Application Note

Rapid Identification of Cryptic Exsolution Lamellae Using BEX

Introduction

Many common rock-forming minerals exhibit extensive solid solutions with complete miscibility at high temperatures. However, as these minerals cool, immiscibility between solid solution species can occur, leading to the formation of exsolution lamellae. These structures arise due to the expulsion of relatively incompatible elements from the crystal lattice (e.g. potassium in pyroxene) as sub-solidus cooling diminishes lattice flexibility. While it is also conceivable that lattice distortion and exsolution might result from high strain, this mechanism is less well understood. Analysing exsolution structures offers valuable insights into the cooling and deformation history of rocks, thereby shedding light on their petrogenesis.

The Challenge

Accurate thermometry using pyroxene exsolution lamellae necessitates a reliable determination of the original homogenised composition before exsolution occurred. The composition of exsolution lamellae can vary within a single crystal, necessitating the precise identification and characterisation of potentially multiple lamellae compositions, including Fe-Ti oxides, orthopyroxene, amphibole, micas, and sub-species of clinopyroxene. Lamellae can also occur on micrometre to millimetre scales, often requiring high spatial resolution analysis to locate them.

Typical analytical workflows involve a sequence starting with light microscopy and BSE imaging which guide targeted EDS or EPMA analyses. Consequently, lamellae that are small or lack significant BSE contrast may remain undetected.

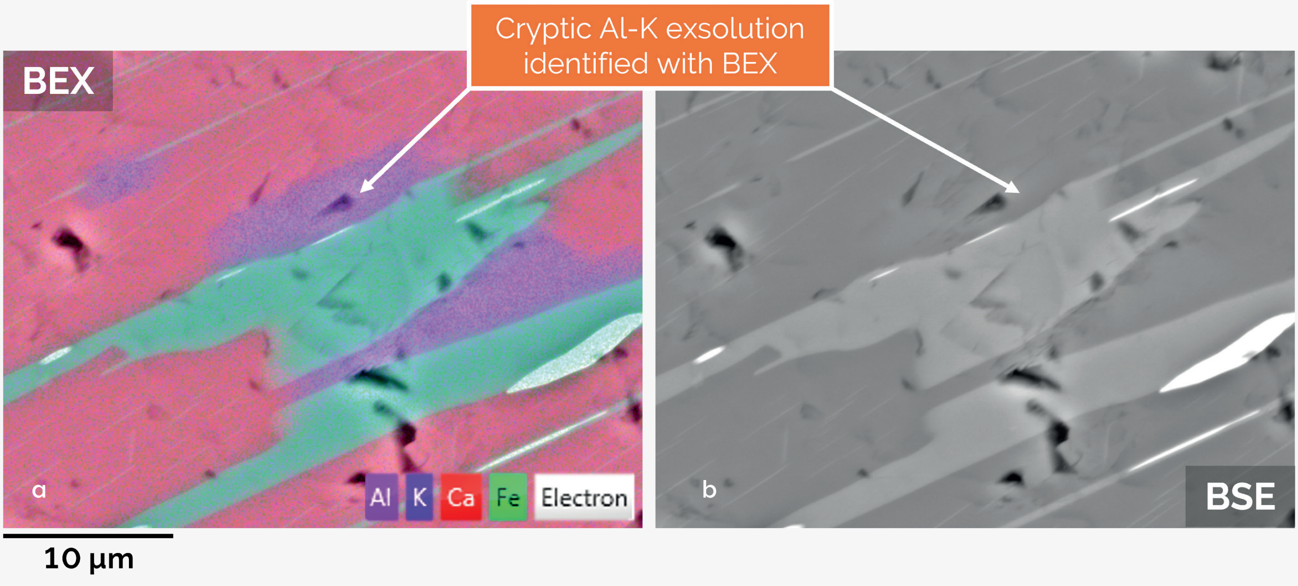

Figure 1. BEX (a) and BSE (b) images displaying the necessity of high-speed X-ray imaging for identifying cryptic Al-K exsolution.

BEX Integrated Exsolution Detection

Using BEX instead of the BSE imaging step (between optical imaging and targeted chemical analysis) enables compositional information to be obtained in real time. This unique combination of simultaneous rapid X-ray mapping and BSE imaging within a single detector can identify cryptic exsolution lamellae within pyroxene. For instance, we analysed a pyroxene-bearing gabbronorite from the Nellore Schist Belt in India. Previous BSE imaging and EPMA mapping had identified Fe-rich, Na-rich, and Ti-rich lamellae with significant BSE contrast (Figure 1a). However, the BEX technique instantly revealed cryptic Al-K-rich lamellae that had previously gone undetected (Figure 1b).

Dr. Anwesha Banerjee of IIT Mumbai comments on the use of BEX for this application, saying, *"Rapid compositional analyses would enable quick characterisation of the pyroxene exsolutions in different orientations. The most significant contribution of this technique has been the ability to resolve the halo of Al-rich phase around the Fe-rich exsolution."* She adds, *"The X-ray elemental maps generated through EPMA did not enunciate this variation, leading us to assume there was an exsolution of only two end-member compositions."*

This new finding may significantly impact our understanding of the thermodynamic history of the lithology, as the original homogenised pyroxene composition could have been markedly different from what was factored into thermometry calculations. The exsolution of Fe, followed by Al and K, may also relate to the sizes of the cations, suggesting an increased period of diffusion during cooling and/or deformation.

Conclusion

In conclusion, we have demonstrated the power of a BEX integrated workflow for revealing previously unknown information, even within extensively studied samples.

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