

INVESTIGATION OF THE EFFECT OF PARTICLE SIZE FRACTION ON THE CHEMICAL COMPOSITION OF SERPENTINITE

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Abstract

The aim of this work was to establish the effect of particle-size fractionation on the distribution of the major and associated chemical components of serpentinite from the Karakalpak deposit. The initial material, weighing 550.20 g, was ground in a ball mill for 30, 60, 90, and 120 min, after which the particle-size distribution was determined by sieve analysis. For elemental analysis, the sample ground for 30 min was selected; five particle-size classes were separated from it, and the elemental contents were determined by inductively coupled plasma (ICP) analysis. It was established that changes in grinding duration were accompanied by a non-monotonic redistribution of the material among the fractions. The results show that selection of a particle-size class should take into account simultaneously the concentration of the target component, the mass yield of the fraction, and the distribution of associated elements. The results can be used as an initial characterization of the raw material before further investigation of its thermal and sulfuric-acid processing.

Keywords

serpentinite; particle-size composition; grinding; magnesium; chemical composition; ICP; fractionation

Introduction

Serpentinite is a multicomponent mineral raw material whose chemical composition may vary depending on its mineralogical composition and the distribution of components among particle-size classes. For the technological processing of such raw materials, it is important to establish not only the overall chemical composition but also the distribution of target and associated components after grinding and fractionation. Magnesium is of particular interest as one of the major components of serpentinite, since the results of fractionation analysis can be used to select conditions for subsequent chemical processing. In this study, serpentinite from the Karakalpak deposit was investigated to determine the effect of grinding duration on particle-size distribution and to establish the distribution of major and associated elements among the separated fractions. Previous studies of serpentinites have addressed their mineralogical and thermal transformations, mechanical activation, acid leaching, and production of magnesium compounds [1–4], while data on the composition and chemical processing of raw materials from the Karakalpak deposit have also been published [4,5].

Методы исследований

The initial serpentinite, weighing 550.20 g, was ground in a ball mill for 30, 60, 90, and 120 min. The particle-size distribution was determined by sieve analysis using an electronic sieve. For each grinding regime, the mass of material passing through the sieve, the mass adhering to the sieve, the mass remaining on the sieve, and the yield of the corresponding fraction were determined. For subsequent elemental analysis, the sample after 30 min of grinding was selected. Five particle-size classes were separated: 0.5, 0.3, 0.1, 0.06, and 0.05 mm. The contents of the major and associated chemical elements were determined by inductively coupled plasma (ICP) analysis. In interpreting the results, both the element concentration and the mass yield of the corresponding fraction were taken into account. The average composition was estimated using mass-fraction weighting. The results of the study are presented in Tables 1 and 2.

Results and Discussion

The sieve analysis results demonstrated a substantial effect of grinding duration on the particle-size distribution of serpentinite. After 30 min, the largest proportion of the material was represented by the 0.1 mm fraction—243.26 g, or 81.90%. After 60 min, the yield of the 0.1 mm fraction decreased to 49.39%, while the shares of the 0.5 and 0.3 mm fractions were 22.12% and 25.24%, respectively. After 90 min, the 0.3 mm fraction became predominant, with a yield of 55.84%. With a further increase in grinding duration to 120 min, the proportion of the 0.1 mm fraction increased again to 79.13%. Thus, the redistribution of the material was non-monotonic. The proportion of the finest fractions, 0.05–0.06 mm, remained small under all investigated conditions.

Table 1 – Fractional composition of serpentinite as a function of grinding duration

Grinding time, min	Sieve opening size, mm	Initial mass on sieve, g	Mass passing through sieve, g	Mass adhering to sieve, g	Mass remaining on sieve, g	Fraction yield, %
30	0.5	297.05	284.69		12.36	4.16
	0.3	284.69	273.38	1.2	11.31	3.8
	0.1	273.38	30.12	2.83	243.26	81.9
	0.06	30.12	1.66	0.9	23.53	7.92
	0.05	1.66	-	-	1.66	0.55
60	0.5	300.07	233.71	-	66.36	22.12
	0.3	233.71	157.74	0.55	75.74	25.24
	0.1	157.74	9.56	0.74	148.18	49.39
	0.06	9.36	1.84	0.1	7.72	2.57
	0.05	1.84	0	-	0.61	0.2

90	0.5	300	237.4	-	62.6	20.86
	0.3	237.4	69.88	0.2	167.52	55.84
	0.1	69.88	1.03	0.45	68.85	22.95
	0.06	1.03	0.68	-	0.35	0.11
	0.05	0	0	-	0	0
120	0.5	300.02	286.01	-	14.01	4.67
	0.3	286.01	240.52	0.48	45.49	15.16
	0.1	240.52	3.12	1	237.4	79.13
	0.06	3.12	1.62	-	1.5	0.5
	0.05	1.62	1.5	-	0.12	0.04

For the sample ground for 30 min, elemental analysis revealed a heterogeneous distribution of components among the particle-size classes. The Mg content ranged from 190,500 g/t in the 0.3 mm fraction to 229,600 g/t in the 0.06 mm fraction. However, the increase in Mg content with decreasing particle size was not monotonic: in the 0.05 mm fraction, the concentration decreased to 210,600 g/t. The Si content varied within a relatively narrow range, from 201,000 to 215,000 g/t, whereas Fe ranged from 36,060 to 48,220 g/t. The 0.06 mm fraction was characterized simultaneously by the highest Mg content and a relatively low Fe content (37,960 g/t). The Al content was 5,319–7,074 g/t, Ca—3,646–4,252 g/t, Cr—4,700–6,400 g/t, Ni—1,810–2,550 g/t, and Cu—67.5–82.4 g/t. The 0.1 mm fraction had the highest mass yield, accounting for 76.80%, whereas the 0.06 mm fraction accounted for 20.31%. Therefore, the higher Mg concentration in the latter should not be evaluated independently of its mass yield.

Table 2 – Chemical composition of different serpentinite fractions

No.	Fraction size, mm	Fraction amount, %	Chemical composition, g/t
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1	0.5	0.382	Mg	Al	Ca	Cr	Fe	Si	Ni	Cu
			228700	7074	3646	6400	44410	202000	2550	78.1
			Y	Zr	Ag	Sb	Cs	La	Ce	Pr
			0.297	1.12	0.024	1.83	0.156	0.574	1.07	0.130
			Ho	Er	Lu	Re	Au	Pb	Bi	Th
			0.013	0.040	0.01	0.01	0.05	23.1	0.022	0.097
2	0.3	1.150	Mg	Al	Ca	Cr	Fe	Si	Ni	Cu
			190500	5319	4079	6350	48220	215000	2300	82.4
			Y	Zr	Ag	Sb	Cs	La	Ce	Pr
			0.190	0.632	0.040	1.75	0.038	0.163	0.344	0.038
			Ho	Er	Lu	Re	Au	Pb	Bi	Th
			0.011	0.025	0.01	0.01	0.05	6.64	0.013	0.034
3	0.1	76.80	Mg	Al	Ca	Cr	Fe	Si	Ni	Cu
			201600	5971	3915	4700	45490	201000	1810	72.3
			Y	Zr	Ag	Sb	Cs	La	Ce	Pr
			0.188	0.588	0.027	1.61	0.043	0.169	0.385	0.045
			Ho	Er	Lu	Re	Au	Pb	Bi	Th
			0.010	0.026	0.01	0.01	0.05	6.40	0.020	0.034
4	0.06	20.31	Mg	Al	Ca	Cr	Fe	Si	Ni	Cu
			229600	6178	4252	5200	37960	213000	2200	71.3
			Y	Zr	Ag	Sb	Cs	La	Ce	Pr
			0.185	0.773	0.018	1.52	0.053	0.196	0.406	0.049
			Ho	Er	Lu	Re	Au	Pb	Bi	Th
			0.010	0.024	0.01	0.01	0.05	5.48	0.022	0.044
5	0.05	1.34	Mg	Al	Ca	Cr	Fe	Si	Ni	Cu
			210600	5912	3772	5100	36060	210000	2200	67.5
			Y	Zr	Ag	Sb	Cs	La	Ce	Pr
			0.185	0.740	10.6	1.54	0.069	0.231	0.538	0.054
			Ho	Er	Lu	Re	Au	Pb	Bi	Th
			0.011	0.030	0.01	0.01	0.05	9.63	0.020	0.040

The distribution of trace elements was also heterogeneous. The most pronounced local variations were observed for Zn, As, Sr, and Ba. The Zn content in the 0.5 mm

fraction reached 431 g/t, whereas in the other fractions it ranged from 24.1 to 32.1 g/t. The maximum As content, 35.7 g/t, was observed in the 0.3 mm fraction; Sr reached 65.7 g/t in the 0.1 mm fraction, while Ba reached 121 g/t in the 0.5 mm fraction. No consistent dependence on particle size was established for most of Y, Zr, Nb, Mo, and the rare-earth elements. The Ag result for the 0.05 mm fraction—10.6 g/t—should be noted separately, whereas its content in the other fractions was 0.018–0.040 g/t. Due to the pronounced difference between this value and the other results, it is appropriate to regard it as an initial experimental value requiring repeated analytical confirmation.

Discussion

Taken together, the results show that fractionation does not lead to simple monotonic enrichment of serpentinite in magnesium as particle size decreases. The highest Mg concentration was identified in the 0.06 mm fraction; however, the largest proportion of the material was concentrated in the 0.1 mm fraction. Therefore, when preparing the raw material for subsequent processing, the feasibility of separating a particular fraction should be evaluated based on a combination of parameters: Mg content, mass yield, and distribution of impurity components. Of particular interest is the combination of a high Mg content and a lower Fe concentration in the 0.06 mm fraction. This feature may be relevant to subsequent acid decomposition; however, the final technological preference for this fraction can only be established based on the actual Mg extraction degree and processing performance indicators [2,3,5].

Conclusion

The study established the effect of grinding duration and subsequent fractionation on the distribution of components in serpentinite from the Karakalpak deposit. After 120 min of grinding, the proportion of the 0.10 mm fraction reached 79.13%; however, the overall change in particle-size composition was non-monotonic. The maximum Mg content, 229,600 g/t, was established in the 0.06 mm fraction, with a yield of 20.31%.

The mass-weighted Mg content of the investigated material was 207,384.3 g/t. The distribution of associated elements was characterized by local maxima, particularly for Zn, As, Sr, and Ba. The data confirm the need to consider jointly the concentration of the target component, the mass yield of the fraction, and the impurity content when selecting conditions for preparing serpentinite for further processing. The results may serve as a basis for subsequent studies of the kinetics and degree of magnesium extraction during sulfuric-acid decomposition.

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