Feldspathic Minerals

Introduction – Apakah itu Feldspar?

Feldspar is the most common rock-forming mineral (about 60% of the earth’s crust) (Kauffman and Van Dyk, 1994). The mineral name feldspar is derived from the German words feld + spar. The word “feld” is “field” in German and “spar” is a term for light colored minerals that break with a smooth surface. Feldspar minerals are usually white or very light in color, have a hardness of 6 on the Mohs’ Scale of Hardness and perfect to good cleavage (plane of breakage) in two directions.

Feldspar is a common name that applies to a group of minerals with a general chemical formula of $\text{X} \text{Al(Al,Si)}_3\text{O}_8$, where X can be sodium (Na) and/or calcium (Ca) and/or potassium (K). (Specific compositional varieties (i.e. albite, microcline…) are discussed under Mineral Descriptions).

Feldspar occurs in igneous, metamorphic and sedimentary rocks and thus can be found throughout different geological environment. It is more commonly found in igneous and metamorphic rocks. Feldspar weathers to kaolin which is the main clay mineral used in ceramics and fine pottery.

Mineral properties

Feldspar is the most common rock-forming mineral. Feldspar is a name for a group of minerals with a general chemical formula of $\text{X} \text{Al(Al,Si)}_3\text{O}_8$, where X can be one or more elements. Feldspar minerals are usually white or very light in color and have a hardness of 6 on the Mohs’ Scale of Hardness. Another physical property of the feldspar group is that the mineral has good cleavage in two directions. The cleavage breaks are about 86° for plagioclase feldspars (albite, oligoclase, andesine, labradorite and anorthite), at 90° for orthoclase and 89.5° for microcline. Upon weathering, feldspar minerals break down to form kaolinite, a clay mineral.

Most deposits offer sodium feldspar as well as potassium feldspar and mixed feldspars. Feldspars are primarily used in industrial applications for their alumina and alkali content. The term feldspar encompasses a whole range of materials. Most of the products we use on a daily basis are made with feldspar: glass for drinking, glass for protection, fibreglass for insulation, the floor tiles and shower basins in our bathrooms, and the tableware from which we eat. Feldspar is part of our daily life.

Feldspar minerals are essential components in igneous, metamorphic and sedimentary rocks, to such an extent that the classification of a number of rocks is based upon feldspar content. Chemically, the feldspars are silicates of aluminium, containing sodium, potassium, iron, calcium, or barium or combinations of these elements.

The crystalline structure of feldspars consists of an infinite network of SiO$_2$ and AlO$_4$ tetrahedra. The mineralogical composition of most feldspars can be expressed in terms of the ternary system Orthoclase (KAlSi$_3$O$_8$), Albite (NaAlSi$_3$O$_8$) and Anorthite (CaAl$_2$Si$_2$O$_8$) (Appendix A). They usually crystallise in the monoclinic or triclinic system.
The minerals whose composition is comprised between Albite and Anorthite are known as the **plagioclase feldspars**, while those comprised between Albite and Orthoclase are called the **alkali feldspars**. This latter category is of particular interest in terms of industrial use of feldspars.

Amongst the numerous rocks in which they are present, feldspars are particularly abundant in igneous rocks like **granite**, which contains from 50 to 70% of alkaline feldspar. Granite is however rarely used for its feldspatic content. However, a whole range of rocks geologically connected to granite are used. Most often, commercial feldspar are mined from **pegmatite** or **feldspathic sand** deposits. **Aplite**, which is a fine-grained igneous rock with the same mineralogical composition as granite, is also frequently mined for its feldspar content.

The minerals of which the composition is comprised between Albite and Anorthite are known as the **plagioclase feldspars**, while those comprised between Albite and Orthoclase are called the **alkali feldspars** due to the presence of alkali metals sodium and potassium. The **alkali feldspars** are of particular interest in terms of industrial use of feldspars. Most often, commercial feldspar is mined from **pegmatite** or **feldspathic sand** deposits. **Aplite**, which is a fine-grained igneous rock with the same mineralogical composition as granite, is also mined frequently for its feldspar content. Alaskite is a granitic rock with few or no dark minerals, and a texture ranging from granitic to pegmatic. Another source of feldspar is **phonolite**, the effusive equivalent. Of **nepheline syenite**, which contains feldspathoids and biotite? Phono;ite is produced commercially in West Germany. In the same country, **rhyolite** is also exploited for feldspar. **Beach sand** and alluvial deposits may contain economic quantities of feldspar, and are mine in Spain. Under certain conditions feldspar decomposes to **koalinitic clay**; if the alteration is only partial, the deposits may contain feldspar, kaolin and quartz.

Feldspar raw materials are rocks with the prevalent portion of minerals of the feldspar group or their mixtures in such a form, quantity and quality, which allow their industrial processing. Feldspars are a group of monoclinic (orthoclase, sanidine) and triclinic (microcline, plagioclases) **potassium** and **sodium-calcium aluminosilicates**, and together with quartz they represent the most common rock forming minerals. For industrial use are suitable are **potassium feldspars** (orthoclase, microcline) and **acid plagioclases** (albite, oligoclase, andesite). Suitable feldspar resources are dike rocks (pegmatites, apilites), igneous rocks (granites) and sediments (feldspar bearing sands and gravel), eventually also residues of
incompletely kaolinized rocks. The major impurities are high content of iron in the feldspar structure (unremoveable) or in the form of admixture (removeable).

**Feldspar from Pegmatite**

The initial production of feldspar was from pegmatite bodies. Pegmatites are bodies of rock commonly of granitic composition that consist mainly of unusually large crystals or masses of quartz, feldspar, and mica. Some pegmatites also contain potentially economic minerals such as fluor spar, beryl, and spodumene. The constituent minerals may occur segregated in zones, an advantage in commercial extraction. Pegmatites crystallize during the last stages of injection of granitic magma. The magmatic fluids are rich in water and cool so slowly that the crystals grow larger than usual. The grain size can range from less than an inch to more than a foot but rarely greater than three feet. Pegmatites range in size from small lens, one to a few feet in thickness, to large tabular bodies tens of feet thick and hundreds of feet long.

Past production came from the larger pegmatites. Mining was labour intensive. Ore was hand cobbled (hand-size pieces are broken by hammer) and sorted by hand. Conventional open-mining methods including removal of overburden, drilling and blasting, loading, and transport by trucks are used to mine ores containing feldspar. The ore is crushed by primary and secondary crushers and ground by jaw crushers, cone crushers, and rod mills until it is reduced to less than 841 um (20 mesh). A froth flotation process is used for most feldspar ore beneficiation.

**Feldspar Occurrence (an example)**

The Spruce Pine (in US) alaskite is a light coloured, medium- to coarse-grained feldspar-quartz-muscovite rock. Alaskite bodies can occur in masses up to several miles in diameter. The average mineral composition of the alaskites is oligoclase feldspar (40%), quartz (25%), microcline feldspar (20%), and muscovite mica (15%). Alaskite also contains minor accessory minerals such as biotite, garnet, epidote, apatite and pyrite (Lesure, 1968; Wiener and Merschat, 1977). In the Spruce Pine district, pegmatites are closely associated with the alaskite bodies and are thought to have crystallized from fluids derived from the alaskite masses in the final stages of crystallization of these igneous bodies.

Feldspar deposits (e.g in the Czech Republic) are represented mostly by feldspar gravel sands, leucocratic granitoids and pegmatite bodies. Recently, the most significant are feldspar deposits originated in source areas of granitic rocks high in feldspar phenocrysts. The most important of them are the area along the upper course of the river Lužnice and the area south of Brno (sediments of the river Jihlava). The sediments are Quaternary fluvial feldspar gravel sands, suitable for production of glazes, household china, sanitary ceramics, glass, etc.

Very important source of feldspar are leucocratic granitoids (granites and granite porphyries, diorites), mostly fine- to medium-grained. They have been explored at many localities occurring in various granite massifs (Chvaletice, Blanice region, Babylon, Blatno, etc.). Besides potential deposits (western Moravia), this category also includes already mined deposits in western Bohemia. The material is used in production of sanitary ceramics, coloured glass, porcelain, grinding wheels, etc.
Application

Generally, feldspar is used in the manufacture of glass products (70%), in ceramics and other products (30%) (Potter, 1996).

Feldspar is an important ingredient in the manufacture of glass. The raw material for glass consists of silica sand, soda ash (sodium carbonate) and limestone (calcium carbonate). Feldspar adds certain qualities to the process. Alumina provides hardness, workability, strength, and makes glass more resistant to chemicals. NaO$_2$ and K$_2$O from feldspar are fluxes. Fluxes reduce the melting temperature so less energy is used and decrease the amount of soda ash needed (Kauffman and Van Dyk, 1994; Bourne, 1994). About 110 pounds of feldspar are used to produce one ton of container glass (soda bottles, e.g.), and 100 pounds are required to produce one ton of flat glass (Alex Glover, 1999, pers. com).

Thirty percent (30%) of feldspar production is used for manufacturing ceramics, especially in commodes and sinks. Italy produces twice the amount of feldspar than the US. In Italy, the majority of feldspar production is for ceramic tile. European houses have ceramic tile flooring as opposed to our usage of wall-to-wall carpeting. Should the use of ceramic tile flooring increase in the US, the demand for feldspar would greatly increase?

In the fabrication of ceramic material, feldspar serves as a flux to form a glassy phase at low temperatures, and as a source of alkalis and alumina in glazes (Appendix B). It improves the strength, toughness, and durability of the ceramic body and cements the crystalline phase of other ingredients. Feldspar is also used in paint, in mild abrasives, urethane, latex foam, and as a welding rod coating.

Basically, the two properties which make feldspars useful for downstream industries are their alkali and alumina content. On those elements we can distinguish three families: Feldspathic sand, Pegmatite and Feldspar. A further distinction can be made between sodium, potassium and mixed feldspars, depending on the type of alkali they contain. Feldspars play an important role as fluxing agents in ceramics and glass applications, and also are used as functional fillers in the paint, plastic, rubber and adhesive industries.

Because of their low melting point, feldspars are used as a melting agent in ceramic mixtures, glass batches, glazes, enamels and also as casting powders in the last years.

For the same purposes there are also used feldspar substitutes, which are rocks with alkali metals confined to some other minerals (mostly nepheline - anhydrous sodium-potassium alumo-silicate). Nepheline syenites are particularly used abroad to substitute for feldspar raw materials.

Glass: Feldspar is an important ingredient in the manufacture of glass and an important raw material as well, because it acts as a fluxing agent, reducing the melting temperature of quartz and helping to control the viscosity of glass. The alkali content in feldspar acts as flux, lowering the glass batch melting temperature, and thus reducing production costs. The alumina acts as a stabiliser and improves the finished product by increasing resistance to impact, bending, and thermal shock, increases viscosity during glass formation, and inhibits devitrification. In general, around 1.5-2.0% Al$_2$O$_3$ is required for container and flat glass and up to 15% for certain glass fibres. Feldspar-silica mixture (often referred to as sandspar (silspar) is often used in glass making.

Ceramics: In the manufacture of ceramics, feldspar is the second most important ingredient after clay. Feldspar does not have a strict melting point, since it melts gradually over a range of temperatures. This greatly facilitates the melting of quartz and clays and, through
appropriate mixing, allows modulations of this important step of ceramic making. Feldspars are used as fluxing agents to form a glassy phase at low temperatures and as a source of alkalies and alumina in glazes. They improve the strength, toughness, and durability of the ceramic body, and cement the crystalline phase of other ingredients, softening, melting and wetting other batch constituents.

Fluxing temperature is depend on free silica content, body composition and the ratio of the alkali oxides (Na$_2$O, K$_2$O, and Li$_2$O). Different ceramic bodies require different degree of vitrification, and hence different types and amounts of flux.

<table>
<thead>
<tr>
<th>Ceramic products</th>
<th>Feldspar (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft porcelains</td>
<td>25 - 40</td>
</tr>
<tr>
<td>Tableware</td>
<td>18-30</td>
</tr>
<tr>
<td>Sanitaryware</td>
<td>30-60</td>
</tr>
<tr>
<td>Whiteware, pottery, and tile</td>
<td>15-35</td>
</tr>
</tbody>
</table>

Note : In ceramic, K-spar is prepared over Na-spar, since it form a highly viscous melt even at very high temperatures and thus prevents distortion during firing.

**Welding:** Feldspar are used in coatings of welding electrode for their fluxing properties, particularly for coating electrodes used in the manual arc process, which is popular for welding ferrous alloys in structural steelwork, shipbuilding, general fabrication industries, and hard-facing. Feldspar’s fluxing properties act as an arc stabilizer and weld pool protector.

Desireable physical and chemical requirements are consistency in particle size and chemical composition. The particle size does not generally exceed 250 microns, though the mean particle size is typically in the 70 micron range.

Feldspars can form between 5-10% of the total dry blend mix. Both potassium and sodium bearing feldspars are utilised, but certain types of feldspar are used for particular types of welding rods.

**Fillers:** Feldspars also are used as fillers and extenders in applications such as paints, plastics and rubber. Beneficial properties of feldspars include good dispersability, high chemical inertness, stable pH, high resistance to abrasion, low viscosity at high filler loading, interesting refractive index and resistance to frosting. The products used in such applications are generally fine-milled grades.

**Enamel frits and glazes:** Feldspar assists the enamel composition, assuring the absence of defects and the neatness of the end product: e.g. enamel frits, ceramic glazes, ceramic tile glazes, sanitaryware, tableware, electrical porcelain and giftware.

**And many other end-uses:** paint, mild abrasives, urethane, welding electrodes (production of steel), latex foam, the welding of rod coating, and road aggregate.

In the flooring sector, feldspar is the main constituent in the body composition. It is used as a flux, lowering the vitrifying temperature of a ceramic body during firing and forming a glassy phase. Surface tensions pull the remaining solid particles together, giving a densification of the ceramic body. With rising temperatures the alkalis become more active and first dissolve the clay particles and then the free silica.
In **tableware**, feldspar gives a good fusibility for a product without defects. In **sanitaryware**, the use of feldspar within vitreous ceramic bodies is used to facilitate the optimization process.

More than 70% of the feldspars produced in the EU are used in the ceramic industry, and most of the rest in the glass production.

In the manufacture of ceramics, feldspar is the second most important ingredient after clay, acting functionally as a flux. Indeed, feldspar does not have a strict melting point, but melt gradually over a range of temperatures. This greatly facilitates the melting of quartz and clays and, through appropriate mixing, allows to modulate this important step of ceramic making.

In the glass industry, feldspars are used for their alumina content and their content of alkali. The alkali act as flux ingredients, lowering the batch melting temperature and therefore contributing to the reduction of production costs. Alumina acts as a matrix former, reducing the tendency for glass to devitrify. It also acts as a stabiliser which improves the chemical durability of glass, as well as its physical resistance. The addition of feldspar to glass also improves the workability of the material produced, making it more suitable e.g. for pressing.

Feldspars are also used as fillers and extenders in applications such as paints, plastics and rubber. Beneficial properties of feldspars include good dispersability, chemical inertness, stable pH, high resistance to abrasion, low viscosity at high filler loading, interesting refractive index and resistance to frosting. The products used in such applications are generally fine-milled grades.

**Feldspar Beneficiation**

Feldspars are either selectively mined or processed by flotation and/or magnetic separation, in order to remove the accessory minerals (e.g. quartz, mica, rutile, etc.) present in the ore. The feldspar may then undergo a milling step which allows to adapt the particle-size to the intended use. The degree of refining and possible milling is very dependant upon the final use of the product. For a number of uses, it is perfectly acceptable, and even advantageous, that the product retains some accessory minerals, e.g. quartz, while at the other extreme some applications require extremely pure and fine-grounded grades. Basically, the two properties which make feldspars useful for downstream industries are their alkali and alumina content.
Processing Technologies

Today the industry insists on high quality raw materials with exacting specifications. Modern mineral processing technology, such as flotation has enabled inferior feldspar to be upgraded to an acceptable level, and thus the reserve base of feldspathic mineral has been considerably increased. Normally feldspar concentrates should meet the following requirements:

- To be low in iron content
- To maintain a proper ratio of \((K_2O+Na_2O)\) to \(SiO_2\)

The normal requirements for iron content \((Fe_2O_3)\) in the feldspar concentrates are

For white glaze \(< 0.3\%\)
For non-white glaze \(< 0.5\%\)
For white-ceramic adobe \(< 0.5\%\)
For non-white adobe \(< 1.0\%\)
For container glass \(< 1.0\%\)
For flat glass \(< 0.6\%\) and \(< 0.08\%\) preferred.

For flat glass, the compositional requirements are:

\[Al_2O_3 > 18\%\]
\[(Na_2O + K_2O) > 10\%\]

Feldspar products terminology:

The question of defining on a common basis the products which are made available to user industries has long been a cumbersome issue. The supplier and user of feldspar worldwide normally have agreed on a standardised definition of the feldspar products which are placed in the world market.

According to that harmonised definition, feldspar products are aluminosilicates with \(SiO_2\) content \(> 58\%\), Alkali content \((Na_2O+K_2O) > 2\%\), Alumina content \((Al_2O_3) > 3\%\) and loss on ignition \(< 3\%\).
Three distinguished families exist:

Feldspatic sand:
with an alkali content \((\text{Na}_2\text{O}+\text{K}_2\text{O}) < 6\%\) or alumina content \((\text{Al}_2\text{O}_3) < 8\%\)

Pegmatite:
with an alkali content \((\text{Na}_2\text{O}+\text{K}_2\text{O}) > 6\%\) and alumina content \((\text{Al}_2\text{O}_3)\) comprised between 8 and 14\%

Feldspar:
with an alkali content \((\text{Na}_2\text{O}+\text{K}_2\text{O}) > 6\%\) and alumina \((\text{Al}_2\text{O}_3)\) content > 14\%

A further distinction can be made between Sodium, Potassium and mixed feldspars, depending on the type of alkali they contain.

In the laboratory analysis exercise is focusing on the chemical analysis of the nine main parameters used for characterising feldspar products, which is the basis of the international (e.g EUROFEL) common terminology:

\[
\text{Na}_2\text{O} / \text{K}_2\text{O} / \text{CaO} / \text{Al}_2\text{O}_3 / \text{SiO}_2 / \text{Fe}_2\text{O}_3 / \text{TiO}_2 / \text{MgO} / \text{Loss on ignition}.
\]

For commercial analysis exercise, samples of commercial of ungrounded product of 300 g batch of each feldspar is prepared. For the preparation of these samples and batches, standardised practices (e.g. quartering etc.) are applied.

No standard analysis method is imposed; the participating laboratories analyse the sample according to the methods they routinely apply. The results are plotted on a graph with sample identification as abscissa and weight percentage as ordinate.

World Market and Prices

Ceramics remains growth driver for feldspar

Strong growth in the production of ceramics, particularly in Italy, Spain and China has been the main driver of the steady rise in feldspar demand seen over the past 20 years, and will remain a major factor in the feldspar industry as future growth. Production of ceramic tiles in the 20 leading countries increased from 2,950Mm\(^2\) in 1995 to over 4,100Mm\(^2\) in 2000. Chinese production increased from under 230Mm\(^2\) in 1995 to 450Mm\(^2\) in 2000, but some producers have reduced capacity in an attempt to increase the quality of the ceramics produced for the export market. This may dampen demand for raw materials, including feldspar, but any subsequent reductions are likely to be more than offset by demand from the domestic market. The ceramics industry consumes around 7.7Mt of feldspar and nepheline syenite each year, accounting for around 55\% of total world demand and over 70\% of European demand. The second largest market for feldspar is the glass industry, accounting for 35\% of world demand. The market for glass grades of feldspar and nepheline syenite is being weakened by the increased use of cullet in preference to mineral raw materials and, in the case of container glass, by the use of alternative packaging materials. The glass industry is therefore expected to show relatively slow rates of growth in feldspar demand (Roskill, 2000).
For an example:

Average prices of sales quoted in the Industrial Minerals magazine were constant during the period 1990-1992. Feldspar prices were increasing in 1993 and in 1995 in consequence of the recovery in demand. Average feldspar prices at yearend were as follows:

A Ceramic grade, powder, 300 mesh, bagged, GBP/t, ex-store GB

B Sand, glass grade, 28 mesh, GBP/t, ex-store GB

C South African, ceramic grade, bagged, USD/t, FOB Durban

D South African, micronised, bagged, USD/t, FOB Durban

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>160.00</td>
<td>182.50</td>
<td>182.50</td>
<td>182.50</td>
<td>182.50</td>
</tr>
<tr>
<td>B</td>
<td>85.00</td>
<td>99.00</td>
<td>99.00</td>
<td>99.00</td>
<td>99.00</td>
</tr>
<tr>
<td>C</td>
<td>140.00</td>
<td>140.00</td>
<td>140.00</td>
<td>150.00</td>
<td>150.00</td>
</tr>
<tr>
<td>D</td>
<td>235.00</td>
<td>235.00</td>
<td>235.00</td>
<td>205.00</td>
<td>205.00</td>
</tr>
</tbody>
</table>

Recycling

Reducing the need for virgin raw materials, reduces the need of feldspar, too. The recycling rate is about 33%, as example, in the USA and as high as 90% in some European countries like Switzerland.

Possible substitutes of feldspar

Feldspar substitutes are materials having alkali metals confined to other minerals than feldspars, like nepheline syenites or nepheline phonolites (in the Czech Republic). These replace feldspars as a melting agent. In other applications (fine abrasives, filler in rubber, plastics and paints), feldspars can be replaced by bauxite, corundum, diatomite, garnet, magnetite, nepheline syenite, olivine, perlite, pumice, silica sand, staurolite, ilmenite, barite, kaolin, mica, wollastonite, calcined alumina hydrate, clays, talc, spodumene, pyrophyllite or their mixtures.
APPENDIX A

MINERAL DESCRIPTIONS

Feldspar minerals can be subdivided into two groups - plagioclase feldspars, and potassium feldspars. Plagioclase feldspars are sodium / calcium aluminium silicates. The plagioclase feldspar series is:

- albite (moonstone) (sodium rich),
- oligoclase,
- andesine,
- labradorite, and
- anorthite (calcium rich).

Potassium feldspars are potassium aluminum silicates. The most common K (potassium) feldspars are microcline (amazonite, moonstone) and orthoclase.

Albite (moonstone)

Chemical Composition: \( (\text{Na,Ca})\text{AlSi}_3\text{O}_8 \)

Sodium, calcium (0 to 10%) aluminum silicate

Class: Silicate

Crystallography: Triclinic; pinacoidal

Habit: Crystals commonly tabular. Usually massive, granular, lamellar. Twinning very common.

Physical properties: Luster vitreous, sometimes pearly. Color white to colorless; occasionally bluish, gray, reddish, greenish depending on impurities. May have opalescent colors (moonstone). Streak white. Transparent to sub-transparent.

Cleavage \{001\} perfect, \{010\} nearly perfect, \{110\} imperfect. Cleavage angle at 86°. Fracture uneven to conchoidal. Brittle. H. 6-6.5. S.G. 2.6-2.63.

Occurrence: Albite is a very common mineral of the plagioclase group of feldspar.

Oligoclase Plagioclase feldspar

Chemical Composition: \( (\text{Na},\text{Ca})\text{AlSi}_3\text{O}_8 \)

Sodium, calcium (10 to 30%) aluminum silicate

Class: Silicate

Crystallography: Triclinic; pinacoidal

Habit: Crystals commonly tabular, uncommon. Usually massive, cleavable, granular, or compact. Twinning common.
Physical properties: Luster vitreous. Colorless, white, gray, greenish, yellowish, brown, reddish, depending on impurities; occasionally shows brilliant reflections from minute specks of hematite giving it a golden shimmer (sunstone). Streak white. Transparent to translucent. Cleavage {001} perfect, {010} nearly perfect, {110} imperfect. Cleavage angle at 86°. Fracture conchoidal to uneven. Brittle. H. 6-6.5. S.G. 2.63-2.67.

Occurrence: Oligoclase occurs in (e.g. the Spruce Pine District in western North Carolina) and is a very common mineral in granites and gneisses.

**Anorthite**

Chemical Composition: CaAl$_2$Si$_2$O$_8$

Calcium aluminum silicate

Class: Silicate

Crystallography: Triclinic; pinacoidal

Habit: Usually massive, cleavable, granular, or compact.


Occurrence: Anorthite occurs in some ultramafic igneous rocks (dunite).

**Potassium feldspars**

**Microcline**

Chemical Composition: KAlSi$_3$O$_8$

Potassium aluminum silicate

Class: Silicate

Crystallography: Triclinic; pinacoidal

Habit: Crystals often short prismatic. Twinning may be present. Often massive, coarsely cleavable to granular.

Physical properties: Luster vitreous, sometimes pearly on cleavage surfaces. Color white, gray, pale cream yellow, flesh pink, various shades of red, green (amazonstone). Streak uncolored to white. Transparent to translucent. Cleavage {001}, {010} perfect at nearly right angles (89.5°). Fracture uneven. Brittle. H. 6-6.5. S.G. 2.56-2.63.

Occurrence: Microcline occurs in granites, granitic gneisses and pegmatites.
Orthoclase

Chemical Composition: $\text{KAlSi}_3\text{O}_8$

Potassium aluminum silicate

Class: Silicate

Crystallography: Monoclinic; prismatic

Habit: Crystals often short prismatic. Twinning may be present. Often massive, coarsely cleavable to granular.

Physical properties: Luster vitreous. Colorless, white, gray, pale yellow, pink, flesh red. Streak colorless to white. Transparent to translucent. Cleavage $\{001\}$, $\{010\}$ perfect at right angles ($90^\circ$). Fracture uneven to conchoidal (like the edge of a glass fragment). Brittle. H. 6-6.5. S.G. 2.55-2.63.

Occurrence: Orthoclase occurs in granites, granitic gneisses and pegmatites.

FELSPAR PRODUCTS AND ORIGINS

a) Feldspar-quartz mixture
b) Potassium feldspar
c) Sodium feldspar
d) Aplite
e) Nepline Syanite
f) Felspar sand
g) Phonolite
h) Pegmatite

Nephline Syenite:

In glass and ceramics, nephline syenite, like feldspar, provides alkalis that act as a flux to lower the melting temperature of a glass or ceramic mixture, prompting faster melting and fuel savings. In glass, nephline syenite also supplies alumina, which gives increased resistance to scratching and breaking, improved thermal endurance, and increased chemical durability.
APPENDIX B

Typical composition of glaze formula

LA MATT GLAZE ON M340 (08/29/89)

NUM: G1219

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>PARTS BY WEIGHT</th>
<th>UNIT OF MEAS. WEIGHT</th>
<th>% BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>POTASH FELDSPAR</td>
<td>51.60</td>
<td>51.10</td>
<td></td>
</tr>
<tr>
<td>FLINT</td>
<td>5.60</td>
<td>5.50</td>
<td></td>
</tr>
<tr>
<td>WHITING</td>
<td>18.80</td>
<td>18.60</td>
<td></td>
</tr>
<tr>
<td>ZINC OXIDE</td>
<td>8.60</td>
<td>8.50</td>
<td></td>
</tr>
<tr>
<td>EPK KAOLIN</td>
<td>15.40</td>
<td>15.20</td>
<td></td>
</tr>
<tr>
<td>$BENTONITE</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

101.00 KG

FORMULA & ANALYSIS

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaO</td>
<td>0.49</td>
<td>11.92</td>
</tr>
<tr>
<td>K2O</td>
<td>0.24</td>
<td>9.75</td>
</tr>
<tr>
<td>MgO</td>
<td>0.00</td>
<td>0.04</td>
</tr>
<tr>
<td>Na2O</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td>ZnO</td>
<td>0.27</td>
<td>9.52</td>
</tr>
<tr>
<td>TiO2</td>
<td>0.00</td>
<td>0.07</td>
</tr>
<tr>
<td>Al2O3</td>
<td>0.39</td>
<td>17.13</td>
</tr>
<tr>
<td>F2O5</td>
<td>0.00</td>
<td>0.04</td>
</tr>
<tr>
<td>SiO2</td>
<td>1.97</td>
<td>51.34</td>
</tr>
<tr>
<td>Fe2O3</td>
<td>0.00</td>
<td>0.17</td>
</tr>
<tr>
<td>L.O.I.</td>
<td>10.54</td>
<td></td>
</tr>
</tbody>
</table>

EXPAN - 8.80

Commercial supply of feldspar

Feldspar in Lumps

<table>
<thead>
<tr>
<th>Specifications</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>K₂O</td>
<td>12% min</td>
<td>9% min</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.2% max</td>
<td>0.5% max</td>
</tr>
<tr>
<td>Sizes</td>
<td>1-10 cm</td>
<td></td>
</tr>
</tbody>
</table>

Packing

1. In bulk
2. In gunny bags or plastic woven bags of 50kg net each
**Feldspar in Powder**

<table>
<thead>
<tr>
<th>Specifications</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>K₂O</td>
<td>12% min</td>
<td>9% min</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.2% max</td>
<td>0.5% max</td>
</tr>
<tr>
<td>Fineness</td>
<td>95% min passing through 100, 200 or 325 mesh</td>
<td></td>
</tr>
</tbody>
</table>

**Packing**

1. In glass-fibre bags of about 40kg net each
2. In 3 ply kraft paper bags of about 40kg net each

**Sodium Feldspar in Lumps**

<table>
<thead>
<tr>
<th>Specifications</th>
<th>8% min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na₂O</td>
<td></td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.2% max</td>
</tr>
<tr>
<td>Sizes</td>
<td>3-15cm</td>
</tr>
</tbody>
</table>

**Packing**

In bulk or in gunny bags of approx 50kg net each

**Sodium Feldspar in Powder**

<table>
<thead>
<tr>
<th>Specifications</th>
<th>8% min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na₂O</td>
<td></td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.2% max</td>
</tr>
<tr>
<td>Fineness</td>
<td>95% passing through 60,120, 200, 325 mesh</td>
</tr>
</tbody>
</table>

**Packing**

In plastic woven bags lined with plastic bags of 50kg net each

For application in ceramics, paints, and tiles feldspar normally dried, and reduce to less than 75um (200 mesh), and should be free from iron-bearing minerals.
PRICE FOR U.S FELDSPAR YEAR 2001
(Dollar per metric Ton)

<table>
<thead>
<tr>
<th>Ceramic grade</th>
<th>Harga (US Dollars)</th>
<th>Malaysian Ringgit</th>
</tr>
</thead>
<tbody>
<tr>
<td>170 to 250 mesh, sodium</td>
<td>66-83</td>
<td>254-319</td>
</tr>
<tr>
<td>200 mesh, potassium</td>
<td>138</td>
<td>531.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Glass grade</th>
<th>Harga (US Dollars)</th>
<th>Malaysian Ringgit</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 mesh, sodium</td>
<td>44-57</td>
<td>169-219</td>
</tr>
<tr>
<td>80 mesh, potassium</td>
<td>94-99</td>
<td>362-381</td>
</tr>
</tbody>
</table>

Sumber: Industrial Mineral No. 411, (Disember 2001), p. 82

Major World Producer of Feldspar (1000 tones)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy</td>
<td>1116</td>
<td>1142</td>
<td>1174</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>635</td>
<td>667</td>
<td>653</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>526</td>
<td>667</td>
<td>653</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soviet Union</td>
<td>340</td>
<td>340</td>
<td>340</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Germany</td>
<td>261</td>
<td>247</td>
<td>216</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>172</td>
<td>274</td>
<td>216</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thailand</td>
<td>105</td>
<td>115</td>
<td>169</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>136</td>
<td>129</td>
<td>140</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mexico</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Romania</td>
<td>86</td>
<td>86</td>
<td>86</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norway</td>
<td>80</td>
<td>80</td>
<td>67</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Africa</td>
<td>33</td>
<td>33</td>
<td>67</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poland</td>
<td>60</td>
<td>60</td>
<td>58</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td>174</td>
<td>47</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>World Total</td>
<td>4500</td>
<td>4400</td>
<td>4500</td>
<td>8650</td>
<td>9830</td>
<td>9500</td>
</tr>
</tbody>
</table>

Malaysian Import from US (metric ton)

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>US Export of Feldspar</td>
<td>82 (US$27,000)</td>
<td>280 (US$69,600)</td>
</tr>
</tbody>
</table>
References:


USM 1993, Short Course on: Industrial Processing of Kaolin, quartz/silica sand and Feldspar, 20th-22nd. April 1993, School of Materials and Mineral Resources Engineering in Collaboration with The Department of Mining and Metallurgical Engineering, University of Queensland, Australia.

Feldspar dan Neplin Syanit

Feldspar digunakan dengan meluas dalam pembuatan gelas, seramik dan pengisi. Hampir 69% keluaran felspar diguna sebagai fluks dalam pengeluaran kaca. Gred kaca ialah 850um (20 mesh). Dalam industri seramik, ia diguna bagi pembuatan produk kelengkapan sanitari, jubin, porselin elektrik, set meja makan (dinner ware) dan licau (glaze).

Grad seramik ialah 75um (200mesh). Neplin syanit diguna dalam pembuatan kaca, seramik dan pengisi. Bahan berkualiti rendah dipakai sebagai granul atap. Dalam pembuatan kaca, ianya menyumbang sumber alkali dan alumina.

Pengeluaran dunia bagi felspar ialah 6.2 mt (6.8 million st) dalam tahun 1996, tinggi sedikit berbanding dengan 1995. Pengeluar utama ialah Itali (1.6 Mt.), Amerika Syarikat (900 kt), Thailand (600 kt (660,000st)), Turki (420kt), German (350kt), Korea (330kt) dan Perancis (310kt).

Harga felspar di Amerika Syarikat dalam tahun 1996 ialah RM 160.00 per ton. Gred seramik bersaiz kasar dipasarkan pada harga RM 240-280.00 per ton. RM 460-500 per ton bagi saiz kurang 45um (-325 mesh) untuk gred seramik. Bagi gred kaca bersaiz 600um (30 mesh) ditawar pada harga RM 160 hingga 200 per ton dan pada saiz 180um (80 mesh) ialah RM 320/t. Di Afrika Selatan gred seramik dijual pada harga RM 560/t. Gred micronised ialah RM 940.00.

Harga Neplin syanit adalah dalam jajaran (e.g Canada) C$20/ton bagi saiz 600um (30 mesh), gred kaca C$69/t) bagi saiz 75um (-200 mesh) bergred seramik.