ZAPIVALOV N.P.
Institute of Petroleum Geology and Geophysics,
Siberian Branch of Russian Academy of Sciences,
Novosibirsk, Russia, ZapivalovNP@ipgg.nsc.ru

Metasomatic Nano-dolomitization is a New trend in stimulation of Petroleum Reservoirs

Abstract:

The behavior of petroleum collectors in porous media greatly depends on nanostructures and nano-dimensional processes in petroliferous strata. Author considers new nanotechnology for petroleum systems on base of the nanoeffects by metasomatic dolomitization.

It is offered to initiate the accelerated technogenic process of metasomatic dolomitization and to create the highly productive centres on fields. As a result the specific surface of hollow space will increase. In bed system many processes become more active: formation of jointing, an overflow of fluid weight from a block matrix in cracks, and even a neogenesis of hydrocarbonic weights. Substantially percolation processes will amplify, efficiency of wells and oil recovery will increase. On occasion process of compulsory and accelerated dolomitization (metasomatosis) can be accompanied with wave and thermal influence.

Successful use of the offered nanotechnology can make essential impact on duration of working out of deposits and final petroreturn.

Keywords: dolomitization, metasomatosis, nanostructures, oil recovery.

1. Dolomites is a good oil reservoir

Carbonate rocks are widely spread on the Earth. They take the second place on the abundance and compose 20% of the sedimentary mantle of the Earth (the first place is occupied by the argillaceous rocks only). This carbonate rock group is studied during more than 250 last years, since it has extremely high significance for geological science and practice. These rocks contain 40% of the world resources of oil.

Some of the carbonate collectors are composed by almost pure limestone, some others by almost pure dolomite, but most of them are composed by homogeneous or changeable mixtures of these two mineral formations. The oil and gas are contained in the natural limestones and dolomite reservoirs. These last are characterized by high production rates mainly because of their high porousity. 80% of hydrocarbon accumulations of the North America are contained in the dolomite collectors. Dolomitization leads to increasing of the pores in dense limestones by means of the arciitecture of the porous domains. For example, in Canada the fluid conductivity of the limestone collectors is 68 mD, and that of the dolomite collectors is 800 mD.

The dolomite is formed during the late epigenetic recrystallization of the magnesium calcite and its decomposition by two phases: dolomite and calcite.

The secondary dolomitization is always accompanied by cracking. Fracturing can provicle high fluid conductivity of the rocks which were impermeable previously. The more new are fractures, the more is their width and the higher is their fluid conductivity.

The origin of the dolomites and the reasons of their high porosity and fluid conductivity attracted attention of investigators for a long time. The chemical formula of the dolomite is $CaMg(CO_3)_2$. The ions Ca^{2+} and Mg^{2+} alternate along the triple axis in its crystalline lattice. The color of the dolomite is grey-white, sometimes it has yellow, brown or greenish shade. Its hardness is 3.5–4.0 , and its density is 2.8–2.9 g/cm^3 . It occupies an intermediate place between calcite and magnesite by solvability in HCl. The basis of numerous discussion on problems of porosity of the dolomites is the theory of Elie de Beaumont invented in 1836. He has shown that the molecular substitution of the limestone by the dolomite leads to decreasing of the volume of the rock by 12-13%.

Petrographic investigations of Holt confirmed this theory of the molecular substitution. It was shown that the crystals of calcite in the limestones have a strong tendency to orientate their axis parallel to the planes of stratification. The crystals of the dolomites are oriented completely disorderly. Holt explained this phenomenon by the fact that dolomite contains much more cavity, hence the packing of its crystals is not so dense as in the limestones.

Holt indicates the disordered orientation of these crystals as the reason of their higher fluid permeability than that of the limestones. The dolomites have much more intercrystalline space, than the limestones, hence the dolomite have higher area of interaction of their mineral part and the fluid circulating in it. One can lost a large number of the oil and gas deposits connected wit the dolomites and dolomitized limestones. For example the oil deposits in the organogenous reefs of the Western Canada are related to the dolomites.

Here, the rocks contain the cavities connected by the fines fractures. They are characterized by non homogeneous primary proposity. The initial rocks there were basically the organogenous limestones. Howerer at the present time they are dolomitized and their primary organogenous structure disappeared completely.

3. Physical-chemical aspects of metasomatosis

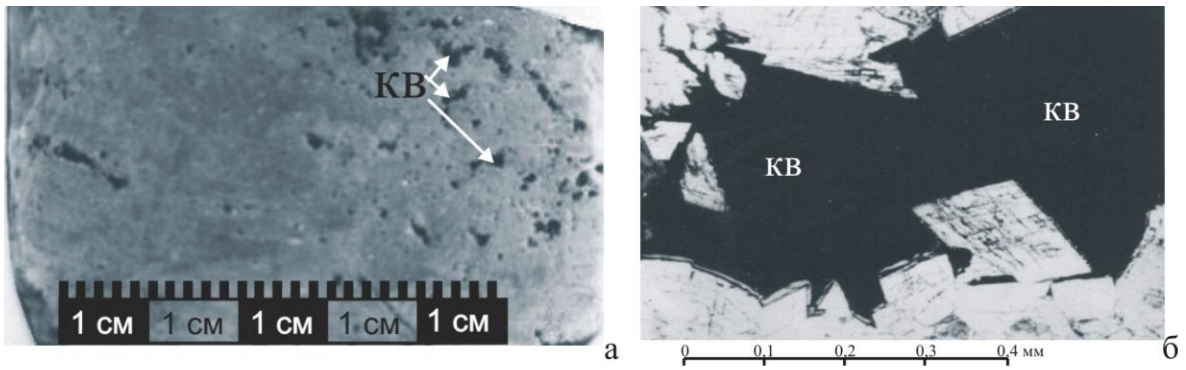
The largest significance in the natural processes has the secondary dolomitization. Actually this is the metasomatosis, here the ions of the calcium in the carbonate are replaced by the ions of magnesium. Metasomatosis is the adaptation reaction of the rocks to changes of physical-chemical conditions of its state. Usually, the metasomatic processes proceed as reactions of the solid rocks and the liquid or gaseous phases when the state of the rocks remains solid. These reactions lead to changes of the chemical content of the rocks by replacement of some minerals by others under action of mobile chemically active heat transfer agent in a gradient thermodynamic field. These processes are not in equilibrium substantially.

The nature of the secondary dolomitization is the following: The radius of the ion of calcium (Ca^{2+}) is 0.99 Å or 99 nm, and the size of ion of magnesium is 0.66 Å or 66 nm. During the process of replacement of Calcium by Magnesium a significant empty space appears. Actually, this is a natural nano-effect. We know that various thermodynamic, chemical etc. processes in the petroliferous strata happen constantly and rather rapidly due to different physical fields such as physical-chemical, mechanical-chemical, and other gradients.

So, it is clear that the natural nano-dimensional metasomatic processes in the carbonate rocks promote formations of high productive collectors.

2. West Siberia. The new data.

In Western Siberia many Paleozoic oil deposits are found out in dolomite limestones. Cracked carbonate rocks compose collectors of porous-fractured type with secondary porosity of the Tchkalovsk, North-Ostaninsk and Urman Paleozoic deposits in West Siberia (fig. 1).



Core **Microsection (in passing light)**

Fig.1. Dolomite of replacement with cavities (KB)

A – well Urmansky 7, depth of 3120 m; B – well North Ostaninsky 7, depth of 2812 m. West Siberia.

The best studied is the Maloichskoe deposit in Novosibirsk region. Here the deepest parametric borehole (Maloichskoe N 4) was drilled in the Niurole paleozoic basin. Its depth is 4600 m., and its drifting in the carbonate paleozoic is 1800 m. The tributary of the oil are obtained from numerous intervals of the open paleozoic cut composed by dolomitized organogenous limestones containing equal quantity of CaO and MgO. A special interest has the face zone in the interval 4538-4600 m. composed by benches of the metasomatic dolomites with large and middle-sized fractures, often fissured and disintegrated (fig. 2).

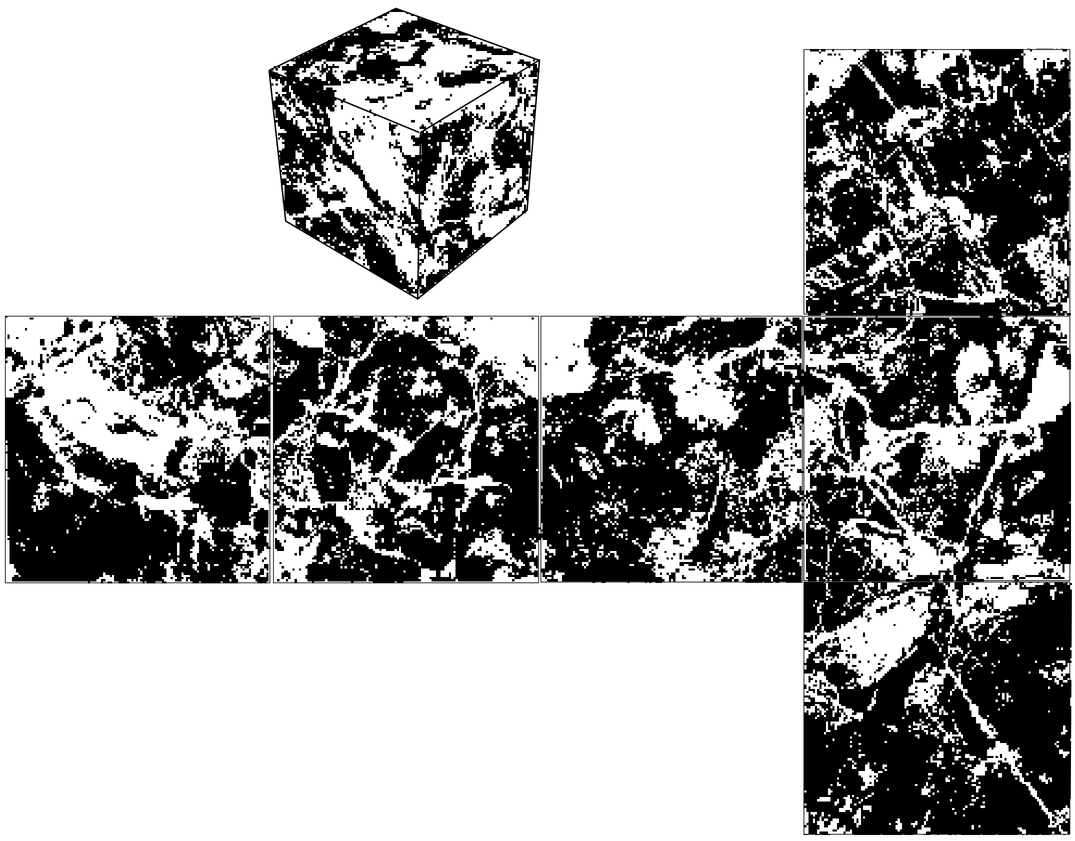


Fig.2. Maloichsky deposit, jointy-cavernous (white) the Devonian organogenous dolomite. West Siberia.

Here, the content of MgO increases till 22% and that of SiO_2 till 0.31% only. The temperature in the strata in that part of the open cut is 160° C. The fracture porosity of the petroliferous rocks of the upper deposit (2850 m.) varies from 0.06% till 0.15%, and the fracture permeability attains 0.005 mkm^2 .

The most productive boreholes are shown on fig. 3.

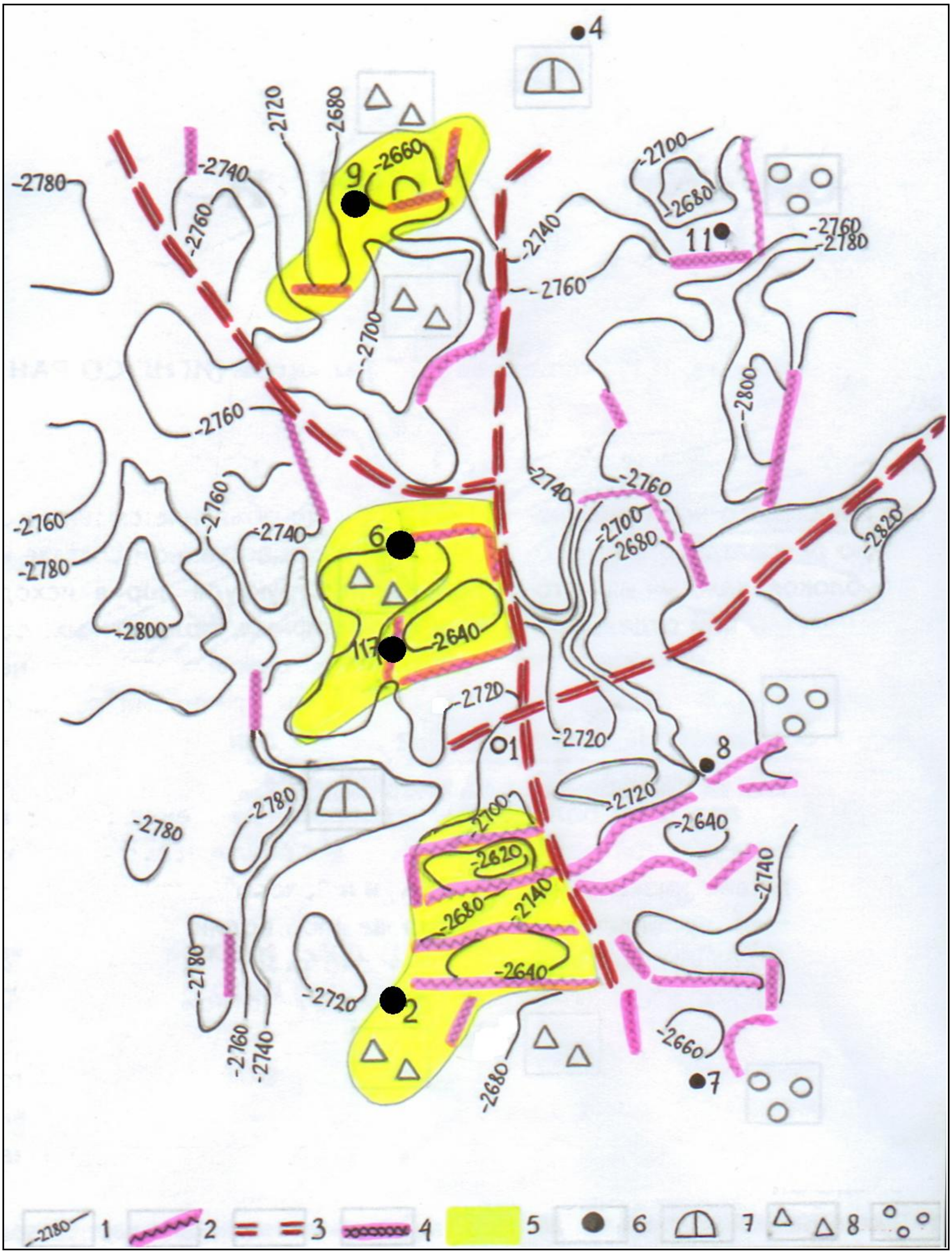


Fig.3. The Maloichsky deposit, the Novosibirsk region. West Siberia.

(Taking into account results of 3h-dimensional seismic prospecting)

1 – Surface isoplasters of carbonaceous Paleozoic breeds, m;
2 – Subvertical zones of erosional-tectonic ledges;
3 – Prospective deep breaks;
4 – Tectonic infringements;
5 – The centres of secondary dolomitisation;
6 – The wells which have given inflow of oil;
7 Lithofacies: 7 – of organogenous reeves; 8 – of advanced loop; 9 – of behindreef lagoons.

4. Practical nanotechnology

Hence, the following question arises: is it possible to initiate an accelerated technology process of metasomatic dolomitization and to create and maintain high-productive sources in the deposit. In fact, this could allow to control of the process of oil field development and to increase the oil recovery factor (coefficient of oil-extracting). For these purposes we should determine the carbonate content of perspective horizons from the data obtained in the first drilled borehole, and to determine the content of the carbonates. Then we can make the decision of realization of the technology of injection of the magniferous liquid, such as ocean water or nano-particles of granulous magnesium.

As a result we shall increase specific area of the pores in order to modify different thermodynamic gradients and to activate (at least within one source) different processes in the sheet deposit, such as formation of fracturing, crossflows of the fluids from block matrix to fissures, and even new growth of the Hydrocarbones masses).

Here the percolation processes will be activated substantially, boreholes productivity and the oil recovery factor increase.

Definitely, these industrial operations correspond to the low impact technology. Actually we just accelerate and control the natural processes. This is one of the key factor which can increase the oil-gas potential of the Paleozoic of the Western Siberia and other regions.

References:

1. N.P. Zapivalov, G.I. Smirnov, V.I. Kharitonov. Fractals and nanostructures in petroleum geology and geophisics, Novosibirsk, Academic Publishing “Geo”, 2009, 132 p.

2. A. Esmaeli. Application of nanotechnology in oil, and gas industry, Report on Intern. Conf. “Petrotech-2009”, 11-15 January 2009, New Delhi, India.

3. N.P. Zapivalov, Trofimuk A.A. Distribution of Oil and Gas in Devonian Rocks of West Siberia, Devonian of the World, Calgary, 1988, Vol. I, pp. 553-556.

4. Élie de Beaumont, J. B. A. L. L. (1854): Note sur l'origine présumée des dolomies. Compt. Rend. (Acad. Sci. Paris), Vol. 39, pp. 525-526.

5. Holt Robert M. Conceptual model for transport processes in the Culebra Dolomite Member, Rustler Formation, 1997.