Micro Tomography of Single Fluid Inclusions

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INTRODUCTION

Fluids can be transported on large distances in the lithosphere. As a consequence, leached elements can be deposited when changes in physical and chemical conditions or mixing of different fluids occur: most ore deposits are build during such events.

Reconstructing past fluid-rock interactions in crustal rocks is thus central for understanding the geological history of a specific zone. Fluid inclusions represent the only direct samples of ancient fluids in many crustal rocks. Many natural minerals contain several generations of fluid inclusions, each one being representative of a distinct hydrothermal event.

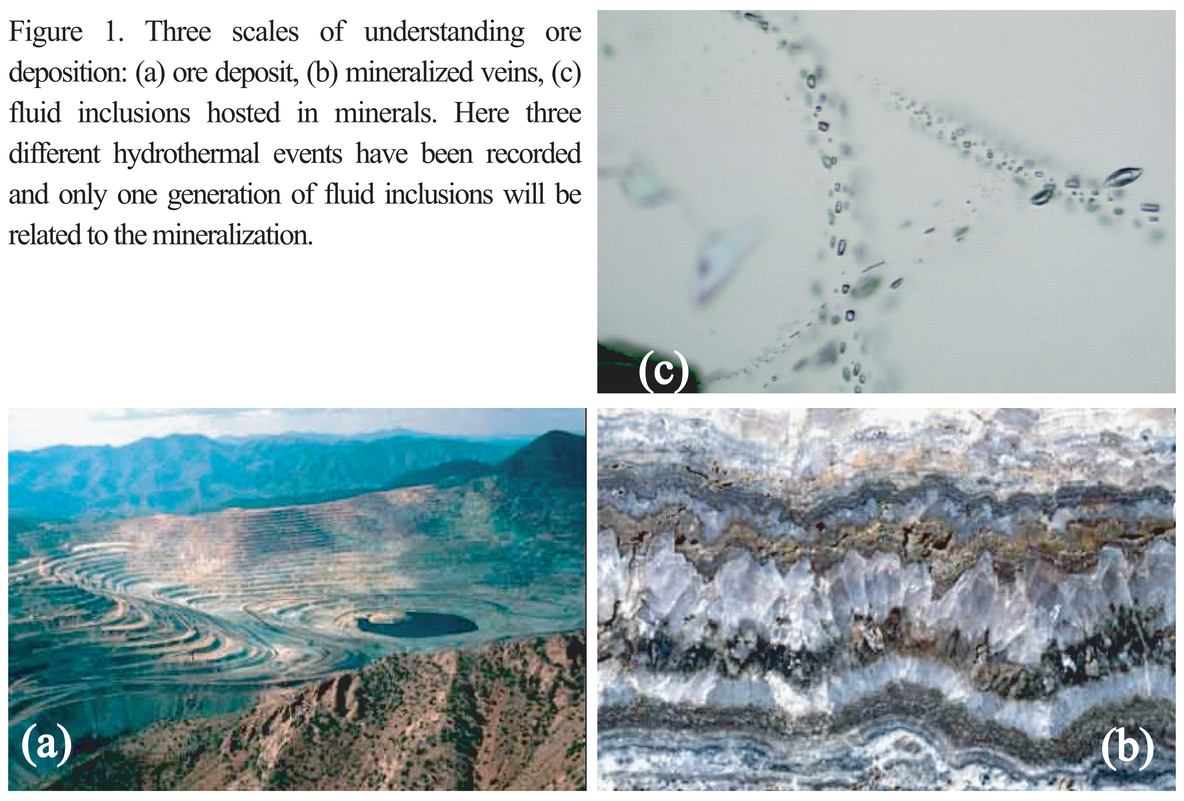


Figure 1. Three scales of understanding ore deposition: (a) ore deposit, (b) mineralized veins, (c) fluid inclusions hosted in minerals. Here three different hydrothermal events have been recorded and only one generation of fluid inclusions will be related to the mineralization.

EXPERIMENTAL SET-UP

The experiments were performed at ESRF BeamLine ID22 (micro-fluorescence, micro-imaging and micro-diffraction). 14 keV monochromatic beam was focused using a KB mirror to a 1*3µm≤ spot onto the sample. The sample and the detector cristal were enclosed in a helium chamber to reduce absorption.

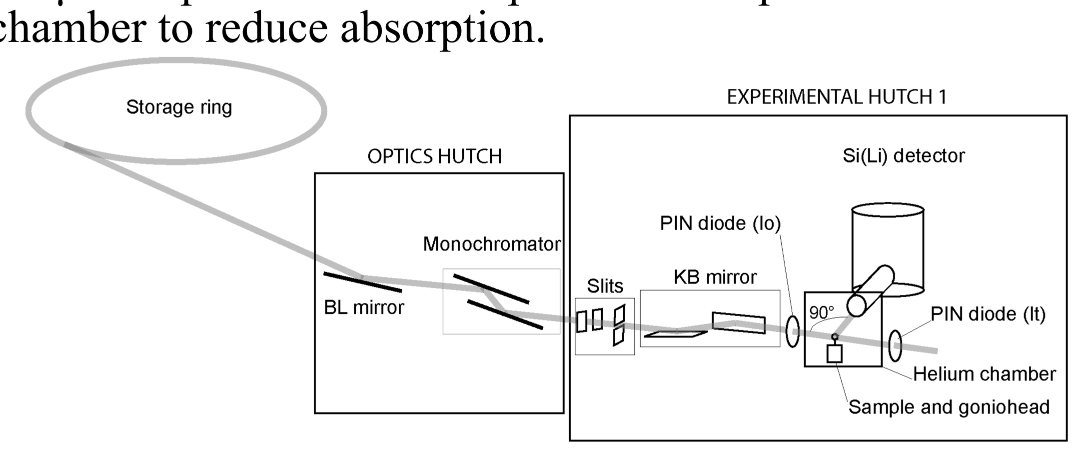
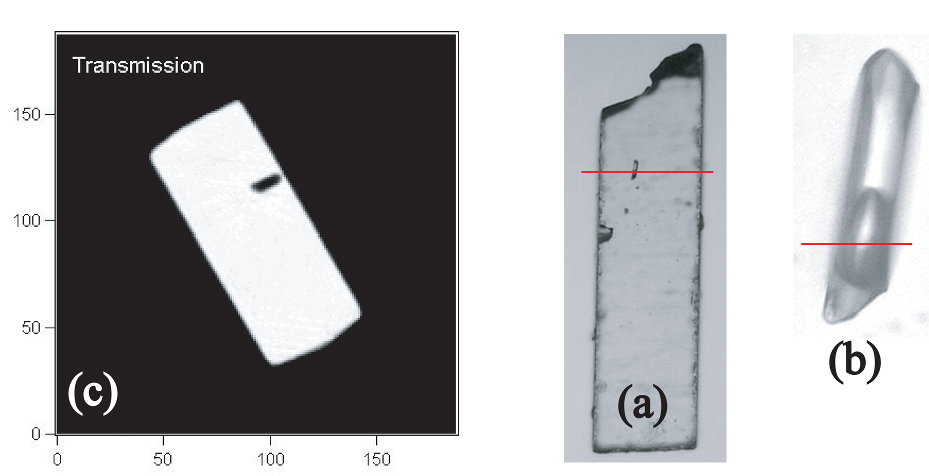


Figure 2: Schematic view of ESRF beamline ID22

LD886 - TECHNICAL LIMITATIONS

LD886 is a quartz sample taken from mesothermal gold-quartz veins at Brusson, Val d'Ayas, western Italian Alps (kindly provided by B. Yardley and L. Diamond). It contains only a single compositionnal type of fluid inclusion previously analyzed by crush leach [1] and with SRXRF [2]. Quartz samples are very pure and host large inclusions, making it well suited for micro fluotomography measurements applied to a single fluid inclusion.

Matrix reconstruction shows Ge, homogeneously distributed, but its low concentration make it sensitive to the angular sampling and Si, which reconstruction displays artifacts due to the strong self-absorption.



The sample preparation lead to metals polltuion during micro-sawing (Cu and Zn), they where detected on the borders of the sample as small grains.

As and Br, present in the inclusion, are well reconstructed and were found in the liquid phase only, at low concentrations.

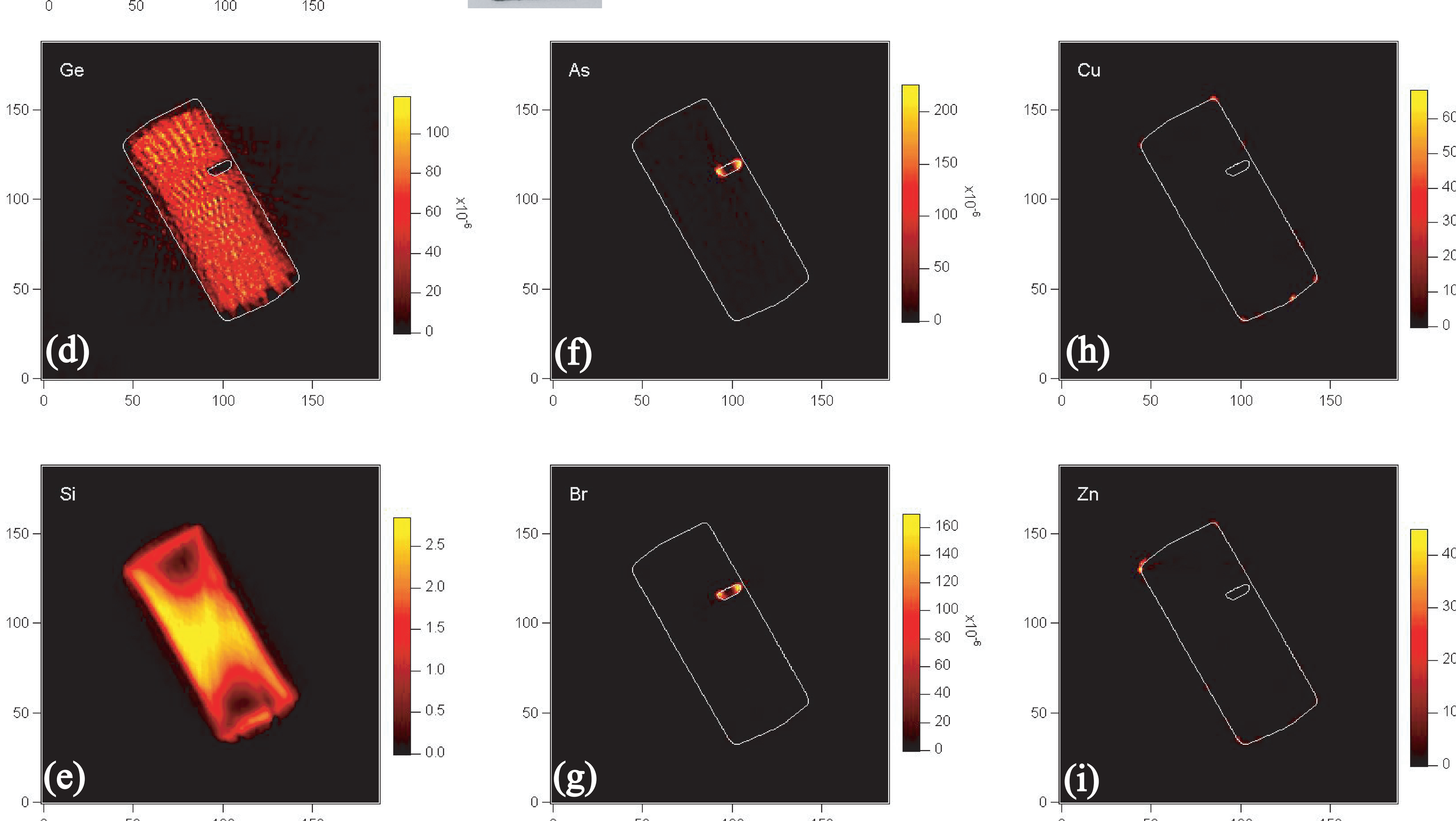


Figure 3: (a) microphotograph of the LD886 sample (b) detailed view of the analyzed fluid inclusion. The red line is the projection of the fluorescence tomography plane of view (c) to (i). (c) sample density calculated from absorption, (d) Ge, (e) Si poorly reconstructed due to strong self-absorption, (f) and (g) As and Br located in the liquid phase of the fluid inclusion, (h) and (i) Cu and Zn deposited by the micro-wire used to cut the sample All concentrations in g/cm3.

GG20 - GEOLOGICAL INTEREST

GG20 is a quartz sample taken from quartz-bearing rocks collected in the Chivor emerald deposit from Columbia (kindly provided by G. Guliani). This sample hosts multiphase inclusions, most of them having three phases: liquid, gas and a NaCl daughter cristal.

The absorption reconstruction shows two dense phases (high absorption) and three fluid inclusions, two of them having their liquid fraction enriched in some elements (Br-Fe-Mn and Br-Fe-Mn-Zn). The solid trapped in the main inclusion contains Pb, As, Fe and Mn. As long as similar solids have not been detected in other inclusions it should be considered as heterogeneously trapped. As such, it would lead to wrong results if studied with destructive methods like crush leach or laser ablation analyses.

The elemental distribution between the liquid, gas and solid phases is of primary interest for geological studies. These reconstructions are direct images of the elemental partitionning,which, through boiling and mixing processes in geological layers, controls economic ore deposition.

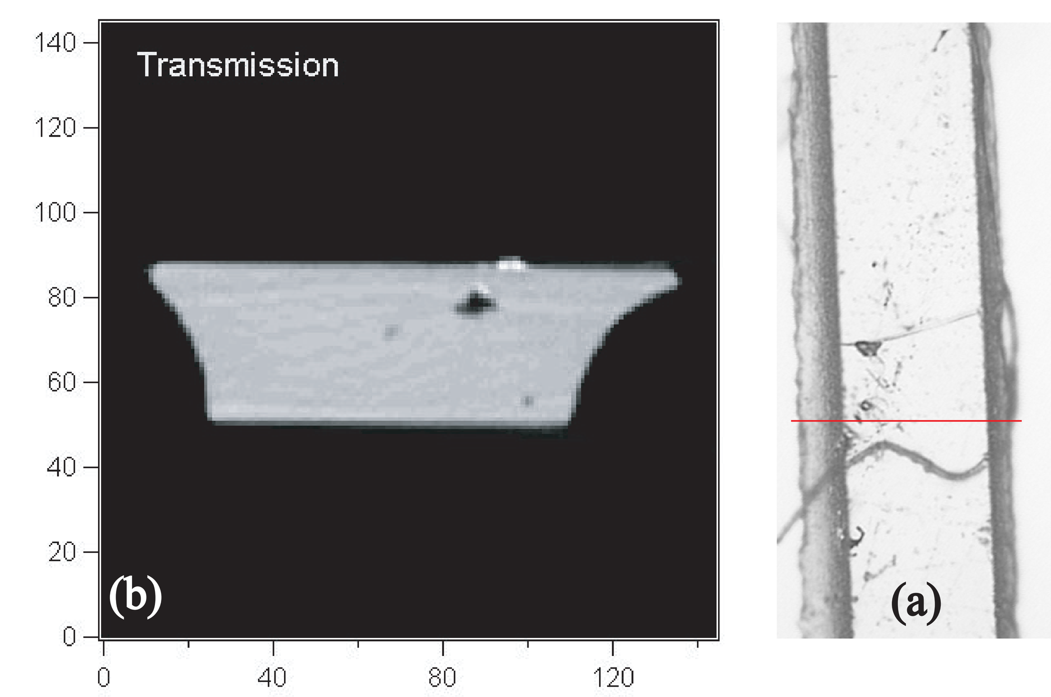
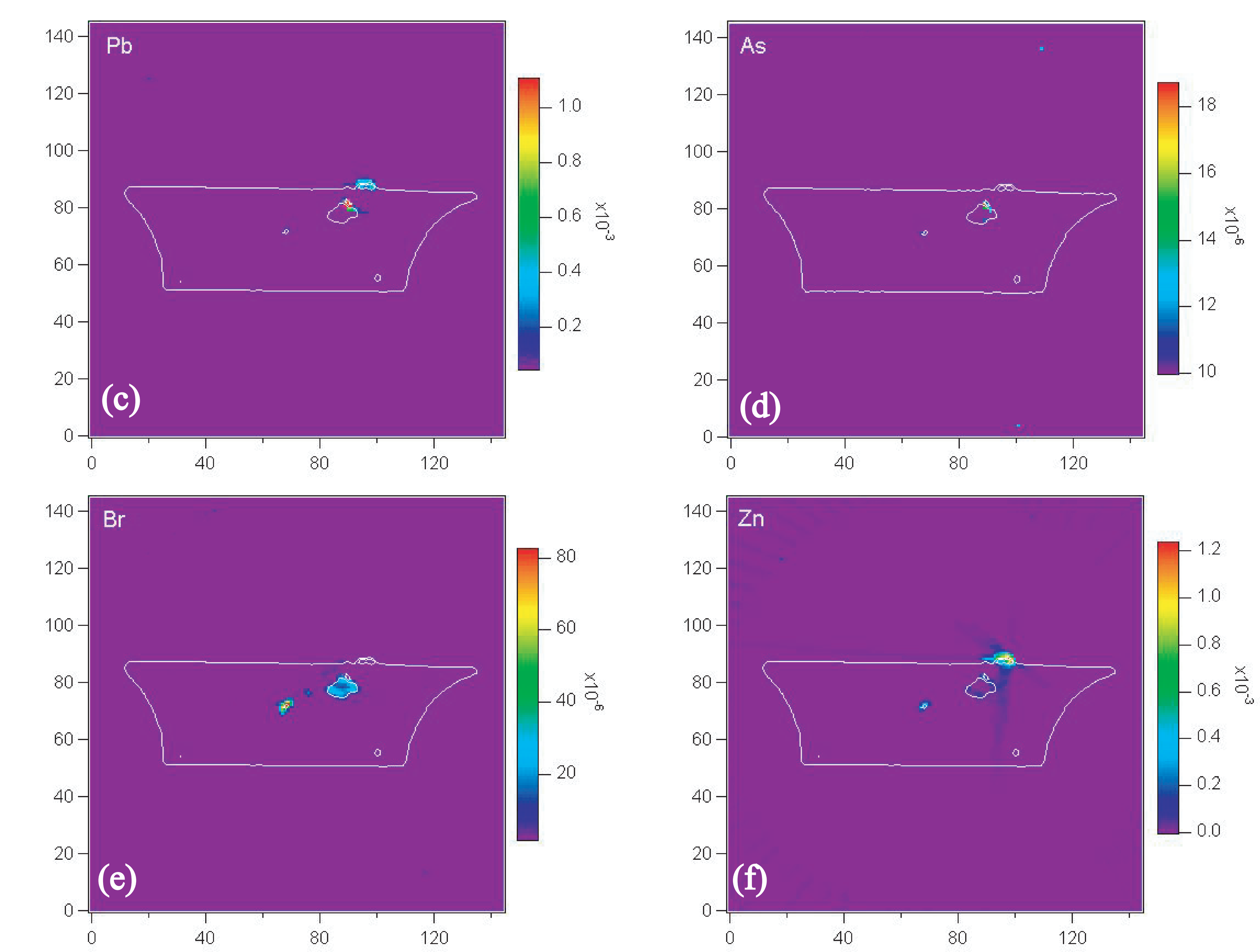


Figure 4: (a) microphotograph of the GG20 sample just after sawing (b) density reconstruction using transmitted intensity (c) Pb is associated with the solid phase includsed in the main inclusion and to a lower extend with the solid phase at the sample surface, (d) As is found in the solid pahse in the main inclusoin, (e) Br is in the liquid phase of two inclusions but more concentrated in one of them and (f) Zn is found in the second solid at the sample surface and in the small inclusion, but not in the main one. All concentrations in g/cm3.



CONCLUSIONS

Micro fluorescence tomography solves two main problems encoutered with micro synchrotron X-ray fluorescence:

i) it gives a **complete reconstruction of the sample geometry**, thus leading to more accurate absolute concentrations

ii) it gives **elemental concentrations in the different phases inside the inclusion**.

At the inclusion size, it is as a significant step forward as the comparison between "single inclusions" and "bulk" studies. **It enables to study elemental partitionning** between the liquid and gas phases, and thus to **better understand geochemical processes taking place during boiling and mixing hydrothermal fluids**. These are the main known condition leading to economic ore formation.

However, micro fluorescence tomography stays time-consuming thus limiting the number of samples studied. In absorbing minerals, it will also not be able to give accurate reconstruction of diluted low Z elements.

References

[1] Yardley B.W.D., Banks D.A., Bottrell S.H., Diamond L.W., Mineral. Mag., 57, 407-422 (1993)

[2] Philippot P., Menez B;, Drakopoulos M., Simionovici A., Snigirev A., Snigireva I., Chemical Geol., 173, 151-158 (2001)