Petroleum systems in carbonate platforms: subsurface examples and outcrop analogs from the former Soviet Union

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DGF – Oliegeologisk foredragsrække

Both shallow water (Bahamian type) and deeper water and/or broad shelf sea (North Sea type) carbonate petroleum systems encompass several fundamental elements: Source rock, reservoir rock, seal rock and trap formation, overburden rock, and the generation-migration-accumulation of petroleum into the reservoir rock. In shallow water carbonates versus pelagic chalks a fundamental difference exists in their reservoir rock type(s), reservoir architectures, reservoir depositional environments, porosity types, sequence stratigraphy, and diagenetic processes.

Carbonate platforms can be divided into a set of fairly predictable depositional environments and standard facies belts. These environments and their contained facies belts are based on lithofacies, biofacies, textures, stratigraphic cycles, sedimentary structures, water depth, platform margin and slope architectures and other parameters. From shallow water to deeper water these depositional environments include: 1) tidal flats, 2) shelf lagoons, 3) middle shelf, 4) reef margin and/or a carbonate sand platform margin, 5) slope, 6) inner basin, and 7) a distal outer basin and/or broad shelf sea. Environments 1-4 commonly form in water depths of 10-20 m or less. Environments 5–7 can form in water depths of hundreds to thousands of meters. In this classification an outer basin and/or broad shelf area can be considered an end-member depositional environment where, in the Late Cretaceous and Paleocene, pelagic carbonate chalks formed (e.g., the North Sea chalks). The pattern expressed by these seven environments and their facies belts results from a combination of numerous factors including geotectonics, climate, shelf type, water depth, water energy, sea-level fluctuations, effects of local and regional slope, and geologic age as it determines the nature and types of carbonate constituents. Thus, as these factors vary in time and space so will details in the facies patterns vary. Also, no one-carbonate platform will necessarily include all seven facies belts.

Source rocks: Devonian–Carboniferous shallow water carbonate platform reservoir oils in the North Caspian Basin are considered to be derived mainly from inner basin, organic rich argillaceous lime mud of Devonian and Carboniferous age. Thus, the source rock and reservoir rocks are laterally and genetically closely linked. In contrast, the North Sea Maastrichtian-Danian chalk oils are mainly sourced from older Kimmeridgian basin-floor mudstone.

Reservoir rocks: In shallow water carbonate platforms reservoir rocks can be quite varied in their architectures and diagenetic attributes. This is due to the wide variety of depositional facies that can form reservoirs and also because many of the constituents consist of unstable aragonite and magnesium calcite. These geochemically unstable components are subject to early marine dolomitization, meteoric diagenesis and early marine cementation. Reservoir types can include tidal flat facies, inner-shelf lagoon wackestones and packstones, carbonate grainstones and reef boundstones on platform margins, and debris flow and turbidity current deposits on slopes and inner-basin settings.

Chalk reservoir rocks: These reservoirs are different than Bahamian-type shallow water carbonate reservoirs due to their depositional setting being commonly in broad pelagic shelf seas and deeper water basins, pelagic facies types, and because their constituents consist largely of geochemically stable low-magnesium calcite. Not only are their reservoir architectures determined by different factors than shallow water reservoirs but also they undergo

different diagenetic alterations. Chalks occur in water depths normally not affected by meteoric diagenesis or early marine dolomitization. Also, most chalks are only moderately affected by seafloor cementation in contrast to shallow water carbonates, which can become cemented rapidly. Porosity loss by cementation in chalks is due to burial and/or postburial processes such as pressure solution and local reprecipitation.

Outcrop analogs and subsurface oil fields: Carbonate facies in the Bolshoi Karatau mountains of southern Kazakhstan provide outcrop analogs for coeval reservoirs in supergiant oil and gas fields in the North Caspian Basin. Standard facies belts 1-6 described above occur in the Bolshoi Karatau. Bolshoi Karatau carbonates record the development of a 4,500–m–thick carbonate platform that evolved close to the North Caspian Basin of western Kazakhstan during the Late Devonian and Carboniferous. The carbonate platforms in the Bolshoi Karatau and the North Caspian basin are similar in several important ways. First, for example, both the Bolshoi Karatau and the Tengiz oil field platforms were initiated in the Late Devonian and ended in the Bashkirian, a span of about 50–55 My. Second, the stratigraphic thickness and facies of the Bolshoi Karatau and the Tengiz oil field are similar. Third, the proven oil reserves in Tengiz occur in the Visean through Bashkirian, and these strata are very well exposed in the Bolshoi Karatau.

In the Bolshoi Karatau, thick stacks of upward–shallowing 3rd-order and 4th-order highstand sequences of dolomitized and karsted platform–margin and platform–interior ooid–bioclastic sands form potential reservoirs. Lower–slope and upper–slope Waulsortian skeletal mud mounds contain abundant marine cement and are relatively tight. Reservoir enhancement is related to early marine dolomitization and meteoric diagenesis. These geometric and diagenetic patterns are analogous to many of the reservoirs in the North Caspian Basin such as in the Karachaganak and Tengiz fields and in Kashagan, the newest supergiant oil field discovered in 2000. Bolshoi Karatau studies provide important data on the characterization of reservoirs in terms of their facies types, spatial distribution on the platforms, sequence stratigraphy, and predictive diagenetic patterns. These outcrop studies are proving to be valuable for better understanding and predicting the subsurface characteristics and development of North Caspian Basin oil and gas reservoirs.

The presentation will be held in English. Non-DGF members are welcome.