# Seismic Velocities and Electrical Resistivities of Ice-Bearing Sediments

# -Ice as Hydrate Equivalent in sandy sediments-

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**Abstract**

Since ice is very similar to hydrate in some of its physical properties it might be used as analog pore fill in a "quick look" experiment where the general dependency of a rock physical property on hydrate content is of greater interest as the absolute accuracy. An important aim of the German national hydrate project SUGAR III was the determination of such dependencies for various scenarios to generate starting models for joint inversion of seismic and electromagnetic data for the Danube Delta. In order to provide these dependencies within a short time we developed such a "quick look" methodology. We used the freezing point depression of a KCl solution to generate a dependency of ice saturation on temperature. For this purpose we had to establish a correction formalism to account for the fact, that ice formation results in a volume increase and water is expelled from the sample during freezing. The correction formalism requires the density of the KCl solution as function of concentration at freezing point, which we measured together with the electrical fluid conductivity. Using a low initial KCl concentration allows to form high ice concentrations before reaching the eutectic temperature of -10.63°C but the initial increase in ice concentrations with decreasing temperature is very strong and the accuracy suffers on the high sensibility to small temperature fluctuations. When using a higher initial KCl concentration the increase of ice content with decreasing temperature is weaker, but the maximum ice concentration which can be reached below the eutectic temperature is much lower. Therefore, we measured the whole saturation range with two different initial KCl solutions a low initial KCl concentration to measure the high ice saturations and a higher initial KCl concentration to get the lower ice saturations with higher accuracy.

Both, the p-wave velocity and the electrical resistivity of a sand sample as a function of ice content were determined at a confining pressure of 1 MPa. The low confining pressure reflects the shallow depth below seafloor of the paleo cannel levee system of the Danube Delta we were focusing on. The measured velocities as function of ice saturation correspond very well with velocities measured on glass bead sediment as function of methane hydrate content, where the pore filling hydrate was formed from methane dissolved in water. The velocity increased from initially 2.1 km/s to about 3.5 km/s at 90% ice saturation. The velocity increase up to about 40% ice saturation is very weak, which supports the assumption of pure pore filling hydrate. Above an ice saturation of 40% the velocity increase with saturation is stronger, which corresponds to the idea of a growing number of contacts between hydrate particles and sand grains, showing an increasing pore-filling and load-bearing character. We could also observe that the absorption (1/Q) increased with increasing ice content from initially 1/Q = 0.12 to 1/Q = 0.25 at 70%. For higher ice saturations the absorption decreased again (1/Q = 0.14 at 90% ice saturation).

For some ice saturations we replaced the remaining water with methane gas and pressurized the methane to hydrate stability conditions. Hydrate starts to form from the remaining bound water and the ice. When the hydrate formation was completed and methane pressure remained constant, water was injected into the sample. Since the water consumed the remaining methane in hydrate formation, we ended with a gas free sample at the end of the procedure. We observed a slight decrease in p-wave velocity and also in resistivity with time due to a recrystallization process probably

transforming the cementing hydrate, which had formed from bound water, to pore filling hydrate. Both, the resistivity and velocity values measured at the end of this recrystallization process fit very well with the dependencies of resistivity and velocity on ice saturation. The hydrate content was determined by collecting and quantifying the amount of methane gas after depressurization at the end of the experiment.

It could be shown that ice freezing from a salt solution in the pore space of a sediment forms as a non-cementing solid porefill like methane hydrate. Thus, this method can be used as a “quick look” into the dependencies of electrical resistivity and sonic wave velocity on hydrate content. The determination of a saturation dependency with two different KCl solutions in saturation steps of about 10% takes about two weeks in our setup with a small sample (diameter = 30mm; length = 60mm). A larger sample would require a longer time for the temperature equilibration. However, because we measured the temperature at the sample surface, we also logged the resistivity to decide if the temperature has equilibrated in the sample. It turned out, that after the sample surface reached the set temperature the resistivity still needed some hours to equilibrate. Compared to hydrate formation from methane dissolved in water, which takes 2 to 3 month for a complete saturation dependence, this “quick look” method is a fast process and a reasonable alternative.