Research Group

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Feldspar in the CIS

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Contents

List of tables

List of figures

Introduction

Feldspars include extensive group of widely spread minerals such as aluminosilicates of potassium, sodium, calcium and barium. These are the major minerals of the Earth's crust.

All feldspars have rather low refractive indices, high hardness (6.0-6.5), perfect cleavage in two directions crossing under 90° approximately, small density (2.5-2.7 g/cm^3).

According to their chemical composition feldspars are divided into three groups: sodium-calcium, potassium-sodium and potassium-baric.

Sodium-calcium feldspars are called plagioclase. Depending on percentage content of anorthite (An) this group of feldspars include: albite ($NaAlSi_3O_8$, 0-10% An), oligoclase (10-30% An), andesine (30-50% An), labradorite (50-70% An), bytownite (70-90% An), anorthite $CaAl_2Si_2O_8$ (90-100% An). The quantity of silicon acid in this row of minerals gradually decreases. According to its content plagioclases are divided into acidic (0-30% An), tertiary (30-60% An) and basic (60-100% An). Fusion temperature of plagioclases vary between 1100 and 1500°C.

Gabbro, anorthosite, basalts and others poor silica basic rocks contain basic plagioclases. Average and acidic plagioclases are contained in diorite, granodiorite, granite, liparite and other more acidic rocks. Plagioclases can be found also in nepheline syenites.

According to their crystallographic features *potassium-sodium feldspars* are divided into monoclinic and triclinic; according to a degree of structure order they can be low (low temperature with ordered structure) and high (high-temperature with disordered structure). Orthoclase ($KAlSi_3O_8$, monoclinic and low temperature) and microcline ($KAlSi_3O_8$, triclinic and the lowest temperature) are the most widespread feldspars. Besides, sanidine (monoclinic and high-temperature) is also a widespread mineral.

This group of pure potassium feldspars contains 16.9% of K_2O, 18.4% of Al_2O_3 and 64.7% of SiO_2. Almost all of potassium feldspars contain small quantities of Na_2O, isomorphic impurity in sodium-feldspar particles and plagioclase interpositions.

Microcline and orthoclase are the main minerals in granitoid, granite pegmatite, nepheline and alkaline sienite minerals. Sanidine, which is not so widespread, can be found in trachyte and liparite minerals.

Potassium-baric feldspars are rarer to compare with other feldspars of other groups. They include hyalophane (K, Na, Ba)$AlSi_3O_8$ and celsian $BaAlSi_3O_8$ minerals. According to crystal form and external appearance they are similar to orthoclase. Hyalophane minerals contains up to 16% BJSC.

The most part of feldspars used in the industry are potassium-sodium feldspars. The most important of them are microcline and a microcline-perthite (microcline with plagioclase interpositions). Their basic source in Russia is ceramic and partially muscovite pegmatite minerals. Pegmatite contains feldspars as heavy macrocrystalline blocks. Determinate intergrowth of feldspars and quartz (pegmatite) often occur, forming graphic texture peculiar to pegmatites only.

Industrial application of feldspars is based on their ability to fuse at relatively low temperatures generating glass. Feldspar with other compounds (Kaolin, quartz, etc.) generates porcelain. Therefore the basic fields of application of feldspar are ceramics and glass industries, where it is one of the major components in ceramic, glass, eglaze and enamel mixtures.

1. World Market Review of Feldspar

Feldspar mining is carried out more than in 50 countries in the world.

World commercial reserves and resources of feldspar ore are not estimated. They are rather seldom cited in statistics and reviews of reserves in different countries.

Feldspar ore is extracted not only from pegmatite deposits but also while developing deposits of alaskitic granites (Sirius-Pine in the USA), aplites deposits (Kamae in Japan, Payne in the USA and Meldon in England). Besides, muscovite and rare-metal granites are being involved into operation in the USA, Germany and France. Nepheline and alkaline syenites from the Blue Mountain deposit in Canada (extraction of 710 Kt in 2004) and the Stierney deposit in Norway (extraction of 340 Kt in 2004) are the largest sources of raw materials for the glass industry.

The output of Italian mica schists and sands deposits is mainly of sodium structure and is used for ceramic tiles production. Phonolites and other igneous rocks deposits are being developed in France. Germany developes pegmatites, kaolinized granitoids and phonolits deposits. Mexico extracts crystal tuffs. In the USA products of any structure (from high potassium content to sodium content) are manufactured while processing of pegmatites (including rare-metal and muscovite) and sands. Significant share of these products are flotation concentrates for ceramics and glass industries. The main source of feldspar ore are pegmatitic veins on Kemya Island in Finland.

According to US Geological Survey (USGS) in 2005 world output of feldspar increased up to 11.5 Mt against 11.1 Mt in 2004.

According to USGS, in 2005 only Italy, Turkey and Thailand extracted above 1 Mt of feldspar per year (table 1). Thus their share of world extraction of this material comprised about 48%.

According to this organization feldspar extraction in Russia in 1998-2005 was only 40-45 Kt annually, but there are no data concerning extraction in Kazakhstan and in Ukraine. According to Infomine in 2005 total volume of feldspar extraction in the CIS was about 0.8 Mt.

There are also no official data concerning feldspar extraction in China at the moment. However, according to Roskill Information Services, the extraction volume of this raw material was 1-2 Mt per year.

Thus, the estimated world total extraction volume of feldspar in 2005 was not less than 13.5-14.5 Mt.

Table 1: World Production of Feldspar in 1998-2005

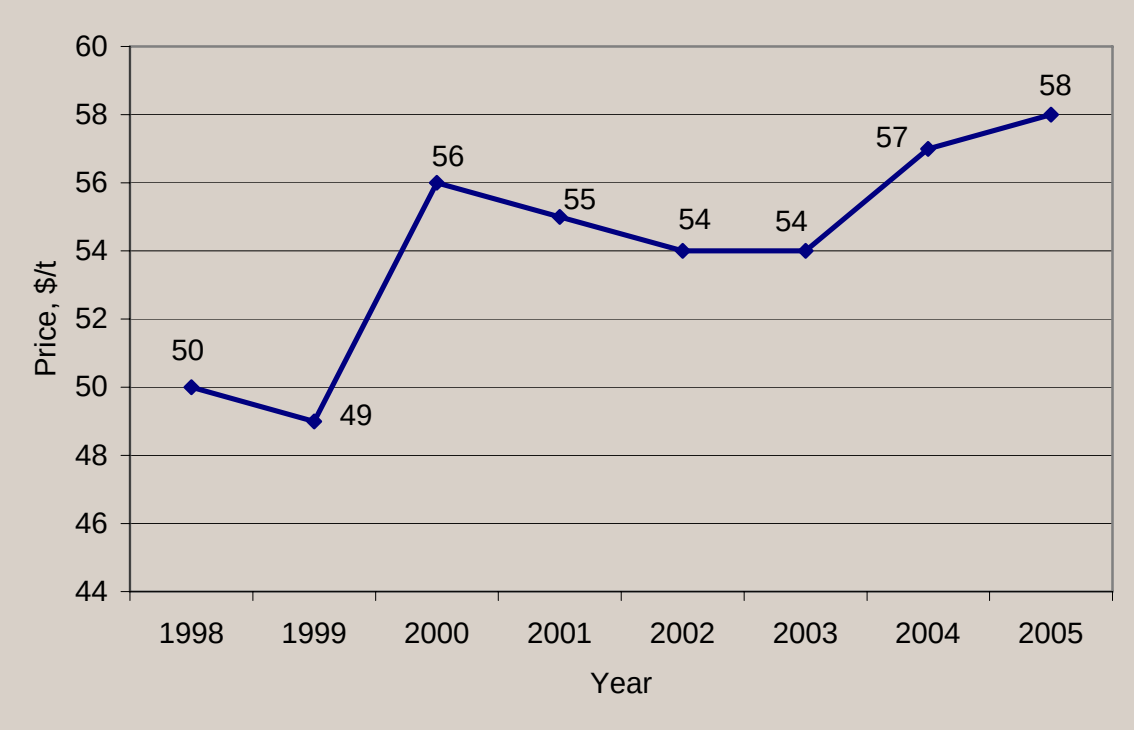
Country	*Output,Kt*							
	1998	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*
Italy	2748	2600	2500	2600	2500	2500	2500	2500
Turkey	1089	1100	1200	1250	1290	1800	1900	2000
Thailand	440	626	543	540	570	780	825	1000
USA	820	875	790	780	880	800	770	760
France	600	600	600	600	620	650	650	650
Republic of Korea	248	250	330	389	415	477	480	550
Germany	450	460	460	460	480	450	450	500
Spain	430	425	425	430	450	450	450	450
Czechia	266	244	337	373	401	421	400	450
Mexico	198	262	334	400	420	330	350	370
Egypt	326	330	330	300	350	350	350	350
Poland	117	120	165	221	293	320	300	320
Iran	186	240	200	204	191	190	200	200
Venezuela	148	156	130	142	147	149	150	175
India	105	105	110	110	110	150	150	150
Portugal	120	115	120	120	120	120	120	120
Colombia	55	55	55	55	93	100	100	100
Others	984	1417	911	1426	1470	1163	955	855
Total in the world	**9330**	**9980**	**9540**	**10400**	**10800**	**11200**	**11100**	**11500**

Source: USGS

In 2002-2005 the US feldspar extraction reduced by 14% and reached 760 Kt ($44 million) in 2005. The share of three leading producers was 70% of the total feldspar extraction in the deposits situated in seven states. The share of North Carolina in the total extraction was approximately 40%. Feldspar was also produced as a by-product during the processing of mica and quartz sand.

Despite of insignificant fluctuations in the end of 1990s - beginning of 2000s the US average prices for feldspar products have recently been growing due to increase in domestic demand and decline of feldspar output. Average US feldspar prices dynamics are shown in figure1.

Figure 1: Average US Feldspar Prices Dynamics



Source: USGS

Feldspar prices in some countries in 2005 are shown in table 2.

Table 2: Feldspar Prices in Some Countries in 2005

Producing country	***Production***	***Terms of delivery***	***Price, $/t***
USA	*Ceramic grade:*		
	170-250 mesh (Na), in bulk	ex-works	60-75
	200 mesh (K), in bulk	ex-works	125
	Glass grade:		
	30 mesh (Na), in bulk	ex-works	40-52
	80 mesh (K), in bulk	ex-works	85-90
Turkey	Crude, 10 mm (Na), in bulk	FOB Gulluk	13-14
	Ground, 63 mkm, in bags	FOB Gulluk	75-80
	Glass grade, 500 mkm, in bags	FOB Gulluk	54-56
Republic of South Africa	Ceramic grade	FOB Durban	112-165
	Micronized	FOB Durban	205
India	Ceramic grade (K), in bulk	FOB India	25-27
	Powder, 200 mesh	FOB India	70

Source: Bulletin of Foreign Commercial Information (BIKI)

Discrete data concerning consumption of feldspar ore in different countries do not let identify complete world consumption structure. The available data show

that the largest countries consuming feldspar ore are those which have well developed building, ceramics and glass industries.

The largest consumer is the USA consuming more than 1 Mt of feldspar ore a year. Except for local feldspar the US industrial enterprises use significant amounts of nepheline syenites (more than 300 Kt) imported from Canada. According to US Geological Survey, in 2004 apparent consumption of feldspar in the USA increased by 1.8% to 1.13 Mt in comparison with the previous year.

In the last years in the US glass industry (including glass fiber and glass containers) there is decline in feldspar consumption. So, according to USGS, in 2003 in the glass industry there was used about 70% of its total consumption. In 2004 the share of feldspar consumption in the glass industry declined to 65 %.

Taiwan is also one of the largest world consumers importing up to 1 Mt a year. The other largest consumers are France, Germany, Italy and Japan using its own and imported raw materials.

Fast development of glass and ceramics industries in the country also made China a large consumer of feldspar. Chinese enterprises use mainly their own feldspar, and volume of imports is insignificant. Estimated feldspar consumption in China has reached 2 Mt a year and it is still growing.

Deposits of ceramic pegmatites cannot satisfy increasing demand for feldspar ore. The world role of granites (alaskites, rapakivi and others), alkaline and nepheline syenites, superfusive rocks, alkaline kaolins, arcosic and feldspar-quartz sands is constantly growing as an alternative source of feldspar ore. It is possible to organize large facilities producing separated ground feldspar products on the basis of deposits of these materials. This situation will help to satisfy completely world demand for feldspar for decades, for some countries - for centuries (the USA, Canada, Norway, Spain, Turkey and Russia).

In the long term the world demand for feldspar will be growing both in traditional spheres of consumption (ceramics-porcelain, glass, building and other industries), and in new spheres of application, especially in glassceramic and bonding materials, enamels and fertilizers. The world consumption of feldspar products is predicted to increase steadily (by 1-2% a year). Well developed foreign feldspar mineral resources base, its large reserves and growth of extracting capacities will allow to satisfy growing world demand for feldspar ore in the long term.