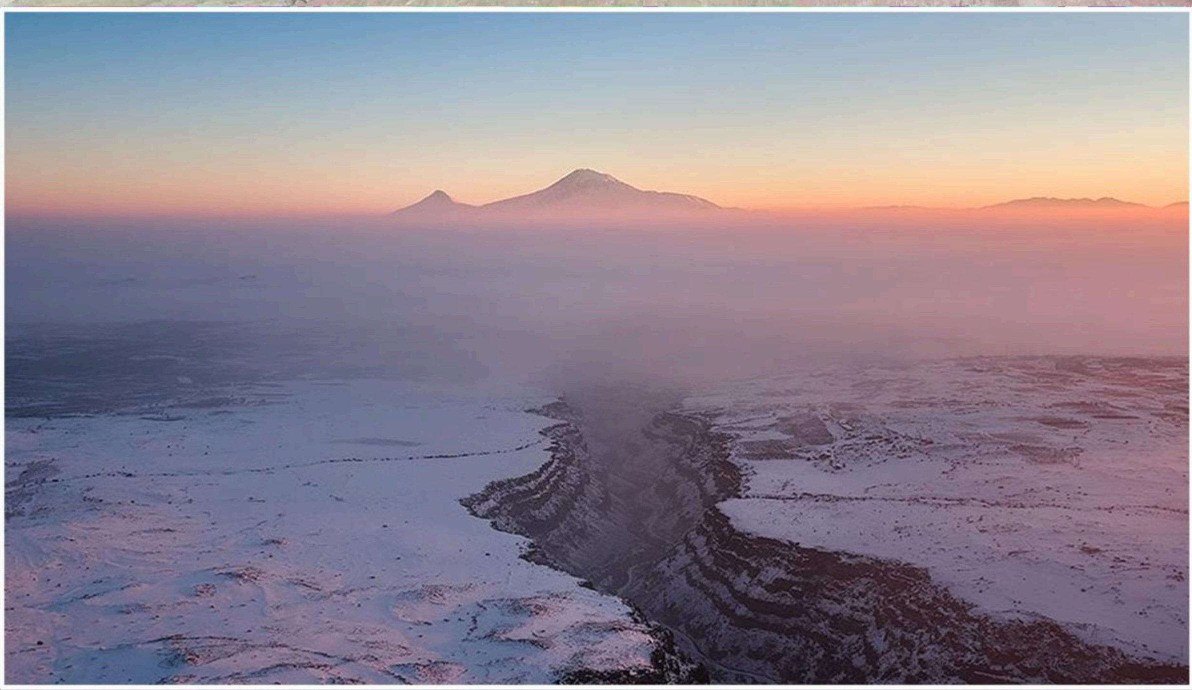
Volcanology 2023

CONTINENTAL COLLISION ZONE VOLCANISM AND ASSOCIATED HAZARDS

International Conference



September 03-08, 2023
Yerevan, Armenia

ՀԱՅԱՍՏԱՆԻ ՀԱՆՐԱՊԵՏՈՒԹՅԱՆ ԳԻՏՈՒԹՅՈՒՆՆԵՐԻ ԱԶԳԱՅԻՆ ԱԿԱԴԵՄԻԱ

ԵՐԿՐԱԲԱՆԱԿԱՆ ԳԻՏՈՒԹՅՈՒՆՆԵՐԻ ԻՆՍՏԻՏՈՒՏ

ՀՐԱԲԽԱԿԱՆՈՒԹՅԱՆ ԵՎ ԵՐԿՐԻ ԸՆԴԵՐՔԻ ՔԻՄԻԱՅԻ ՄԻՋԱԶԳԱՅԻՆ ԱՍՈՑԻԱՑԻԱ

ՀՀ ԿԳՄՍՆ
ԲԱՐՁՐԱԳՈՒՅՆ ԿՐԹՈՒԹՅԱՆ և ԳԻՏՈՒԹՅԱՆ ԿՈՄԻՏԵ

«ԿՈԼԼԻԶԻՈՆ ԳՈՏՈՒ ՀՐԱԲԽԱԿԱՆՈՒԹՅՈՒՆԸ ԵՎ ԱՌՆՉՎՈՂ ՎՏԱՆԳՆԵՐԸ»

ՄԻՋԱԶԳԱՅԻՆ ԳԻՏԱԺՈՂՈՎ

ԳԻՏԱԺՈՂՈՎԻ ԾՐԱԳԻՐ

ԷՔՍԿՈՒՐՍԻԱՆԵՐԻ ԾՐԱԳԻՐ

ՍԵՂՄԱԳՐԵՐԻ ԺՈՂՈՎԱԾՈՒ

03-08 Սեպտեմբեր 2023

Հետ-կոնֆերանսային էքսկուրսիաներ 09-11 Սեպտեմբեր, 2023

ԵՐԵՎԱՆ, ՀԱՅԱՍՏԱՆ

ԵՐԵՎԱՆ-2023

NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF ARMENIA

INSTITUTE OF GEOLOGICAL SCIENCES

INTERNATIONAL ASSOCIATION OF VOLCANOLOGY AND CHEMISTRY OF THE EARTH'S INTERIOR

HIGHER EDUCATION AND SCIENCE COMMITTEE OF REPUBLIC OF ARMENIA

“CONTINENTAL COLLISION ZONE VOLCANISM AND ASSOCIATED HAZARDS”

INTERNATIONAL CONFERENCE

CONFERENCE PROGRAM
EXCURSIONS PROGRAM
ABSTRACTS VOLUME

03-08 September 2023
Post-conference field trips 09-11 September 2023
YEREVAN, ARMENIA

YEREVAN – 2023

The Organizing Committee and the Institute of Geological Sciences (IGS) of the Armenian National Academy of Sciences announce the international conference on “Continental collision zone volcanism and associated hazards” to be held in Yerevan on September 03-08, 2023. The conference aims to bring together members of the scientific community active in various aspects of volcanology, volcanic hazards, petrology, geochemistry, volcano-seismology, environmental impacts of volcanism, geothermal energy and other related disciplines.

Leading scientists as well as young scholars will present talks and posters and will be offered plenty of opportunities to exchange their experiences, as well as to discuss recent innovations and further challenges in volcanology.

The conference to be held on September 03-08 2023 will include two all-day conference field trips (September 06 and 08) and for interested participants there is possibility of extended post-conference field trips three days long (September 09-11) to visit notable volcanoes and key historical sites across Armenia.

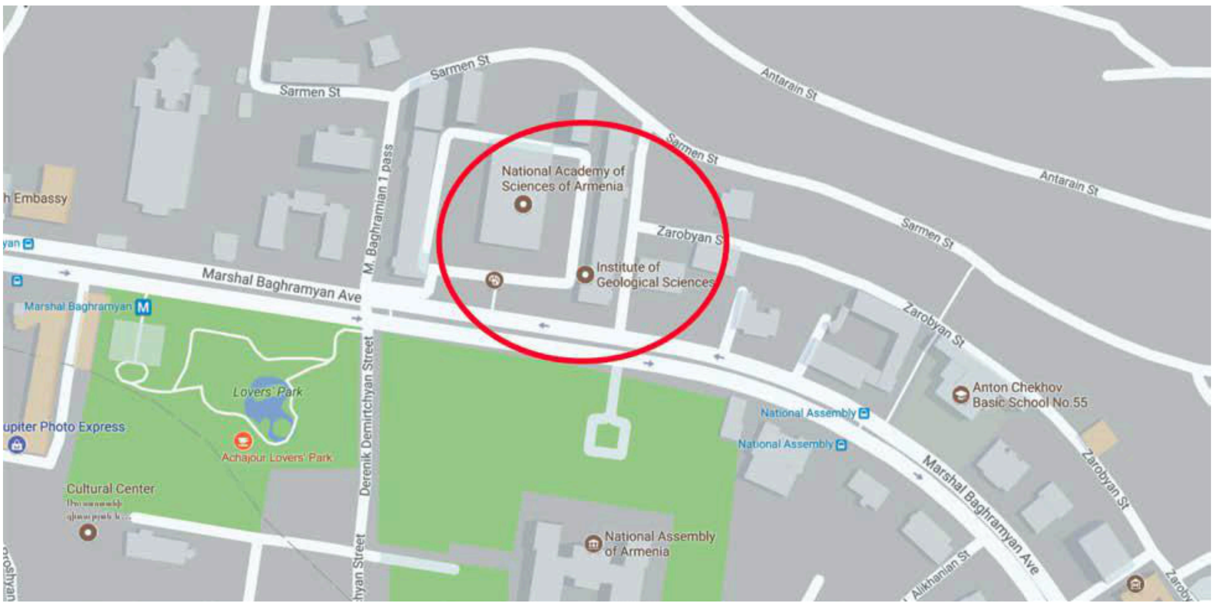
BACKGROUND ON VOLCANISM IN ARMENIA

Evidence of the Quaternary and Holocene volcanism in Armenia include plateau-basalt lavas, several large stratovolcanoes (e.g. Aragats) and associated ignimbrites. In this unique volcanic region, there are more than 500 Quaternary-Holocene monogenetic volcanoes located in several volcanic fields/highlands and forming one of the densest volcano clusters on the Earth. Compositionally, Armenian Quaternary magmas range from picrites and basanites to rhyolites and reveal unique geochemical fingerprints of collision zone volcanism that differ from those at island arcs, continental intraplate/oceanic islands settings and mid-ocean ridges. Volcanism that has been active in the Holocene and over the historical period, as well as seismic swarms of volcano-tectonic origin provide evidence for potential volcanic hazards in the entire region of the Anatolian-Armenian-Iranian orogenic plateau.

CONFERENCE VENUE

1. SESSIONS: Presidium of the National Academy of Sciences of the Republic of Armenia

M. Baghramyan Avenue 24, Yerevan



2. ICEBREAKER Reception meeting at the Geological Museum of the Institute of Geological Sciences of Armenian National Academy of Sciences, At 18.00, M. Baghramyan Avenue 24a Entrance to the museum is from the opposite side of the building of the Institute of Geological Sciences.

KEYNOTE LECTURES:

Prof. Julian Pearce, Geochemical interpretation of collision volcanism

Prof. Donald Dingwell, Melt chemistry and the eruptive properties of high silica explosive systems

Prof. Charles Connor, Building lava flow libraries to assess lava flow hazards in distributed volcanic fields

Prof. Karoly Nemeth, Volcanic architecture of one of Earth's largest long-lived mature intracontinental monogenetic volcanic province: western Arabian Peninsula

Dr. Ivan Savov, Generation of petrologically and isotopically unique post-collisional magmatic reservoir under Armenia

Prof. Dork Sahagian, Drivers of explosive volcanic eruptions

Dr.Sci. Khachatur Meliksetian, Collision related volcanism of Armenia: geodynamic setting and geochemistry

Conference web site: https://volcanology2023.geology.am

LOCAL ORGANIZING COMMITTEE

Khachatur Meliksetian (Head of the Local Organizing Committee)
Edmond Grigoryan
Hripsime Gevorgyan
Lilit Sargsyan
Elya Sahakyan
Gevorg Navasardyan
Narek Sahakyan

SCIENTIFIC PROGRAM COMMITTEE

Khachatur Meliksetian (IGS, Armenia)
Ruben Jrbashyan, (IGS, Armenia)
Mark Allen (University of Durham, UK)
Julian Pearce (Cardiff University, UK)
Charles Connor (University of South Florida, USA)
Donald Dingwell (LMU Munich, Germany)
Antonio Costa (INGV, Italy)
Olivier Bachmann (ETH Zürich, Switzerland)
Andrew Bell (University of Edinburgh, Scotland, UK)
Christoph Breitkreuz (TU Bergakademie Freiberg, Germany)
Ulrich Küppers (LMU Munich, Germany)
Guido Giordano (University of Roma, Italy)
Ralf Halama (Keele University, UK)
Jean-Phillipe Metaxian (University of Paris, CNRS, France)
Iain Neill (University of Glasgow, Scotland, UK)
Igor Nikogosian (Free University of Amsterdam, the Netherlands)
Anna Volynets (Institute of volcanology and seismology, Russia)
Ivan Savov (University of Leeds, UK)
Pavel Plechov (Fersman Mineralogical Museum, Russia)
Hripsime Gevorgyan (TU Bergakademie Freiberg, Germany)
Dork Sahagian (Lehigh University, USA)
Ara Avagyan (IGS, Armenia)
Ghazar Galoyan (IGS, Armenia)
Lilit Sahakyan (IGS, Armenia)

CONFERENCE SESSIONS

- **I. Geochemical fingerprinting of volcanism, convergent margin volcanism**
- **II. Volcanism and geodynamics, volcano-tectonic interactions, volcanic hazard assessment**
- **III. Volcano-seismology, geophysics, seismic tomography**
- **IV. Ignimbrites and Plinian eruptions**
- **V. Volcanism and geothermal energy resources**

Official Language of the Conference is English

CONFERENCE SCHEDULE

- ***September 03, 2023-Arrival to Yerevan and Icebreaker reception meeting***
- ***September 04, 2023-Opening and General Session, keynote lectures***
- ***September 05 and 07, 2023 - Conference section sessions by topics***
- ***September 06 and 08, 2023 - Mid-conference field trips***
- ***September 09, 10,11, 2023 - Post-conference field trips***
- ***September 12, 2023 - Departure***

CONFERENCE PROGRAM

03-08 September, NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF ARMENIA, M. Baghramyan Avenue 24

03 SEPTEMBER

Icebreaker: reception meeting at the Geological Museum of the Institute of Geological Sciences of Armenian National Academy of Sciences, At 18.00, M. Baghramyan Avenue 24a

04 SEPTEMBER

Hall of Presidium of the National Academy of Sciences of the Republic of Armenia

M. Baghramyan Avenue 24a

9:00-10:00 Registration

10:00-10:30 Opening and welcome address by:

President of the Armenian National Academy of Sciences, **Academician Ashot Saghyan**

Director of the Institute of Geological Sciences, of Armenian National Academy of Sciences

Dr. Sci. Khachatur Meliksetian

Director of Mineralogical Museum, named after A. Fersman, Moscow Russia, **Prof. Pavel Plechov**

Director of Department of Earth and Environmental Sciences of the Ludwig Maximilian University of Munich, Germany, **Prof. Donald Dingwell**

Earth & Environmental Sciences at Lehigh University, USA, **Prof. Dork Sahagian**

School of Earth and Environment, University of Leeds, UK **Dr. Ivan Savov**

10:30- 11:00 - Coffee break

PLENARY SESSION, KEYNOTE LECTURES:

Chairperson: Dr. Khachatur Meliksetian

11:00-11:30 Julian Pearce. Geochemical interpretation of collision volcanism.

11:30-12:00 Donald Dingwell. Melt chemistry and the eruptive properties of high silica explosive systems

12:00-12:30 Dork Sahagian. Drivers of explosive volcanic eruptions.

12:30-13:00 Karoly Nemeth. Volcanic architecture of one of Earth's largest long-lived mature intracontinental monogenetic volcanic province: western Arabian Peninsula.

13:00- 14:00 - Lunch break

PLENARY SESSION, KEYNOTE LECTURES:

Chairperson: Prof. Donald Dingwell

14:00-14:30 Khachatur Meliksetian. Collision related volcanism of Armenia: geodynamic setting and geochemistry.

14:30-15:00 Ivan Savov. Generation of petrologically and isotopically unique post collisional magmatic reservoir under Armenia.

15:00-15:30 Charles Connor. Building lava flow libraries to assess lava flow hazards in distributed volcanic fields.

15:30- 16:00 - Coffee break

SESSION I. GEOCHEMICAL FINGERPRINTING OF VOLCANISM, CONVERGENT MARGIN VOLCANISM:

Chairperson: Dr. Ivan Savov.

16:00-16:20 Pavel Plechov. Evolution of Island-arc magma sources: from primitive to mature arc.

16:20-16:40 Iain Neill. Re-thinking Caledonian collision magmatism in Scotland, and related ideas for Armenian studies.

16:40-17:00 Vadim Kamenetsky. Volatiles in kimberlite magmas – what drives ascent and causes explosive eruption?

17:00-17:20 Eilish Brennan. Boron and B-Sr-Nd isotopes as tracers of FME and volatile enrichments in the mantle source of Kamchatka arc basalts, insights from Kozelsky, Avachinsky and Khangar mafic series.

17:20-17:40. Anna Volynets. Arc monogenetic volcanism in the active fault zone (Sredinny range of Kamchatka): geochemical diversity of volcanic rocks and magmatic melts.

17:40-18:00 S. Heidari. Post collision evidences of magmatism in the NW of Iran.

05 SEPTEMBER

SESSION I. GEOCHEMICAL FINGERPRINTING OF VOLCANISM, CONVERGENT MARGIN VOLCANISM:

Chairperson: Prof. Karoly Nemeth

09:00-09:20 Olga Bergal-Kuvikas. Monogenetic volcanism in Malko-Petropavlovsk zone of transverse dislocations, Kamchatka.

09:20-09:40 Vesta Davydova. Copper redistribution from shallow oxidized magmas to mafic enclaves under Bezymianny volcano, Kamchatka.

09:40-10:00 Ghazar Galoyan. The earliest mesozoic manifestations of volcanism in the Lesser Caucasus (Republics of Armenia and Karabagh) in the Jurassic.

10:00-10:20 George Ovsyannikov. Mineral associations of middle Jurassic island-arc Pervomay-Ayudag intrusive complex, Crimea: genetical evolution and melt modelling.

10:20- 11:00 - Coffee break

11:00-11:20 Vasily Shcherbakov. Geochemical, isotopic and petrological constraints on the origin and evolution of the recent silicic magmatism of the Greater Caucasus.

11:20-11:40 M. Shchekleina. Pre-eruptive magma chamber conditions of the Rauchua tephra.

11:40-12:00 Tahereh Parsa. Late Cenozoic volcanic rocks of northern Zanjan, NW Iran.

12.00–13.00 UNIFIED POSTER SESSION

Igor Nikogosian. Geochronology and geochemistry of Mesozoic basic magmatism and geodynamics of South Armenian block.

Aazd Karimi. The research of post-collisional adakites in central Iran, Urumiyeh-Dokhtar magmatic belt.

Shirin Koohi. Ultrapotassic volcanism from Islamic peninsula, NW Iran.

O. Khubaeva. Hydrothermal eruptions in the coastal zone of Iturup island (Kuril islands).

Gevorg Navasardyan. Volcano-tectonic interactions and transition from polygenetic to monogenetic volcanism in the Lesser Caucasus (Armenia).

Ara Avagyan. Surface ruptures of volcano-gravitational origin on the territory of the Republic of Armenia.

Rogelio Ramos Aguilar. Geoscientific analysis of structural collapses in the city of Juan C. Bonilla,Puebla, Mexico (2021).

A. Khomchanovsky. Hazard to the coast after powerful earthquakes.

Jing-Hui Tong. Regional ariations in azimuthal anisotropy in the upper mantle beneath the eastern anatolia-caucasus: effect of recent lithospheric delamination.

Giada Fernandez. New insights into middle-late Pleistocene volcanic activity from Campi Flegrei (~ 160 - 90 ka).

Edmond Grigoryan. Plinain fall deposits from Ararat stratovolcano preserved in Armenia.

Gayane Grigoryan. The essence of geotourism at the department of volcanology, Geological museum named after professor H. Karapetyan of IGS, NAS Armenia.

R. Gasparyan. On the issue of the prospects of the Jermakhbyur geothermal system of the Syunik marz of the RA.

Anton Nuzdaev. Accumulations of mercury in altered rocks in thermal fields of the Bolshoi Semyachik volcanic massif (Kamchatka, Russia).

A. Kupchinenko. Secondary mineral formation on the surface of geothermal fields of the Bolshoi Semiachik volcanic complex, Kamchatka, Russia.

13:00- 14:00 - Lunch break

SESSION II. VOLCANISM AND GEODYNAMICS, VOLCANO-TECTONIC INTERACTIONS, VOLCANIC HAZARD ASSESSMENT

Chairperson: Prof. Dork Sahagian

14:00:14:20 **Peter LaFemina.** Cascading hazards in a migrating forearc-arc system: earthquake-earthquake and earthquake-eruption triggering in

Nicaragua.

14:20-14:40 Abdulrahman Alsowaigh. Monitoring of volcanic activity of one of the youngest active monogenetic volcanic field (Harrat) around Al Madinah, Western Saudi Arabia.

14:40-15:00 Yoshiyuki Yasuike. Considerations on volcanic hazard assessment for safety evaluation of nuclear facilities in Japan.

15:00-15:20 Khachatur Meliksetian. Probabilistic volcanic hazard assessment of Armenian nuclear power plant according to IAEA guidelines.

15:20-15:40 Ara Avagyan. Prehistoric petroglyphs showing a volcanic eruption.

15.40–17.00 CONTINUATION OF UNIFIED POSTER SESSION AND COFFEE BREAK

17:00-17:20 Katie Preece. New $^{40}Ar/^{39}Ar$ geochronology of Debed lavas, Northern Armenia.

17:20-17:40 Priya Minhas The evolution, eruptive recurrence rates and behaviour of monogenetic volcanism in the Gegham highlands, Central Armenia.

17:40-18:00 Monireh Kheirkhah. A brief summary of late Cenozoic collision magmatism across Iran.

06 SEPTEMBER

MID-CONFERENCE EXCURSION DAY 1, SEPTEMBER 06 (see pages 16-20 for details) 09:30 from the National Academy of Sciences of the Republic of Armenia

07 SEPTEMBER

SESSION III. VOLCANO-SEISMOLOGY, GEOPHYSICS, SEISMIC TOMOGRAPHY:

Chairperson: Dr. Lilit Sargsyan

09:00-09:20 Tai-Lin Tseng. The Transition of Crustal Properties, Lithospheric Thickness and Mantle Deformations in the Eastern Anatolia-Caucasus: Volcanisms Correlated?

09:20-09:40 Jean-Philippe Métaxian. Monitoring volcanic activity using dense networks of seismic sensors.

09:40-10:00 Andrew Bell. What might we expect from seismicity at volcanoes reawakening after long periods of dormancy? – lessons from recent unrest in Ecuador.

10:00-10:20 Elya Sahakyan. The features of seismic activity in the Gegham volcanic ridge (Armenia) determined by the temporary installed seismic network.

10:20-10:40 Jing-Hui Tong Regional variations in azimuthal anisotropy in the upper mantle beneath the Eastern Anatolia-Caucasus: effect of recent lithospheric delamination

10:40- 11:00 - Coffee break

SESSION IV. IGNIMBRITES AND PLINIAN ERUPTIONS:

Chairperson: Dr. Jean-Philippe Métaxian

11:00-11:20 Ulrich Küppers. Message in a pyroclast.

11:20-11:40 Hripsime Gevorgyan. Volcano-magmatic evolution of the "shield-like" Aragats stratovolcano, Armenia.

11:40-12:00 Gino González. Long-lasting eruption cycle of the caldera-forming Neapolitan Yellow tuff, Campi Flegrei, Italy

12:00-12:20 S. Smirnov. Formation of voluminous dacitic magmas of large caldera eruptions through a partial melting of amphibole-bearing shallow crust in southern Kuril Islands.

12:20-12:40 G. Portilla. On the influence of volcanism on climate change from a geological point of view.

12:40-13:00 Mehmet Bayraktutan. Erzurum Neogene caldera, Eastern Turkey: volcanic structures and active tectonics

13:00- 14:00 - Lunch break

SESSION V. VOLCANISM AND GEOTHERMAL ENERGY RESOURCES:

Session sponsored by PEER Sciences Project 9-252: Assessment of geothermal energy resources and natural hazards in Armenia

Chairperson: Prof. Clive Oppenheimer

14:00-14:20 Khachatur Meliksetian. Assessment of deep geothermal energy potential in Armenia

14:20-14:40 Natasha Toghramadjian. Application of ambient noise tomography (ANT) for geothermal exploration (Gegham volcanic ridge area) preliminary results.

14:40-15:00 E. Zhitova. Structural mineralogy and features of formation of a number of complex iron sulfates from low-temperature volcanic environments of Kamchatka.

15:00-15:20 Alexander Belousov. Periodicity of geyser eruptions: 82 years of observations in Kamchatka Peninsula, Russia.

15:20-15:40 Narek Sahakyan. Initial assessment of the geothermal potential of the thermomineral waters of the Hrazdan river middle stream catchment in Armenia.

15:40- 16:00 - Coffee break

16:00-17:00 Summary and conclusions

19:00 CONFERENCE DINNER AT PANDOK YEREVAN RESTAURANT,

ADDRESS: 91 TERYAN STREET

08 SEPTEMBER

MID-CONFERENCE EXCURSION DAY 2, SEPTEMBER 08

(see pages 20-27 for details)

09:00 from National Academy of Sciences of the Republic of Armenia

SEPTEMBER 09,10,11

POST-CONFERENCE EXCURSIONS,

(see pages 28-37 for details)

MID-CONFERENCE EXCURSIONS PROGRAM

(COST INCLUDED IN REGISTRATION FEE)

MID-CONFERENCE EXCURSION DAY 1, SEPTEMBER 06

1. Matenadaran - Scientific Research Institute of Ancient Manuscripts
2. Garni Hellenistic Temple and Fortress
3. Azat River Canyon and thick columnar joint lava flows
4. Geghard Monastery and thick volcanoclastic suite
5. Return to Yerevan

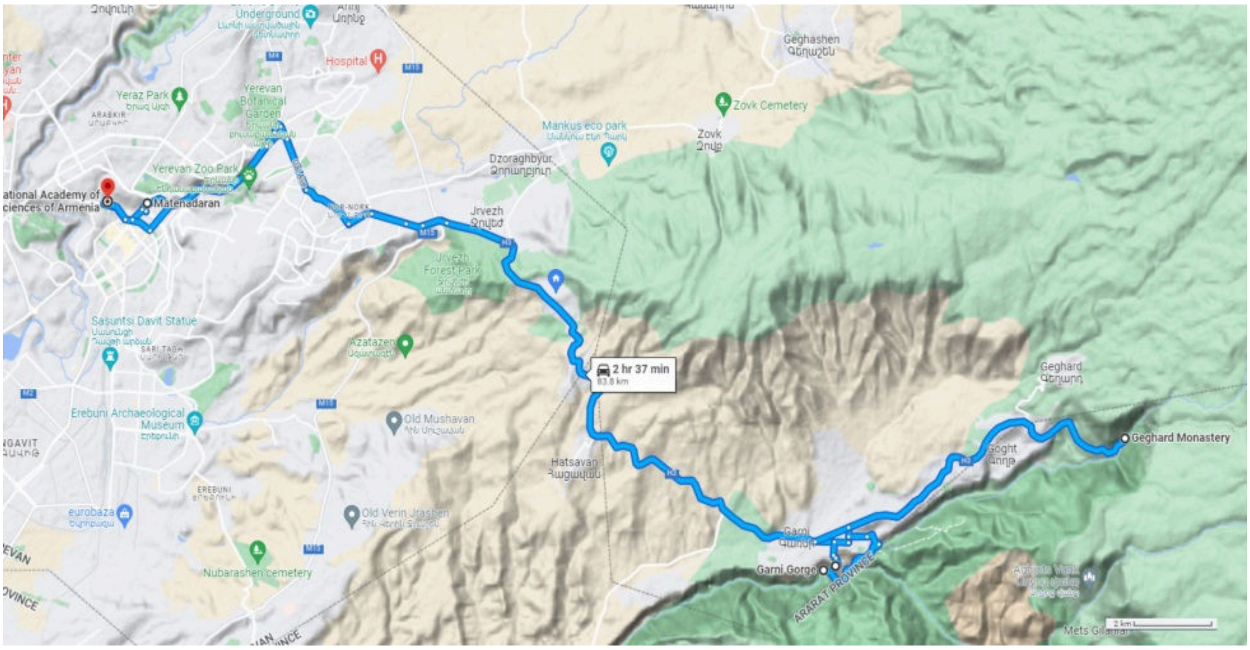


Figure 1.1. Route of first day mid-conference trip

First, we will visit Mesrop Mashtots Matenadaran, a repository of ancient manuscripts, a research institute and a museum in Yerevan. It holds one of the world's richest repositories of medieval manuscripts and books which span a broad range of subjects, including history, philosophy, medicine, literature, art history and cosmography in Armenian and many other languages (Fig. 1.2).

Afterwards we will visit Garni Fortress and the 1st century AD Classical Hellenistic Temple of Garni. It is located 28 km away from Yerevan. The fortification at Garni was a summer residence of the kings and the place where their troops were stationed. The structures of Garni combine elements of Hellenistic and national culture, which is evidence of antique influences and the distinctive building traditions of the Armenian people (Fig. 1.3).

Then the buses will take a route to the Azat River’s spectacular gorge, located a short distance from the temple, and see spectacular columnar jointing in a lava flow (dated 127 Ka years), and the Garni active fault. The source of the lava flow is within Gegham volcanic upland. Hexagonal prisms formed in the canyon are related to the slow cooling and cracking of lava flow in Armenia. It was given the name “Symphony of stone” and is recognized as a geological monument. (Fig. 1.4).

After lunch, we will visit the 4th-13th Century AD Geghard Monastery and view of Vokhchaberd volcanoclastic suite of the Upper-Miocene-Pliocene Age. The monastery complex was founded in the 4th century by Gregory the Illuminator at the site of a sacred spring inside a cave. Garni and Geghard are located in the foothills of the Gegham volcanic ridge's foothills in central Armenia (Figs. 1.4, 1.5 and 1.6).

Figure 1.2. *Matenadaran Scientific Research Institute of Ancient Manuscripts after Mesrop Mashtots.*

Figure 1.3*. Garni Hellenistic temple, 1st century AD.*

Figure 1.4. *Columnar joint trachybasaltic andesite lava flow in the canyon of Azat River near Garni.*

Figure 1.5. *General view of Vokhchaberd Late Miocene-Early Pliocene volcanoclastic suite cut by canyon of Azat river and Geghard Monastery.*

Figure 1.6. *Geghard Monastery, 4-13 century AD.*

MID-CONFERENCE EXCURSION DAY 2, SEPTEMBER 08

1. Aragats volcano and the Armenian ignimbrites (650 Ka)
2. Amberd historical fortress
3. Irind volcano and unique Plinian eruption section
4. Arteni rhyolite volcano (1.5 Ma)
5. Barozh mid-late Paleolithic open air site and obsidian workshop
6. Return to Yerevan

Figure 1.7. *Route of second day mid-conference trip*

Aragats volcano and Armenian Ignimbrites

A short stop at the foothills of Quaternary Aragats volcano. Aragats (4090m, Figs. 1.8, 1.9) is one the largest volcanoes in the entire region. It produced central vent (inc. Plinian VEI ≥ 5) and monogenetic type flank eruptions along with periphery plateaus with a total area greater than 5000 km^2, known as Aragats volcanic province (AVP). The AVP includes the composite cone of Aragats volcano, the peak of which is built on a summit plateau consisting of a ~45 km diameter shield structure with dozens of flank vents, scattered monogenetic cinder cones on the adjacent volcanic plateaus, and the neighboring stratovolcano of Arailer.

The vast fields of lava flows, ranging in composition from basalts to dacites and ignimbrites formed from Plinian eruptions in Armenia are related to Aragats volcano (Figure 10). New K-Ar and $^{40}Ar/^{39}Ar$ age determinations of groundmass and separated plagioclase samples indicate that volcanism at AVP began ~2.5 Ma, while the most recent volcanic activity is 0.49 Ma for a Plinian eruption of trachydacites from 1) the Irind flank vent, 2) basaltic trachyandesite lava flows from Tirinkatar (0.48-0.61Ma), Kakavasar, (0.52-0.54 Ma) and Ashtarak (0.58 Ma) monogenetic flank centers (Fig. 1.10), and 3) trachyandesites of Jrbazhan volcano on the summit plateau of Aragats (0.52 Ma). The Aragats stratovolcano itself is estimated to have been active between about 1 Ma to ~0.5Ma.

***Figure 1.8**. Aragats stratovolcano, 4090 m. a.s.l. last central vent and flank activity ~500 Ka.*

Figure 1.9. *The highest northern summit of Aragats stratovolcano (4090 m. a.s.l.)*

Figure 1.10. *Ignimbrites of Byurakan type with columnar joints covered by Tirinkatar trachybasaltic andesite lava flow. Note the columnar joints structure in ignimbrites..*

Amberd historical fortress

Amberd, a medieval fortress in Armenia (Fig. 1.11), is located on the southern slopes of Mount Aragats, on a triangular cape where the rivers Arkashen and Amberd join. Amberd means "a fortress in the clouds," a fitting name considering its elevation at 2 300 m above sea level. The mansion and some sections of the walls were constructed in the 7th century by the noble house of Kamsarakan. The site incorporates a rich variety of buildings including a church, a chapel, baths, walls and several gates.

Figure 1.11. *Amberd historical fortress and Ararat stratovolcano in the background*

Irind volcano Plinian eruption section

The Irind vent is located on the slopes of Aragats stratovolcano. Following the pyroclastic Plinian VEI=4 eruption that produced a ~13 m thick pumice fall deposit (Figs. 1.12 and 1.13) with overlaying ignimbrite, a voluminous (2.9-3.6 km^3) effusive eruption of Irind created up to 120 m thick trachydacite lava flows that extended 18 km from the vent, demonstrating the relatively low viscosity of Irind magma, unusual for such felsic lavas. The Irind eruption products are characterized by a plagioclase-two pyroxene mineral association that is atypical for Aragats. Our results support the view that often small eruptive vents (Irind) on the slopes of large coeval stratovolcanoes (Aragats) are not necessarily tapping the voluminous magma mushes underneath and are capable to deliver independent Plinian eruptions. The compositional differences between the volcanic products of the Irind cone compared to the main volcanic edifice of Aragats suggests that these are triggered by intrusions of hot, volatile-rich and alkaline felsic magmas that did not mix well with the otherwise dominant and older magmatic system beneath Aragats.

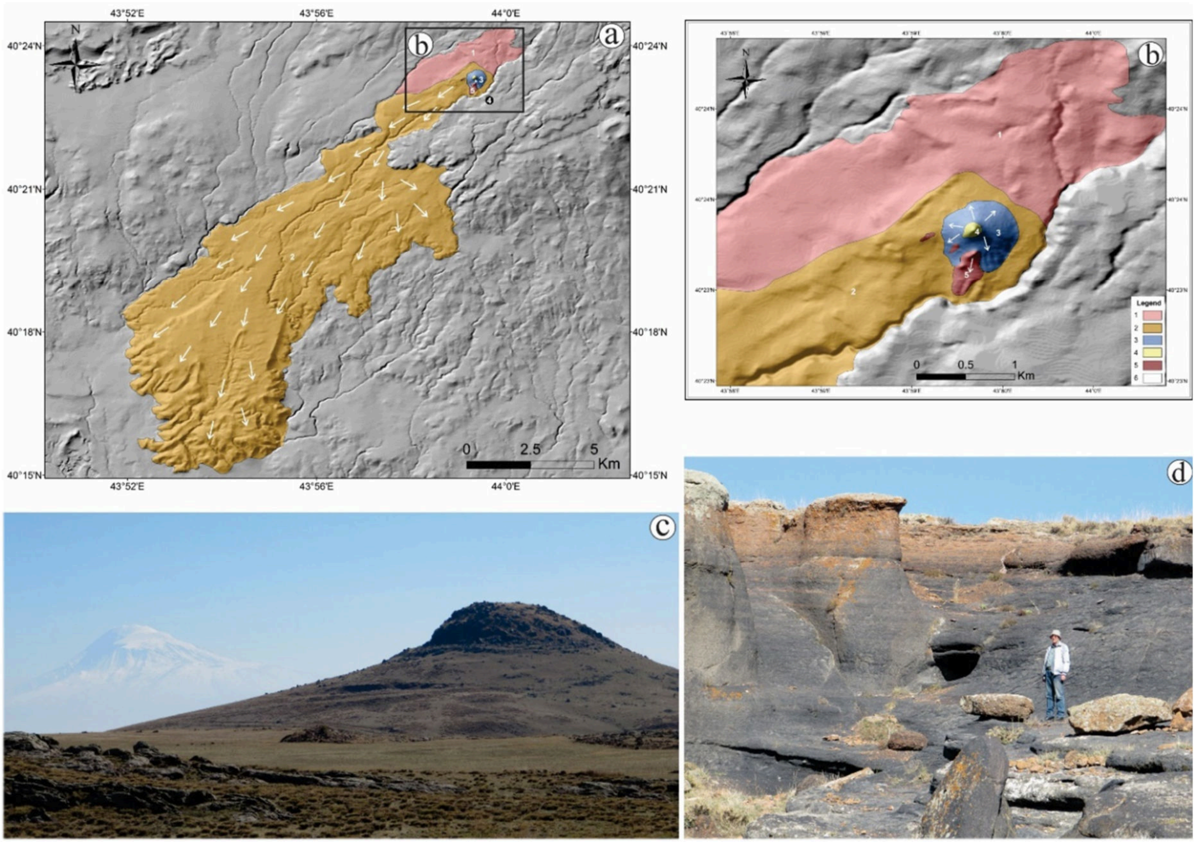


Figure 1.12. *Overview (a) and close-up (b) sketch maps of the Irind volcano and its products. Legend: 1. Explosive Sub Plinian phase, 2. Effusive phase, 3. The contour of Irind volcano, 4. Trachydacite dome (plug) of Irind volcano, 5. Lavas from a system of cracks. White arrows show directions of lava flows (c) Photograph of the vent/plug of Irind volcano with Ararat stratovolcano in the background (in white). (d) Black-reddish column-collapse vitrophyre outcropping on the western flank of Irind volcano.*

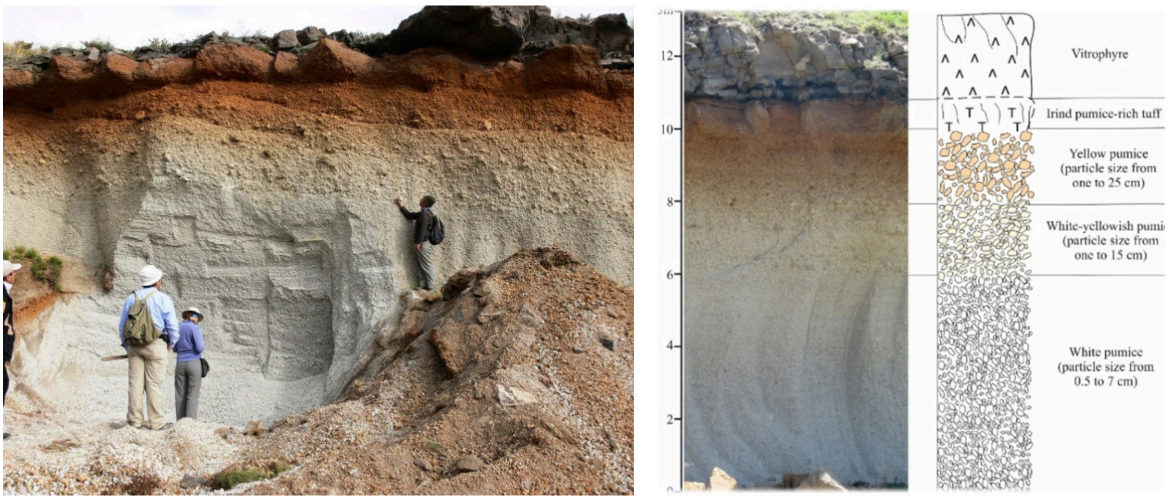


***Figure 1.13**. Plinian pumice fall and ignimbrite cover (left); Plinian fall deposit section (right)*

Arteni rhyolite (obsidian) volcano

Arteni volcanic complex (Figures 1.14, 1.15) is located within Aragats volcanic province; the age of Arteni rhyolites considered to be early Pleistocene, K-Ar ages yielded: for Medz Arteni 1.45-1.5 Ma (Chernishev et al., 2002), fission tracks (1.27 Ma; Oddone et al., 1999) and 1,26 Ma for Pokr Arteni

(Lebedev et al., 2011). Thus, rhyolitic eruptions and the formation of domes of Arteni volcano correspond to the Early Pleistocene. Eruption products of Arteni volcano are covered by more recent middle Pleistocene andesitic lava flows of the neighboring Kabakhler cinder cone and ignimbrites of Aragats stratovolcano.

Arteni is the most compound rhyolitic volcanic complex in Armenia and consists of two independent rhyolitic volcanoes: Mets (Big) and Pokr (Little) Arteni (2047 and 1754 m asl, respectively). Volcanic activity began with an eruption of perlite-pumice pyroclastics, followed by eruptions of detrital perlite and zonal obsidian that flowed westward and southward. Shorter flows also went northward (Fig. 1.15). Arteni obsidian is of high quality. "Smoky quartz" with varieties such as translucent, reddish-brown and black are observed- see (Karapetyan (1972) for details.

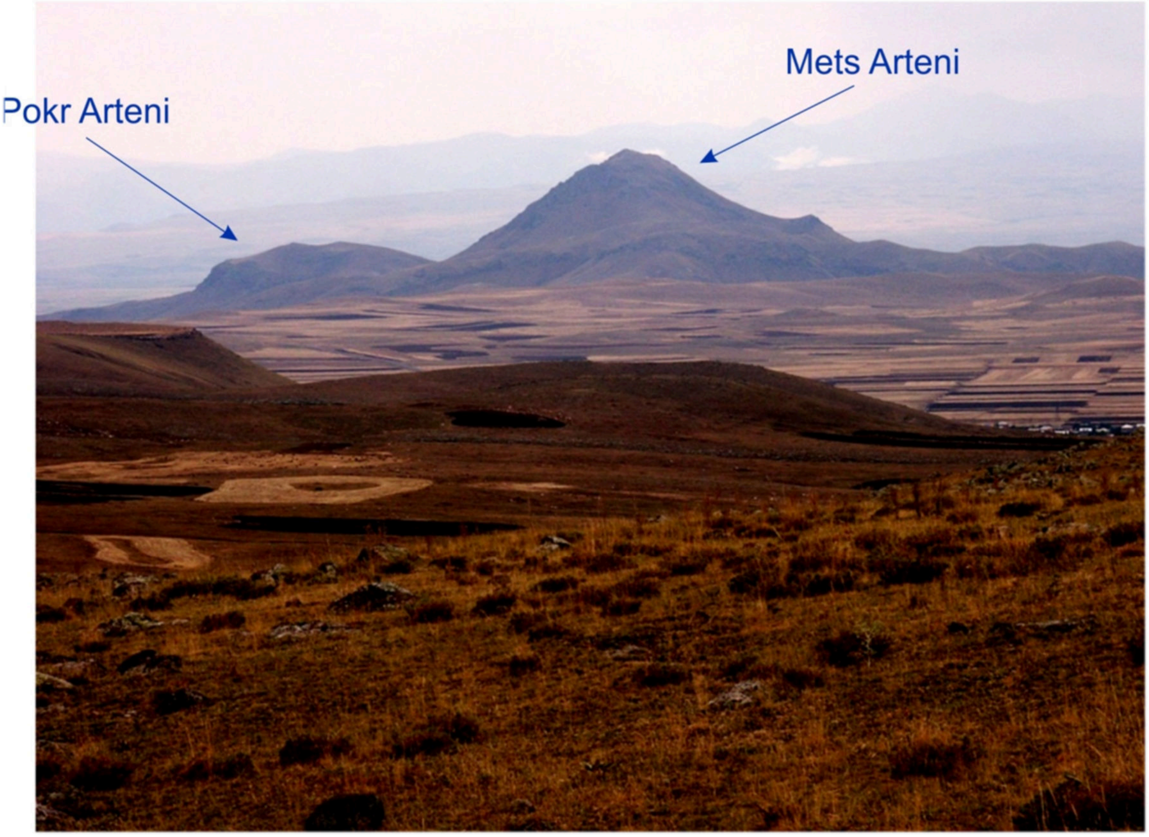


Figure 1.14. *Arteni volcanic complex in Armenia, Aragats volcanic province.*

Figure 1.15. *Products of explosive eruptions of rhyolite pumice and perlite pyroclastics (left). Obsidian cliff in small modern quarry across a lava flow erupted from Pokr Arteni volcano (right).*

Barozh Middle Paleolithic open air site and obsidian workshop

The newly discovered site of Barozh 12 open air Middle Paleolithic site was studied recently by the international archaeological team, summarized in Glauberman et al., (2013). It is located in western Armenia, near Arteni volcano (Fig. 1.16). The site yielded significant data on Late Middle Paleolithic technology, land use, and lithic economy in a region that has heretofore been little explored. The lithic assemblage (Fig. 1.17) appears similar to those from other later Middle Palaeolithic sites in the region and could date to the time range when archaic and anatomically modern species populations overlapped temporally and/or geographically. Barozh 12 is a large, high-density Middle Paleolithic site. The surface of a 1m×1m unit, and a 0.50m × 0.50m × 0.95m deep test trench yielded 1174 artifacts. Based on preliminary analysis of samples from the surface (n = 102) and excavated artifact assemblages (n = 340), both display typo-technological characteristics of the Middle Palaeolithic in the region. Both discoidal and triangular Levallois core reduction is observed on discarded cores and flakes, as are numerous retouched pieces, predominantly classified as points, blades, and a variety of unifacial scrapers. Surface and excavated artifacts are of all size classes and technological categories, including tool re-sharpening flakes and core trimming elements. Artifacts class frequencies and cortex analysis also suggest that all stages of core reduction and tool use, maintenance and discard occurred on site. Preliminary results of portable X-Ray fluorescence (pXRF) on a small sample of obsidian artifacts (mainly retouched pieces) indicate that most were manufactured from local (1-2km) Pokr and Mets Arteni material, while a smaller number of artifacts were manufactured on material that originates from 80km –>100km away. Varying frequencies of local and ‘imported’ raw materials observed in small samples from stratified archaeological levels suggest dynamic raw material transport patterns over time.

Figure 1.16. View of Barozh open-air Paleolithic site and test trench. Arteni volcano is in the background.

The extent of a ‘raw material exploitation territory’ is suggested by obsidian sourcing though only to the east of the site. Further pXRF study of obsidian raw materials in conjunction with further analysis of artifact manufacture and discard patterns, will elucidate regional-scale technological and land use behavior. These first results of survey, lithic assemblage analysis, and test excavation indicate that Barozh 12 was frequently reoccupied over time for a variety of uses, and may be considered a ‘central place’ in the regional settlement and mobility system.

***Figure 1.17**. Artifacts from the test trench at Barozh12 (after Glauberman et al., 2013).*

2. Post-conference excursions, September 09-11
(cost 350 USD)

Excursions program

Post-conference excursion day 1, September 09

1. Shamiram volcanic plateau
2. Shamiram and Karmratar volcanoes
3. Yerevan ignimbrites and Artik "lava-like" ignimbrites
4. Harichavank monastery
5. Return to Yerevan

***Figure 2.1.** Post-conference trip route, day 1*

Shamiram volcanic plateau

The Shamiram plateau occupies the southern periphery of the Aragats volcano, where the topography changes from gentle slopes to the flat relief of the Ararat basin.

The Shamiram Plateau is of volcanic origin and is formed by thick sequences of lava flows and ignimbrites. 16 cinder cones with lateral vents and two maar-like structures reflect a long history of monogenic volcanism that eventually created the plateau itself between ~1.54-0.64 Ma. Of particular interest regarding the geology, volcanology, and stratigraphy of the Shamiram Plateau is the location of the Armenian Nuclear power plant (ANPP) site, directly next to the southern edge of the Shamiram Plateau, and near the volcanoes of the Dashtakar group, where lavas are covered by lacustrine deposits of the Ararat Depression.

The cinder cones on the Shamiram plateau have been grouped into 5 separate clusters, namely: Shamiram, Karmratar, Blrashark, Dashtakar, Atomakhumb. The northern slopes of Shamiram, Karmratar, Atomakhumb, and Blashark cones (850-750 Ka), oriented towards Aragats stratovolcano, are covered by ignimbrites, (655 Ka, $^{40}Ar/^{39}Ar$). While Dashtakar cones are younger and belong to post-ignimbrite stage of volcanism of the Aragats volcanic province (647 Ka, $^{40}Ar/^{39}Ar$). Data from wells drilled at the ANPP site show that Miocene sedimentary formations are located at the base of the plateau, at a depth of ~360-393 m from the surface. According to the results of $^{40}Ar/^{39}Ar$ dating, the oldest lava flow from borehole 3NA is dated at 1.54±0.024 Ka, that probably belongs to yearly stages of activity of Aragats. The youngest lava flow found on the Shamiram plateau is the 22 km long Tirinkatar lava flow, 0.614±0.019 Ma, originated from a side vent on the slopes of Aragats.

Ignimbrites are also found inside the craters of Shamiram, Karmratar and two other Atomahumb cinder cones. Figure 2.2 shows the presence of ignimbrites in the crater of the Kamratar volcano cinder cone, reaching a height of 140 m above the base, which indicates the high kinetic energy of the pyroclastic flow and it’s ability to override topographic barriers, since immediately after the cone ignimbrite cover continues.

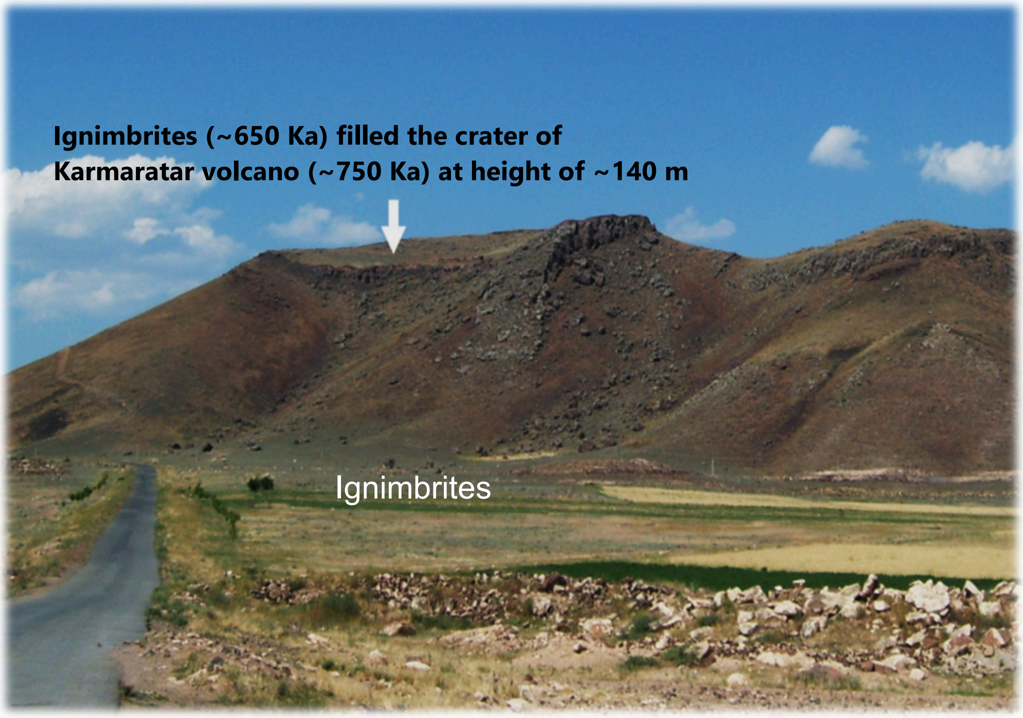


Figure 2.2. *Karmaratar volcano with crater filled by ignimbrites*

Harichavank monastery

The peculiarity of Haritchavank Monastery is that large stones (Artik-type strongly welded ignimbrite, 0.71 Ma) of different shades were used for its construction (Fig. 2.3). Multicolored elements create a unique pattern on the walls of the building. Harichavank is one of the most famous monastic centers in Armenia and it was especially renowned for its school and scriptorium. The oldest part of this Armenian monastery is the Church of St. Gregory the Illuminator; it is a domed structure that is usually placed in the category of so-called “Mastara-style” churches. The founding date of the monastery is unknown, but probably it was built no later than the 7th century, when the St. Gregory church was erected.

Figure 2.3. Harichavank monastery build of strongly welded Artik-type ignimbrites (0.71 ma) and a cliff by same ignimbrite.

Post-conference excursion day 2, September 10

1. Nor Geghi Mid-Paleolithic site (400-200 Ka).
2. Gutansar volcano
3. Sevan peninsula, Sevanavank monastery
4. Stay in Martuni

Figure 2.4. *Post-conference trip route, day 2*

Nor Geghi-1 Lower to Middle Paleolithic site

The Nor-Geghi-1 site is located in the canyon of the Hrasdan river, and marks the Lower to Middle Paleolithic transition (~400,000 to 200,000 years BC). The site contains dated sections of lava flows, volcanic ash and paleosols with tools (Fig. 2.5). It was studied by an international archaeological team, whose research is summarized in Adler et al., (2014).

The Lower to Middle Paleolithic transition (~400,000 to 200,000 years ago) is marked by technical, behavioral, and anatomical changes among hominin populations throughout Africa and Eurasia. The replacement of bifacial stone tools, such as handaxes, by tools made on flakes detached from Levallois cores documents the most important conceptual shift in stone tool production strategies since the advent of bifacial technology more than one million years earlier and has been argued to result from the expansion of archaic Homo sapiens out of Africa. Data from Nor Geghi 1, Armenia, record the earliest synchronous use of bifacial and Levallois technology outside Africa and are consistent with the hypothesis that this transition occurred independently within geographically dispersed, technologically precocious hominin populations with a shared technological ancestry. The archaeology of Nor Geghi-1 is contained within alluvial sediments sandwiched between an upper (Basalt 1) and a lower (Basalt 7) lava flow (Fig. 2.6). The $^{40}Ar/^{39}Ar$ technique was used to date Basalt 7 (441 ± 6 ka) and Basalt 1 (197 ± 7ka) thereby bracketing the stratified alluvial sediments between late OIS 12 and the end of OIS 7 (Fig. 2.7). The five stratigraphic units recorded between the basalts (from bottom to top, Units 5 to 1) form a normally bedded sequence of fine-grained sedimentary beds, with minor sands and gravels toward the base.

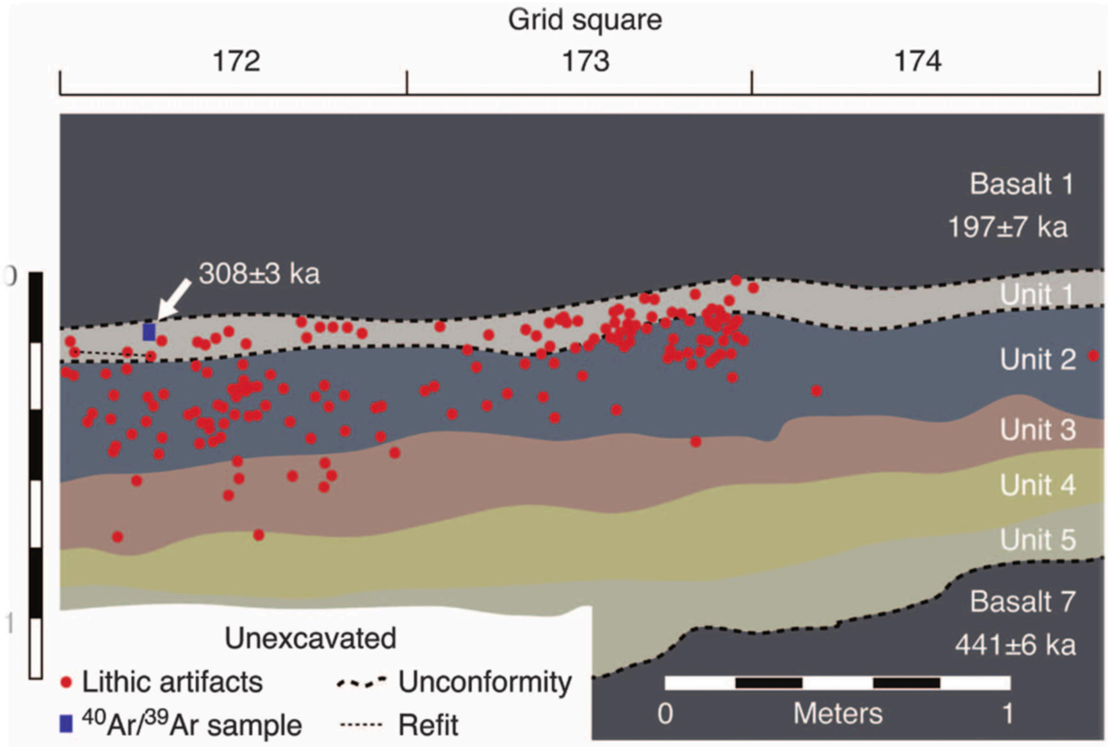


Figure 2.5. *Representative stratigraphic section at Nor Geghi-1 site (after Adler et al., 2013)*

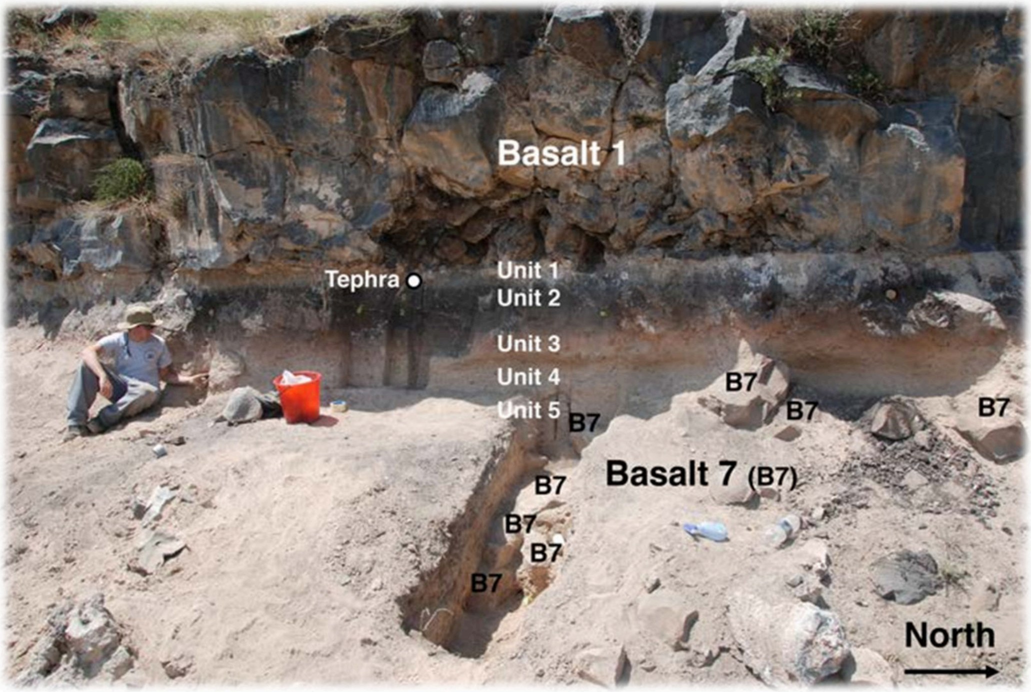


Figure 2.6. *The northern area of excavation illustrating the locations of Basalts 1 and 7, the $^{40}Ar/^{39}Ar$-dated tephra sample from Unit 1, and Units 5–1 (after Adler et al., 2013).*

Gutansar volcano

The Gutansar volcanic complex, located near the Hrazdan Gorge, represents a bi-modal volcanic system: rhyolitic dome cut by basaltic-andesite cinder cone. It is one of the most archaeologically important obsidian sources in the South Caucasus. Gutansar volcano is shown in Figure 2.7. The activity of Gutansar began with eruptions of rhyolitic pyroclastic material followed by rhyolitic flows and obsidians, (Fig. 2.8) and ended with quite lengthy flows of rhyolitic and dacitic lava, the final portions of which plugged the volcano channels and formed typical dome-shaped structures. In the late Middle Pleistocene (~200 Ka), the volcano was cut by other volcanoes of andesite and basaltic andesite composition (Fig. 2.9), which erupted extended lava flows. A large crater (600 m in diameter, 5-8 m deep) formed on the Gutansar summit during the Late Pleistocene. The Large rhyolite-obsidian Extrusion (Djraber extrusion) occupies an area between the villages of Fantan, Gyumush (Karenis), Djraber, and Charentsavan city.

Figure 2.7. *Gutansar volcano, Gegham volcanic upland.*

Figure 2.8. Scoria open pit on the slopes of *Gutansar volcano (photo by Tigran Amaryan)*

Figure 2.9. *Jraber extrusive body related to the Gutansar volcanic complex. Obsidian outcrop near the Yerevan-Sevan highway.*

Lake Sevan.

Lake Sevan is the largest freshwater lake in Armenia and the entire western Asia region (Fig. 2.10). The altitude of the lake is ~1900 m. The geology of the lake and its surroundings represent an interesting combination of Quaternary and Holocene tectonics and volcanism. The area of the lake is ~1241 km^2, with a watershed of 4891 km^2. The northern part of the lake is named the Lesser Sevan and has the greatest depth (83 m). The southern part, or the Greater Sevan, is twice as large as the Lesser Sevan, but it is only up to 30 m deep.

Figure 2.10. *Lake Sevan with volcanoes of Gegham highland in the background*

Geologically, the northeastern shore of Lake Sevan is characterized by the occurrence of an ophiolitic suture of Middle Jurassic to Early Cretaceous age that corresponds to the structural boundary between the periphery of Eurasia and the South Armenian block (Galoyan et al., 2009; Sosson et al., 2010; Asatryan et al., 2010). The continental collision occurred to the north of the South Armenian block during the Paleocene (Sosson et al., 2010).

The Gegham volcanic upland in central Armenia, located south of Lake Sevan is a typical example of monogenetic volcanism in Armenia and is presented morphologically by an elongated oval shield. The highest point of the Gegham upland, among 127 known volcanic centers, is Azhdahak volcano, 3597 m. The period of activity of the Gegham volcanic upland ranged from Late Miocene (Baghdasaryan & Ghukasyan, 1985) until the Holocene (Karakhanyan et al., 2003). Within the upland, Late Pliocene-Quaternary volcanic activity is represented by volcanic products erupted from monogenic centers varying in composition form trachybasalts, baslatic-trachyandesites,-trachyandesites to trachytes trachydacites and trachyrhyolites, (Jrbashyan et al., 2007).

The right-lateral strike-slip Pambak-Sevan-Syunik fault system, described in the next section, branches into two segments near the northern shore of the lake. One of the segments, PSSF-2, stretches along the northeastern shore of the lake and south of the thrusts associated with the ophiolitic suture. The second segment, PSSF-3, stretches across the lake floor and emerges on its southeastern shore. The western shore of the lake is framed by the N-S-striking system of the normal Gavaraghet faults defining horst and graben structures (Fig. 2.11). The volcanic ridges of Gheham and Vardenis, including many centers of Quaternary monogenetic volcanism, represent the western and southern boundaries of the Lake Sevan basin.

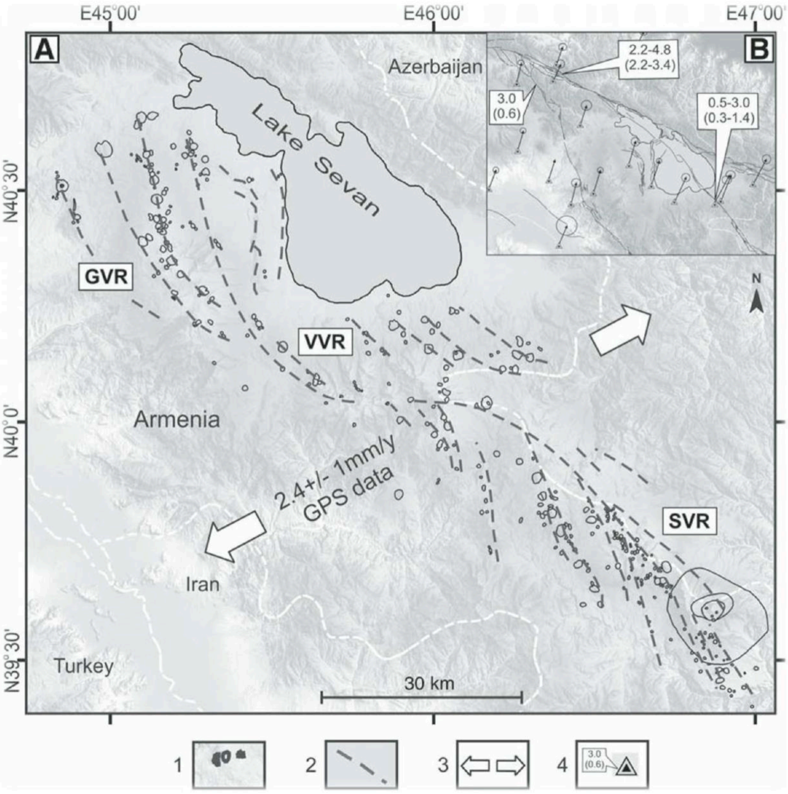


Figure 2.11. *(A) Linear clusters of Quaternary and Holocene volcanoes bearing evidence of NE-SW extension. 1—Quaternary volcanoes; 2—linear clusters of volcanoes; 3—extension directions and velocities according to global positioning system (GPS) data (Davtyan, 2007); 4—horizontal slip rates from long-term geological data and GPS measurements (mm/yr), placed above and below in parentheses, respectively. (B) Slip-rate data from the geological and GPS data. GVR—Ghegam volcanic ridge; VVR—Vardenis volcanic ridge; SVR—Syunik volcanic ridge. (After Karakhanyan et al., 2017)*

Sevan Peninsula and Sevanavank monastery

Sevanavank is a 9th century monastic complex located on a peninsula at the northwestern shore of Lake Sevan (Fig. 2.12). Sevanavank is a monastic complex located on a peninsula at the northwestern shore of Lake Sevan in the Gegharkunik Province of Armenia, not far from the town of Sevan. Initially the monastery was built at the southern shore of a small island. After the artificial draining of Lake Sevan, which started in mid-twentieth century during Soviet times, the water level fell about 20 meters, and the island transformed into a peninsula.

Figure 2.12. *Sevanavank monastery (9th century AD) on Sevan peninsula*

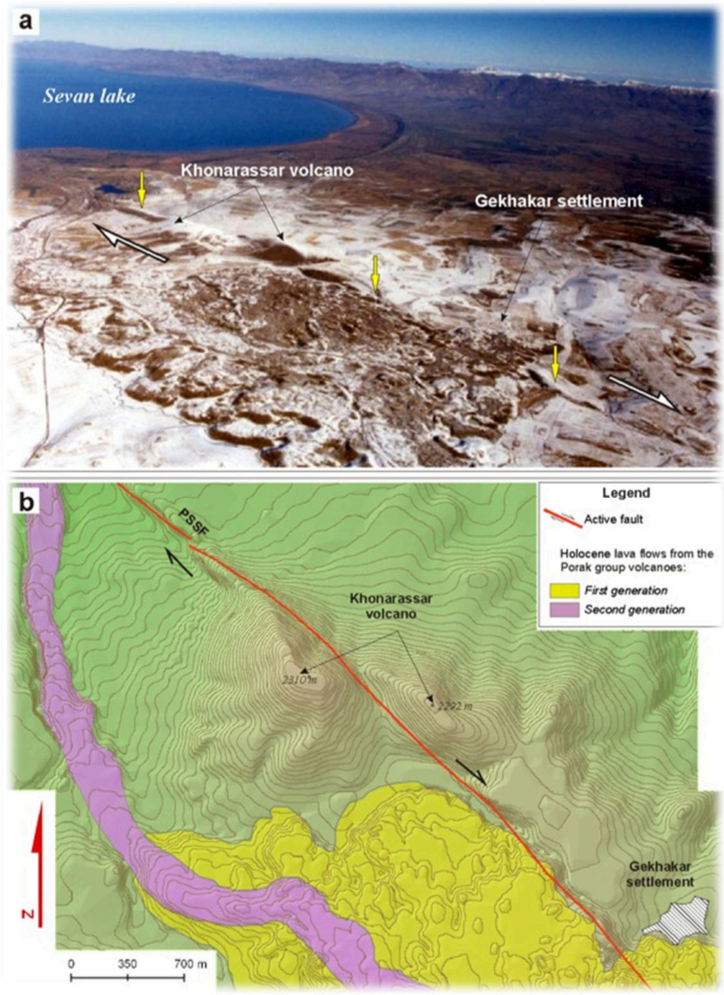
According to an inscription in one of the churches, the monastery of Sevanavank was founded in 874 by Princess Mariam, the daughter of Ashot I (who became a king a decade later). At the time, Armenia was still struggling to free itself from Arab rule. The two churches of the complex, Surp Arakelots meaning the "Holy Apostles" and Surp Astvatsatsin meaning the "Holy Mother of God", are both similar cruciform plan structures with octagonal tambours. Adjacent are the ruins of a gavit whose roof was originally supported by six wooden columns. Some of the remains of the gavit and its columns can be seen in the Yerevan Museum of History. Reconstruction and restoration efforts took place from 1956 to 1957.

POST-CONFERENCE EXCURSION DAY 3, SEPTEMBER 11

1. Khonarasar volcano split by an active fault
2. Armaghan volcano
3. Vayotssar volcano
4. Return to Yerevan

Figure 2.13. *Post-conference trip route, day 3*

Khonarassar volcano



Khonarhasar is located in Gegharkunik marz, about 2.5 km south of Lchavan village. Volcano represents unique site linked to volcanism and active tectonics. The Khonarhassar segment of the Pambak-Sevan-Sunik strike-slip fault splits and displaced Khonarasar volcano with offset up to 750 m, (Philip et al., 2017), figure 2.14. The minimum slip rate of the fault was estimated at 0.53 ± 0.04 mm/year over an interval of 1.4 Ma considering the age of Khonarhassar volcano is 1.4 Ma K/Ar age determination. (Philip et al., 2001).

Figure 2.14. *a) Aerial photo of Khonarassar volcano split and displaced by about 750 m. by fault b) simplified geological map of Khonarasar volcano.*

Vayotssar volcano

Vayotssar is a large monogenetic volcano (cinder cone) that has been wonderfully preserved with a peak elevation of 2586.3 m (Fig. 2.15). The cone base diameter is 1600 m, and its relative height is 330 m. A funnel-shaped crater has been well preserved on the volcano summit and has a diameter of 500 m and the depth of 100 m. Crater walls are inclined 35° to the horizon. There are shallow vertical fractures on the volcanic body (linear erosion gullies, barrancoses) spreading from the crater to the base. The cone is mainly composed of scoria of lapilli dimensions. $^{40}Ar/^{39}Ar$ age determinations for lava flow of second generation yielded ~31 Ka. A few small open mines of scoria sand are present in the northern part of the volcano, which expose cinder stratification reflecting pulses of Strombolian explosive eruptions. Stepwise concentric gravitational terraces have developed on the cone slopes. The cinder cone and the described structural features are illustrated in Figures 3.3 and 3.4. Circumferential NW-SE oriented lava extrusions can be observed on the southwestern side of the cinder cone base (Fig. 2.16.). These lavas ultimately plugged the volcanic fissures that erupted late-stage lava flows The longer flow travelled up the Arpa River gorge and covered river terraces. The lava flow is traversed by the Malishka-Vaik section of the Yerevan-Meghri Highway, where it is possible to view the lava flow and its blocky nature. The Bronze Age to Middle ages settlement of Moz, situated on the margin of this lava flow, was destroyed by earthquake in 735 AD is. Armenian historian Movses Kaghankatvatsi (tenth century AD) writes: «Impenetrable darkness covered the Mozan region and the place shook for 40 days; thousands of people were buried alive under ground. This is why the place was called Vayots Dzor».

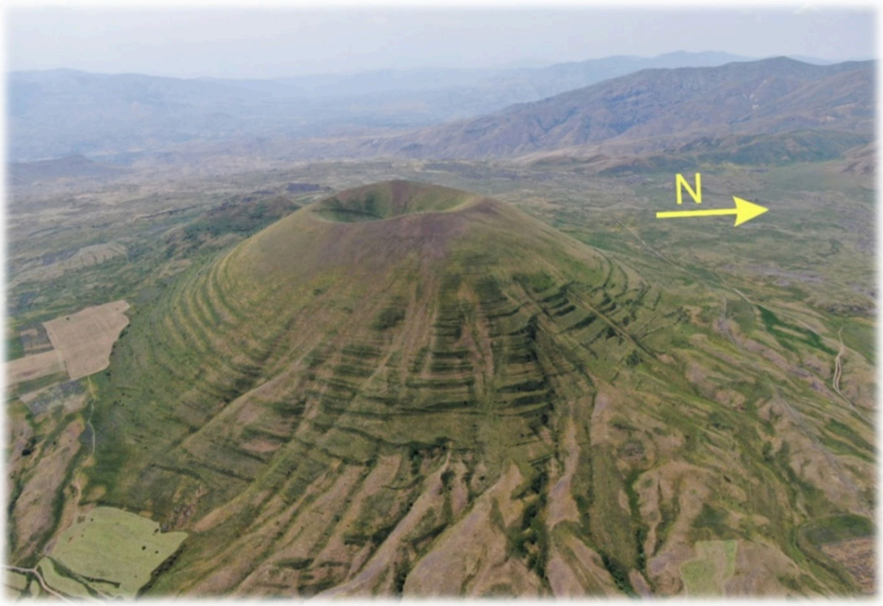


Figure 2.15. *Vayotssar Volcano and vertical linear gullies (barrancoses) and step-wise gravitational concentric terraces.*

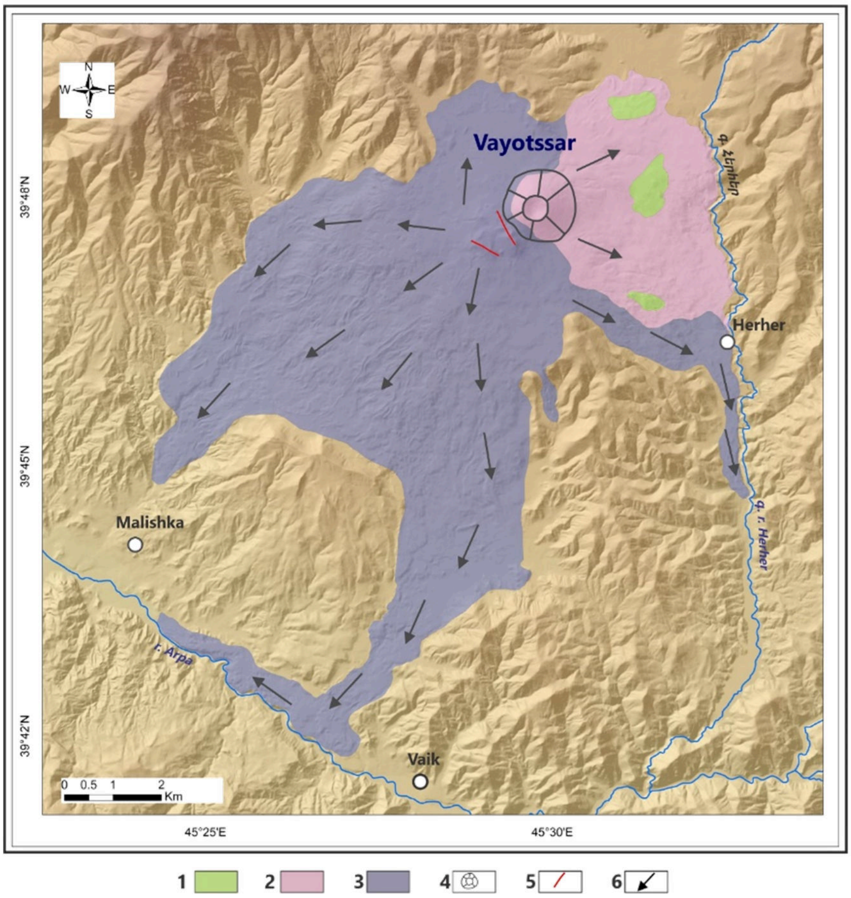


Figure. 2.16. *Simplified geological map of Vayotssar volcano. Late stage of the Late Pleistocene: 1. Pyroclastic units; 2. Generation 1 of the trachybasaltic andesite lava; 3. Generation 2 of the trachybasaltic andesite lava; 4. Vayotssar cinder cone; 5. Volcanic fissures that ejected the lava; 6. Directions of lava flows*

ABSTRACTS

1. GEOCHEMICAL FINGERPRINTING OF VOLCANISM, CONVERGENT MARGIN VOLCANISM

GEOCHEMICAL INTERPRETATION OF COLLISION VOLCANISM

Julian A. Pearce[1,2]

[1] School of Earth and Environmental Sciences, Cardiff University, Park Place, Cardiff CF10 3AT, UK PearceJA@cf.ac.uk . *[2] London Centre for Ore Deposits and Exploration (LODE), Natural History Museum, Cromwell Road,*
London SW7 5BD, UK

Collision volcanism may be defined as volcanism that takes place during an orogeny from the moment that continental subduction starts to the end of orogenic collapse. There are many types of collision-driven volcanic province: continent-island arc collision (e.g. Banda arc); continent-active margin collision (e.g. Tibet, Turkey-Iran); continent-rear-arc collision (e.g. Bolivia Altiplano); continent-continent collision (e.g. Tuscany); and island arc-island arc collision (e.g. Sangihe Arc). Superimposed on this variability is the fact that every orogeny is different in detail. Nonetheless, there is a general theme of cyclicity on different time scales. This starts with syn-collision volcanism resulting from the subduction of an ocean-continent transition zone and continental margins, and continues, typically following a volcanic gap, through post-collision volcanism. The latter can be subdivided into orogenic volcanism, which is related to thickened crust, and post-orogenic, which is related to orogenic collapse. Commonly, collision volcanism is preceded by normal arc volcanism and followed by normal intraplate volcanism. The basis of fingerprinting collision terranes is to use geochemical proxies for mantle and subduction fluxes, slab temperatures, and depths and degrees of melting. For example, syn-collision volcanism is characterized by a large subduction flux relative to mantle flux because of the high input flux of fusible sediment and crust coupled with limited mantle flow, and because of high slab temperatures resulting from the decrease in subduction rate. The resulting geochemical patterns have extreme LILE and significant HFSE enrichment relative to MORB and with large negative Nb-Ta and Ti anomalies. Post-collision volcanism is, however, more complex, involving variable combinations of slab detachment, delamination, and slab roll-back (orogenic) and extension (post-orogenic), coupled with variable degrees of interaction with continental crust. In this talk, I will summarize the principal features of collision volcanism from a petrogenetic perspective. I will then present new work, which focuses on the interplay between a geochemical proxy (Th/Nb) for crustal input (subduction and assimilation) and a proxy (Ti/Yb) for residual garnet. This methodology can be used to add further insights into the petrogenetic evolution of the Tertiary-Recent, Arabia-Eurasia collision volcanism across the Anatolia- Caucasus transect.

GENERATION OF PETROLOGICALLY AND ISOTOPICALLY UNIQUE POST-COLLISIONAL MAGMATIC RESERVOIR UNDER ARMENIA

Ivan P. Savov
Institute of Geophysics &Tectonics, School of Earth &Environment, University of Leeds, UK;
I.Savov@leeds.ac.uk

The Armenian Highland is the only place on Earth where young volcanism is occurring above actively colliding major tectonic plates. The landscape is covered by deposits and features that reflect spectacular examples of both focused and distributed post-collisional volcanism. The focused volcanism is expressed superbly by the large Quaternary shield-like edifice of the Aragats stratovolcano (4090m) that erupts very thick lava flows with mostly andesite-dacite composition and voluminous series of dacitic ignimbrites (tuffs). The Armenian capital Yerevan and the currently functioning Metzamor NPP are built on top of or nearby such deposits. The distributed volcanism is very-well recorded within a series of SE-NW striking Quaternary monogenetic fields associated with several large caldera-forming complexes and abundant pull-apart basins and faults (Syunik-Vardenis-Gegham [SVG] Magmatic Province). The post-collisional rocks erupted at SVG represent the entire range of volcanic products (basanite to rhyolite) that are distinct in respect to other volcanoes across to Anatolia-Armenia-Iran plateau and are compositionally similar to those of Aragats. Nearly all of the magmas erupting at these Armenian post-collisional settings are with non-hydrous mineralogy (OL+PX+PLAG) and usually erupt transitional in composition (between classical CA arc and tholeiitic OIB) volcanic products. I will evaluate the petrology and geochemistry of selected well-interrogated magmatic suites and contrast them against “classical” continental arc and rift-related assemblages. My focus will be on the systematics of Sr, Nd and B isotopes, which together with the mineralogy and the trace element signatures reveal a surprisingly homogeneous igneous magmatic source that feeds volcanism. I will evaluate possible mechanism to form such distinct isotopic reservoir and highlight possible future studies that may shed further light into the sources and driving forces of post-collisional volcanism. I will speculate on how such cloistered chemical signatures can be further used in various provenance studies (archaeology, human evolution, tephrostratigraphy, paleoclimate, etc.).

COLLISION RELATED VOLCANISM OF ARMENIA: GEODYNAMIC SETTING AND GEOCHEMISTRY

Khachatur Meliksetian
Institute of Geological Sciences, National Academy of Sciences of Armenia, 24a Marshal Baghramyan Avenue, Yerevan, Armenia, khachatur.meliksetian@geology.am

Territory of Armenia is located in NE part of the Anatolian-Armenian-Iranian orogenic plateau in a continental collision zone composed of different geotectonic units such as South Armenian Block of Gondwanian origin, Somkheto-Karabakh Mesozoic island arc, Amasia-Sevan-Akera suture zone, and two over imposed units: Paleogene volcanic belt and finally widespread post-collisional volcanism lasted from late Miocene to Holocene-Historical times.

Quaternary volcanism in Armenia is characterized by different eruptions styles from plateau-basaltic-like voluminous fissure eruptions to ignimbrite-forming Plinian eruptions from stratovolcanoes as well as five distributed volcanic fields, representing one of the densest monogenetic clusters on the Earth (Sugden et al. 2021). Monogenetic clusters are oriented NW to SE, perpendicular to the major stress direction related to the movement of the Arabian plate from SW to NE.

Volcanic activity in Armenia is characterized by diverse compositions – ranging from basanites to rhyolites and variable alkalinity.

Large-volume plateau-basaltic magmatism to the north of Amasia-Sevan-Akera suture zone can be explained as a result of the detachment of the northern Pontide slab in the late Miocene (Skolbeltsyn, 2014, Neill et al, 2015), apart from the detachment of the southern slab beneath Bitlis-Zagros suture (Keskin et al., 1998), which caused the rise of hot asthenosphere within the territory of Armenia and the entire northern part of the Armenian Highland and triggered large-scale melting of the lithospheric mantle.

Geochemical variations from North to South are observed and are linked to changes in lithospheric thickenss and melting depths and lithospheric mantle sources. Post-collisional volcanism of Armenia is associated with two different mantle sources. One of them is the “dolerite” lithospheric mantle source and the second one is Kapan and Syunik-II source of basanites partially exposed also in the volcanism of Vardenis upland. A comprehensive analysis of geochemical characteristics of volcanism of Javakheti plateau, Aragats, Gegham and Kars-Erzrum plateaus demonstrate their uniformity. Therefore, Vardenis and Syunik represent a boundary between two different mantle domains: Kars-Erzrum-Javakheti-Gegham (“dolerite”) to the north-northwest and Syunik-Kapan- NW Iran (“basanite”) to the south. The influence of Mesozoic subduction is observed in the “dolerite” mantle source, while in the south, in “basanite” source, the influence of distinct subduction components associated with the younger Zagros subduction is well pronounced.

By using Sr/Y geochemical proxy as an indicator of crustal thickness, it is demonstrated that within the NE part of the Armenian Highland, the Moho depth surface increases in the direction from northwest to southeast: from Javakheti Ridge and Aragats to Syunik volcanic highland and NW Iran. These data indicate that the boundary between the area of thickening of the crust and lithospheric delamination lies at the border of Gegham and Vardenis volcanic highlands.

As a result of spatial analysis of geochronological data of the entire region, it turns out, that in the Arabian collision zone, lateral migration of slab break-off events and associated initiation of post-collisional magmatism occurred from the northwest (11-10 Ma) to the southeast (6 Ma), which can be explained by the slab-breakoff model (Wortel & Sparkman, 2000).

EVOLUTION OF ISLAND-ARC MAGMA SOURCES: FROM PRIMITIVE TO MATURE ARC

Pavel Yu. Plechov

Fersman Mineralogical Museum of Russian Academy of Science, Leninsky prospect 18-1, Moscow, Russia,
pplechov@gmail.com

The main idea of the supposed model is step-by-step involving of additional sources of melting to magma generation processes during the evolution of an island arc system. Each stage of an island arc evolution is characterized by a specific set of volcanic series.

Primitive island arcs are defined by fluid induced melting of a mantle wedge above a subducted slab. As a result, Hi-Mg Low-K series are predominant volcanic rocks in primitive island arcs. The thickness of the island arc crust is growing up during island arc evolution and magmas could be more evolved with island arc crust growth. This crust is consisting of volcanogenic material, which is usually altered to greenschists, which could be easily transformed to amphibolites in lower parts of island arc crust. Thus, the primitive island arc became a developed island arc with a crust that consists of greenschists and amphibolite after several million years.

Partial melting of greenschists or amphibolite could produce silica-rich melts, which are typical for developed island arc. Partial melting of amphibolites in water-saturated conditions at pressure 0.8-1 GPa could produce andesibasalts or even basalts (at a high degree of partial melting). Amphibole-bearing restite could preserve a significant amount of LREE, Nb, Ti and K. As a result of melting of the island arc lower crust we can expect magmas which are well corresponding to Low-K tholeitic island arc series of volcanic fronts of developed island arcs.

Plechov, (2008) suggest that in developed island arcs magma can rise simultaneously from several levels of the island arc system: 1) High-Mg Low-K basalts could be generated by fluid-induced melting of the mantle wedge; 2) Low-K basaltic andesites and basalts are forms by amphibolite melting at the lower crust conditions; 3) silica-rich magmas could be formed by melting of island arc upper crust metamorphic rocks. All these magmas could be mixing each other in transitional magma chambers and then erupt in the same volcanic center with hybrid rocks forming. Magma mixing is a complicated factor for the clear determination of volcanic series for a lot of island arc volcanoes.

Mature suprasubduction systems (like Japan or Kamchatka) consist of accreted ancient and modern volcanic arcs. New volcanic front starts to form following the scenario described above, whereas the former volcanic arc shifts to back-arc settings. Lower part of the crust in the former volcanic arc is consists of pyroxenites or amphibole-bearing pyroxenites (as a residual of partial melting of ampibolites). The pyroxenite part of the lower crust has a higher density than undergoing peridotite mantle. It could delaminate and produce enriched in LREE, Nb, Ti, K magma in comparison with the ”typical” island arc calc-alkaline series. Recently, we described Holcene garnet-pyroxenite-derived magma in the area of Kamchatka, which is outside of modern subduction zone influence [Nekrylov et al., 2018], which justifies the proposed model for the evolution of island-arc volcanism. Assuming the model, the geochemical zoning of synchronous volcanism across mature (two or more chains) island arc systems could be explained by several levels of magma sources, developing as the island-arc system evolves.

RE-THINKING CALEDONIAN COLLISION MAGMATISM IN SCOTLAND, AND RELATED IDEAS FOR ARMENIAN STUDIES

Iain Neill, Eilidh Milne, Careen MacRae, Chloe Gemmell

Geographical and Earth Sciences, University of Glasgow; Molema Building, Lilybank Gardens, Glasgow G12 8QQ, Scotland, iain.neill@glasgow.ac.uk

Slab roll-back and break-off, mantle flow, lithospheric stability and thickness, and crustal stress all affect collision zone magmatism. In deep time, these inter-relationships are blurred by erosion, tectonism, and missing geophysical constraints. We rely heavily on data from the magmatic record to infer past geodynamics. One such example is magmatism in Scotland resulting from Iapetus subduction and the ~450-390 Ma ‘Caledonian’ collision of Baltica, Laurentia, and Avalonia. Magmatism is preserved in chemically diverse plutons (misleadingly) termed Newer Granites, and associated volcanic rocks. We might consider the plutons as analogous to the magma plumbing beneath Armenia and its neighbors today.

Caledonian plutons are of renewed interest because of geothermal energy and mineral prospects. However, we haven’t fully appreciated how geodynamic processes relate to magmatism and economic potential. Some studies are a generation old, have inconsistent geochronological control, rely heavily on whole rock geochemistry, don’t apply the modern concept of trans-crustal magmatism, and use slab break-off *a priori* to explain magmatic output at the end of collision. Our aim is to rationalize our understanding of Caledonian magmatism in Scotland, to ground future funding applications on its economic legacy. Starting with the Northern Highlands and Southern Uplands plutons, we have recently begun this modernization with laser ablation accessory mineral U-Pb geochronology and trace element geochemical studies.

The Northern Highlands were part of the Laurentian upper plate during the convergence of Baltica. Plutons emplaced in the mid crust from ~440 Ma onwards contain populations of antecrystic zircons. Initial zircon growth predates emplacement by up to ~20 Myr. Older zircons represent crystallization in a deep crustal hot zone. The persistence of the hot zone during the period ~450-430 Ma, when few plutons were emplaced, is consistent with compression at the onset of Baltica-Laurentia collision. At ~425 Ma, uplift, renewed plutonism, and intra-montane sedimentation, potentially identify slab roll-back or break-off prior to the onset of crustal extension at ~415 Ma, when further plutons were emplaced.

The Southern Uplands were the Laurentian accretionary prism which finished accreting sediment at ~425 Ma during Avalonia-Laurentia convergence. Plutonism and volcanism from ~415 Ma onwards post-date accretion, however studies including ours still identify antecrystic zircons supporting a ~10-15 Myr period of hot zone storage. Therefore, crustal stress probably dictates magmatic emplacement, and the *a priori* association of slab break-off with an immediate upsurge in magmatism is tenuous.

In the Armenian context, petrogenetic and geochronological studies often use whole rock and K-Ar and Ar-Ar data. Where and when magma was stored at depth prior to eruption has not been constrained. It is also challenging to determine how recent magmatism has been affected by assimilation of older but chemically similar arc crust, potentially significant for the redistribution of sulfide mineralization. Interrogation of the accessory mineral record of collision volcanism, akin to ongoing work on the Caledonian plutons, could be a cost-effective approach to widely answering those questions.

THE EARLIEST MESOZOIC MANIFESTATIONS OF VOLCANISM IN THE LESSER CAUCASUS (REPUBLICS OF ARMENIA AND KARABAGH) IN THE JURASSIC

Ghazar Galoyan

Institute of Geological Sciences, NAS RA, 24a M. Baghramian Ave., Yerevan, 0019, Republic of Armenia,
E-mail: ghazar.galoyan@gmail.com

The age and geotectonic history of basaltic magmatism of the Mesozoic is especially important for unraveling the geological evolution of the Lesser Caucasus (LC) as part of the Alpine–Himalayan orogenic belt. The issues for understanding and comprehensive interpretation of tectonic setting of the LC ophiolites with adjacent Somkheto–Karabagh and Spitak–Kapan Jurassic–Cretaceous zones have been discussed and summarized recently (e.g., Rolland et al., 2009, 2010, 2020; Sosson et al., 2010; Hassig et al., 2013, 2015; Galoyan, 2008, 2020, 2021; Galoyan et al., 2009, 2013, 2018).

Until we have no stratigraphic records or geochronological results of the Mesozoic basaltic lavas, the question of their dating is solved indirectly. In the LC the granitoids of various ages are widespread in which plagiogranite (trondhjemite) intrusions of, e.g., Lower–Middle Jurassic are well known in different tectonic-magmatic zones (summarized in Galoyan, 2021). Trondhjemites are especially common in the Somkheto–Karabagh tectonic belt (in NE Armenia and W Azerbaijan), in the Spitak–Kapan volcanic zone (e.g., in Karabagh territory), and in their intermediate Amasia–Sevan–Hakari (ASH) ophiolite zone (e.g., in Sevan area).

One of U-Pb dated plagiogranites (~177 Ma; Galoyan et al., 2013) from the Berdadzor intrusion, next to the ‘highway’ between towns Shushi–Berdzor (Lachin), intruded the pillow basalts of considered Bathonian age (e.g., Abdullaev et al., 1974). The Dali trondhjemite stock-like intrusion (~172 Ma) in Sevan ophiolite is also emplaced in basaltic pillow lavas which are of unknown age due to the lack of sediments (Galoyan, 2020). The stratigraphic base of these volcanites remains unknown.

Another dated plagiogranite is Haghpat intrusion (165 ± 4 Ma; Galoyan et al., 2018), located in the Lower-Middle Jurassic volcanic, tuffaceous series (“Debed suite”), in the Alaverdi region of N Armenia. Starting with Azaryan’s (1963) monograph, the majority of subsequent works attributed the Debed suite to the Upper Bajocian, but Melkonyan (1970), considered this and overlain “Koshaberd” suites to be of Lower Bajocian. Aslanyan (1949, 1958) was the only one who thought that the Debed suite might be older (Upper Triassic-Lower Liassic).

The environment of the volcanism is important and now we know that the main hosting formations of these intrusions in northern Armenia, in the Sevan ophiolite, and in the Artsakh territory are pillow basalts and basaltic andesites. Their rare earth element (REE) spectra supposed the melting from an already LREE-depleted mantle portion or even from a mantle melting that is similar to the MORB source (Galoyan et al., 2009, 2013, 2018).

From the above ages, it’s clear that hosting the trondhjemites pillows could not be Bajocian and Bathonian as considered before, and should possibly be, at least, Pliensbachian–Toarcian, given the Toarcian age (~177 Ma) of Berdadzor massif. Even older ages are obtained on plagiogranites in W Azerbaijan (~180 Ma; Sadikhov, Shatova, 2016). Therefore, considering these facts, the age of the host effusions located actually both south and north of the ASH ophiolite zone should be minimum Pliensbachian–Toarcian. This is new evidence of the earliest Mesozoic magmatic activity(ies) being related to any of the subduction models in the LC, which was unknown or somehow ignored (?) till the present. Alternatively, some of these pillow basalts might also belong to a pre-existing oceanic crust (Paleotethys?) that was older than Lower Jurassic.

VOLATILES IN KIMBERLITE MAGMAS – WHAT DRIVES ASCENT AND CAUSES EXPLOSIVE ERUPTION?

Vadim S. Kamenetsky
Institute of Volcanology and Seismology FEB RAS, Petropavlovsk-Kamchatsky, Russia;
dima.kamenetsky@hotmail.com

Existing reconstructions of the kimberlite melt emphasize carbonate-bearing ultramafic compositions with significant amounts of dissolved volatiles CO_2 and H_2O (10-20 wt.%). These volatiles are considered to be a major factor in reducing the viscosity of the kimberlite melt, governing fast ascent from mantle depths. The exsolution of these volatiles from the melt during ascent and emplacement is viewed as being responsible for the violent eruption of kimberlite magma, related brecciation of country rocks, and fragmentation of the magma. Magmatic volatiles and groundwaters have an unequivocal role in present models of kimberlite emplacement (fluidisation and phreatomagmatism, respectively). Over the last 20 years, our studies of melt inclusions in kimberlites worldwide have provided key constraints on compositional properties of the kimberlite melt and shown that neither CO_2 nor H_2O in the form of degassed fluids could be responsible for the hallmark “explosivity” of kimberlite magmas.

The alkali-rich carbonatite-chloride composition of the kimberlite primary melts recorded in melt inclusions hosted by main kimberlite mineral constituents (olivine, apatite, Cr-spinel, monticellite) are essentially anhydrous and CO_2 is effectively stored in liquidus carbonates (shortite, Na-dolomite, calcite. Such Si-undersaturated compositions are prone to reactions with wall-rock peridotite, followed by carbonate–silicate melt immiscibility at high pressure, and ultimately the CO_2 saturation of the silicate melt component. The resultant fluid exsolution lowers magma density and viscosity and may drive crack propagation and emplacement of kimberlite magma with a load of entrained material into the crust.

Massive degassing of H_2O and CO_2 from the kimberlite magma upon emplacement is highly unlikely, because the melt is poor in H_2O, and CO_2 is bonded in the carbonatitic melt. After the crystallization of olivine, the kimberlite melt evolves towards essentially dry carbonate-chloride compositions. However, the decarbonation interaction between olivine and the residual carbonate-rich melt, recorded in the assemblage of monticellite, periclase, Fe-Mg-oxides, and fluid bubbles of CO_2, may occur in some cases.

All previous models of kimberlite melt emplacement have not gone beyond degassing of the volatile-saturated silicate melt and its passive interaction with groundwaters. However, kimberlite explosions are unexpectedly powerful for small kimberlite volumes. We suggest that while magma ascent is driven by buoyancy, explosions in the crust are the consequence of detonation of reduced hydrogen species (H_2, CH_4 and hydrocarbons).

On emplacement, the magma releases the dissolved silicate component in the form of olivine and minor phlogopite and monticellite, thus driving the residual melt towards the initial chloride-carbonate composition. This is followed by gravitational separation of silicate solids to the roots of kimberlite dykes, whereas light, low-viscosity chloride-carbonate melt is squeezed to the top. Post-magmatic serpentinization of olivine cumulates generates abundant H_2 and CH_4 that ascent to the carbonate-rich tops, where ‘cold’ explosions and brecciation of already solid magma occur. This unconventional model may explain the pipe-like shape of kimberlite bodies, explosive activity over an extended time span with intermittent phases of quiescence and consolidation, and excavation of rocks from the top down to 100’s m below the surface.

MINERAL ASSOCIATIONS OF MIDDLE JURASSIC ISLAND-ARC PERVOMAY-AYUDAG INTRUSIVE COMPLEX, CRIMEA: GENETICAL EVOLUTION AND MELT MODELLING

George N. Ovsyannikov[1,2], Evgenia S. Semikolennykh[3]
[1]Lomonosov Moscow State University, Geology Faculty, Moscow, Russia, e-mail: george_ovs@mail.ru
[2]Institute of Volcanology and Seismology FEB RAS, Petropavlovsk-Kamchatsky, Russia
[3]St. Petersburg State University, Institute of Earth Sciences, St. Petersburg, Russia

Mountain Crimea is a part of the giant Alpine-Himalayan fold system. It includes folded Middle Triassic – Early Jurassic turbiditic deposits with thrust-folded overlaying Late Jurassic – Neogene carbonate rocks (Khain, 2001, Nikishin et al., 2015). Plagiolherzolites, olivine gabbro-norites, quartz gabbro-norites and plagiogranites of hypabyssal Pervomay-Ayudag island-arc complex intruded in the Middle Jurassic 169-171 Ma (Meijers et al., 2010). In the Late Jurassic low-grade metamorphism occurred over the Crimea and magmatic rocks were altered.

The study includes 9 intrusive bodies located over the southern coast of the Crimea and Bodrak river basin. There are mostly small dikes and stokes composed of olivine gabbro-norites and gabbro norites, whereas other rock types (plagiolherzolites, plagiogranites and quartz gabbro) are less widespread. Most researchers conclude, that all rock types are the products of fractional crystallization of mafic melt.

Seven mineral associations were described for the Pervomay-Auydag island-arc complex, including main (olivine, plagioclase and pyroxenes) and accessory (chromium spinel, titanomagnetite, armalcolite, baddeleyite, allanite-(Ce), etc.) magmatic minerals. First and second mineral associations are considered as cumulative; they consist of fully altered olivine, plagioclase (An_{92-90}) and chromium spinel. The third and fourth associations are the main ones; they include plagioclase (An_{89-50}), monoclinic and orthopyroxenes, titanomagnetite, accessory armalcolite, baddeleyite and zirconolite. Fifth to seventh mineral associations are the products of residual melt crystallization, consisting of plagioclase (An_{49-14}), pargasite, biotite, quartz, accessory allanite-Ce and zircon. Fractional crystallization conforms the Bowen's reaction series.

The P-T-parameters and compositions of altered magmatic minerals fractional crystallization were simulated using COMAGMAT-3 (Ariskin and Barmina, 2004). The inputs are: melt composition (wt. %) – SiO_2 47.86, TiO_2 0.88, Al_2O_3 19.67, FeO 7.01, MnO 0.13, MgO 9.43, CaO 12.62, Na_2O 2.14, K_2O 0.14, P_2O_5 0.13; H_2O content (wt. %) - 8.00; max. An-content in plagioclase (mol. %) – 92; max. Al_2O_3 content in monoclinic pyroxene (wt. %) – 16.00, pressure (kbar) – 6,5-7. The outputs are: max. Fo content in olivine – 88,80; max. temperature (°C) – 1060.

GEOCHRONOLOGY AND GEOCHEMISTRY OF MESOZOIC BASIC MAGMATISM AND GEODYNAMICS OF SOUTH ARMENIAN BLOCK

Igor K. Nikogosian[1,2], Antoine J.J. Bracco Gartner[1], Paul R.D. Mason[2], Douwe J.J. van Hinsbergen[2], Klaudia Kuiper[1], Uwe Kirscher[3], Sergei Matveev[2], Araik Grigoryan[4], Edmond Grigoryan[4], Arsen Israyelyan[4], Manfred J. van Bergen[2], Janne M. Koornneef[1], Jan R. Wijbrans[1], Gareth R. Davies[1], Khachatur Meliksetian[4]

1 Faculty of Science, Vrije Universiteit Amsterdam, De Boelelaan 1085, 1081 HV Amsterdam, The Netherlands
igorniko22@gmail.com
2 Department of Earth Sciences, Utrecht University, Princetonlaan 8a, 3584 CB Utrecht, The Netherlands
3 Department of Geosciences, University of Tübingen, Schnarrenbergstraße 94–96, 72076 Tübingen, Germany
4 Institute of Geological Sciences, Armenian National Academy of Sciences, 24a Marshal Baghramyan Ave, Yerevan 0019, Armenia

The Permian breakup of Gondwana initiated the formation of the Cimmerian microcontinents, which accreted to the southern Eurasian margin upon closure of the Palaeotethys and Neotethys oceans and formed the Arabian-Eurasian collision zone. One of these Gondwana-derived fragments is the South Armenian Block (SAB), a continental fragment presently separated from the neighbouring terranes of Central Iran, the Pontides and Taurides by ophiolite-bearing suture zones.

Current study reports new geochronological, geochemical and palaeomagnetic data on Precambrian metamorphic basement and magmatic intrusions into the Late Devonian sedimentary cover of the SAB to constraints on the origin and geodynamic history of the SAB in the context of Permian–Triassic breakup of the NE Gondwanan margin, the opening of the Neotethys Ocean, and the Mesozoic kinematic history of the SAB.

Zircon age distributions (~3.6 Ga to ~100 Ma) and their continental geochemical fingerprint definitely establish a Gondwanan origin for the SAB.

Trondhjemite intrusions into the metamorphic basement at ~263 Ma exhibit an adakitic, slab-melt affinity, reflects magma genesis in an active continental margin, consistent with a SW-dipping subduction zone active at the NE Gondwanan margin (Pontides and SAB) during the Middle–Late Permian.

Mafic alkaline intrusions dated ~246 Ma (OIB) and ~235 Ma (P-MORB), reflect the products of asthenospheric melting, as well as melt derivation from a more depleted, shallower mantle source. This set of intrusions is typical of initial continental rifting and early-stage oceanic spreading and suggests a phase of extensional tectonics in the SAB during the Middle Triassic. We infer that this activity marks the incipient breakup of the NE Gondwanan margin and the subsequent opening of the Neotethys Ocean.

Andesitic dykes at ~117 Ma testify as the subduction-related magmatism and explained by a NE-directed subduction system at the southern margin of the SAB, driven by forearc spreading in the Eurasian margin, which led to the cessation of the SAB drift and accommodated compression south of the SAB in Late Jurassic–Early Cretaceous times.

We provide a new geodynamic interpretation of the SAB since the Permian, started as rifting from Gondwana, then reached the Iranian margin in Early Jurassic times with episodes of continental intraplate magmatism (~189 Ma) and NE-dipping subduction-related magmatism in Late Jurassic to Early Cretaceous time.

ARC MONOGENETIC VOLCANISM IN THE ACTIVE FAULT ZONE (SREDINNY RANGE OF KAMCHATKA): GEOCHEMICAL DIVERSITY OF VOLCANIC ROCKS AND MAGMATIC MELTS

Anna O. Volynets[1], Nikolai Nekrylov[1,2,3], Natalia Gorbach[1], Georgy Ovsyannikov[1,4], Maria Tolstykh[5], Maria Pevzner[6], Egor Zelenin[6], Vasily Shcherbakov[4], Vladimir Lebedev[7], Anastasia Plechova[5], Andrey Babansky[7]

[1]Institute of Volcanology and Seismology FEB RAS, bul'v. Piipa 9, Petropavlovsk-Kamchatsky, 683006, Russia, e-mail: a.volynets@gmail.com ; [2]Fersman Mineralogical Museum, Leninskiy av., 18/2, Moscow, Russia, 115162; [3]Institute of Geological Sciences, Armenian National Academy of Sciences, 24a Marshal Baghramyan Ave, Yerevan 0019, Armenia; [4]Moscow State University, Geological Department, Vorobievy Gory 1, Moscow, Russia; [5]Vernadsky Institute of Geochemistry and Analytical Chemistry RAS, ul. Kosygina 19, Moscow, 119091, Russia; [6]Geological Institute RAS, Pyzhevskii per. 7, Moscow, 119017, Russia; [7]Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry RAS, Staromonetny per. 35, Moscow, 119017, Russia

The Kamchatka volcanic arc is a long-lived subduction system situated in the northwestern portion of the Pacific Ring of Fire. It has a complex geological history and is located at the triple-junction of the Pacific, Bering Sea and Eurasian plates. There are three volcanic zones in Kamchatka, running parallel to the trench: the Eastern Volcanic Front (EVF), the Central Kamchatka Depression (CKD), and the Sredinny Range (SR), which is situated in the back-arc region. The active Benioff zone is located beneath the volcanoes of the EVF and CKD at depths ranging from approximately 100 to 180 km (Gorbatov et al., 1997). Under the SR, the slab is visualized in the southern part – at ~400 km depth beneath the Khangar volcano and at ~300 km depth beneath the volcanoes of the eastern flank of the SR, up to the latitude of the Bystraya river. At the latitude of the Alney-Chashakondzha volcanic massif, a large SW-NE active fault zone crosses the main watershed of the Sredinny Range at an azimuth of 40° (Zelenin and Garipova, 2022). We report the composition and K-Ar ages of a representative collection of volcanic rocks that erupted within three monogenetic volcanic fields of this active fault zone: Tigilsky Dol, Mount Oxi massif and Anaunsky Dol. The studied rocks display a wide range of compositions (medium-K moderate-Mg, high-K, high-Ti, high-Mg basalts, and high-LREE picrobasalts) and widespread distribution of high-Mg varieties confined to the faults. The main periods of volcanic activation within the studied area occurred during 4.3–3, 2, 1.5, 1 Ma and from 0.3 to <0.05 Ma. Primitive rocks first emerged on the surface at 3.5 Ma. The massive manifestation of the high-Mg volcanism took place at 1.5–1 and 0.3 Ma, which could be related to the formation of the FZ. For the first time, we documented rocks with high-LREE picrobasaltic composition (1.5 Ma) in Kamchatka. The Fo content in olivine phenocrysts reaches 93.2 mol%, which is the highest value known for Quaternary Kamchatka basalts. Minor element contents in the olivine (Ni, Mn and Ca) indicate that source lithologies were highly heterogeneous even for individual eruptions. The olivine and olivine-hosted Cr-spinel show that all studied rocks crystallized in the same temperature range (1111–1292 °C) while the oxygen fugacity varied for different samples from ΔQFM +0.7 to +2.0 log. units. The melt inclusions study showed that Mg basalts of Mt. Oxi massif and high-LREE picrobasalts of Tigilsky Dol have different fluid sources, enriched and depleted in water and Cl, respectively. We argue that in the case of Mt. Oxi massif, the fluid source was likely the remains of the Pacific slab under the Sredinny Range, while in the case of high-LREE picrobasalts of the Tigilsky Dol, it was the lithospheric lithologies. The low content of S and the high of Cu in oxidized high-LREE basalts provide additional evidence in favor of their origin due to the re-melting of sulfur-poor lithospheric lithologies. Both the fault zone and the lithosphere re-activation in the region are likely linked to the regional stress field in the area.

POST COLLISION EVIDENCES OF MAGMATISM IN THE NW OF IRAN

Seyed Mehran Heidari [1] , Marzieh Mirzakhanian[2]

[1] Research Institute for Earth Sciences, Geological Survey of Iran, Tehran, Iran
Sm.heidari@gmail.com, [2] Expert of Exploration Management, National Oil Company, Tehran, Iran

The magmatic belt in NW Iran is a part of northeastern rim of the metamorphic-magmatic portion of Sanandaj-Sirjan zone (S.S.Z) and Central Iran which, has been crosscut by the Eocene to the Quaternary magmatic belt during the Zagros orogeny. This magmatic belt with NW trending in this area is a part of the Urumieh-Dokhtar magmatic arc (UDMA) which has been classified into 3 different phases by radiometric dating, including early (16-24 Ma), middle-late (10-12 Ma), and late Miocene (8> Ma). Results of major elements of volcanic complexes which are related to early and middle-late, two phases, suggest that they are classified in the sub-alkaline, medium to high potassic series and contain andesite, trachy-andesite, dacite, trachydacite, and rhyolite. These igneous rocks are characterized with amounts of SiO_2 between 54 to 78%, Na_2O +K_2O>5%, MgO <5%, TiO_2<0.7% and mainly Al_2O_3>15%. These characteristics together with the amounts of Yb and Y, less than or equal to 2 and 18 ppm, respectively indicate the shoshonite nature of these complexes. These samples belong to mild alkalinity (high K) of the calc-alkaline compositions related to I-type or magmatic arc, which have been formed in collisional to post-collisional stages. Some of the samples show evidences of adakite signatures which indicate to slab melting. The magmatism also illustrates some overlapping in trace element signatures which presumably point to the fact that they have been formed from one source although in two phases. They show a little contrast, which is related to differences in composition, fractionation, presumably assimilation, and alteration of rocks in diverse parts. The Primitive mantle-normalized trace element variation diagram of these phases (both two phases) points to enrichments in large ion lithophile elements (LILE) such as Cs, Rb, Ba, Th, U, K, Pb and LREEs such as La, Ce, Pr, Nd whereas it shows depletion in HFSEs such as Ti, Nb and P. The low amount of Y (> 30 ppm) and low enrichment in heavy REE are the other characteristics of these complexes. These characteristics together with the depletion of phosphorus and titanium, indicate fractionation while abundances of elements such as Pb, Th, and U are evidence of contamination in these complexes. However, the most important diversity between these two phases is more fractionation of the middle-late phase relative to the early Miocene phase. Therefore, the lower and middle-late Miocene magmatic phases lying within the high K calc-alkaline magmatic arc of an active continental margin which have been formed in syn- to post-collisional field. The typical magmatic arcs have minor differences from the studied magmas in having lesser contents of alkalinity, which points to their formation in an extensional regime on the contrary to compression which is the main characteristic of magmatic arcs.

MONOGENETIC VOLCANISM IN MALKO-PETROPAVLOVSK ZONE OF TRANSVERSE DISLOCATIONS, KAMCHATKA

Olga V. Bergal-Kuvikas
Institute of Volcanology and Seismology FEB RAS, Petropavlovsk-Kamchatsky, Russia
E-mail: kuvikas@mail.ru

The Malko-Petropavlovsk zone of transverse dislocations (MPZ) was formed on the extension of the deep Avachinsky transform fault in perpendicular relation to the subduction trench (Bushenkova et al., 2023). It is a natural boundary between variously aged slabs in Kamchatka (103–105 Ma under Southern Kamchatka and 87–92 Ma under the Eastern volcanic belt) (Gordeev and Bergal-Kuvikas, 2022). Monogenetic cinder cones in the MPZ are randomly distributed along these long-lived rupture zones (Bergal-Kuvikas et al., 2022). Based on whole rock and trace element geochemistry, Pb-Sr-Nd isotopic ratios of monogenetic cinder cone magmas were shown to tap the enriched mantle source (low $^{143}Nd/^{144}Nd$ isotopic ratios (0.512959– 0.512999), and changed as $^{87}Sr/^{86}Sr$ (0.703356–0.703451) and $^{206}Pb/^{204}Pb$ (18.30–18.45), $^{208}Pb/^{207}Pb$ (38.00–38.12) isotopic ratios). High Nb/Yb and La/Yb ratios, without significant inputs of the slab’s components (the lowest Ba, Th content), indicate decompression melting predominately.

In order to study magma plumbing systems in the crust we focused on the investigation of quarries and sections of Shlakovaya Mnt. Shlakovaya Mnt. is a Holocene monogenetic cinder cone, which is located close to Vilyuchinsk city. Numerous years the scoria from Mnt. Shlakovaya was used for construction works. Currently quarries and sections are located on various altitudes of Mnt. Shlakovaya and they are interesting for studying magma genesis and evolution in the crust. Samples on the top and upper quarry are characterized by relatively low MgO (6-7 wt. %) and high Sr (545-563 ppm). Samples from low quarry have higher contents of MgO (>7.5 wt. %) and low Sr variations (498-486 ppm). Obtained results suggest for the complicated process of magma evolution of basaltic andesitic magmas (SiO_2 50.08-51.68 wt. %) in the crust.

The research was supported by the Russian Science Foundation № 22-77-10019, https://rscf.ru/project/22-77-10019/.

COPPER REDISTRIBUTION FROM SHALLOW OXIDIZED MAGMAS TO MAFIC ENCLAVES UNDER BEZYMIANNY VOLCANO, KAMCHATKA

Vesta O. Davydova[1], Vasily D. Shcherbakov[1], Pavel Yu. Plechov[1,2], Vasily O. Yapaskurt[1]
[1] Lomonosov Moscow State University, Geological Departments, Leninskii Gory, 1, 119191 Moscow, Russia, vestadav@gmail.com , [2] Fersman Mineralogical Museum RAS, Leninskiy prospekt 18/2, 119071 Moscow, Russia

The accumulation and subsequent remobilization of copper during magmatic processes in shallow magmatic bodies are critical prerequisites for the development of porphyry deposits in subduction zones. World scientists are actively discussing the behavior of chalcophile elements in subduction systems, which commonly host porphyry copper deposits (PCD), but metals sources, transport mechanisms, and factors that control deposit fertility are not completely understood, and actively discussed.

The magmatic stage plays a key role in the preliminary concentration and redeposition of metals before PCD formation (Hedenquist and Lowenstern, 1994; Sillitoe, 2010; Blundy et al., 2015). How do Cu-poor parental magmas turn into Cu-source for PCD? Is this regulated by ordinary magmatic evolution, or does it require a combination of processes? Using sulfides formed at different magmatic levels can contribute to a better understanding of the ore-forming process, including accumulation and transport processes. The study of mafic enclaves and xenoliths in conjunction with their host island-arc andesites offers such an opportunity. Mafic enclaves are formed by injected magma in a magmatic reservoir under contrasted P-T-X conditions. Often, ascended magmas contain early associations, which record magmatic history at lower levels. Such enclaves widely occur in the pyroclastic deposits of Bezymianny volcano, Kamchatka (Shcherbakov, Plechov, 2010; Turner et al., 2013; Davydova et al., 2017, 2022). A study of sulfides from mafic enclaves, cumulates, and host andesite will allow a better understanding of how chalcophile elements behave during magma evolution.

We report anomalously copper-enriched mafic enclaves (up to 330 ppm vs 30-50 ppm in host andesite and basaltic andesite) from Bezymianny volcano, Kamchatka, and report the changes in oxygen fugacity and evolution of sulfide phases throughout the crustal magma plumbing system. Erupted lavas contain only rare tiny Fe-Cu sulfides in magnetite and phenocrysts resorption zones. In contrast, mafic enclaves contain numerous sulfide globules. Their composition evolves from early Cu-poor MSS (pyrrhotite crystals framed by thin ISS rims) enclosed in phenocrysts to ISS (close to cubanite composition) in matrix glass and pores. The observed increase of copper content in sulfide along with crystallization requires the addition of Cu from external sources. Based on mineral oxybarometry, we show that the oxygen fugacity of shallow-stored magma (less than one kbar) is between NNO and NNO+1. Both the oxidized state and active degassing of S-bearing aqueous fluid, which keeps sulfur concentrations in silicate melts below the sulfide saturation level, provide instability of sulfide phases in the shallow chamber and incompatible behavior of chalcophile elements. Consequently, copper accumulates in silicate melt until conditions shift. The regular influx of sulfide-bearing magma from deeper levels (9-2 kbar, near NNO) and associated S-bearing fluid induce redistribution of copper from the oxidized melt and fluid of shallow-stored magma. During the reaction between Cu-bearing fluid from shallow magma and S-bearing fluids, copper is precipitated in tiny sulfides in host magma, and redistributed into mafic enclaves due to chemical potential differences.

This work was supported by the Russian Science Foundation (22-77-00016).

BORON AND B-SR-ND ISOTOPES AS TRACERS OF FME AND VOLATILE ENRICHMENTS IN THE MANTLE SOURCE OF KAMCHATKA ARC BASALTS, INSIGHTS FROM KOZELSKY, AVACHINSKY AND KHANGAR MAFIC SERIES

E. Brennan[1], I.P. Savov[1], S. Agostini[2], T. Churikova[3], B. Gordeychik[3,4], D.J. Morgan[1] M. Pevzner[5]

[1] School of Earth and Environment, University of Leeds, Woodhouse, UK, eeebr@leeds.ac.uk ; [2] IGG-CNR-Pisa, Italy; [3] Institute of Volcanology and Seismology- FEB RAS, Petropavlovsk-Kamchatsky, Russia; [4] Institute of Experimental Mineralogy- RAS, Chernogolovka, Russia [5] Geological Institute -RAS, Moscow

The voluminous magmatic outputs from the old, cold, and altered Pacific slab under the Kamchatka Peninsula creates an ideal environment to utilise B and B isotopes to faithfully trace volatile release across subduction zones. Here we report new petrological and geochemical results (XRF, EMPA, SEM, ICP-MS, and TIMS) from the forearc-situated Kozelsky and Avachinsky volcanoes (Avacha Group) with respect to the back arc volcano Khangar. We will present a first geochemical and petrological typification of Kozelsky. The sampled olivine-phyric basalts from the Avacha Group record high MgO (5-15 wt%), Ni (15-250 ppm) and Cr (60-800 ppm) abundances. The whole rock $^{87/86}$Sr and $^{143/144}$Nd ratios of these volcanoes show narrow ranges (~0.70335 and ~0.51305, respectively), revealing dominantly mantle wedge (non-crustal) magma sources. Such isotopic signatures are nearly identical to those of high-MgO basaltic lava and tephra from the Tolbachik monogenetic field in the Central Kamchatka Depression (the second volcanic belt with slab depths of ~200km) (Iveson et al., 2021, 2022; Gorbtov et al., 1997]. Kozelsky magmas sample very shallow depths to the slab of less than 90km (Syracuse and Abers, 2006). New whole rock B and B isotope data reveals serpentinite-forearc mélange influenced outputs [e.g. high B and heavy $\delta^{11}B$ (up to >+2 to +5‰)]; this deviates from the expected deep sourced slab melt contribution (+2‰, Li et al., 2023) which whilst has an influence, alone cannot source these magmas. This is also in contrast to AOC (altered oceanic crust) melt-dominating mantle metasomatism in the arc belts with deeper subducting slabs (i.e. Tolbachik: Iveson et al., 2021, 2022; Gorbtov et al., 1997;EB : Iveson et al., 2021). Therefore, such excess, non-sediment sourced B and enriched $\delta^{11}B$ should be derived from dehydrated and with heavy $\delta^{11}B$ AOC (McCaig et al., 2018) or forearc, serpentinite, melange rocks associated with the subducting slabs, supporting the mélange model of slab material transport (Nielsen and Marschall, 2017). Moreover, Khangar, which samples a depth to the slab of ~350km, has the expected dominantly OIB signature with a much lighter $\delta^{11}B$ signature (-5 to -10‰, EB, Iveson et al, 2022) and lower B concentrations from a volatile starved slab. We are now focussing on the analysis of $\delta^{11}B$ and hydrous contributions in melt inclusions, to further trace the non-crustal, boron-depleted, and isotopically light arc mantle background across the Kamchatka arc. Our results will evaluate if systematic variations in B-Sr-Nd isotopes and trace element ratios can be linked to across-arc change in depth to a slab of the magma source and/or reveal details about the prevailing geodynamic regime.

PRE-ERUPTIVE MAGMA CHAMBER CONDITIONS OF THE RAUCHUA TEPHRA

Shchekleina M.D.[1], Portnyagin M.V.[2], Shcherbakov V.D.[3], Ponomareva V.V.[4], Dirksen O.V.[5], P. Yu. Plechov[6]

[1] Fersman Mineralogical Museum RAS; Leninsky prospect, Moscow, Russia, mary.shec@yandex.ru ; [2] GEOMAR; Kiel, Germany, mportnyagin@geomar.de; [3] Lomonosov Moscow State University; Vorobyovy hills, Moscow, Russia; vasiliy7@gmail.com; [4] Institute of Volcanology and Seismology FEB RAS; Piip blvd, Petropavlovsk-Kamchatsky, Russia, vera.ponomareva1@gmail.com; [5] Institute of Volcanology and Seismology FEB RAS; Piip blvd, Petropavlovsk-Kamchatsky, Russia, oleg.dirksen@gmail.com; [6] Fersman Mineralogical Museum RAS; Leninsky prospect, Moscow, Russia, pplechov@gmail.com;

The Rauchua tephra eruption occurred ~177 ka in Kamchatka and had large magnitude M>6.5 (Ponomareva et al.,2013), comparable with catastrophic 1883 Krakatoa eruption (Pyle, 2000). The studied Rauchua tephra sample was collected on the right bank of the Kirganik river in central Kamchatka. Description of the minerals and glass association and estimation of pre-eruptive conditions are made for the first time in this work. The sample consists of rhyolitic pumice, solid rock and mineral clasts. Minerals are presented by weakly zoned plagioclase phenocrysts An_{29-55}, K_2O = 0.15-0.37 wt.%, totally unzoned magnesian hornblende Mg# = 0.66, Al_2O_3 = 5.39-7.61 wt.% and orthopyroxene Mg# = 0.64. Melt inclusions from 80 to 130 μm in diameter occur in plagioclase cores. Small inclusions of apatite, plagioclase, zircon, titanomagnetite, and ilmenite trace growth zones in magnesian hornblende and orthopyroxene. We suggest that titanomagnetite and ilmenite are in equilibrium, because they were found in the same amphibole and pyroxene growth zones, and also reveal equilibrium Mg/Mn partitioning (Bacon and Hirschmann, 1988). Crystallization temperature estimates based on the amphibole (Ridolfi, 2021) and titanomagnetite-ilmenite (Ghiorso and Evans, 2008) compositions are 827±22°C and 834 °C, respectively. Pressures estimates based on amphibole compositions (Ridolfi, 2021) range from 105 MPa to 148 MPa (on average 120±13 MPa).

Assuming the average density of the Kamchatka crust equal to $2.5 \cdot 10^3$ kg/m^3 we estimate the location of the magma chamber between 4 and 6 km depth. Oxygen fugacity estimated from amphibole composition (Ridolfi, 2021) is ΔNNO = 0.8±0.4 and from magnetite-ilmenite equilibria Ghiorso and Evans, 2008 ΔNNO = 1.1. the average contents of volatile components Cl and SO_3 in matrix tephra glasses are 0.15 wt.% and 0.01 wt.% and in glasses of melt inclusions - 0.16 wt.% and 0.01 wt.%, respectively. Water content in plagioclase-hosted melt inclusions estimated with measured oxygen corresponds to 5.2 - 8.2 wt.% (in average 5.6 wt.%). According to the difference in sums of tephra and melt inclusion glasses analysis can be suggested that nearly 4.3 wt.% (from 50 to 100%) of H_2O degassed during the eruption. The emission of chlorine and sulfur due to syn-eruptive degassing was negligible and could not contribute significantly to the total amount of volatile emission at this eruption.

The processing of the analytical data and work on the manuscript were supported by the Russian Science Foundation grant #22-17-00074, https://rscf.ru/en/project/22-17-00074/

GEOCHEMICAL, ISOTOPIC AND PETROLOGICAL CONSTRAINTS ON THE ORIGIN AND EVOLUTION OF THE RECENT SILICIC MAGMATISM OF THE GREATER CAUCASUS

Vasily Shcherbakov[1], Ilya Bindeman[2], Viktor Gazeev[3]

[1] Lomonosov Moscow State University, Geological Departments, Leninskie Gory, 1, 119191 Moscow, Russia, vsh@geol.msu.ru, [2] Department of Earth Sciences, University of Oregon, Eugene, OR 97403, USA, [3] Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry (IGEM) of the Russian Academy of Sciences, 119017 Moscow, Russia

Significant volumes of rhyolites and granites of the Pliocene-Pleistocene age are exposed in the collision zone of the Greater Caucasus, Russia. The volcanic history of the region includes ignimbrites and lavas associated with the Chegem caldera (2.9 Ma) and Elbrus volcano (1.98 and 0.7 Ma) and rhyolitic necks and granites in Tyrnyauz (1.98 Ma). They are characterized by a similar bulk and mineral composition and close ratios of incompatible elements, which indicates their related origin. The 1.98 Ma Elbrus ignimbrites, compared to the 2.9 Ma Chegem ignimbrites, have elevated concentrations of both compatible (Cr, Sr, Ca, Ni) and incompatible elements (Cs, Rb, U). We argue that the Elbrus ignimbrites were produced from magma geochemically similar to Chegem rhyolites through fractionation crystallization coupled with the assimilation of crustal material. The 1.98 Ma Eldjuta granites of Tyrnyauz and early ignimbrites of the Elbrus region (1.98 Ma) are temporally coeval, similar mineralogically, and have comparable major and trace element composition, which indicates that the Elbrus ignimbrites probably erupted from the area of modern Tyrnyauz; the Eldjurta granite could represent a plutonic reservoir that fed this eruption. Late ignimbrites of Elbrus (0.7 Ma) and subsequent lavas demonstrate progressively more mafic mineral assemblage and bulk rock composition in comparison with rhyolites. This indicates their origin in response to the mixing of rhyolites with magmas of a more basic composition at the late stage of magma system development. The composition of these basic magmas may be close to the basaltic trachyandesite, the flows exposed along the periphery of the Elbrus volcano. All studied young volcanic rocks of the Greater Caucasus are characterized by depletion in HSFE and enrichment in LILE, Li, and Pb, which emphasizes the close relationship of young silicic magmatism with magmas of suprasubduction geochemical affinity. An important geochemical feature is the enrichment of U up to 8 ppm and Th up to 35 ppm. The trace element composition of the rocks indicates that the original rhyolitic magma of Chegem ignimbrites caldera was formed at >80%–90% fractionation of calc-alkaline arc basalts with increased alkalinity. This observation, in addition to published data for isotopic composition (O-Hf-Sr) of the same units, shows that the crustal isotopic signatures of silicic volcanics may arise due to the subduction-induced fertilization of peridotites producing parental basaltic magmas before a delamination episode reactivated the melting of the former mantle and the lower crust.

THE RESEARCH OF POST-COLLISIONAL ADAKITES IN CENTRAL IRAN, URUMIYEH-DOKHTAR MAGMATIC BELT

Azad Karimi[1], Monireh Kheirkhah[2]
[1]Ph.D., Geochemical Exploration Department, Geological Survey of Iran, Tehran, Iran, Azadi Square, Meraj Avenue, Tehran, Iran karimizh@gmail.com; [2] Research Institute for Earth Sciences, Geological Survey of Iran; Azadi Square, Meraj Avenue, Tehran, Iran, kheirkhah.monireh1@gmail.com

The study area is in SW of Qom; the central Urumieh-Dokhtar magmatic belt, within the Turkish-Iranian Plateau. Eocene to Miocene volcano-sediment units are the main geological units in this area. Dacite and andesite lavas are dominant. These rocks are composed of mainly felspar (plagioclase, sanidine) with a minor amount of amphibole, and pyroxene. Petrographic pieces of evidence such as glomeroporphyric, sieved plagioclase crystals, rounded rims of plagioclase phenocrysts as pieces of evidence for disequilibrium conditions, show the effects of fractionation, magma mixing, and crustal contamination processes. Based on major element geochemistry, the rocks are sodic with low to medium potassium content and calc-alkaline affinity. By chondrite-normalized REE patterns and primitive mantle-normalized spider diagram, the studied rocks are characterized by LREE and LILE enrichment and HREE and HFSE depletion. Depleted HFS elements such as Ta, Nb, and Ti point to the characteristics of magmas associated with subduction-related volcanism. The dacitic rocks are characterized by low Y and high Sr concentrations (high Sr/Y). These geochemical characteristics indicate that they are adakite in nature. In classification diagrams, these volcanic rocks are situated in the high silica adakites (HAS) field. Low Y and high Sr concentrations and LREE/HREE ratios are the characteristics of slab melt-derived adakites. These features show that parental magma generated from the melting of the eclogite or amphibolite garnet rocks of metamorphosed Neo Tethys oceanic lithosphere during its subduction beneath the Iranian Plateau and form the Urumieh-Dokhtar magmatic belt. The parental magma has affected by assimilation, fractional crystallization (AFC processes), and crustal contamination, during the ascent to the surface.

LATE CENOZOIC VOLCANIC ROCKS OF NORTHERN ZANJAN, NW IRAN

Tahereh Parsa, Monireh Kheirkhah
Research Institute for Earth Sciences, Geological Survey of Iran, Tehran, Iran t.parsa1992@gmail.com

This area is located in the western Alborz-Azerbaijan Zone, northwest Iran. According to field observations, the Oligocene volcanic rocks show acidic to intermediate composition. Based on petrographic studies, the acidic volcanic rocks indicate rhyolitic-dacite in composition with halo-porphyritic to hyalo-microlithic porphyritic (trachytic) textures. The main phenocrysts include sanidine, quartz, plagioclase, biotite, and hornblende; and the secondary minerals are sericite, carbonates, chlorite, and clay minerals. existence of sieve texture and zoning in plagioclase phenocrysts, corrosion, and roundness in phenocrysts. The lava's presence of two types of glasses with different chemical compositions reveals a lack of physicochemical equilibrium and might be because of magma mixing. Geochemical studies showed that volcanic rocks are in the category of meta luminous, high-k calc-alkaline to shoshonite. In the chondrite normalized REE diagrams, the studied rocks display more enrichment of LREEs than HREEs. Enrichment in LREEs and depletion in HREEs are characteristics of calc-alkaline volcanic

rocks in active continental margins. Furthermore, these rocks show enrichment in LILEs and depletion in HFSEs such as Nb, Ta, and Ti. These features are indicative of magmatic rocks of subduction settings. Based on tectonic discrimination diagrams, the studied rocks belonged to the post-orogenic granites. Geochemical evidence suggested that the parent magma of acidic lavas has been derived from the partial melting of the lower crust.

ULTRAPOTASSIC VOLCANISM FROM ISLAMIC PENINSULA, NW IRAN

Shirin Koohi, Monireh Kheirkhah

Research Institute for Earth Sciences, Geological Survey of Iran, Tehran, Iran, koohi_sh@yahoo.com

The ultrapotassic magmatism is one of the important events of the late Miocene post-collisional zone in the Turkish-Iranian orogenic plateau. The volcanic lavas of the Islamic peninsula, in NW Iran provide insights into the evolution of the alkaline-enriched potassium. The volcanic activities in this area occur in a variety of potassic to ultrapotassic alkaline magma that spans the range of composition from tephrite, leucite-bearing basanite to trachyte. Some volcanoclastic rocks are cut by leucite basanite and tephritic latter dykes. Based on petrography studies, the samples indicate some evidence of mingling, magma mixing, crustal contamination, assimilation by continental crustal, and fractional crystallization (AFC processes). The important evidence which could be pointed out is contained gelomeroporphyritic texture, sieve, and dusty textures in some of the phenocrysts (especially clinopyroxenes), oscillatory and reverse zoning minerals, and the existence of some mafic enclaved in felsic volcanic rocks. Effects of subduction factors are magma mixing, assimilation of continental crustal rocks, and fractional crystallization during the ascending magma to the surface. They are the most important magmatic processes of these volcanic ultrapotassic centers. The trend of major and minor oxides, relative to the percentage of silicon dioxide (SiO2) in the Hacker diagrams, are indicated by crystal fractionation. By geochemical studies, In the multielement diagrams, the depletion of Ti and Nb elements and enrichment of LILE elements, compared to the HREE, can be related to crustal components for the late Cenozoic magmatism collision zone. It is suggested that volcanic activities during the late Miocene were generated from a metasomatized asthenosphere mantle, with the garnet lherzolite source, by a low degree of partial melting (2 to 5 percent) and has been contaminated by continental crust in its ascents to surface.

2. VOLCANISM AND GEODYNAMICS, VOLCANO-TECTONIC INTERACTIONS, VOLCANIC HAZARD ASSESSMENT

VOLCANIC ARCHITECTURE OF ONE OF EARTH’S LARGEST LONG-LIVED MATURE INTRACONTINENTAL MONOGENETIC VOLCANIC PROVINCE: WESTERN ARABIAN PENINSULA

Károly Németh[1,2,3]

[1] *Saudi Geological Survey, National Program for Earthquakes and Volcanoes, Jeddah, Saudi Arabia,* nemeth.k@sgs.gov.sa, [2] *Institute of Earth Physics and Space Science, Lithosphere Research Group, Sopron, Hungary,* [3] *Volcanic Risk Solutions, Massey University, Palmerston north, New Zealand*

The western part of the Arabian Peninsula is the home of one of the most extensive if not the largest Neogene monogenetic volcanic province on Earth. The western Arabian volcanic fields, primarily located in the territory of the Kingdom of Saudi Arabia are diverse in geological sense and commonly exhibiting all known geological and geomorphological features we tend to define monogenetic volcanism that as a whole is long-lived and sustained, commonly referred as mature. The maturity of the monogenetic fields here also add extra variables to consider its geological architecture, namely their complex magmatic spectrum from the dominant mafic varieties to the rare more silicic extremities. Western Saudi Arabia hosts at least 13 distinct large volcanic fields that covers a total area of about 180,000 km^2 each having more than five source vents. Most of these volcanic fields are dominated by long-lived and extensive lava flow fields that cover large surface areas, and commonly captured in paleo-valleys or broad, but shallow terrestrial sedimentary basins. Geomorphic inversion in the past millions of years, accompanied with uplift and block-collapse events generated landscapes in the largest harrats similar to those commonly associated with flood basalt. Harrat Khaybar is one of the large volcanic fields by volcano numbers and surface area covered by lava located north of the city of Al Madinah. Similarly, large and extensive volcanic fields exists south of the city named as Harrat Rahat. Currently around 3000 volcanoes been identified and confirmed, within 95% formed in the Pliocene to Holocene. The surface preservation of most of the volcanic fields are great due to the arid climate, however since the Pleistocene pluvial and wet periods frequently alternated with arid conditions effecting the style of volcanism. There are evidences in the geological record that phreatomagmatic volcanoes formed among these volcanic fields frequently due to the results of explosive magma and ground-water table interactions putting about 10% of the total number of vents experienced phreatomagmatism, mostly in those areas in the eastern side of the Arabian Shield. While basaltic volcanic products dominate the field, trachytic or potash rhyolite lava domes and block-and-ash fans are also known from the central part of the volcanic fields. Interestingly, young silicic eruptions have also been recognized in the Harrat Rahat, dating silicic lava domes and their block-and-ash fans to be ~4500 years old. Here we provide a systematic characterization of the dispersed volcanic fields of western Saudi Arabia that are while produced large volume of lava fields, their individual source vents retained monogenetic characters. This is also valid for silicic edifices suggesting deeper lithosphere structure as a reason preventing to establish stabile melt rise and formation of conduits of central volcanoes. Instead, producing “one-shot” eruptions and dispersed vent systems.

BUILDING LAVA FLOW LIBRARIES TO ASSESS LAVA FLOW HAZARDS IN DISTRIBUTED VOLCANIC FIELDS

C. B. Connor and L. J. Connor
School of Geosciences, University of South Florida, Tampa, FL, USA, cbconnor@usf.edu

Volcanic hazards arise from distributed volcanism in many parts of the world, including in the Armenian highlands that are dominated by post-collisional volcanism. Lava flow hazard assessments can be a vexing issue in distributed volcanic fields because new vents may form and erupt lavas in the future at any number of locations. In contrast to many central-vent volcanic systems where lava flows are much more likely to originate repeatedly from a specific vent, hazards associated with lava inundation in distributed volcanic fields are themselves distributed. We present a strategy to efficiently evaluate lava flow hazards by developing a lava library of flow simulations. The lava library is part of a highly modular logic tree-based approach to lava flow hazard assessment that is designed to allow for flexible and rapid updates. This type of hazard assessment requires (1) a fast and reliable model to simulate lava flows, (2) a method of identifying regions of a volcanic field from which lavas may erupt that can impact an area of interest (AOI), and (3) a library of simulation results that can be used to assess hazards from a broad range of source vents and a broad range of statistical models, particularly as these data and statistical models change with time. The utility of a lava library of simulation output is demonstrated using MOLASSES, the MOdular Lava Simulation Software for the Earth Sciences. This numerical model was originally developed to model lava flow hazards for the Armenia Nuclear Power Plant, and has been updated through several iterations. The library is constructed to help forecast lava flow hazards on the eastern Snake River Plain (ESRP), a vast and active distributed volcanic field.

Lava flows on the ESRP are characterized by large volumes (< 15 cubic kilometer), large areas of inundation (<750 square kilometer) and eruption from distributed sources. We demonstrate the lava library approach by first defining two areas of interest (AOIs) on the ESRP that extend radially 1 to 1.5 km from the center of each AOI. A lava library is designed to facilitate estimation of the probability that lava will inundate these AOIs given the occurrence of an eruption.

A screening analysis for lava flow hazards is performed using MOLASSES. The screening analysis is designed to determine the largest possible lava flows and determine if these might reach a given AOI from a given vent location. Screened-in areas are lava catchments, defined as areas within which lava flows may erupt from source vents and conceivably reach an AOI. For the two example AOIs on the ESRP, the lava catchment areas are 136 km2 and 2500 km2, a function of the surrounding terrain and of potential lava flow volume. For each AOI, thousands of lava flow simulations are created for potential source vents within the screened-in area of the lava catchment. Results are stored in a lava library that documents the flow parameters for every simulation. The advantages of creating a lava library are: (1) it can be used in a logic tree with a variety of statistical models for recurrence rate and/or spatial density of volcanic eruptions, without re-running simulations when these models change, as they invariably do; (2) the library can be used to consider a variety of deterministic scenarios, such as during table-top exercises, again without needing to re-run simulations; (3) the lava library documents the model inputs and outputs used to construct the hazard assessment, which is vital for hazard model evaluation. The lava library concept is applicable to distributed volcanic fields and other volcanic systems such as rift zones and calderas, where source vent locations are uncertain, and can be used to help guide further investigations and to raise awareness of lava flow hazards. Similar libraries may be constructed for tephra fallout and related hazards, using a broad range of models.

CASCADING HAZARDS IN A MIGRATING FOREARC-ARC SYSTEM: EARTHQUAKE-EARTHQUAKE AND EARTHQUAKE-ERUPTION TRIGGERING IN NICARAGUA

P. C. La Femina[1,2,3] & M. Higgins[1,4]

[1]Department of Geosciences, The Pennsylvania State University, University Park, Pennsylvania, USA; [2]Alfred Wegener Institute for Polar & Marine Research, Bremerhaven, Germany, peter.lafemina@awi.de; [3]Universitat Bremen, Bremen, Germany, [4]Department of Earth and Environment, Florida International University, Miami, Florida, USA

Strain partitioning in the Central American convergent margin between the subducting Cocos Plate and Caribbean Plate is accommodated along the Middle America Trench and faults in the forearc-arc regions. In Nicaragua northwest-directed (margin parallel) forearc motion occurs on northeast (margin normal) and northwest (margin parallel) trending faults within the arc. The proximity of active faults and magmatic systems has historically led to magma-tectonic interactions. We investigate the active tectonics of Nicaragua, and present two instances of triggered earthquake sequences and volcanic eruptions. The 1999 eruption of Cerro Negro volcano was preceded (~11 hrs) by four ~M5.2 earthquakes and coincided with regional aftershocks and triggered earthquakes. Coulomb failure stress modeling indicates the earthquakes triggered a sequence of regional earthquakes and reduced normal stress on the Cerro Negro-Cerro La Mula volcanic alignment leading to magma migration and eruption along an ~100 m long fissure.

We use GPS-derived co-seismic displacements and relocated earthquake aftershocks to study the April 10, 2014 (M_w 6.1), September 15, 2016 (M_w 5.7), and September 28, 2016 (M_w 5.5) as a triggered sequence of earthquakes on faults that accommodate forearc motion. Our analyses and modeling indicate that the April 10, 2014 earthquake ruptured a previously unmapped margin parallel right-lateral strike-slip fault in Lago de Managua (Xolotlan) and that the September 2016 earthquakes ruptured mapped arc-normal, left-lateral and oblique-slip faults. The April 10, 2014 earthquake promoted failure of the September 2016 earthquake faults by imparting static Coulomb failure stress changes of 0.02 MPa to 0.07 MPa. Additionally, the September 15, 2016, earthquake promoted failure (static Coulomb failure stress change of 0.08 MPa to 0.1 MPa) on a sub-parallel fault that ruptured five hours after the mainshock. The April 10, 2014 earthquake displaced the flank of Momotombo volcano ~6 cm coseismically and dilated (10s of μStrain) the shallow magma system of Momotombo Volcano, which led to magma injection, ascent, and eruption on December 1, 2015, after ~100 years of quiescence. In total, this sequence represents the potential for cascading hazards in a forearc-arc system, with earthquake and magmatic triggering over short spatial (10’s km) and temporal (yrs) scales.

PREHISTORIC PETROGLYPHS SHOWING A VOLCANIC ERUPTION

A. Avagyan[1], J-F. Ritz[2], P-H. Blard[3], Ph. Munch[2], P.G. Valla[4], M. Condomines[2], S. Nomade[5], K. Tokhatyan[6], R. Haroutiunian[1]

[1]. Institute of Geological Sciences, National Academy of Sciences of Armenia, 24a Marshal Baghramyan, Yerevan, Armenia, avagn1064@gmail.com, [2]. Géosciences Montpellier, Université de Montpellier , CNRS, 34095 Montpellier Cedex 05, France., [3]. CRPG, UMR 7358 , CNRS, Nancy Université, Vandoeuvre-lès-Nancy, France, [4]. ISTerre, Univ. Grenoble Alpes, CNRS, Grenoble, France, 6. Institute of History, National Academy of Sciences of Armenia, Yerevan, Armenia. 5. LSCE, UMR 8212, CEA Saclay, Bat 714, Site de l'Orme des Merisiers, Chemin de Saint Aubin - RD 128, F-91191 Gif sur Yvette Cedex – France

Prehistoric engravings and drawings provide information on the environment in which prehistoric men were living. They notably depict daily life events such as hunting scenes, which allow apprehending what kind of wild animals men where hunting. Drawings referring to events other than these daily life scenes are rare. For instance, engravings and drawings representing volcanic eruptions has been described in very few cases. They are particularly interesting because they bear witness to the interest that men has taken in these phenomena and also raise the question of the volcanic eruption age. In this paper, we are interested in dating the engravings representing a volcanic eruption found on a basaltic boulder located within a 30-km long elongated transtensional zone along the Pambak-Sevan-Syunik righ-lateral strike slip fault. Two volcanic massifs are located at the tips of the transtensional zone.

The Porak massif to the NW, situated 11 km is in direct sight from the boulder field within which was found the studied petroglyph, while the Karkar massif is situated 22 km south-eastwards, and cannot be seen from the petroglyph site.

We indirectly determined the two possible ages of the petroghyphs by dating the latest volcanic eruptions within the Porak and Karkar volcanic massifs with cosmogenic ^{3}He on pyroxene. We also determined the exposure age of the boulder field using cosmogenic ^{3}He dating, attempted to make a direct OSL surface-exposure age and provided an OSL minimum burial age for the fine sediments trapped below the studied boulder. We also analyzed the (^{226}Ra/^{230}Th) activity ratio of the youngest lava flow within the Porak volcano, and did two ^{40}Ar/^{39}Ar ages of the most recent volcanic eruptions within the two massifs.

Our geochronological results, completed with some glacial modelling and their interpretations, suggest that the studied area (the carved boulder field) was not totally covered by ice – at least locally - during the global LGM (MIS 2), allowing the prehistoric men to live or at least hunt in the area and carve petroglyphs on boulders situated at 3000 m asl.

SURFACE RUPTURES OF VOLCANIO-GRAVITATIONAL- ORIGIN ON THE TERRITORY OF THE REPUBLIC OF ARMENIA

A. Avagyan[1], J-F.Ritz[2], H.Nazari[3]

[1]. Institute of Geological Sciences, National Academy of Sciences of Armenia, 24a Marshal Baghramyan, Yerevan, Armenia, avagn1064@gmail.com, [2] Geosciences Montpellier, UMR 5243, CNRS, University of Montpellier, France, [3] UNESCO Chair on Coastal Geo-Hazard Analysis, Research Institute for Earth Sciences, Tehran-Iran.

In the Armenian territory, there are many surface ruptures as well as gravitational cracks, mostly volcanic or of uncertain origin. They are observed in volcanogenic terrestrial or lacustrine sediments and lavas.

The kinematics and propagation patterns of the faults show the relationship of their origin with the circumference of the volcanic structures and their position relative to their center, showing multidirectional propagation, often radial-concentric distribution associated with the formation or collapse of the volcanic structure.

Deformations of the pre-eruption site, dyke injections, micro-shocks of magma displacement and main shocks of its eruption interacting with gravity force led to the observed volcanogenic, volcano-tectonic, and gravitational deformations.

These observations are important to avoid seismic hazard overestimation and its related risks.

PROBABILISTIC VOLCANIC HAZARD ASSESSMENT OF ARMENIAN NUCLEAR POWER PLANT ACCORDING TO IAEA GUIDELINES

Khachatur Meliksetian[1], Charles Connor[2], Laura Connor[3], Ivan Savov[5] Ralf Halama[4], Gevorg Navasardyan[1], Ruben Jrbashyan[1], Osamu Ishizuka[6]

[1]Institute of Geological Sciences of NAS of the Republic of Armenia 0019, Yerevan, 24a Marshal Baghramyan Ave, km@geology.am, [2]School of Geoscience, University of South Florida,4202 E. Fowler Avenue, NES 107, Tampa, FL 33620-555, USA. [3]Desperate Measures International, LLC, 113 1st Ave NW, Lutz, Florida, 33548, USA. [4]School of Geography, Geology and the Environment, University of Keele, Staffordshire, ST5 5BG, UK, [5]School of Earth and Enviroment, University of Leeds, LS12 2JP, UK; [6]Institute of Geoscience and Geoinformation, Geological Survey of Japan, AIST, Central 7, 1-1-1, Higashi,, Tsukuba, Ibaraki, 305-8567 Japan

In 2009, the Government of the Republic of Armenia announced, that the construction of the new nuclear power plant (NPP) with capacity of 1200 MW was planned to start at the beginning of 2011 and to be completed by 2017, aiming to replace Unit 2 of the Armenian Nuclear Power Plant (ANPP). Considering the existence of an operating power plant in Armenia and presence of appropriate infrastructure, the decision was made that the new nuclear unit would be built close to the operating Armenian NPP site. The government initiated tender for research work on seismic and volcanic hazard assessments and detailed research on geotechnical conditions of ANPP site. Research under this tender was handled by international consortium.

The ANPP is located in a region of Quaternary (<2.58 Ma) and Holocene-Historical (<11.7 Ka) volcanism. Because of this fact, volcanic hazards potentially exist for facilities at the ANPP site, and these hazards must be evaluated in a quantitative way. This is consistent with safety guidelines of International Atomic Energy Agency, (e.g. IAEA SSG-21).

Detailed analyses of potential volcanic hazards at the ANPP site follow International Atomic Energy Agency (IAEA) guidelines provided for volcanic hazard assessment and include the following major tasks (Connor et al., 2011):

Development of a GIS volcanological database of the ANPP site in regional (300 km zone), near regional (50 km zone) and site vicinity area (8 km zone), which includes detailed geological maps, boreholes, geologic data on the extent, timing and nature of past volcanic activity in the region;

Development of a conceptual model of volcanism in the site region based on geochemical and petrologic studies, as well as information about the tectonic setting and geologic history of volcanism; Detailed analyses of the recurrence rate using $^{40}Ar/^{39}Ar$ dating and estimation of the potential magnitude (eruption source parameters) of each volcanic phenomena that may impact the ANPP site;

Numerical simulations of specific volcanic phenomena, such as tephra fallout, opening of monogenetic vents, PDCs and lava flows, was used to estimate the probability that such phenomena have an effect the site.

It is important to note, that after the report by Connor et al., 2011 was completed, during 2013-2015 Armenia volcanology team discovered distal tephra fall deposits in Armenia, originated, based on geochemical investigations and $^{40}Ar/^{39}Ar$ dating from Nemrut (~194 ka) and Ararat (~500 ka) Holocene-historically active volcanoes. A new stratigraphy of Plinian eruptions of Aragats volcano constrained by Ar-Ar nage determinations Gevorgyan et al., 2020)strongly support the existence of potential distal tephra fallout hazard in the region and indicate re-evaluation of volcanic tephra fallout hazard assessment for ANPP site is warranted. This is potentially significant, considering plans to build new NPP in Armenia in future, announced by the government of Armenia in 2022.

CONSIDERATIONS ON VOLCANIC HAZARD ASSESSMENT FOR SAFETY EVALUATION OF NUCLEAR FACILITIES IN JAPAN

Yoshiyuki Yasuike

Nuclear Regulation Authority, Division of Research for Earthquake and Tsunami, 1-9-9 Roppongi-First Bldg. 15F Roppongi, Minato-ku, Tokyo, Japan boltmany@outlook.jp , yasuike_yoshiyuki_7ws@nra.go.jp

Recent developments in volcanic research, such as geophysical exploration and analytical techniques, have provided us with a better understanding of the magmatic processes that lead to eruptions and the subsurface structures around volcanoes. On the other hand, there are still many issues to be addressed to realize the prediction or forecasting of volcanic activities that can ensure sufficient lead time to prepare for eruptions, which many volcanologists and volcano disaster prevention officials are seeking. Although there are many volcanoes in Japan, only a limited number of nuclear facilities have undergone volcanic impact assessments. Following the severe accident at a nuclear power station caused by the 2011 off the Pacific coast of Tohoku Earthquake, new regulatory requirements were established, and an assessment of volcanic effects was added to the list of natural phenomena subject to review, and a volcanic hazard assessment for nuclear facilities has been conducted.

Many nuclear facilities in Japan are separated from active volcanoes (volcanoes that have been active for approximately 10,000 years or less) by about 50 km, so there is no need to evaluate pyroclastic flows, lava flows, or other volcanic events that directly affect the siting of the facility. However, there are volcanoes scattered throughout Kyushu and Hokkaido aria, such as Aso and Aira, that have experienced caldera-forming eruptions in the past, and these volcanoes are also subject to evaluation.

This presentation summarizes the results of a geophysical survey conducted as part of our research project on volcanoes that have undergone caldera-forming eruptions in the past to investigate their activity histories to date, magma processes, and current volcanic conditions. In addition, we propose a long-term hazard assessment for volcanoes that have experienced large-scale eruptions such as caldera-forming eruptions by combining geological and petrological investigations of past volcanic activity with geophysical studies of current volcanic conditions.

In the caldera volcanoes studied in the research project, the depth of magma chamber just before eruption was estimated to be in the range of 4 to 10 km, and the time scale from the formation of an eruption-capable magma chamber to the eruption was estimated to be several hundred to several thousand years. In addition, as a survey of the current state of the caldera volcano, seismic observations on land and observations using the broadband MT method were conducted to investigate the subsurface structure up to approximately 20 km below the caldera.

As a case study of evaluation, we have evaluated the long-term hazard of the Aira caldera, where widespread crustal deformation has been observed in the vicinity of the caldera. The approximately 30 ka caldera-forming eruption of Aira caldera occurred after a series of small eruptions that erupted silicic magma after about 60 ka, and the depth of these magma reservoirs is estimated to have been located at about 4 to 6 km. Although crustal deformations suggestive of magma supply and a low-velocity region 15 km below the caldera have been observed in the present Aira caldera, it is estimated that it will take long time for a magma chamber to form in the shallow area below the caldera, which is typical of caldera-forming eruptions. Since there are uncertainties in the magma accumulation process under the Aira caldera, it is required that monitoring of crustal deformation and seismic activity of the caldera volcano be continued.

A BRIEF SUMMARY OF LATE CENOZOIC COLLISION MAGMATISM ACROSS IRAN

Monireh Kheirkhah[1], Mark Allen[2] Iain Neill[3]

[1] Research Institute for Earth Sciences, Geological Survey of Iran; Azadi Square, Meraj Avenue, Tehran, Iran
Kheirkhah.monireh1@gmail.com
[2] Department of Earth Sciences, Durham University, South Road, Durham DH1 3LE, England, United Kingdom
; [3]Geographical and Earth Sciences, University of Glasgow, Gregory Building, Lilybank Gardens, Glasgow G12 8QQ, Scotland, United Kingdom

Widespread but scattered late Cenozoic volcanic centres are distributed across the territory of Iran, which represent magmatism generated as the result of the Arabia-Eurasia collision. The centres are predominantly located north of the Bitlis-Zagros suture, i.e., on the Eurasian, hangingwall side of the collision. This distribution immediately suggests the role of water and an elemental budget provided during the pre-collision subduction of the Neo-Tethys Ocean. Initial collision was as long ago as ~35 Ma, near the Eocene-Oligocene boundary. Pre-collision magmatism and rifting were intense and switched off abruptly at this time, which if not a marker for initial collision itself was surely an indication of a major change in subduction regime. Magmatism has occurred sporadically since this time, but there appears to have been an upsurge since the middle Miocene (~16 Ma), for reasons that are not entirely clear. Space-time distributions in magmatism have variously been interpreted as showing diachroneity in initial collision, or no such pattern. Compositions are highly variable between individual centres, and range from lavas that are hard to distinguish from active continental margins (e.g., Ararat), highly-enriched small-degree melts with supra-subduction trace element patterns (Hamadan), OIB-like basalts (east Iran), ultrapotassic rocks (Eslamy) and adakites (Dehaj). Models that involve slab break-off or wholesale delamination of the lower lithosphere don’t fit the observed distribution of centres, or the range in compositions. We invoke small-scale sublithospheric convection as the best explanation for the collective characteristics.

VOLCANO-TECTONIC INTERACTIONS AND TRANSITION FROM POLYGENETIC TO MONOGENETIC VOLCANISM IN THE LESSER CAUCASUS (ARMENIA)

Gevorg Navasardyan[1], Ivan Savov[2], Edmond Grigoryan[1], Patrick Sugden[2], Jean-Philippe Metaxian[3], Khachatur Meliksetian[1]

[1] Institute of Geological Sciences, National Academy of Sciences of Armenia, 24a Marshal Baghramyan Avenue, Yerevan, Armenia , gn@geology.am; [2] Institute of Geophysics and Tectonics, School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK; [3] Institut de Physique du Globe de Paris, 1 Rue Jussieu, Paris.

The Lesser Caucasus Mountains sit on a transition within the Arabia-Eurasia collision zone between a very thin lithosphere (< 100 km) to the west, under Eastern Anatolia, and a very thick lithospheric root (up to 200 km) in the east, under western Iran. A transect of volcanic highlands running from north-west to south-east in the Lesser Caucasus allows to look at the effects of lithosphere thickness variations on the geochemistry of volcanic rocks in this continental collision zone (Sugden et al., 2019). Volcanic rocks from across the region show a wide compositional range from basanites to rhyolites, and have arc-like geochemical characteristics.

Temporal and spatial relationships between polygenetic and monogenetic volcanic activity as well as transitions from one to another are among fundamental problems in volcanology.

In Armenia from central part to south are located post-collisional Geghama, Vardenis and Syunik volcanic uplands. One of the general features of volcanism in Armenia, in the majority, is a combination of polygenic and monogenic volcanism, the latter being manifested both on the slopes of the polygenic volcano and on the peripheral plateaus. On the whole in these uplands are spread 367 monogenetic volcanoes.

In order to determine the age of transition from polygenic to monogenic volcanism, more than two dozen $^{40}Ar/^{39}Ar$ dating's were carried out in different uplands from the key volcanic series.

Geological evidence such as presence of thick (about 500m) Vokhchaberd volcanoclastic suite at foothills of Geghama upland suggests presence of stratovolcano (caldera-?) activity in Late Miocene-Pliocene (K-Ar dating data 3.4-6.7Ma; Bagdasaryan et al, 1985). After the polygenic volcanism the volcanism of Geghama upland is accompanied by fissure (plateau basalt) and then monogenic volcanism. Plateau basalts of Geghama upland age of these are $^{40}Ar/^{39}Ar$ 2.37±0.03 Ma (Neill et al., 2015). According to Meliksetian (2018), for monogenetic volcanoes there are age data from Jraber obsidian (1.2±0.5 Ma), extended flows from the Geghama upland - Argavand (221.1±5.0 Ka), Gutansar flow (314.1±16.2 Ka), Garni columnar flow (127.7±2.6 Ka) and lavas overlapping the Garni flow (49.9±9.2 Ka), which show the chronological and stratigraphic position volcanic activity of Geghama upland.

Taking into account available age determinations it is obvious that the volcanism of the Geghama upland continued from the Late Miocene time and up to the Upper Pleistocene and Holocene, and at the turn of the Pliocene-Quaternary period in, due to changes in volcano-tectonic conditions, a change occurred in polygenic explosive-effusive volcanism to predominantly effusive monogenetic and this transition has an interval of ~1.1 Ma.

Our $^{40}Ar/^{39}Ar$ ages of monogenetic volcanism from the Vardenis and Syunik uplands are younger than 1.5 Ma, suggesting that the bulk of exposed post-collisional volcanic rocks are from mid- to late Pleistocene eruptions. However, the ignimbrite age of 6Ma shows the region has been host to post-collisional volcanism since at least the late Miocene. The new ages confirm that a transition from polygenetic to monogenetic volcanism occurred around 1Ma in the Syunik upland, while in the Vardenis upland to the north volcanism was already monogenetic by 1.4Ma.

NEW $^{40}Ar/^{39}Ar$ GEOCHRONOLOGY OF DEBED LAVAS, NORTHERN ARMENIA

Katie Preece[1], Darren Mark[2], Keith Wilkinson[3], Dmitri Arakelyan[4], Jenni Sherriff[5], Rhys Timms[6], Christina Manning[7]

[1]Dept. of Geography, Faculty of Science and Engineering, Swansea University, UK, k.j.preece@swansea.ac.uk ; [2]Scottish Universities Environmental Research Centre, East Kilbride, UK; [3]Dept. of Archaeology and Anthropology, University of Winchester, UK; [4]Institute of Geological Sciences, National Academy of Sciences of the Republic of Armenia; [5]Dept. of Geography, King's College London, UK; [6]School of Archaeology, Geography and Environmental Science, University of Reading, UK; [7]Dept. of Earth Sciences, Royal Holloway, University of London, UK

The Southern Caucasus is the site of an extensive basaltic province, covering parts of Armenia, Georgia and Turkey. The lavas are thought to have been fed by eruptions located on the Javakheti Plateau (Georgia – Armenia) and the adjoining Kars-Erzurum Plateau (Turkey), during the Late Pliocene – Early Pleistocene [1]. With an estimated volume ≥ 2250 km^3, it has been proposed that this province is the youngest and smallest continental flood basalt province on Earth [2]. The region is also important archaeologically, with the earliest hominin fossils outside Africa (~ 1.8 Ma) found in sediments overlying similar lavas in Dmanisi (Georgia) [3, 4], the discovery of which transformed understanding of early hominin expansion and the relationship between the European and African Palaeolithic.

This study focusses on lavas in the south-eastern portion of the basalt province, in the Debed Gorge, Northern Armenia. Here, mildly-alkaline basalt to basaltic andesite lava flowed down the Debed palaeo-valley, forming a lava plateau. We present new field observations, $^{40}Ar/^{39}Ar$ geochronology, and whole rock geochemical data in order to elucidate the volcanic history of the region. Results indicate that the Debed lavas were emplaced between 2.0 and 1.85 Ma. The ages reveal that archaeology-bearing sediment sequences overlying flows could be contemporaneous with Dmanisi, thereby highlighting the regions potential for future archaeological work critical to understanding the nature and timing of hominin dispersal.

THE EVOLUTION, ERUPTIVE RECURRENCE RATES AND BEHAVIOUR OF MONOGENETIC VOLCANISM IN THE GEGHAM HIGHLANDS, CENTRAL ARMENIA

Priya Minhas[1], Katie Preece[2], Khachatur Meliksetian[3], Edmond Grigoryan[3], Richard Johnston[4], Darren Mark[5]

[1]Department of Geography, Faculty of Science and Engineering, Swansea University, Singleton Park, Swansea, UK, 2156698@swansea.ac.uk ; [2] Department of Geography, Faculty of Science and Engineering, Swansea University, Singleton Park, Swansea, UK; [3] Institute of Geological Sciences, Armenian National Academy of Sciences, 24a Marshal Baghramian Avenue, 0019, Yerevan, Armenia; [4] AIM Facility, Faculty of Science and Engineering, Swansea University, Bay Campus, Swansea, UK; [5] Scottish Universities Environmental Research Centre, Rankine Avenue, Scottish Enterprise and Technology Park, East Kilbride, UK

The Gegham Highland volcanic field is the site of one of the densest clusters of monogenetic vents anywhere in the world [1]. It consists of >120 Pleistocene-Holocene monogenetic scoria cones and lava domes contained within a 65km long, 35km wide, NW/SE trending area. The vents were formed during strombolian to violent strombolian eruptions which produced extensive lava flows, scoria, and spatter with basalt, trachybasalt and basaltic trachyandesite compositions [1, 2].

The timing of volcanism in the Gegham Highlands is uncertain. K-Ar dating of past eruptive activity in the region has yielded ages between 700 ka and < 50 ka, with uncertainties for the youngest eruptions approaching ± 100 % [2,3]. Archaeological evidence suggests eruptive activity in the region may be as young as ~3.5 ka [4]. Recent studies suggest a link between seismic swarms in the Gegham Highlands and an active magmatic system [1]. With uncertainty regarding the timing of the last eruption and the potential threat of future volcanism, high precision $^{40}Ar/^{39}Ar$ ages for past eruptions are critical to underpin spatial and temporal volcanic modelling of the Gegham Highlands, to understand possible future eruption scenarios.

This project will use $^{40}Ar/^{39}Ar$ geochronology to determine the spatio-temporal evolution and eruptive recurrence rates of monogenetic volcanism in the Gegham Highlands. New $^{40}Ar/^{39}Ar$ ages will be used to inform statistical modelling forecasting the location and timing of a possible future eruption. In addition, constraints on magma ascent and eruptive behaviour will be gained from textural analysis using Scanning Electron Microscopy and X-ray micro-CT/microscopy. Overall, the results from this project will be used to inform hazard assessment in Armenia and provide insight into evolution of monogenetic volcanic fields in continental-collision zones worldwide.

MONITORING OF VOLCANIC ACTIVITY OF ONE OF THE YOUNGEST ACTIVE MONOGENETIC VOLCANIC FIELD (HARRAT) AROUND AL MADINAH, WESTERN SAUDI ARABIA

Abdulrahman Alsowaigh [1], Khaled Abdulhafez [1], Mahmoud Ashor [1], Turki Hablil [1], Ahmed Hosny [1,2], Károly Németh [1,3,4], Fawaz Moqeem[1], Majed Al-Mutairi[1]

[1] National Program of Earthquakes and Volcanoes, Geohazard Centre, Saudi Geological Survey (SGS), Jeddah, Saudi Arabia, email: sowaigh.ag@sgs.org.sa, [2] National Research Institute of Astronomy and Geophysics, (NRAIG), Cairo, Egypt, [3] School of Agriculture and Environment, Massey University, Palmerston North, New Zealan, [4] Lithosphere Research Group, Institute of Earth Physics and Space Science, Sopron, Hungary

Al-Madinah Al-Munawwarah is a city of nearly 1.5 million people with double in population during main pilgrimage times. The city is in the northern part of the Arabian Shield and surrounded by three active Quaternary volcanic fields as each hosts volcanic sites formed in the past 10 ka. The Harrat Khaybar (also known as Waqim) from a well-defined lava-dominated volcanic field is in the north of the city. Harrat Al-Madina upon Al Madinah developed, is part of the extensive Harrat Rahat’s northern tip. Harrat al-Wabra is in the western side of the city. The distribution of these harrats is linked to the initiation of the Red Sea rift system at the end of the Oligocene era, or the beginning of the Miocene (~25 Ma). The volcanic eruptions of these harrats are among the largest volcanic field-building volcanic eruptions in the world. Harrat al-Madinah in the south is one of the volcanically most active part of the region, where geological mapping distinguished more than thirteen volcanic eruptions generating extensive complex transitional type of lava fields occurred during the past five thousand years that is equivalent to a major lava emitting volcanic eruption in every four hundred years. There are historic accounts for young volcanic events such as the eruption of year 21 AH (644 CE), however its source still under debate. In contrast, the most recent volcanic eruption in the Arabian Peninsula in the year 654 AH (1256 CE) formed a 2.3 km-long fissure. Seven well-distinguished spatter and scoria cones formed and a complex transitional lava flow travelled toward the early settlement of Al Madinah at least 15 km to the north and accompanied with repeated explosive phases leaving behind extensive ash plains. The terminus of these lava flows marks the southernmost tip of the runways of the Al Madinah International Airport. This scenario graphically demonstrates what a similar eruption like the 1256 CE event could pose to the modern urban environment and highlights the need to employ an effective volcanic hazard monitoring and mitigation strategy in the region what the Saudi Geological Survey’s National

Program for Earthquakes and Volcanoes manages. In addition, the Harrat Khaybar is also volcanically active, as it contains thermal activity and gas discharge in some locations. As a continuous and periodical monitoring, it is necessary to monitor these activities by measuring thermal activity twice a year in ~250 wells distributed in and around these harrats, as well as measuring the emission of gases. The measurements over a period of a decade indicate some elevated temperature at a rate up to 3-8 degrees in Harrat Al-Madinah. This variation could be accounted to the presence of shallow level magma as some geophysical data indicates potential fluid in depth. To increase monitoring capability and mitigating volcanic risk, seismic and specific volcanic monitoring stations are currently being added to the geohazard monitoring network of the Saudi Geological Survey.

GEOSCIENTIFIC ANALYSIS OF STRUCTURAL COLLAPSES IN THE CITY OF JUAN C. BONILLA,PUEBLA, MEXICO (2021)

Rogelio Ramos Aguilar[1], Patricia Máximo Romero[1], Víctor Galindo López[1], Máximo Ávila Cruz[1], María de la Cruz Vázquez García[2], Victoriano Covarrubias Salvatori[3]

[1] Meritorious Autonomous University of Puebla, Faculty of Engineering; University City s/n, Puebla, Puebla, Mexico, rogelio.ramos@correo.buap.mx; [2] Geographic Images S.A. de C.V.; Guadalajara, Mexico, mayanegui@icloud.com; [3] Council of Science and Technology of the State of Puebla; Privada B Poniente de la 16de Sept. 4511, Huexotitla, Puebla, Puebla, México, victoriano.covarrubias@puebla.gob.mx

The work was supported by the Council of Science and Technology of the State of Puebla, it is based on a general analysis from the geosciences of the collapse in the crop fields of Santa María Zacatepec, in the city of Juan C. Bonilla. In the development, the technique of Remote Sensing is applied, allowing to interpret combinations of bands and to determine the geometry, geology, geomorphology and cartography of the site.

A summary analysis of the work performed is presented, in addition to showing simulation models of the hydrological expenditure and water acceleration in the runoff structural slopes, datathat were used for the mapping and graphic modeling.

The geomorphological, geological and topographical study of the site was carried out withsatellite and aerial telemetric techniques, and specialized software was also used for geodetic surveys to obtain 2D and 3D models of the analysis area.

The surveys of the site were carried out with the objective of recognizing the shape of the structure and identifying potentially risky areas for the population near the collapse.

The slope by distance-elevation, acceleration-height, water flow and force were determined to conclude that the collapse zone puts the population at risk.

HAZARD TO THE COAST AFTER POWERFUL EARTHQUAKES

Khomchanovsky A.L.
Institute of Volcanology and Seismology, Far Eastern Branch of the Russian Academy of Sciences, Petropavlovsk-Kamchatsky, 9 Piip Boulevard, Russia, khomscience@mail.ru

The research was conducted on the coast of Iturup Island. The island is located in the southern segment of the Kurilo-Kamchatka subduction zone at a distance of about 200 km from the trench. The depth of the slab is about 50 km under the eastern segment of the coast and 70 km under the western segment. According to our earlier paleoseismological studies at such a distance from the deepwater trench during strong earthquakes coseismic surface subsidence from 0.5 to 2 m may occur. The same deformations are reflected in the Okada model.

In July-August 2022, paleoseismological research was carried out on Iturup Island within the framework of the RRF project "Study of volcanic, seismic and tsunami hazard and assessment of geothermal resources for developing territories of the Kuril Islands". The purpose of the research is to find and study geological traces of the strongest earthquakes that occurred in the southern segment of the Kurilo-Kamchatka subduction zone in the Holocene. During such earthquakes sharp vertical positive or negative movements with amplitudes up to the first meters, the so-called coseismic deformations, may take place on the coasts opposite to the origin place. If elevation occurs, the water edge recedes toward the sea, and a step is formed on the shore - an elevated accumulative or abrasion terrace. When the coastline sinks, however, erosion starts, as a result of which the water edge advances toward the land, part of the marine terrace is eroded away, and a new, higher storm wall is formed on the coast, which usually overlaps the erosion ledge of the older terrace. Thus, the geological evidences of the coseismic subsidence are imprinted in the relief (the ancient beach ridges are lower than the younger ones) and the presence of buried scarps in the body of the marine accumulative terrace. The methodology of the mention paleoseismological studies is reflected in more detail in the following works [1, 2]. Traces of six powerful earthquakes, which caused coseismic subsidence, were found on Iturup Island on the western coast. The average interval between them is approximately 330 years. The last earthquake probably occurred in 1958. Amplitude of the subsidence was 30 cm.

In this work, numerical simulations of coastal retreat after relative sea level rise associated with coseismic surface subsidence were performed. The Kuril Bay was chosen as the main area for modeling. The largest settlement of the island, Kurilsk, and all major infrastructure is located here. Kurilsk - fishermen road which is about 3 kilometers long is located just in 30-100 meters from the active coastal ledge. These facts confirm not only the scientific but also the practical relevance of the study.

The well-known Bruun-Zenkovich model was chosen for numerical modeling. The description of this model is given in. Its practical workability is confirmed in the following publications.

Calculations by Bruun's formula show the following coastal recession at the corresponding coastal subsidence: at 0.5 m subsidence, the recession is 85 m; at 1 m subsidence, the recession – 170 m; at 2 m subsidence, the recession – 340 m.

From these calculations, it is clear that even with minimal amplitudes of subsidence which occurred less than 100 years ago, there is a danger to the infrastructure of the island. From similar works in kind it is proved that erosion can last up to 20 years and the restoration of the coast to its former parameters – about 40 years. However, additional research is needed to model these quantitative indicators.

This study was supported by grant #21-17-00049 of the Russian Science Foundation, https://rscf.ru/project/21-17-00049, supervised by E.I. Gordeev

THE ESSENCE OF GEOTOURISM AT THE DEPARTMENT OF VOLCANOLOGY, GEOLOGICAL MUSEUM NAMED AFTER PROFESSOR H. KARAPETYAN OF IGS, NAS ARMENIA

Gayane Grigoryan, Narine Poghosyan, Marine Badalyan, Ruben Davtyan
Institute of Geological Sciences, National Academy of Sciences of Armenia, 24a Marshal Baghramyan Avenue, Yerevan, Armenia, Email: gayane347@gmail.com

The entire area of the Armenian Plateau, expanding from Lake Van to its western borders, including Ararat, Sipan, Tondrak and the present-day territory of Armenia, is covered with various types of volcanic rocks of the latest Pliocene-Quaternary age (basalts, andesites, tuffs, felsites, obsidians). This covers about 2/3 of the actual territory of Armenia. Among 550 volcanoes on this territory, only 16 are the so called "acid" volcanoes, which erupted and ejected lavas of rhyolite-rhyolite-dacite composition, obsidians, perlite and pumice. These volcanoes, along with all other volcanoes, are part of young volcanic belt of Armenia, which extends from the North-West to the South-East.

Geological Museum of IGS named after H. Karapetyan was establish in 1937, almost 85 years, various rocks of volcanic origin, such as tephras, lavas, volcanic bombs of various shapes and compositions were collected and are exhibited in the Geological Museum. This section of the museum is of great interest and importance for scientific and educational purposes. It also serves the fundamentals for the development of scientific and educational tourism in Armenia.

This report presents unique geological monuments of volcanic origin of the territory of Armenia.

They are: the Arteni complex, the Mets and Pokr Arteni, Hatis, Gutansar, Jraber, Spitakasar and Geghasar, Khorapor, Bazenk, Mets, Mijnek and Pokr Satanakars, Mets and Pokr Sevkars.

Specimens collected by outstanding geologists are exhibited at the Geological Museum, and some of them are:

1. Collection of K.I. Karapetyan - Quaternary lavas of the Geghama Range;
2. Collection of K.G. Shirinyan, S. H. Karapetyan - young volcanic rocks of Syunik;
3. Collection of H.T. Karapetyan, K.G. Shirinyan, S.H. Karapetyan - basalts, andesite-basalts, andesites of Armenia;
4. Collection of R.T. Jrbashyan. Paleogene volcanic series of central Armenia;
5. Collection of S.H. Karapetyan: obsidians, volcanic bombs;
6. Donations of unique volcanic formations brought from different countries by H. Maghakyan, R. Melkonyan, Kh. Meliksetyan, L. Sahakyan.

All are on display in the volcanology section at the Geological Museum of the Institute of Geological Sciences.

The museum-visitor relationship requires education in the museum's scientific and cultural space. The theoretical and methodological principles are based on museum pedagogy, the main functional procedure is the organization of alternative and sustainable education for all target groups.

Also, training courses for guides are organized. In recent years, the museum organizes open-air study sessions outside the museum, such as, part of a special scientific expedition named "The Road of Obsidian", visits to obsidian deposits were organized to introduce young volcanos, the volcanic outcomes, tools made by pre-historic humans, the role and the significance of obsidian in historical, mythological and folk arts.

Similar programs contribute to the development of Geotourism.

Thus, the museum is an educational platform for students, schoolchildren and adults.

3. VOLCANO-SEISMOLOGY, GEOPHYSICS, SEISMIC TOMOGRAPHY

THE TRANSITION OF CRUSTAL PROPERTIES, LITHOSPHERIC THICKNESS AND MANTLE DEFORMATIONS IN THE EASTERN ANATOLIA-CAUCASUS: VOLCANISMS CORRELATED?

Tai-Lin Tseng[1], Jing-Hui Tong[2], Khachatur Meliksetian[3], Bor-Shouh Huang[4]

[1] Department of Geosciences, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Taipei, Taiwan, tailintseng@ntu.edu.tw ; [2] Department of Geosciences, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Taipei, Taiwan; [3]Institute of Geological Sciences, National Academy of Sciences, 24AM, Baghramyan Ave.,Yerevan, Republic of Armenia; [4]Institute of Earth Sciences, Academia Sinica, 128, Sec. 2, Academia Rd., Taipei, Taiwan

Region from eastern Turkey to the Caucasus is an active orogeny in southern Eurasia that shows complicated crustal deformation, neotectonic structures and post-collisional volcanisms. With increasingly more studies published, significant lateral changes are now better delineated; however, the correlations between them are less discussed. Here we try to combine results from different studies to understand the relations behind in collision process. For the whole region, the stress field is predominantly controlled by northward impinging of Arabia plate, which is evident by earthquake focal mechanisms showing sub-NS oriented maximum principal stress. In response to the convergence, large shortening is taken place in the Caucasus mountains, while as conjugate strike-slip systems are developed in the relatively rigid plateaus of eastern Turkey and Armenia. The transition of crustal stress is near the Javakheti volcanic ridge (44˚E, 41˚N) in the Lesser Caucasus, near the border of southern Georgia. Interestingly, straight south of Javakheti, there are two large stratovolcanoes Aragats and Ararat developed in valleys bounded between major strike-slip faults. Sharp change in various properties seems to occur near 44–45˚E longitude. For example, beneath the Greater Caucasus east of 45˚E, the Moho depth is deeper and the subduction related seismicity dipping north are abundant. The E-W division is near Kazbek stratovolcano where slab-tear is speculated underneath. The geodetic data, on the other hand, also exhibit diverging motion, with greater NE component and speed in region east of 44˚E that is possibly influenced by subduction. Shear-wave splitting time drops by nearly 40% from Turkey toward Armenia indicating flow pattern change. The coincidence of these phenomena suggests that the relative motion between eastern and western part of the Caucasus region, divided along ~44–45˚E, may play an important role during the development of volcanoes. The mantle flow might be guided along this boundary, which is also the edge of undelaminated lithosphere.

MONITORING VOLCANIC ACTIVITY USING DENSE NETWORKS OF SEISMIC SENSORS

Jean-Philippe Métaxian

Institut de Physique du Globe de Paris, Université Paris Cité, metaxian@ipgp.fr 1, rue Jussieu,75005 Paris, France

The seismic activity observed on volcanoes is characterized by a wide variety of signals, both in frequency and duration. It is accepted that there are 2 main categories of volcano seismic signals: those corresponding to rock fracturing processes, comparable to earthquakes produced by displacements on faults, and those associated with fluid movements (water, gas, magma). This second category is characterized by low-frequency signals (< 5 Hz) including long-period, very-long-period and tremor signals. LPs and so-called hybrid signals (a combination of fracturing processes and cavity oscillation due to fluid movements) may be proxies for magma movements in the conduit of andesite-type volcanoes as well as dome growth. When VLP sources are deep, they are associated with intrusive processes. Tremors reflect a wide range of phreatic or magmatic processes, hydrothermal activity, degassing, magmatic emission, lava flows, etc. Most of the time, seismic signals associated with fluid movements are characterized by emergent onsets, frequently the absence of identifiable P or S waves, a duration ranging from a few seconds to several days or even a quasi-permanent signal in the case of tremors.

Locating the source of signals generated by fluid movements and tracking it in space and time is essential for monitoring volcano activity. This is difficult to achieve with traditional seismic methods based on the pointing of seismic phases since they are often unidentifiable. Dense seismic networks make it possible to use the similarity of signals recorded by spatially close sensors to characterize the wave field passing through the array. With a sufficient number of sensors to achieve redundancy of information, and a geometry adapted to the wavelength of the observed signals, the slowness vector of the dominant wavefield can be estimated. The slowness vector is used to extract the back-azimuth and the apparent wave propagation velocity. A dense network indicates the propagation direction, gives an idea of the source depth and the wave type. Locating sources requires 2 or more favorably arranged arrays.

Applications of dense seismic networks will be shown on different volcanoes of andesic (Ubinas, Peru; Merapi, Indonesia) and strombolian (Stromboli, Italy) types. Several volcanic processes will be illustrated, including Vulcanian and phreatic explosions, pyroclastic flows. This type of methodology is applicable to different contexts of active volcanism and geothermal activity. It is integrated into permanent monitoring networks, as is the case at Merapi in Indonesia.

WHAT MIGHT WE EXPECT FROM SEISMICITY AT VOLCANOES REAWAKENING AFTER LONG PERIODS OF DORMANCY? – LESSONS FROM RECENT UNREST IN ECUADOR

Andrew Bell

School of GeoSciences, University of Edinburgh, a.bell@ed.ac.uk

Hazardous future eruptions in continental collision zones will occur at volcanoes which have been dormant for many centuries. For such volcanoes there is no empirical record of the nature of unrest that precedes eruption, so eruption forecasts and crisis management will rely on experience from analogous volcanoes and physical/theoretical models. Here I call on observations made as long-dormant subduction zone volcanoes reawaken in Ecuador to consider the nature of seismicity which could be expected to precede an eruption at a stratovolcano in a continental collision zone. After quiescence periods of >100 years, both Cotopaxi and Cayambe volcanoes have recently shown renewed signs of unrest. In 2015 Cotopaxi displayed increasing rates and magnitudes of volcano-tectonic earthquakes low-frequency seismicity, vent-clearing explosions and tremor before minor ash emission events. In late 2022, renewed ash emission pulses were accompanied by tremor signals, but only minor earthquakes, suggesting re-activation of an already partially open system. In 2016, a few months after a large regional earthquake, Cayambe volcano underwent a seismic crisis with escalating rates of volcano-tectonic earthquakes and deformation, before a gradual cessation. These observations are broadly consistent with physical models for the re-activation of volcanic systems, but suggest that the trajectory of these processes can be intermittent, piecemeal, and multi-directional. Plans for managing such crises need to incorporate an expectation for multiple ‘false alarms’ and should be supported by investment in long-term baseline monitoring.

REGIONAL VARIATIONS IN AZIMUTHAL ANISOTROPY IN THE UPPER MANTLE BENEATH THE EASTERN ANATOLIA-CAUCASUS: EFFECT OF RECENT LITHOSPHERIC DELAMINATION

Jing-Hui Tong[1], Tai-Lin Tseng[2], Pei-Ying Patty Lin[3], Khachatur Meliksetian[4],Bor-Shouh Huang[5]

[1] Department of Geosciences, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Da’an, Taipei, Taiwan, r09224220@g.ntu.edu.tw; [2] Department of Geosciences, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Da’an, Taipei, Taiwan; [3] Department of Earth Sciences, National Taiwan Normal University, No. 88, Sec. 4, Tingzhou Rd., Wenshan, Taipei,Taiwan; [4]Institute of Geological Sciences, National Academy of Sciences, 24, Marshall Baghramian Ave. 0019 Yerevan,Republic of Armenia; [5]Institute of Earth Sciences, Academia Sinica, 128, Sec. 2, Academia Road, Nangang, Taipei, Taiwan

The Caucasus region in west Asia is a natural laboratory to study dynamics of continental collision between the Arabian and Eurasian Plates that initiated about 25 Ma. Based on geophysical and geochemical evidences in the past 20 years, the mechanism known as lithospheric delamination, has been proposed to explain the activities of post-collisional volcanisms from eastern Anatolian Plateau to Northwest Iranian Plateau. The Armenian highland is in the unique location where the Pleistocene-Holocene volcanisms are pervasively covered and the lithosphere thickness gradates toward the no-mantle-lid Anatolia. In the Northwest Armenia under Aragat stratovolcano, the lowermost crust probably had also been removed by a recent delamination, leaving unusually thin crust with high average *Vp/Vs* ratio. A remaining keyquestion is how the lithospheric delamination influence the mantle flow at deep depth beneath thevolcanic plateau. In this study, we use regional arrays in Armenia and its vicinity to explore the lithospheric deformation and asthenospheric flow in detail based on azimuthal anisotropy constrained by shear-wave splitting (SWS) of the *SK(K)S* phases. Overall, the pattern of 167 high-quality SWS results shows a predominant fast-direction of 45° with average delay time of

0.92 s. Both splitting parameters are greatly consistent with the previous results in the eastern Anatolia (55° and 1.3 s), which is characterized by a extremely thin lithosphere (<50 km) after delamination at ~6.5 Ma. To explain such large-scale signature in anisotropy, we propose a two- layer model that integrate the plate-coupled mantle flow (65°, ENE-WSW orientated) in the uppermost asthenosphere overlying on top of another deeper flow (sub-N-S orientated) at the depth range of 100-200 km, which is likely transported from Afar-upwelling at far distances. A regional transition in splitting behavior is observed beneath central Armenia, characterized by gradual tapering down of the delay time with the fast-direction leaning toward the edge contourof the undelaminated lithosphere. Our seismic evidences corroborate well with the variation of lithospheric thickness and the inevitable gradient in mantle thermal laterally under Armenia, which promote the Rayleigh-Taylor instabilities for enhanced vertical-oriented mantle flow, giving smaller SWS splitting.

THE FEATURES OF SEISMIC ACTIVITY IN THE GEGHAM VOLCANIC RIDGE (ARMENIA) DETERMINED BY THE TEMPRORARY INTALLED SEISMIC NETWORK

L.Sargsyan, E.Sahakyan, A.Levonyan, H.Demirchyan, A.Juharyan, G.Navasardyan, E.Grigoryan, Kh.Meliksetian, H. Babayan, M. Gevorgayn, G. Babayan

Institute of Geological Sciences, NAS RA, 24a M. Baghramian Ave., Yerevan 0019, Republic of Armenia

s.sargsyan.lilit@gmail.com

Armenia, SE Turkey and NW Iran are located in the central part of the Arabian lithospheric collisional zone, a region which experiences N–S shortening and E–W extension accompanied by intense faulting, strong earthquakes and active volcanism. The Gegham volcanic upland is centrally located in the Neogene-Quaternary volcanic belt of the Armenian Highland. The duration of volcanism within the Gegham ridge spans from the Late Miocene to the Holocene. The Gegham Volcanic Ridge (GVR) in central Armenia is one of the densest clusters of individual monogenetic volcanoes in the world. The volcanically young Gegham Ridge holds great potential as a geothermal energy source.

Our study area, Gegham Volcanic Ridge, is located between the system of Gegham Ridge Fault (GF1) and the Gavaraghet Fault (GF2). The faults in the axial part of the Gegham ridge (GF1) represent fracturing structures related to eruptions of numerous Quaternary volcanoes, forming linearly elongating clusters, and have not showed any significant tectonic or seismic activity. The Gavaraghet Fault (GF2) is the most active fault in the Gegham system, and was associated with a few historical and recent earthquakes. From 2014-2018, earthquake swarms were recorded in the GVR region; we analyzed these swarms to characterize the relationship between tectonic and volcanic processes, and to improve volcanic hazard assessment for this area.

To investigate current seismic activity in the study area, as well as possible swarms in volcanic arcs, we deployed three more temporary seismic stations (LNRR, ZVSV, and ZAR) alongside the existing seismic networks. Using all available seismic records from all stations, we recalculate event parameters in order to maximize the resolved accuracy of epicenters and hypocenters. Analyzing all seismic activity in the region from 2014-2023, we find that the Gegham area remains seismically active in terms of small earthquakes ($M<=3.5$).

We also calculate the source mechanisms of earthquakes using digital waveform data recorded by seismic stations of the Armenian seismic networks (including the three new temporary seismic stations mentioned above). Based on the polarity of the first motion of the P-wave, we construct the focal mechanisms of a set of earthquakes that occurred from 2022-2023 with high reliability. For these calculations, all data were first relocated using local and regional seismic network data, in order to reduce main parameter uncertainties in the earthquake catalogue.

4. Ignimbrites and Plinian eruptions

MELT CHEMISTRY AND THE ERUPTIVE PROPERTIES OF HIGH SILICA EXPLOSIVE SYSTEMS

Dingwell, Donald B.
Ludwig-Maximilians-Universität (LMU), Munich, Germany, dingwell@lmu.de

Melt chemistry is a long-investigated and highly complex variable in the properties of high silica magmas that are the end products of continental collision zone volcanism. Its most dramatic expression in terms of melt properties is the viscosity of the melt phase. Magmas are of course distinguished rheologically from their single-phase parental liquids by the crystals and bubbles that grow in them during cooling and decompression. The physical effects of both have been extensively investigated and their most dramatic effect on magma rheology lies in their general ability to drive the viscoelastic response of the bulk into the non-Newtonian regime.

Using several recent examples of experiments and analysis of the rheology of these magmas, I will argue that it nevertheless remains the chemistry of the melt phase that dominates the bulk viscosity and which controls the response of the magmatic suspension to phase separation (through crystallisation and vesiculation) in the relevant stages of much of high silica volcanism. The remarkable properties of high temperature liquid silicates dominate the expression of volcanism on Earth.

DRIVERS OF EXPLOSIVE VOLCANIC ERUPTIONS

Dork Sahagian
Lehigh University Bethlehem, PA, USA, Dork.Sahagian@Lehigh.edu

Explosive volcanic eruptions are driven by the ascent and rapid expansion of vesiculating silicic magma in volcanic conduits. A series of processes is involved, starting with bubble nucleation, then bubble growth, and finally fragmentation to ash near the volcanic vent.

As magma containing dissolved volatiles (notably H2O) undergoes buoyant ascent in the plumbing system beneath a volcano, the it becomes saturated and then oversaturated in H2O because solubility is reduced due to decreasing pressure. At some point, the oversaturation overcomes the potential barriers to bubble nucleation. These barriers arise from the high surface tension pressure involved in tiny bubbles, and are reduced significantly in the presence of microlites that reduce the activation energy required for nucleation on crystal surfaces. As such, heterogeneous nucleation can occur at the lowest oversaturation, and homogeneous nucleation requires greater oversaturation. In unusual cases, when nucleation may be suppressed to the point where oversaturation is extreme, spontaneous phase separation may ensue, leading to uphill diffusion and spinodal decomposition. The style of nucleation strongly controls the number density of nucleation sites, and thus the number density and size distribution of resulting bubbles that drive eruption. Yet, nucleation is the least well understood process in the sequence that drives eruptions.

Once bubbles have nucleated, further decompression during magma ascent causes them to grow by diffusion of H2O into existing bubbles (due to decreasing solubility) and decompression due to ascent. In this dynamic system, there are three terms of pressure within a bubble: Hydrostatic pressure (ambient), surface tension pressure, and dynamic pressure arising from the resistance of viscous magma to bubble expansion. The relative contribution of each evolves during magma rise and bubble growth.

As a parcel of bubbly magma ascends in (conceptually simple) conduit, bubble growth causes expansion and thus causes it to accelerate the parcels above. This positive feedback can lead to extremely rapid ascent and decompression at the vent. With such rapid decompression, solubility declines quickly, increasing oversaturation of the melt between bubbles. In some cases, oversaturation may reach the level to trigger another phase of bubble nucleation of syn-eruptive bubbles between the pre-eruptive bubbles. This is common in explosive eruptions of VEI 4 or greater, but not observed in less violent cases (<VEI 4). The nucleation of a second set of bubbles greatly reduces the diffusion distance of dissolved water into bubbles, and thus enables more rapid expansion of the magmatic foam, further increasing explosivity.

The rapid expansion of bubbles at low pressure near the vent leads to dominance of dynamic pressure within them. When this pressure exceeds the strength of bubble walls and Plateau borders, they rupture, and fragmentation of the foam ensues, leading to formation of ash. The nature of the ash depends on the style of nucleation and resulting bubble size distribution. If all bubbles are identical (i.e. spinodal decomposition, or even homogeneous nucleation), they will all burst at once in a sudden explosion, and only simple ash will be erupted. If, however, there is a broad bubble size distribution and thus varying wall thickness, larger bubbles will burst first, leaving interstitial smaller bubbles between intact as the ash is quenched in the eruptive column. This makes compound ash that resembles tiny pumice fragments. As such, the morphology of erupted ash can be in indicator of the processes that drive explosive volcanic eruptions.

MESSAGE IN A PYROCLAST

Kueppers, Ulrich[1], Esenyel, Sarp[1], Pisello, Alessandro[3], Hornby, Adrian[3], Dingwell, Donald B.[1]

[1] Ludwig-Maximilians-Universität (LMU), Munich, Germany, u.kueppers@lmu.de;, [2] Università di Perugia, Perugia, Italy, [3] Cornell University, Cornell, USA

Plinian and sub-Plinian eruptions are characterized by a somewhat continuous (for a few hours or days) ejection of gas and pyroclasts into the atmosphere, resulting in an overall buoyant plume that reaches tens of kilometers of height. Depending on eruption dynamics and pyroclast characteristics, size- and density-dependent selective settling will take place to form sheet-like fallout deposits that commonly mantle topography. The dispersal and related area covered depends on eruption plume height and meteorologic conditions. If the eruption column (partially) collapses due to insufficient air entrainment, ground-hugging and devastating pyroclastic density currents (PDC) are generated.

Pyroclasts are a direct proxy of magma fragmentation and subsequent clast transport and sedimentation processes. The related deposits are commonly studied to 1) describe magma storage and ascent conditions, 2) quantify the erupted volume, and 3) describe possible eruption fluctuations. To this end, grain size distribution and deposit thickness are studied most as they are influenced by intrinsic (e.g. crystal content and size, vesicle shape, size, overpressure) and extrinsic factors (e.g. fragmentation efficiency, dispersal conditions, transport processes).

Here, we will show how pyroclasts can reveal more messages. Porosity of individual clasts has been measured and variations shed light on magma ascent and outgassing conditions and help to explain eruptions intensity variations. Pumice clasts are mechanically weak. As a result, a thorough shape description is essential to constrain transport processes in the conduit and beyond. Beside the aspect ratio of pyroclasts, they can be found as angular and rounded. Using laboratory tumbling experiments, the degree of ash generation during secondary processes has been assessed for several parameters. The combination of field-based analysis and empirical findings from repeatable laboratory experiments will contribute to a better understanding of the observed dynamics of eruption and transport processes and accordingly help to assess the hazards of future eruptions.

VOLCANO-MAGMATIC EVOLUTION OF THE "SHIELD-LIKE" ARAGATS STRATOVOLCANO, ARMENIA

Hripsime Gevorgyan[1,2], Alexander Repstock[3], Christoph Breitkreuz[4], Khachatur Meliksetian[2], Bernhard Schulz[1], Uwe Kirscher[5], Arsen Israyelyan[2]

[1]Institute for Mineralogy, TU Bergakademie Freiberg, Brennhausgasse 14, 09599 Freiberg, Germany ***Hripsime.Gevorgyan@mineral.tu-freiberg.de****; [2]Institute of Geological Sciences, National Academy of Sciences of Armenia, Marshal Baghramyan Avenue, 0019 Yerevan, Armenia; [3]Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie, Department for Geology, Pillnitzer Platz 3, 01326 Dresden, Germany; [4]Institute for Geology, TU Bergakademie Freiberg, Bernhard-von-Cotta Straße 2, 09599 Freiberg, Germany; [5]Earth dynamics Research Group, The Institute for Geoscience Research, School of Earth and Planetary Sciences, Curtin University, Perth 6845, Australia*

The Quaternary post-collisional magmatic activity of the Lesser Caucasus formed numerous multi-compositional volcanic provinces and individual stratovolcanoes. Herein, the volcanic and volcano-sedimentary successions of the Aragats volcanic province (AVP) provide the full record of processes from magma genesis to the development of the volcanic edifices.

Cataclysmic multi-eruptions from the central vent(s) of the Aragats stratovolcano led to the formation of Quaternary ring plain- and valley-confined pyroclastic deposits within the Matuyama (0.97-0.90 Ma, $^{40}Ar/^{39}Ar$) and Brunhes magnetic polarity chrons (0.75-0.65 Ma, $^{40}Ar/^{39}Ar$, Gevorgyan et al., 2020; Kirscher et al., 2020). These pyroclastic deposits are remarkable for their widespread lateral and vertical lithofacies variation, which can be attributed to (sub-) plinian eruptions and variable processes during deposition.

The eruptions led to the emplacement of chemically zoned ignimbrites that show gradational vertical variations in composition, crystallinity, welding characteristics, colors, and lithofacies. The pyroclastic sheets comprise three pre-ignimbrite fallout layers and six pyroclastic flow units. Based on diversity in crystal content, mineral- and geochemical composition, and age constraints, two groups can be distinguished: (i) trachydacitic-trachytic to rhyolitic older crystal-poor amphibole-bearing (Qasakh, Amberd, Baghramyan) and (ii) trachyandesitic to -dacitic younger crystal-rich, pyroxene-bearing units (Artik, Shamiram-Byurakan, and Gyumri). Internal and external textures of phenocrysts from the younger units suggest non-uniform reheating and remobilization of resident silicic magma by the recurring recharge of mantle-derived magmas. Whereas, distinct narrow breakdown rims of some amphibole from the older units are the result of rapid/multi-step decompression during magma ascent. Triggered by the recurring recharge, mixing and mingling were essential processes for the younger units to remobilize portions of the crystal mush. The predominance of banded pumice blocks in the Artik unit is a further correlative marker of magma-mingling processes (Gevorgyan et al., 2018, 2020).

Thermobarometry on mineral-liquid and mineral-mineral pairs within the ignimbrites reveals two different levels of magma chambers: a shallow hydrous crystal-poor (~13 km) and a mid-crustal hotter anhydrous crystal-rich magma storage (~25 km). The presence of two magma chambers is also confirmed by Zr-contents from bulk-rock analyses. Multi-element patterns demonstrate the important role of fractional crystallization and subduction fingerprinting for AVP pyroclastics, lavas, and volcanic products of adjacent regions, indicating a similar magma source (Gevorgyan et al., 2018).

The complex pre- and syn-eruptive processes are approached from various sides, e.g. petrological analysis of the eruptive products, estimation of volume and areal distributions, age determinations, paleomagnetic constraints including flow direction estimates using anisotropy of magnetic susceptibility, and source localization. In general, the pyroclastic record at Mt. Aragats provides unprecedented insights into the evolution of Late Cenozoic igneous processes in the Lesser Caucasus.

NEW INSIGHTS INTO MIDDLE-LATE PLEISTOCENE VOLCANIC ACTIVITY FROM CAMPI FLEGREI (~ 160 - 90 KA)

Giada Fernandez[1], Biagio Giaccio[2], Antonio Costa[3], Lorenzo Monaco[1], Sebastien Nomade[4], Paul Albert[5], Alison Pereira[6], Molly Flynn[5], Niklas Leicher[7], Federico Lucchi[8], Paola Petrosino[9], Danilo Mauro Palladino[1], Alfonsa Milia[10], Donatella Insinga[10], Sabine Wulf[11], Rebecca Kearney[12], Daniel Veres[13], Diana Jordanova[14], Gianluca Sottili[1]

[1]Department of Earth Sciences, "Sapienza" University of Rome, Rome, Italy; giada.fernandez@uniroma1.it [2]Istituto di Geologia Ambientale e Geoingegneria, CNR, Rome, Italy; [3]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Bologna, Italy; [4]Laboratoire de Sciences du Climat et de l'Environnement, CEA, UMR 8212, UVSQ, IPSL and Université de Paris-Saclay, Gif-sur-Yvette, France; [5]Department of Geography, Swansea University, Swansea SA2 8PP, UK; [6]Université Paris-Saclay, UMR 8148, Laboratoire GEOPS, Orsay, France; [7]Institute of Geology and Mineralogy, University of Cologne, Cologne, Germany; [8]Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Università di Bologna, 40126 Bologna, Italy; [9]Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse, Università degli Studi di Napoli Federico II, Naples, Italy; [10]CNR-ISMAR, Istituto di Scienze Marine, Calata Porta di Massa, Interno Porto di Napoli 80, 80133 Napoli, Italy; [11]School of the Environment, Geography and Geosciences, University of Portsmouth, Buckingham Building, Lion Terrace, Portsmouth, PO1 3HE, United Kingdom; [12]Research Laboratory for Archaeology and the History of Art, School of Archaeology, University of Oxford; [13]Institute of Speleology, Romanian Academy, Clinicilor 5, 400006 Cluj-Napoca, Romania; [14]National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Acad. G. Bonchev, bl.3, 1113, Sofia, Bulgaria

Assessing the history, dynamics and magnitude of past explosive volcanic eruptions relies on i) the completeness of the stratigraphic records; ii) a widespread spatial distribution of sites; iii) the sedimentological features of the pyroclastic deposits. Near-vent volcanic successions provide fundamental but often patchy information, both in terms of record completeness (e.g., scarce accessibility to the older deposits) and of the spatial variability of the sedimentological features. Hence, medial to distal sections represent more integrative records and therefore need to be studied with great attention.

Campi Flegrei (CF) is among the most productive volcanoes of the Mediterranean area, with a volcanic history comprised of well-known caldera-forming eruptions (e.g., Campanian Ignimbrite, CI, ~40 ka; Neapolitan Yellow Tuff, NYT, ~14 ka). Furthermore, recent studies correlated a well-known widespread distal ash layer, the so-called Y-3, with a poorly exposed proximal CF pyroclastic unit (Masseria del Monte Tuff, 29 ka), allowing a re-assessment of the magnitude of this eruption, now recognized as a third large-magnitude (VEI 6) eruption at CF. The discovery of this large eruption reduces drastically the recurrence intervals of large-magnitude events at CF and has major implications for volcanic hazard assessment.

While the most powerful Late Pleistocene (e.g., post-NYT and partially post-CI) eruptions at CF have been the subject of extensive investigations, less is known about its earliest activity. Motivated by this knowledge gap, we have reviewed the research on Middle-Late Pleistocene eruptions from the CF (~160-90 ka) in light of new compositional (EMPA + LA-ICP-MS), grain-size distribution (dry/wet sieving and laser) and chronological ($^{40}Ar/^{39}Ar$ dating) data of tephra layers from proximal and distal settings, including inland and offshore records. Our study constitutes a long-term overview and provides essential information concerning the recurrence times of large explosive activity at CF. It also sets the basis for modelling dispersion as well as eruptive dynamics parameters of pre-CI large-magnitude eruptions. Thus, it represents the first cornerstone that will help providing future eruptive scenarios, needed to better assess the volcanic hazard in the Neapolitan area.

ON THE INFLUENCE OF VOLCANISM ON CLIMATE CHANGE FROM A GEOLOGICAL POINT OF VIEW

Portilla G., M.E.
National University of Colombia; Bogotá Campus, mportillag@unal.edu.co

From a geological point of view, there is no climate change as such, rather a climatic variability, because the Earth’s temperature shows a trend of cooling instead of warming since the Eocene Epoch (56 My). Climate is defined as the mean value of atmospheric variables for 30 years; therefore, climate change refers to a change in the Expected Value of those atmospheric variables for at least 100 years. However, from a meteorological point of view, it is very clear that starting from 1900, there is a noticeable climate change towards warming due mainly to anthropogenic activities.

On the other hand, it is accepted that volcanism played a crucial role in the early days of planet Earth, basically providing the gases and components for the primitive atmosphere and contributing to the environmental processes that regulate climate. It is also known that large effusive and explosive volcanic eruptions may have been associated with biotic extinctions by injecting huge amounts of particulate matter and sulfur components into the atmosphere.

Notwithstanding that some volcanic super-eruptions such as Deccan Traps (66 My), Yellowstone (650 ky), or more common small to moderate eruptions such as Santorini (Late Bronze Era, 1650 BCE), Vesuvius (79 CE), Tambora (1815), Krakatau (1883), Mount Saint Helens (1980), Nevado del Ruiz (1985), Mount Pinatubo (1991), Mount Etna (daily), among others; volcanoes bring about near 650 million tons of carbon dioxide to the atmosphere per year. In the meantime, automotive and industrial anthropogenic activities nowadays produce almost 30 billion tons annually, and they will be doing the same thing until next century.

In a nutshell, volcanic activity besides natural phenomenon produces a very tiny fraction of greenhouse gas emissions compared to polluters’ activity (burning fossil fuels by current anthropic business). The former provides life, the latter only death, or at least, a bad environment.

In this conference the role and the impact of volcanic activity on the environment will be presented, and also its probable role in the times to come.

PLINAIN FALL DEPOSITS FROM ARARAT STRATOVOLCANO PRESERVED IN ARMENIA

E. Grigoryan[1], Kh. Meliksetian[1], I.Savov[2], G. Navasardyan[1], N. Sahakyan[1], M. Bangoyan[1]

[1] Institute of Geological Sciences, National Academy of Sciences, Armenia, [2] School of Earth & Environment, University of Leeds, UK,

In the geological history of the Anatolian-Armenian-Iranian orogenic plateau, a significant role was played by continental collision related volcanism. One of the essential features of the volcanism of the regionally extensive collisional zone is the diversity of eruption styles, as well as the presence of a large number of Plinian eruptions with the VEI ranging 4 to 6 during the Pliocene and Pleistocene. These eruptions have contributed to the distal tephra fallout deposits and voluminous ignimbrite shields resulted. In Armenia, tephra layers present in Pleistocene geological record provide important information about these violent explosive eruptions, which are important for geological evolution, human geography and palaeoenviroment of the region.

Among the important deposits of tephra present in Armenia are included in the geological records of the Ararat depression. These deposits include pumice fall deposits from the Holocene historically active volcano Ararat. Deposits of the Ararat tephra are loose and not welded, it should be noted that they are observed only in sections in small depressions or in areas where they were quickly overlain by younger, colluvium deposits. The fall of the Ararat tephra was studied by a number of newly discovered outcrops covering an area of about 1200 km^2. Thus, the spatial extent of the explosive deposits of Ararat is much larger, but poorly preserved due to rapid erosion and there are areas where the tephra have been redeposited and mixed with other rocks of the formation. The tephra were erupted from historically active Ararat stratovolcano. Those tephra are from mid K_2O calc-alkaline and volatile-rich (>4.6 wt% H2O; amph-bearing) magmas (Meliksetian et al., 2015), which is not similar to the composition of the igneous volcanic formations of Aragats and Gegham in Armenia.

FORMATION OF VOLUMINOUS DACITIC MAGMAS OF LARGE CALDERA ERUPTIONS THROUGH A PARTIAL MELTING OF AMPHIBOLE-BEARING SHALLOW CRUST IN SOUTHERN KURIL ISLANDS

Smirnov S.[1], Kotov A.[2], Nizametdinov I.[1], Kuzmin D.[1],Timina T.[1]

[1] VS Sobolev Institute of Geology and Mineralogy SB RAS, Novosibirsk. Koptyuga ave 3, Russia, ssmr@igm.nsc.ru, [2] Graduate School of Environmental Studies, Tohoku University, Sendai 980-8579, Japan, kotov.alexey.s1@dc.tohoku.ac.jp

Caldera forming eruptions are the most powerful and devastating volcanic cataclysms in nature. The most violent of these events occur generally within active continental margins. Meanwhile, they are also typical for collisional volcanic zones, e.g. Chegem caldera in Main Caucasus Range. Revealing the main causes of caldera eruptions face researchers with determination of nature and conditions of evolution of their magma reservoirs. This includes two major problems: deciphering of magma source and nature, and reconstruction of processes occurring immediately before the catastrophic cataclysm.

Our study have been focused on reconstruction of processes, which took place in the plumbing systems of caldera volcanoes, which were formed at the turn of Pleistocene and Holocene in the Southern part of Kuril Island Arc: Mendeleev (Kunashir Isl); Lvinaya Past’ and Vetrovoy Isthmus (Iturup Isl). Catastrophic explosive eruptions of these volcanoes occurred between 40 and 12.5 years ago. Their dacitic magmas comprised rhyolitic-rhyodacitic melt with abundant phenocrysts of plagiocalse and quartz, minerals of preceding peritectic reactions (two pyroxenes, plagioclase and Fe-Ti oxides). Reservoirs of Mendeleeva and Vetrovoy Isthmus eruptions experienced extensive magma degassing resulting in abundant H_2O-CO_2 fluids, while increase of water activity in the Lvinaya Past' reservoir manifested in formation of hornblende phenocrysts.

Detailed study of fluid and melt inclusions demonstrated that dacitic magmas of all the three eruptions were formed due to partial melting of amphibole-bearing substrates in the upper arc crust within first 12 km. The partial melts were accumulated and stored at 3 – 4 km below the Earth's surface and their H_2O contents were 3 – 7 wt. %, which is close to fluid saturation at the reported storage depths.

The example of Mendeleev caldera showed that the formation of reservoirs of caldera volcanoes in Southern Kuril Islands at the end of Pleistocene might be caused by transformation from stretching to compression geodynamic mode. This prevented infiltration of upper crust by voluminous hot mantle magmas. As a result, they were accumulated at the Moho and lower crustal depths. This led to appearance of intense thermal anomalies that caused formation of the crustal amphibole-bearing substrates and their partial dehydration melting. This melting gave rise to large shallow crustal reservoirs and outburst of caldera-forming catastrophic volcanism at the end of Pleistocene in the Southern part of Kuril Islands.

LONG-LASTING ERUPTION CYCLE OF THE CALDERA-FORMING NEAPOLITAN YELLOW TUFF, CAMPI FLEGREI, ITALY

Gino González[1,2], Roberto Sulpizio[1], Antonio Costa[1], Roberto Isaia[3], Federico Lucchi[4], Jacopo Natale[1], Lorenzo Monaco[5], Sébastien Nomade[6], Alison Pereira[6], Giuseppe Siani[6] and Daniela Mele[1].

[1] Dipartimento di Scienza della Terra e Geoambientali, University of Bari AldoMoro, Italy. ginovolcanico@gmail.com , [2] Istituto Nazionale di Geofisica e Vulcanologia, sezione di Bologna, Italy.[3] Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Italy. [4] Dipartimento di Scienza Biologiche, Geologiche e Ambientali, University of Bologna, Italy. [5] Dipartimento di Scienza della Terra, University of Pisa, Italy. [6] Université Paris-Saclay, UMR 8148, Laboratoire GEOPS, France

Large explosive eruptions are among the most extreme geological events that can occur on Earth. The products generated by this kind of eruptions can cover areas >1000 km^2 with a significant amount of ashes. However, the occurrence of such events in human times is unusual. The way to understand how these eruptions occurred is studying their volcanic deposits.

Campi Flegrei (CF), as part of the densely inhabited metropolitan area of Naples, is the most active volcanic caldera in Europe and poses a risk to >2 millions of people who live in the surrounding area. Among the complex eruptive history of the CFC, the Neapolitan Yellow Tuff (NYT) eruption is the last major caldera-forming eruption, which took place about 14.0 k.a. ago.

Unlike other large CF eruptions, NYT is dominated by pyroclastic density currents, with only minor contribution of fallout, either from Plinian and co-ignimbritic columns. It makes so challenging represents a challenge to the reconstruction of the stratigraphy of the eruption and to our understanding of the dynamics of the caldera forming event.

We reappraise here the stratigraphy of the NYT previously described in the 90s in order to understand the eruptive dynamics, fragmentation processes and caldera dynamics associated.

Our main findings are: 1) the primary fragmentation process of the NYT was purely magmatic and not phreatomagmatic as previously proposed; 2) distinct chemical variations along the stratigraphic succession allow to characterize the different magma types that fed the eruption phases and trace their contribution-dispersal in distal setting; 3) the volume erupted has been estimated around 25 km3 (15 km3 DRE), similar to the volume we recalculated for the NYT caldera; 4) lines of evidences in distal sedimentary archives would suggest that the NYT was possibly formed by a long lasting eruption cycle in a time span of several years or decades.

Contrary to the classical points of view of a single catastrophic event, our results support the notion that a cycle of relatively moderate, but temporally closely-related eruptions, are able to generate a such caldera, which can growth incrementally.

ERZURUM NEOGENE CALDERA, EASTERN TURKEY: VOLCANIC STRUCTURES AND ACTIVE TECTONICS

Mehmet Salih Bayraktutan

Erzurum Metro. Municipality;Geohazard Tech. Adviser, e-mail batuta59ms@gmail.com; Erzurum. Turkey

Erzurum Neogene Basin in Northeastern Turkey - consists of three major formations: (i) Basement Late Miocene Palandoken Volcanics that is dominanted by basaltic andesite, andesite lava flows, and pyroclastic flows, with rhyolite and perlite lenses. (ii) Pliocene volcano-sedimentary sequences (Gelinkaya Formation) accumulated on Palandoken volcanics disconformably and in places by transitional contacts. White-colored sand, calcerous shale, volcanic weak consolidated sandstones, diatomite lenses, lignite intercalations, fossiliferous lacustrine limestones. Late (iii) Pliocene- Quaternary Volcanism, Kargapazarı Formation that is represented by basalt floods and vast basaltic flows related to the fissure eruption. Erzurum Basin basin presents the best evidence of the currently active tectonic inversion mechanism. It lies within a broad zone of ENE-trending dextral strike-slip Erzurum Fault Zone (EFZ), which is approximately the same age as North and East Anatolian Faults (NAF and EAF). However, it has a more complex role in the displacement of crustal material, mobilized by the northward collision of the Arabian Plate with the Eurasian Plate, at the end of the Miocene. The EFZ interacts with strike-slip tensional faults of different orientations, like NNE-trending sinistral Dumlu and Cobandede Faults. Major elements of the EFZ, Ermecik Faults (North margin), Kandilli- Palandoken Faults (South margin), and Dumlu faults outline the approximately triangular-shaped Erzurum Basin.

Interdisciplinary investigations of Erzurum Basin, and several others in eastern Turkey have identified a range of volcanic landforms reflecting dynamic responses to past and present compressional tectonic controls. Detailed work has focused on the Erzurum Basin. At present, they are being overridden by thrusts from the north and south, over Pliocene White Formation. This basin was formed by a combination of normal and strike-slip activity, which has prevented the east-west extension of a fault-bound wedge in response to north-south tectonic shortening. the structural-tectonic evolutionary history of Erzurum Basin is quite distinct from pull-apart basins which are common along the NAF and EAF Zones. Other complications in this region include the rotation and folding of faults and their later reuse. Karasu basin shortened by N-S compression, resulted in the inversion of N and S marginal faults into reverse even thrust faults. The basin floor dips eastward. Lateral extension prevented by Dumlu Tectono-Volcanic threshold. Basin experienced N-S shortening without any E-W extension. Compression compensated by thrusts, reverse and overturned faults, concentric rotational volcanic structures, fan deltas, and slump structures formed inside Pliocene mud-sand-diatomite-bentonite-fine pyroclastic sedimentary sequences. In general, volcanic basements wide-spread in Eastern Turkey reveal circular volcanic morpho-tectonic structures. Several outcrops around Erzurum Basin. At the center, a roughly circular depression (Erzurum-Palandoken Caldera) formed during Late Miocene-Early Pliocene. Initially, marginal master fault surfaces were dipping to the basin center, but as N-S compression increased in time, Fault Planes along N and S margins gradually gained vertical positions and in later stages of compression they turned into reverse and thrusts. Basin internal architecture experienced inversion as a result of N-S shorthening and basin narrowing caused the deepening of Karasu Basin>1000 m. Repeated (overturned anticlines) thrust planes along the Telsizler Ranges, striking across Erzurum Urban Area-South of University Dormitories. Repeated series of Alluvial Fans, Fan Deltas along the Ermecik-Gelinkaya segment, provides much evidence of inversion.

5. VOLCANISM AND GEOTHERMAL ENERGY RESOURCES

Session sponsored by PEER Sciences Project 9-252: Assessment of geothermal energy resources and natural hazards in Armenia

ASSESSMENT OF DEEP GEOTHERMAL ENERGY POTENTIAL IN ARMENIA

Khachatur Meliksetian[1], Gevorg Navasardyan[1], Lilit Sargsyan[1], Natasha Toghramajian[2], Andrey Medvedev[3], Hrach Shahinyan[1], Narek Sahakyan[1], Edmond Grigoryan[1], Peter LaFemina[4], Charles Connor[5], Vassily Lavrushin[6], Elya Sahakyan[1], Ivan Savov[7]

[1]Institute of Geological Sciences, Armenian National Academy of Sciences, Yerevan, Armenia, [2]Department of Earth and Planetary Sciences, Harvard University, USA, [3]Center for Ecological-Noosphere Studies, Armenian National Academy of Sciences, Yerevan, Armenia, [4]Department of Geosciences State College, The Pennsylvania State University, USA, [5]School of geosciences, college of arts and sciences, University of South Florida. USA, [6]Geological Institute of Russian Academy of Sciences, Moscow, Russia, [7]School of Earth & Environment, University of Leeds, UK,

Armenia is a landlocked country in the South Caucasus region, situated between Iran, Georgia, Azerbaijan and Turkey. Since Neogene to Quaternary times, the territory of Armenia has been located in a continental collision zone collision zone (i.e., collision of the Arabian and Eurasian plates) and exposed to transpressional tectonics resulting in widespread and long-lasting polygenetic and monogenetic volcanic activity.

The studies of spatial density of vents in Armenia (Weller et al., 2018, Sugden et al. 2021) demonstrate that Armenia is one of the densest clusters of Quaternary monogenetic volcanoes on Earth: in total, 516 volcanoes are mapped within the area of ~30,000 km^2. The geology of Armenia with its volcanoes and active faults being potential source of hazards at the same time, has an important potential for geothermal energy, whilst much of Armenia’s current energy production is from imported fossil and nuclear fuel. Presence of hot springs up to 64 °C and volcano-tectonic earthquakes prove active geothermal processes in depths. It is noteworthy, many dozens of sources and boreholes with thermal mineral waters are found in close proximity to volcanic systems and active faults. Our preliminary geochemical and isotope studies of mineral waters and free gases, aiming to apply geochemical thermometers to investigate the formation temperature of waters demonstrate several geothermal anomalies in Armenia. This contribution will present unified geological, geophysical, volcanological, geochemical database with selection of promising sites for further studies of geothermal energy potential of Armenia, and some preliminary results of application of ambient noise tomography (ANT) and satellite data.

APPLICATION OF AMBIENT NOISE TOMOGRAPHY (ANT) FOR GEOTHERMAL EXPLORATION (GEGHAM VOLCANIC RIDGE AREA) PRELIMNARY RESULTS

N. Toghramadjian[1], L. Sargsyan[2], E. Sahakyan[2], K. Meliksetian[2]

[1]Department of Earth and Planetary Sciences, Harvard University, United States, natasha_toghramadjian@g.harvard.edu, [2] Institute of Geological Sciences, NAS RA, 24a M. Baghramian Ave., Yerevan 0019, Republic of Armenia

The rapid development of both temporary and permanent seismic monitoring networks in the Institute of Geological sciences of Armenian National Academy of Sciences, Armenia has greatly augmented the study of deformational processes in volcano-tectonically active regions in the Arabia-Eurasia continental collision zone.

The Gegham volcanic upland is located in the central part of the Neogene-Quaternary volcanic belt of the Armenian Highland (Karakhanyan et al. 2003, Karakhanyan et al. 2002). The Gegham upland holds potential for geothermal energy development, but the high cost of exploration and exploitation present significant obstacles.

Ambient noise seismology offers a cost-effective and methodologically well-established alternative approach. Ambient noise tomography (ANT) leverages the seismic noise propagating through a target region as a permanent, passive energy source of energy, avoiding the need for active sources such as earthquakes or explosions.

In this study, we calculate the cross-correlation functions (CCF) of several years of seismic noise recordings across hundreds of pairs of stations in the Gegham volcanic ridge, providing an estimate of the empirical Green's function between each pair. The resulting correlogram is similar to the signal that would be obtained if an impulsive source occurred at one station and was recorded by the other one.

We perform frequency-time analysis on these CCFs to analyze the dispersion of Rayleigh and Love wave velocities. Our continuing work aims to invert these dispersion results for subsurface velocity structure, allowing us to assess the geologic and geothermal properties of the Gegham ridge.

ON THE ISSUE OF THE PROSPECTS OF THE JERMAKHBYUR GEOTHERMAL SYSTEM OF THE SYUNIK MARZ OF THE RA

Gasparyan R.K.

Institute of Geophysics and Engineering Seismology of the National Academy Sciences of Republic of Armenia, V. Sargsyan,5,Gyumri, 3115, RA. E-mail: rolan_gasparyan@mail.ru

For The Republic of Armenia an actual and important problem is search of geothermal sources of the Earth, as one of alternative energy sources. Absence of traditional kinds of power resources, forces to pay for the further development of power capacities of republic special attention to this problem. Thanks to wide development the newest volcanic processes of territory of RA concerns to the most perspective regions of Small Caucasus concerning development of geothermal energy (Badalyan, 2000, Henneberger at al., 2000). In a basis of the presented report results of the special ground geophysical researches conducted in 2004 within the limits of the Jermakhbyur hydrothermal system, a part of Gegam- Syunic neovolcanic belts of Armenia, have laid down.

The lead complex of geophysical researches has been called to confirm presence before the revealed geothermal anomaly, to define character and position elements the magmatic centers or intrusion, and also to reveal the proved preconditions of presence of the movable heat-carriers.

The following complex of geophysical and geochemical methods has been applied to the decision of the specified problems: magnetotelluric sounding (MTS), audiomagnetotelluric sounding (AMTS), gravity-magnetic survey and radioisotope geochemistry. According to gravity-magnetic researches on a site the graben type structure for the first time is revealed, in which center, on depth of 0.5-1.5 km, is established presence intrusive bodies (presumably not cooled down magmatic body). By MTS and AMTS data on depth 1800-2000m are localized a little high-conductivity subzones, one of which is located to the south of the Jermakhbyur, in a southwest part before the revealed seismic heterogeneity (Gasparyan at al., 2005). The second conducting zone is in a southeast part of the first profile on distance of 1.2 km from volcanic cone Karkar.

In the geoelectric attitude both anomalous zones are caused by presence on above-listed depths of the hydrothermal heat-carrier which power resistance makes from 10 up to 20 ohm.m. By results of geophysical researches in view of data earlier conducted works, geophysical 2D model of the Jermakhbyur geothermal system is developed and constructed.

The results of hydro chemical and radioisotope () analysis of the waters of the Jermahbyur geothermal spring indicate the meteoric origin of the deep coolant. Anomalous concentrations in the waters of the source and the calculated values of geothermometers give grounds to estimate the temperature of the coolant at a depth of 140 to 200°C.

The conducted geophysical studies have revealed a number of additional and very convincing prerequisites confirming the objective prospects of the Jermakhbyur geothermal system for the presence of a geothermal deposit of a fissure-vein type.

On the basis of base geophysical model the starting variant of conceptual model of the future geothermal deposit on which the basic geostructural elements of geothermal systems are displayed is offered and the most perspective sites, for location explorative holes are localized.

STRUCTURAL MINERALOGY AND FEATURES OF FORMATION OF A NUMBER OF COMPLEX IRON SULFATES FROM LOW-TEMPERATURE VOLCANIC ENVIRONMENTS OF KAMCHATKA

Zhitova E.S.[1], Sheveleva R.M.[1,2], Kupchinenko A.N.[1], Zolotarev A.A.[2], Nuzhdaev A.A.[2]

[1] Institute of Volcanology and Seismology FEB RAS; Petropavlovsk-Kamchatsky Piip blvd 9, zhitova_es@mail.ru ; [2] St. Petersburg State University; St. Petersburg University emb. 7/9

Geothermal activity is a companion of active tectonic processes, which is manifested in part by the formation of geothermal fields in the suprasubduction zone, for example, the Kuril-Kamchatka belt. As a rule, the rocks that make up the upper part of the geothermal field are argilized and covered with secondary efflorescence minerals. These efflorescence minerals were studied by us from the geothermal fields of Kamchatka associated with the active volcanoes Mutnovsky, Koshelevsky, Kambalny, and the Bolshoy Semyachik complex. Research methods included, mainly, powder and single-crystal X-ray diffraction, electron-microprobe analysis, which made it possible to obtain detailed information on the chemical composition and crystal structure of these minerals. Mostly surface efflorescence minerals are hydrated sulfates, some of which bear the geochemical imprint of volcanic activity by incorporating impurities or main components specific to these settings, and some are formed exclusively as a result of the process of leaching of source rocks by thermal waters of predominantly acidic composition. Despite the fact that hydrated sulfates form in the same setting and association, their potential indicator role is different. The data can be useful in studying the mineralogy of Mars and other planets of the Solar system, where similar mineral associations are found.

The study has been supported by grant of the President of the Russian Federation for young candidates of sciences MK-451.2022.1.5 «Structural mineralogy, genesis and stability of a number of complex iron sulfates». The study has been undertaken using facilities of XRD and Geomodel Resource Centres of St. Petersburg State University.

SECONDARY MINERAL FORMATION ON THE SURFACE OF GEOTHERMAL FIELDS OF THE BOLSHOI SEMIACHIK VOLCANIC COMPLEX, KAMCHATKA, RUSSIA

Kupchinenko A.N.[1], Sheveleva R.M.[1,2], Zhitova E.S.[1], Nazarova M.A.[1], Plutakhina E.Y.[1] and Vlasenko N.S.[2]

[1] Institute of Volcanology and Seismology, Russian Academy of Sciences, Petropavlovsk-Kamchatsky, Russia, 683006; zhitova_es@mail.ru, [2] St. Petersburg State University, St. Petersburg 199034, Russia

This work is devoted to the study of mineral parageneses formed on the surface of geothermal fields of the Bolshoi Semiachik volcanic complex (low-temperature surface hydrothermal process). To date, there is practically no data on its mineral paragenesis: major geological expeditions were conducted in the 1960s, and some additional studies were conducted in the 1980s.

Researchers' interest in iron sulfate formed as a result of low-temperature hydrothermal activity is caused, in particular, by the fact that the same mineral associations were found on Mars. Accordingly, the creation of a high-quality database on such phases is relevant both for the development of fundamental knowledge about minerals and for the purpose of application in planetary science. In addition, there is an affinity between the conditions of mineral formation in thermal fields and the conditions of acid leaching (acid mine drainage).

We have studied efflorescent minerals from the surface of geothermal fields at the Severny (North) Crater of the Central Semiachik volcano (the Bolshoi Semiachik volcanic complex, Kamchatka, Russia). The salt efflorescent covers heated soils (up to 70 °C) around steaming vents and pods. The samples were identified using powder X-ray diffraction analysis and energy dispersive X-ray spectroscopy.

The most abundant sulphate efflorescent minerals are the copiapite group, coquimbite, halotrichite and alunogen. In association with them, minerals of the voltaite group, tschermigite, gypsum, chalcanthite, rhomboclase are found. Sometimes there are butlerite, mohrite, riotintoite, baryte, hydrocerussite, sabieite, carlsonite, jarosite, mascagnite. The listed minerals are typomorphic for a low-temperature surface hydrothermal process. Noteworthy, there is the wide development of various hydrated sulfates with iron and/or ammonium as the main cations.

The study is carried out using facilities of “XRD” and “Geomodel” Resource Centres of St. Petersburg State University, the Laboratory of Volcanogenic Ore Formation and the Analytical Center of the IVS FEB RAS. The study has been supported by MK-451.2022.1.5 project for young candidates of sciences.

PERIODICITY OF GEYSER ERUPTIONS: 82 YEARS OF OBSERVATIONS IN KAMCHATKA PENINSULA, RUSSIA

Belousov Alexander, Belousova Marina
Institute of Volcanology and Seismology, Piip boulevard 9, Petropavlovsk-Kamchatsky, Russia, email: belousov@mail.ru

Geysers are natural thermal springs that demonstrate intermittent, quasi-periodic discharge where eruptions of boiling water and steam are separated by clearly defined periods of repose. Geysers are rare hydrothermal phenomenon, and most of them are found in three locations (so-called "geyser fields"): Yellowstone (USA), El Tatio (Chile) and Valley of Geysers (Russia). Time interval between successive geyser's eruptions (IBE) represents important characteristic of a geyser's activity, which depends on both internal structure of the geyser's feeding system and the intensity of hydrothermal discharge of the area. IBEs of geysers range from minutes to many hours and commonly are rather stable. Long-term monitoring of changes of geyser's IBEs allows to infer changes of intensity of the feeding hydrothermal activity, as well as get clues to mechanisms of geyser eruptions.

We have analyzed data of measurements of IBEs of 22 active geysers of the Valley of Geysers at Kamchatka, which is the second largest geyser field on Earth. The analyzed data were collected by a number of researchers (including us) since the discovery of the geysers in 1941. Most of the geysers have demonstrated rather stable IBEs over the 80 years of observations. However, short-term abrupt changes as well as long-term gradual changes of the IBEs of several of the studied geysers were revealed.

The abrupt short-term changes were mostly caused by transient changes of local weather and/or hydrologic conditions. Such changes were common for geysers with relatively wide conduits located near river channels. For example, the geyser Kotly (Pots), having IBE of about 20 minutes during warm, sunny days, notably increased its IBE, or stopped to erupt during cold, windy and rainy days.

The long-term abrupt changes of IBEs were mostly caused by notable changes of the geyser's feeding conduit. For example, geyser Velikan (Giant), which originally had IBE of about 5-7 hours, abruptly shortened its IBE to 40-60 minutes, when its conduit became partially filled by rock debris of the 2014 mud flow.

The long-term gradual changes of the IBEs revealed for several geysers are probably associated with changes of the feeding hydrothermal input from the depth. For example, geyser Fontan (Fountain) demonstrated very stable IBE 15-20 minutes from 1941 until 2015, but then its IBE started to lengthen up to 30-40 minutes, probably in response to the 2007 and 2014 voluminous landslides that notably changed hydrogeological situation in the Geyser Valley.

HYDROTHERMAL ERUPTIONS IN THE COASTAL ZONE OF ITURUP ISLAND (KURIL IslANDS)

Khubaeva O.[1], Sergeeva A.[1] Khomchanovsky A.[1]

[1] *Institute of Volcanology and Seysmology FEB RAS; 9 Piip Boulevard, Petropavlovsk-Kamchatsky, 683006, Russia, grifon03@yandex.ru*

The aim of the study is to identify the genesis of the origin of the thermal lake on Iturup Island; to assess the physical and chemical characteristics of the lake and the risks of hydrothermal explosions.

Utinaya Banya Lake is located 12 km southeast of Reidovo village, in the central part of Iturup Island (Kuril Islands, Russia). The area around the lake is a hilly plain with absolute elevations not exceeding 66 meters. In 2020-23, we conducted research in the area of Utinaya Banya Lake. The results obtained allowed us to suggest that the lake is of explosive origin and represents a maar formed as a result of a series of hydrothermal eruptions.

The lake is located at the intersection of two NE and NW strike-slip faults, away from volcanic structures, at the boundary of a high-density tectonic destruction zone. For the central part of Fr. A 3D model of tectonic fragmentation [Taskin and Sidorov, 2014] to a depth of 2500 m was constructed for the central part of Iturup Island. The vertical section from this model beneath Utinaya Banya Lake shows areas of high density fractures that are similar to feeder channels on volcanoes. This may indicate the presence of an intrusive body at depth, which performs the role of a source of thermal supply of thermal springs at the bottom of the lake.

The shape of the lake basin is close to oval, in profile the basin is complicated by a V-shaped depression. In this place, an acoustic gap from an underwater gas-hydrothermal source is traced. Depths in the lake are not evenly distributed. The structure of the lake bottom can be divided into two parts, having a shape close to funnels: the largest eastern part, with a depth of up to 1.5 m, it occupies about half of the area of the reservoir; a small western funnel with a diameter of about 5 m and a depth of up to 1 m. [Degterev et al. 2022] Lake bottom temperatures in these places have the highest values (up to 19 ℃ - in winter).

Based on leveling profiles and bathymetric survey data, a 3D relief model of Utinaya Banya Lake was built. On the model, a shaft is clearly visible around the lake.

Pitting was carried out along the perimeter of the lake (on the shaft and behind the shaft). The data from the pits showed an inverted/disturbed depositional sequence on the lake sides - where sedimentary lake sediments were buried beneath a layer of rock-forming minerals. The composition of the water indicates that the lake is actively fed by deep hydrothermal fluids, with the risk of hydrothermal explosions.

To assess the risks of hydrothermal explosions in the future, a Na/K-geothermometer was used, which shows a high temperature of water composition formation, in the range of 230 - 290ºC . Water vapor pressure at these temperatures is in the range of about 25 - 100 atm, which in the long term may result in the destruction of the upper water table and hydrothermal explosion. The funnel-shaped profile of the lake bottom and the inverted/disturbed order of sediments on the sides of the lake indicate that hydrothermal explosions have occurred in the history of the lake.

ACCUMULATIONS OF MERCURY IN ALTERED ROCKS IN THERMAL FIELDS OF THE BOLSHOI SEMYACHIK VOLCANIC MASSIF (KAMCHATKA, RUSSIA)

Nuzdaev A.A.

Institute of Volcanology and Seismology, Far East Branch, Russian Academy of Sciences, Russia, Petropavlovsk-Kamchatsky, 9 Piipa Boulevard, nuzhdaev@gmail.com

This paper presents data obtained as a result of work on thermal fields associated with the Bolshoi Semyachik volcanic massif. Thermal fields are currently poorly studied due to their inaccessibility. For the first time data on mercury concentrations in hydrothermal solutions, in clay strata and in altered rocks have been obtained for thermal fields. The data show that mercury, coming with hydrothermal solutions, accumulates in altered rocks. The highest concentrations of mercury are characteristic of the clay strata on the surface of thermal fields. Different forms of mercury accumulation are characteristic of hydrothermally altered rocks at different stages of hydrothermal alteration.

INITIAL ASSESSMENT OF THE GEOTHERMAL POTENTIAL OF THE THERMOMINERAL WATERS OF THE HRAZDAN RIVER MIDDLE STREAM CATCHMENT IN ARMENIA

Narek Sahakyan[1], Khachatur Meliksetian[1], Hrachya Shahinyan[1], Shushan Zaqaryan[1], Shushan Gyulnazaryan[1], Avetik Galstyan[1], Edmond Grigoryan[1],

[1] *Institute of Geological Sciences, National Academy of Sciences, Republic of Armenia*
narek.sahakyan@geology.am

The study area of this work is the middle stream catchment of the Hrazdan River of Armenia, in particular 10 wells of thermomineral waters of the area. This work was carried out during the period of 2022-2023, and in the framework of this work, the hydrochemical composition and the features of the formation of these waters were studied. Based on the collected data, the equilibrium temperatures of thermomineral waters were calculated based on the cationic (Mg/Li, Na/Li, Na/K, K/Mg) and anionic (Si) geothermometers. The maximum temperatures were shown by Na/Ka and Na/Li, and the lowest temperatures by Mg/Li and K/Mg geothermometric formulas.

The depths of the maximum geothermometer temperatures of waters were also calculated, based on the zoning of the geothermal gradient of Armenia (Badalyan, 2000). According to the mentioned source, the predominant geothermal gradient in our study area is 9-10^{0}C/100m.

According to the obtained data, the thermomineral water of Kaqavadzor well (the area geothermal gradient is 7^{0}C/100m) has the maximum equilibrium temperature: 296^{0}C (Na/Ka geothermometer) and 270^{0}C (Na/Li geothermometer). However, it also shows the lowest temperature 45^{0}C according to the K/Mg geothermometer. Among all water samples, the least difference based on the mentioned five geothermometers is shown by the water coming out of the "Hot water" well in Hankavan: the difference between maximum (226^{0}C - Na/Li) and minimum (99^{0}C - K/Mg) geothermometric temperatures is 127. Calculated geothermal maximum temperature differences for 5 of the studied waters range from 85-247^{0}C, and the geothermal gradient is 10^{0}C /100m for the area of all of these 5 water wells

In the framework of this study, the results show that the maximum equilibrium temperatures of these thermomineral waters are the ones located in Garni and Marmarik fault zones. And these faults are located between Aragats and Geghama volcanic plateaus. With these faults, heat rises and that contributes to the increase in the temperature of the underground water in the area.

The data of the study are applicable in the research conducted for the purpose of studying geothermal energy potential. Calculations show that some thermal waters in the area have suitable heat potential, which, later proving its economic benefit can be used for energy production. However, still there is a need to clarify the reasons for the inconsistency of the results between different geothermometers and the connection of thermomineral waters with the tectonics and volcanism of the area.