P-40 MECHANISMS OF FLUID EMISSIONS – THE CASE STUDY OF REGNANO MUD VOLCANO, N-APENNINES, ITALY

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Summary

The seep of Regnano mud volcano, where mud is extruded in association with saline water and light hydrocarbons, is located at the surface emergence of a normal fault making part of an extensional system active after the arly Pleistocene. Chemical analysis and geological setting indicate that this system cuts previous chain thrusts and drains a Miocene reservoir which trapped deeper fluids migrated from the underlying Mesozoic units.

Introduction

Spontaneous fluid emissions, extruding saline waters, gas and oil, are widespread along the Apenninic chain (e.g. Borgia et al., 1986; Nanni and Vivalda, 1999). In the Northern Apennines, alongside the Po Valley of the Emilia-Romagna region, seeps are mainly concentrated along two belts. The first belt stretches along the foothills while the second one is more internal, not far from the main orographic divide (Fig. 1). Mud volcanoes, made up by mud breccias and mudflows, are locally associated with the seeps. A geologic scheme of the Apenninic surficial geology, with locations of the escaping fluids, is reported in Fig. 1.

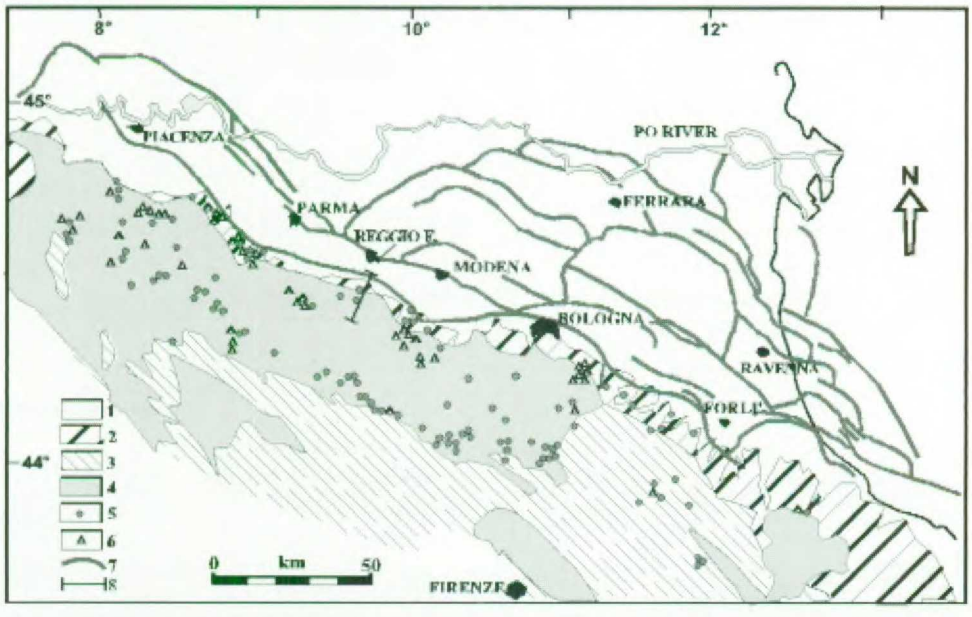

Fig. 1 - Geologic scheme and locations of the fluid emissions alongside the Po valley. 1- Continental Quaternary; 2- Marine to continental Plio-Pleistocene foredeep units at the foothills; 3- Miocene foredeep units; 4- Ligurian-Epiligurian units; 5- spontaneous fluid emissions; 6- oil and gas from surficial drilled wells; 7 - thrust front in the subsurface; 8 - Trace of the section of Fig. 4. Modified after Borgia et al. (1986).

This study aims to determinate the origin and mechanisms of fluid emissions in the case of the Regnano mud volcano (Reggio Emilia province, Fig. 1), one the most famous in the Emilia-Romagna region and whose activity has been reported for almost two centuries, by an analysis of fluid emissions compared to the interpretation of the geologic setting at surface and in cross section.

Methods

Spontaneous fluid emissions at Regnano have been sampled monthly for some months, including a significant paroxismal event, occurred in march 1999, whose magnitude had never been matched at least the last twenty years. Samples have been analyzed for their physico-chemical, isotopic and bacteriological characters. The study of the fluids was integrated by an accurate field survey and by the biostratigraphical analysis on the ejected muds.

Results of the fluid analysis

The saline water of Regnano is cold (T ranging from 12° to 17°C), has a salinity lower than sea water and the isotopic record indicates a formation water without meteoric mixing (Fig. 2).

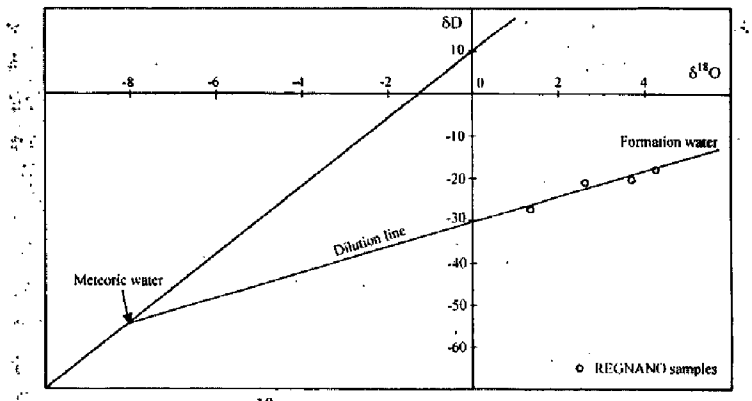

Fig. 2 - δD versus $\delta^{18}O$ of the sampled water.

Table 1 reports the ionic content calculated as ratios plotted versus Cl^-. Data are relative to the samples collected during the paroxismal event. These are, however, very similar to those obtained during other samplings. In comparison to sea water, at Regnano, in presence of a relatively low chlorinity, the Ca^{2+}/Cl^- and Mg^{2+}/Cl^- ratios decrease while Na^+/Cl^- and HCO_3^-/Cl^- increase.

Table 1. Ionic content in sea water and at Regnano seep, calculated as ratio plotted versus Cl^-

Ratio	Sea water Cl^- 18,980 ppm	Ratio	Regnano: 30.03.1999 Cl^- 8875 ppm
Ca^{++}/Cl^-	0.021	Ca^{++}/Cl^-	0.0065
Mg^{++}/Cl^-	0.067	Mg^{++}/Cl^-	0.0097
Na^+/Cl^-	0.53	Na^+/Cl^-	0.69
K^+/Cl^-	0.02	K^+/Cl^-	0.0025
HCO_3^-/Cl^-	0.0074	HCO_3^-/Cl^-	0.33
SO_4^{2-}/Cl^-	0.14	SO_4^{2-}/Cl^-	0.00022

These results support the hypothesis that the Regnano waters are a type of membrane filtered connate water (sensu White, 1965). In this case we can infer that the ionic content depends on the passage of H_2O, Na^+ and of uncharged H_2CO_3 through fine grained membranes, while Ca^{2+} and Mg^{2+} are adsorbed by the cation-exchanging clays. The dissociation of H_2CO_3 increases the alcalinity of the solution. The range of measured pH, always over 7.8, supports this interpretation.

Another significant datum about the water concerns the occurrence of a population of active sulfate reducers bacteria with an incubation temperature of 35°C. The H_2S content (about 2 mg/l), the low SO_4^{2-}/Cl^- value and probably part of the HCO_3^- in the water are therefore due to the present bacterial activity. The composition of the gas, sampled during the same fluid emission (Fig. 3), is over 90% methane, probably linked to a thermogenic or mixed origin (Mattavelli et al., 1983).

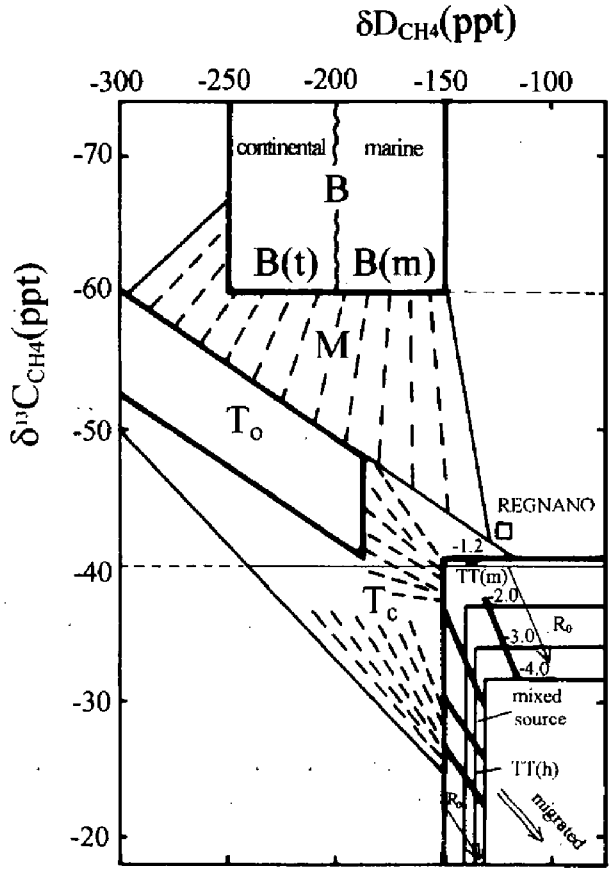

Fig. 3 - Isotopic composition of Regnano gas samples. Diagram after Schoell (1983). Primary gases: B = bacterial; T= thermogenic associated; TT = nonassociated deep dry gases; M = mixing of thermogenic and bacterial gases.

Geologic interpretation and mechanism of fluid emissions

In the Regnano area, the geology is largely dominated by the Ligurian nappe, a remnant of the Tethyan accretionary prism. The Ligurian units were accompained, during the Tertiary translation, by the deposition of the normal marine units (Epiligurian) on their top. The S-N cross section of Fig. 4, modified after Zanzucchi (1980) on the base of a new field survey, reports the geologic setting from Regnano to the Po Plain. This portion of the chain is made up by the superposition of the Ligurian-Epiligurian units on the Miocene foredeep. The tectonic pile, has been deformed by thrusting during the early-middle Pliocene. After the early Pleistocene, it has been cut by a system of normal faults (Fig. 4). The Regnano and other minor seeps are located at the surface emergence of these normal faults. The mud ejected with the fluids contains microfossils of middle Eocene age, suggesting a provenance from the base of the Epiligurian sequence. Our interpretation is that the fluids, were generated inside deeper tectonic units, which include Mesozoic evaporites and carbonates. They first migrated, during the Pliocene compressive deformation, in the Miocene reservoir and, subsequently, arised to the surface utilizing pathways opened by the normal faults. During the recharging time interval, at a depth of about 2000 m, the bacterial activity develops, inducing alteration of C_2-C_4 gas molecules. The normal faults, draining the reservoir, have probably prevented the accumulation of the fluids in the culmination of the thrust ramp (Fig. 4).

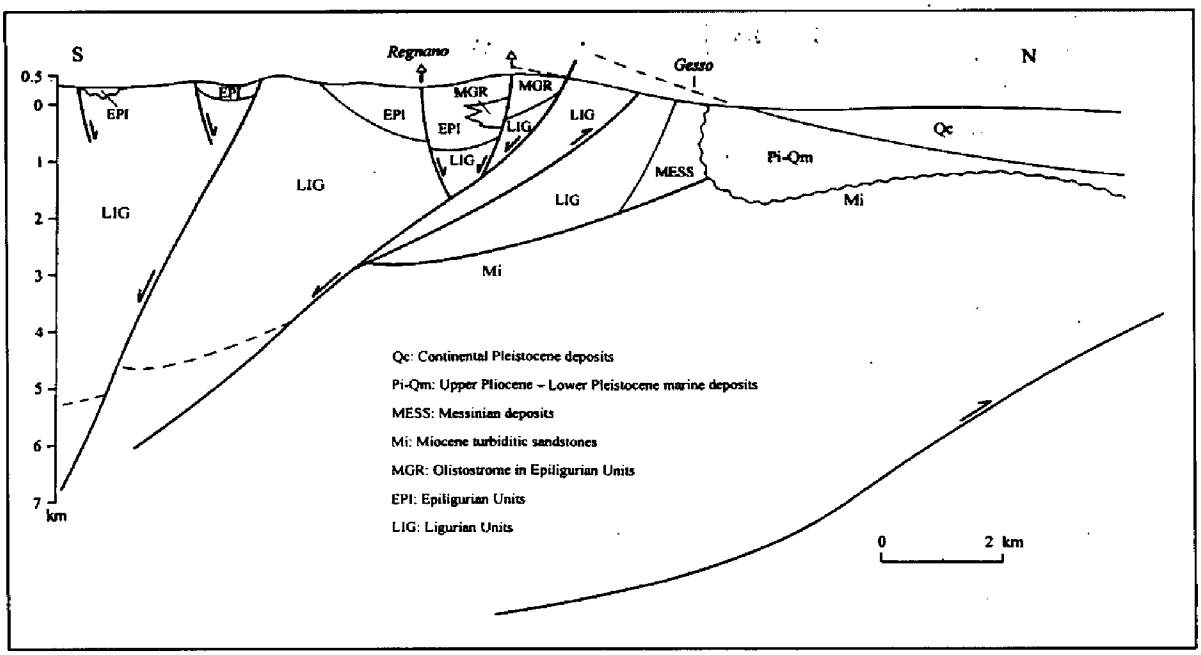

Fig. 4 - Section across the foothills of Emilia region, showing the superposition of Ligurian-Epiligurian units over the deformed Miocene foredeep units. Note the normal faults cutting the whole edifice. Triangles marks the mud volcanoes.

Acknowledgments

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