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Thermal Anomalies on Savich Cone, Kikhpinych Volcano, Kamchatka: IR Surveys and Land-Based Observations for 30 Years (1982 through 2012)

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Abstract—An analysis of data from nadir aerial thermal surveys of 2010 and 2012, as well as from a land-based IR survey of 2010, showed changes in the thermal regime of anomalies on Savich Cone (Kikhpinych Volcano, Kamchatka) compared with the 1982 and 1993 surveys. It was noted that the temperature increased in the upper part of the cone, new warm patches appeared in the near-crater zone of the cone, and white sublimates appeared in the southwestern and southeastern sectors of the crater. The last feature was new.

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INTRODUCTION

The Kikhpinych long-lived volcanic center (KLLVC), which was identified by V.I. Belousov (1978), is situated in Kamchatka, in the area of the Kronotskii State Biosphere Nature Reserve. The Center includes several structures of different origin and ages. One of these is Staryi Kikhpinych Volcano (or Pik). It originated in the Eastern Volcanic Zone during Middle to Upper Pleistocene time (Braitseva et al., 1989, 1991). The Staryi Kikhpinych (SK) edifice is the base for two basaltic cones of Molodoi Kikhpinych: the West Cone (WC) and Savich Cone (SC), as well as for the dacitic Sopka Zheltaya Volcano, which is somewhat southward of these. The history of the evolution and the dynamics of the activity for Molodoi Kikhpinych Volcano were described in (Braitseva et al., 1989); the volcanic hazard that can possibly emanate from Kikhpinych was evaluated by Ponomareva and Braitseva (1991). A long-term forecast for this volcano can be found in (*Noveishii* ..., 2005). The present study is concerned with thermal anomalies (TA) on Savich Cone. The anomalies were surveyed by land-based techniques in August 1982, and afterwards in 1997 and 2010. An aerial thermal survey of the area was conducted in 1982 and 1989 using an AGA-Thermovision 680 instrument (1 pix ~ 10 m), and in 2010 and 2012 using a high resolution ThermaCam P 640 instrument (1 pix ~ 1.4 m). For 1993 we used NASA data (TIMS).

RESULTS OF SURVEYS

The present paper provides a detailed account of the changes that had occurred on Savich Cone between 1982 and 2012. Figure 1 shows how the thermal anomalies varied between 1993 and 2012 as revealed by the aerial thermal survey; we show the overall view of the cone in 1999 where the positions of the TAs are marked (see Fig. 1a). The anomalies were identified from a NASA thermal survey of 1993 and nadir thermal aerial photographic surveys in 2010 and 2012 (see Figs. 1b, 1c, 1d). The 1993 airview clearly reveals ten TAs, which had become 14 by 2010. In addition, several anomalies became greater in extent and brightness. The warm area in the upper part of the cone increased in 2010, and TA 9 considerably gained in areal extent compared with 1993. Large TAs 12 and 13 appeared on the eastern slope, a small new TA 11 on the southern, but TA 8 was considerably reduced. The anomaly structure had changed. It is clearly seen that the thermal anomalies in the northern sector of the crater grew less intensive in 2010, but more so in the southern sector, while the eastern slope grew warmer. The intensities of TA 1, TA 4, TA 7, and TA 9 increased considerably in 2012 compared with 2010, but TA 12 and TA 13 were somewhat reduced. The 2010 survey was carried out by S.A. Chirkov from an MI-8 helicopter (H_{abs} = 3000 m). Figures 1e and 1f show a thermogram and an overview of the terrain where TA 10 was observed. One can clearly discern white sublimates that had not previously been detected in the Savich Cone crater.

Routine flights around active volcanoes in October 2009 revealed strong steaming at the summit of Savich Cone. Figures 2a, 2b, 2c, and 2d show the positions of individual TAs (1 through 14).

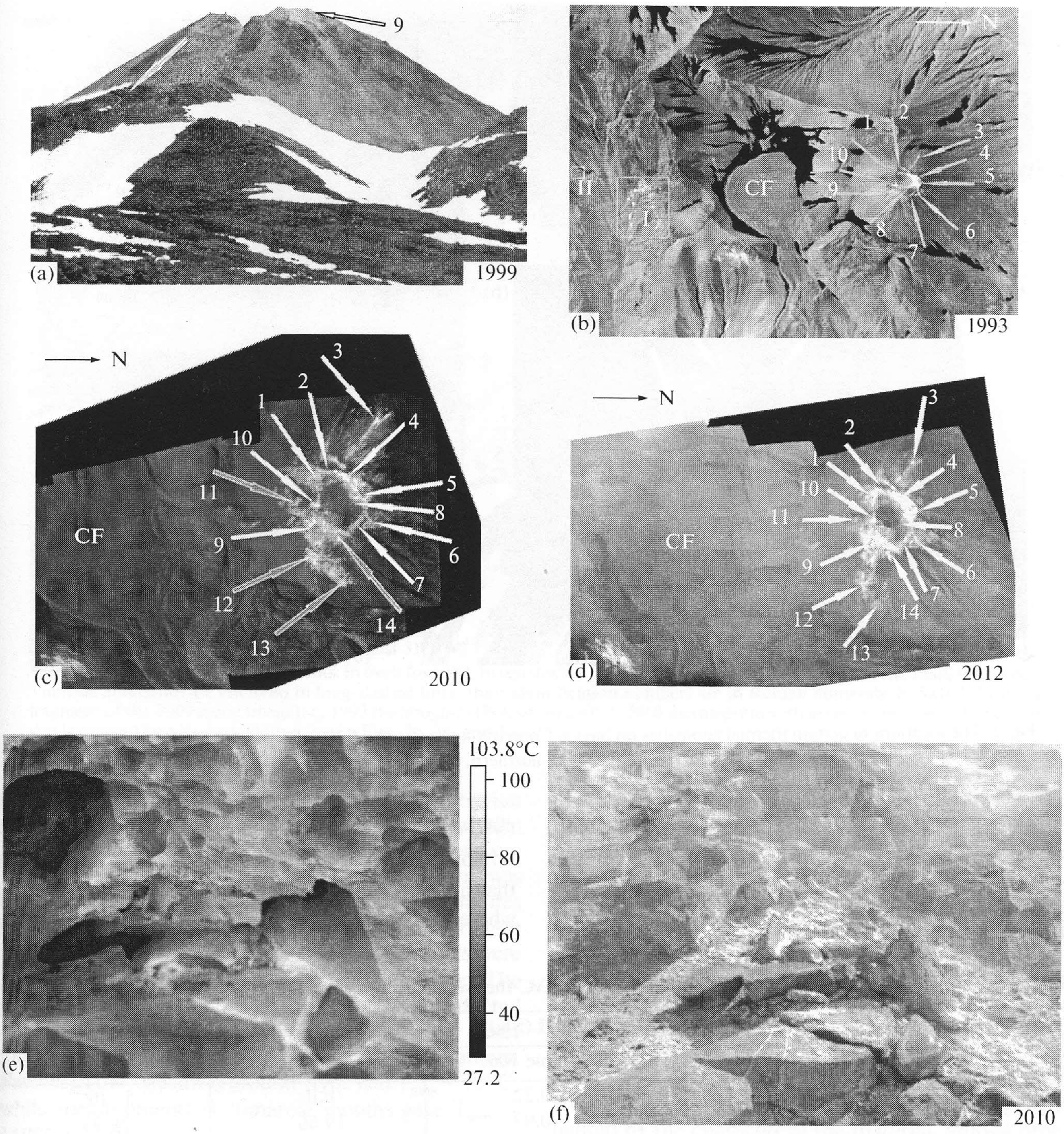

Fig. 1. Thermal anomalies on Savich Cone. The numerals at the arrows are anomaly identification numbers.
a, Savich Cone (SC), view from southeast (photographed by V.L. Leonov in 1999), arrows denote TA 9 (unfilled) and the source of the circular flow (dashed); b, IR view in 1993, *thermal fields* in the SC crater: TF I is North field, TF II is South field; c, IR view of SC crater taken in 2010: (dashed arrows mark new TAs); d, IR view in 2012; e, 2010 thermogram, a fragment of TA 10 in Savich Cone crater; f, photograph of the same fragment. CF stands for circular flow at the base of Savich Cone.

We proceed to consider the temperature variations on Savich Cone from land-based measurements. The crater was found to have T = 52°C in 1981 (personal communication by G.A. Karpov). A small number of noticeable steam-and-gas discharges were observed on Savich Cone in August 1982 (Fig. 3a), with the highest temperatures occurring in the volcano's northwestern sector (T = 72–76°C, T_{max} ~ 76°C). Gas was sampled from a fumarole with T = 63°C in the eastern sector of the crater (Table 1). The gas had essentially the composition of air, while the

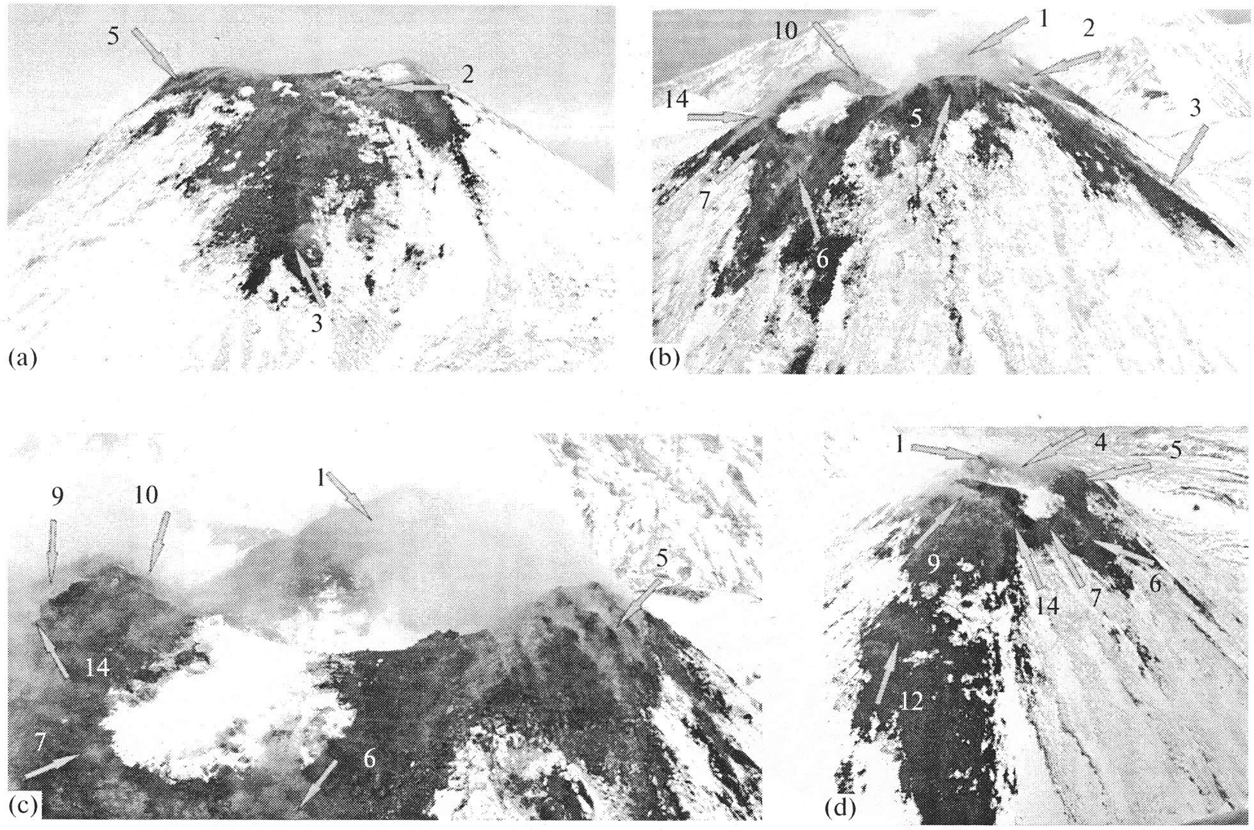

Fig. 2. The locations of certain thermal anomalies on Savich Cone (photographed by S.V. Sokorenko in 2009). a–d sectors: a, western (arrow indicates west edge of TA 2), b, northern, c, northeastern, and d, eastern sector.

concentration of CO_2 was a mere 3.43%, in contrast to the Staryi Kikhpinych fumaroles, where its concentration reached 74–87%. No sulfurous gases were found on the cone, while the fumarole gas in the Staryi Kikhpinych (SK) crater contained 0.8–0.9% of H_2S. The concentration of CH_4 in the gas is a few orders of magnitude below that at the fumaroles in the SK crater. Fields I and II where gas was sampled in the crater of Staryi Kikhpinych

Table 1. The composition of fumarole gases in certain KLLVC thermal fields

Components	**TF II** (SK)	**TF I** (SK)	Savich Cone	*
	sample 810	sample 1067	sample 1058	Air
H_2	n.d.	0.22	n.d.	$5 \cdot 10^{-5}$
O_2	0.93	0.93	19.66	20.95
N_2	18.66	6.2	76.03	78.09
Ar	0.19	0.03	0.88	0.93
CO_2	73.64	87.17	3.43	0.03
H_2S	0.79	0.89	n.d.	
CH_4	5.79	4.56	$0.8 \cdot 10^{-4}$	
C_3H_8	$0.98 \cdot 10^{-4}$	n.d.	n.d.	
C_3H_6	n.d.	$2.5 \cdot 10^{-4}$	n.d.	
T, °C	93	97	68	
O_2/N_2	0.05	0.15	0.258	0.268

n.o. means a concentration below detection threshold. * (*Khimicheskii* ..., 1983).
The analyses were performed at the Institute of Volcanology and Seismology, Far East Branch, Russian Academy of Sciences. Analyst E.N. Dekshtein.

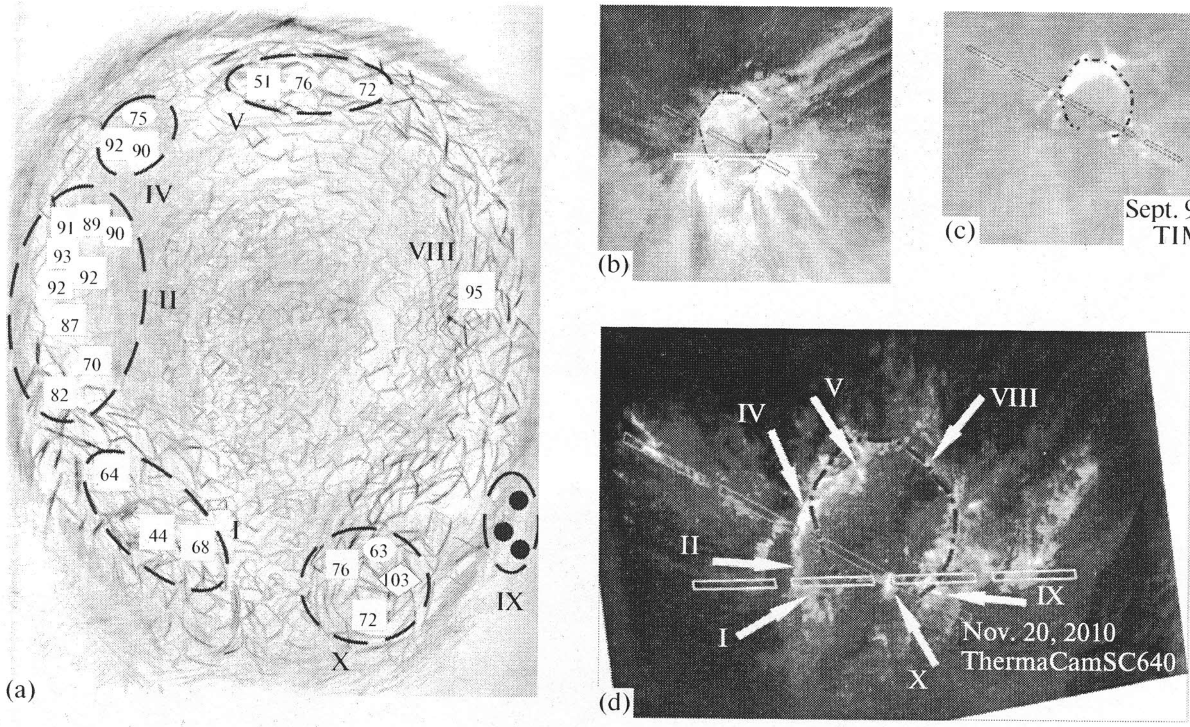

Fig. 3. A map of Savich Cone taken on August 31, 1997.
a, temperatures at steam-and-gas vents: in ovals for 1982; in squares for 1997; in a diamond for 2010; filled circles mark fumaroles. Thermal anomalies are enclosed in long-dashed lines, their identification numbers are in Roman numerals; b, Savich Cone (a fragment of the 2009 space image); c, 1993 thermogram (NASA image); d, 2010 thermogram with anomaly numbers. The crater rim is marked by a dashed–dotted line in Figs. 3b, 3c, and 3d.

are marked in Fig. 1b. The basaltic andesites on Savich Cone (Leonov and Grib, 2004) changed at the fumarole mouths to become red clay in 1982, no sublimates were observed in the crater, even no gypsum, although this was a frequent occurrence in the SK crater. Temperatures were measured at 18 steam-and-gas vents in 1997 (see Fig. 3a), $T_{max} \sim 95°C$. Three steam-and-gas vents were found in the eastern sector of the crater outer slope. The land-based surveys of Savich Cone that were conducted on August 13, 2010 gave the temperatures on the crater inner slopes as measured by a thermovision instrument. Patches of the "steaming ground" type had $T_{max} \sim 75°C$, while measurements at fumarole mouths gave $T_{max} \sim 110°C$ (see Fig. 3a).

Figure 3b shows part of a high resolution satellite photograph where the crater rim is marked by a dashed–dotted line. Figure 3c shows an image recorded by the NASA TIMS complex in 1993. Three sets of anomalies can be seen in this photograph, which are situated (a) along an NW–SE line, (b) in the crater (mostly inside it), and (c) along an arc that is outside the crater on the eastern slope. One can see that anomalies of different intensities combine to form several sets. A thermogram of the cone recorded on October 16, 2010, i.e., 17 years later, shows the thermal anomalies to be more spotty (see Fig. 3d). The anomalies have changed structure. The following sets can be identified: (1) along a NW–SE line, but which is shorter than the preceding line; (2) on the crater; (3) a new nearly east–west set. Comparison of the thermograms suggests that the intensity in the northern part of the crater decreased and that in the southern increased. The eastern slope was warmer compared with the preceding years.

A panning photograph of the inner crater slopes was taken (Fig. 4a) in 2010 , including one in the infrared range (see Fig. 4b). To the right of arrow 9 one can see a block subsiding, with the subsidence being highlighted by the character of the material, among other things. Steam-and-gas discharges are seen at the southern boundary of the block with white sublimates forming near the vents (see Fig. 1f). Similar sublimates were also noticed in the upper zone of TA 1.

Figures 5a, 5b, 5c, 5d, 5e, 5f, 5g, and 5h show the locations of TA 1, TA 2, TA 3, TA 4, and TA 10 in the crater of Savich Cone. The larger fumaroles are concentrated in the upper part of TA 1 (see Figs. 5a, 5b) at the bases of large blocks that lie along the edges of an oval patch (see Fig. 5a). Buzzing and hissing were heard at the mouths of some fumaroles, indicating the rather

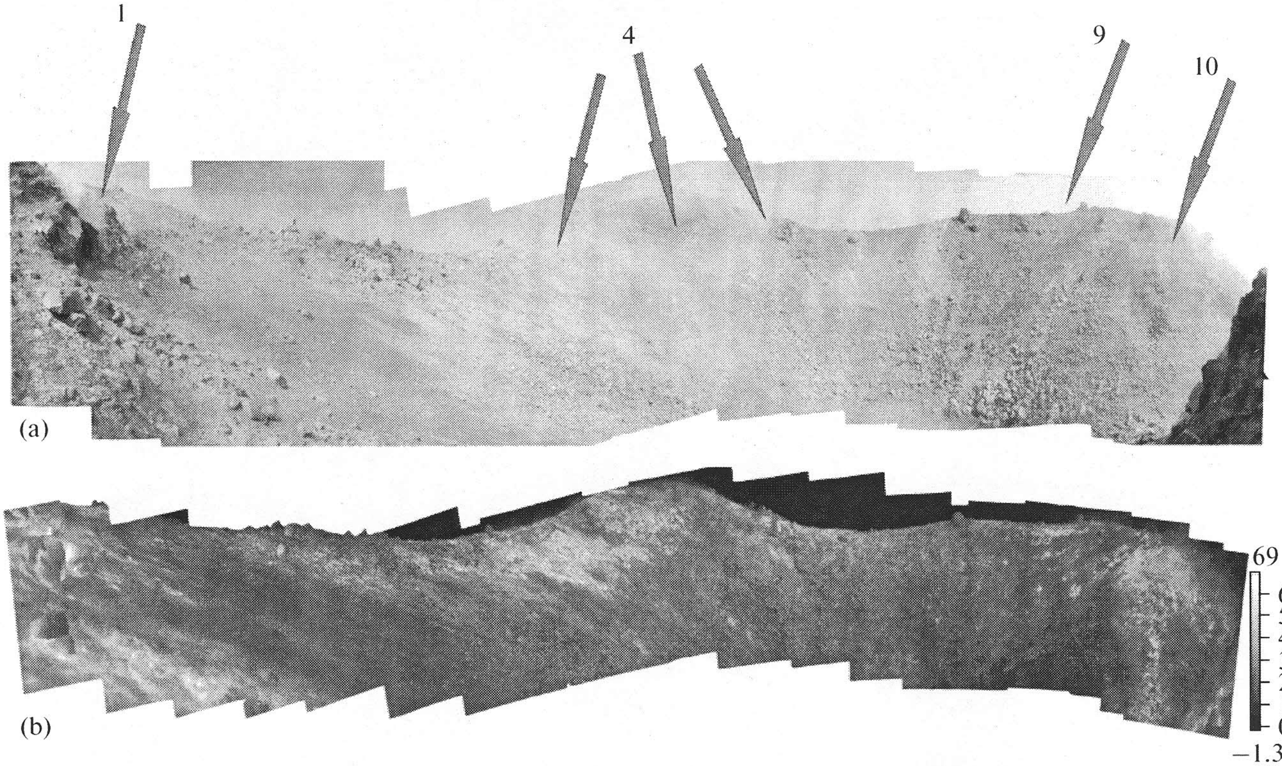

Fig. 4. A panning photograph of Savich Cone crater taken on August 13, 2010.
a panning photograph; b corresponding thermogram (ThermaCam P 640, °C). Numerals are anomaly identification numbers.

high pressure of the gas that was being released. No such occurrences were recorded in 1982 or in 1997.

The unfilled arrow in Fig. 5a shows a block in the crater of Savich Cone whose surface is like a slickenside. No such formations had been noticed in the crater before. The unfilled arrow in Figs. 5c and 5d in the area of TA 4 marks a drop-shaped vent in bedrock with a fumarole in its upper part (see Fig. 5d) that was not there in 1998 (see Fig. 5c). Figure 5e shows TA 10 as of 1999, its 2010 location is clearly apparent in Fig. 5f. The locations of TA 2 and TA 3 are shown in Fig. 5g, with TA 2 being displayed in more detail in Fig. 5h. The location of TA 9 can be clearly discerned in Fig. 1a. There were no steam-and-gas vents at the crater edge and on the outer slopes of Savich Cone in 1976–1982, 1986 and 1997.

The topographic map of 1941 has a *geyser* legend around the southern end of the circular flow (CF) near the base of Savich Cone, with a crater containing two small lakes at that location on the bottom in 2010 (Fig. 6a, arrow II). During many years the base of the circular flow has been under snow, even at the end of August. A bluish patch (as if thawed from below) could be discerned around arrow II in white perennial snow (see Fig. 6b). Arrow I in Figs. 6a and 6b shows a brook that starts from below a landslide in the middle of the western slope. The ferruginous sediment in the brook bed, which can be clearly seen in the 2010 photograph, was not there in 1982. The brook issued from below the landslide, but went under the snow patch. Water was sampled at the head of the brook in 1982; its composition is shown in Table 2 (sample 1060). This is acid SO_4–Ca water with an appreciable quantity of Al (28.1 mg/L) and a mere 0.5 mg/L of Fe^{3+} (see Table 2), as well as 3.8 mg/L of NH_4^- and 2.7 mg/L of H_3BO_3. A high-ground((verkhov..)) lake is marked by arrow II at the base of the circular flow on the snow patch (see Fig. 6b); water was sampled from the upper lake in 1997 (see Table 2, sample 1534). The water is near neutral ($Cl : HCO_3 : SO_4 = 1 : 1 : 1$). A crater was seen at the sampling site in August 2010 with two small lakes of greenish water being located on its bottom (see Fig. 6c), with the eastern lake being smaller than the western. It might be that the solution in the lakes consists of condensates of fumarole gases that are diluted with water from the brook marked by arrow I (see Figs. 6a, 6b). In these figures arrow III marks a stone ridge that serves as a positioning aid.

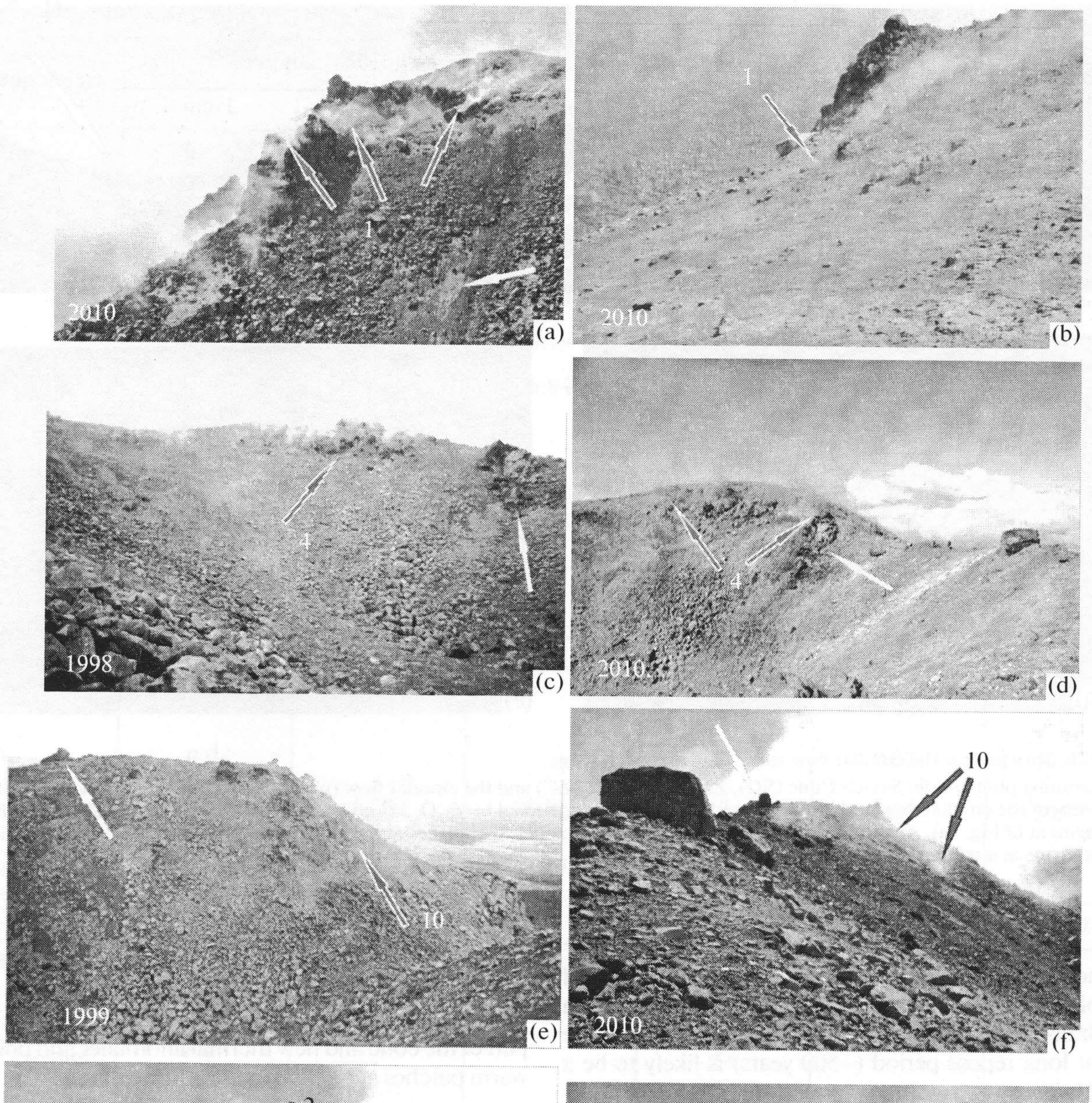

Fig. 5. Locations of thermal anomalies on Savich Cone (a, b, d, and f–h photographed by Ya.D. Murav'ev, c and e by I.B. Slovtsov).
a–b are individual fragments of TA 1; c–d show TA 4; e–f show TA 10; g shows TA 2 and TA 3 (arrow 2 indicates west edge of TA 2); h shows TA 2 in more detail (arrow indicates east edge of this TA, the west edge being off the framing area). Unfilled arrows mark the following features: a, block with the surface like a slickenside; c and d show bedrock exposure of drop-like appearance; e and f show a noticeable block that serves as a reference.

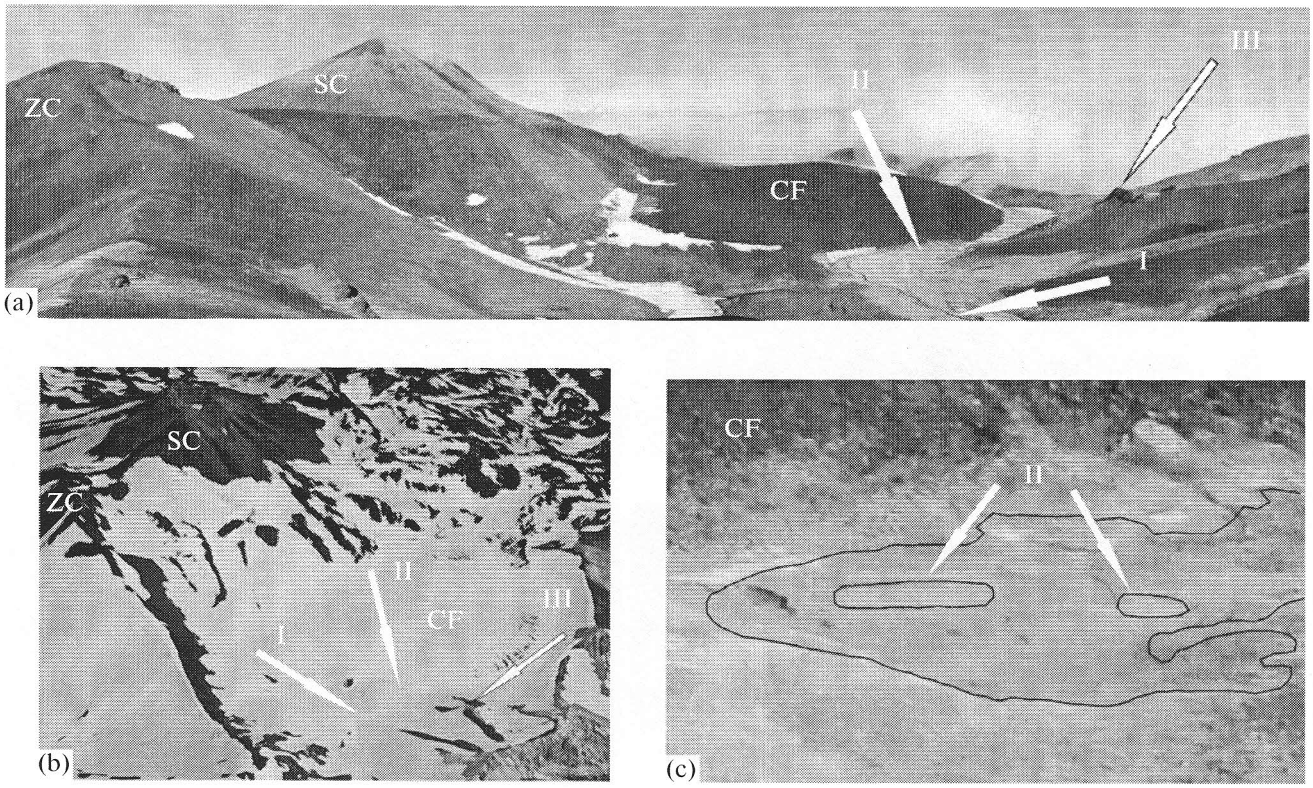

Fig. 6. Springs near the circular flow at the base of Savich Cone.
a, panning photograph: Savich Cone (SC), Zapadnyi Cone (ZC) and the circular flow (photographed by S.A. Chirkov in 2010); b, view of the circular flow and Savich Cone from SW (photographed by Ya.D. Murav'ev in 2009); c, south edge of circular flow (fragment of Fig. 6a). Arrows: I, a spring on west slope of cirque; II, small lakes at the base of the circular flow; III, a stone ridge that serves as a reference.

RESULTS AND DISCUSSION

The researchers who studied the history of activity of Kikhpinych Volcano (Braitseva et al., 1989; Ponomareva and Braitseva, 1991; *Noveishii* ..., 2005) believe that the current long repose period (~500 years) is likely to be a period between two major cycles of activity. However, they do not rule out that the period is merely an intermission during the normal activity of Savich Cone. The interval between consecutive eruptions has been between 200 and 400 years in the past. In that case, they believe that Kikhpinych can be expected to erupt in the near future.

An uplift of about 15 cm was recorded in 2001–2003 in the eastern side of the Uzon–Geyser-Valley depression (Lundgren and Lu, 2006). Geophysical observations by the microseismic sounding method began in 2009 in order to reconstruct the deep structure of the Uzon–Geyser-Valley depression. The results of this work (Kugaenko et al., 2010a, 2010b) showed agreement between the geometry of deep features as identified and a model for magma emplacement in the upper crust as suggested from satellite interferometry (Lundgren and Lu, 2006). The shape they hypothesize for current magma emplacement was defined as a thin sill that propagates along weakened zones in the crust. It is quite reasonable that events such as the uplift of 15 cm in the eastern side of the Uzon–Geyser-Valley depression must have been somehow affected the KLLVC, including Savich Cone. Recently, the temperature rapidly increased in the upper part of the cone and new thermal anomalies and new large warm patches appeared on the cone slopes.

The results of seismological field observations in the area of study were given by Kugaenko et al. (2010c). Numerous earthquakes have been recorded that the regional network missed and the existence of a local seismicity of low energy classes has been confirmed. The distribution of the hypocenters of local seismic events is in agreement with the deep model for the source of surface deformation as developed on the basis of SAR interferometry (Lundgren and Lu, 2006).

The earthquakes are concentrated in two spatially isolated sets of events that are related to the KLLVC (Kugaenko et al., 2010c). The few low energy earthquakes of the first set occurred at depths of 2 to 5 km. The inclined plane that delimits the hypocenters of this set plunges from the Geyser Valley westward, under the zone of extrusive domes in the eastern part of the depression. The second set is related to a zone of hydrothermal occurrences on the western slope of Staryi Kikhpinych Volcano

Table 2. The water composition in the area of the circular flow (near Savich Cone)

Components	Sample 1060, brook on slope			Sample 1534, upper lake		
	mg/L	mg-equ.	mg-equ. %	mg/L	mg-equ.	mg-equ. %
H^+	0.5	0.65	9.26			
NH_4^+	3.8	0.21	2.99	<0.1		
Na^+	3.1	0.13	1.85	0.5	0.02	31.75
K^+	0.5	0.01	0.14	0.1	0.003	4.76
Ca^{2+}	48.0	2.40	34.19	0.8	0.04	63.49
Mg^{2+}	6.0	0.48	6.84	<0.1		
Mn^{2+}	<0.2			<0.2		
Fe^{2+}	<0.3			<0.3		
Fe^{3+}	0.4	0.02	0.28	<0.3		
Al^{3+}	28.1	3.12	44.45	<0.3		
SK	90.5	7.02	100	1.4	0.063	100
Cl^-	n.d.			0.7	0.02	30.77
F^-	n.d.			0.06	0.005	7.69
HCO_3^-	n.d.			1.2	0.02	30.77
SO_4^{2+}	300.0	6.24	98.71	1.0	0.02	30.77
HSO_4^-	7.8	0.08	1.29			
SA	307.8	6.32	100	2.96	0.065	100
H_3BO_3	2.7			<1.2		
$H_4SiO_{4\ colloid}$	n.d.			<2		
$H_4SiO_{4\ dissolved}$	n.d.			<2		
M, g/L	0.40			0.044		
pH lab.	3.32			6.26		
T, °C	<16			<16		
Year of sampling	Aug. 16, 1982			Aug. 30, 1997		

The analyses were performed at the Institute of Volcanology and Seismology, Far East Branch, Russian Academy of Sciences. Analyst S.V. Sergeeva.

and is confined to the depth range down to 2 km. The recorded seismic events were treated by Kugaenko et al. (2010c) as a manifestation of the KLLVC activity and as evidence of the ongoing evolution of the Kikhpinych Volcanic Center.

This paper attempts to show that the upper part of Savich Cone became much warmer during recent years, especially its outer slopes. Just a few small fumaroles were observed in the Cone crater in 1982, while they became appreciably more numerous in 1997 (see Fig. 3). The number of thermal anomalies increased from 10 to 14 between 1993 and 2010 and the cone was seen to have warm patches of the "steaming soil" type. The white sublimates (see Fig. 1f) that were detected in the southwestern and southeastern sectors of the crater were absent from it before. Two new features, which are marked by unfilled arrows (see Figs. 5a, 5c, 5d), appeared in the southwestern and western sectors of the crater, or rather they became accessible to view, but were not there previously. Their appearance on the surface was probably due to the material of the cone being displaced as a result of the earthquakes that have occurred after 1982, e.g., in 1983 or in 1997, when Kikhpinych Volcano was in an intensity VI zone (Gusev et al., 1998; Zobin et al., 1985, 1986). Some individual displacements of segments and the subsidence that affected certain parts of the cone might have been the response to large ($M \geq 6.8$) earthquakes (1983, 1996, and 1997). Some contribution might also have been supplied by a landslide on Vodopadnyi Brook in 2007. The present authors remarked previously (Kardanova and Dubrovskaya, 1994, 2005) concerning the renewal of deep processes beneath Kikhpinych Volcano, with these processes causing the descent of lahars and slides, and collapses, as well as manifesting themselves in increased thermal activity on the cone. The KLLVC activity is also indicated by numerous earthquakes that have been recorded around the western slope of Staryi Kikhpinych Volcano, earthquakes that have not been detected by the regional network, as well as the presence of a local seismic activity of lower energy classes (Kugaenko et al., 2010c).

A collapse and a slide occurred in the eastern slope of the Uzon–Geyser-Valley depression in the area of the Verkhne-Geizernyi thermal field (upstream of the Troinoi waterfall) on January 4, 2014 (Leonov, 2014), providing evidence of ongoing activity in the KLLVC area.

CONCLUSIONS

It has been shown that the processes that are occurring on Savich Cone and in the crater of Staryi Kikhpinych Volcano provide evidence of renewed processes that are occurring at depth beneath Kikhpinych Volcano. The study of the Savich Cone calls for very careful scrutiny. It should be noted that no fumaroles had been observed either on Savich Cone itself or above its rim until 1997, inclusive. However, the following processes became appreciably more noticeable recently:

(1) the temperature in the upper part of the cone sharply increased;

(2) new thermal anomalies and new warm patches were formed on the cone slopes;

(3) white sublimates appeared in the southeastern and southwestern sectors of the crater, no such thing being observed previously;

(4) gas was issuing at high pressures (noise and whistle) in the TA 1 area in 2010;

(5) the number of fumaroles sharply increased.

The temperature and gas composition should be monitored in the Savich crater, along with similar measurements in the water of small lakes near the southern termination of the circular flow. Data of this type would help to clarify the dynamics of the processes that are occurring beneath Kikhpinych Volcano and would mitigate the impact of its possible eruptions in the future.

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ТЕРМОАНОМАЛИИ КОНУСА САВИЧА (ВУЛКАН КИХПИНЫЧ, КАМЧАТКА): РЕЗУЛЬТАТЫ ДАННЫХ ИК-СЪЕМКИ И НАЗЕМНЫХ НАБЛЮДЕНИЙ ЗА 30 ЛЕТ (1982–2012 гг.)

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Анализ материалов плановой аэротепловой съемки 2010 и 2012 гг., а также наземной ИК-съемки 2010 г. показал изменения в температурном режиме аномалий конуса Савича (вулкан Кихпиныч, Камчатка) по сравнению со съемками 1982 и 1993 гг. Было отмечено повышение температуры в верхней части конуса, появление новых прогретых площадок в прикратерной зоне конуса и появление отсутствовавших ранее белых возгонов в юго-западном и юго-восточном секторах кратера.

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Кихпинычский долгоживущий вулканический центр (КДВЦ), выделенный В.И. Белоусовым [1978], расположен на Камчатке, на территории Кроноцкого государственного природного биосферного заповедника. Этот центр включает несколько разнородных и разновозрастных сооружений. Одно из них – вулкан Старый Кихпиныч (Пик) возник в среднем – верхнем плейстоцене в Восточной вулканической зоне [Брайцева и др., 1985; 1991]. Постройка вулкана Старый Кихпиныч (СК) служит основанием для двух базальтовых конусов Молодого Кихпиныча: Западного (кЗ) и Савича (кС) и, расположенного южнее, дацитового вулкана Сопка Желтая. История формирования и динамика активности вулкана Молодой Кихпиныч показана в [Брайцева и др., 1985]; оценка вулканической опасности вулкана Кихпиныч в [Пономарева, Брайцева, 1990]; долгосрочный прогноз для него в [Новейший ..., 2005]. В данной статье рассматриваются термоаномалии (ТА) конуса Савича. Термоаномалии изучались наземными методами в августе 1982, 1997, 2010 гг. Аэротепловая съемка района проводилась в 1982, 1989 гг. тепловизором AGA-Thermovision 680 (1 pix ~10 м), в 2010 и 2012 гг. – тепловизором высокого разрешения ThermaCam P 640 (1 pix ~1.4 м), в 1993 г. – данные NASA (TIMS).

РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЯ

В данной статье подробно рассмотрены изменения, произошедшие на конусе Савича с 1982 по 2012 гг. На рисунке 1 показано изменение термоаномалий с 1993 по 2012 гг. по результатам аэротепловой съемки; приведен общий вид конуса в 1999 г., где отмечено положение ТА 9 (см. рис. 1а). Термоаномалии получены в результате тепловой съемки NASA в 1993 г. и плановых тепловых аэрофотосъемок 2010 и 2012 гг. (см. рис. 1б, 1в, 1г). На снимке 1993 г. четко видны десять ТА, количество которых в 2010 г. увеличилось до 14, кроме того, увеличились площади и яркость отдельных аномалий. В 2010 г. было зафиксировано увеличение площади прогрева верхней части конуса, площадь ТА 9 по сравнению с 1993 г. сильно увеличилась. На восточном склоне появились большие ТА 12 и ТА 13, на южном склоне – новая небольшая ТА 11, но сильно сократилась ТА 8. Изменилась структура аномалий. Хорошо видно, что в 2010 г. интенсивность термоаномалий в северном секторе кратера уменьшилась, в южном – увеличилась, восточный склон стал теплее. В 2012 г. по сравнению с 2010 г. значительно увеличилась интенсивность ТА 1, ТА 4, ТА 7 и ТА 9, но несколько ослабли ТА 12 и ТА 13. Съемки 2010 г. проводились с вертолета МИ-8 С.А. Чирковым ($H_{абс.}$ = 3000 м). На рис. 1д, 1е приведены термограмма и фотосопровождение участка ТА 10, где хорошо видны белые возгоны, ранее в кратере конуса Савича не отмечавшиеся.

При проведении в октябре 2009 г. плановых облетов действующих вулканов было зафиксировано сильное парение вершины конуса Савича. На рис. 2а, 2б, 2в, 2г показано положение отдельных ТА (1-14).

Рассмотрим изменения температуры на конусе Савича, полученные в результате наземных измерений. В 1981 г. в кратере была отмечена Т = = 52°С (устное сообщение Г.А. Карпова). В августе 1982 г. на конусе Савича было зафиксировано всего несколько заметных парогазовых выходов

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Thermal Anomalies on Savich Cone, Kikhpinych Volcano, Kamchatka: IR Surveys and Land-Based Observations for 30 Years (1982 through 2012)

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Abstract—An analysis of data from nadir aerial thermal surveys of 2010 and 2012, as well as from a land-based IR survey of 2010, showed changes in the thermal regime of anomalies on Savich Cone (Kikhpinych Volcano, Kamchatka) compared with the 1982 and 1993 surveys. It was noted that the temperature increased in the upper part of the cone, new warm patches appeared in the near-crater zone of the cone, and white sublimates appeared in the southwestern and southeastern sectors of the crater. The last feature was new.