Original mineralogy of the Upper Jurassic carbonates in the Kopet-Dagh Basin, NE Iran

Mohammad Ali Kavoosi

National Iranian Oil Company Exploration Directorate, 1st Deadend, Seoul Street, NE Sheikh Bahaei Square, PO Box 19395-6669, Tehran, Iran
E-mail address: m.kavoosi@niocexp.ir

Abstract

The Kopet Dagh Basin in northeast Iran contains giant Khangiran and Gonbadli gas fields. This study deals with the main hydrocarbon reservoir of Upper Jurassic (Oxfordian-Tithonian) Mozduran Formation, which is composed mainly of limestone and dolomite, with minor amounts of marl/shale, siliciclastics and evaporites. The objective of this study is carbonate mineralogy of the Mozduran Formation. Thin sections were stained by alizarin-red S to detect dolomitization of grains and cements. Regarding diagenetic products and their diagenetic environments, selected samples were observed with a cathodoluminescent microscope (Nikon CL, CCL 8200) at the Research Institute of Petroleum Industry (R.I.P.I). Detailed field studies, petrographic investigations and facies analyses of eight surface sections and four wells, led to the recognition of several facies that define deep basin, fore-shoal, shelf margin, lagoonal, tidal flat and coastal plain facies belts, which deposited on a rimmed-shelf and a carbonate ramp during Oxfordian and Kimmeridgian respectively.

Our petrographic and CL studies indicate, lack of leached ooids (Oxfordian) with preserved radial and concentric fabrics indicates primary low-Mg calcite mineralogy. In contrast, at Khangiran and Gonbadli gas fields, Kimmeridgian ooids are aragonitic. In the Mozduran Formation, pay zones are located in Kimmeridgian deposits. Reservoir facies are composed of tubiphytes boundstones, tubiphytes packstone and grainstone, microbialite boundstone, dolomitized ooid grainstone/packstone and dolostones. Mentioned facies stack aggradationally and were cemented by marine cements with isopachous, fibrous and acicular fringe fabrics, assign a windward margin and high permeability of sediments at the Khangiran-30 well location. In the mentioned intervals due to hypersalinity and presence of sulfide ions concentration, aragonite tends to form in preference to calcite. Kimmeridgian ooids in the basin show both original aragonite and high-Mg calcite mineralogy that have been completely dolomitized, so the original fabric has been destroyed, but ghosts of spherical shapes characterize ooid grains. Despite the fact that ooids have been dolomitized, marine cements of mentioned carbonates at Khangiran field show excellent preservation. Some cements (isopachous) show mimetic dolomitization. Increased hypersalinity, evaporite precipitation and consequently an increase in the Mg/Ca ratio, along with increasing high temperature (inferred from increasing evaporites), led to the preferential formation of aragonite to calcite. The aragonite mineralogy could be a result of evaporite precipitation and consequently an increase in Mg/Ca ratio. In southern outcrops of the Kopet Dagh Mountain Range, ooids in ooid gainstones with quartz nuclei have preserved radial and concentric fabrics. It shows there is a probable relationship between siliciclastic input and calcite mineralogy. The presence of preserved ooids with radial and concentric cortexes in shallow-water settings which are near to a siliciclastic source, together with the formation of aragonitic ooids accompanied with evaporites in the gasfields, suggest that the mineralogy was probably controlled by salinity variations.

Key words: *Mozduran Formation; Gas reservoir; Aragonite mineralogy; Kimmeridgian; Kopet Dagh*

INTRODUCTION

The Kopet-Dagh orogenic belt is an inverted basin (Allen *et al*., 2003) extending from the east of the Caspian Sea to NE Iran, Turkmenistan and north Afghanistan (Afshar-Harb, 1979; Buryakovsky et al., 2001). Following the closure of Palaeo-Tethys in the Middle Triassic (Alavi et al., 1997) and the opening of Neo-Tethys during the Early to Middle Jurassic (Buryakovsky *et al*., 2001), the Kopet Dagh Basin formed in an extensional regime during the Middle Jurassic (Kavoosi et al., 2009a, 2009b). Over 6000 m of sedimentary rocks ranging in age from Middle Jurassic to Miocene were deposited in the basin (Afshar-Harb, 1979) and can be assigned to five major transgressive-regressive sequences (Moussavi-Harami and Brenner, 1992). Jurassic-Cenozoic carbonates and siliciclastics unconformably overlie Palaeozoic (basement) and Triassic rocks (Ulmishek, 2004).

The Kopet-Dagh Basin hosts the giant Khangiran and Gonbadli gas fields (Fig. 1) discovered in 1968 and 1969 respectively, which produce from the Upper Jurassic Mozduran Formation, which is the main reservoir unit. The formation is composed mainly of limestone and dolomite with minor marl/shale, sandstone and evaporites, and crops out along the Kopet-Dagh Range. The major source rock interval occurs in the Middle–Upper Jurassic shales and carbonates of the Chaman Bid Formation (Fig. 2) (Afshar-Harb, 1979; Mahboubi et al., 2001); upper Bajocian to Bathonian mudstones of the Kashafrud Formation may also have generated hydrocarbons (Poursoltani et al., 2007).

The objective of this study is to report on original mineralogy of the Mozduran Formation by means of petrography and cathodoluminescent studies.

MATERIALS AND METHODS

Detailed field studies, microscope-based investigations, microfacies and wireline log analyses were carried out on three outcrop sections (Ghorghoreh, Padehi and Shurijeh) and on well successions at the Khangiran and Gonbadli gas fields (Fig. 1). Over 2000 samples of the Upper Jurassic Mozduran Formation from the gasfields and the outcrops were studied. Thin sections from outcrop sections, well cuttings and cores together with well logs (gamma ray, sonic, density, neutron and resistivity) were used.

Surface sections were measured by a Jacob Staff, meanwhile; directional samples were taken systematically every two meters. Thin sections were stained by alizarin-red S (Dickson, 1965) to detect dolomitization of grains especially cements. Thin sections were studied for petrographic and facies analyses. Dunham's classification (1962) was used for carbonate facies nomenclature with the exception that the upper size-limit for micrite was set at 0.06 mm. Regarding diagenetic products and their diagenetic environments, selected samples were observed with a cathodoluminescent microscope (Nikon CL, CCL 8200) at the Research Institute of Petroleum Industry (R.I.P.I) of National Iranian Oil Company (N.I.O.C).

RESEVOIR DIAGENESIS

The main hydrocarbon pay zones at the Khangiran and Gonbadli fields are located in HSTs in sequences KIM1 and KIM2 (Kavoosi et al., 2009b; Kavoosi, 2009b). In the Mozduran Formation, reservoir facies are composed of tubiphytes boundstones, tubiphytes packstone and grainstone, microbialite boundstone, dolomitized ooid grainstone/packstone and dolostones. Aggredation of mentioned facies with corals boundstone in some intervals by marine cements with isopachous, fibrous and acicular fringe fabrics, assign presence of a reef on windward margin and the high permeability of sediments at the *Khangiran-30* well location. Petrographic analyses and wireline logs indicate that reservoir quality has been controlled by depositional facies and diagenetic processes (dolomitization) (Kavoosi et al., 2009b). Dolomitization and intercrystalline porosity increase upwards in the succession (late HST) especially when anhydrites cap the parasequences. Marine cements, vadose silts, acicular fringe aragonitic cements in the reef, and the lack of them at well Gonbadli-2 indicates that Khangiran-30 had a higher palaeogeography during deposition of this sequence (Kavoosi et al., 2009b). Vadose silts and acicular fringe cements are rare during aggradation and are more common during progradation (e.g. Della Porta et al., 2004).

Our petrographic studies indicate that Oxfordian ooids in the Mozduran Formation have preserved their radial and concentric fabrics that indicate their primary mineralogy was composed of low-Mg calcite (LMC); however, Kimmeridgian ooids show both original aragonite and high-Mg calcite mineralogy that have been completely dolomitized so the original fabric has been destroyed, but ghosts of spherical shapes characterize ooid grains. At Khangiran and Gonbadli, Kimmeridgian ooids are aragonitic. Despite the fact that ooids have been dolomitized, marine cements at Khangiran-30 show excellent preservation. Some cements (isopachous) show mimetic dolomitization. Preservation of the original aragonitic fabric of the cement suggests that dolomitization took place before aragonite inversion to calcite (Corsetti et al., 2006). At *Khangiran-30*, reefs/patch reefs developed in the lower and middle Kimmeridgian deposits. Increased hyper-salinity, evaporite precipitation and consequently an increase in the Mg/Ca ratio, along with increasing high temperature (inferred from increasing evaporites), led to the preferential formation of aragonite to calcite. The aragonite mineralogy could be a result of evaporite precipitation and consequently an increase in Mg/Ca ratio; a high Mg/Ca ratio is thought to favour aragonite seas (Hardie, 1996). The presence of preserved ooids with radial and concentric cortices in shallow-water settings which are near to a siliciclastic source, together with the formation of aragonitic ooids accompanied with evaporites in the gas fields, suggest that the mineralogy was probably controlled by salinity variations.

CONCLUSIONS

Our petrographic studies indicate that Oxfordian ooids in the Mozduran Formation have preserved their radial and concentric fabrics that indicate their primary mineralogy was composed of low-Mg calcite (LMC). Kimmeridgian ooids show both original aragonite and high-Mg calcite mineralogy that have been completely dolomitized so the original fabric has been destroyed, but ghosts of spherical shapes characterize ooid grains. Increased hypersalinity, evaporite precipitation and consequently an increase in the

Mg/Ca ratio, along with increasing high temperature (inferred from increasing evaporate deposits such as gypsum/anhydrite), led to the preferential formation of aragonite to calcite. The aragonite mineralogy could be a result of evaporate precipitation and consequently an increase in Mg/Ca ratio. The presence of preserved ooids with radial and concentric cortices in shallow-water settings which are near to a siliciclastic source, together with the formation of aragonitic ooids accompanied with evaporites in the gas fields, suggest that the mineralogy was probably controlled by salinity variations.

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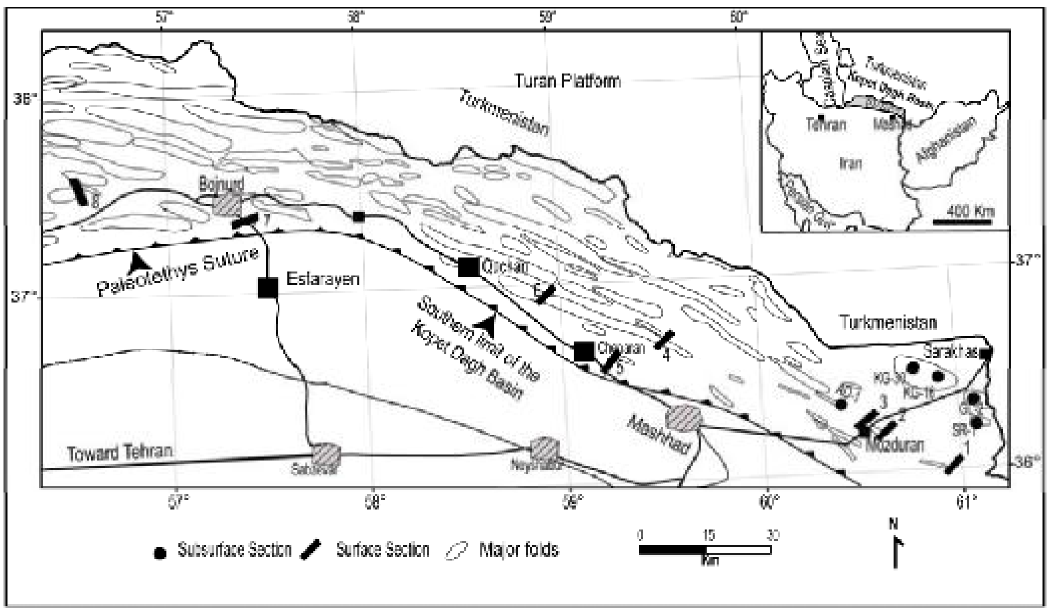

Figure1: Location map of the study area that shows drilled well and measured surface section position.

Figure 2: A) Low-Mg calcite mineralogy is indicated by preservation of ooid fabrics.XPL B) Spheroidal fabric indicates aragonitic mineralogy of cement. PPL C) Fibrous/isopachous cement that followed by bladed cements support aragonitic and high Mg-calcite, respectively.

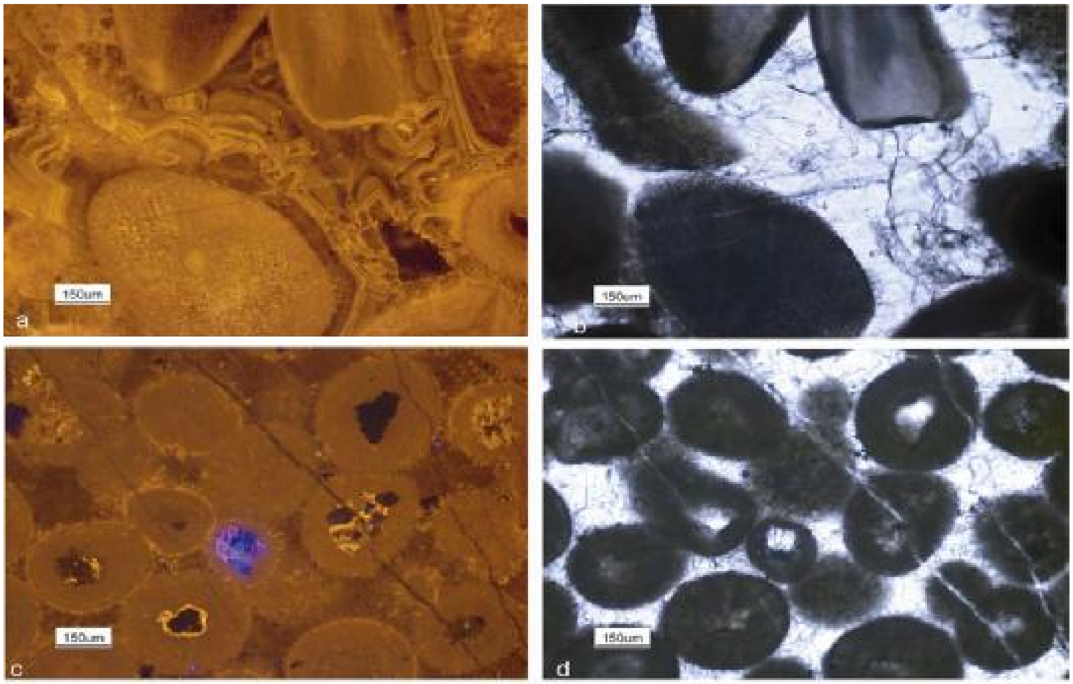

Figure 3: a) Indicates cementation in marine and fresh-water phreatic zone. c) Ooids have been cemented in fresh-water and deep burial diagenetic environments. Most of cementation took place in deep burial diagenetic environment.