The effect of original carbonate mineralogy on diagenetic and porosity evolution in the Kangan Formation, South Pars Field, Persian Gulf

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Abstract
The Lower Triassic Kangan Formation is a carbonate-evaporite succession, which is part of the largest carbonate reservoir in the South Pars Field in the Persian Gulf. In this study petrographic investigations, indicate that aragonite was origininal carbonate mineralogy. Based on the abundance of leaching of skeletal grains such as bivalves , gastropods, evaporites & early diagenetic dolomites in the Kangan carbonates are similar to those of modern warm water shallow-marine carbonates. Isopachous and fibrous intragranular sparry calcite cements resemble modern aragonite morphologies. Deformed ooids and spalled ooids indicate aragonite dissolution during meteoric diagenisis. As aragonite is susceptible to dissolution and dolomitization, so the diagenetic processes, especially porosity evolution are very important in enhancement of reservoir quality.

Introduction
The Kangan Formation is Early Triassic (Scythian) in age (Motiei, 1993). Kangan carbonates from the South Pars are providing favorable reservoirs for the accumulation of gas. In this study, the thickness of section is about 150m and more than 400 uncovered polished thin sections were studied. Those were stained with alizarin-red S solutions (Dickson, 1965) to identify calcite from dolomite mineralogy. The classification of carbonate rocks followed the nomenclature of Dunham (1962) and Flugle (2004). The aim of this paper is to describe and interpret original carbonate mineralogy of Kangan Formation, based on petrographic studies and the effect on diagenesis and porosity evolution (Adabi & Rao, 1991). On the other hand, the primary morphology and carbonate mineralogy depends primarily on water temperature, similar to observations in modern carbonates. In Recent tropical warm shallow marine carbonates (temperatures >25ºC), meta-stable aragonite is the predominant mineral, with variable amounts of high-Mg calcite (Milliman 1974).

Stratigraphy and geologic setting
This study deals with Early Triassic Kangan Formation, that is exposed in south west Iran, which is considered as upper part of Dehram Group. The lower contact with the Dalan Formation is disconformable and the upper contact with the Dashtak Formation (Aghar shale member) is conformable (Ghazban, 2007) .The South Pars Filed, one of the important offshore filed in the world, is located on the Iran-Qatar border in the Persian Gulf (Fig.1). The litohlogy of Kangan carbonate is composed mainly of dolomite and limestone with minor amounts of anhydrite.

Petrography
The Kangan carbonates consist of skeletal and non-skeletal grains, abundant sparry calcite cement, micrite, early and late diagenetic dolomites and minor evaporates (anhydrite). 2

Skeletal grains

Skeletal grains are bivalves, gastropods, claraia, spirorbis, ostracodes and stromatolites. Shells structure of claraia, ostracodes and spirorbis consists of well preserved calcite (HMC- LMC), whereas shells of bivalves and gastropods composed of aragonite are not preserved due to dissolution and precipitation of cement specially, anhydrite or dolomite cements in the Kangan carbonate (Fig.2A).

Non-skeletal grains

Non-skeletal grains consist of ooids, intraclasts and pellets. In modern marine aragonitic ooids, the concentric structures dominate in high-energy environments, such as platform margin oolitic shoals of the Bahamas and tidal channels and deltas of the Persian Gulf (Loreau and Purser.1973). The tidal channels of Kangan consist mainly of ooids with aragonite mineralogy, therefore deformed ooids structure such as spalled ooids are present (Fig.2B).

Cementation

Different generations of sparry calcite cementation are recognized in the Kangan limestones ranging from marine, meteoric to burial cements. Isopachous calcite cement, are first generation cement (Marine cement) in this study. Meteoric equant to mosaic sparry calcite cement and later followed by drusy phreatic cements, which are other cements in the Kangan Formation (Fig.2C, 2D, 2E) .Coarse dolomite (baroque or saddle) and poikilotopic anhydrite are burial cements in the Kangan limestones. In some part of succession, early cements resulted in preservation of primary porosity and even these cements have been replaced by dolomite.

Evaporites

Anhydrite and gypsum are common minerals in dolostone reservoirs. Most of the gypsum changed to anhydrite. Anhydrite present in most of the facies and has filed pores such as interparticle, moldic and fenestral pores, thus it called cement (Lucia, 2007). Poikilotopic, pore-filling and nodular (Fig.2F), anhydrite is the most common form of anhydrite in some dolostone.

Dolomitization

Two types of dolomite occur in the Kangan Formation. The early diagenetic dolomites are equicrystalline and are mainly confined to unfossiliferous supratidal sediments. The late diagenetic dolomites are inequicrystalline and completely replaced limestones. The replacement of dolomite in Kangan facies is fabric destructive and fabric selective dolomite such as ooids, intraclasts and some of the bioclasts with aragonite mineralogy (Fig.2G). Dolomitization connect voids and increase the permeability.

Dissolution

The observations suggest that solution process in carbonate facies lead to creation mold and vuggy pore space (Lucia, 2007). Due to this process on meteoric phase in the Kangan Formation facies, ooid grains and some skeletal (gastropods and some bivalves) have dissolved in grain- dominated facies because their mineralogy are aragonite and so, the moldic porosity is very common (Fig.2H).

Porosity

Dissolution has important effect on increasing of porosity and lead to enhancement of reservoir quality. Porosity is mainly secondary (fabric selective and non-fabric selective porosity) such as moldic, vuggy, intergranular and channel porosity in the Kangan Formation (Fig .2I, 2J).The reason for this porosity was aragonite mineralogy of some skeletal and non-skeletal grains in this study. Creation of new pore spaces through this process has increased the porosity, but cementation by calcite it has occluded interparticle pores and permeability of the facies.

Conclusions

Result of petrography evidences indicate that aragonite was the predominant primary mineral in the Early Triassic carbonates deposited in the Kangan Formation in South Pars Filed, Persian Gulf. The criteria include the following: a) The mineralogy of gastropods, bivalves and ooids are aragonite. b) Spalled ooids indicative of aragonite dissolution during meteoric diagenesis. c) Isopachous cement is common in modern aragonite deposits. d) Presence of anhydrite cements that has filed pores such as interparticle, moldic and fenestral pores. e) Dolomitization of aragonite bioclasts. f) The oomoldic porosity is very common in the Kangan carbonates.It should be noted that aragonite mineralogy is susceptible to diagenesis and porosity evolution. However, cementation, dolomitiziation and anhydritization had most effect on declining the porosity and permeability, whereas dissolution have caused that reservoir quality improve.

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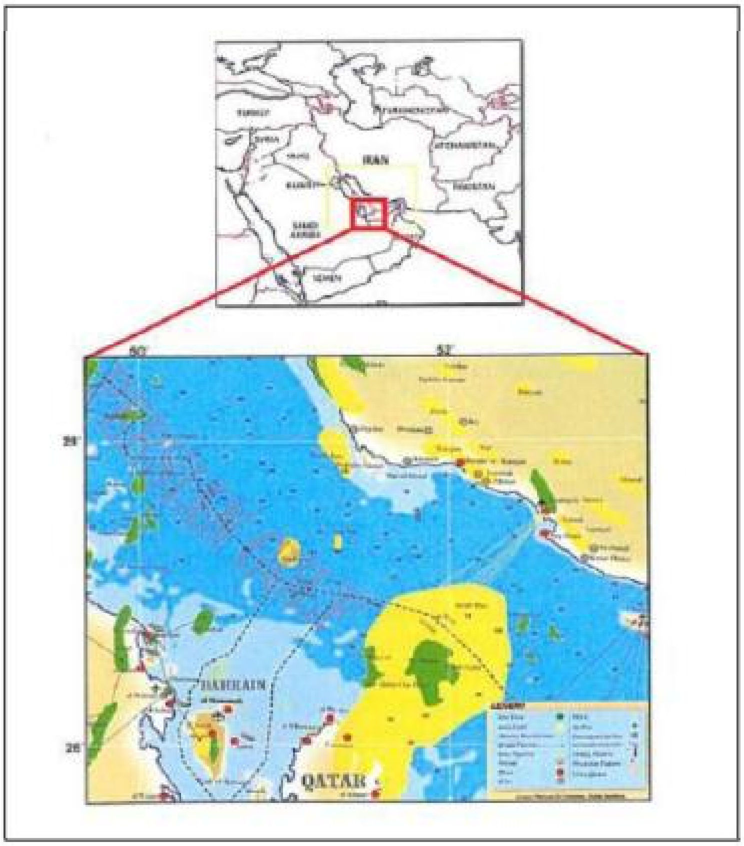

Fig. 1. Location map of study area in IRAN

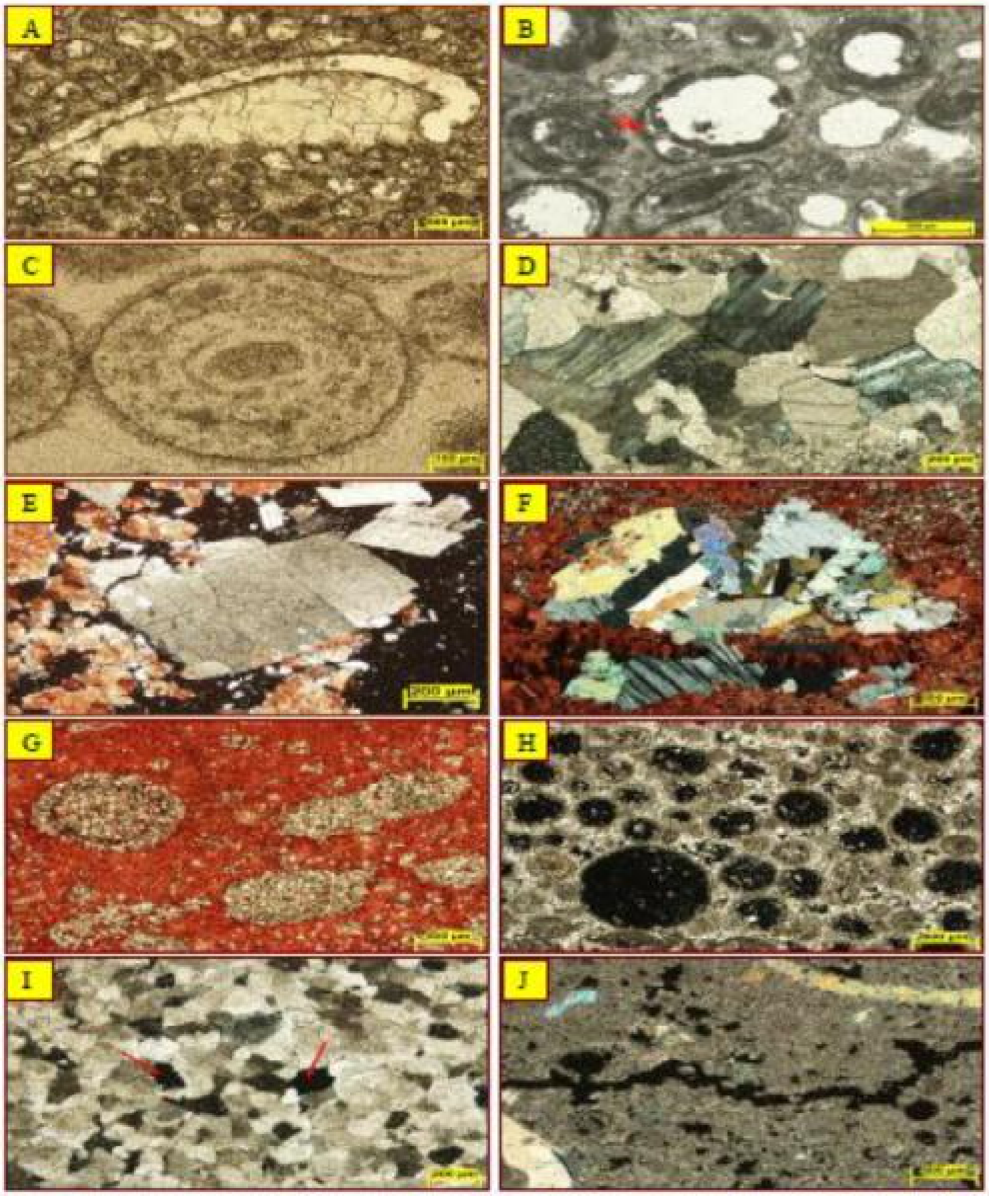

Fig. 2. Photomicrographs of carbonates from the Kangan Formation. A. Bioclast ooid grainstone. Bivalve is dissolved & mold is filled with dolomite. B. Ooid grainstone. Spalled ooid is showed with red arrow; outer layers are broken whereas the inner ones are intact. C. Ooid grainstone. Isopachous cement around the ooids. D. Meteoric cement. Drusy phreatic cement. E. Burial cement. Saddle dolomite with cloudy appearance is filled vuggy porosity. F. Evaporite. Anhydrite cement with calcite & dolomite. G. Dolomitized intraclast ooid packestone. Fabric selective dolomite (dolomitization of ooid & intraclast). H. Dolomitized ooid grainstone. Oomoldic (moldic porosity). I. Dolostone. Intergranular porosity (red arrows). J. Dolomudstone. Channel porosity.