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DISTRIBUTION OF CALCITE CEMENTS AND THEIR INFLUENCE ON RESERVOIRS IN THE PRODUCTIVE SERIES OF THE SOUTH CASPIAN AND KUR BASINS

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Summary. The quality of the reservoirs in the Productive Series in the South Caspian and Kur Basins is directly influenced by calcite cementation and compaction. Studying these processes provides an opportunity to analyze diagenetic patterns in sandstones and especially the influence of carbonate cementation on fluvial deltaic sandstones. Precipitation of calcite cement during compaction in clastic rocks significantly affects the permeability of reservoirs and fluid flow during oil and gas production. From this point of view, the distribution characteristics of calcite cement concretions in the reservoirs of the Upper Productive Series in the South Caspian and Kur Basins, and their impact on porosity, permeability and fluid flow have been studied. The distribution of calcite concretions was mapped in outcrops of the Upper Productive Series sandstones in the Yasamal (Shubany) anticline in the western flank of the South Caspian Basin. Large, tabular calcite concretions in this fluvial-deltaic sandstone generally follow basinward-inclined bedding. Based on the XRD and SEM data, a large amount of calcite cement precipitation in the sandstones of the Upper Productive Series (Bal VIII and Bal VI horizons) in the Yasamal (Shubany) anticline has reduced the porosity and permeability for fluid flow. Understanding the depositional environment of calcite cement precipitation observed in the sandstones of the Productive Series in the South Caspian Basin is crucial in evaluating the quality of the analogue reservoirs in the Kur Basin. The presence of large volumes of calcite cement significantly affects the petrophysical properties of reservoirs, which makes studying their origin important.

Introduction

The porosity and permeability of reservoir rock can be controlled by various geological and sedimentological processes. Primary porosity is the direct consequence of lithology, fabric, and texture of clastic rocks, while secondary porosity is generated afterward, through diagenetic processes caused by alteration of the original sediments. Carbonate cement strongly affects fluid flow in sandstone reservoirs, as it is usually distributed unevenly with stratification and concretions, which commonly create barriers to fluid transmission and pressure compartments. These concretions, as one of the features of diagenetic processes such as compaction or the formation of cement can reduce the initial porosity during burial and create a diagenetic fingerprint to the permeability distribution as well, which should be incorporated into reservoir models for simulation fluid flow. Considerable research works have been attracted on impact of calcite cement diagenesis to reservoir quality in sandstones (e.g., Kantorowicz et al., 1987; Saigal, Bjørlykke, 1987; Walderhang et al., 1989; Bjorkum, Walderhang, 1990; Sulivan, McBride, 1991; Ortoleva,1994; McBride et al., 1995; Mozley, Davis, 1996; Crossey et al., 1996; Milliken et al., 1998; Morad, 1998; Walderhang, Bjorkum, 1998; Worden, Matray, 1998; Klein et al.,1999; Dutton et al., 2000; Taylor et al., 2000; Dutton et al., 2002; Boles, Ramseyer, 2002; Dutton, 2008; Delu Xie et al., 2020; Zeynalov, 2024).

However, calcite cements generally occur as irregularly distributed concretions in sandstones, and quantifying the effect of concretionary carbonate cement on fluid flow in sandstone reservoirs is not easy. This makes it challenging to forecast diagenetic permeability modifications in the subsurface from spaced wells. Therefore, an outcrop study can help to observe a continuous image of the spread of cement in analogues reservoirs.

In this paper, we studied distribution of calcite cement concretions in the exposed Upper Productive Series (Balakhany suite) of the Absheron peninsula, South Caspian Basin, and their impact on porosity and permeability properties of sandstone reservoirs of the Balakhany VIII (Bal VIII) and Balakhany VI (Bal VI) horizons.

In our study, calcite concretions were mapped in a well-exposed outcrop of the Balakhany Suite sandstones (Bal VIII and Bal VI horizons) of the Upper Productive Series fluvial-deltaic sandstones in the Yasamal Valley of Absheron peninsula in the western flank of the South Caspian Basin.

Our goals were to (1) quantify the volume and spatial distribution of calcite concretions, (2) analyze the effect of the cement on fluid flow, and (3) provide comparison of petrophysical properties of calcite-rich consolidated and unconsolidated sandstones data that can be used to condition models of concretionary calcite-cement distribution in the subsurface. Our study demonstrates the importance of diagenesis-modified permeability distribution in consolidated tight sandstones for reservoir models.

Geological settings

The South Caspian and Kur Basins are the main geostructural elements in the Caspian and Caucasus regions of the Alpine-Himalayan folded belt. The South Caspian Basin encompasses the territory of the south part of the Caspian Sea. It is bordered by the Kur Basin in the east, which covers the intermontane area of Azerbaijan and SE Georgia (Fig.1).

The South Caspian Basin's basement surface lies at a depth of 22–25 km, making it one of the deepest basins in the world. The sedimentary fill of the South Caspian Basin has been significantly deformed and folded. The folded succession is unconformably overlain by the Lower Pliocene–Quaternary sediments (Zonenshain, Le Pichon, 1986; Granath, Baganz, 1996; Jackson et al., 2002; Allen et al., 2002; Allen et al., 2003; Brunet et al., 2003; Abdullayev et al., 2018).

Compared to the South Caspian Basin, the Kur Basin has more complicated geological history with multi-phase active tectonic processes accompanied by the collision, accretion, and rotation of the plates of the Eastern European Platform and Arabian plate during the Eocene-Pliocene period which were accompanied by different types of volcanogenic processes, abrupt changes in facies and facies associations, and stratigraphically irregular oil and gas accumulations in volcanic, carbonate and siliciclastic rocks. The Kur intermountain basin is a large structural element separating the Greater and Lesser Caucasus Mountain systems and is represented by the Lower Kur and Middle Kur (Yevlakh-Agjabedi trough, interfluve of the Kur and Gabyrry, Ajinohur trough) and Upper Kur (Kartly) sub-basins.

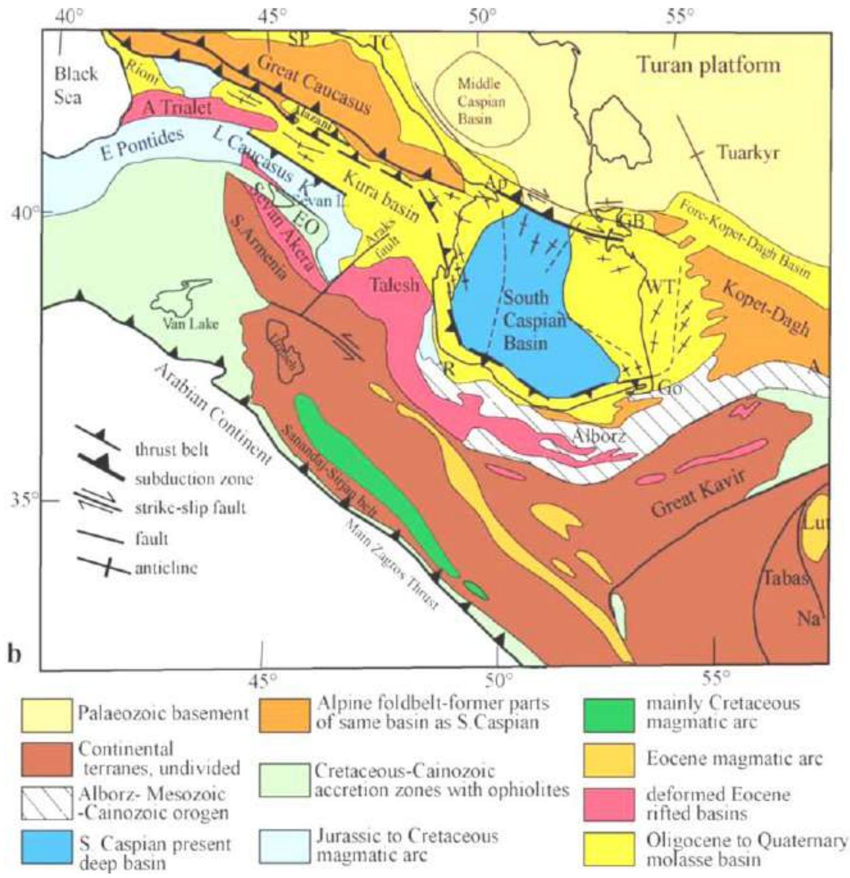


Fig. 1. Regional geological map of Caspian region main tectonic units (from Brunet et al., 2003)

The eastern part of the basin called the Lower Kur sub-basin is close in its deep structure and geological development to the South Caspian Basin, which in relatively recent Pliocene-Quaternary period was characterized by high rates of sedimentation. Tectonically, the Lower Kur is a deep buried sub-basin (the depth of the crystalline basement is 20-22 km) extending towards the General Caucasus. Although the Lower Kur sub-basin is the eastern part of the Kur intermountain basin, in general this indicates that it is a northeastern extension and the bay of the South Caspian Basin. The latter idea is confirmed by the mutual similarity of the elements of the geological structure and the history of geological development both in the Southern Caspian Basin and in the Lower Kur Basin (Khain, Shardanov, 1952; Zonenshain, Le Pichon, 1986; Granath, Baganz, 1996; Devlin et al., 1999; Jackson et al., 2002; Allen et al., 2002; Allen et al., 2003; Brunet et al., 2003; Guliyev et al., 2003; Golonka, 2004; Kadirov, 2004; Artyushkov, 2007; Nemcok et al., 2011; Forte et al., 2012; Kadirov and Safarov, 2014; Javanshir et al., 2015; Alizadeh et al., 2016; Abdullayev et al., 2018).

In the South Caspian and Kur Basins, oil and gas reservoirs are associated with a wider stratigraphic interval from the Upper Cretaceous to the Lower Pliocene rocks. The majority of the reservoirs are located in the Lower Pliocene Productive Series sandstones (Ushkin, 1916; Gorin, 1939; Aliev, 1960; Alizadeh et al., 1966; Guliyev et al., 2003; Aliyeva, 2005; Alizadeh et al., 2018).

The Productive Series considered being the main reservoir facies in the South Caspian and nearby Lower Kur Basins (the eastern part of the Kur Basin) were transported and deposited by the Paleo-Volga, Paleo-Amu Darya, Paleo-Kur and Paleo-Pirsagat rivers after the isolation of the Caspian Lake from the world ocean in the Late Miocene. The giant Paleo-Volga River played a significant role in bringing a large quantity of sand-rich sediments of the Productive Series, which caused the creation of quartz-rich, high-quality reservoirs of sandstones distributed toward Absheron and the NW part of the Baku archipelago in the South Caspian and Lower Kur sub-basins. (Jones, Simmons, 1996; Granath, Baganz, 1996; Reynolds et al., 1998; Devlin et al., 1999; Morton et al., 2003; Hinds et al., 2004; Aliyeva, 2005; Hinds et al., 2007; Green et al., 2009; Abdullayev et al., 2018; Zeynalov, Alkhasli, 2018; Zeynalov, 2022).

Facies of the Productive Series have a very wide distribution and mainly are represented by the alternation of sand, sandstone, shales and sometimes with coarse grained rock fragments with thickness of more than 3500 meters. Thick strata of conglomerates and breccia of the Productive Series appeared in the peripheral parts of the Lower Kur Basin. The most productive reservoirs of the Productive Series in the South Caspian Basin are associated with the Fasila and the Balakhany suits in its upper section, and their analogues in the Lower Kur sub-basin are XIV–XX horizons.

Calcite cementation and diagenesis are one of the important control elements of the quality of these fluvial deltaic reservoirs. In some cases, cementation and compaction can reduce porosity, and in other instances, cemented sediment can create dissolution resulting in increasing pore spaces and permeability of reservoirs.

Such calcite cement occurrence is observed in the outcrops of the Balakhany suite's fluvial-deltaic sandstones in the Lower Pliocene Productive Series in the Absheron Peninsula and which is considered a good analogue of the major reservoirs of the Azeri-Chirag-Azeri (ACG) field in the South Caspian Basin and the Lesser Harami, Greater Harami, Pirsagat, etc. fields in the Lower Kur sub-basin (Zeynalov et al., 2017; Zeynalov, Alkhasli, 2018; Alkhasli et al., 2022; Zeynalov, 2022).

Sharp facies changes characterised by fluvial-deltaic and lacustrine depositional environments in the geological section of the Productive Series indicate its heterogeneity of reservoir properties. The Balakhany, Sabunchu, and Surakhany suites of the upper section of the Productive series are exposed at the Yasamal (Shubany) anticline in the Absheron peninsula, specifically in the area of the SE and NNE plunging of the Shubany anticline. In this regard, it is very important to pay attention to the study of controlling factors affecting the quality of reservoirs including the calcite cement diagenesis of rocks, both in the South Caspian Basin and in the neighbouring Kur Basin.

The Shubany anticline is situated in the Absheron peninsula of the western flank of the South Caspian Basin. On the limbs and periclinal ends of the anticline fold, sandy and shaly sediments of the Balakhany, Sabunchu, and Surakhany suits of the Productive Series are widely exposed. The anticline structure is sharply asymmetrical. At the same time on the western limb, dipping angles of the layers varies within 45-65^0, and on the eastern limb the layers are placed on their heads and in places overturned. As the fold submerges, dipping angles gradually decrease. The anticline has plunging structure and was complicated by three longitudinal faults and one of which has thrust character formed as a result of thrusting the west limb and dome of the anticline to the east limb (Fig. 2). The thrust merges at depth with another longitudinal fault. A number of small transverse faults were also revealed (Alizadeh et al., 1966).

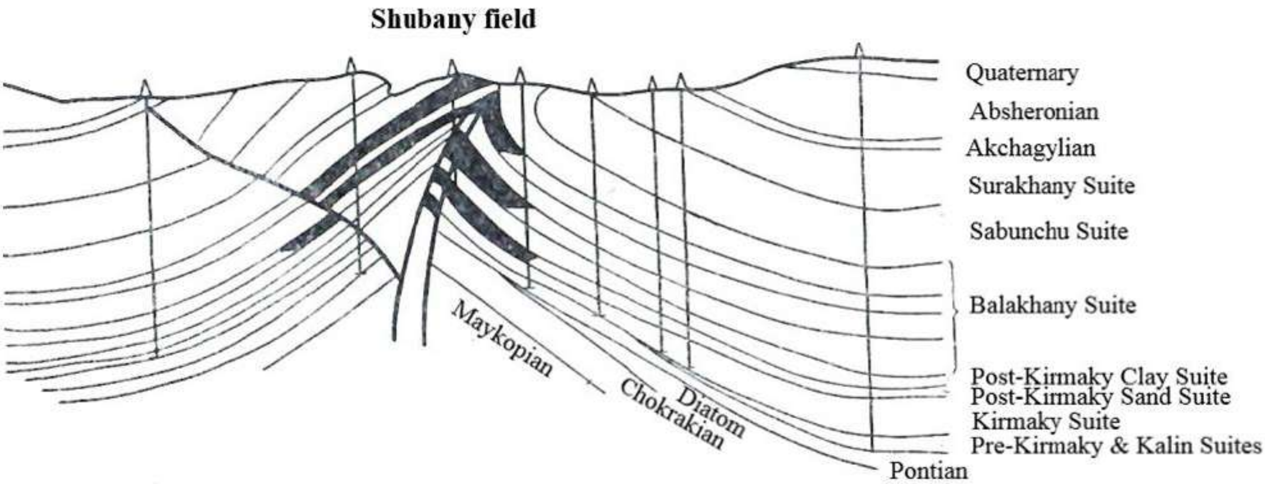


Fig. 2. Schematic cross sections through the Shubany oil field illustrating outcropping and the presence of oil accumulations in the Upper Productive Series (Balakhany, Post-Kirmaky Sand Suits) (From Alizadeh et al., 1966)

The Shubany anticline has the most favourable conditions for studying calcite cement concretions on the well-outcropping Upper Productive Series, which was chosen as the main area of investigation of the study of the mentioned problem (Fig.3).

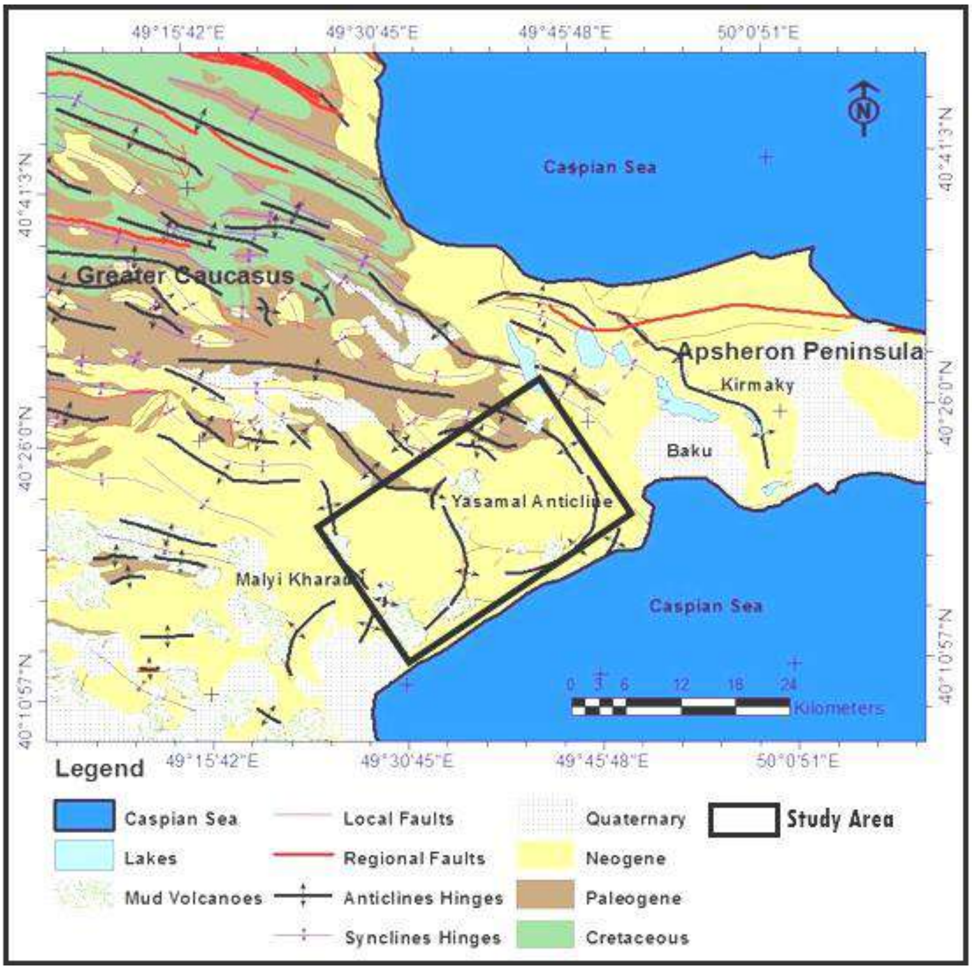


Fig. 3. Geological map of the Absheron peninsula and surrounded area showing location of the study area (from Allen et al., 2003)

Methodology

Field measurements using a Gamma Ray Spectrometer and laboratory study of the XRD, SEM, Thin Section Petrography, porosity, and permeability measurements were used to map the distribution of calcite cement concretions in the outcrop, quantify the volume and spatial distribution of calcite concretions, analyse the cement's effect on fluid flow, and provide a comparison of petrophysical properties.

The fieldwork survey was conducted in the Shubany anticline, where calcite cement precipitation was observed in outcrops of sandstones of the Balakhany Suite with fluvial-deltaic depositional environment. For these purposes, field measurements were performed across the sand-dominated Balakhany VI and Balakhany VIII horizons using the Gamma Ray Spectrometer (MGS-150).

Measurements were conducted in two locations: in the southern (log1) and northern (log 2) parts of the outcrop of the east limb with a length of 5.1 km (Fig.4), where calcite cement concretions are widely distributed in amalgamated broad, shallow channels of coarse-to-medium grained sandstone of the Balakhany VIII horizon and proximal floodplain and major channel sands with planar based, sheet-like medium-fine-grained sandstone of the Balakhany VI horizon of the Balakhany suite. These sand-dominated horizons were deposited during increased fluvial-deltaic discharge and coarse to medium-fine-grained sediment input to the South Caspian Basin.

Measurements show that calcite-rich sandstones are distributed along the east limb of the anticline starting from the north end of the structure and extending around two km towards the south. Calcite cement is precipitated mostly in channel-fill fluvial sandstones in the form of tabular concretions (Fig.5). These concretions generally follow basin ward-inclined bedding but in rare cases terminate within a bed across facies.

In some surveillances, calcite concretions have eroded, since being exposed as an outcrop, and hematite has precipitated in the resulting pores giving the concretions a reddish-dominated colour, easily distinguished from unconsolidated sandstones around them. However, field measurements alone are not sufficient for a full evaluation of the properties of the revealed calcite cement-rich rock units. Properties of calcite cement diagenesis were also studied on the micro-scale to look for their dependency on intrinsic rock properties based on merged analysis of thin section petrography and laboratory measurements such as the XRD and SEM on samples acquired from the outcrops of the mentioned sandstone horizons in the Shubany anticline.

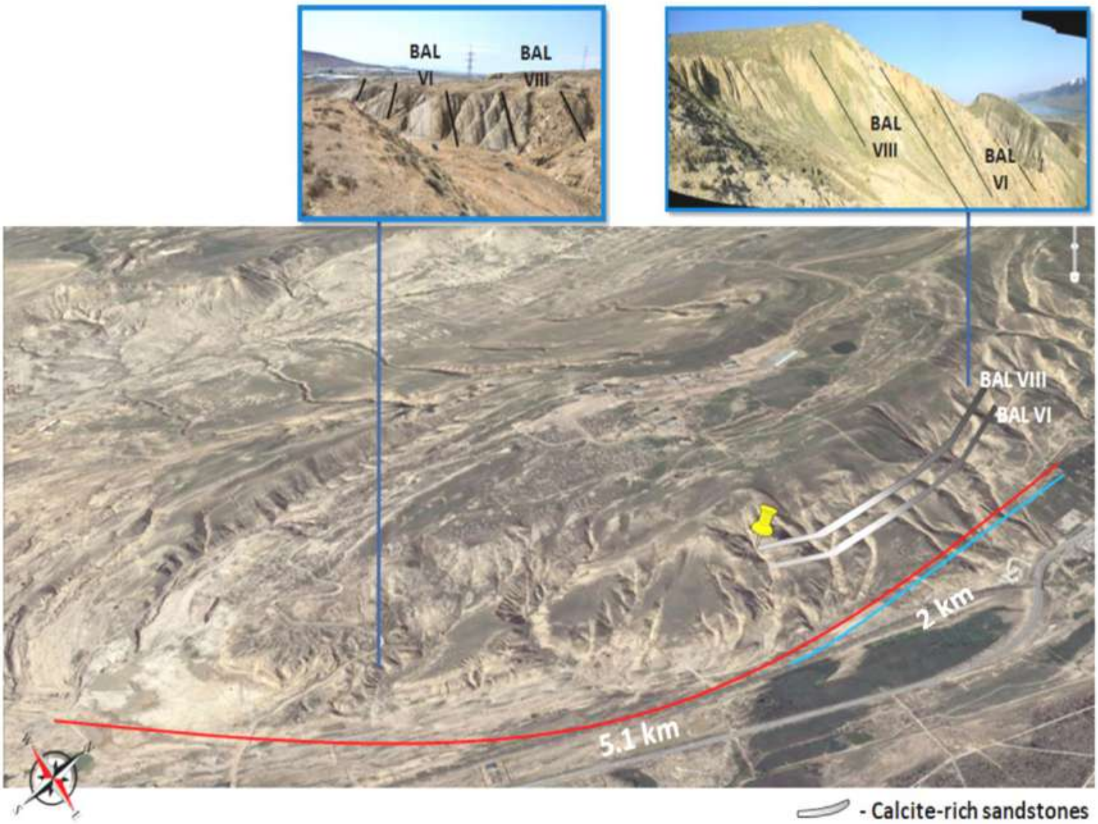


Fig. 4. Calcite cement concretions in Balakhany VIII and Balakhany VI horizons' sandstones observed at NE limb, Shubany anticline (Zeynalov et al., 2017)

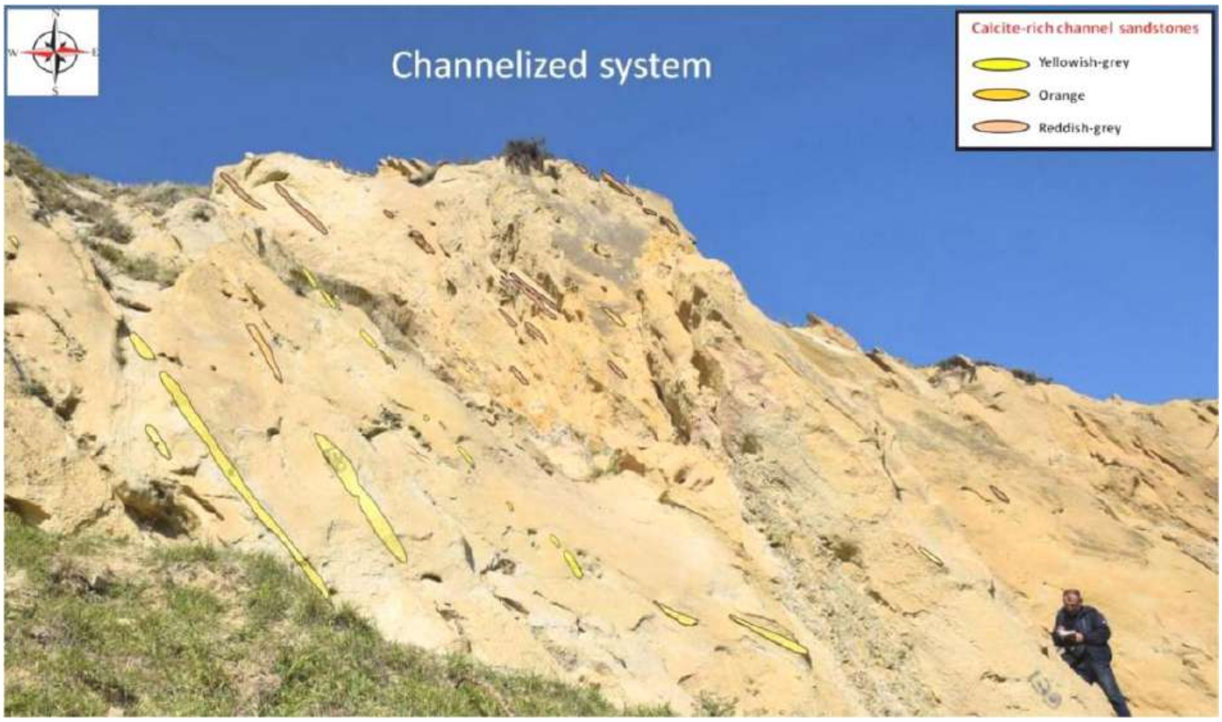


Fig. 5. Distribution of the calcite concretions in Bal VIII horizon sandstones in the northern part of the east limb, Shubany anticline (Zeynalov et al., 2017)

Results of the XRD measurements of sandstone samples from the Balakhany suite show that they have abrupt changes in volumes of minerals in the whole mineralogical composition (Fig.6). Based on this measurement calcite cement precipitation makes up 10-18% of rocks in the SE limb while in the NE limb of the Subany anticline, it makes up 40-45%, comprising almost half of the rock composition. Feldspar and clay minerals are of low percentages, and, hence, calcite is the dominant cementing material in observed sandstones.

A higher concentration of deformation bands was observed in the northern part of the eastern limb of the Shubany anticline, where calcite precipitation occurred. Calcite cement-rich sandstones undergo strong diagenesis and are abundant in deformation bands commonly displaying a clustered pattern (Fig.7).

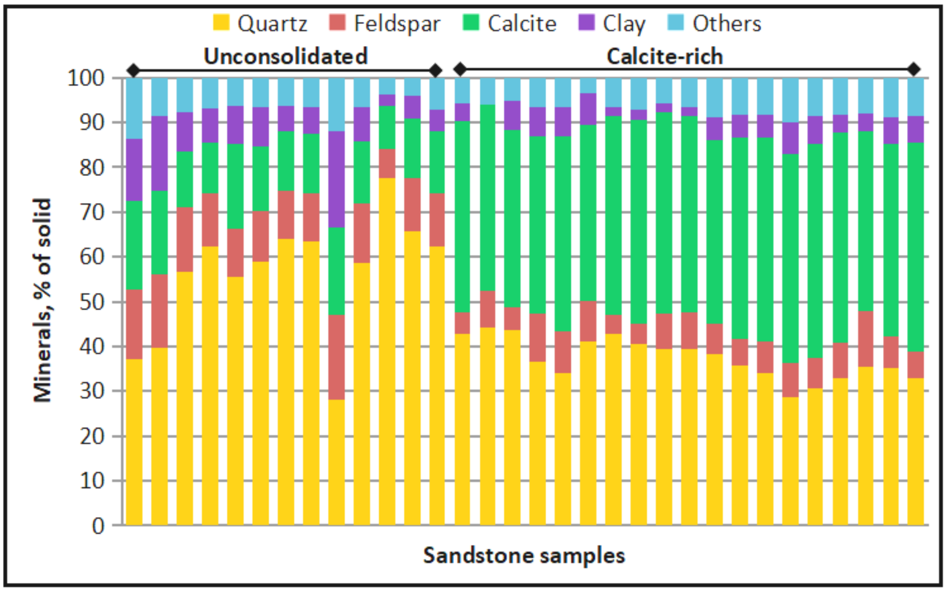


Fig. 6. Bar chart displaying fractions of per mineral species from sandstone plugs on the Balakhany VIII and Balakhany VI sandstones based on XRD measurements

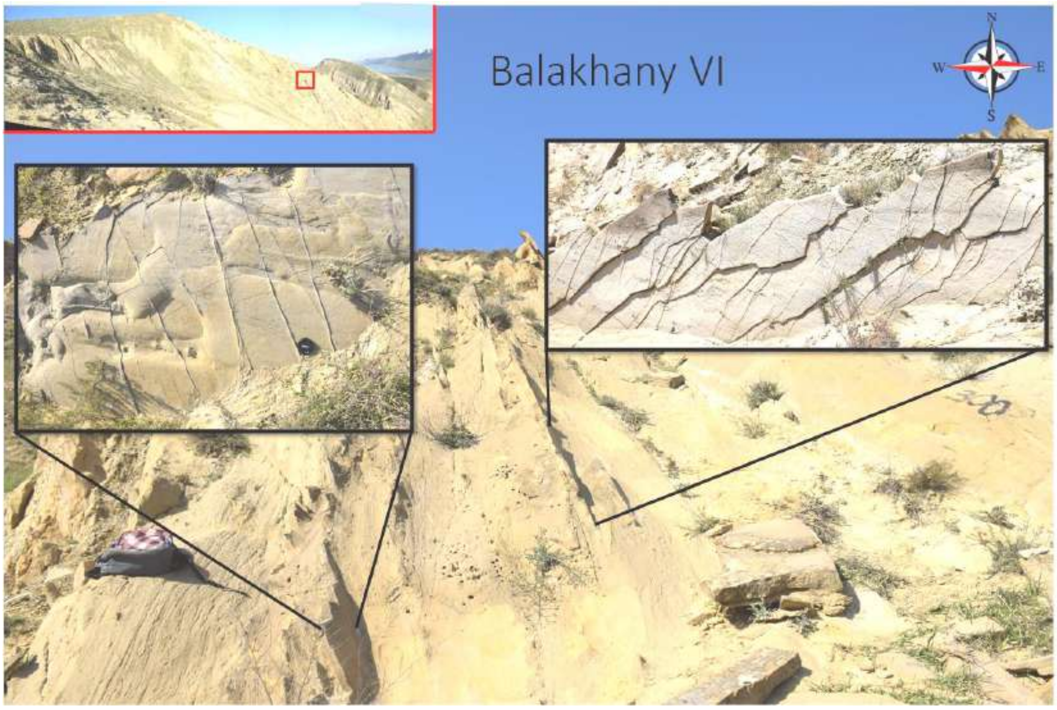
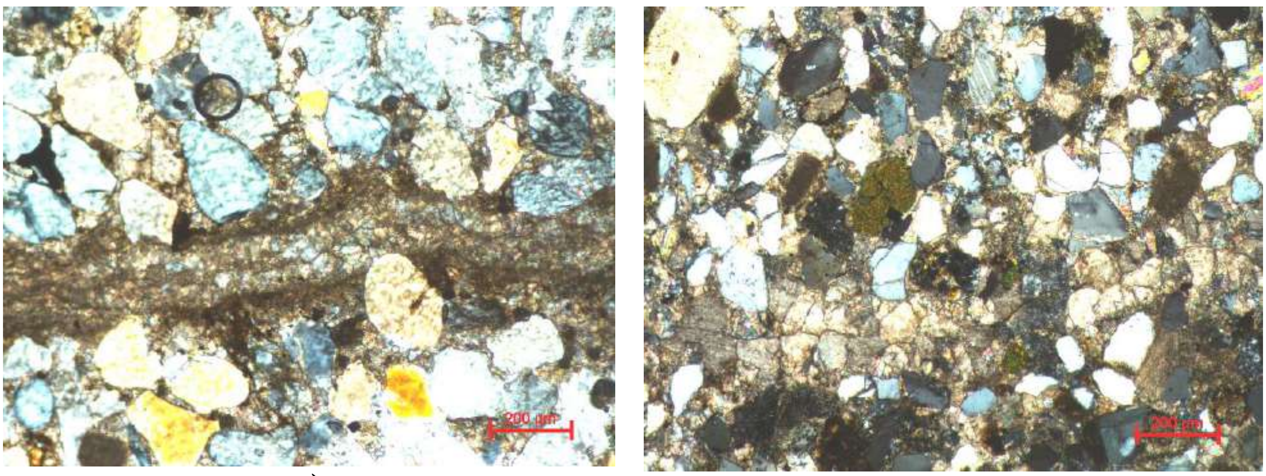


Fig. 7. Calcite-rich sandstone layers of the Balakhany VI complicated by deformation bands in the NE limb of the Shubany anticline (Zeynalov et al., 2017)

Thin sections allowed checking grain arrangements in rock bodies filled with calcite cement (Fig.8). The photomicrographs of the thin sections display a high degree of compaction and cementation in both examples of calcite-rich sandstones. Grain morphology varies from subangular to subrounded, and grain size is medium to fine with uniform distribution. These samples display the dissolution of grains generated by deterioration with grain size reduction (Fig. 8a) and calcite cement concretions deteriorated within the deformation band, meaning calcite precipitated prior to formation of deformation band (Fig. 8b).

The SEM images allowed visualization of pore space filling by calcite cement. Quartz grains were outlined based on the distribution of Si elements inside the sample (Fig. 9c). Si can be a constituent of several minerals other than quartz, such as feldspars and clays. Therefore, to separate quartz (SiO_2) those grains with only Si responses were selected. Any other element responds, such as K, Na, Ca, and Al along with Si are indicators of feldspar/clay minerals. Calcite cement was outlined in the same way based on the distribution of Ca inside of the sample (Fig.9d). As seen in Fig. 9c and Fig. 9d, calcite cement fills up much of the pore space. Figure 9b shows a quartz grain coated by calcite crystals. Based on XRD measurements, calcite comprises 45% of this sandstone sample.



a) b)

Fig. 8. Photomicrographs of calcite-rich sandstone samples: (a) a mixture of quartz, feldspar, and calcite-cement with deformation band (Balakhany VI sample); (b) Calcite cement-rich, minor feldspar with deformation band (Balakhany VIII sample)

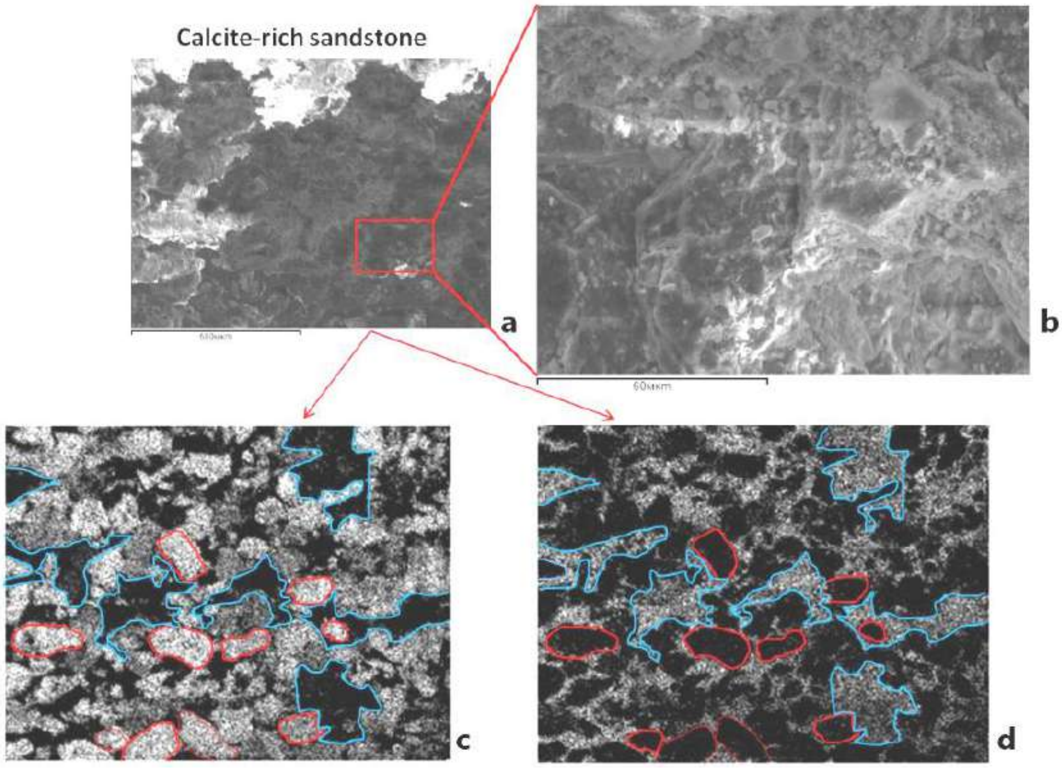


Fig. 9. SEM images visualizations of pore space filled by calcite cement in the Bal VIII horizon sandstone: (a) stacked SEM image of a calcite-rich sample; (b) zoomed in section of A, displaying coating of a quartz grain by calcite cement; (c) distribution of Si, and (d) distribution of Ca inside of the sample. Example quartz grains and calcite cement are outlined in red and blue, respectively

Since a lot of the pore space is occupied, calcite cementation significantly reduces porosity and, hence, the permeability of the rocks. It is observed in comparison of the petrophysical properties of calcite-rich and unconsolidated sandstones (Fig.10).

There is a sharp decrease in porosity and permeability as calcite cement volume increases in the Balakhany VIII horizon sandstones, which negatively impacts to reservoir quality in the northern part of the east limb of the anticline.

A comparison of porosity with the amount of calcite fraction in its mineral composition is also considered. Here, an increase of 40-45% in the amount of calcite fraction increased the consolidation of the rock, which caused a significant decrease in porosity (Fig. 11a). The same pattern is observed in comparison with the permeability. The amount of calcite fraction in the rock is more than 40% increasing its consolidation degree, so the permeability is significantly reduced (Fig. 11a).

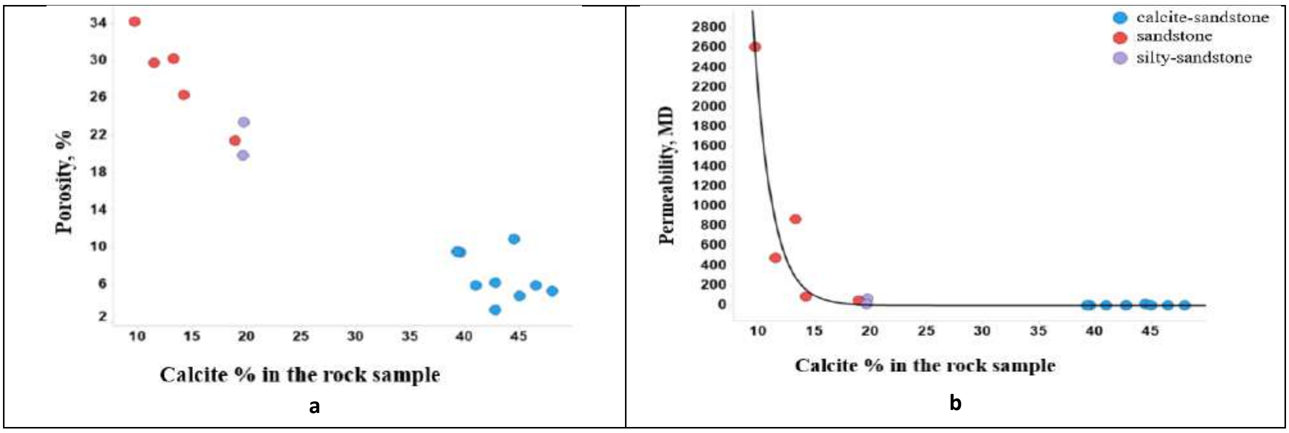


Fig. 10. (a) Porosity vs calcite fraction plots for rock sample; (b) Permeability vs calcite fraction plots for rock sample

The amounts of total clay and calcite cement content and their effect on the porosity of sandstone rock samples from the Balakhany VIII and Balakhany VI horizons were also studied. Results of the laboratory measurement show that the porosity is 20-30% when the content of both total clay and calcite in rock samples is no more than 10-15 %. Conversely, when the clay content exceeded 20%, the porosity dropped below 20%, especially with lower volumes of calcite cement (10-12 %) (Fig.11c).

If we make the same comparison of the permeability properties of the rock, a similar case can be observed here. Thus, when the amount of both total clay and calcite in the rock sample varies between 10-12%, it can be observed that the permeability value is more than 1000 mD, and if the percentage of total clay is more than 20% and the amount of calcite is low, the permeability decreases significantly to less than 20 mD (Fig.11d).

Discussion of results

The presence of calcite cement concretions in the pore space of sandstone rocks increased consolidation reducing the porosity and permeability of reservoirs for fluid flow in the Balakhany suite, primarily in the Balakhany VIII and Balakhany VI horizons in the north-eastern limb of the Shubany. These are potentially good analogues of the ACG reservoirs in the South Caspian Basin and the Lesser Harami, Greater Harami, and Pirsagat fields in the Kur Basin. Most of the sandstone reservoirs in these areas are related to the upper part of the Productive Series. Based on well data, high-volume calcite cement is distributed irregularly in these sandstones.

The highest calcite cement fraction significantly reduced effective porosity in the lower permeable facies. The increasing calcite cement fraction is caused by increasing concretion size. Analysis of these features reveals that concretions make flow paths more tortuous and retard flow in the coarser facies near the top of the sandstone. The fastest path through the sandstone is in the lightly cemented, high net-to-gross center of the sandstone body. The upward-increasing cement fraction is caused by upward-increasing concretion size.

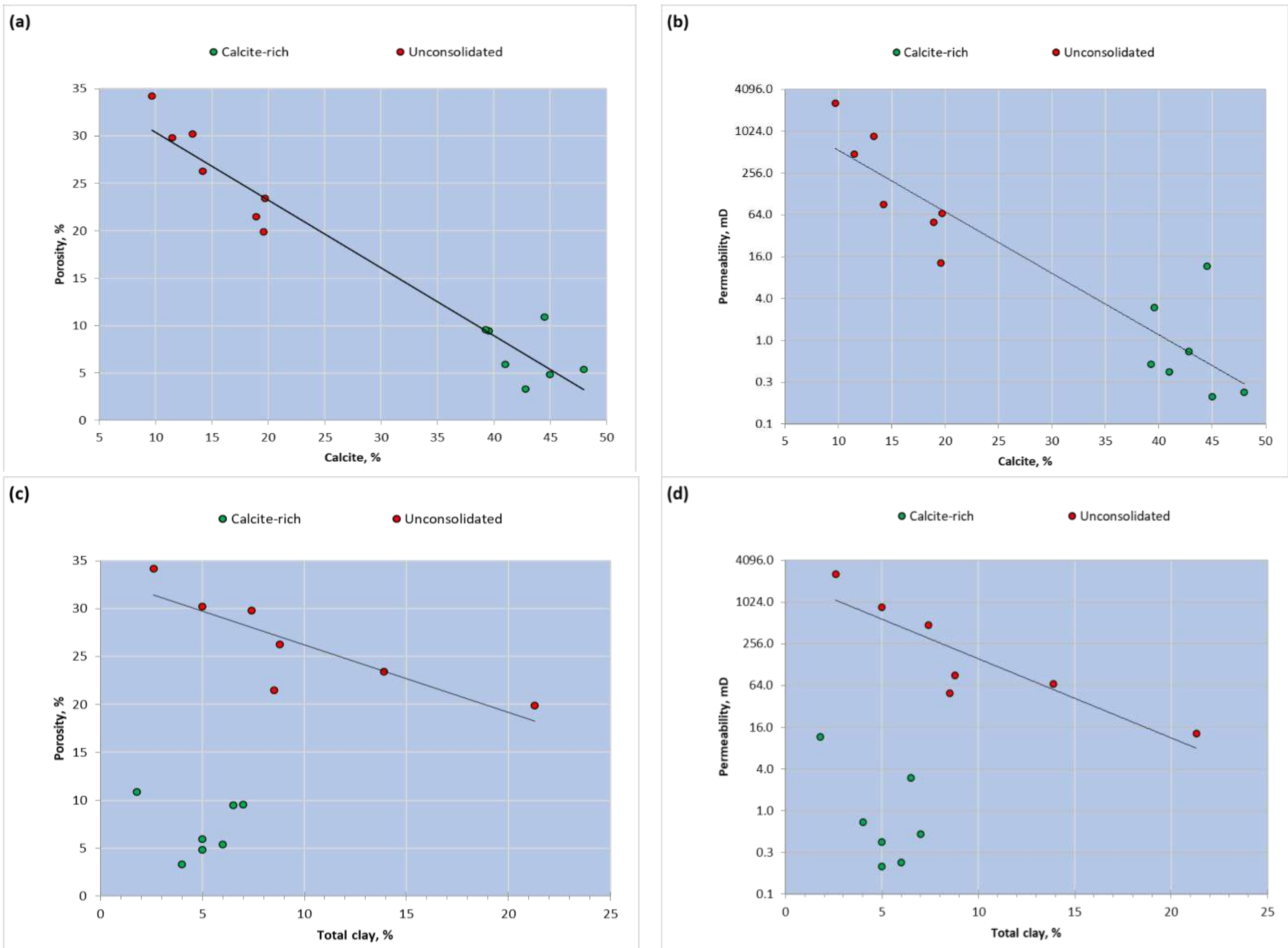


Fig. 11. (a) – Porosity vs calcite cement volume for rock sample; (b) – Permeability vs calcite cement volume plots for rock sample; (c) – Porosity vs total clay volume for rock sample; (b) – Permeability vs total clay volume for rock sample of the Balakhany VIII and Balakhany VI horizons

The Balakhany suite sandstone facies of the Productive series were formed during the period of increased fluvial-deltaic discharge and sediment supply, while mudstone-prone settings. Fresh groundwater is considered the primary source for the precipitation of calcite cement concretions in this suite. Climatic changes, fluctuations of the Caspian Lake, and groundwater flow direction influenced on the formation of calcite concretions in fluvial channel sandstones in the NE limb of the Shubany anticline.

Understanding the depositional environment of calcite cement precipitation observed in the sandstones of the Balakhany suite in Shubany field of the South Caspian Basin is crucial in evaluating the quality of the analogue's reservoirs in the Kur Basin. The varying volume of calcite cement in sandstones can significantly affect the petrophysical properties of reservoirs, making its study essential.

Conclusions

The sandstones of the Balakhany VI and Balakhany VIII horizons in the South Caspian Basin, and their analogues in the Kur Basin, were formed due to a high amount of sediment input and fluvial-deltaic discharge deposits. Fresh groundwater is considered the primary source for the precipitation of calcite cement concretions in these horizons.

The calcite cement concretions observed in the sandstones of the Balakhany VI and Balakhany VIII horizons can be used to indicate the presence of groundwater calcrete. These concretions formed during both humid and arid climatic periods and are linked to the high-frequency base-level fluctuations of Caspian Lake, which are caused by the oscillation of the water table and groundwater flow direction influenced on the formation of calcite concretions in braided fluvial channel sandstones.

A large amount of calcite cement precipitation (more than 30%) in the sandstones of the Balakhany VIII and Balakhany VI horizons has reduced the porosity and permeability, while a small amount of these cements (less than 15%) played a significant role in increasing quality of reservoirs in the South Caspian Basin.

Irregular distribution of calcite cement concretions is strong evidence of their fluvial-deltaic depositional environments which is revealed by labyrinth type of architecture of calcite cement rich sandstones of the Balakhany VIII and Balakhany VI horizons in the Shubany field of the South Caspian Basin. These results can be applied to the nearby Kur Basin to evaluate the properties of similar reservoirs. These results can be applied to the nearby Kur Basin to evaluate the properties of similar reservoirs.

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REFERENCES

Abdullayev NR, Weber J, van Baak GC et al (2018) Detrital zircon and apatite constraints on depositional ages, sedimentation rates and provenance: Pliocene Productive Series South Caspian, Basin, Azerbaijan. Basin Res 30(5):835–862. https://doi.org/10.1111/bre.12283

Aliev AK (1960) Geology and hydrocarbons of the Kura-Araks Region. Azerneftneshr, Baku, p 361 (in Russian)

Aliyeva EGM (2005) Reservoirs of the lower Pliocene productive series at the western flank of the south Caspian basin. Lithology and Mineral Resources 40(3):267–278

Alizadeh AA, Ahmedov HA, Ahmedov AM et al (1966) Geology of oil and gas fields in Azerbaijan. Nedra, Moscow, p 392 (in Russian)

Alizadeh AA, Guliev IS, Mamedov PZ (2018) Productive strata of Azerbaijan. vol 2, Nedra, Moscow, p 236 (in Russian)

Alizadeh AA, Guliyev IS, Kadirov FA, Eppelbaum LV (2016) Geosciences in Azerbaijan. Geology, vol 1, Springer. Heidelberg, New York, p 239

Alkhasli S, Zeynalov G, Shahtakhtinskiy A (2022) Quantifying occurrence of deformation bands in sandstone as a function of structural and petrophysical factors and their impact on reservoir quality: an example from outcrop analog of Productive Series (Pliocene), South Caspian Basin. Journal of Petrol Explor Prod Technol 12:1977–1995. https://doi.org/10.1007/s13202-021-01448-z

Allen MB, Vincent SJ, Alsop GI, Ismail-zadeh AJ, Flecker R (2003) Late Cenozoic deformation in the South Caspian region: effects of a rigid basement block within a collision zone. Tectonophysics 366(3–4):223–239. https://doi.org/:10.1016/S0040-1951(03)00098-2

Allen MB, Jones S, Ismail-Zadeh A et al (2002) Onset of subduction as the cause of rapid Pliocene–Quaternary subsidence in the South Caspian Basin. Geology 30(9):775–778

Artyushkov EV (2007) Formation of the superdeep South Caspian basin: subsidence driven by phase change in continental crust. Russian Geology and Geophysics 48(12):1002–1014

Bjørkum PA, Walderhaug O (1990) Lateral extent of calcite cemented zones in shallow marine sandstones. In: Buller AT, Berg E, Hjelmeland O (eds) North Sea oil and gas reservoirs–II. Graham and Trotman, London, pp 331–336

Boles JR, Ramseyer K (2002) Diagenetic carbonate in Miocene sandstone reservoir, San Joaquin Basin, California. Am Assoc Pet Geol Bull 71(12):1475–1487

Brunet MF, Korotaev MV Ershov AV, Nikishin AM (2003) The South Caspian basin: a review of its evolution from subsidence modeling. In: Brunet M-F, Cloetingh S (eds) Integrated Peri-Tethyan Basins Studies (Peri-Tethys Programme). Sedimentary Geology 156(4):119–148

Crossey LJ, Loucks R, Totten MW (1996) Siliciclastic diagenesis and fluid flow: concepts and applications. SEPM Special Publication 55, p 222

Delu Xie, Suping Yao, Jian Cao, Wenxuan Hu, Yang Qin (2020) Origin of calcite cements and their impact on reservoir heterogeneity in the Triassic Yanchang Formation, Ordos Basin, China: A combined petrological and geochemical study. Marine and Petroleum Geology 117(104376). https://doi.org/10.1016/j.marpetgeo.2020.104376

Devlin WJ, Cogswell JM, Gaskins GM et al (1999) South Caspian Basin: Young, Cool, and Full of Promise. GSA TODAY A Publication of the Geological Society of America 9(7):1–2

Dutton SP (2008) Calcite cement in Permian deep-water sandstones Delaware Basin, west Texas: origin, distribution, and effect on reservoir properties. Am Assoc Pet Geol Bull 92(6):765–787

Dutton SP, White CD, Willis BJ, Novakovic J (2002) Calcite cement distribution and its effect on fluid flow in a deltaic sandstone, Frontier Formation, Wyoming. AAPG Bulletin 86(12):2007–2021

Dutton SP, Willis BJ, White CD, Bhattacharya JP (2000) Outcrop characterization of reservoir quality and interwell-scale cement distribution in a tide-influenced delta, Frontier Formation, Wyoming, USA. Clay Minerals 35(1): 95–105. https://doi.org/: 10.1180/000985500546756

Forte A, Cowgill E, Bernardin et al (2012) Late Cenozoic deformation of the Kur fold-thrust belt, southern Greater Caucasus. Geological Society of America Bulletin 122(3):465–486

Gamkrelidze I (1986) Geodynamic evolution of the Caucasus and adjacent areas in Alpine time. Tectonophysics 127(3-4):261–277. https://doi.org/10.1016/0040-1951(86)90064-8

Golonka J (2004) Plate tectonic evolution of the southern margin of Eurasia in Mesozoic and Cenozoic. Tectonophysics 381(1):233–273

Gorin VA (1939) Productive Series of Absheron Peninsula. AzGonti, Baku, p 12–19 (in Russian)

Granath JW, Baganz OW (1996) A review of Neogene subsidence mechanisms for the South Caspian basin. In: 3rd Annual meeting and fieldtrip of IGCP project N 369 ‘‘Comparative evolution of Peri-Tethyan rift basins’’, Centennial Celebration of EGSMA, 19 – 24 November, Cairo, Egypt, pp 24–25

Green T, Abdullayev N, Hossack J, Riley G, Roberts AM (2009) Sedimentation and subsidence in the South Caspian Basin, Azerbaijan. In: Brunet M-F, Wilmsen M, Granath JW (eds.) South Caspian to Central Iran Basins. Geological Society of London, Special Publication, London, vol 312, pp 241–260

Guliyev IS, Mamedov PZ, Feyzullayev AA et al (2003) Hydrocarbon systems of the South Caspian Basin, Nafta-press, Baku, p 205

Hinds D, Simmons MD, Allen MB, Aliyeva E (2007) Architecture variability in the Pereriva and Balakhany suites of the Neogene productive series, Azerbaijan: implications for reservoir quality. In: Yilmaz PO, Isaksen GH (eds) Oil and Gas of the Greater Caspian Area, AAPG Studies in Geology, Tulsa, vol 55, pp 87–107. https://dx.doi.org/10.1306/1205841St553010

Hinds DJ, Aliyeva E, Allen MB, Davies CE et al (2004) Sedimentation in a discharge dominated fluvial-lacustrine system: the Neogene Productive Series of the South Caspian Basin, Azerbaijan. Mar Pet Geol 21(5):613–638. https://doi.org/10.1016/j.marpetgeo.2004.01.009

Jackson J, Priestley K, Allen M, Berberian M (2002) Active tectonics of the south Caspian basin. Geophysics Journal International 148(2):214–245. https://doi.org/10.1046/j.1365-246X.2002.01588.x

Javanshir RJ, Riley GW, Duppenbecker SJ, Abdullayev NR (2015) Validation of lateral fluid flow in an overpressured sand-shale sequence during development of Azeri-Chirag-Gunashli oil field and SD gas field: South Caspian Basin, Azerbaijan. Mar Pet Geol 59:593-610.

Jones RW, Simmons MD (1996) A review of the stratigraphy of Eastern Paratethys (Oligocene-Holocene). Bulletin of the National History Museum, London 52(1):25–49

Kadirov FA (2004) Gravity model of lithosphere in the Caucasus-Caspian Region. In: South Caspian Basin: Geology, geophysics, oil and gas content, Nafta Press. Baku, Azerbaijan, p 333

Kadirov FA, Safarov RT (2014) Current crustal deformation within the Azerbaijan territory. Seismoprognosis observations in the territory of Azerbaijan 11(1):34–37

Kantorowicz JD, Bryant ID, Dawans JM (1987) Controls on the permeability and distribution of carbonate cements in Jurassic sandstones: Bridport Sands, southern England, and Viking Group, Troll field, Norway. In: Marshall JD (ed) Diagenesis of sedimentary sequences, Oxford, Blackwell, p 103–118

Khain VE, Shardanov AN (1952) Geological history and structure of the Kura basin. Baku, Azerbaijan Academy of Sciences Publ, p 348

Klein JS, Mozley P, Campbell A, Cole R (1999) Spatial distribution of carbon and oxygen isotopes in laterally extensive carbonate-cemented layers: implications for mode of growth and subsurface identification. J Sedim Res 69:184–191

McBride EF, Milliken KL, Cavazza W et al (1995) Heterogeneous distribution of calcite cement at the outcrop scale in Tertiary sandstones, northern Apennines, Italy. AAPG Bulletin 79(7): 1044–1063

Milliken KL, McBride EF, Cavazza W et al (1998) Geochemical history of calcite precipitation in Tertiary sandstones, northern Apennines, Italy. In: Morad S (ed) Carbonate cementation in sandstones: International Association of Sedimentologists, Special Publication 26:213–239

Morad S (1998) Carbonate cementation in sandstones: distribution patterns and geochemical evolution. In: Morad S (ed) Carbonate cementation in sandstones: International Association of Sedimentologists, Special Publication 26:1–26

Morton A, Allen M, Simmons M et al (2003) Provenance patterns in a neotectonic basin: Pliocene and Quaternary sediment supply to the South Caspian. Basin Research 15(3):321–337

Mozley PS, Davis JM (1996) Relationship between oriented calcite concretions and permeability correlation structure in an alluvial aquifer, Sierra Ladrones Formation, New Mexico. J Sed Res 66:11–16

Nemcok M, Feyzullayev AA, Kadirov FA et al (2011) Neotectonics of the Caucasus and Kura Valley, Azerbaijan. Global Engineers and Technologists Review 1:1–14

Ortoleva PJ (ed) (1994) Basin compartments and seals. AAPG Memoir 61, p 477

Reynolds AD, Simmons MD, Bowman MBJ et al (1998) Implications of outcrop geology for reservoirs in the Neogene productive series: Apsheron Peninsula, Azerbaijan. AAPG Bulletin 82(1):25–49

Saigal GC, Bjørlykke K (1987) Carbonate cements in clastic reservoir rocks from offshore Norway – relationships between isotopic composition, textural development and burial depth. In: Marshall JD (ed) Diagenesis of sedimentary sequences, Oxford, Blackwell, Geological Society, Special Publication 36:313–324

Sullivan KB, McBride EF (1991) Diagenesis of sandstones at shale contacts and diagenetic heterogeneity, Frio Formation. AAPG Bulletin 75(1):121–138

Taylor KG, Gawthorpe RL, Curtis CD, et al (2000) Carbonate cementation within a sequence stratigraphic framework: the Upper Cretaceous sandstones of Book Cliffs, Utah–Colorado. Journal of Sedimentary Research 70:360–372

Uskin NI (1916) Stratigraphy and tectonics of the Productive Series of the Balakhany-Sabunchi-Ramany oil-producing region. Baku, p 80 (in Russian)

Walderhaug O, Bjørkum PA (1998) Calcite growth in shallow marine sandstones: growth mechanisms and geometry. In: Morad S (ed) Carbonate cementation in sandstones: International Association of Sedimentologists, Special Publication 26:179–192

Walderhaug O, Bjørkum PA, Nordgard-Bolas HM (1989) Correlation of calcite-cemented layers in shallow-marine sandstones of the Fensfjord Formation in the Brage field. In Collinson JD (ed) Correlation in hydrocarbon exploration, Graham and Trotman, London, p 367–375

Worden RH, Matray JM (1998) Carbonate cement in the Triassic Chaunoy Formation of the Paris basin: distribution and effect on flow properties. In: Morad S (ed) Carbonate cementation in sandstones, International Association of Sedimentologists, Special Publication 26:163–177

Zeynalov G**,** Alkhasli S, Shahtakhtinskiy A (2017) Outcrop analogue study of deformation bands and their impact on rock properties of the Productive Series in South Caspian Basin. OnePetro, Society of Petroleum Engineers, p 20. https://doi.org/10.2118/189018-MS

Zeynalov G, Alkhasli Sh (2018) Structural deformation and its impact to sandstone reservoirs in Eastern Azerbaijan. The 80th EAGE Conference & Exhibition,11-14 June 2018, Copenhagen, Denmark, EarthDoc, Vol 2018, p 1–5. https://doi.org/10.3997/2214-4609.201801590

Zeynalov GA (2024) Calcite diagenesis impact on sandstone reservoirs of the Productive Series in South Caspian and Kura Basins, 85th EAGE Annual Conference & Exhibition, Jun 2024, Oslo, Norway, EarthDoc, Volume 2024, p 1–5. https://doi.org/10.3997/2214-4609.202410156

Zeynalov GA (2022) Environmental facies analysis of the Productive Series in the Kura Basin, Azerbaijan. 83rd Annual EAGE Conference Proceedings, Exhibition, Spain, Madrid, Jun 2022, EarthDoc, Volume 2022, p 1–5. https://doi.org/10.3997/2214-4609.202210479

Zonenshain LP, Le Pichon X (1986) Deep basins of the Black Sea and Caspian Sea as remnants of Mesozoic back-arc basins. Tectonophysics 123:2181–211

РАСПРЕДЕЛЕНИЕ КАЛЬЦИТОВЫХ ЦЕМЕНТОВ И ИХ ВЛИЯНИЕ НА РЕЗЕРВУАРЫ В ПРОДУКТИВНОЙ ТОЛЩЕ ЮЖНО-КАСПИЙСКОГО И КУРИНСКОГО БАССЕЙНОВ

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Резюме. Качество коллекторов продуктивной толщи нижнего плиоцена в бассейнах Южного Каспия и Куры напрямую контролируется кальцитовой цементацией и уплотнением, связанными с седиментационными условиями. Изучение взаимодействия этих процессов в коллекторах даёт возможность проанализировать закономерности диагенеза в флювиально-дельтовых песчаниках, особенно с учётом малоизученного влияния карбонатной цементации в флювиально-дельтовых фациях. Выпадение кальцитового цемента при уплотнении осадочных пород существенно влияет на проницаемость песчаных коллекторов и фильтрацию флюидов при добыче нефти и газа. С этой точки зрения изучены особенности распределения конкреций кальцитового цемента в песчаниках верхней продуктивной толщи Южно-Каспийского и Куринского бассейнов и их влияние на пористость, проницаемость и фильтрацию флюидов. Распределение кальцитовых конкреций было картировано в выходах песчаников верхней части продуктивной толщи Ясамальской (Шубанинской) антиклинали на западном фланге Южно-Каспийской впадины. Крупные пластинчатые кальцитовые конкреции в этих флювиально-дельтовых песчаниках, как правило, следуют наклону слоистости в сторону бассейна. По данным рентгеновской дифракции (XRD) и сканирующей электронной микроскопии (SEM) высокое содержание кальцитовых цементных конкреций, присутствующих в песчаниках верхней части продуктивной толщи (балаханский VIII и балаханский VI горизонты) Ясамальской (Шубанинской) антиклинали, значительно снижает пористость и проницаемость для потока флюида. Понимание условий осадконакопления кальцитовой цементации, наблюдаемых в песчаниках продуктивной толщи на западном борту Южно-Каспийского бассейна, имеет важное значение для оценки качества аналоговых коллекторов в песчаниках соседнего Куринского бассейна. Наличие большого объёма кальцитового цемента существенно влияет на петрофизические свойства коллекторов, что обуславливает важность изучения их происхождения.

Ключевые слова*: кальцитовый цемент, Южно-Каспийский бассейн, Куринский бассейн, диагенез, поток жидкости, продуктивная толща*

CƏNUBİ XƏZƏR VƏ KÜR HÖVZƏLƏRİNDƏ MƏHSULDAR QAT ÇÖKÜNTÜLƏRİNDƏ KALSİT SEMENTLƏRİNİN PAYLANMASI VƏ ONLARIN KOLLEKTOR SÜXURLARINA TƏSİRİ

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Xülasə. Cənubi Xəzər və Kür hövzələrində Alt Pliosenin Məhsuldar qat çöküntülərinin kollektor süxurlarının keyfiyyəti çöküntü toplanma şəraiti ilə əlaqədar olaraq, birbaşa kalsit sementləşməsinin və sıxlaşmasının xarakterindən asılıdır. Çay-delta qumdaşı kollektorlarında bu proseslərin qarşılıqlı öyrənilməsi həmin qumdaşıların diagenetik xüsusiyyətlərini, xüsusən də çay-delta fasiyasında zəif öyrənilmiş karbonat sementləşməsinin təsirini təhlil etməyə imkan verir. Çökmə süxurların sıxlaşması zamanı kalsit sementinin çökməsi neft və qazın hasilatı dövründə qumlu kollektorların keçriciliyinə və mayelərin süzülməsinə əhəmiyyətli dərəcədə təsir göstərir. Bu nöqteyi nəzərdən Cənubi Xəzər və Kür hövzələrində Məhsuldar qatın üst hissəsinin qumdaşılarında kalsit sement konkresiyalarının paylanmasının xüsusiyyətləri və onların məsaməliyə, keçiriciliyə və mayelərin süzülməsinə təsiri öyrənilmişdir. Cənubi Xəzər hövzəsinin qərb kənarında Yasamal (Şubanı) antiklinalında Məhsuldar qatın üst hissəsinin qumdaşı süxurlarının yerüstü çıxıntılarında kalsit konkresiyalarının paylanması xəritəyə alınmışdır. Bu çay-delta qumdaşılarında qat-qat kalsit konkresiyaları adətən hövzəyə doğru laylanma yamacı istiqamətində yayılmışlar. Rentgen Difraksiyası (XRD) və Skan Edən Elektron Mikroskop (SEM) məlumatlarına əsasən, Yasamal (Şubanı) antilkinalında Məhsuldar qatın üst hissəsinin (Balaxanı VIII və Balaxanı VI horizontlarında) qumdaşılarının tərkibində mövcud olan yüksək miqdarda kalsit sement konkresiyaları məsaməliyi və maye axını keçiriçiliyini əhəmiyyətli dərəcədə azaldır. Cənubi Xəzər hövzəsinin qərb kənarında Məhsuldar qatın qumdaşılarında müşahidə olunan kalsit sementininin çökmə şəraitinin başa düşülməsi qonşu Kür hövzəsindəki qumdaşı kollektorlarının keyfiyyətinin qiymətləndirilməsi üçün çox vacibdir. Qeyd edilən qumdaşıların tərkibində böyük həcmdə kalsit sementinin mövcud olması onların kollektorlarının petrofizik xüsusiyyətlərinə əhəmiyyətli dərəcədə təsir göstərir və bu da onun mənşəyinin öyrənilməsinin vacibliyini şərtləndirir.

Açar sözlər: *kalsit sementi, Cənubi Xəzər hövzəsi, Kür hövzəsi, diagenez, maye axını, Məhsuldar qat*