CONTRASTING HYDROTHERMAL ACTIVITY AT SIERRA NEGRA AND ALCEDO VOLCANOES, GALAPAGOS ARCHIPELAGO, ECUADOR

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Sierra Negra and Alcedo volcanoes are adjacent tholeiitic shields with summit calderas located on Isabela Island in the Galápagos Archipelago. Although basaltic eruptions have characterized the evolution of these volcanoes, Alcedo has produced minor volumes of rhyolite lavas and tephras dated at roughly 100 ka. Fumaroles and ephemeral acid-sulfate seeps occur within the calderas of both volcanoes whereas neutral-chloride and dilute steam-heated hot springs are absent.

Fumarolic activity inside Sierra Negra (Mina Azufral) is fault-controlled along the west margin of a horst and discharge temperatures are ≤210°C (Jan.-Feb., 1995). Water content of the total gas is approximately 75 mol-%, and noncondensible gases consist of approximately 97 mol-% CO_2, and approximately 85% SO_2 of the total sulfur gas. Relative amounts of He, Ar, and N_2 show a distinct hot spot signature ($^3He/^4He = 17.4 \pm 0.3\ R_A$). The $\delta^{13}C$-CO_2 is approximately –3.6‰ and $\delta^{34}S_T$ is approximately +3.3‰. The $\delta D/\delta^{18}O$ of fumarole H_2O indicates steam separation from local meteoric waters whose estimated minimum mean residence time from ^3H analyses is ≤40 years.

Fumarolic activity at Alcedo is controlled by a caldera-margin fault containing at least seven hydrothermal explosion craters, and by an intracaldera rhyolite vent. Two explosion craters formed in 1993-1994 produce ~15 m^3/s of steam, yet discharge temperatures are ≤97°C. Water content of the total gas is 95-97 mol-%, noncondensible gas is 92-98 mol-% CO_2, and sulfur gas is dominated by H_2S. Relative amounts of He, Ar, and N_2 show extensive mixing between hot spot and air or air-saturated meteoric water components but the average $^3He/^4He = 15.5 \pm 0.4\ R_A$. The $\delta^{13}C$-CO_2 is approximately –3.5‰ and $\delta^{34}S_T$ is approximately –0.8‰. The $\delta D/\delta^{18}O$ of fumarole steam indicates separation from a rather homogeneous reservoir that is enriched 3-5‰ in ^{18}O compared with local meteoric water. ^3H indicates this reservoir water has a maximum mean residence time of about 400 y and empirical gas geothermometry indicates a reservoir temperature of 260-320°C. The intracaldera hydrothermal reservoir in Alcedo is probably capable of producing up to 150 MW(e). However, environmental concerns as well as lack of infrastructure and power users will limit the development of this resource.

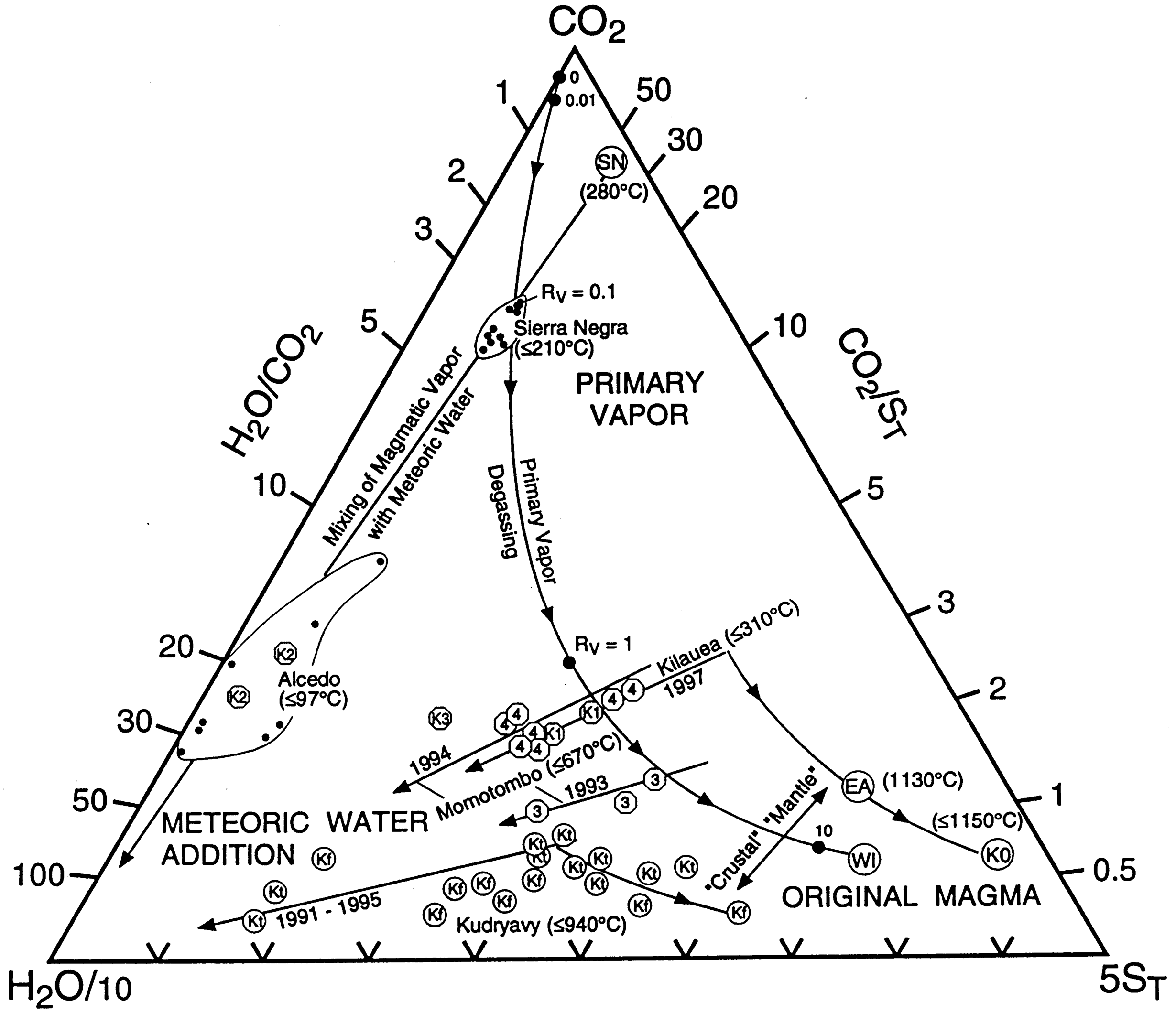

Figure 1: Triangular plot of CO_2, S_T, H_2O for gas compositions from Sierra Negra (Mina Azufral) and Alcedo (values in mol-%); Sierra Negra gases are relatively CO_2-rich, probably originating from degassed primary vapor of basalt magma. Addition of some meteoric water distinguishes our 1995 samples from the earlier sample of Giggenbach (1996; point SN). Alcedo gases appear to be mixtures of a primary vapor and considerably more meteoric water. Mixing with meteoric water is apparently common at other well-characterized basalt volcanoes. Symbols and data: Black dots inside clouds represent our data for Alcedo and Sierra Negra

volcanoes; EA, SN, WI (Erta'Ale, Sierra Negra, and White Island; Giggenbach, 1996); K0 (Kilauea; Greenland, 1984); K1, K2, K3 (Kilauea; Goff and McMurtry, 2000); Kf, Kt (Kudryavy; Fischer et al., 1998 and Taran et al., 1995, respectively); 3, 4 (Momotombo, 1993 and 1994, respectively; P. LaFemina and D. Counce, unpub.). Figure modified from Giggenbach (1996).

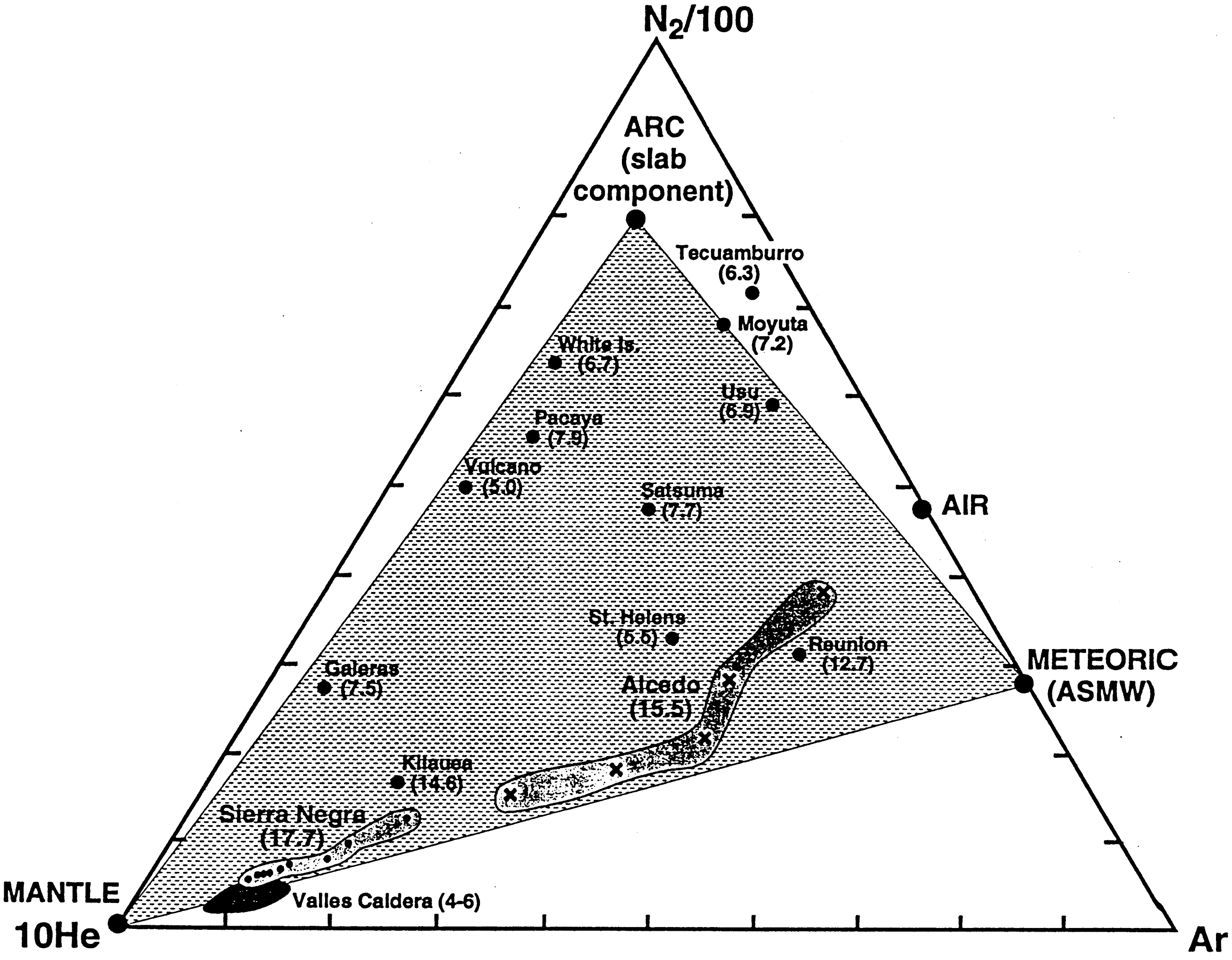

Figure 2: Triangular plot of He, N_2, Ar for gas compositions from Sierra Negra and Alcedo volcanoes compared to some other volcanoes and volcanic-hosted geothermal systems (values in mol-%); values in parentheses give the He-isotope ratios. Mina Azufral gases show a distinct mantle signature but also show dilution with ASMW. Alcedo gases show considerably more dilution with ASMW and with air than Sierra Negra gases. Example arc volcanoes are relatively

enriched in N_2 compared with hot spot volcanoes, independent of magma composition, because of nitrogen addition from the underlying slab. Interestingly, Valles caldera, which has produced more than 600 km^3 of predominately high-silica rhyolite from 1.62 Ma to 60 ka, presently discharges hydrothermal gases with obvious mantle affinities. Data sources: Vulcano, Usu, and White Is. (Giggenbach and Matsuo, 1991); Reunion (Marty et al., 1993); Galeras, Kilauea, Moyuta, Pacaya, Satsuma, St. Helens, and Tecuamburro (Janik et al., 1992; Goff and McMurtry, 2000; Hilton, McMurtry, and Goff, unpub. data); Valles Caldera (Smith and Kennedy, 1985; Goff and Gardner, 1994). Figure modified from Goff and Janik (1993).

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