



Abstract

Microthermometric study of fluid inclusions in Neogene shallow intrusions from the Inner Carpathian arc (Romania)

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Abstract

Fluid inclusions have been observed in quartz phenocrystals of the most acid facies (rhyolite and dacite) of the subvolcanic area (Rodna-Bârgău Mountains) in the East Carpathians. All identified fluid inclusions are aqueous (H₂O–NaCl system). They occur either as primary or pseudosecondary and secondary fluid inclusions. Homogenisation, both to liquid and vapor, occurs between 120 and 540 °C. The general evolution of aqueous fluids is to decreasing salinity with decreasing temperature. Relatively low salinities (from 6 to 1.4 wt.% NaCl eq.) could indicate the presence of meteoric water. The occurrence of exploded fluid inclusions indicates strong decompression regime during magma uplift.

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1. Introduction

There are at present few published data on the subvolcanic area of East Carpathian arc. The present work is the first study aimed to characterize fluid inclusions in the shallow intrusions from this area, in order to better understand the role of fluid phases during magmatic evolution.

2. Geologic frame

The investigated area (Rodna-Bârgău Mountains) is located on the Tisia-Getia block, close to the point of

connection of ALCAPA block and eastern European Plate (Fig. 1, insert). The calc-alkaline magmatism from the subvolcanic zone is related to Neogene continental collision in the Carpatho–Pannonian area (e.g. Rădulescu and Săndulescu, 1976). The age of the magmatites is 11–9 Ma, similar to other volcanic activity in the East Carpathians (Pécskay et al., 1995). The particular tectono-structural setting of the subvolcanic area has given rise to some peculiarities within the magmatic rocks, such as exclusively subvolcanic nature, a large variation of petrographic types from basaltic andesites to rhyolites and the occurrence of primary garnet-bearing rocks.

Within the subvolcanic segment, Rodna-Bârgău area is the most complex and extended. The intrusive bodies from the Rodna Mountains, hosted by metamorphic rocks, are represented by Parva rhyolites,

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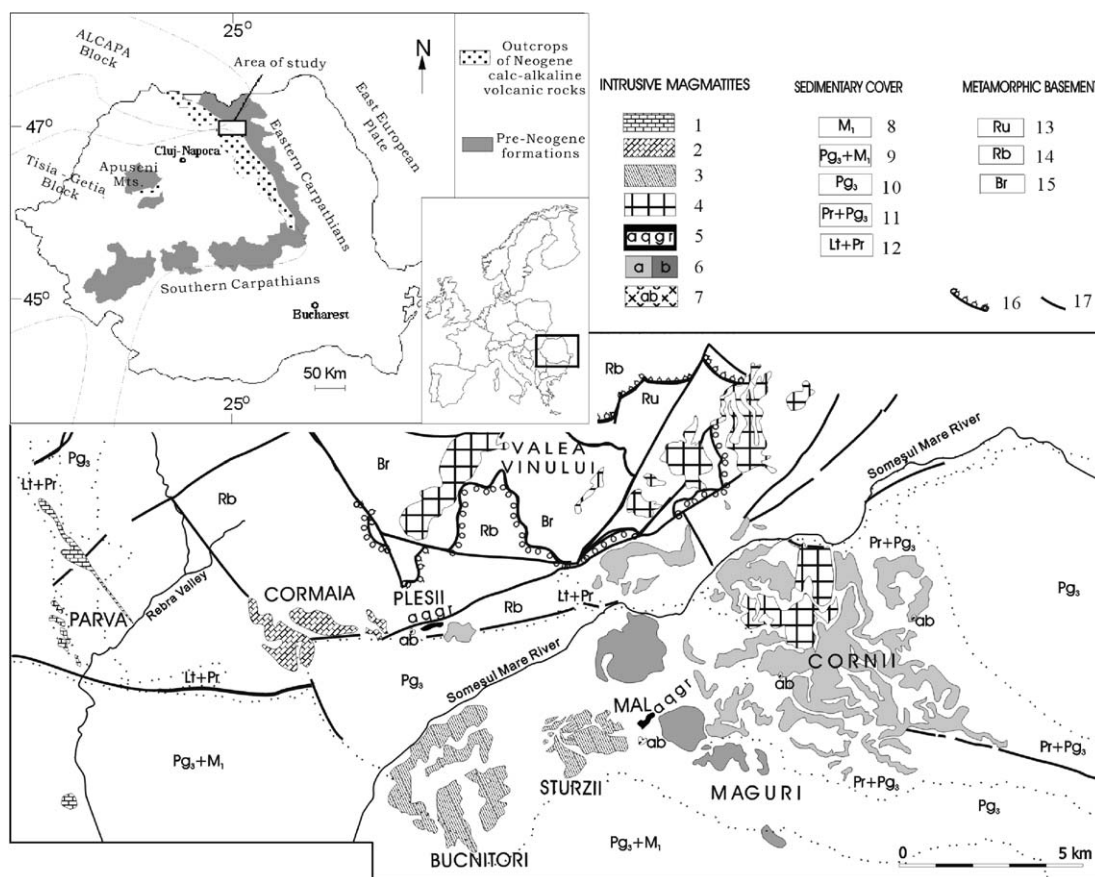


Fig. 1. Geological sketch map of the Rodna-Bârgău Mountains. Legend: *Intrusive magmatites* (Pannonian): (1) rhyolites; (2) rhyo-dacites; (3) dacites; (4) hornblende quartz andesites \pm biotite; (5) garnet quartz andesites; (6) andesites (a), micro-diorites (b) (hornblende \pm pyroxene); (7) basaltic andesites; *sedimentary cover*: (8) shales, sandstones, pyroclastites (Lowe Miocene); (9) sandstones (Borșa Formation) (Paleogene–Lower Miocene); (10) shales, sandstones (Paleogene); (11) marls, shales, breccias (Priabonian–Paleogene); (12) limestones, sandstones, conglomerates (Lutetian–Priabonian); *metamorphic basement*: (13) Rusaia metamorphic series (Silurian); (14) Rebra metamorphic series (Silurian–Lower Precambrian); (15) Bretila metamorphic series (Lower Precambrian); (16) shear zone; (17) fault.

Cormaia rhyodacites and Valea Vinului quartz andesites, respectively. Sedimentary flysch deposits represent the host-rocks of the intrusive bodies in the Bârgău Mountains. The main intrusive structures are: Bucnitori, Sturzii (dacites), Pleșii-Mal (garnet quartz andesites), Cornii (andesites) and Măguri (microdiorites) (Fig. 1). The intrusions vary in volume and have a surface exposure from 1 (Parva, Pleșii-Mal, Bucnitori) to 20 km² (Cornii).

Transitional textures occur between subvolcanic and plutonic facies, and between hypabyssal and volcanic-like facies. There is a relatively high degree of crystallization and most of the rocks are porphyritic.

The main minerals are: plagioclase feldspars, amphiboles, biotite, quartz and subordinated potassic feldspars.

3. Methods and material study

A petrographic examination of doubly polished thick sections of Parva rhyolite and Bucnitori dacite was carried out. Fluid inclusions have been observed in quartz phenocrystals.

Microthermometric measurements were made with a Linkam stage at the *Centro di Studio per il Quater-*

nario e l'Evoluzione Ambientale—CNR (at present Istituto di Geologia Ambientale e Geoingegneria—IGAG), Rome, Italy. The stage was calibrated using synthetic and natural fluid inclusions of pure H₂O and CO₂ for the melting temperature of H₂O at 0 °C and CO₂ at −56.6 °C. The instrumental uncertainty was ± 0.1 °C in the freezing mode.

The Raman spectrometry has been performed at the University of Siena, Italy.

4. Results

4.1. Parva rhyolite

The examined quartz grains have size ranging from 0.5 to 2 mm. The fluid inclusions are located around the rim of the crystals, suggesting that they are formed in the late stage of the crystal growth. The dimension of the fluid inclusions varies from about 1–3 to about 30 μm.

Two types of fluid inclusions were identified: two phases V+L, V-rich and L-rich, and three phase

V+L+S fluid inclusions. Most of the fluid inclusions form clusters or are disposed along trails.

Microthermometric measurements made on 60 fluid inclusions revealed that they all contain an aqueous fluid. Last ice melting temperatures in L-rich inclusions range from −3.5 to −0.6 °C. Subsequently, the salinity of these fluid inclusions was calculated to be relatively low, varying from 5.71 to 1.05 wt.% NaCl eq. (data from Bodnar and Vityk, 1994).

Most fluid inclusions homogenize to liquid from 258 to 420 °C, with a peak of the histogram between 340 and 360 °C. The vapour-rich inclusions homogenize to vapour between 320 and 380 °C. Few V-rich inclusions were found to homogenize to vapour at higher temperatures, between 480 and 540 °C (Fig. 2). Higher temperature are also possible but were not reached because of instrumental limitation. The three phase fluid inclusions finally homogenize to liquid between 496 and 527 °C. The solid phases occupy about 10% of the fluid inclusions volume at room temperature. They dissolve between 224 and 245 °C. The equivalent salinities are between 30 and 33 wt.% NaCl eq.

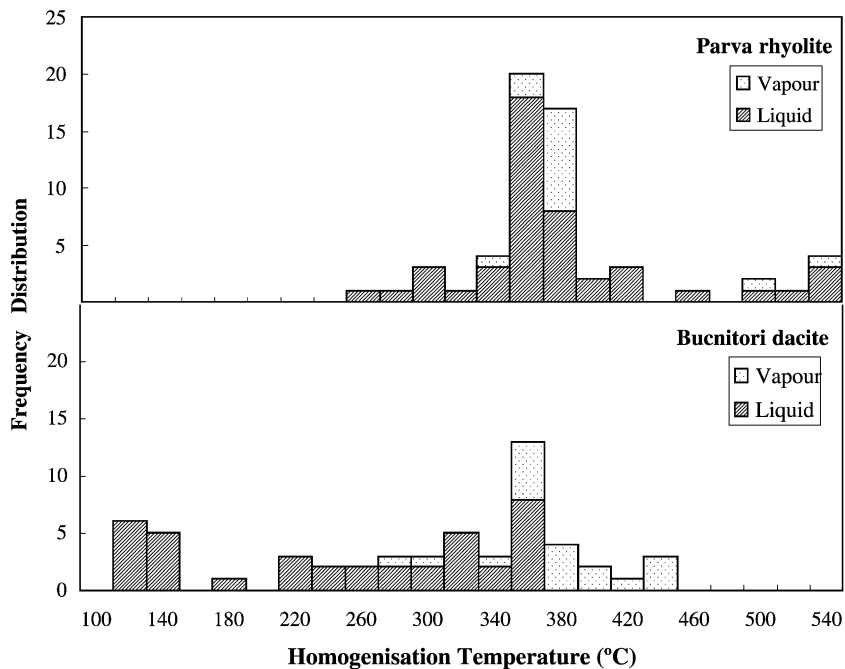


Fig. 2. Histogram of homogenisation temperatures of fluid inclusions in quartz: Parva rhyolite (up) and Bucnitori dacite (down).

Overlap of the histograms of homogenisation to liquid and to vapour reflects separation of a vapour phase that coexists with a liquid one at the same temperatures. For a water–salt system, the term of “boiling” is assumed (Roedder, 1984). In this case, the homogenisation temperature corresponds to trapping temperature, no pressure correction is needed (Roedder, op. cit.).

Data points for the Parva rhyolite (black dots) in Fig. 3 cluster in two well-separated domains, one corresponding to high salinity, high temperature (three phase inclusions), the second one around 370 °C, without any intermediate point.

4.2. Bucnitori dacite

In most of the quartz grains (1–2.5 mm in diameter) within Bucnitori dacite three classes of fluid inclusions were observed: (1) one phase fluid inclusions, usually in trails disposed along the fractures of the quartz grains; (2) two-phases fluid inclusions, either V-rich or L-rich, which occur both as trails (V-rich) or isolated (very small ones (< 10 µm diameter) or in a doubtful, uncertain occurrence (20–30 µm across with a filling degree of about 80 vol.% at room temperature) (L-rich); (3) exploded fluid inclusions surrounded by small fluid inclusions, one phase (V) or two phases L+V, V-rich (< 10 µm diameter). These were not considered for measurements. The type of fluid inclusions and their relationship with the

host mineral were the discrimination criteria between the three classes.

According to the results of the microthermometric measurements, the fluid inclusions contain aqueous fluids. The T_{m-ice} vary between –0.8 and –4.2 °C, which correspond to a range of salinity from 1.4 to 6.7 wt.% NaCl eq. For some inclusions, the eutectic temperature could also be determined. It ranges between –21.5 and –19 °C corresponding to the NaCl–H₂O system.

Most of the fluid inclusions homogenize within a wide range of temperature, between 220 and 440 °C, both to liquid and to vapour (Fig. 2). A group of fluid inclusions (L-rich) homogenize to liquid at relatively lower temperature (131–140 °C).

The lithostatic pressure corrections of the peaks of the homogenisation temperatures were made using the diagrams of Potter (1977) for 5% NaCl solutions in order to determine the trapping temperature of the fluid inclusions. A temperature correction of about 80 °C is to be added to the T_h values.

The variation of the salinity with temperature (Fig. 3) is relatively scattered; however, a tendency of decreasing salinity with decreasing temperature can be assumed.

The Raman spectrometry revealed that the vapour phase is exclusively represented by water vapour; neither CO₂ nor other Raman active constituents (e.g. CH₄, H₂S and N₂) could be identified from the obtained spectrum.

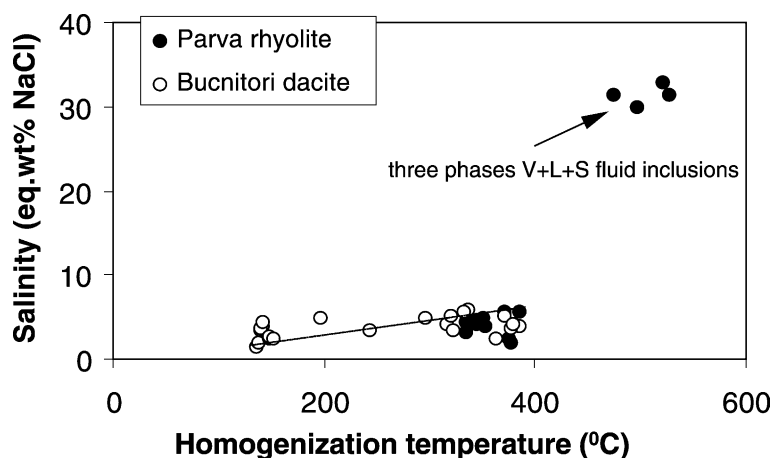


Fig. 3. Correlation between salinity and homogenisation temperatures of fluid inclusions in quartz.

5. Discussion and conclusions

All identified fluid inclusions are aqueous; C–N–S species were not detected either by microthermometry or Raman spectroscopy. They occur either as primary fluid inclusions or as pseudosecondary and secondary fluid inclusions. There is no evidence of melt inclusions.

Most of the fluid inclusions homogenize between 220 and 440 °C, both to liquid and vapor. Partial decrepitation of fluid inclusions and retrapping of the fluid during magma ascent may explain the wide range of homogenisation temperatures.

Frequent occurrences of exploded fluid inclusions indicate a decompression regime during magma uplift. This finding coincides well with the presence of igneous primary garnets (almandine) in the host dacite. Because of the limited stability field of the garnet, rapid ascent of the magma to surface is an important requirement for the petrogenesis of garnet-bearing igneous rocks (Harangi et al., 2001). The decompression regime, highlighted for the Bucnitori dacite, could favor the rapid uprise of magmas and preservation of the garnets.

We assume that the high temperature, high salinity fluids within Parva rhyolite are early, most probably magmatic, followed by a boiling event of the hydrothermal system, possibly related to a change of fluid pressure from litho- to hydrostatic and dilution by the meteoric fluids, at about 400 °C. This is a common fluid evolution process in shallow intrusives, notably in porphyry copper deposits (e.g. Wikinson, 2001).

For Bucnitori dacite, the general evolution of aqueous fluids is to decreasing salinity with decreasing temperature, indicating mixing with externally derived fluids. Relatively low salinities could indicate the presence of meteoric water.

The highlighted characteristics of the fluid inclusions suggest the tendency of the intrusive bodies to

evolve towards a porphyry copper system. Its evolution probably stopped because of the small size of the intrusions that could not induce extensive circulation of the wallrock-derived fluids.

Acknowledgements

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