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FENNOSCANDIAN ACIDIC PYROCLASTICS (HÄLLEFLINTAS AND LEPTITES) ASSOCIATED WITH THE PRECAMBRIAN ORE DEPOSITS

– for Contributing to the Palaeozoic Volcanic Activities in Northeast Japan, part 1.

by

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(with 6 text-figures and 4 tables)

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Abstract

Fennoscandian hälleflintas and leptites of 188 samples published up to the present, which in many cases are genetically associated with the ore mineralization, are petrochemically reexamined and recalculated herein with the purpose to contribute in near future on studying of the Palaeozoic volcanic activities belonging to the Japanese Variscan Orogeny in Northeast Japan.

Introduction

Professor M. Minato, and his students, of the Department of Geology and Mineralogy, Hokkaido University, have in detail elucidated the Palaeozoic stratigraphy in the Kitakami mountains, Northeast Japan, by their vigorous researches for approximately forty years.

According to them (Minato, 1950, 1955; Minato et al., 1975), in the eugeosynclinal stage of the Abean Orogeny (the Japanese Variscan) there are fairly volumetric piles of the acidic volcanic products, together with a great piles of the basic and intermediate pyroclastics. Especially, in the *Ohno Series* of the Lower Devonian the acidic volcanics with intercalating normal sediments attain to 340 m in thickness, while in the *Nakazato Series* of the Middle Devonian the basic pyroclastics with intercalating acidics and normal sediments attain to 730 m in thickness. On the other hand, in the *Kamine Series* (correlated to the *Ohno Series*) of the Hitachi mine district, where is located in the southern extremity of the Abukuma mountains, the leptite and hälleflinta members attain to at least 1500 m in thickness and in the *Ohkadoya Series* (correlated partly to the *Nakazato Series*) the basic pyroclastics with intercalating acidics and normal sediments attain to at least 2500 m in thickness. The *Ohkadoya Series* may be not denied to include formation correlatable to the Gevetian besides Eifelian, since it is far thicker than the *Nakazato Series* and acidic volcanics are rather common compared to the *Nakazato Series* (Watanabe, 1971, 1975). It should be noted that the presence of acidic volcanics is widely known in the Givetian in various parts of the Variscan terrain, viz. Gornyy Altay (Central- and East-Altay), Budnyy Altay (Zmeinogorsk-Tarkhanny belt and Kolyvan-River belt), Tom-Kolyvan Province and Kuznetsk basin. However, this problem is not finally settled in Japan, because of lacking of fossil evidences.

The aim of the present paper, as a preliminary study, is for contributing to the acidic volcanic activities of the Japanese Variscan Orogeny, compared to those of the Precambrian in Fennoscandia from lithological and lithochemical points of view, at which the present author stayed and studied during 1972–1975.

A brief historical review of the studies in Fennoscandia.

Terminology of leptites

The term leptite was introduced by Hummel (1875), but it was not until the International Geological Congress of 1910 that the term came into common use in Swedish geological literature. Earlier used terms are *eurite* (Forsselles, 1854), *hälleflintgneiss* (Santesson, 1877), *granulite* (Törnebohm, 1880) and *felsitoid* (Munthe and A. Gavelin, 1907), to signify those aphanitic or fine-grained metamorphic Archean rocks, which are composed mainly of quartz and feldspars with subordinate amounts of coloured minerals.

Before going on the genetic problem, it seems suitable at this point to give a brief survey of the interpretations of the leptites, which have been put forward during this century. The concept leptite has been defined in different ways by different authors. The hypothesis given by Johansson (1906, 1907, 1924) is now not entirely accepted. According to him all the rocks belonging to the leptite formation comprise infracrustal magmatic rocks which have received their composition through differentiation in situ. Strong criticism has been however directed at this interpretation by Holmqvist (1907), Högbom (1910), Geijer (1921), Lindroth (1922), Sundius (1923), Magnusson (1925) and others. According to these authors leptite consists mainly of lavas (possibly also hyperbyssal rocks) and tuffs which have been subjected to weaker or stronger metamorphism. This view has been supported by discoveries of preserved textures such as ash texture, porphyritic texture, different groundmass textures and also banding etc. (Nordenskjöld, 1894, 1896; Lindroth, 1922; Magnusson, 1925, 1940). Sederholm (1907) also defined the leptites as a very fine-grained to aphanitic gneiss. Among the Swedish hälleflintgneiss-like rocks which have been called "granulite" are actually included various rocks. The term granulite used in the other parts of the world does not always correspond to the Swedish usage, and the same situation seems to apply to the granulites in Finnish Lapland. Among them are new varieties, so far as outer appearance and mineral composition are concerned, which correspond completely to the typical granulites of Saxony (the Leptynites), but there are also many more gneissic varieties, injected by very garnet-rich pegmatitic veined rocks. The altered psammite from Suoniemi, which Sederholm referred to as leptite after Hummel, has a rather gneissose appearance, particularly in the section close to the granite basement. According to Högbom (1910), the typical leptites are dense, fine-grained metamorphic rocks which in their chemical and mineralogical composition agree with gneiss. Micas are generally present, though mostly subordinate in amount. Garnet occurs in some varieties, but is seldom prominent. Geijer and Magnusson (1944) gave the following definition: "by the term leptite we now mean a metamorphic (recrystallized) supracrustal rock, with approximately granitic composition, which has a secondary grain size between 0.03 and 0.05 mm as a lower limit and 0.5(–1) mm, excluding phenocrysts which may be present". Geijer (1944) subsequently greatly widened the concept of leptite and partly abandoned the strict limit which was defined by Geijer and Magnusson, especially in terms of chemical and mineralogical composition of leptite. Geijer and Magnusson (1944) divided the leptites into the rhyolite (leptites s.s.) and meta-dacite types. The former was classified on the basis of quantity and type of alkali feldspar into K-extremes, K-dominants, Alkali-intermediates, Na-dominants and Na-extremes. The latter (meta-dacite plus meta-andesite) differ from the leptites s.s. in having a higher calcium content, higher content of mafic minerals and a lower quartz content. Henriques (1964) used the term leptite for supracrustal, recrystallized rocks, of the Zinkgruvan (Åmmeberg) mine, Central Sweden, belonging to the older parts of the Archean. They are, as a rule, quartz- and feldspar-bearing rocks, having a composition which widely varies and whose grain size is 0.03 and 0.06 mm with the exception of phenocrysts which may be present. Under such circumference, the name of leptite has been applied to many different types of rocks in Sweden. For examples, the terms that have been used for leptites consisting of quartz, oligoclase-andesine, microcline and mafic minerals, include porphyritic plagioclase leptite (Geijer, 1923), plagioclase potassium-leptite (Geijer, 1936), CaO-rich intermediate leptite (Lindroth, 1924) and potassium-calcium-leptite (Magnusson, 1938). A quantitative mineral classification, according to Johannsen's system (1931), actually shows that the rocks in the cases mentioned above have a composition which corresponds to that of rhyodacite.

The leptites also comprise non-eruptive rocks. According to Geijer (1917), a number of quartz-rich, well banded leptites in the Falun mine district, Sweden, can be chemical sediments. Backlund (1938) stated that leptites consist, besides volcanic material, of epiclastic, sometimes granitized sediments. Concerning leptites which were identical with those of the Zinkgruvan district and found some miles further west, Du Rietz (1948) wrote, "at least the main part of the leptites in the area have been fine-grained arkoses or tuff; it is hard to decide which, due to the metamorphism of the rocks".

Whether the chemical composition of the leptites is primary or not has been discussed in detail. Johansson (1906, 1907) did not consider that the leptites had undergone any essential alterations since they were formed. Sundius (1923) wrote, "it can thus probably be assumed that the chemical characters of the leptites and hälleflintas are primary, produced through differentiation in the magma which has produced their material". The same opinion was expressed by Geijer (1917, 1923, 1936) and Magnusson (1925, 1940).

In connection with ore and rock formation of different types, the leptites have, however, sometimes been subjected to considerable chemical and mineralogical alteration. The magnesia-metasomatic alterations connected with the Middle Svecofennian granites, which have been postulated in various ore field (Eskola, 1914; Geijer, 1917, 1923, 1936; Magnusson, 1925, 1940; Hjelmqvist, 1942), are occasionally recognized, however, alteration does not occur in any part of the Zinkgruvan district. According to Henriques (1964), there are admittedly rocks with a composition corresponding to magnesia-metasomatically altered leptites, i.e. rocks of quartzitic character with a high content of aluminum- and magnesium-rich minerals such as andalusite, cordierite and almandine. Primarily, however, these rocks were epiclastic sediments with admixture of pyroclastic material.

Magnusson (1929, 1932, 1937, 1940) and others stated that sodic leptites were, in some cases, formed from potassic leptites through the effects of sodium-rich solutions emanating from granites, often in connection with ore formation. Alterations of this type have not been observed in the Zinkgruvan ore field either as already stated.

Terms in the present usage

Most of the Swedish geologists, anyhow, use the term of leptite in the following sense at present; the salic volcanics, depending on their metamorphic state, are classified into hälleflintas and leptites. In the former, textural changes beyond devitrification are small, and even groundmass texture such as spherulitic and micropoikilitic textures are preserved in the flows, and glass-shred textures in ash tuffs. The hälleflinta facies is preserved only in a few districts, such as Grythyttan ore district in the western part of the region (Sundius, 1923). In the leptites, again, phenocrysts, when originally present, generally remain intact, but the groundmass is entirely recrystallized. The limit between leptite against hälleflinta is set at a groundmass grain size of 0.03 – 0.05 mm. This is a threshold value generally distinguishable by unaided eyes. The upper grain-size limit for leptite is about 0.5 mm; beyond that, the contrast between phenocrysts and groundmass disappears, and the rock becomes a gneiss. It is worth while mentioned that a kind of textural metamorphism represented by the leptites is very rare, and the need for a special term was considered only for these Svecofennian volcanics (Geijer, 1963).

Geological setting of the hälleflintas and leptites in Fennoscandia including mineralogical and chemical characters of the rocks

The current view for the sequence of the Precambrian of Sweden may be tabulated below (Geijer, 1963).

	Southwestern Sweden	Southeastern and Central Sweden	Northern Sweden
Eocambrian	Visingsö F.	Visingsö F.	Varegian Sparagmite F.
Post-Archean	Dalslandian	Jotnian Sub-Jotnian	Jotnian Sub-Jotnian
Archean	Gothian Pre-Gothian	Gothian Svecofennian	Karelian Svecofennian

According to Magnusson (1960), the stratigraphical relationship settled in the field and available absolute age determinations showed that the order of the cycles from the oldest to the youngest is as the following: Pre-Gothian → Svionian → Karelian → Gothian → Dalslandian.

The Pre-Gothian Cycle

According to Magnusson (1960) and Geijer (1963), the rocks of Pre -Gothian cycle appear only in southwestern Sweden where they form a broad belt from Scania to the Norwegian border. They contain mainly gray veined gneisses, augen gneisses, red veined gneisses, hyperites and amphibolites. The charnockites of the Varberg district have been recognized as supracrustal remnant in the gneisses, on the coast about 70 km south of Göteborg (Quensel, 1951). Together with the gneisses named above there appear here and there more fine-grained gneisses, which probably are supracrustal rocks, lavas and tuffs. The latter often show a distinct bedding. These volcanic rocks vary from red to gray types. North of the Karlstad region there appears in Horrsjöberget a quartzite rich in kyanite, together with a relatively well preserved porphyritic rock.

The Svionian Cycle

The Finnish geologists use the term instead of the Svecofennian for this cycle. The term was originally proposed by W. Ramsay (1909) for the old orogenic belt stretching from Southeastern Finland to eastern Värmland, Sweden. Furthermore the term was introduced by J.J. Sederholm (1932) for part of the oldest Archean rocks of Southern Finland including quartzites, schists and limestones corresponding to part of the leptite system of Central Sweden. The thorough investigations within the large region of this cycle have been brought in the iron ore bearing region of Central Sweden. The supracrustal rocks are here acidic volcanics (leptites and hälleflintas), less abundant basic volcanics, slates, graywackes, quartzites, and conglomerates. In the Grythyttan ore field, Svealand, Central Sweden, the supracrustal rocks are best preserved. At the bottom of the series there are hälleflintas rich in sodium and with intercalation of limestone and iron ore, poor in manganese. Then follow hälleflintas with potassium dominating over sodium and with intercalated layers of limestones and manganiferous iron ores. Some of the hälleflintas are lavas, others are tuffs. In the lavas there appear phenocrysts of quartz and feldspars, micropoikilitic, granophyric, spherulitic and fluidal structures. The tuffs often show good vitroclastic structure and a distinct bedding. Through more or less intensive tectonic movements of this cycle, the supracrustal rocks were metamorphosed. The hälleflintas, the best preserved acidic volcanics with dense groundmasses, became altered to leptites. The leptites have granoblastic textures. Solutions driven at the granite front may have been the cause of the metamorphic alterations (magnesia-metasomatism), through which the leptites have been altered to mica schists, usually characterized by such minerals as cordierite, gedrite, andalusite, and almandine in varying proportions. Where these alterations have been strong, the mica schists have gone over to quartzites characterized by the minerals listed above (Magnusson, 1960). In central Norrland, Sweden, the supracrustal rocks are graywackes and slates with subordinate quartzitic intercalations. Volcanic rocks are very rare. Svionian rocks of southern Norrland is strongly metamorphosed by metasomatic alterations in connection with the palingenic processes that occurred in this region in late Svionian time. The dominating volcanic rocks are acidic and are considered as more or less strongly altered leptites, which are usually developed as veined gneisses.

According to Gavelin (1955), a scheme of the various rock groups of the Västerbotten county, southern Swedish Lapland, is given below (the figures to the right side show the areal proportions of the various rocks within the area):

Rapakivi granite, disbase	Subjotnian and Jotnian eruptives $< 0.1\%$
Adak granite Series Sorsele granite Series	Karelian granites and gabbros 3.5%
The Vargfors Series	Karelian sediments and volcanites 0.6%
Unconformity	
Revsund granite Series	Late- or post-orogenic Svecofennian granites and gabbros 47.8%
Gneisses of phyllite Series and of Jörn granites	Svecofennian gneisses 31.0%
The Jörn granite Series	Early-orogenic Svecofennian granites and gabbros 3.0%
The Arvidsjaur Series	Upper Svecofennian volcanites 2.8%
The phyllite Series	The middle, mainly sedimentary supracrustal Svecofennian Series 9.6%
The Skellefte volcanite Series	The lower, mainly volcanic supracrustal Svecofennian Series 1.7%

The lower volcanic series, the *Skellefte Series,* consists of meta-liparitic, meta-keratophyric, meta-dacitic, meta-andesitic and meta-basaltic lavas and tuffs. This order gives also main stratigraphic sequence from the bottom to the top of the series. The upper series, the *Arvidsjaur Series,* consists of meta-liparitic, meta-dacitic, meta-andesitic and meta-basaltic lavas and, to a lesser degree, of tuffs. The meta-basaltic lavas from the lowest parts of the series are overlain by successively more acid volcanites with meta-liparites at the top of the column. On comparing the chemical characteristics of the lower and the upper volcanic series, the latter is more alkaline in character than the former. The acidic rocks of the *Skellefte Series* are definitely soda-dominant (Niggli's number $k = 0.12 - 0.29$), whereas the acidic rocks of the *Arvidsjaur Series* have intermediate alkali proportion ($k = 0.46 - 0.47$) (Gavelin, 1955).

Eskola (1914) divided the leptites of Finland into two groups: (1) the blastoporphyritic leptites and (2) the even-grained leptites. The former group comprises rocks which have readily recognizable phenocrysts of quartz set in a fine-grained groundmass. When not greatly changed by metamorphism, phenocrysts of feldspar are also evident. This group is believed to represent metamorphosed porphyritic rocks. The second group includes mainly leptite which shows a thoroughly fine-grained texture. These rocks are believed to be partly of igneous, partly of sedimentary in origin. In many cases it is impossible to determine their origin with certainty. According to him, cordierite-leptite has been separated from the leptites proper. This has a composition of argillaceous sediments. By increasing in the coarseness of the texture, the leptites pass gradually into gneissic rocks. Such rocks being not genetically different from the leptites, have been termed leptitic gneiss. Certain leptitic rocks which show fragmental structure have been termed agglomeratic leptites. As for the origin of the leptitic rocks, he stated that the bedded or laminated structure in the leptites could hardly be accounted for, unless the structure is assumed to be original bedding or stratification of the material. Some of the layers are like volcanic rocks, others have the composition of aluminous sediments and still other intercalated layers are of limestones. This must be attributed to the alteration of various volcanic and sedimentary materials in the deposition of the leptite series.

Sederholm (1932) mentioned the leptite formation in Fennoscandia as following: "the oldest supracrustal rock known in Fennoscandia are better represented in the eastern part of middle Sweden than in any other region. Here these rocks are in some cases only slightly metamorphic. Most common among them are feldspathiferous schistose rocks, partly aphanitic, the so-called hälleflintas, partly fine-grained and then generally called leptites in Sweden. Most of these rocks are acidic volcanics, lavas or tuffs, or intrusive rocks that have solidified quite near the surface. They are usually either very rich in potash (up to 10 percent, and in exceptional cases even more) or else in soda, while rocks of intermediate composition are less common. Associated with the leptites iron ores occur, partly magnetitic, partly hematitic. They have obviously been formed by same volcanic activity as the leptites. Many leptitic rocks, and some of the associated iron ores, show a distinct bedding, and clastic rocks containing rounded pebbles have been observed, both furnishing evidence of the presence of water at that early period. The hypothesis that this formation is "pre-aquatic" seems therefore not sufficiently warranted by facts. In the Svionian of SW. Finland, which is a direct continuation of the leptite formation, lying in the Svecofennian range which stretches from middle Sweden to Southern Finland, leptites of acidic composition are less common than Sweden, and iron ore bodies are rare and usually small".

Geijer (1936) stated that supracrustal rocks in Central Sweden had the chemical composition approximately of granites or related igneous rocks, with a recrystallized texture (apart from certain relic features) and with a size of grain that lies between 0.03 – 0.05 mm and 0.5 (–1) mm, the former figure representing the boundary against hälleflintas, and the latter against gneisses. Where relic grains occur, the figures quoted apply to the recrystallized groundmass. In the Norberg leptites, Central Sweden, about 0.08 mm is a normal upper boundary. The relic features observed there are phenocrysts of quartz and of feldspar, and stratification. Generally, stratification and porphyritic texture are not found together but exceptions occur. With regard to the chemical composition, the following groups stand out: "soda-leptites", formed by almost pure albite feldspar and quartz, with little amount of other minerals; "potash-leptites", carrying microcline as their dominant feldspar, but not with such a preponderance as albite of the former group; "plagioclase potash-leptites", corresponding to dacites and quartz-latites; and "hornblende -bearing plagioclase leptites", a group of little quantitative importance which may be compared with andesites. The "plagioclase potash-leptites" are invariably porphyritic, with phenocrysts of plagioclase (normally oligoclase) and often also of quartz. Geological conditions of the leptite formation described above may be found in the areas where cordierite-bearing mica schist and/or "ore quartzite" are developed, and where rocks generally carry skarn minerals. These typically belong to the set of rocks normally accompanying sulphide mineralization in Central Sweden. They are products by alteration of leptites as similar as sericite- or chlorite-bearing quartzite which are formed in connection with certain phases of hydrothermal sulphide mineralization.

Discussion and conclusion, with special reference to the Palaeozoic volcanic activities in Northeast Japan

Judging from the geological literatures (appendix 3), Fennoscandian acidic volcanics show various sorts of rock facies as lavas and pyroclastics, ranging widely in chemical and mineralogical composition from rhyolites to andesites and have been formerly described as hälleflintas, leptites (quartzitic, banded, blastoporphyritic, porphyritic, spotty, feldspar-rich, even-grained, banded gneissose and others), syenite-leptite, quartz-porphyry, schlieric porphyry (ignimbrite), quartz-keratophyre, keratophyre, felsite, somewhat metamorphosed sodic-biotite leptite (sillimanite-gneiss), syenite-porphyry (leptite gneiss), rhyodacite, meta-dacite, meta-andesite, fine-grained arkoses and granitized sediments. From petrochemical point of view, all these rocks have been originally described in general as K-extremes, K-dominants, Alkali -intermediates, Na-dominants and Na-extremes for K-leptite, Alkali-intermediate leptite, intermediate Na-leptite and Na-leptite.

The rocks listed up in Appendix 1 may be plotted on a tetrahedral diagram (al-alk-fm-c) based on Niggli's system. Fig. 1 is the Niggli's diagram in which all the recalculated data (apprendix 2) of the above-mentioned rocks are plotted. In this diagram, most of data are plotted on the so-called "eruptive fields" in isosceles triangles belonging to sections I, II, III, IV and V, which mean relatively lower ratio for c: femic. Generally they are relatively high in alkali and aluminum. However, siliceous schists/leptites of the Hitachi mine show petrochemical nature for relatively low in alkali, aluminum and c: femic.

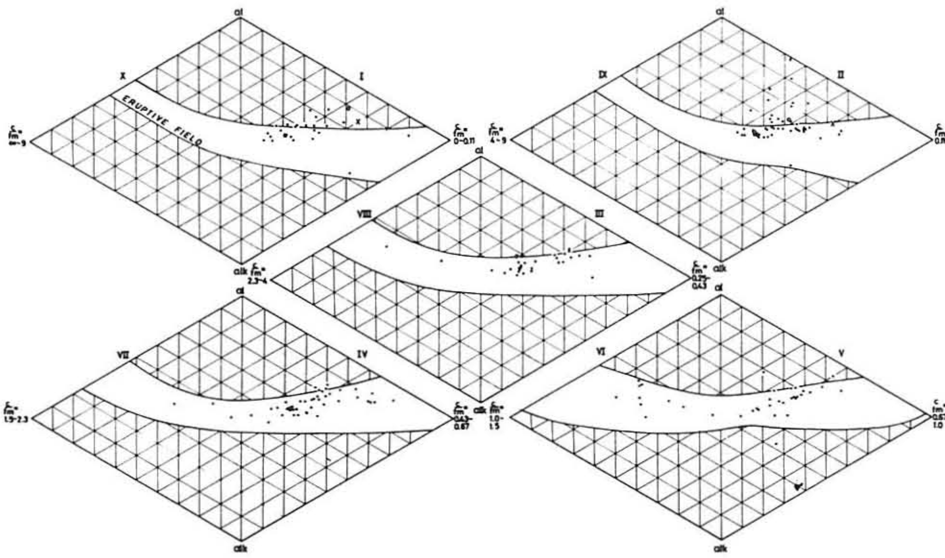

Fig. 1 Cross-sections I-X, II-IX, III-VIII, IV-VII and V-VI, in Niggli's system.

section	c : fm ratio
I	0.00 – 0.11
II	0.11 – 0.25
III	0.25 – 0.43
IV	0.43 – 0.67
V	0.67 – 1
VI	1 – 1.5
VII	1.5 – 2.3
VIII	2.3 – 4
IX	4 – 9
X	9 – ∞

Solid circles: Whole Sweden. Open circles: Some parts of Finland.
Crosses: Hitachi, Japan.

Fig. 2 shows the k-mg relationship for magmas of the soda and potash series; each point is similarly inscribed with its si-value. The data plotting on the rectangular diagram widely distribute in range from kalium-rich to natrium-rich. Rocks of the Hitachi mine are relatively low in alkali as shown in Fig. 1, although high in ratio for Na:K.

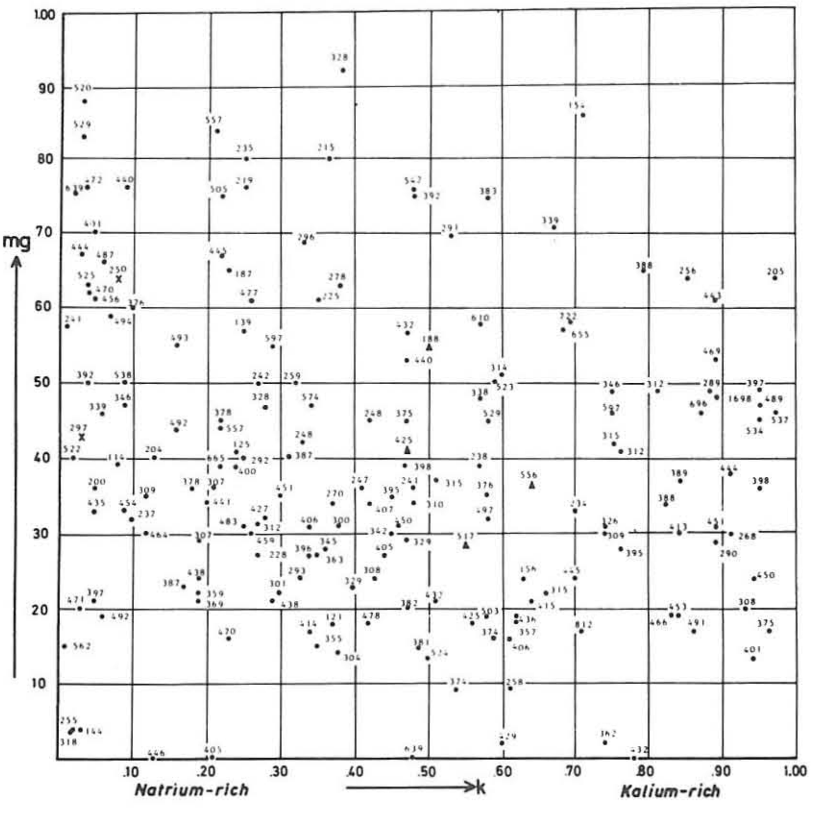

Fig. 2 The k-mg relationships for magmas of the soda and potash series. The figures are the Si-values. Solid cricles: whole Sweden. Solid triangles: Finland. Crosses: Hitachi, Japan.

A triangle diagram showing the proportion of quartz, orthoclase and plagioclase for leptites and hälleflintas is shown in Fig. 3. They show the extremely wide range, from meta-andesite lacking in normative quartz to quartzitic leptite or from natrium leptite to kalium leptite having approximately 80 percent normative orthoclase. These of the Hitachi mine, however, are low in orthoclase. Fig. 4 is a combined normative diagram for 'Orthoclase

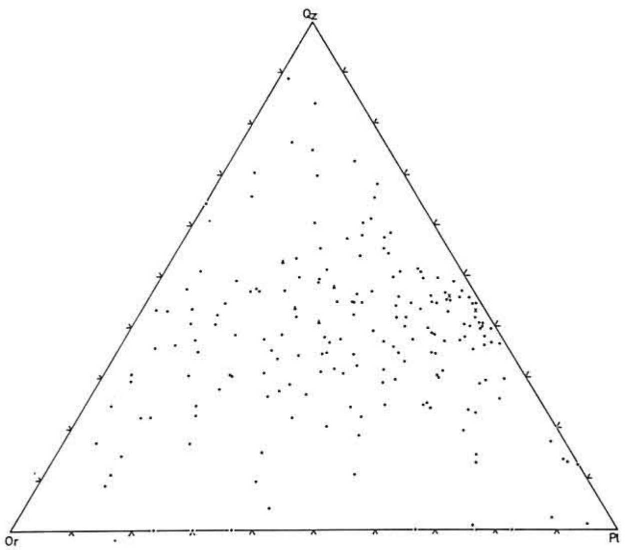

Fig. 3 Diagram showing the proportions of quartz and feldspars of leptites and hälleflintas. Solid circles: whole Sweden. Solid triangles: Finland. Crosses: Hitachi, Japan.

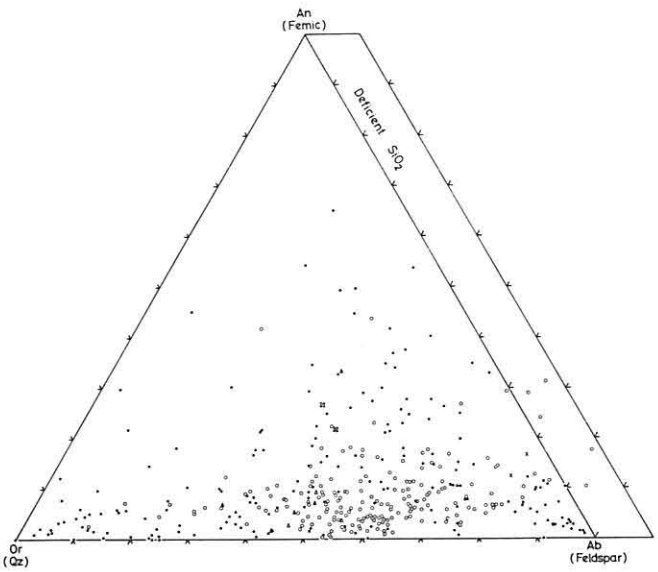

Fig. 4 Diagram for Orthoclase-Albite-Anorthite and Quartz-Feldspar-Femic, modified from Larsen's diagram. Small solid circles: Or-Ab-An for whole Sweden. Large open circles: Quartz-Feldspar-Femic for whole Sweden. Solid triangles: Or-Ab-An for Finland. Open triangles: Quartz-Feldspar-Femic for Finland. Crosses: Or-Ab-An for Hitachi, Japan. Andrew's crosses: Quartz-Feldspar-Femic for Hitachi.

-Albite-Anorthite and Quartz-Feldspar-Femic, which is more or less modified from Larsen's diagram. The data show wide ranges for Or-Ab-An and Qz-Feldspar-Femic. Also rocks of the Hitachi mine are extremely poor in orthoclase, but quartz is intermediate in quantity.

Fig. 5 is the chemical data of all the specimens in question plotting on the Sawarizki's (Zavaritsky's) ACBS-diagram. The basic numerical characteristic may be expressed by the ratio of four quantities—$\underline{a} : \underline{c} : \underline{b} : \underline{s}$, where $\underline{a} + \underline{c} + \underline{b} + \underline{s} = 100$. Explanation will be described below. $\underline{a}$: The relative number of atoms of the alkali metals contained in aluminum silicates and, consequently, combined with atoms of Al in the crystal lattice of minerals. $\underline{c}$: The relative number of atoms of calcium that may be included in aluminum silicate (in the combination $CaAl_2$). In some rocks calcium aluminum silicate is absent. Instead of it there may be ferrisilicate of sodium; this case will be examined separately. $\underline{b}$: The relative number of all remaining metallic atoms excluding silicon (and titanium), not entering in the aluminum silicates and

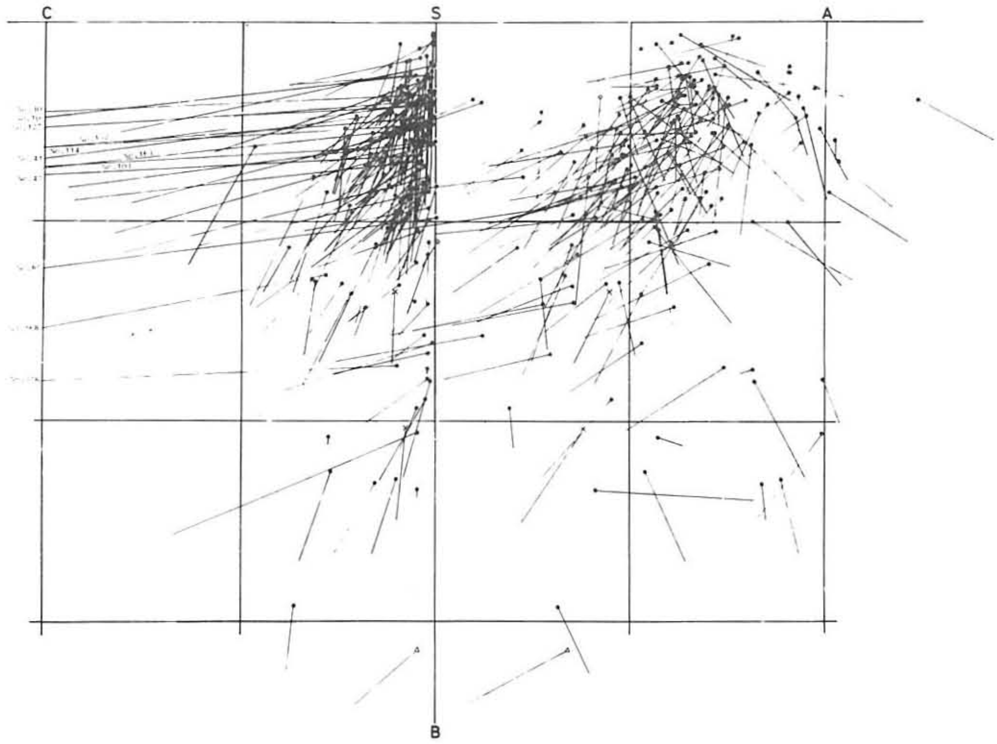

Fig. 5 The chemical data of all the specimens plotting on the Sawarizki's (Zavaritsky's) ACBS-diagram. Solid circles: whole Sweden. Open triangles: Finland. Crosses: Hitachi, Japan.

ferrisilicates of sodium, and taking part mainly in the structure of ordinary silicates. s: Relative number of atoms of silicon (and titanium). The ratio of sialic to femic components can be judged by the value of b, and an excess or dificiency of silica is shown by the relative value of s. The character of the sialic components can be evaluated from the ratio of a to c. We note now the features of chemical composition that are graphically expressed by the length and direction of the vector. A short vector indicates an abundance of magnesium; a more or less gently sloping vector is resulted from an abundance of free lime. Because of the conventions adopted for construction of the vectors, the expressed ratio of $f' : m' : c'$ are directions down to the right, and vectors expressing $a' : f' : m'$ point down to the left. The latter is a result of compositions supersaturated with alumina, and the greater the surplus of alumina, lesser the steepness of the slope of the vector. The second

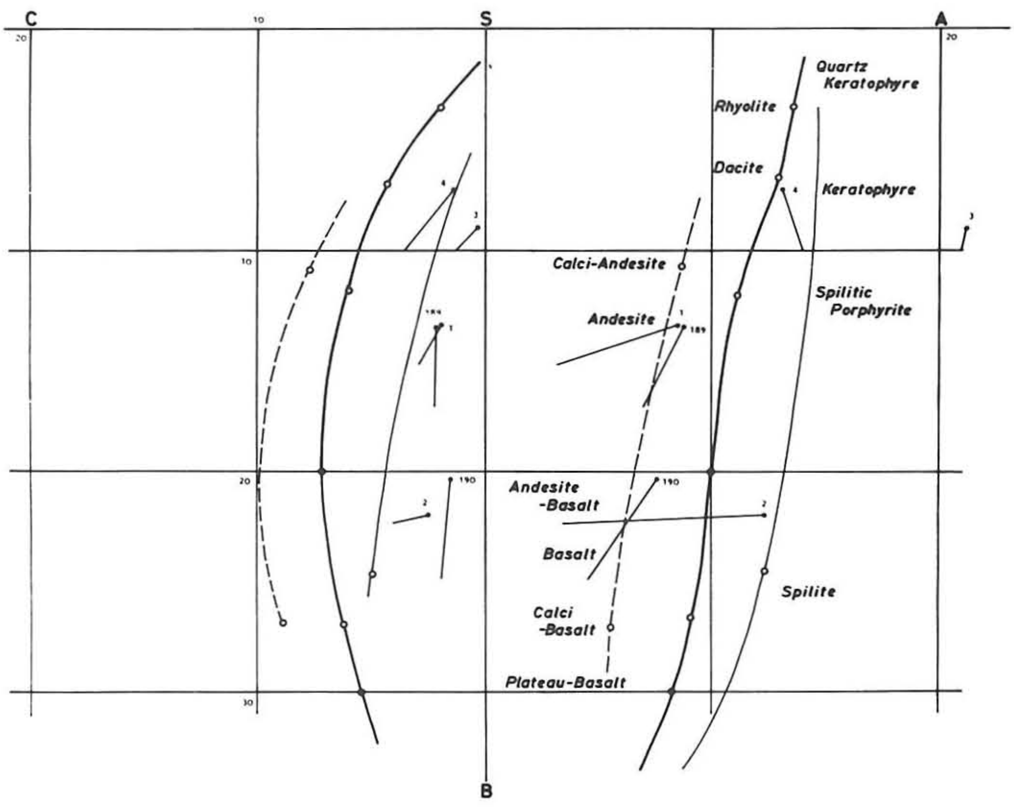

Fig. 6 The chemical data of leptites from the Hitachi mine district, compared with those of keratophyres described by Johannsen (1932), setting up in ACBS-diagram (cfr. Appendix 4). Thread-line: alkalic rock series. Bold-line: calc-alkalic rock series. Brocken-line: calcic rock series.

supplementary numerical characteristics represent only one ratio – $n = Na : (Na + K)$ in the parameter a. It may be expressed either as a point on some segment of a line or by the trend of a line making an angle between two other lines. As a result for n, the steeper the line on the diagram, the greater the Na in aluminum silicates; the more gentle in its slope, the greater the abundance of potassium-aluminum silicates.

By this method we can combine the diagrams of the basic characteristics and the supplementary characteristics on the planes of projection of the three-dimensional diagram of the basic characteristics. We may construct a great number of vectors on the plane of projection ASB and combine with them a great number of directional lines in the plane of projection CSB. Thus the vectors on the planes ASB and CSB by projection, establish vectors in space, and we may substitute for the numerical characteristics of a rock vector in space.

Fig. 6 indicates that two analyses: the weakly metamorphosed leptites (siliceous schists) belonging to the *Kamine Series* of the Lower Devonian at the Hitachi mine district, and four analyses: keratophyres quoted from Johannsen (1932), converted into various characteristics according to Zavaritsky and a petrochemical diagram of these data was set up (cfr. appendix 4).

Putting together the deportment of the figurative points of the basic and supplementary characteristics in Figs. 5 and 6, the following conclusion may be obtained:

(1) Fennoscandian leptites and hälleflintas in question distribute in ranging widely from keratophyre-spilite line to calc-alkali line, viz. alkaline to tholeiite character.

(2) As to four supplementary characteristics ($\underline{f'}$, $\underline{m'}$, $\underline{a'}$, $\underline{c'}$), they are congested with compositions supersaturated with alkalis, or with normal andesite-basalt series (in these cases vector directions point down to the right on the plane ASB), and with compositions supersaturated with alumina (vector direction inclines to the left).

(3) Most of them are rich in alkali as a whole ($\underline{a}$ in the parameter A is not less than 10 percent). While, judging from the supplementary characteristic "n" on the plane CSB, leptites and hälleflintas in question are classified into five groups, namely k-extremes, K-dominants, Alkali-intermediates, Na-dominants and Na-extremes, in spite of various sorts of rock species from a lot of different occurrences mentioned afore.

(4) In Fig. 6, it is rather difficult to pick up a chemical tendency in those of the Hitachi district, because of only two analyses. However, both have the chemical compositions saturated with alumina, and with high in "n" value (97 for no. 189 and 92 for no. 190 respectively).

Some authors, as already mentioned, have stressed the extremely violent volcanic activities occurred in the Palaeozoic Era of Northeast Japan (Minato, 1950, 1955; Suzuki and Minato, 1954, 1958; Minato et al., 1975). They said: "the entire thickness of the Ohno series is estimated to be at least 340 m. Flows of dacite, porphyrite, latite, keratophyre, quartz keratophyre, and their tuffs are predominant; no less than 73% of the whole thickness of this series is represented by those volcanic products. The Nakazato series is at least more than 730 m in thickness and is also predominantly composed of dacite, keratophyric rocks of either flows or tuffs. The volcanic products are frequently intercalated especially in the low part of this series. A thick diabasic tuff, about 110 m in thickness is to be found at the lowest part of this series. The total sum of the thickness of the pyroclastic sediments above described together with flows may be estimated to be about 200 m, which accounts for about 27% of the entire thickness of this series. The volcanic activity was specially violent in the Kitakami mountains, during the periods ranging from the Lower to the Middle Devonian, while the volcanisms were much weaker in the Silurian as well as the Upper Devonian" (Suzuki and Minato, 1954).

In the meantime, the Palaeozoic formations of the Hitachi mine district, located southern end of the Abukuma terrain, seem to represent a time interval extending from the Devonian to Upper Permian. The lowest Palaeozoic unit, the *Kamine Series*, is composed of acidic pyroclastics such as leptite and hälleflinta, which were identified at Stockholms University by Professor Gavelin, accompanied by a few thin intercalating diabasic tuff seams. The series is divided into three members, viz. leptite-, hälleflinta- and schistose green rock-members in ascending order. The entire thickness of the *Kamine Series* is estimated to be at least 1500 m. Overlying the series, the *Ohkadoya Series* which may be probably correlatable to the *Nakazato Series*, is mainly composed of diabasic pyroclastics with intercalating pillow lavas, slate, sandstone, thin layers of limestone, conglomerate and acidic tuff. The *Ohkadoya Series* at least more than 2500 m in thickness and no less than 70 percent of the whole thickness of this series is represented by the volcanic products, among which diabasic pyroclastics in rough estimation seem to occupy five times of acidic pyroclastics in thickness. The *Ohkadoya Series* is overlain unconformably by a fossiliferous limestone sequence, entirely with no sign of such volcanics, of Upper Viséan age, called the *Sugimoto Series*. The series is correlated with the *Onimaru Series* of the Kitakami mountains. Although both of the older series mentioned above are partially metamorphosed, at least to green schist facies, the *Sugimoto Series* shows no sign of regional metamorphism. Accordingly, the metamorphism may be correlated to the *Shizu phase* of the Abean Orogenic Movement in Northeast Japan established by Minato (1968). This event, in turn has been correlated with Pre-Chesterian or Pre-Upper Viséan time.

To sum up the foregoing, it may be concluded that the volcanic activities in the Hitachi mine district as well as those in the Kitakami mountains were also violent during the periods ranging from the Lower to the Middle Devonian and, as a whole, turned from the acidics into basics in ascending order.

In Northeast Japan so far, proving fruitful in terms of the lithostratigraphical and biostratigraphical studies, few studies on the above-mentioned volcanic products combined with the stratigraphical sequences in the Palaeozoic era have been carried out from the petrographical and petrochemical points of view. It will be of great importance to petrochemically elucidate the volcanic activities in the Palaeozoic era in Northeast Japan to clarify the Abean Orogeny.

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Appendix 1 A list table of chemical analyses of leptites and hälleflintas in certain districts.

(A) Whole Sweden

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	P_2O_5	$BaSO_4$	S	CO_2	F	Total	Ref
1	91.67	.15	4.18	.31	.72	.01	.50	.15	.14	1.58	.43	-	.04	.02	.01	-		99.96	42
2	83.27	nd	8.19	1.41	1.56	-	.32	.45	.62	2.35	Ig.L	.93						99.10	92
3	83.15	.13	7.92	1.23	.65	tr	1.40	1.22	.87	1.93	1.35		.38					100.23	7
4	82.63	.28	8.79	.06	2.07	.02	.80	1.60	2.03	.82		.71	.18					99.99	66
5	82.38	.06	10.55	.04	.08	tr	.12	.42	6.10	.19		.05	.01	-	.01	nd		100.01	102
6	81.02	.13	10.90	.42	.96	-	.68	.32	.38	3.65	1.37		.03	.06	-	-		99.92	42
7	80.96	.06	9.74	.37	1.14	.03	.00	.76	2.63	3.64	.11	.04	.00	.05	.02	.18	-	99.73	83
8	80.56	.06	10.29	.10	.09	tr	.14	.15	1.85	6.01		.25	.01	.12	.01	.18		99.82	102
9	80.53	nd	11.21	.28	.45	tr	.06	.51	6.55	.12	Ig.L	.67						100.38	92
10	80.28	.15	11.35	.07	.28	.01	1.18	.35	5.94	.26		.42	tr		.02			100.31	62
11	79.90	.09	9.83	1.47	.09	.03	.63	.25	1.35	6.21	.12		.01	.28	.02			100.28	21
12	79.85	.07	11.23	.12	.55	.01	.33	.24	4.03	3.17		.38	.01	.09	.01	nd		100.09	62
13	79.85	.05	11.62	.30	.11	.003	1.06	.61	4.00	1.61		.77	-	.04	-	nd		100.023	102
14	79.85	.22	12.09	.11	.14	.01	1.20	.23	5.97	.30		.40	.05		-			100.57	25
15	79.84	.17	9.60	.20	1.60	.04	1.16	1.94	1.78	1.13	1.82		.05			.71		100.04	13
16	79.65	.16	12.05	.11	.30	.01	.24	1.97	4.62	.73		.20	.02	.02	.01			100.09	66
17	79.20	.24	12.61	.08	.05	tr	.08	.18	7.29	.15		.14	.05	.01	.01	nd		100.09	102
18	79.20	.34	9.93	.18	2.04	.05	.54	1.43	2.83	1.23	.50		.13	tr	.02	-	C=1.36	100.18	42
19	79.16	.11	12.02	.16	.36	.03	.48	.44	6.31	.39		.43	nd	.03	.01	nd		99.53	25
20	78.96	nd	9.37	.19	1.51	.42	.96	1.42	2.07	4.27	1.64	nd		nd		nd		100.81	32
21	78.30	nd	12.71	.21	1.74	-	1.35	.58	.49	1.04		1.85	nd			nd		98.27	31
22	78.25	.19	12.27	.05	.57	.01	1.22	.35	6.33	.33		.60	tr		.02			100.19	62
23	78.24	.43	10.82	.28	1.00	.01	2.20	.37	3.56	1.53		1.53	.09					100.06	66
24	78.16	.15	12.02	2.00	.29	.04	.29	1.28	5.11	.54	Ig.L	.44	.05		-			100.37	61
25	78.02	nd	14.36	.70	.26	-	1.46	.34	1.41	2.04	.40	nd	nd			nd		98.99	30
26	77.99	.15	12.52	.40	.34	.01	.63	.62	5.90	.73	Ig.L	.51	.03					99.83	57
27	77.90	nd	11.90	.71	2.83	nd	.42	.62	1.84	3.98	.78	nd	nd			nd		100.98	32
28	77.87	.07	12.95	.25	1.16	.01	.59	1.86	3.64	1.03		.61	.01					100.05	66
29	77.75	.14	12.35	.34	.70	.007	.94	.28	6.55	.41	.31		.02	.02	.00	.06		99.877	69
30	77.59	.17	11.61	.92	.24	.01	.50	.13	.27	8.82		.11	tr		.11			100.48	62
31	77.53	nd	11.39	.76	.62	.26	1.07	1.39	3.97	1.11	.98	nd	nd			nd		99.08	30
32	77.40	.13	13.08	.51	.26	nd	1.22	.78	6.22	.85	.05			tr				100.50	48
33	77.21	.21	13.00	.40	.20	nd	.55	1.52	6.23	.53	.16							100.01	48
34	77.18	.20	13.59	.58	.30	.02	.12	1.38	6.04	.29	Ig.L	.40	.05		-			100.15	61
35	77.06	.13	12.69	.48	.07	tr	.02	.15	4.01	5.07		.36		.02				100.06	23
36	77.01	nd	11.39	1.67	1.04	-	2.25	.39	2.67	1.40		2.01	nd			nd		99.83	31
37	77.00	.17	12.25	.50	.86	.05	1.54	.84	5.69	.25	Ig.L	.96	.05		-			100.16	61
38	76.93	nd	12.08	2.23	1.80	nd	1.01	1.73	3.18	1.91	1.58	nd	nd			nd		101.45	54
39	76.92	.15	14.52	.31	.65	-	.53	1.32	1.36	3.02	1.27		.03	.08	-	-		100.16	42
40	76.87	nd	10.01	1.03	3.71	nd	1.25	.66	4.41	.66	1.18	nd	nd			nd		99.78	86
41	76.85	.09	11.39	1.81	-	.09	1.04	2.26	.49	5.98	Ig.L	.44	nd			-		100.44	81
42	76.83	.16	12.78	.35	1.22	.06	1.95	.06	4.31	1.92		.42	tr		-			100.06	62
43	76.83	nd	13.43	.24	.99	-	.27	.87	5.80	1.17		1.34	nd			nd		100.94	31
44	76,79	.10	10.12	1.20	3.83	-	1.32	.92	4.50	.40	Ig.L	1.20	.02					100.22	57
45	76.76	nd	11.67	1.07	1.25	.22	1.82	2.51	1.79	2.44	.19	nd	nd			nd		99.72	30
46	76.70	.09	12.04	.76	.72	.04	.36	.93	2.45	5.19		..67	.01	.06	.01	nd		100.03	25
47	76.64	.21	9.94	1.04	1.97	.08	1.47	.73	.23	6.53		1.06	.05	.19	-			100.14	22
48	76.62	.15	13.20	.08	1.16	.04	1.41	.49	5.85	.61		.25	.09		-			99.95	62
49	76.54	nd	12.67	1.75	.87	-	1.57	2.67	1.52	2.03	1.32	nd	nd			nd		100.94	30
50	76.50	.11	11.92	1.54	1.14	.04	.26	1.72	3.99	1.80	Ig.L	.70	.12		-			99.84	61
51	76.48	nd	12.37	1.55	1.06	-	.27	.99	3.16	3.49	Ig.L	.22						99.59	44
52	76.43	nd	11.34	2.72	1.10	nd	.89	1.18	2.83	1.44	1.43	nd	n.			nd		99.36	54
53	76.40	nd	11.57	1.00	1.67	-	.62	2.56	2.43	3.14		1.13	nd			nd		100.52	31
54	76.10	.26	12.39	.16	2.52	.03	tr	1.63	4.67	.99	.07	.04			.17	.90		99.93	13
55	76.05	nd	8.39	.53	.48	-	1.19	2.28	8.91	.70	Ig.L	1.52						99.57	92
56	75.98	.18	12.09	.51	2.16	.05	.65	.41	4.45	2.34		.94	.05		.20	-		100.01	101
57	75.92	.10	12.99	.61	1.20	.10	.28	2.10	3.98	2.42	Ig.L	.44	.17		-			100.31	61

(continued)

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	P_2O_5	$BaSO_4$	S	CO_2	F	Total	Ref
58	75.76	nd	12.78	1.91	1.32	–	.92	1.87	2.50	1.63	1.22	nd	nd			nd		99.91	30
59	75.43	.00	10.88	1.88	2.61	.03	1.09	1.30	2.21	1.65	1.07	.33	.19		1.34	.99			
															-0=S: 0.50			100.50	8
60	75.31	.16	11.03	2.37	1.69	.19	2.22	1.15	4.67	.25	Ig.L 1.10		.07	nd	nd	nd		100.21	70
61	75.26	.10	12.36	.46	.81	.04	.17	1.01	1.09	8.48	–		.08		–			99.86	61
62	75.24	nd	12.58	.84	1.72	tr	.42	1.22	4.84	1.70	Ig.L .81							99.37	92
63	75.22	.12	12.77	.70	1.58	.12	.32	1.52	3.06	4.66	Ig.L .40		.08		–			100.55	61
64	75.13	.25	12.84	.31	2.16	.06	.71	1.13	4.32	1.62	1.27		.05		.05	–		99.90	101
65	75.11	.12	12.56	1.11	.10	.01	.11	.14	.93	8.91	.38		.01	.26	.01	nd		99.76	25
66	75.00	.10	12.17	2.10	.58	.12	.30	.84	2.57	6.38	Ig.L .50		.05		–			100.71	61
67	74.719	nd	11.931	–	1.741	.198	.459	1.311	.654	8.123	Ig.L 1.087							100.223	93
68	74.69	.27	12.00	1.66	1.35	.04	.51	.21	1.88	6.91	.30			.05				99.87	21
69	74.68	.12	12.41	.80	1.46	.02	1.85	.02	.55	6.98	.97		.02	.10	–	nd		99.98	102
70 ·	74.50	.18	13.13	1.60	1.36	.02	.30	1.42	4.08	3.21	.39		.01	.01	.06			100.27	19
71	74.49	.14	11.74	1.67	.27	.04	.09	1.04	.46	9.48	.25	nd	tr	.17		.18		100.02	1
72	74.41	.16	12.61	2.86	.18	.01	.36	.10	.95	7.97	.41		tr		–			100.92	62
73	74.23	.13	12.00	.42	1.55	–	3.27	1.61	1.75	3.58	.93	.11	.03	.13	–	.15	.06		
														-0=F:0.03				99.97	103
74	74.08	.13	13.00	1.10	2.81	– ·	.57	.88	5.97	.51	Ig.L 1.05		.05					100.15	57
75	73.99	.13	14.47	.43	1.71	.05	.99	3.84	2.86	1.15	.51		.04		–			100.17	35
76	73.95	.55	14.25	.86	1.29	.06	.79	3.80	2.30	1.08	.43		.05		–			99.41	35
77	73.94	.26	12.75	.53	3.53	.04	.01	1.30	4.95	2.01	.10	.07	.00	.09	.09	–		99.75	83
78	73.92	.26	13.28	.72	1.60	.08	.26	.72	3.00	5.61	.46	(.08)	.04	.01	.04		.18		
															-0=F.S:0.09			100.09	40
79	73.84	.20	11.20	4.20	1.50	.08	1.07	1.10	3.30	2.48	Ig.L .60		.14		.25			99.96	57
80	73.835	nd	3.892	11.162(10.046)		tr	.935	.883	5.292	4.186	Ig.L .537							100.722	92
81	73.826	nd	12.570	1.295	1.944	.331	1.262	2.169	3.179	2.149	Ig.L 1.832							100.602	92
82	73.80	.15	13.81	.44	1.29	tr	1.45	.98	6.46	1.04	.59		.10	nd	nd	nd		100.11	70
83	73.79	nd	12.50	1.89	1.42	nd	1.09	.33	3.57	4.92	Ig.L .54		nd					100.05	54
84	73.73	nd	12.43	2.49	2.81	nd	.52	.54	6.55		.93	nd	nd			nd		100.00	54
85	73.69	.36	13.57	.42	.62	.02	1.70	.36	3.75	5.25	.32		.06		–			100.12	100
86	73.68	.12	12.67	1.96	–	.00	.39	3.52	1.29	6.22	Ig.L .00		–			.16		100.01	81
87	73.61	.10	12.81	2.14	.90	.15	.96	2.16	4.76	1.57	Ig.L .70		.10		–			99.96	61
88	73.58	.17	12.76	.64	1.72	.05	.78	.67	.49	7.32	1.36	(.10)	.03	.09	.06		.05		
															-0=F.S:0.04			99.73	40
89	73.52	nd	11.33	3.54	1.92	nd	1.42	.62	1.00	6.80	1.42	nd	nd			nd		101.57	86
90	73.46	–	11.41	.94		–	.41	.23	.33	8.11	2.19		nd	–	–	3.24		100.32	1
91	73.44	.27	11.20	.82	1.80	.09	.51	3.49	2.77	3.29	.75		.02	.04	nd	1.53		100.02	70
92	73.37	.33	12.70	1.53	2.52	.08	.64	2.75	3.64	1.11	1.46		.07		.04	–		100.24	101
93	73.30	.26	13.49	2.01	.51	.59	.04	.54	2.51	5.73	.29	.07	.01	.58	–	–	.05	99.98	84
94	73.24	.12	12.75	2.98	3.14	.16	1.41	.34	.49	3.67	1.19		.04					99.53	81
95	73.23	.31	13.65	.78	2.26	.06	1.50	2.10	2.41	3.19	.37	–	.08					99.94	7
96	73.21	nd	14.59	.68	3.40	–	1.09	1.03	2.01	2.20	1.76	nd	nd			nd		99.97	30
97	73.20	nd	12.55	.46	2.20	.81	1.05	.93	3.24	4.02	.55		nd			nd		99.01	31
98	72.92	.10	13.67	2.18	1.15	.11	.32	1.32	3.53	4.95	Ig.L .48		.06		–			100.79	61
99	72.91	.30	13.03	1.78	3.04	.07	.67	2.88	3.39	1.19	.70		.08		.10	–		100.14	101
100	72.66	.18	12.13	.39	2.19	–	4.02	2.61	1.09	3.38	1.25	.12	.03	.07	–	.08	.04		
															-0=F:0.02			100.22	103
101	72.52	.34	13.75	.78	1.86	.06	.29	.80	2.58	6.14	.47	(.07)	.06	.03	.11		.04		
															-0=F.S:0.06			99.77	40
102	72.50	nd	13.59	2.27	2.64	.23	1.45	1.62	1.38	2.98	.99	nd	nd			nd		99.65	30
103	72.23	.12	11.91	.23	2.38	.29	1.47	2.83	.19	5.28	1.97		.03	.01	nd	.80		99.74	70
104	72.16	nd	12.76	1.85	1.59	.39	.60	1.93	5.39	1.95	.26	nd	nd			nd		99.42	30
105	72.16	nd	12.18	2.57	2.06	nd	.65	.93	1.68	4.64	2.29	nd	nd			nd		99.16	86
106	72.15	.31	14.02	.65	1.88	.05	.36	1.50	3.50	4.74	.55	(.06)	.04	.09	.04		.05		
															-0=F.S:0.03			99.06	40
107	71.88	:14	11.84	1.03	.32	.04	1.19	1.83	1.45	8.50	.56	.06	.02	.02	.05	1.07	.02	100.02	85
108	71.75	.40	15.36	.48	1.51	.52	.00	.36	1.19	6.29	1.84	.13	.01	.00	–	–	.04	99.88	84

(continued)

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	P_2O_5	$BaSO_4$	S	CO_2	F	Total	Ref
109	71.60	.72	14.63	1.05	1.77	.03	1.26	3.91	4.00	.37		.30	.21	nd	nd	nd		99.85	66
110	71.57	.35	13.14	1.55	3.05	.02	2.17	.33	5.37	.79		1.58	.02	.04	-	nd		99.98	102
111	71.53	.22	13.51	1.55	1.16	.01	.22	.26	.46	10.50		.49	.05	-	.06	-		100.02	1
112	71.51	.13	14.78	1.47	.18	.10	.30	1.55	4.97	4.14	Ig.L	.12	.08		-			99.33	61
113	71.43	.40	14.16	.36	.94	.09	.45	.06	1.34	10.72		.45	.05	.01	tr	-		100.46	60
114	71.22	.38	12.77	.26	2.47	.03	.82	.22	.40	9.39		1.06	.09	.03	nd	nd		99.68	70
115	71.04	nd	4.74	13.01	5.04	-	2.56	1.22	1.28	.83		.34	nd			nd		100.06	31
116	70.90	.44	14.70	1.79	.46	.01	.10	.30	3.85	6.93		.17	.02		.05			99.72	23
117	70.89	nd	13.22	3.19	2.59	-	1.14	1.19	3.46	3.04	Ig.L	1.83						100.55	92
118	70.87	.39	13.79	.53	2.42	.06	.31	1.18	2.79	6.22	1.25	(.06)	.04	.03	.03		.09		
															-0=F:0.04			99.96	40
119	70.82	.24	13.21	1.04	2.08	.11	1.66	.14	1.89	8.79		.43	.01					100.42	62
120	70.32	nd	14.77	2.64	1.05	-	.83	1.84	3.19	4.04	.73	nd	nd			nd		99.41	30
121	70.08	.76	13.14	-	4.24	.12	.94	2.92	2.93	3.94		1.00	.11	-	-			100.18	68
122	69.86	.30	14.37	1.46	2.54	.07	.49	.54	2.54	6.44	.70	(.12)	.05	.04	.48	.10	.12		
															-0=F.S:0.23			99.87	40
123	69.80	nd	15.35	1.85	1.65	.19	.88	3.39	4.10	2.25	.64	nd	nd			nd		100.10	30
124	69.69	.46	14.18	2.69	.65	.11	.11	.07	2.22	9.28	.54	-	.06	.03	-	-		100.09	24
125	65.59	.50	15.01	.31	1.97	.04	2.79	5.01	2.28	1.67	.27	.06	.21		.01			99.72	8
126	69.46	.30	15.41	.96	2.50	.10	1.57	.92	4.41	2.60		1.68	.05					99.96	13
127	69.44	nd	13.62	1.58	.95	.31	.31	.32	.28	11.32	.39	nd	nd			nd		98.52	30
128	69.36	.45	15.00	2.84	.55	.10	.49	.41	5.23	5.31	.25		.08	.06				100.04	23
129	69.21	.32	16.07	.86	2.09	.09	.76	3.08	3.03	2.80		1.49	.08		.14	-		100.02	101
130	69.10	.13	16.56	.61	1.58	.01	1.13	.07	3.17	6.25		1.44	.02	.18	.04	nd		100.29	102
131	68.96	.80	13.30	-	5.50	.16	1.71	1.44	4.78	1.85		1.12	.17	-	-			99.79	68
132	68.94	.76	14.21	2.24	3.08	.01	1.51	.80	6.02	1.16		1.16	.13	.01	-			100.03	68
133	68.86	nd	15.84	.95	1.81	nd	.87	1.48	3.77	5.93	Ig.L	.42	nd					99.93	54
134	68.690	nd	12.276	2.149	1.418	-	.828	4.014	4.666	4.333	Ig.L	1.637						100.011	92
135	68.50	.73	14.05	1.19	4.60	.04	1.26	1.76	4.57	1.64		1.38	.18	.10	-			100.00	68
136	68.45	.41	12.94	-	6.01	.15	.95	1.40	2.21	6.27	Ig.L	.96	.12	nd	nd	nd		99.87	70
137	68.39	.43	15.34	1.62	2.06	.05	.62	3.54	3.18	3.73		.80	.09	.11	.02	nd		99.98	25
138	68.11	.50	15.12	1.16	1.03	.01	1.18	.80	3.50	7.96		.67	.02	.02	.02			100.08	23
139	68.10	.50	15.85	1.94	.72	tr	.58	.12	2.30	9.84		.42	.08	-	-	-		100.45	1
140	68.05	.21	17.20	.41	1.89	.07	.69	2.14	3.55	4.94	.45		.07	.22		-			
															FeS_2=0.03			99.92	42
141	67.98	.21	14.43	3.22	3.07	.08	.57	2.25	3.60	3.36		.70	.14					99.61	21
142	67.76	.75	13.86	.99	4.21	.02	4.75	.45	2.81	2.55		1.28	.19	nd	nd	nd		99.62	66
143	67.72	.71	12.91	1.12	5.16	.10	3.50	5.76	2.81	1.62	2.66	.21	.30		.69			99.87	8
144	67.70	.88	15.21	.52	2.49	.08	1.63	1.93	1.13	7.12		1.18	.14					100.01	66
145	67.18	.65	13.25	2.73	3.17	.02	1.36	1.10	1.60	7.02		1.45	.13	.19	-			99.85	68
146	66.96	nd	16.78	1.00	1.99	-	1.17	.71	1.71	7.51		.80	nd			nd		98.63	31
147	66.87	.78	13.33	5.65	1.48	.01	1.21	1.37	4.23	3.16		1.37	.22	nd	.07	nd		99.75	70
148	66.66	nd	16.84	1.40	3.88	nd	1.47	6.04	1.20	1.00	1.39	nd	nd			nd		99.88	45
149	66.61	.51	14.74	.57	2.59	.07	1.17	4.22	4.10	2.11	.56	.12	.12			1.47	.01		
															FeS_2=0.66			99.63	82
150	66.42	.93	13.23	1.55	5.49	.02	2.36	.09	1.23	5.84		2.70	.11					99.97	66
151	66.33	nd	15.55	1.44	.99	nd	1.75	5.90	7.74	tr	Ig.L	.30	nd					100.00	54
152	66.32	.46	14.78	2.90	1.13	.04	.52	.78	.60	11.77		.50	.10	.17	-	.07		100.14	1
153	65.95	.66	14.02	1.10	3.97	.08	2.81	5.60	2.01	1.41	1.86	.10	.25					99.82	8
154	65.93	.55	15.27	.05	2.83	.02	.07	.90	8.41	.33	.59	.01	.13			.24	.01		
													FeS=0.68		FeS_2=3.87			99.89	82
155	65.76	-	17.81		3.21	-	1.55	.32	.93	10.01		-	-	-	-	-		99.59	1
156	65.71	1.45	18.25	.26	1.35	.01	2.09	.88	3.08	5.41	.66	.18	.10			ZrO_2=0.61		100.04	8
157	65.089	nd	13.300	4.272	3.715	.476	2.621	5.499	1.266	1.808	Ig.L	1.380						99.426	92
158	65.00	nd	14.58	3.04	.94	.64	1.96	2.72	4.94	5.38	.44	nd	nd			nd		99.64	30
159	64.76	.65	15.16	1.51	4.13	.10	2.15	4.00	3.57	2.62		1.03	.15	.12	.015	nd		99.965	25
160	64.75	.52	15.85	2.45	1.36	.04	.79	.51	.94	11.48		.95	.06	.28	-	.05		100.03	1
161	64.65	.13	17.02	1.34	4.78	.09	1.92	3.97	2.39	2.45	.90	.13	.46					100.23	7

(continued)

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	P_2O_5	$BaSO_4$	S	CO_2	F	Total	Ref
162	64.36	.62	19.85	.17	1.17	.01	2.78	5.21	3.70	1.85	.05	.21						100.13	8
163	63.82	.61	15.75	2.58	.96	.06	.79	1.84	.79	12.14	.31		.04	.20	-	.31		100.20	1
164	63.56	nd	15.23	10.25	(9.22)	tr	.23	.37	7.95	.26	Ig.L 1.54							99.39	92
165	63.32	1.72	17.30	2.03	1.82	.05	.94	2.42	8.73	1.38	.24	-	tr	-	.03	-	-	99.98	47
166	63.27	.10	15.94	3.16	.40	.15	1.22	3.16	3.96	8.12	.31		.06	-	-	nd		99.85	60
167	62.93	.85	16.40	4.47	1.56	.01	.31	.65	3.60	8.51	.37	-	.23	-	.02	-	-	99.91	47
168	62.73	.26	14.80	-	3.25	.30	3.57	4.39	.43	3.76	1.76	-	.09	.04		-	.01	99.79	42
													C=1.46		FeS_2=2.95				
169	62.58	.83	16.98	.46	3.90	-	3.66	3.59	3.17	2.56	1.79	.28	.11	.02	.02	.06	.01		
														-O=F:0.00				100.02	103
170	62.55	nd	20.23	.38	.50	-	2.09	8.53	2.70	2.35	.55	nd	nd			nd		99.88	30
171	62.13	.15	21.38	.64	.84	.01	2.51	4.49	4.68	2.33	.73	.16	.23		.41				
														-O=S:0.15				100.54	8
172	61.56	.12	13.59	2.16	3.16	.07	5.44	4.41	6.17	2.77	.24	-	.03	.04	-	-	-	99.76	47
173	61.49	nd	16.03	6.26	1.85	-	2.72	5.79	3.73	.78	1.13	nd	nd			nd		99.78	30
174	61.170	nd	19.450	3.020	3.177	nd	1.245	2.952	4.105	2.300	Ig.L 2.025							99.444	92
175	60.54	.38	18.40	.18	1.56	.01	.49	1.27	3.59	12.67	Ig.L .74		.13	nd	tr	nd		100.41	1
176	57.47	.62	20.81	.87	2.27	.14	3.20	1.66	.16	9.94	3.05		.01	.07	nd	nd		100.27	102
177	57.10	.10	7.37	-	2.06	.07	.66	16.61	3.49	.31	.16		.14	nd	nd	12.18		100.25	70
178	54.058	nd	16.235	3.066	5.422	tr	5.909	8.370	3.677	1.891	Ig.L 1.714							100.342	92
179	52.91	.12	23.04	1.20	.54	.19	6.37	.78	2.72	9.95	1.50		.28		.09	S_2=0.24		99.69	62
180	52.67	nd	16.24	11.69	6.99	-	.44	6.53	4.87	.17	.83		nd			nd		100.43	31
181	52.52	1.71	15.33	8.37	5.36	.04	2.25	1.66	3.28	8.55	.28	-	.53	.11	.02	-		100.01	47
182	50.07	nd	15.53	5.14	11.00	nd	5.68	9.72	2.67	.42	.09	nd	nd			nd		100.32	32
183	49.27	1.30	16.24	11.38	2.76	.07	4.94	3.31	6.16	2.96	.24	-	1.39	-	.00	-	-	100.02	23
184	47.14	.99	16.50	12.51	7.40	.02	2.30	2.82	4.57	4.10	.97	-	.53	.11	-	-	-	99.96	23
(B) Orijärvi region																			
185	78.40	.17	12.13	.66	.76	.03	.43	.64	1.68	4.52	.61	.13						100.16	9
186	76.86	.16	11.12	.69	1.40	.02	.42	.24	2.68	4.96	1.02	.05	.08	.10	.23	-		100.13	107
187	74.50	.27	12.11	.59	2.81	.05	1.35	.76	2.55	3.39	.95	.38						99.71	9
188	57.95	.75	20.11	.53	7.38	.07	5.36	.81	1.78	2.72	1.99	.06	.35	.21	.44	-		100.47	107
(C) Hitachi district																			
189	67.42	.42	11.74	.54	5.67	.63	2.88	1.73	3.98	.19	2.45		.31	nd		.09			
				FeS_2=1.05 Au=nd Ag=nd Cu=0.02 PbS=0.01 ZnS=0.02														99.15	34
190	65.00	.54	13.11	1.23	4.35	.22	5.73	1.27	3.34	.49	3.33		.31	nd		.03			
				FeS_2=0.09 Au=0.1gr Ag=0.5gr Cu=0.02 PbS=0.01 ZnS=0.02														99.09	34

Appendix 2 A list table of CIPW's norm and Niggli's value of analysed rocks listed up in Appendix 1.

	Or	Ab	An	Qz	Feld	Fem	Qz	Or	Pl	fels	fem	al	fm	c	alk	si	k	mg	Qz
1	84.5	10.5	5.1	85.8	11.3	2.9	88.4	9.8	1.8	97.1	2.9	46	30	3	21	1698	.89	.48	1514
2	65.0	24.6	10.5	72.9	22.6	4.5	76.2	15.4	8.3	95.4	4.6	47	28	5	20	812	.71	.17	632
3	50.0	32.5	17.2	69.5	23.5	7.0	74.8	12.7	12.5	93.2	6.8	40	31	11	18	722	.59	.58	550
4	16.7	59.3	24.0	63.8	29.7	6.5	68.2	5.3	26.5	93.6	6.4	42	25	14	20	665	.22	.39	485
5	2.1	96.3	1.6	45.4	53.6	1.0	45.9	1.1	53.0	99.0	1.0	48	2	3	47	639	.02	.75	351
6	82.4	12.2	5.4	66.7	28.2	5.1	70.6	24.2	5.2	96.1	3.9	55	19	3	23	696	.87	.46	504
7	45.3	46.8	7.9	49.7	47.9	2.4	51.0	22.2	26.8	97.6	2.4	45	10	7	38	639	.48	.00	387
8	68.5	30.1	1.4	46.9	52.5	.6	47.2	36.2	16.6	99.4	.6	49	3	2	46	655	.68	.57	371
9	1.2	97.3	1.5	41.1	57.0	1.9	41.9	.01	57.5	98.2	1.8	46	5	4	45	562	.01	.15	282
10	2.8	94.0	3.2	42.5	53.9	3.6	44.1	1.6	54.3	96.5	3.5	44	14	2	39	529	.03	.83	273
11	74.4	23.4	2.3	47.1	49.7	3.2	48.7	38.2	13.1	96.8	3.2	43	16	2	39	597	.75	.46	341
12	34.7	63.2	2.2	43.5	54.6	1.9	44.3	19.3	36.4	98.1	1.9	47	8	2	43	574	.34	.47	302
13	20.4	73.1	6.5	49.0	47.6	3.4	50.7	10.1	39.2	96.7	3.3	48	13	5	34	557	.21	.84	321
14	3.3	95.1	1.7	42.4	53.7	3.9	44.1	1.8	54.1	96.2	3.8	46	13	2	39	520	.03	.88	264
15	21.3	48.5	30.1	61.1	32.5	6.5	65.3	7.4	27.3	93.7	6.3	42	24	16	18	597	.29	.55	425
16	8.1	73.7	18.3	45.5	53.2	1.3	46.1	4.4	49.5	98.7	1.3	48	5	14	33	538	.09	.50	406
17	1.3	97.6	1.0	35.9	62.9	1.2	36.4	.8	62.8	98.8	1.2	49	2	2	47	522	.02	.40	234
18	19.3	63.8	16.8	54.4	38.8	6.8	58.4	8.0	33.6	93.2	6.8	41	23	11	25	557	.22	.44	357
19	3.9	92.3	3.8	39.5	58.4	2.1	40.4	2.4	57.3	98.0	2.0	47	8	3	42	525	.04	.63	257
20	54.4	37.7	7.9	45.7	46.7	7.6	49.5	27.5	23.0	92.5	7.5	37	21	10	32	529	.58	.45	301
21	46.6	31.5	21.9	77.2	15.2	7.4	83.6	7.7	8.8	93.1	6.9	58	28	5	9	610	.58	.57	474
22	3.4	93.6	3.0	37.8	58.0	4.2	39.5	2.1	58.5	95.8	4.2	44	15	2	38	478	.03	.76	226
23	22.3	74.5	3.2	49.6	42.3	8.1	54.0	10.3	35.7	92.1	7.9	41	28	2	28	505	.22	.75	293
24	5.3	82.4	12.3	44.2	52.6	3.2	45.7	2.9	51.4	96.8	3.2	46	14	9	33	492	.06	.19	260
25	47.0	46.5	6.5	66.1	28.6	5.3	69.8	14.2	16.0	95.2	4.8	59	20	3	18	542	.48	.76	370
26	7.5	87.4	5.1	39.4	58.0	2.6	40.4	4.5	55.1	97.4	2.6	47	10	4	39	494	.07	.59	238
27	55.8	36.9	7.3	49.6	43.5	6.9	53.3	26.1	20.6	93.5	6.5	45	22	4	28	503	.58	.19	291
28	13.2	66.8	20.0	48.6	47.5	3.9	50.6	6.5	42.9	96.2	3.8	48	13	13	27	492	.16	.44	284
29	4.1	93.8	2.2	36.3	59.8	3.9	37.8	2.5	59.7	96.1	3.9	44	14	2	40	470	.04	.62	210
30	96.1	2.9	1.0	42.2	55.1	2.7	43.4	54.4	2.2	97.4	2.6	47	12	1	40	537	.97	.46	277
31	13.9	71.5	14.6	46.7	48.4	4.9	49.1	7.1	43.9	95.2	4.8	43	19	10	29	493	.16	.55	277
32	8.2	85.6	6.3	34.5	61.3	4.2	36.0	5.2	58.8	95.9	4.1	44	14	5	38	440	.09	.76	188
33	4.5	85.5	10.0	35.6	61.3	3.1	36.8	2.9	60.4	96.8	3.1	45	8	10	37	456	.05	.61	208
34	2.8	86.1	11.1	38.4	59.8	1.8	39.1	1.7	59.2	98.2	1.8	49	5	9	37	471	.03	.20	223
35	46.4	52.5	1.1	34.2	64.4	1.4	34.7	30.3	35.0	98.5	1.5	51	3	1	44	524	.50	.13	248
36	25.2	68.9	5.9	55.6	35.2	9.2	61.3	9.8	29.0	91.3	8.7	42	34	3	22	477	.26	.61	289
37	2.7	90.0	7.3	39.4	54.6	6.0	41.9	1.6	56.5	94.0	6.0	42	20	5	33	444	.03	.67	212
38	24.1	57.6	18.4	45.7	47.1	7.2	49.2	12.2	38.6	92.9	7.1	40	26	10	24	427	.28	.32	231
39	49.9	32.2	17.9	58.2	38.7	3.1	60.1	19.9	20.0	97.2	2.8	58	11	9	22	523	.59	.50	335
40	8.8	83.9	7.3	43.7	45.5	10.8	49.0	4.5	46.5	89.3	10.7	35	33	4	28	454	.09	.33	242
41	69.9	8.2	21.9	44.6	50.9	4.5	46.7	37.3	16.0	95.5	4.5	41	18	15	26	469	.89	.53	265
42	23.5	75.9	.6	42.3	50.0	7.7	45.8	12.7	41.4	92.5	7.5	43	25	.3	31	445	.22	.67	231
43	11.5	81.4	7.2	36.2	61.1	2.7	37.2	7.2	55.6	97.4	2.6	47	8	5	39	464	.12	.30	208
44	5.2	84.8	10.0	43.1	45.5	11.4	48.7	2.7	48.7	88.6	11.4	34	35	5	26	435	.05	.33	231
45	34.4	36.0	29.6	49.1	42.8	8.1	53.4	16.0	30.6	92.1	7.9	39	27	15	19	432	.47	.57	256
46	54.8	37.0	8.2	40.4	56.7	2.9	41.6	32.0	26.4	97.2	2.8	46	11	6	37	497	.58	.32	249
47	87.9	4.4	7.7	46.2	44.5	9.3	50.9	43.1	5.9	90.8	9.2	37	30	5	28	489	.95	.47	277
48	6.5	90.0	3.5	37.5	56.4	6.1	40.0	3.9	56.1	94.0	6.0	44	18	3	35	437	.06	.66	197
49	31.5	33.8	34.8	53.7	39.5	6.8	57.7	13.3	29.0	93.4	.6	43	25	16	16	440	.47	.53	276
50	20.4	64.6	15.0	43.0	52.9	4.1	44.8	11.2	44.0	95.9	4.1	43	15	11	30	470	.23	.16	250
51	39.5	51.2	9.4	43.0	52.5	4.5	44.6	21.9	33.5	96.4	3.6	46	15	6	33	478	.42	.18	246
52	22.1	62.6	15.3	53.4	40.2	6.4	57.1	9.5	33.4	93.5	6.5	42	27	8	23	483	.25	.31	291
53	36.7	40.7	22.6	43.4	50.8	5.8	46.1	19.8	34.1	94.2	5.8	40	18	16	25	450	.46	.31	250
54	10.9	74.0	15.1	40.6	54.5	4.9	42.7	6.3	51.0	95.1	4.9	46	13	10	31	446	.13	.00	222
55	9.0	91.0	.0	37.8	43.9	18.3	46.3	4.8	48.9	81.7	18.3	26	14	13	48	401	.05	.70	175
56	26.0	70.7	3.4	39.0	54.7	6.3	41.6	15.1	43.2	93.8	6.2	43	19	3	35	459	.26	.30	219
57	24.8	58.6	16.5	38.4	57.7	3.9	40.0	14.9	45.1	96.1	3.9	44	11	13	31	438	.29	.21	214

(continued)

	Or	Ab	An	Qz	Feld	Fem	Qz	Or	Pl	fels	fem	al	fm	c	alk	si	k	mg	Qz
58	24.1	52.8	23.1	51.8	42.1	6.1	55.2	10.8	34.0	94.0	6.0	45	23	12	20	451	.30	.35	271
59	28.9	55.3	15.8	54.2	36.0	9.8	60.1	11.5	28.4	90.6	9.4	40	32	9	20	466	.34	.31	286
60	3.1	85.3	11.6	41.9	47.3	10.8	47:0	1.7	51.3	89.3	10.7	34	35	7	24	392	.04	.50	196
61	79.4	14.6	6.0	34.0	63.2	2.8	35.0	51.6	13.4	97.2	2.8	45	8	7	40	466	.83	.19	206
62	17.6	71.8	10.6	37.0	58.1	4.9	38.9	10.7	50.3	95.2	4.8	43	16	7	34	438	.19	.24	202
63	45.5	42.8	11.8	35.0	60.5	4.5	36.7	28.8	34.5	95.5	4.5	43	13	9	34	432	.51	.21	196
64	18.5	71.1	10.4	40.4	53.2	6.4	43.1	10.5	46.3	93.7	6.3	44	19	7	30	441	.20	.34	221
65	85.9	12.8	1.4	35.3	62.7	2.0	36.3	54.7	9.0	98.4	1.6	49	7	1	43	491	.86	.17	219
66	60.6	34.5	4.9	33.8	62.2	4.0	35.2	39.3	25.5	97.2	2.8	42	15	5	38	436	.62	.19	184
67	81.1	9.2	9.7	35.3	59.6	5.1	37.2	50.9	11.9	94.9	5.1	42	14	8	35	451	.89	.31	211
68	70.7	27.5	1.8	36.4	58.6	5.0	38.3	43.6	18.1	95.1	4.9	42	19	1	37	445	.70	.24	197
69	89.9	10.1	.0	43.5	48.3	8.2	47.4	47.3	5.3	92.0	8.0	43	27	-	30	443	.89	.61	223
70	31.3	57.1	11.6	34.8	60.8	4.4	36.4	19.9	43.7	95.7	4.3	43	16	8	33	414	.34	.17	182
71	90.9	5.9	3.2	34.3	62.2	3.5	35.6	58.6	5.9	96.5	3.5	42	12	7	39	450	.94	.24	194
72	83.9	15.1	1.0	38.7	57.1	4.2	40.4	50.0	9.6	95.8	4.2	45	18	1	36	453	.84	.19	209
73	48.3	33.8	17.9	41.7	45.5	12.8	48.4	24.9	26.6	88.5	11.5	37	34	9	20	383	.58	.75	203
74	5.2	87.7	7.1	33.7	58.8	7.5	36.4	3.3	60.3	92.6	7.4	41	22	5	32	397	.05	.21	169
75	13.6	48.5	37.9	43.0	50.8	6.2	45.8	7.4	46.8	93.9	6.1	44	17	21	18	378	.22	.45	206
76	14.3	43.8	41.9	48.6	46.0	5.4	51.4	6.9	41.7	94.8	5.2	45	17	22	16	400	.24	.39	236
77	19.7	69.6	10.7	32.4	60.6	7.0	34.8	12.8	52.3	93.0	7.0	41	18	8	33	405	.21	-	173
78	53.5	41.0	5.5	32.8	62.9	4.3	34.3	35.2	30.6	95.7	4.3	45	13	5	37	425	.56	.18	177
79	31.6	58.5	10.0	42.3	48.6	9.1	46.6	16.9	36.6	90.9	9.1	35	32	6	26	396	.34	.27	192
80	100.0	0.0	0.0	37.2	21.1	41.7	63.8	36.2	0.0	59.7	40.3	11	47	4	37	355	.35	.15	185
81	25.5	53.2	21.3	40.0	51.7	8.3	43.6	14.4	42.0	91.8	8.2	39	25	12	24	387	.31	.40	191
82	9.4	84.0	6.6	27.8	65.7	6.5	29.7	6.6	63.7	93.5	6.5	41	18	5	35	376	.10	.60	136
83	47.8	49.6	2.7	31.9	61.6	6.5	34.1	31.5	34.4	93.5	6.5	40	23	2	36	398	.47	.39	154
84																			
85	48.3	49.4	2.3	29.0	65.1	5.9	30.8	33.4	35.8	94.1	5.9	42	18	2	37	392	.48	.75	144
86	63.0	18.9	18.1	35.2	58.7	6.1	37.5	39.4	23.1	93.9	6.1	40	12	20	28	395	.76	.28	183
87	15.9	68.8	15.4	34.7	58.9	6.4	37.1	9.9	53.0	93.6	6.4	38	20	12	29	378	.18	.36	162
88	85.6	8.2	6.2	41.0	53.0	6.0	43.6	48.2	8.1	94.2	5.8	45	19	4	31	444	.91	.38	220
89	77.7	16.4	5.9	38.4	52.2	9.4	42.4	44.8	12.8	90.8	9.2	35	34	3	28	388	.82	.34	176
90	92.8	5.1	2.2	42.2	55.7	2.1	43.1	52.8	4.1	97.9	2.1	49	10	2	40	534	.95	.45	274
91	37.9	45.6	16.5	38.3	52.5	9.2	42.2	21.9	35.9	90.8	9.2	36	16	21	26	405	.44	.27	201
92	12.9	60.8	26.3	40.8	51.6	7.6	44.1	7.2	48.7	92.4	7.6	40	22	16	22	387	.17	.23	199
93	58.7	36.7	4.6	36.8	59.6	3.6	38.2	36.3	25.6	96.4	3.6	46	15	4	35	429	.60	.02	189
94	79.3	15.2	5.5	57.3	30.0	12.7	65.6	27.3	7.1	88.3	11.7	42	40	2	16	413	.83	.30	249
95	38.3	41.1	20.3	40.3	50.7	9.0	44.3	21.3	34.4	91.3	8.7	41	25	12	23	375	.47	.45	183
96	37.0	48.5	14.5	51.3	38.5	10.2	57.1	15.9	27.0	90.5	9.5	48	28	6	18	409	.42	.33	237
97	42.6	49.2	8.3	34.1	57.3	8.6	37.3	26.7	36.0	91.4	8.6	40	24	5	31	395	.45	.35	171
98	44.8	45.7	9.5	30.2	65.2	4.6	31.6	30.6	37.8	95.4	4.6	42	17	7	34	381	.49	.15	145
99	14.2	57.9	28.0	40.7	50.4	8.9	44.7	7.8	47.5	91.2	8.8	39	25	16	21	369	.19	.21	185
100	47.6	21.9	30.5	41.8	43.3	14.9	49.1	24.2	26.7	85.4	14.6	33	39	13	15	339	.67	.73	179
101	58.8	35.4	5.9	31.8	63.2	5.0	33.5	39.1	27.4	95.0	5.0	45	15	5	36	403	.61	.16	159
102	47.2	31.3	21.5	49.2	39.8	11.0	55.2	21.1	23.9	89.6	10.4	41	32	9	17	376	.58	.35	208
103	66.9	3.4	29.7	42.4	48.5	9.1	46.7	35.7	17.7	90.9	9.1	39	25	17	19	397	.95	.49	221
104	18.6	73.5	7.9	28.8	62.8	8.4	31.4	12.7	55.8	91.7	8.3	37	20	10	32	359	.19	.22	131
105	59.3	30.8	9.9	43.5	49.1	7.4	47.0	31.4	21.6	92.8	7.2	41	27	6	26	415	.64	.21	211
106	43.2	45.6	11.2	29.3	65.7	5.0	30.8	29.9	39.3	95.0	5.0	43	14	9	34	382	.48	.2/	146
107	79.5	19.4	1.1	27.6	63.8	8.6	30.2	55.5	14.3	91.3	8.7	38	15	11	37	388	.79	.65	140
108	75.9	20.5	3.6	42.3	53.2	4.5	44.3	42.3	13.4	95.8	4.2	55	12	2	31	432	.78	-	208
109	3.9	61.1	35.0	36.6	56.1	7.3	39.5	2.4	58.1	92.7	7.3	41	20	20	20	339	.06	.46	159
110	9.0	88.1	3.0	33.3	54.0	12.7	38.1	5.5	56.3	87.7	12.3	37	34	2	28	346	.09	.47	134
111	92.7	5.8	1.5	28.2	68.0	3.8	29.3	65.5	5.2	96.2	3.8	44	14	2	40	401	.94	.15	141
112	33.9	58.0	8.1	24.0	72.5	3.5	24.8	25.5	49.7	96.5	3.5	44	9	9	38	363	.35	.27	111
113	84.8	15.2	.04	21.6	75.0	3.4	22.4	65.9	11.8	96.6	3.4	45	10	.3	44	389	.84	.37	113
114	93.7	5.4	.9	28.5	64.3	7.2	30.7	64.9	4.4	92.8	7.2	42	19	1	37	398	.95	.36	150

(continued)

	Or	Ab	An	Qz	Feld	Fem	Qz	Or	Pl	fels	fem	al	fm	c	alk	si	k	mg	Qz
115	24.5	53.8	21.8	53.8	20.4	25.8	72.5	6.7	20.8	74.2	25.8	12	75	5	8	301	.30	.22	169
116	54.5	43.6	1.9	21.7	75.0	3.3	22.4	42.3	35.3	96.7	3.3	46	10	2	43	374	.54	.09	102
117	33.8	55.1	11.1	35.2	54.9	9.9	39.0	20.6	40.4	97.7	2.3	38	31	6	26	345	.36	.28	141
118	55.7	35.8	8.6	26.9	67.2	5.9	28.6	39.8	31.7	94.1	5.9	43	16	7	35	374	.59	.16	134
119	75.8	23.3	1.0	22.3	68.8	8.9	24.5	57.2	18.3	91.1	8.9	38	25	1	37	346	.75	.49	98
120	39.8	45.0	15.2	32.2	61.5	6.3	34.3	26.1	39.5	93.8	6.2	42	20	10	28	342	.45	.30	130
121	39.4	41.9	18.7	28.3	59.5	12.2	32.2	26.7	41.1	87.8	12.2	36	24	15	25	329	.47	.29	129
122	61.4	34.7	3.9	28.4	64.3	7.3	30.6	42.6	26.7	92.8	7.2	43	20	3	33	357	.62	.18	125
123	20.5	53.6	26.0	28.2	65.1	6.7	30.2	14.3	55.5	93.3	6.7	40	19	16	24	312	.27	.31	166
124	75.0	25.0	0.0	21.5	73.9	4.6	22.5	58.1	19.4	95.4	4.6	43	15	.3	42	362	.74	.02	54
125	18.7	36.5	44.9	34.9	53.5	11.6	39.5	11.3	49.2	88.5	11.5	38	26	23	14	296	.33	.69	140
126	27.0	65.5	7.6	29.7	60.3	10.0	33.0	18.1	48.9	90.4	9.6	43	25	5	28	328	.28	.45	116
127	94.4	3.3	2.3	23.5	72.4	4.1	24.5	71.3	4.2	95.9	4.1	43	15	2	40	375	.96	.17	115
128	40.8	57.7	1.5	17.8	76.8	5.4	18.8	33.1	48.0	94.6	5.4	42	16	2	40	329	.40	.23	69
129	29.0	44.9	26.1	33.5	59.5	7.0	36.1	18.6	45.4	93.2	6.8	45	17	16	22	328	.38	.92	140
130	57.7	41.9	.4	25.5	67.9	6.6	27.3	42.0	30.7	93.8	6.2	48	17	1	35	338	.57	.48	98
131	19.0	70.3	10.8	25.4	59.0	15.6	30.0	13.6	56.7	84.6	15.4	35	32	7	26	307	.21	.36	97
132	11.2	83.5	5.3	25.5	62.9	11.6	28.9	8.0	63.2	88.6	11.4	37	29	4	30	309	.12	.35	89
133	47.2	43.0	9.9	18.8	75.0	6.2	20.1	37.7	42.2	93.9	6.1	42	16	7	34	315	.51	.37	79
134	39.2	60.5	.3	19.4	66.0	14.6	22.7	30.3	47.0	85.4	14.6	32	18	19	32	300	.38	.31	72
135	17.3	69.0	13.8	28.6	58.0	13.4	33.0	11.6	55.4	86.9	13.1	37	30	8	24	307	.19	.29	111
136	59.8	30.1	10.1	23.0	62.8	14.2	26.8	43.7	29.5	85.8	14.2	35	30	7	28	315	.66	.22	103
137	33.6	41.1	25.3	26.9	66.1	7.0	28.9	23.9	47.2	93.0	7.0	41	18	17	25	308	.43	.24	108
138	59.8	37.6	2.6	14.3	79.1	6.6	15.3	50.6	34.0	93.5	6.5	41	16	4	39	314	.60	.51	58
139	74.4	24.9	.7	16.4	78.6	5.0	17.2	61.5	21.2	95.1	4.9	45	14	1	41	326	.74	.31	62
140	42.0	43.2	14.8	22.5	71.6	5.9	23.9	32.0	44.1	94.2	5.8	46	14	10	30	310	.48	.34	90
141	32.7	50.2	17.2	28.3	62.0	9.7	31.3	22.4	46.2	90.4	9.6	38	26	11	25	304	.38	.14	104
142	37.7	59.5	2.9	34.2	43.3	22.5	44.1	21.0	34.8	78.9	21.1	33	47	2	18	278	.38	.63	106
143	18.6	46.5	34.9	26.5	50.3	23.2	34.5	12.2	53.3	76.7	23.3	27	38	22	13	242	.27	.50	90
144	69.6	15.8	14.6	27.4	62.6	10.0	30.4	48.4	21.2	90.3	9.7	41	23	10	26	312	.81	.49	108
145	69.5	22.7	7.9	26.7	61.6	11.7	30.2	48.5	21.3	88.4	11.6	36	31	6	28	309	.74	.30	97
146	71.2	23.2	5.6	25.5	66.8	7.7	27.6	51.6	20.8	92.7	7.3	47	19	4	30	315	.75	.42	95
147	31.2	58.8	10.1	26.3	62.0	11.7	29.8	21.9	48.3	88.4	11.6	34	32	7	27	293	.33	.24	85
148	12.8	22.0	65.2	39.8	48.1	12.1	45.3	7.0	47.7	88.2	11.8	40	26	26	7	270	.37	.34	142
149	19.8	55.3	24.9	24.4	64.8	10.8	27.4	14.4	58.2	89.2	10.8	38	19	20	23	292	.25	.40	100
150	76.6	23.1	.3	32.6	48.6	18.8	40.2	45.8	14.0	82.1	17.9	36	40	1	23	.312	.76	.41	120
151	0.0	89.5	10.5	10.5	73.4	16.1	12.5	0.0	87.5	83.9	16.1	33	17	23	27	241	-	.58	33
152	89.7	6.8	3.6	15.5	77.8	6.7	17.2	77.0	5.8	93.4	6.6	40	18	4	38	308	.93	.20	56
153	16.5	33.7	49.8	31.8	51.5	16.7	38.2	10.2	51.6	83.3	16.7	32	33	24	11	259	.32	.50	115
154	2.6	93.6	3.9	13.0	80.4	6.6	13.9	2.2	83.8	93.5	6.5	43	12	5	40	318	.02	.04	58
155	86.4	11.5	2.0	20.4	72.2	7.4	22.1	67.4	10.6	93.0	7.0	46	21	1	32	289	.88	.49	61
156	51.8	42.1	6.1	24.5	66.5	9.3	26.7	37.9	35.4	91.2	8.8	48	20	4	28	291	.53	.70	79
157	22.9	22.9	54.2	34.4	47.6	18.0	41.9	13.3	44.8	81.9	18.1	29	40	22	9	241	.48	.36	105
158	42.2	55.5	2.3	9.4	75.9	14.7	11.0	37.6	51.4	85.3	14.7	33	25	11	31	248	.42	.45	24
159	24.5	47.7	27.9	20.7	64.0	15.3	24.4	18.5	57.1	84.7	15.3	34	30	16	20	248	.33	.42	68
160	87.0	10.2	2.8	13.7	79.3	7.0	14.7	74.2	11.0	93.0	7.0	42	19	2	37	290	.89	.29	42
161	28.0	39.1	32.9	29.2	54.4	16.4	34.9	18.2	46.8	84.2	15.8	38	30	16	15	247	.41	.36	87
162	16.3	46.8	36.9	21.2	68.8	10.0	23.5	12.5	64.0	90.2	9.8	43	19	20	18	235	.25	.80	63
163	87.3	8.3	4.4	7.6	82.3	10.1	8.4	80.0	11.6	89.8	10.2	39	17	8	36	268	.91	.30	24
164	2.4	94.9	2.8	15.7	73.1	11.2	17.7	1.9	80.4	88.9	11.1	34	32	2	32	255	.02	.04	27
165	9.7	85.8	4.5	2.3	86.4	11.3	2.6	9.4	88.0	88.6	11.4	38	17	10	35	237	.10	.32	-3
166	57.6	40.4	2.0	3.8	83.2	13.0	4.4	55.0	40.5	87.0	13.0	35	18	13	34	238	.57	.39	2
167	60.3	36.7	3.0	8.6	83.3	8.1	9.4	54.7	35.9	91.9	8.1	40	21	3	36	258	.61	.09	14
168	47.2	7.7	45.1	31.3	51.5	17.2	37.8	29.4	32.9	83.3	16.7	35	34	19	11	256	.85	.64	122
169	25.5	45.3	29.1	20.0	621	17.9	24.4	19.3	56.3	82.6	17.4	36	33	14	17	225	.35	.61	57
170	19.0	31.3	49.7	17.7	73.3	9.0	19.4	15.3	65.2	91.0	9.0	41	13	32	14	215	.36	.80	59
171	18.5	53.3	28.2	13.4	77.4	9.2	14.8	15.8	69.4	91.2	8.8	44	18	17	21	219	.25	.76	35

(continued)

	Or	Ab	An	Qz	Feld	Fem	Qz	Or	Pl	fels	fem	al	fm	c	alk	si	k	mg	Qz
172	23.5	74.8	1.7	.3	70.1	29.6	.3	23.3	76.2	70.4	29.6	24	38	14	23	187	.23	.65	- 5
173	8.2	51.6	40.2	21.3	61.7	17.0	25.7	6.1	68.2	83.0	17.0	31	34	21	14	204	.13	.40	48
174	21.6	55.2	23.2	20.3	6'.0	11.7	23.0	16.6	60.4	88.9	11.1	43	25	12	20	228	.27	.27	48
175	76.1	23.9	0.0	0.0	91.5	8.5	0.0	76.1	23.9	91.5	8.5	42	8	5	45	234	.70	.33	-63
176	86.0	1.9	12.1	10.0	75.6	14.4	11.7	76.0	12.3	86.5	13.5	44	27	6	23	205	.97	.64	13
177	5.1	84.8	10.1	16.6	39.6	43.8	29.5	3.6	66.9	56.2	43.8	15	10	62	12	200	.05	.36	52
178	17.3	48.3	34.5	0.0	65.4	34.6	0.0	17.3	83.0	65.4	34.6	25	40	23	12	139	.25	.57	- 9
179	70.0	27.4	2.6	0.0	86.3	13.7	0.0	70.0	30.0	86.3	13.7	39	32	2	26	154	.71	.86	-50
180	1.6	65.2	34.8	9.9	63.4	26.7	13.4	1.4	85.3	74.3	25.7	6	42	19	13	144	.03	.04	- 8
181	63.2	34.7	2.1	0.0	77.2	22.8	0.0	63.2	36.8	77.2	22.8	27	42	5	26	156	.63	.24	-48
182	4.5	41.6	53.9	.5	54.1	45.4	1.0	4.5	94.5	54.6	45.4	21	49	24	7	114	.08	.39	-14
183	23.0	67.0	10.1	0.0	72.2	27.8	0.0	23.0	77.0	72.2	27.8	24	47	9	20	125	.24	.41	-55
184	33.1	52.5	14.3	0.0	72.5	27.5	0.0	33.1	66.9	72.5	27.5	25	49	8	18	121	.37	.18	-51
185	60.5	32.3	7.2	51.1	45.8	3.1	52.7	28.6	18.7	96.4	3.6	51	13	5	32	556	.64	.37	328
186	55.6	43.0	1.4	41.6	54.0	4.4	43.5	31.4	25.1	94.3	5.7	44	15	2	39	517	.55	.29	261
187	44.1	47.6	8.3	43.1	47.4	9.5	43.6	23.1	29.3	89.3	10.7	41	28	5	26	425	.47	.41	221
188	48.5	45.5	6.0	27.2	39.2	33.6	40.9	28.6	30.5	71.0	29.0	38	48	3	11	188	.50	.55	44
189	2.7	80.0	16.4	33.9	44.7	21.4	43.2	1.5	55.3	79.2	20.8	30	44	8	17	297	.03	.43	129
190	8.1	79.2	12.7	33.6	39.5	26.6	45.9	4.4	49.7	74.6	25.4	30	52	5	14	250	.08	.64	94

Appendix 3 Originally described rock-names, localities and analysts of the specimens

1 light-gray quartzitic leptite, N. of Lilla Sillvik, Utö, Anal., R. Mauzelius
2 hälleflinta, Jernboås parish, Örebro country, Anal., H. Santesson
3 quartzitic leptite, Hamrånge, coast of S. Norrland, Anal., N. Sahlbom
4 pegmatized leptite-gneiss, SW. of Sandstugan, Flens parish, Anal., G. Assarsson
5 light-red banded hälleflinta (lower hälleflinta zone), E. of Svanvik, Grythytte district, Anal., R. Mauzelius
6 quartz-stained leptite, Lilla Sillvik, Utö, Anal., R. Mauzelius
7 lipartie, Laver mine, Anal., Th. Berggren
8 quartz-porphyry (upper hälleflinta zone), Kullberget, Grythytte district, Anal., R. Mauzelius
9 hälleflinta, Hjulsjö parish, Örebro county, Anal., H. Santesson
10 Na-leptite, Järnvägsskärningen, N. of disponentbostaden, Odal district, Persberg mine, Anal., G. Nyblom
11 K-leptite, Riddarhytte ore field, Anal., R. Mauzelius
12 black hälleflinta (=quartz-porphyry) (upper hälleflinta zone), Malmbergersdden, Grythytte district, Anal., R. Mauzelius
13 Na-leptite, quartz-porphyritic, Mimer, Norberg mine district, Anal., A. Bygdén
14 Na-leptite, Odal district, Persberg mine, Anal., N. Sahlbom
15 quartz-porphyry, 700 m E. of Maurliden, Malånäs district, Västerbotten, Anal., L. Borgstedt
16 homogeneous leptite-gneiss, Oscar mine, Sköldinge parish, Anal., R. Mauzelius
17 red banded hälleflinta (lower hälleflinta zone), E. of Baståsen, Grythytte district, Anal., R. Mauzelius
18 dark-leptite, E. of Restavik, Utö, Anal., R. Mauzelius
19 Na-leptite, quartz-porphyritic, Kallmorbergsgruvan, 182 ML., Anal., A. Bygdén
20 leptite, Sjömo, parish of Götlunda, Örebro county, Anal., G. Nauckhoff
21 leptite, parish of Västanfors, Engelsberg county, Anal., O. Gumaelius
22 Na-leptite, Odal district, Persberg, Anal., G. Nyblom

23 homogeneous leptite-gneiss, Vilhelmina mine, Sköldinge parish, Anal., G. Assarsson
24 Na-leptite, Bispberg, Anal., G.T. Lindroth
25 leptite, Jokannisbäck, lands of Sala, Anal., O. Gumaelius
26 porphyritic leptite with granophyre texture in groundmass, Ramhäll, Uppland, Anal., R. Mauzelius
27 leptite, W. of Lysinge, parish of Glanshammer, Örebro county, Anal., G. Nauckhoff
28 leptite-gneiss, Skirtorp in Floda parish, Anal., G. Assarsson
29 Na-leptite, Markdal mine, Anal., A. Bygdén
30 K-leptite, Back mine, Långban mine, Anal., N. Sahlbom
31 hälleflinta, Gytberget at Järndammen, parish of Sala, Anal., O. Gumaelius
32 light-grayish yellow Na-leptite, Open pit, N. Nyberg field, Anal. N. Sahlbom
33 red-flamy intermediate Na-leptite, N. of the Tolvman mine, S. Nyberg field, Anal., N. Sahlbom
34 Na-leptite, Bispberg, Anal., G.T. Lindroth
35 hälleflinta, N. of the Puoitak farm, Gällivare, Anal., G. Assarsson
36 leptite, Stortjärn, E. of Lake Dagarn, parish of Västanfors, Engelsberg county, Anal., O. Gumaelius
37 Na-leptite, Bispberg, Anal., G.T. Lindroth
38 leptite, Bördstorp, Claestorp county, Anal., H. Santesson
39 leptite, light part of a layer, E. shore of Utö, Anal., R. Mauzelius
40 hälleflinta, E. of Knifsta, parish of Lena, Anal., A.L. Th. Pettersson
41 dark-stripe part in quartz-studded hälleflinta, Örner shaft, Central field, Dannemora, Anal., N. Sahlbom
42 Na-leptite, Finnmossen mine, Nordmark, Anal., N. Sahlbom
43 leptite, between Mortorp and Buskgården, parish of Västanfors, Engelsberg county, Anal., O. Gumaelius
44 porthyritic leptie, Ramhäll, Uppland, Anal., R. Mauzelius
45 leptite, Jokannisbäck, lands of Sala, Anal., O. Gumaelius
46 k-leptite, quartz-porphyritic, NW. of St. Malmkärra, Norberg district, Anal., A. Bygdén
47 k-leptite, Stråssa, Anal., A. Bygdén
48 Na-leptite, 260 ML, Nordmark, Odal district, Anal., N. Sahlbom
49 hälleflinta, Lars Matwberget, NNE. of Eklöfstorp, lands of Sala, Anal., O. Gumaelius
50 alkaliintermediate leptite, Bispberg, Anal., G.T. Lindroth
51 hälleflinta, W. side of S. Slsjön, Laxarby parish, Elfsborgs county, Anal., D. Hummel
52 leptite. Åndenäs, parish of Regna, Claestorp county, Anal., H. Santesson
53 leptite, Lorttjärnarna, parish of Norberg, Engelsberg county, Anal., O. Gumaelius
54 quartz-keratophyre, 200 m S. of Maurliden, Anal., Th. Berggren
55 hälleflinta, Bora parish, Örebro county, Anal., A.V. Cronqvist
56 felsite, Drottningstövaren, Falun mine, Anal., K. Schröder
57 alkaliintermediate leptite, Bispberg, Anal., G.T. Lindroth
58 hälleflinta, at the high-road near the parsonage of Kila, Anal., O. Gumaelius
59 graphite-bearing leptite, Svensbo, Anal., N. Sahlbom
60 Na-leptite, Yxsjö district, Ljusnarsberg ore field, Anal., G.T. Lindroth
61 K-leptite, Bispberg, Anal., G.T. Lindroth
62 hälleflinta, middle South Ekeberget and Löffallet, Grythytte parish, Örebro county, Anal., O. Gumaelius
63 alkaliintermediate leptite, Bispberg, Anal., G.T. Lindroth
64 felsite, Bockskägget, Falun mine, Anal., K. Schröder
65 K-leptite, quartz-porphyritic, 150 m S. of St. Hedbergsgruvan, Norberg district, Anal., A. Bygdén

66 alkaliintermediate leptite, Bispberg, Anal., G.T. Lindroth
67 hälleflinta, NW. of Öfverby, Bondkyrka parish, Upsala county, Anal., O. Gumaelius
68 K-leptite, Riddarhytte ore field, Anal., R. Mauzelius and G. Assarsson
69 black-layered hälleflinta (upper hälleflinta zone), Högbornstjärn, Grythytte district, Anal., G. Assarsson
70 alkaliintermediate leptite, Puttbo, Falun mine, Anal., R. Mauzelius
71 K-leptite, the neighbourhood of the manor-house of Nävekvarn, parish of Tunaberg, Anal., A. Bygdén
72 K-leptite, Järnvägsskärningen, 1.5 km S. of Långban station, Anal., N. Sahlbom
73 dark-gray leptite, crosscut SE. of St. Limskär, S. of Runmarö, Anal., A.M. Byström
74 porphyritic leptite, Ramhäll, Uppland, Anal., R. Mauzelius
75 leptite, Utö, Anal., R. Mauzelius
76 leptitegneiss, Romeleklint, Anal., S. Palmqvist
77 banded tuff, Låver mine, Anal., Th. Berggren
78 quartz-porphyry, 2 km ENE. of Vimo, Anal., A. Aaremäe
79 banded leptite, Ramhäll, Uppland, Anal., R. Mauzelius
80 hälleflinta, Dalskogs parish, Elfskorg county, Anal., A.H. Wahlqvist
81 hälleflinta, S. of Vestergården, Ånimskog parish, Elfsborgs county, Anal., J.O. Fries
82 Na-leptite, Yxsjö district, Ljusnarsberg ore field. Anal., G.T. Lindroth
83 leptite, Björke, parish of Regna, Claestorp county, Anal., A. Hasselbom
84 leptite, Ejerdingstorp, Claestorp county, Anal., H. Santesson
85 alkaliintermediate leptite, Finnmossen mine, Nordmark, Anal., N. Sahlbom
86 light-stripe part in quartz-studded hälleflinta, Örner shaft, Central field, Dannemora, Anal., N. Sahlbom
87 alkaliintermediate leptite, Bispberg, Anal., G.T. Lindroth
88 hälleflinta, limestone quarry of Annefors, Fredriksberg, Anal., A. Aaremäe
89 hälleflinta, NE. of Uggelbol, parish of Tensta, Anal., A.L. Th. Pettersson
90 gray K-leptite, Syrtorp, Tunaberg, Anal., A. Bygdén
91 feldspar-rich leptite, Svartvik mine, Ljusnarsberg ore field, Anal., G. Assarsson
92 felsite, Skåningen, Falun mine, Anal., K. Schröder
93 quartz-porphyry, Hårås, Ultevis, Anal., F. Swenborg
94 quartz-studded hälleflinta, Örner shaft, Central field, Dannemore, Anal., N. Sahlbom
95 leptitic gneiss (hälleflint-gneiss), Axmars, coast of Norrland, Anal., N. Sahlbom
96 hälleflinta, NW. of Tärna church, parish of Sala, Anal., O. Gumaelius
97 leptite, at the high-road between Simla and Lillån, parish of Västanfors, Engelsberg county, Anal., O. Gumaelius
98 alkaliintermediate leptite, Bispberg, Anal., G.T. Lindroth
99 felsite, Boman, Falun mine, Anal., G. Nyblom
100 dark-gray leptite, Strömskär, E. side of Ladholmen, Anal., A.M. Byström
101 schlieric porphyry (ignimbrite), 2 km S. of Unntorp, Anal., A. Aaremäe
102 hälleflinta, at the road of Hälla, parish of Kumla, Anal., O. Gumaelius
103 K-leptite, Ställberg mine, Ljusnarsberg ore field, Anal., G. Assarsson
104 hälleflinta, Skuggan, the lands of Sala, Anal., O. Gumaelius
105 hälleflinta, W. of Igelsjötorp, parish of Tensta, Anal., A.L. Pettersson
106 quartz-porphyry, 1 km S. of Knästen, Grängelsberg, Anal., A. Aaremäe
107 tuff, St. Sjö district, Anal., A. Aaremäe
108 red leptite, Tjatitsvare, Snavva, Anal., F. Swenborg
109 weakly skarnized leptite-gneiss, Skalunda mine, Sköldinge parish, Anal., G. Blix
110 quartz-porphyry (upper hälleflinta zone), Sikfors, Grythytte district, Anal., G. Assarsson

111 K-leptite, Stampers, Sala, Anal., Hj. Sjögren
112 alkaliintermediate leptite, Bispberg, Anal., G.T. Lindroth
113 K-leptite, Åmmeberg zinc mine, Anal., N. Sahlbom
114 K-leptite, Basttjärns mine, Ljusnarsberg ore field, Anal., G. Assarsson
115 leptite, Aspbenning, parish of Västanfors county, Engelsberg county, Anal., O. Gumaelius
116 K-leptite, Gällivare ore field, Anal., N. Sahlbom
117 hälleflinta, Regna parish, Östergötland county, Anal., A. Hasselbom
118 quartz-porphyry rich is phenocrysts, Hökberget, Anal., A. Aaremäe
119 K-leptite, Backmine, Jakobsberg, Nordmark, Anal., N. Sahlbom
120 hälleflinta, W. of Björnhammaren, the lands of Sala, Anal., O. Gumaelius
121 Kali-calc-leptite, Täppan, Anal., A. Grabe
122 schlieric porphyry (ignimbrite), 2 km S. of Älvdalen, Anal., A. Aaremäe
123 hälleflinta, Tyskbo backe, parish of Kila, Anal., O. Gumaelius
124 quartz-porphyry, Ekströmsberg, Anal., A. Aaremäe
125 amphibolitic leptite-gneiss, South Syensbo, Anal., N. Sahlbom
126 quartz-porphyry, about 700 m W. of the Bjurträsk ores, Malånäs district, Västerbotten, Anal., L. Borgstedt
127 hälleflinta, Märrgölen, W. of the Sala mine, Anal., O. Gumaelius
128 leptite, Gällivare ore field, Anal., N. Sahlbom
129 felsite, Stöten, Falun mine, Anal., K. Schröder
130 gray tuffaceous hälleflinta, S. of Brevik, Grythytte district, Anal., R. Mauzelius
131 Na-leptite, Exportfeld, Anal., A Grabe
132 Na-leptite, Exportfeld, 270 ML., Anal., G. Assarsson
133 leptite, Backa mine, Claestorp county, Anal., A. Hasselbom
134 hälleflinta, Tössö parish, Elfborg county, Anal., M. Stolpe
135 Na-leptite, Exportfeld, 270 ML., Anal., G. Assarsson
136 basic K-leptite, Lomberg district, Ljusnarsberg ore field, Anal., A. Grabe
137 feldspar-rich leptite, Landsvägen, E. of Gäsen, Norberg district, Anal., A. Bygdén
138 K-leptite, Gällivare ore field, Anal., N. Sahlbom
139 K-leptite, Betesholmen, Runmarö, Skärgård, Anal., A. Bygdén
140 gray leptite, near Lilla Sillvik, E. side of Utö, Anal., R. Mauzelius
141 leptite, Riddarhytte ore field, Anal., R. Mauzelius
142 pegmatitized leptite-gneiss, Skalunda mine, Sköldinge parish, Anal., G. Blix
143 amphibolitic leptite-gneiss, N. of Mansjö, Anal., H. von Eckermann and G. Hanglund
144 weakly skarnized leptite-gneiss, Gölstuga mine, Floda parish, Anal., G. Assarsson
145 K-leptite, Ombergfeld, 270 ML, Anal., G. Assarsson
146 K-leptite, Lorttjärnarna, parish of Norberg, Engelsberg county, Anal., O. Gumaelius
147 leptite, Lomberg district, Ljusnarsberg ore field, Anal., G. Assarsson
148 garnet-bearing leptite, the islet SW. of Kråmö, the Trosa archipelago, Anal., A. Hasselbom
149 keratophyre, southern crosscut, 250 ML., Boliden mine, Anal., Th. Berggren
150 strongly pegmatitized leptite-gneiss, Landsvägddkärning, S. of Gölstrgu mine, Floda parish, Anal., G. Assarsson
151 leptite, Alsäter, Claestorp county, Anal., A. Hasselbom
152 K-leptite, Lillsjö district, Anal., A. Bygdén
153 amphibolitic leptite-gneiss, SE. of Lake Gryoken, Anal., H. von Eckermann
154 keratophyre, northern crosscut, 130 ML., Boliden mine, Anal., Th. Berggren
155 K-leptite, Betesholmen, Runmarö, Skärgård, Anal., A. Bygdén
156 banded gneissose leptite, Gäddtjärn iron mine, Anal., H. von Eckermann

157 hälleflinta, Vaksala parish, Upsala county, Anal., M. Stolpe
158 hälleflinta, W. side of Åbykilen, parish of Sala, Anal., O. Gumaelius
159 feldspar-rich leptite, SE. of Ungtjärn, Norberg district, Anal., A. Bygdén
160 K-leptite, Glan mine, Doverstorp district, Anal., A. Bygdén
161 leptitic gneiss (hälleflint-gneiss), Hamrångefjärden, coast of S. Norrlan, Anal., N. Sahlbom
162 spotty leptite, Gäddtjärn iron mine, Anal., N. Sahlbom
163 K-leptite, Lillsjö district, Anal., A. Bygdén
164 hälleflinta, Dalskog parish, Elfsborg county, Anal., V. Karlsson
165 leptite-gneiss (syenite-porphyry)? Malmberget, Anal., G. Nyblom
166 K-leptite, Åmmeberg zinc mine, Anal., N. Sahlbom
167 leptite-gneiss (syenite-porphyry), Malmberget, Anal., G. Nyblom
168 black hälleflinta, Spens mine, Utö, Anal., R. Mauzelius
169 dark-gray leptite, S. of Rågskär, E. of N. Nämdö, Anal., A.M. Byström
170 hälleflinta, Märrgölen, W. of the Sala mine, Anal., O. Gumaelius
171 sillimanite-gneiss (sodic biotite-leptite), south Svensbo, Anal., N. Sahlbom
172 syenite-leptite, Malmberget, Anal., R. Mauzelius
173 hälleflinta, the croft W. of Hälla, parish of Kila, Anal., O. Gumaelius
174 hälleflinta, N. of Nyfla, Upsala county, Anal., M. Stolpe
175 K-leptite, Dalby, the neighbourhood of Åmmeberg, Anal., A. Bygdén
176 black hälleflinta (upper hälleflinta zone), E. of Sivergruvan, Anal., G. Assarsson
177 calcite-rich leptite, Yxsjö district, Ljusnarsberg ore field, Anal., G.T. Lindroth
178 hälleflinta, W. of W. Sjögar, Tydie parish, Elfborg county, Anal., J.O. Fries
179 leptite, metasomatically altered, the Japan room, Långban mine, Anal., N. Sahlbom
180 leptite, N. of Flobo, parish of Västanfors, Engelsberg county, Anal., O. Gumaelius
181 syenite-leptite, Malmberget, Anal., R. Mauzelius
182 leptite, Gunnarsökna, parish of Lillkyrka, Örebro county, Anal., G. Nauckhoff
183 basic syenite-porphyry (leptite), Malmberget, Anal., N. Sahlbom
184 basic syenite-porphyry (leptite), Malmberget, Anal., G. Assarsson
185 leptite, 1 km S. of Aijala, Kisko, Finland, Anal., O. Stenberg
186 layered leptite (light-layer), Haapaniemi, Kisko, Orijärvi region, Finland, Anal., M. Tavela
187 leptite, S. of the village of Lapinkylä, Kisko, Orijärvi region, Anal., M. Tavela
188 layered leptite (dark-layer), Haapaniemi, Kisko, Orijärvi region, Finland, Anal., M. Tavela
189 siliceous schist (leptite), the Kamine formation near the Hitachi mine district, Anal., Chem. lab. of the mine
190 siliceous schist (leptite), the Kamine formation near the Hitachi mine district, Anal., Chem. lab. of the mine

Appendix 4 Keratophyres by Johannsen and siliceous schists (leptites) of the Hitachi mine district.

	(1)	(2)	(3)	(4)	(189)	(190)
SiO_2	70.57	54.41	61.86	69.48	67.42	65.00
TiO_2	.06	.54	.10	.14	.42	.54
Al_2O_3	15.39	27.04	16.58	11.99	11.74	13.11
Fe_2O_3	2.77	1.88	2.17	2.54	.54	1.23
FeO	1.81	.11	6.39	2.46	5.67	4.35
MnO	.05	-	tr	.20	.63	.22
MgO	1.52	.51	.54	1.16	2.88	5.73
CaO	1.66	2.00	.28	1.72	1.73	1.27
Na_2O	2.61	1.14	4.98	3.33	3.98	3.34
K_2O	2.21	6.71	5.34	4.01	.19	.49
$H_2O(+)$	1.12	3.36	1.95	1.56	2.45	3.33
$H_2O(-)$				.32		
P_2O_5	.34	.08	.11	.08	.31	.31
CO_2	.24	1.22	.30	1.34	.09	.03
SO_3	-	.29	.12	-	-	-
S	.09	-	-	-	-	-
NiO	-	-	-	.03	nd	nd
FeS_2	-	-	-	.05	1.05	.09
Cu	nd	nd	nd	nd	.02	.02
PbS	nd	nd	nd	nd	.01	.01
ZnS	nd	nd	nd	nd	.02	.02
Au	nd	nd	nd	nd	nd	.1 gr.
Ag	nd	nd	nd	nd	nd	.5 gr.
Total	100.44	99.29	100.72	100.41	99.15	99.09
a	8.5	12.3	21.2	13.1	8.8	7.6
c	1.9	2.5	.3	1.4	2.1	1.5
b	13.4	22.0	9.0	7.3	13.5	20.4
s	76.1	63.2	69.5	78.2	75.6	70.5
n	64	20	52	56	97	92
f'	29	8	88	64	46	25
m'	18	4	11	27	36	45
c'	-	-	-	9	-	-
a'	53	88	2	-	18	30

(1) Keratophyres.Cerro de los Llanganates,Ecuador. Analyst.F.V.Wolff.
(2) " .Wibbecke,Westfalia.Analyst.O.Mügge.
(3) " .Ortberg bei Elbingerode,Harz. Analyst.K.A.Lossen.
(4) " .Gavin on Lairs,Campsie Falls,near Glasgow.Analyst.Geol.Surv.Great Britain.
(189) Siliceous schist(leptite termed by the author). Hitachi mine district.Analyst.Chem.Labr. of the mine.
(190) " " ("). ditto .Analyst. ditto