Structure, substance and near-surface magmatic chambers of Mutnovsky and Gorely volcanoes (Mutnovsky geothermal region, Kamchatka). III. Gorelovsky volcanic center of Mutnovsky geothermal area

O B Selyangin
Research Geotecnological Center of FEB RAS, Petropavlovsk-Kamchatsky, Severo-Vostochnoye shosse, 30, Russia
E-mail: nigtc@kscnet.ru

Abstract. The information about the structure, development and composition of the rocks of long-lived Gorelovsky volcanic center, which modern activity stage is represented by multicone intracaldera Gorely volcano with a developed fracture (rift) zone is shown. The features of magma activity in the conditions of low density of hosting crustal rocks are discussed. The conjugation of the directional evolution of magmatic material and magma-conductive structure of the volcanic centre with the formation of modern near-surface magmatic chamber of Gorely volcano is represented.

Key words: volcanic centre, caldera, magma-feeding structure, rift zone, magma chamber.

1. Gorelovsky volcanic center and Gorely volcano

Mutnovsky and Gorely volcanoes significantly differ in prehistory and development character in spite of general closeness of the spatial and structural positions, the similarity of ridged forms and activity types in historical time.

The structure of Gorely volcano is a linear volcanic ridge of 3 km length along the crest elongated in sublatitudinal, west-north-western direction. It consists of three main long-acting cones (Gorely-1-3, complexes G1-G3, Figure 1 in [19]) and more than three dozens of cones of one-act lateral breakthroughs. The whole structure is located in a large volcano-tectonic depression –caldera with oval form elongated to the north-west and sizes along the axes of 9 × 13 km. In contrast to Mutnovsky volcano Gorely volcano continues the development of more ancient volcanic center (the Gorelovsky volcanic center) after a radical transformation of it magma-conductive structure. Modern Gorely volcano also distinguishes by significantly low height (the maximum height is 1829 m), structure volume (~25 km³), explosivity index (20-30%) and, respectively, the slopes steepness as well as increased lavas fluidity. According to these features Gorely volcano can be classified as shield-shaped, i.e. as an intermediate type to the flat shield mainly lava structures with the features of the Hawaiian and Icelandic types.

As opposed to the latest explosive activity of Mutnovsky volcano developed by the time of 7-8 thousand years ago, Gorely volcano has been actively growing and developing until the present time alternating the explosions with numerous and varied outflows of lava flows.

The rocks of Mutnovsky volcano mostly belong to tholeiite series with a high ferruginosity of its intermediate, ferrobasal t-basaltic andesite members and under subordinate development of hybrid calc-alkaline ones. Volcanic rocks of the Gorelovsky center are calc-alkaline with relative enrichment
by iron, rather increased contents of alkalies (especially of K\textsubscript{2}O) and great development of magmas hybridism at a late stage of its activities.

Age differentiation of Gorely volcano structure was carried out on basis of detailed mapping and tephrochronological researches allowed to date its Holocene effusive formations [15]. Quite mountain volcano location, severe climate and long periods without vegetation are responsible for a small quantity of buried organic matter in its tephra mass. In lower places of the volcano environs where vegetation could grow the tephra horizons already pinch out the volumes of which (even during the largest eruptions of significantly lava Gorely volcano) did not exceed 0.01 km\textsuperscript{3}. As a result, direct \textsuperscript{14}C-age determination of some structure elements (cones, flows, breakthroughs) has been possible only in individual cases. The main method of their dating was the comparison of private tephra sections overlying them with a total (consolidated) section for the whole of the volcano and the position of the horizons of dated transit tephra of other volcanoes (Table 1). Thus, obtained values of the age of about dozen lava flows of the main volcano cones and their lateral breakthroughs are used for direct and indirect correlations with other elements of the structure.

Figure 1 presents the brief chronostratigraphic column of Gorely volcano. It shows its activity in Holocene in general terms. The activity has an expressed cyclical nature. On the background of relatively equal distribution of pyroclastic material in the section the volcano lavas are combined in discrete, clearly separated age groups including both terminal and lateral outflows. Within each group the flows are overlapped by the same soil-pyroclastic cover. It indicates that the eruptions of each period of mass lava outflows were close in time.

1.1. Pre-caldera structure and Gorely volcano caldera

Caldera appeared in the summit part of complex pre-caldera volcanic structure – the pra-Gorely volcano. It was, apparently, a large multy-discharge extrusive-lava complex (Q\textsubscript{2}, Figure 1 in [19]) of ~12 x 15 km, a little elongated in north-eastern direction. The peripheral parts of large flows of andesite and dacite composition lopped by caldera bench, some extrusions, dikes and necks of dacite-rhyodacites, a number of ancient lateral cones and flows of basalts and basaltic andesites have kept. In particular, the only episode of some magma breakthroughs in the zone between Gorely and Mutnovsky volcanoes (spatially and structurally referred, however, towards the latter) refers to pre-caldera period. Breakthroughs have formed two echelon-like shifted chains of cinder cones of the same type subaphric basalts exposed from under the cover of ignimbrites at the south-eastern side of caldera and southern foot of the Dvugorbaya mountain (Figure 1 in [19]).

Table 1

| Volcano                | Index  | Previous | Radiocarb on age, \( ^{14}\text{C}\)-years ago | Description                                                                 | Bulk chemical composition | Composition features            |
|------------------------|--------|----------|-----------------------------------------------|----------------------------------------------------------------------------|---------------------------|---------------------------------|
| Ksudach, Shutybel cone | КШт    | Ксд      | 1907                                          | Volcanic sand of «salt and pepper» color with inclusion of pumice gravel    | A                         | Low K\textsubscript{2}O concentration, lack of hornblende |
| Opala, Barany Amphiteatr crater | ОП      | Оп       | 1500                                          | White or yellow volcanic sand with gravel and pumice lapilli                | Р-РД                      | High K\textsubscript{2}O concentration, biotite presence |
| Ksudach, caldera V     | КСд    | Хд       | 1800                                          | Yellow or gray volcanic sand with gravel and                                | Д                         | Low K\textsubscript{2}O concentration, lack of |


\[2\]
| Location                        | Symbol | Sample Code | Age (yr) | Description                                                                 | K2O Concentration |
|--------------------------------|--------|-------------|----------|------------------------------------------------------------------------------|-------------------|
| Avacha (?)                     | AB2    | TP1         | 4000     | pumice lapilli White or yellow volcanic sand                                | A                 |
| Opala volcano region           | ОΠ1р   | TP2         | 4600     | hornblende, pumice lapilli Bright-yellow thin ash with inclusion of gravel   | P-RД              |
| Ksudach, caldera IV            | KC2    | TP3         | 6000     | hornblende, pumice lapilli Beige, greeny-beige gravel with inclusion of dark-gray gravel | A                 |
| Kurilskoye lake-Iliinskaya caldera | KO   | TP1         | 7700     | hornblende, pumice lapilli Light-yellow volcanic sand with inclusion of pumice gravel | Д                 |
| ?                              | –      | –           | 9000-9200| hornblende, pumice lapilli Pale-gray thin ash                               | A                 |

Note. Ashes are listed from up to down along the section (from young to ancient).
* Average radiocarbon age of ashes is rounded to the hundreds.
** A, Д, РД, P – andesite, dacite, rhyodacite, rhyolite, correspondingly. Bulk chemical composition of ashes in the region of Gorely volcano can differ from this ash composition next to the volcano-source due to aeolian minerals separation [2]. K2O concentrations gradation is according to the work data [4].

Caldera has formed as a result of multiple failure of a large magma chamber roof embedded into the earth crust – like reaction to its exhausting by the series of great eruptions of gas-saturated andesitic and dacitic magma. Pumice-falls generated by them and highly mobile pyroclastic flows formed multiple cover of pumice tuffs, mainly ignimbrites (four cooled units \(Q_3\), Figure 1 in [19]). Pyroclastic flows spread to a distance of 25-30 km from the center of the eruptions flooding and leveling old topography to the level of 1100 m near the caldera, with a gradual fall at the distance. The territory of their distribution is estimated about 600 km\(^2\), the thickness in the palaeotopography depressions is up to 400 m, volume is \(\sim 100 \text{ km}^3\) [5]. Over the surface of low-inclined pumice-ignimbrite plateau the remnants of pre-caldera structures exceeding its level are exposed as "islands".

Caldera formation, as noted, is dated by tephrostratigraphy method (~38-40 thou. years ago) according to the relations of the ignimbrites of Gorelovsky centre with the same and sub-simultaneous deposits of the Opala volcano caldera in the west [9]. However, direct \(\text{Ar}^{40}/\text{Ar}^{39}\)-dating (given at the beginning of the work) of the low units of ignimbrite thickness of the region [14] spatially referring to caldera indicate more ancient beginning of the caldera-forming process to middle Pleistocene.

The emission of a large portion of dacite pumice was the latest one in a series of caldera-forming eruptions. They deposited within the caldera and mainly on the outer slopes at the north-western part of its perimeter (although, as it was discussed above, some researchers refer the pumice of Mutnovsky-3 caldera to them [11, 16]. Their blanket-like cover \(\{(Q_3^3)\), Figure 1 in [19]\) (dissected by erosion now) had a thickness of up to 30 m (at an average 12-15 m). Deposits belong to the facies of pyroclastic flows. According to the erosion of the underlying ignimbrites the pumice eruption was significantly interrupted in time from the main stage of caldera-formation and possibly it was the beginning of another early postcaldera stage of volcanism of the Gorelovsky center described below. It is supposed that this pyroclastics emission (blowing) could be accompanied by a small additional depression of the north-western part of caldera bottom. In the northern part of the structure there is the allotment of clothing of ignimbrite side by young pumices, with their falling under intracaldera volcanic and proluvial-lake deposits (see section, Figure 1 in [19]).
Figure 1. Schematic composite section of Holocene soil-pyroclastic cover of the region of Gorely volcano and the stratigraphic lavas position of the volcano relative to the regional marking ashes layers [35]. Tephra of Gorely volcano: 1 – volcanic sands, 2 – lapilli and gravel cinder, 3 – explosive deposits. Individual tephra layers of Mutnovsky volcano: 4 – stratified volcanic black sands. Marking
tephra layers: 5 – light gray fine ash; 6 – lensoid layer of yellow fine-grained volcanic sand; 7 – gravel and pumice lapilli with an admixture of volcanic sand; 8 – gravel and pumice lapilli. Radiocarbon age of marking ashes layers [2] is rounded to hundreds of years. Tephra indices of Gorely and Mutnovsky volcanoes and radiocarbon dates are according to [9]. Indices of age groups of lava flows correspond to the same on the map of Figure 1 in [19].

The height of benches restricting caldera above the modern level of deposits filling its deposits basin reaches 250–300 m; the true depth of failure significantly exceeds these values. The boundaries of the structure (under the total curves) sometimes have scalloped-bay-like contours that distinguish the Gorely volcano caldera from many similar structures with usual round-funnel forms; for the latter we can assume a combined explosion-failure mechanism of formation. Caldera of Gorely volcano is a typical structure of the failure like Krakatau type restricted by steeply dipping arc faults-discharges. It is confirmed by magmatic permeability of particular areas of boundary caldera commissure along which magma breakthroughs of early post-caldera complex described below occurred later with chains formation of extrusions and cinder cones with lava flows.

For a long time the formed caldera was a closed (inland) lake reservoir, and later during the last glaciation (25–10 thou. years ago) it was a large ice reservoir. Ice armor spread with long tongues in the valleys through the lowered areas of sides. The largest ones cut ignimbrite plateau to the south and north-west from caldera.

1.2. Early post-caldera complex

Upon completing caldera formation a new stage of the Gorelovsky center activity was expressed by much discharge volcanism spatial rigidly connected with the caldera and differentiated according to the composition from basalts to dacites. This activity coincided with the second phase beginning of late Pleistocene glaciation. Now its derivatives are represented by a discontinuous chain of monogenic volcanic edifices: basalt–andesite cinder cones with flows or (more often) without them, dacite extrusions, necks and flows located on the crest of caldera bench or on a small distance on the outer slopes of the caldera (Krasnaya mountain, etc., Figure 1 in [19]).

The activity of the mentioned stage in time and space followed after the eruption of above-described pumices: the majority part of the accumulative structures is underlain by loose pumices minimal eroded; and almost all eruptions structures are located at the north-western part of the ring side of caldera to which pumices fields adjoin. It is interesting an "on-crest" location of many cinder cones often at the very edge of caldera bench; although according to a hydrodynamic position it would seem that magma breakthroughs could occur at the base of the bench much easier. The explanation of such cones localization seems to be connected with the fact of their formation under glaciation when caldera was filled with glacier up to the brim. The glacier eliminated the potential benefits of breakthroughs at lower hypsometric levels and, possibly, its pressure was responsible for the formation of magma-conductive fissures subparallel to caldera discharges. With the introduction under the glacier tuya-like form of a number of dacite extrusions in the south-western and western caldera parts characterized by visible hardness of their hyalites and sometimes well-developed columnar structure may be connected.

1.3. Gorely-1 volcano

Gorely volcano began to operate during glacial time through the glacier. Apparently, the unique design of two early cones (western (Gorely-1) and medium (Gorely-2)) with steep benches of 80-100 m height partly filled by lavas of young eruptions at the foot is connected with this fact. It is supposed that their origin is based on the covering of the frontal parts of lava flows on glacier slowly spreading and destroying them.

In the cliffs there is an interbedding of relatively small lava flows often clothing the bench of lava flows and large block lava with the characteristics of a sharp super cooling and chilling. In plan the bench of the ancient foot has irregular bay-like contours. Some its benches-tongues are exposed close to caldera side; for some of them there is a connection with the increased number of lateral
breakthroughs in corresponding sectors of the volcano structure. On the south-western flank of the volcano in the band of the fissures and monogenic cones of its rift zone the high foot of the structure adjoins to the caldera bench leveling it completely.

The formation of western ancient cone of Gorely-1 (complex G₁, Figure 1 in [19]) as part of the whole volcano structure are overlapped by the full Holocene cover of its tephra and, thus, referred to the end of late Pleistocene period (Q₄). The cone is composed by the rocks of basalt - andesite series. The structure volume is ~14 km³. Its open western part is moderately eroded, its coeval edifices of the lateral eruptions on the slopes are absent with the exception of craters of phreatic explosions at andesitic flow of its north-western foot. The activity of Gorely-1 volcano has finished by a large pyroclastic eruption covered its slopes with a bumpy cloak of bomb-block of andesite agglomerate-agglutinate of 25-30 m caked in some places to the formation of lava-like differences. Apparently, this eruption is connected with the formation of a large (~ 0,7×1,4 km) oval crater (the summit caldera?) with inclined edge to the east crowning the cone. The lower eastern part of its crest and bottom are overlapped by volcanic rocks of Gorely-2 cone. Horseshoe-shaped remnant of the western part of the crest rises 80-90 m above the bottom; its maximum height is 1763 m. In the bench under the cover of agglutinate the andesite flows are exposed in interbedding with moderate amount of pyroclastic material, in the middle of the "horseshoe" there is a discordant body (neck) of andesites, and at the foot of the bench there is later destroyed one-act cone composed by cinders of olivine basaltic andesites.

1.4. Gorely-2 volcano

The vent of Gorely-2 volcano (complex G₂, Figure 1 in [19], Q₄₋Q₁) has formed at a low eastern edge of the described crater of Gorely-1 volcano. Modern height is 1829 m, volume is ~9 km³.

The most ancient flows exposed on the surface of its main cone and some lateral breakthroughs are overlapped by soil-pyroclastic cover which is slightly younger than the cover overlapping moraine and corresponding the entire Holocene. In the lower part it contains pale-gray fine ash of 9000-9200 years old, and sometimes several tephra horizons of Gorely volcano underlaying it including slag Γ₄ (Figure 1). Lavas outflows of this group can be occurred 9200-9500 years ago.

The second group of lavas of Gorely-2 volcano belongs to the end of early Holocene (8000 years ago) because it lies directly under the marking ash interlayer KO (Figure 1, Table 1). This group is marked supposedly according to one section in the northern part of the caldera; it does not exclude the probability of nonconservation (erosion) here more ancient ashes and, in this case, these lavas belonging to the first group.

Thus, Gorely-2 volcano formed mainly at the end of the last phase of glaciation and at the beginning of post-glacial Holocene. During this mature stage the development of Gorely-2 volcano was accompanied by many lateral and eccentric breakthroughs of magma on its slopes and at the feet as well as through a dead structure of Gorely-1 volcano and beyond the caldera along fissure (rift) zone formed at this time (Figure 1 in [19]). With its formation in the development of the whole structure there is a tendency of in and out movement of the center of its activity. For Gorely-2 volcano it was expressed in elongated, oval in plan shape of its multicroater structure in which three stratocones closely combined are observable unclearly (Figure 2). It resumed its activities after the formation of Gorely-3 volcano and it is active now. The corresponding derivatives of its activity are discussed below in the description of younger elements of the volcano structure.

Rocks composition of Gorely-2 volcano ranges from basalts to andesite-dacites with a great predominance of intermediate basaltic andesite differences. The appearance of Gorely-2 volcano is connected with the change of petrographic and genetic types of volcano rocks reflecting, apparently,
Figure 2. Geological-morphological scheme of a summit zone of Gorely volcano. 1 – topographic contours; 2) craters of the Gorely-2 volcano and their numbers – from early to late; 3) brows of erosion gullies and barrancos; 4) cinder cones of lateral breakthroughs; 5) complexes of craters filling of Gorely-2 volcano; 6) thermal platforms and temperature values of their heating in 1980; 7) outputs gas-steam streams (fumaroles, solfataras, mofettes); 8) fissures. Color and G1, G2, G3 indices show the volcanites complexes of main cones composing the structure of Gorely volcano (Gorely 1-3) and young outflows according to the map Figure 1 in [19].

The structure of Gorely-2 volcano is crowned by a compact group of nesting craters appearing successively one inside the other or superimposed on the previous with more or less shift (Figure 2). There are six large craters with the diameters of 500-700 m, two small volcanic sinks and current narrow (80-90 m) pit-shaped crater active in present time that some eccentric "placed" in a bigger one early according to the ratio of their ridges forms with complexes of filling deposits. The easternmost crater with the depth of 200 m contains a cold lake.

The complexes remnants of earlier craters filling demonstrate the cyclical activity nature of Gorely-2 volcano at the stage when it reached maximum height and stopped growing. Flat-layered bands of fragmentary material and lavas which manifest remains of lava lakes existed here overlay the layers clothing bottoms and walls bases of these craters. Apparently, lakes activity (often closed) usually finished by breakthroughs on the slopes of the structure with the outflow of magma from the summit crater and its walls failure. Thus, last terminal effusion on Gorely volcano described below has finished.

These ratios indicate sharply contrast nature of volcanism dynamics of the late stage: each cycle began with a great explosive activity and failure forming crater bowl, after that the period of alternation
of purely effusive activity with long stages of weaker explosive eruptions and gradual crater filling began. This filling, however, did not restore the initial cone height, but did not even reach the crater edges; moreover, the filling level of each subsequent one was lower than the previous one (single exception is a young east crater that didn’t almost fill and it contained only small cinder cone). Thus, under the conditions of cone maximum height the volcanism continues as the alternation of its destructive (failure of structure part) and constructive (partial recovery) components with the predominance of destructions. Another way of “survival” of the volcano is the shift of its magma-conductive vent at a lower altitude level, i.e. channel migration.

Described cycllicity of volcanic activity reflects a large-scale redistribution of gas magma components in the feeding system of the volcano acting as a separator of gas-magma mixture. During long quiescent stages gases enrich its upper levels providing rapid explosive beginning of each cycle with the following quieter eruption of lower magma portions depleted by gas.

This conclusion is some alternative to the definition of the historical summit eruptions of Gorely volcano as predominantly phreatic ones. Driving force of such eruptions is not only its own gases magma, but evaporation under its contact with groundwater. Apparently, it is more correct to qualify Gorely eruptions as ultravolcanic having in mind the main role of magmatic gases. There are no reasons to suppose the existence of a large permanent groundwater reservoir [6] under the volcano because recently summit explosive eruptions have alternated with purely effusive. It is confirmed by the fact that the eccentric and lateral eruptions taken place in the most flooded areas of the volcano feet formed usual cinder cones without the removal of fragmented base rocks typical for hydromagmatism and without the formation of such typical forms as maars. The direct confirmation of magmatic, predominantly juvenile nature of gases exhaled by the volcano was vent activity that occurred in June, 2009 at the foot of the north-eastern wall of one of the summit craters of Gorely-2 volcano (crater 9, Figure 2). There was intense but almost non-explosive emission of gases with the temperature of 870 – 900°C there. The mixture contained about 93.5% of H_2O, 2.6% of CO_2, 2.2% of SO_2, 1.1% of HCl, 0.3% of HF, 0.2% of H_2, its consumption reached 11 tons per day [1]. The thermal lake which was in an adjacent crater 8 (Figure 2) has dried almost completely by 2012. It is, obviously, just the filtration of its waters provided substantial share of water mentioned in the analysis.

1.5. **Gorely-3 volcano**

Next third cone (Complex G3, Figure 1 in [19], \(Q^3_t\)) has formed on the south-eastern slope of Gorely-2 volcano. It is the lowest (1698 m) and low-volume (~2 km^3) one as if the immature cone as part of the whole volcano structure. It is composed by pyroclastics and lavas of basaltic-andesite composition belonging to the third age group (Figure 1, Table 1). They are overlapped by soil-pyroclastic cover containing marking tephra layer KC2 with the age of ~6000 years in the lower parts and the horizon of sandy loam. Effusions may be occurred in two stages because some flows are overlapped by cinders horizon. All lavas erupted in the range of 6200-6500 years ago which is indicated by the date of 6490 + 230 years obtained below on the section, and the fact that flows are not overlapped by cinder \(\Gamma_{02}\). In addition to lavas of the cone of Gorely-3 volcano the flows of a number of lateral breakthroughs on its slopes and on the slopes at the northern foot of Gorely-2 volcano (Figure 1 in [19]) are a part of a group of mentioned age.

On the top of Gorely-3 volcano there is a crater with the diameter of 500 m and the depth of 180 m. External and some parts of the internal slopes of the crater are clothed by a layer of lava-like agglutinate of basaltic andesite. It is the result of lava flowing during last eruption connected with the crater. The crater bottom is a cold lake, but its eastern and northern walls in the upper parts have warmed up and they emit from the fissures barely visible vapor streams with the temperature of 30-50°C.

Apparently, Gorely-3 volcano has formed completely during the described activity cycle; later it could manifest only a weak explosive activity according to the activation of the volcano rift system. Lavas of the following fourth age group are only on the north-western and south-western slopes of Gorely-2 volcano. They are also connected with the development of the fracture zone (Figure 1 in
They are overlain by a cover that contains the marking tephra horizon Оптр (4600 years ago) and the horizon of sand loams in the lower parts; on some of them cinders layer Гш1 is located (Figure 1). This lavas flow occurred 5500 years ago, as shown by the date of 5530 ± 120 years obtained under the cinder Гш1.

In further history of Gorely volcano the largest effusive eruptions (though they were during the activity of its summit craters) were directly connected with the development of its rift system become the leading element of magma-conductive volcano structure.

1.6. Lateral breakthroughs and volcano rift zone

Magma-conductive structure of Gorely volcano is a complex type combining central and fissure types. It is supposed that the first type is a system of tube-like channel with possible chambers-upswells. This system formed on the initial fissure magma conduit. Such system is the most resistant to heat losses and it preserves magma changing its composition for a long time and consequently the ability to its conductivity. It provides multiple eruptions from spatial stable centers and the growth of volcanic cones up to the limit (hydrostatic) level of magma rising. Close to it a new refilling of chamber-channel system by deep magma creates fissure-stress in the structure implemented by lateral breakthroughs. Due to the rapid magma solidification in thin fracture conduits they usually act one time, and new breakthroughs happen through new fissures.

The analysis of the structural position of lateral (eccentric) breakthroughs gives the information about the structure and functioning of the upper layer of magma-feeding system of the volcano.

The breakthroughs distribution on the surface and at the feet of the structure (Figure 1 in [19] and figure 3) is uneven. On Gorely-1 volcano there are not edifices of lateral eruptions synchronous to it; perhaps they took place, but they were buried by a layer of agglutinates of its last terminal eruption. All observed edifices of young breakthroughs including those that located on the slopes of Gorely-1 volcano belong to the activity time of two last volcano cones starting from the stage of maturity and growth end of Gorely-2 volcano (early Holocene).

According to the structural position all breakthroughs can be divided into three groups (Figure 3): 1) eccentric confined to the ring seam of the caldera; 2) lateral (“parasitic”) situated on the open slopes of Gorely-2 volcano; 3) confined to a branched fissure (rift) zone crossing the entire volcano.
Figure 3. Structural scheme of the Gorelovsky volcanic center.

1 – caldera contour of Gorely volcano on the bench brow (a) and block contours of the proposed additional drawdown (depression) marked by the ensemble of eccentric breakthroughs; 2 – crater (a) and lava bocca (b); 3 – cinder cones of the breakthroughs of before-caldera and early post-caldera complexes (a), lateral breakthroughs of Gorely volcano (b); 4 – extrusions of (a) and dikes (b); 5 – faults: with evidence blocks shift (a), zero-amplitude (b), buried and supposed (c); 6 – volcano rift system; G-1-3 – cones of Gorely 1-3 volcanoes as part of the whole structures; M – Mutnovsky volcano.

The breakthroughs of the first group form a chain at the foot of the north-western part of caldera bench repeating its shape in plan and connected with young movements of caldera bottom. Another possible variant of their structural control is the location of the fissures radial to the central structure bumped in caldera side on the lower endings. But this variant doesn’t find visible structural evidence (real fissures are not observed). But at the same time the tangential orientation of magma conduit manifested on the example of a double cinder cone at the northern edge of the caldera. To confirm the connection of this breakthroughs chain with sub-ring caldera fault it is necessary to remember the fact that it actually duplicates similar chain in shape and length of early-post-caldera breakthroughs outside on the crest of caldera bench described above.

In the south-east the discussing arc-like number of cinder cones forms a ring by the same chain of breakthroughs maximum removed from the top of the volcano but located just the same and at a considerable distance from caldera bench at the feet of Gorely-2 and Gorely-3 volcanoes. This group of breakthroughs fixes the north-western boundary of amagmatic zone impermeable for young breakthroughs between Gorely and Mutnovsky volcanoes. Thus, the zone includes both the part of
caldera bottom within which radial fissures did not enter and where new depressions didn’t happen. A part of the mentioned lateral cones is located not at the lowest levels of the volcano foot but on the edge of its high bench.

Generally described sub-ring ensemble of breakthroughs completes the whole intracaldera areal of their distribution in the north-western part of the structure. It can be assumed that here the renewal of caldera depression during the eruption of post-ignimbrite pumices happened on the contour marked by breakthroughs, and apparently, the pulsating volcano chamber was projected on this part of the caldera during the periods of the greatest growth.

Lateral breakthroughs are mainly connected with the activity of the highest and most mature cone of Gorely-2 volcano. They are mostly located on the open slopes of the eastern part of its structure, although, perhaps, earlier part of them was buried under the thickness of the rocks of Gorely-3 volcano. Among them there are both single cinder cones and the groups of breakthroughs connected with long radial fissures, sometimes with cinder cones in their upper part and pure lava boccas down the slope. Due to a small height and short activity duration of "immature" Gorely-3 volcano it is hardly to connect any of cinder cones on its slopes with it; the largest of them have evidently connection with the rift system of fissures. Their direct connection with Gorely-2 volcano is equally improbable due to the obvious energy disadvantageousness of magma breakthrough through the extra rocks thickness and necessity of its rise to a greater height.

Breakthroughs confined to the fracture system are located on the slopes of inactive Gorely-1 and 3 volcanoes as well as outside the volcano and caldera. They are localized along the arc-shaped system of fissures crossing the whole volcano from the south-west to south-east, as well as along its short north-western branch on the slope of Gorely-1 volcano (Figure 1 in [19] and figure 3). The south-eastern part of the system closing in the direction with the line of Mutnovsky volcano – Gorely volcano earlier controlled the shift of the channel and ridged form of Gorely volcano.

Usually such shift occurs consistently in one direction, and forming volcanic ridge buries fracture system which regenerating only from time to time on some parts. The originality of Gorely volcano is in the youthification and growing of “see-through” of fracture zone through the structure including its dead elements and in return move of the main volcano channel through it after the formation of Gorely-3 volcano. The characteristic feature of the development of the fracture system during late stages is the activations simultaneity in its opposite branches and effusive eruptions throughout its length. It is also important a linear growth and activation of the thermal field on the volcano top before its modern explosive eruptions of the central type. Figure 10 shows the position of the thermal volcano places on one of the peaks of their activity before the eruption of 1980 recorded by I. T. Kirsanov and Ozerv [6]. Obviously, magma rising to the central channel is accompanied by the structure spreading along the fissures of rift zone that become the conduits of magmatic emanations again.

In plan the most active part is a form of angular arc with sharp breaks at the intersections of the caldera side and at the summit craters of Gorely-1 and 2 volcanoes (Figure 3). At the eastern foot of Gorely-3 volcano it is sharply discontinued bumped in amagmatic zone between Gorely and Mutnovsky volcanoes.

The development beginning of the fracture zone in the described configuration refers to before Holocene. It is noted by curious structure (the Dinosaur breakthrough) on the outer south-western slope of the caldera, i.e. the steep-sided serrate ridge of cinder-bomb agglutinate with the traces of several craters formed as a result of fissure eruptions inside the ice cover [5].

Later in the first part of Holocene in the zone of fracture system stretching up to a dozen significantly effusive eruptions have happened. Their edifices are presented by cinder cones both outside the caldera and inside it at the western foot of Gorely-1 volcano and on the slope of Gorely-3 volcano (Figure 3). The role of fracture system as a part of magma-conductive volcano structure has increased with time, and if during early stages the eruptions in the fracture zone alternated with the episodes of independent activity of summit craters (including Gorely-3 volcano) and the formation of lateral breakthroughs in other places of the structure, but two last episodes of significant lava outflows (the fifth and sixth groups of the flows) are connected with fracture zone only.
The largest basaltic andesites flows of the fifth age group similar in chemical and mineral composition (\(Q^4\), Figure 1 in [19]) poured out practically simultaneously in the north-western and south-eastern branches of the rift system. In the north-west it is a wide flow of the natural boundaries of the Kekurny cape spread 9 km beyond the caldera. The edifice of the eruption is a large cinder cone bifid at the lower end of two-kilometer fissure that cut the slope of Gorely-1 volcano from the top. In the south-east the extensive multi-arm flow has poured out on the slope of Gorely-3 volcano from the horseshoe cone eroded by lava. Both flows occupy similar position in the section of soil-pyroclastic cover and have the age of \(\sim\)3,000 years as the dating of the underlying interlayer soil (3500 + 70 years ago) and marking horizon KC\(_1\) (~1800 years ago) in overlapping tephra layers show. The total lavas volume is estimated \(\sim\)0.25 km\(^3\).

The last sixth series of lava outflows (\(Q^4\), figure 1 in [19]) and a geological and structural situation of their manifestation are the most informative to understand functioning of fracture system of the volcano and its interaction with the system chamber-channel. The eruptions are dated by the 18th century. This time south-eastern and south-western branches of the rift became more active along the whole length. Lavas outflows have occupied the structure together with a summit crater. Large flows of typical megaplagiophyric andesites and basaltic andesites flew from the fissures on the slopes of Gorely-1 and-3 volcanoes, from the mentioned lava lake in a summit south-western crater of Gorely-2 volcano and especially great in after-caldera part of a south-western branch of a fissure zone. Structure unity, identity of lavas composition from different points of flowing and uniformity of their petrographic shape demonstrate that it was actually one long eruption of layered magma from the shallow chamber. Soil-pyroclastic cover overlapping its lavas contains tephra horizon (eruption of the Shtyubel cone in 1907) underlyng by layers of volcanic sand of Mutnovsky volcano and slightly humic sandy loam. Below under lavas the soil dating of 200 ± 100 years (Figure 6 in [20]) was received. The researcher of the Hawaiian geophysical observatory J. Lokwood has selected the bush branches which have shown age 560 + 45 and 420 + 50 years from the soil under two different flows of this group. However, wood hasn't been charred by flows, and its age is, obviously, connected with the previous time of the soil formation determined by an interval of 200-650 years [8]. Thus, teprochronological data is also compatible that all lavas outflow of the described group happened close/at the same time about 200-250 years ago.

The sequence of events can be built on basis of logical assumption that more acidic lavas erupted first and that the eruption generally developed from summit part of the structure to its feet. It has begun from fissure opening and outflow of olivine-bearing megaplagiophyric andesites on the eastern volcano slope of Gorely-3 volcano at the height from 1650 to 1500 m, and then on the western volcano slope of Gorely-1 volcano. They were two flows from the lower parts of the fissure which have consistently opened at the heights of 1550-1375 and 1450-1350 m. It was purely effusive eruption: small embankments of spraying directly at a fissure are connected only with the first flow.

Apparently, that time the moderate explosives "cleaned" the crater on the top of Gorely-2 volcano, and during the following stage of the eruption the crater was filled by lava lake of olivine megaplagiophyric basaltic andesites. It poured as a large flow on the southern slope of the structure. Then fissure development in its western bottom at the place of crossing of a buried caldera side (where lava hasn't appeared) and further with the direction change (Figure 3) on the external south-western slope of the caldera continued. Six breakthroughs appeared consistently here: a single cone of bomb agglutinate; a couple of contiguous cones (with lower of which the short flow of basaltic andesites is connected with the features of intermediate composition); a small effusive dome without pyroclastic traces; two larger cones in the lowest place (~ 900 m) of breakthroughs zones, at the bottom of a small middle-late Pleistocene Yagodny volcano (9 km from a summit crater of Gorely-2 volcano). The largest flow of the whole eruption extended ~ 20 km along the valleys of the Kekurny brook and Levaya Opala river is connected with the last cones. All lavas composition (in some places close to pahoehoe type) is similar to basaltic andesites of a summit crater; only in some cumulative differences (in a mentioned effusive dome) it reaches basalt. Perhaps, the descending of lava lake and failures nowadays formed the observed collapsed crater containing active explosive one have been connected.
with this outflow. Total lavas volume is ~ 0.2 km$^3$. According to the formation of cinder cones on the places of breakthroughs the basaltic andesites magma was more gas-saturated than andesite magma of the first portions of the eruption.

The structural aspect of out-caldera eruption is very interesting. It is connected with a rift formation as volcanogenic graben of 5.5 km length and 200-500 m width with lowering amplitude of the surface of the surrounding pumice field to 6–8 m. The depression is accurately localized near the described breakthroughs fading both up the external slope of caldera and at the top of Yagodny volcano. Yagodny volcano was actually the only positive element of a relief on the route of fissure opening and introduction of the dike feeding breakthroughs (Figure 6). But it wasn’t, however, overcome by them. Such dependence on a relief demonstrates rather near-surface and lateral dike distribution than fissure opening and filling by magma from below directly from the chamber. Apparently, there was the introduction of so-called blade-shaped [14] inclined dike at the level of neutral magma buoyancy – it was probable at the thicknesses highest levels of Neogene and early Quaternary basaltoids of the base of pre-caldera structure. The dike, apparently, bumped in a dense kernel (volcanic neck) of Yagodny volcano formed the similarity of the pressure artesian basin (the secondary chamber) by walls separation. Its depression appeared due to its draining by breakthroughs.

It is not clearly whether every breakthrough of out-caldera part of a fracture zone formed by lateral intrusions. Some of them could be fed by steep-ascending dikes. There could also be multiple hidden introductions of bladed dikes which weren't finished by breakthroughs on a surface. Anyway, however, the belonging of volcano rocks and far remote breakthroughs to one source and breakthroughs location in one strip of stretching of a strictly set orientation are very essential.

The term "volcanic rift" (rift on a volcano) is used here as understanding of the researchers of Hawaiian volcanoes. They described the appearance of triple systems of fissuring running out of the summit crater, depressions and primary concentration of lateral breakthroughs [7] on the slopes of mature structures. Active usually are only two branches of such system while the third one is oppressed and can die off.

According to obvious connection of such zones with the central structures it is possible to suppose their nature to be volcano-TECTONIC. However, in contrast to the structures like "hot spots" in linear island-arc structures such rift zones on the volcanoes have orientation uniformity. In Kamchatka it corresponds to volcanic chains stretching and regional dislocations plan (along convergent borders of tectonic plates), and rift zones are connected in uniform transvolcanic and transcaldera systems. Such is, for example, a general system of magma-controlling fissures of Eastern Kamchatka which stretches with cranked breaks and imbricate shifts to the north-east from the region which is located to the south from Akademiy Naun volcano through caldera complexes and Karymsky, Maly Semyachik, Bolshoi Semyachik volcanoes to the Uzon caldera and Krasheninnikov volcano [13].

Visible structural unity and extension of such regional systems raise a question: are they really uniform and through-crust? According to the facts of stability of spatial position of the volcanic centers (along the zone the continuous volcanic ridge isn't formed), confinedness of monogenic breakthroughs and the most essential depressions to the volcanic centers of certain (mature) stages it could be possible that similar systems consist of separate rift zones. They develop as the elements of magma-conductive structures of the volcanic centers at the upper levels of crust complying the regional plan of extension zones and large crust structures, and they indirectly mark the position of the general deep area of a magma-generation and the chain of diapirs crowning it. It is confirmed by petrogeochemical relationship of eruptions products in rift systems and in the volcanic centers generating them. The source of stretching tensions and magmatic substance of such zones is, most likely, the near-surface chambers. They are periodically fed by deep magma, but worse and worse drained by central volcano channel in process of achievement of growth limits and owing to the restriction lateral migration opportunities of the channels by calderas.

On Gorely volcano a young rift system (according to Hawaiian example) has also three branches, one of which (north-western) is developed less. Only out-caldera south-western branch stretching in the direction of seismoactive graben on Asacha volcano [6] and young volcanoes at the northern foot of its
massive (Figure 2 in [19], Figure 3) is close to the Kamchatka north-eastern orientation of volcanic chains from two most developed branches. To the east after breaks at caldera side and summit craters of Gorely volcano the rift system (as it is noted) develops towards Mutnovsky volcano bumped in amagmatic zone dividing them nowadays. Amagmatic zone, however, was permeable for magma breakthroughs during late Pleistocene at pre-caldera stage of the Gorelovsky center development; and on the most ancient cone of Mutnovsky volcano a swarm of basalt-andesite dikes similar in age for the breakthroughs is located similar to the row of these breakthroughs. As it was noted Mutnovsky volcano localization fixes the second turn in a Z-shaped bend of the regional magma-controlling structure which earlier was North-Mutnovsky fractured zone.

1.7. Periodicity of volcanism and forecast of Gorely volcano activity

To sum up the result of description of the volcano development we will emphasize that only upper Holocene "cover" of mature, earlier created structure reflecting the mode of the last constructive and destructive stage of its development was available for detailed study and dating.

For significantly lava structure (which Gorely volcano is) the series of the outflows close in time indicate, obviously, the stages of maximum intensity of volcanic process – the most intensive heat efflux from substance. They intertongue by long periods of alternation and rest state (fumarole activity) and moderate explosive eruptions – pyroclastic, phreatomagmatic, phreatic (ultravolcanic). Such activity cycles measured by periods duration from one till other flash of effusive activity manifest the certain orientation to change the mode of Gorely volcano volcanism in Holocene connected with reorganization of its magma-conductive system. If large effusions of the first three cycles of the dated volcano history happened with the intervals of 700–1800 (on average 1250) years, two last cycles had two times longer duration – 2500 and 2750 years when rift zone in discharge of magma substance became leading. Under the stability of the tendency the following large effusive eruption on Gorely volcano can happen in a rift zone in ~ 2000.

1.8. Development and probable structure of magma-feeding system of the volcanic center

The geophysical, geological-and-structural and petrologic data available today allow making a number of approximate assumptions about the development of magma-feeding system of the Gorelovsky center in evolutionary and historical approach.

Figure 4 shows the distribution of rocks compositions in age complexes and structural elements of the Gorelovsky volcanic center. According to basalts manifestation during the activity of significantly dacite-andesite pra-Gorely volcano the center volcanism was initially connected with basalt magma; and there are no reasons to identify its chamber with the supposed acid intrusive in the interior of the Gorelovsky block (which is, probably, more ancient and consolidated). The introduction of basalt magma into the stratified pluton on the level of its neutral buoyancy between more basic lower part and granite upper part (it is possible with partial assimilation of the latter) is obviously possible.
Figure 4. The distribution of rocks compositions in the age complexes of the Gorelovsky volcanic center. I – before-caldara complex; II – syncaldera; III – early postcaldera complex; IV – Gorely-1 volcano; V – Gorely-2 volcano; VI – Gorely-3 volcano; VII – volcanites of the rift system. There is a number of tests on the vertical axis.

For modern Gorely volcano the caldera existence and wide development of hybridism in the products of its activity do rather obvious the presence of rather low-deep magmatic reservoir – the peripheral center directly feeding it under it. It could keep as a residual from caldera-forming stage – in a sharply reduced volume, ”flattened” by roof failure. Further eruption of post-ignimbrite pumices should be connected, probably, with chamber refilling by a large portion of deep basaltic magma which has partially pushed out residual acid melting partially mixed with it and evolved with the formation of dacite-basalt magmas range of early-postcaldera complex.

The approximate assessment of chamber depth of this time and temperature of pumice-forming melting was made on sensitive to $P_{H_2O}$ relation in pumices of standard quantities of plagioclase and
pyroxene in comparison with experimentally obtained parameters of corresponding cotectic relations [10]. Use of glass compositions of fresh pumices with a small (the first percent) content of inclusions equilibrium to it is optimum for this method. Bulk analyses give a little overestimated values of pressure, however in the case under consideration they are more preferable: uneven distribution of alkalis with variations of compositions from corundum- to acmite-standard was revealed in the pumices of Gorely volcano subjected to diagenesis by the microprobe analysis of glass. The plagioclase-pyroxene relation on gross pumices compositions and on one of the "normal" qualitatively corresponding to real mineralogy of microprobe analyses (Table 2) was applied on the diagram (Figure 5). According to the provided data it is possible to estimate the depth of upper edge of the chamber at 3–5 km.

Table 2

Chemical and norm composition of Gorely center pumices

|       | 1     | 2     | 3     |
|-------|-------|-------|-------|
| SiO₂  | 66.00 | 66.28 | 68.17 |
| TiO₂  | 0.79  | 0.71  | 0.70  |
| Al₂O₃ | 16.48 | 15.54 | 15.88 |
| Fe₂O₃ | 0.91  | 0.56  | 0.86  |
| FeO   | 3.01  | 2.95  | 1.59  |
| MnO   | 0.10  | 0.14  | 0.05  |
| MgO   | 1.55  | 1.50  | 0.45  |
| CaO   | 2.99  | 3.43  | 3.22  |
| Na₂O  | 4.96  | 4.67  | 4.59  |
| K₂O   | 3.03  | 3.03  | 4.39  |
| P₂O₅  | 0.18  | 0.19  | 0.15  |
| Q     | 15.68 | 17.71 | 18.13 |
| Or    | 17.91 | 17.91 | 25.94 |
| Ab    | 41.97 | 39.52 | 38.84 |
| An    | 13.66 | 12.49 | 9.76  |
| Di    | –     | 2.70  | 4.33  |
| C     | 0.04  | –     | –     |
| Hy    | 1.52  | 5.62  | 0.10  |
| Mt    | 1.32  | 2.26  | 1.25  |
| Il    | 1.50  | 1.35  | 1.35  |
| Ap    | 0.42  | 0.44  | 0.35  |
| PL    | 0.88  | 0.86  | 0.92  |
| PL+Px |       |       |       |

Note: 1, 2 – bulk pumices composition; 3 – glass composition.
Analytics: T G Osetrova, T M Filosophova
Figure 5. The ratio composition – $P_{H_2O}$ – Т°C for pumices of the Gorelovsky volcanic center, according to [10]. 1 – bulk composition of pumice; 2 – the composition of its glass.

The north-western part of the caldera contoured outside by subring ensemble of cones of postcaldera breaks is considered to be the chamber projection on a day surface for early stages of Gorely-1 volcano development. The chamber, most likely, had the form of sill roundish in the plan or more likely laccolith with a summit part under the vent of Gorely-1 volcano and the diameter of 8-10 km. Further the chamber operated in the mode of alternation of the following states: 1) relative closeness (during calm periods), volume reductions and form change due to magma crystallization in regional parts and accumulation of near-bottom accumulative rocks; 2) new refilling by main magma with the increase of reservoir volume or a partial its devastation (depletion) by eruptions. Rather small distribution of mixed rocks in the structure of Gorely-1 volcano and visible prevalence of "pure" andesites show those small volumes of chamber refilling more often just pushed out magma of a summit zone, being differentiated at a base (bottom).

Possibly, the most essential increases of the sizes and changes of chamber geometry occur due to the difficulty of its draining by the eruptions under the reaching of maximum volcano height and provide necessary reorganization of its magma-conductive system. Such event took place before the appearing of Gorely-2 volcano; the powerful final eruption of Gorely-1 and its great crater formation (summit caldera?) could be connected with it.

According to the sizes of a subring complex of intracaldera eccentric breakthroughs (which rocks are similar to the developed ones on Gorely-2 volcano) the chamber diameter reached 8-9 km at this time again. Since this time among the products of its activity the volcanites of mixed, hybrid character and actually of one type of mixture – with the formation of macroscopically uniform rocks, but with non-equilibrium associations of phenocrysts (the products of mixing) are sharply prevailing. The mixed rocks of banded type or with dolerite-like basic inclusions (the products of minling) are rare.

A small volume and possible less deep position have to promote such style of its functioning according to spatial and geometrical parameters of the chamber; according to material characteristics it is perhaps a smaller compositions contrast of mixing magmas [12]. Data on rocks and minerals compositions and analysis of possible mix lines show that andesites are one of the final members of
mixtures (57–60% of SiO2, including megaplagiophyric) with a paragenesis of inclusions of plagioclase An_{50,60} + clinopyroxene + orthopyroxene + titanomagnetite manifested not in numerous flows. The second extreme ingredient is basalt magma not erupted pure. The majority of mixed rocks has a considerable variability of minerals composition of basalt paragenesis showing that magmas of different stages of differentiation were often the ingredients of mixtures.

The conservation of material and structural features of hybridism (inclusions non-equilibrium, return zonality, orthopyroxene bordering by clinopyroxene, etc.) demonstrates fast development of mixture process and short duration of the period (days – months) from the first contact of ingredients before mixture eruption onto a surface [12]. In dynamic aspect such process can develop as a result of high-speed injection of hot basic magma in the volume of more acidic melting with boiling and mixture eruption. Another variant is chamber refilling by more gas-saturated basic magma forming bottom layer and differentiating up to equalizing of its density with the overlapping magma mainly due to vesiculation with the subsequent mixing and eruption [3]. Inclusions absence of crystal accumulative rocks in lavas of Gorely volcano indicates the process developing less fast.

Even the minimum time break from the beginning of chamber refilling till mixture eruption assumes the increase of its sizes. The same follows from the prevalence of mixed rocks in a described part of the volcano history. Permanent manifestation of hybridism demands regular reproduction of andesite component of the mixtures and, therefore, the reduction of chamber volume under the differentiation of initial magma (under its basalt composition – not less than twice during one cycle). Without periodic restoration (increase) of chamber volume (it isn't necessary in connection with the eruptions) it would lead to its fast degeneration. Such volume increase has to happen by introduction of portions of deep magma over a layer of bottom accumulative rocks with possible sill-like distribution out of the chamber. Accumulative rocks accumulation and sills introduction form constantly increasing local level of neutral buoyancy of basaltoid magma surrounded by less dense rocks and cause gradual “emersion, rising” of the chamber [17].

According to stated structures it is obviously possible to connect independent geophysical data of the upper boundary of "anomalous object" [18] or "pluton roof" at the depth of 2 km with the position of the upper edge of a modern chamber of Gorely volcano. The laccolith-like reservoir within the caldera with the thickness of the first hundreds of meters extended along a rift zone with upper part under crater complex of Gorely-2 volcano is supposed.

It is convenient to show the scheme of chamber functioning and interaction of the central and fracture elements of magma-conductive structure of the volcano (Figure 6) on the example of its last effusive eruption described above. After chamber refilling by basalt magma its mixture with andesite magma didn’t cover the whole volume. It is possible, because of its partial degassing at chamber top. During the eruption the appeared stratification remained in general; it allows to represent its dynamics as the positions sequence of moving boundary of the section of andesite and hybrid basaltic andesite magmas at their differential current in a dike.

Figure 6 presents the hypothetical section of magma-conductive volcano structure in the plane of dike fed this eruption and central channel. In the conditions of central channel blocking, perhaps, the continuing feed of the chamber the fissure opening and dike formation from its summit part with further fan-like dividing at the level of volcanic structure has begun. Magma of megaplagiophyric andesites was “pushed out” on its slopes by boiling basalict andesite magma which has reached a summit crater after that. After a short activity of lava lake the fissure opening continued down a south-western slope of the structure beyond the caldera; it happened with the formation of an inclined blade-shaped dike and series of breakthroughs in a rift zone.
Figure 6. The supposed structure of magma-feeding system of Gorely volcano and the scheme of its latest effusive eruption development (section is in the plane of the dike feeding it). 1 – magma in chamber, dike and flows, channel contours of the in the plane of dike and separation boundary of magma of andesite (above) and andesibasalt (below) composition; 2 – rocks of the marginal groups and cumulates; 3 – Yagodny volcano neck; 4 – fissures planes; 5 – caldera discharges. See text.

The presented data of history and regularities of the Gorelovsky volcanic center development is summarized in the following conclusions:

1. The volcanism of the Gorelovsky center developed on the area of crust deconsolidation manifested by negative gravitational anomaly. Rocks structure and composition of the center evolved from large dacite-andesite massive of the pra-Gorely volcano with episodic manifestations of basalts, through caldera formation with the eruption of large volumes of dacite-andesite pyroclastic, formation of a subring complex of multi-vents dacite-basalt volcanism – to the formation of significantly basaltoid, linearly-ridged intracaldera structure of Gorely volcano and a rift zone on it.

2. Increase of basaltoid share in the activity products of the center was accompanied by the transformation of its magma-conductive structure from deep- and large-chamber central to central-fracture with rather small low-deep chamber and a rift zone connected with it. Gradual chambers "emersion(rising)" (chambers) on the forming prism of accumulative rocks and sills formed by basalt magma – as the mechanism specific to develop basalt magmatism and volcanism in the environment of rather low density is supposed.

3. Magma supply mechanism onto the surface changes from mainly successive "pushing through" of magmas-differentiates and products of a possible magmatic assimilation, with rare episodes when shielding acid masses are turned by basalts to pre-eruptive mixture of basalt magma with them. It gives the possibility to its transit (without delays in the centers) entering the surface further and, respectively, to transformation of magma-conductive structure in a simple "direct-flow" as magmatic column and (or) fractures system.

4. Rift systems similar to a developed one on Gorely volcano are genetically connected with the peripheral chambers and they indirectly mark the position of regional deep zones of a magma-generation and crust stretching. A rift system of Gorely volcano fixes a steep turn of the South-Kamchatka regional zone to the ocean finding out the influence of a large crust structure – Malki-Petropavlovsk zone of cross dislocations.
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