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Research paper

Kaolin deposits and their uses: Northern Brazil and Georgia, USA

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ABSTRACT

Kaolin mineral-bearing rocks are classified by their mineralogy and texture, which delineate their potential use. Refractory clay products are made from a continuum of ores comprising fire clay, bauxitic kaolin and bauxite. Ceramic clay products are made from a range of ores comprising near pure kaolin, ball clays, plastic clays, kaolinitic sandstone and china clays along with some other clay minerals that impart plasticity and having some other non-clay minerals such as quartz and feldspar that allow a white-burnt appearance at a specified melting temperature. Pigments and additives are beneficiated from kaolinitic rocks that have textures which permit particle dispersion for size classification and for removal of impurities. The diverse mineralogy and texture found in Georgia, USA sedimentary kaolin deposits explain their range of beneficiation processes and uses. Capim [Brazil] soft kaolins are mostly used for pigment applications because of their mineralogical purity, ease of dispersion and geological homogeneity, which permits large-scale production of products having consistent quality.

1. Introduction

Kaolin mineralogy and texture have a continuum with other kaolin mineral-bearing rocks such as bauxites, ball clays, plastic clays and kaolinitic sandstones. The uses of kaolin-bearing ores follow the same general classification with bauxitic kaolins used for refractories; micaceous and/or smectitic kaolins used for ceramics; and easily dispersed kaolin and quartz-bearing kaolin used for pigments and additives. Nearly pure kaolin allows for a wide range of uses so long as its textural features such as hardness, dispersibility and plasticity permit processing. Ultimately deposit economics determine a kaolinitic ore's most suitable use. The mineralogy, texture and use of different kaolin types are examined in the context of examples from deposits mined in northern Brazil near Rio Capim and in Georgia, USA.

1.1. Previous work

Haydn Murray was a key authority on World kaolin deposits and their use. His work involves studies on the geology and origin of kaolin deposits in Georgia and South Carolina (Murray, 1976), Arkansas (Salter and Murray, 1993), Idaho (Pruett and Murray, 1993), Kentucky, Tennessee and Missouri (Murray, 1982), Saskatchewan (Pruett and Murray, 1991), northern Brazil (Murray et al., 2007; dos Santos et al., 2007), Argentina (Dominguez et al., 2010), Guyana and Surinam (Murray, 2008), China (Yuan and Murray, 1993), New Zealand (Harvey and Murray, 1993). His work relating kaolin mineralogy to their applications as paper and paint pigments, as functional fillers for rubber, plastics and ink, as raw materials for ceramics, fiberglass and cement, and for multiple small volume specialty applications is described in Murray (2007). Dr. Murray's contributions are well established and a significant portion of his studies were based on his fundamental understanding of the Georgia, USA kaolins and those of northern Brazil.

1.2. Types of kaolin

Kaolin deposits are subdivided into the general categories of primary and sedimentary based on their genesis and geological occurrence. Primary deposits include residual weathering horizons, and hydrothermal alteration zones along fracture networks, that are hosted in feldspathic igneous rocks such as granite and feldspathic metamorphic rocks such as gneiss. The term kaolin originates from a primary deposit located in China (Chen et al., 1997) and the term is synonymous with china clay. Sedimentary kaolin is transported kaolin hosted in siliciclastic sediments. Sedimentary kaolin comprise of a continuum that range from mostly detrital kaolinite particles deposited as clay- or silt-sized sediments to mostly kaolinized sediments that were initially comprised of feldspar particles, mica particles and labile rock fragments that altered to kaolin minerals by processes of weathering, post-depositional alteration, or both. Mining methods applied to most sedimentary deposits are similar because spatial uniformity along the primary bedding

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plane direction versus perpendicular to bedding surfaces which shows more mineralogical and textural variation.

1.3. Classification of kaolin mineral-bearing rocks

The general mineralogical classification of economic kaolin-bearing rocks is summarized in Fig. 1, and though most of the terms used apply to sedimentary deposits, primary kaolin have similar mineral content and in many examples similar texture. The general mineralogical classifications uses three ternary diagrams to differentiate kaolin type based on the relative concentration of the two or three most abundant mineral groups. The ternary diagrams have one apex for kaolin minerals group, with kaolinite being the most common phase in economic deposits, halloysite being uncommon, and dickite and nacrite being rare. The ternary diagrams formed with the kaolin minerals apex are (a) with alumina hydroxides such as gibbsite, boehmite and diaspore, and with titania, and iron oxides and hydroxides, (b) with quartz and possible unaltered feldspar, and with titania and iron oxides and hydroxides, and (c) with quartz and possible unaltered feldspar, and with other phyllosilicates such as micas, illite, smectite, hydroxyl interlayer vermiculite and other mixed-layered clay mineral. The adjacent arrangement of the three ternary diagrams is useful for display of the large mineralogical variation of kaolin and kaolinitic rocks. Bauxitic mineral assemblages comprised of alumina hydroxides typically don't occur with rocks containing high concentrations of quartz, feldspar and alkali-bearing phyllosilicates such as mica. Ball clays are typically nearly white after firing (Hosterman, 1984) because they have low amounts of iron-bearing minerals and titania (McCuiston and Wilson, 2006).

1.3.1. Bauxitic ores

The ternary diagram on the left in Fig. 1 shows the bauxitic and refractory clays. These clays typically contain very low amounts of alkali elements and their primary silica source is kaolinite. Bauxitic kaolin or clay contains no more than 50 wt.% bauxitic minerals (Gordon et al., 1958; Konta, 1958) and have between 47% and 65% alumina on a fully calcined basis (Anon, 1997), which represents between 2% and 35% gibbsite content with kaolinite. High amounts of iron oxides and hydroxides, and titania limit a bauxite or kaolin's use for most refractory, ceramic and pigment applications. Gordon et al. (1958) set 17.4 wt.% as the maximum iron oxide/hydroxide and titania mineral concentration limit for low iron bauxite and bauxitic kaolin, and they set 50 wt.% as the maximum iron oxide/hydroxide and titania mineral limit for high iron bauxite and bauxitic kaolin. Maximum iron oxide/hydroxide and titania amounts proposed by Gordon et al. (op. cit.) for low iron bauxite and low iron bauxitic kaolin are not appropriate for all applications such as refractories having iron oxide amounts less than about 3 wt.% (Anon, 1992).

1.3.2. Kaolin

Kaolin is a claystone comprised mostly of kaolin minerals that is white or nearly white, or can be beneficiated or fired to become white or nearly white. Iron-bearing minerals such as hematite, goethite and anatase (Pruett, 2012) are the most common discoloring minerals in kaolin ore. Beneficiating a kaolin to be nearly white is probable for kaolin ore containing a total less than about 6 wt.% of iron oxides and hydroxides, and titania (Pruett and Alves, 2013), and beneficiating a nearly white clay is possible though economically more difficult for some kaolin containing higher amounts of iron oxides and hydroxides, and anatase. Keller (1968) described clays containing greater than 3 wt.% iron oxides, that typically contained 1% to 3% titania, as useless to the ceramist. The maximum iron oxide/hydroxide and titania levels for kaolin is established at about 10 wt.% in Fig. 1 with the knowledge that iron oxide/hydroxide and titania texture and mineralogy combined with beneficiation process determine if a kaolin can be beneficiated or fired to nearly white.

1.3.3. Kaolin containing quartz and feldspar

Many sedimentary kaolin deposits have textures ranging from mudstone to kaolinitic sandstone that are described by the kaolin-quartz-iron oxide/titania ternary diagram shown in the center of Fig. 1. The minimum amount of kaolin minerals in kaolin ore deposit is defined by Harbin and Bates (1984) as about 10 wt.%. Kaolinitic sandstone has between 10% and 50% kaolin minerals, as do many saprolite and hydrothermal kaolin deposits that contain quartz and possibly some unaltered feldspar. Sandy kaolin generally has between 5% and 50% sand-

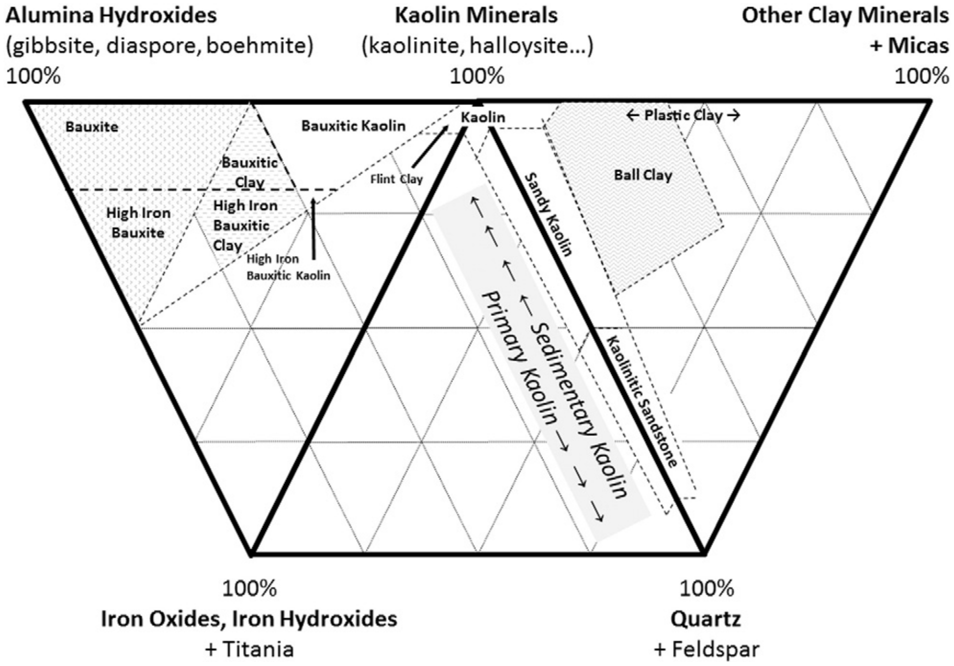

Fig. 1. Three ternary diagrams used for the classification of industrial clay ores that contain high amounts of kaolin minerals or mined for kaolin used in industrial applications. The ternary diagram used for classifying an ore is selected by the most abundant mineral assemblage: kaolin minerals–alumina hydroxides–iron/titanium oxides (left), kaolin minerals–iron/titanium oxides–quartz/feldspar (middle), or kaolin minerals–quartz/feldspar–other phyllosilicates (right).