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Lithological Discrimination in Deeply Weathered Terrains Using Multielement Geochemistry – An Example from the Yanfolila Gold Project, Mali

Introduction

Lithogeochemistry has been successfully applied to mineral exploration in deeply weathered terrains (e.g. Prendergast 2007; Whitbread & Moore 2004). Previously published studies have concentrated on the application to fresh rock but have used elements that are sufficiently immobile for the outcomes to be applied at different levels of regolith profile. A challenge for many exploration projects is to be consistent in the logging of lithologies, particularly when these are weathered. This article describes an ongoing case study from an exploration project in Mali, West Africa for the application of lithological discriminators determined first in fresh rock and then applied to saprolite and soil material. Robust classification templates are constructed for the fresh, saprolite and soil material and incorporated into a commercial software program so that the project team can rapidly classify new data.

The project team was interested in determining if robust classification templates could be established for the discrimination of rock types in fresh samples that could then be applied to the weathered zone and then even to surface soil samples. Furthermore there was particular interest in finding out if any successful outcomes could be reproduced with data from a field portable XRF (pXRF) instrument.

For the fresh material, pulps of drill core samples at a 20 m interval were submitted for multielement analysis using a 4-acid digest followed by a combination of ICP-MS and ICP-AES which allowed the detection of a wide range of elements at low detection limits (method ME-MS61 at ALS). With the data from the drill core, exploratory data analysis was carried out using the geochemical software ioGAS© in order to de-

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Yanfolila Gold Project

Gold Fields Ltd. is actively exploring in West Africa and one of their major projects is the Yanfolila Gold Project in Southwest Mali (Fig. 1). The project includes two significant deposits, Komana West and Komana East, and has a previously announced resource of 0.84 Moz. This case study is focussed on Komana East. The deposits are hosted in a volcano-sedimentary sequence that is part of a middle Proterozoic Birimian age greenstone belt. The stratigraphy from west to east is basalt, sandstone and siltstone, intrusive dolerite and sandstone. The mineralization is hosted in siltstones and intrusive dolerite and the style is typical of orogenic gold systems with gold associated with pyrite and albite/K-feldspar alteration. Consistent logging of the main rock types is difficult because of the intense weathering and strong hydrothermal alteration. Even differentiating between basalt and sandstone/siltstone can be difficult when the rocks are weathered - since even colour is not a reliable discrimination criterion.

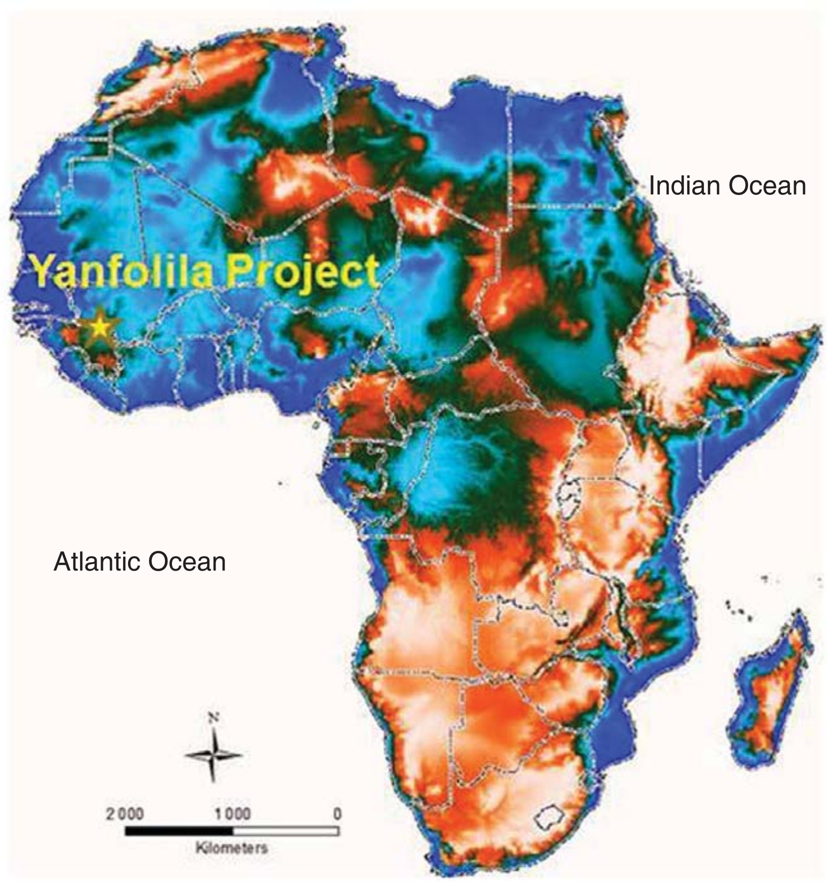

Figure 1. Location of the Yanfolila Gold Project in southwest Mali (backdrop is a digital elevation model for Africa).

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termine the trace elements that were geochemically characteristic of the main lithologies, i.e. basalt, siliclastic sediments and mafic schists. Table 1 shows the elements that characterise the different lithologies. The main method of determination was to colour the sample plots according to lithology determined by the geologist and then construct bivariate plots of the more immobile elements such as Ti, Cr, and Zr. Spatially separate groupings for the different lithologies determined from the geologists logging were achieved with the plots for Ti-Zr, Ti-Cr and Mn-Sr. A Cr-Ti diagram produces

Rock Type	ME-MS61- High Values	ME-MS61- Low Values	Detectable by pXRF - High Values
Mafic schist	Cr, Cs, Ni, P, Sr		Cr, Sr
Basalts	Mn, Sc, Ti, V,	Ce, La, Th, Zr	Mn, Ti, V
Sandstones/siltstones	Rb, Th		Rb, Th

Based on 2230 samples

Table 1. Elements that are elevated or depleted in the main lithologies (mafic schists, basalt, sandstones/siltstones) and those that are detectable by the pXRF.

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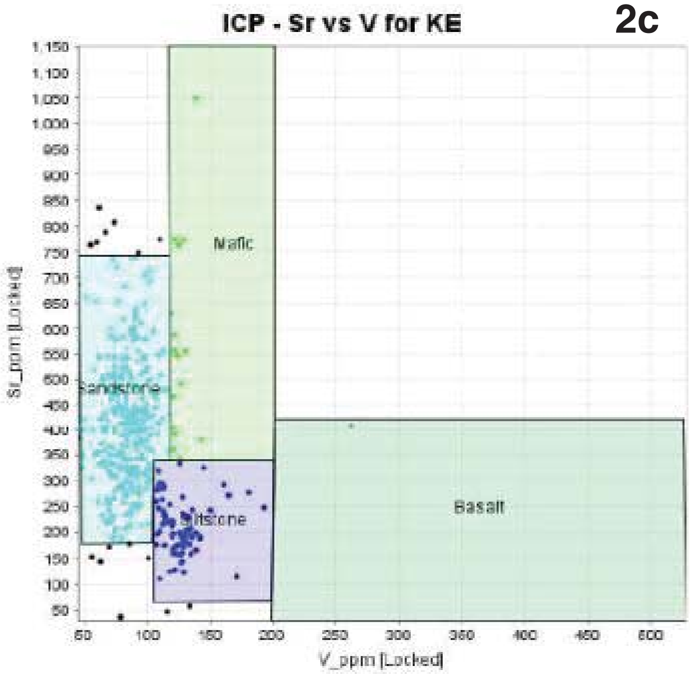
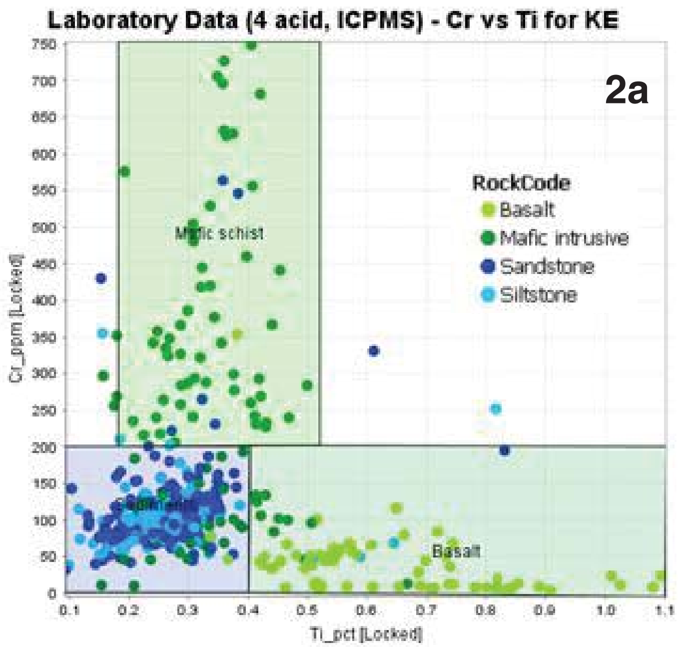
particularly good discrimination of the main lithologies and further discrimination between sandstone and siltstones is achieved with the Sr-V plot. When sufficient separation of lithologies on these diagrams was achieved, then templates could be created and used. The templates were then entered in a software program ioGAS© that is optimized for geochemical data analysis (iogas.net/).

Application of the Cr-Ti template is shown in Figure 2. Figure 2a shows the classification according to the geologist's logging and then classified using the Cr-Ti template (Fig. 2b).





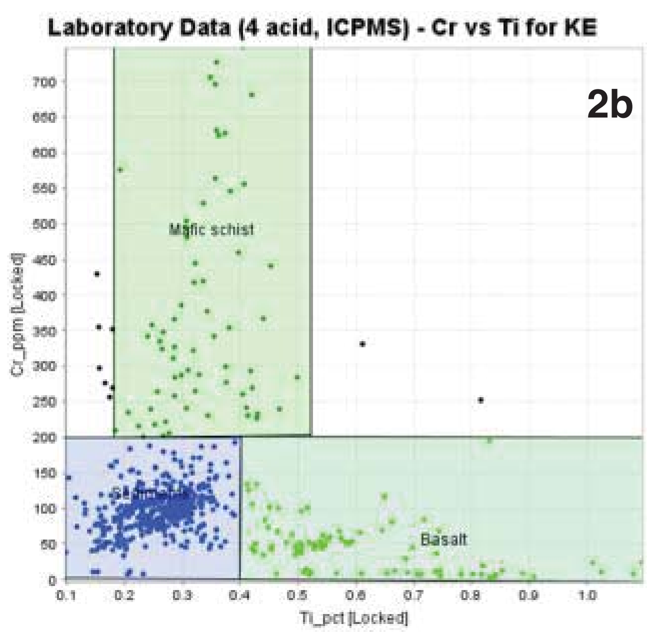
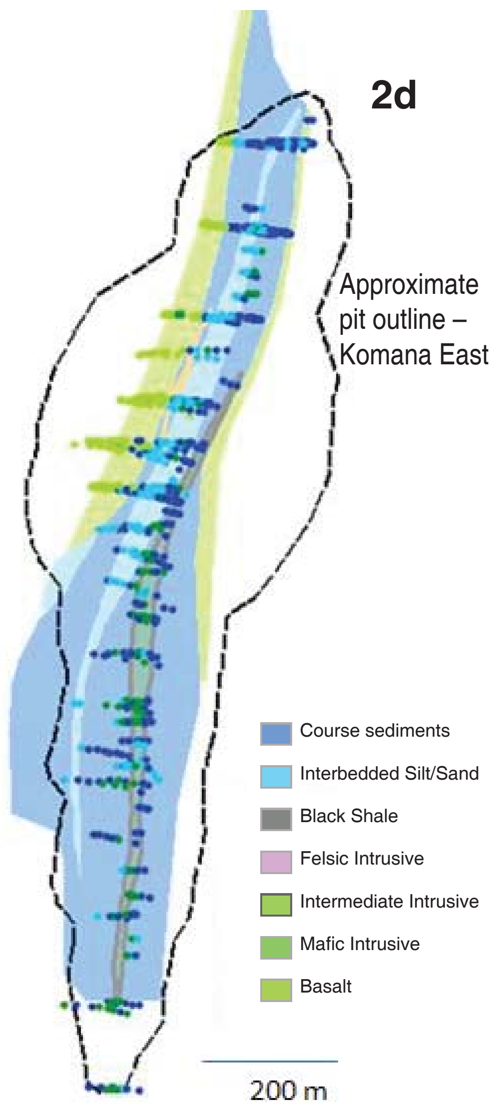


Figure 2a. Cr- Ti classification diagram with samples coloured according to the geologists' logging.

Figure 2b. The same classification template as in 2a but with samples not classified according to this template.

Figure 2c. Sr-V classification diagram for just the samples classified as sediments in the Cr-Ti diagram.

Figure 2d. Classification from the Cr-Ti and Sr-V templates plotted on the geological map produced from logging of drill core.



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The sediments were classified into sandstone and siltstones using the Sr-V template, which is shown in Figure 2c. The resulting classification is plotted on the bedrock geology map which was produced from logging of the diamond drill core (Fig. 2d). The classification using geochemistry corresponds reasonably well with the geological interpretation and gives confidence to the methodology.

The next stage was to determine if a similar outcome with the geochemical classification could be achieved using the portable XRF instrument. Portable field instrumentation is becoming more widely used and is a major change for how some fieldwork using exploration geochemistry is carried out. The instrument is portable and provides results at the actual sample location or in the field camp quickly – for example the project team in Mali is set up to analyze about 200 sample pulps or sieved soil samples per day.

Validation of the pXRF instrument and data are important. Before using the instrument for characterisation work, the pXRF data were calibrated with lab or "real data". Quality control protocols were also set up for the routine readings and these included using certified standards.

Pulps from five lines of drill holes across the northern part of Komana East were analysed using the pXRF. The Cr-Ti template constructed from the laboratory data was modified by using equivalent breaks on the probability plots for pXRF data. Figure 3 shows the results, after classification, with

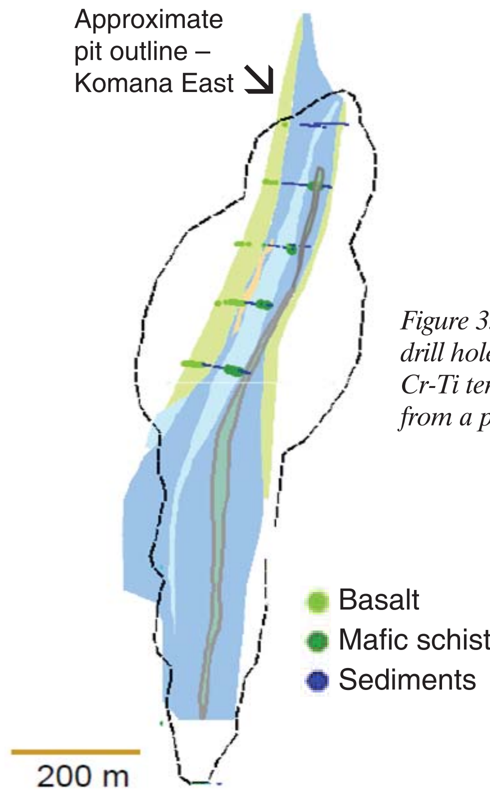

Figure 3. Classification of drill hole samples using a Cr-Ti template with data from a pXRF.

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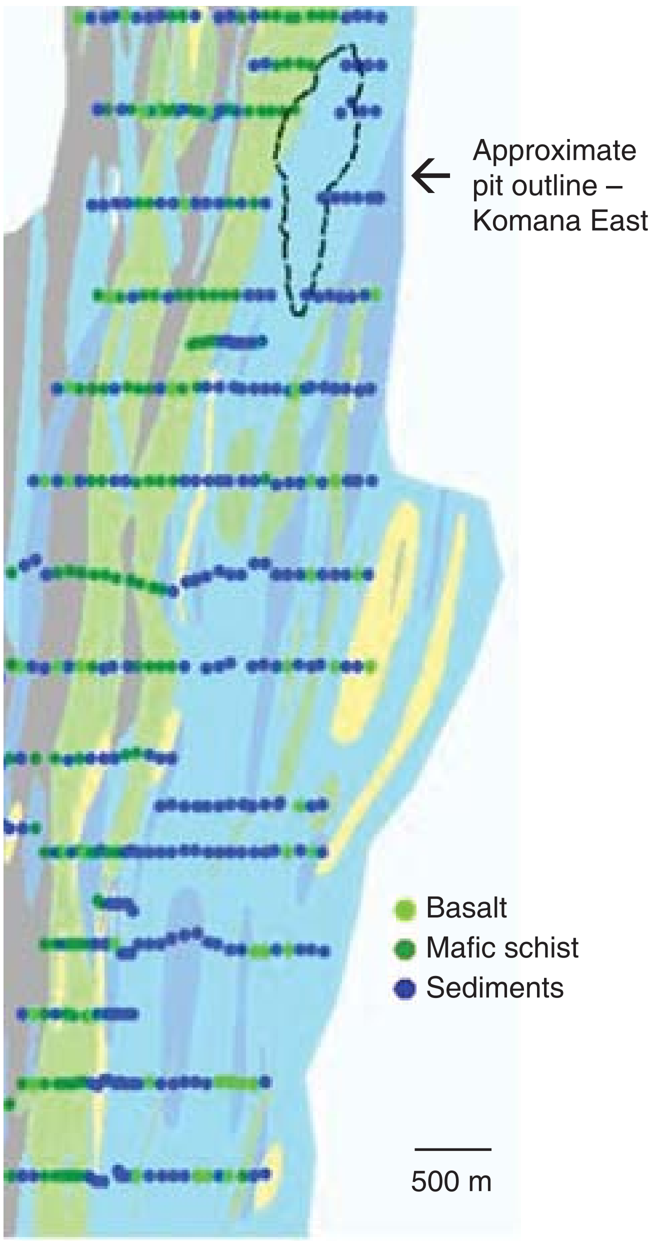
basalts and mafic schists being correctly identified.

Use of the pXRF becomes even more useful in the weathered environment. There is moderate to deep weathering of up to ~50 m in the Yanfolila area. The project uses angled air core drilling to obtain a consistent sample at blade refusal (which is usually 20-50 meters) and this is usually from the lower saprolite. Geologists can find it difficult to identify the primary bedrock lithology because of the intense weathering.

Samples from the bottom of the hole were sent to the laboratory for analysis by the same analytical method described for the drill core. Figure 4 shows the distribution of air core



Laboratory Data (4 acid, ICPMS) Cr vs Ti for KE

Figure 4. Classification of bottom of hole air samples (weathered samples) laboratory data using the Cr-Ti template. The samples are plotted on the geology map made by geologists from logging of drill core.

drilling for the Yanfolila project plotted on the district scale bedrock geology map. These samples have been classified with the Cr-Ti template constructed using fresh material using laboratory data and the results show that basalts and mafic schists are distinguished from the sediments.

As with the fresh material, the practical value of classification templates can be significant if the data from a portable XRF can be used. Field portable XRF data of the district wide bottom of hole air core samples are not available, so bottom of hole samples from a line of air core holes that traverses from Komana West to East were analysed using a pXRF. The results were classified using the Cr-Ti plot that was used with p-XRF discrimination parameters for fresh material. Figure 5 shows that sample classification using pXRF data agrees with the district scale geological map. The results shown here and other work carried on classifying weathered samples from RC drilling using laboratory and pXRF data have given the project geologists confidence in using lithogeochemical data to discriminate between rock types and has led to much improved consistency with the logging. The project team is now analysing all bottom of hole

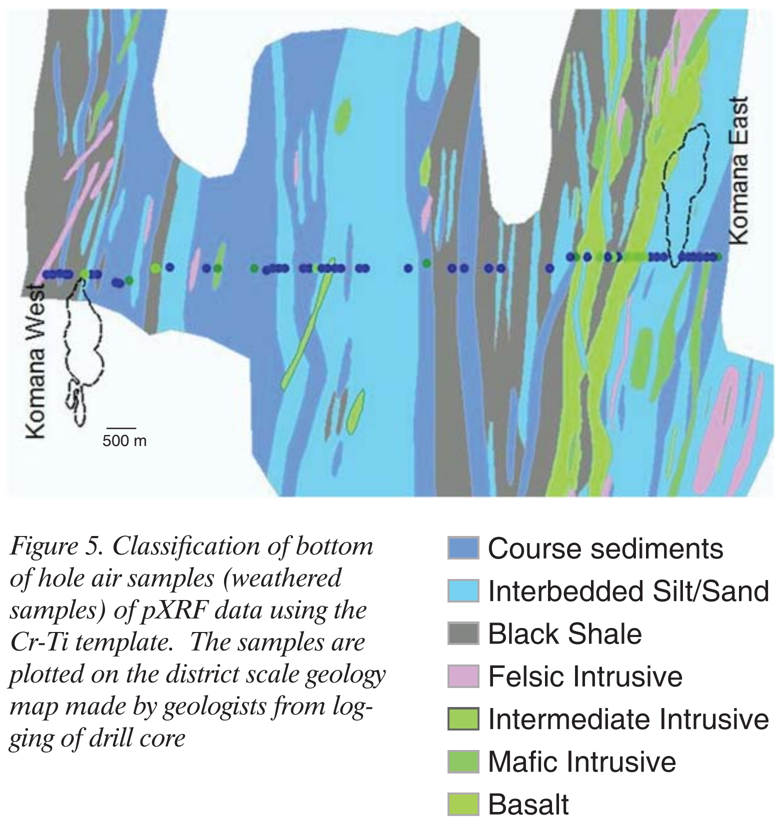


Figure 5. Classification of bottom of hole air samples (weathered samples) of pXRF data using the Cr-Ti template. The samples are plotted on the district scale geology map made by geologists from logging of drill core

air core samples from the weathered zone using the pXRF.

Soil sampling is used as a first pass exploration technique and also as a follow up technique for target definition. While used primarily for the detection of Au and, in some cases, pathfinder elements such as As and W, the possibility of applying the classification templates so as to characterise conceptually important basalt and other mafic lithologies was also investigated.

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The regolith in the Yanfolila area is a result of savannah type climate and is made up of a lateritic duricrust or cuirasse plateau underlain by a thin mottled zone and then an upper and lower saprolite. The landscape is formed by the scarp retreat and stripping through erosion of these distinct cuirasse plateaus which gives rise to erosional scarps and larger areas of proximally redistributed cuirasse material. With the exception of areas with depositional cover the regolith is thought to be relatively in situ.

Komana East is covered by 200 m x 50 m soil samples and the locations are shown in Figure 6a. Samples that cover the areas of transported cover (called the depositional regime on the regolith map) were considered to be ineffective and were removed from further consideration in this study. Classification using results from the laboratory analysis was carried out using a published classification plot for volcanic rocks using Ti-Zr (Hallberg 1984). The results of this classification plotted on the district scale regolith map illustrate that a broad distinction can be made between the mafic and sedimentary sequences in the belt.

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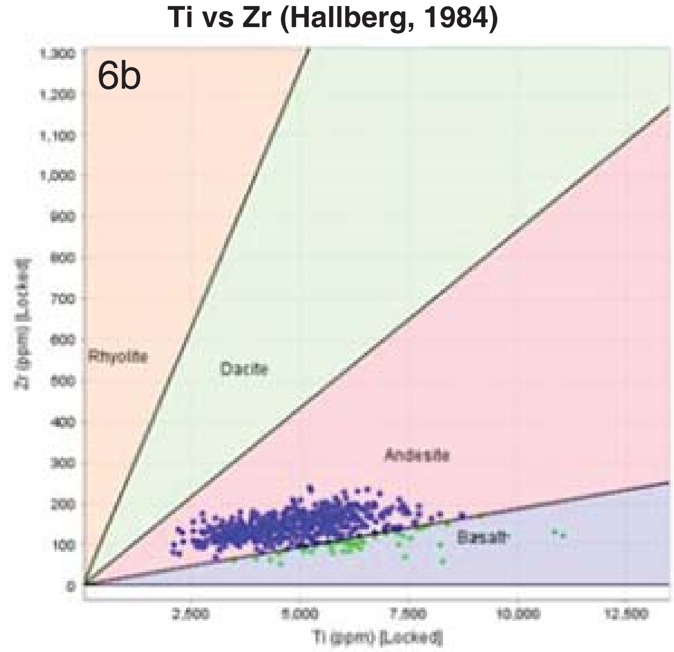

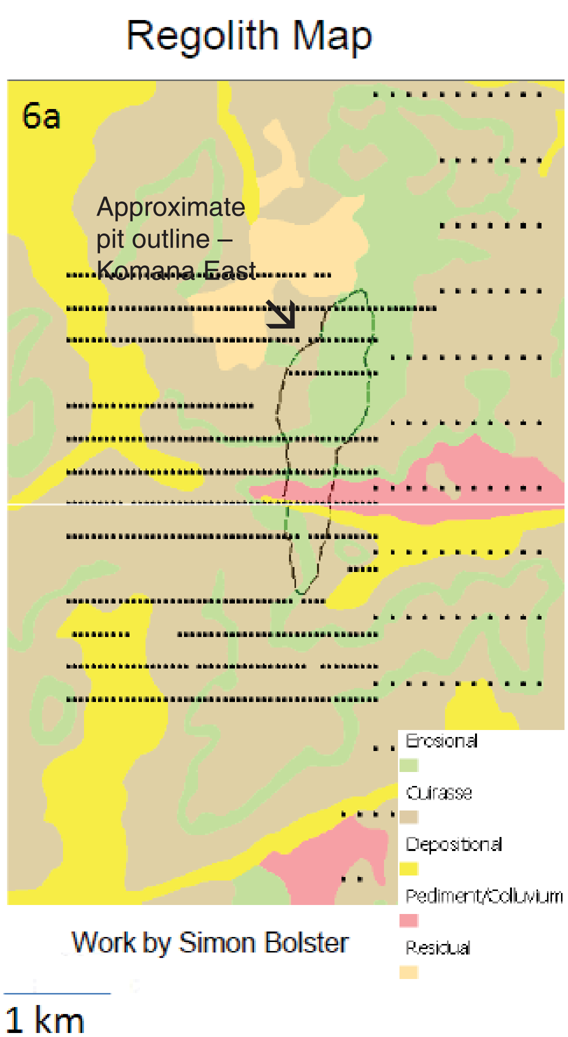

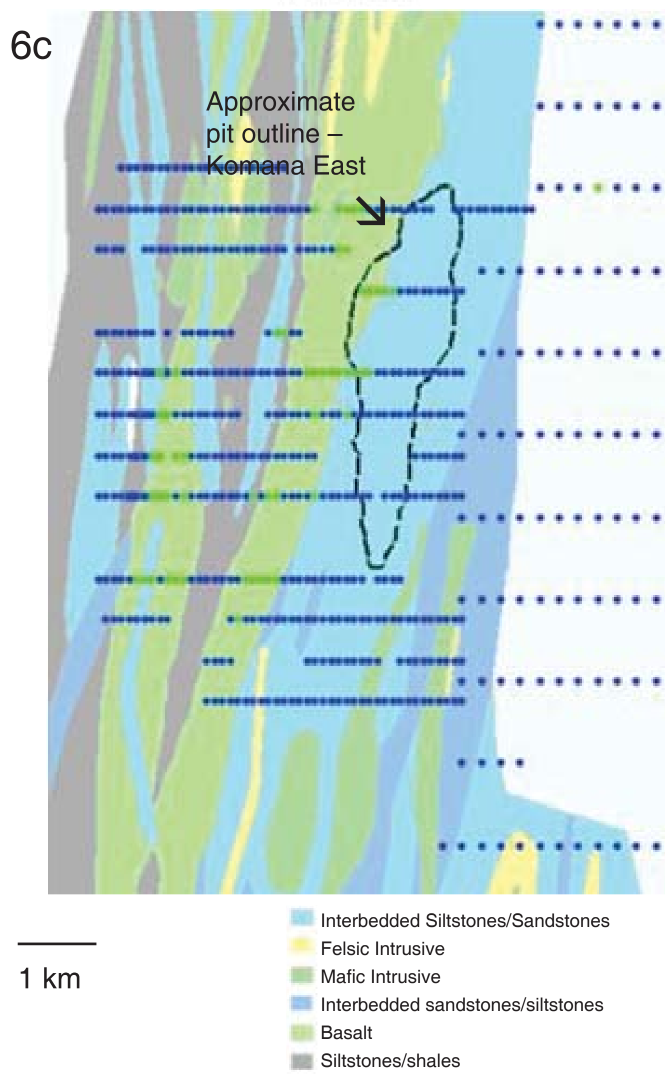

Figure 6a. Location of soil samples plotted on top of regolith map Figure 6b. Classification of soil samples using Ti-Zr plot and laboratory data. Samples that are from a depositional regime have been removed. Figure 6c. Results of the classification plotted on the district scale geology map

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This case history is an example from an exploration project in SW Mali showing how multielement geochemistry can be used to distinguish between different lithologies in fresh material and how this knowledge can be applied in the weathered environment and to a lesser extent with surface soil samples. These methods are particularly useful where consistent identification of the different lithologies by the project geologists is almost impossible.

While there have been other examples of this approach described in the last few years, a new dimension has been added here by using a portable field instrument to achieve the same outcomes. The exciting possibility is that the role of exploration geochemistry is expanding to the world of real time data and this is likely to significantly change how exploration work is carried out.

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