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# A new rock classification system applied to ultrabasic-alkaline and phoscorite-carbonatite rocks

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ABSTRACT. — The logically strict and simple universal systems to display the composition of any rock composition is suggested, which facilitates creation of databanks, search and grouping of materials in them. The ultrabasic-alkaline and carbonatite-phoscorite chemical rock composition is classified and ordered according to the suggested and described RHA method. R – the rank formula – is the succession of component's symbols ranged according to the diminishing of their content in the analysis. If components are chemical elements, the rank formula (*Rchem*) will correspond to a set of element symbols ranked in order of decreasing atomic %. Collections of more than 900 rank formulas (*Rchem*) with corresponding values of complexity measure (*Hn*) and purity measure (*An*) and about 500 RHA indexes for typical rock types are available on the web-sites: http://www.emse.fr/~moutte/rha and http://www.geology.pu.ru/niizk/RHA.html (see files: *RHA_collect.txt*, *RHA_typical.xls* and the file *RHACollectHelp*). If components are minerals, the rank formula (*Rmin*) of a rock composition will correspond to a set of mineral symbols ranked in order of decreasing molecular %. The simple nomenclature of phoscorites and carbonatites based on use of rank formulas *Rmin* is worked out.

RIASSUNTO. — In questo contributo è suggerito un sistema universale, rigorosamente logico e semplice, per visualizzare la composizione di qualsiasi roccia, che faciliti la creazione di banche dati, e la ricerca e raggruppamento di materiali in esse. La composizione chimica di rocce ultrabasiche alcaline e carbonatitico-foscoritico è classificata e ordinata in accordo con il metodo RHA qui suggerito e descritto. R – formula di rank – è la successione dei simboli di componente ordinati secondo la diminuzione del loro contenuto nell'analisi. Se i componenti sono elementi chimici, la formula di rank (Rchem) corrisponderà and un set di simboli di elemento organizzati nell'ordine di diminuzione di % atomico. La collezione di più di 900 formule di rank (Rchem) con i corrispondenti valori di misure di complessità (Hn) e di misure di purezza (An) di circa 500 indici RHA di tipi di rocce comuni sono disponibili nei web-site: http://www.emse.fr/~moutte/rha e http://www.geology.pu.ru/niizk/RHA.html (vedi files: RHA_collect.txt, RHA_typical.xls e il file RHACollectHelp).

Se i componenti sono minerali, la formula di rank (Rmin) di una composizione di roccia corrisponderà ad un set di simboli di minerali organizzati nell'ordine di diminuzione del % molecolare. In questo contributo viene ricavata la semplice nomenclatura delle rocce phoscoritiche e carbonatitiche con l'applicazione delle formule di rank Rmin.

KEY WORDS: *rock classification, RHA method, phoscorite-carbonatites*

## INTRODUCTION

In terms of chemical composition, firstly of the «sacred» for petrologists $SiO_2$ amount, most ultrabasic-alkaline and phoscorite*-

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carbonatite rocks (UAPC) can be categorized as ultrabasic. The $SiO_2$ content of these rocks from different locations varies from 46–30 wt.% (foidites) to 24-0.5 % (phoscorite-carbonatite series). Their alkali ($Na_2O+K_2O$) content increases from 0.5-4 wt. % in the earliest olivinites and pyroxenites to 1.5-7.5 % in turjaites and other melilite rocks, and at least to 5.5-16 % in ijolites and syenites. The alkali content is low in phoscorites and carbonatites (0.2-3 wt.%). The diagrams widely used at display of silicate rock composition were useless for systems extremely enriched with carbon, calcium, iron, phosphorus and other elements. Being not systematised, the big sets of analyses did not allow quickly to reveal similar compositions, to estimate the representatively compositions in different areas of chemical space, to trace the links between separate groups of rocks.

## DESCRIPTION OF *RHA* METHOD FOR ROCK CLASSIFICATION

The large number of attempts to order the chemical or mineral compositions of various rock types, and the numerous problems of nomenclature result essentially from the absence of a general logical approach. Most of above mentioned problems were dissolved by use of a method *RHA*, applied for any geochemical systems [11]. The *RHA* language is implemented in a new computer program, called «PETROS-2» (author Moshkin S.), which can fulfil also several other mineralogical and petrological tasks. The existing Russian version of PETROS-2 is now localised for English users.

The description of a given analysis in the *RHA* system consists of three parameters: *R* - the Rank formula, *H* – Entropy and *A* - Anentropy. If components are chemical elements, the rank formula (*Rchem*) of a given analysis will correspond to a set of element symbols ranked in order of decreasing atomic %. The complexity of an analysis is measured by the information entropy, which was defined by Shannon [13] as $H = - \Sigma(p_1 \ln(p_i))$, where $p_i$ is the atomic amount of the element. In order to normalise *H* to the interval 0 - 1, *H* is redefined as $Hn = H/\ln(n)$, where *n* is the number of elements in *R*. The purity of an analysis is measured by the anentropy which, according to Petrov, is defined by $A = - (1/n) \Sigma(\ln(p_i)) - \ln(n)$. To normalise *A* to the interval 0–1, the anentropy *A* should be divided into $A^{\#}$ – the anentropy of the «analytical absolutely pure system», in which $p_1 = 0.99955$, $p_2 = p_3 = ... = p_{10} = 0.00005$.

Using the *R, H,* and *A*, which can serve as a «rock's composition passport», all rocks without any exceptions could be clear displayed and simple (monosemantically) classified. It gives the possibility to search for analogues in any data sets, to identify, compare and group the analyses.

## CHEMICAL *RHA* CLASSIFICATION OF ULTRABASIC-ALKALINE AND PHOSCORITE-CARBONATITE ROCKS

We compiled a collection of whole-rock analyses for the world-wide UAPC (in total, more than 900 entries), and calculated *R*, *H* and *A* for each of these analyses. The Exel-files are available on the web-sites (see abstract). Our data base includes 250 unpublished original analyses (Ecole de Mines de Saint Etienne, XRF and ICP-AES methods by which were determined 35 components; analysts F. Gallice and J. Moutte) of UAPC. Theses analyses of rocks from Kola intrusions (Kovdor, Vuoriyarvi, Turiy Peninsula, and Sallanlatvi) are available on the web-site http://www.emse.fr/~moutte. These samples were collected during two joint expeditions to Kola Peninsula, which were supported by

* in comparison with the traditional definition of "phoscorite as a magnetite-olivine-apatite rock connected with carbonatites" [8] we suggest a modified one: "phoscorites are plutonic ultramafic rocks (M >90%), composed of phosphate, oxide, carbonate, and silicate, that occur in close spatial and temporal association with carbonatites and often form multiphase phoscorite-carbonatite series".

INTAS grant (1999 and 2000). Some rock names were defined more precisely after we calculated their *R*. The data base includes also 65 original analyses of Kovdor UAPC rocks [12]. Other analyses were scanned from published tables, afterwards transferred via Fine Reader to Exel program, and the control of sums permitted to exclude some wrong or unsure analyses.

The rank formulas for only 44 rock's analyses from this collection including that, which names are not in general uses, or discontinued are represented in Tab. 1. The rank formula (*Rchem*) of a given analysis corresponds to a «word», in which the «letters» are the symbols of the chemical elements. These «words» – the *R's* – are ordered according to the «alphabet», in our case, the succession of the chemical elements in the Periodic Table.

The first position in all rank formulas is occupied by oxygen (O); seven elements, H, C, Na, Mg, Si, Ca and Fe, occupy the second rank, and this second element depends on the rock considered, e.g. in carbonatites it is mostly C or Ca, and in various phoscorites it can be Fe, Ca or Mg. The chemical similarity of some groups of rocks is reflected in the 2nd, 3rd, 4th etc. ranks. The symbol «=» between two elements shows that $p_i/p_{i+1} \leq 1{,}15$. This can help to define the presence of some minerals using the *Rchem*, in particular Ca = C obviously correspond to presence of calcite (Tab. 1, Nos. 1, 6, 7, 31-34, 36-37), Ba = S evidently testifies to presence of barite.

The calculated *Rchem* illustrates the striking compositional diversity of UAPC. This diversity can be quantified by measuring the distance expressed in at. % between the chemical analyses using the Euclid formula: $Euc = \sqrt{(O_1-O_2)^2 + (Si_1-Si_2)^2 + (Ti_1-Ti_2)^2 + \ldots (U_1-U_2)^2}$. This distance for 25 from our set of analyses is represented in Tab. 2. The distance between all silicate rocks and phoscorites or carbonatites is particularly significant (>14-20); the distance between olivinite and pyroxenite is > 15, and between turjaite and ijolite about 9-12. Especially small is the distance between all chemically similar rocks in spite of their different names (see Tab. 2, Nos. 2 and 3, 32 and 33 etc.). Notice that for the gabbro-granite series, the *Rchem* diversity alongside with the distance between various rock types is much lower than for the UAPC database. So, the distance between granite and diorite or gabbro is 5 and 8, respectively. In addition, on the same web-site one can compare the degree of variability *Rchem* of the UAPC with that of the granites (file *RHAGranite.xls*).

The observed chemical diversity is reflected in the petrography of the intrusions, each of which represents a specific combination of different rocks. The composition and nature of parental magma is likely to be responsible for the chemical and petrographic diversity of the UAPC. Such parameters as enrichment of the magma in alkaline elements, its high dissolution potential and low viscosity are of especial importance, along side with the regime of magma crystallisation and differentiation processes controlled by cooling rate and tectonic conditions. The average compositions of the Kola UAPC complexes (Tab. 1, No 20) approach that of olivine melilitite (Tab. 1, No 18), which probably represents the composition of primary magmas [6, 9]. The composition of katungites also could be considered close to composition of parental magma, if not their enrichment in water (Tab. 1, No 14 and 16).

## Nomenclature of phoscorite-carbonatite rock series bases on *RHA* method

Using the same logical approach it is possible to receive the modal description of rock composition and its ordering. So, the mineral rank formulas (*Rmin*) composed of mineral name abbreviations ranked in order of decreasing of mineral content can be used as a basis for simple display, classification and rational nomenclature of mineral rock's composition. According to the *RHA* method, the predominant mineral occupies the first position in *Rmin*. Taking this in account, we

TABLE 1

*Rank formulas (Rchem) of some ultrabasic-alkaline and phoscorite-carbonatite rocks*

| No | Rchem | | | | | | | | | | Hn | *An* | Rock name, [Ref.], *Tab.*, -No anal. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | O | H | Ca= | C | Si | Mg | Al | *FE* | K | P | 0.628 | 0.199 | Carbonatite lapilli tuff [15] *2* -C11B |
| 2 | O | C | Ca | Mg | Fe | P | Al= | Si | Mn | H | 0.519 | 0.278 | Rauhaugite I, [1] *6* - 3 |
| 3 | O | C | Ca | Mg | Fe | P | Si= | Mn | **Al** | K | 0.515 | 0.397 | Dolomitite [12] *6.1* - 7 |
| 4 | O | C | Ca | Mg | Fe | S | Al= | Si= | **Ba** | H | 0.561 | 0.192 | Rauhaugite II, [1] *6* - 4 |
| 5 | O | *C* | Ca | Mg | Fe | Mn | Al | S= | Si | H | 0.545 | 0.228 | Beforsite [3] *5* - 2, G672 |
| 6 | O | C= | Ca | *SI* | Fe | Mg | Mn | Al | Na | K | 0.480 | 0.312 | Sövite siderite [3] *2* - 3, 1377 |
| 7 | O | C= | Ca | Fe | H | Si= | Mg | Ti= | Al= | P | 0.467 | 0.383 | Ferrocarbonatite [7] *p. 318* - HF661 |
| 8 | O | C | Ca | Ba= | Si | Sr | Al | K | Fe | Na | 0.589 | 0.173 | Carbonatite Ca-Ba, [5] *10* - 1 |
| 9 | O | Na | C | Ca | K | F | Cl | S | Sr | P | 0.627 | 0.183 | Natrocarbonatite [9] *1* - BD4157 |
| 10 | O | Mg | Si | H | Fe | Ca | C | S | Al | Ti | 0.588 | 0.226 | Olivinite [author's data] - 4046 |
| 11 | O | Mg | Si | Ca | P | Fe | Al= | H= | C= | Na | 0.570 | 0.250 | Forsteritite apatite [12] *5.2* - 6 |
| 12 | O | Mg | Si | Fe | H | Ca | Al | C | Mn= | P | 0.532 | 0.273 | Olivinite (av. of 3 an.) [6] *25* - 1 |
| 13 | O | Mg | Si | Fe= | Ca | P | Na | Al | Mn | C | 0.518 | 0.299 | Forsteritite apatite [12] *5.2* - 5 |
| 14 | O | Si | H | Mg= | Ca | Fe | Al | K= | Ti | *NA* | 0.666 | 0.113 | Katungite [4] *IV* - E |
| 15 | O | Si | C= | Ca | H | Al= | K | Fe | Mn | *TI* | 0.609 | 0.159 | Sövite agglomerate [3] *2* - 1, 1185 |
| 16 | O | Si | Mg= | H= | Ca | Fe | Al | K | Ti= | Na | 0.666 | 0.116 | Katungite [4] *IV* - D |
| 17 | O | Si | Mg | Ca | H= | Fe | Al | Na | Ti | K | 0.653 | 0.118 | Melilitite leucitic [4] *IV* - H |
| 18 | O | Si | Mg | Ca= | Al | Fe | Na | *TI*= | K | P | 0.610 | 0.152 | Melilitite olivine [8] *65* - 4 |
| 19 | O | Si | Mg= | Ca | Fe | H | Al | Ti | K= | Na | 0.584 | 0.206 | Pyroxenite, [6] *199* - 15 |
| **20** | **O** | **Si** | **Mg** | **Ca** | **Fe** | **Al** | **Na** | **H** | **C=** | **Ti** | **0.634** | **0.129** | **Av. comp. Kola UAPC [6] *204* -1** |
| 21 | O | Si | Mg= | Ca | Fe | Ti | Al | H | Na | S | 0.583 | 0.199 | Pyroxenite [6] *199* - 13 |
| 22 | O | Si | Al | Na | Ca | Mg | K | Fe= | H | Ti | 0.613 | 0.158 | Ijolite [12] *3.5* - 5 |
| 23 | O | Si | Ca= | H= | Mg | Fe= | Al | Na= | K | C | 0.674 | 0.115 | Alnöite, [4] *IV* - G |
| 24 | O | Si= | Ca | C | H | Fe | K | Al | Mg= | Na | 0.630 | 0.137 | Orthoclasite carb. [7] *p.316* - 523 |
| 25 | O | Si | Ca= | Mg | H | Al | Fe | Na | K | Ti | 0.654 | 0.128 | Kugdite [12] *3.2* - 3 |
| 26 | O | Si | Ca= | Mg= | H | Al | Fe | K | C= | Na | 0.659 | 0.112 | Ouachitite [4] *IV* - B |
| 27 | O | Si | Ca | Mg | Al | H | Fe= | Na | K | P | 0.579 | 0.212 | Turjaite pyroxene [6] *27* - 2 |

CONTINUED: *Table 1*

| No | | Rchem | | | | | | | | | Hn | *An* | Rock name, [Ref.], *Tab.*, -No anal. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 28 | O | Si | Ca | Mg | Fe | Al | **H** | Na | Ti | K | 0.620 | 0.158 | Unkompahgrite [12] *3.2*- 4 |
| 29 | O | Si | Ca | Mg | Fe | Al | **Na** | H | Ti | K | 0.618 | 0.181 | Kugdite [12] *3.2* - 2 |
| 30 | O | Ca | C | H | Si | Mg | **Al** | Fe | K | P | 0.621 | 0.180 | Carbonatite hypab. [14] *6*-PO2-5 |
| 31 | O | Ca= | C | H | Si= | Fe | **Na=** | Mg | Al= | P | 0.506 | 0.257 | Alvikite limonitic [7] *p. 317* - 340 |
| 32 | O | Ca= | *C* | H | Fe | Si= | Mg | Na | P= | Al | 0.553 | 0.221 | Ferrocarbonatite [7] *p. 318* - 423 |
| 33 | O | Ca= | *C* | H | Fe | Si | **P=** | Mg= | Na | Al | 0.548 | 0.231 | Sövite [7] *p. 318* - 428 |
| 34 | O | Ca= | *C* | Mg | Fe= | P | **Si** | Na= | K= | Al | 0.478 | 0.339 | Calcitite [12] 6.*1* - 5 |
| 35 | O | Ca | *C* | Si= | Mg | H | Al | Fe | K | P | 0.618 | 0.177 | Carbonatite hypab. [14] *6* -PO2-1 |
| 36 | O | Ca= | C | Fe | P= | Na | Mg | **Al=** | Si | Mn | 0.448 | 0.392 | Alvikite [7] *p.317* - MC12 |
| 37 | O | Ca= | C | Fe | P | Na | Si | **Mg** | Ti | H | 0.472 | 0.357 | Ferrocarbonatite [7] *p. 318* -NDS6 |
| 38 | O | Ca | Si | P | Fe | Mg | Al | C | **Na** | K | 0.587 | 0.183 | Nelsonite [2] *12, p.180* - 90 |
| 39 | O | Ca | P | Mg | Fe= | Si | **C** | H= | Na | K | 0.563 | 0.218 | Apatitite [12] 5.2 - 7 |
| 40 | O | Ca | Fe | P= | **Si** | Mg | **Al** | K | C= | Na | 0.598 | 0.174 | Nelsonite [2] *12, p.180* - 89 |
| 41 | O | Fe | Mg | C | Ca= | Si | **Al** | Ti | P | Na | 0.559 | 0.235 | Magnetitite dolomite [12] *5.2* -14 |
| 42 | O | Fe | Mg= | Ca | P | Si | **F** | **Al** | H= | Ti | 0.603 | 0.190 | Magnetitite apatite [12] *5.2* - 9 |
| 43 | O | Fe | Mg | Ca | S= | Si | P= | C | **Al=** | H | 0.665 | 0.114 | Magnetitite calcite [12] *5.2* - 11 |
| 44 | O | Fe | Ca= | Si | Mg | Al | **P** | Ti= | Na | K | 0.476 | 0.240 | Magnetitite [2] *12, p.180* - 94 |

TABLE 2

| | 1 | 2 | 3 | 5 | 8 | 9 | 12 | 16 | 18 | 19 | 20 | 22 | 23 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 0.0 | | | | | | | | | | | | | |
| **2** | 21.0 | 0.0 | | | | | | | | | | | | |
| **3** | 21.0 | 2.1 | 0.0 | | | | | | | | | | | |
| **5** | 20.8 | 4.0 | 5.4 | 0.0 | | | | | | | | | | |
| **8** | 18.4 | 12.0 | 12.5 | 11.0 | 0.0 | | | | | | | | | |
| **9** | 28.1 | 24.7 | 25.2 | 24.0 | 24.0 | 0.0 | | | | | | | | |
| **12** | 28.5 | 28.8 | 28.0 | 30.2 | 29.9 | 37.1 | 0.0 | | | | | | | |
| **16** | 17.0 | 24.4 | 23.9 | 24.5 | 20.6 | 30.2 | 16.9 | 0.0 | | | | | | |
| **18** | 23.5 | 24.8 | 24.5 | 25.1 | 20.9 | 31.1 | 16.0 | 8.3 | 0.0 | | | | | |
| **19** | 21.8 | 25.0 | 24.5 | 25.2 | 20.9 | 32.7 | 16.5 | 7.1 | 5.9 | 0.0 | | | | |
| **20** | **21.1** | **23.3** | **22.9** | **23.5** | **19.7** | **29.5** | **15.5** | **6.1** | **3.2** | **5.0** | **0.0** | | | |
| **22** | 23.9 | 27.4 | 27.4 | 27.3 | 21.8 | 29.1 | 21.9 | 11.3 | 7.8 | 11.7 | **9.0** | 0.0 | | |
| **23** | 15.4 | 23.4 | 22.9 | 23.5 | 19.4 | 29.2 | 18.4 | 2.2 | 9.3 | 8.1 | **7.0** | 11.5 | 0.0 | |
| **25** | 18.2 | 24.6 | 24.1 | 24.8 | 20.2 | 29.9 | 17.8 | 3.2 | 6.6 | 6.5 | **5.1** | 8.7 | 3.5 | 0.0 |
| **26** | 17.6 | 23.4 | 23.1 | 23.5 | 18.9 | 29.4 | 18.2 | 3.3 | 6.6 | 6.5 | **4.9** | 9.0 | 3.7 | 2.6 |
| **27** | 21.5 | 24.8 | 24.1 | 25.2 | 19.6 | 32.0 | 21.4 | 10.1 | 9.8 | 7.1 | **9.4** | 12.6 | 9.8 | 8.5 |
| **28** | 20.8 | 24.4 | 23.9 | 24.3 | 18.5 | 30.4 | 19.0 | 6.7 | 5.6 | 4.0 | **4.6** | 9.3 | 6.9 | 5.0 |
| **30** | 10.6 | 12.7 | 12.4 | 12.6 | 8.5 | 24.5 | 26.7 | 15.6 | 19.0 | 17.7 | **17.0** | 20.6 | 13.9 | 15.9 |
| **32** | 16.9 | 11.5 | 11.3 | 10.3 | 9.5 | 24.9 | 33.6 | 23.7 | 26.1 | 25.0 | **24.3** | 27.4 | 22.1 | 23.9 |
| **33** | 16.3 | 12.1 | 11.9 | 11.2 | 9.8 | 25.2 | 33.9 | 23.8 | 26.4 | 25.2 | **24.5** | 27.5 | 22.0 | 23.9 |
| **35** | 14.1 | 11.9 | 11.2 | 12.3 | 8.4 | 25.5 | 24.6 | 14.9 | 17.2 | 16.1 | **15.3** | 19.5 | 13.5 | 15.0 |
| **36** | 23.2 | 11.7 | 11.8 | 11.0 | 11.4 | 26.8 | 37.2 | 28.7 | 29.7 | 28.9 | **28.2** | 31.0 | 27.2 | 28.5 |
| **38** | 22.0 | 21.4 | 20.5 | 21.5 | 17.2 | 30.5 | 25.0 | 14.9 | 14.9 | 13.6 | **13.9** | 18.1 | 13.9 | 14.4 |
| **39** | 23.4 | 21.1 | 19.8 | 21.8 | 18.5 | 31.3 | 27.8 | 19.9 | 20.8 | 19.8 | **19.7** | 24.0 | 18.8 | 19.9 |
| **41** | 27.7 | 27.7 | 27.7 | 23.4 | 24.8 | 31.9 | 23.1 | 21.5 | 21.6 | 21.6 | **19.8** | 26.1 | 21.6 | 22.8 |

Numbers of analyses correspond to that in the Table 1.

propose as a most simple classification for phoscorite-carbonatite rocks – the classification according to the dominant mineral. Rocks with predominant forsterite, magnetite, apatite, calcite and dolomite will be given the corresponding root-names forsteritite, magnetitite, apatitite, calcitite and dolomitite, respectively. The terms magnetitite, calcitite and the similar to apatitite – apatitolite, were used before to define the rocks of corresponding composition [8]. The names suggested for carbonatites could be used as short synonyms of calcite-, dolomite- etc. carbonatites. For a more detail characterisation of any rock type, it is possible to use two or three symbols of components listed in order of decreasing modal abundance (in opposite to increasing modal abundances according to IUGS system). For the more widespread phoscorite-carbonatite 4-component system, Apatite – Forsterite – Magnetite – Calcite the *Rmin* should be represented by the permutations of these components, i.e. by 24 *Rmin*. As abbreviations, it is convenient to use the initial letters of the principal minerals, e.g. FA for forsterite > apatite rock, MAF for magnetite > apatite > forsterite rock etc. The conformity of *Rchem* and *Rmin* for 12 samples of carbonatites and phoscorites from Kovdor intrusion is shown in Tab. 3. If the information about modal composition of rocks is incomplete or absent it is possible to use of their *Rchem* for most objective and complete description of any multi-component system.

*The distance in atomic % between various rocks calculated using the Euclid formula*

| 26 | 27 | 28 | 30 | 32 | 33 | 35 | 36 | 38 | 39 | 41 | Rock name, [Ref.], No anal. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Carbonatite lapilli tuff [15]*2* - C11B |
| | | | | | | | | | | | Rauhaugite I [1] *6* - 3 |
| | | | | | | | | | | | Dolomitite [12] *6.1* - 7 |
| | | | | | | | | | | | Beforsite [3] *5*-2, G672 |
| | | | | | | | | | | | Carbonatite Ca-Ba [5] *10* - 1 |
| | | | | | | | | | | | Natrocarbonatite [9] *1* - BD4157 |
| | | | | | | | | | | | Olivinite (av. of 3 an.) [6] *25* - 1 |
| | | | | | | | | | | | Katungite [4] *IV* - E |
| | | | | | | | | | | | Melilitite olivine [8] *65* - 4 |
| | | | | | | | | | | | Pyroxenite [6] *199* - 15 |
| | | | | | | | | | | | **Av. comp. Kola UAPC[6] *204*-1** |
| | | | | | | | | | | | Ijolite [12] *3.5* - 5 |
| | | | | | | | | | | | Alnöite [4] *IV* - G |
| | | | | | | | | | | | Kugdite [12] *3.2* - 3 |
| 0.0 | | | | | | | | | | | Ouachitite [4] *IV* - B |
| 9.3 | 0.0 | | | | | | | | | | Turjaite pyroxene [6] *27* - 2 |
| 5.3 | 6.0 | 0.0 | | | | | | | | | Uncompahgrite [12] *3.2* - 4 |
| 15.1 | 16.1 | 16.3 | 0.0 | | | | | | | | Carbonatite hypabis. [14] *6* - 1 |
| 22.9 | 22.8 | 23.4 | 8.56 | 0.0 | | | | | | | Ferrocarbonatite [7] *p. 318* - 423 |
| 23.0 | 22.8 | 23.6 | 8.37 | 1.35 | 0 | | | | | | Sövite [7] *p. 318* - 428 |
| 14.3 | 14.4 | 14.9 | 3.7 | 9.8 | 9.9 | 0 | | | | | Carbonatite hypabis. [14] *6* - PO2-1 |
| 27.5 | 26.3 | 27.5 | 13.9 | 6.8 | 7.2 | 14.2 | 0.0 | | | | Alvikite [7] *p.317* - MC12 |
| 14.0 | 11.8 | 12.1 | 14.4 | 18.8 | 19.1 | 12.9 | 22.1 | 0.0 | | | Nelsonite [2] *12. p.180* - 90 |
| 19.6 | 17.5 | 18.7 | 16.1 | 18.6 | 18.8 | 14.6 | 21.3 | 7.6 | 0 | | Apatitite [12] *5.2* - 7 |
| 21.8 | 26.1 | 21.7 | 24.2 | 27.2 | 28.1 | 23.0 | 30.8 | 22.2 | 25.3 | 0 | Magnetitite dolomite [12] *5.2* - 14 |

The traditional classification on the base of rock's mode composition is good only for that types composed of not more than 3 rock forming minerals and it is possible to use for them the binary or ternary diagrams. Phoscorite-carbonatite rocks are composed mainly of 4 minerals, magnetite, forsterite, apatite and carbonate (calcite, dolomite, ankerite, siderite). So, we should display their composition on the 4- and even more-component diagram and in particular for their chemical composition would be most informative the Fe-Si-P-C diagram. Each of these elements more or less determines the corresponding above-mentioned minerals, while elements like Ca and Mg enter in various minerals. Nevertheless it is impossible to show the really chemical diversity of the carbonatite-phoscorite rock series on any binary or ternary diagram. So, on the C-P-Fe triangular (Fig. 1) the different rocks (which analyses were selected from our data base) more or less plot in corresponding sectors but presence of such rock forming minerals as forsterite, phlogopite or diopside could not be displayed. On the diagram Si-P-Fe (Fig. 2) in the contrary, the carbon caused by carbonates cannot be shown. It is noteworthy that there exist the continuous row of compositions between carbonatites and phoscorites. This proves the necessity to consider the phoscorites and carbonatites as generically related uniform rock group. Using of any sort of diagrams including TAS, QAPF and so on we are compelled to ignore the

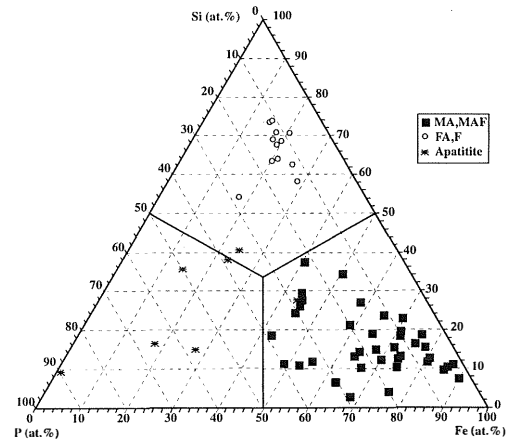


Fig. 1 – Chemical composition of carbonatites and phoscorites on ternary diagram C-P-Fe. Abbreviations: rocks MC – magnetite-calcite, MCF – magnetite-calcite-forsterite, MD – magnetite-dolomite, MDF – magnetite-dolomite-forsterite; tphl – tetra-ferriphlogopite.

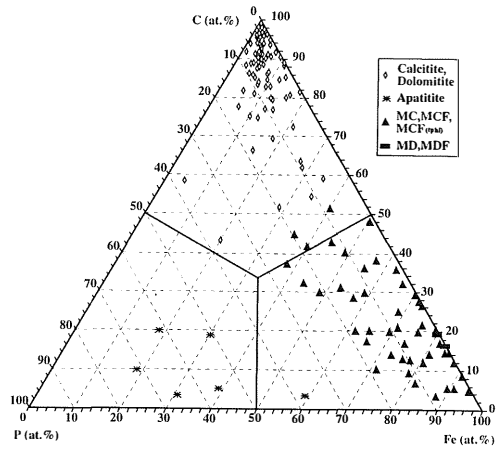


Fig. 2 – Chemical composition of phoscorites on ternary diagram Si-P-Fe. Abbreviations: rocks – FA – forsterite-apatite, F – forsteritite, MA – magnetite-apatite, MAF – magnetite-apatite-forsterite.

TABLE 3

*Comparison of rank formulas Rchem and Rmin of the rocks from Kovdor phoscorite-carbonatite complex*

| No | *Rchem* | | | | | | *Rmin* | | | | | Suggested rock names and abbreviations (*Rmin*) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *O* | **C** | **Ca** | **Mg** | Fe | P | **Dol** | Ap= | Mag | Cal | Phl | dolomitite (DAM) |
| 2 | **O** | **Mg** | **Si** | P= | Fe= | Ca | **Fo** | Ap | Mag | Phl | | forsteritite (FAM) |
| 3 | **O** | **Mg** | **Si** | Ca= | P | Fe | **Fo** | Ap | Mag | Phl | | forsteritite (FAM) |
| 4 | **O** | **Ca** | **C** | Mg= | P | Fe | **Cal** | Dol | Ap | Mag | Tphl | calcitite (CDA) |
| 5 | **O** | **Ca=** | **C** | Mg | P | Fe | **Cal** | Dol | Ap= | Mag | Tphl | calcitite (CDA) |
| 6 | **O** | **Ca=** | **C** | Mg | Fe | P | **Cal** | Fo | Ap= | Mag | | calcitite (CFA) |
| 7 | **O** | **Ca** | **P** | Mg= | Fe | Si | **Ap** | Fo | Mag | Phl | Cal | apatitite (AFM) |
| 8 | **O** | **Ca** | **P** | Mg | Fe= | Si | **Ap** | Fo | Cal | Mag | Phl | apatitite (AFC) |
| 9 | **O** | **Fe** | Mg | C | Ca= | Si | **Mag** | Dol= | Fo | Tphl | Ap | magnetitite (MDF) |
| 10 | **O** | **Fe** | Mg | Ca | P | Si | **Mag** | Cal | Fo | Ap | Phl | magnetitite (MCF) |
| 11 | **O** | **Fe** | Mg | Ca | P | Si | **Mag** | Fo | Ap | Cal | Phl | magnetitite (MFA) |
| 12 | **O** | **Fe** | Ca= | Mg | P | C= | **Mag** | Cal | Fo | Ap | Tphl | magnetitite (MCF) |

Abbreviations: for minerals in *R*: Ap – apatite, Cal – calcite, Dol – dolomite, Fo – forsterite, Mag – magnetite, Phl –phlogopite, Tphl – tetra-ferriphlogopite; for rocks: A – apatite, C – calcite, D – dolomite, F – forsterite. **Bold** point out the main components.

presence of some important components at classified objects. In the contrary, the *RHA* method accounts most components of the system without any discrimination.

## CONCLUSION

The difference and preference of the *RHA* method in comparison with the traditional principles of rock's classification [8] is in its universality, methodical and logical unity of the approach to the description and systematisation of the chemical and mineral composition. The results of *RHA* system do not depend from the operator: the systematisation is made automatically only on the base of rock's composition. Using this method one can distinguish the various rock series (with different *Rchem* and *Rmin, H* and *A*) and also group them on the base of any sort similarity of these characteristics. It is enable to discredit some local rock names if their analyses have similar *Rchem*, *Rmin, H* and *A* to rocks with generally accepted names. The *RHA* method gives the possibilities also reveal the evolutionary trends in rock series (on diagrams *H* and *A,* what was not shown in this short article).

The suggested *RHA* system is not alternative another traditional methods of rock's classification, and can be used as an additional and independent tool for ordering and systematisation of all modal and chemical data and enables to be guided in continuous space of chemical rock's composition. The *RHA* method expands prospects of cognition of geological objects.

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