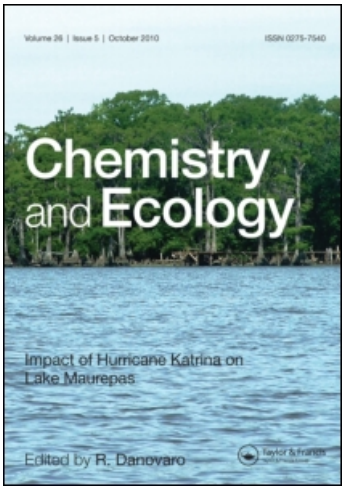

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ENVIRONMENTAL RADIOACTIVITY AND VOLCANOLOGICAL FEATURES OF THREE ISLANDS OF THE MEDITERRANEAN SEA (PANTELLERIA, USTICA AND VULCANO)

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The Mediterranean Sea is an area of great interest for its volcanic activities. This paper presents a comparative study of radiometric and chemical data regarding three volcanic islands located in southern Italy (Pantelleria, Ustica, and Vulcano) characterized by different magmatic histories. Measurements of radionuclide contents and chemical composition of rock samples belonging to the main lithologies present in the three islands were carried out. The observed correlations among radiometric, chemical and mineralogical data reflect the differences in the volcanological genesis and suggest some hypotheses on the magmatic evolution.

KEY WORDS: Radioactivity, volcanic rocks, magmatism.

INTRODUCTION

Different geodynamic environments lead to eruptive products characterized by different content of primordial radionuclides (^{40}K, ^{238}U and ^{232}Th). Within the framework of studies on natural radioactivity in volcanic islands of southern Italy (Brai *et al.*, 1988; Brai *et al.*, 1992; Brai *et al.*, 1995) it seemed useful to compare the content of radionuclides in the volcanic rocks of three islands, Pantelleria, Ustica, and Vulcano, which are geologically "young" (< 1 My) and characterized by different magmatic evolutive processes (Barberi *et al.*, 1974; Cinque *et al.*, 1988).

GEOLOGICAL SETTINGS

Pantelleria

The island of Pantelleria is located about 70 km far from Africa and 85 km from Sicily. It is the emerging part of a submarine volcano, with maximum elevation 836 m a.s.l. at Montagna Grande, emerging from 1600 m below sea-level.

From a geodynamic point of view, it can be considered an "intra-plate" volcano, being located within the African plate. The island is characterized by the occurrence of a bimodal association of basaltic and trachytic-rhyolite products, the former being only 6% of the emerging rocks (Brai *et al.*, 1992).

The oldest rocks are visible in the southern part of the island and date about 300,000 y. On the other hand, almost all the emerging rocks are less than 50,000 y old (Rittmann, 1967).

The last subaereal activity is represented by the "Mursia" basaltic lava flows and cinder cones. The geological history of the island, characterized by explosive events during which ignimbrite deposits were formed, suggests that the next volcanic activities are expected in the next 1,000 y (Civetta *et al.*, 1984).

Ustica

The island of Ustica, 37 miles N-NW of Palermo (Sicily), is the relict of a large volcanic edifice, first submarine, then subaerial, which developed in the Quaternary. The island is 248 m above a.s.l. and its base lies about 2000 m below sea level.

The rocks of the island are volcanic, except in a small sedimentary area in the western coast. The products of submarine volcanic activity are mainly alkaline basalts. They outcrop in the lowest part of the island as lavas with glassy crusts, sometimes brecciated and mixed with sedimentary material, known in the literature as pillow and pillow breccias. Subaerial activity gave rise to lava flows, pyroclastic deposits, dykes and domes, with a definite evolutionary trend from alkaline basalt to trachyte, and a clear alkaline-sodic magmatological affinity (Cinque *et al.*, 1988).

Vulcano

The Aeolian islands are a volcanic arc of seven islands and three seamounts, located on the south-eastern continental slope of the Tyrrhenian abyssal plate. Vulcano is the more southerly of the arc. Its products are associated with the late stage evolution of the arc magmatism (Keller, 1980). The rocks of the island are all volcanic, from basalts to rhyolites.

The geological history of Vulcano started during the Upper Pleistocene with the formation of a large stratovolcano. The last eruption on Vulcano occurred in the 1888–1890 (Keller, 1980) and the present activity is restricted to fumarolic emissions mainly in the northern part of the island.

MATERIALS AND METHODS

Samples of rocks from the three islands were collected in different sites, chosen among the representative lithologies, and analyzed to determine their contents of radioactive constituents (^{40}K, ^{238}U, ^{232}Th).

Specific activities were evaluated by gamma spectrometry on the samples powdered, dried and sealed into a 1 litre Marinelli beaker. Measurements were carried out after 20 days, to make sure that isotopic equilibrium was reached.

Gamma spectrometry measurements were performed by a Hp-Ge detector, with efficiency of 32%, resolution of 1.8 keV. The spectrometer was calibrated by the standard soil NBS SRM 4353, consisting of approximately 900 g of air-dried, powdered soil, containing all the radionuclides of interest. Lower detection limits (LDL) for 1000 min of count acquisition was 3.2–8.9 Bq kg^{-1} for ^{40}K, 0.26–0.61 Bq kg^{-1} for ^{232}Th, 0.59–1.8 Bq kg^{-1} for ^{238}U.

Data were corrected for density by comparison with samples whose densities range from 0.7 kg l^{-1} to 1.6 kg l^{-1} and known specific activities.

The ^{238}U and ^{232}Th contents were computed from ^{214}Bi (609 keV) and ^{228}Ac (911 keV) activities, if the equilibrium among the nuclides of the series exists.

Mineralogical and petrographic features of the rock samples were determined by XRD and polarized microscopy. Chemical analyses were performed by X ray fluorescence (XRF).

RESULTS AND DISCUSSION

The TAS diagram (Total Alkali Silica Diagram, Fig. 1) was used to group, from a petrographic point of view, the rocks analyzed. The diagram shows a general trend from basaltic (low values of SiO_2 and alkalis) to trachytic products, characterized by increasing of silica and alkali contents. Ustica is characterized, essentially, by basic products. They generally outcrop in the lower part of the island, while more acidic products, less abundant, are found in the upper part. The absence of rhyolitic rocks indicates a reduced magmatic evolution.

The rocks of Vulcano can be assembled in three main groups: 1) basaltic typologies, 2) rocks ranging from trachybasalt to trachyandesitic types, and 3) trachyan-

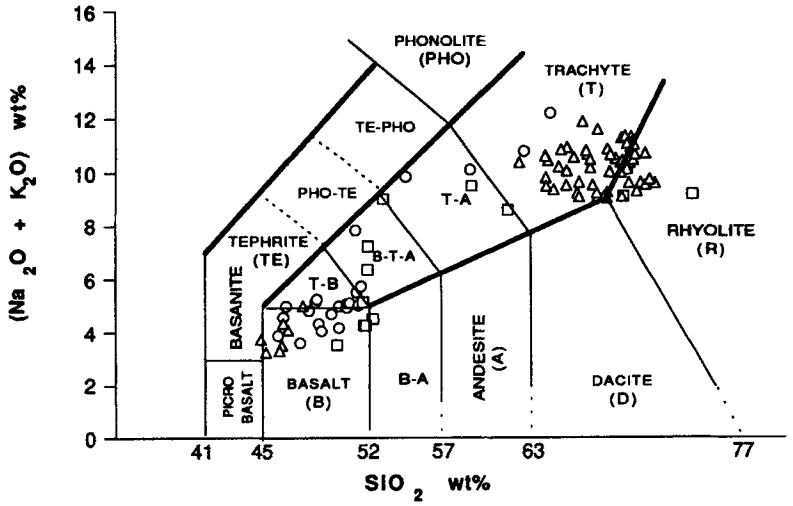

Figure 1 Total alkali-silica diagram (TAS) Ustica (○) Vulcano (□) and Pantelleria (Δ).

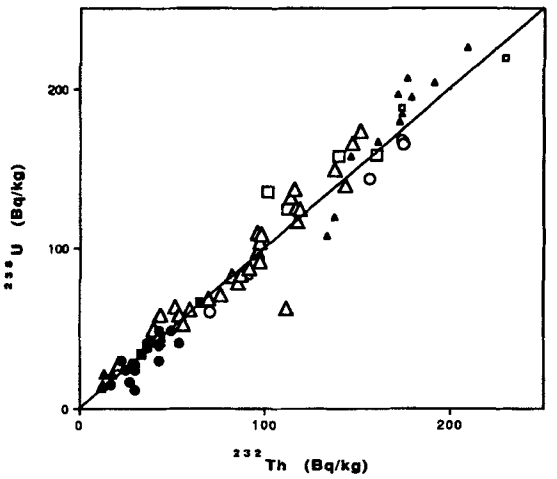

Figure 2 Correlation diagram between ^{238}U and ^{232}Th activities of rock samples. Ustica (○) Vulcano (□) and Pantelleria (Δ). The full marks are the values for basalts, the greatest empty marks are trachytes, and the empty small marks indicate rhyolites.

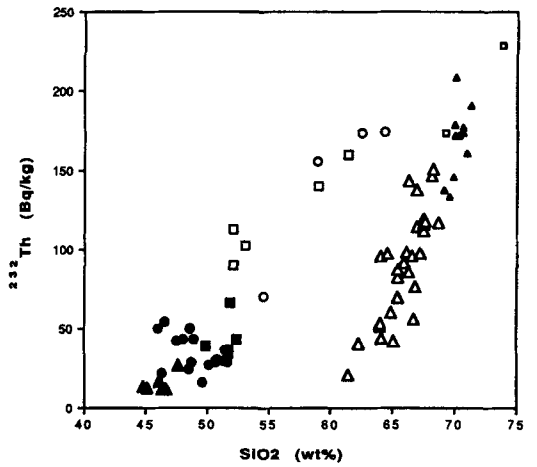

Figure 3 Correlation diagram between ^{232}Th activities and SiO_2 of rock samples. Ustica (○) Vulcano (□) and Pantelleria (Δ). The full marks are the values for basalts, the greatest empty marks are trachytes and the empty small marks indicate rhyolites.

desitic-rhyolitic rocks. Hence the lavas of the island show a complete magmatic differentiation.

Pantelleria is characterized, as previously said, by the occurrence of a bimodal association of basaltic and trachytic-rhyolitic products. The most representative lithologies (green tuff, pantellerite and pumice, about 94%) belong to the group of

trachytic-rhyolitic products, even though they differ in volcanological history and formation mechanism.

Figure 2 shows the good correlation observed between the ^{232}Th and ^{238}U activities. Samples from the basaltic group have the lowest concentrations of radionuclides, whereas those of rhyolitic group the highest; samples from trachybasalt to trachyandesitic lithotypes exhibit intermediate values. These results are in agreement with the geochemical behaviour of uranium and thorium compounds in igneous rocks (Civetta *et al.*, 1973). In fact, both thorium and uranium prefer to remain in the melt during the magmatic differentiation and, consequently, the lowest values of activities (<50 Bq kg^{-1}) were measured in basalts (less differentiated products) while the highest ones (>150 Bq kg^{-1}) in the rhyolites, differentiated products of the islands of Vulcano and Pantelleria.

Comparing the SiO_2 content with the ^{232}Th specific activity (Fig. 3) it is evident that the basaltic products of Pantelleria are not directly related to the trachytes and the rhyolites present in the island. On the other hand, a clear relationship exists between the former ones and the more differentiated products of the islands of Ustica and Vulcano.

CONCLUSIONS

The study of the natural radionuclides, along with the chemical and petrographic data, allows us to express some hypotheses about the magmatic source and evolution of the three islands. The highest values of primordial radionuclides are found in the rhyolitic rocks and the lowest ones in basalts.

Information about the homogeneity of the "Mantle" can be obtained from the chemical composition of primary basaltic melts, being less affected by the evolutive processes. On the other hand, the wide range of observed values of chemical and radiometric data for the basaltic products for the three islands should suggest that the magmatic sources are not quite homogeneous. The study of the behaviour of some trace elements allows us to exclude it if other possible evolutive processes have modified the basaltic products, even though an homogeneous magmatic source is present.

Acknowledgement

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