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腾冲火山区壳内岩浆囊现今温度:来自温泉逸出气体 CO_2、CH_4间碳同位素分馏的估计

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摘要：

温度是岩浆囊的重要物理参数,获取温度参数并监测其变化对更好地理解岩浆囊的物理化学性质和行为、评价火山的活动性和喷发危险性具有重要的理论和现实意义。本文通过对温泉逸出气体CO_2和CH_4碳同位素样品的采集、分析测试,利用Horita通过实验矫正的Richet的平衡分馏系数的理论计算数据,通过拟合得到的CO_2-CH_4碳同位素平衡分馏方程$T(\mathrm{K})=3880.3(1000\ln\alpha_{(CO_2-CH_4)})^{-0.5984}$,计算了腾冲火山区现存3个岩浆囊的温度。结果表明:在整个腾冲火山区,由CO_2和CH_4的碳同位素分馏值计算的气体源区平衡温度最低397℃,最高1163℃,平均615℃。腾冲火山区的3个岩浆囊中,南部五合-龙江-浦川岩浆囊的现今温度在464~1163℃,平均773℃,温度最高;中部腾冲-和顺-热海岩浆囊的现今温度在438~773℃间,平均达566℃,温度次之;北部马站-曲石-永安岩浆囊的现今温度在397~651℃间,平均达524℃,温度最低。我们认为,腾冲火山区地下岩浆囊顶部气体富集区目前的温度变化范围为400~1200℃,岩浆囊的实际温度应高于平均值615℃。3个岩浆囊的边缘温度可能在400~600℃间,中心温度可能在700~1200℃间。3个岩浆囊中心的现今温度已达到流纹岩浆(600~900℃)、安山岩(800~1100℃)和玄武岩浆(1000~1250℃)的形成温度,进一步说明腾冲火山区目前3个岩浆囊是客观存在的。另外,我们发现在用δ-Δ图解法判断CO_2-CH_4间碳同位素分馏平衡的过程中,在保持2条拟合直线的斜率符号相反的条件下,无论如何剔除数据点,都不能使$\delta^{13}C_{CO_2}$-$\Delta_{CO_2-CH_4}$拟合直线的截距b_{CO_2}和$\delta^{13}C_{CH_4}$-$\Delta_{CO_2-CH_4}$拟合直线的截距b_{CH_4}之差b_Δ小于0.1245,说明2条拟合直线的交点不能落于δ轴上,而这一数值与Horita方程的常数项接近,这说明CO_2-CH_4间碳同位素分馏方程中确实存在常数项,CO_2和CH_4间在再高的温度下都存在碳同位素的分馏。δ-Δ图解法判断CO_2-CH_4间碳同位素分馏平衡准则应修正为:在保持2条拟合直线的斜率符号相反的条件下,$\delta^{13}C_{CO_2}$-$\Delta_{CO_2-CH_4}$拟合直线和$\delta^{13}C_{CH_4}$-$\Delta_{CO_2-CH_4}$拟合直线应相交于δ轴附近截距差0.1245处。

英文摘要：

Temperature is an important physical parameter of magma. It has important theoretical and practical significance to acquire and monitor temperature parameter of magma chambers for better understanding changes in the physical and chemical properties and behavior of a volcano, and for better assessing its activity and eruption risk. Here we report the carbon isotope composition data of CO_2 and CH_4 that collect from thermal springs in the Tengchong volcanic field (TVF) and the temperatures of the existing three magma chambers within crust beneath the TVF, which, are calculated with carbon isotope equilibrium fractionation equation $T(\mathrm{K})=3880.3(1000\ln\alpha_{(CO_2-CH_4)})^{-0.5984}$ between CO_2 and CH_4 that fit from Horita's experimental correction of Richet's theoretical fractionation factor data between them. Our results show that, the lowest carbon isotope equilibrium fractionation temperature between CO_2 and CH_4 of gas source area, is 397℃, the highest one, up to 1163℃, the average value, 615℃ in the TVF and that, among the 3 crustal magma chambers in the TVF, the southern Wuhe-Longjiang-Puchuan one has highest present-day temperature, which ranges from 464℃ to 1163℃, with an average of 773℃; the central Tengchong-Heshun-Rehai one has higher temperature, which ranges from 438℃ to 773℃, with an average of 566℃; the northern Mazhan-Qushi-Yongan one has the lowest temperature, which ranges from 397℃ to 651℃, with an average of 524℃. We believe that the current temperature of the gas-rich region at the top of those 3 magma chambers in TVF varies from 400℃ to 1200℃, the actual average temperature of those 3 magma chambers should be higher than 615℃, the temperature of the core of those 3 magma chambers may be 700~1200℃, that of marginal region of those 3 magma chambers may be 400~600℃. The current temperature of the center of those 3 magma chambers has reached which rhyolitic magma (600~900℃), andesitic magma (800~1100℃) and basaltic magma (1000~1250℃) form in, suggesting further, in turn, that there exist objectively those 3 magma chambers in TVF. In addition, we find that, in the process of determining whether the carbon isotope fractionation equilibrium between CO_2 and CH_4 achieve or not with the δ-Δ diagram method, under the conditions that the slope sign of two fitting straight lines maintain always the opposite, no matter how exclud data points, one can not make the difference b_Δ of the intercept b_{CO_2} of $\delta^{13}C_{CO_2}$-$\Delta_{CO_2-CH_4}$ fitting straight line in the δ-axis and the intercept b_{CH_4} of $\delta^{13}C_{CH_4}$-$\Delta_{CO_2-CH_4}$ fitting straight line in the δ-axis less than 0.1245, indicating that the intersection point of the two fitting straight lines can not fall in the δ-axis. And this value is near the constant item of Horita's equation, sugestting that there exists really a constant item in the equation of carbon isotope fractionation equilibrium between CO_2 and CH_4, and that the carbon isotope fractionation between CO_2 and CH_4 exists allways at no matter how high temperature. The δ-Δ diagram guidelines of determining the carbon isotope fractionation equilibrium b etween CO_2 and CH_4 should be amended as follows: under the conditions that the sign of the slope of the two fitting lines keep allways opposite, the $\delta^{13}C_{CO_2}$-$\Delta_{CO_2\text{-}CH_4}$ fitting straight line and the $\delta^{13}C_{CH_4}$- $\Delta_{CO_2\text{-}CH_4}$ fitting straight line should intersect near the δ-axis with intercept difference 0.1245.

关键词： 温度 岩浆囊 同位素地热温标 温泉气体 腾冲火山区

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