1. ABSTRACT

Homogenization temperature variations of several degrees Celsius or more are often observed within a fluid inclusion group that appear to have trapped the same homogeneous fluid at the same time and presumably at the same P-T condition. For inclusions that homogenize at ~200°C, much of the observed variation can be attributed to the size of the inclusions. Larger inclusions homogenize at higher temperatures compared to smaller inclusions with the same density. The relationship between inclusion size and observed homogenization temperature is predicted by the Young-Laplace equation that relates the stability of a vapor bubble to the surface tension and pressure differential across the vapor-liquid interface. Vapor bubbles instantly collapse when the vapor bubble radius becomes less than a critical radius. During heating, the critical vapor bubble radius varies from about 0.01 to 3 µm for low temperature aqueous fluid inclusions. The Gibbs free energy of vaporization of water decreases with increasing temperature and increases with both increasing critical vapor bubble radius and homogenization temperature. As a result of surface tension effects, the highest measured homogenization temperature, obtained from the largest inclusion in the group of coeval inclusions, most closely approximates the homogenization temperature that would have been expected based on the inclusion size. For inclusions ranging in volume from 10 to 100 µm, and having densities such that the homogenization temperatures are ~200°C, homogenization temperatures may vary by about 1–3°C, depending on the inclusion size.

2. INTRODUCTION

The most important step in the collection and interpretation of data from fluid inclusions is to identify fluid inclusion assemblages (FIAs) of groups of inclusions trapped "at the same time" and, by extension, at the same temperature and pressure (Demouch, 1995; Goldstein and Reynolds, 1994). The microthermometric behavior of the FIAs should show similar homogenization temperatures within the precision of the measurement. If the P-T conditions change during trapping of fluid inclusions, the effect of varying trapping conditions within a FIA would be reflected in the homogenization temperatures, relative to the rate of change of the P-T conditions.

With increasing microthermometry techniques, the homogenization temperature of fluid inclusions that homogenize to the liquid phase can be determined with a precision (reproducibility) of 0.1°C. The accuracy of this determination varies with temperature, and is generally estimated to be about 0.5°C for the measured T, i.e., σT = 0.5°C at 200°C. Synthetic fluid inclusions in the one-body phase-field and are formed at a known and relatively constant temperature and pressure, and from a fluid of known and constant composition. Microscopic examination of synthetic fluid inclusions (Fig. 5) often reveals T, variations of about 5–10°C and the bubble in the smaller inclusions will reach the critical radius, r, and the bubble becomes unstable temperature. Once the radius of the vapor bubble becomes smaller than the critical radius, r, the bubble instantly collapses to reduce its Gibbs free energy. For a bubble in a liquid, the Gibbs free energy change associated with the growth or shrinkage of a vapor bubble as a function of the critical bubble radius (1.0 to 0.51 µm) is described by Equation (4). The Gibbs free energy function is calculated for the bubble radius r = 0.9 µm (Fig. 6a), or 0.51 µm, and becomes nil at the critical point of water, 374.1°C, where the distinction between liquid and vapor disappears. As an approaches 0.51, the bubble no longer exists. The existence of a bubble in a liquid can be described in terms of the surface free energy of the bubble. The force across the bubble liquid interface is due to the surface free energy of the bubble. The force across the bubble-liquid interface equals the surface tension of the system. The relationship between pressure and surface tension is described by the Young-Laplace equation (Locock-2000; de Gemera et al. 2004).

2. RESULTS

Every FIA measured in this study is significant in demonstrating the importance of the bubble in explaining the variations in the measured temperatures. The measured T, variations from a fluid of the same composition. Within the same FIA, small variations in the measured temperature are seen within the same FIA. The relationship between inclusion size and homogenization temperature is similar for larger inclusions, as was observed during microthermometric analysis of inclusions in the study. Fluid inclusions in an FIA that trapped a single-phase homogeneous fluid at the same time and pressure will increase in size, and at any temperature the volume per centimeter in each inclusion. The relationship between inclusion size and observed homogenization temperature is predicted by the Young-Laplace equation that relates the stability of a vapor bubble to the surface tension and pressure differential across the vapor-liquid interface. Vapor bubbles instantly collapse when the vapor bubble radius becomes less than a critical radius. During heating, the critical vapor bubble radius varies from about 0.01 to 3 µm for low temperature aqueous fluid inclusions. The Gibbs free energy of vaporization of water decreases with increasing temperature and increases with both increasing critical vapor bubble radius and homogenization temperature. As a result of surface tension effects, the highest measured homogenization temperature, obtained from the largest inclusion in the group of coeval inclusions, most closely approximates the homogenization temperature that would have been expected based on the inclusion size. For inclusions ranging in volume from 10 to 100 µm, and having densities such that the homogenization temperatures are ~200°C, homogenization temperatures may vary by about 1–3°C, depending on the inclusion size.

3. DISCUSSION

Fluid inclusions in an FIA that trapped a single-phase homogeneous fluid at the same time and pressure will increase in size, and at any temperature the volume per centimeter in each inclusion. The relationship between inclusion size and observed homogenization temperature is predicted by the Young-Laplace equation that relates the stability of a vapor bubble to the surface tension and pressure differential across the vapor-liquid interface. Vapor bubbles instantly collapse when the vapor bubble radius becomes less than a critical radius. During heating, the critical vapor bubble radius varies from about 0.01 to 3 µm for low temperature aqueous fluid inclusions. The Gibbs free energy of vaporization of water decreases with increasing temperature and increases with both increasing critical vapor bubble radius and homogenization temperature. As a result of surface tension effects, the highest measured homogenization temperature, obtained from the largest inclusion in the group of coeval inclusions, most closely approximates the homogenization temperature that would have been expected based on the inclusion size. For inclusions ranging in volume from 10 to 100 µm, and having densities such that the homogenization temperatures are ~200°C, homogenization temperatures may vary by about 1–3°C, depending on the inclusion size.

4. CONCLUSIONS

Results of this study suggest that T, and fluid inclusions may vary by a few degrees, even when the inclusions are trapped at exactly the same temperature and pressure and from a fluid of the same composition. In this study, the fluid inclusions homogenized at slightly lower temperature compared to larger inclusions. In most fluid inclusion studies, this variation in T, is sufficiently small that it can be ignored (and would likely not be recognized in most studies). The dependence of the homogenization temperature on fluid composition illustrates that the surface tension and pressure to the surface tension of the liquid-vapor interface and the radius of the vapor bubble. The fluid inclusion method to be used for determining homogenization temperatures at low and high pressures and temperatures should be considered for low temperature, diagnostic environments and synthetic fluid inclusion techniques. Based on this study the homogenization temperature of the largest inclusion in the FIA would most closely represent the correct homogenization temperature and fluid composition.

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