, 310 meters, respectively. In this region, the Shurijeh Formation overlies the Kashafrud Formation with fault-related, gradational contacts with Tirgan Formation at the top (Fig. 2). The Shurijeh Formation is composed of a lower conglomeratic unit, a middle sandstone unit, an upper conglomeratic-sandstone unit. A few layers of mudstone, calcrete nodules, horizons have been observed in the middle unit.

Based on texture, sedimentary structures, three clastic lithofacies including gravely (Gcm, Gp, Gh), sandy (Sm, Sp, St, Sh), muddy (Fm), one nonclastic facies paleosol (P) have been identified. On the basis of facies changes, unimodal sedimentary structures (planar, trough cross-bedding), presence of fining-upward cycles, their lower erosional contacts, siliciclastic sediments of Shurijeh Formation have been interpreted to be deposited in fluvial depositional systems (Moussavi-Harami and Brenner, 1990). Thick gravely, sandy facies, absence of lateral accretion beds, low frequency of fine grain flood plain deposits, paleocurrent analysis suggest that deposition may have taken place in low sinuosity proximal channels (e.g. Huerta and Armenteros, 2005). Therefore, Neocomian siliciclastic rocks can be deposited in proximal braided rivers with gravely bed load (Fig. 3). Paleocurrent analysis is shown that this river has been flowed toward the northwest of the study area during the Neocomian Time.

Petrographic data (mineralogical composition), field studies, paleocurrent analysis, regional geology indicate that the source area for these siliciclastic sediments was probably the paleotethys rocks that are cropped out in southeast of the study area (Moussavi-Harami and Brenner, 1990).

Diagenetic processes operated on the siliciclastic sediments of the Shurijeh Formation are compaction (physical, chemical), cementation (iron oxide, calcite, silica), dolomitization, alteration, dissolution, fracturing. Our study shows that these processes have taken place during three stages: eogenesis, mesogenesis, telogenesis.

3. Material, methods

We used a database of 150 samples collected from three measured stratigraphic sections through the Shurijeh Formation (Fig. 4). Thin sections were stained with an Alizarin Red S, Potassium Ferricyanide mixture (Dickson, 1966) to differentiate nonferroan from ferroan calcite. 45 polished thin sections with

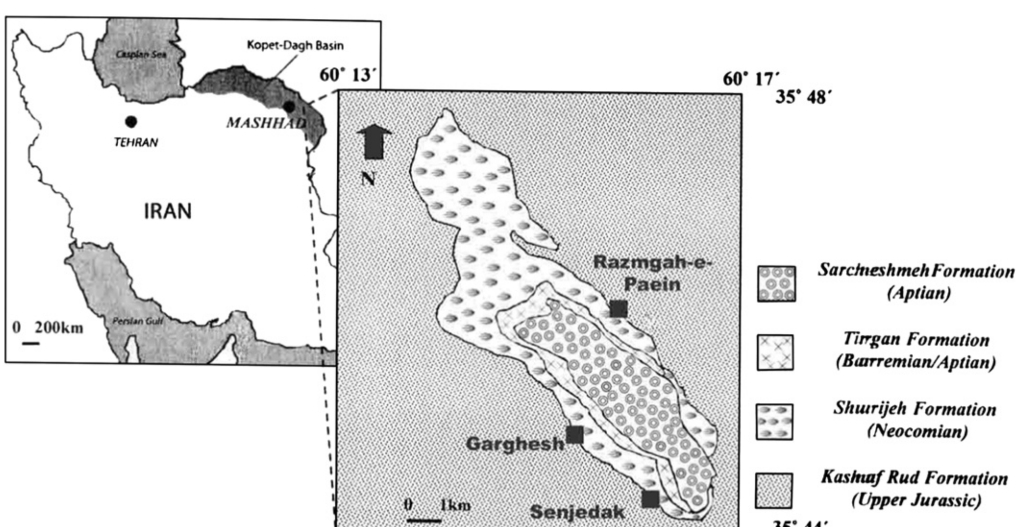

Fig. 1. Simplified geological map of the study area in NE Iran; inset box shows the location of measured stratigraphic sections: Senjedak; Razmgah-e-Paein; Garghesh (modified from Ghaemi and Hosseini, 1999).