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Geologic Development of the Karymshina Caldera, Kamchatka, Russia, with Special Reference to Its Hydrothermal Systems

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ABSTRACT

Data on a caldera discovered in 2006 are reported. The caldera formed in southern Kamchatka during Eopleistocene time (1.2 to 1.5 Ma). The caldera boundaries have been reconstructed and its dimensions determined (approximately 15-25 km). The area of study contains several groups of thermal springs: the Bol'she-Bannaya, Mal. Bannaya, Karymchina, Karymshina, and Verkhne-Paratunka ones. The largest are the Bol'she-Bannaya springs; these were investigated extensively by many different methods during the 1970s. The reconstruction of the boundary to the large caldera that exists in the area (Leonov, Rogozin, 2007) yields a different setting of the present-day hydrothermal systems, in particular, of the Bol'she-Bannaya system. The caldera boundary has been found to pass through the Bol'she-Bannaya springs area. It was also found that numerous emplacements of acid lavas (domes, dikes, short lava flows) occur at the boundary throughout its length, these formations being rather young, less than 0.5–0.8 Ma. These data suggest that the present-day hydrothermal activity in the area is related, on the one hand, to increased crustal permeability at the caldera boundary (due to the faults that exist there), while on the other hand, the large magma chamber existing in the area (above which the caldera was generated in the Eopleistocene followed by a resurgent dome in the Lower/Middle Pleistocene) retains its heat and continues to supply it to the fluids and water that are circulating around it.

1. INTRODUCTION

The area of our interest is located in the southern part of the Kamchatka peninsular, over 50 km to the southwest of Pertopavlovsk-Kamchatsky city. It is a rock massif with single summits to 1200-1300 m in height. The highest is the mountain Tolsty Mys (1343 m). Many rivers rise from this mountain slopes and the nearest summits and flow eastwards to the Pacific Ocean and westwards to the Sea of Okhotsk (fig. 1).

The acid tuffs and ignimbrites series cover considerable part of the observed region, but the area of their distribution is very restrictive and directed to the northwest. The size of the area is 50x20 km. V.S. Sheimovich (1979) regarded that acid rocks of this region were Middle Miocene "Berezovskaya suite". The rocks deposit area is 1000 km^2. The "Berezovskaya suite" rocks thickness is over 1000 m. The "Berezovskaya suite" rocks contain 25% of ignimbrites and acid rocks total volume is 300 km^3.

Petrenko and Bolshakov (1991), Petrenko (1999), Sheimovich and Karpenko (1996), Bindeman et al. (2009) received new data on the K-Ar and Ar-Ar ages of the observed rocks. Base on these data we revised the age of the Banno-Karymshinskaya zone of acid tuffs and ignimbrites to Eo-pleistocene. We define that the rhyolite intrusion belongs to quaternary period (0.5-0.8 Ma BP).

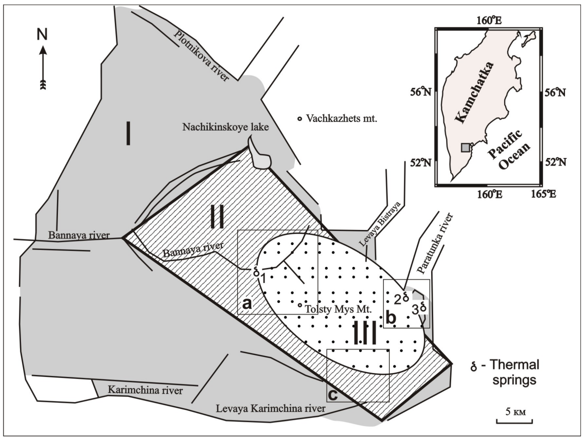

Figure 1. Position of the Karymshina caldera and comparison with the volcanotectonic depressions (VTD) that have previously been identified in the area: (I) Karymshina VTD (Lonshakov, 1979), (II) Bannaya-Karymshina VTD (Sheimovich and Kchatskin, 1996), (III) Karymshina caldera. (1, 2, 3) groups of thermal springs: (1) Bol'she-Bannaya, (2) Karymshina, (3) Verkhne-Paratunka. Rectangles mark areas that have been studied in detail: (a) upper reaches of Bannaya R., (b) Babii Kamen', (c) Karymchina--Karymshina pass.

New age for dacite-rhyolite formation rocks of the observed region allow distinguish specific Karymshinsky volcanic complex (Sheimovich and Kchatskin, 1996). This complex comprises thick, observed earlier in this region, acid tuffs and ignimbrites series, and numerous subvolcanic bodies, occur in the field of acid rocks of the region. Rocks of Karymshinsky volcano-tectonic complex bent for large volcano-tectonic Banno-Karymshinskaya depression. The boundaries of the depression are notional (fig. 1). The authors did not consider this depression as caldera; they associated tuffs and ignimbrites with intrusions and thought that the Karymshinsky complex rocks have been formed in the result of areal extrusive volcanism manifestation (Sheimovich and Kchatskin, 1996). At the same time, as mentioned by these authors themselves, the Karymshina complex is thus far little known: its structure has not been determined; there is no complete petrochemical composition and no clear knowledge of the boundary of the depression. Overall, great uncertainty still prevails as to the geology of the study area, the stratigraphy of the constituent rocks, and the evolution of the relevant volcanism. All previous information must be revised.

2. IDENTIFICATION OF A DEPRESSION BOUNDARY IN SEVERAL AREAS

We shall briefly discuss the geological structure of three areas we have studied in detail. The rocks of the Karymshina complex which fill the Karymshina caldera are of one and the same type in all the three areas; they are mostly ignimbrites or crystalline clastic tuffs saturated with fragments of plagioclase, quartz, and biotite, which make up 45-50% of the entire rock volume. Plagioclase prevails, its largest fragments are as large as 1.5-2 mm, with the more common size being within 0.5 mm. Both individual grains and fragments of monomineral aggregates are encountered. The phenocrysts are affected by fritting and resorption, and contain melt inclusions. The quartz is in the same state. Biotite (0.3-0.5 mm) forms flaky grains and thin laths, occasionally curved and split ones. Some grains show disintegration textures at the edges with mineralizing and feldspar minerals excreted. The groundmass consists of brown devitrified glass with preserved outlines of ash particles. The rock composition corresponds to rhyolite and has 70-72% SiO_2 content.

2.1 The Upper Reaches of the Bannaya River Area

The youngest formations in the upper reaches of the Bannaya River and in the Bol'she-Bannaya steam-hydrothermal field were previously considered to be the volcanoes of mounts Goryachaya and Yagodnaya (Serezhnikov and Zimin, 1976). It was thought, in particular, that the large rhyolite extrusions in mounts Sunduk, Zub'ya, etc., represent one of the last manifestations of acid volcanism associated with the volcano of Mount Goryachaya. A magma chamber was supposed to exist beneath that volcano, with the chamber being the source of heat for the thermal water that is being discharged in the Bol'she-Bannaya field area (Kraevoi et al., 1976). Today these notions should be revised.

Based on the new datings of rocks in the Karymshina complex (Sheimovich and Golovin, 2003; Sheimovich and Karpenko, 1996; Sheimovich and Khatskin, 1996) and on field observations, we came to the conclusion that the ignimbrites that widely occur in the upper reaches of the Bannaya River and the rhyolite tuffs that belong to the Karymshina complex fill a major depression. They are much younger than the lavas that compose the volcano of Mount Goryachaya (Fig. 2, 3). The extrusions of mounts Sunduk and Zub'ya, as well as other cutting rhyolite bodies, are even younger; they are of Middle Pleistocene age (Sheimovich and Golovin, 2003) and are totally unrelated to the volcanoes of mounts Goryachaya, Yagodnaya, etc. These extrusions have penetrated into the depression and mostly tend to occur at the depression boundaries (Fig. 3).

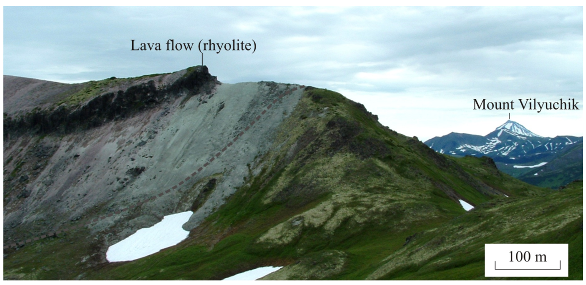

Figure 2. Karymshina complex tuffs and a small lava flow lying inside them, adjacent to precaldera lavas (slopes of Mount Yagodnaya). Dashed line shows the contact between precaldera and postcaldera deposits.

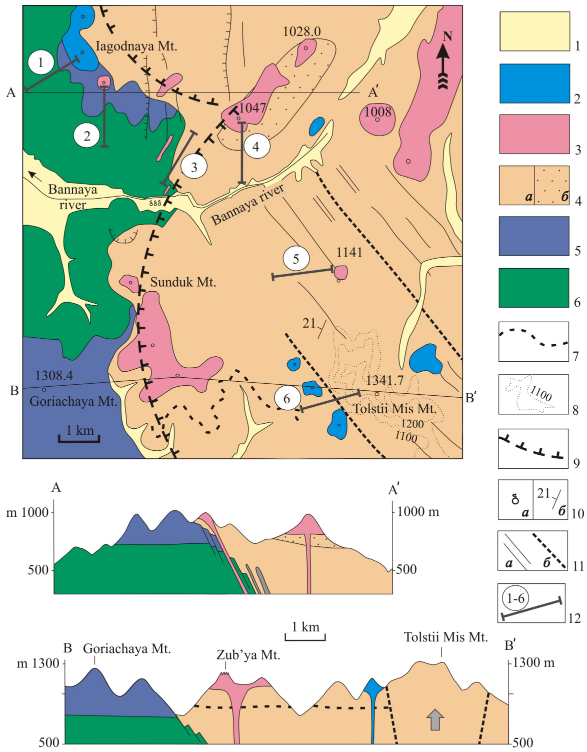

Figure 3. Geological structure and geological cross-sections for the upper reaches of Bannaya River area: (1) deposits in river valleys (Upper Pleistocene--Holocene), (2) small volcanic structures composed of basaltic lavas (Middle Pleistocene), (3) extrusions, dikes, and flows consisting of rhyolites and rhyodacites (Middle Pleistocene), (4) tuffs and ignimbrites of the Karymshina complex (a) (Eopleistocene), tuff sandstones and tuff aleurolites---lacustrine deposits (b) (Lower Pleistocene), (5) dacite lavas that compose the massifs of mounts Goryachaya and Yagodnaya (Upper Pliocene), (6) undissected Pliocene deposits, (7) marker horizon of dacite lavas in the Karymshina complex, (8) relief isolines in the Mount Tolstyi Mys area (m), (9) reconstructed boundaries of large depressions filled with Karymshina complex rocks, (10) thermal springs (a), attitude parameters (b), (11) faults: (a) fractures and normal faults, (b) reverse faults that bound the Mount Tolstyi Mys uplift, (12) locations of cross-sections (1--6) shown in Fig. 3. The upward arrow in cross-section marks the Tolstyi Mys uplift.

Several features should be noted in the disposition of rocks in the Karymshina complex for the area considered. In the first place, the rocks are found in many places to be adjacent to the lavas that compose the volcanoes of mounts Goryachaya and Yagodnaya, and to wedge out on their slopes (Fig. 2). No rocks of that complex have been detected in the Bannaya River valley downstream of the Bol'she-Bannaya Springs. Secondly, the Karymshina complex shows a dramatic increase in thickness to the east of mounts Goryachaya and Yagodnaya where the total visible thickness of these deposits exceeds 1000 m (Fig. 4). Thirdly, an extended volcanic glass bed 20-25 m thick was detected among the tuffs in the upper reaches of the Pravaya Karymchina River, and the bed can be considered as a marker horizon.

Special mention is due to the massif of Mount Tolstyi Mys. Previously that uplift was thought to be a volcano of Miocene age (Serezhnikov, Zimin, 1976). Our research showed that Mount Tolstyi Mys is the highest in the area and is composed of the same tuffs and ignimbrites of the Karymshina complex as the adjacent areas (Fig. 3). Its distinguishing feature consists in the fact that the rocks of the complex are much higher on Mount Tolstyi Mys and have a different attitude (Figs. 4, 5). We regard Mount Tolstyi Mys as an uplifted block. The uplift is bounded by northwest trending faults that have clear expression in the relief. In addition, numerous smaller volcanoes and extrusions of basaltic and andesite-basaltic composition formed along the boundary of the uplift, both in the southwest and northeast, providing evidence of long-lived, deep-seated, permeable zones situated along the uplift boundaries. Our profiles can be used to estimate the amplitude of the Tolstyi Mys uplifted block, which is at least 200 m (Fig. 3).

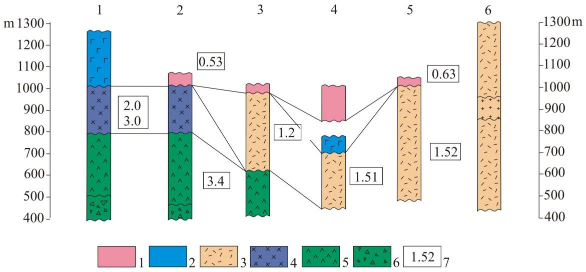

Figure 4. Comparison between the deposits exposed in the walls of Bannaya R. and on slopes of Mount Tolstyi Mys. Location of cross-sections (1--6) is shown in Fig. 3: (1) rhyolites, (2) basalts, (3) ignimbrites, crystalline clastic tuffs, (4) dacites, (5) andesites (subvolcanic bodies), (6) tuffs and tuff breccia, (7) K--Ar age, Ma, after Sheimovich and Golovin (2003).

Based on the layering of deposits in the Karymshina complex, we think that the Bannaya-Karymshina depression has a nearly north--south boundary in the area of study. The boundary passes from the upper reaches of the Pravaya Karymchina River along the foot of Mount Goryachaya toward the Bol'she-Bannaya Springs and further northeast along the valley of a brook to a mountain pass situated near the 1047.0-m extrusion. That part of the depression boundary forms an arc with a radius of approximately 7 km and a center near the northern foot of Mount Tolstyi Mys. The boundary deviates westward in the north of the area considered, where the edge of another depression seems to be located.

Figure 5. View of Mount Tolstyi Mys from northwest. Marked are boundaries of the resurgent uplift and a number of small basaltic volcanoes situated along the southwestern boundary of the uplift. On the slopes of Mount Tolstyi Mys are ignimbrite beds steeply dipping northward.

2.2 The Babii Kamen' Area

The geological structure of this area is well known (VSEGEI, 2000; Serezhnikov and Zimin, 1976; Favorskaya et al., 1965). The rocks of the Karymshina rhyodacite complex are represented there by a thick sequence of densely welded ignimbrites (Fig. 6). The uppermost part of the Karymshina complex cross-section is here occupied, similarly to the preceding area, by thin-bedded deposits of lacustrine origin (tuff aleurolites and tuff sandstones). Taken as a whole, the Karymshina rocks compose the entire cross-section (about 1000 m thick) in the west of the area and wedge out gradually toward the east part of it (Fig. 6). The boundary of the Bannaya-Karymshina depression thus passes approximately across the center of the area, near the extrusions of mounts Goryachaya and Babii Kamen'. The extrusive domes themselves, similarly to the larger domes in the other areas described above, are composed of the same quartz-biotite rhyolites. Also, similarly to the other areas considered, the domes seem to be situated on the faults that bound the Bannaya-Karymshina depression, which, in the case under consideration, are on those which define its eastward limit.

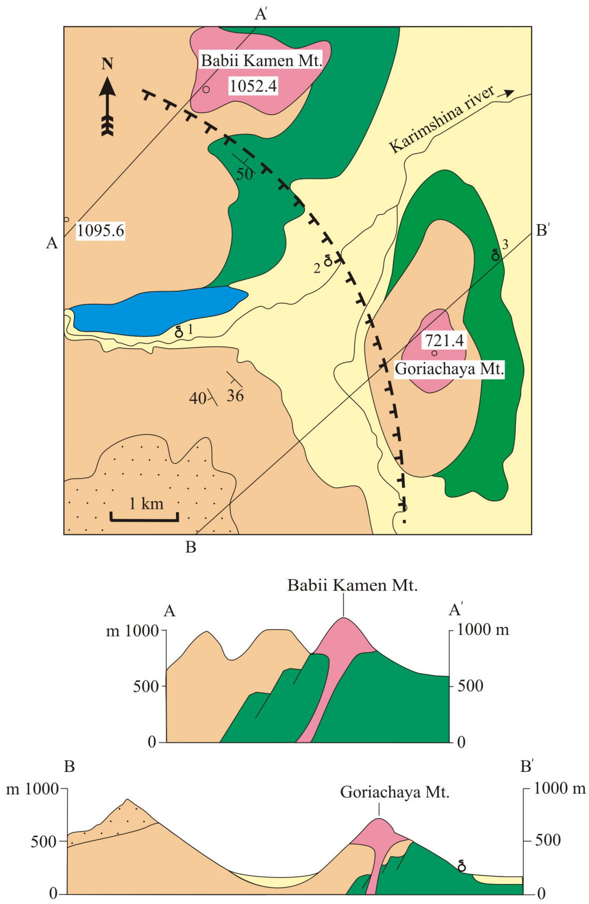

Figure 6. Geological structure and geological cross-sections through the Babii Kamen' area. For notation see Fig. 3. Thermal springs: (1) Verkhne-Karymshina, (2) Karymshina, (3) Verkhne-Paratunka.

2.3 The Pereval (Pass) Area

This area is situated near the divide of the Karymshina and Karymchina rivers. The deposits of the Karymshina volcanogenic complex in this area occupy the entire northern part situated in the upper reaches of the Karymshina, Ovrazh'ya, and Poperechnaya rivers (Fig. 7). No rocks of the complex have been found further south, in the upper reaches of the Srednyaya and Levaya Karymchina rivers. Accordingly, the boundary of the Bannaya-Karymshina depression passes there along the divide ranges, approximately east-west. Rocks of this complex have been found in the near-divide part as high as absolute altitudes of 1000-1100 m, with thin-bedded lacustrine deposits (tuff aleurolites and tuff sandstones) being detected at many locations in the upper part of the relevant cross-sections. Overlap has been found to be ubiquitous between rocks of the complex and the lavas that are remnants of the volcanoes which formed the depression walls (Fig. 8).

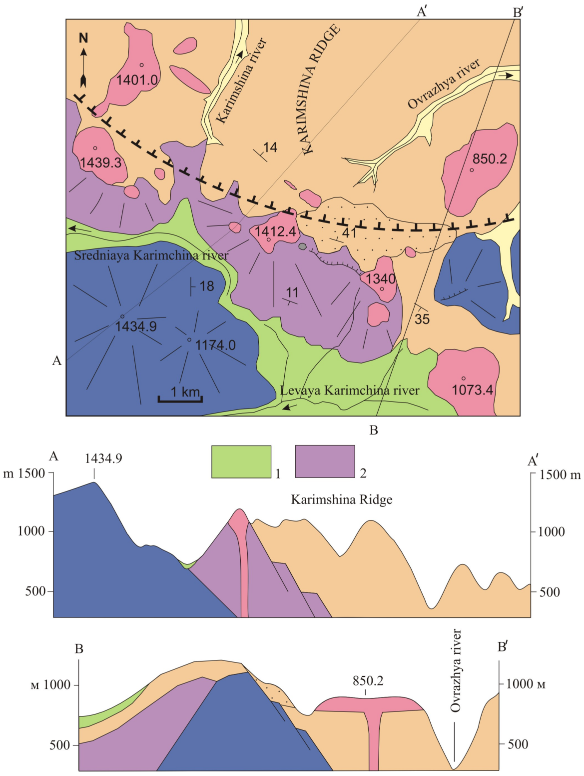

Figure 7. Map of geological structure and geological cross-sections in the Pereval area: (1) ignimbrites of Gorelyi Volcano (Upper Pleistocene), (2) rhyolite and rhyodacite lavas that compose a number of small structures situated along the southern boundary of the Karymshina caldera (Upper Pliocene). The other notation see Fig. 3.

Similarly to the preceding area, there are abundant extrusive domes, dikes, and remnants of short lava flows composed of rhyolite and rhyodacite near the depression boundaries (Fig. 8).

In the southern part of the area we found ignimbrites of the Karymshina complex on the outer slope of the depression: the ignimbrite layer dips steeply southwest, following the relief (Fig. 7). This is one of the few areas where ignimbrites have been preserved in the sinking of the depression wall, this being a situation that is quite common in many calderas in Kamchatka and worldwide (Leonov, 2003; Lipman, 2000).

The wall of the Bannaya-Karymshina depression in the area under consideration is composed of the remnants of several volcanoes whose structures have largely been destroyed, but can be reconstructed using elements of the attitude of the lavas that compose the volcanoes. Two structures are conspicuous on the left bank of the Srednyaya Karymchina River. One is a large volcano which Sheimovich (1979) previously identified and named Lev. Karymchina Volcano (altitude 1434.9 m). The other volcano is to the east of this, its highest altitude is 1174.0 m. The two volcanoes have lava compositions ranging between basalts and andesites. Northeast of them is a northwest trending band consisting of three small volcanoes (of diameter 3-4 km) having lavas with compositions between dacite and rhyolite (Fig. 9). It is these structures which make the wall of the Bannaya-Karymshina depression in the area under consideration.

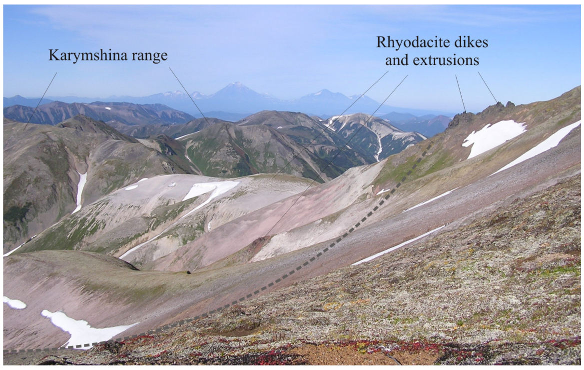

Figure 8. Contact between the Karymshina complex deposits (left) that compose Karymshina Range and fill the Karymshina caldera and the older rocks that compose the caldera wall (right). Marked are numerous dikes and small rhyodacite extrusions confined to caldera boundary.

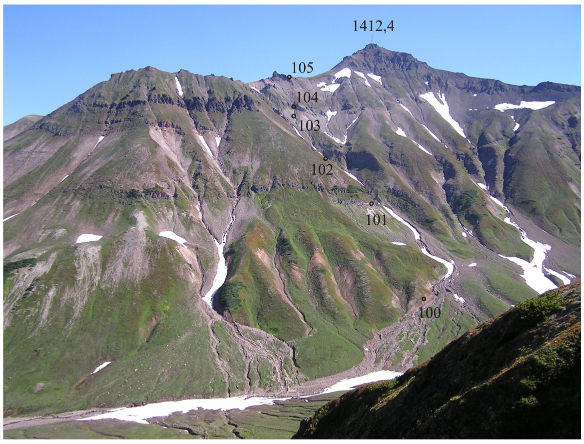

Figure 9. A view of a small precaldera volcano in the upper reaches of the Sr. Karymchina R. One can see bluffs composed of dacite and rhyodacite lavas with intervening tuff beds. Near the summit ridge (site 105) are rhyolite extrusions emplaced later, during the generation of the Karymshina caldera. Numerals denote observation sites.

3. A DISCUSSION OF THE DATA

The new data quoted above on the geological structure of the three areas situated in the upper reaches of the Bannaya and Karymchina rivers and near the Karymshina River, suggest the existence of a large depression which must be regarded as a resurgent caldera. It is elongate in the northwest direction and has the following dimensions: 15 km along the minor axis and 25 km along the major axis (Fig. 10); it is thus the largest caldera of those now known to exist in Kamchatka. The distinguishing feature peculiar to this structure among the other calderas known to exist in Kamchatka is the fact that a major uplifted block (a resurgent dome) has been reconstructed in the northwest of the depression. It is by now firmly established that the uplifted block is elongate in the northwest direction and is approximately 4 by 12 km in size. The uplift amplitude is estimated to be 200 m. The block has well-defined tectonic boundaries, being bounded by faults trending northwest and northeast.

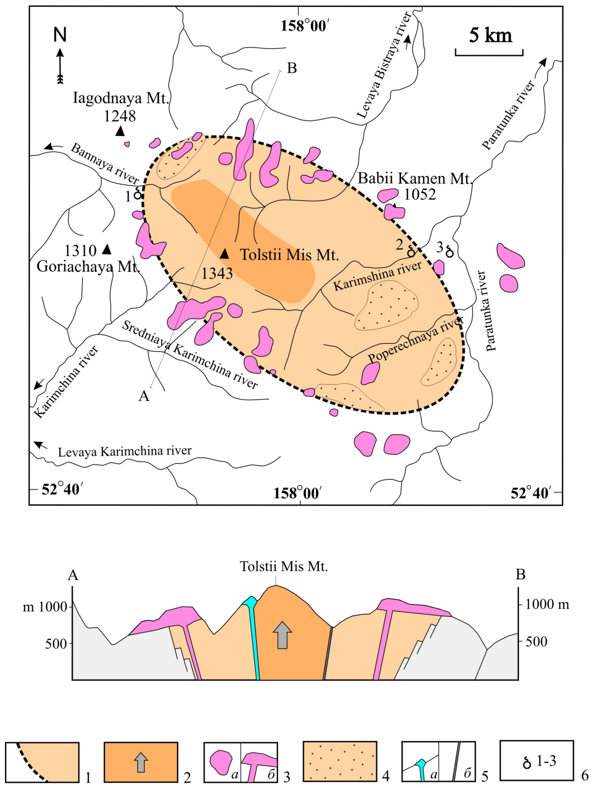

Figure 10. A summary map showing the boundary of Karymshina caldera and its internal structure: (1) boundary of Karymshina caldera and the deposits that fill it (only shown in cross-section), (2) resurgent uplift, (3) rhyolite extrusions and associated lava flows: (a) on map, (b) in cross-section, (4) areas of detected lacustrine deposits (tuff sandstone and tuff aleurolite), (5) small volcanic structures composed of basaltic lavas (a) and ore veins (b) situated at edges of resurgent uplift, (6) thermal springs: (1) Bol'she-Bannaya, (2) Karymshina, (3) Verkhne-Paratunka.

3.1 The Reconstruction of the Lakes that Filled the Caldera

Although most of the caldera is filled with ignimbrites and acid tuffs more than 1000 m thick, an extensive sedimentary field has been identified in the southeast of the caldera, namely, sandstones and aleurolites above the tuffs and ignimbrites. The top of these deposits is everywhere at absolute altitudes of 1000-1100 m; from this it can be hypothesized that the surface of the lake that had filled the caldera was at this level in the past (Figs. 3, 6, 7). The presence of sedimentary facies shows that a large lake existed after the formation of the caldera in its southeastern part. Lakes may have existed in other parts of the caldera also, since thin lacustrine deposits were encountered, in particular, in its northernmost part (Fig. 3).

3.2 Postcaldera Volcanism

Another feature of this caldera is also the fact that numerous rhyolite domes were emplaced along its rim during the postcaldera time (Figs. 10). Some of the domes are associated with thick lava flows which dip at low angles from the caldera center to the rim. The wide occurrence of rhyolite domes in the area has long been known, some domes have been studied in sufficient detail (Aprelkov, Sheimovich, 1963), but the structural setting of the domes was not clear, with these features being usually regarded as a result of areal rhyolite volcanism (Sheimovich, Khatskin, 1996). At the present time it can be asserted that the majority of the domes are situated in the caldera, mostly close to the caldera rim. The larger domes occur at the edges of the resurgent block. A dome with a flat summit (altitude 850 m) found in the south of the caldera is situated on the strongly eroded surface of tuffs and ignimbrites that fill the caldera (Fig. 7, cross-section B-B'). This fact demonstrates that the rhyolites were also emplaced much later than the origin of the depression, when its fill had been strongly eroded.

3.3 The Caldera Age

The available data on the age of the tuffs and ignimbrites in the Karymshina volcanic complex (Sheimovich, Golovin, 2003; Sheimovich, Karpenko, 1996) suggest 1.2-1.5 Ma for the generation of the caldera. The age of the rhyolites that compose the numerous domes situated inside and along the rim of the caldera is 0.5-0.8 Ma based on available data (Sheimovich, Golovin, 2003; Sheimovich, Karpenko, 1996). It can be supposed that the resurgent uplift originated in the caldera at that time.

3.4 The Rock Volume Erupted at the Generation of the Caldera

The volume of pyroclastics ejected at the generation of this caldera is hard to estimate, because it has been largely destroyed by erosion. It can be approximately estimated based on the caldera dimensions and on the calculations given in (Mason et al., 2004).

It is a known fact that the erupted material due to the generation of a large caldera is deposited, first, inside the caldera itself; secondly, in the form of ignimbrite sheets around the caldera; and thirdly, as ash that can be transported to great distances. The total volume of erupted material is the sum of these three components. Almost all known major ignimbrite-generating eruptions took place long ago (millions of years). In particular, Mason et al. (2004) distinguished two periods of particularly frequent eruptions of this kind, 1 to 13 Ma and 25 to 37 Ma. Most of the material that was ejected by these eruptions has by now been eroded or buried by younger deposits. For this reason we are more often than not unable to calculate the true volumes of erupted material, but still are in a position to make some indirect estimates of them.

Based on the calculations given in (Lipman, 1984; Mason et al., 2004; Sparks and Walker, 1977), it can be approximately assumed that the three components in the total volume of erupted products associated with major calderas, viz., intracaldera fill, ignimbrite sheets around calderas, and the ash transported to great distances, are approximately equal when converted to compact rock. Proceeding from these assumptions, and knowing the volume of intracaldera deposits for the caldera under study (about 300 km^3), we can estimate the total volume of associated rock. The volume of intracaldera fill when converted to compact rock (assuming the magma density to be 2.4 g/cm^3 and ignimbrite density 2.2 g/cm^3) is found to be 275 km^3. The total volume of material ejected during the generation of this caldera must then be about 825 km^3.

Mason et al. (2004) have proposed classifying eruptions which have discharged more than 10^{15} kg as the largest explosive eruptions on Earth. In recent years it is just such eruptions that began to be called supereruptions, and the associated locations supervolcanoes (Bindeman, 2006). The review (Mason et al., 2004) cites 28 such eruptions occurring worldwide during the period from the Ordovician to the Pleistocene. The generation of the caldera described in the present paper is fully entitled to be termed a supereruption, since the total weight of erupted material must have been 2 x 10^{15} kg based on the total erupted volume (825 km^3). When the size of an eruption is estimated based on its magnitude (Pyle, 2000), then eruptions of magnitude 8 or greater must be classed as the largest, according to (Mason et al., 2004). The magnitude of the eruptions that were occurring during the generation of the caldera in the area of study can be estimated as 8.1-8.3 (Mason et al., 2004).

3.5 The Structural Setting of Present-Day Hydrothermal Systems

The area of study contains several groups of thermal springs: the Bol'she-Bannaya, Mal. Bannaya, Karymchina, Karymshina, and Verkhne-Paratunka ones. The largest are the Bol'she-Bannaya springs; these were investigated extensively by many different methods during the 1970s, wells were drilled and a hydrothermal power station was envisaged in the future. The hypothetical model of the hydrothermal systems situated in the drainage areas of the Bannaya and Karymchina rivers developed at that time (Kraevoi et al., 1976) supposed that a magma chamber beneath Mount Goryachaya was the source of those thermal waters. It was also supposed that the thermal supply of such systems is provided by endogenous fluids, in accordance with the concepts previously put forward by V.V. Aver'ev (1966).

The reconstruction of the boundary to the large caldera that exists in the area yields a different setting of the present-day hydrothermal systems, in particular, of the Bol'she-Bannaya system. As has been demonstrated above, the volcano of Mount Goryachaya is an old one, so there is no reason to suppose the existence of a magma chamber beneath it at the present time to supply heat to hydrothermal systems. On the other hand, the caldera boundary has been found to pass through the Bol'she-Bannaya springs area (Figs. 3, 10). It was also found that numerous emplacements of acid lavas (domes, dikes, short lava flows) occur at the boundary throughout its length, these formations being rather young, less than 0.5-0.8 Ma (Sheimovich, Golovin, 2003). These data suggest that the present-day hydrothermal activity in the area is related, on the one hand, to increased crustal permeability at the caldera boundary (due to the faults that exist there), while on the other hand, the large magma chamber existing in the area (above which the caldera was generated in the Eopleistocene followed by a resurgent dome in the Lower/Middle Pleistocene) retains its heat and continues to supply it to the fluids and water that are circulating around it. It thus appears that the setting of the Bol'she-Bannaya hydrothermal system is controlled by the deep incision of the Bannaya River valley which traverses the caldera rim in the northwest (Figs. 3, 10). The setting of the Karymshina hydrothermal system is controlled by the deep incision of the Karymshina River valley which traverses the caldera rim in the east (Figs. 6, 10). The Verkhne-Paratunka thermal springs also seem to be related to the faults that bound the caldera on the east.

3.6 New Views on the Structural Controls of Ore Deposits in the Area of Study

The area contains a whole series of deposits and mineral occurrences of the gold--silver formation extending in a northwest band (Litvinov et al., 1999). It is thought that mineral occurrences and deposits are localized in a zone of major northwest trending normal faults that traverse southern Kamchatka along the boundary of the transverse Nachiki fold-block zone (Litvinov et al., 1999; Petrenko, 1999). The above data throw a new light on the structural controls of gold and silver occurrences and deposits in the area of study. We hypothesize that these controls are exerted by the faults that bound the caldera, as well as by the faults that bound the resurgent uplift situated in the caldera. In particular, known mineral occurrences in the upper reaches of the Bannaya, Levaya Bystraya, and Karymshina rivers are located along the fault that bounds the resurgent uplift on the northeast. A detailed study of the structural controls of gold and silver deposits in the area of study is a task for the future. Special research is needed for the purpose, but it seems to us evident that the generation of a major shallow magma chamber, the associated subsidence, and the subsequent emplacement of large volumes of acid magma have all been leading factors that gave rise to both hydrothermal and ore systems there.

CONCLUSIONS

(1) A new large caldera has been identified in the area of the Karymshina volcanic complex previously recognized in southern Kamchatka (Sheimovich, Khatskin, 1996)], and its dimensions have been determined (15x25 km). The caldera is not identical with the volcanotectonic depressions identified previously in the area of study, viz., the Karymshina (Lonshakov, 1979) and Bannaya-Karymshina (Sheimovich, Khatskin, 1996) depressions, so it has been given a new name, the Karymshina caldera.

(2) A tectonic uplift has been reconstructed in the northwestern part of this caldera, the uplift being regarded as a resurgent dome. The uplift has been found to be 4 by 12 km in size and to be elongate northwest. The uplift amplitude was estimated as 200 m. The uplifted block is bounded by straight northeast and northwest trending faults. We also reconstructed the boundary of a lake that had existed in the caldera south of the resurgent uplift.

(3) It was found that the Karymshina rocks (mostly acid tuffs and ignimbrites) that fill the caldera are everywhere adjacent to the lavas that compose the volcanoes of mounts Goryachaya, Yagodnaya, Levaya Karymchina, etc., which extend in a band trending northwest along the western boundary of the caldera. It has thus been unambiguously established that the above volcanoes are older and must be considered as evidence of a major volcanic phase that preceded the caldera generation.

(4) New data were obtained on the setting of the rhyolite domes widely abundant in the area of study. It was shown that they are mostly confined to the boundaries of the caldera and to the boundary of the resurgent dome situated in it. Most of the domes were emplaced much later following caldera generation, they have ages of 0.5--0.8 Ma (Sheimovich, Golovin, 2003; Sheimovich, Karpenko, 1996), and they should be regarded as a consequence of postcaldera volcanism. We also identified a postcaldera basaltic volcanic phase whose manifestations are strictly confined to the boundary of the resurgent dome.

(5) An approximate volume of material erupted during the generation of the caldera has been calculated, viz., about 825 km^3, which makes a weight of $2x10^{15}$ kg. This eruption should therefore be regarded as the largest so far known to have occurred in Kamchatka and be classed among the great eruptions worldwide (Mason et al., 2004).

(6) The structural setting of the present-day hydrothermal systems in the area of study has been revised. It is shown that all larger hydrothermal systems (the Bol'she-Bannaya, Karymshina, and Verkhne-Paratunka ones) are confined to the boundaries of the Karymshina caldera. A new approach has also been advocated for determining the controls of the mineral occurrences and ore deposits known in the area. It is shown that the identification of the Karymshina caldera makes it possible to regard these ore deposits as a consequence of the existing large magma chamber above which the caldera was generated.

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