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Research paper

Behavior of talc and mica in copper ore flotation

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ABSTRACT

Talc and mica are major gangue minerals in many base metal ores including sulfide ores. Talc is a naturally hydrophobic mineral, and therefore it is easily floatable. There have been many studies to overcome this problem, and depress talc with various reagents. In this study the flotation of a copper ore in the presence of talc and muscovite was studied. It was found that talc can affect copper flotation mainly via froth phase. The copper grade and recovery were affected in the presence of only 7% talc. On the other hand, muscovite influenced the pulp phase via affecting the pulp rheology. The copper flotation grade was reduced in the presence of high amount (30%) of muscovite due to the entrainment, but its effect on the copper recovery was negligible.

1. Introduction

It is well known that clays have the potential to significantly affect mineral processing (Ndlovu et al., 2013; Basnayaka et al., 2017). In particular, copper ores often contain different clays which can affect metallurgical processing such as flotation. Therefore, the deleterious effect of clays on froth flotation has been a topic of interest to many researchers. Since copper flotation is quite important in many countries such as Australia, Chile, South Africa, Canada, USA, copper ores or pure copper containing minerals (e.g. chalcopyrite) have been often used in these studies. While the effect of some clays such as kaolinite and bentonite on mineral flotation has been widely investigated (Wang et al., 2015), there is no systematic study on the effect of talc and muscovite (as representative of Mg and Al containing clays, respectively).

Clays are phyllosilicates made up of varying combinations of stacked tetrahedral (T) and octahedral (O) sheets. A tetrahedral sheet comprises silicon-oxygen (Si—O) tetrahedrons with shared basal oxygen molecules making up the T layer. The octahedral layer, on the other hand, takes on the structure of either brucite ($Mg(OH)_2$) or gibbsite ($Al(OH)_3$). These T and O layers are held together by strong hydrogen bonds to form either 1:1 clays, consisting of one tetrahedral and one octahedral sheet in a T-O formation, or 2:1 clays, where 2 tetrahedral sheets are bonded with one octahedral sheet in a T-O-T structure.

Talc ($Mg_3(Si_2O_5)_2(OH)_2$) has a T-O-T (2:1 structure), comprising an octahedral brucite O layer sandwiched between 2 silica T layers. T-O-T layers are held together by weak van der Waals forces (Fig. 1). This structure results in a talc surface structure comprising two different surfaces, the basal cleavage face and the edge. The face surface, which occupies approximately 90% of the talc surface, consists of a tetrahedral siloxane surface with inert –Si-O-Si- links, and is nonpolar, and therefore, hydrophobic. Conversely, the edge surface is hydrophilic due to the presence of pH dependent SiOH and MgOH groups. The proportionally larger face surface area gives talc its natural hydrophobic character (Deer et al., 1992).

Muscovite (KAl_2 ($AlSi_3O_{10}$)$(OH)_2$) also has a T-O-T (2:1) layered structure, with a gibbsite O sheet held between the silica layers (Fig. 1). The tetrahedral layer is negatively charged due to isomorphic substitution of about 1/4 of the Si^{4+} ions by Al^{3+} ions. These negative charges are balanced by interlayer K^+ ions, which hold subsequent T-O-T structures together. This results in a T-O-T —K— T-O-T layer that bind to another T-O-T –K– T-O-T layer by weak van der Waals bonds. It is along these layers of weak bonding that the prominent cleavage in the sheet silicates occurs.

Talc causes processing problems due to its hydrophobicity which makes this mineral naturally floatable. In addition, as talc is a magnesium silicate mineral, large quantities of talc in flotation concentrates cause problems during smelting, often resulting in the imposition of smelter penalties for mineral processing companies (Beattie et al., 2006). The depression of talc in flotation, and its interaction with natural or synthetic depressants have been widely investigated (provide refs). However, the actual effect of this phyllosilicate in flotation, and in particular its separate effect on pulp and froth phases in flotation is not well known. In addition, the critical concentrations which must be considered in designing mineral process plants when dealing with talc containing ores is also not known. There is also very little research that

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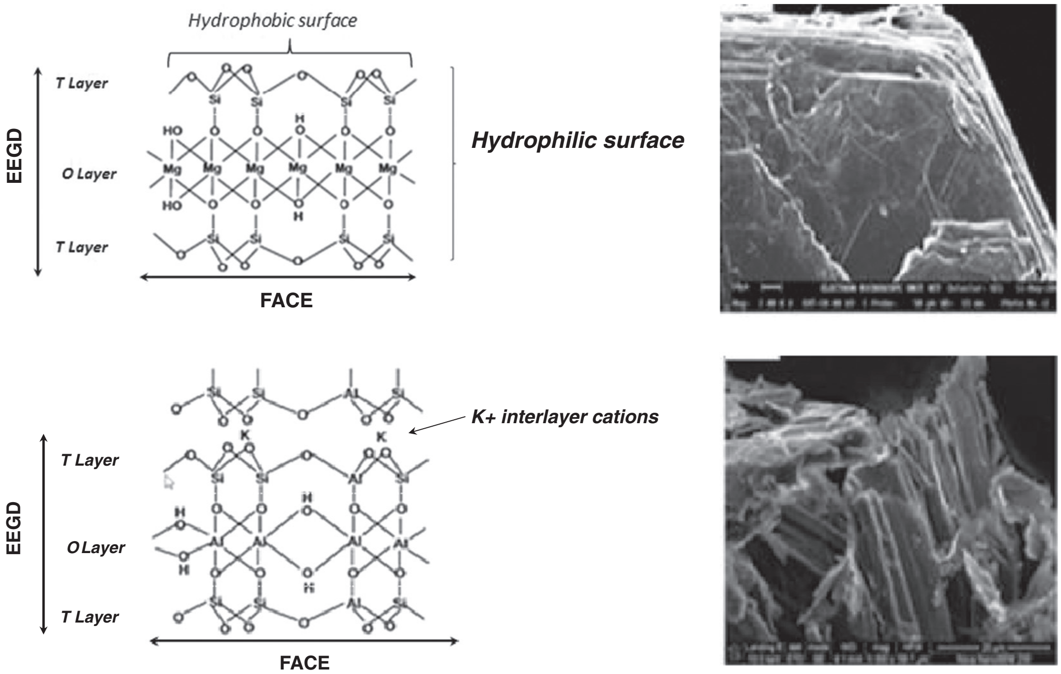

Fig. 1. Schematic of the structure and SEM images of talc (top), and muscovite (bottom) (Yan et al., 2011; Ndlovu et al., 2013).

investigates the effects of muscovite on flotation.

The aim of this study is to understand the effects of talc and muscovite (as representative of Mg and Al containing clays, respectively) on the flotation of a copper ore through examination of the grade and recovery behaviour, pulp rheology, and froth characteristics. In particular, it investigates whether the pulp or froth phase are affected in the presence of these clay gangue minerals. The critical concentration at which such deleterious effects are occurred is also investigated. When these deleterious effects are fully understood then the ways to prevent these effect, and how to separate these type of clays from an ore would be the subject of future investigations.

2. Materials and experimental methods

A high level summary of the approach used, outlining the materials, and measurements conducted is given in Fig. 2.

2.1. Materials

The copper ore sample was obtained from Northparkes Copper & Gold Mine, Australia. This ore was chosen due to its relatively unproblematic flotation characteristics. Such an ore provides a formidable baseline for the identification of the deleterious effects of clays. The chemical assays of the ore sample contains 0.5% Cu, 3.8% Fe, and 0.3% S. The mineralogical analysis of the ore determined using XRD is presented in Table 1. Talc and muscovite samples were obtained from Ward's Science. The chemical analysis of the clay samples have been also provided in Table 2.

2.2. Flotation tests

Flotation tests were conducted using a bottom driven flotation cell (JKTech, Australia). The bottom driven cells allow the operator to remove froth from the entire surface of the flotation cell. This minimizes operator error and maximizes test reproducibility. The ore was ground to P_{80} of 90 µm (P_{50} of 50 µm). Tests were conducted on slurries comprising the copper ore and varying concentrations of talc and muscovite. The flotation tests were conducted at 32 wt% slurry (as it is common in flotation work). The overall slurry wt% was kept constant despite the increasing addition of talc and muscovite in order to avoid the effects of slurry wt% on the rheology. In each case, the low grade copper ore was "doped" with increasing concentrations of talc and muscovite and the grade and recovery were determined. The pH was maintained at pH 9.8 using KOH and/or HCl. This is the pH condition at which most industrial flotation operations are conducted. Potassium amyl xanthate (PAX, obtained from Tall Bennett Group) and methyl isobutyl carbinol (MIBC, obtained from Shell Chimie) were used as collector and frother, at dosages of 100 g/t and 40 ppm, respectively. For each test, three concentrates were collected at 10 s intervals over 1, 3 and 5 min (cumulative). The air flow rate, conditioning time, and impeller speed were 3 L/min, 1 min, and 1000 rpm, respectively. The experiments were carried out using Brisbane tap water.

During flotation, froth images were taken and analysed using VisioFroth software developed by Metso Minerals Cisa for bubble size distribution. A full description of the VisioFroth system is given by Runge et al. (2007), and it has been used in different studies (Kurniawan et al., 2011; Wei et al., 2014).

2.3. Froth stability tests

Froth stability is known to play an important role in determining mineral flotation recovery and selectivity (Tang et al., 1989; Barbian et al., 2005; Ozdemir, 2013). The presence of clays in ores can dramatically affect froth stability (Karakashev et al., 2011; Farrokhpay et al., 2016). When clays are present as individual particles, they may adsorb a large amount of reagents due to their large surface area. Therefore, they may decrease froth stability. Froth can also become highly flocculated and dry, and therefore difficult to be removed during the flotation. On the other hand, the presence of fine particles may increase the froth stability, something which is often referred to as "Pickering stabilization".

The effect of talc and muscovite on the froth stability of copper ore slurry was investigated using a froth column (Fig. 3). The froth stability was analysed using slurries of similar concentrations of the ore and talc/muscovite as used in the flotation tests. A similar method has previously been used to assess froth stability (Zanin and Grano, 2006; Farrokhpay and Zanin, 2012). The column is equipped with an impeller to ensure sufficient pulp agitation. In each case, a 2 L slurry comprising