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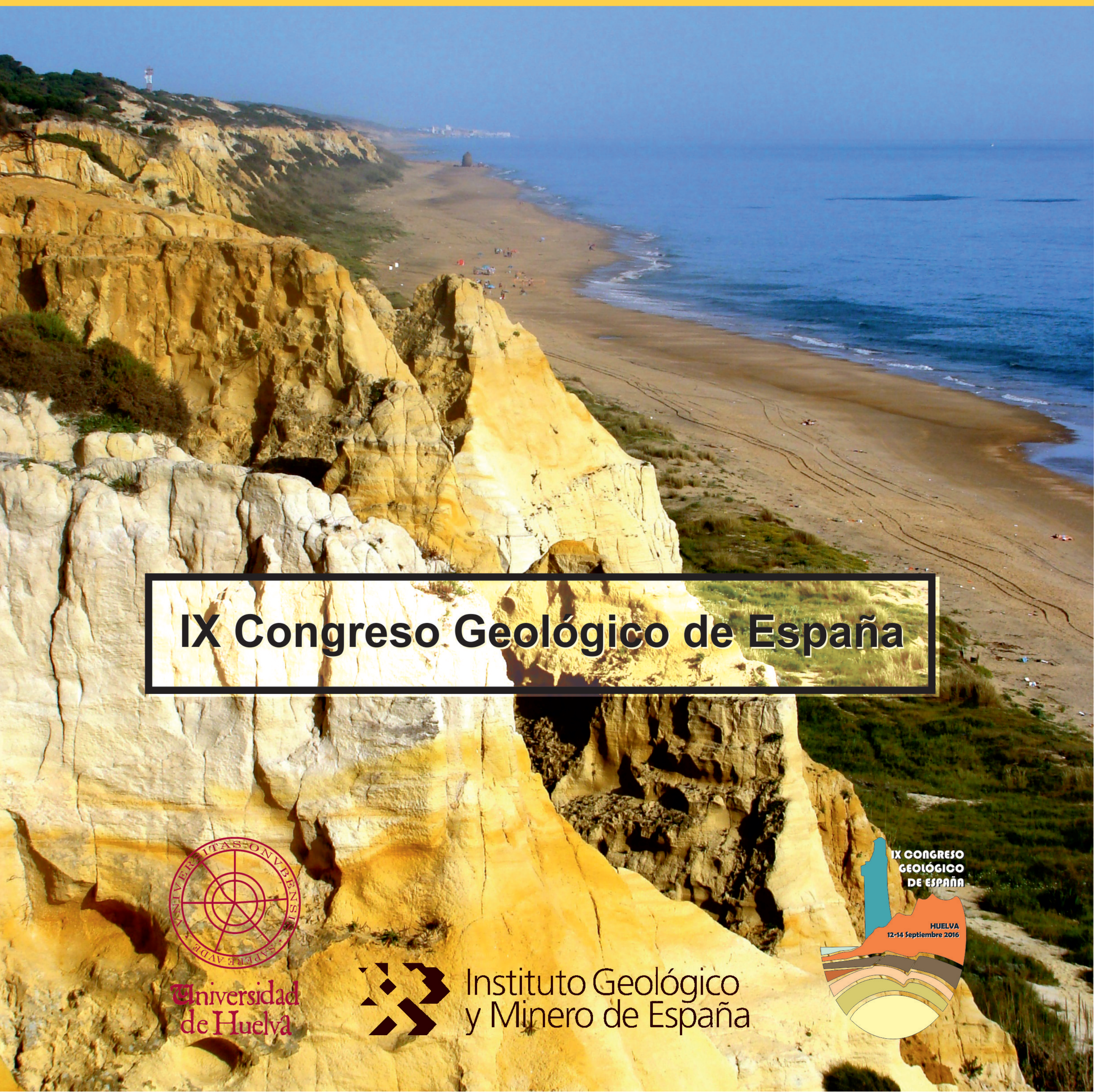

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Marine gas hydrate: a future resource of natural gas for Europe?
Hidratos de gas marinos: ¿un recurso futuro de gas natural para Europa?

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Abstract: Gas hydrates are crystalline compounds where a molecule of gas, mainly methane, is trapped in a cage of ice-water molecules. The importance of gas hydrates in nature is very high because it is an alternative source of energy and play a major role in the delicate balance of the global climate and in the marine geological risks. MIGRATE COST action is designed to integrate the experience of a large number of European research groups and industrial players to promote the development of multidisciplinary knowledge on the potential of gas hydrates as energy resource in Europe. Two of the objectives of the action aim to estimate the European inventory of exploitable gas hydrates and to assess environmental risks. In this work we show the occurrences of gas hydrates described in European margins including the Iberian Peninsula, with a first approximation on the thickness and location of the area of stability of gas hydrates in the Iberian margin.

Key words: Gas hydrate; exploration, production; environmental risk, continental margins

Resumen: *Los hidratos de gas son compuestos cristalinos donde una molécula de gas, principalmente metano, queda atrapada en una red de moléculas de agua en forma de hielo. La importancia de los hidratos de gas en la naturaleza es muy alta ya que constituye una fuente alternativa de energía y a su vez juegan un papel importante en el delicado equilibrio del clima a nivel global y en los riesgos geológicos en el ámbito marino. La acción COST MIGRATE está diseñada con el fin de integrar la experiencia de un gran número de grupos de investigación europeos y agentes del sector para promover el desarrollo de conocimientos multidisciplinarios sobre el potencial de los hidratos de gas como fuente de energía en Europa. Dos de los objetivos de esta acción son realizar un inventario europeo de hidratos de gas explotables y evaluar los riesgos ambientales. En este trabajo se muestran los principales indicios de hidratos de gas en los márgenes europeos incluida la Península Ibérica, con una primera aproximación sobre el espesor y situación de la zona de estabilidad de hidratos de gas en el margen Ibérico.*

Palabras clave:. Hidratos de gas, exploración, producción, riesgos ambientales, márgenes continentales

INTRODUCTION

Gas hydrates (GH) are ice-like crystalline compounds in which low molecular weight gases are embedded in cages formed by water molecules. Gas hydrates are stable at specific thermodynamic conditions (Sloan and Koh, 2008, and references therein). In marine settings, these generally correspond to water depths between 600-3000 m, although in polar areas hydrate can be stable at shallower depths (> 350 mwd). Hydrates are mostly made of biogenic (microbial) methane, although thermogenic gas hydrates also exist in petroleum areas as the Gulf of Mexico or the Caspian Sea. In marine environments, the gas hydrate stability zone – GHSZ, extends from the seafloor down to a depth where the temperature rise and hydrates became unstable. This base can expand to a thousand meters below the seafloor at deep waters.

The presence of GH can be detected by its geophysical, geological or geochemical signatures. One of the most common proxies is the acoustic expression presented in seismic records as an anomalous reflector known as BSR (bottom simulating reflector). Identifying BSRs has revealed the presence of gas hydrates in many continental margins as in the Blake Ridge in the North Atlantic Ocean, the Gulf of Mexico etc. Nevertheless, gas hydrates can also occur in the absence of a BSR, and it has been shown that their presence may be more sensitively detected from the distribution of electrical resistivity, derived from controlled source electromagnetic measurements (CSEM).

Due to the vast resources of gas hydrates that potentially exist in nature, they have been considered as an alternative source of energy, but they can also play a leading role in the delicate global climate balance and in the generation of geological hazards. For these reasons, since the 1970s scientists have been trying to quantify the global inventory of this resource, but these estimates have large uncertainties and so this is still a major challenge for the scientific community. The number of studies based on approximations from direct and indirect data is very high, and the estimation of global volumes of gas or the inventory of gas hydrates have significantly changed from the first approaches based on extrapolations from field data to the present geochemical model-derived estimations.

Current trends point out to the development of complex models that integrate an increasing number of variables on spatial data grids, such as those developed by Piñero et al. (2013), that presented a method based on transfer functions showing an estimation of C stored in the ocean floor in the form of hydrates between 3 and 445 Gt C, depending on compaction conditions and sedimentation. In addition to the parameters considered by these authors, methane migration from deep areas was added, so, the initial estimation of can be up to about 550 GtC. The degree of uncertainty and disparity of the data on the amount of existing hydrates is still quite large. Estimates of methane hydrates in the permafrost globally indicate that resources are almost two orders of magnitude lower than in the marine environment (Sloan and Koh, 2008).

Although the mapping of the areas where hydrates are stable on the seabed is very broad and covers a major part of continental margins, deposits are not as abundant as expected, since the key is the availability of methane gas in the system. Direct data, that include retrieved hydrates or inferred by the presence of BSRs, account for only a small part of the theoretical estimations. The challenge, as occur in the case of conventional hydrocarbons, is to know exactly the specific points where they exist and the calculation of reserves, which is not easy, due to the lack of specific data on marine environments.

A prerequisite for an economically recoverable gas hydrate reservoir is adequate permeability of the gas hydrate-bearing sediment. Sandy sediment are the primary target marine reservoirs in the search for exploitable gas hydrate deposits. Turbidite-sequences and buried channel levees are the favorable settings, with high porosity and permeability where hydrates occupy the intergranular space. Hydrate sands can have saturation values ranging from 60% to 90%.

Different techniques have been tested for producing methane. The release of the gas can be induced by any or a combination of three techniques (the first two involving dissociation) i) increasing the temperature, ii) decreasing the pressure in the geological formation, and iii) chemical activation, notably the injection of CO_2 which exchanges with and releases CH_4 molecules from the hydrate structures.

Numerous countries around the world (e.g. Japan, South Korea, USA, China, Taiwan, India, New Zealand, Canada and Russia) are investing in hydrate R & D to explore their coasts and national waters, constrain the resource potential, and develop technologies for gas production from gas hydrates. This fact is due to gas hydrates may be considered as promising energy resource but with the present knowledge, the commercial dimension of hydrates is still unknown. Exploitation cost and technical difficulties associated to its submarine location are problems to be solved. But also economic situation of the energy market or the price of other conventional or unconventional sources are key parameters. Despite this, currently, there is an international consensus on further progress in the investigation of marine GH. The main research programs are being directed by the governments of countries like the US, China, Japan, Canada, India, Korea, Taiwan, Germany, Norway, Russia and New Zealand, with a very important support of large companies in the Oil & Gas sector.

In this paper we focus on the targets of the European COST action MIGRATE and also a brief compilation of the presence of gas and hydrates at the Iberian continental margins will be presented.

MIGRATE

The COST action MIGRATE (https://www.migrate-cost.eu) hosted in Geomar Helmholtz Centre for Ocean Research, Kiel (Germany), is designed to integrate the expertise of a large number of European research groups and industrial players to promote the development of multidisciplinary knowledge on the potential of gas hydrates as energy resource. In particular, MIGRATE aims to i) estimate the European inventory of exploitable gas hydrates, ii) evaluate current gas hydrate technologies for exploration, production and monitoring, iii) assess environmental risks, and iv) prepare a field production test in European waters. National efforts will be coordinated through four Working Groups focusing on: 1. Resource assessment, 2. Exploration, production, and monitoring technologies. 3. Environmental challenges, 4. Integration, public perception, and dissemination.

GH IN EUROPEAN CONTINENTAL MARGINS

Natural gas from gas hydrate deposits could play an important role in the future European energy system. It could i) enhance the security of energy supply, ii) contribute to the reduction of CO_2 emissions by replacing coal, and iii) complement renewable energies and stabilize the power grid by proving electricity during low-wind and/or low-light periods. Ultimately, gas hydrates could replace Europe's conventional gas reserves that will be depleted within the next decades and mitigate the growing dependence of Europe on natural gas imports.

A Worldwide Gas seeping and gas Hydrates database can be found in (http://woodshole.er.usgs.gov/project-pages/hydrates/. Judd and Hovland (2007) described several examples of potential candidates for future exploitation in European continental margins.

The major gas hydrate regions on consideration in the action are: Barents Sea, Nyegga, South-West Greenland, Svalbard, Eastern Mediterranean, Black Sea, Western Black Sea, Eastern Black Sea, Southern Black Sea, Western Sea of Marmara, Gulf of Cadiz, and North-West Spain (Gran Burato).

The Barents Sea has been extensively studied because it is an area with a wide variety of source rocks and traces of hydrocarbons at different stratigraphic levels. A significant portion of these hydrocarbons have migrated towards the surface being trapped today as gas hydrates. In the continental shelf of Svalbard (Norway), seismic data indicate a wide distribution of gas hydrates and free gas in several areas, such as Vestnesa Ridge and the Fram Strait. The Mediterranean Sea, presents some areas with signs and structures associated with fluid flow and the presence of gas hydrates. One of the main areas is in the Eastern Mediterranean off the coast of Turkey, known as Anaximander seamounts area.

The Black Sea has the most favorable conditions for the formation and accumulation of gas and gas hydrates due to the large amount of organic matter contents in the sediments, the high sedimentation rates associated with the discharge of large rivers (Danube, Dnieper and Dniester) and long periods of anoxia. The zone of gas hydrate stability has an average thickness of 300 m and occurs at water depths of between 620 m and 700 m occupying an area of 288,100 km^2. Estimates of free gas content and gas hydrates are $10\text{-}50 \cdot 10^{12}\ m^3$ and $0{,}1\text{-}1 \cdot 10^{12}\ m^3$.

In the framework of the MIGRATE action, a series of maps presenting hydrate indicators are in progress. These indicators include: direct sampling, BSR, gas seepage, pore water anomaly, gas chimney, velocity anomaly, high reflectivity zone, high resistivity, conventional petroleum provinces and Seabed Features.

GH IN IBERIAN CONTINENTAL MARGINS

Free-gas (shallow gas) is frequent in Iberian continental margins in a wide variety of geological contexts as summarized recently by Garcia-Gil *et al.*, (2015), but GH are confirmed only in the south west Atlantic Margin. There are numerous areas along the Spanish continental margin (Garcia-Gil *et al*, 2015 and references therein): The *NE Mediterranean* margin in the sectors of Cataluña-Murcia-Baleares (Cap de Creus, prodeltas of the rivers Muga-Fluvià, Ter, Besós-Llobregat, the Ebro delta and continental slope Columbretes, Menor Sea slope and the Balearic margin). Along the sector of the *Alborán Sea* there is also evidence of the presence of shallow gas in the Almeria margin and in the Marginal Djibouti Platform, Guadalhorce prodelta and also in the western part of the Alborán Sea basin. The evidence of shallow gas in the *Sector of Galicia* has been intensely identified and described in the sediments of the Rias Baixas and there is a large depression, called "O Burato ERGAP" in the Galician continental margin slope, where escape of fluids have been detected by seismic and sediment cores. Rey et al. (2010) further reported the occurrence of two more giant pock marks in the Galician Continental Margin slope associated to extensive and intense fluid escape activity connected with deep gas reservoirs and supported by physicochemical evidence in piston cores. Shallow gas in estuarine environments, such as in the *Ria de Aveiro*, are also known (Duarte et al 2007). On the other hand, the *Cantabrian Sea* gas presence is also detected in the continental slope of Galicia-Ortegal Spur and in the Basque continental shelf and in the upper Basque slope -southern flank of the Cap Breton and in the marginal platform of Landes.

The continental margin of the *Gulf of Cádiz* (Atlantic margins of Spain-Portugal and Morocco) is an area where for over 15 years national and international groups have been working on various aspects related to the presence and migration of methane. Evidence is the presence of free gas in sediments, surface structures like pockmarks, diapirs and mud volcanoes as well as records of discontinuous BSR. Recently has come to interesting conclusions about the diversity and origin of fluids involved in the different areas, highlighting the contribution of deep sourced fluids (Hensen et al 2007, 2015). Although there is no evidence of the existence of large volumes of gas hydrates at a regional scale, some studies relate the mud volcanoes as being associated with the expulsion of thermogenic gas. The occurrence of hydrates has been confirmed in 6 of these mud volcanoes (Pinheiro et al 2003; Hensen et al 2007, 2015), but strong indications of their presence are found in much more (Leon et al 2012). The hydrates occurrences at the Mud volcanoes represent between 3 and 16% of the volume of sediment, occupying from 5 to 31 % of the porosity (Mazurenko et al. 2002) and occur at Moroccan and Portuguese continental margins.

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REFERENCES

Duarte, H., Pinheiro, L.M., Teixeira, F.C. and Monteiro, J.H., (2007): High-resolution seismic imaging of gas accumulations and seepage in the sediments of the Ria de Aveiro barrier lagoon (Portugal). Geo-Marine Letters, 27: 115-126.

García-Gil, S., Cartelle, V., de Blas, E., de Carlos, A., Díez, R., Durán, R., Ferrín, A., García-Moreiras, I., García-García, A., Iglesias, J., Martínez-Carreño, N., Muñoz Sobrino, C. and Ramírez-Pérez, A., (2015): Gas somero en el margen continental Ibérico. *Boletín Geológico y Minero*, 126: 575-608.

Judd, A. y Hovland, M. (2009): *Seabed Fluid Flow The Impact on Geology, Biology and the Marine Environment*. Cambridge, 475 pp.

Hensen, C., Nuzzo, M., Hornibrook, E., Pinheiro, L.M., Bock, B., Magalhães, V.H. and Brückmann, W., (2007): Sources of mud volcano fluids in the Gulf of Cadiz - indications for hydrothermally altered fluids. *Geochimica et Cosmochimica Acta*, 71: 1232-1248.

Hensen, C., Scholz, F., Nuzzo, M., Valadares, V., Gràcia, E., Terrinha, P., Liebetrau, V., Kaul, N., Silva, S., Martínez-Loriente, S., Bartolome, R., Piñero, E., Magalhães, V.H., Schmidt, M., Weise, S.M., Cunha, M., Hilario, A., Perea, H., Rovelli, L. and Lackschewitz, K., (2015): Strike-slip faults mediate the rise of crustal-derived fluids and mud volcanism in the deep sea. *Geology*, 43: 339-342..

León, R., Somoza, L., Medialdea, T., Vázquez, J.T., González, F.J., López-González, N., Casas, D., Mata, M.D., Fernández-Puga, M.D., Gimeénez-Moreno, C.J. and Díaz-del-Rio, V., (2012):. New discoveries of mud volcanoes on the Moroccan Atlantic continental margin (Gulf of Cadiz): morpho-structural characterization. *Geo-Marine Letters*, 32(5-6): 473-488.

Mazurenko, L.L., Soloviev, V.A., Belenkaya, I., Ivanov, M.K. and Pinheiro, L.M. (2002): Mud volcano gas hydrates in the Gulf of Cadiz. *Terra Nova*, 14, 321-329.

Piñero, E., Marquardt, M. Hensen, C. Haeckel, M. and Wallmann, W. (2013): Estimation of the global inventory of methane hydrates in marine sediments using transfer functions. *Biogeosciences*, 10, 959–975.

Rey, D & Gran Burato Science Team (2010): GB4240 CruiseTechnical Report. Convenio de colaboración entre a Universidade de Vigo e a Consellería de Economía e Industria da Xunta de Galicia para a exploración da morfoestrutura singular da marxen continental occidental de Galicia coñecida como O Gran Burato. Universidade de Vigo.Gran burato MSC

Sloan E. D. and Koh C. (2008): *Clathrate hydrates of natural gases*. 3rd ed., CRC press, Boca Raton, FL