POLSKIE TOWARZYSTWO MINERALOGICZNE – PRACE SPECJALNE
MINERALOGICAL SOCIETY OF POLAND – SPECIAL PAPERS
Zeszyt 24, 2004; Volume 24, 2004

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ROCK-WATER SYSTEM IN SEDIMENTARY BASINS – NEW APPROACH

Abstract: Main components and influencing agents of rock-water system in sedimentary basins have been presented. Complex consideration of inorganic and organic components interaction in changing PVTX conditions could be only correct way for proper interpretation of sedimentary basin evolution. The example presented in this paper showed like conventional method for basin history evaluation should be replaced by dynamic method, taking into account all rock-water system component and controlling agents.

Keywords: PVTX conditions, minerals, formation waters, hydrocarbons, microbes

INTRODUCTION

Basin sedimentary fill built by minerals forming rocks, organic matter, and formation waters is a medium called rock-water system for various physico-chemical processes in PVTX conditions. Primary components: minerals, organic matter and water, form together system under crucial control of agents like: temperature and pressure, often with microbial influences.

Special emphasis is done here to show some agents which certainly play significant role in diagenesis of sedimentary rocks and evolution of waters. Various processes which take place in pore spaces of basin deposits, are usually interpreted selectively as inorganic or organic, and mineral or formation water systems. Only common treatment and complex investigation of all rock-water components and influencing agents can give proper diagnosis, which is shown in example.

This research was supported by the Warsaw University (project no. BST-977/4), and KBN-State Committee for Scientific Research (project no. 3 P04D 023 25).

BASIC SYSTEM COMPONENTS

Rock-water system is created by some basic components, which play main role in framing early, transitional, and final conditions of subsurface environment.

Inorganic mineral compounds exhibit all mineral assemblage of detrital and diagenetic origin. Detrital minerals are key medium for chemical processes in pore spaces, and important source of main ions for neomorphic mineral growth in silicate as well as in carbonate system. Diagenetic minerals can dramatically change rock cubature allowing or precluding fluids and gases flow and halt later mineral changes and growth.

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Organic compounds being detrital organic remains or liquid hydrocarbons filling pore spaces can effectively play the same role as inorganic minerals and are able to transport into the solution several anions and cations which potentially control new diagenetic minerals crystallization.

Formation waters can be significantly changed by rock-water interactions from their former sedimentary chemical characteristics to the completely new ionic contents. Formation water can dissolve and alter rock-forming minerals and deliver elemental components for new minerals growth transporting vast amounts of fluids and gases.

AGENTS CONTROLLING SYSTEM

Temperature is transferred by conduction though rock particles or convection of fluids in sedimentary sequences. Events of greater heat flow could result in more intensive organic matter maturation or setting new hydrological system. Due to both processes, water and gases with ions, inorganic, and organic molecules are transported by diffusion or fluid flow in permeable or semi-permeable rocks and change former rock-water system.

Pressure of changing conditions can significantly modify chemical and volumetric properties of rock-system components in scale of a sedimentary basin, compartment system, single trap or even concretion. During building overpressure, often even over lithostatic, several additional chemical or mechanical reactions can impact on the system. Isolated pressure compartments can be subject of a different diagenetic processes in comparison to neighbouring open rock system. In overpressured sequences low-metamorphic conditions or significant tectonic deformations can be generated on local scale. Mechanical failure due overpressure can result in faulting or capillary pressure enforcing with vast ionic and gases transfer though leaking seal rock complexes. The importance of pressure condition prediction in understanding of diagenetic processes could be meaningfully illustrated by an example of lack of sand compaction and diagenesis in sediments observed to the depth more then 3 km in the Gulf Coast, USA (see Dickinson 1953).

Hydrocarbons are composed by great number of organic compounds, which are often selectively distributed on the way of source-carrier-reservoir rocks. Compound differentiation in oil column can have great impact on crystallization of new diagenetic minerals (Ratulowski et al. 2003). Various distribution in one compartment of crude or heavy oils, light petroleum converted to gas condensate or non- or hydrocarbon gases can drastically change main chemical evolution of local rock-water systems and give great inconsistencies in basin history understanding and modelling.

Microbes activities and its products have been observed in sedimentary sequences to 6 km depth at 200°C and 80 MPa (Nielsen et al., 1996). Actual microbes survival at such environment can be caused by their potential for long-lasting incubation till building new favourable conditions for reactivation. Rebuilding of proper conditions for bacterial activity can be produced while changing PVTX conditions in physico-chemically evolving compartments or by tectonic basin activity, when oxygenated water flow into bacterially-infected compartment can generate surface-like conditions. Then all features or chemical record of organic matter burial diagenesis zones (Irwin et al. 1977) can be found even in deep burial settings, which can lad to misinterpretations.

COMPARISON OF “CONVENTIONAL” AND “DYNAMIC” METHOD

Conventional method interpretations are constructed, considering the thermal history basin modelling, calculation of diagenetic mineral growth temperatures and environment recognized from isotopes and fluid inclusion studies. Then compared together, they are correlated with processes and water types evolution. The theoretical example (Fig. 1A), stemming from the North Sea basin, shows sequence of diagenetic minerals crystallization in changing conditions. The growth of chlorite has been calculated from oxygen isotopes, which marked mixed sedimentary marine-meteoric waters and temperatures of ~60°C during progressive deposits burial. The time of this event has been dated according to thermal modelling. The growth conditions of the next mineral, calcite, deduced from carbon and oxygen isotopes and fluid inclusions indicated the meteoric waters environment of ~75°C with influence of organic matter maturation products. Plotting of these values on the subsidence curve with thermal modelling data, related the growth of calcite to the episode of the area uplift. The crystallization of quartz overgrowths, the latest mineral in diagenetic sequence, estimated on the basis of oxygen isotopes and fluid inclusions, indicated conditions of basinal brines saturated with liquid hydrocarbons at ~120°C. That time, due to correlation to basin thermal history, would be a period of oil charging into reservoir rocks.

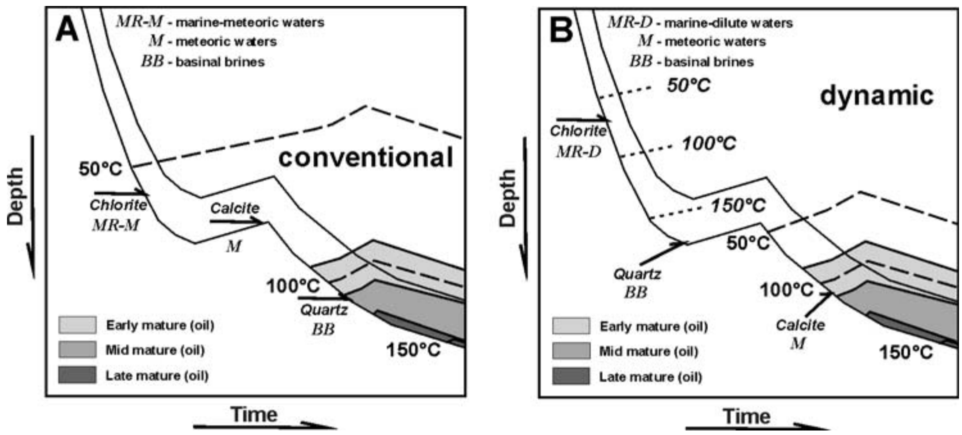

Fig. 1. Subsidence curves with modelled thermal history. A) Conventional method of mineral growth conditions evaluation related to the thermal history. Temperature values are from thermal modelling. B) Dynamic method taking into account all rock-water system components and controlling agents. Dotted isotherms labelled in italics were calculated on the basis of the physico-chemical processes.

Dynamic method interpretations take into account all agents controlling rock-water interactions. In such way (Fig. 1B), chlorite growth would be connected to the rapid subsidence and fast creation of high pressure in pore spaces. In such overpressure conditions, the sedimentary marine waters would be mixed with dilute waters produced by dehydration process while smectite to illite conversion in fine-grained deposits. Then oxygen isotopes values should be calculated in respect to temperature as in the conventional system type, at ~60°C, but arising earlier in basin history. The second diagenetic mineral would be quartz overgrowths. The crystallization temperature true values of ~175°C have been calculated with use of CH_4-filled inclusions by pressure correction. This implies great difference between conventional and dynamic method applied. In this case, quartz cements would growth earlier in convection thermal regime of higher temperature and pressure, in basinal brines with liquid and gaseous hydrocarbons solutions. This indicates much earlier time of reservoir charging by oil and gas in the basin history. More intensively subsiding distant source basin then would supply waters and hydrocarbons to the trap area. The latest in diagenetic sequence mineral, calcite, with growth environment calculated from carbon and oxygen isotopes and fluid inclusion measurements, would indicate the conditions of meteoric water with CO_2+N_2 solutions of ~110°C (pressure correction applied). Calcite growth would happen in conductive thermal regime. While tectonic basin activity, descending surface waters with microbes would infect hydrocarbons in underpressured reservoir rocks and convert accumulated methane to carbon dioxide.

SUMMARY

Understanding of the rock-water system evolution in sedimentary basins requires detailed analysis of all system-building components in changing physico-chemical conditions. Taking into account of the all products of coexisted inorganic and organic solids and solutions in dynamically changing temperature and pressure settings during basin sedimentary and tectonic development, yield more reliable information about past geologic processes.

REFERENCES

DICKINSON G., 1953: Geological aspects of abnormal reservoir pressures in Gulf Coast, Louisiana. AAPG Bull., 37: 410-432.

IRWIN H., CURTIS C., COLEMAN M., 1977: Isotopic evidence for source of diagenetic carbonates formed during burial of organic-rich sediments. Nature, 269: 209-213.

NILSEN R.K., BEEDER J., THORSTENSON T., TORSVIK T., 1996: Distribution of thermophilic marine sulfate reducers in North Sea oil field waters and oil reservoirs. App. & Environ. Microbiology, 62, 1793-1798.

RATULOWSKI J., FUEX A.N., WESTRICH J.T., SIELER J.J., 2003: Theoretical and experimental investigation of isothermal compositional grading. SPE Reservoir Evaluation & Engineering, 6: 168-175.