Structure, substance and near-surface magmatic chambers of Mutnovsky and Gorely volcanoes (Mutnovsky geothermal region, Kamchatka). IV. Magma evolution of Mutnovsky and Gorely volcanoes. Geological and energetic aspects

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Abstract. Serial belonging and features of rocks evolution of the South-Kamchatka volcanoes Mutnovsky and Gorely occupying different positions in the structure of cross petrochemical zonality of island arc system are discussed. Basalt-riodacite rocks series of the Mutnovsky volcano was formed as a result of differentiation of parent magma of high-aluminous tholeiite composition with rare mixture of its derivatives. The rocks of Gorely volcano with similar range of silica acidity have increased potassium alkalinity and belong to the transition type from tholeiite to calc-alkali. Magma mixture of different stages of differentiation played a significant role to form it. This phenomenon confinedness to specific stages of volcanic systems evolution allows to estimate general energetic orientation of their development, with the increase or decrease of the share of the best heat capacity basalt substance in the material composition erupted by them.

1. Comparative analysis of magmatic substance evolution of Mutnovsky and Gorely volcanoes. The role of magmas mixture in the development of magma-feeding systems

Rocks composition of Mutnovsky and Gorely volcanoes reflects their position in the zone continent-ocean and, respectively, in the system of cross zonality of the island-arc.

Rocks of Mutnovsky volcano nearest to the ocean belong to a high-aluminous, moderate-alkaline, moderate-potassium tholeiitic series (Table 1, Figures a, b) with the enrichment of its intermediate, basalt-basaltic andesites derivatives by iron oxides. The part of such rocks, however, doesn't have iron enrichment and it is close to a calc-alkaline series (Figure b). Rocks of the Mutnovsky-2 cone closest to the ocean are a little more ferrous ("tholeiitic") than the Mutnovsky-1 cone which is the most remote (under similar parameters of alkalinity). It is generally congruent with the tendency of all-arc petrochemical zonality. Rocks of two latest volcano cones located between the first ones have the features of intermediate to calc-alkaline.

As it was noted, in the structure of Mutnovsky volcano the basalts and basaltic andesites composing up to 80% of its volume absolutely prevail. The distribution of rocks compositions according to heterochronous elements of the volcano is shown in Figure 5 in [6]. According to the structures, mineral and chemical compositions volcano basaltoids vary between three of their extreme versions: rather rare moderate-magnesian containing the increased quantity of phenocrysts of olivine and augite together with the calcium plagioclase (anorthite, bytownite-anorthite); widespread high-aluminous basalts essentially plagioclase;
### Compositions of typical kinds of Mutnovsky volcano rocks

| Age complex | No | SiO$_2$ | TiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | FeO | MnO | MgO | CaO | Na$_2$O | K$_2$O | H$_2$O– | H$_2$O$^+$ | P$_2$O$_5$ | Total |
|-------------|----|---------|---------|-------------|-------------|-----|-----|-----|-----|-------|-------|---------|---------|---------|--------|-------|
| Mutnovsky 1 | 1  | 50.52   | 1.09    | 17.75       | 3.20        | 7.73| 0.16| 7.16| 8.62| 2.41  | 0.54  | 0.38    | 0.58    | 0.13   | 100.29 |
|             | 2  | 51.56   | 1.04    | 22.55       | 3.27        | 4.94| 0.21| 3.18| 8.56| 2.82  | 0.59  | 0.52    | 0.96    | 0.15   | 100.35 |
|             | 3  | 50.88   | 1.36    | 18.49       | 5.77        | 6.32| 0.26| 4.78| 7.50| 2.94  | 0.54  | 0.45    | 0.64    | 0.18   | 100.11 |
|             | 4  | 59.36   | 1.01    | 17.87       | 2.37        | 4.37| 0.16| 2.18| 5.46| 4.32  | 1.02  | 0.41    | 0.71    | 0.31   | 99.55  |
|             | 5  | 65.08   | 0.61    | 15.84       | 3.24        | 1.87| 0.14| 1.67| 4.34| 3.92  | 1.96  | 0.89    | 0.24    | 0.10   | 99.90  |
| Mutnovsky 2 | 6  | 50.88   | 1.26    | 17.90       | 2.03        | 8.10| 0.22| 5.36| 9.76| 2.70  | 0.60  | 0.35    | 0.81    | 0.21   | 100.18 |
|             | 7  | 59.88   | 1.26    | 16.33       | 1.93        | 6.15| 0.16| 1.96| 4.74| 4.63  | 1.51  | 0.53    | 0.43    | 0.45   | 99.96  |
|             | 8  | 53.36   | 1.35    | 17.05       | 5.14        | 5.66| 0.18| 3.92| 7.86| 3.31  | 0.78  | 0.60    | 0.57    | 0.23   | 100.01 |
| Mutnovsky 3 | 9  | 50.04   | 0.85    | 19.35       | 2.70        | 6.12| 0.12| 5.06| 10.70| 2.28  | 0.54  | 0.80    | 0.34    | 0.16   | 99.65  |
|             | 10 | 72.38   | 0.57    | 13.43       | 1.67        | 2.21| 0.03| 0.54| 1.82| 3.93  | 8.12  | 0.50    | 0.20    | 0.08   | 100.48 |
|             | 11 | 48.76   | 0.90    | 17.31       | 1.13        | 5.88| 0.11| 8.00| 10.64| 2.01  | 0.27  | 0.41    | 1.20    | 0.21   | 99.64  |
|             | 12 | 65.90   | 0.71    | 15.63       | 4.00        | 2.13| 0.07| 0.82| 2.04| 4.39  | 3.12  | 0.56    | 2.89    | 0.20   | 99.70  |
|             | 13 | 70.84   | 0.42    | 14.70       | 2.05        | 1.50| 0.02| 0.30| 1.90| 3.55  | 3.12  | 0.38    | 1.18    | 0.09   | 100.05 |
| Mutnovsky 4 | 14 | 49.74   | 1.08    | 18.69       | 3.66        | 5.67| 0.16| 5.64| 10.76| 2.54  | 0.54  | 0.34    | 0.52    | 0.23   | 99.57  |
|             | 15 | 53.82   | 1.12    | 17.41       | 2.14        | 7.41| 0.16| 4.04| 8.88| 2.64  | 0.98  | 0.19    | 0.19    | 0.22   | 99.01  |
|             | 16 | 54.02   | 1.00    | 17.37       | 2.50        | 6.38| 0.15| 5.00| 8.95| 3.09  | 1.20  | 0.06    | 0.19    | 0.18   | 99.60  |

Notes: 1 – magnesial basalt, north-eastern foot of Mutnovsky-1 volcano; 2 – high-alumina basalt, south-western slope; 3 – high-ferrian basalt, northern foot; 4 – andesite, southern slope; 5 – quartziferous amphibole-biotite dacite with gomoeogene basalts inclusions, northern slope; 6 – basalt, south-eastern foot of Mutnovsky-2 volcano; 7 – aphyric ferroandesite, eastern slope; 8 – andesibasalt of intercaldera cone, volcano top (benchmark is 2353 m); 9 – basalt, north-eastern slope of Mutnovsky-3 volcano; 10 – rhyodacite, flow in the section of northern caldera wall; 11 – magnesial basalt of lateral breakthrough next to south-western foot; 12 – dacite, pumice of caldera-forming eruption next to Pemovskaya mountain; 13 – rhyodacite of intercaldera extrusion; 14 – basalt, western part of crater crest of Mutnovsky-4 volcano; 15 – andesitesalucifer of intercaldera cone of Mutnovsky-4 volcano; 16 – andesibasalt, bomb of the deposits of the Active Crater.

Analysis are made in a chemical laboratory of the Institute of volcanology of FEB RAS, the analytic is T G Osetrova.
aphyric-sub aphyric high-ferrous basalts and basaltic andesites. These extreme types are met in the structure of Mutnovsky-1 volcano more often, in younger cones intermediate differences prevail.

Rocks formation of these types is provided by fractionation of the specified minerals association: the selective precipitation of olivine and augite from magnesian magmas which gives plagioclase-enriched high-aluminous compositions or by joint removal of all three minerals enriching residual melting by iron.
Rocks of average-acid composition contain sodic plagioclase as phenocrysts (labrador-andesine), high- and low-calcium pyroxenes (augite and hypersthene) and titanomagnetite which crystallization beginning stops the enrichment of melting by iron and changes the evolution direction of a series towards magma enrichment by earth silicons and alkalis.

Only one time during the activity of Mutnovsky-1 volcano was erupted hybrid quartz dacites containing hydroxyl-containing minerals – amphibole and biotite accept the phenocrysts of "dry" minerals. They indicate the increased content of water dissolved in magma and, probably, deeper origin of these rocks.

Magma mixing and mingling of different stages of differentiation was the second important factor of an observed variety of Mutnovsky volcano rocks. Products of these processes, mainly intermediate, of average silicate compositions get serial features of calc-alkaline ones. Depending on structures contrast and volume ratios of mixing magmas either externally uniform rocks which hybrid nature is identified according to a joint presence of minerals of both associations described above at them or half homogenized banded and spotted differences (mainly in pyroclastites) were formed. Or at last it can be acid lavas similar described above of breccias-like shape because of numerous inclusions of basaltoids as a result of introduction, disintegration and hardening crystallization of a hot basalt magma in colder acid one.

Basalt-rhyodacite series of rocks of the Gorelovsky volcanic center remote from the ocean 12 km further than Mutnovsky volcano shows noticeable petrochemical differences from activity products of the latter.

The compositions of typical rocks kinds and their general distribution in age complexes of the center are given in Table 2 and shown in Figure 4 in [6]. The overwhelming part of average – acid rocks of the series is concentrated in pre-caldera formations of the center, in the deposits of caldera-forming eruptions and in the first cone of a modern structure. Basalts and basaltic andesites which are rare among these early formations manifest in not numerous edifices of the eruptions on the center periphery. In the middle of its structure basalts manifested on Gorely-2 and-3 volcanoes, however, hybrid basaltic andesites are absolutely prevailing in their structures and in even-aged lateral breakthroughs.

In general the series of the Gorelovsky volcanites begins with several more silicic basalts (51-52% of SiO₂) than Mutnovsky volcano series (49%). It differs in lowered alumina, ferruginosity and rather increased alkalinity – mainly, due to potassium oxide (Figure G). Its content (higher in basalts) shows also significantly higher rate of accumulation in more evolving derivatives reaching the maximum 3,2% at 58% of SiO₂ against 66% of SiO₂ in Mutnovsky volcano series. At the same time the increased contents and the greatest rate of K₂O accumulation are typical for volcanic rocks of two latest, average and south-eastern cones of the volcano and its rift zone. This parameter changes in space (and time) and it is completely opposite all-arc.

More often basalts of the Gorelovsky center don't show contents variability of magnesia and alumina typical for Mutnovsky analogs, they don't also manifest absolute accumulation of iron oxides typical for near-ocean volcanoes, except for a low-representative, unfortunately, series of volcanic rocks of early post-caldera complex (Figure D). According to these features and increased alkalinity they belong to calc-alkaline series. However, in the hemicrystalline inclusions of cumulative gabbro-dolerites rare on Gorely volcano there are glasses with the content of the general FeO from 11,5 to 13,5%.

Mineral composition of volcanic rocks of the Gorelovsky center (mainly porphyritic) differs from observed in Mutnovsky rocks by some features. The phenocrysts in basalts are presented by less calcium plagioclase (bytownite), olivine, augite and rare chromous spinel, but, as a rule, with the impurity of hypersthene and more sodic plagioclase. The rocks of an average – acid composition contain titanomagnetite - two-pyroxenes - plagioclase association of phenocrysts similar to Mutnovsky analogs; volcanic rocks with hydroxyl-containing minerals aren't met.

The essential difference of the volcanic rocks series of the Gorelovsky center from mutnovsky series is much greater development of the process of magmas mixture in the range of rather low-contrast basic-average compositions. At the same time, if the mixture on Mutnovsky volcano was, generally, an incidental phenomenon on average-late stages of the development of each of its cones, then in the Gorelovsky center it was in large quantities when Gorely-2 and-3 volcanoes formed, in lavas of breakthroughs on their slopes and in a rift zone, i.e. with clear confinedness to the late stage of the whole volcanic center development. In its previous history mainly unmixed andesite-rhyodacite volcanites of "pure evolution lines" erupted, with mixture episodes within the same range of compositions syneruptive mixture in
### Table 2

Representative analysis of rocks of the Gorely volcanic center

| Age complex               | No | SiO₂  | TiO₂  | Al₂O₃ | Fe₂O₃ | FeO   | MnO   | MgO   | CaO   | Na₂O  | K₂O   | H₂O⁺  | H₂O⁻  | P₂O₅  | Total |
|---------------------------|----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Before caldera complex    | 1  | 67.84 | 0.67  | 16.00 | 1.14  | 2.01  | 0.08  | 0.60  | 2.42  | 5.02  | 3.26  | 0.24  | 0.25  | 0.12  | 99.65 |
|                           | 2  | 52.00 | 1.36  | 17.49 | 3.38  | 6.35  | 0.18  | 5.19  | 9.18  | 3.23  | 0.96  | 0.12  | 0.12  | 0.37  | 99.63 |
| Caldera-forming eruptions | 3  | 61.68 | 1.21  | 16.90 | 2.21  | 3.76  | 0.18  | 1.84  | 3.64  | 4.73  | 2.15  | 0.50  | 1.05  | 0.42  | 100.27|
|                           | 4  | 65.21 | 1.14  | 15.18 | 2.15  | 2.67  | 0.15  | 1.10  | 3.40  | 4.76  | 3.05  | 0.20  | –     | 0.30  | 100.41|
| Gorely -1                 | 5  | 53.32 | 1.42  | 17.35 | 2.32  | 6.29  | 0.14  | 4.48  | 8.88  | 3.18  | 1.78  | 0.04  | 0.14  | 0.34  | 99.68 |
|                           | 6  | 57.54 | 1.32  | 16.28 | 2.28  | 5.89  | 0.15  | 2.64  | 6.40  | 3.99  | 2.21  | 0.44  | 0.30  | 0.34  | 99.78 |
| Gorely -2                 | 7  | 51.88 | 1.18  | 17.62 | 3.72  | 5.69  | 0.19  | 5.48  | 8.68  | 3.14  | 1.29  | 0.28  | 0.15  | 0.27  | 99.57 |
|                           | 8  | 59.78 | 1.43  | 15.42 | 1.64  | 6.29  | 0.15  | 2.06  | 5.20  | 3.81  | 3.05  | 0.23  | 0.13  | 0.44  | 99.63 |
|                           | 9  | 55.40 | 1.25  | 17.04 | 2.18  | 6.49  | 0.19  | 4.08  | 6.80  | 3.46  | 1.97  | 0.25  | 0.22  | 0.43  | 99.76 |
| Gorely -3                 | 10 | 53.38 | 1.24  | 16.60 | 2.23  | 6.87  | 0.19  | 6.24  | 7.58  | 3.24  | 1.72  | 0.34  | –     | 0.32  | 99.99 |
|                           | 11 | 60.57 | 1.51  | 15.15 | 1.47  | 6.30  | 0.20  | 2.00  | 5.80  | 3.93  | 3.00  | 0.12  | –     | 0.48  | 100.53|
| Rift zone                 | 12 | 58.55 | 1.51  | 16.46 | 1.58  | 6.71  | 0.15  | 2.56  | 6.14  | 3.50  | 2.70  | 0.16  | –     | 0.47  | 100.49|
|                           | 13 | 52.98 | 1.16  | 17.14 | 2.82  | 8.41  | 0.15  | 5.66  | 8.50  | 3.08  | 2.98  | 0.02  | 0.12  | 0.28  | 99.61 |

Notes: 1 – dacite lava in the base of eastern caldera side; 2 – basalt of the group of before caldera lateral breakthroughs at south-eastern side; 3 – andesitic ignimbrite of the second below thickness horizon, the Ospasy ravine; 4 – ignimbrite of dacitic composition, north-western foot of Mutnovsky volcano; 5 – andesibasalt flow in the bench of south-western foot of Gorely-1 volcano; 6 – anesitic agglomerate of near-top part of its western slope; 7 – basalt of Gorely-2 volcano top (benchmark is 1829 m); 8 – andesite of north-eastern slope of Gorely-2 volcano; 9 – andesibasalt thickness filling of its western crater; 10 – andesibasalt of eastern slope of Gorely-3 volcano; 11 – andesite of eastern slope of Gorely-3 volcano, north-eastern slope; 12 – andesite of fracture breakthrough in the eastern rift branch, eastern slope of Gorely-3 volcano; 13 – basalt of the flow in graben of out-caldera south-western rift zone.

Analysis are made in a chemical laboratory of the Institute of volcanology of FEB RAS, the analytics are T G Osetrova, G F Knyazeva.
ignimbrites) and single manifestations of lavas with basic inclusions (early post-caldera complex).

On Gorely-2 and-3 volcanoes there is the mixture type typical for basalt–andesite range of compositions – with the formation of externally uniform basaltic andesites with mixed associations of minerals. Acid ingredient of mixtures is presented in the Gorely-2 cone by single flows of two-pyroxene-plagioclase andesites-andesidacites similar to developed in earlier complexes. The basalt component does not manifest pure, all basalts have the traces of admixing of acid material expressed in joint presence of olivine and hypersthene, in presence of many glassy microinclusions in the kernels and zones of plagioclases, hypersthene bordering by augite. According to the least evolved minerals compositions in noted related crystal inclusions the pure basalt ingredient of mixing products can be presented by magma in balance with a paragenesis of olivine Fo84 + plagioclase An90 + clinopyroxene Fs12 ± chromous spinel. The analysis of possible lines of mixture shows that the most widespread in late cones of Gorely volcano basaltic andesites could be formed by the mixing of basalt magma (or a little more differentiated) with 20-60% of andesite magma. Large bladed phenocrysts of plagioclase typical only for these volcanic rocks and didn’t manifest in the rocks of the center earlier crystallized, most likely, from the mixed melts.

Thus, basalt-andesite part of calci-alkalic series of the Gorelovsky center (as well as some rocks of Mutnovsky volcano) was formed as a result of magmas mixing of different stages of differentiation and it is hybrid – in contrast to the "real" calc-alkaline series formed by either melting of crust rocks or fractionation from basalts of minerals associations with crystallizing titanomagnetite – with simultaneous assimilation of crust rocks or without it. As mixing is possible also inside such (independent) calc-alkaline series the differences with hybrid connected with tholeiite series are, obviously, in the ways of magma differentiation of the latter to the formation of acid ingredients of magmatic mixtures.

Ferruterous basites presence in early postcaldera comple. Crystallization in other basalts of Gorely volcano of their above-noted "own" crystal phase (despite impurity of chromous spinel) indicate the enrichment of residual melting with iron oxides. It shows the compositions of glasses of mentioned crystal inclusions. Therefore, the differentiation up to andesite and more acid compositions in rather strongly alkaline series of the volcanic rocks of Gorely volcano was similar one in the moderate-alkaline series of Mutnovsky volcano, through tholeiite way and through a certain maximum of ferruginosity. On reaching this maximum the crystallisation of the following magnetite-containing paragenesis of minerals by magma caused its falling and enrichment of the latest differentiates with silicon dioxide and alkalis.

However, in the series of the volcanic rocks of Gorely volcano (at contrast to Mutnovsky volcano series) high-ferruterous derivatives are exotic, and melts of the majority of the basic rocks of Gorely volcano shows significantly smaller bulk density (Figures C and F). Magma-conductive system of the Gorelovsky center, obviously, doesn't let pass onto the surface neither heavy initial basalt magma nor its even denser (either equal or a little smaller density – depending on water accumulation) high-ferruterous derivatives leaving them to be differentiated at the depth to "checkpoints" andesite compositions. In the activity of Gorely volcano late cones they sometimes manifested independently, but mostly became the ingredients of mixtures with primitive basalt magma some kind of "floats" capable to carry it to the surface.

Localization of the Gorelovsky volcanic center in the zone of negative gravitational anomaly and deeper position of the cretaceous base shows that the factor of such regulation of the supplying of magmas of different composition to the surface is a low density of the rocks containing magmatic system and fulfilling the role of the density filter. Magmas mixture in tholeiite series with the formation of hybrid calc-alkaline is the way to "turn" "unpromising for eruption" derivatives by basalt magma by the other (besides differentiation and opposite its character) way of auto regulation and self-maintenance of volcanic magmatic process [4] in specific external circumstances.

The activity mode of magma-feeding system of the volcano (during which only mixed lavas erupt almost constantly) assumes a certain balance of chamber sizes and magma differentiation speed, frequency and volumes of its refilling by fresh initial magma, chamber degrees devastation(depletion) by eruptions. The mode of periodic refilling and chamber partial devastations(depletions) (or volume increase) which is the effective mechanism to enrich magmas by noncompatible components [2] can be not in a smaller measure responsible for their increased potassium-bearing than the degree of melting in a mantle wedge and admixing of the precipitations of subducted ocean plate to the initial magma melting [1].
The calc-alkaline volcanic rocks of early stages of the Gorelovsky center evolution representing mainly the andesite-rhyodacite part of its series could be also differentiated on a tholeiite development getting the features of calc-alkaline ones due to the selective precipitation of titanomagnetite.

The role of the rocks host magma systems as density filters is rather noticeable at a comparison of activity products of two discrete volcanoes. In less obvious form this role has to affect also on each of them in a process of their growth. So, the existence of rather high-ferrerterous rocks on Mutnovsky-1 volcano mainly located at the feet and lower horizons of the structure doesn’t mean yet that their compositions were the most high-ferrerterous in the trends of initial magma differentiation: melting rich in ferrum could not manifest on the surface. The approximate assessment of such hidden maximum of absolute accumulation of iron oxides in the volcanites series can be received graphically, by extrapolation up to crossing of lines of possible initial enrichment in "a spinel corner" and further rocks impoverishment by these oxides – for example, on the diagrams of FeO-SiO₂. For Mutnovsky volcano series such maximum could make 13.5% of the general of FeO against really manifested of 11.5%.

Widespread and actively studied during last decades the phenomenon of magmas mixture is still considered itself out of a wide context of cause and effect relationship. The analysis of structural-and-material evolution of two volcanoes located close but on the sites with rather contrast density properties of crust shows that magmas mixture takes a certain place in evolution of magmatic systems being shown at its intermediate stages when basalt magma isn’t still or already good at a direct independent raising to the surface any more. Large-scale manifestation of basalt-andesite products of mixing at a late stage of the Gorelovsky center development after a long period of significantly acid volcanism clearly appoints a tendency for future eruptions of pure basalts and, thus, for further energetically-rising development of the center. Multicone Mutnovsky volcano develops in a long-period-pulsing integrally stable mode. The example of energetically-ascending development is another south Kamchatka volcano Ksudach on which after the formation of caldera in a large stratocone by tholeiite basaltoids the rocks of intracaldera structures of all further cycles of its activity are presented by mixed lavas of intermediate and calc-alkaline character [4] with the share of basalt ingredient which is progressively decreasing in them.

Essential general properties of hybrid magmas of basalt- basaltic andesite compositions which are similar for mixed dacitic lavas with basaltoid inclusions, but manifested incomparably more visible are much more reduced viscosity, explosiveness, and, respectively, high fluidity of their lavas forming the flows of a low thickness, but up to tens km long. These rocks as well as heated dacitic matrix of lavas with the inclusions are also distinguished by increased glassy of basic masses. However, in rather uniform basic calc-alkaline volcanic rocks formed by tholeiite ingredients mixture with fast alignment of mixtures temperature this property is already connected with the features of their composition: lowered alumina and increased potassium alkalinity detaining mass crystallization of plagioclase microlites as the main factor to increase of magma (lava) viscosity at the exit from the vent and in the flows on the surface – in spite of volatile components loss. Obviously, the possibility of long explosive-free high-temperature degassing of the convecting magmas of near-surface volcanoes chambers that manifested on Mutnovsky volcano during decades and last years on Gorely volcano is connected with this feature. The reduced viscosity and explosiveness, increased fluidity of mainly basaltic andesites hybrid magmas have also direct reflection in systematically smaller absolute heights and steepness of the volcanic structures formed by them compared with formed by "pure" volcanites of tholeiite profile. Less noticeable in linear structures like volcanic ridges these regularities can be perfectly expressed on the volcanoes of a strictly central type of development. In particular, Ksudach volcano mentioned above with its telescoped calderas complex and intercaldera cones which are less and less high from cycle to cycle represents especially bright example of the volcano development with a progressive decrease of the absolute height [4].

2. Conclusions
Mutnovsky and Gorely volcanoes are one of the most perspective objects for geotechnological development in Kamchatka territory – due to favorable features of their development, the most detailed study of their structure, presence of low-deep magmatic centers in them achievable under modern methods of drilling, and rather developed region infrastructure: roads to the regional center, electric power from the Mutnovskaya GeoEP located close, and also primary availability by means of the seismic and volcanic forecast and danger prevention. Development of energy resources of these volcanoes chambers with possible co-current extraction of various useful components of magmatic
fluids could provide a significant gain of economic capacity of the region and new fundamental and experimental scientific knowledge.

Acknowledgements
The author thanks his colleagues Ye M Gazzaeva, I V Maslovskaya and R I Pashkevich for their help for implementation of this work.

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