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Mineral characterization as a tool in the implementation of geometallurgy into industrial mineral mining

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ABSTRACT

Industrial minerals play an important role in the Norwegian mining industry. The presented research focuses on defining marble deposit variability in order to evaluate parameters that can potentially be related to downstream process performance. Two types of marble raw material (K2 and K5) from the Verdalskalk open pit, used for precipitated calcium carbonate production (PCC) were tested for possible differences within texture, grain boundaries shape, grain size, accessory mineral assemblage. Additionally, surface hardness was measured using the Proceq Equotip 3 D device. K5 type was found to be finer-grained compared to K2. The presence of quartz was more pronounced in K2 type material, which possessed higher surface hardness values and presented higher variation of those.

1. Introduction

With growing needs for ores and industrial minerals it has become essential to aim at constant improvement in recognition of the deposits and commodities not only in the geological but also mineral processing sense.

Chemical analysis and geological mapping are the main tools used to classify the raw material into different types and qualities. The presented study aims to recognize, describe and quantify mineralogical and textural properties of a calcite marble deposit and define parameters that can be used for qualifying the deposit into different geometallurgical domains.

The specific objectives of this research are:

- to describe and compare the mineralogical and textural properties of two types of marble used for Precipitated Calcium Carbonate (PCC) production
- to present and compare surface hardness test results for both types of marble
- to define potential links between surface hardness values and the mineralogical and textural properties
- to verify the appropriateness of the Equotip 3 D as a portable time- and cost efficient geometallurgical test tool for surface hardness measurement in marble deposits.

2. Background

The Tromsdalen deposit operated by Verdalskalk AS is located in Mid-Norway. The deposit, being low metamorphic grade calcitic marble of the Ordovician period, is estimated to be 7.5 billion tonnes. The marble unit is situated between greenschist and phyllite units (Fig. 1A). Due to folding the units occurs in reverse order, with greenschist situated on top the marble and phyllitic strata laying underneath (Gautneb, 2012).

The Tromsdalen marble is fine to medium grained, greyish with lighter and darker bands (Fig. 1B). The typical marble is relatively pure. Most common impurities for Tromsdalen marble are iron oxides, iron sulfides and silicate minerals. Graphite, pyrite, quartz, pyroxene, muscovite and apatite are typical for carbonate rocks (Korneliussen et al., 2014).

The marble is mined in an open pit operation. Based on chemical data as well as physical appearance (color), the deposit is subdivided into 6 marble types (Table 1). The types are assigned to production qualities based on the CaO, Fe_2O_3, SiO_2 and Al_2O_3 content. XRF analysis control is performed on drill cores, drill chips and along production line.

The A (pure) quality consists of types K1, K2 and K5 and is used as raw material for the burned and slaked lime production. The blasts consisting of blended pure and impure marble (e.g. K2 and K3) are classified as B (standard) quality and used as feed to a kiln operated by a different company with lower purity standards. The lower purity K3 and K4 type raw material is used for cement production (C quality).

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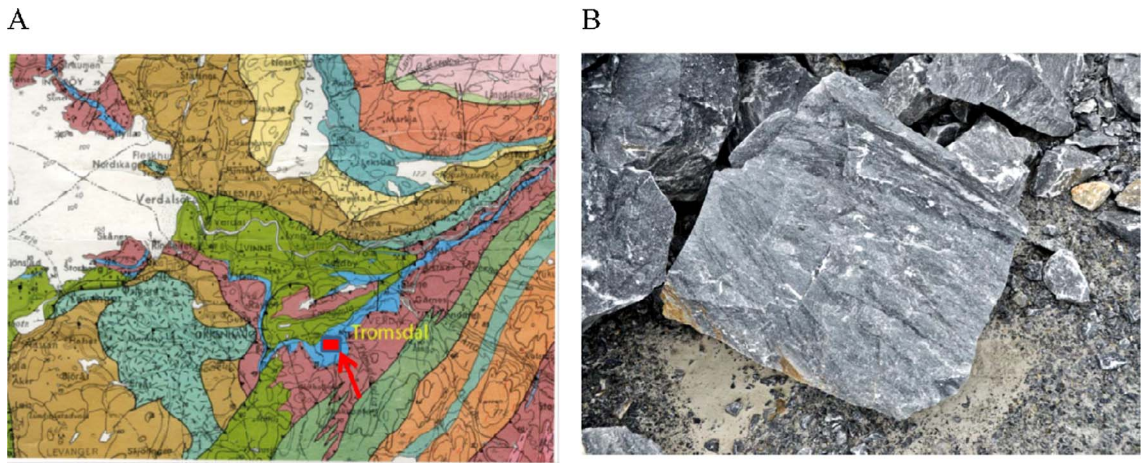

Fig. 1. Geological overview of the Tromsdalen area (A); the marble unit (blue) is located between greenschist to SE (violet) and phyllite to NW (green) (Gautneb, 2012). Typical Tromsdalen marble (B).

Table 1
Quality requirements for marble types in Tromsdalen deposit.

Type No.	Name	Quality requirements		
		CaO (wt%)	Fe_2O_3 (wt%)	SiO_2 (wt%)
K1	Light-grey pure marble	> 54.5	< 0.06	< 0.5
K2	Dark-grey pure marble	> 54.5	< 0.06	< 0.5
K3	Dark-grey impure marble	> 50.0	> 0.12	No requirements, given the purity of the deposit
K4	Light-grey impure marble	> 50.0	> 0.12	
K5	Black marble, pure	> 54.5	< 0.06	< 0.5
K6	White marble, impure	Waste material, no requirements		

Type K6 occurs as a thin strata on a contact with a greenschist unit and is not utilized in production due to high impurity levels (Ruiz J.R., pers.com, 06.03.2015).

The raw material of pure quality is crushed and screened at the mine site before it is transported by truck to the kiln, where it is converted to quicklime (burned lime, CaO), which is the main product from the mine. The CaO is used for PCC production. The crushing plant at the mine site consists of roller crushers with primary and secondary crushing lines. Crushed products are screened to the 30–100 mm fraction, which is then fed to the kiln. At Verdalskalk the calcium oxide is produced in a two-shaft Maerz kiln due to the reaction:

$CaCO_3 + Heat \rightarrow CaO + CO_2\uparrow$, in temperatures reaching 1000–1200 °C in the burning zone (Storli, A.M., pers.com, 07.03.2015).

Currently, marble types K2 and K5 are fed directly to the kiln. They both are of equally high purity but there is an indication, based on operator experience, that marble type K2 has less stable processing performance in the kiln than marble type K5. With similar geochemical data between marble types K2 and K5, there is a need for understanding which mineralogical parameters other than bulk geochemistry influence the kiln performance.

Hence it is reported (Boynton, 1966) that grain size differences can cause changing of the calcite heating pattern in the kiln, as coarse grains tend to crack instead of dissociate, therefore this parameter should be taken into account when classifying raw material into processing types.

The current research is a part of the project aiming at incorporating the aspects of geometallurgy into industrial mineral operations. Typically, geometallurgy is used in metal mining. However, it can be also used for better recognition of process performance and quality needs within industrial minerals.

The main goal of this study is to define new key performance indicators (KPIs) within industrial mineral mining, establishing the links between them and “traditional” indicators such as chemistry, and searching for geometallurgical tests that are suitable for industrial minerals operations. Lischuk et al. (2015) described two main approaches to establish the links utilized in geometallurgy: the mineralogical approach and geometallurgical tests. In the presented research both approaches were applied: mineralogical characterization of the commodity was performed and surface hardness test was examined as potential geometallurgical testing method.

3. Materials and methods

3.1. Materials

3.1.1. Mineralogy

The sampling campaign for the microscopic study was performed in the Tromsdalen calcite marble deposit in the blast piles after production blasting.

Material from four production blasts, VB11-2016, VB13-2016, VB16-2016 and VB19-2016 was tested and 9 samples were collected from each blast (Table 2). In order to test potential variabilities of the marble within mostly homogenous blasts the samples were collected along the pile and the emphasis was laid on collecting samples that showed visual variations. The distribution of the samples along the blasts is illustrated in Fig. 2.

Blasts of two different marble types – K2 and K5, both used as a raw material for the kiln, were selected for the study.

3.1.2. Surface hardness

For the surface hardness measurements, the sampling areas were selected among the largest, stable blast fragments (Fig. 3) and the measuring points were located on the most even surfaces with minor topography and fractures, and with the least trace of weathering and alteration.

A total amount of 110 sample surfaces from 10 separate production