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Discussion

Historical volcanoes of Armenia and adjacent areas: What is revisited?

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Abstract

The validity of some data in Karakhanian et al. [Karakhanian, A., Djrbashian, R., Trifonov V., Philip H., Arakelian S., Avagian, A., 2002. Holocene–historical volcanism and active faults as natural risk factor for Armenia and adjacent countries. Journal of Volcanology and Geothermal Research, 113, 1, 319–344; Karakhanian, A., Jrbashyan, R., Trifonov, V., Philip, H., Arakelian, S., Avagyan, A., Baghdassaryan, H., Davtian, V., Ghoukassyan, Yu., 2003. Volcanic hazards in the region of the Armenian nuclear power plant. Journal of Volcanology and Geothermal Research, 126/1–2, 31–62] that are revisited by R. Haroutiunian is considered. A conclusion is made that the revisions suggested by Haroutiunian concern unessential parts of the content of work by Karakhanian et al. [Karakhanian, A., Djrbashian, R., Trifonov V., Philip H., Arakelian S., Avagian, A., 2002. Holocene–historical volcanism and active faults as natural risk factor for Armenia and adjacent countries. Journal of Volcanology and Geothermal Research, 113, 1, 319–344; Karakhanian, A., Jrbashyan, R., Trifonov, V., Philip, H., Arakelian, S., Avagyan, A., Baghdassaryan, H., Davtian, V., Ghoukassyan, Yu., 2003. Volcanic hazards in the region of the Armenian nuclear power plant. Journal of Volcanology and Geothermal Research, 126/1–2, 31–62]. This article presents new evidence and re-proves the earlier conclusions that are disputed or revised by R. Haroutiunian.

Keywords: Armenia; volcanic eruption; earthquake; historical evidence

1. Introduction

R. Haroutiunian's publication on *Historical Volcanoes in Armenia and Adjacent Areas Revisited* is the third one the author has published on this topic recently. The two preceding publications (Haroutiunian, 2004, 2005) and the article published in this volume of JVGR are focused on the criticism and revisiting of the data presented in our publication of 2002 (Karakhanian et al., 2002). In many aspects, these publications of R. Haroutiunian repeat one another.

With time, any publication becomes out of date and must be revisited. The article of Karakhanian et al. (2002) in JVGR was prepared in 1999 and it is natural

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that since then new evidence has been accumulated both by the authors, and by other researchers. In 2004, Karakhanyan et al. published an article in an Armenian scientific journal (Karakhanian et al., 2004) trying to summarize new evidence related to some of active volcanoes in Armenia, in response to the criticism of R. Haroutiunian and re-prove the earlier suggestions published by Karakhanian et al. (2003, 2004). However, the Armenian publication of Karakhanian et al. (2004) is not easily accessible for the audience of JVGR. Therefore, the authors have decided to take the opportunity kindly provided by JVGR editors and to use the forum of this international journal to express their view and validate again some of their statements disputed and/or revisited by R. Haroutiunian.

1.1. About a subaqueous eruption in Lake Van in 1650

Certainly, the description Milton (1985) gives of the effects observed on 27.10.1650 is well consistent with one of a volcanic eruption, so Haroutiunian presented a really striking example of historical evidence about volcanic eruption in Lake Van.

Obviously, the record about the phenomenon observed on 13.04.1692 and quoted in Karakhanian et al. (2002) has many fewer details that can be interpreted as volcanic effects. Nevertheless, a volcanic phenomenon still could be suggested, and we do not think that a sandstorm mentioned by Haroutiunian is a more plausible, or the only possible interpretation. Haroutiunian published his finding of Milton's data in 2001 (Haroutiunian, 2001), after the paper by Karakhanian et al. (2002) was submitted to JVGR. This could explain the skepticism we expressed with respect to the date of 27.10.1650 first mentioned in our publication of 1997. During the preparation of the manuscript for the publication of Karakhanian et al. (1997), with the kind suggestion of Haroutiunian (and with reference to his personal communication), we included a brief mention of volcanic events in the Lake Van region recorded by historical chronicles in 1111 and 1650. However, Haroutiunian had not then communicated any additional data in support of the reality of a volcanic eruption in 1650 in the Lake Van Region. Now, we have revised our previously skeptical opinion.

1.2. On the eruption of volcanoes of the Porak Group

Studying the Pambak-Sevan-Synik Fault (PSSF) in 1998, we noticed that volcanoes of the Porak Group were located directly in the zone of this fault that is the most active one in Armenia. In 1990–1999, we conducted several field investigations within this segment of the PSSF, including active fault mapping, and studies of paleoseismicity, archaeo-seismicity, and volcanism. Geologists from Armenia, France and Russia took part in the studies (Trifonov et al., 1994; Philip and Karakhanian, 1999; Philip et al., 2001). Our publication of 2002 in JVGR was also based on the results of the 1990–1999 surveys.

After 2001, our geological and archeological studies in the Porak Volcano region have been extended considerably and involved a larger number of participants, among them the NAS Institute of Geological Sciences (Armenia), GEORISK Scientific Research CJS (Armenia), NAS Institute of Archaeology and Ethnography (Armenia), Institute CORBY, Maison de l'Orient (Lyon 2 University, France), Montpellier-2 University (France), and the Geology Institute of the Russian Academy of Sciences (Russia). In part, new evidence from these studies is presented in Trifonov and Karakhanyan (2004) and Karakhanian et al. (2004). The latest research results are now prepared for publication.

Below, we will try to re-justify our statements revisited by Haroutiunian. The first and most substantial of the suggested revisions is that the eruption of Porak in the 8th century B.C. was not actually accompanied by a strong earthquake. Then Haroutiunian states that eruption happened not only in 782–773 B.C., as indicated in Karakhanian et al. (2002), but also 40 years later, in 742–739 B.C.

Porak Volcano is located in a clearly identifiable structure of a pull-apart basin, formed by the active PSSF. The data of GPS measurements show that rates of right-lateral strike–slip motions along the PSSF at this site correspond to 2–2.9 mm/year, and extension rates are within 2.5–3.5 mm/year (Karakhanyan et al., 2004; Davtyan et al., in press).

At the fault segment located near Porak Volcano, we identified clear scarps of surface ruptures generated by strong earthquakes and cutting through Holocene lava flows. The paleoseismological trenching (12 trenches in total) provided us 26 samples studied by the radiocarbon and archeological methods for dating. This allowed us to construe the age of the three strong seismic events that had produced the surface ruptures and scarps at the site. The first event happened about 19,790 years BP, the second was between 5208 and 4487 B.C., and the third one, as attested by ^{14}C analysis, occurred between 1000 and 500 B.C. (Philip et al., 2001; Karakhanian et al., 2002, 2004).

The archaeological studies in the region of Porak Volcano enabled the discovery of a few ancient

settlements and necropolises with evidence of strong earthquake impacts in the past. In the largest of these settlements, surface rupture from a strong earthquake dislocated an old wall by 1.8 m horizontally, and by 0.8 m vertically (Avagyan, 2001; Philip et al., 2001; Karakhanian et al., 2002, 2004). At a distance of 5 km from the settlement, surface rupture dislocated an ancient grave (kurgan), and five paleoseismological trenches and archeological excavations conducted at that site in 2004–2005 permitted a preliminary estimation of the earthquake date by the 9th–7th centuries B.C. The archeological digs within the ancient settlement itself helped to better constrain the time interval of the earthquake. By preliminary assessments, collapsed walls observed in many places within the settlement must be related to the 8th–7th centuries B.C. In the near future, age estimates will be completed for all samples and a publication on the results will be prepared. The earthquake magnitude estimates were derived by Wells and Coppersmith (1994) based on the values of vertical and horizontal displacements along the fault (Avagyan, 2001; Philip et al., 2001; Karakhanian et al., 2004).

The field investigations near Porak Volcano revealed four generations of Holocene age lava flows (Karakhanian et al., 2002, 2004). A group of six petroglyphs depicting an erupting volcano was found to the southeast of Porak Volcano (Karakhanian et al., 2002; Avagyan et al., 2003; Karakhanian et al., 2004). By archaeological estimates, the age of the petroglyphs corresponds to the 5th millennium B.C. Lengthy stone walls rest on the surface of Holocene lava of the first, second and third generations and stretch for 15 km from the settlement we excavated to the Porak Volcano (Karakhanian et al., 2002, 2004). The stone walls abruptly come to an end near the last Holocene flow of the fourth generation. We suppose that the last lava flow could cover the walls and this is the reason for the break. The age of the walls corresponds to the age of stone structures in the ancient settlement of the 8th–7th centuries. The last consideration may be consistent with the accounts contained in the cuneiform inscriptions of Argishti I and Sardouri II that are discussed below.

The inscription left by Argishti I tells: 'By the grandeur of Khalda, Argishti says, when I again laid the siege of the (town) of Behoura, Mount Bamni in the area of Behoura Town was destroyed … smoke and soot now rise from it to the sun. When Mount Bamni was destroyed, I took the town of Behoura' (Ohanessian and Abramian, 1981). The cuneiform inscription of King Sardouri II, son of Argishti I, says: 'Sardouri says, …the people who ran away frightened of the arms and climbed Mount Ushkiani and Bamni; I encircled them and killed, others who escaped were burned by Teishebah the God' (Melikashvili, 1960). The inscription of Argishti I and, to a lesser extent, the one left by Sardouri II, have been many times interpreted as evidence of a natural calamity —an earthquake (Karakhanyan, 1993; Satian, 1994; Karakhanian et al., 1997; Philip et al., 2001) and/or a volcanic eruption (Philip and Karakhanian, 1999; Haroutiunian, 1999, 2001; Karakhanian et al., 2002, 2004). The inscription of Argishti I is dated to a period of 782–773 B.C., and the one of Sardouri II to 742–739 B.C. (Ohanessian and Abramian, 1981; Melikashvili, 1960). It is still difficult to identify definitively whether there were two eruptions—one in 782–773 and one in 742–739 B.C., as suggested by Haroutiunian (2004), or only the eruption that happened at the time of Argishti I (Karakhanian et al., 2002, 2004).

We think that the text of Argishti's cuneiform inscription can be rather confidently interpreted as a description of some natural cataclysm, including a volcanic eruption. The text left by Sardouri II is more allegorical and can be interpreted as indirect evidence, since it has no direct indication of a volcanic eruption and mentions only the deity of Taishebah burning the people who took cover on Mounts Bamni and Ushkiani. S. Hmayakyan, an urartologist who works at the Institute of Archaeology of Armenia, believes that such a phrase could indirectly indicate a volcanic eruption, but, in the meantime, it could be just a standard curse addressed to the enemies that fled (personal communication). Taishebah, an Urartian divinity, likewise its Hurrian analog Tesh'shob, corresponded primarily to the Thunderer who ruled over lightning, thunders, winds, rains and other elemental forces of the nature, and also the underground kingdom of the dead. Volcanic plateaus and highlands of Cappadocia and the Armenian Taurus were the main regions of worship for these deities. Considering this, one can, with great caution, suggest that the mentioned divinities could have a relation to such elemental phenomena as volcanic eruptions. In the meantime, Taishebah had another title, in addition to that of the Thunderer. He was an esteemed Deity of War and Battles (Piotrovsky, 1959), so this also could explain why Sardouri II addressed this divinity telling about his victory over the enemy who had fled. We think that because of the allegorical and indirect character of the account in the inscription of Sardouri II, and until additional proofs are collected, an eruption date within the period of Argishti's inscription, i.e., 782–773 B.C., is more plausible.

The new evidence we found recently demonstrates that the uncertainty of the historical data about the

location of this eruption appears much greater than we assumed earlier. Our previous publications (Karakhanian et al., 1997; Philip et al., 2001; Karakhanian et al., 2002, 2004) and also the works of Haroutiunian (1999, 2001, 2004, and this JVGR volume) located Behoura Town in the southeastern sector of the Lake Sevan Basin; Mounts Bamni and Ushkiani were identified in the same area and thought to be corresponding to Porak Volcano. After our latest consultations with urartology experts, we have to revise the unambiguous location of Behoura Town and Mounts Bamni and Ushkiani in the Porak Volcano area. Below, we will show that opinions on the geographic location of these place names are still controversial, obscure and call for additional study.

According to N. Harutyunyan (1985) and O. Hakobian et al. (1986), mounts Bamni and Ushkiani, as well as the area/town Bihouriani, were located in the southern part of the Lake Sevan basin, in the east of the Vardenis Upland that is the area of the Porak Volcano. This was used to conclude that Mount Bamni corresponds to Porak Volcano (Haroutiunian, 1999; Philip and Karakhanian, 1999; Haroutiunian, 2001; Karakhanian et al., 2002, 2004). On the contrary, S. Petrosyan (1984) believes that Mounts Bamni and Ushkiani were located on the opposite northern and north-eastern shores of Lake Sevan and corresponded to the Eastern Sevan (Shah-Dag) Ridge and the Sotk Ridge, respectively. The results published in the volume prepared by the Armenian–Italian Archaeological Expedition (2002) may appear very important for studying geographic locations described in both cuneiform inscriptions. The expedition found that the military campaign of Argishti I was finished on the western shore of Lake Sevan, and this king never visited the Porak Volcano region (Hmayakyan, 1996; The North-Eastern Frontier Urartians and Non-Urartians in the Sevan Lake Basin. 1: The Southern Shores, 2002). Hmayakyan, the Armenian coordinator of this expedition, thinks that precise location of Mounts Bamni and Ushkiani is largely unknown, and that Behoura Town could be located either in the Sevan basin, or to the west of Lake Van, at a considerable distance from Lake Sevan (personal communication). The historical data have not yet provided any definitive and clear indication on the geography of Mounts Bamni and Ushkiani, and Behoura Town, mentioned by the cuneiform inscriptions of Argishti I and Sardouri II, and, as a sequence, the location of the natural disaster cannot be established precisely. Today, several models of geographic location can be suggested for these place-names, and Vardenis Upland and Porak volcano are among these. However, it is still impossible to judge which model is the most credible.

The following conclusion can be made upon the analysis of information about volcanoes of the Porak Group available for the present:

(1) Geological, paleoseismological and archaeological data indicate that strong earthquakes repeatedly occurred in the region of the Holocene volcanoes in the Porak group. The earliest of them could date back to about 19,790 years BP, the second was between 5208 and 4487 B.C., and the third must be related to the 8th–7th centuries B.C.
(2) The geological and archaeological evidence allow identification of four generations of the Holocene lava and suggest that the two latest eruptions of lava could happen in the 5th millennium B.C. (the petroglyphic picture) and in the 8th–7th centuries B.C. (the age of stone walls).
(3) The historical evidence is uncertain. To a larger extent, the geographic locations and interpretations of the events described by the cuneiform inscriptions of Argishti I and Sardouri II are still unclear and controversial. One of such interpretations of Argishti's inscription, and suggested covering of the old walls by fourth-generation lava, may imply that Porak Volcano erupted in 782–773 B.C. The eruption of the same volcano in 742–739 B.C. suggested by Haroutiunian based on the inscription of Sardouri II looks less plausible.

1.3. The Ararat volcano

In this part of his observations, Haroutiunian addresses a greater number of mistakes made by Karakhanian et al. (2002) in the analysis of the obscure indications of volcanic eruptions on Ararat in the first half of the 2nd century B.C. and in late 3rd to early 4th century AD, provided by the texts of Armenian chroniclers and historians—Movses Khorenatsi, Aghatanghehos and Alishan.

Indeed, we mentioned the possibility of a volcanic eruption on Ararat in the first half of the 2nd century A.D. by interpreting the legend about the birth of Vahagn, an ancient Armenian deity, and a few other related traditions narrated by Movses Khorenatsi, a historian of the 5th century AD (Karakhanian et al., 2004). Jonaidi (1979), Etmekjian (1988) and Berberian (1994) interpreted this legend as an evidence of volcanic eruption. New information we collected after 1999 allows us to confirm the plausibility of the earlier suggested link

between the described event and a volcanic eruption on Ararat and to date it back not to the 2nd century AD, but the 6th century B.C. Karakhanyan and Abgaryan (2004) present a detailed analysis and justification in support of the credibility of this event. Excerpts from the chronicle sources we used to support the plausibility of volcanic phenomena on Ararat late in the 3rd–early 4th century A.D. were annexed to the article (Appendices 3 and 4, Karakhanian et al., 2002), while the geographic locations of respective events were based on the content of the chronicles, and on the work of Zeitunian, an acknowledged Armenian historian (Zeitounian, 1991). Considering the uncertainty of the historical and mythological evidence, we characterized this information as obscure (Karakhanian et al., 2002).

Haroutiunian supposes that the data on the description of volcanic eruption on Ararat in 1840 as well as the determination of the location of the northeastern slope of Ararat, as well as the volcanic process and its consequences, particularly the formation of mudslides down from the volcano's slope and an allegedly pyroclastic flow were distorted. Below we will briefly comment on the evidence we used as a basis for our work of 2002.

The earthquake and eruption in 1840 caused total destruction and death of all of the population in the Akory Village and the St. Jacob's Monastery, located in the Akory Canyon on the northeastern slope of Ararat. Haroutiunian (2005) dislocates the Akory Village by 4 km, and the St. Jacob's Monastery by 6 km to the east of their actual position and places them not along the Akory Canyon, but beyond it—across the slope of Ararat. In fact, the monastery and the chapel of St. Jacob were located inside the Akory Canyon, and the village of Akory was at the canyon end. These locations are described by Parrot (1834) and Abich (1847) and shown accurately on page 17 of the historical map in the volume of *Armenia: A Historical Atlas* (Hewsen, 2001). The locations of the village and the monastery is shown also on the old Russian maps of the *Elizavetpolskaya Gubernia* (a Russian Empire province) prepared in 1873 and 1908 and also on the modern topography map (1:50,000 scale, prepared by the USSR State Cartography Administration). Chapter 13 in Lynch (1910) describes in detail the locations of the Akory Village, the St. Jacob monastery and the chapel, and of the nearby spring.

We assumed that there was a pyroclastic flow during the 1840 eruption considering the following eyewitness accounts. The recollection by a peasant from the Akory Village is quoted by Lynch (1910) and Zeitounian (1991): 'A terrible thunder was heard from the side of the Akory Canyon and a sudden wind blow rushed upon with a hurricane strength, which toppled over everything. From the same side, a huge dust cloud rose, and another dark cloud was seen under it. After a minute-long pause, the same things repeated, but this time a dark mass was tearing along to us from the canyon with sounds of rustling and muffled bursts. It reached the people who were on their way to the village and swallowed up everything. The mass was glowing with the crimson light and rolling towards the gardens, destroying stone fences on its way and pulling trees out with their roots.' Another eyewitness recollection was published by Alishan (1890) and again by Lynch (1910): 'A strong earthquake happened, Mount Ararat was torn apart from bottom to top, a flame burst out of there mixed with a flame-colored and black whirl that sounded as a thunder and rolled down like an arrow towards the Akory Village'. One more piece of eyewitness evidence is quoted by Alishan (1890) and Zeitounian (1991): 'The earth gaped and flame burst out from Mount Ararat as a miraculous wind mixed with fire, which burned like sulfur and, heading towards Ararat, it enveloped the St. Jacob's Monastery and, having thrown everything on the Akory Village, split in two parts. The same black whirl mixed with fire engulfed snow and ice of Ararat, fell on the village and destroyed everything.'

(1) These, as well as many other accounts, lead us to suggest that a glowing cloud or a pyroclastic avalanche, as well as a debris flow, could have happened during the 1840 eruption. The deposits of that glowing cloud (pyroclastic avalanche) and debris flow were indicated in the work of Karakhanian et al. (2002) in Fig. 15 (2). Those are not glacial deposits as Haroutiunian (2005) thinks. The geological maps of Ararat prepared by Blumenthal (1959) and Lambert et al. (1974) indicate the deposits as tuff and tuff agglomerates.

(2) The formation of lahar-type landslide immediately after the earthquake of 1840 was described in detail in many works (Voskoboinikov, 1840; Abich, 1847; Alishan, 1890; Lynch, 1910; Ambraseys and Melville, 1982; Eisbacher and Clague, 1984). The summary of these events was presented in Karakhanian et al. (2002) and we do not repeat it here. Ferraud (1994) also considers that the eruption in 1840 was accompanied by ash blow and lahar-landslide and resembled the phreatic eruption on Soufriere in 1976, as well as lahars observed during the eruption of Nevado del Ruiz and on Mount St. Helens in 1980.

1.4. On the strong earthquake–volcanic eruption relation

Haroutiunian considers that it has been known for a long time that there is no connection between tectonic earthquakes and volcanic eruptions, except for isolated occurrences and tries to dispute the statement Karakhanian et al. (2002) allegedly made about the existence of a causal link between tectonic earthquakes and volcanic eruptions. In doing so, a phrase from Karakhanian et al. (2002) is quoted, "In many cases, historical volcanic activity coincided with strong earthquakes in time and place." Unfortunately, this phrase is taken out of the context of our publication in 2002 and Haroutiunian forgets to mention the text that followed. Karakhanian et al. (2002) stated that they "do not intend to study possible causative links between the processes of volcanic and seismic activity," but believed this would be a "fascinating issue … for targeted research." Neither we, nor Haroutiunian, had studied this problem specifically. The problem of the relationship between tectonic earthquakes and volcanic eruptions is very complicated and along with studies in support of such relation (Doumas, 1990; Hill et al., 1993; Guidoboni et al., 1994; Hill et al., 2002; Rogozhin et al., 2004), there are authors who deny it.

However, we can make the following observations for the area of Armenia:

(1) A clear spatial relationship between surface ruptures generated by strong earthquakes, on the one hand, and Pleistocene–Holocene volcanoes and lava eruption centers, on the other, has been observed for many centers of areal volcanism located within pull-apart basins.
(2) Some of the earthquake date estimates derived by radiocarbon and archaeological methods have provided figures approaching the volcano eruption dates (Karakhanian et al., 1997, 2002, 2004). Similar results were obtained for the Greater Caucasus (Rogozhin et al., 2004). Certainly, ^{14}C analyses and archaeological techniques produce the ranges of uncertainties in date definition accuracy that is much disliked by Haroutiunian; however, for now we know of no other means to estimate such ages.
(3) Written historical sources contain evidence and description of phenomena similar to volcanic effects that occurred at the time or immediately after strong earthquakes in Armenia, and beyond it (Greece, Syria, and Anatolia). The eruption of 1840 is a good and not the sole example of such coincidence. Annex 1 (5, 6, 7, and 9) in Karakhanian et al. (2002) cited other examples.
(4) The mechanism considered for the volcanoes of the Karckar Group can be suggested to explain this relation (Karakhanian et al., 1997). With the shallow occurrence of magma pockets (3–15 km) in pull-apart basin structures, 40–50-km-long earthquake ruptures forming at depths up to 15–20 km (the depth range of the seismic foci layer for strong earthquakes in Armenia) could penetrate the magma pockets and trigger eruptions. Eruptions and other volcanic effects can occur directly at the moment of an earthquake, or shortly after it. Nevertheless, this is only a hypothesis and the proposed mechanism may not be repeating in time, or in space. In any case, the combination between strong tectonic earthquakes and volcanic eruptions in space and time represents a real, though not a universal, phenomenon, many aspects of which still have to be studied.

The temperature of mineral springs is not the most important factor to characterize the Holocene–historical volcanism in Armenia. Nevertheless, we will cite the references used to indicate thermal spring temperatures in our publications: Jermouk–maximum surface temperature of 63–67 °C; Vorotan–40 °C on the surface; Jermakhpyur–99 °C 1 km deep in a well (Assessment of … 1998, p. 2–7, 2–14, 2–7, 2–9). The highest temperature for the Histissou spring at the surface is 60 °C (Kashkai, 1952).

1.5. Conclusion

(1) The Holocene–historical volcanism is still insufficiently studied in Armenia and may be interpreted diversely like any complex natural phenomenon. Using diverse techniques, scientists may arrive at different explanations of the same effect. Co-existence of various points of view is normal for the evolution of a study, while revisiting of research results helps to improve our knowledge.
(2) In our view, in revisiting our publications (Karakhanian et al., 2002, 2003), Haroutiunian is concerned with the unessential part of their content, putting forward arguments that are sometimes questionable. Readers of JVGR are free to decide whether the statements revisited by Haroutiunian can be accepted, or not.
(3) To a certain extent, the divergence of conclusions made by Karakhanyan et al. and by Haroutiunian

can be explained by the difference of approaches. Haroutiunian has based his research mostly on his studies of written historical sources without even short-term field inspections of the studied objects. We consider fieldwork as the main research method and supplement this with laboratory estimation of ages, remote sensing methods, GIS analysis, and other techniques. In the meantime, we apply an interdisciplinary approach involving a wide range of experts in geology, geophysics, archaeology and history.

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