

EARTHQUAKE-INDUCED METHANE MIGRATION THROUGH THE GAS HYDRATE STABILITY ZONE IN THE SUBDUCTION REGIME OFFSHORE PAKISTAN

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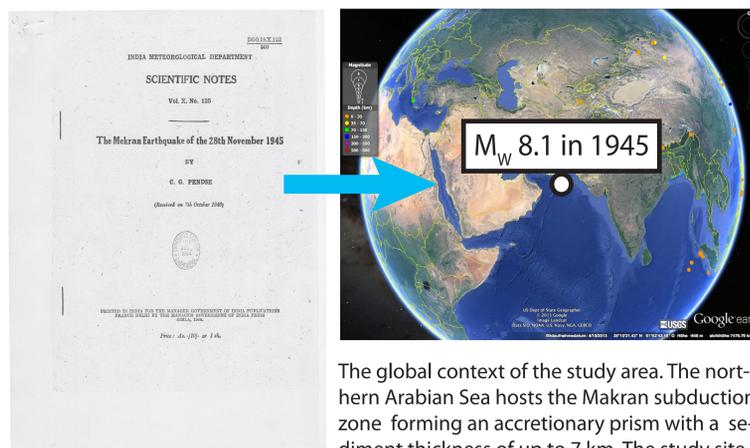
Abstract

Although gas hydrates often occur in seismically active regions, the role of earthquakes as triggers of hydrocarbon seepage through gas hydrate-bearing sediments has been only superficially addressed. The Makran continental margin offshore Pakistan hosts hydrocarbon-laden sediments and gas hydrates and is prone to vigorous seismicity. The area was visited in the frame of RV METEOR expedition M 74/3 in 2007 (Bohrmann et al. 2008). Here we present geochemical evidence for a substantial increase in upward gas flux inducing methane emission into the water column and gas hydrate formation in the sediment, a phenomenon which occurred within a few decades of the strongest earthquake ever reported for the entire Arabian Sea. We propose a causal relation and present reflection seismic data supporting our hypothesis that co-seismic ground shaking induced mechanical fracturing of gas hydrate-bearing sediments creating pathways for free gas to migrate from a shallow reservoir within the gas hydrate stability zone into the water column. Our findings lead to conclude that hydrocarbon seepage triggered by earthquakes might play a role for carbon budgets at other seismically active continental margins. The newly identified process presented here can help interpret data from similar sites.

Find the corresponding paper here:

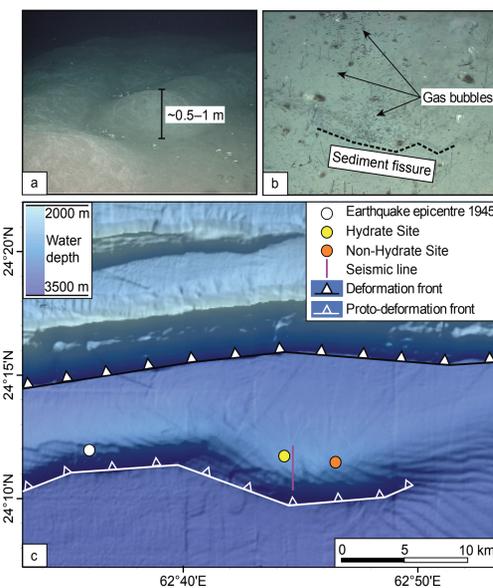
Fischer D, Mogollón JM, Strasser M, Pape T, Bohrmann G, Fekete N, Spiess V, Kasten S (2013) Subduction zone earthquake as potential trigger of submarine hydrocarbon seepage. NATURE GEOSCIENCE 6(8) 647-651

Study site/earthquake epicenter

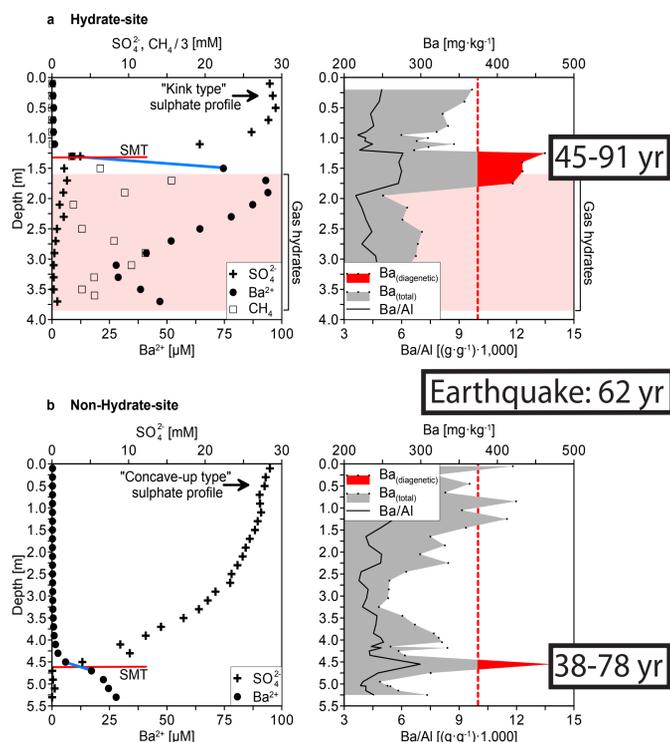


Cover page of the first scientific description of the 1945 earthquake (Pendse 1945). The global context of the study area. The northern Arabian Sea hosts the Makran subduction zone forming an accretionary prism with a sediment thickness of up to 7 km. The study site, Nascent Ridge (3165 m water depth), is the youngest tectonic feature of the local structural framework. The epicenter of the $M_w 8.1$ earthquake (Pendse 1945) was 15 km to the W of the study sites.

ROV images/ bathymetry

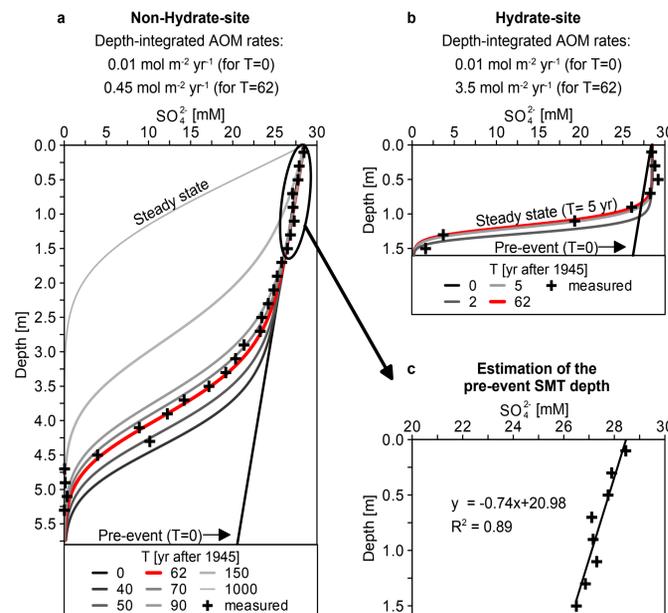


Formation time of barite enrichments



Formation times of authigenic barite enrichments were calculated based on diffusive fluxes of dissolved Ba²⁺ into the precipitation zones of both cores. They encompass the time that has elapsed between the earthquake in 1945 and sampling in 2007 and suggest causal relation.

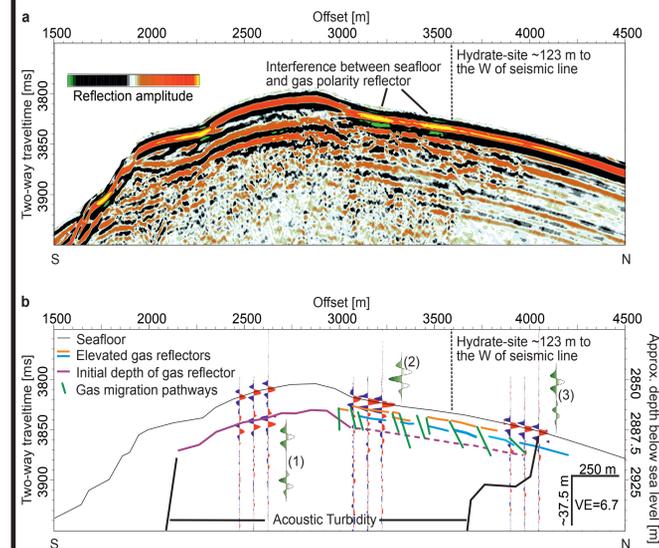
Transport/reaction modeling of pore water profiles



Transport/reaction modeling of pore water profiles enabled us to simulate the evolution of the measured sulfate profiles over time. Best fit to measured profiles when assuming:

- a) the injection of free methane gas to shallow depths of 5.9 mbsf. at the Non-Hydrate Site during or shortly after the earthquake and
- b) a pre-event depth of the SMT of 21 m. At the Hydrate Site steady-state conditions are already reached within 5 yr after the event (bubble irrigation).

Seismic evidence for free gas mobilization



Conclusions

- Three independent geochemical and seismic indicators suggest substantial increase in CH₄ flux a few decades before sampling
- Mechanical fracturing of gas hydrate-rich sediments through seismic ground shaking
- Earthquakes can trigger the release of hydrocarbons from the seafloor

Cited references:

Bohrmann G and cruise participants (2008) Report and preliminary results of R/V Meteor cruise M74/3, Fujairah-Male, 30 October-28 November, 2007. Cold seeps of the Makran subduction zone (Continental margin off Pakistan); Berichte, Fachbereich 5, Universität Bremen, edited by: Bohrmann, G., and Ohling, G., Bremen, 161 pp.
Pendse C G (1945) The Mekran earthquake of the 28th November 1945. India Meteorological Department Scientific Notes 10, 141-146

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