

TruMap is a revolutionary new way to collect and display mapping data with all the speed of traditional mapping and spectrum processing power of Tru-Q in real time. TruMap displays the real variation of X-rays from the elements in the specimen, if you are used to using traditional digital mapping the results may surprise you.

Introduction

X-ray mapping has proved a powerful tool in the examination and interpretation of multi structural materials in the electron microscope. Simple digital mapping has been replaced by spectral mapping where spectral data is collected on a pixel by pixel basis and elemental spectra and quantitative maps can be constructed after the fact.

Digital maps are created by displaying the number of X-rays detected from a particular energy range at each pixel. However, as well as characteristic X-rays from a particular element, unwanted counts from overlapping elemental peaks or from the X-ray background can create misleading results.

The traditional solution to this has been to use quantitative mapping which processes the spectrum at each pixel to separate overlaps and remove background contribution. In some cases the data are processed further to determine the quantitative result at each pixel. Although this technique can produce excellent results, long data processing times and the large number of counts needed for successful data processing have limited its applicability.

With TruMap in **AZtec**, Oxford Instruments has developed an algorithm for peak deconvolution and background removal that is fast enough to work in real time, calculating maps in seconds during or after acquisition. Using the Tru-Q data processing technology including FLS and QCAL, it also uniquely works on low and high count datasets without bias. This means a true picture of the elements in the sample is displayed with little or no trade-off in time or resolution.



Why is this TruMap important?

TruMap gives the operator the ability to observe background-free maps in which elemental overlaps have been removed in real time!

It is a perfect compliment for large area SDD detectors which can produce maps with more data than ever before. The maps being collected using SDD are bright and detailed, but much of the new data are actually not real and hinders understanding of the sample.

- Peak overlaps mean that element maps may in reality be showing the variation of other overlapped elements
- High count rate maps are sensitive enough to pick up X-ray variations due to changes in the X-ray background. Phases with heavier elements emit more X-rays, than phases with lighter elements and some features in X-ray maps may appear real but are, in actual fact, artifacts

TruMap removes these artefacts to give the right rather than the bright picture of the sample.

Comparison of Digital and TruMaps from a Paint Cross-section sample

To illustrate the power of TruMap, a paint cross-section from a demolition site was studied. The main interest in this sample was to identify whether any elements that may be harmful to health were present (e.g. lead, arsenic or cadmium).

A spectral map collected using **AZtec** SmartMap from the paint sample can be displayed using digital mapping or TruMap methods. Digital mapping of elements in the sample (Fig 1) show the presence of significant amounts of lead, associated with sulfur and lower levels of iron and silicon.

Another major constituent of the sample appears to be rich in titanium and barium.

While most of these elements are associated with white pigments in paint the results are not consistent with expected white pigment phases, such as white lead (lead carbonate), barium sulfate and titanium dioxide.

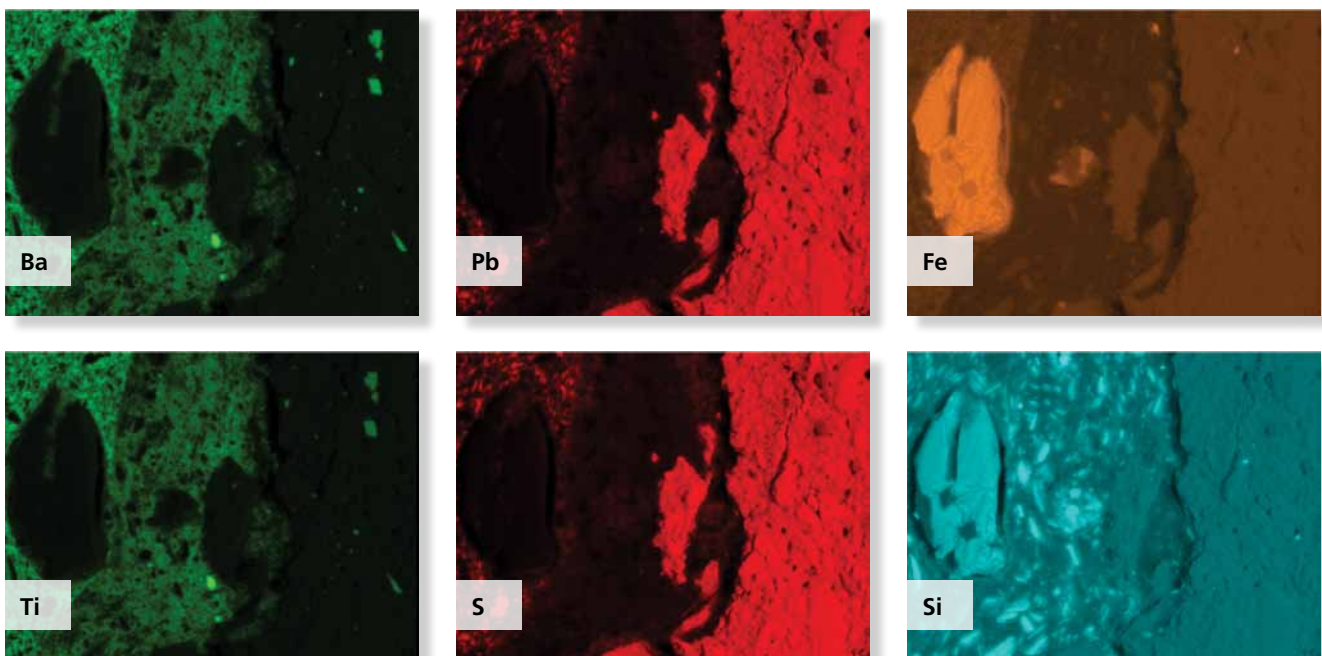


Figure 1 Digital maps of barium, lead, iron, titanium, sulfur and silicon from a paint cross section.

Recalculating this data as a TruMap takes seconds, and reveals a completely different but more accurate picture of this specimen (Figure 2). It is confirmed that lead is a major element in the specimen, not associated with sulfur but only with minor levels

of oxygen and carbon (not shown). The sulfur is sometimes associated with barium as barium sulfate particles. The titanium is also only associated with oxygen as titanium dioxide. The iron is concentrated mainly in one large iron silicate particle.

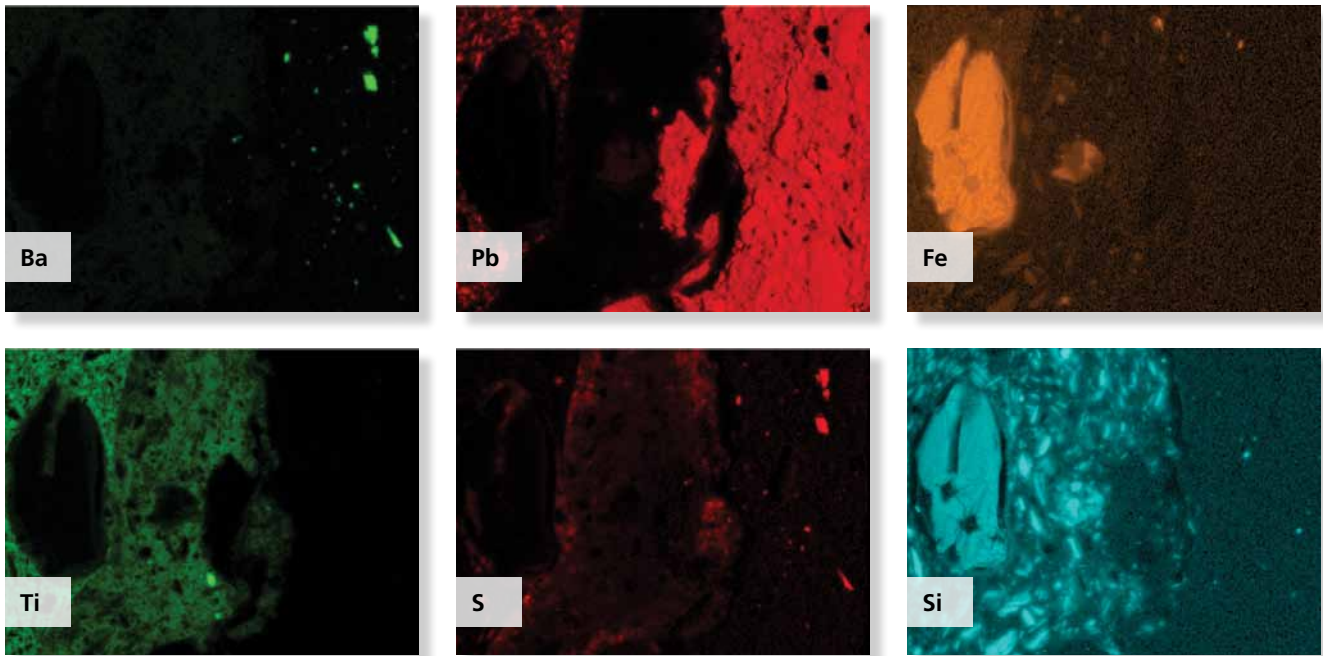


Figure 2 TruMaps of barium, lead, iron, titanium, sulfur and silicon from a paint cross section, showing accurate elemental distributions.

Why are TruMaps of the Paint Cross section so different from the digital maps?

Why in the digital maps did lead and sulfur seem to be in one phase and titanium and barium in another, when the TruMaps revealed that the only common phase for the elements contained barium and sulfur?

The reason is that the digital maps did not show where elements are associated in the specimen, but where they are associated in the X-ray spectrum. Sulfur K and lead M lines overlap, and when the counts for the sulfur energy window are counted by the software they will include both sulfur

and lead (Figure 3a). Similarly barium L and titanium K lines overlap, so the energy window for barium will also include a significant amount of the titanium signal (Figure 3b). **AZtec** software warns the user of these problems when showing digital maps using SmartMap, it is then a good time to recalculate the data using TruMap.

By using Tru-Q technology, TruMap separates out the overlaps and determines correctly which X-rays come from which element.

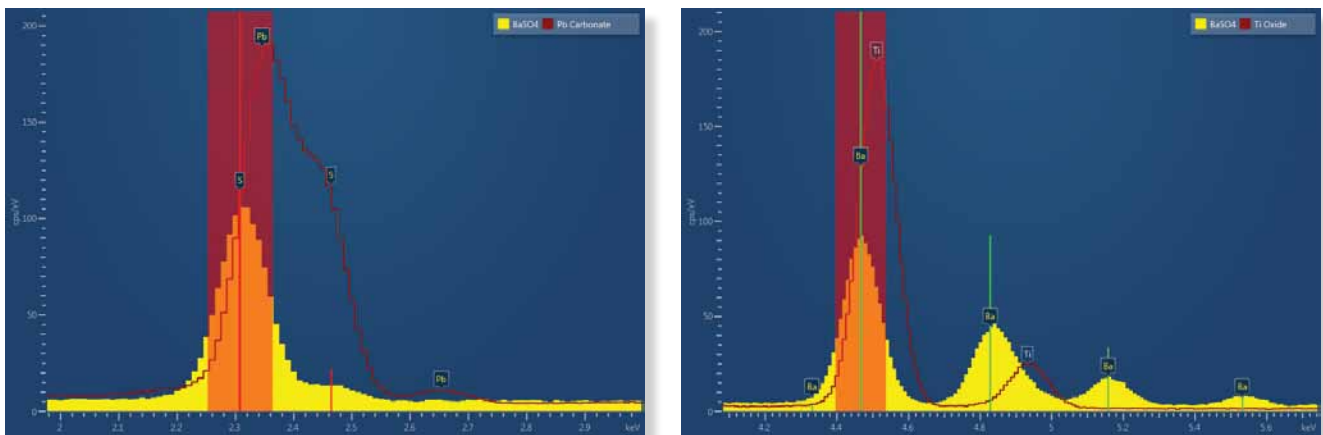


Figure 3 Spectra indicating the placement of the energy windows used for calculation of A) sulfur digital maps and B) barium digital maps. It can be seen that in A) the sulfur map will also include X-rays from lead in the lead carbonate phase and in B) the barium map will include X-rays from titanium in the titanium dioxide phase.

TruMap gives a real picture for elements where there are no overlaps

The iron map in Figure 1 suggested concentrations of iron were associated with lead in the right part of the mapped area. TruMap casts doubt on this finding, suggesting iron levels are low in this area of the sample. This example shows misleading results: firstly due to the addition of the signal from varying X-ray backgrounds, and, secondly, the variations due to the candidate elements studied. The iron map in Figure 1 may look like it has more information than the iron TruMap in Figure 2, but that is because only the iron TruMap is linked to the real information.

By reconstructing spectra from areas of different iron composition and comparing the intensity of X-rays at the energy of the iron K line we can see the reason for this anomaly (Figure 4). The highest intensity of iron comes from

the bright phase in the iron map. However, the next most intense comes from the lead-rich area to the right of the map (lead carbonate - spectrum2). Here, the intensity can be seen to be simply due to the higher background caused by higher X-ray emission from heavier lead rich areas. The area on the far left of the map, is actually the second most rich in iron (spectrum4), but has similar intensity to the background in spectrum2, and therefore also in the iron digital map. In reality the area with the lowest intensity in the iron digital map also contains a trace level of iron (Spectrum3), as correctly predicted by the iron TruMap. Therefore TruMap not only removes false data, but enhances sensitivity of extremely low count rate information, to extract the real variation of minor elements in a sample.

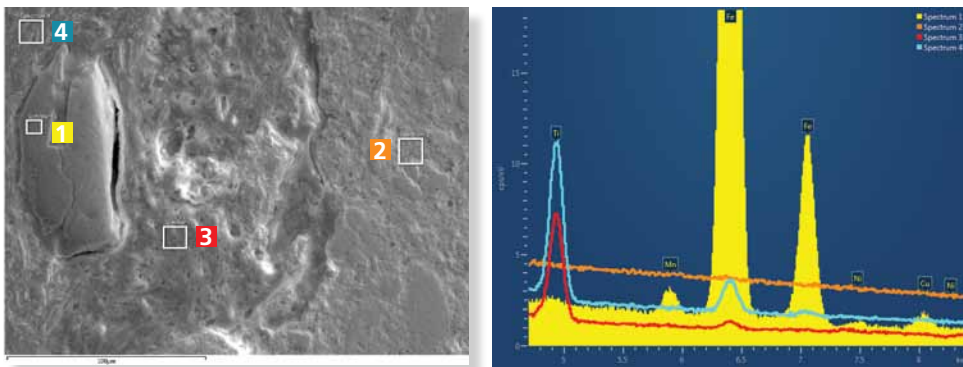


Figure 4 Spectra collected from four areas of the paint cross-section. A) Areas of analysis shown on the secondary electron image. B) Spectra from 1) the iron-rich silicate, 2) lead carbonate and 3/4) areas with minor concentrations of iron at varying concentrations.

One final feature of the TruMaps to note is that if the data is real it is not lost. Take for example the silicon TruMap in Figure 2. Although the silicon signal has been removed from the lead carbonate phase, the remainder of the sample where the silicon is real shows the same intensity at the same resolution as the Si digital map in Figure 1.

Summary

TruMap is a unique method of generating X-maps corrected for background and peak overlaps, in real time and on any level of data. It removes false information from other elements, and from variations in the X-ray background. It also enhances real variations, often extremely subtle, that are hidden by these none-element variations. It therefore gives more real data, and is more sensitive than digital mapping, but with no time penalty. It also works on all count rates and levels of data: if you can see something in a digital map, provided it is real you will see it the same or better with a TruMap. Only with the accuracy and power of **AZtec** is this possible: once you have tried it you will never map any other way.

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