Scientific Report of STSM

COST Action: Migrate

Host Institute

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Supervisor

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By:
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1 Objective

Estimates of hydrate content based on controlled source electromagnetic (CSEM) data are commonly larger than those based on wide-angle seismic data. This discrepancy could be explained by the presence of methane gas within hydrate-bearing sediments, which is possible according to thermodynamic theory. When hydrates form, small pockets of gas or water can become trapped inside the solid hydrate grains, as seen by SEM and X-ray CT studies(Sel 2015; Hu et al. 2014).Hydrates can block contact between free gas and water, also resulting in formation of free gas pockets. Methane gas-bearing sediments and methane hydrate-bearing sediments have different P- and S-wave velocities but have similarly high resistivity. The density of methane in free gas is less than the density of methane in hydrate, so methane content could be over-predicted by electrical methods and under predicted by seismic methods. Such over prediction from electrical method was also seen in laboratory studies performed at the National Oceanography Centre (NOC)/University of Southampton. We infer that this deviation is because all methane gas is not converted to hydrates which could be caused by a) water/gas trapped inside hydrate grains and b) hydrate blocks the contact between water and methane reducing further hydrate formation. In principle, this explanation should be valid independently on how hydrate is formed. The objective was to see if there is any deviation between hydrate saturation calculated independently from thermodynamics, salinity (Priegnitz et al., 2015) and Archie's Law. This will enable us to have a control on the use of Archie's law to estimate hydrate content.

2 Description of the work carried out during the STSM

2.1 LARS

The initial idea was to form hydrates in LARS and then compare the hydrate saturation calculated independently from Archie's law and salinity of the pore fluid, but this could not be carried our due to inhomogeneous distribution of hydrates. Archie's law is generally used for calculating the bulk hydrate saturation, so an inhomogeneous distribution of hydrates would not give a reliable result. So another experimental setup was used for having a more homogenous distribution of hydrates.

2.2 System for experimental petro physics – SEPP

SEPP consist basically of an autoclave with a heating/cooling jacked containing the sample setup. The internal setup is mounted at the top closure of the autoclave containing the feedthroughs for confining pressure oil, pore fluid in- and outlet, and the signal lines (Figure 1). The sand sample (30mm in diameter and 60mm in length) is separated from the confining pressure oil due to a Viton jacked and the Hastelloy end caps. The end caps contain the p- and s-wave transducers and are used as current electrodes. A resistive length sensor is mounted between the end caps to record changes in sample length. To control the sample temperature a Pt100 temperature sensor is attached to the Viton jacked. The fluid feedthroughs in the end caps allow pumping the pore fluid through the sample, to apply a certain pore pressure or to exchange the pore fluid. To simulate in situ pressure and temperature conditions the autoclave is connected to a confining pressure syringe pump (ISCO 100DM) and to a thermostat (Huber K6s-CC-NR; see Figure 1).

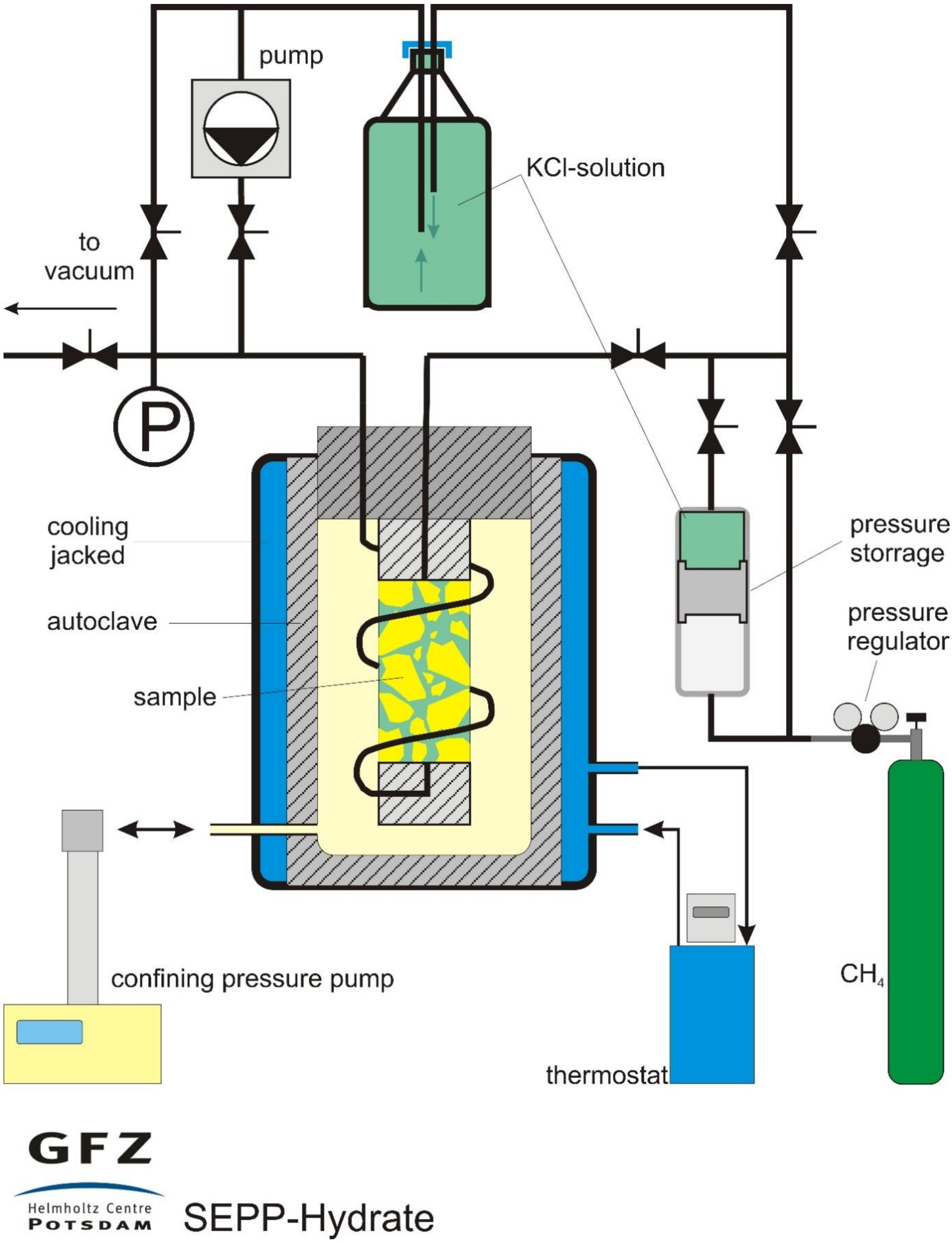

Figure 1: Schematic diagram of the experimental set up.

2.3 Method

KCl solution was injected into the sample and then taken to sub zero temperature to form ice. The temperature controlled the amount of ice formation (Hall et al., 1988 – see references). After ice formation methane gas was injected to remove the remaining water and system was left for one or two days for the free methane gas to interact with ice and form methane hydrates. After hydrate formation, water was injected and kept at constant pore pressure for recrystallization of hydrates to more pore filling morphology(Choi et al. 2014).

Hydrate was then dissociated and methane gas was collected to find the hydrate content. Two different experiments were done with different hydrate saturation.

3 Main Results

Hydrate content was calculated from resistivity using Archie's law and from methane gas collected from hydrate dissociation. Figure 2 shows the bulk restivity variation during hydrate formation and dissociation cycle. Table 1 describes the main results and calculations for the experiment. It is evident that Archie's law gives around 10-15% over estimate of hydrate saturation which is consistent with study of (Priegnitz et al. 2015).

Table 1: Experimental Data and Results

	TEST 1	TEST 2	UNITS
SAMPLE VOLUME	43.36	43.36	CCM
QUARTZ VOLUME	24.17	24.17	CCM
PORE VOLUME	19.19	19.19	CCM
POROSITY	44.3	44.3	%
CH4-VOLUME COLLECTED	336	1444	CCM
HYDRATE VOLUME	2.04	8.80	CCM
HYDRATE SATURATION	10.67	45.88	%
WATER SATURATED RESISTANCE	27.8	48	OHM
TEMPERATURE	21	2	°C
TEM. CORRECTED	50.27	48	OHM
FLUID CONDUCTIVITY	80.8	55.3	MS/CM
FROZEN RESISTANCE	91.7	136	OHM
ICE CONTENT	50	60	%
TEMPERATURE	-5.3	-6.9	GRAD
RESISTANCE WITH HYDRATE AND BRINE	65	185	OHM
TEMPERATURE	2	2	GRAD
RESISTIVITY INDEX	1.29	3.85	
N	1.93	1.93	
SW FROM ARCHIES	0.87	0.49	
HYDRATE SATURATION (FROM ARCHIES)	12.46	50.29	%
%ERROR IN HYDRATE SATURATION	-16.71	-9.61	%

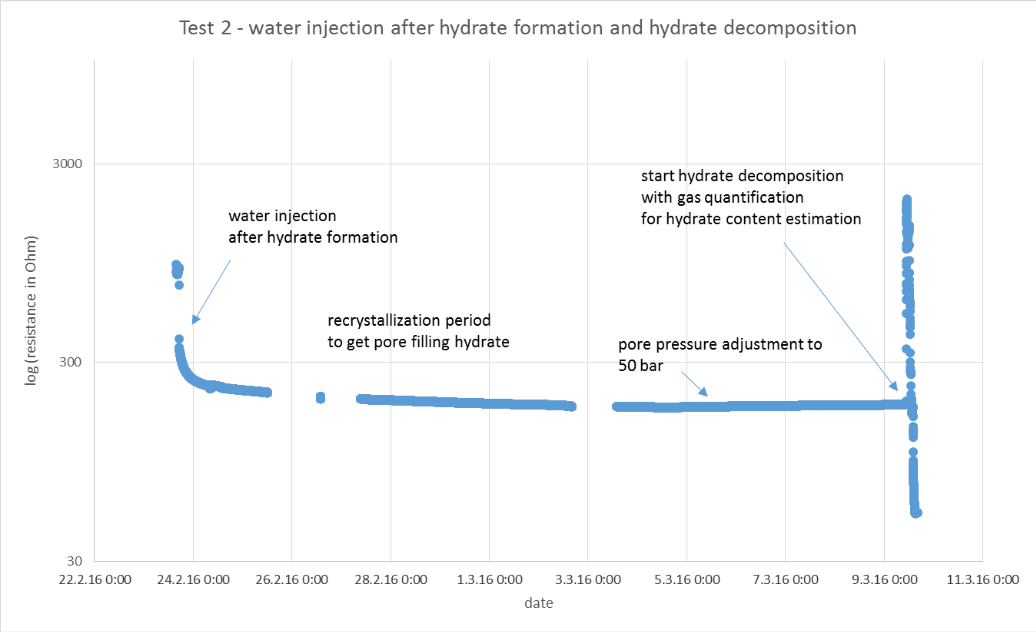

Figure 2: Variation of bulk resistance of the sample over the cycle of hydrate formation and dissociation.

4 Future collaboration.

Archie's law is widely used for resource estimation of hydrates from resistivity data. This experiment was performed in a small setup but study in field scale is necessary to understand this aspect in much more details. Future collaboration could help in doing this study in LARS. LARS being a much bigger setup could help in understanding the application of Archie's law for hydrate quantification in field scale, which is the main goal of this COST Action. Before this COST Action does field production of hydrate, it would be helpful to test the use of Archie's law in a field scale. This future collaboration could not only help this COST action but also help the global scientific understanding of hydrate quantification from resistivity.

5 Foreseen publications/articles resulting from the STSM

More experiments with different types of sediments and a wider spectrum of hydrate saturations would be necessary to complete the validation. If we will be able to provide these measurements in the future collaboration it will result in a publication.

6 References

Choi, J.H. et al., 2014. Laboratory formation of noncementing hydrates in sandy sediments. *Geochemistry, Geophysics, Geosystems*, 15(4), pp.1648–1656.

Hall, Donald L., S. Michael Sterner, and Robert J. Bodnar. "Freezing point depression of NaCl-KCl-H 2 O solutions." Economic Geology 83.1 (1988): 197-202.

Hu, G. et al., 2014. Gas Hydrate Distribution in Sediment Pore Space and Its Impact on Acoustic Properties of Hydrate-Bearing Sediments.

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Sel, K., 2015. Microstructure of hydrate-bearing sediments and determination of P-wave velocities based on high-resolution synchrotron tomographic data. *SEG Technical Program Expanded Abstracts*. Available at: http://dx.doi.org/10.1190/segam2015-5924023.1.

7 Time Frame

Start Date: 31.1.2016
End Date: 24.2.2016

8 Confirmation by the host institution of the successful execution of the STSM

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Potsdam, March 17, 2016

Confirmation by the host institution of successful execution of STSM
Dear Mr. Sahoo,

I have read the final report written by Sourav Sahoo about his experimental work carried out during his STSM visit to GFZ Potsdam. The aim was to validate the use of Archie's equation to estimate hydrate saturation based on the electrical resistivity of hydrate-bearing sediment. Although, it turned out that the hydrate distribution in the "Large Reservoir Simulator" was too inhomogeneous to use the measured resistivity data for the validation, the STSM was a real success. Mr. Sahoo used another setup to form hydrate in sand samples with a homogenous hydrate distribution and measured the electrical resistivity as a function of hydrate saturation. These date have been suitable for the validation and showed that the use of the Archie equation results in an overestimation of the hydrate content of about 10% - 15%. This shows that the empirical Archie parameter have to be recalibrated for their application for hydrate-bearing formations. I am very satisfied with the results of the STSM visit. I hope we will continue the collaboration and exchange of data and experiences in future, since the validation or calibration of interpretation models like the Archie equation is an important task for the exploration of hydrate-bearing reservoirs.

Potsdam, 17th of March

Erik Spangenberg

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