High ^{3}He gas emissions from the Irpinian Apennine: Mantle relations and genetic hypothesis (*)(**)

F. ITALIANO (1), M. MARTELLI (3), G. MARTINELLI (2) and P. M. NUCCIO (1)(3)

(1) *Istituto Geochimica dei Fluidi, CNR - Palermo, Italy*
(2) *Servizio Cartografico & Geologico, Regione Emilia-Romagna - Bologna, Italy*
(3) *Dipartimento di Chimica e Fisica della Terra (CFTA), Università di Palermo - Palermo, Italy*

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Summary. — A gas geochemical prospection has been carried out in a tectonically active area located in the Southern Apenninic Belt (Italy) with the purpose to investigate the origin of local gaseous emissions. On the basis of helium isotopic ratios, a high contribution of deep-marked fluids has been recognised. Local field evidences of gases flow rate do not seem consistent with only a mantle provenance of the fluids. It seems likely that the gases source has to be located at shallower depth than the crust-mantle transition.

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1. – Introduction

The Irpinia and Basilicata Apennine is characterised by strong CO_2 dominating gases emissions, that have been studied since at least the mid-nineteenth century (Balderer and Martinelli, 1995). One of these, the Mefite d'Ansanto (fig. 1) emission, has been known since the Roman age for the vehemence of its gas output (Santoli, 1783). The purpose of this work is to investigate the origin of local gaseous emissions, with particular regard to the Mefite d'Ansanto emission.

2. – Geological and geophysical setting

The Apennines are a Neogene and Quaternary thrust belt located in the hangingwall of a W-directed subduction, detected by seismicity and tomografy and active since at least the Early Miocene (Spakman, 1989; Amato *et al.*, 1993).

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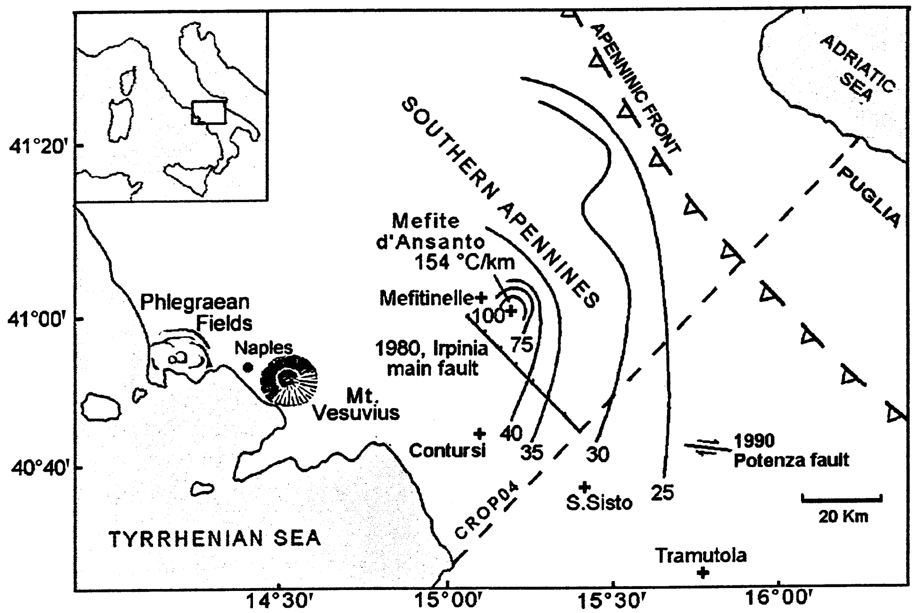

Fig 1. – Location of the sampling sites in Irpinia and Basilicata Apennines.

Although Southern Apennines originate from compressive tectonics, the actual stress field acting on the Apenninic chain is extensional and oriented NE-SW (Pantosti and Valensise, 1993; Valensise *et al.*, 1993): it is documented by widespread normal faulting NW-SE (Ciaranfi *et al.*, 1983; Pantosti and Valensise, 1993).

One of the most important events occurred in the Apennines in this century, the Irpinia 23/11/1980 earthquake ($M = 6.9$), took place in one of these faults (Ciaranfi *et al.*, 1983; Pantosti e Valensise, 1993; Valensise *et al.*, 1993).

3. – Experimental

We have collected gaseous samples into glass containers with two vacuum valves. Gaseous composition was investigated by a Perkin-Helmer 8500 Gaschromatograph.

In order to obtain isotopic $^3He/^4He$ ratios, each gas sample was introduced into a metallic vacuum line and purified using a hot titanium-zirconium getter and two charcoal traps held at 77 K. The $^4He/^{20}Ne$ ratios were measured by a quadrupole mass spectrometer. Helium was completely separated from neon by a cryogenic charcoal trap held at 40 K and transferred into a high-precision mass spectrometer (modified VG5400, VG Isotopes). Ion beams of $^3He^+$ and $^4He^+$ were detected with a double collector system at the same time. Atmospheric helium was used as a running standard.

CO_2 fluxes have been estimated by measuring the actual flux at some emission point and by scaling the obtained low-flux measurements resulting with the high-flux emissions.

4. – Results and discussion

Chemical and isotopic $^3He/^4He$ gases analysis yielded to important information about fluids properties. Our samples show a wide compositional range (table I): the most intense emissions (Mefite d'Ansanto, Mefitinelle) are CO_2 dominated, while others are N_2 dominated (S. Cataldo) or CH_4 dominated (Tramutola).

The $^3He/^4He$ isotopic ratio shows the existence of a helium mantle contribution to some of the sampled emissions displaying values well above the typical crustal value, and reaching 2.84 Ra at the Mefite d'Ansanto emission, located in the epicentral area of the 23/11/1980 earthquake ($M = 6.9$).

The highest fluxes have been recorded at the Mefite d'Ansanto emission (CO_2 dominated, 96-98%), where gas discharge has an estimated output of the order of a few cubic meters per second. Weaker gas discharges, releasing deep-marked fluids, take also place in the surroundings over an area of some squared kilometres.

Considering for the entire Mefite d'Ansanto area a minimum discharge rate of 1 m^3/s and using the measured helium concentration with its isotopic ratio, we estimated a total helium output in the range of 4.3×10^{18} atoms $m^{-2} s^{-1}$ and a ^{3}He output of 1.7×10^{13} atoms $m^{-2} s^{-1}$ (table II).

Table II compares the estimated helium flux for Mefite d'Ansanto with the He and ^{3}He fluxes considered normal from the continental crust. This comparison shows that the estimated fluxes are 8 orders of magnitude larger than those normally measured in the continental crust. It means that the normally assumed He production rate in crustal rocks is absolutely inadequate to sustain the estimated Mefite fluxes. The released "continental" helium is almost all of crustal genesis (99%; O'Nions and Oxburg, 1983). Furthermore, the ^{3}He Mefite flux is 11 orders of magnitude larger than the normal flow in the continental crust, clearly showing that from a genetic point of view the released helium is not simply of crustal origin.

A contribution of mantle fluids seems thus to be present in the Mefite d'Ansanto gas emissions. In this hypothesis, we have to find a mechanism that allows the release of

TABLE I. – *Chemical composition of the investigated gas samples.*

Site	Date	He ppm	H_2 ppm	N_2(%)	CO ppm	CH_4(%)	CO_2(%)
Mefite d'Ansanto	29/06/96	8	36	1.6	0	0.2	98.1
Mefitinelle	29/06/96	9	0	3	5	0.3	97.1
S. Cataldo	23/04/96	97	10	79.9	0	19.2	0.9
Tramutola	11/04/96	250	0	17.4	22	81.6	0.9

TABLE II. – $^3He/^4He$ *isotopic composition of the investigated gas samples.*

Site	Date	Rc/Ra
Mefite d'Ansanto	29/09/96	2.84
Mefitinelle	01/07/96	2.35
S. Cataldo	22/04/96	0.09
Tramutola	08/04/96	1.19
Contursi	27/06/98	1.43
S. Sisto	30/06/96	1.33

Table III. – *Data regarding continental areas (after O'Nions and Oxburg,* 1983) *and* ϕ_{Heat} *at Mefite d'Ansanto (after Mongelli et al.*, 1996).

	Continents	Mefite d'Ansanto
ϕ_{He} (atoms $m^{-2} s^{-1}$)	2.8×10^{10}	4.3×10^{18}
$\phi_{^3\text{He}}$ (atoms $m^{-2} s^{-1}$)	7×10^{2}	1.7×10^{13}
ϕ_{Heat} ($mW\,m^{-2}$)	63	215

such measured gas flux, taking into consideration that in this region the crust-mantle transition is about 30 km deep (Panza *et al.*, 1980).

Considering that, through a permeable medium, the flow of a fluid (having its own density and viscosity characteristics) depends on the pressure gradient and on the permeability of the medium (Darcy's law), it is necessary to suppose very high permeability values in this region to support the observed fluxes. The permeability for a given rock thickness would be estimated following the relation proposed by Criss and Taylor (1986). However, considering the crustal thickness in the order of 30 km, the permeability would be too low to sustain the observed intense gas fluxes. Table III shows that the heat flux measured in the area is at least three times the normal heat flux in the continental environment. Supposing that heat and gas come from the same deep source, we hypothesize that it has to be located at shallower depth than the crust-mantle transition. If the hypothesis is correct, the possibility that intrusive bodies exist beneath the area has to be taken into account.

5. – Conclusions

Investigation on gaseous emissions of Irpinian Apennines, and particularly speculations about the $^3He/^4He$ ratio, allowed us to recognise a high contribution of deep-marked fluids to the region.

The important contribution of deep helium (mantle-type) marks the Mefite d'Ansanto gaseous emissions. However, the huge discharge of deep-marked gases does not seem consistent with only a mantle provenance of the fluids: that is because the crust-mantle transition is about 30 km deep. In order to sustain the observed flow, it seems thus necessary to rise the gases source to an intracrustal site. This leads to the conclusion that the source of Mefite d'Ansanto gases could be an intrusive body.

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