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Theses of PhD dissertation

SEDIMENTOLOGICAL MODELING OF SZŐREG-1 GAS CAP BASED ON CLASSICAL SEDIMENTOLOGICAL AND GEOSTATISTICAL METHODS AS WELL AS CT-SURVEYS

SZILÁGYINÉ SEBŐK SZILVIA

Supervisor:
DR GEIGER JÁNOS
associate professor

FACULTY OF SCIENCE AND INFORMATICS
DEPARTMENT OF GEOLOGY AND PALAEONTOLOGY
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1. SCIENTIFIC AND HISTORICAL BACKGROUND

In January 2006 the Hungarian Parliament passed a law on implementation of a strategic gas storage, and spelt a tender for its implementation. The winner of the tender - MOL Plc - started to design and develop a security mobile storage with a nominal capacity of 1.2 billion m^3. The proposed gas storage is situated in the Szőreg-1 reservoir of Algyő Field.

The matter of the subject is related to the data processing and data analysis carried out partly by the author ***(GEIGER – SEBŐK 2008, 2009)***, framed by a R&D project (No. UX7317.10.45/95) in the University of Szeged, Department of Palaeontology and Geology running from 2006 to 2009, and to the previous research results of the author ***(SEBŐK 2006, 2008)*** joining to this topic.

The mostly fine clastic, lacustrine Pannonian sequences in the Carpathian Basin are found in large areas and thickness. These sequences are outstanding from the country's economy providing hydrocarbon reservoirs, lignite and various other raw materials in Hungary. No wonder that research on Pannonian strata dates back more than 130 years.

Due to the continuous development of the research methods the revision of previous scientific results was necessary several times. The *Congeria* genus is widespread in Pannonian strata and was described in 1835 by ***PARTSCH (1835)***. Initially, research was based on bio-and lithostratigraphic correlation (***FUCHS (1870, 1870), HÖRNES (1862, 1870), BÖCK (1875, 1875), HALAVÁTS (1882, 1886, 1892, 1911, 1923)***). One of the main merits of the Balaton Monograph of ***LÓCZY (1913***) was the detailed study of the shoreline of Lake Pannon. ***STRAUSZ (1942, 1958, 1949)*** aimed to clarify the use of Pannonian fauna in biostratigraphy and also recognized the cyclic nature of sedimentation.

In terms of the earliest identification of Pannonian sedimentary facies works of ***SÜMEGHY 1939, STEVANOVIC 1951, STRAUSZ 1943, 1971, SZÉLES 1971*** should be emphasized. ***SZÉLES (1968)*** pointed to a clear difference between Lower- and Upper Pannonian in which the mixing of Lower and Upper Pannonian fauna was explained by the abnormal settlement of species.

The idea of the delta model of lacustrine basin infill was raised in the works of ***MUCSI (1973), MUCSI&RÉVÉSZ (1975)*** and ***RÉVÉSZ (1980)***.

RÉVÉSZ (1980) pointed out a more accurate understanding of the infilling process with the detection of multiple delta cycles of the Upper

Pannonian sediments of the Algyő Formation and developing the basis for the litostratigraphical subdivision of Pannonian stratas of the Great Hungarian Plain ***(GAJDOS*** et al. ***1983)***.

By the 1970s and 1980s it has been clearly verified that the Lower and Upper Pannonian units are unsuitable stratigrgaphic markers because they represent different sedimentary environments. The recognition of the time-transgressivity of the Lower and Upper Pannonian boundary by ***KORPÁS-HÓDI (1983)*** played the next significant step ahead. ***POGÁCSÁS (1984)*** showed that the boundary of deepwater Lower and shallow water Upper Pannonian previously fixed by geophisical logs corresponds to different dates in the basin. The delta model was first applied to Pannonian sediments by ***BÉRCZI&PHILLIPS (1985)*** who identified the boundary of Lower and Upper Pannonian as a boundary of a deltaslope-deltafront prograding from the northwest.

MATTICK et al.***(1985)*** during the analysis of seismic sections of the south-eastern part of the Great Hungarian Plain established a delta prograding model occuring in two cycles.

BÉRCZI (1988) attested 5 accumulation environments: basal turbidites, deep-water fine-grained basal sediments, delta front turbidites, shelfslope sediments and sediments of shallow lakes and braided rivers. ***BÉRCZI*** and others ***(1988)*** demonstrated that within the Pannonian (sl) sequences at the basin areas, the deep basin and shelf facies are interfingered by transitional ones. Furthermore the Lower Pannonian delta sediments grades to fluviolacustrine sediments towards the Upper Pannonian.

GEIGER (1988) aimed to establish a megascale basin-development model with quantitative methods through the morphological examination of the sedimentary units of the megacycles of delta progradation which played an important role in the filling process of the basin of the Great Hungarian Plain. Three megacycles of delta progradation were identified via Markov analysis of the deposits.

A new lithogenetic approach was developed by ***SZALAY&SZENTGYÖRGYI (1988)*** to show that the distribution of the lower series of Pannonian (sl) sediments in the basin is not uniform as they accumulated only in the deepest regions.

POGÁCSÁS et al. ***(1989)*** regarding the sediment hiatuses within the delta sequences as a local autocyclic phenomena, assigned date data to the main hiatuses by magnetostratigraphical study of strata of boreholes. It was later defined ***(POGÁCSÁS*** et al ***1992)*** and a connection was assumed between the fluctuation of water level of the seas and the Pannonian Lake based on the feasable third and fourth order cycles.

JUHÁSZ&MAGYAR (1992) pointed to a relationship between the Pannonian lithofacies and mollusk biofacies and identified the Lower Pannonian – defined by ***SZÉLES (1971)*** – with a deep water facies, as well as the Upper Pannonian with the fossils of delta plain and the transitional unit with the upper, coastal part of the deltaslope and with the deltafront. It was shown that the mollusk biofacies associated to lithofacies namely sedimentary environments, thus cannot be assigned to age margins.

The evolution of the Pannonian Basin and the relationship of Pannonian Lake and the Parathetys were examined by ***ROYDEN*** et al***, 1983, HORVÁTH, 1995.*** , ***VAKARCS 1997, VAKARCS*** et al, ***1998***.

The works of ***POSTMA 1990, FISHER*** et al, in ***ELLIOT, 1986*** is also dealing with the evolution of the delta system within the basin.

The Szőreg-1 reservoir is one of the gas-capped oil deposits in the Algyő structure located in the Upper Pannonian Újfalu Formation, which was accumulated in delta sediments ***(NAGY*** et al***, 2008)***. During production the model of the reservoir in 1979 was based on the quantitative data of logs of 494 wellbores, which had not been available before. This adaptation divides the reservoir to five layers. In 1997 a new 3D geological evaluation and sedimentological model was made in a geocellular approach ***(GEIGER*** et al ***1998)***. The main scope of this model is to simulate the even possible fluid flows or which have already taken place in the reservoir. In 2004 new intended vertical wells were drilled to start the exploitation of Szőreg-1 gas cap.

2. OBJECTIVES OF THE THESIS

The exploitation of Szőreg-1 reservoir was launched with oil production, then water injection in 1967 and continued in 1994 with gas production. The latest 3-D model of the the gas cap showed a river system starting from the water body to the gas cap with an average width of 200-300 meters and a length of 4-5 kilometers. Therefore from the point of production and storage it is not insignificant where and how the planned drilling will transverse the channel sediments. The complex sedimentological evaluation of recent core data may provide answers to the lateral extensibility of sedimentary facies with the sand or porosity contours of the former structural model. Furthermore it can be also tested whether or not the new results fit into any of the previous models available for the reservoir.

A further issue is the micro-scale effect of the channel system components on the storage properties.

This thesis is dealing with the geology and sedimentology of the rock body containing the gas cap of Szőreg-1 reservoir. The thesis is diveded into 3 main parts, which is already traditional in sedimentology: micro-, macro-, and megascale analyses. In this context the paper is dealing with the following problems:

- Sedimentary genetic subdivision of cores based on sedimentary structures;
- The spatial extension of resulting genetic units neighbouring the wells, and inserting to a former model;
- The relationship of petrophysical properties, the poresize distribution and the sediementary facies within Szőreg-1 reservoir;
- The relationship of the position of gas-liquid contact and the sedimentary genetic units;
- Modeling of micro-scale fluid flow relations on the basis of CT surveys in a cross-bedded sedimentary rock, and the question of spatial extension;
- Possible mega-scale flow conditions in the reservoir;

With the help of these surveys, the specification of the known sediementary history of Szőreg-1 reservoir can be carried out particularly considering the spatial development of sand bodies and the heterogeneity of petrophysical properties within the sedimenetary environments.

3. METHODS OF SURVEYS

Modeling was based on geophysical and petrophysical data of core surveys, detailed core descriptions, data of granulometric studies, carbonate content measurements, data of CT measurements and scanning electron microscopy.

Data processing was executed in the spirit of the scale-approach of classical sedimentology.

Mapping was implemented by Surfer 8.0 (Golden Software). Stratigraphical sections were created by Strater (Golden Software).

Geostatistical data exploration was executed by using software packages SPSS Statistics (IBM product) , Statgraphics Plus 5.1 (StatPoint Technologies), and MS Excel, whereas the processing of CT data was carried out by MVE (Medical Volume Explorer), Med Image (University of North Carolina), Osiris (University Hospital of Geneva), AFENÉBE (CT Data Processing and Preparation Against Merging Nominal Points, ***GEIGER, 2005)*** softwares.

4. NEW SCIENTIFIC RESULTS

T1. New results of examinations concerning the petrophysical and textural features of Szőreg-1 reservoir

a) According to our findings, the studied petrophisical, textural properties and the sedimentary facies identified in the reservoir are closely related. Based on the examined parameters, the following order of quality can be set up among the sedimentary facies:

1. Sandstones of prograding crevasse splays (with high standard deviation of permeability)
2. Sandstones of distributary channels
3. Sandstones of crevasse splays
4. Sandstones of distributary channel-natural levee complexes
5. Sediments of abandonments after crevassing processes

b) According to the findings of mercury test run on cores, the factor analysis exploring the relationships between textural and petrophisical properties, and the measurement of carbonate content it is found, that in the test samples during litification the primary pore space is determinant, which was mainly formed by sorting or sudden sedimentation as well as erosional processes. Thus, the sedimentary genetics of the rock is reflected in its petrophysical properties. The calcite and dolomite content in sandstones reduce the porosity and permeability. An increrase in carbonate content narrows the pore space between 2.5 -5 .0 microns in favour of pores between 0.1-0.235 microns. This should be considered in planning workovers for improving porosity and permeability However diagenetic effects – such as the effect of carbonate minerals – are of primary importance in influencing physical properties at the level of micropores. So at the current state of diagenesis the primary pore space is not predominantly affected. Based on the results of factor analysis, the least affected pores by secondary effects and the most stable pores are in the range of 7.5 to 15 microns.

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T2. New results concerning the sedimentary genetics of Szőreg-1 reservoir

The previously known spatial position, extension and development history of the northern and south-southwestern distributary mouth bars was refined with a delineation of a prograding distributary mouth bar from the east. Smaller distributary channels was also clearly identified and delineated. According to our findings this eastern distributary mouth bar- and channel system also played an important role in formation of the gas cap of Szőreg-1 reservoir.

T3. New results of normal and fluid flow CT measurements

a) It was demonstrated, that the main conductivity surfaces are at the border of the two different rock types (sand and silt), since fluid flow and recharge is much faster here than within the pure sand or a sand caharcterised by smaller Hounsfiled Units. In the sample examined the rock parts characterised by 2-6% porosity at the border of two different rocktypes behave as first „invasion corridors" at the beginning of charging process. The rockparts with a higher porosity join in later. Rock parts with the highest effective permeabilty (22-28%) are the last participants of the recharge process.

b) In the samples examined, for storage processes rock parts with smaller pressure contrast, while for the displacement processes rock parts with bigger pressure contrast are more suitable..

T4. The possible effect of amalgamation surfaces on fluid flows

According to our findings of tests run ont he test sample, amalgamation surfaces may slightly slow down small scale vertical fluid flows. The surface itself does not form a barrier, but may slow vertical fluid flows by forming smaller collector areas. However, in mega-scale vertical communication of channel sediments through the amalgamation of channel deposits may be achieved

T5. New results of the relationship between gas-water contact, sand bodies and the possible fluid flow conditions within the rock body of Szőreg-1 reservoir:

From the point of groundwater flow, sediments of fringe mouth bars represent the largest flow potential. However, the gas- liquid contact is not affected by the flows starting from these mouth bars. Flows starting off from the central areas do not enter the marginal zone. A potential risk factor might be the extreme vicinity of flow paths starting off from the mouth bars on the northern marginal areas to the boundary of gas cap. In these areas a more approppriate monitoring and caution is needed to prevent wells from early water cut during the production and injection processes.

5. PUBLICATIONS

ORAL PRESENTATION

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(2.) Geiger János- **Sebők Szilvia (2008)**: A Szőreg-1 gázsapkára fúrt magok komplex üledékföldtani vizsgálata. *II. MOL Jelentés.*

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6. FURTHER USE OF NEW RESULTS

New findings reported in this thesis may be used to refine an earlier model of the reservoir and gain a better understanding of the processes that take place in the reservoir body. The results of petrophysical and textural surveys can assist in planning more accurate measures of future exploitation as well as to the safer operation of the reservoir and contribute to a potential problem solving.

The genetic history demonstrated on detailed sand content maps with the spatial extension of sand contours of strata and delineation of genetic sand bodies can assist appointing subsequent wells.

The analysis of CT data can be extended to CT examinations with at least two phase fluid-flow model to help understanding of the realtionship of bedding structures and flow processes in micro and macro scale as well with the introduction of oil and water.

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