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Nils-Axel Mörner

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# Methane hydrate in crystalline bedrock and explosive methane venting tectonics

**Nils-Axel Mörner** [a,*]

[a] *Paleogeophysics & Geodynamics, Stockholm, Sweden*

ABSTRACT

Methane hydrate (clathrate, ice) does not only form in shelf environments, but may also accumulate in voids and fractures in continental crystalline rocks. This has turned out to be the case in formerly glaciated areas where the waxing and waning of thick ice caps following the Quaternary alterations between Ice Ages and Interglacial implied very large changes both in temperature and pressure in the bedrock below. The Swedish situation is highlighted. Seepage of methane gas from the crystalline bedrock is recorded. Methane accumulated as ice in fractures and voids in the rock. In postglacial time, such accumulations vented explosively, generating "methane venting tectonics". This occurred both spontaneously as a function of changes in temperature and load-pressure, and partly as violent deformational events as a function of earthquake events. Whilst most venting events refer to the time of deglaciation, three major deformational events occurred shortly after the uplift induced land emergence in Late Holocene time. A possible analogous event in association with the 1988 Saguenay earthquake in Canada is revisited.

Keywords:
Methane hydrate, Methane gas venting, Methane venting tectonics, Paleoseismology, Bedrock caves, Crystalline bedrock, Fennoscandia

* Corresponding author.
*E-mail address:* morner@pog.nu (N.-A. Mörner)

## 1. Introduction

In nature on Planet Earth, methane occurs in two "phases" (or stages); methane gas and methane hydrate (clathrate), which is a solid substance of methane and water molecules and hence often is called "methane ice" (Kvenvolden, 1993). This phase is only stable as a function of temperature and pressure. The methane gas hydrate storages (reservoirs) in deposits on the continental margins (in the depth ranges of 350 to 5000 m) are enormous (Paull et al., 2013) and may amount to some 74,400 Gt (Kladia and Sandler, 2005). The occurrence of methane gas hydrate in continental deposits is much less known (Chistyakov, 2013), however.

Lithospheric degassing is nowadays a well-established fact (Mörner and Etiope, 2002), constantly being updated by new measurements (Etiope et al., 2016), and not least the establishment of fracking technology of enormous new "shale gas" resources in the bedrock (IEA, 2012). Degassing also occur in the crystalline bedrock in Fennoscandia (Mörner, 2014).

The formation of methane hydrate ($CH_4 \cdot 5.75H_2O$ or $4CH_4 \cdot 23H_2O$) in the subsurface is a function of temperature, pressure and the local geothermal gradient (Fig. 1), besides the access to water (in fractures and voids). In the Fennoscandian crust, the geothermal gradient is