Origin of crosscutting dissolution surfaces in magmatic plagioclase

AKIRA TSUNE*

Deep Ocean Resources Development Company, Ltd., 1-3-15, Nihonbashi-Horisode-cho, Chuoh-ku, Tokyo 103-0012, Japan

ABSTRACT

Crosscutting dissolution surfaces (DSs) are rare features observed in magmatic plagioclase crystals. In this study, crosscutting DSs of dacititic plagioclase crystals from the Shirahama Group, Izu Peninsula, Japan, were investigated using a Nomarski differential interference contrast imaging microscope and chemical compositional data. Crosscutting DS slopes were examined by tracing digitized images. The following features of crosscutting DSs are reported for the first time: (1) traces of the crosscutting DSs showed parabolic-like shapes; (2) crosscutting DSs were found on select (adjacent or opposite) faces of the crystals suggesting a preferential dissolution of a limited area of the plagioclase; (3) projecting points were observed with directional characteristics; and (4) square or angular patterns were found in the less dissolved parts of the crystals. The formation of crosscutting features is controlled by dissolution and crystal settling into hotter magma. Process velocities depend on the physical properties of the magma, such that a description of crosscutting features can reveal valuable information about the magmatic environment and the dynamic behavior of crystals.

Keywords: Plagioclase, dissolution surface, oscillatory zoning, crystal settling, crystal dissolution

INTRODUCTION

Plagioclase zoning reflects the history of the physical and chemical properties of the magmatic melt within which a crystal grows (e.g., Wiebe 1968; Anderson 1984; Shore and Fowler 1996; Hattori and Sato 1996; Stewart and Fowler 2001; Landi et al. 2004; Perugini et al. 2005). Many researchers have observed and provided descriptions of plagioclase zoning features (e.g., Anderson 1984; Pearce and Kolinsnik 1990; Pearce 1994; Ginibre et al. 2002; Tsune and Toramaru 2008). Pearce and Kolinsnik (1990) classified such zoning into two types according to compositional differences (amplitude of oscillation), zone thicknesses (wavelength of oscillation), and morphologies (e.g., flatness of the interface between neighboring zones). Type 1 zones are characterized by small amplitudes (<5 An%), small wavelengths (<10 μm), and flat interfaces between zones and are likely the result of crystal growth kinetics (e.g., Haase et al. 1980; Allègre et al. 1981; Lasaga 1982; L’Heureux and Fowler 1996; Tsune and Toramaru 2007, 2008). Type 2 zones are characterized by large amplitudes (5 to 30 An%) and large wavelengths (10 to 50 μm) and are attributed to magma dynamics (Pearce and Kolinsnik 1990; Singer et al. 1993, 1995). Dissolution tracks (morphological features of the interface characterized by rounded corners and rough interfaces) are common in Type 2 zones (Tsukiyama 1985; Pearce and Kolinsnik 1990; Stamatelopoulou-Seymour et al. 1990), suggesting that crystal dissolution events are involved in the formation of Type 2 zones (Pearce and Kolinsnik 1990).

Dissolution tracks are also called dissolution surfaces (DSs; Stamatelopoulou-Seymour et al. 1990) because the tracks correspond to the previous crystal surfaces that formed when the dissolution events occurred. Crosscutting DSs have textures similar to those observed as angular unconformities in stratigraphic studies (Pearce and Kolinsnik 1990) and provide information with regard to the dynamic behavior of the magma as they are generally associated with magmatic convection, mixing, and injection of new magma (e.g., Kawamoto 1992; Singer et al. 1993, 1995; Stewart and Fowler 2001; Couch et al. 2001; Landi et al. 2004). Although Pearce and Kolinsnik (1990) and Singer et al. (1995) suggest that crosscutting features contain information with respect to the dynamic behavior of magma, neither detailed descriptions nor interpretations have been presented.

This study presents new observations of crosscutting DSs for plagioclase crystals from dacites in the Shirahama Group, Japan (Tamura 1995). Key features are noted that reveal the relationship between crosscutting DSs and dynamic magma behavior. The most important finding is that crosscutting features are observed on many crystal faces as a result of preferential dissolution on limited sections of the crystal. The conditions under which crosscutting DSs are formed are quantitatively discussed and a model is proposed to show that the formation of crosscutting features can be attributed to localized dissolution events that occur during crystal settling. Furthermore, the model suggests that the dynamic behavior of magma causes crystal settling.

INTERPRETATIONS OF THE ZONES IN PLAGIOCLASE CRYSTALS

The underlying interpretations and terminology of zones based on Pearce and Kolinsnik (1990) and Pearce (1994) are described below. Zones grow in a tree-ring fashion, such that an individual and traceable zone boundary (interface or surface) around a crystal expresses a one-time crystal-melt interface. Stratigraphic approaches can be applied to interpret the origins of zones in that, for example, crosscutting DSs formed after the growth of crosscut inner zones. Morphological features of the DSs such as roundness and roughness are also important to understand plagioclase dissolution. Crystal dissolution occurs preferentially at crystal corners, such that rounded DSs (Figs. 1a and 1b) are relatively common. On the other hand, the rough-