SELENIUM IN CERTAIN METAMORPHIC ROCKS

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The selenium contents of Precambrian metamorphic rocks from Finland were studied and tentative averages are presented. The pattern of the distribution of selenium in metamorphic rocks can be summarized as follows:

Selenium most probably does not enter into the structures of the common silicate minerals, but rather is incorporated in the accessory sulphide phase. The distribution of selenium in the rocks studied greatly resembles that distribution which is found in sediments. The highest contents are found in mica schists, phyllites and especially in sulphide bearing black schists. These are all metamorphosed clays possibly containing organic matter before metamorphism. In exogenic processes selenides are oxidised to elemental selenium which, being colloidal, is electrically charged and adsorbed by clay minerals.

Selenium contents are low in silicium rich rocks. In many gneisses and clastic quartzites the contents are less than 20 ppb, which is the lower limit of the analytical method used. Rocks which are derived of calcium and magnesium rich carbonate sediments are also nearly devoid of this element. The selenium that is found in the latter probably reflects the content of clay fraction and organic matter in the primary sediment.

Under metamorphism the rocks seem to loose a great part of that selenium which has originally been present in the unmetamorphosed sediment.

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Introduction

As a part of a study of the distribution and geochemical behaviour of selenium in the Finnish Precambrian, this paper deals with the highly metamorphic rocks.

Previous data for the contents of selenium in the metamorphic rocks of Finland are very scanty, the only work known to the author being that of Peltola (1960) which gives selenium contents in the black schist of the Outokumpu region.

The distribution of selenium in low metamorphic sedimentary rocks is quite well known especially in seleniferous areas were selenium is found in toxic concentrations (Beath and Gilbert 1936; Beath, Gilbert and Eppson 1937; Beath, Hagner and Gilbert 1946; Buryanova 1961; Coleman 1956; Coleman and Delevaux 1957; Davidson and Powers 1959; Krauskopf 1955;

Moxon, Olson, Searight and Sandals 1938; Searight, Moxon, Hilmoe and Whitehead 1946; Trelease and Beath 1949; Williams and Byers 1935; and 1936).

The geochemical behaviour of selenium is dominated by its isomorphic substitution with sulphur in sulphides and consequently its geochemistry, to a high degree, resembles that of sulphur.

In the following the selenium contents of the various metamorphic rock groups are briefly reviewed.

Gneisses

On the basis of the data summarized in Table 1, Nos. 1—36, the selenium contents in gneissose rocks are diagrammatically presented in Fig. 1.

The selenium contents varies within relatively wide limits and depends largely on the amount of sulphide phase present. In many of the gneisses studied the selenium content was below the limit of detection of the method used. The low content in high siliceous gneisses parallels that of granites (Brunfelt and Steinness 1967; Koljonen 1971).

Quartzites, meta-arkose and graywacke

Table 1, Nos. 37—46, histogram in Fig. 1. The content of selenium is quite low. It is, however, interesting to note that selenium is found at all in this rock group. The selenium was probably adsorbed in clay minerals and partly retained during the metamorphism. Under mechanical and chemical weathering the selenium-bearing minerals (sulphides and dark minerals) are likely to be disintegrated. Clastic quartzites are therefore devoid of this element and selenium preferably occurs in sediments formed partly of siliceous gels. High selenium concentrations are known from Icelandic geyserites (Koljonen 1971).

Huhma (1970a, 63; and b, 24—26) suggested that some quartzites in the Outokumpu area are not sedimentary quartzites as proposed earlier. According to him no clastic textures can be observed in these rocks and the trace element pattern differs from that of sands.

Quartzites which are partly or wholly formed from SiO_2-gels should contain more selenium than the clastic quartzites proper.

Conglomerates

Table 1, Nos. 67—70, histogram in Fig. 1.

The selenium content is transitional between those of the mica schists and sedimentary amphibolites usually constituting the matrix and, on the other hand, quartzites and magmatic rocks which form pebbles.

Mica schists, phyllites and black schists

Table 1, Nos. 47—60, histogram in Fig. 1.

The selenium contents as illustrated in the histogram of Fig. 1, are high. Mica schists are metamorphic derivatives of clays in which selenium is adsorbed. The selenide ion is not easily oxidised to soluble selenite but to elemental selenium which is stable under the most exogenic conditions. As it is colloidal, it is easily adsorbed to clay minerals and other colloids (cf. Coleman and Dlevaux 1957; Fleming and Walsh 1957; Green 1959; Miller 1937; Miller and Brown 1938; Moxon, Olson, Searight and Sandals 1938; Searight, Moxon, Hilmoe and Whitehead 1946; Williams and Byers 1935; and 1936). Selenium participates in the biogeochemical processes and is enriched in black schists containing graphite and sulphides in abundance (cf. Beath and Gilbert 1936; Beath, Hagner and Gilbert 1946; Byers and Knight 1935; Byers, Williams and Lakin 1936; Chentzov 1963; Davidson and Gulbrandsen 1957; Fleming and Walsh 1957; Gibson and Selvig 1944; Keys and White 1956; Lakin, Williams and Byers 1938; Meixner 1954, 20; Miller 1937; Oksanen 1965, Robinson 1933). The varved schist, Ylöjärvi, Siivikkala (Table 1, No. 48) contains 300 ppb selenium, one of the highest Se concentration found in mica schists. The same rock contains the carbon sacks »Corycium enigmaticum» which, according to Sederholm (1897, 91) and Rankama (1948, 389—416; and 1950, 75) represent fossils, the carbon being of organic origin. This interpretation is in accordance with the high selenium content.

The high selenium contents found in black schists by the author are in accordance with those presented by Peltola (1960). The selenium content can vary in black schists within very wide limits according to their sulphide contents and the content of the original organic matter.

Amphibolites

The selenium contents are presented in Table 1, Nos. 61—66, and the histogram of Fig. 1. The contents range between those of mica schists and carbonate rocks.

Carbonate rocks

The selenium contents (Table 1, Nos. 71—75, Fig. 1) are very low, this being in accordance with the chemistry of selenium. In basic surroundings it forms soluble salts — selenites — which can easily migrate out of the system and may participate in the biocycle (Olson, Jornlin and Moxon 1942; Olson, Whitehead and Moxon 1942). The carbonatite of Siilinjärvi, Finland, (Koljonen 1973) is probably of magmatic origin and is discussed in connection with the magmatic rocks (Puustinen 1968; and 1969).

Miscellaneous schists and rocks

Table 1, Nos. 76—80.

The selenium content is low. Due to the scarcity of available data the distribution will not be discussed in this connection. The ultrabasic rock No. 80 occurs in limestone and accordingly does not contain any selenium, an interesting observation since the sample abundantly contains biotite which in mica schists and especially in plutonic rocks often indicates high selenium contents (Koljonen 1971, 9).

Skarn rocks

Table 1, Nos. 81—82.

This rock type also includes diopside gneiss No. 8. All the specimens show significantly low selenium contents. These rocks are probably formed in basic oxidising conditions.

The skarn rocks connected with sulphidic ores are excluded in this connection and discussed separately.

Serpentine rocks

Table 1. Nos. 83—86.

The selenium contents are high in this rock group. In the Outokumpu region the serpentine rocks have been interpreted as products of hydrothermal metamorphism (Haapala 1936; Wiik 1953), apparently caused by selenium-rich emanations. Serpentine rocks are often connected with sulphidic ore mineralisations in this area and the high sulphur content in serpentine rocks is demostrated by the analyses given by Haapala (1936, 61—62) and Wiik (1953, 48—55).

Metamorphic rocks of volcanogenic origin

Table 1, Nos. 87—96. The selenium contents are lower than those commonly found in present-day volcanic rocks (cf. Bellini 1907; Brown 1916; Byers, William and Lakin 1936; Clarke 1924; Davidson and Powers 1959; Quercigh 1925; Zambonini and Coniglio 1925; Zies 1929, 26—27, 40—41). In volcanogenic metamorphic rocks the selenium contents have been appreciably decreased by exogenic processes (weathering and low temperature hydrothermal leaching) and by metamorphism. During weathering of low iron rocks with a high silicium content, the selenium begins to migrate and may, if the selenium content is sufficiently high, cause toxic diseases in animals (Trelease and Beath 1949).

Dynamometamorphic rock

The sample (Table 1, No. 97) is from s small, nearly black and about 30 cm broad vein in gneiss. Since the selenium content of the gneiss is very low, it is interesting to find some selenium in this glassy silica-rich vein. Selenium usually tends to follow iron in rocks. The phenomenon of the enrichment of selenium in vein rocks has been discussed by Koljonen (1971, 11—12). It seems obvious that selenium begins to migrate and tends to move along fissures and shear zones. The same phenomenon is seen in the mica schist No. 51, which displays well developed microfolds. In the rocks selenium is enriched in the small quartz vein. Peltola (1960, 73—74) observed an analogous phenomenon in black schist. He states: »The abundant occurrence of sulphide in the carbon-poor layers in black schist as conformable concentrations would seem to indicate their mobilization during the inital stage of deformation particularly in shear zones parallel to the bedding of black schist».

Shock-metamorphic rocks

The petrological study of these rocks was made by M. Lehtinen, who kindly placed several samples of the Lappajärvi shock-metamorphic rocks at the author's disposal (Table 1, Nos. 98—101). The selenium content is unusually high compared with other rocks of high SiO_2

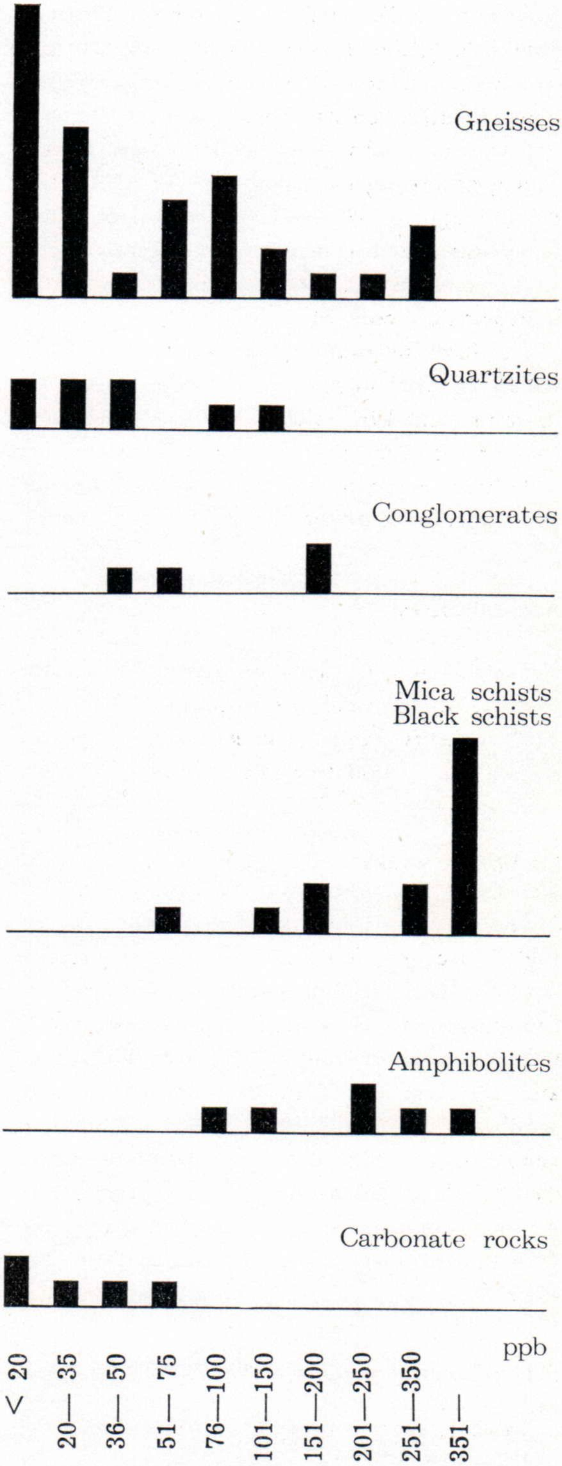

Fig. 1. Review of the selenium contents in metamorphic rock studied (■ one sample)

contents. The comparison can be made between granites with a tentative average Se content (Koljonen 1971) 25 ppb and gneisses with a mean, according to Table 1, of 62 ppb. The gneisses in the Lappajärvi area normally contain less selenium (Nos. 10, 11, 32). Since the meteorites contain 2 000—50 000 ppb of this element (DuFresne 1960; Pelly and Lipschutz 1970; Sindeeva 1964) it can be considered possible that the selenium contents reflect the primary concentration of the meteorite, which has caused the impact, and increased the selenium content of the shock-metamorphic rocks.

Summary

The contents of selenium varies in metamorphic rocks within wider limits than in plutonic rocks. The average values presented below only indicate the general tendency of the distribution:

	Nos.	Se ppb
Gneiss	2—36	62
Quartzite	37—44	43
Conglomerate	67—70	120
Mica schist	47—52	190
Black schist	53—60	9 900
Amphibolite	61—66	240
Carbonate rocks	71—75	25
Metamorphic volcanics	87—96	36

Selenium tends to enrich in the melanocratic rocks and also the rocks which have contained organic matter before metamorphism. This is observed as an increase in the selenium contents in amphibolites, mica schists, black schists and coals (cf. Goldschmidt 1962, 538—539). The carbonate rocks analyzed in this study are nearly monomineralic, homogeneous, crystalline limestones without any fossil remains. They may have lost the original selenium content during metamorphism. Calcium does not form any selenides and, therefore, cannot retain selenium. The selenium content of calcareous clay sediments may well be retained through metamorphism as in amphibolite and black schist (cf. Peltola 1960, 90—95), which may contain appreciable concentrations of selenium.

The selenium content in metamorphic volcanogenic rocks is unexpectedly low when compared with other silica-poor sedimentary rocks. Noteworthy is that the average content is near 54 ppb's Se which is the average of the dyke rocks: albite diabases, trachyandesites, plagioclase porphyrites and feldspar porphyrites (Koljonen 1971, 139—144) of volcanic origin.

Some of the samples of volcanogenic rocks which do not contain detectable selenium contents are from the surroundings of the town of Porvoo and especially from the island of Suur-Pellinki situated near contact to the younger Onas granite. It is, therefore, possible that volcanics have lost part of their selenium content by thermal contact metamorphism.

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Mr. Olavi Y. Nurminen assisted me to handle the samples and Mr. Urpo Eklund drew the histogram.

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TABLE 1

Selenium contents of the metamorphic rocks

No.	Rock and locality	Selenium content ppb
1	Biotite gneiss, contains sulphide veinlets. Mikkeli mlk., Finland (Frosterus 1900; and 1903, 8—11)	1 980
2	Gneiss granite, contains poor sulphide impregnation. Kiihtelysvaara, Pölkkylampi, Finland (Frosterus and Wilkman 1920, 14—16; and 1924; Nykänen 1971, 97—98)	320
3	Gneiss (leptite), contains poor sulphide impregnation. Vihti, Olkkola, Finland (Härme 1958; and 1960, 14—16)	280
4	Biotite gneiss. Sipoo, Skräddarby, Finland (Härme 1962, 113—125)	250
5	Biotite gneiss. Vimpeli, Finland (Saksela 1934; and 1935, 6—7; Laitakari 1942, 11—14)	170
6	Quartz-feldspar schist (leptite). Ylöjärvi, Kiviniemenlahti, Finland (Simonen 1952, 10—14, 49—50; and 1953b)	120
7	Granulite. Inari, Finland (Hackman 1905, 102; Eskola 1932; Sahama 1936a, 1—113; and b, 267—274; Erämetsä 1938, 12, 49; Rankama 1946, 28—39)	110
8	Cordierite-garnet gneiss. Helsinki, Oulunkylä, Finland (Parras 1958, 90—93; Härme 1965)	93
9	Paragneiss. Kuopio mlk., Jynkänlahti, Finland (Wilkman 1923, 8—14; Preston 1954, 16—24)	92
10	Gneiss (leptite). Salla, Finland (Lauerma 1967)	87
11	Gneiss (leptite). Salla, Finland (Lauerma 1967)	87
12	Gneiss. Petäjävesi, Kintaus, Finland (Frosterus 1900; and 1903, 8—11; Rouhunkoski 1959, 50—54).	86
13	Pyroxene gneiss. Espoo, Nuuksio, Finland (Sederholm 1928, 74—75; Parras 1958, 96—103)	72
14	Biotite gneiss. Nastola, Finland (Lehijärvi 1964 a; and 1964 b, 10—15)	63
15	Biotite gneiss. Kaavi, Luikonlahti, Finland (Frosterus and Wilkman 1920, 40; and 1924; Vorma 1956, 7—9; Peltola 1960, 27—28: Saikkonen 1962, 6—8; Björnberg 1965, 9—10)	55
16	Biotite gneiss. Sipoo, Skräddarby, Finland (Härme 1962, 113—125)	53
17	Gneiss (augen gneiss). Valåsen, Immelport, Sweden	37
18	Cordierite gneiss, contains pinite. Helsinki, Kivikko, Finland (Parras 1958, 90—93; Härme 1965)	35
19	Pyroxene gneiss. Espoo, Nuuksio, Finland (Sederholm 1928, 74—75; Simonen 1941, 130; Parras 1958, 96—103)	32
20	Biotite gneiss. Mikkeli mlk., Finland (Frosterus 1900; and 1903, 8—11)	30
21	Biotite gneiss. Mikkeli mlk., Kalvitsa, Finland (Frosterus 1900; and 1903, 8—11)	29
22	Biotite-plagioclase gneiss. Heinola, Finland (Frosterus 1900; and 1903, 8—11; Savolahti 1962, 48—50, Table 6, Anal. 1)	24
23	Gneiss. Sipoo, Skräddarby, Finland (Sederholm 1928, 74—75; Härme 1962, 113—125)	24
24	Pyroxene gneiss. Espoo, Nuuksio, Finland (Sederholm 1928, 74—75; Simonen 1941, 130; Parras 1958, 96—103)	20
25	Biotite-plagioclase gneiss. Heinola, Finland (Frosterus 1900; and 1903, 8—11; Savolahti 1962, 45—50, Table 6, Anal. 2)	n.d.
26	Biotite gneiss, contains gaphite. Lappajärvi, Lamminkylä, Finland (Saksela 1934; and 1935, 6—7; Laitakari 1942, 38—40; Lehtinen 1970)	n.d.
27	Gneiss. Vimpeli, Finland (Saksela 1934; and 1935, 6—7; Laitakari 1942, 11—14)	n.d.
28	Garnet-cordierite gneiss. Raisio, Finland (Parras 1958, 90—93; Härme 1960, 12—14)	n.d.
29	Diopside gneiss. Vihti, Olkola, Finland (Parras 1958, 103—107)	n.d.
30	Feldspar gneiss. Vantaa, Viinikkala, Finland (Härme 1965)	n.d.
31	Cordierite-garnet gneiss (kinzigite). Helsinki, Käpylä, Finland (Erämetsä 1938, 49; Parras 1958, 90—93; Härme 1965, 28—32)	n.d.
32	Biotite gneiss. Helsinki, Käpylä, Finland (Parras 1958, 90—93; Härme 1965, 11, 28—32)	n.d.
33	Cordierite-garnet gneiss (kinzigite). Helsinki, Käpylä, Finland (Erämetsä 1938, 49; Parras 1958, 90—93; Härme 1965, 28—32)	n.d.
34	Biotite gneiss. Siilinjärvi, Asikkala, Finland (Wilkman 1933, 92; Puustinen 1968, 14—15, 77—79; and 1969, 89—92)	n.d.
35	Gneiss (fenite). Siilinjärvi, Asikkala, Finland (Wilkman etc.)	n.d.
36	Biotite gneiss. Siilinjärvi, Asikkala, Finland (Wilkman etc.)	n.d.
37	Quartzite. Kiihtelysvaara, Pölkkylampi, Finland (Ojakangas 1965, 13—14; Carlson 1967, 39—54; Nykänen 1971, 98—100)	125
38	Quartzite. Kiihtelysvaara, Pölkkylampi, Finland (Ojakangas etc.)	83
39	Quartzite. Kemi mlk., Akkunusjoki, Finland (Härme 1949, 11—12; Enkovaara, Härme, and Väyrynen 1953, 83—84; Mikkola 1960, 156—157; Kahma, Siikarla, Veltheim, Vaasjoki, and Heikkinen 1962, 32—33; Näykki 1964, 18—21; Ojakangas 1965, 16)	40
40	Quartzite. Kuopio, Neulamäki, Finland (Wilkman 1923, 14—27; Preston 1954, 38—44)	40
41	Sericite quartzite. Eno, Paukkajavaara, Finland (Tyni 1960, 12—13; Ojakangas 1965, 14—15; Piirainen 1968, 17—25)	34
42	Quartzite, contains 0.40 % Mn. Kiihtelysvaara, Raatevaara, Finland (Ojakangas 1965, 13—14; Carlson 1967, 48)	20
43	Arkose quartzite. Kontiolahti, Finland (Ojakangas 1965, 13—14)	n.d.
44	Sericite quartzite. Kiihtelysvaara, Raatevaara, Pölkkylampi, Finland (Ojakangas 1965, 13—14; Carlson 1967, 39—54)	n.d.
45	Meta-arkose. Suodenniemi, Finland (Sederholm 1903; 1913, 32—34; and 1931, 43—47; Simonen 1953a, 33—34)	110
46	Graywacke. Nokia, Finland (Simonen 1953a, 31—37; Marmo 1957, 10)	69
47	Mica schist (microfolded). Kiihtelysvaara, Heinävaara, Finland (Frosterus and Wilkman 1920, 109—112; Carlson 1967, 9—11)	310
48	Varved mica schist. Ylöjärvi, Siivikkala, Finland (Sederholm 1897, 82—93; and 1931, 10; Rankama 1948, 389; van Straaten 1949, 14—18; Rankama 1950, 75; Seitsaari 1951, 22—25; Simonen and Kouvo 1951, 93—114; Simonen 1952, 7—10, 47—49; and 1953 b; Lonka 1967, 19, 20; Matisto 1969, 199—202)	300
49	Phyllitic mica schist. Kiihtelysvaara, Heinävaara, Finland (Frosterus and Wilkman 1920, 109—112; Carlson 1967, 9—11; Nykänen 1971, 107)	170
50	Mica schist. Kiihtelysvaara, Heinävaara, Finland (Frosterus etc.)	110
51	Mica schist. Kontiolahti, Heinävaara, Finland (Frosterus and Wilkman 1920, 109—112; Lonka 1967, 32)	61
52	Staurolite mica schist. Tohmajärvi, Finland (Frosterus and Wilkman 1920, 110—112; Juurinen 1956, 13; Nykänen 1967; and 1971, 97, 104)	170
53	Black schist. Sotkamo, Talvivaara, Finland (Wilkman 1929; and 1931, 188; Marmo 1960, 53, 58, 65; Lonka 1967, 27—28)	37 000
54	Black schist. Kaavi, Luikonlahti, Finland (Vähätalo 1953, Append. I; Peltola 1960, 27—28, 78, 80)	17 500
55	Black schist. Kuhmoinen, Patavesi, Finland (Frosterus 1900; and 1903)	9 100
56	Black schist. Lapua, Finland (Saksela 1934; and 1935, 32; Laitakari 1942, 18)	8 700
57	Black schist. Pyhäselkä, Mulo, road cut, Finland (Peltola 1960, 50—57, 80; Lonka 1967, 19)	4 100
58	Black schist. Tuusniemi, Paakkila, Finland (Vähätalo 1953, Append. I; Peltola 1960, Append. I)	1 700
59	Black schist. Valåsen, Immelport, Sweden	640
60	Black schist. Jäppilä, Finland (Frosterus 1900)	570
61	Amphibolite. Kuopio, Neulamäki, Finland (Wilkman 1923, 12—13; Preston 1954, 15—16)	420
62	Amphibolite. Pertunmaa, Kuortti, Finland (Frosterus 1900; and 1903)	340
63	Amphibolite. Kuhmoinen, Patavesi, Finland (Frosterus 1900; and 1903) —	240
64	Amphibolite. Kinnula, Jääjoki, Finland (Nykänen 1962; and 1963, 12—13, Table I, Anal. 1)	210

No.	Rock and locality	Selenium content ppb
65	Amphibolite. Kuopio, Neulalahti, Finland (Wilkman 1923, 12—13; Preston 1954, 15—16)	150
66	Amphibolite (granitized). Kuhmoinen, Finland (Frosterus 1900; and 1903)	93
67	Conglomerate, contains poor sulphide impregnation. Kiihtelysvaara, Pölkkylampi, Finland (Frosterus and Wilkman 1920, 148; Carlson 1967, 26—34; Nykänen 1971, 98—100)	200
68	Conglomerate. Liperi, Venehpohja, Finland (Frosterus and Wilkman 1924, 65—66)	160
69	Conglomerate. Lavia, Harju, Finland (Sederholm 1931, 11, 48—58)	74
70	Conglomerate, contains quartz pebbles. Eno, Paukkajanvaara, Finland (Frosterus and Wilkman 1920, 149; and 1924; Tyni 1960, 13—15)	40
71	Dolomite rock. Soanlahti, Soanjoki, USSR. (Eskola, Hackman, Laitakari and Wilkman 1919, 161—165; Hausen 1930, 72—80)	51
72	Limestone. Särkisalo, Förby, Finland (Eskola, Hackman, Laitakari and Wilkman 1919, 66—68; Ahlfors 1954, 81—82)	45
73	Limestone, contains fluorite. Parainen, Finland (Eskola, Hackman, Laitakari and Wilkman 1919, 89—93; Laitakari 1921, 12—15; Metzger 1954, 53—58)	30
74	Limestone. Parainen, Finland (Eskola etc.)	n.d.
75	Limestone. Lohja, Tytyri, Finland (Eskola, Hackman, Laitakari and Wilkman 1919, 40—42; Kalla 1952; Parras and Tavela 1954, 71—73)	n.d.
76	Chlorite-quartz schist. Siilinjärvi, Asikkala, Finland (Puustinen 1968)	n.d.
77	Talc schist. Sotkamo, Lahnaslampi, Finland (Salminen 1935, 19; Wiik 1953, 51; Vesasalo 1961, 11, 103)	26
78	Biotite-quartz-lime schist. Siilinjärvi, Asikkala, Finland (Puustinen 1968)	145
79	Garnet-glaucophane schist. Tierra del Fuego, Seno Martinez, Bahia Plüschow, Argentina (Kranck 1932, 14, 53)	31
80	Ultrabasic rock in limestone. Vihti, Olkkala, Finland (Eskola, Hackman, Laitakari and Wilkman 1919, 32—35; Härme 1960, Append. 2)	n.d.
81	Garnet skarn in magnetite ore. Helsinki, Laajasalo, Stansvik, Finland (Tammekann 1925, 1—26; Sahama 1936b, 273; Seitsaari 1943, 38—41; Rankama 1944, 25; Aurola 1956, 13—38; Virtanen 1959, 36—40)	n.d.
82	Diopside skarn in magnetite ore. Helsinki, Laajasalo, Stansvik, Finland (Tammekann 1925, 1—26; Seitsaari 1943, 38—41; Aurola 1956, 11—38; Virtanen 1959, 36—40)	n.d.
83	Serpentine rock. Tuusniemi, Paakkila, Finland (Haapala 1936, 58—63; Suila 1950, 16—39; Wiik 1953, 8, 10, 48; Vesasalo 1961, 11, 104)	2 810
84	Serpentine rock. Tuusniemi, Paakkila, Finland (Haapala etc.)	1 200
85	Serpentine rock. Rovaniemi, Misi, Finland (Nuutilainen 1968, 25, Anal. 1, 53—63)	160
86	Serpentine rock, contains amphibole. Nivala, Finland (Saksela and Hackzell 1938, 73—79; Huhta 1953, 21—25; Papunen 1970, 23—25)	30
87	Agglomerate. Ylöjärvi, Kiviniemi, Finland (Simonen 1952, 17—20, Map I; and 1953 b)	n.d.
88	Volcanogenic schist. Hyvinkää, Finland (Kaitaro 1956)	100
89	Volcanogenic schist. Porvoo, Nyttisholmen, Finland (Sederholm 1923, 18—68; Laitala 1964)	76
90	Tuffite. Pernaja, Finland (Laitakari and Simonen 1962; and 1963, 13—17)	50
91	Tuffite. Porvoo, Ednäs, Finland (Sederholm 1923, 18—68; Laitala 1964; Koljonen 1965, 31)	21
92	Tuffite. Porvoo, Älskholmen, Finland (Sederholm 1923, 18—68; Laitala 1964)	n.d.
93	Basaltic vein. Porvoo, Ednäs, Finland (Sederholm etc.)	n.d.
94	Uralite porphyrite (pillow lava). Porvoo, Suur-Pellinki, Finland (Sederholm etc.)	59
95	Basic volcananogenic rock (uralite porphyrite). Hyvinkää, Kytäjä, Finland (Kaitaro 1956; Härme 1960, 20—23)	51
96	Uralite porphyrite. Porvoo, Suur-Pellinki, Finland (Sederholm 1923, 18—68; Laitala 1965)	n.d.
97	Blastomylonite. Vimpeli, Koskela, River Savo, Finland	180
	Shock-metamorphic rocks of the Lake Lappajärvi area (Eskola 1921, 11—13; Saksela 1935, 5; Laitakari 1942, 38—40; Lehtinen 1970, 89—93):	
98	Kärnäite, type II (Lehtinen, in press). Alajärvi, Kaartusenneva, Finland	493
99	Kärnäite, type II (Lehtinen, in press). Vimpeli, Kotkaniemi, Pokelanniemi, Finland	362
100	Fallout-breccia (Lehtinen, in press). Alajärvi, Kaartusenneva, Finland	122
101	Ligh coloured, leached kärnäite, type II (Lehtinen, in press). Alajärvi, Autioniemi, Finland	99

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