MULTI-DISCIPLINARY APPROACH FOR EFFECTIVE CHARACTERIZATION OF BATTERIES AND BATTERY MINERALS

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Summary: Growing battery use leads to a growing need of efficient characterization of batteries and battery minerals. We have developed a workflow where x-ray tomography is combined with other methods to produce high quality 3D data from batteries and battery minerals. This exponentially increases the efficiency of the characterization compared to traditional methods.

1. INTRODUCTION

With exponential increase in the amount of battery-powered devices – from smartphones to electric cars – high quality characterization of geomaterials becomes increasingly important. This is true for primary raw materials (ores) as well as for recycled materials (batteries). There is a growing need therefore to be able to characterize the economic potential of such materials accurately and comprehensively. Improving knowledge on the inner structure and chemistry of batteries can increase their efficiency, as well as their recyclability, providing more raw materials and a more efficient use for them.

2. EXPERIMENTAL METHOD

Traditionally, such analysis of geological samples is done with bulk or 2D surface methods applied directly to the sample surface or the surface of a carefully prepared thin section. Automated analysis tools, such as QEMSCAN (Quantitative Evaluation of Minerals by SCANning electron microscopy) with SEM-EDS (Scanning Electron Microscopy – Energy Dispersive X-ray Spectroscopy), have become quite efficient and convenient, while more interactive tools, such as EPMA (Electron Probe Microanalyzer) or LA-ICP-MS (Laser Ablation – Inductively Coupled Plasma Mass Spectroscopy) provide unparalleled accuracy on elements covering almost the entire periodic table. The main drawback with 2D surface methods is knowing a priori where to section a 3D sample in order to obtain the best representative analysis. Contextual knowledge of the sample material can help a lot, but an economically significant part of the sample may nevertheless remain unexamined. We have therefore developed a workflow which takes away most of the subjectivity and chance of preparing 2D slices from 3D objects, such as rocks. The process begins with a non-destructive XCT (X-ray Computed Tomography) scan of a complete sample. Efficient scanning of samples at the drill core scale and larger (up to 30 cm in diameter) has only recently been made possible in Finland with the installation of GTK's new XCT equipment. The resulting tomographic image shows the internal structure, along with the heterogeneities, and can be used to locate areas of specific interest to the analyst. Thin sections, both optical and polished, are then prepared so as to deliberately intercept the features of interest observed within the 3D volumes. When this workflow is applied to batteries, the XCT image is used to determine where in the battery to drill samples for LA-ICP-MS. The first step of the workflow, XCT, is non-destructive and can later be used as a map for all subsequent analyses. GTK has a unique facility in Finland with XCT and advanced 2D mineralogical, geochemical and isotopic analysis systems in the same laboratory, with the researchers working in close collaboration.

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3. RESULTS

We present results where this workflow has been successfully applied to the discovery of minerals in exploration samples of commercial importance (see Fig. 1), efficiently combining XCT with QEMSCAN. We also present preliminary results from similar workflow on other types of materials, such as batteries, that includes trace element analysis by LA-ICP-MS. We show that expanding from 2D to 3D, improves exponentially the scientific and economic evaluation of a sample.

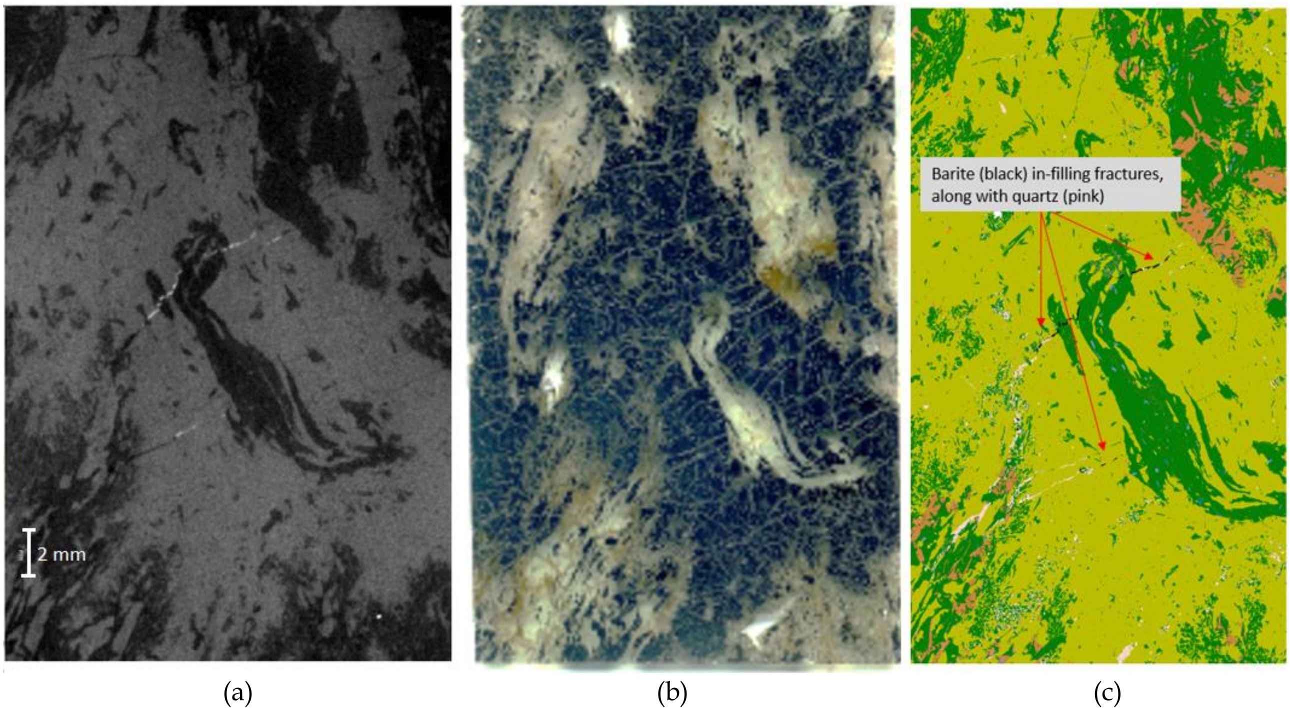

Figure 1: (a): Cross-section from the 3D tomographic image, showing an area of interest (light grayscale value equals high density). (b): Optical thin-section of the same location, preparation aided by the tomographic image. (c): QEMSCAN analysis of the thin-section, identifying the interesting fracture-filling mineral as barite.