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Scientific note

Porosity, Cementation, Diagenesis and Their Influence on the Productive Capability of Sandstone Reservoirs in the Sava Depression (Croatia)

PROCEEDINGS

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Key words: Secondary porosity, Cementation, Diagenesis, Reservoir quality, Petrography, Sedimentology.

Ključne riječi: sekundarni porozitet, cementacija, dijageneza, kvaliteta rezervoara, petrografija, sedimentologija.

Abstract

The sandstone reservoirs in the Sava depression lost their primary porosity through compaction and cementation in the early stage of diagenesis. Dissolution events enlarged porosity and created reservoirs that were composed mainly of secondary porosity, but some zones of these reservoirs were destroyed by precipitation of late Fe-rich calcite and dolomite cement. Three groups of sandstones differing in reservoir quality are identified - highly porous litharenites, litharenites with intermediate porosity, and weakly porous, highly cemented litharenites. The type of porosity depends on the clay content in sandstones, which is the result of water energy and depositional environment.

Sažetak

Većina primarnog poroziteta pješčanih rezervoara Savske depresije nestala je zbog kompakcije i cementacije u ranom stadiju dijageneze. Naknadni procesi otapanja doveli su do stvaranja sekundarnog poroziteta, ali neke zone promatranih rezervoara su uništene precipitacijom kasnodijagenetskog fero-kalcitnog i dolomitnog cementa. S obzirom na svojstva rezervoara izdvojene su tri grupe pješčenjaka - jako porozni litoareniti, litoareniti sa srednjim vrijednostima poroziteta i slabo porozni, čvrsto cementirani litoareniti. Vrijednosti poroziteta ovisne su o sadržaju gline u pješčenjacima, što je u vezi s energijom vode i uvjetima taloženja.

1. INTRODUCTION

Regional influences on reservoir quality include depositional environment, initial composition of the sand and associated muds, texture, time, subsidence rate, pressure, thermal gradient, pore fluid composition and diagenetic history (LOUCKS et al., 1985).

The main purpose of this study is to investigate diagenetic processes and their influence on reservoir properties of oil-gas fields in the Sava depression (Fig. 1). The similarities in diagenetic and reservoir properties characterizing these rocks permit the development of a diagenetic model that is of general applicability.

In the cored intervals of all fields, oil-bearing sandstones and well cemented sandstone zones were noticed (Fig. 2). These differences were studied in detail.

2. GEOLOGICAL SETTING

The Sava depression is located some 40 km southeast from Zagreb (Fig. 1) and consists of a few oil-gas fields where hydrocarbons accumulated in upper Miocene sandstone-marlstone sequences.

The distribution and geometry of sandstone bodies were strongly influenced by depositional palaeoenvironment, deltaic and shelf processes. Deposition of Iva-sandstones from the Ivanić Production Field occured on a shallow indented shelf, where elongate, lenticular, sheet-like and chanel-filled sand bodies, as well as interbar and shelf marls have been developed (TADEJ & KRIZMANIĆ, 1995). The Poljana sandstones of the Žutica field are interpreted as a dendritic palaeodrainage pattern characterized by the three major channel sandstone bodies (SAFTIĆ et al., 1995). Thicknesses of the separate sand bodies in the Sava depression vary from few metres up to several hundred metres.

3. METHODOLOGY

Sandstone samples from a few hundred metre cored intervals of different productive formations were chosen for intensive study. Standard core descriptions of lithology and structural characteristics were performed. Several hundred thin-sections were examined with optical microscopy to determine mineral composition and porosity. Thin-sections were stained with both Alizarin red-S and potassium ferricyanide for the purpose of carbonate mineral identification. Routine point counts were done to quantify mineral composition and thin-section porosity. Grain size and sorting were determined.

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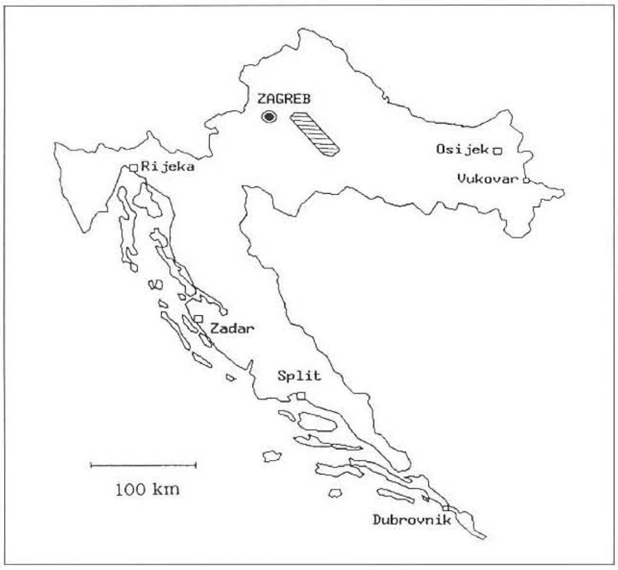

Fig. 1 The position of oil-gas fields in Sava depression.

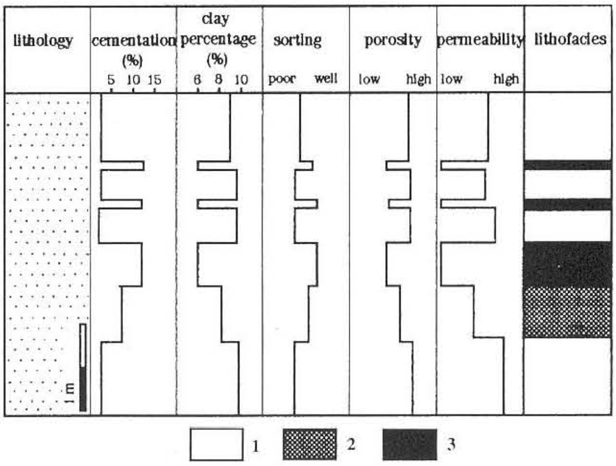

Fig. 2 Schematic column - correlation of sedimentary, diagenetic and reservoir properties of Upper Miocene litharenites in Sava depression. Legend: 1) litharenite with less than 5% cement and high permeability (30-380 x $10^{-3}\mu m^2$); 2) litharenite with 5-10% cement and intermediate permeability (7-105 x $10^{-3}\mu m^2$); 3) litharenite, tightly cemented (up to 20% cement), with very low permeability (0.05-10 x $10^{-3}\mu m^2$).

Porosity and permeability were measured on core plugs. Selected samples were analyzed with scanning electron microscope (SEM) for mineral composition, microporosity and diagenetic products, and with X-ray diffractometar for mineral composition.

4. PETROGRAPHY

The sandstone reservoirs in the Sava depression are fine to medium grained (0.08-0.4 mm), mostly well sorted. No major compositional variations are observed when two fields are compared. Mineralogically, the sandstones are relatively uniform, aside from various amounts of carbonate cements and clays. Sandstones mostly consist of quartz and dolomite rock fragments. Less abundant are micas, altered feldspars, chlorite, and chert, quartzite and mica-schist rock fragments.

Sandstones can be differentiated in their cement composition and proportion. Early diagenetic calcite cement is rarely preserved. Detrital grains appear to be "floating" in calcite (Plate I, Fig. 1). In highly porous sandstones (Plate I, Fig. 2) micropores are sporadically filled with Fe-dolomite and Fe-calcite, and some clay minerals. Late carbonate cements (Plate I, Fig. 4) infilling secondary intergranular pores are commonly Fe-rich (Fe-calcite, Fe-dolomite). Unlike early poikilotopic Fe-calcite, this late cement infilled residual pore spaces that remained after compaction.

Point count analyses indicate the typical major components of sandstones are quartz (40-50%), rock fragments (15-25%), micas (10-15%), feldspars (5-10%) and cement (5-20%). X-ray diffraction gave semiquantitative analyses of sandstone comparable with petrographic and point count data. SEM analysis displayed variations of clay mineral content in the productive sandstones and well cemented sandstones. In porous oil saturated zones illite, in the form of coatings and pore fillings (Plate II, Fig. 1), and pore filling kaolinite (Plate II, Fig. 2) were determined. In strongly cemented sandstones clay minerals are sporadically present.

5. POROSITY AND DIAGENESIS

In the burial history of sands much of the porosity is lost through compaction and cementation processes. Early carbonate cement, primarly calcite may be interpreted as pre-compaction, inasmuch as the detrital sand grains appear to be "floating" in calcite. These cements are rarely preserved.

Dissolution of early diagenetic calcite cement and unstable grains is the main secondary porosity formational event. It has been suggested (SCHMIDT et al., 1979) that the primary agent responsible for carbonate dissolution in the subsurface is carbonic acid formed by the generation of carbon dioxide during the thermal maturation of organic matter in sediments. Shale compaction yields large volumes of water that may be available for dissolution reactions in sandstones. It is probable that the more porous horizons were never completely cemented with calcite, and intergranular porosity has been enhanced there by dissolution of some calcite.

In well cemented zones, late carbonate cements infilling secondary pores are commonly iron-rich. Their occurrence is probably related to the release of iron and magnesium from the illitization processes in adjacent shales (BOLES & FRANKS, 1979). Carbonate cement distribution depends on the clay content in sandstones, as well as to the proximity of the shales that presumably sourced the material for cementation, both depending on depositional processes.

Other diagenetic processes such as quartz overgrowths, precipitation of kaolinite from pore fluids, alteration of feldspars, late chlorite and pyrite formation are volumetrically minor and/or locally significant.

6. RESERVOIR QUALITY

Variation in porosity and permeability at depth is a function of sedimentary conditions, cementation and dissolution. The relationship between sandstone body geometry and the distribution of diagenetic elements are critical aspects of reservoir heterogeneity.

In all studied fields sandstones can be divided into three groups differing in cementation rate and porosity-permeability patterns. In first group are sandstones with less than 5% cement, and with high porosity (23-33%) and permeability (30-380 x $10^{-3}\mu m^2$) values. Microporosity is high, and pore sizes of 50 µm - 0.1 mm predominate. The second group are sandstones with 5-10% cement and average porosity 19-30% and permeability 7-105 x $10^{-3}\mu m^2$. Pore sizes vary from 10-50 µm. Highly cemented (up to 20 % cement) and fortunately less abundant are sandstones of the third group. Porosity and permeability values are very low (porosity 2-3%, permeability 0.05-10 x $10^{-3}\mu m^2$). Microporosity is poor with pore dimensions of 0-10 µm.

Although there are no significant variations in detrital mineralogy of all three sandstone groups, some differences can be highlighted. Primarly, it is the clay content that mostly depends on water energy and depositional conditions. In general, the fairweather clay rich sediments are weakly cemented, and the clay poor storm deposits well cemented (KANTOROWICZ et al., 1987).

Carbonate cemented layers can be recognized in logs because they generate very high resistivity peaks. Definition of lateral extension of these cemented layers is important because they represent barriers for oil displacement.

7. CONCLUSION

Using a combination of petrographical, petrophysical and sedimentological techniques, diagenetic processes can be identified. The similarities in the geological evolution of reservoirs resulted in recognizable and ubiquitous diagenetic processes. Definition of depositional environments, body geometry, lateral extension and diagenetic processes are leading to better understanding of reservoir properties, and have to be assessed during the evaluation of new exploration prospects.

8. REFERENCES

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PLATE I

Fig. 1 Litharenite with early diagenetic calcite cement (red). Some of the sand grains are nearly surrounded by, or appear to be "floating" in the calcite cement.

Fig. 2 Highly porous, oil-saturated (brown) litharenite. First group of sandstones with high reservoir quality.

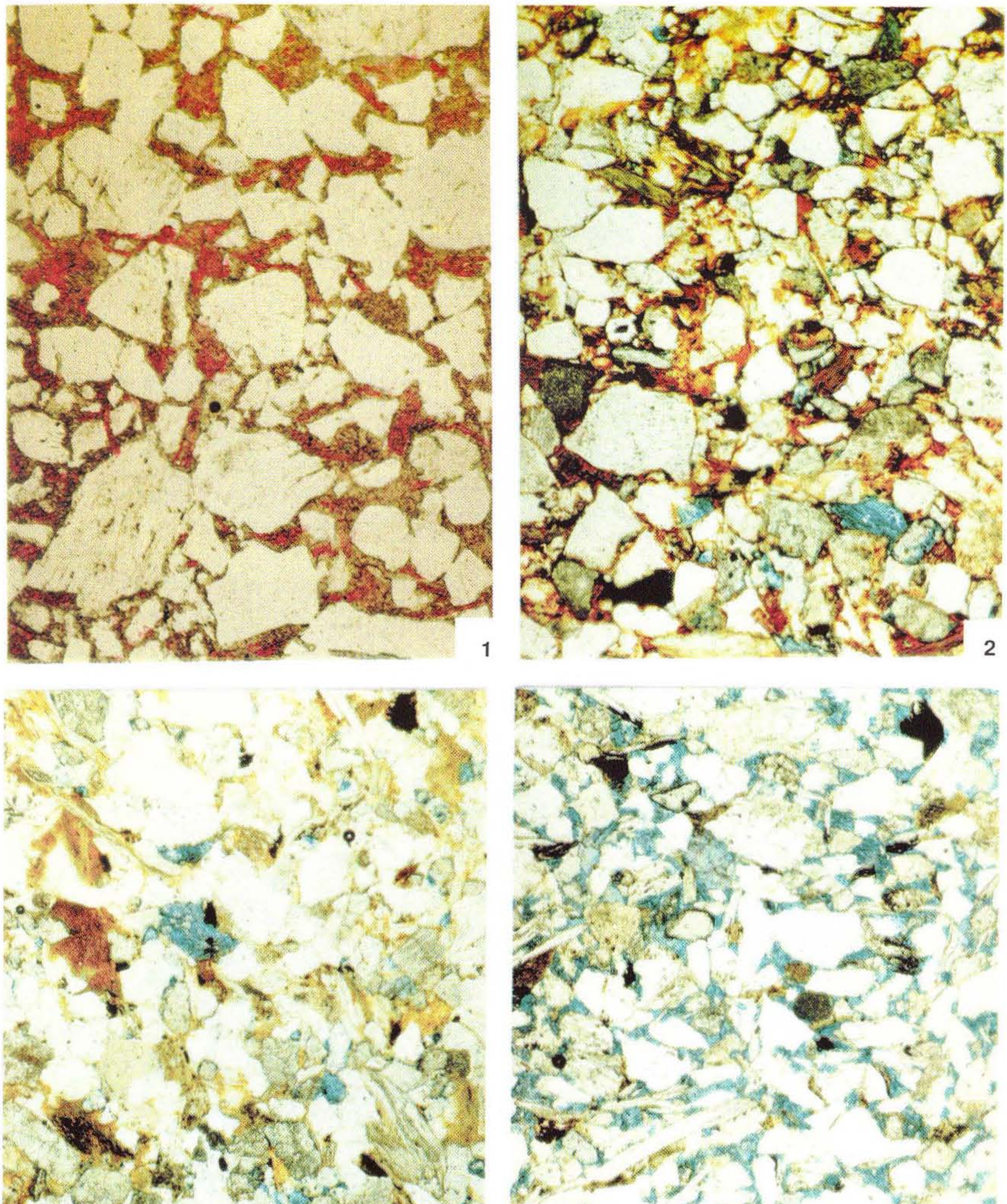
Fig. 3 Litharenite with moderate porosity and cementation. Second group of sandstones with medium reservoir quality.

Fig. 4 Highly cemented (Fe-dolomite, blue) weakly porous litharenites. Third group of sandstones with low reservoir quality.

PLATE II

Fig. 1 SEM photomicrograph of illite in the form of a grain coating.

Fig. 2 SEM photomicrograph of pore filling kaolinite. Note abundant intergranular porosity.



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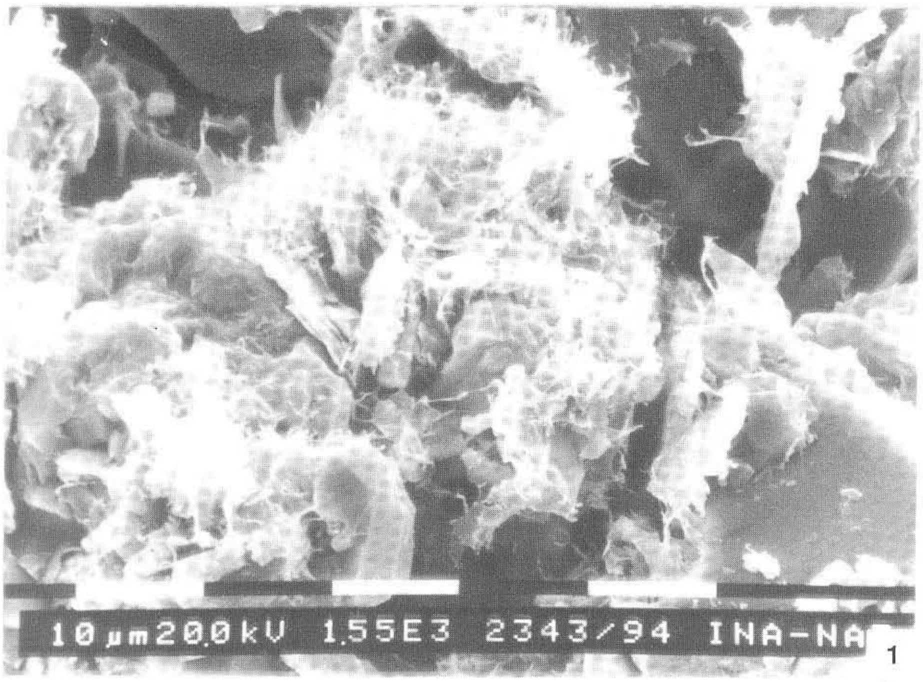
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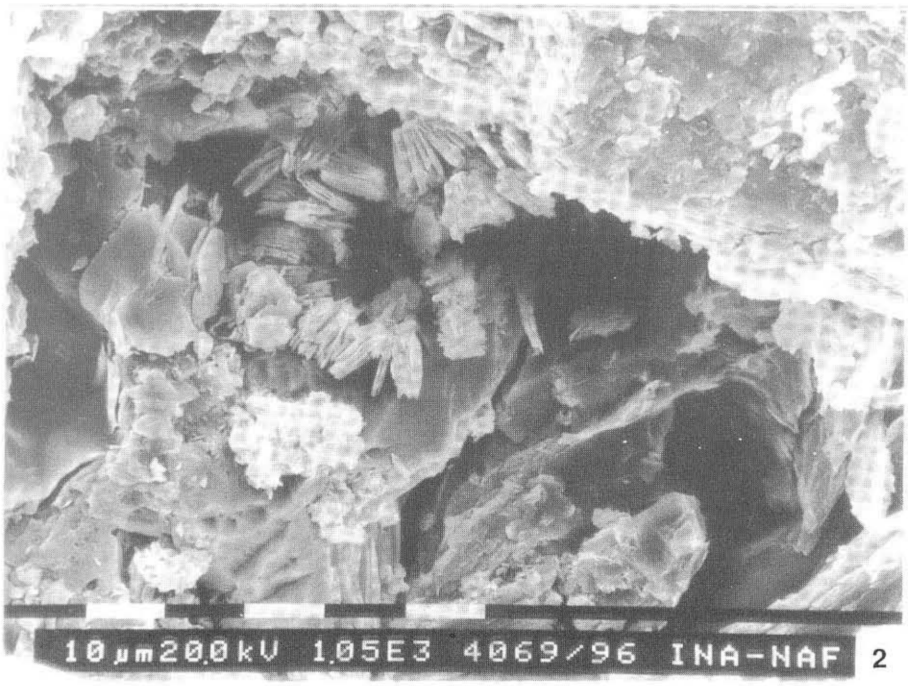
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