Geothermal Volcanology Workshop 2020

1st CIRCULAR

Institute of Volcanology and Seismology, Far Eastern Branch, Russian Academy of Sciences, Petropavlovsk-Kamchatsky, September 03-08, 2020

Geothermal Volcanology Workshop 2020 will be held from 05 to 09 September 2020 in Petropavlovsk-Kamchatsky, Russia. Kamchatka is an active volcanic, seismic and hydrothermal region. Active volcanism is accompanied by magma injections into host structures, magmatic fracturing, and the formation of hydrothermal systems adjacent to volcanoes. Geo-scientific and engineering studies of productive geothermal reservoirs are a necessary condition for their effective use for heat and power supply, and for balneological use. Geomechanical analysis of the magmatic fracturing regime with seismic data is extremely important for predicting volcanic, magma-hydrothermal activity, and strong earthquakes forecasts, and for understanding producing geothermal reservoirs and hard-to-recover hydrocarbon formation conditions. The interdisciplinary focus and unique place of this workshop and field trips are stimulating breakthrough ideas, international scientific-technical cooperation, and multiple applications in Earth Science.

Topics of scientific sessions:

- Magma-hydrothermal systems
- Hydrothermal systems in volcanic areas
- Seismicity in geofluid volcanic and hydrothermal systems with active faults
- Magmatic feeding systems of active volcanoes
- Modeling the natural state and exploitation of geothermal reservoirs, applications to reserves estimation, feasibility study & investment
- Relationships among geothermal energy, magmatism, metallogeny, secondary mineralization and permeability
- Production geothermal reservoirs and hard-to-recover hydrocarbon formation conditions
- Mechanism of geysers and other cyclic phenomena in hydrothermal systems
- Diagenetic alteration of host rocks by hydrothermal fluid circulation
Language of the Workshop – English\Russian

Program Organizing Committee:
Dr. A.V. Kiryukhin (IVS FEB RAS) (Chair), Dr. J. Eichelberger (AUF, USA) (Co-Chair), Dr. G.A. Karpov (IVS FEB RAS), Dr. G.N Kopylova (KB EGS EAS), Dr. T. Korovina (JSC «Coretest Services», Tyumen), Dr. D. Nielson (DOSECC, USA), Dr. I.F. Delemen (IVS FEB RAS).

Technical Organizing Committee:

Meeting format:
Oral (including invited), no more than one from each meeting participant.

Location:
Institute of Volcanology and Seismology FEB RAS, Piip 9 Petropavlovsk-Kamchatsky, Russia.

(1) Avachinsky Volcano & Koryaksky Volcano’s Dyke Fields & Thermal Mineral Springs

This field trip lasts 14 hours (from 9-00 to 21-00). The number of participants is up to 40. Transport (car+walk), map and route points (Figure 1): IVS FEB RAS – Avachinsky Base /IVS Base (AVH) – trekking (4 hr) to Avachinsky Volcano somma ridge (2100 masl) – ascending (3 hr) to Avachinsky Volcano Cone (2750 masl) – descending (4 hr) to Avachinsky Base (AVH) – IVS FEB RAS. 2 meal stops (lunchbox + tea). Price 4 000 rubles per one participant. Prepayment at registration desk.

Optional trip on helicopter Robinson 44. Number of participants is up to 10. Flight route (1 hr) - Avachinsky Base /IVS Base (AVH) - Dyke field on the south slope of Koryaksky volcano – Koryaksky Narzan (K8) – Koryaksky Narzan (K2) – Koryaksky Narzan (K1) – Isotovsky Hot Spring (IS) - Avachinsky Base (AVH). The trip costs 22 000 rubles/per one helicopter hr/per one participant. Prepayment at registration desk.

Figure 1 Geological map of the Koryaksky–Avachinsky volcanogenic complex. Legend: (1) The summits of the Avachinsky, Koryaksky, Kozelsky, Arik, and Aag volcanoes; (2) Avachinsky, Koryaksky, Kozelsky volcanoes and their eruptive products; (3) Pinachevsky extrusions Q2-3; (4) thermal features (for details, see Table 1): FA - fumaroles on Avachinsky Volcano; FK - fumaroles on Koryaksky Volcano; K1, K2, K3, K7, K8 - thermal mineral springs of Koryaksky Narzan; IS - Izotovsky; VD - Vodopadny; CH - Chistinsky; Va - Vakinsky; (5) deep hydrogeological wells; (6) KB GS RAS seismograph stations; (7) dykes traced to -3000 masl below Koryaksky Volcano and to 1500 masl below Avachinsky Volcano; (8) glaciers. Note: The isolines show the topographic surface, and the ticks along the axes represent intervals of 5 km.
The Avachinsky-Koryaksky volcanogenic complex (Figure 1), which has an area of 2530 km$^2$, is located 25 km from Petropavlovsk-Kamchatsky City and includes five Quaternary volcanoes (two of which, Avachinsky (2750 masl) and Koryaksky (3456 masl), are active), and is located within a depression that has formed in Cretaceous basement rocks. Magma injection zones (dykes and chamber-like shapes) are defined by plane-oriented clusters of local earthquakes that occur during volcanic activity (mostly in 2008-2011) below Koryaksky and Avachinsky volcanoes at depths ranging from -4.0 to -2.0 km and +1.0 to +2.0 km, respectively. Water isotopic ($\delta$D, $\delta$18O) data indicate that these volcanoes act as recharge areas for their adjacent thermal mineral springs (Koryaksky Narzans, Isotovskiy and Pinachevsky) and the wells of the Bystrinsky and Elizovo aquifers. Carbon $\delta^{13}$C data in CO$_2$ from CO$_2$ springs in the northern foothills of Koryaksky Volcano reflect the magmatic origin of CO$_2$. Carbon $\delta^{13}$C data in methane CH$_4$ reservoirs penetrated by wells in the Neogene-Quaternary layer around Koryaksky and Avachinsky volcanoes indicate the thermobiogenic origin of methane.

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(2) Mutnovsky and Paratunsky Geothermal Areas

This field trip lasts 14 hours (from 9:00 to 21:00). Number of participants is up to 40. Transport (car+walk), map and route points (Figures 2 & 3): IVS FEB RAS – V-Paratunsky hot springs – IVS FEB RAS (track-car); V-Paratunsky hot springs – Vilyuchinsky Volcano – Gorely Volcano caldera – Dyke Fields at the entrance to Mutnovsky Volcano Crater (3) – Mutnovsky Volcano Crater and Active Vent – Volcannaya river/Waterfall 60 m – IVS FEB RAS. 2 meal stops (lunchbox + tea). Price 4 000 rubles per one participant. Prepayment at registration desk.

Optional trip on helicopter Robinson 44. Number of participants is up to 10. Flight route (1.5 hr) – Nikolaevka airport - V-Paratunsky hot springs – Vilyuchinsky Volcano – N-Zhirovskoy hot spring (16) – Voynovskoy hot spring (16) – V-Mutovskiy GeoPP 12 MWe – Mutnovsky GeoPP 50 MWe – Dachny Steam Jets (7) – Dyke Field in Mutnovsky Volcano Crater (3) – Vulcannaya River Waterfall 60 m – Cold Springs in Gorely Volcano - Nikolaevka airport. The trip costs 22 000 rubles/per one helicopter hr /per one participant. Prepayment at registration desk.

The Mutnovsky geothermal area is part of the Eastern Kamchatka active volcano belt. Mutnovsky, 80 ka old and an aging strato-volcano (a complex of 4 composite volcanic cones), acts as a magma- and water-injector into the 25-km-long North Mutnovsky extension zone (Figure 2). Magmatic injection events (dykes) are associated with plane-oriented MEQ (Micro Earth Quakes) clusters, most of them occurring in the NE sector of the volcano (2 x 10 km$^2$) at elevations from -4 to -2 km, while some magmatic injections occur at elevations from -6 to -4 km below the Mutnovsky geothermal production field. Water recharge of production reservoirs is from the Mutnovsky volcano crater glacier (+1500 to +1800 masl), as confirmed by water isotopic data ($\delta$D, $\delta$18O) of production wells at an earlier stage of development. The Mutnovsky (Dachny) 260-310°C high-temperature production geothermal reservoir with a volume of 16 km$^3$ is at the junction of NNE- and NE-striking normal faults, which coincides with the current dominant dyke injection orientation. TOUGH2-modeling estimates of the reservoir properties are as follows: the reservoir permeability is 90-600 e-15 m$^2$, the deep upflow recharge is 80 kg/s and the enthalpy is 1420 kJ/kg. Modeling shows that the reservoir is capable of yielding 65-83 MWe of sustainable production until 2055, if additional production drilling in the SE part of the field is performed. Moreover, this power value may increase to 87-105 MWe if binary technologies are applied.
Modeling also shows that the predicted power is sensitive to local meteoric water influx during development. Conceptual iTOUGH2-EOS1sc thermal hydrodynamic modeling of the Mutnovsky magma-hydrothermal system generally explains its evolution over the last 1500-5000 years in terms of heat recharge by dyke injection from the Mutnovsky-4 conduit and water recharge through the Mutnovsky-2 and Mutnovsky-3 craters.

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The Paratunsky low temperature geothermal field (Figure 3) has been operating since 1964. During the period of exploitation from 1966-2014, 321 Mt of thermal water (Cl-Na, Cl-SO\textsubscript{4}-Na composition, M up to 2600 ppm) with temperatures of 70-100°C were extracted and used for district heating, balneology and greenhouses. The structure of the 40 km\textsuperscript{3} Paratunsky low temperature (80-110°C) geothermal volcanogenic reservoir was structurally characterized, hot water upflow regions and the 3D permeability distribution were identified with hydrogeological data, and the distribution of the feed zones and 3D temperatures were constrained by 3D spline approximation. Water isotope and gas (N\textsubscript{2} 96-98%) data analysis indicated that the main recharge region of the Paratunsky geothermal reservoirs is the Viluychinsky Volcano (2173 masl) and adjacent elevated structures, located 10-25 km south from the geothermal field. Production zones occur under conditions of radial extension, possibly caused by magmatic heat sources below the reservoir and/or hydraulic fracturing due to the elevated position of the Viluychinsky Volcano’s recharge region.

TOUGH2 modeling of the thermo-hydrodynamic natural state and the history of exploitation (involving pressure, temperature and chemical response to utilization) between 1965 and 2014 yield estimates of hot water upflow rates (190 kg/s), production reservoir compressibility of up to $4\times10^{-8}$ Pa\textsuperscript{-1} and permeability of up to 1.4 D. Modeling confirmed areal discharge of the thermal water from the production reservoir in the top groundwater aquifer (top Dirichlet boundary conditions). Modeling of the chemical (Cl-) history of exploitation provides an explanation of gradual Cl- accumulation due to the inflow of chloride-containing water through the eastern (open) boundary of the geothermal reservoirs. Modeling of the long-term exploitation until 2040 with an exploitation load of 256 kg/s shows only a low pressure drop (0.7 bars) and an insignificant drop of temperatures in the production geothermal reservoir of the Paratunsky geothermal field.

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Figure 2. Schematic map and topography of the Mutnovsky geothermal area, grid scale 1 km. Legend: 1 – Production 2D plane zone traces at -250 masl; 2 – Magmatic injection (dykes) 2009-2016 traces at -3000 masl; 3 – thermal features (1-18, see below); 4 – wells; 5 – rectangle is a detailed TH model area; 6 – temperature isolines at -250 masl; 7 – AB – line of cross-section; and 8 – Glacier in the Mutnovsky volcano crater. Note-1: M₁, M₂, M₃, M₄ – funnels of Mutnovsky volcanoes 1, 2, 3 and 4, respectively (see section 2.3 for details). Note-2: MGeoPP – the existing Mutnovsky geothermal power plant 50 MWe installed; VMGeoPP – the existing Verkhne-Mutnovsky geothermal power plant 12 MWe installed; Dachny, Vulkannyi, V-Zhirovsksy, Zhirovsksy-1, Zhirovsksy-2, and Vilyuchinsky – the potential sites for additional geothermal electricity production. Thermal features: 1 – Active vent funnel, 2-Bottom field, 3- Upper field, 4,5 – North-Mutnovsky East and West, respectively, 6 – New 2003, 7 – Dachny (Active), 8 – Radon spring, 9 - Medveji, 10 – Gorely volcano gas emission jets, 11 – Verkhne-Mutnovsky, 12 – Piratovsky spring, 13 – Voinovsky spring, 14,15 – Verkhne-Zhirovsksy chloride hot springs and fumaroles, respectively, 16,17 – Nizhne-Zhirovsksy chloride hot springs, and 18,19 – Vilyuchinsky chloride hot springs and well R27, respectively.
Figure 3  Paratunsky geothermal fields thermo-geo-filtration structure and recharge conditions, with topographical elevations shown, grid scale 1 km. Legend: 1 – counters of production geothermal reservoirs at -750 masl based on geoisotherm 75°C (Paratunsky) and 60°C (Verkhne-Paratunsky); 2 – Holocene lava flows and cinder cones; 3 – Rhyolite extrusions 0.5-0.8 MY; 4 – water recharge regions for the Paratunsky geothermal reservoirs (with an elevation of more than 1000 masl); 5- Horizontal projections of fluid flows from recharge regions to the production geothermal reservoirs; 6 – Chloride water attracted into the production reservoir due to its exploitation; 7 – Hot springs; 8 – Production zone traces at -750 masl; 9 – Caldera rim 1.2-1.5 MY (Leonov et al., 2007).
(3) Valley of Geysers

The field trip lasts 10 hours (from 9-00 to 21-00). Number of participants is up to 40. Helicopter MI-8 flights are supported by «Vityaz-Travel» [http://vityaz.travel/valley] Nikolayevka Airport – Valley of Geysers – Uzon Caldera – Nalychevsky Hot Springs - Nikolayevka Airport. Each group is accompanied by a qualified guide. Hot meals are supplied during this field trip. Swimming in a Nalychevsky hot springs is available. IVS FEB RAS supported transfer to Nikolayevka airport. The trip costs 45 000 rubles per one participant. Prepayment at registration desk.

The Geysers Valley hydrothermal system (Figure 4) is hosted within a system of two permeable faults (revealed by mapping thermal features), located above a suggested magmatic body and recharged by meteoric water along the outcrops of rhyolite-dacite extrusions. Fast erosion is stimulating the significant discharge rate and landslide events. The Giant Landslide took place on June 3, 2007, when 20 x 10⁶ m³ of rocks flowed 2 km downstream, more than 23 geysers were buried or submerged, and Podprudnoe Lake was dammed, injecting cold water into submerged geysers. Possible triggers of the Giant Landslide include the inclination of the sliding plane towards the Geysernaya river basin, a pressure increase in the fluid-magma system, hanging block saturation by water during spring flooding, hydrothermal alteration weakening of the sliding plane, and steam explosions.

Monitoring of the Velikan and Bolshoy geysers after the landslide and before a mudflow on 3.01.2014 (which destroyed the dam and almost completely drained Podprudnoe Lake) shows that the interval between eruptions (IBE) of the Bolshoy Geyser decreased from 108 to 63 min and that the IBE of the Velikan Geyser slowly declined over three years from 379 min to 335 min. The seasonal hydrological cycle of the Velikan Geyser shows an increase in the IBE during winter (average of 41 min increase). A dilution of the chloride deep components of the Bolshoy (-17%) and Velikan Geysers (-12%) is also observed. A local TOUGH2 model of the Velikan geyser was developed and successfully calibrated against temperature observations at both the mid-height and base of the conduit of the Velikan Geyser, which shows the essential role of the CO₂ in the activity of the geyser. A reservoir model of shallow production geysers was also developed. This 2D model describes changes in thermal hydrodynamic state and evolving chloride concentrations in the areas of most prominent discharge, both at steady state and when perturbed by cold water injection from Podprudnoe Lake and other cold water sources (after 3.06.2007). A “well on deliverability” option was used to model the geyser discharge features in the model. The modeled increases in geyser discharge that is caused by an increase in the reservoir pressure from cold water injection reasonably matches observations of IBE decreases in the Bolshoy (~58%) and Velikan Geysers (~9%).

1941-2017 period of the Valley of Geysers monitoring (Kamchatka, Kronotsky Reserve) reveals a very dynamic geyser behavior under natural state conditions: significant changes of IBE and power of eruptions, chloride and other chemical components, and pre-eruption bottom temperature. Nevertheless, the total deep thermal water discharge remains relatively stable. Thus all of the changes are caused by redistribution of the thermal discharge due to Giant Landslide of June 3, 2007, Mudflow of Jan. 3, 2014 and other events of geothermal caprock erosion and water injection into the geothermal reservoir. Temperature logging in geysers Velikan (1994, 2007, 2015, 2016, 2017) and Bolshoy (2015, 2016, 2017) conduits shows pre-eruption temperatures below boiling at corresponding hydrostatic pressure, meaning that CO₂ creates gas-lift upflow conditions in geyser conduits. Velikan geyser IBE history can be explained by gradual decline in CO₂ recharge (1941-2013), followed by significant dilution of CO₂ recharge after the mudflow of Jan. 3, 2014. This also reshaped the geyser’s conduit and diminished its fountain height.
Figure 4 Schematic map of the Valley of Geysers. Legend: 1 - Alluvial and glacial deposits \( Q_{3,4} \); 2 - permeable units of rhyolite, dacite and andesite extrusions \( \alpha Q_{3}^{1-2} \); 3 - basalt, andesite, and dacite lavas and pyroclastics \( \alpha Q_{3}^{3-4} \); 4 – low permeability units of caldera lake deposits \( Q_{3}^{4} \), which are intruded by a dyke complex \( Q_{3}^{3-1} \); 5 – assumed thermal fluid-conducting faults; 6 – Uzon-Geysernaya caldera boundary; 7 - uplifted area that is associated with the contours of the active magma reservoir (Lundgren et al., 2006); 8 - geysers and hot springs (for enumeration, see Table 6 in Kiryukhin, 2016); 9 - Podprudnoe Lake and Podprudnoe Lake-2 dumb by mudflows; 10 - catastrophic landslide-mudflow on 3.06.2007; 11 - landslide-mudflow on 3.01.2014; 12 – Geysernaya river flow rate measurement points: a – Podprudnoe Lake exit, b – Geysernaya river mouth. Grid scale – 500 m. AB – grey dotted line of cross-section.

Ref:
(4) Volcanological Museum of the Institute of Volcanology & Seismology FEB RAS

One hour during September 4th 2020 (time TBD).

Transport:
Daily flights between Moscow and Petropavlovsk-Kamchatsky, frequent flights from, Khabarovsky and Vladivostok. Participants from the US west coast can take the following routes to Petropavlovsk-Kamchatsky **SEA-FRA-SVO-PKC or SEA-JFK-SVO-PKC or SEA-ICN-VVO-PKC**. Participants from Japan can take flights through Vladivostok.

Weather:
The beginning of September in Petropavlovsk-Kamchatsky is usually sunny with a temperature of +16 °C, but the possibility of a rain is not ruled out.

Cost:
**Workshop registration fee: 3000 rub.** (includes the expenses for organization and conducting of the workshop and general events).

Accommodation: Hotels "Edelweiss", "Petropavlovsk", "Avacha" and "Oktyabrskaya". The most inexpensive rooms (about $ 100) are in the hotel "Edelweiss", which is located near the Institute of Volcanology and Seismology FEB RAS.

Support: The workshop supported by Russian Foundation for Basic Research (RFBR). The organizers also anticipate support from the Russian Foundation for Scientific Research (RSF), JSC Teplo Zemli, JSC Geotherm, International Geothermal Association (IGA), PJSC Gazpromneft.

For all questions concerning the organization of the meeting, contact Tatiana Rychkova and Evgenia Chernykh [GeothermalVolcanology2020@gmail.com](mailto:GeothermalVolcanology2020@gmail.com)

The following schedule, with updates, is also on the website of IVS FEB RAS: [http://www.kscnet.ru/ivs/](http://www.kscnet.ru/ivs/).
Short Abstracts

Abstract submission is until May 1, 2020.
Abstract submissions should be 0.5 page or less, 12 point Times New Roman, 1-inch margins, and include title, author(s), author(s) affiliation, author(s) email, and abstract text. Please do not include any graphics.
Please submit your abstract via e-mail GeothermalVolcanology2020@gmail.com

Abstracts will be reviewed with regard to scientific quality and suitability for the conference.
Accepted abstracts will be designated for either oral or poster presentation at the discretion of the organizing committee; authors with a preference for poster presentation should note this on the online submission form.
Each presenting author is generally allowed one paper or poster as a first author at the conference; multiple presentations will be dependent on the available program space.
The notification of acceptance of abstracts will be sent by June 1, 2020.

Extended Abstracts

FORMAT and LENGTH: Extended Abstracts should be 4 pages, 12 point Times New Roman, 1-inch margins, and include title, author(s), author(s) affiliation, author(s) email, and abstract text. This length includes all figures, tables and references.
The due date for submitting extended abstracts will be August 1, 2020.

Presentations PPT

SUBMIT your presentation to GeothermalVolcanology2020@gmail.com
no later than September, 1st 2020.

DOCUMENT NAME for your file upload: Last name_First word of Session name_First 4-5 words of Title_version # (EXAMPLE: Prieto_Geologic_Giving a presentation on the_v3)

TIME ALLOTTED for Oral Presentations: 20 minutes total (13 minutes talk + 5 minutes for discussion + 2 minutes for changeover between speakers)

Schedule of the GVW-2019 and Field Trips

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<td>Registration (continues) Technical Sessions</td>
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