



Self-mixing magma in the Ruiz Peak rhyodacite (New Mexico, USA): A mechanism explaining the formation of long period polytypes of mica



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ABSTRACT

The rhyodacite of Ruiz Peak Volcano (New Mexico, USA) is an exceptional rock because it contains both long period and short period polytypes of mica. Our petrographic study shows that this rhyodacite is characterized by numerous disequilibrium textures of phenocrysts (mica, amphibole, clinopyroxene, olivine and plagioclase) contained within both dark-grey and reddish coloured groundmass. The presence of two groundmasses, as well as of disequilibrium textures (reaction rims, resorption, dendritic, skeletal morphologies, etc.) suggests a complex magmatic history. These two types of groundmass are not due to a mixing of magmas but result from a degassing process during the magma ascent in the conduit. The disequilibrium textures are interpreted to be the result of small, short-lived convection cells in the magmatic chamber, which may allow crystal-crystal, crystal-spiral and spiral-spiral interactions to occur, leading to the formation of long period polytypes of mica. For the first time, the relationships between the crystallographic features of mica and the host-rock formation are underlined in this study. It follows that long period polytypes of mica can be considered markers of the complex history of magmas.

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1. Introduction

Mica structure is based on an octahedral sheet (O) between two tetrahedral sheets (T), forming a T-O-T or 2:1 layer, also known as the M layer (Takéuchi, 1971; Takéuchi and Haga, 1971). The M layers can take six orientations, rotated by angles multiples of 60° and they are expressed by OD symbols (Dornberger-Schiff et al., 1982) (Fig. 1a). The stacking of the M layer along the c axis gives rise to different mica polytypes. Polytypes with stacking sequences of several tens to hundreds of Å are not common and are termed 'long period' to distinguish them from shorter (10 to 30 Å) and more frequent polytypes (Fig. 1). Long period polytypes do not have a defined thermodynamic field of stability (Bozhilov et al., 2009).

The coexistence of short and long period polytypes in the same rock is extremely rare, but occurs in the Ruiz Peak Volcano rhyodacite (New Mexico, USA), where one third of micas are long period polytypes (Ross et al., 1966). This explains why crystallographers and mineralogists have been particularly interested in this rock since the 1960s. In fact, most of long period polytypes reported in literature come from this rock: 3A₁, 4M₂, 8M₈, 8A₁₂, 8A₁, 10A₃, 11M₁, 14A₁, 23A₁ (Ross et al., 1966), 8A₂ (Nespolo and Takeda, 1999), 32A₁, 36A₂ (Kogure and Nespolo, 1999), 4M₃ (Pignatelli et al., 2011), and 5M₃ (Pignatelli and

Nespolo, 2011). Only few examples of long-period polytypes found in other rocks are known: 4M₃ polytype of titanium phlogopite from the kamptonite dike of Vostochniy Priazov - Azov Sea region, Russia (Zhuklistov et al., 1988), 3A₁ polytype of annite from the alkalic trachyte of the Khibiny pluton, Russia (Borutskiy et al., 1987), the 94-layer polytype of Mg-rich annite from dacite rocks of Džep, Serbia (Fregola and Scandale, 2011), 6M₁ and 3M₁ polytypes found in a lepidolite from Tørdal, Norway (Rule et al., 1987), and 3A₁, 5A₂ muscovite polytypes synthesized by Baronnet et al. (1976).

Several hypotheses have been proposed to explain the formation of long period polytypes: i) kinetic factors (Baronnet, 1992; Baronnet et al., 1981; Kogure and Nespolo, 1999; Sunagawa et al., 1968); ii) structural controls, where strength varies as a function of the thermodynamic conditions during growth (Güven, 1971; Smith and Yoder, 1956); iii) non-equilibrium conditions related to compositional fluctuation of fluid during crystallization (Fregola et al., 2009; Xu and Veblen, 1995); iv) the formation of a screw dislocation with an unfaulted ("Perfect Matrix Model", Baronnet, 1975) or faulted exposed ledge ("Faulted Matrix Model", Pandey et al., 1982); and finally, v) perturbations occurring during the growth ("perturbative theory", Nespolo, 2001) i.e., spiral-spiral interactions, spiral-crystal interactions ("platelet mechanism", Takeda and Ross, 1995) and crystal-crystal interactions.

Despite these diverse explanations, the formation of long period polytypes, as well as their coexistence with short polytypes, are not yet well-understood due to the scarce information available on both

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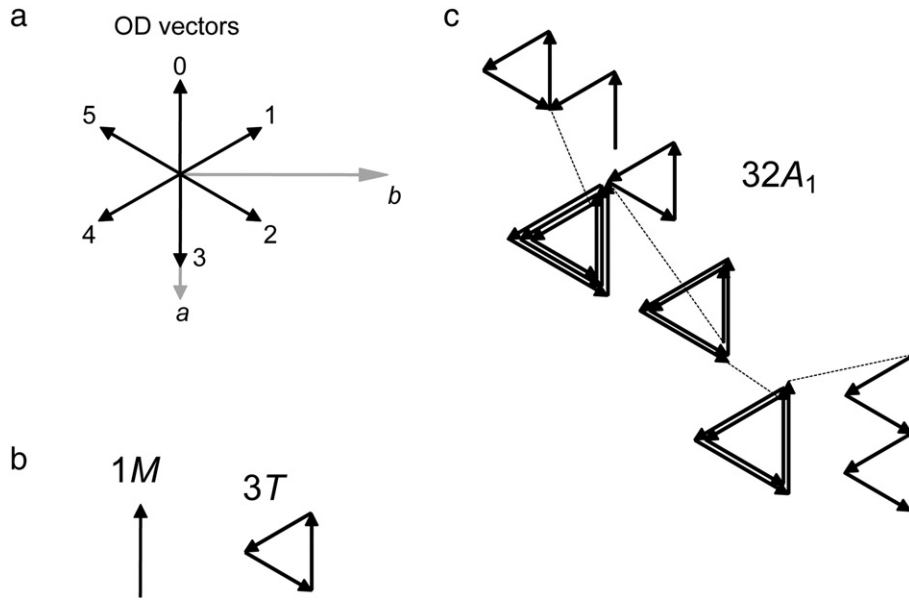


Fig. 1. (a) OD vectors indicating the orientation of M layers. Stacking sequences of two short period polytypes, i.e. 1M and 3T (b) and a long period polytype (c) (32A₁ - Kogure and Nespolo, 1999). 1M, 3T and 32A₁ are Ramsdell symbols (1947) written as NS_n, where N is the number of layers, S is the symmetry and n generally indicates the order in which polytypes are discovered.

polytypism and host-rock relationships. The Ruiz Peak rhyodacite is therefore an important example that may shed new light on these relationships. Reconstruction of the formation and geological history of the Ruiz Peak rhyodacite is therefore essential to better understand the growth conditions of long period polytypes of mica. In this paper, we present a detailed petrographic and mineralogical description of Ruiz Peak rhyodacite and we propose a new hypothesis for its formation, taking into account the disequilibrium textures of minerals. Our hypothesis is based on a self-mixing magma process that enables the formation of long period polytypes of mica. This hypothesis also describes how the formation of two groundmasses with different degrees of vesiculation is due to the degassing during the magmatic ascent and not to the mixing between mafic (basaltic andesite) and felsic (rhyolite) magmas as previously put forward by Guilbeau (1982) and Guilbeau and Kudo (1985).

2. Geological setting

Ruiz Peak Volcano is located in the Jemez Mountains (Fig. 2), a region that covers nearly 4000 km² in the north of New Mexico (Guilbeau, 1982). The Jemez Mountains were formed by intense volcanic activity that started in early Pliocene and culminated with an explosive caldera-forming eruption during the Pleistocene (Kudo, 1974). Pre-, post- and caldera formation rocks were studied by several authors in the 1960s and 1970s (Bailey et al., 1969; Ross et al., 1961; Smith and Bailey, 1966, 1968; Smith et al., 1970). Bailey et al. (1969) divided the oldest pre-caldera stratigraphic group, the “Keres Group”, into four geological formations (Table 1). The sample studied here belongs to an additional formation, the “rhyodacite of La Jara Canyon”, which is missing in the classification of Bailey et al. (1969) but was later identified by Guilbeau (1982) and Guilbeau and Kudo (1985). This formation corresponds to a dome and flow sequence located in the southern part of Ruiz Peak area (Guilbeau, 1982) (Fig. 2). According to Takeda and Ross (1975), the sample is collected from the top of the flow that is generated by the collapse and fragmentation of the dome.

It should be noted that we didn't collect the sample, as it was kindly provided by Malcom Ross. The sample is the same one used for all previous studies about long period polytypes from Ruiz Peak (Kogure and Nespolo, 1999; Nespolo and Takeda, 1999; Pignatelli and Nespolo, 2011; Pignatelli et al., 2011; Ross et al., 1966). It is the reference sample

with the highest content of long period polytypes found on the Earth so far and it is, thus, the best candidate to understand the relationships between the polytypism and the magmatic processes.

3. Analytical techniques

Polished thin sections were cut parallel to the polished surface of the rhyodacite sample (Fig. 3). Petrographic and textural studies were undertaken using several techniques.

Images of mineral textures were obtained by back-scattered electron imagery (BSE), using a scanning electron microscope (SEM) JEOL J7600F at SCMEM laboratory (University of Lorraine). The images were acquired using an accelerating voltage of 15 kV and a beam current of 1.2 nA. The same acquisition conditions were used to determine the compositions of the different types of groundmass, but data were instead collected in raster mode with probe diameters of ~60, 30 and 15 μm (rastered areas of 3600 μm²; 900 μm² and 225 μm² respectively). Three probe diameters were used in order to consider the different sizes of crystals and/or vesicles. The used standard were: albite for Na, forsterite for Mg, corundum for Al, orthoclase for K, andradite for Ca, pyrophanite for Ti and Mn, hematite for Fe. Mineral chemical compositions were determined by electron microprobe analysis (EMPA) at SCMEM laboratory (University of Lorraine) using a CAMECA SX100 microprobe. Minerals were analysed with an accelerating voltage of 15 kV, a beam current of 12 nA and a minimum probe diameter of 1 μm. The total iron content was reported as FeO. The microprobe was calibrated using the following standards: Amelia albite for Na and Si, San Carlos forsterite for Mg, corundum for Al, orthoclase for K, andradite from Corsica (BRGM) for Ca, pyrophanite for Ti and Mn, hematite for Fe, Cr₂O₃ for Cr, baryte for Ba and topaz for F.

Raman spectra were recorded using a LabRAM HR spectrometer (Horiba Jobin Yvon) equipped with a 600 g mm⁻¹ grating and an Edge filter at GeoRessources laboratory (University of Lorraine). The confocal hole aperture was set to 500 μm and the slit aperture to 100 μm. The excitation beam was provided by a Stabilite 2017 Ar⁺ laser (Spectra Physics, Newport Corporation) at 514.53 nm and 50 mW power, using a ×100 objective (Olympus) to focus on the sample. Acquisition time accumulations of 5 and 10 s were selected to optimize the signal-to-noise ratio (S/N).

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