Goldschmidt 2000
September 3rd–8th, 2000
Oxford, UK.

Journal of Conference Abstracts
Volume 5(2), 819

Gas Geochemistry of Mud Volcanoes from Trinidad: Surface Evidence of Deep Gas Reservoirs, Modified by Vertical Migration

Alain Prinzhofer (alain.prinzhofer@ifp.fr)[1], **Anne Battani** (anne.battani@ifp.fr)[1], **Christopher Ballentine** (ballentine@erdw.ethz.ch)[2], **Eric Deville** (eric.deville@ifp.fr)[1], **Jean Paul Herbin** (j-paul.herbin@ifp.fr)[1] & **Jean Pierre Houzay** (jean-pierre.houzay@elf-p.fr)[3]

[1] IFP, 1&4, avenue de Bois-Préau, 92852 Rueil-Malmaison Cedex, France, France
[2] ETH, Isotopengeologie NO C 61, Sonneggstr. 5 - CH-8092 Zurich, Switzerland
[3] ELF- CSTJF, Avenue Larribau, 64018 Pau Cedex, France

Interpreting surface evidences to infer deeper structures or processes has always been a major goal in Earth Sciences. Gas and oil exploration has started in observing the oil and gas seeps above possible reservoirs, and the best understanding of any superficial information is still a critical issue. The island of Trinidad has been a well known target for oil production for more than one century, and presents also series of mud volcanoes, with continuous gas bubbling. We have analyzed gases bubbling from the mud volcanoes, and associated gases with oil in deeper reservoirs, in order to understand the possible relationships between these two families.

The main inland hydrocarbon province is located in the southern zone of the island, separated by faults from a northern metamorphic belt, and a middle zone apparently a sterile sedimentary basin. An isolated dry gas field is located in the middle part of the island, and was also sampled. All the other fields are oil fields, with a small proportion of associated gas. They are generated from a Cretaceous source rock, and are accumulated in the Tertiary part of the sedimentary column.

The mud volcanoes are also located mainly on the southern shore, sometimes exactly at the apex of oil and gas fields, and have been extensively studied for their water and mineral compositions (Higgins & Saunders, 1974; Dia et al., 1999). They show generally persistent modest gas bubbling, and some rare catastrophic eruptions with large emissions of mud flows and breccias. The large volume of fossil mud formations indicates that this type of dynamics has been occurring for a long time. A probably underestimated flux of gas, from the actual production, is of 200TCF per million years. This impressive emission of gas must be clarified in terms of source and migration processes.

The chemical and isotopic signatures of the gases associated with oil in the reservoirs are typical of thermogenic gas generated in the oil windows. The isolated gas field in the middle of the island is a purely bacterial gas. This is demonstrated with both chemical and isotopic compositions.

The mud volcanoes gases have intermediate values between thermogenic and bacterial signatures. The hypothesis of a mixture between these two end-members must be discarded, as in a mixing diagram C2/C1 versus the $\delta^{13}C$ of methane (Prinzhofer & Pernaton, 1997), the bacterial end-member would be expected with values between -33 and -52, a range of values too enriched in ^{13}C for a bacterial activity. We conclude that the hydrocarbon gases found in the mud volcanoes are purely thermogenic gases. However, the extreme dryness of these gases cannot be directly related to the generation of the gases but rather to post-genetic processes (Prinzhofer et al., 2000).

The associated δCO_2 in relatively small amounts in both the reservoirs and mud volcanoes gases show a very large range of $\delta^{13}C$ values, from - 25 to +22 per mil. A surprising correlation does exist between the isotopic compositions of the δCO_2 and the proportions of δCO_2. This log-normal correlation (Figure 2) cannot be explained by a mixing but by a segregation process. Possible interaction of the gas molecules with the solid part of the mud may explain these trends.

The gases associated to mud volcanoes come from the same source as the gases associated with reservoirs oils. This is corroborated by the composition of the hydrocarbons and of δCO_2 and by the radiogenic fraction of the associated noble gases. To explain the extreme dryness of the mud volcanoes gases, we suggest a process of migration involving solubilisation/diffusion in water, and preferential adsorption of the larger molecules on the solid network of the mud. Mud volcanoes gases could be interacting with an active aquifer, inducing a dilution of the conservative noble gases carried with this aquifer, to the deeper noble gases, enriched in radiogenic isotopes. A simple modelling of the noble gas concentrations enables to explain the large amount of thermogenic gas lost though the surface with the mud volcanoes, and the very poor efficiency of accumulation of gas in the reservoirs.

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