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CONTENTS OF RARE AND ORE ELEMENTS IN QUARTZ FROM DIFFERENT AGE MAGMATIC FORMATIONS AND METAMORPHIC SERIES OF THE GREAT CAUCASUS

(Fig. 1, Tabs. 5)

Abstract: Authors determined contents of 19 elements from metamorphic series and from 10 magmatic formations of different age at the Great Caucasus. The data obtained lead to conclusion that contents and accumulation coefficients (K_H) of certain elements in quartz from the rocks of polyphase plutons can be used as ore potential indicators; quartz inherits geochemical features of the host rocks; considerably increased W contents in quartz from the rocks of all investigated formations in combination with the data on associated with certain formations W-ore mineralization permits to distinguish Caucasus orogenic belt as a potentially W-bearing province.

Резюме: На основании определения содержаний 19 элементов в кварцах из метаморфических образований и пород 10 разновозрастных магматических формаций Большого Кавказа установлено, что: содержания и коэффициенты накопления (K_H) ряда элементов в кварцах из пород, слагающих многофазные интрузивы, могут использоваться для оценки их потенциальной рудоносности; кварцы наследуют геохимические особенности материнских пород; резко повышенные содержания W в кварцах из пород всех рассмотренных формаций в сочетании с данными о связи с ними W оруднения позволили отнести Кавказскую складчатую область к числу потенциально вольфрамоносных металлогенических провинций.

Introduction

Carrying out geochemical study of quartz (evaluating Nb, Ta, Th, Hf, W, Sn, Mo, Zn, Cu, Ni, Co, Sc, Be, Li, Rb, Cs, K, Na, Fe, contents) from the Pre-Palaeozoic rocks (Afanas'yev et al., 1971) of metamorphic core of the Great Caucasus anticlynorium and magmatic formations, making up different age (Proterozoic?—Pliocene—Quaternary) series, which manifest the replacement of geodynamic regimes within various structural-formational zones composing the Caucasian polycyclic moving area during its evolution, the authors put forward the following tasks:

1. To characterize quartz from the rocks of the studied formations by means of contents of the above mentioned elements to find out if there is any geochemical specialization of quartz from the rocks, which characterize concrete evolu-

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tionary stages (geosyncline, inversion, orogeny) of Caucasian moving area within the Baikalian(?), Caledonian, Hercynian and Alpine tectono-magmatic cycles.

2. To clear up if the quartz inherits geochemical properties of host-rocks.

3. To define whether there are any regularities in the change of ore and rare elements' contents under transformation (i.e. regional metamorphism and anatectic melting processes) of mica schists and gneisses into the rocks of granite-migmatite formation.

4. To find out tendencies in the change of contents of a number of ore and rare elements in quartz from the rocks corresponding to the successive phases of certain formations' intrusion.

5. To investigate the possibilities of use of the data on the contents of a number of elements in quartz and their accumulation coefficiencies in order to define potentially rare-metal and ore-bearing formations.

Basing on these tasks we have sampled eleven magmatic and metamorphic formations. Taking into account the fact that these formations belong to different structural-formational zones (SFZ), the authors considered it necessary to give breaf geological-petrographic and metallogenic characteristics of SFZ within which the investigated formations are developed. Each of the investigated formations was given a number depending on its age (1 — the most ancient, XI — the youngest) despite of its location within a certain SFZ.

Petrologic-geological characteristics of formations

Evolution of magmatism within the Great Caucasus and manifestation of ore mineralization are connected with the evolution of large structural-formation zones (SFZ). From the north to the south the following zones have been singled aut (by Afanasiev et al., 1971): Bechasynskaya, Peredovoy, the Main Ridge and the Southern slope. Evolutionary history and structure of these SFZ differ, and they are bordered by really existing faults or weakened zones. The present day block structure of the Great Caucasus is characterized by a composition of long-living weakened sublatitudinal deep-formed zones and submeridional ones (Khain, 1961; Gurbanov et al., 1978).

Bechasynskaya SFZ has two layer structure. Its basement is composed by highly dislocated Precambrian and Early Proterozoic metamorphic schists and gneisses, among which para- and orthorocks interrupted by Variscan late orogenic granitoids are defined. The zone is similar to the SFZ of the Main Ridge as far as the degree of granitoid magmatism manifestation is concerned. The rocks of basement are outcropped only in the valleys of large rivers.

The structure of sedimentary cover if compared to the one of the basement is comparatively simple, it is composed by non-dislocated Lower Jurassic sand--clay, spatially by coal-bearing and terrigenous-volcanogenic molassa formation of Middle—Upper Carboniferous and Permian age. Beginning with the Middle Carboniferous the Bechasynskaya SFZ is undergoing the subplatform stage of evolution.

Within the above SFZ quartz from the following rock formations has been analyzed (see Tab. 1).

Table 1

Concise geologo-petrologic characteristics of magmatic formations of the Great Caucasus

Tectono-magmatic cycle	Formation, its age and place in the evolution of the Caucasian fold area	Position of a formation in structural-formational zones of the Great Caucasus	Petrographic composition of rocks included into the formation	Metallogenic specifics of the formation
1	2	3	4	5
Baikalian (?)	I. Metaplagiogranite, early geosyncline of Proterozoic(?) age interrupted by orthoclase gneissic granites.	Outcrops in Bechasynskaya SFZ, in PZ_3 transformed into subplatform stage of evolution (basin of the Bolshaya Laba river).	Metaplagiogranites: plagioclase (An_{10-16}), quartz, muscovite, superimposed albite, accessory-sphene, apatite.	Quartz-scheelite vein mineralization is associated with the rocks of this formation.
	II. Orthoclase gneissic granite, post-folding of Proterozoic (?) age. Granites have active contact with host rocks.	Ditto (Moschevaya river-the Bolshaya Laba's tributary).	Orthoclase gneissic granites with intensively sericitic plagioclase (An_{20-26}), orthoclase, cataclastic quartz, chloritic biotite, apatite, magnetite, pyrite, seldom-sphene.	Cu-Zn and Ba vein mineralization is associated with the rocks of this formation.
	III. Crystallinicum. Ortho-and pararocks, metamorphozed under the conditions of amphibolite facies of middle depth metamorphism.	Related to SFZ of the Main Ridge and makes up its crystalline basement.	Mica schists, biotite and amphibole-biotite ortho- and para-gneisses migmatized to different degrees amphibolites, plagiomigmatites.	Sometimes with amphibolite beds and quartz veins ore manifestations of scheelite are associated. Quartz-mica schist and gneisses are spatially associated with disperced arsenopyrite and pyrite.
Caledonian	IV. Granite-migmatite, late kinematic of Variscan (?) or Pre-Variscan age.	Related to the SFZ of the Main Ridge.	Binary feldspar granite-migmatites, leucocratic granites, composing lens-like concordant bodies with gneiss-like texture.	Insignificant scheelite manifestations are known.
Hercynian Middle Hercynian	V. Gabbro-diorite plagiogranite, late geosyncline, age, according to radiologic data (K-Ar method) 365—330 mln. years.	Spread mainly in the SFZ of the Main Ridge and in a minor degree-within SFZ of the Peredovoy Ridge.	Rocks of the formation compose multi-phase intrusive massifs. The following phases of intrusion are distingguished: gabbro and gabbro diorites, diorites, granodiorites and plagiogranites. Pyroxen-amphibolite paragenesis of dark coloured minerals and presence of gneiss-like textures are typical.	Insignificant manifestations of vein molybdenite and chalcopyrite are associated with the rocks of this formation.

1st continuation of Tab. 1

1	2	3	4	5
Hercynian, Late Hercynian	VI. Rhyolite, early orogenic, Middle Carboniferous.	Outcropped in the SFZ of the Peredovoy Ridge.	Rhyolites and their tuffs composing horizons in between Middle Carboniferous molassa deposits.	Polymetallic Pb-Zn and Sb-Hg ore manifestations of mineralogic interest are associated with the rocks of the formation.
	VII. Granodiorite-granite early orogenic, aged 308—270 mln. years according to radiological data (K—Ar method).	Developed in the SFZ of the Main Ridge.	Rocks of the formation compose multiphase intrusive massifs, the following successive phases of intrusion are distinguished: granodiorites, biotite and two-mica-granites and their vein derivatives — muscovite and leucocratic granites, alaskites, aplites and pegmatites. Massive textures and mica paragenesis of dark coloured minerals are typical.	Quartz vein type ore manifestations of Pb, Zn, W, Au-As are associated with biotite and two-mica granites, Be, W, Sn nd Ta-Nb mineralization as associated with alaskites and pegmatites.
Late Hercynian	VIII. Granodiorite-granite late orogenic, aged 270—240 mln. years according to radiologic data (K-Ar method).	Manifested in Bechasynskaya SFZ.	Rock of the formation compose multiphase intrusive massifs. The following successive phases of intrusion are distinguished: quartz diorites, granitoids, granites, aplites, pegmatites. Accessory — zircon, apatite, sphene, magnetite, molybdenite scheelite, topaz, tourmaline.	a) Economic vein Ba deposit; b) manifestations of Mo, Cu, Pb, W of contact-metasomatic and hydrothermal—metasomatic genesis.
Early Alpine	IX. Gabbro-granite, syn-inversional, aged 168—148 mln. years according to radiologic data (K-Ar method).	Outcropped in the eastern part of the Main Ridge SFZ (Osetia).	Rocks of the formation compose multiphase intrusive massifs, the following successive intrusion phases are distinguished: quartz diorites, granitoids, granites, aplites and pegmatites. Characterised by amphibol-biotite paragenesis of dark coloured minerals and massive textures.	The following ore manifestations are associated with the rocks of this formation: a) magnetite and cupreous skarn, b) quartz-molybdenite-chalcopyrite veins.

2nd continuation of Tab. 1

Tectonomagmatic cycle	Formation, its age and place in the evolution of the Caucasian fold area	Position of a formation in structural-formational zones of the Great Caucasus	Petrographic composition of rocks included into the formation	Metallogenic specifics of the formation
1	2	3	4	5
Early Alpine	X. Subalkaline and alkaline granites, early orogenic, aged according to radiologic data (K-Ar method) as Late Cretaceous(?) 85—61 mln years.	Related to the southern SFZ of the Main Range Zone in its juncture with the SFZ of the south Slope.	The rocks the formation compose fracture like bodies, more seldom multiphase intrusive massifs, the following successive phases of intrusion are distinguished: grey hornblende granites, red pegmatoid granites, alkaline aegirine-riebeckite granites, aplites and pegmatites.	Quartz-polymetallic and molybdene ore manifestations of vein type are associated with the rock of 1st and 2nd phases of intrusion. Ore manifestations of rare earth Sn and Be of mineralogic interest are associated with the rocks of the 3rd phase of intrusion.
Late	XI. Granitoid volcano-plutonic, late orogenic aged 4.4—0.85 mln. years according to radiologic data (K-Ar method).	Related to the north and south peripheries of the Main Ridge SFZ.	The rocks of the formation compose fracture-like bodies and multiphase intrusive massifs. The following successive phases of intrusion are distinguished: granodiorites, granites, aplites and pegmatites.	Molybdenite-scheelite bearing skarns, quartz molybdene and quartz-arsenopyrite vein ore mineralization with Sn, Ag and Be of no economic value are associated with the rocks of this formation.

Within the Peredovoy SFZ all the evolutionary stages of the Variscan geosyncline are well manifested from the initial stage (Ordovician—Sillurian) up to orogeny (Middle Carboniferous—Permian). Each of the stages is characterized by certain magmatic formations. The SFZ is characterized by ultrabasic intrusions, early geosyncline basalt plagiorhyolite Devonian association, Late Palaeozoic thin andesitic covers, dacites, lyparites and their tuffs of orogenic stage. The zone has chalcopyrite mineralization of the Devonian age and Lower Carboniferous magnetite metallization. Cupreous sandstones and tiny gold placers formed in the Upper Palaeozoic (Chernitsin et al., 1971).

Within the above SFZ quartz from the following formations has been analysed (see Tab. 1).

SFZ of the Main Ridge acquired anticlynorial structure in Hercinian time while the SFZ of the Peredovoy Ridge adjacing to it in the north turned to be a graben synclinorium. In its residual basins volcanogenic-terrigenous molassas were accumulated in Permian—Carboniferous ($P—C_{2-3}$) time. It is supposed that in Carboniferous—Permian and Permian the Main Ridge anticlyne underwent intensive upward movements accompanied by postkinematic—early orogenic granodiorite-granite intrusions what is confirmed by radiological data (Gurbanov et al., 1984). Forming of SFZ was participated by intensively dislocated metamorphic formations of Precambrian (?) age, belonging to amphibolite and epidote-amphibolite middle-depth metamorphic facies as well as to anatectic autochthonous granite-migmatites and interrupted by granitoids of early orogenic stage. These rocks are covered by the Late Carboniferous, Permian and Lower Jurassic transgressive non-dislocated deposits.

The SFZ is characterised by a certain tendency to heridity, expressed by the fact that during all the evolutionary epochs it presented the area of maximal generation of granitic magmas while significant bodies of basic magmatic rocks are absent. According to the data of V. B. Chernitsin (Chernitsin al., 1971) typomorphic metals for SFZ for Hercynian tectonomagmatic cycle are the following: As, Mo, W, Ta, Nb; for early Alpian cycle — As, Mo, W etc.; for the late Alpian — Mo, W, Bi, Sn etc. what also proves the existance of metallogenic heridity for this zone.

The choice of quartz to solve the above tasks is based upon the fact, that quartz, if compared to other rock-forming minerals in completely crystalline magmatic rocks appears as a rule, at the late phase of melt crystallization, evolution of which results in outflow of fluids, ore bearing ones among them. That is why we supposed, that the analyzed quartz might carry information about geochemical particularities of granitoids as well as about the contents of a member of ore and rare elements in the residual melt, which takes part in the formation of hydrothermal and hydrothermal-metasomatic mineralization.

Simultaneously with the quartz from "ore-free" granites, the quartz from different-age granitoids and pegmatites with which spatially or genetically W, Mo, Pb-Zn and rare metal mineralization is associated was analyzed to check the supposition. To obtain the correct data we used the quartz only from the rocks, that as the petrographic data proved had not undergone the influence of different superimposed processes.

Moreover in order to promote additional conrol, by means of EPR (electron-paramagnetic resonance) method with the help of Bruker EK 200D SRC spectrometer under T = 18—22 °C and liquid nitrogene we studied a stable paramagnetic center AL-O^- (replacement of Al by Si in silica-oxygene tetrahedrum with localization of non-coupled electron at a neighbouring atom of oxygen) we also investigated quartz from the rocks of the magmatic formations under the study and from a number of hydrothermal deposits. As a result we found out that the average contents of Al-O^- centers in quartz from granite is equal to 20 arbitrary units, what makes it sharply different from hydrothermal quartz as the quartz from ore bearing veins contains 10 arbitrary units of this center, and quartz from ore-free veins — 7 a.u. Therefore, hydrothermal quartz was not present in the studied samples.

It is worth stating, that within the recent 30 years quartz from quartz-vein formations, from pegmatites and more seldom, from granites has being studied in order to prove the genetic relation of endogenous mineralization and magmatism, to decode the temperature conditions of melt crystallization as well as those of regional metamorphism, to find out vertical temperature zoning on the example of a number of hydrothermal deposits.

The works of the initial period (late 50ties) gave the data on contents of petrogenic elements Na, K, Al, Mg, Fe and volatiles — Cl, F, SO_4, CO_2 in quartz (Ermakov, 1957) a less amount of works was devoted to the study of contents of ore and rare elements in quartz from diorites, granodiorites and granites. Geochemical literature presents data on quantitative definition of Li, B, U, Be, Sn, Mo, Ta, Nb, and Pb in quartz from pegmatites and more seldom from granites (Tausson et al., 1956; Zemskaya et al., 1984; Denned, 1967; Kuroda—Sandell, 1954). Works of Stavrov (Stavrov, 1961; Stavrov et al., 1975) devoted to the contents of some ore and rare elements in quartz from pegmatites and granitoids allowed him to put forward the method of "quartzmetry" aimed at establishing the potential ore-bearing properties of intrusions and hydrothermal veins.

Valuable data on the contents of a number of elements in quartz from different-age granodiorites are given in the works of Lyakhovitch (Lyakhovitch, 1972, 1983). The calculated average contents of elements-admixtures in quartz from granitoids of the U.S.S.R. and the changes in the contents of a number of elements in quartz from granitoids making up polyphase massifs are shown. There is a clear tendency to maximal accumulation of elements-admixtures in the late differentiates, what on his opinion, is one of the features characterizing ore-bearing potential of granitoids.

Moreover, the recent studies show the possibility to use data on isomorphic admixtures (Al, Ti, etc.) in quartz to decode the crystallization conditions of granitoid melt (Manuilova et al., 1983; Denner, 1967). A lot of works (Manuilova et al., 1983 etc.) is devoted to typomorphism of spectroscopic properties of quartz according to EPR data. The work of Zemskaya (Zemskaya—Lyapunov, 1984) is devoted to typochemical particularities of quartz from granitic pegmatites.

Method of sampling and preparation of samples

In order to get sufficient material on rock-forming and accessory minerals, the samples were chipped from the 100 m^2 net. Depending on the size of the

Table 2
Average contents (ppm) of rare and ore elements in quartz from the rocks of different formations of the Great Caucasus

Formation, number of samples	Nb	Ta	Th	Hf	W	Sn	Mo	Zn
1	2	3	4	5	6	7	8	9
I. Metaplagiogranite PR^3 (?) (2)	14.0 14.0—14.0	0.04 0.03—0.05	0.25 0.23—0.28	1.2 1.0—1.4	25.0 20.0—30.0	3.0 3.0—3.0	1.0 1.0—1.0	*
II. Orthoclase gneissic granites PR^3 (?) (2)	10.0 10.0—10.0	0.05 0.028—0.09	0.4 0.2—0.83	1.3 0.86—1.5	29.3 8.0—40.0	2.7 2.0—3.0	0.9 0.8—1.0	1.1 1.0—1.1
III. Crystallinicum (mica schists, gneisses) PR^3 — (4)	10.0 10.0—10.0	0.02 0.01—0.05	0.3 0.1—0.48	0.8 0.34—1.4	30.0 30.0—30.0	2.0 2.0—2.0	1.0 1.0—1.0	1.6 1.1—2.4
IV. Granite-migmatite — 0 (?) (11)	10.0 10.0—10.0	0.08 0.01—0.49	0.9 0.2—2.6	0.8 0.33—2.1	31.4 15.0—40.0	2.1 2.0—3.0	0.8 0.7—1.0	1.2 0.8—4.0
V. Gabbro-diorite-plagiogranite late geosyncline D_3-C_1 (9)	10.0 10.0—10.0	0.03 0.01—0.06	1.1 0.03—6.6	1.4 0.1—5.0	27.6 8.0—40.0	2.4 2.0—3.0	0.8 0.8—1.0	3.7 2.6—4.8
VI. Early orogenic rhyolite — C_2 (1)	*	0.04	0.8	0.6	30.0	2.0	0.8	*
VII. Early orogenic granodiorite-granite (32)	9.1 3.5—21.0	0.04 0.01—0.1	1.8 0.035—5.9	1.9 0.1—14.0	25.8 8.0—40.0	2.9 2.0—5.0	1.0 0.7—2.0	1.5 0.7—4.8
VIII. Late-orogenic granodiorite-granite (3)	8.5 7.0—10.0	0.02 0.02—0.03	0.5 0.46—0.6	0.40 0.31—0.5	31.7 10.0—50.0	2.3 2.0—3.0	1.6 0.8—2.0	4.7 2.2—7.2
IX. Gabbro-granite late-geosyncline granodiorite (1)	5.0	0.05	1.4	0.49	10.0	2.0	0.7	*
X. Orogenic subalkaline and alkaline granites (5)	5.0 5.0—5.0	0.74 0.06—2.5	3.9 1.3—8.6	12.9 2.3—48.0	15.7 8.0—30.0	3.9 2.0—8.0	0.8 0.8—0.8	*
XI. Orogenic granitoid volcano-plutonic (8)	6.2 4.0—7.0	0.12 0.01—0.26	3.0 0.6—6.6	1.4 0.14—2.0	21.3 10.0—30.0	1.6 0.7—9.0 (69)	0.8 0.7—3.0 (69)	25.1 25.0—30.0 (61)
Average contents in quartz from granites of the U.S.S.R.	5.5 (325)	0.2 (322)	1.2 (251)	0.7 (252)	2.1 (428)	6.6 (582)	1.8 (671)	17.6 (412)

1st continuation of Tab. 2

Cu	Ni	Co	Sc	Be	Li	Rb	Cs	Fe	Na	K/Rb
*	*	0.12 / 0.086—0.16	0.18 / 0.17—0.19	0.5 / 0—1.0	*	8 / 2.0—14.0	0.16 / 0.086—0.23	1040 / 380—1110	1110 / 1080—1140	413
1.7 / 1.1—2.3	3.0 / 3.0—3.0	0.18 / 0.077—0.32	0.18 / 0.089—0.32	2.0 / 2.0—2.0	0.4 / 0.23—0.6	4.0 / 1.0—10.0	0.13 / 0.04—0.31	209 / 130—288	547 / 510—600	543
0.8 / 0.4—1.0	3.0 / 3.0—3.0	0.09 / 0.028—0.16	0.3 / 0.036—0.51	*	1.1 / 0.9—1.5	2.9 / 1.2—4.5	0.05 / 0.03—0.062	114 / 41—150	540 / 240—1140	250
0.5 / 0.2—1.2	3.3 / 3.0—5.3	0.06 / 0.01—0.19	0.2 / 0.053—1.0	10.7 / 1.0—37.0	0.8 / 0.08—1.8	16.5 / 1.0—94.0	0.19 / 0.02—1.2	35 / 28—73	196 / 130—280	273
1.4 / 1.2—1.5	3.0 / 3.0—3.0	0.3 / 0.06—1.1	0.4 / 0.097—2.0	1.9 / 0.8—4.0	1.4 / 1.4—1.4	41.6 / 1.0—139.0	0.58 / 0.01—2.1	437 / 390—710	290 / 250—330	770
*	*	0.03	0.3	0.8	*	3.8	0.33	*	*	*
0.7 / 0.2—2.3	3.0 / 3.0—3.0	0.12 / 0.01—1.2	0.20 / 0.03—0.6	1.1 / 0.2—2.0	2.6 / 0.6—8.6	17.1 / 1.5—130.0	0.25 / 0.02—1.7	120 / 85—270	297 / 170—390	498
2.2 / 1.2—3.2	3.0 / 3.0—3.0	0.16 / 0.094—0.27	0.1 / 0.051—0.26	0.8 / 0.6—2.0	0.6 / 0.1—0.9	3.2 / 0.8—5.3	0.12 / 0.12—0.12	69 / 47—85	590 / 460—710	325
*	*	0.24	0.28	1.0	2.6	4.8	0.13	160	1440	1099
*	*	0.16 / 0.05—0.48	0.20 / 0.032—0.5	2.4 / 0.8—5.0	6.0 / 1.4—11.0	35.4 / 3.5—90.0	0.48 / 0.25—1.2	2380 / 540—4100	500 / 450—560	2166
*	3.7 / 1.5—22.0 (61)	0.21 / 0.08—0.4	0.13 / 0.03—0.23	2.0 / 0.2—4.6	21.7 / 14.8—31.0	20.1 / 10.0—32.1	1.0 / 0.6—1.4	*	*	*
6.2 (425)	3.9 (118)	0.17 (330)	0.22 (342)	1.0 (476)	11.3 (293)	3.9 (280)	0.4 (326)	*	*	*

Notes: A) Tab. 2 show a contents in the form of a fraction $\frac{3.9}{2.0-8.0}$ where the numerator — the average values and denominator — minimal and maximal values; B) Tabs. 2, 3, 5 — number of analysis on the bases of which the average contents are calculated are shown in brackets; C) The cases where the values have not been established are shown*.

rock grains and the degree of homogeneity, the net was either shrinked or stretched. Altogether, from the rocks of 11 formations under study 146 mineralogic samples weighing 20—30 kg each have been taken, but, unfortunately, at the present stage of work not all the formations have been illustrated by a number of samples sufficient for statistic processing.

The samples were crushed and by means of flotation 99—100 % pure monomineral quartz was singled out. To minimize quartz agregation with other minerals for further investigations it has been singled out from fraction 0.25 mm, than it was crushed to 0.075 mm and reflotated. Attrition of quartz has been done in agath mills.

Analytical methods of study

To define the contents of elements in quartz its monomineral fractions were analysed qualitatively a number of methods with the following sensibility (ppm): neutron-activation — Th = 0.008; Hf, Cs = 0.06; Co = 0.05; Ta,Sc = 0.01; atomic-absorbtion (Varian — 875, Perkin Elmer — 403) — Ni = 4.0; Mn = 1.0; Zn, Cu = 0.1; Li = 0.3; Ba, Sr, Fe = 10.0; quantitative-spectral — Sn, Cu, W = 3.0; Nb = 2.0; Mo, Be = 1.0; flame photometry — Li = 0.5; Rb = 5.0; K, Na = 50.0.

Tab. 2 gives average contents of elements in quartz from the studied formations calculated on the basis of 1250 cases. Average contents of rare and ore elements in quartz from the rocks corresponding successive phases of intrusion for four formations are given in Tab. 3.

During the following discussions of the results of the studies we took into account the fact that the main factors defining the contents of microelements in quartz are: concentration of elements in the mineral forming media; acidity-alkalinity of the media; rate of the melt crystallization and its temperature (Lazarenko et al., 1974). While analyzing the contents of ore and rare elements we were aware of the fact that elements present in quartz may occur in various forms:

— isomorphic form, replacing atinyion Si^{4+} (0.39 A°), experimental studies (Zemskaya et al., 1984) proved isomorphic entry into quartz for Al, Ti, Ge, Ga, Li, W, P, only;

— in the form of absorbed atoms, concentrating on the facets and defects of a mineral;

— in form of non-structured (colloidal) admixtures;

— as a part of gas-liquid inclusions, usually present in quartz in different quantities.

The most frequent are two forms of the entry of rare and ore elements: isomorphic (dispersed) and mineral (concentrated).

Isomorphic entry of a number of elements into quartz grid may occur according to the scheme: $Si^{4+} - Al^{3+} + R^{+}$ where R^{+} are ions of alkali metals. It is stated that univalent metals' inons are located in hollow channals of the framework along (0001) and their presence is reflected by a_0 parameter of quartz.

The mineral form of rare and ore elements is provided for by the presence of their own minerals in quartz. To detect the presence of micro- and gas-inclusions they have been studied in the scanning electron microscope Geol ISM—T—20 and with the help of X-ray analyser Geol IXA—50A. As a result mi-

Table 3

Average contents (ppm) of rare and ore elements in quartz from the rocks of different phases of intrusions of multiphase intrusives of the Great Caucasus

Formation	Rocks of phases of intrusion	Nb	Ta	Th	Hf	W	Mo	Sn	Zn	Sc	Co	Ni	Cu	Be	Li	Rb	Cs
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
V	1. Quartz gabbro	*	0.025 (2)	0.82 (2)	2.28 (2)	8.0 (1)	0.8 (1)	2.0 (1)	*	0.32 (2)	0.82 (2)	*	*	2.0 (1)	*	57.0 (2)	0.96 (2)
	2. Quartz diorite	*	0.01 (1)	0.18 (1)	0.47 (1)	30.0 (1)	1.0 (1)	2.0 (2)	4.8 (1)	0.1 (1)	0.21 (1)	3.0 (1)	1.2 (1)	*	1.6 (1)	1.4 (1)	0.09 (1)
	3. Granodiorite	10.0 (1)	0.03 (4)	1.87 (4)	0.81 (4)	40.0 (1)	0.8 (1)	3.0 (1)	2.6 (1)	0.6 (4)	0.13 (4)	3.0 (1)	1.5 (1)	0.8 (1)	1.2 (1)	36.5 (4)	0.58 (4)
	4. Plagiogranite	10.0 (1)	0.03 (2)	0.20 (2)	1.42 (2)	30.0 (2)	0.8 (2)	2.5 (2)	*	0.34 (2)	0.20 (2)	*	*	2.4 (2)	*	56.3 (2)	0.43 (2)
VII	1. Granodiorite	8.4 (4)	0.03 (4)	0.37 (4)	0.36 (4)	32.5 (4)	0.78 (4)	2.0 (4)	0.7 (2)	0.11 (4)	0.35 (4)	3.0 (2)	0.2 (1)	1.0 (1)	1.0 (2)	2.5 (4)	0.04 (4)
	2. Biotite granites	9.0 (9)	0.04 (14)	1.1 (14)	0.72 (14)	24.4 (13)	1.1 (13)	3.0 (13)	1.9 (7)	0.19 (14)	0.10 (14)	3.0 (5)	0.8 (7)	1.2 (8)	1.5 (8)	21.9 (14)	0.34 (14)
	3. Two-mica granites	9.4 (12)	0.04 (12)	3.3 (12)	4.02 (12)	25.0 (11)	1.01 (11)	2.8 (11)	1.4 (5)	0.29 (12)	0.08 (11)	3.0 (4)	0.6 (4)	0.8 (4)	5.1 (6)	14.4 (12)	0.23 (12)
	5. alaskite granites	*	0.04 (2)	1.1 (2)	0.78 (2)	*	*	*	0.7 (1)	0.52 (2)	0.04 (2)	3.0 (1)	0.2 (1)	*	0.2 (1)	28.5 (2)	0.19 (2)
VIII	1. Granodiorites	8.5 (2)	0.04 (2)	0.50 (2)	0.49 (2)	27.5 (2)	1.4 (2)	2.5 (2)	7.2 (1)	0.10 (2)	0.20 (2)	3.0 (1)	3.2 (1)	0.8 (1)	0.9 (2)	2.2 (2)	0.10 (2)
	2. Granites	*	0.02 (1)	0.46 (1)	0.31 (1)	40.0 (1)	2.0 (1)	2.0 (1)	2.2 (1)	0.05 (1)	0.09 (1)	*	1.2 (1)	*	0.1 (1)	5.3 (1)	0.16 (1)
X	1. Hornblende granites	5.0 (1)	0.05 (1)	1.3 (1)	3.0 (1)	8.0 (1)	0.7 (1)	2.0 (1)	*	0.16 (1)	0.04 (1)	*	*	0.8 (1)	11.0 (1)	4.0 (1)	0.25 (1)
	2. Pegmatoid granites	*	0.44 (2)	4.2 (2)	4.2 (2)	30.0 (1)	0.8 (2)	2.9 (2)	*	0.36 (2)	0.28 (2)	*	*	2.0 (2)	1.4 (1)	21.0 (2)	0.31 (2)
	3. alkaline granites	5.0 (1)	1.4 (2)	4.9 (2)	26.6 (1)	9.0 (1)	0.8 (1)	8.0 (1)	*	0.05 (2)	0.11 (2)	*	*	5.0 (1)	5.5 (1)	65.5 (2)	0.76 (2)

Note: Formations V — gabbro-diorite-plagiogranite, D^3—C_1; VII — granodiorite-granite early orogenic, C_2 — P; VIII — granodiorite-granite orogenic, P; X — sub-alkaline granites K_2; * — values have not been defined.

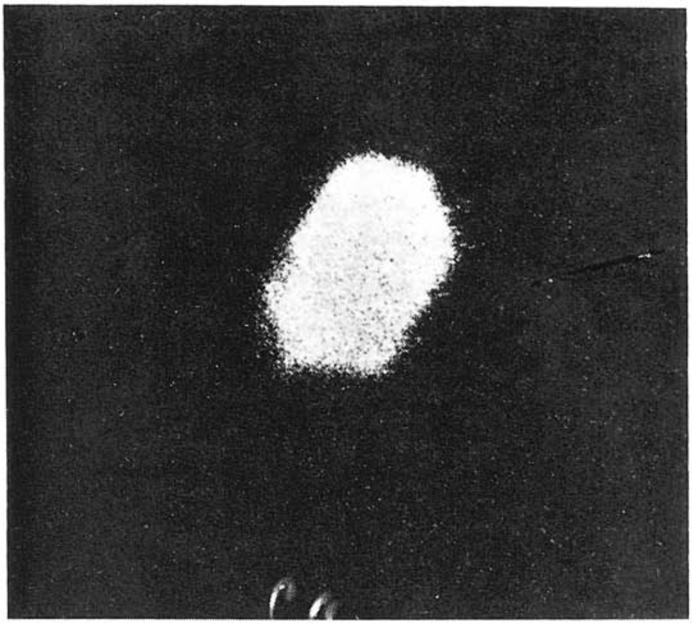

Fig. 1a. Microinclusions of apatite in quartz, enlarged 350×.

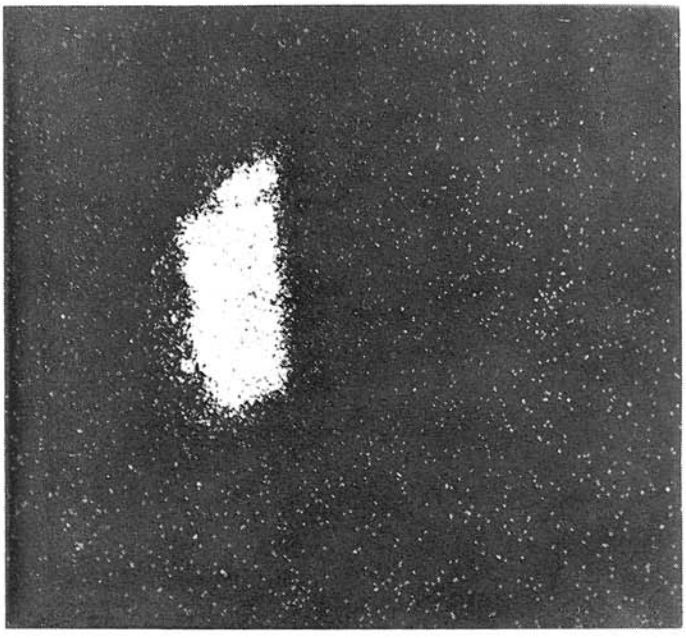

Fig. 1b. Microinclusions of feldspar in quartz, enlarged 350×.

croinclusions of apatite, zircon, magnetite and feldspar (Fig. 1b) have been found. In apatite inclusions contents of Ce and Nd achieve 0.01 %.

Despite of such a variety of forms of entry of rare and ore elements into quartz, we suppose, that their contents should reflect the geochemical particularities of the final stages of melt crystallization, simultaneous to quartz crystallization.

To compare average contents of rare and ore elements in quartz and the rocks from which they extracted, we have analyzed 1472 rock samples. Elements contents in the rocks were defined by E. A. Korina in the laboratory of sprectral analysis of IGEM of the U.S.S.R. Ac. Sci. with the help of complete semiquantitative spectral analysis in powder samples by means of evaporation from the channel of the electrod of DC coal arc with a cathodic-anodic exciter.

Elements' contents were defined with the following sensibility (ppm): Nb, Sc = 10; Sn = 7—8; Zn = 20—30; Cu = 4—6; Ni, Co = 7—9; Be = 0.8—0.9. Average contents of a number of elements in a number of rocks under the study is given in Tab. 5.

Ore and rare elements in quartz from the rocks of the studied formations

Tab. 2 gives contents of 19 elements in quartz from each of the rock formations of the Great Caucasus. The same table shows average contents of the same elements in quartz from the granitoids of the U.S.S.R. (Lyakhovitch, 1986).

Comparison of average contents of rare and ore elements in quartz from intrusive granites of the U.S.S.R. and from magmatic formation rocks of the Great Caucasus shows that the latter are characterized by lower contents of majority of elements. Higher contents of some elements are exclusive, such as Nb — 1.1—2.5 times; Be — 1.1—10.7 times; Rb — 1.1—9.1 times and especially W — 4.8—15.1 times and Hf — 1.1—18.4 times.

One can notice certain tendencies in the change of the contents of a number of elements in the quartz from the rocks of magmatic formations, which manifest the alterations of geodynamic regime in the evolution of polycyclic Caucasian moving area from the Baikalian (?) up to the Late Post-Alpine tectono-magmatic cycle.

Comparison of contents of the elements under consideration in the quartz from the rocks of the late geosyncline formations V and IX which reflect cyclicity in the evolution of the Caucasian moving area reveals a certain tendency. It is, that for the quartz from the more ancient (Middle Palaeozoic) gabbro-diorite-plagiogranite formation V the most characteristic are the higher contents of Nb, Be, — 2 times; Hf, W — 2.7 times; Sc, Co — 1.4; Rb — 8.6; Cs — 4.4 times and lower contents of Ta, Th, and Li, if compared to their contents in the quartz from the rocks of the Middle—Late Jurassic gabbro-granite formation IX.

In the course of evolution there was an increase of the average value of K/Rb ratio in the quartz from the rocks of these formations. So, in the quartz from formation V it is equal to 770, while in the quartz from the rocks of formation IX — to 1099.

Comparison of values of the contents of rare and ore elements in quartz from the rocks of formations II, VI, VII, VIII, X, XI which manifest the beginning of orogeny in the evolution of the Caucasian polycyclic moving area during the Baikalian (?), Hercynian, Alpine cycles revealed the following tendencies:
— in quartz from the rocks of orogenic formations contents of W, Sn, Mo are higher and contents of Co and Sc are lower if compared to such from the rocks of the late geosyncline formation. Moreover, the quartz of orogenic formations is characterized by lower (325—543) values of K/Rb ratio, than those from the rocks of the late geosyncline formations (770—1099).
— in quartz from the rocks formed during the Baikalian (?) tectono-magmatic cycle maximal contents (ppm) of Nb = 10.0 and higher contents of Co = 0.18; Be = 2.0 were stated.
— comparative analysis of contents of a number of elements in quartz from the rocks of early orogenic (VII) and late orogenic (VIII) granodiorite-granite formations, which appeared at the final stage of the Hercynian tectono-magmatic cycle made it evident that guartz from the latter is characterized by maximal contents (ppm) of W = 31.7; Mo = 1.6 and Cu = 2.2 while that of formation VII — by higher contents of Nb = 9.1 and Sn = 2.9.
— in quartz from the rocks of sub-alkaline and alkaline granites formation (X) which appeared in Alpine tectono-magmatic cycle we observed maximal (ppm) contents of Ta = 0.74; Th = 3.9; Hf = 12.9; Sn = 3.9; Be =2.4; Rb = = 35.4; Cs = 0.48.

To reveal tendencies in the change of contents of elements in the quartz from the rocks formed in the process of long-term melt differentiation, corresponding results of investigation of quartz from the rocks of successive phases of intrusions for four formations — V, VII, VIII and X are shown in Tab. 3.

Prior to the consideration of the results it is worthy emphasizing that conclusions made on the basis of Tab. 3 have preliminary character, as the number of analyzed quartz samples is not sufficient for statistic treatment. Anyhow, there are certain tendencies in the change of contents of some elements in the quartz from the rocks corresponding to successive (from the early to the late) phases of the intrusion for the above formations.

Quartz from the rocks presenting successive dfferentiates of formation V has the following particularities in the behaviour of a number of elements:
— contents of Ta, Mo and Sn remain practically constant, quartz from the rocks of the initial phase of intrusion (quartz gabbros) has higher, if compared to the quartz from the rocks of other phases, contents of Hf — 2.0—5.6 times; Co — 4 times; Cs — 1.6—2.2 times;
— for quartz of the late phases of intrusion (granodiorites) maximal contents (ppm) of Th = 1.87; W = 40; Sn = 3.0; Sc = 0.6 have been established;
— in quartz from the rocks presenting the final differentiation products (plagiogranites) there is only a tiny accumulation of Be.

For quartz from the rocks presenting successive differentiates of formation VII the following tendencies in the contents of a number of elements have been established:
— contents of Ta and Ni practically do not change;
— quartz from the rocks of the initial phase of intrusion (granodiorites) is rich, if compared to the quartz of all the successive phases, in W and Co, while quartz from the rocks of the late phase (alaskites, pegmatites) is rich only in Sc and Rb;

— in quartz from the rocks, corresponding to successive phases of intrusion (from the initial to the final) as a whole, there is a tendency to increase of the contens of Nb, Th, Hf, Sn, Mo, Sc, Li, Zn, Rb, and to decrease of the contents of W, Co;

— maximal contents (ppm) of Sn = 3.0; Zn = 1.9; Be = 1.2; Cs = 0.34 have been established in quartz from biotite granites (the second phase of intrusion) while Th = 3.3; Hf = 4.02 and Li = 5.1 in quartz from two-mica granites (the third phase of intrusion).

In contents of a number of elements from the rocks corresponding to successive differentiates of formation VIII there are the following tendencies:

— in quartz from granodiorites (the initial phase of intrusion) there are maximal contents of (ppm): Ta = 0.04; Zn = 7.2; Co = 0.2; Cu = 3.2; Li =0.9 while in quartz from biotite granites (the second phase of intrusion) W = 40.0; Mo = 2.0 and Rb = 5.3;

— in course of granodiorite melt differentiation, the quartz from the rocks of final members has the higher contents of W, Mo, Rb, Cs and lower contents of Ta, Hf, Sn, Zn, Sc, Co, Cu, Li.

Considering the contents of ore and rare elements in quartz from the rocks corresponding to the successive phases of orogenic formation (X) — sub-alkaline and alkaline granites revealed the following tendencies:

— in quartz from the rocks of successive phases of intrusion (from early up to the late ones) there is the growth of contents of Ta, Th, Hf, Sn, Be, Rb, Cs;

— in quartz from hornblende granites (the first phase of intrusion) the maximal contents of Li = 11.0 (ppm) has been established;

— in quartz from alkaline granites (the final phase of intrusion) the maximal contents (ppm) of Ta = 1.4; Th = 4.9; Hf = 26.6; Sn = 8.0; Be = 5.0; Rb = 65.6; Cs = 0.76 and minimal contents of Nb = 5.0 have been established if compared with those in quartz from the rocks of the above formations V, VII, VIII.

To find out the possibility to use the contents and values of accumulation coefficient (K_{H}) of ore and rare elements in quartz from the rocks of the investigated formations for evaluation of the probably ore-bearing properties of concrete formations, we took samples from the rocks with which the ore mineralization is connected spatially or genetically (C h e r n i t z i n et al., 1979).

For example, with biotite granites (second phase of intrusion) formation (VII), Pb-Zn, Be and Sn mineralization is associated; in the quartz of these granites maximal for all the intrusive phases contents (ppm) of Zn = 1.9; Be = 1.2; Sn = 3.0 have been established. Ta-Nb, Pb-Zn, W-Mo and Li mineralization is associated with two-mica granites (the third phase of intrusion). Higher contents of Nb = 9.4; Th =3.3; W = 25.0; Zn = 1.4 and Li = 5.1; Hf = 4.02 (ppm) have been established in the quartz from these rocks if compared to the rocks of other phases of intrusion.

With granodiorites (first phase of intrusions) of formation VIII Pb—Zn and Cu mineralization are associated. Quartz from these rocks contains maximal amounts of Zn = 7.2 and Cu = 3.2 (ppm). Granites (second phase of intrusion) are associated with Mo, W and Ba mineralizations, quartz from these rocks contains maximal for this formation amounts of Mo = 2.0 and W = 40.0.

Quartz from the rocks of early orogenic sub-alkaline-alkaline granitic formation (X) proved to be the most informative. For instance, W, Mo, Co mineralizations are associated with pegmatoid granites (second phase of intrusion): quartz of these rocks contains maximal for this formation amounts (ppm) of $W = 30.0$; $Co = 0.28$; and $Mo = 0.8$. Rare metal and rare earth mineralizations are associated with alkaline aegirine-riebeckite granites (third phase of intrusion), quartz from these rocks contains maximal values of $Ta = 1.4$; $Th = 4.9$; $Hf = 26.6$; $Sn = 8.0$; $Be = 5.0$; $Rb = 65.5$; $Cs = 0.76$ (ppm).

The above data on three formations (VII, VIII and X) shows the direct dependance between certain-metal ore-bearing properties of polyphase intrusives and the content values of the said elements in the quartz from the rocks of these formations.

Moreover one more important particularity is worth mentioning: in granitoids corresponding to the concrete phases of intrusion of the three investigated formations, in quartz for which there are high contents of Pb, Zn, Ta, Nb, Cu, W, Mo, Sn accessory minerals of the mentioned elements have been found (Gurbanov — Cambel et al., 1984).

This fact, on the opinion of Lyakhovitch (Lyakhovitch, 1983) also witnesses for ore-bearing potential of granitoids, corresponding to concrete intrusive phases of the above formations. It should be born in mind that majority of samples from the rock formations V, VII, VIII, X has been taken also from the massifs, having poly-phase structure due to a high differentiation rate of melts. A number of scientists consider (Lyakhovitch, 1983; Tausson et al., 1956; Kuroda, 1954) this to be one of the good signs for formation of potentially ore-bearing intrusions, as often we observe accumulations (up to considerable contents) of rare and ore elements in late differentiates.

To reflect this peculiarity in the behaviour of a number of elements we use an accumulation coefficient K_H. The value K_H reflects such an important detail (Lyakhovitch, 1983) as prevailing dispersion of elements in crystal grids of minerals from the rocks of early crystallization stages ($K_H < 1$), or their detachment and accumulation in the minerals of the rocks of the late stages of granitoid intrusives evolution ($K_H > 1$).

Values K_H of ore elements in quartz of granitoid polyphase intrusives are shown in Tab. 4 for four formations. As one can see if compared with the quartz from the rock of the 1st phase of intrusion, there is the most considerable contents growth of K_H W in the quartz from granitoids of 2nd and especially 3rd phases of intrusion for formations V, VIII and X; Mo — in the quartz from granitoids of 2nd phase of intrusion of formations V, VII and VIII; Sn — in quartz from granitoids of the 3rd phase of intrusion of formations V and VII and especially X; Zn and Cu — in quartz from granitoids of the 2nd and 3rd phases of intrusion of formation VII respectively.

Analysis of K_H allows to come to the following suppositions on the ore-generating ability for a number of rock elements, corresponding to the successive phases of intrusion of four formations (Tab. 4):

— gabbro-diorite-plagiogranite formation V:

quartz diorite may be potentially W and in a minor degree Mo bearing;
granodiorites may be potentially W and in minor degree Sn bearing:

— granodiorite-granite early orogenic formation VII:

biotite granites — potentially Zn, Cu, in a minor degree Mo and Sn ore-bearing; two-mica granites possess considerable ore-generating ability for Zn, Cu, in a minor degree — Mo, Sn and W;

— granodiorite-granite late-orogenic formation VIII:
granites — potentially W and Mo ore-bearing;

— formation of orogenic sub-alkaline and alkaline granites X:
pegmatoid granites — potentially W and in a minor degree Sn and Mo ore-bearing;

— alkaline granites — potentially Sn and in a minor degree W and Mo bearing.

Table 4
Accumulation coefficient K_H values for some ore elements in quartz from granitoids of different phases of intrusion of a number of magmatic formations

Formation, age	Intrusion phase	K_H				
		W	Mo	Sn	Zn	Cu
V. Gabbro-diorite-plagiogranite late geosyncline	2	3.8	1.3	1.0		
$D_3 - C_1$	3	5.0	1.0	1.5		
VIII. Granodiorite-granite late orogenic	2	0.8	1.4	1.5	3.0	4.0
$C_2 - P_1$	3	1.1	1.3	1.4	2.0	3.0
VIII. Granodiorite-granite late orogenic P	2	1.5	1.4	0.8	0.3	0.4
X. Orogenic, of subalkaline and alkaline granites	2	4.0	1.0	1.5		
K_2	3	1.1	1.0	4.0		

It should be mentioned that the above suppositions on ore-bearing potential go in good accordance with the geological data we have at our disposal (Chernitzin et al., 1971) on the relation between the corresponding ore mineralization with the rocks of the above specified magmatic formations (V, VII, VIII).

Great importance is given to the data on the changes of contents of ore and rare elements in quartz, which take place under anatectic melting of mica schists and gneisses (formation III) in the process of regional Variscan (?) or more ancient metamorphism under the conditions of amphibolite and epidot-amphibolite middle-depth facies and formation, at their expence, of the rocks of granite-migmatite formations (IV) (Gurbanov et al., 1984; von Platen, 1967).

We stated that under this process the contents of Nb, Hf and Sn in the quartz from the rocks of these formations do not change. Anyhow, in the quartz from the rocks of granite-migmatite formation we observed the growth of contents (Tab. 2) of Ta — in 4 times; Th — 3 times; Cs — 3.8 times; Rb — 5.6 times and an insignifficant increase of contents of Co — in 1.1 times and W — by 1.4 ppm what can be explained by the additional supply of the matter taking place under metamorphic conditions. Simultaneously, in quartz from the rocks of granite-migmatite formation takes place insignificant (if compared with that in mica schists and gneisses) decrease of contents of Sn, Zn, Sc, Ni,

Table 5

Average contents (ppm) of some rare and ore elements in the rocks of the crystalline core and the magmatic formations of the Great Caucasus under study

Formation	I Metaplagiogranite PR^3 (?) (22)	II Orthoclase gneissic granites PR^3 (?) (16)	III Crystallinicum (mica schists, gneisses) (73) PR^3 — ϵ_1 (?)	IV Granite-migmatite ϵ — 0 (?) (92)	V Gabbro-diorite plagiogranite $D_3 - C_1$ (105)	VI Rhyolite C_2 (15)	VII Granodiorite-granite C_2 — P (960)	VIII Granodiorite P (117)	IX Gabbro-granite J_{2-3} (41)	X Subalkaline and alkaline granites K_2 (390)	XI Granitoid volcano plutonic (109) N_2^3-Q
Elements											
Nb	1.0	3.0	12.0	12.0	17.0	*	12.0	12.0	12.0	29.0	11.0
Sn	1.0	1.0	3.0	4.0	4.0	*	7.0	5.0	4.0	9.0	7.0
Mo	1.0	*	2.0	1.0	2.0	2.0	1.0	3.0	1.0	2.0	2.0
Zn	15.0	25.0	87.0	52.0	51.0	85.0	53.0	49.0	44.0	81.0	70.0
Cu	32.0	28.0	29.0	14.0	32.0	10.0	15.0	29.0	26.0	26.0	55.0
Ni	11.0	8.0	21.0	10.0	23.0	10.0	12.0	15.0	49.0	10.0	27.0
Co	11.0	15.0	15.0	5.0	20.0	11.0	5.0	9.0	9.0	19.0	16.0
Sc	*	8.0	23.0	6.0	14.0	20.0	5.0	9.0	8.0	47.0	9.0
Be	5.0	4.0	3.0	3.0	4.0	3.0	5.0	3.0	3.0	8.0	5.0

Cu, Li what, probably happens due to carry out of material during regional metamorphism.

Taking into account the wide spread of granite-migmatite rocks of formation (IV) among the structures of the crystalline core of the Great Caucasus accumulations of Ta, Th and W present a certain interest as, under favourable conditions, an ore body might be formed.

Comparison of average contents of rare and ore elements in the rocks of different formations (Tab. 5) with their contents in quartz from the rocks of the same formations (Tab. 2) has been of a great interest. A curious tendency was revealed: quartz, no matter how simple its composition might seam, inherits geochemical particularities of a parent rock.

So, higher, if compared with granitoids of other formations, contents of Sn and Be in alkaline and sub-alkaline granites (formation X) are reflected by the higher contents of the said elements in quartz from the rocks of the same formation; high contents of Mo in the rocks of granodiorite-granite late orogenic formations (VIII) and Sc in formations III, V and VI is inherited by quartz from the rocks. For such elements as Cu, Zn, Ni, Li this dependance has not been established, as we did not distinguish them in the rocks of a number of formations.

Conclusions

Analysis of data on average contents of ore and rare elements in quartz from the rocks different age (from the Middle Riphean? up to Pliocene—Quarternary) magmatic formations and metamorphic series, developed in three structural-formational zones (Bechasynskaya, Peredovoy and the Main Ridge) of the Great Caucasus allowed to come to the following conclusions:

1. Quartz from the orogenic formations rocks (II, VI, VII, VIII, X, XI) are characterized, in general, by a higher (if compared with those from the rocks of the late orogenic formations V and IX) contents of W, Sn, Mo and relatively lower contents of Co and Sc.

Quartz from the rocks of orogenic formations are characterized by lower (325—543) values of K/Rb ratio if compared with analogous ratio in quartz from the rocks of the late geosyncline formations (770—1099).

2. Basing on the example of the late geosyncline gabbro-diorite-plagiogranite (V), early orogenic granodiorite-granite (VII), late-orogenic granodiorite-granite (VIII) formations and a formation of sub-alkaline and alkaline granites (X) it has been stated, that in the quartz from the rocks corresponding to the successive phases of intrusion of these formations, at final stages of magmatic activity, concentration of some rare and ore elements takes place. For example, quartz from the rocks of formation V is rich in Th, W, Sn, Be, Sc; quartz from formation VII — in Nb, Th, Hf, Mo, Sc, Li, Rb; from formation VIII — W, Mo, Rb, Cs; and from the rocks of formation X — in Ta Th, Hf, Sn, Be, Rb, Cs.

3. It is shown that contents and values of accumulation coefficients K_H of ore and rare elements in quartz from the rocks composing polyphase intrusives may be used for evaluation of potential ore-bearing properties of the rocks.

4. It is stated that quartz inherits geochemical properties of the parent rock.

5. It is shown that during the process of metamorphic transformation of the rocks (formation III — mica schists and gneisses) of the crystalline core of the

Great Caucasus into the granite-migmatite formation IV in quartz from the rocks of formation IV the contents of Ta increases 4 times; Th — 3 times; Rb — 5.6 times; Cs — 3.8 times and W — by 1.4 ppm. Simultaneously the contents of Mo decreases 1.2 times; Zn, Co, Li — 1.3 times; Cu — 1.6 times; Sc — 1.5 times.

6. While comparing the average W contents in quartz from the granitoids of the U.S.S.R. and that of metamorphic series and 10 different age magmatic formations, developed in three structural-formational zones (Bechasynskaya, Peredovoy and the Main Ridge) of the Great Caucasus we have established that W contents increases sharply (4.8—15.1 times). This fact, together with multiple data on association of W mineralization (Chernitzin et al., 1971) with different age (from the Middle-Riphean ? up to Pliocene—Quarternary) rocks of magmatic formations presents a certain interest for metallogenic modelling. Higher contents of W (30 ppm) in quartz from the most ancient metamorphic rocks of the crystalline core of the Great Caucasus also presents some interest as, in the caurse of evolution of the Caucasian moving area during Baikalian (?), Caledonian, Hercynian and Alpine tectono-magmatic cycles from the rocks which had been already rich in W and had been forming sialic crust of the moving area, granitoids had been melted out inheriting richness in W. Combination of the above factors allowed us to put forward a supposition that the Caucasian moving area might be refered to W-bearing provinces.

REFERENCES

AFANAS'YEV, G. D. — BORSUK, A. M. — KONDAKOV, L. A., 1971: The true magmatic associations of the Northern Caucases. Izv. Akad. Nauk SSSR, Ser. geol. (Moscow), 7, pp. 3—27.

AFANAS'YEV, G. D. — GURBANOV, A. G., 1974: Mesozoic—Cenozoic subalkaline intrusive magmatism of the axial portion of the Main Caucasian range as in the Kardyvach Magmatic Focus (Northwestern Caucasus). Izv. Akad. Nauk SSSR, Ser. geol. (Moscow), 1, pp. 19—45.

BORSUK, A. M., 1979: Mesozoic and Cenozoic magmatic formations of the Great Caucasus. Nauka, Moscow, 298 pp.

VINOGRADOV, A. P., 1962: Average contents of chemical elements in the main types of magmatic rocks of the Earth's crust. Geokhimia (Moscow), 7, pp. 555—571.

GURBANOV, A. G. — ZEMBATOV, S. S., 1978: Submeridional weak zones and their role in the localization of polymetalic mineralization in the north Osetia. Izv. Akad. Nauk SSSR, Ser. geol. (Moscow), 5, pp. 106—120.

GURBANOV, A. G. — CAMBEL, B. — MACEK, J., 1984: Comparative analysis of the Variscan granitoids of the Great Caucasus and Western Carpathians. Geol. Zbor.Geol. carpath. (Bratislava), 31, 1, pp. 61—90.

ERMAKOV, N. P., 1957: Significance of mineral inclusions research for the ore--formation theory and study of mineral-forming media. Vol. of ALL-Union scientif.--research inst. of optic min. raw mat., 1, 2, pp. 9—29.

ZEMSKAYA, I. P. — LYAPUNOV, S. M., 1984: Typochemical properties of quartz from granitic pegmatites. In: Typochemics of minerals of granitic pegmatites. IMGRE, Moscow, pp. 46—54.

LAZARENKO, E. K. — PAVLISHIN, N. V., 1974: Typomorphic properties of quartz. In: Quartz typomorphism in Ukraine. Naukova Dumka, pp. 3—11.

LYAKHOVITCH, V. V., 1972: Rare elements in granitoid rock forming minerals. Nedra, Moscow, 199 pp.

LYAKHOVITCH, V. V., 1983: Ore-generating property factors of granitoids. Nauka, Moscow, 254 pp.

LYAKHOVITCH, T. T., 1986: Quartz typochemistry in granitoids. Summary of the dissertation for the degree of a candidate of geol. sci., Moscow, 16 pp.

MANUILOVA, M. M. — DANILEVITCH, A. M. — KIRIKOV, A. L., 1983: Structural alluminium admixture in quartz as an indicator of granitoid formation conditions. Sov. Geol. (Moscow), 7, pp. 77—87.

STAVROV, O. D., 1961: Data on the rare elements contents in quartz. Geokhimia (Moscow), 7, pp. 508—514.

STAVROV, O. D. — ZOZULYA, T. A., 1975: K/Rb ratio in quartz from the tin-ore deposits — indicator of their relation to the magmatic origin. Geokhimia (Moscow), 7, pp. 1043—1048.

TAUSSON, L. V. — KRAVCHENKO, L. A., 1956: Peculiarities of the Pb and Zn distribution in the minerals of Caledonian granitoids of Susamyr Batholith (Central Tien-Shan). Geokhimia (Moscow), 1, pp. 81—89.

VON PLATEN, 1967: The anatexsis experimental study and genesis of migmatites. In: The nature of metamorphism. Mir, Moscow, pp. 211—226.

KHAIN, B. E., 1968: Tectonic zoning. In: Geology of the USSR. Nedra, Moscow, IX, pp. 566—572.

CHERNITZIN, V. B. — ANDRUSHCHUK, V. L. — RUBTSOV, N. F., 1971: Metallogenetic zones of Central and North-Western Caucasus. Nedra, Moscow, 207 pp.

DENNEN, W. H., 1967: Trace elements in quartz as indicators of Provenance. Geol. Soc. Amer. Bull. (New York), 78, 1, pp. 125—130.

KURODA, P. K., 1954: Geochemistry of molybdenum. Geochim. cosmochim. Acta (London), 6, 1, pp. 35—63.

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