Dynamic of gas hydrate deposits evolution under subaqueous conditions

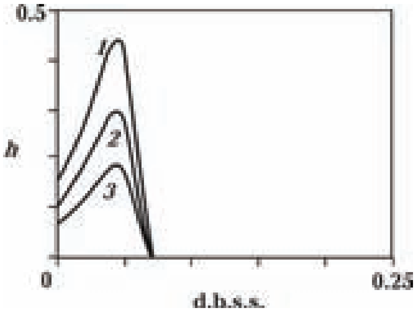
© E. Suetnova, 2010

Institute of Physics of the Earth, RAS, Moscow, Russia
elena_suetnova@mail.ru

At present, more than 100 areas of gas hydrate manifestations in sediments have been revealed by various geophysical (mainly seismic) methods. Subsurface filtration is the most powerful process of gas and fluid transport into hydrate stability zone to form gas hydrate deposits in sediments [Davie, Buffet, 2002]. Pressures and temperatures favorable for the formation and stability of gas hydrates are widespread in seafloor structures, particularly, at continental margins, where accumulated sediments contain appreciable amounts of biological material, ensuring gas (mainly methane) influx into crustal fluids. Depths of hydrate stability interval and hydrate saturation are different in natural conditions. These differences were interpreted usually in the frame of thermal regime peculiarity. Peculiarity of sediment accumulation processes was not considered usually, but the sedimentation regime determined the evolution of porosity, permeability, fluid pressure and filtration rate in accumulating sediments [Suetnova, Vasseur, 2000]. Thus, to understand the mechanisms of accumulation and evolution of hydrate deposits in sediments during geological history it is necessary to study the complex geophysical process of porosity, filtration and hydrate accumulation evolution. The author's recent results of numerical modeling of gas hydrate accumulation in dependence on geophysical condition of sedimentation are presented below.

Methods and results. Gas and fluid filtration is determined by compaction during sediments pill growing, so, hydrate accumulation depends on se-dimentation and compaction history of sediments. Interrelated processes of filtration and visco-elastic sediment compaction during sediment column gro-wing are accounted for system of nonlinear differen-tial equations supplemented by appropriate boun-dary conditions [Suetnova, Vasseur, 2000]. The system was reduced to a dimensionless form in order to reveal its characteristic scales [Barenblatt, 1982]. The dimensionality analysis of parameters and variables of the system reveals the compaction-related length L and time T scales characteristic of the problem considered [Suetnova, Vasseur, 2000].

Thus, the system in the dimensionless form with these scales contains the dimensionless characteristic similarity numbers V=V0/ L/T, and DA□□-¸ and, con-sequently, the depth and time distributions of the dimensionless porosity, the velocities of the sedi-ment matrix and pore fluid, and the hydrate con-centration, which are obtained as solutions of the system of equations, depend on these similarity numbers. Changes in the values of permeability, vis-cosity, and sedimentation rate alter the values of the characteristic similarity numbers of the com-paction process, controlling the fluid flow in sedi-ments [Suetnova, Vasseur, 2000]. Therefore, regu-lar patterns of accumulation of gas hydrates in a growing layer of sediments depending on their physi-cal and hydrodynamic properties and sedimenta-tion rates can be determined as a function of the similarity numbers of the problem of visco-elastic compaction. To reveal the dynamic of hydrate accumulation the set of model calculation were performed using geophysical data on known hydrate regions. The influences of hydrate saturations on free pore volume and Damkohler number were taken into account in the calculations [Suetnova, 2007]. Results of the calculations show that hydrate accumulation essentially influences on pore fluid filtration process. Calculations of time-dependent evolution of gas hydrate deposits show that the rate of hydrate accumulation is higher in the case of developing overpressures compaction than in equilibrium compaction process; provided that real sedimentation rate and final sediment thickness and overburden pressure are equal in both case, but rheological and hydrodynamic property are different (Figure, Table).



Comparison of hydrate saturation versus distance from sediment surface, normalized to sediment final thickness, resulting after 2 m.years of sedimentation. Number of curve corresponds to the values of parameters, listed at table 1 at the same lines number.

№	t	V_0, m/s	m_0	η, Pa·s	μ, Pa·s	ρ_f, kg/m^3	ρ_s, kg/m^3	B, 1/Pa	k_0, m^2	V	D
1	7.7	10^{-10}	0.3	$5\cdot10^{20}$	$2.6\cdot10^{-3}$	$1.0\cdot10^{3}$	$2.65\cdot10^{3}$	10^{-9}	10^{-14}	0.06	0.06
2	0.77	10^{-10}	0.3	$5\cdot10^{21}$	$2.6\cdot10^{-3}$	$1.0\cdot10^{3}$	$2.65\cdot10^{3}$	10^{-8}	10^{-15}	0.6	0.6
3	0.77	10^{-10}	0.3	$5\cdot10^{21}$	$2.6\cdot10^{-3}$	$1.0\cdot10^{3}$	$2.65\cdot10^{3}$	10^{-9}	10^{-15}	0.6	0.06

Conclusions. The results of modeling interrelated processes of sediment compaction, filtration and hydrate accumulation during geological history of sediment pile forming gives the theoretical and numerical base to understand the dependence of hydrate accumulation dynamic on mechanical and hydrodynamic processes in sediments which determined it's dynamic during geological time.

References

Barenblatt G. I. Similarity, Self-Similarity, and Intermediate Asymptotics. — Leningrad: Gidrometeoizdat, 1982. — 255 p. (in Russian).

Davie M. K., Buffet B. A. A comparison of methane sources using numerical model for the hydrate formation. Proceeding of the 4 international conference of gas hydrate. — Japan: Yokogama, 2002. — P. 25—30.

Suetnova E. I. Accumulation of Gas Hydrates and Compaction of Accumulating Sediments: The Interaction Problem // Dokl. Akad. Nauk. — 2007. — **415**(6). — P. 818—822 (in Russian).

Suetnova E. I., Vasseur G. 1-D modeling rock compaction in sedimentary basin using visco-elastic rheology // Earth Planet. Sci. Lett. — 2000. — **178**. — P. 373—383.