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Carbonate cements investigation in Permo-Triassic Dalan-Kangan reservoirs: Case study in Persian Gulf, Iran

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A b s t r a c t

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This study is conducted to investigate carbonate cement in the Permo-Triassic Dalan-Kangan reservoirs in the Persian Gulf. Samples were analyzed through conventional, cathodoluminescence, and fluid inclusion microscopic techniques. The studied thin sections are cemented by calcite, and dolomite precipitated from marine, meteoric and burial waters that circulated through the sediments during the early and burial diagenesis.

The sequence has gone through five stages of calcite and dolomite cementation that completely or partially occluded pores. Each stage represents a distinctive cement texture, precipitating at specific temperatures, salinity and burial conditions. Precipitation occurred from very early to late diagenesis stages.Cement types appear to be early (1) granular isopachous calcite, with red CL, burial and meteoric (2 , 3) equant calcite with dull red and bright orange CL, burial (4) coarse sparry calcite with dull CL, and (5) fairly coarse secondary dolomite (100<size micron) rhombs with zoning red CL,. With progressive burial and increaseing temperature, fluids are responsible for the cement precipitation in Kangan and Dalan Formations can be subdivided into three groups. Group 1 is fluid with calcite composition, has Th values (126 C), and salinity (16 wt.% NaCl equivalent) and is interpreted to have precipitated during shallow burial from porewater influenced by meteoric water. Group 2 fluid with dolomite composition has Th values (127 C) and salinity (17 wt.% NaCl equivalent), demonstrated that the coarse dolomite crystals was precipitated possibly during shallow burial. Group 3 occurring along fractures is characterized by high Th values (169°C) and salinity (17.5 wt.% NaCl equivalent). It means the fluids with higher temperature, migrated from deeper parts of the basin and filled fractures during deep burial. The oil inclusions with yellow fluorescent can be observed in 3 samples in fracture filling calcite from Dalan Formation. It can be interpreted that oil inclusions are secondary and oil migration posdate the precipitation of fracture filling cements.

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1. Introduction

The studied area is one of the gas fields which is located in the Persian Gulf. Permo-Triassic carbonates (“Khuff equivalent”) form the most important producing reservoir in the Persian Gulf and surrounding area [1,2]. Previous studies have shown that carbonate reservoir rocks can be extremely heterogeneous in nature [3,4]. More than 60% of the reservoir rocks at this field are dolomitized and anhydrite occurs in close association with the dolomites, reflecting the influence of hypersaline depositional conditions on both calcium sulphate precipitation and dolomitization [3].

This paper were studied to recognize different carbonate cements occluding the pore spaces in the permo-triassic Kangan-Dalan carbonates reservoir. Calcite and dolomite cements that formed during burial are found in many carbonate oil reservoirs.

2. Theory

Diagenesis in rocks is generally taken as any process that acts upon sediment or rock that alters it chemical, physical, or textural character. Kangan/Dalan carbonates are extremely susceptible to mineralogical and textural change, cementation and dissolution. These alterations can occur at any time from initial deposition to deep burial. Most diagenetic changes affect porosity, thus must be considered in the exploration for carbonates. The diagenesis of carbonates can take place in many settings: the marine environment during deposition of the sediment, near the sediment surface where fresh waters pierce the sediments, or in brines of the deeper subsurface.

Major diagenetic processes affecting carbonate sediments and rocks in Kangan-Dalan Formation in this well are Bioturbation, micritization, compaction, cementation, neomorphism, dissolution, dolomitization, fracturing and Evaporite mineralization, however; in this paper cementation is illustrated. Cementation comprises processes leading to the precipitation of minerals in primary or secondary pores and requires the super saturation of pore fluids with respect to the mineral. In this case, a chemical precipitate usually calcium carbonate fills the pores. The common type of carbonate calcite cements that has affected the pores are isopachous, equant and course (Figure 1).

Isopachous rim cement forms as a relatively thin film around skeletal grains. This type is not widely distributed. The isopachous nature of this calcite phase indicates precipitation in the marine-pheriatic environment where the all pore spaces are filled with marine water. Under CL the isopachous cement is non- luminescent(Figure 1).

Equant cement occured as pore filling material occluding different types of pore spaces including fractures, interparticle pores, intraparticle porosity such as pore spaces within gastropod and foraminifera. Two luminescent of this cement, the dull red and light bright orange luminescent, shows that it was formed under two different fluid compositions. The bright light orange luminescent (type II, equant calcite) has formed after dolomite cements. Under optical conventional microscope equant calcite attacked to dolomite cement crystals (Figure 1).

Coarse blocky cement filled the facture and molds. It has dull luminescent (Figure 1).

Secondary dolomitization was occurred as cement in some molds and vugs in Kangan-Dalan Formations and they have zoning red luminescence (Figure 1).

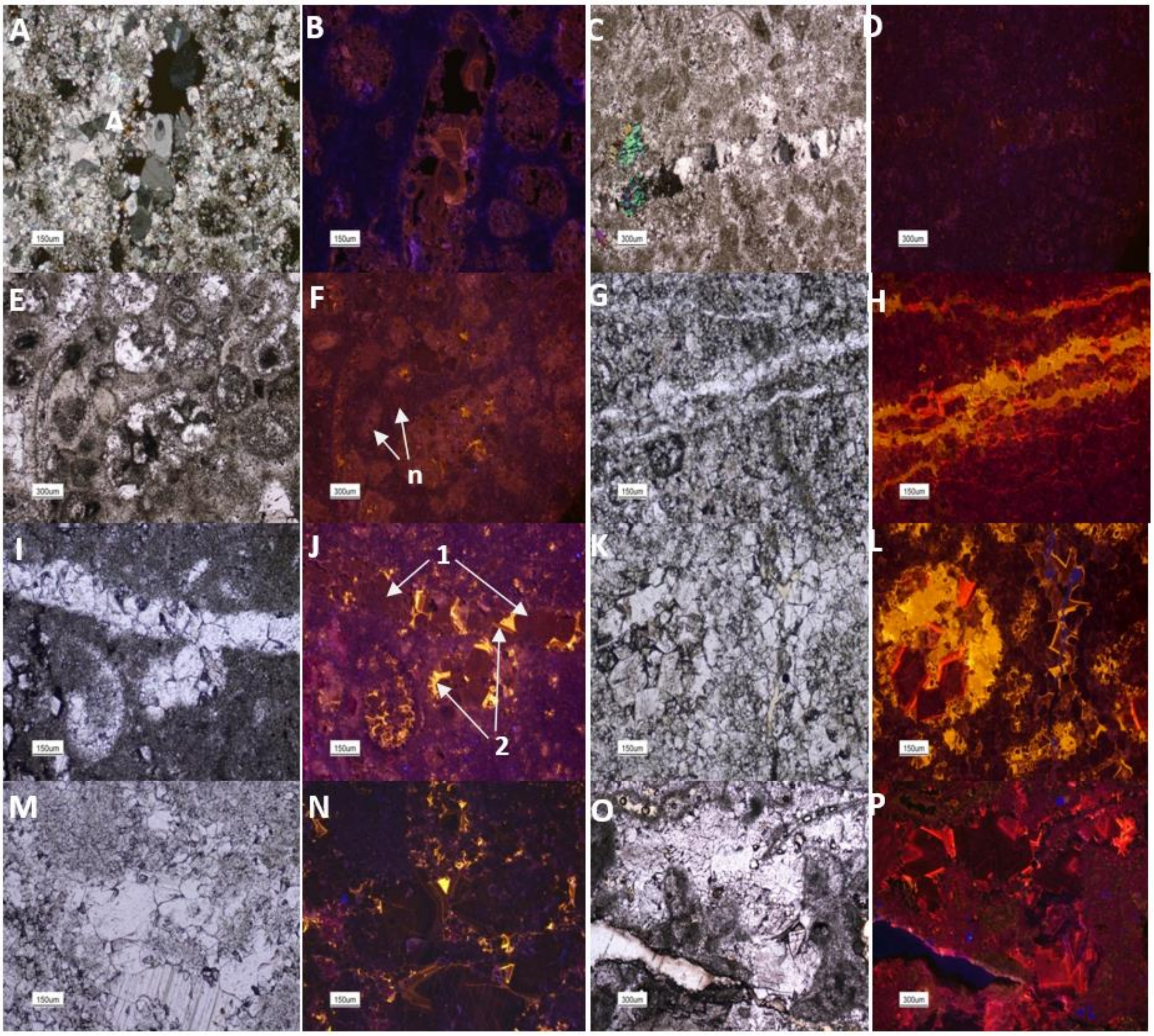

Fig. 1: (A) Equant calcite cement in mold pore space, XPL, and (B) Dull red luminescence (C) Equant burial fracture filing cement- (D) Dull red luminescence (E)Isopachouse fringe (early marine cement) (F) Non luminescence (n) (G)Equant calcite fracture filing cement, (H) Light bright yellow luminescence (I)Mold and fracture filling equant calcite cement, (J) Two generation of calcite cement dull (1) and light bright yellow (2) luminescence (K) Coarse dolomite and equant and coarse pore filing calcite cement, (L) Three generation carbonate cement (coarse dull luminesence, zoning red luminescence dolomite and equant II yellow luminescence) (M) Coarse burial and equant meteoric cements, (N) Two generations dull and Bright light orange luminescence (O) Dolomite pore filling cement, (P) Zoning red luminescence

3. Fluid Inclusion Study

Fluid inclusions are fluid filled vacuoles sealed within minerals. When a crystal precipitates from a liquid, the surface of crystal growth will, inevitably, be less than perfect. Fluid inclusions can be considered as time capsules storing information about temperature and fluid compositions. They may provide valuable information about minimum entrapment temperature of primary fluids. The reported results of fluid inclusions petrography and microthermometric analyses provide the base of considerations about the diagenetic history of the sedimentary sequence in this area. In this study, 3 types of coarse crystalline calcite and dolomite cements were selected for fluid inclusion analysis. Special emphasis was placed on selecting fluid inclusion assemblages (FIAs), who represent the groups of fluid inclusions that presumably trapped at about the same time [5]. If the appropriate fluid inclusions are present, the second step involves verifying the fluid inclusions composition (aqueous or oil inclusion). To distinguish between the two, a microscope with UV epifluorescence attachment must be used. Under UV, most oil- filled inclusions fluoresce revealing a particular color depending on the maturity of the oil. Aqueous inclusions do not fluoresce [10,11].

Petrographic observation show that all of fluid inclusions within calcite cements (pore-filling and fracture-filling) were two-phase aqueous inclusions, while in dolomite cements, two types of inclusions were identified: two-phase aqueous inclusions and hydrocarbon inclusions. Following to this petrographic study, the selected samples were cut into small chips for the microthermometric study.

The determination of temperature of phase change within fluid inclusions during heating and cooling of samples is termed microthermometry. The salinity (wt.% NaCl equivalent) of aqueous inclusions was calculated based on Tmice values according to conversion tables proposed by [12]. Based on petrographic and fluid inclusion analysis, fluids responsible for these cement precipitation in Kangan and Dalan Formations can be subdivided into three groups. Group 1 is fluid with calcite composition, have Th values (mean=126 C), and salinity (mean=16 wt.% NaCl equivalent) and is interpreted to have precipitated during early burial from porewater influenced by meteoric water. Group 2 fluid with dolomite composition have Th values (mean=127°C) and salinity (mean=17 wt.% NaCl equivalent), demonstrated that the coarse dolomite crystals was precipitated possibly during shallow burial. Group 3 occurring along fractures is characterized by high Th values (mean=169 C) and salinity (mean=17.5 wt.% NaCl equivalent). This data point out to precipitation of this cement from saline brines over a range of temperatures. It means the fluids with higher temperature, migrated from deeper parts of the basin and filled fractures during deep burial. These 3 groups are characterized by different Th and salinity values of primary inclusions (Figure.2). Hydrocarbon inclusions can be observed in 3 samples. All of these samples belong to Dalan Formation (oil layer member) and they show yellow fluorescent. It seems that they are secondary inclusions, therefore it can be interpreted that oil inclusions are secondary and oil migration postdates the precipitation of cements. Some of photomicrographs of aqueous and oil inclusions were shown in Figure 3.

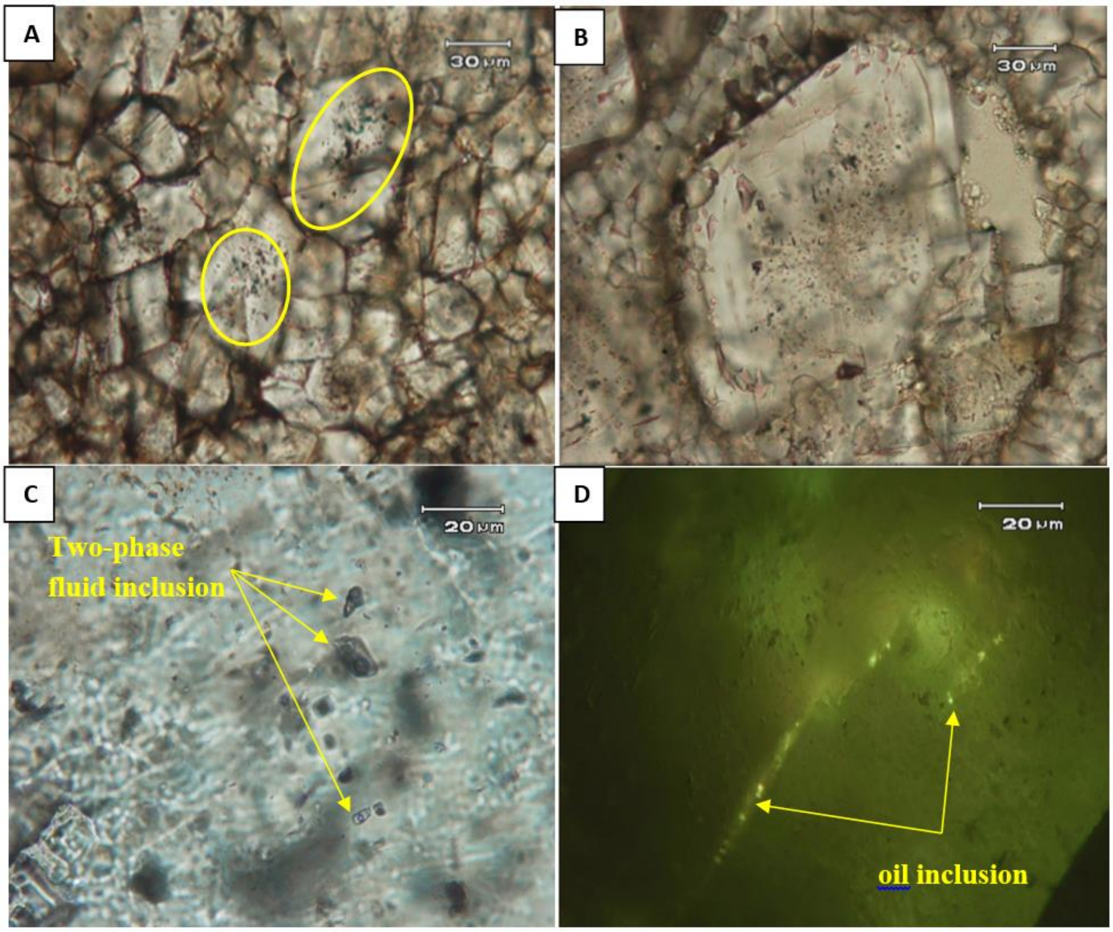

Fig. 2: Photomicrographs of fluid and oil inclusions within coarse crystalline cements in Kangan and Dalan Formations: (A) Small fluid inclusions in pore-filling calcite cement, ppl. (B) Small fluid inclusions in pore-filling dolomite cement, ppl. (C) Medium to large two-phase fluid inclusions in fracture-filling calcite cement, ppl. (D) Secondary oil inclusions which formed along of microcracks, UV light.

4. Conclusion

The Kangan and Dalan Formations are Permo-Triassic carbonates ("Khuff equivalent") form the most important producing reservoir in the Persian Gulf and surrounding area. Thin isopachous calcite in the form of thin irregular calcitic rim with non luminescent precipitated as early alterations on sea floor which is post-date sedimentation, therefore, have been interpreted as early marine cements. Pores occluding carbonate cement is one of the important diagenetic processes affecting carbonate sediments and rocks in Kangan-Dalan Formations in this well. petrography and cathodoluminescence observations revealed that cement types appear to be have two type meteoric (2) equant (bright orange CL) and burial (3) equant calcite(dull red CL), burial (4) coarse spary calcite (dull to non luminescent), and (5) dolomite, airly coarse secondary dolomite (100<size micron) rhombs (zoning red CL). All these processes are indicative of changes from marine phreatic - freshwater phreatric and burial diagenetic environments.

Fluid inclusions analysis has done on 3 types of coarse crystalline calcite and dolomite cements. Based on this investigation, fluids responsible for these cement precipitation in Kangan and Dalan Formations can be subdivided into three groups. Group 1 is fluid with calcite composition is interpreted to have precipitated during early burial from porewater influenced by meteoric water. Group 2 fluid with dolomite composition was precipitated possibly during shallow burial. Group 3 occurring along fractures is characterized by high Th values and it means the fluids with higher temperature, migrated from deeper parts of the basin and filled fractures during deep burial. Oil inclusion were observed only in oil layer in Dalan Formation and it seems that they are secondary and oil migration postdates the precipitation of cements.

Paragenetic of diagenetic processes of Kangan – Dalan Formations are shown in Figure 4.

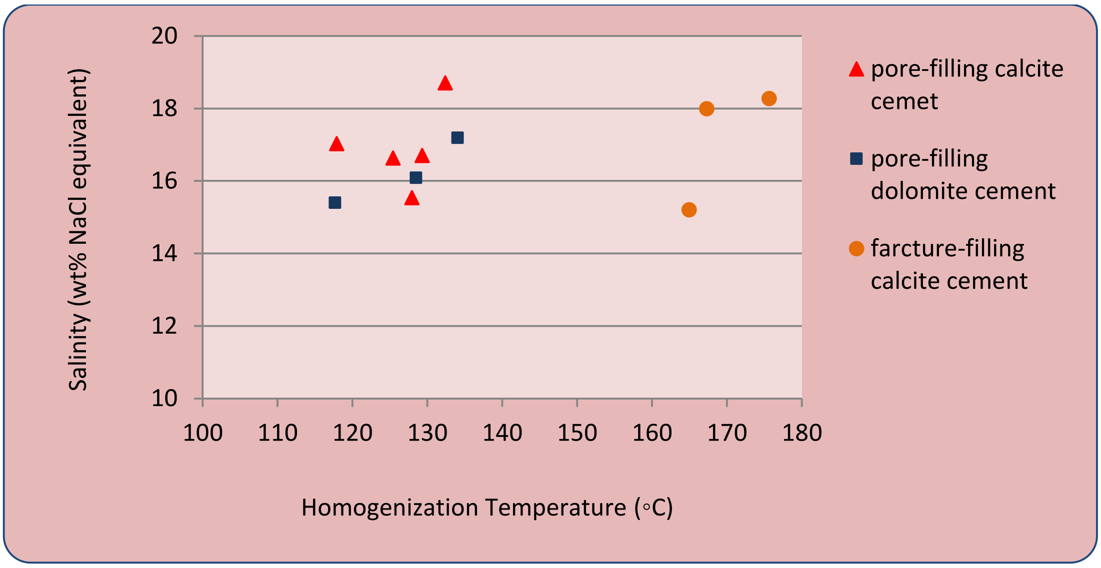

Fig. 3: A cross plot of homogenization temperature (Th) and salinity values (wt.% NaCl equivalent) of fluid inclusions measured from coarse-crystalline calcite and dolomite cements from Kangan and Dalan Formations. Each point represents a fluid inclusion assemblages (FIAs), who demonstrator of the groups of fluid inclusions that presumably trapped at about the same time.

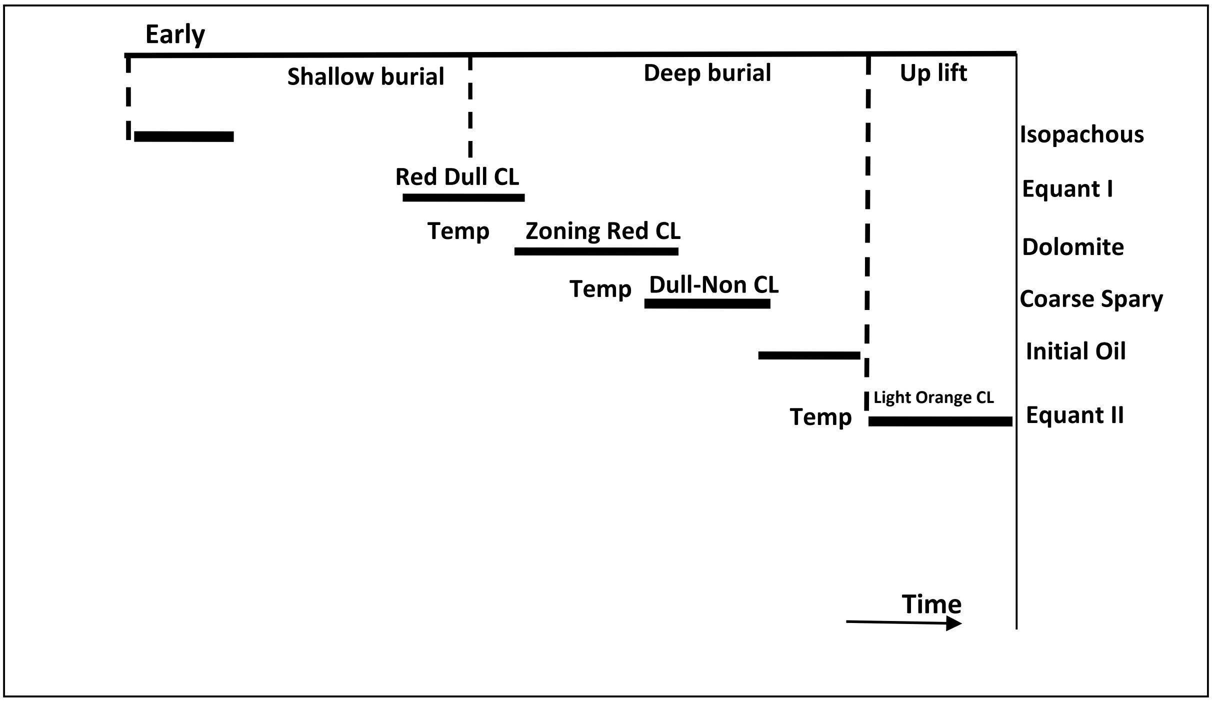

Fig. 4: Diagenetic Paragenesis of Carbonate cement in Kangan-Dalan Formation.

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