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CHEMICAL SYSTEM EVOLUTION DURING OIL CHARGING INTO SANDSTONE RESERVOIR, STĘŻYCA FIELD, LUBLIN BASIN, SE POLAND

Abstract: During oil migration from Devonian and Carboniferous source rocks the siliceous and carbonate chemical systems dominated respectively in diagenetic processes. Understanding of hydrocarbon and formation water origin on the basis of thermal regimes evolution of the source rocks area, not only on the basis of the reservoir rocks, gave opportunity to reliable system recognition.

Keywords: gas and oil field, diagenetic minerals, formation waters, PVTX system, SE Poland

INTRODUCTION

Chemical features of the oil and gas field formation are often shown in the light of organic material diagenesis or proved by modelling. Stężyca gas and oil field located in the north-western part of the strike-slip Mazowsze-Lublin through of Lublin basin, formed through Late Devonian to Permian (*see* Żelichowski, Porzycki 1983, Żelichowski 1987; Fig. 1A) gave a good opportunity to show how use of various geological and geochemical methods can highlight the reasonable history of the presented here gas and oil accumulation.

The "dynamic method" (Żywiecki 2004) of understanding of the sedimentary basin thermal history led to proper recognition of PVTX conditions of the main diagenetic processes in the basin scale and gas and oil charging episodes. Connection of diagenetic minerals growth in environment of parent formation waters and recent pore spaces-filled brine analysis gave the straight way to find the compartment activity during Lublin through sub-basins strike-slip movements of pull-apart and pop-up source-reservoir rocks relations.

ANALYTICAL TECHNIQUES

Seismic, core and log material have been studied for creation of geological and structural history of field formation with trap and reservoir model composition (Figs. 1C, 3D), and petrographic and geochemical analysis have been done for chemical field evolution understanding. Recent pore water chemical composition (Fig. 3D) was analysed on the AAS Solar 919 Unicam equipment; formation pressures were measured while drilling (PO&GC S.A. 1994-1999). Detrital and diagenetic minerals were identified by XRD diffraction. Fossil formation waters (Fig. 3C) were studied in fluid inclusions in main diagenetic minerals (quartz overgrowths, saddle dolomite and calcite crystals;

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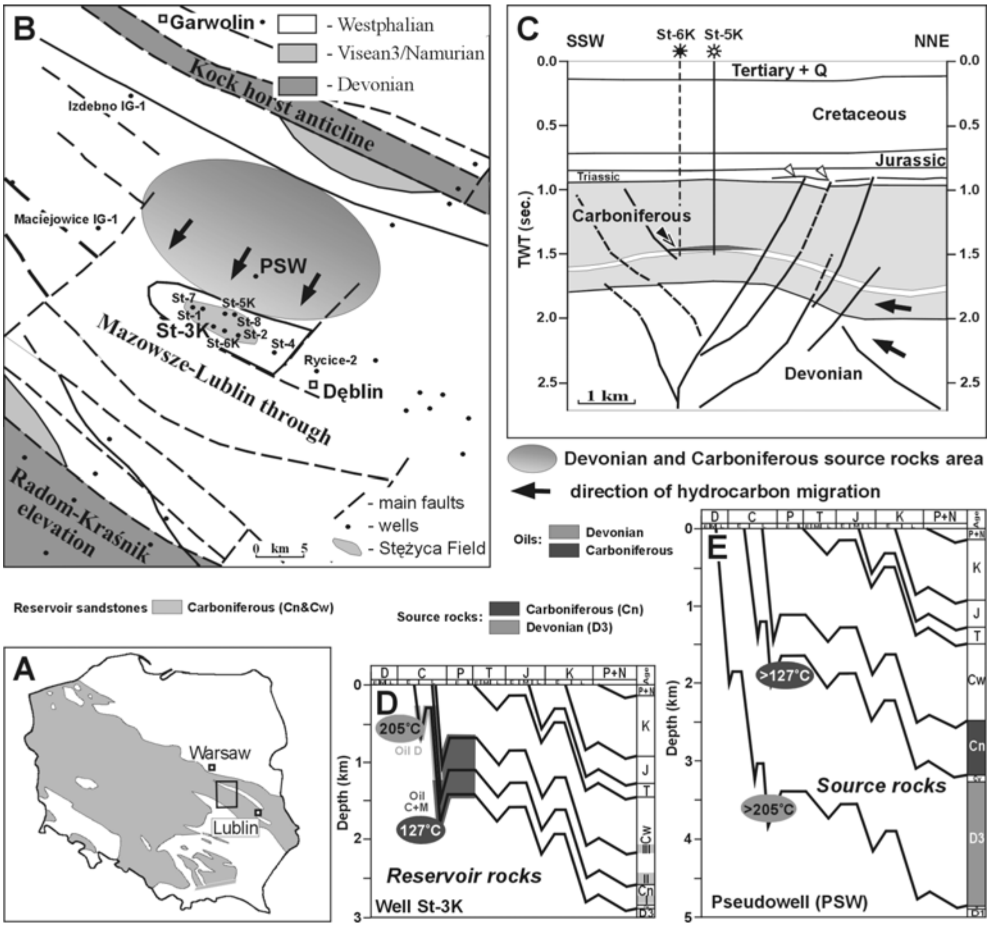

Fig. 1. (A) Study area on the map of Poland with boundaries of the Carboniferous deposits recent extent. (B) NW part of the Mazowsze-Lublin through with the Stężyca field area, the drilled wells marked. Arrows show direction of hydrocarbon migration from north-east source rock sub-basin to the field reservoir rocks. The modelled well St-3K (*see* D) and pseudowell (PSW, *see* E) enlarged. (C) Cross-section though Stężyca field pop-up with tectonic flower structure interpreted from seismic data. White arrowheads show evidence of strike-slip movements not only of Carboniferous but also of the Late Triassic age. Black arrows indicate direction of hydrocarbon migration to the Carboniferous reservoir sandstones from the Late Devonian (D3) and Carboniferous (Cn – Namurian) source rock sequences. Double arrowhead shows oil saturation only in south-western field reservoir area. (D) Burial curve of the Carboniferous sandstone reservoir rocks from well St-3K. Minimal temperatures (from homogenization temperatures in diagenetic minerals) of reservoir pore fluids during two episodes of oil and gas charging into the trap are given. (E) Burial curve of the Devonian and Carboniferous source rocks from pseudowell (PSW) from HC generating sub-basin located to the NE (*see* B). The temperatures of HC generation in the source rocks area were much higher than temperatures of fluids connected with oil and gas charging in the reservoir rocks.

Żywiecki 2003). Fluid inclusion analysis in was done by LINKAM TP92 stage with heating-cooling HFS 91 equipment, calibrated by SynFlinc synthetic fluid inclusions with accuracy of ±0.2°C. Recognizing of primary inclusions, fluid salinity, gas types, and solute composition were done according to works of Roedder (1984), Kerkhof (1990), and Kozłowski (1984).

DISCUSSION

Recognition of diagenetic minerals occurring in pore spaces in sandstone reservoirs (Figs. 1C, 3B) in the studied area allowed to distinguish the two main chemical systems dominating during physico-chemical evolution of these rocks. In the studied sedimentary siliciclastic environments (*see* Fig. 2), the siliceous system related with oil emplacement from Devonian source rocks created the extensive cementation of sandstones by quartz overgrowth with 205°C minimal temperature of $CaCl_2$-type solutions or fresh-water parent fluids (Fig.3A). Water and hydrocarbons (HC) migrated from high overpressured Devonian sequences had fresh-water signature because of smectite to illite recrystallization caused intensive water dilution; there occurred mixing of the remnant marine Devonian waters with meteoric ones in the reservoir.

The carbonate diagenetic system started to dominate (Fig. 2) during oil charging into sandstone reservoirs from the Carboniferous source rocks. Saddle dolomite and calcite cements grew then from aqueous solution of 127°C minimal temperatures in NaCl-dominated system (Fig. 3A). Such system type was induced by high water salinity increasing in subsiding source rocks basin to the north (see Fig. 1A), due to silicate minerals growth and water flow from Carboniferous deposits. Some meteoric water infiltration involved oils in reservoirs to the bacterial oxidation and fermentation processes checked by stable carbon isotope study (*see* Żywiecki 2003). In shallower stratigraphic positions, the last diagenetic mineral – calcite cement – formed from $CaCl_2$-dominated water system due to Zechstein evaporate brines infiltration (*see* Fig. 3B).

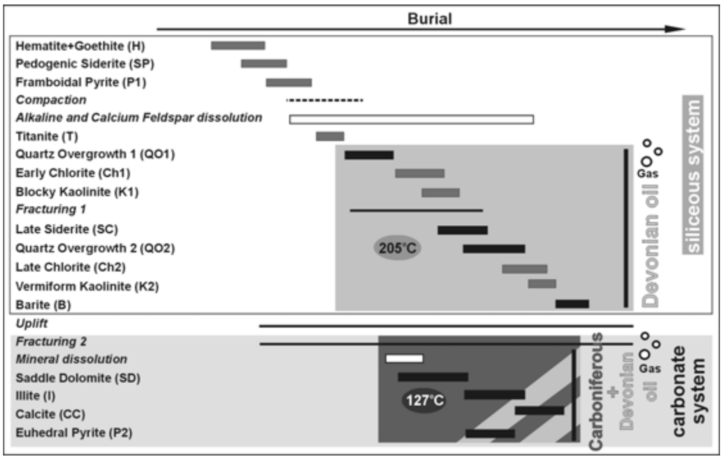

Fig. 2. Sequence of diagenetic minerals growth during HC migration from the Devonian source rock while siliceous system dominance and from Carboniferous source rock while carbonate system dominance. Reservoir temperatures of the main mineral-forming processes are from homogenization temperatures of fluid inclusions (*see* Fig. 3C).

CONCLUSIONS

After three reservoir levels filling by HC and trap next preservation from Late Permian to the recent, conditions in pore spaces were stable. Recentlt, the fist reservoir has waters of 18.9-61.5 g/L salinity and hydrostatic pressures of HC saturated zones with 24-26 MPa. Zones in this reservoir saturated only by waters has very distinct undepressure of 9 MPa (*see explanation to* Fig. 3B). The second reservoir has waters of 151.8-253.7 g/L with slightly altered relict meteoric water of river channel bottoms with salinity 4.6 g/L, and pressure of 21-23 MPa. The third reservoir has water salinity of 123.9-172.3 g/L and hydrostatic pressure of 18-20 MPa. Still the Devonian sequence yields high ovepressure of 46 MPa. Up-side-down oil and gas distribution in 3 reservoirs (Żywiecki, Matyasik 2000; Żywiecki 2002): Carboniferous HC in the first one, Devonian and mixed in the second one, and Devonian in the third one (Figs. 2, 3B), and consideration in thermal modeling of water evolution in source rocks for HC, not only water evolution in reservoir rocks (Figs. 1D, 1E, 2), confirm chemical system history of siliceous and carbonate domination.

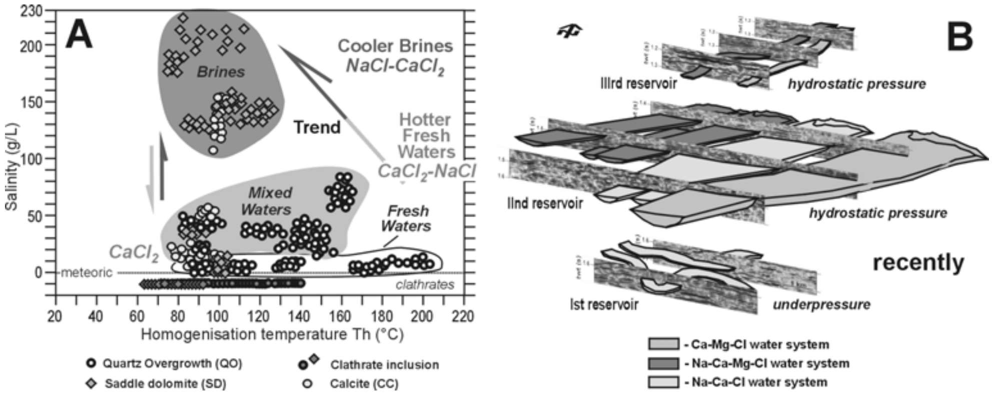

Fig. 3. (A) Relation of homogenization temperatures to the salinity of formation water being parent solution of the main diagenetic minerals in the reservoir sandstones. Initially, the siliceous system of fresh water – $CaCl_2$ solution and higher temperatures are related to the Devonian HC migration. Cooler and most saline brines of the NaCl system are related to the carbonate system of Carboniferous HC migration. (B) Recent formation water systems in reservoir sandstones. The second and the third reservoir of hydrostatic pressures are filled by saline brines of Na-Ca-Mg-Cl and Ca-Mg-Cl systems related to the second oil charging episode and infiltration of evaporate surface brines, respectively. The first reservoir exhibits the freshest waters of Na-Ca-Cl system with underpressure conditions connected to the final Stężyca field formation of Mesozoic meteoric water aquifer activity.

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