BEHAVIOR OF SELENIUM IN SILICIC VEIN ROCKS AND NEAR GRANITIC CONTACTS

Tapio Koljonen

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Selenium is very mobile in the conditions under which granitic rocks are crystallized and is depleted in silicic plutonic rocks and in pegmatites. It tends to separate from magma and be enriched into gaseous phase. The concentrations found in migmatized and fenitized rocks are much lower than the mean in metamorphic rocks. Therefore selenium appears to migrate along fractures early in the metamorphic process and most of it before anatectic melts are formed.

The selenium released from magma or by metamorphism from bedrock may later, with sulfur, form metasomatic ores and low temperature mineralizations, or it may appear at the surface in volcanic emanations and hot springs. Iron prevents to some extent the migration of selenium from magmatic melts and rocks.

Tapio Koljonen, Department of Geology and Mineralogy, University of Helsinki, SF-00170 Helsinki 17, Finland.

Introduction

The behavior of selenium during endogenic processes is similar to that of sulfur. It is very mobile and is enriches into hydrothermal and even telethermal sulfidic ores with Cu, Ag, Au, Hg, Pb, Sb, Bi, Te, and U. Sulfur usually predominates and only in Lucky Boy Mine in the USA (Becker 1888; McCaskey 1912) have selenides (onofrite Hg(S,Se), and tiemannite HgSe) been the main ore minerals. The contents of sulfides from different kinds of formations have been studied by Sindeeva (1964) and Tischendorf (1966).

During the differentiation of rocks, Se tends to accompany iron (Koljonen 1973a). It is depleted in peridotites and especially in dunites but is enriched in melanocratic gabbros (average 108 ppb). The concentration decreases in calc-alkalic rocks as the silica content increases, being in granites often under 10 ppb (average 25 ppb). In pegmatites the concentration increases slowly, step by step, as the crystallization temperature decreases and Se can be found low-temperature mineral deposits. Its is especially enriched into hot springs (Zies 1929; Vaupell 1938; Roberts 1940; Koljonen 1973a) and into volcanic emanations (Zambonini and Coniglio 1925; Geilmann and Biltz 1931; Byers *et al.* 1936; Friend and Allachin 1941; Di Franco 1942, Kaplan *et al.* 1969).

In this study the behavior of Se is investigated near the contact of granites with country rock, and in pegmatites and other silicic vein rocks, mostly from Finland.

Samples

Most of the analyses set out in Table 1 have been presented earlier in the author's report (1973a, b) of Se contents in igneous and metamorphic rocks. Since geological references are to be found in those papers, only supplementary information is added in Table 1. Rocks from the same locality are displayed as a group.

In the following the behavior of selenium near contacts of various types is briefly reviewed.

Contacts of granite and metamorphic country rock (Table 1, Groups *1*—*4*)

Selenium is very mobile during the emplacement of granitic rocks and is depleted in granites. In orbicular granites, which are zoned enclaves in granites (*cf.* Simonen 1941; Didier 1973), and which in the author's opinion are hybrids formed when silicic magma comes into contact with more basic country rock, the concentration is higher than the average in granites. In Espoo (Table 1, Group *1*) the content is decreased in pyroxene gneiss when granitization is apparent and is low in orbicular granite; but in both cases it is still higher than in granites. In Kuru (Table 1, Group *2*) the content in orbicular granite is higher than in granite and lower than in gabbro from the same area. Selenium contents support the origin of the these rocks through the assimilation of country rock.

In the rapakivi granites there is more Se (56 ppb) than the average in granites. Selenium content is low in the contact zone (Table 1, Groups *3*, and *4*) but seems to have increased a little, metasomatically, near the immediate contact.

Around Wiborg massif, to which Suomenniemi, Mäntyharju and Onas granites belong as small satellites, is a thermometamorphic aureole about five kilometers broad (Vorma 1972). In this, microcline has been transformed into orthoclase and the country rock near the contacts metamorphosed in places to hornfelses. With the increased temperature during the emplacement of rapakivi granites, selenium seems to have migrated out from the country rock (*cf.* Table 1, Nos. 8, 11, and 88).

Alkalic rocks and carbonatites contain little Se. The concentration in the fenite and the surrounding gneisses in the carbonatite complex of Siilinjärvi is low (Table 1, Group *14*) as it is in syenites, which probably originated in part through metasomatism.

Contacts of silicic dykes with plutonic country rock (Table 1, Groups *5*—*14*)

In silicic dykes Se concentration is usually lower than in the country rock when the content in the country rock is high (average in igneous rocks 48 ppb), but some Se is found even when the content is low. In this last case the content over a large area is probably being reflected.

The selenium contents in a small granitic even-grained vein, which probably is a wholly recrystallized old fracture, and in homogenous granite (Table 1, Nos. 21 and 22) were found to be the same.

Contacts of silicic vein rock with metamorphic country rock (Table 1, Groups *15*—*27*)

On the average, metamorphic rocks contain more selenium than plutonic rocks do. This is reflected in silicic veins, which contain more Se in areas where metamorphic rocks prevail. Concentration is greatest in veins situated in sulfide rich gneiss or in black schist (Table 1, Nos. 41, and 60). In those located in highly metamorphic areas (*e.g.* migmatized), as in southern Finland (*cf.* Table 1, Nos. 52, 54, and 56), Se content is less than in those in areas where the grade of metamorphism is low (*cf.* Table 1, Nos. 63, 65, and 67).

Selenium seems to have migrated along fractures before the emplacement of the pegmatite dykes and its concentration is decreased in the country rock near the vein (Table 1, Groups *16* and *26*). In mica schist (Table 1, Groups *23* and *24*) selenium has migrated with quartz to small veinlets, although in magmatic or anatectic conditions it does not accompany silica. In migmatized rocks the highest concentration is found in the dark colored part (Table 1, Group *16*) but in both melanocratic and leucocratic parts it is less than in unmigmatized rock.

Probably most or the selenium found in pegmatites and in silicic veins has entered the dyke from the country rock. Selenium concentrated in late volatile differentiates of cooling magma seems to have separated into hydrothermal solutions and migrated in advance much before the pegmatitic solutions. Nevertheless, it is possible that the hydrothermal solutions earlier increased the content in the country rock.

Contact of igneous and metasomatic rocks (Table 1, Group *28*)

The antophyllite asbestos deposits at Paakkila are rootless lensses in gneiss (Wiik 1953, p. 10) formed through hydrothermal alteration of ultrabasic rocks by solutions rich in selenium. Younger Maarianvaara granite cuts the formation. Selenium content in the deposit decreases near the contact and the pegmatite seems to be contaminated with selenium migrating out from the country rock.

Dynamometamorphic rock (Table 1, Group *29*)

The blastomylonite (No. 83) is a dark-colored glassy vein in gneiss, 30-cm wide, which originated when country rock was broken in movements. Selenium content in it is much higher than in the surrounding area, probably indicating that selenium migrated into the fracture during the movements. The phenomenon is analogous to the formation of sulfide films on the walls of joints.

Behavior of selenium in fissures that are more or less open to the surface (Table 1, Groups *30—34*)

Near the surface, where temperature and pressure decrease, selenium separates in gaseous form from the cooling and crystallizing magma and is strongly enriched into volcanic emanations. The selenium content in soils of volcanic areas is commonly high (Koljonen 1973a, p. 18).

In silicic vein rocks formed near the surface, selenium content is very low. In the granophyre and leucocratic gabbro from Iceland (Table 1, Group *30*) no Se is found, although the average in basalts is 150 ppb (17 specimens) and in rhyolites 120 ppb (11 specimens). Also the content in basic veins in Pellinki and in the porphyry veins (9 specimens) associated with rapakivi granites (average 56 ppb) is under 10 ppb. However, in one sample, from the contact of a quartz porphyry in Wiborg massif, 110 ppb Se was found.

Summary

During the emplacement of plutonic rock, a great part of the selenium present in the bedrock tends to migrate out of the system. Metasomatism occurs, but since Se concentration in plutonic rocks is usually low, the increase affects only the immediate contact.

Selenium released from magma migrates in hydrothermal solutions before the pegmatitic phase and only traces are found in pegmatites. Nevertheless, the content in pegmatites is often greater than in granites. Selenium is usually absent (< 10 ppb) from large granitic dykes, but country rock looses part of its Se to the dykes when the content in it is high (Fig. 1). When the silicic veins are small, Se content reflects the concentration found in bedrock. The

TABLE 1

Selenium content in silicic vein rocks and near granitic contacts

Group	No.	Rock and locality	Selenium content ppb
		Contacts of igneous and metamorphic rocks	
1		Espoo, Nuuksio, Koivula, Finland	
	1	Pyroxene gneiss	72
	2	Pegmatite. 1-m wide granitic dyke in pyroxene greiss	32
	3	Pyroxene gneiss, granitized. 20 m from the contact with orbicular granite	20
	4	Orbicular granite	30
2		Kuru, Parkusjärvi, quarry, Finland	
	5	Orbicular granite	126
	6	Gabbro	200
	7	Granite	< 10
3		Mäntyharju, Kesiönjärvi, Finland	
	8	Biotite-plagioclase gneiss	< 10
	9	Biotite-plagioclase gneiss. 0.5-m from the contact with rapakivi granite	24
	10	Biotite rapakivi	60
4		Suomenniemi area, Finland	
	11	Granite. Country rock	< 10
	12	Hornblende rapakivi, contact variation	19
	13	Hornblende rapakivi.	30
		Contacts of silicic dykes with plutonic rock	
5		Mäntsälä, Soukkio, Finland	
	14	Peridotite	70
	15	Gabbro	58
	16	Pegmatite. 2-m wide granitic dyke in peridotite	< 10
6		Kemiö, feldspar-quartz quarry, Finland	
	17	Gabbro. 2 m from the contact with pegmatite	210
	18	Pegmatite. Granitic dyke, over 20 m wide	< 10
7		Järvenpää, Finland	
	19	Granodiorite	56
	20	Pegmatite. 1-m wide dyke in granodiorite	< 10
8		Jämsänkoski, Finland	
	21	Granite, coarse-grained	37
	22	Granite, small and even-grained variety. 0.5-m wide dyke	37
9		Heinola, Mäntyharju area, Ahvenisto, Finland	
	23	Biotite rapakivi	44
	24	Granite porphyry. 0.5-m wide dyke in biotite rapakivi	< 10
10		Heinola, Mäntyharju area, Kukkamäki, Finland	
	25	Biotite rapakivi. From the contact with granite prophyry	36
	26	Granite porphyry. 0.5-m wide dyke in biotite rapakivi	< 10
11		Vihti, Olkkola, Finland	
	27	Granite	< 10
	28	Pegmatite. 1-m wide dyke in granite	< 10
12		Petäjävesi, Kintaus, Finland	
	29	Gneiss	86
	30	Silicic vein. 3-m wide vein in granite, 300 m from gneiss	56
	31	Granite, porphyritic	26
	32	Granite	< 10
13		Petäjävesi, Finland	
	33	Granite	< 10
	34	Granite	< 10
	35	Pegmatite. 5-m wide granitic dyke	72
14		Siilinjärvi carbonatite complex, Asikkala, Finland	
	36	Syenite	< 10
	37	Gneiss, fenite. 15 m from the contact with syenite	< 10
	38	Biotite gneiss containing small silicic veins. 150 m from the contact with syenite	< 10
	39	Biotite gneiss. 200 m from the contact with syenite	< 10
	40	Pegmatite. 2-m wide dyke in syenite	18
		Contacts of silicic veins with metamorphic rock	
15		Mikkeli, Finland	
	41	Mica gneiss containing pyrite dissemination	2 000
	42	Pegmatite. 1-m wide granitic dyke in mica gneiss	110
	43	Granite. Lens in mica gneiss, about 30 m wide	30
16		Sipoo, Skräddarby, Finland	
	44	Mica gneiss. 5-m from contact with pegmatite	250
	45	Migmatite. Melanocratic, mica rich part. 40 cm from contact with pegmatite	53
	46	Migmatite. Leucocratic part. 40 cm from contact with pegmatite	24
	47	Pegmatite. 2-m wide granitic dyke	34
17		Valåsen, Immelport, Sweden	
	48	Biotite gneiss	230
	49	Pegmatite. 0.5-m wide granitic dyke	90
18		Kuopio, Jynkänlahti, Petosenmäki, Finland	
	50	Paragneiss	92
	51	Aplite. 0.5-m wide granitic vein	29
19		Helsinki, Malmi, Kivikko, Finland	
	52	Cordierite gneiss containing pinite	35
	53	Pegmatite. 0.5-m wide granitic dyke	< 10
20		Vantaa, Seutula, Finland	
	54	Mica gneiss	< 10
	55	Pegmatite containing cordierite. 0.5-m wide granitic vein	20
21		Helsinki, Käpylä, Taivaskallio, Panuntie, Finland	
	56	Cordierite-garnet gneiss, kinzigite	< 20
	57	Cordierite-garnet gneiss. Melanocratic part	< 10
	58	Cordierite-garnet gneiss. Leucocratic part	< 10
	59	Quartz vein. 20-cm wide veinlet in cordierite-garnet gneiss	68
22		Valåsen, Immelport, Sweden	
	60	Sulfide schist	920
	61	Sulfide schist	640
	62	Pegmatite. 1-m wide granitic dyke in sulfide schist	71
23		Kiihtelysvaara, Heinävaara, Finland	
	63	Phyllite	310
	64	Quartz vein. 20-cm thick concordant layer in phyllite	290
24		Kiihtelysvaara, Heinävaara, Finland	
	65	Phyllite	170
	66	Quartz vein. 4-cm thick, small, concordant lens separated from phyllite	102
25		Kuopio, Neulalahti, Finland	
	67	Amphibolite	420
	68	Amphibolite	150
	69	Aplitic granite	285
	70	Granite. Small, under 50 meters wide	51
26		Kuhmoinen, Finland	
	71	Amphibolite	240
	72	Granitized amphibolite. 30 cm from the contact with pegmatite	93
	73	Pegmatite. 1-m wide granitic vein	< 10
27		Porvoo, Suur-Pellinki, Ednäs, Finland	
	74	Tuffite	21
	75	Pegmatite. 1-m wide granitic dyke	69
		Contact of igneous and metasomatic rocks	
28		Tuusniemi, Paakkila, Finland	
	76	Tremolite rock containing rich sulfide dissemination. From the central part of an asbestos lens about 100—200 m wide	4 950
	77	Serpentine rock. From the central part of the lens	2 810
	78	Anthophyllite asbestos rock. 10 m from the contact with granite	1 200
	79	Granite 10-m wide dyke	30
	80	»Maarianvaara»-granite. Host to the granite dyke. Two specimens. Kaavi—Tuusniemi	< 10
		In dynamometamorphic rock	
29		Vimpeli, Finland	
	81	Gneiss	< 10
	82	Pegmatite. 1-m wide granitic dyke in gneiss	< 10
	83	Blastomylonite. Silicic, glassy vein in gneiss	180

Group	No.	Rock and locality	Selenium content ppb
		In dyke rocks with more or less open channels to surface	
30		Iceland	
	84	Average in basalts (17 specimens)	150
	85	Average in rhyolites and obsidians (11 specimens)	120
	86	Gabbro. Leucocratic, in basalt. Snaefellsnes, Lysuskard	< 10
	87	Granophyre. 1-m wide dyke in basalt. Snaefellsnes, Laxa	< 10
31		Pellinki area, Finland	
	88	Metavolcanics. Average of 8 specimens (Laitala 1973)	32
	89	Basic dyke. 0.5-m wide dyke in metavolcanics (Laitala 1973, p. 69—70)	< 10
32		Suomenniemi area, Finland	
	90	Rapakivi (2 specimens)	25
	91	Porphyry aplite in rapakivi (2 specimens) ...	< 10
33		Mäntyharju area, Finland	
	92	Rapakivi (4 specimens)	66
	93	Granite porphyry in rapakivi (2 specimens) ..	< 10
34		Wiborg massif, Finland	
	94	Rapakivi (11 specimens)	65
	95	Quartz porphyry, granite porphyry, porphyry aplite in rapakivi	< 10

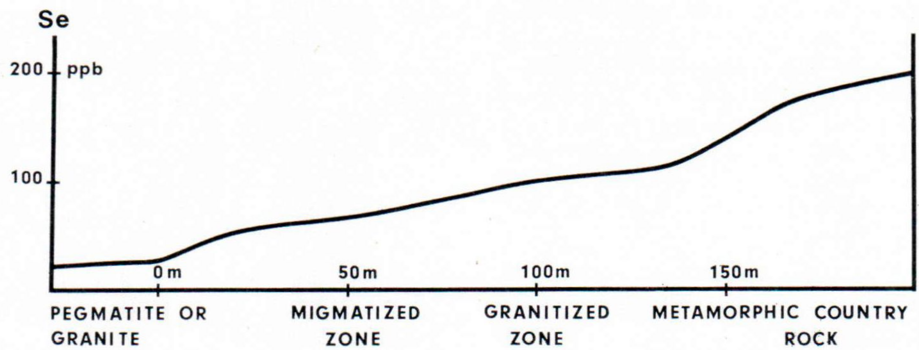

Fig. 1. Schematic representation of the variation in selenium content in country rock near contacts with pegmatite (or granite). Distances are estimates from distances that varied from meters to hundrets of meters.

greatest concentrations are found in small quartz secretions, indicating early mobilization during metamorphism. Selenium also migrates during tectonic movements and tends to accumulate in fissures or concentrates with sulfides as ore dissemination in suitable areas of country rock.

When the fissure channel is open to the surface, as in volcanic areas, the pressure in the magma decreases. Gaseous selenium escapes along with other volatile substances, resulting in a decreased Se content in the vein. The high silica content of magma encourages the process because silicic magma is viscous and advances sluggishly.

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