ECONOMIC AND EXPLORATORY REVIEW OF GAS HYDRATES AND OTHER GAS MANIFESTATIONS OF THE URUGUAYAN CONTINENTAL SHELF

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ABSTRACT
This contribution aims to publicize the efforts made in the identification of gas hydrates in the Uruguayan continental shelf, analyze the most outstanding aspects related to its energy potential, as well as include this topic in other areas of knowledge for a comprehensive understanding of the subject. The hydrates, crystalline solid formed mainly by water and natural gas, are reservoirs of carbon that occur naturally in the continents in permafrost areas, and at sea, in the offshore basins of continental margins. They contain more than twice the total carbon in the world, surpassing the conventional hydrocarbon reserves. Principal energy programs foresee its commercial exploitation by 2015. International research programs include not only the energy aspect, but studying such systems considering their participation in the global carbon cycle, climate change and benthic communities associated with them. In our country, several seismic surveys showed evidence of the presence of gas hydrates in continental shelf and the surrounding area. The first survey was carried out by Brazil in the south of the Brazilian continental shelf, ANCAP then showed the continuity of the hydrate layer on the Uruguayan continental shelf and estimated the gas potential of the mineralized layer (87 TCF). Finally, the BGR survey verified the existence of seismic evidence of gas hydrates layer and the presence of free gas below these. The typical seismic response of gas hydrate and free gas is the BSR (Bottom Simulating Reflector) and is interpreted as a positive intensity reflection, followed by a negative intensity, showing the wave passage from a high acoustic impedance zone to a low acoustic impedance zone.

Keywords: gas hydrates, thermogenic gas migration pathways, Uruguayan continental shelf

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NOMENCLATURE
Bottom Simulating Reflector: BSR
Gas Hydrate Stability Zone: GHSZ
Two-way travel time: TWT
Trillion of cubic feet: TCF
Thousand tons of oil equivalent: ktoe
Seaward-dipping-reflectors: SDR

INTRODUCTION
As a result of the worldwide energy crisis, there are many projects aiming at developing unconventional energy resources. One of these unconventional hydrocarbon resources is gas hydrates, whose commercial exploitation would mean access to reserves that may exceed by more than twice those of conventional hydrocarbons [1]. This paper presents seismic evidence of the presence of gas hydrates and other gas manifestations on the Uruguayan continental shelf, in the Pelotas, Punta del Este and Oriental del Plata basins (figure 1). It also presents an estimate of reserves using different criteria, always considering that the compound hosted within the lattice of water molecules is methane [2]. This compound, which in the considered environments can have a biogenic or thermogenic origin, is the most frequent among others such as H$_2$S, CO$_2$, C$_2$H$_6$, etc.

Regarding gas manifestations in the form of seepages, there are also discoveries in Norway [3] and Brazil [4] among others. There are currently several international projects conducting research and generating technology for the commercial exploitation of this resource, among them are the National Methane Hydrate R & D Program in the USA and the MH21 Program in Japan.

METHODOLOGY
The direct sampling of gas hydrates, both onshore and offshore, is becoming increasingly frequent. Hydrate cores were obtained for the first time in the Black Sea by Yefromova in 1972, and subsequently in the USA, Canada, Chile, Japan, India and most recently in China [5]. However, the most frequent indications of the presence of gas hydrates are based on the analysis and interpretation of reflection seismic data. At the regional level, gas hydrate accumulations have been identified through reflection seismic data along the Argentine [6] [7] and Brazilian [8] [9] continental margin. The existence of gas hydrate in the Uruguayan shelf results from the analysis and interpretation of almost 14000 km of reflection seismic lines surveyed by Geophysical Service Incorporated (GSI), Compagnie Generale de Geophysique (CGG) and Western Geophysical, in different surveys for oil exploration by ANCAP, EXXON and CHEVRON [10]. In several of these seismic lines, associated with postmiocenic sequences, the presence of several Bottom Simulating Reflectors (BSRs) were identified. BSRs are frequently used in the indirect diagnosis of gas hydrate accumulations [11] [12]. The identification of the hydrate areas was based on the analysis of seismic lines 29, 31, 33, 35 (figure...
2), 37, 39 and 41 of EXXON, 1, 2, 3, 4, 5, 6 and 7 of G.S.I., as well as lines 2 and 4 of the last speculative non-exclusive seismic survey conducted by CGG [10].

The acquisition parameters for the seismic study of EXXON (figure 2) were 2400 m streamer length, 48 channels and airguns were used as energy source to 25 feet deep. With a shotpoint interval of 50 m and recording filters, low: 8 Hz 18 dB/Oct, high: 62 Hz 72 dB/Oct.

The anomaly is also presented in the study by the German company BGR that was aimed at determining the outer limits of the continental shelf of Uruguay. Among others results, this work led to the identification of the BSR signal attributed by the authors to the presence of gas hydrate [13]. The section of the line BGR04-01 from which this conclusion is extracted from, is shown in figure 3.

Bear in mind that in this last section and another for the line surveyed by CGG (figure 4), in the same domain of the Pelotas basin, phenomena associated with gas migration may be interpreted.

The interval in which gas hydrate is interpreted to occur corresponds to the Gas Hydrate Stability Zone (GHSZ) predicted for methane hydrate based on thermobaric conditions [10]. These conditions are common along continental margins (slope and basin) [10]. As a result of this analysis, a map was made showing the distribution of the seismic anomaly in the deep field of Uruguayan eastern offshore basins [10]. This anomaly is relatively continuous, forming an area of elongated shape of SW-NE direction of approximately 5000 km² (figure 5), and is developed in water depths of 350 to 2200 meters (1200 and 4000 ms).
DISCUSSION

The presence of gas hydrates accumulations in Uruguayan ocean waters is located in the geological domains of the Oriental del Plata basin and in the deep areas of Pelotas and Punta del Este basins [10]. These basins are associated with areas having high rates of organic debris generation, high sedimentation and burial rate. These are presumably associated regionally with significant contributions and progradations from the Rio de la Plata – Cono de Rio Grande system [14]. This situation, coupled with the presence of cold Antarctic waters, would have created conditions for the accumulation and preservation of gas hydrates in the domain east of the Uruguayan offshore basins, as well as in the Brazilian Pelotas Basin [9]. Locally, it is likely that the burial and preservation conditions of organic matter are related to the progradations from the Alto del Polonio and Continental slope of the eastern sector of the Uruguayan territorial sea, an aspect that is suggested through the seismic lines EXXON 29, 32, 33 and 41 of the Pelotas and Oriental del Plata basins [10].

It is also possible that a portion of the methane that forms the gas hydrates mineralized layer results from thermogenic contribution from the migration of gas generated from deeper layers of the offshore basins [15]. Under this latter scenario, there is also the possibility that gas volumes are accumulated below the BSR in plays where hydrate-bearing layers act as a seal for stratigraphic traps [10]. Regarding this, figure 4 shows seismic evidence of rising fluids from depth. This could be an indication of thermogenic gas migration pathways which appear in the seismic sections as gas chimneys, supplying gas to the GHSZ.

Other phenomena related to gas migration are shown in figure 3. The escape of fluids (that may be water, gas or oil) results in seepages. Fluid escape results in pockmarks on the seafloor. These appear on the seismic sections as V-shaped structures. A possible source of the fluid that generates the pockmarks could be from the destabilization of the hydrates, which may take place from variations in the stability conditions, such as a drop in pressure or temperature increase.

It is probable that the Vs observed in figure 3 between TWT 3.2 s and 3.0 s, are pockmarks. Here, the loss of the BSR signal coincides with the collapse area which could be caused by the destabilization of hydrates, or a failure in the hydrate seal with the consequent release of gas. This could lead to the disappearance of the BSR in that area, and the generation of a new BSR at greater depth.

The work performed by Rose et al. [4] agrees with the identification of seepages at bathymetries in the order of 3000 m in the Brazilian side of the Pelotas basin. These areas are of great interest for direct sampling to determine nature and origin of these fluids.
All indications of gas hydrates in the Uruguayan shelf came through seismic surveys for oil and gas exploration, targets much deeper than the zones where hydrates are stable. For that reason, the parameters for the acquisition were not adequate to obtain information that would allow a detailed analysis of the hydrate interest area. There has also been no drilling in these areas so no sediment samples have been obtained. For these reasons, quantifying calculations have been done on the basis of criteria obtained from literature, applied to the interest areas.

The following are the calculations made to carry out the quantification of gas hydrates deposits:

1st criteria
Taking into account that the interest area covers a minimum of 5000 km$^2$ and the thickness of the mineralized sections would be in the order of 200 m (calculated on the basis of a minimum intervallic velocity of 1600 m/s in the GHSZ, and a TWT of 250 ms for the less developed areas); for an average gas hydrate concentration conservatively estimated at 1.5% of the total sedimentary volume [9], the primary valuation of the resource in situ would be 1.5 x $10^{10}$ m$^3$, which is equivalent to a theoretical volume of gas in normal conditions (0°C, 1atm) of 87 TCF.

2nd criteria
The second criterion of quantification was taken as a reference to the work of Yuan et al (1996) [16] in the northern Cascadia continental slope off Vancouver Island, which reached a value of methane gas at STP of 800 m$^3$ per square meter of seafloor (including the amount of free gas below the BSR). Taking this into account, for the indicated area of 5000 km$^2$, the theoretical volume of gas in standard conditions would be 141 TCF.

3rd criteria
For this criterion we use data from cores of the first gas hydrate drilling expedition in China in July 2007 [5] where were found sediment layers with gas hydrates from 10 to 25 m thick directly above the BSR and 20% - 40% of gas hydrates as a percentage of pore volume. Therefore, considering that hydrates are found within the sedimentary volume given by an area of 5000 km$^2$ and 25 m thick, using a concentration of 20% of the poral volume and a porosity of 60% [17] (for high porosity unconsolidated sediments), quantification of gas hydrates in situ would be 1.5 x $10^{10}$ m$^3$, which is equivalent to a theoretical volume of gas under normal conditions of 87 TCF.

Considering conservatively that the theoretical gas volume under normal conditions that is stored in the form of gas hydrates is 87 TCF, and taking into account that during the year 2006 the total energy consumption of Uruguay was 2431.9 ktoe [18], the in-place reserves of gas hydrates represent 850 years of energy consumption. This does not consider efficiencies or recovery rates inherent in the production process.

Another way to visualize the importance of access to this resource appears in comparing the estimated in-place reserves with annual natural gas consumption, which was 0.00359 TCF in 2006. This means that Uruguay could become a potential natural gas exporter in a region of great energy demand.

CONCLUSIONS
Uruguay has a latent potential energy resource. Gas hydrate represents, according to the measurement criteria used in this work, many years of supply. Additional exploration potential exists in the form of “free” gas accumulations of thermogenic origin, possibly associated with stratigraphic traps.

These important aspects are the basis for the design of new exploratory projects with the aim of identifying possible drilling sites for sample characterization. This will require a detailed seismic survey for shallow areas of the Pelotas basin.

REFERENCES