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PROSPECTS FOR THE DEVELOPMENT OF OIL FIELDS IN LEBANON

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The search for oil fields near the coast of Lebanon is of current importance for the forecast assessment of the country's energy security. The paper attempts to analyze and understand the basics of the oil/water/surface interaction in the presence of surfactants and their effect on improving the displacement of water by oil from the surface.

Introduction. Early estimation of Lebanon's offshore reserve potential ranges into the hundred of millions of barrels of oil and 25 trillion cubic feet (Tcf) natural gas resources located in its offshore territories. These estimations are based on 2D and 3D seismic studies and are mainly performed by Petroleum Geo Services (PGS) and Spectrum. The first offshore exploration well was drilled and completed in Block 4 on 8 May 2020. The drilling activities started with the arrival of the *Tungsten Explorer* drillship on 25 February 2020. Traces of gas were observed, confirming the presence of hydrocarbon reserves. However, these traces are not enough to yield a commercial quantity (EUROMENA Energy). Furthermore, the gas-bearing Tamar sands formation, located beneath the Mediterranean Sea, was not encountered in this well, indicating that the well was not extended to this formation.

According to the report published in March 2010 by U.S. Geological survey (USGS) [7], the Levant basin, which covers Lebanese, Palestinian and part of Cyprus offshore, has mean probable undiscovered oil resources of 1.7 billion barrels and, more significantly, mean probable undiscovered resources of natural gas resources of 122 Tcf. Total had already drilled a well in Block 4 earlier that year but it did not find sandstone reservoirs such as those found in Palestine and Cyprus (Fig. 1). "The lithology Total found in block 4 exploration well had a carbonated formation which could be a reservoir rock but these types of rocks need to be further evaluated since the drilling focused only on sandstone reservoirs. The Jurassic carbonate platform in Lebanon, as well as in the neighbouring countries, includes thick pervasive dolostones (exceeding 1000m in thickness) which are believed to have resulted through hydrothermal dolomitisation of pre-existing Early Jurassic, seepage reflux dolostones and Middle-to-Late Jurassic limestones [1].

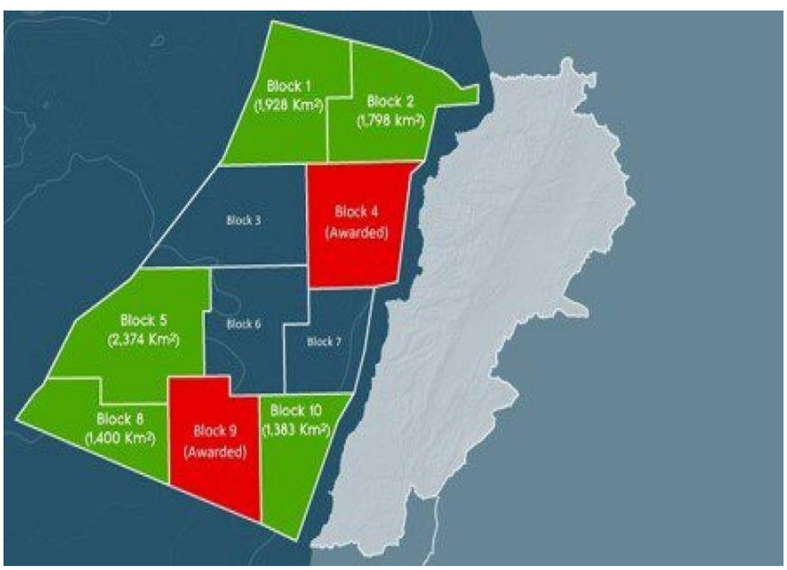

Fig. 1. – Offshore blocks in Lebanon. Source: Lebanese Petroleum Administration

Dolomitisation took place during a time span stretching from the Late Jurassic to the Early Cretaceous (ca. 10 million years approximately), coinciding with major uplifts and subaerial conditions that occurred together with faulting and volcanic activities. Recent fieldwork led to the discovery of a 'tongue'-shaped dolostone body (350m in length) within the latest Jurassic limestone strata in central Mount Lebanon. Sampling was performed systematically along four almost parallel profiles crossing the dolomite 'tongue' lengthwise. In total, 70 core-drilled samples were collected from the dolostones, as well as from the nearby partly dolomitised limestones, sandstones and volcanic deposits.

Purpose of the work – to assess the problems of extracting oil in Lebanon and put forward some solutions.

Methodology. A project started to understand the fundamentals of "Chemical Injection based Enhanced Oil Recovery in Hydrocarbon Reservoirs". QCM-D for the purpose. This research will help understand the fundamentals of the interaction of oil/water/surface in the presence of surfactants and the impact of these surfactants on changing the wettability of the surface and, hence, improve water displacing oil from the surface. Very few people used QCM-D for such applications. Therefore, we believe that this research will lead to new and innovative results. The research will benefit from the cross-domain expertise in the Chemical and Petroleum Engineering Department. The first environmental impact assessment (EIA) study for petroleum activities was conducted in line with the Lebanese regulations by the operator block 4 for the upcoming petroleum activities and was approved by the ministry of environment in February 2020. Carbonate reservoir modeling: How can you ensure optimal drilling and production in carbonate reservoirs? It requires new tools, techniques, and interpretation methodologies that harness and utilize borehole measurements with high-resolution 3D surface seismic surveys.

Near-wellbore scale: As carbonate rock has been compressed over geological time, its character has changed from its original state due to diagenesis. This process caused the pores to change in size and geometry and may have also created stylolite flow barriers over large areas. Evaluating the complex heterogeneous rock can therefore be problematic, particularly as rock properties may vary greatly across the field. Porosity, permeability, and saturation are therefore some of the most important factors for reservoir modeling and production planning. Our proprietary interpretation methodology and workflow provide a rapid, robust, and comprehensive petrophysical description, including evaluations of lithology, porosity, pore geometry, fluid saturations, relative permeability, and primary drainage capillary pressure curves. This information can aid in detecting fractures, optimizing completion program design, and estimating recoverable reserves. With an understanding of the carbonate rock formation at the micro and macro scale, specific intervals can also be reopened using hydraulic fracturing techniques. Postulated Palaeozoic facies also offer favorable potential. The effects of limited extrusive phases in the Late Jurassic/Early Cretaceous and the Late Neogene are examined and considered as non-critical to hydrocarbon accumulation other than on a very limited local structure scale, while the structural effects of Neogene horizontal displacements along the length of the country are taken into account in the presentation of three exploration options designed to look thoroughly at pre-Jurassic prospects.

A two-stage dolomitisation model for the Jurassic carbonates in Lebanon has recently been proposed by the authors. According to this model, second-stage Late Jurassic hydrothermal dolomitisation is believed to have occurred as a result of the circulation of mixed dolomitising fluids along fault. Dolomitization is a geological process by which the carbonate mineral dolomite is formed when magnesium ions replace calcium ions in another carbonate mineral, calcite. It is common for this mineral alteration into dolomite to take place due to evaporation of water in the sabkha area [1]. Dolomitization involves substantial amount of recrystallization. This process is described by the stoichiometric equation:

$$2\,CaCO_3(\text{calcite}) + Mg_2+ \leftrightarrow CaMg(CO_3)_2(\text{dolomite}) + Ca_2+$$

Resultes. Dolomitization depends on specific conditions which include low Ca:Mg ratio in solution, reactant surface area, the mineralogy of the reactant, high temperatures which represent the thermodynamic stability of the system, and the presence of kinetic inhibitors such as sulfate [2]. Diagenesis may include conversion of limestone to dolomite by magnesium-rich fluids. There is considerable evidence of replacement of limestone by dolomite, including sharp replacement boundaries that cut across bedding. Ordinary seawater is capable of converting calcite to dolomite, if the seawater is regularly flushed through the rock, as by the ebb and flow of tides (tidal pumping). Once dolomitization begins, it proceeds rapidly, so that there is very little carbonate rock containing mixed calcite and dolomite. Carbonate rock tends to be either almost all calcite/aragonite or almost all dolomite [5].

In Case 1, the concentration of SO_4^{2-} in the injected water was 10 times higher than that in the Base Case (Fig. 2).

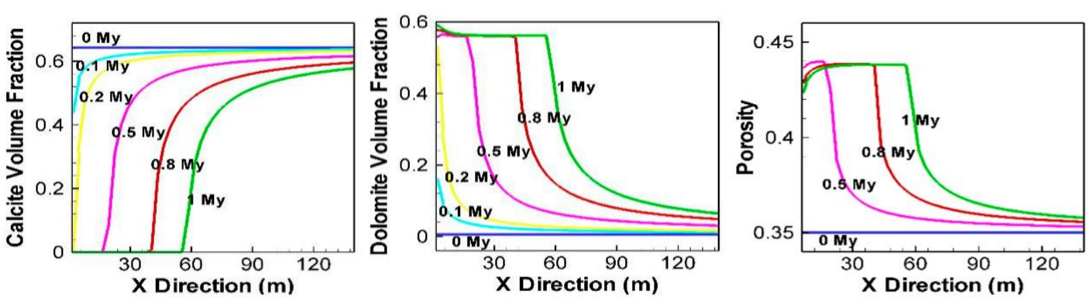

Fig. 2. – Calcite and dolomite content and porosity evolution (Base Case)

Results in Fig.2 show that the calcite nearest to the injection point dissolved first and gradually transformed to dolomite. No calcite was found within 70 m of the injection point after 1 My, when the dolomite content was up to 0.55. During the transformation of calcite to dolomite, the generated Ca^{2+} moved continuously to the right area as the water flows. When Ca^{2+} and SO_4^{2-} concentrations in the system reached the conditions for gypsum precipitation, gypsum was formed. As the curve of gypsum content shows, the content reached the highest value at a distance of 10 m from the injection point after 0.5 My. With continuous injection of external fluids, more and more gypsum precipitated. The gypsum content was close to 0.4 between 20 and 80 m from the injection point after 1 My. The porosity increased to about 0.45 within 20 m of the injection point after 0.5 My, whereas it decreased to about 0.05 between 20 and 80 m from the injection point after 1 My.

Conclusions. A series of test analysis and numerical simulation were combined to study the effects of various factors (such as temperature, flow rate, seawater concentration, Mg/Ca ratio, pH and SO4s concentration) on dolomitization during diagenesis in carbonate reservoirs. The degree of dolomitization varied with the flow rate and other hydrodynamic conditions of the external fluid. The better the hydrodynamic conditions were, the faster the fluid migration was, which then pushed the reaction and expanded the scope of dolomitization. Different solution properties and minerals also led to various levels of dolomitization. During successive diagenetic stages under different sedimentary environments with various temperatures, minerals, solutions and other conditions, reservoir experienced complicated fluid–rock reactions. The diagenetic process and porosity evolution curves in four different sedimentary environments were reestablished in the studied area. The main controlling factors of dolomitization were identified, which is helpful to clarify the genesis and distribution of carbonate reservoirs. As the fluid–rock interaction mechanism in carbonate reservoirs is a complex process, further experimental and numerical simulation studies are planned to elaborate and enhance our understanding.

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