Costa Rican Volcanological and Seismological Observatory

Costa Rican Volcano Monitoring System

Universidad Nacional

OVSICORI-UNA

Special Report to the Global Volcanism Program, Smithsonian Institution.

Poas Volcano Activity during March 2006

General trends prior to the March, 2006 activity: (January, 2005- February, 2006):

During the year 2005 volcano seismicity from Poas volcano increased 24% with respect to the year 2004. Long period events reached a total of 97.099 with a daily average of 266 events. The total number and daily number of events recorded during the year 2005 is similar to those recorded during the years 1987 and 1988 when fumarolic activity was located at the bottom of the crater lake, Laguna Caliente, inside Poas active crater. During 1987-1988 phreatic eruptions were originated from Laguna Caliente producing water columns with lake sediments and blocks that reached variable elevation above the active crater before falling back into the main crater.

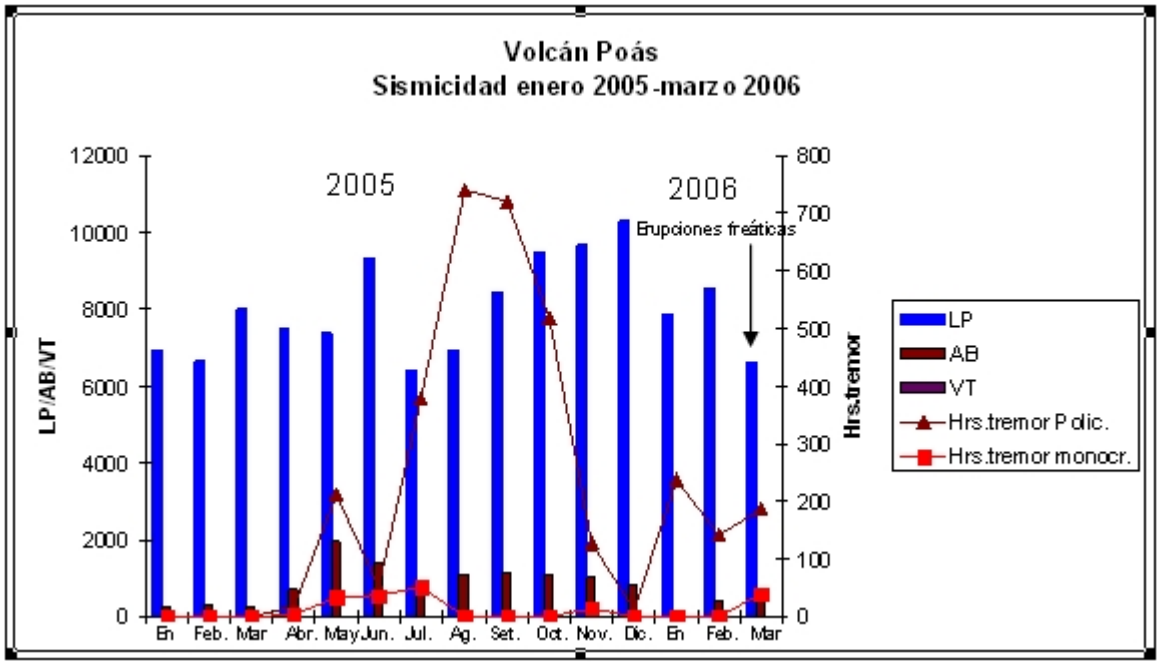


Figure 1: Summary of Poas volcano seismicity from January, 2005- March, 2006 based on records from the POA2 seismic station of OVSICORI-UNA.

After February, 2005 the number of intermediate frequency events (AB) increased 64% (opening of new fumaroles) and this trend continued between April and December, 2005. May and June, 2005 had the highest number of intermediate frequency events. The number of hours of polychromatic tremor was very high in May and between July and November, 2005. The total number of monochromatic tremor hours peaked during May, June and July, 2005. Between May 8-19, 2005 Poas volcano recorded 207 tremor hours with 34.5 tremor hours of monochromatic tremor that often occurred as banded tremor. The temperature of Laguna Caliente increased 13 ^{o}C between April and May, 2005. In January, 2005 Laguna Caliente reached its highest level in 50 years. Laguna Caliente had a temperature of 22 ^{o}C (figure 5) and an approximated volume of 1875000 cubic meters of water (figure 6). During the following year (Feb. 2005-Feb. 2006) the lake decreased its level 10 meters and only gained 2 meters during the rainy season. Exsolution of HCl from the hyperacid lake produced environmental acidification that mainly affected the main crater and surrounding area. The pH decreased from 1.2 in January, 2005 to 0.6 in early 2006 (figure 5).

The opening of fumaroles inside Laguna Caliente evidenced by the changes in its water temperature, level and color from green turquoise to grey in late March, 2005, as well as the previously mentioned changes in the volcano seismicity (mainly large increments in monochromatic tremors between May and July, 2005), were interpreted as the result of a new small shallow intrusion under Laguna Caliente that induced the opening of new fumaroles and large increments in heat flow.

The fumaroles present in the NE and E crater wall, produced by a similar shallow intrusion occurred in early 2000, continued active until present. The gas composition of the north fumarole reduced its percentage of CO2, and to some extent SO2 after March, 2005 despite of the large number of tremor hours of harmonic monochromatic and polychromatic tremor recorded after May, 2005. The composition of the gas analyses of the north fumarole during 2005 and 2006 suggest that this fumarole is not connected directly with the fumaroles beneath the crater lake. Nevertheless, an important increment in the temperature of the fumaroles occurred after March, 2005, followed about 5 months later by a modest increment of the magmatic componets of the north fumarole. A new fumarole opened in 2004 in the intermediate East terrace of the crater wall has been increasing its gas emissions. This was the only fumarole sampled after the phreatic eruptions appeared inside the lake for safety reasons. The gas analyses of the East terrace fumarole collected April 03, 2006 have

similar characteristics to the gas analyses performed to the North fumarole on February 28, 2006. That analysis has very small amounts of CO2, H2S and HCl. A similar percentage of SO2 as for February 28, 2006 and minimal amounts of uncompressible (or residual) gases suggesting that the NE and E wall fumaroles are not connected to the source of the crater lake fumaroles (figure 2).

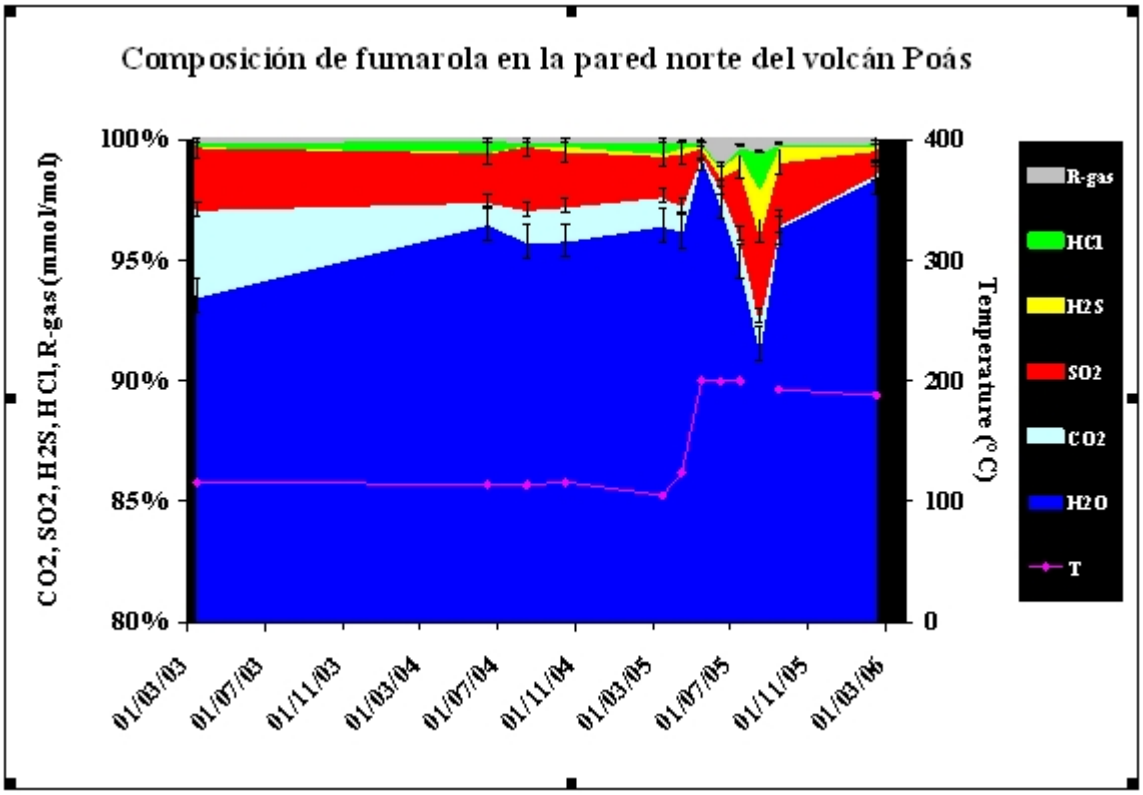


Figure 2: Gas composition of the North wall fumarole March, 2003 to March, 2006.

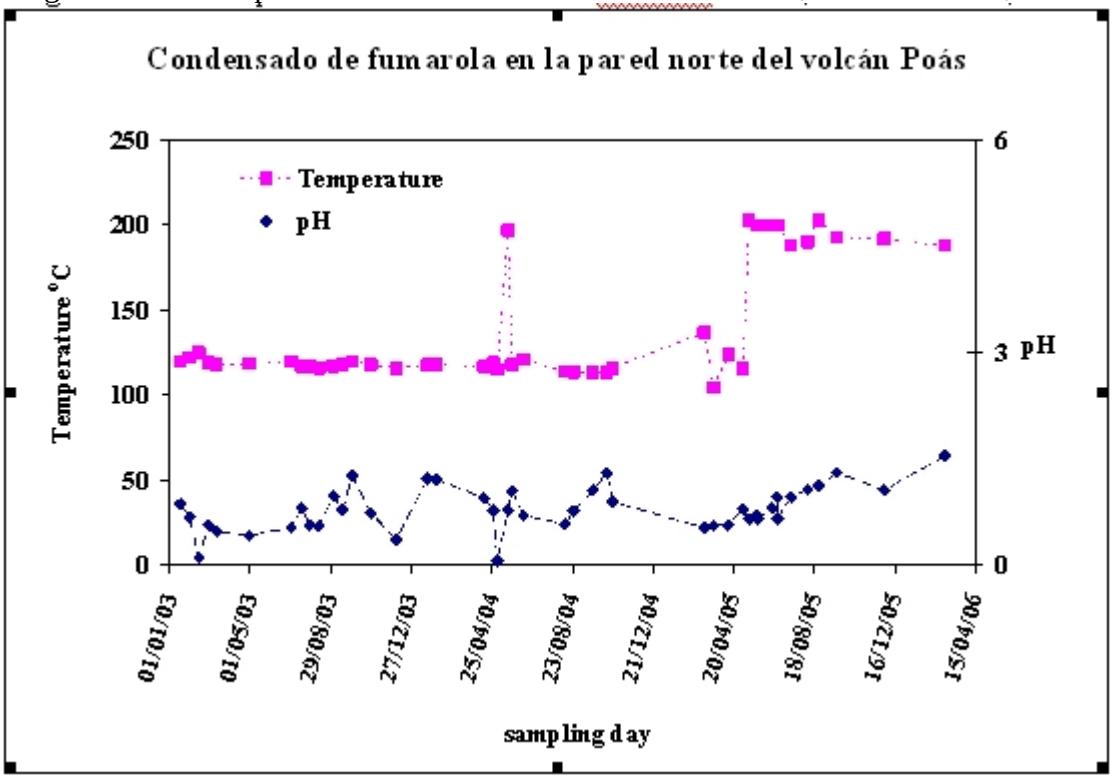


Figure 3: Temperature of the north fumarole and pH of its gas condensate. Notice that despite of the large increment in temperature after May, 2005, there was no change in the pH of the gas condensate, suggesting that the north fumarole is not connected to the lake bottom fumaroles.

Sampling day	Temperature (°C)	pH
22/10/2004	**~89-90**	**2.302**
25/03/2006	**91**	**1.802**
03/04/2006	**94**	**2.160**

Figure 4: The pH of the gas condensate from the intermediate terrace fumarole was more acid on March 25, 2006. A sample collected April 03, 2006 showed a mild increment in temperature and a small decrement in pH.

During January, 2006, polychromatic tremor incremented 94% with respect to the previous month, and intermediate frequency events (AB) and LP events decreased. During February, 2006 monochromatic tremor increased, while the polychromatic tremor and the intermediate frequency events (AB) continued similar to January, 2006. Long period earthquakes increased 8% with respect to January, 2006.

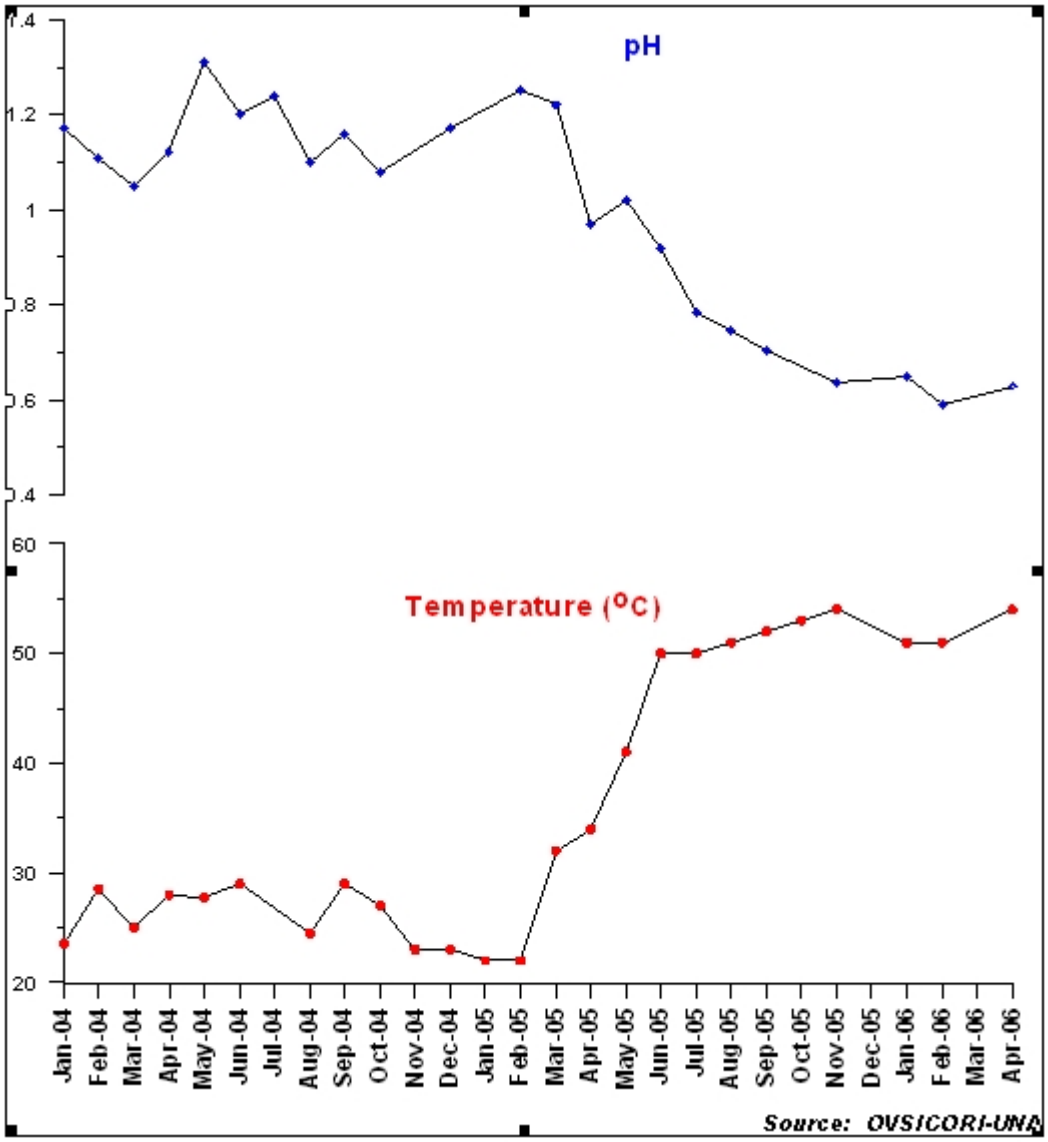


Figure 5: Changes in temperature and pH of the hyperacid water of Laguna Caliente, Poas volcano main crater lake between January, 2004 and April, 2006.

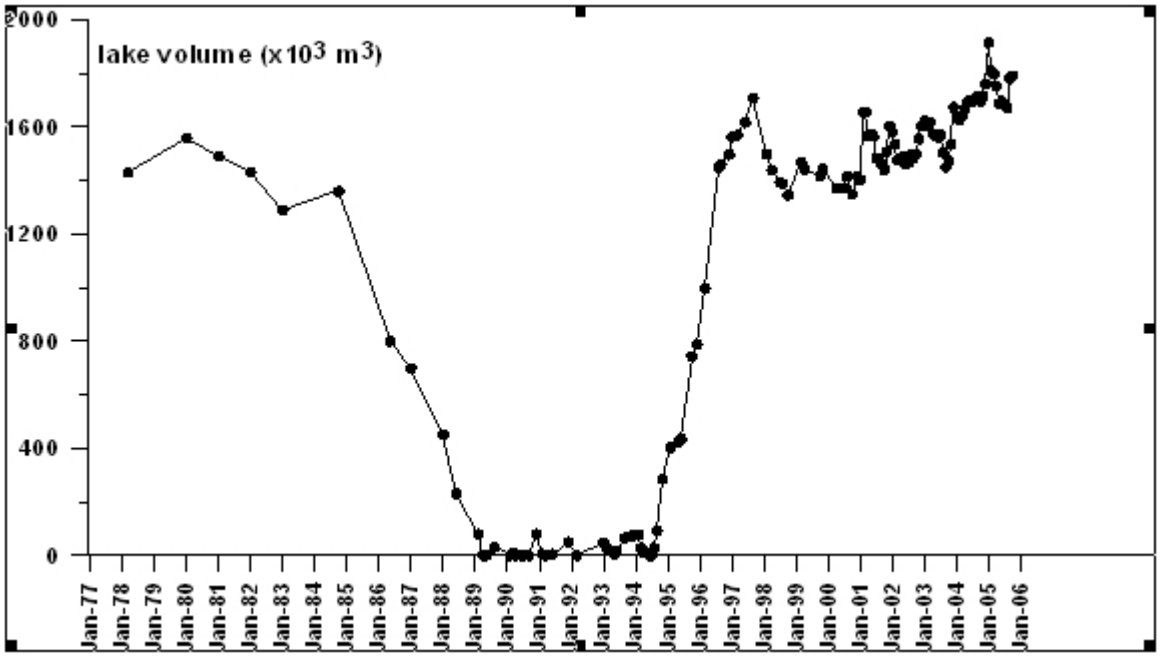


Figure 6: Variations in the volume of Laguna Caliente, Poas main crater lake, 1977-2006. Depth of the lake was about 45 m in late 2005. Notice that the lake increased its temperature from 51 ^{o}C by February, 28, 2006 to 54 ^{o}C by April 01, 2006, but in contrast, the lake pH reached a minimum of 0.59 by February 28, 2006, This pH increased to 0.65 by April 01, 2006 and 0.71 by April 06, 2006.

Poas Volcano Activity during March, 2006:

Since early February, 2006, the LP seismicity gradually increased. This trend continued during March, 2006 reaching a peak March, 17-21, 2006. AB seismicity continued at the similar levels as for February, 2006 (figure 7). From March, 1-18, a total of 45 tremor hours of polychromatic tremor was recorded suggesting only movement of hydrothermal fluids below the bottom of Laguna Caliente. No monochromatic tremor was recorded before March, 21.

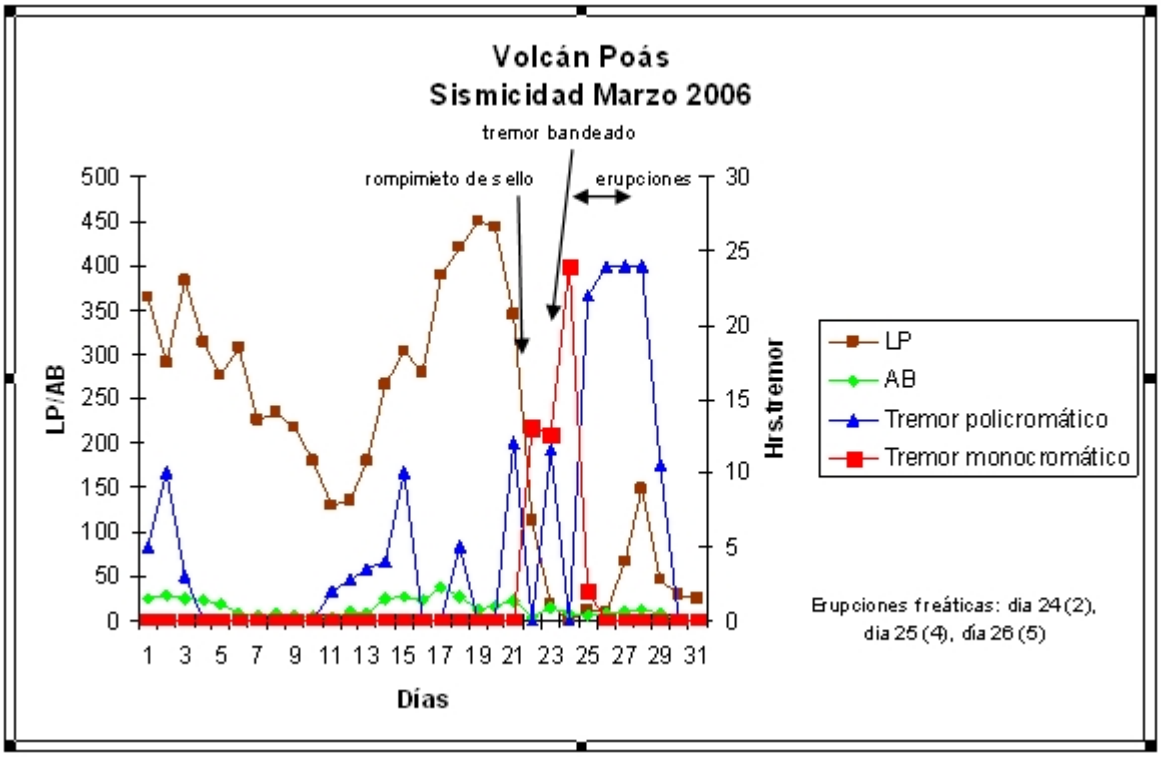
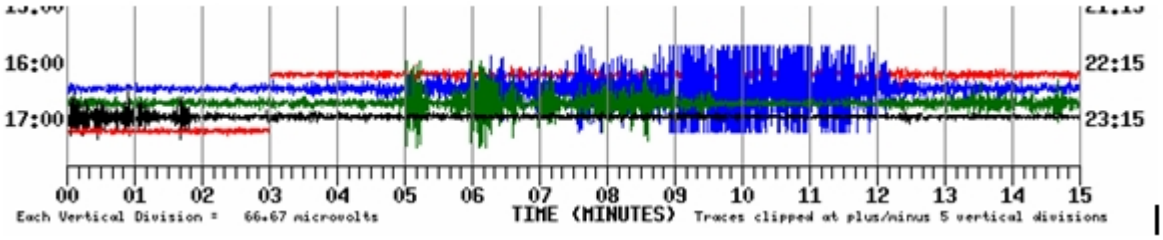


Figure 7: Seismicity of Poas volcano during March, 2006 based on records from the POA2 seismic station of OVSICORI-UNA.

On March 21, 22:19 hrs GMT (figure 8) a first high frequency signal, that lasted 8 minutes, was recorded. This signal was followed by a second high frequency signal that lasted 5 minutes. The maximum frequency of these signals was 7.5 Hz. Immediately, a reduction of the LP events occurred for a period of 14 hours. During that period of time the intermediate frequency (AB) events recorded had higher frequencies and intensity than usual. Their frequencies were up to 3 Hz and their durations up to 50 seconds (figure 9).



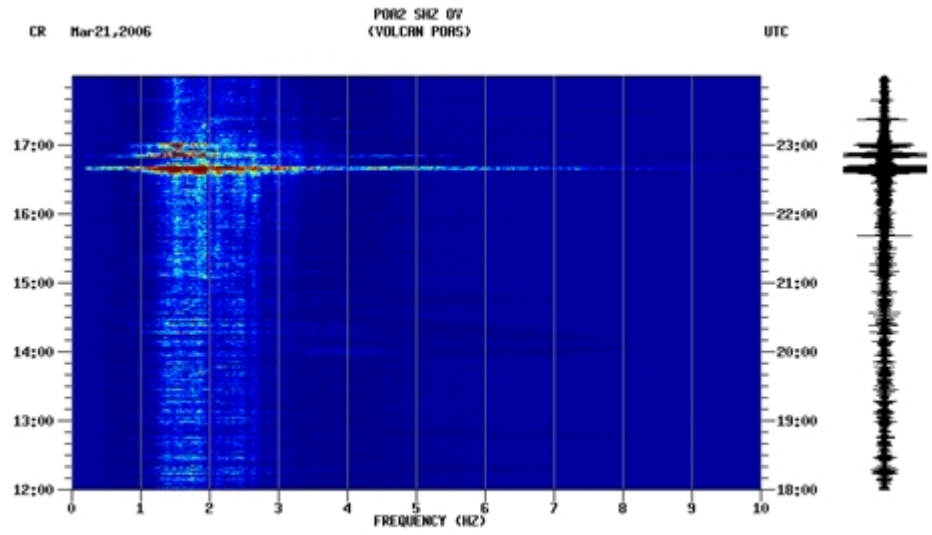


Figure 8: Signal and spectrogram of the seal rupture signal recorded March 21, 2006 at 22:19 hrs GMT.

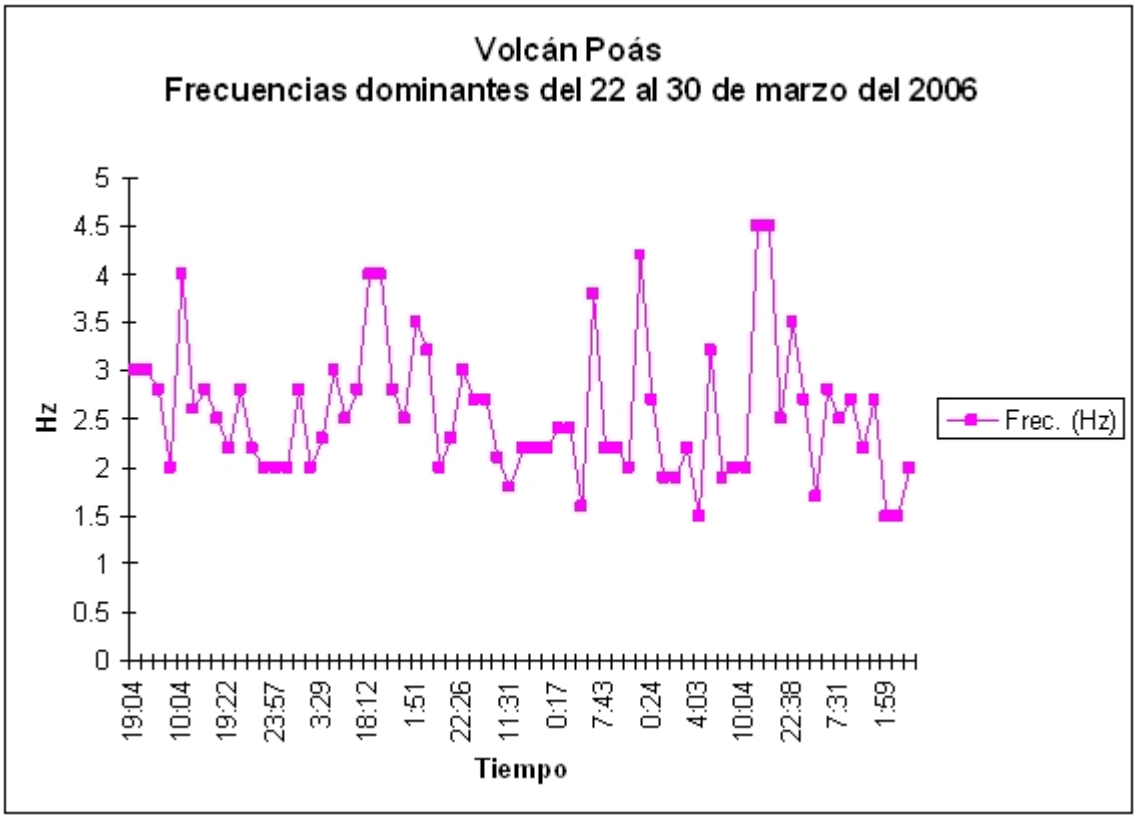


Figure 9: Intermediate frequency events (AB) that followed the “seal rupture” occurred on March, 21, 2006. The horizontal axis is time.

On March, 23, 2006 at 12:17 hrs GMT, a band of monochromatic tremor that lasted for 3:18 hours was recorded. This tremor had dominant frequencies of 1.5 Hz. After 5:14 hrs a new band of monochromatic tremor was recorded. This band had similar dominant frequencies as the first band and lasted for 4:15 hrs. Between the first and the second tremor bands 3 intermediate frequency (AB) events occurred with maximum frequencies of 2.8 Hz (figure 9). After the second band 7 intermediate frequency (AB) events were recorded with similar maximum frequencies (figure 9).

On March, 23, 2006 at 03:43 hrs GMT monochromatic harmonic tremor started to be recorded and continued until March 25, 2006 at 06:25 hrs GMT with a total duration of 26:42 hrs. The dominant frequency was 1.5 Hz. Also, during the same period of time 6 intermediate frequency (AB) events were recorded. Phreatic eruptions started around noon (local time) March, 24, 2006 when harmonic monochromatic tremor was being recorded (figure 10). Phreatic eruptions continued for at least three days after the initial eruption on March 24, 2006.

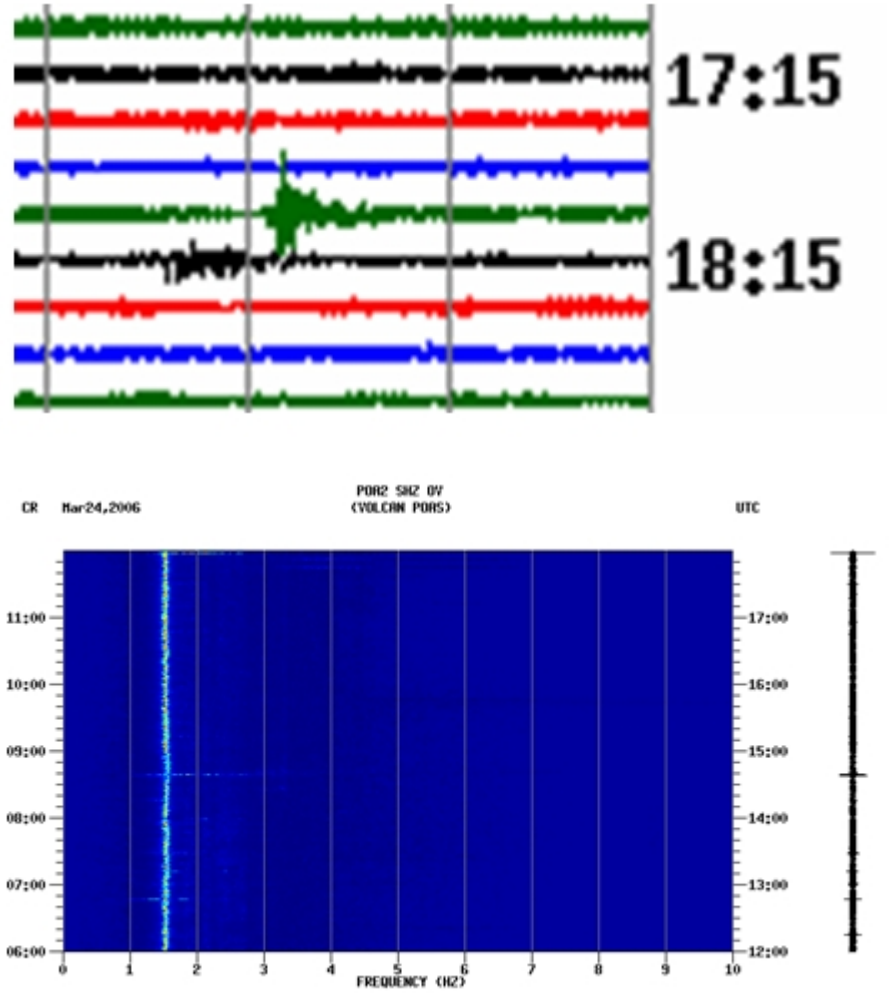


Figure 10: Seismic signal and spectrogram corresponding to the first phreatic eruption occurred at 17:57 hrs GMT, March 24, 2006. The seismic signal in the spectrogram is located in the upper part of the spectrogram with a dominant frequency of 2.8 Hz. The dominant frequency in the rest of the spectrogram corresponds to the monochromatic harmonic tremor.

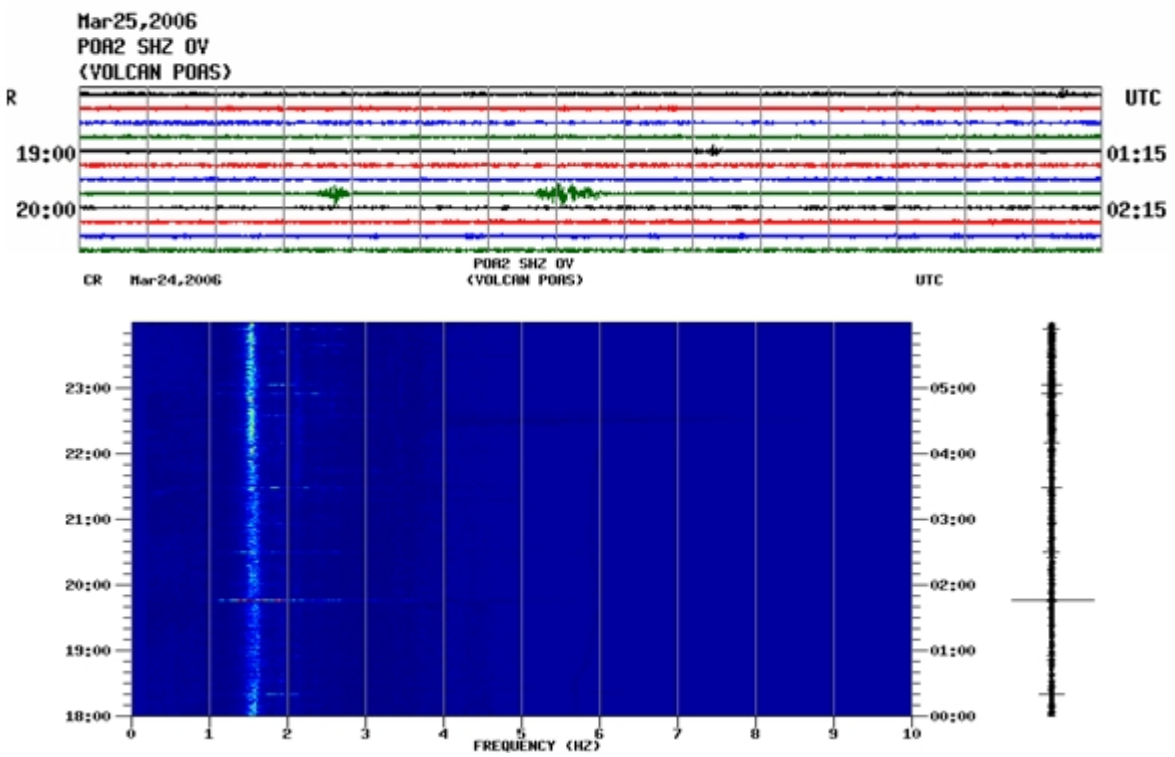


Figure 11: Spectrogram of the phreatic eruption occurred March 24 at 19:51 hrs local time (01:51 hrs GMT). The dominant frequency (1.5 Hz) corresponds to the monochromatic harmonic tremor. Notice that this phreatic eruption was preceded by a smaller phreatic eruption at 01:48 hrs GMT.

The sequence of events occurred between March 21 and March 24 could be interpreted as a shallow intrusion after the magma carapace of the shallow level magma chamber located a few hundred meters below Poas crater was broken. Probably, the volume of magma involved was very small, as for similar intrusions occurred at Poas in the past, but enough to increase dramatically the heat flow and to trigger (after several hours of monochromatic tremor) phreatic eruptions inside Laguna Caliente, that continued for a few days after that type of tremor was no longer recorded.

The nature of the tremor recorded changed from monochromatic to polychromatic tremor after March, 25, 2006 at 06:26 hrs GMT. The polychromatic tremor had two predominant frequencies: 1.5 Hz and 1.8 Hz (figure 12). Very vigorous polychromatic tremor continued until March 26, 2006 at 01:50 hrs GMT when its intensity gradually started to decrease suggesting a significant decrement in the hydrothermal activity beneath the volcano. By March 29 the duration of the polychromatic tremor decreased about 50 % and continued decreasing its intensity during the following 40 hours, when the tremor disappeared. The LP events decreased March 22-31, 2006.

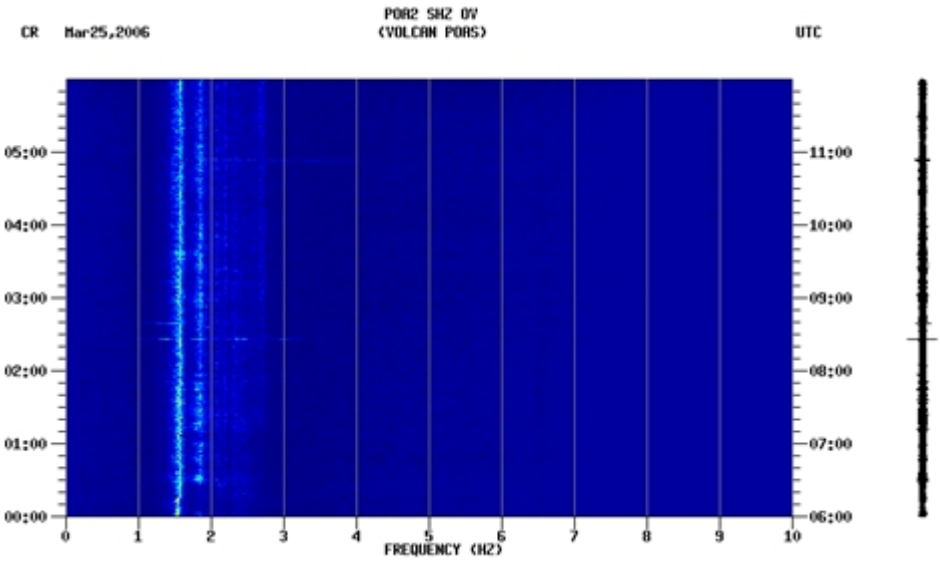


Figure 12: Spectrogram of polychromatic tremor with dominant frequencies at 1.5 Hz and 1.8 Hz. This tremor started to be recorded March 25, 2006 after 00:06 GMT.

Eleven eruptions were recognized in the seismic records between March 24 and March 31, 2006. Their existence was validated in the field for only two eruptions, due to the bad weather conditions that prevailed during most of the time when the volcano was more active than usual. Of the total number of eruptions recognized in the seismic records, at least four of them correspond to phreatic eruptions. Fine lake sediments and acid water from the lake was transported by the prevailing wind up to 5 km to the SW of the main crater (figure 22). Blocks produced by the phreatic explosions reached a maximum distance of 700 m from the center of the lake, falling without exception inside Poas main crater (figure 18).

No Significant Deformations Associated with the March, 2006 Activity:

A network of permanent reflectors has been installed at Poas since April, 2006. Periodically, elements of this network are measured. Inclined distances are measured across Poas main crater from a pillar located on the south rim of Poas crater to a fixed reflector located outside the NE, N and NW rim of the main crater and two distances are also measured between the pillar and reflectors located S and SW of the pillar (figure 13). Yellow circles outside the main crater represent bench marks of the leveling line between the Picnic area and the National Park building. The encircled yellow squares represent the intracrater leveling line that has not been reoccupied yet for safety reasons. Red dots represent bench marks of Poas geodetic network.

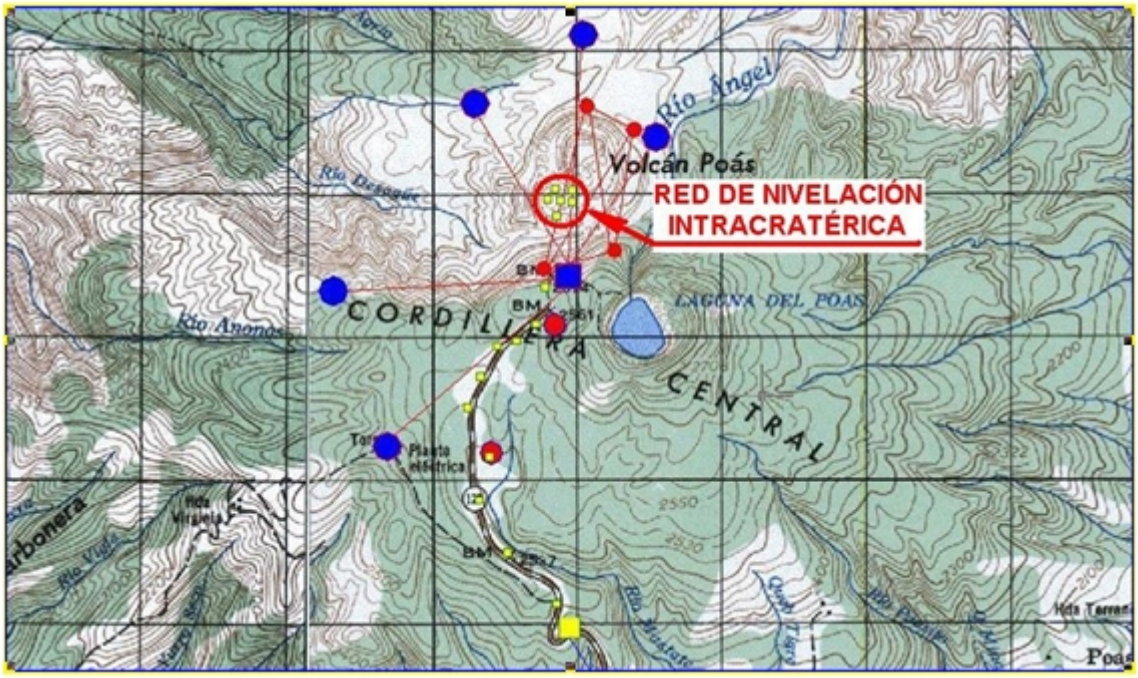


Figure 13: Deformation network for Poas volcano. The blue square is the pillar and the blue circles are the fixed reflectors.

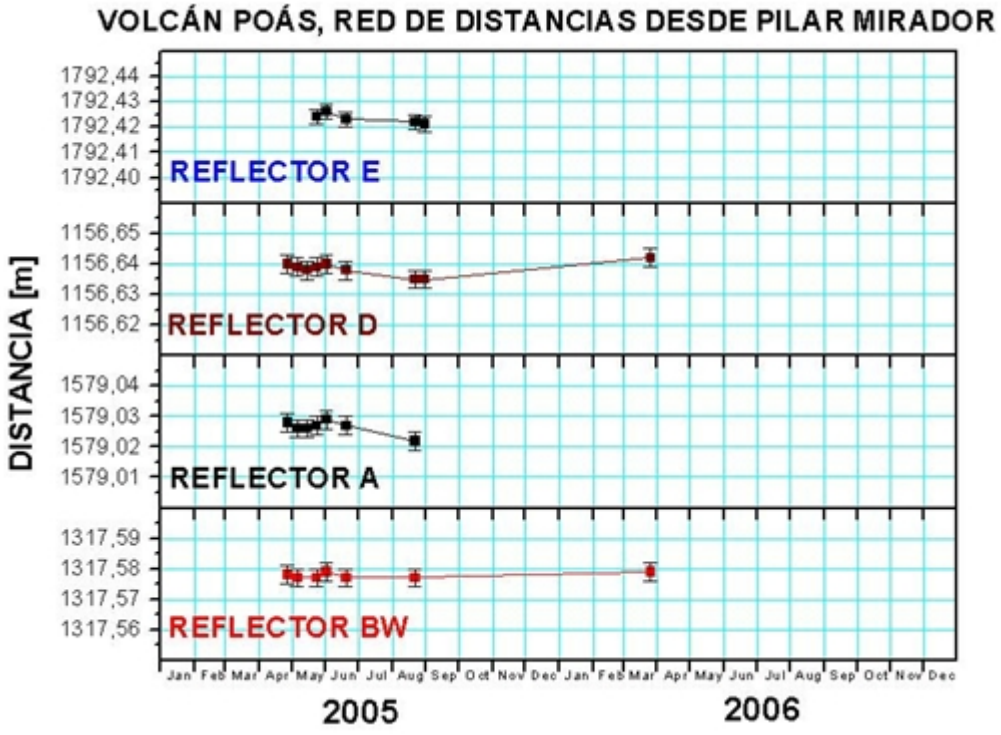


Figure 14: Inclined distances across the main crater of Poas measured from a pillar to fixed reflectors. This figure shows error bars that represent the typical dispersion of 3 mm present in these measurements.

During the time of increased activity at Poas volcano, it was possible to measure only two distances due to the bad weather. Nevertheless, the measured distances do not show significant deformations.

The trigonometric leveling line between the Picnic area and the National Park edifice has been measured several times since 1991. The difference in elevation between 5 bench marks located south of the main crater in a radial array is measure. The last measurement was performed on February, 28, 2006. The average lineal regression of the results obtained since 1991 is consistent with a deflation of 1.3 µrad / year (figure 15). This deflation is very small to interpret short period changes, nevertheless, the long period trend at Poas volcano continue to be consistent with a very slow deflation of the volcano according to these data.

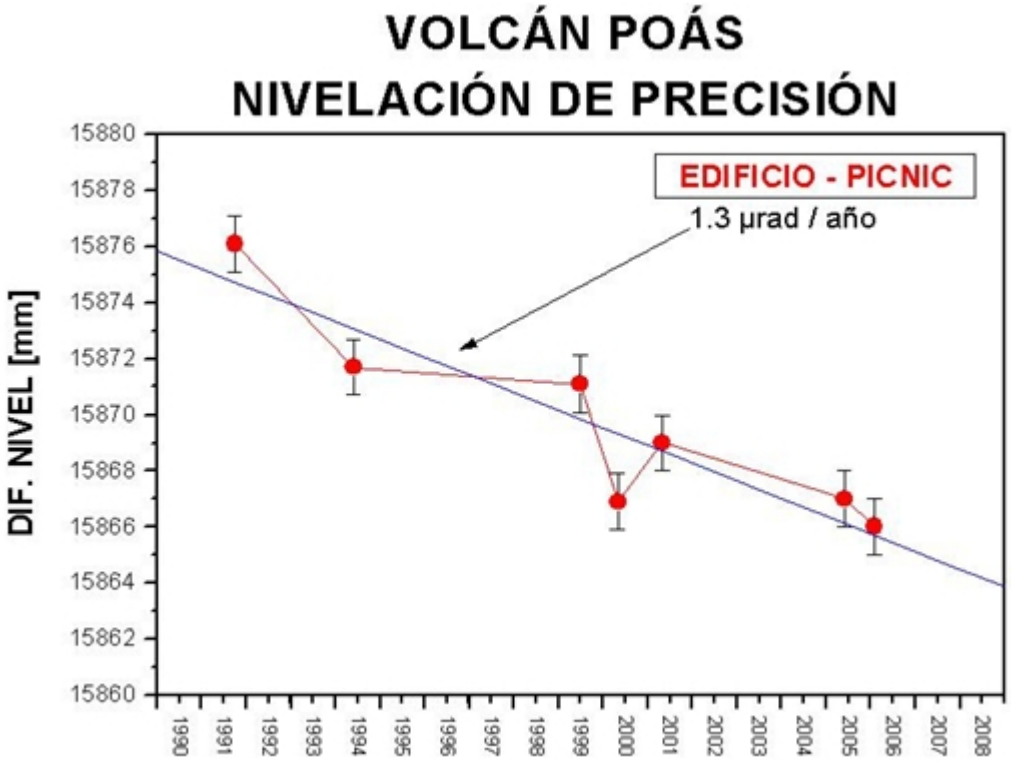


Figure 15: Changes in elevation of the radial line between the Picnic area and the Nacional Park building using trigonometric leveling.

The observed deformations are very small and within the error bars. The inclined distances across the main crater, despite that a full reoccupation has not been performed, suggest that the volcano did not show deformation prior to or as a result of the activity that occurred in March, 2006. In contrast, the leveling data measured between the Picnic area and the National Park building in a radial array to the main crater; suggest a long term deflation trend of 1.3 µrad / year since 1991. This trend did not show any changes up to three weeks prior to the eruption (last measurement).

Documentation of the effects of the phreatic eruptions occurred in March, 2006

The phreatic eruption occurred around noon (local time) on March 24, 2006 issued an inclined column of water, sediments and pre-existent blocks towards the south of Laguna Caliente. This eruption was observed by several visitors from the crater lookout that reported that a water

column issued from the lake surpassed the dome and the acid water, sediments and blocks emitted felt on the flat area, south of the lake (figures 17 and 22).

Figure 16: Vigorous evaporation of the lake observed on March 24, 2006 during the afternoon, after the initial phreatic eruption.

Figure 17: Vigorous evaporation of the lake observed March, 24, 2006 during the afternoon, before the weather deteriorated. Notice that the drainages between the observer and the lake have plenty water after the phreatic eruption occurred around noon that was directed towards the observer.

Figure 18: Area affected by one of the phreatic eruptions occurred at 19:51 hrs local time, in the evening of March 24, 2006. The array of abundant metric size block near the lake suggests that the source of the phreatic eruption was the SE corner of the lake.

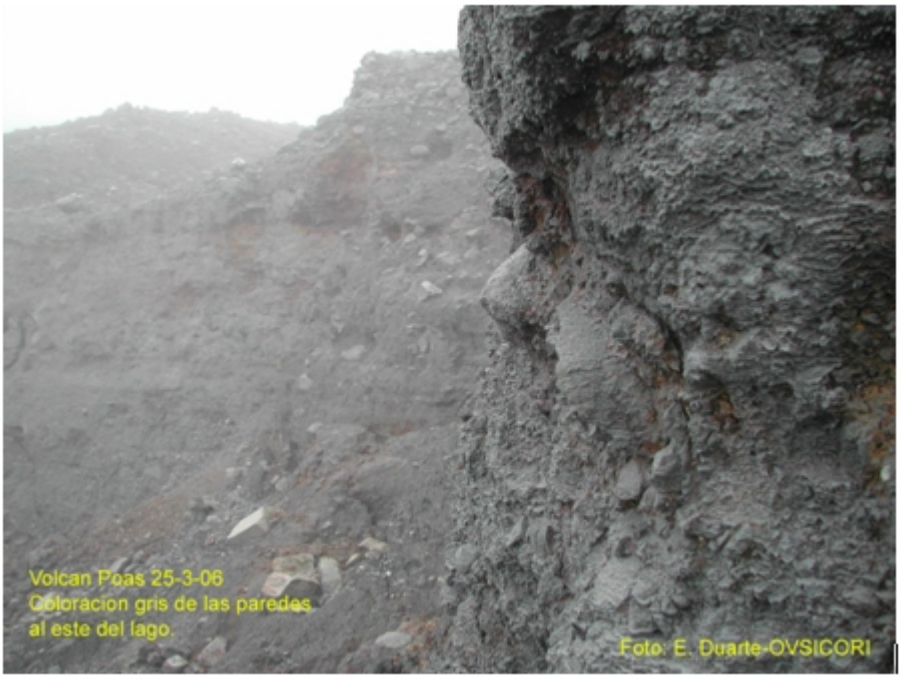


Figure 19: East crater wall covered with fine sediments from the lake bottom emitted by a phreatic eruption the evening of March 24, 2006.

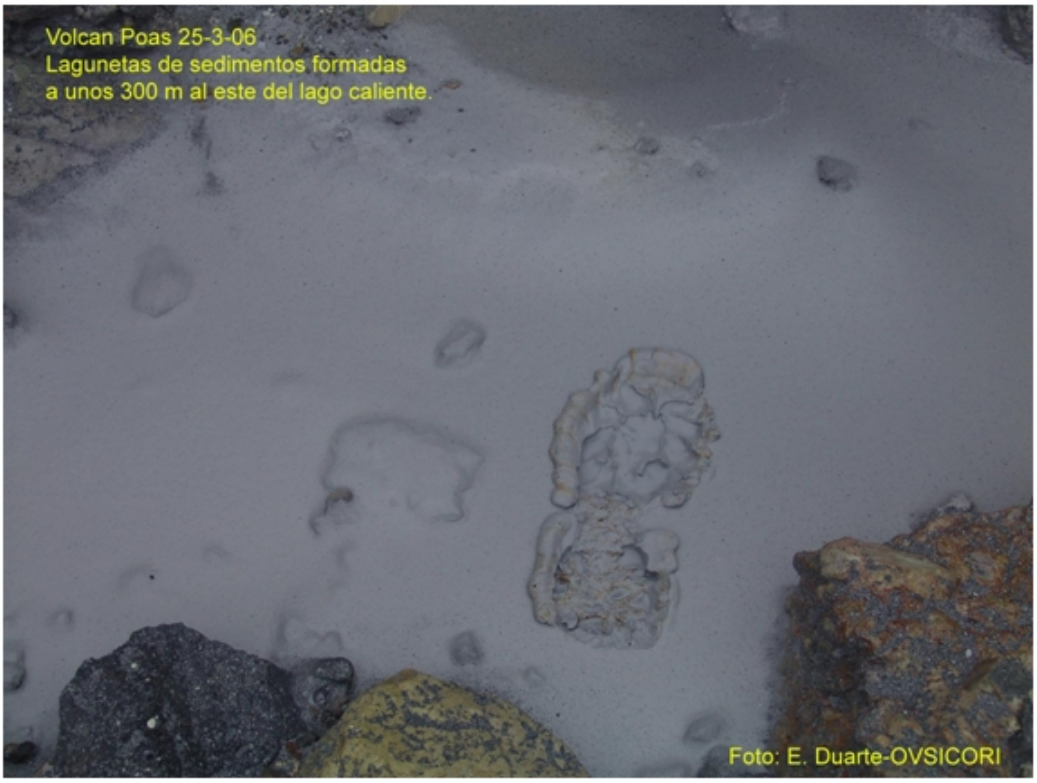


Figure 20: Sediments deposited in small depressions located in the intermediate terrace about 300 m east of the lake border.

Figure 21: Impact craters observed East of Laguna Caliente on March 25, 2006.

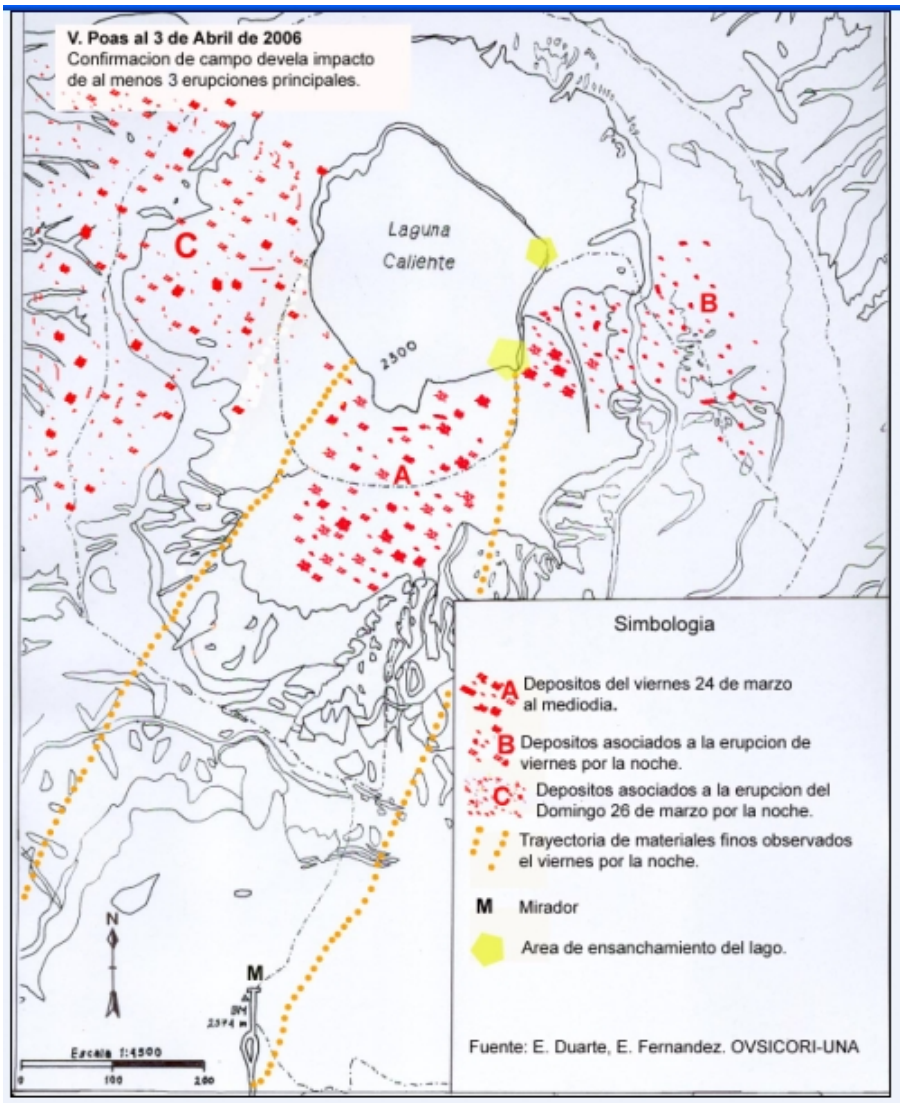


Figure 22: Area affected by the three largest eruptions occurred on March 24, 2006. A is the phreatic eruption occurred at noon and B is the phreatic eruption occurred around 20 hrs local time. Impact craters are schematically represented in red. The light bigger yellow area corresponds to the source of the blocks for the evening eruption. This eruption expanded the lake SE border. The yellow dots identify the area where fine sediments and acid water from the lake felt on March 24 at night. A third eruption sent mainly lake sediments to the W and NW of the active lake, but the extension of the volcanic products issued by that eruption has not been totally mapped yet.

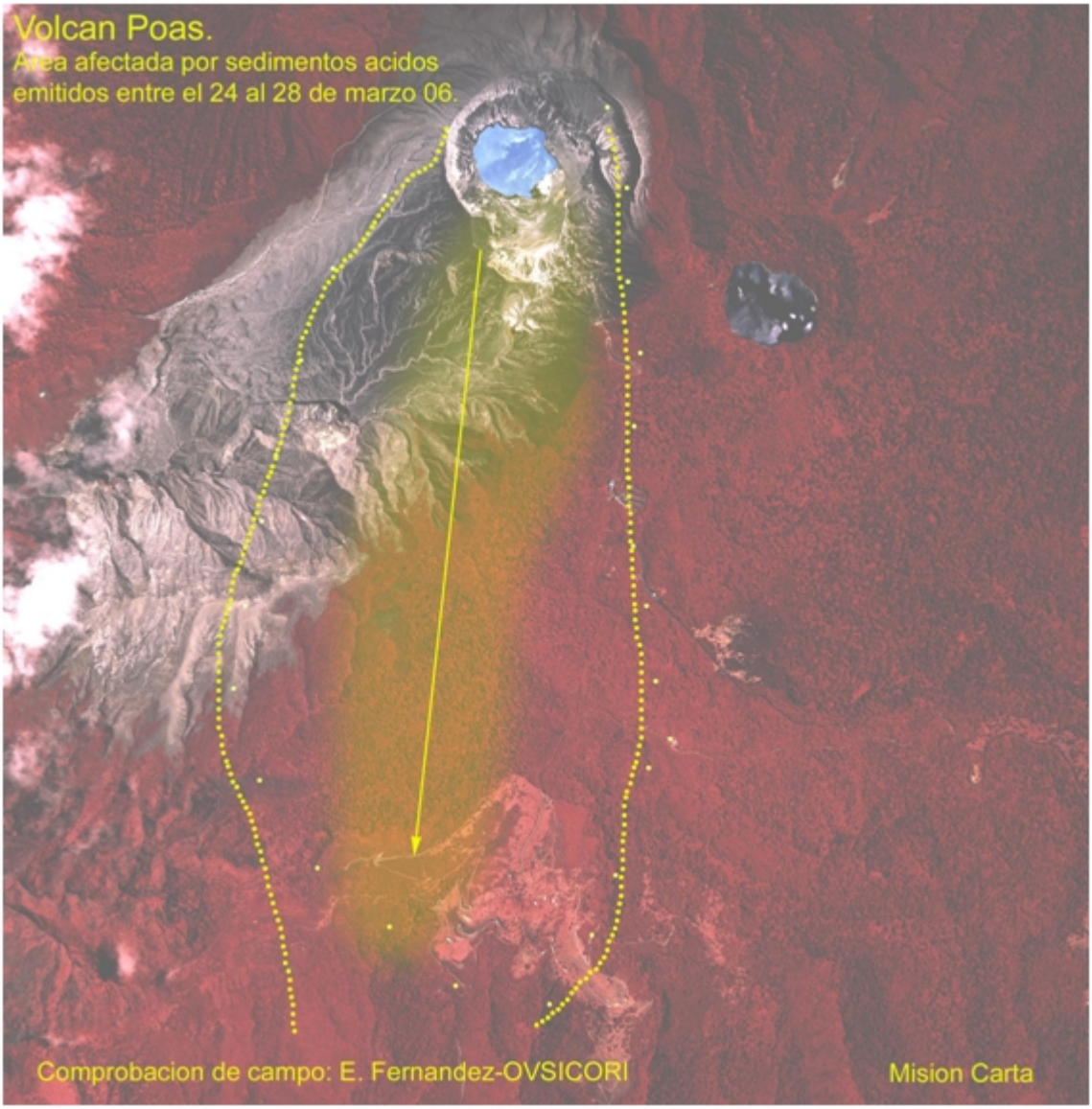


Figure 23: Distribution of acid water and fine sediments from the lake produced by the evening eruption on March 24, 2006. The maximum extension of the sediments was approximately 5 km to the SW of the main Poas crater.

Figure 24: The SE corner of the lake is the origin of the phreatic explosion issued towards the east on March 24, 2006. This area corresponds to the yellow areas near the SE corner of the lake in figure 18.

Figure 25: The SE corner of the lake rim expanded as a result of the March 24, 2006 evening phreatic eruption.

Figure 26: Meter sized block found on the lower terrace, east of the lake border. Notice the surface alteration on these blocks that correlate with the alteration observed in the SE corner of the lake (figures 19 and 20).

Figure 27: Block fragment emplaced hot and impregnated with sulphur as indicated by the sulphur exudated to its surface after emplacement. Sulphur impregnated blocks were emitted by the March 24, 2006 noon eruption.

Figure 28: West crater rim covered with coarse sediments that reached beyond 300 meters westwards.

Figure 29: Small rounded block showing melted sulphur. Found few meters beyond the west crater rim, associated to the eruption witnessed Sunday 26, night.

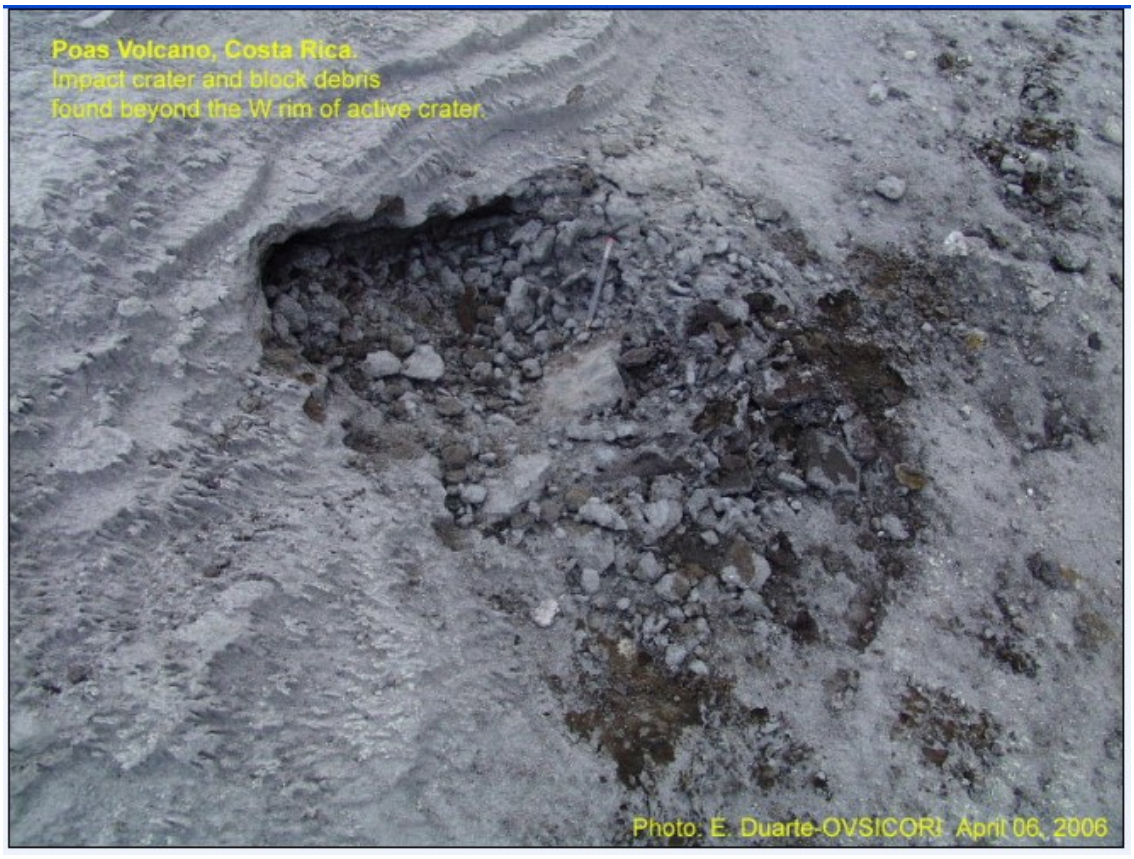


Figure 30: Impact craters observed west of Laguna Caliente, probably produced from eruption on March 26, 2006.

Figure 31: Preexistent block ejected towards west and emplaced beyond the crater rim.

Figure 32: Reworked mixed material found on the flat area, beyond the crater rim, towards northwest. Deposit associated to eruption from Sunday 26, night.

At least three phreatic eruptions deposited significant amounts of sediment and blocks outside the lake. Blocks from two eruptions fell inside the main crater of Poas volcano, while scattered blocks from a third one (C) fell outside the west rim of the hot lake. The first eruption was directed towards the south (March 24, 11:57 hrs local time, figure 22). The second eruption was directed towards the east (March 24, 19:48 hrs local time). The third eruption was directed towards the west (March 26, 21:12 hrs local time, figure 22). All information provided here is preliminary and subjected to changes after complete fieldwork and laboratory analisis.

Information to compile this report was provided by the following OVSICORI-UNA staff and faculty members (in alphabetical order): V. Barboza, E. Duarte, E. Fernández, E. Hernández, L. Hernández, E. Malavassi, T. Marino, M. Martínez, W. Sáenz, R. Van der Laat.