

# The Birth of a New Extrusive Dome of the Sheveluch Volcano (Kamchatka) in 2024 according to Continuous Satellite Monitoring in the VolSatView Information System

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**Abstract**—Sheveluch is one of the most active volcanoes in Kamchatka. Its modern edifice includes three main elements: Old Sheveluch, an ancient caldera and Young Sheveluch. On the southeastern slope of Old Sheveluch, there is a group of ancient extrusive domes (from south to north): Sherokhovataya, Krasnaya, Karan, and Sopochka na sklone. Only in the area of the Karan dome are there heated areas with mofets temperature of 70–96°C. After the powerful explosive eruption of the Sheveluch volcano in April 2023, the gas–steam activity of the Karan dome intensified, and a thermal anomaly began to be noted in satellite images of the area of this dome. On April 26, 2024, in a *JPSS-1* satellite image at 15:07 UTC, Kamchatkan Volcanic Eruption Response Team scientists discovered a bright thermal anomaly in the area of the Karan dome; that is, they recorded a unique phenomenon on this day: the birth of a new volcanogenic formation—the new lava dome. It was given the name 300 Years of the Russian Academy of Sciences. As of June 7, 2024, the size of the new dome was 800 × 500 m and the area of the dome crown was 0.19 km<sup>2</sup>. The eruption of the new lava dome 300 Years of the Russian Academy of Sciences is continuing.

**Keywords:** volcano, Sheveluch, Kamchatka, extrusive eruption, 300 Years of the Russian Academy of Sciences lava dome, satellite monitoring, VolSatView information system, Kamchatkan Volcanic Eruption Response Team (KVERT)

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## INTRODUCTION

Sheveluch is one of the most active volcanoes in Kamchatka, located in the northern part of the Central Kamchatka Depression, 50 km from Klyuchi and 450 km from Petropavlovsk-Kamchatsky (<http://www.kscnet.ru/ivs/kvert/volc?name=Sheveluch>). Sheveluch is one of the largest volcanic structures in Kamchatka: the diameter of its base reaches 45–50 km, and the area is not less than 1300 km<sup>2</sup>. The volcano began to form about 60–70 thousand years ago [12]. Its modern structure includes three main elements: Old Sheveluch (3283 m), an ancient caldera, and Young Sheveluch (2800 m). In the Young Shevelucha crater, a lava dome has been growing since August 1980, the activity of which is represented by extrusive, effusive, and explosive (Vulcanian type) eruptions [4, 9].

On the southwestern slope of Old Sheveluch, there is a group of well-preserved ancient extrusive domes, confined to a fault with a north–northeast strike (south to north): Sherokhovataya, Krasnaya, Karan,

and Sopochka na sklone [7]. Only in the area of the Karan dome are there heated areas, the mofets activity of which has been studied by volcanologists since 1937–1938 [2]. The temperature of the mofet remained at approximately the same level (varying within the range from 70 to 96°C) throughout the entire observation period (for example, [1–3, 7, 8]). Occasionally in the 20th and 21st centuries, increased gas–steam activity was observed in the Karan dome.

Daily satellite monitoring of the Sheveluch volcano is carried out by scientists from the Kamchatkan Volcanic Eruption Response Team (KVERT) of the Institute of Volcanology and Seismology (IVS) of the Far East Branch (FEB) of the Russian Academy of Sciences (RAS) since 2002 [4, 9]. Since 2014, it has been carried out using the Remote Monitoring of the Activity of Volcanoes in Kamchatka and the Kuril Islands information system (IS) (VolSatView, <http://kamchatka.volcanoes.smislab.ru>) [4, 10, 11]. For monitoring the volcano, the VolSatView IS contains promptly updated medium and low resolution data from satellite



**Fig. 1.** Example of high gas-steam activity of the Karan dome on the southwestern slope of the Sheveluch volcano on September 21, 2023. Photo by I.A. Nuzhdaev.

systems: *NOAA-18/19* (National Oceanic and Atmospheric Administration), *Terra* and *Aqua*, *Suomi NPP* (National Polar-orbiting Partnership) and *JPSS-1/2* (Joint Polar Satellite System), *Sentinel-3A/3B*, *Meteor-M-2*, and *Himawari-8/9*, as well as high-resolution images from *Landsat-7/8/9* and *Sentinel-1A/1B/2A/2B* satellites, among others [4, 9, 10], as well as various tools for analyzing these data and the results of their processing.

#### THE BIRTH OF A NEW EXTRUSIVE DOME OF THE SHEVELUCH VOLCANO

After a powerful explosive eruption of the Sheveluch volcano in 2023, which continued continuously from April 10 to 13 [5], a large fissure zone formed on the southwestern slope of the volcano in the area of ancient lava domes (oral communication by V.I. Frolov, employee of the Institute of Volcanology and Seismology, FEB RAS). After the weather improved in the Sheveluch area on April 30, 2023, several large fumaroles were discovered on the Karan dome, and their activity subsequently remained high: the gas-steam column sometimes rose to 3–3.5 km above sea level (a.s.l.) (Fig. 1).

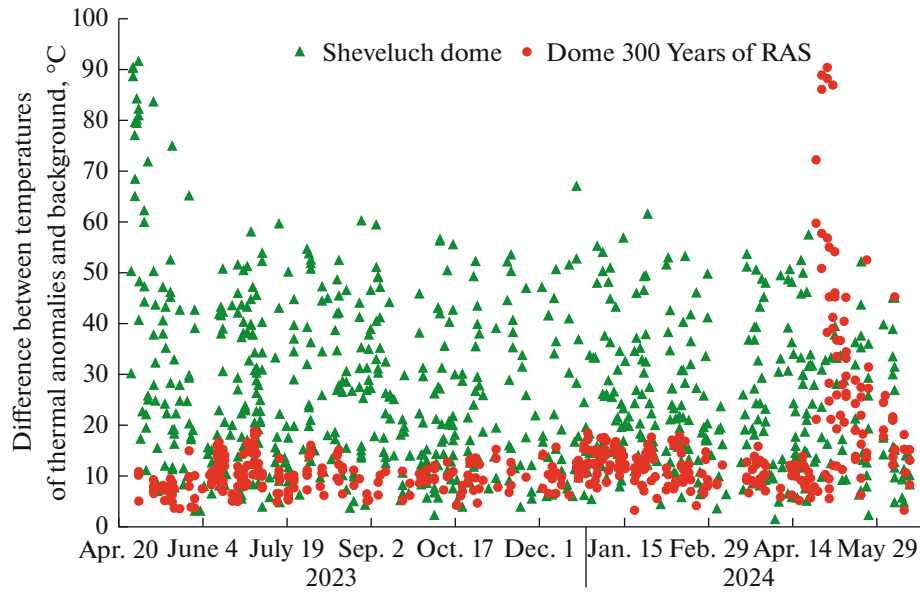
On the same day, KVERT scientists suggested the possible appearance of a new lava dome in the Karan area ([https://t.me/IViS\\_DVO\\_RAN/161](https://t.me/IViS_DVO_RAN/161)). Since April 30, 2023, a thermal anomaly has been observed in the area of the Karan dome (Fig. 2). The Value of Temperature Difference between the thermal Anomaly and the Background (VTDAB) from April 30, 2023

to April 26, 2024 varied from 2.1 to 18.8°C, averaging 9.6°C (a sample of 642 nighttime VTDAB based on AVHRR data (Advanced Very-High-Resolution Radiometer), MODIS (Moderate Resolution Imaging Spectroradiometer), VIIRS (Visible Infrared Imaging Radiometer Suite), SLSTR (Sea and Land Surface Temperature Radiometer), and MSU-MR (Multi-zone low-resolution scanning device)). As can be clearly seen from Fig. 2, the temperature of the anomaly in the area of the Karan dome was significantly lower than the temperature of the anomaly in the area of the active Young Sheveluch dome.

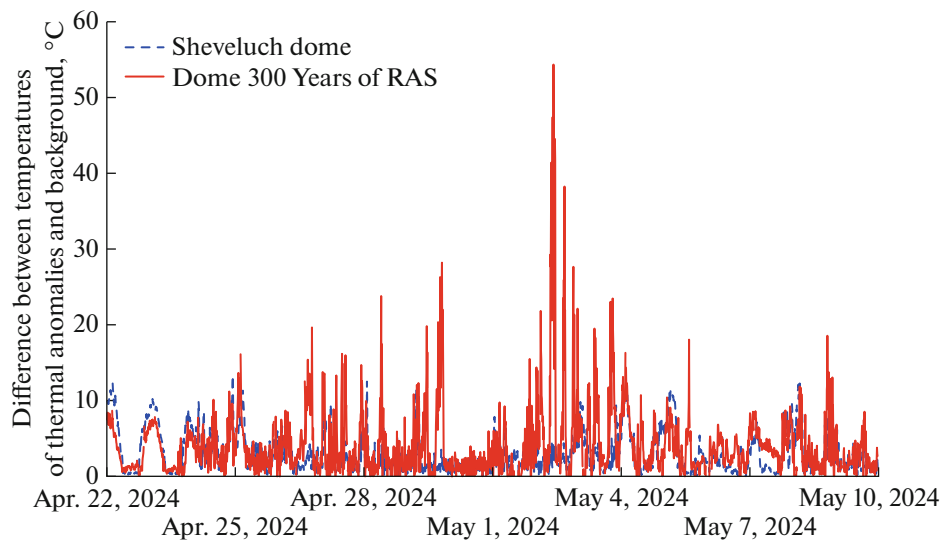
On the *JPSS-1* satellite image (VIIRS instrument, fourth channel) from April 26, 2024, at 15:07 UTC (in the area of the Karan dome), a bright thermal anomaly was discovered, the VTDAB of which increased from 8 to 59.7°C (see Fig. 2), and at 16:23 UTC it reached 95°C (according to data from the *Aqua* satellite, MODIS instrument).

Our studies of the thermal activity of the Young Sheveluch volcano revealed that the background activity for it is the VTDAB 20°C [9]. A sharp increase in the VTDAB above the background activity indicates the appearance of magmatic matter at the earth's surface. Consequently, on April 26, 2024, KVERT scientists recorded a unique phenomenon: the birth of a new volcanic formation—a lava dome, which was named the 300 Years of RAS.

The bright glow of the dome began to be observed at night by video cameras operating in infrared mode (see, for example, <http://www.kscnet.ru/ivs/kvert/imgs/2966.jpg>). Powerful gas-steam activity with



**Fig. 2.** The Value of Temperature Difference between the thermal Anomaly and the Background of the active dome of the Young Sheveluch volcano and the 300 Years of the Russian Academy of Sciences dome in 2023–2024 according to night data from *JPSS-1/2* and *Suomi NPP* satellites (fourth channel of the VIIRS device) from the VolSatView information system.



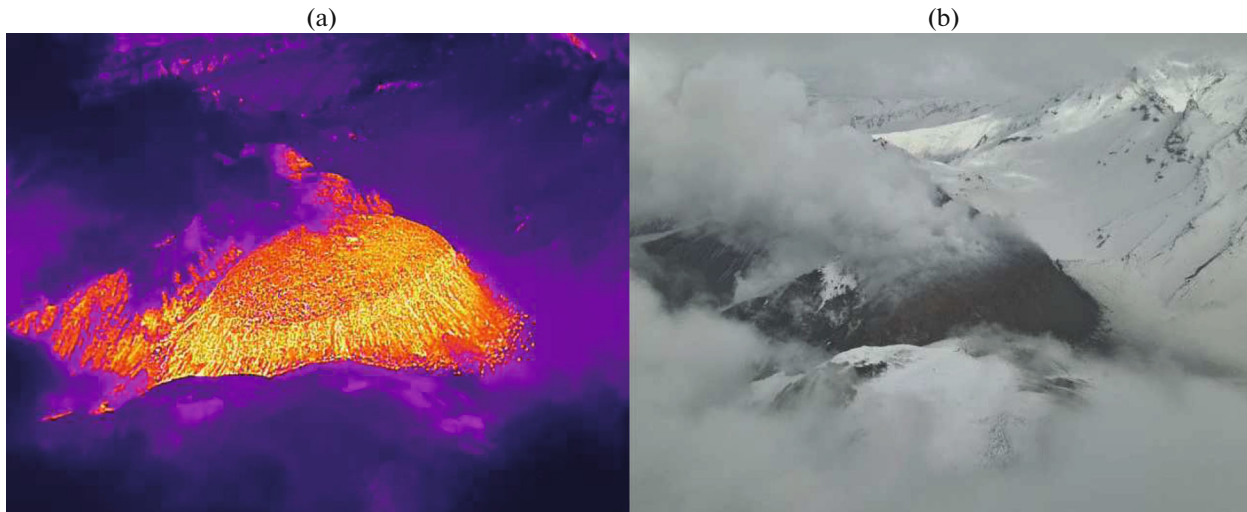
**Fig. 3.** Difference in the temperature values of thermal anomalies and the background of the active dome of the Young Sheveluch volcano and the 300 Years of the Russian Academy of Sciences dome in the period from April 22 to May 10, 2024, according to day and night data of the *Himawari-9* satellite (4  $\mu\text{m}$  channel of the AHI device).

the removal of volcanogenic aerosols up to 4 km a.s.l. accompanies the extruded out of the 300 Years of the Russian Academy of Sciences dome (see, for example, <http://www.kscnet.ru/ivs/kvert/imgs/2965.jpg>).

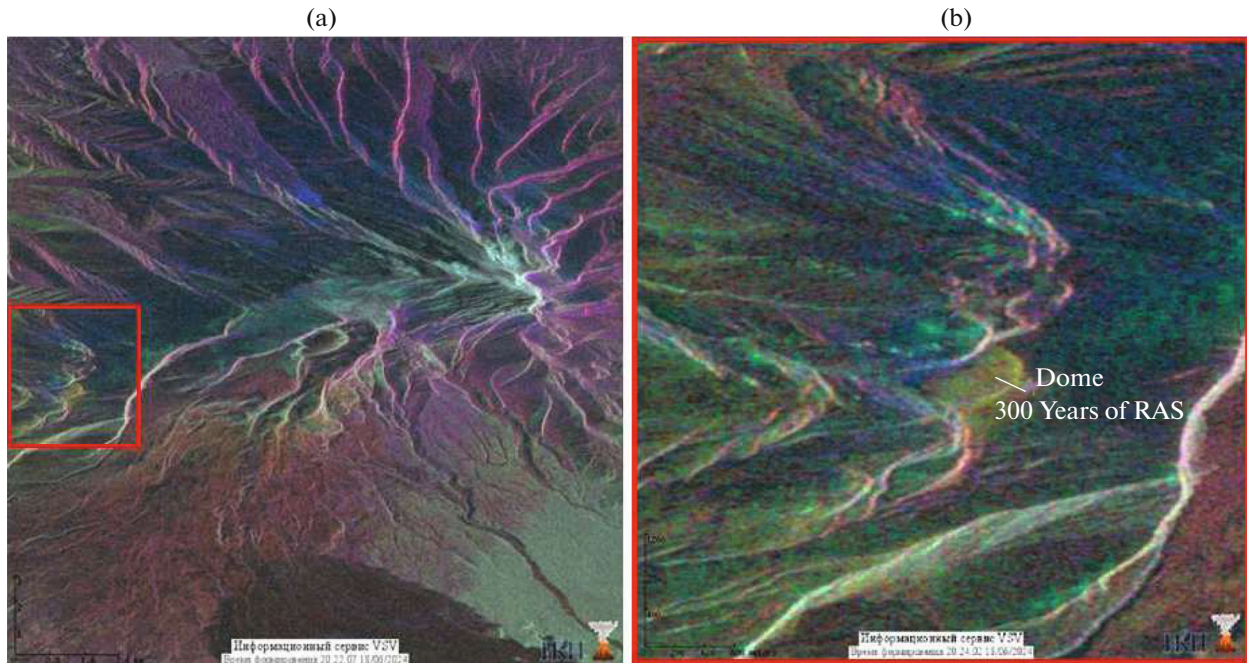
The new dome grew most vigorously in the first weeks, with the maximum VTDAB of  $90.4^{\circ}\text{C}$  recorded on May 2, 2024, on the *Suomi NPP* satellite image at 16:07 UTC (see Fig. 2). Subsequently, the temperature of the lava dome began to gradually decrease, which is probably due to the large volume of cooling lava and agglomerate material blocking the channel for the supply of fresh magmatic matter.

More detailed time dynamics of the change in VTDAB in the area of the Sheveluch domes obtained on the basis of data from the 4- $\mu\text{m}$  channel of the AHI (Advanced Himawari Imager) instrument of the *Himawari-9* satellite in the period from April 22 to May 10, 2024, is presented in Fig. 3. The spatial resolution of the AHI device is 0.5 km in the visible channel and 1 km in the IR channel at the subsatellite point. The frequency of the device's shooting of the Earth's surface is one picture every 10 min. For example, in Fig. 3, a gradual increase in the thermal activity of the new dome 300 Years of the Russian Academy of Sciences is observed, as well as its culmination is on





**Fig. 4.** Images of the new lava dome 300 Years of the Russian Academy of Sciences at the southeastern foot of the ancient Karan dome of the Sheveluch volcano in (a) infrared and (b) visible channels obtained on May 8, 2024, using the DJI Mavic 3 Thermal system.



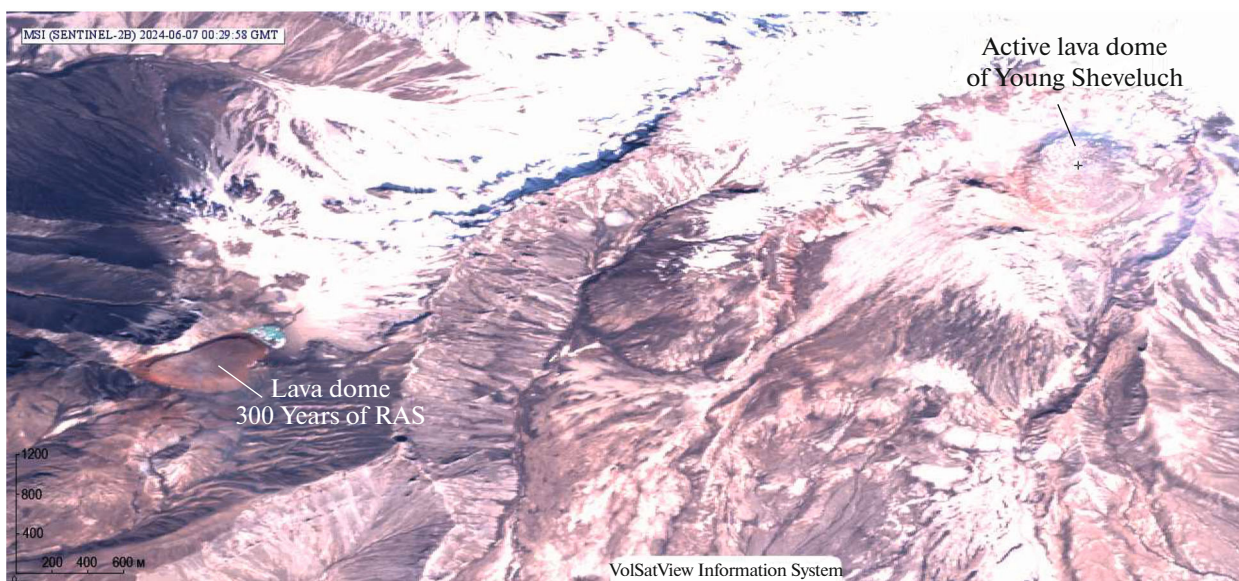
**Fig. 5.** (a) New lava dome 300 Years of the Russian Academy of Sciences and (b) a fourfold enlarged image (red square in Fig. 5a). Color-synthesized multitemporal image obtained from *Sentinel-1A* satellite data (VV polarization, descending session). R—data for June 6, 2024; G—data for May 13, 2024; B—data for January 26, 2024.

May 2, 2024 (VTDAB reached  $54^{\circ}\text{C}$ ), in contrast to the Young Sheveluch dome, the thermal activity of which remained at the same level on average (VTDAB did not exceed  $10\text{--}13^{\circ}\text{C}$ ). Information on VTDAB obtained from different satellite data (VIIRS and AHI instruments) equally clearly shows the culmination events associated with active volcanism.

According to the Support Aviation Control Service  $\text{SO}_2$  and Ash Notification System (<http://sacs.aeronomie.be>), using the TROPOMI (Tropospheric Ozone-Monitoring Instrument) tool, a cloud of sulfur dioxide ( $\text{SO}_2$ ) with an area of  $40789\text{ km}^2$  and a mass of

$1.438\text{ kt}$  was noted in the 300 Years of RAS lava dome area on May 4, 2024 ([https://sacs.aeronomie.be/alert/TropomiNrt/2024/05.alt/04/img/20240504\\_030541\\_111\\_vcd\\_interpol.gif](https://sacs.aeronomie.be/alert/TropomiNrt/2024/05.alt/04/img/20240504_030541_111_vcd_interpol.gif)).

Infrared photography of the new dome was carried out by I.A. Nuzhdaev on May 8, 2024 (Fig. 4). The dome-shaped structure of the extrusion crown is well expressed, with steep cliffs in its summit part and numerous hot avalanches along its entire perimeter. The extrude of the dome is accompanied by powerful gas-steam activity. The height of the dome was estimated at  $70\text{ m}$ , and the diameter of its base exceeded



**Fig. 6.** New lava dome 300 Years of the Russian Academy of Sciences on a *Sentinel-2B* satellite image from 00:29 UTC June 7, 2024. Data from the VolSatView information system.

400 m ([http://www.kscnet.ru/ivs/volcanoes/inform\\_messages/2024/Sheveluch\\_04/](http://www.kscnet.ru/ivs/volcanoes/inform_messages/2024/Sheveluch_04/)).

The new dome is clearly visible in the radar data obtained by the *Sentinel-1A* satellite during downlink sessions (Fig. 5). It should be noted that during the ascending sessions of the same satellite the dome is practically invisible.

In the image from the *Sentinel-2B* satellite (with an MSI (Multispectral Instrument)) from 00:29 UTC June 7, 2024, the dome 300 years of the Russian Academy of Sciences is well expressed: it is located at the southeastern foot of the Karan dome, where the highest-temperature mofets with a temperature of  $95^{\circ}\text{C}$  were previously noted [3]. The dome, about 100 m high, extends (at an azimuth of  $260^{\circ}$ ) for 800 m along a small ravine; its width reaches 500 m, and its southeastern part has already crossed the edge of the ravine. The area of the dome's crown is  $0.19\text{ km}^2$ , and the area of its foot is  $0.28\text{ km}^2$ . A small dammed lake measuring  $244 \times 160\text{ m}$  and an area of  $0.03\text{ km}^2$  adjoins the northwestern side of the dome (Fig. 6). The size of the active dome of the Young Sheveluch volcano reaches  $1000 \times 900\text{ m}$ , and the visible area of the dome is  $0.7\text{ km}^2$  (Fig. 6).

## CONCLUSIONS

On April 26, 2024, a unique event occurred: the birth of the volcanic formation of the Sheveluch volcano, a new lava dome, named 300 Years of the Russian Academy of Sciences. The appearance of the dome was predicted by KVERT scientists on April 30, 2023, and, thanks to daily satellite monitoring of the

volcano in the VolSatView information system, it was recorded by them on April 26, 2024.

Thermal and gas-steam activity in the area of the ancient Karan dome began to be noted after a powerful eruption of the Young Sheveluch volcano on April 10–13, 2023. Over the course of a year, a channel was developed through which magmatic matter was extruded onto the surface on April 26, 2024. As of June 7, 2024, the dimensions of the dome 300 Years of the Russian Academy of Sciences are height 100 m, length 800 m, width 500 m, and area of the dome crown  $0.19\text{ km}^2$ . The eruption of the 300 Years of the Russian Academy of Sciences is continuing.

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#### CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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