XVIII. CONGRESS OF HUNGARIAN GEOMATHEMATICS

&

VII. CONGRESS OF CROATIAN AND HUNGARIAN GEOMATHEMATICS

(CCHG 2015)

"THE GEOMATHEMATICAL MODELS: THE MIRRORS OF GEOLOGICAL REALITY OR SCIENCE FICTIONS?"

ABSTRACT & PROGRAM BOOK

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IMPRESSUM

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NOTE

The content of proceedings has not been passed English proof reading by native speaker, and that is why solely the authors are responsible for the quality of language usage.

PROGRAM

Thursday (21th May)

10:30-11:00 - OPENING CEREMONY

Janina **HORVÁTH** chairman, János **GEIGER** co-chairman, Marko **CVETKOVIĆ** co-chairman, Viktor **VOLFORD**, chairman of IAMG Stud.Szeged

You are kindly requested to arrive in time

11:00-12:15 – 1st SECTION

Chairman: Marko CVETKOVIĆ

11:00 – 11:25	István **NEMES**
Combined Capillary Curves	
11:25 – 11:50	János **GEIGER**
Some applications of Markov-type sequential Gaussian co-simulations	
11:50 – 12:15	Kálmán **BENEDEK**
DFN Modelling: recent trends, capabilities, applications	
12:15 – 12:40	László **GYŐRY**
iCore – a unique approach to packing generation	
12:40 – 13:00	Janina **HORVÁTH**
Identification of facies using Unsupervised Neural Network	

13:00 – 14:30 - Lunch break (Finger lunch in the lounge)

14:30- 2nd SECTION

Chairman: János GEIGER

14:30 – 14:55	Bruno SAFTIĆ, Iva TOMLJENOVIĆ, D. Arandia-KREŠIĆ, M. RISEK
Porosity distribition models for numerical estimates of the regional CO_2 storage potential in clastic sediments	
14:55 – 15:20	Marija **PODBOJEC**
Preliminary estimate of CO_2 storage capacity by geomodelling in Upper Miocene sandstones in the western part of Sava depression	
15:20 – 15:45	Marko **CVETKOVIĆ**
Biogenic reactions and methane expulsion modelling from source rocks of Ravneš Member, Sava Depression	

15:45 – 16:10 - Coffee break

16:10 – 17:35	Angelika **SÓLA**
Facies study to enhance ultimate oil recovery: A case history from Algyő field, SE – Hungary	
17:35 – 18:00	János **BLAHÓ**
Facies modelling in the focus of reservoir modelling	
18:00 – 18:10	Levente **KISS (e-poster presentation)**
3D modelling of a hydrocarbon reservoir formed in a delta slope	

19:00 - Dinner (Varga Csárda)

Friday (22st May)

9:00-10:15 – 3rd Section

Chairman: Omar SLIMAN

9:00 – 9:25	Tomislav **BAKETARIC**
Subsurface modelling of the Neogene-Quaternary sediments based on digitalization of handmade regional geological maps	
9:25 – 9:50	Marcell **LUX**
Evaluation and Optimization of Multi-Lateral Wells Using MODFLOW- Unstructured Grid Code	
9:50 – 10:15	Viktória **PATAKI**
3D modelling of a clastic turbiditic system and its uncertainty assessment: a case study from the Pannonian Basin, Hungary	
10:15 – 10:40	Zsuzsa **BRINZANEK** and Sándor TÓTH
Reservoir geology re-evaluation – case study of gas field of Pannonian age	

10:40 – 11:00 - Coffee break

11:00-12:15 - 4th Section

Chairman: Janina HORVÁTH

11:00 11:25	Andrea **WÁGENHOFFER**
Modeling geological structures with Training Image for Multiple-Point approach: from Theory to Practice	
11:25 – 11:50	Petra **SLAVINIĆ**
Subsurface volume calculation – a comparison between mathematical integration and cell-based models	
11:50 – 12:15	Noémi **JAKAB**
Uncertainty assessment based on static connectivity metrics and information entropy	

12:30 – 14:30 - Lunch break Lunch break (Finger lunch in the lounge)

14:30- 16:00 5th Section

Chairman: István NEMES

14:30 - 14:55	Viktor **VOLFORD**
Application of 3D seismic data to constrain the reservoir models	
15:20 – 15:45	Omar **SLIMAN**
Uncertainty delineation from the petrophysical modelling of Lower Nubian Reservoir	
15:45 – 16:00	László **ZILAHI-SEBESS** and Erika BODA
Recommended principles of the qualifications of geothermal plays	

16:00 – 16:20 - Coffee break

16:20- 18:00 6th Section

Chairman: István Gábor HATVANI

16:20 – 16:45	Gábor **SZATMÁRI**
Using a sequential stochastic simulation approach based on regression kriging to generate functional soil maps	
16:45 – 17:10	Dániel **TOPÁL,** István Gábor HATVANI, István MATYASOVSZKY, Zoltán KERN
Break-point detection algorithms tested on artificial time series	
17:10 – 17:35	Sándor **GULYÁS,** Csilla BALOGH, Antónia MARCSIK, Pál SÜMEGI, Dávid KÓKAI
Geometric morphometric analysis of artificially distorted skulls from an Avar Age site near Makó, SE Hungary	
17:35 – 18:00	Petra **BODOR ,** József KOVÁCS, Anita ERŐSS, Judit MÁDL-SZŐNYI
Time series data analysis of parameters of lukewarm springs from the Rózsadomb area, Hungary	

18:30 - Dinner in the 'Puszta'

The 'Tuk-Tuk' departs at 18:30 from the square next to congress centre. If you late you will walk…

From 22:00 (p.m.) shuttle bus is available from the site to 'Congress centre'

Saturday (23st May)

9:00- 10:15 76th Section

Chairman: János Geiger

9:00 – 9:25	Szabolcs **BORKA**
Analysis of deep-water clastic depositional systems' lithofacies based on their genetic by application of Markov chains and entropy tests	
9:25 – 9:50	Mátyás **SANOCKI**
Importance of proper layering of 3D grids; how bedding parallel layering can enchance solve long-lasting stratigraphical and structural geological problems - a case study of facies modeling from the Tóalmas region, Hungary	

9:50 – 10:15 - Coffee break

10:15-11:30 - Workshop

Scope: "Geological models supported by geomathematics: the mirrors of geological reality or science fictions?"

First rule of the workshop: „Keep it in practice!"

- What is a model?
- Is modelling really necessary? Why?
- What are the goals of building models?
- What types of approaches are used for modelling in the industry?
- What are the most important input data?
- Common gaps and controversies in input data, challenges during setting up a geological model
- Processes and methods to overcome these difficulties
- How to handle uncertainties? How to differentiate and mitigate stochastic and conceptual uncertainty?
- Feedback on the models

Moderators: István **NEMES,** Mátyás **SANOCKI**

Reservoir Geologists at MOL Group

11:30 – 12:00 – Closing ceremony

ABSTRACTS

Subsurface modelling of the Neogene-Quaternary sediments based on digitalization of handmade regional geological maps

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The goal was the accurate digitalization and subsurface modelling of the paper-based geological maps. The research area covers approximately 1053 square kilometres located in Croatian part of Pannonian Basin System, Sava Depression, i.e. in surrounding of Stružec Oil Field. Data input for the structural analysis were from structural maps previously handmade (interpolated) by VELIĆ (1980). Set included five structural maps based on regional e-log markers and one map of pre-Neogene top. All were digitalized in program ArcGIS. Structural contours and around 150 faults were exported into Petrel software where they were further processed and regrouped. From such digitalized and processed data the digital geological model (geomodel) was made using complex fault framework. The study concerned the advantages and errors that occur during creation of such geomodel. It clearly displays relations between major and minor faults and fault slips, geological structures and structural traps in 3D (e.g. anticline of the Stružec Field). Another advantage is multicolored presentation of depths and faults, which enables easier recognition of geological structures and potential traps for hydrocarbons. Errors and issues can occur during digitalization of contour lines, selection of the appropriate algorithm and those ones that arise when model is created.

REFERENCES:

VELIĆ, J. (1980): Geološka građa zapadnog dijela Savske depresije [Geological structures of western part of Sava Depression – in Croatian]. -PhD Thesis, University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Zagreb, 137 p.

Key words: subsurface modelling, handmade interpolation, digitalization, Sava Depression, Stružec Field

DFN Modelling: recent trends, capabilities, applications

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In the previous decades discrete fracture network modelling underwent fundamental changes and developments. This process was fuelled primarily by the recognition that structural discontinuities control flow, stability, transport, porosity, etc. in fractured rocks and by the increasing need from the market side to better represent the geometry of fracture networks in real industrial projects. This presentation attempts to summarize recent trends, capabilities and applications of DFN theory, but no details of DFN fundamentals will be shown here. The main topics covered are: basics and techniques to build up realistic DFN models, testing the geometry and parametrization of DFN's, implementation of double porosity models (static and dynamic), actual stage of coupled (hydro-mechanical) DFN approaches, implementation of hydraulic fracturing and geomechanical applications in the mining industry.

Key words – DFN, double porosity, coupled models, hydraulic fracturing, geomechanics

Facies modelling in the focus of reservoir modelling

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The Department of Reservoir Geology at MOL Plc. was equipped with high level software capabilities a few years ago to become able to perform enhanced reservoir modelling jobs. ROXAR IRAP RMS software is an excellent and constantly developing 3D modelling tool that helped us to acquire useful experience; the results have been presented at scientific meetings. Although the mathematics of the 3D modelling is straightforward, we always need to find the best methods under various conditions to achieve optimal results. Facies modelling is a crucial step at building sophisticated models assessing the genetics and geometry of the reservoirs with methods of geomathematics. Case studies from the Algyő Field are presented in this paper. The selected modelling technics, methods are dependent on the number of wells, the type of data existing in the wells, the seismic data available, the actual hypothesis of the depositional environments and sedimentary facies or stratigraphic pattern. The case studies prove the usefulness of the correct facies models predicting the real flow directions, water influx directions, connections or separations between sandstone bodies inside a reservoir with highly variable lithology.

Key words: facies modelling, reservoir modelling, depositional environments, flow directions, sandstone bodies

Time series data analysis of parameters of lukewarm springs from the Rózsadomb area, Hungary

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The Rózsadomb area is one of the three main discharge areas of the Buda Thermal Karst. Here both warm (>36,7°C) and lukewarm (20 – 36,7°C) springs arise. It is an important area from both a theoretical, and a practical point of view to understand the temporal changes of the physico-chemical parameters of lukewarm waters. The warm springs are fed by regional flow systems, while the lukewarm waters are originated from intermediate flow systems. The exact recharge area of these intermediate flow systems is not known, presumably the water infiltrates through the open karst surfaces in Pilis and Buda Hills.

The effect of River Danube and precipitation are the two main influential factors of the groundwater and the springs in this area. The aim of the study was to analyze the changes of the physico-chemical parameters (temperature, volume discharge, pH, electric conductivity) of the lukewarm springs and the influence of precipitation and the River Danube. Furthermore, the effect of precipitation was analyzed in the theoretical recharge area of the lukewarm waters.

Correlation- and cross correlation analyses were used to study the relationship between the two influential factors and the parameters of the lukewarm springs. The effect of precipitation on the karst water level in the theoretical recharge area was studied in six wells based on dynamic factor analysis.

Keywords – Buda Thermal Karst, lukewarm springs, cross correlation, dynamic factor analysis

Analysis of deep-water clastic depositional systems' lithofacies based on their genetic by application of Markov chains and entropy tests

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In the past few decades the process-sedimentology has become more and more important in the characterization of the deep-water clastic depositional systems. In this way, the recognized faciological attributes can be associated with the depositional processes (e.g. deposits of slumps, sandy debris flows, turbidity currents etc). In this paper this approach is presented through two case studies of Tercier deep-water sequences of the Pannonian-basin.

The cyclicity of sedimentary sequences can be easily revealed by using Markov chains. Though Markov chain analysis has broad application in mainly fluvial depositional environments, its utilization is uncommon in deep-water systems.

In this context genetic litofacies were determined and analysed by embedded Markov chains. The randomness in the presence of lithofacies within a cycle was estimated by entropy tests (entropy after depositional, before depositional, for the whole system). Consequently the relationships between lithofacies were revealed. Of course it was necessary to interpret the statigraphy of the sequences in terms of „general" sedimentology, focusing on the structural elements. For this purpose, well-logs and standard deep-water models were applied.

The consequences coming from the comparison of „general" sequences (composed of architectural elements), the genetic-based sequences (showing the distributions of the genetic lithofacies) and the lithofacies relationships were discussed in details. In this way connections were found between the architectural elements and cyclic patterns of the lithofacies in each well.

Key words: Markov chains, Pannon-basin, deep-water systems, genetic lithofacies, depositional process

Reservoir geology re-evaluation – case study of gas field of Pannonian age

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Reservoir geological re-evaluation of hydrocarbon reserves has become an important task in Hungary as part of MOL Group's Exploration and Production 200 Kilo Barrel Oil Equivalent Program (200 KBDOE PROGRAM), that is to achieve 200 kboe daily production. The field presented in this paper is located in the Pannonian Basin System in Nagykunsági Neogene Basin and the turbidite sandstone reservoir is part of Pannonian age Szolnoki Formation. The goal of the assessment of this gas field is to decide whether to restart production. It was registered as a discovery until 2003, when after a re-testing process in 2005, production had been started. After some months of production, the field had closed because of increasing water yield. In the meantime, a 3D seismic survey was performed and interpreted and re-evaluation of reservoir geology was accomplished. The aim was to verify the original geological model and to estimate the Gas-Initially-in-Place (GIIP). Resources calculation based on the new reservoir geological model cut back original quantity of HC. Taking into account the new calculations it seemed to be worth drilling a new production well in order to deplete the target reservoir.

Key words – reservoir re-evaluation, hydrocarbon reserves, Pannonian Basin System.

Biogenic reactions and methane expulsion modelling from source rocks of Ravneš Member, Sava Depression

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In the evaluation of the initial hydrocarbon prospectively of the entire Lonja Formation (approximate Pliocene, Pleistocene and Holocene sequence), the Lower Pliocene Ravneš Member was used as analogy. In this member we tested the possibility of the HC generation based on biogenic reactions.

This member bears large volumes of coal and organic rich clays with type III and IV kerogene. The current depth of this member is a maximum of -1300 m in the deepest part of the Depression and the timing is sufficient for releasing the biogenic derived methane. Ravneš Member, as well as the whole Lonja Formation is being tested for HC potential based on the analogy of the Adriatic offshore biogenic gas accumulations of large volumes and frequent gas shows in the shallow intervals within the research area. Structural model was obtained from previous research. Facies maps of Ravneš Members were made using the combination of neural networks for input preparation and using convergent interpolation for actual mapping. Spatial distribution of geochemical properties was also mapped trough the exploration area. Generation potential was obtained by 3D basin modelling in Schlumberger PetroMod software.

Key words: Basin modelling, biogenic reactions, Pliocene, Sava Depression, Croatia

Some applications of Markov-type sequential Gaussian co-simulations

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The assessment of measured water levels in a monitoring system is not a trivial task, at all. The basic problems can be addressed to two corner-points. Sometimes the water levels are very close to the surface. In this situation the absolute errors associated to the estimation surface may result in uplifting of the estimated levels above the surface. Also, the water levels measured in consecutive periods are not independent on one another. So their independent maps may not reflect the proper temporal movement of water levels. As a practical solution a sequence of Markov-type co-simulations are used. In this case, a simulation at a particular period is constrained by the water surface estimated for the immediately preceding period. The results are compared with that of collocated co-simulations, collocated co-kriging, and independent sequence of sequential Gaussian simulations.

The basic ideas behind the co-simulation are also suitable for the estimation of rock body morphology when the rate of sedimentation is primarily controlled by the base morphology. In this case the thickness simulation is constrained by the base surface, and the model uncertainty is expressed by the uncertainty of thickness simulation.

Key words: Sequential Gaussian co-simulation, Markov-type co-simulation, monitoring system

iCore – a unique approach to packing generation

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A combined approach based on grain size distribution and microscopic investigation of grain shapes is applied to generate virtual packing of grains. The grain shapes are always convex but vary on a wide scale from flat and angular to rounded and spherical with a given probability of geological occurrence. Each grain is characterized by an equivalent volume taken from experimental grain size distributions. Grain packs for a specified porosity value are generated through sedimentary, compaction and diagenetic steps. The method for compaction is the biased random walk method with a collision detection of Gilbert – Johnson – Keerthi. The porosity adjusted packs are then used for modelling conventional and special core analytical measurements.

Geometric morphometric analysis of artificially distorted skulls from an Avar Age site near Makó, SE Hungary

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Intentional cranial deformation was once commonly practiced in a number of cultures, including those of Egypt, China, South America as well as some groups (Huns, Gepids, Avars) populating the Carpathian Basin in Late Antiquity (300-700 AD). Flat shapes, elongated ones, conical ones are the most common of the head forms achieved. The practice of cranial deformation takes its origin in an attempt to (i) emulate those groups of the population in which elongated head shape was a natural condition, and to signify group affiliation, or (ii) at creating a skull shape that is aesthetically more pleasing or associated with desirable attributes.

There is no established classification system of cranial deformations. Many scientists have developed their own classification systems, but they have not agreed on a single classification for all forms that are seen. This is equally true for metrics. Traditionally the so-called Oetteking-Ginzburg-Žirov index is used to express the degree of deformation calculated as the ratio of the basion-antibasion and glabella-inion metric distances of the skull. This index however may not document minor regional differences in the ratio of head deformation correctly on the one hand. In addition it is not applicable to fragment skulls, where the referred anatomic landmark points are missing. Geometric morphometric techniques can offer a good solution to quantify cranial vault shapes. Shape differences within and between groups can be statistically analyzed and visualized. This way even minor regional difference in deformations can be assessed. The slightly deformed female skulls of the Avar Age cemetery near Makó has been analyzed for shape differences. The outline of the cranial vault was digitized in lateral view from the glabella to the lambda using anatomical and pseudo landmark points. General Procrustes Analysis was used to remove differences in location, rotation and size. The residual shape variables were assessed statistically and visually using multivariate statistical techniques to highlight major components of shape variation (PCA) and potential differences (CVA). According to initial findings, the majority of shape variation was anatomically and age controlled. In front and back views sings of taphonomic distortion could have been identified as well. CVA classification yielded a better classification system than the traditional metric index. Our work is supported by OTKA Grant No. 109-510.

Key words: artificial cranial deformation, geometric morphometrics, Avar Age, SE Hungary

Identification of facies using Unsupervised Neural Network

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Clastic sedimentology, and within that facies analysis, have used applied mathematics approaches for a long time. Several mathematical and statistical applications help in facies analysis. After the 1960-1970s the multivariate statistical approaches became widespread in the field of sedimentology. Multivariate analysis is able to handle simultaneous observations, several data points, and to analyse more than one outcome variable. Since the aim is a kind of pattern recognition (facies) using high-dimensional properties, the most suitable methods are the classification processes. In these approaches, the basic principle is the following: the more similar the way in which the samples are deposited, the closer their positions are in the property space, and thus they belong to the same group using the clustering method. The goal is to form units which are able to describe sedimentary facies through common characteristics. Nowadays, principal component analysis (PCA), discriminant function analysis (DFA), K-means analysis and several types of artificial neural network are frequently applied techniques for facies identification based on core data, e-log data or a combination. In case of both approaches (PCA, DFA) the projection inflicts a kind of distortion on the original data dimension. These projections are simple linear maps of the multidimensional dataset or singular value decompositions. K-means clustering method is a classical and widely used clustering process. This method is a centre-based algorithm, and it is considered very efficient for clustering large and high-dimensional datasets. The K-means method applies centroids as prototypes to represent a subset or group in the overall dataset but some test proof that this method was not able to recognise clusters in any situation and sometimes failed to find any reasonable groups. Since that kind of non-linear clustering process like Kohonen network are more efficient. Kohonen network is an unsupervised network which can solve specific problems of indirect data mining, such as, clustering, pattern recognition and visualisation. As a tool for identification, Kohonen network has been demonstrated in several publications.

It is able to handle separation of such clusters which has complex structure in the property space (so-called chain-link clusters) or clusters which are described variables with non-linear relation. So, these techniques work well in the case of totally missing linear connection, as well. E.g. poro-perm relation is not a linear one, but these properties can be used for meaningful separation of samples.

Key words: Clustering, facies analysis, unsupervised neural network

Uncertainty assessment based on static connectivity metrics and information entropy

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Uncertainties are inherent features of geological models, however, so far no general approach exists to visualize and communicate them. In this work we apply static connectivity metrics to characterize these uncertainties and to outline possible, characteristically different scenarios from stochastic simulation outputs.

Global metrics of connectivity, also called geo-body or geo-object connectivity, are related to the overall structure of the simulated media. These metrics are particularly useful, firstly, because the connectivity structure of the heterogeneity is a property that strongly influences subsurface flow, and also, because on the basis of these geo-objects, fields, which otherwise show the same characteristics from a statistical point view, become distinguishable. This is due to the fact that most common methods used to describe the spatial distribution of a field, are based on two-point statistics, such as the covariance or variogram. However, these metrics only describe the probability of having a certain value at a location given the value at another location, but they do not reflect the possibility of having a connection between these locations.

Regardless of these beneficial features, connectivity metrics have rarely been used in Hungarian literature, hence we chose to focus our paper on this topic.

Key words – connectivity, uncertainty assessment, geological modeling, sequential gaussian simulation

3D modelling of a hydrocarbon reservoir formed in a delta slope

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This paper presents a 3D statistically supported geological model for a reservoir formed on a Pannonian delta slope. The study area is a part of the Algyő hydrocarbon field in south-eastern Hungary. The main goals of this work were to locate and separate those slumped sediment bodies with high porosity and permeability, which originated from the upper region of delta, and to determine the local flow direction.

The available dataset consisted of stratigraphical and lithological information, furthermore porosity, permeability, effective thickness, hydraulic conductivity of reservoir sections.

The workflow starts with the by-well calculations of weighted averages of porosity and permeability data available for reservoir sections. The weighting factor was the effective thicknesses of the permeable sections. These well-averaged data was the input of variography. The main transport direction was assumed to be parallel with the main axis of the geometric anisotropy of porosity and permeability data. Results suggested that the local transport direction might be from SE.

Thereafter, this data was used to build a model by a directional weighting algorithm. This algorithm was chosen because it can use the result of the variography. At the same time, a lithological model was created. As the final step these two models was compared to reveal the difference between petrophysical and lithological continuity and to validate the result.

Key words: Algyő Field, transport direction, porosity, permeability and lithological model, variography

Evaluation and Optimization of Multi-Lateral Wells Using MODFLOW-Unstructured Grid Code

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Multi-lateral wells have been increasingly used in recent years by different industries including oil and gas, coal bed methane and water production. The common purpose of these wells is achieving higher production rate per well. With the continuous advancement in technology more and more sophisticated well patterns and geometries are possible to be implemented in practice. Therefore, there is an increasing need for the improvement of modelling techniques as well.

Complicated well geometries and the relatively small diameter of the laterals require high resolution models in the vicinity of the wells. With structured finite difference grids this can only be achieved by unnecessary refinements even far away from the wellbores causing an undesirable increase in CPU time. However the model will still suffer from orientation problems as laterals will not coincide with rows or columns of the rectangular mesh in most of the cases.

In our work we applied unstructured grids to model multi-lateral wells using the MODFLOW-USG code which simulates groundwater flow using a generalized control volume finite-difference approach, which allows grids other than orthogonal structured grids. This offers a solution for orientation problems and also allows for sufficiently small cell size around the laterals without overly increasing the number of cells in the whole model domain. The paper compares unstructured and structured models of multi-lateral wells along the above-mentioned principles.

The second part of the paper aims at the optimization of multi-lateral well geometry by evaluating the effect of length, angle and number of laterals. During the optimization we consider the possible advantages of minimizing drawdown instead of maximizing flow rates.

Key words: unstructured grid, multi-lateral well, hydrodynamic modelling

Combined Capillary Curves

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The main aim of the presentation is to describe a new concept at studying and modelling the relationship between initial water saturation profile and capillarity in water-wet HC-reservoirs, and describe the available measurement methods and possible applications. As a side track it aims to highlight the derivable parameters of mercury capillary curves using the Thomeer-method.

Capillarity of reservoir and seal rocks bears with a huge effect from the geological modelling throughout the history matching and even at EOR/IOR methods. The capillary behaviour plays a significant role in subsurface processes, and since they can be estimated by the rocks' capillary curves, these data are crucial and extremely useful.

There are two widely used methods available for quantifying capillary features of rocks. The mercury injection method's primary advantage is that it is capable to map the entire pore system, but it has a serious disadvantage, namely that it does not reveal irreducible water. On the other hand, the centrifuge method is suitable to measure irreducible water saturation of samples.

Since the mercury capillary curves themselves can lead to over-, or underestimation regarding in-place volumes, reserves and reservoir behaviour, the need for a proper capillary curve is reasoned.

Applying the presented method normalization of the mercury capillary curves becomes possible, and the application of this new, combined capillary curve, representing the pros of both measuring method, for engineering calculations becomes viable Thomeer-method.

A comparison of this approach and another widely used saturation modelling method showed an overestimation of HCIIP, reserves and recovery factors in the latter case.

The exact results of these calculations (employing actual reservoir data) shall be presented supposing different reservoir sizes, i.e. a wide range of hydrocarbon column.

Key words: capillarity, combined capillary curve, water saturation, Thomeer parameters

3D modelling of a clastic turbiditic system and its uncertainty assessment: a case study from the Pannonian Basin, Hungary

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This paper presents a case study of reservoir characterisation, consisting of the explicit modelling of lithofacies and petrophysical attributes (porosity, permeability), the value, variability and spatial distribution of which have control on the fluid flow behaviour of the reservoir. Modelling the known heterogeneities (conditioning to well observations), simulating the spatial variability of the attributes at the interwell region and assessing the uncertainty are the main stages to establish the reservoir model.

The study area is located at the Great Hungarian Plain and is characterised by Lower Pannonian turbiditic sediments. The top and thickness maps of the reservoir were provided by E-type estimation of 100 stochastic realizations, applying sequential Gaussian simulation. Multivariate statistical techniques have enabled probabilistic discrimination of the different electrofacies. Four, statistically different groups could be separated using K-means cluster analysis of spontaneous potential and porosity log values, which results have been verified by discriminant function analysis. Each electrofacies were given geological meaning by assigning lithofacies equivalent to each of the clusters, incorporating the information coming from the core observations. The spatial distribution of each of the lithofacies was simulated in three dimensions. Stochastic simulation methods were applied to simulate the interwell variability and spatial distribution of the petrophysical attributes (porosity, permeability) specific to lithofacies. As a final step of the investigation, the uncertainty concerning the lateral continuity of the variables was assessed by providing maps of the probability of exceeding critical values, and determining the distribution of possible outcomes given by the several realizations in each grid point.

Key words: turbiditic system, electrofacies analysis, stochastic simulation, uncertainty assessment

Preliminary estimate of CO_2 storage capacity by geomodelling in Upper Miocene sandstones in the western part of Sava depression

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A preliminary assessment of the capacity of regional geological storage in the western part of Sava Depression was based on 15 deep exploration wells. Poljana Sanstones, a regional deep saline aquifer is suggested to be a promising underground facility for the storage of CO_2 in the study area. Poljana Sandstones (member of Kloštar Ivanić Formation) have favourable petrophysical properties and are situated at reasonable depths. According to previous investigations, at depths greater than 800 meters supercritical conditions of temperature and pressure CO_2 are achieved, which ensures easy and safe injection into storage underground facilities. For creation of model in Petrel various data was used and included density of CO_2 distribution, porosity, effective thickness and relative depth of sandstone. Porosity distribution was made based on neutron porosity logs. The most important parameter in estimate of storage capacity is effective thickness, which was defined by two E – log markers R_v and Z'. Hence, the effective thicknes was used for plane of top and base of sandstones. Density distribution of CO_2 was created according to their spatial distribution regarding the depth and the temperature. Capacity of storage of CO_2 was calculated by volumetric method.

The use of calculated model can subsequently determine the amount of CO_2 storage in underground facilities of the study area. This may find application in spatial planning and in directing investment in those studies that lead to local estimates of storage capacity of the selected deep saline aquifer.

Key words: Petrel model, Poljana Sandstones, capacity of storage of CO_2, porosity, Sava Depression

Porosity distribition models for numerical estimates of the regional CO2 storage potential in clastic sediments

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Regional evaluation of the CO2 geological storage potential presumes estimates of various rock properties (depth, effective thickness, pressure, temperature and porosity). Modelling the spatial distribution of porosity is often burdened by scarce input data. The existing model for the Upper Miocene sandstone layers of the deep saline aquifer Poljana in the western part of Sava depression made by Iva Kolenković in her PhD Thesis is based on the quantitative interpretation of well logs in 20 wells, which is a relatively small number of input data for an extensive exploration area. To compensate for this and to increase reliability of a porosity model, two new maps were constructed. One of them based on the regional regression analysis of the dependance of porosity with mean depth of the regional saline aquifer, which rendered a good solution for simple evaluations in the lack of data. The flaw of this method is an assumption that porosity varies only with depth, i.e. with compaction, which led to overestimated values for shallow layers and underestimated values for the same sediments in deeper structural units. Considering that in the exploration area sandstones were deposited by turbidity currents, this assumption resulted in reduced values of specific CO2 storage capacity in central areas with thick layers of sandstone, and therefore the overall storage capacity in the deep saline aquifer Poljana was underestimated. The second map was constructed based on the regional regression analysis of the dependance of porosity on two parameters – mean depth and effective thickness. In the central, deeper areas, increased values of specific storage capacity were obtained in respect to the first model. In both cases, the porosity values were also estimated for wells without corresponding well logs, and the reliability of the calculation of specific and total CO2 storage capacity was increased. Tested models can be used for planning of detailed exploration in areas with larger potential, i.e. at the most prospective locations.

Key words: CO2 geological storage, Sava depression, Poljana sandstones, porosity, CO2 storage capacity

Importance of proper layering of 3D grids; how bedding parallel layering can enhance solve long-lasting stratigraphical and structural geological problems - a case study of facies modelling from the Toalmás region, Hungary

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Importance of proper layering in 3D grids is often underestimated. Layering should reflect the genetics of the given depositional system which is in focus of the modelling. In many cases due to the long burial and tectonic history of the modelled area, standard methods like bottom/top conform or proportional layering results in distorted statistics of grid scaled-up well data which is inappropriate for property modelling and prediction in areas outside of wellbore control. This paper describes a case study of using bedding dip-parallel layering to understand the relationship between some neighbouring wells which show very different lithology.

Key words: facies modelling, VPC, bedding parallel layering

Subsurface volume calculation – a comparison between mathematical integration and cell-based models

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The calculation of geological structures volumes is one of the primary goals of interest when dealing with exploration or production of oil and gas in general. Most of those calculations are based on advanced software packages but still in some cases detail mathematical workflow (equations) has to be presented for legislative validation of reserves. In this paper a comparison is given between volume calculations of geological structures using trapezoidal and Simpson's rule and the ones obtained from cell-based models. Comparison in calculation is illustrated with four structural models; sphere, brachianticline, stratigraphic trap due to lateral facies change and anticline structural faulted trap. The Simpson's rule is regularly applied for hydrocarbon reservoir volume calculation and shows best results when structure is close to a regular anticline. However, it cannot be applied in all of the cases as the rule suffers from sensitivity to the number (even or odd) of members, i.e. volumes defined by isopaches. Trapezoidal rule can be applied in all of the cases but tends to be less accurate than the Simpson's rule. In general, structures calculated with Simpson's rule have underestimated volume and the ones by trapezoidal overestimated in comparison with the model derived value from the Petrel software. Such differences in calculated volumes are larger as the irregularity of the structure increases.

Key words: volume calculation, Simpson's rule, trapezoidal rule, cell-based volume.

Uncertainty delineation from the petrophysical modelling of Lower Nubian Reservoir

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Effective management of petroleum reservoirs regularly requires detailed spatial models of the reservoir namely; facies modelling and their petrophysical properties modelling. Because spatial heterogeneity of these properties is commonly complicated and the available information is limited, it is impossible (even unrealistic) to build any deterministic models that represents the actual heterogeneity of the reservoir. By accepting and understanding these limitations it becomes sensible to translate the imperfect knowledge into a probabilistic framework. In general, uncertainty can be interpreted as imperfectness of our knowledge. In the characterization of petroleum reservoirs local, regional and response uncertainty were defined. Local uncertainties are uncertainties about the value of a petrophysical attribute at an un-sampled location. Spatial uncertainties are joint uncertainties of values at several locations taken together.

In this work those thoughts were applied in the geostatistical analysis of the uncertainty of spatial distributions of the petrophysical properties namely; well-averaged porosity, permeability and shale volume properties coming from quantitative well log interpretations of the Lower Nubian sandstone reservoir. This paper attempted to relate the different uncertainties of reservoir rock properties, namely porosity, permeability and shale fraction, to geological controls of heterogeneities. These controls, such as sedimentary facieses, diagenetic trace prints, and thicknesses variation can provide a detailed description of uncertainties. In general, uncertainties associated with the reservoir properties can be related to the small scale heterogeneities of the Lower Nubian reservoir rocks.

Key words: uncertainties, petrophysical modelling, Lower Nubian.

Using a sequential stochastic simulation approach based on regression kriging to generate functional soil maps

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Numerous algorithms have been applied to model the spatial variability of soil related attributes and to generate functional soil maps. Nowadays, regression kriging (RK) is one of the most frequently used techniques, which relies on regionalized variable theory. Nevertheless, RK has some shortcomings, e.g. it is not able to model the spatial uncertainty. In this study the test-results of a sequential stochastic simulation approach based on regression kriging (SSSRK) on a pilot area in the Mezőföld region, in Central Hungary is presented. The main aim was to model the spatial variability of soil organic matter (SOM) content using SSSRK with the constraint that the generated realizations have to reproduce the model statistics (e.g. variogram model). As a first step RK model was built up, providing the base for SSSRK. 100 realizations were generated reproducing the model statistics. It was found that SSSRK can be used to model the spatial uncertainty. SSSRK's realizations provided an opportunity to delineate areas (with probabilities), where the SOM content is low (less than 2%), moderate (2-3.5%) or high (more than 3.5%). The functional information obtained is of high interest for precision agriculture. Shannon's entropy was calculated for these functional "maps", which can be used to visualize uncertainties in this functional information. In conclusion it can be said that SSSRK is a valuable technique to model the spatial variability and uncertainty of the target variable and to complete RK's several shortcomings. Furthermore, Shannon's entropy seems to be a promising index to provide useful information about the uncertainties of functional soil maps.

Key words: sequential simulation; regression kriging; spatial uncertainty

Facies study to enhance ultimate oil recovery: A case history from Algyő field, SE – Hungary

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Algyő field is the largest and most significant oil and gas field in Hungary. It consists of about 50 (fifty) hydrodynamic units: about ten larger, saturated (gas capped) oil reservoir with moderate edge water drive in the Pliocene ("Upper Pannonian" in field nomenclature) and Upper Miocene ("Lower Pannonian"). Subordinately bottom water drive deposits (Csongrád-Dél-2, gas – capped oil, Deszk – Horizon, a non-associated gas deposit in the Upper – Miocene basal conglomerate and in the underlying fractured crystalline basement) have been discovered. The reservoirs developed in the pro-delta, delta front delta plain units of a NW-SE running paleo (Late Miocene-Pliocene) Algyő progradational siliciclastic delta system.

The distribution of the hydrocarbon saturation in the reservoirs is tightly controlled by the lithology/facies distribution, particularly in case of the highly heterogeneous depositional environments like delta slope, pro-delta units. The lithological control is manifested by: (1) a systematic rise of the OWC (oil water contact) in the poorly permeable eastern, south eastern flanks of the great gas-capped reservoirs in the delta plain system; (2) a number of lithologically trapped small under-saturated oil/non-associated gas accumulation in the "Lower Pannonian" (pro-delta) beds

At present, all accumulations have been depleted or are at the tail end of her production cycle. To prolong it and thus to enhance the ultimate oil recovery, it is of utmost importance to detect and locate by-passed oil patches and to intensify the oil production also from the reservoirs with no by – passed oil. Each operative intervention needs well established 3 D facies model.

The CSD-3 oil reservoir developed in the delta front delta plain transition zone of a NW-SE running Algyő delta system Depositional environments/facies have been identified as follows: channels, levees, point bars, swamps, distributary mouth bars, sheet sands. The mapping of the facies-distribution allows estimate the Petroleum – Initially – in Place (PIIP) and its distribution by facies. Thru the case history of the evaluation of the production intensification in the CSD-3 oil deposit this study presents the utility and importance of a facies modelling.

Key words: Algyő-field, by-passed oil, PIIP, delta, facies model

Break-point detection algorithms tested on artificial time series

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Environmental time series often contain break-points of different origin; i.e. break-points caused by (i) shifts, (ii) changes in their trend and/or (iii) their variance. In the present study artificially generated time series with white- and red noise patterns are explored by multiple break (kink) point detection methods. The time series were modified so that the exact "place" of the artificial break points would be known, providing a sufficient testing ground for the study. Thus, the aim was to test the sensitivity of different break-point detection methods, for break points of different origin and degree. The last 25% of the time-series was modified, for example by (iii) changing the variance of the data by the order of 0.25, 0.5, 1 and 2 times of its original variance. Consequently, it was tested how accurately the different break-point methods can find the place of the modifications. It is assumed that the different computational methodologies tested (e.g. cross-entropy approach, trend analysis etc.) are sensitive to the different types of modifications. The results will presumably have a broad implication including e.g. environmental- and climate sciences where time series are the subjects of analyses.

Key words: artificial noise, break-point detection, cross entropy method, time series analysis, trend distortion

Application of 3D seismic data to constrain the reservoir models

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Well data provides frequently used dataset for building geological probabilistic models in order to characterize the target reservoirs but the relevance of the seismic surveys in the exploration and development of oil and gas fields can be perceptible in the last decades.

Exploration is enhanced by spatial predictions of the corresponding rock-types with different petrophysical properties in order to have ability to designate the promising reservoirs. Well logs provide high resolution information about rock and fluid properties in vertical section, but their utility is limited in lateral extent. Although their importance is inevitable for determining the lithology types based upon direct measurements around the wellbore. In contrary, seismic data have good spatial coverage which represents different measurement scale but can contribute the proper correlation between wells. Due to this fact a lot of researches have focused on the integration of the seismic and well data to reduce the uncertainty which associated with geological models coming from the sparse information from the wells at the development stage. The main idea is to use the information about the spatial variation of a well sampled variable originated from 3D seismic to help to interpolate a sparsely sampled variable derived from conventional well logs. The preconditions rely on a statistical relationship between seismic and internal properties or lithofacies to characterize the local distributions of these properties at any location of the reservoir by using co-simulation algorithm. The spatial continuity pattern of the combined primary and secondary variable can be modelled by cross-variograms. In this way the distribution of the sedimentary facies according to their petrophysical properties could be mapped with lower uncertainty and greater geological realism which are relevant in the sense of reducing the risk which is the unavoidable part of the exploration.

Key words: 3D seismic, co-simulation, correlation, reservoir modelling, uncertainty

Modeling geological structures with Training Image for Multiple-Point approach: from Theory to Practice

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Two geostatistical approaches are traditionally used to build models of facies spatial distribution: the variogram-based approach and the object-based approach. The disadvantage of variogram is the very limited measures of spatial pattern, since the variogram measures the relation between two-points in space only. On the other hand, the object-based algorithms give representations of curvilinear or complex facies geometries, but the disadvantage of object-based algorithms is the data conditioning. The multiple-point approach includes the ability to reproduce the 'shape' of object-based techniques with the easy data-conditioning of variogram-based techniques. The training image is a conceptual model depicting the geological structure to be reproduced in multiple stochastic realizations. Facies modelling software contains libraries of training images, however, these conceptual images originate mainly from the North Sea reservoirs. The Pannonian facies (and same environments) have some special properties therefore the facies geometries in the composite modules are not convenient in all cases. They are as follows: (1) the size of the Pannonian basin and its rate of subsidence is not comparable with the North Sea basins; (2) complex tectonics were active in differential tectonic subsidence; (3) relative sea level fluctuation resulted in complex spread of facies; (4) the Pannonian environments are characterized by various directions of sediment transport with different intensity. The generation of training images (which consist of facies) is based on two main steps: (1) defining the geometry of facies and transforming the geometry to a rasterized form with a python script and (2) for any given shape, the interaction with previous shapes must be specified in TiGenerator program (a single program within the SGeMS-frame).

Key words: multiple-point approach, training image, Pannonian facies

Recommended principles of the qualifications of geothermal plays

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The need for a prioritisation of areas proposed for the geothermal concessions has been suggested already in 2011, when only three public report had already done on recommended areas At the first three areas rank, it has been suggested to choose a standard area for the sake of later comparability and then we started to develop the criteria that goes far beyond the area qualification based on estimation of reserves using geoscience only. Initially we considered the standard area as a kind of unit and we evaluate the others qualitatively and strongly subjective mode on the basis of the following criteria: the coverage of nature reserves, knowledge on geology, interference with the CH production.

Key words: geothermal potential, ranking, exploitability, research index