µXRF APPLICATION NOTES

# Micro-XRF analysis for geological applications

## Introduction

*Figure 1: The XGT-5000 XRF microscope*

The fast non-destructive elemental analysis provided by the award winning XGT-5000 x-ray fluorescence microscope is used by researchers across the world for characterisation of rocks and mineral samples to further their understanding of geological processes and rock formation.

With its unique 10 µm x-ray beam, the XGT-5000 allows even microscopic particles and features to be accurately probed, and the capability for large area mapping (up to 200 mm x 200 mm depending upon configuration) within spacious sample chambers means that sample preparation (cutting, grinding) is not required for even very large samples.

## Granite

Granite is a very common rock across the world, but can be subject to landslides following heavy rain, particularly in humid regions. In 1999, Hiroshima in western Japan was hit by a rainstorm which caused numerous granite landslides and many casualties. The cause of these shallow landslides is weathering of the granite structure, and a deeper understanding of the weathering processes is very important for the prediction and prevention of this type of landslide disaster.

The main mineral species contained in granite are as follows:

| | |
|---|---|
| Quartz | $SiO_2$ |
| Plagioclase | $(Na.Ca)[Al(Si, Al)Si_2O_8]$ |
| Potash feldspar | $(K,Na)AlSi_3O_8$ |
| Biotite | $K(Mg,Fe)_3(AlSi_{13}O_{10})(OH)_2$ |

When granite is weathered, iron in biotite is frequently dissolved by rain water and migrates along microcracks within the main structure. These microcracks form through stress release and differential volume change of constituent minerals, and with continued leaching of iron species through the granite their presence will increase, thus weakening the rock structure.

Elemental mapping with the XGT-5000 presents a fast and convenient method for researchers to identify the mineral distribution within the granite, which is essential to investigate microcrack formation process (Figure 2).

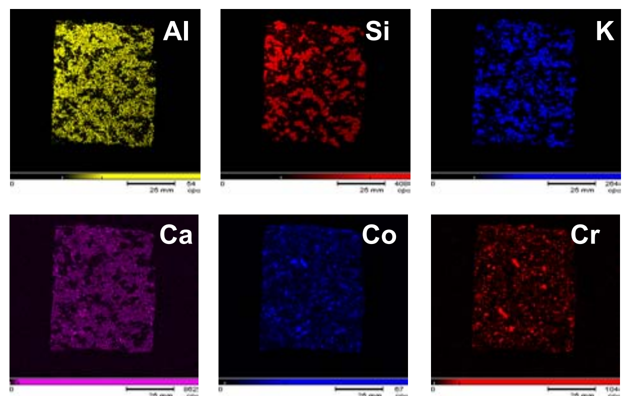


*Figure 2: Elemental mapped images (100 mm x 100 mm) obtained from the granite sample with 100 µm beam*

It is particularly interesting to investigate the distribution of iron in the granite, and comparison of the visual and elemental images starts to shed light on the weathering processes in the rock. In Figure 3, the distribution of iron is shown in the mapped XRF image, and a band of increased concentration is clearly visible, illustrating the leaching from the surface downwards. This corresponds directly with visible colouration within the optical image.

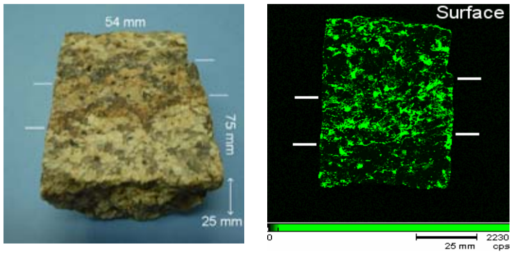


*Figure 3: (Left) Optical image and (right) mapped XRF image of iron (Fe) distribution in granite sample. The main region of accumulated iron through leaching is indicated.*

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## Kimberlite

A rich source of diamond, kimberlite rock is mined across the world for the precious gem – as a result, there is much interest in its geogical structure, in order to provide an understanding of its formation processes to assist the mining industry.

XGT-5000 analysis of a 4x3 cm² section of kimberlite quickly allowed the rock's mineral distribution to be visualised. The rock contains abundant crystals of olivine $(Mg,Fe,Ni)_2SiO_4$ and one zoned, partially altered crystal of garnet. The garnet crystal is immediately identified by its alteration rim comprised of potassium rich mica. High potassium content also shows the locations of mica crystals within the matrix.

The olivine crystals are black in the potassium and calcium images but have various shades in the iron and nickel images. These variations indicate the remarkable extent to which the compositions of these elements vary from crystal to crystal. In the Fe image, the olivine grains are seen to have thin Fe-rich rims. Notice also the additional information on physical structure provided by the transmission x-ray imaging.

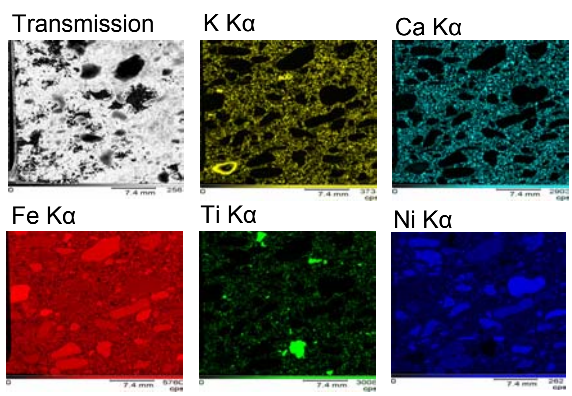


*Figure 4: Mapped images showing transmitted x-ray intensity and elemental distribution in a kimberlite section.*

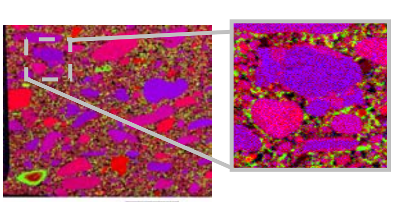

*Figure 5: Composite image (Fe+K+Ni) of kimberlite section – the zoom image illustrates the high spatial resolution available with the XGT-5000.*

The Material Phase Analysis software module on the XGT-5000, making use of Principal Components Analysis, can be used to group together regions of similar elemental composition. As a result it is possible to visualise where specific minerals are located within the sample (Figure 6). Thus, garnet with its outer mica region (green/blue), olivine crystals (pink/red – varying composition), and titanium rich ilmenite (yellow) can be quickly identified.

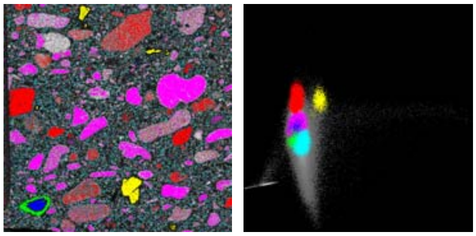

*Figure 6: (Left) Composite phase image of kimberlite section – see text for assignment of colours, (right) principal components cluster diagram*

## Summary

Deeper understanding into rock formation and weathering processes is easily possible with the XGT-5000 – it allows fast elemental characterisation for even very large samples, and with its unique 10 µm beam is ideally suited for analysis of microscopic fragments or features.

The elemental images which it provides yield valuable information about the structural make up of geologically important materials.

## Acknowledgements

Prof. Masahiro Chigira (Disaster Prevention Research Institute, Kyoto University, Japan) and Dr Nicholas Arndt (Université Joseph Fourier, Grenoble, France) are kindly thanked for the data relating to the granite and kimberlite samples respectively, and useful discussions in preparing this application note.

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