Field evaluation of fine grained industrial minerals

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Abstract: Evaluation of exploration targets for potential industrial minerals can sometimes be complex as many minerals share similar appearance and geological association. Examples include sepiolite, kaolin, pyrophyllite, zeolite and even bentonite which can all occur as pale-coloured, fine-grained alteration products within siliceous volcaniclastic sequences. This paper describes some simple physical and chemical test methods useful in field evaluation of certain industrial minerals. Such test methods rely on the determination of key characteristic or 'index' properties. They can be incorporated into 'screening programmes' to assist identification of high quality material in the field, to reduce the volume of laboratory analysis required by eliminating material of poorer quality. The methodologies are illustrated with examples from industrial mineral evaluation studies carried out by the British Geological Survey (BGS), including density testing to discriminate limestone from dolomite, classification of diatomite using physical property testing and identification of zeolite-rich rocks using a field test based on the rehydration of zeolite.

End of Abstract

Exploration for potential industrial minerals is largely based on knowledge of their mode of formation and likely geological associations (Carr, 1994; Harben and Kuzvart, 1996). Simple terrain models, otherwise known as industrial mineral domains (Mathers and Scott, this volume), can be used to inform an exploration programme by describing the geological and geographical setting in which potential industrial minerals deposits may occur. For example, large areas of the developing world (particularly Africa, South America and Asia) are dominated by basement terrains. These are characterised by high-grade metamorphic rocks, such as schist and gneiss, that may host a variety of industrial minerals such as asbestos, feldspar, graphite, kaolin, kyanite, marble, mica, sillimanite, talc and wollastonite (Bloodworth, 1994). Field identification of these minerals is based on their characteristic visual appearance and physical properties (Mathers, 1998). However, some industrial minerals may be difficult to identify as they occur as fine-grained, pale-coloured material, often in association with industrial minerals of similar appearance. It is at this stage of exploration that field test methods can be a useful aide to the identification and preliminary evaluation of industrial minerals. Field test methods used by the BGS in recent projects in developing countries are discussed below.

Dolomite-limestone test method

It is important, for cement resource prospecting, that a field geologist is able to quantify the relative amount of dolomite present in a carbonate rock. However the properties that are used to identify dolomite, such as crystal form, texture, colour, hardness, reaction with hydrochloric acid and staining, cannot always be relied upon when attempting to determine the dolomite content (Harrison *et al*, 1998). An alternative is mineral density, as the specific gravity of calcite and dolomite (2.71 g/cm^3 and 2.9 g/cm^3 respectively), is sufficiently different to enable a simple, density test method to effectively discriminate between calcite-rich and dolomite-rich carbonates.

The density test method is based upon that used in magnesite exploration in British Columbia, Canada by Simandl *et al* (1993). Sodium polytungstate ($3Na_2WO_4.9WO_3.H_2O$), which is a non-toxic, water soluble inorganic salt, is used as an alternative to toxic heavy liquids (such as bromoform and di-iodomethane) traditionally used for heavy media separation (Sometu, 2000). Sodium polytungstate dissolved in de-ionised water in varying weight : volume proportions can be used to form solutions with densities in the range 1 to 3.1 g/cm^3. The response of a rock chip placed into a solution, i.e. whether it sinks or floats, allows its density to be determined.

Exploration for carbonate resources, especially for the production of Ordinary Portland Cement, requires the identification of carbonate raw material with less than 3% MgO; equivalent to 13.7%

dolomite (Harrison, DJ, 1992). Sodium polytungstate solutions with densities of 2.7 g/cm^3, 2.75 g/cm^3, 2.8 g/cm^3 and 2.85 g/cm^3 enable the identification of carbonates with dolomite contents that are low (<10 wt%), moderately low (<30 wt%), moderately high (>30 wt%) and high (>65 wt%). The method was used in the assessment of the Ratburi Limestone from Surat Thani, Thailand. The dolomite content of the rock chips used in the field test was determined using a PIMA (Portable Infrared Mineral Analyser) and by TGA (Thermogravimetric analysis) (Table1 & Figure 1). The results show that the density-test correctly discriminated between dolomite and limestone in 95% of the rock chips tested. The method is a rapid and effective means of screening dolomite from limestone, enabling more efficient use of resources during exploration.

Diatomite classification test methods

The assessment of diatomite resources is typically based on laboratory evaluation of its characteristic properties. High purity diatomite has a white colour, high silica content, low specific gravity, low bulk density and high porosity. However, information can also be gathered during field exploration that can be used to classify the relative quality of diatomite for industrial use.

Field investigation of the diatomite found within the Lampang Basin of northern Thailand involved logging of quarry sections to determine lithology, nature of the beds, sedimentary structures, fracturing and faulting, presence of clay, iron and grit, colour, hardness, consolidation and density and approximate particle-size (Inglethorpe et al, 1998). The diatomite quality was determined by evaluating selected physical properties (Munsell colour, specific gravity, block density, calculated porosity and moisture content) of spot samples from the quarry sections. The chemistry of selected samples was determined by X-ray fluorescence (XRF) analysis. These data were used to generate graphical logs, an example of which is shown in Figure 2.

Some of the key features can be related to the quality of the Thai diatomite. The higher quality diatomite has a white colour (related to the visual colour; although this is influenced by its moisture content), a low Al_2O_3 content (related to the presence of clay) and a low Fe_2O_3 content (related to iron-staining). Thai diatomite identified as "high quality" by the field observations has a white colour, 75 to 80% SiO_2, 10 to 12% Al_2O_3, <5% Fe_2O_3, specific gravity 2.2 to 2.25 g/cm^3, block density 0.5 to 0.65 g/cm^3 and porosity 70 to 80%. The properties of this diatomite are similar to that produced commercially for the filter-aid market. This approach to diatomite exploration is a useful means of focusing limited exploration resources on material with a greater commercial potential.

Zeolite identification test method

Natural zeolites can readily be confused with other fine-grained industrial minerals such as bentonite, diatomite or chalk. Accurate identification and quantification of zeolite relies primarily on laboratory techniques as X-ray diffraction and thermal analysis. However, field methods exist that can indicate the presence and relative proportions of zeolite in rock samples.

A field test (based on Culfraz *et al*, 1973) was developed that relies on the reversible hydration characteristics of zeolite, specifically the exothermic nature of the rehydration process. Small samples (5 grams) of crushed zeolite (<1mm) are dehydrated by heating in a steel crucible to 350ºC and allowed to cool. Deionised water is added and the temperature is monitored. A sample of pure clinoptilolite (95%) would produce a temperature rise due to rehydration of approximately 10ºC. Samples can be classified as having low, medium and high zeolite contents - any rise in temperature >2ºC is an indication of the presence of a significant amount of zeolite.

During recent exploration work in Ecuador terrain models were used to identify the likely location of zeolite-rich rocks. Zeolites are found in a variety of geological settings, although the commercially exploited varieties (clinoptilolite, chabazite, erionite, mordenite and phillipsite) usually occur in altered, glassy volcaniclastic rocks, typically with a rhyolitic to dacitic composition. Localities within the Eocene-Miocene lacustrine tuff sequences in southern Ecuador and in Quaternary tuffs and lacustrine sediments to the north of Quito rocks were identified as ideal targets for zeolite exploration. Rocks containing zeolite were identified using a PIMA and the field test employed to determine the relative zeolite content of selected samples The field trials (selected results in Table 2) successfully indicated the presence of zeolite-bearing rocks.

Conclusions

Exploration for industrial minerals relies on an understanding of their likely mode of occurrence (geological setting). Field identification of industrial minerals is generally straightforward, but many have common geological associations and positive identification may be difficult, particularly if they are fine-grained. Field test methods can be useful for positive identification, and even quantification, of industrial minerals without lengthy and expensive laboratory analysis. Field test methodologies used in developing countries illustrate the value of this approach. The presence and relative proportions of dolomite occurring in carbonate rocks can be determined using the non-toxic heavy liquid, sodium polytungstate, as dolomite has a higher density than calcite. Systematic section logging and observation of physical properties such as colour, bulk density, particle-size and the presence of clay and iron staining can be used to assess the quality of diatomite sequences. The purity of natural zeolites can be assessed through the use of a field test that exploits their reversible hydration characteristics - rehydration of zeolite is exothermic and the rise in temperature is directly related to the zeolite content.

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Table 1. Selected density test, PIMA and TGA results, Ratburi limestone, Surat Thani, Thailand

Sample	**Dolomite**			**Calcite**	
Number (BST)	**Density test**	**PIMA**	**TGA**	**PIMA**	**TGA**
	Wt %	Wt %	Wt %	Wt %	Wt %
15	>65	90	91	10	9
29	>65	96	91	4	10
30	<30	18	2	82	99
34	<30	5	2	96	98
35	<30	12	7	89	91

NB PIMA = Portable Infrared Mineral Analayser; TGA = Thermogravimetric analysis.

Table 2. Selected zeolite field test results, southern Ecuador, 2000

Sample	**Description**	**Locality**	**Temperature rise** (°C)
PDEC56	Rhyolitic pumice lapilli tuff	Pimo	6.713
PDEC57	Rhyolitic pumice lapilli tuff	Pimo	7.083
PDEC58	Rhyolitic pumice lapilli tuff	Pimo	7.831
PDEC77	Tuffaceous sandstones & siltstones	Saraguro	8.563
PDEC106	Zeolitised rhyolitic tuff	Oña	10.152

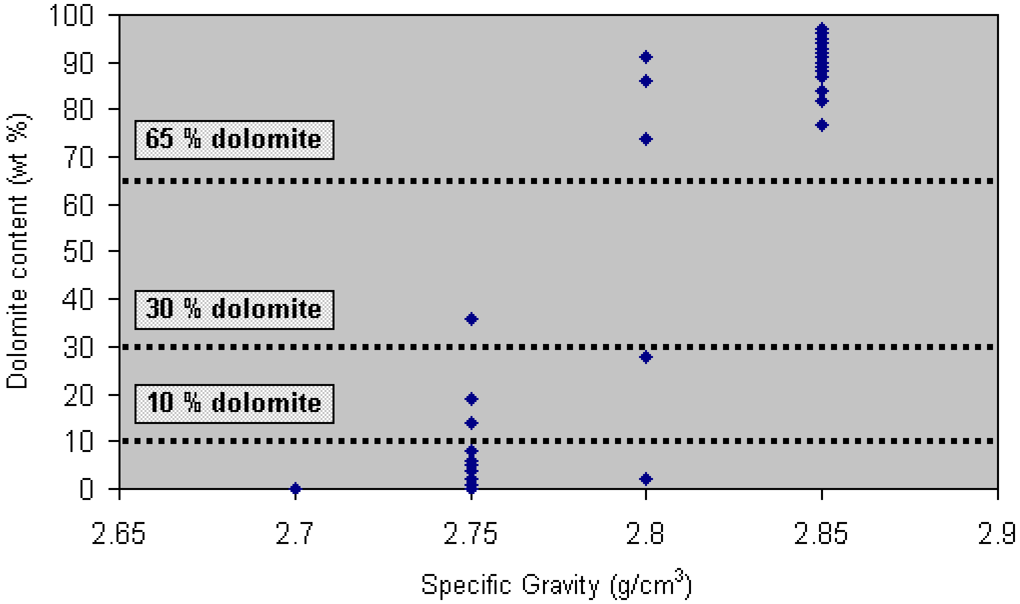

Fig. 1. *Sodium polytungstate density-test screening of dolomite and limestone samples, Surat Thani, Thailand*

(**NB** Specific gravity, in g/cm^3, of rock chips equivalent to dolomite content, wt %, as follows: 2.7 g/cm^3 = <10%, 2.75 g/cm^3 = <30%, 2.8 g/cm^3 = >30% and 2.85 g/cm^3 = >65%)