SHORT TERM SCIENTIFIC MISSION (STSM)
SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: ES1405 - Marine gas hydrate - an indigenous resource of natural gas for Europe (MIGRATE)

STSM title: Gas hydrate dissociation/formation: a look to the processes involved

STSM start and end date: 14/01/2019 to 27/01/2019

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PURPOSE OF THE STSM:

The purpose of this STSM was to learn the fundamentals of transient modelling of the behaviour of marine gas hydrate bearing systems and to test how these concepts are implemented and applied in TOUGH+HYDRATE code (Moridis et al., 2012). During my MSc thesis I was able to model the changes in thickness of the Gas Hydrate Stability Zone (GHSZ) due to ocean warming, assuming steady-state conditions. However, I noticed some limitations on this approach and therefore I wanted to learn more about transient thermo-hydraulic multiphase fluid flow processes, in combination with gas hydrate dissociation/formation. This STSM at NOC, under the supervision of Dr. Hector Marín-Moreno, has been a perfect opportunity to do this.

My STSM fits well with one of the objectives of WG 1 "Resource Assessment", within the COST Action-MIGRATE. In fact, the WG1 main goal is to constrain the amount and distribution of gas hydrates in European waters to assess its potential as an energy resource. One of the specific activities of this working group is to evaluate basin modelling approaches for the simulation of gas hydrate accumulation. Learning about transient modelling and how to use the T+H code has been, therefore, consistent with the MIGRATE WG1 objectives.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

During my two-weeks stay at NOC, my work has been mainly divided into two parts. During the first week, I focused on the study of the transient processes involved during gas hydrate formation/dissociation. Dr. Marín-Moreno proposed me some literature and reference material to study. Every day, I went through new concepts and, systematically, I discussed them in daily meetings with him. In particular, I was asked to understand the main differences between the steady-state modelling approach and the transient one and to familiarize with the dominant processes and parameters governing the latter.

In the second part of the STSM, I focused on the basics of T+H. TOUGH+HYDRATE v1.2 is a code for the simulation of the behaviour of hydrate-bearing geologic systems (Moridis et al., 2012). I spent some time studying how the code is structured and how the processes I studied are organised in it. During my last days, I was able to perform and discuss my first test runs. From this point of view, it was my very first approach

ever in numerical modelling and in running a code, so I spent also some time figuring out the format of the input data.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

During the STSM, I was able to learn the basics of gas hydrate transient modelling. The main difference between the two types of modelling is represented by time. While the steady-state approach should be applied only to stable hydrate systems, the transient modelling can evaluate the evolution of systems, considering some additional features that contribute to gas hydrate formation/dissociation and gas migration to the seafloor.

The steady-state approach has some main assumptions, which are different from the transient one. First, it assumes that the heat driven by a warming ocean has enough time to spread throughout the GHSZ (Marín-Moreno et al., 2015). This means, for example, that with an increase of the ocean warmth between two progressive time stages (t_1 and t_2), the geothermal gradient at t_2 would be shifted towards higher temperatures, parallel to that at t_1. In transient modelling, instead, the time for thermal diffusion at greater depths is considered. **Fig.1** represents an example of how heat diffuses in depths through time, modelled with the transient-state approach. Consequently, in steady-state modelling, the dissociation is thought to start at the base of the GHSZ, while the transient modelling may consider the first effect of warming at shallower depths, at the top of the GHSZ.
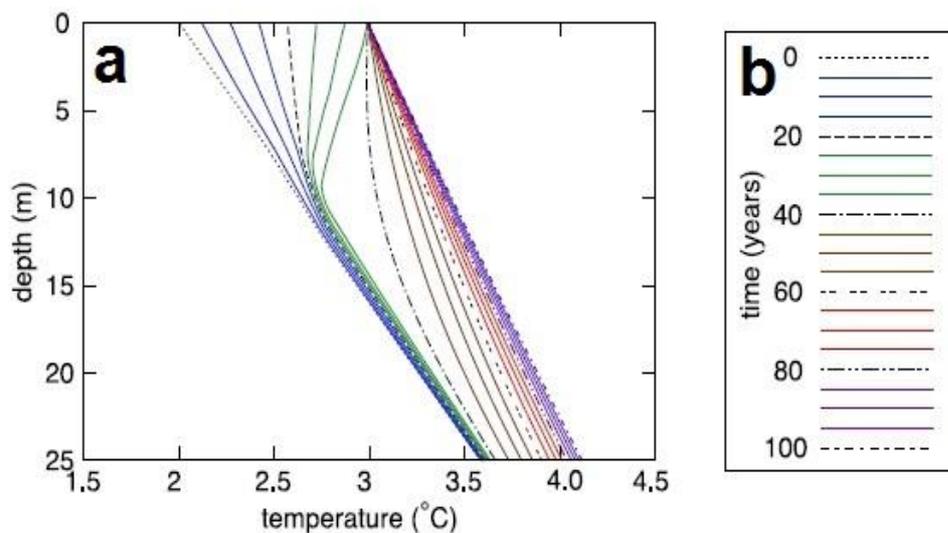

Fig. 1 Heat diffusion in transient modelling: (a) Geothermal gradient resulting from a warming seabed at different time; (b) Isolines of time since the start of the model, in years (from Thatcher et al., 2013).

Moreover, the steady-state approach considers no hydrate formation/dissociation within the GHSZ and no latent heat (Marín-Moreno et al., 2015). Contrarily, in transient modelling we can observe that the heat coming from a warming ocean is used in gas hydrate dissociation, since it is an endothermic process. This leads to the introduction of the "self-preservation" concept. In fact, as underlined by Thatcher et al. (2013), the dissociation process induces the release of freshwater and free gas and an increase of pressure in the system, which all together contribute to increase the stability of gas hydrate. These processes are constantly compensated by the heat coming from the warming ocean. As a consequence, the gas hydrate dissociation occurs as a "step process". **Fig. 2** shows a plot from Moridis et al. (2012) for the thermal stimulation dissociation test, which was carried out in this STSM as well. The amount of CH_4 released is not linear with time: this is consistent with the transient modelling concepts.
In addition, the amount of free gas released by dissociation has to deal with permeability and critical gas saturations, which depend both on the properties of the rock and the presence of gas hydrate.

In light of this, TOUGH+HYDRATE can model the non-isothermal gas release, phase behaviour and flow of fluids and heat. It can describe all possible hydrate dissociation mechanisms, like depressurization, thermal stimulation, inhibitor-induced effects, and represent different boundary conditions. Once the input file is written, the initial conditions are set and the mesh grid is built, the code can be executed to produce the model.
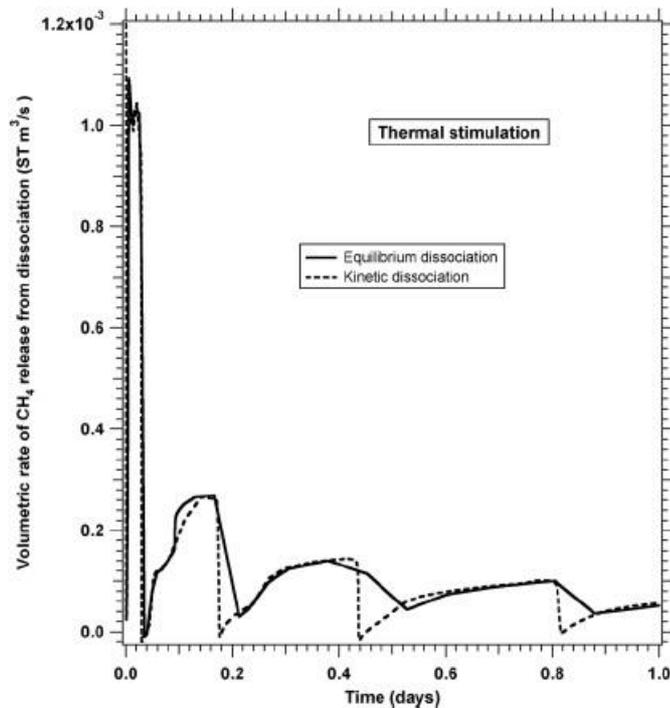

Fig. 2 Comparison of the rates of CH_4 release from hydrate dissociation caused by thermal stimulation. Data have been modelled using the T+H code (from Moridis et al., 2012).

FUTURE COLLABORATIONS (if applicable)

The collaboration with the Host Institution has been very satisfying and productive. My knowledge of gas hydrate modelling has improved and I hope I will have the opportunity to work again with Dr. Marín-Moreno. During my PhD, over the next three years, I will try to evaluate the effects of geo-hazards (for example, earthquakes) on gas hydrate stability along the Chilean Margin. In particular, it would be interesting to understand if an earthquake could induce a variation in pressure that could destabilize, directly or indirectly, gas hydrates. Trying to quantify this change in pressure is a big challenge but it could be thought as a new trigger mechanism for gas hydrate instability. Running various tests using this change in pressure could be an alternative boundary condition to experiment in the transient modelling of gas hydrate behaviour.

REFERENCES

Marín-Moreno, H., Giustiniani, M., & Tinivella, U. (2015). The potential response of the hydrate reservoir in the South Shetland Margin, Antarctic Peninsula, to ocean warming over the 21st century. Polar Research, 34(1), 27443.

Moridis, G. J. (2012). TOUGH+ HYDRATE v1. 2 User's Manual: A Code for the Simulation of System Behavior in Hydrate-Bearing Geologic Media.

Thatcher, K. E., Westbrook, G. K., Sarkar, S., & Minshull, T. A. (2013). Methane release from warming‐induced hydrate dissociation in the West Svalbard continental margin: Timing, rates, and geological controls. Journal of Geophysical Research: Solid Earth, 118(1), 22-38.