Changes in the structure and composition of a mineral (e.g. plagioclase, amphibole, clinopyroxene or biotite) can play a valuable role in indicating the evolutionary history of magma mixing processes (Kuscu, 2001). Most zoning studies in magmatic systems carried out to date have addressed plagioclase feldspar because the chemical variations in this mineral can readily be inferred from its optical properties in polarized light using an optical microscope (Hibbard, 1981).

The formation of complex chemical zoning in plagioclase depends on the change of crystallization conditions (e.g. pressure, temperature and volatile content of the magma) (Lofgren, 1974; Tsuchiyama, 1985; Di, et al, 2003). Thus when crystals grow in the magma chamber, their grain-scale inhomogeneity, they may contain a record of the processes during that growth. Growing crystals record different environments and crystallization conditions (e.g. mixing of magmas, degassing, assimilation).

“Normal” zoning in plagioclase is the direct result of magma cooling. “Reverse” zoning is less common and the zonation genetics are interpreted differently by different authors. For example, temperature and pressure effects have been proposed to result from crystals settling into deeper, hotter magma (Anderson et al. 2000) or from reheating due to magma recharge (Ruprecht and Wörner, 2007). It has also been argued that crystallization of calcic plagioclase is caused by assimilation limestone during magmatic eruption. By contrast, changes in temperature, pressure and H2O content will affect the anorthite component (An) content but will cause little change in minor elements (e.g. Fe, Sr, Ba, etc.). This is because the bulk compositional change of the host magma would have a stronger impact on Sr, Mg and Fe in the plagioclase than the effect of changing partition coefficients due to changing An in the crystal (Ginibre and Wörner , 2007). The relationships between the concentration of minor elements in feldspar and the An can be used to determine the formation mechanisms of reverse zoning pattern. If the content of minor elements varies with change in An

Plagioclase Zoning as a Record of Magma Evolution

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Fig. 1. Microphotographs showing zoning and the previous resorption (black) in plagioclase (a) and back-scattered electron images of the plagioclase (b) from trachyandesite at Wuchagou. Numbers refer to the electron probe analyses.
component, we can conclude that the crystal grew in a magma mixing environment.

We investigated plagioclase in Mesozoic trachyandesite from the Wuchagou area, Da Hinggan Mountains, Inner Mongolia. Techniques used in the study of typical zoning patterns were optical microscopy (Fig. 1a), then BSE imaging (Fig. 1b), followed by quantitative major and trace element analysis by electron probe microanalyzer.

To emphasize the changes in element concentrations, we selected a profile through the crystal for quantitative analysis (Fig. 1b). The spacing of analytical points is 40 μm approximately. All of the points eluded the inclusions. The feldspar nomenclature diagram based on the data acquired from electron microprobe shows that the plagioclases consist mainly of labradorite, with subordinate oligoclase and andesine.

The appearance of each reverse zoning indicates that a new mafic magma entered the system and completely mixed with the resident magma just prior to eruption. These crystal rims have grown over a resorption surface. As the mixed magma cooled off gradually, the crystal continued to grow around the resorption boundary.

In conclusion, our results suggest that the plagioclase in this district should have experienced at least three stages of magma mixing during the process of plagioclase crystallization.

References
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