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Earth's degassing

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It is presented an overview of the studies which has been developed for the quantification and the mapping of Earth degassing processes. Both measurements methods and applications will be synthetically discussed. The lecture is divided in two parts: 1- measuring diffuse degassing (Tuesday 21 September 2010) and 2- CO_2 balance of aquifers and derivation of regional budget and maps of CO_2 Earth degassing (Thursday 23 September 2010) .

1-MEASURING CO_2 SOIL DEGASSING (Tuesday 21 September 2010)

The method used to measure the flux of CO_2 (ϕCO_2) in the areas characterized by diffuse emission from the ground is based on the principle of the accumulation chamber (Parkinson 1981; Baubron et al., 1990; Baubron et al., 1991), which was modified according to the so called method 'measure at time 0' (AC0) described by Tonani and Miele (1991), Chiodini et al. (1996) and Chiodini et al. (1998). The method AC0 consists in the measure of the time variation of the concentration of CO_2, C_{CO2}, inside a cylindrical chamber with an open side facing the ground. At the first instant, theoretically at the time 0, ϕCO_2 is a function of the derivative of the curve C_{CO2} vs. time:$\phi CO_2 = K\, dC_{CO2}/dt$, where the constant K has the dimension of a length, depends on the instrumental characteristics, and can be estimate by experimental tests. Soil flux data have generally a logarithmic distribution which complicate their treatment. A stochastic simulation algorithm has been selected with the objective of mapping the degassing areas, i.e., defining the diffuse degassing structures, and evaluating the total emitted CO_2 with the associated uncertainty (Cardellini et al., 2003). The method has been largely applied to investigations related to volcanological themes. Degassing of magmatic bodies and/or hydrothermal systems produces different exhalative phenomena at the surface, such as: strong degassing from active craters and formation of volcanic plumes, fumarolic emission, areas of diffuse emission of gas (mainly CO_2) both associated or not with fumarolic fields. The interpretations of the first campaigns, performed about 10-15 years ago, suggested that the gas is not released uniformly from the whole volcanic areas, but from relatively small regions, which have been called Diffuse Degassing Structures (DDS). The studied cases highlighted that: (i) the amounts of energy released by DDS are comparable, in a few cases, to those released by volcanoes during an eruption; (ii) the energy released by the DDS are very large and

normally constitute the main term in the energetic balance of quiescent volcanoes (Chiodini et al., 2001, 2005); (iii) the DDS are associated to dynamically active systems of fractures, which have geometries different from those in the surrounding areas (Chiodini et al., 2001; Caliro et al., 2004). The soil CO_2 flux data, together with other information on subsurface structures and conditions, can provide the necessary constraints to perform physical modelling of the hydrothermal fluid circulation in volcanic and non-volcanic areas. At la Solfatara of Pozzuoli numerical simulations, constrained by CO_2 flux data, described the ascent and evolution of a hot, multi-phase and multi-component fluid, composed of water and carbon dioxide, through a homogeneous, porous medium (Todesco et al, 2003). This model reproduced some of the main features which characterize the natural system, including the energy budget associated with the ascent and condensation of hot fluids, and the development of a single-phase gas region whose existence was inferred from independent chemical data. Furthermore the comparison between the results of the numerical modelling of the hydrothermal circulation and geophysical and geochemical monitoring data showed that periods of intense degassing processes triggered volcanic unrest periods at Phlegrean Fields (i.e. 3 meters of ground uplifting and thousands earthquakes which caused the evacuation of 20000 people in 1983) as well as in other volcanoes in the world (Chiodini et al., 2003)

2. CARBON BALANCE OF AQUIFERS AND DERIVATION OF REGIONAL BUDGET AND MAPS OF CO_2 EARTH DEGASSING: THE CASE OF CENTRAL AND SOUTHERN ITALY (Thursday 23 September 2010)

The second lecture will be focused on the carbon balance of large aquifers and on the derivation of regional map of CO_2 Earth degassing. Carbon dioxide fluxes from the ground to the atmosphere can be adequately measured with the accumulation chamber method in the very anomalous areas of active volcanoes and of natural cold gas emissions. However the same method can not be used for the study of low CO_2 fluxes, fed by deep sources, that could regionally affect large areas because most of the gas is dissolved by the groundwaters and released as dissolved carbon species by the water springs. In this cases the mass balance of the inorganic carbon dissolved into the groundwaters of regional aquifers can be suitably used to quantify the diffuse CO_2 emission over large areas. The method, based on the chemical and isotopic analysis of the main springs, was firstly applied to the Apennine area of Central Italy (Chiodini et al., 2000) and subsequently it was extended to the Southern Apennines and to the Tyrrhenian sector of Italy (Chiodini et al., 2004). The main results were the elaboration of the first regional map of CO_2 Earth degassing from a large area (most of central and south Italy) and the estimation of the total amount of CO_2 involved. The investigation showed that a globally significant amount of deeply derived CO_2 (10% of the

estimated global CO_2 emitted from subaerial volcanoes) is released by two large areas located in western Italy. Furthermore the Earth degassing map highlighted an intriguing coincidence among seismicity and the eastern boundary of the CO_2 anomaly suggesting a primary role of degassing process in the geodinamic of the region.

A set of recently acquired data on the aquifers located in the epicentral areas of the 'L'Aquila 2009' earthquakes will be presented and discussed. The data clearly show the presence of a deep source of gas whose original composition has been estimated on the base of the composition of the gas dissolved in the groundwaters. The gas entering the aquifers results rich in radiogenic He and in nitrogen, a characteristic typical of the gas emissions located in the pre-Apennine sector which are fed by deep pressurized reservoirs. Fluid pulses from such deep high pressurised zones have been taught to have a direct role in the seismogenetic processes.