Poás Volcano: Decreasing phreatic activity and visible incandescence during the day since July 2011
Activity report August 31st, 2011

View of the active crater of Poás volcano from SE. The shining in the plume is due to the resplendence of the incandescence of the "Dome" (photo: G.Avard, OVSICORI-UNA).

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Abstract

Since mid-July 2011, incandescence is visible during the day on the "Dome" of Poás volcano, Costa Rica. This observation is the most spectacular illustration of a change of activity that started several months before. Using data from seismic, deformation, geochemical and field measurements, we intend to expose this change of activity and compare it to the volcanic phase that occurred between 1980 and 1989. We propose two interpretations: 1) the intrusion of a fresh batch of magma although we find no evidence in the data at hand, and 2) a change in the hydrothermal plumbing system that deviated the flux from the lake to the "Dome". Depending on the precipitation rates in the following months, possible consequences of this change of activity could be the disappearance of the lake and the enhancement of the sub-aerial emission of gases and particles into the atmosphere with a strong impact on the surrounding environment.

I_ Introduction

Poás (*Fig.* 1) is a calc-alkaline basaltic and andesitic stratovolcano (*Prosser & Carr,* 1987) located in the Cordillera Volcánica Central of Costa Rica which last extrusive activity occurred between 1953 and 1955. Two vents distant by about 150m were active during this eruption cycle: the southern one formed a small composite pyroclastic cone ~40m high in 1955, often described as the "Dome"; the northern one collapsed to fill with meteoric water forming again a hot acidic lake by 1961 (*Martínez et al*., 2000).

Figure 1: Aerial photo of Poás volcano and its active crater (photo taken on February 27th, 2011)

Since 1977, periods of intermittent phreatic eruptions have occurred in the lake generating geyser-like explosions from several meters to several hundred of meters high (*Bennett and Raccichini*, 1978a,b; *Bennett* 1979; *Francis et al*., 1980).

II_ Observations

Visual and geochemical observations

Recently, the lake has shown a decrease of phreatic activity, ending a period of intensification between 2006 and the first half of 2011 (*Fig. 2*). From frequent phreatic eruptions (*Fig. 2c*) of low to moderate energy (or intensity) observed during March-June 2011 (several per day to a few per hour) the frequency seems to have lowered drastically since the end of June. To confirm this observation, the coloration of the lake is turning from grey in May 2011 to greenish since then. The turning of the lake to a green color reflects a decrease in turbulence, due to the weakening of subaqueous fumarolic discharge into the lake that prevents the grey sediments from the lake bottom to mix up with the water column.

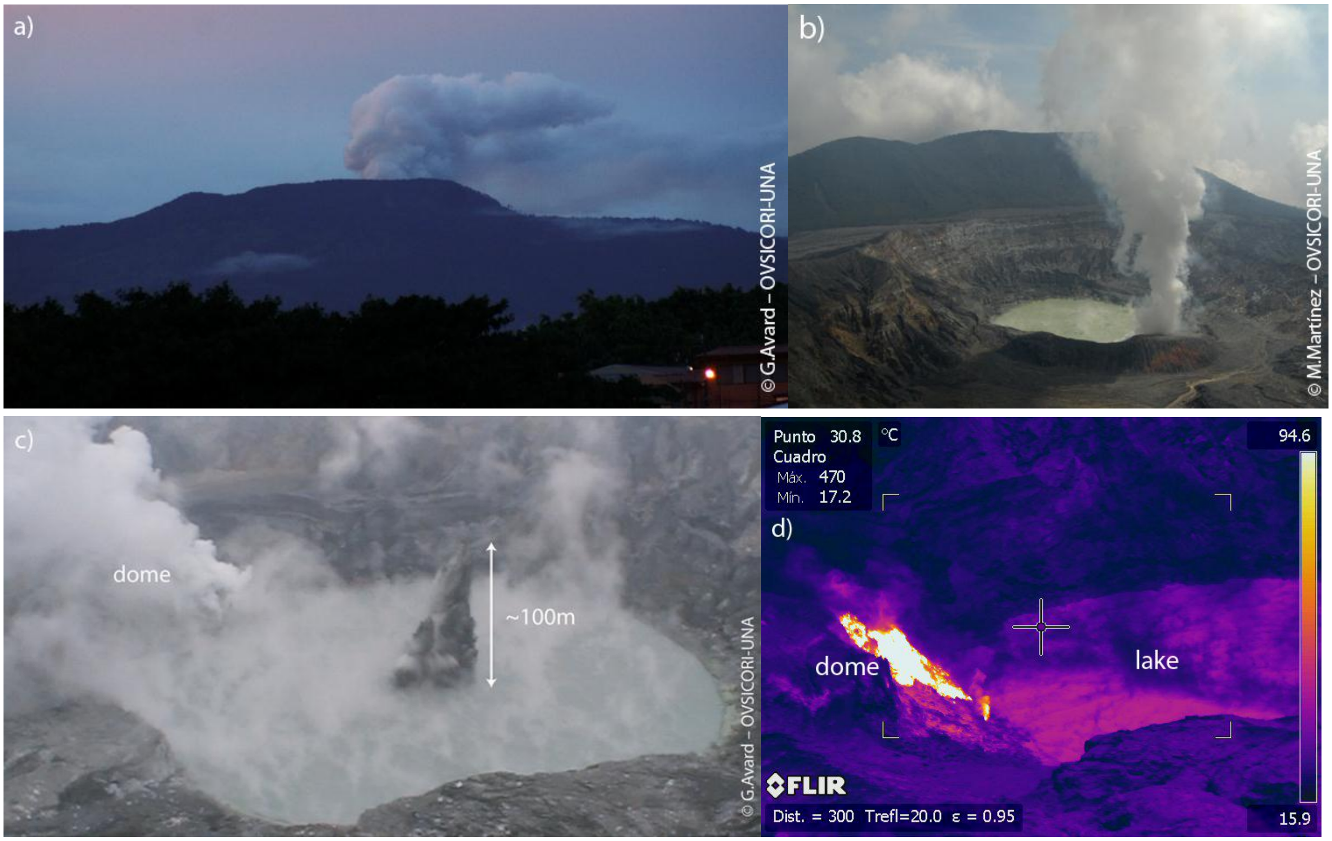


Figure 2: Poás volcano. a) Plume of Poás seen from Heredia on July 3rd, 2011. b) Active crater from the Mirador on May 18th, 2011. c) Phreatic eruption few hours later the same day. d) FLIR®thermal image of the acid lake and "Dome" taken from the eastern edge of the crater rim at ca.500m distance on August 9th, 2011.

Quantitatively, we notice *Figure 3* that the lake has entered a shrinking phase since mid-2006, loosing ~94% of its volume in 4.7 yr. This tendency was preceded by a general increasing trend in the acidity (lower pH´s) and in the lake temperature observed throughout 2005-2006 which continues today with some fluctuations. Between 2005 and 2011, the lake has changed its pH and temperature from 1.22 to -0.72 (minus 0.72) and from 32°C to 62°C respectively. Notice that the abrupt drop of temperature observed late 2008 and early 2009 matches with the M_w6.2 Cinchona earthquake occurred on January 8th, 2009 (*Pacheco et al.*, 2009). Moreover, the sulphate/chloride ratio has shown a general increasing trend even if a problem with the chromatograph prevented a regular survey since May 2009. However the missing analyses are now in process.

From 2006 to 2009, the lake volume decreased steadily fast, whereas it continued in 2010 but at a slower rate. However, between April and July 2011 the lake accelerated its reduction, loosing 42% in volume between April 26th and June 23rd, and dropping its level by 1.10m between May 27th and July 22nd. During the same period its temperature oscillated between 53 and 62°C with a maximum in May and June 2011. Its pH has become even more negative since April 2011.

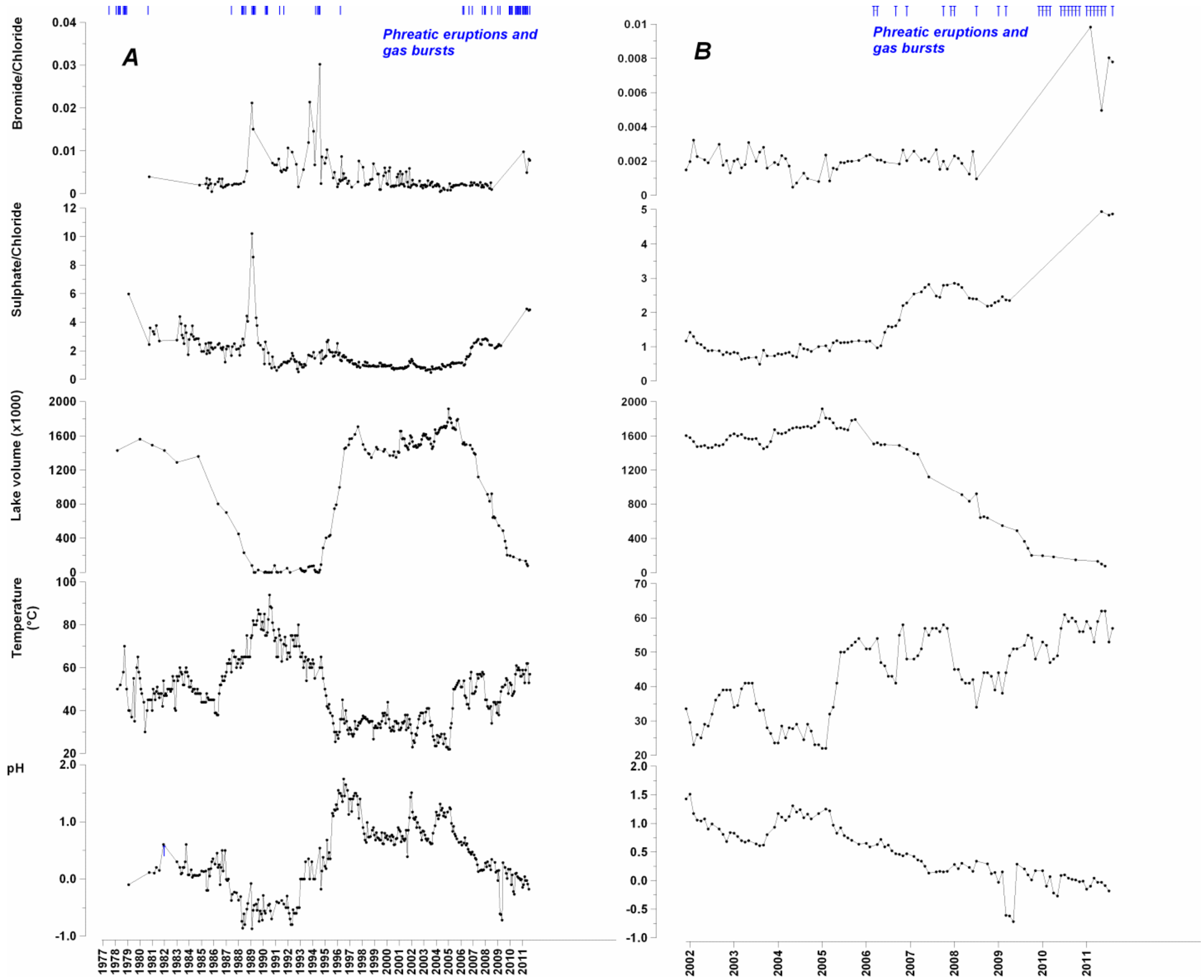
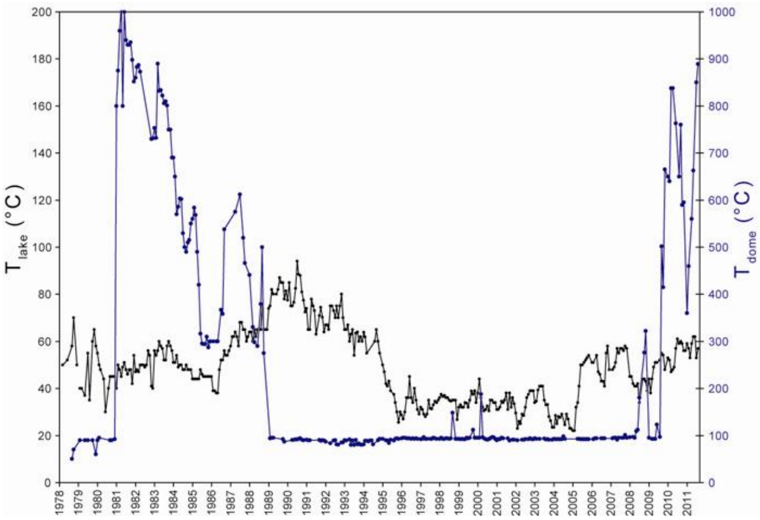


Figure 3: Recording of the lake pH, temperature, calculated volume and chemical ratios in: A) the period 1977-2011 and B) the period 2002-2011. Lake volume is given in cubic meters.

Direct measurements of fumaroles temperature on the "Dome" using a thermocouple of super-alloy show a relatively short-lived sharp increase of the temperature between May and November 2008 from 109°C to 322°C (*Fig. 4a*), and more recently a large increase between June 2009 and August 2011 from 123°C to 889°C. Due to such a high heat output through the "Dome", incandescence by day has been noticed since mid-July 2011 (*Fig. 4b*). Night observation shows various types of glowing depending on the temperature of the gas, from blue to white through yellow and red (*Fig. 4c*). Vigorous flames are noticeable due to the hot gases combustion reaction with the atmospheric oxygen (*Fig. 4d*). We emphasize that the major blue glow comes from a vent that formed between August 9th and August 26th. This new hydrothermal vent is about 6m wide and is surrounded by a deposition of fine particles associated to its formation.

a)



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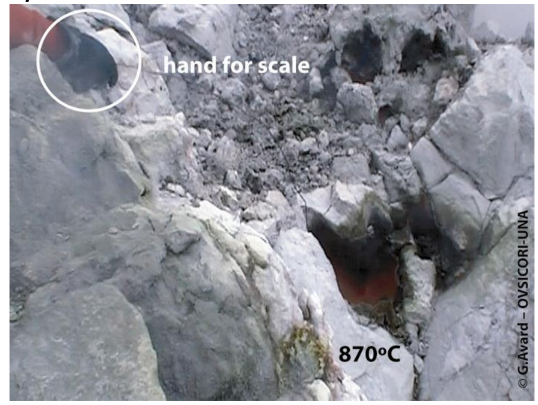

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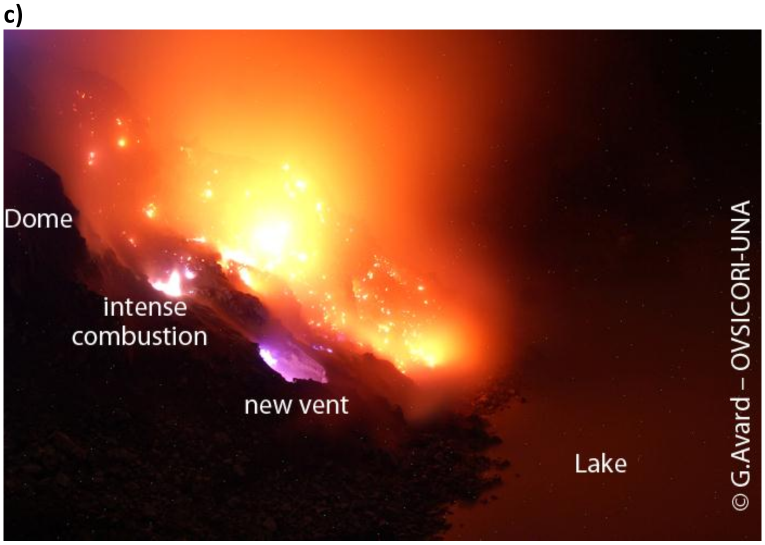

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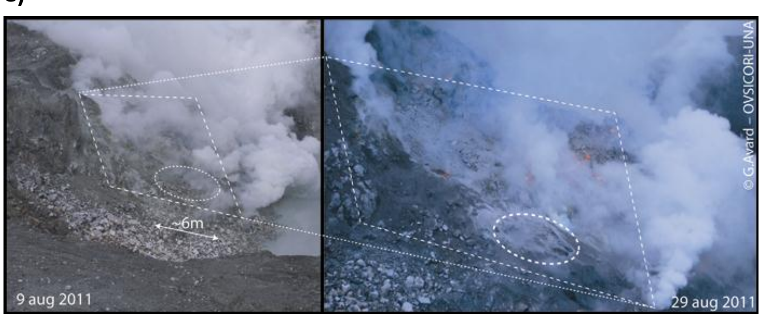


Figure 4:

a) Evolution of the temperature of the lake (in black) and the temperature of the dome fumaroles (in blue).

b) Incandescence visible by day on the "Dome" (July 23rd, 2011). Note the thermocouple inserted in the glowing vent.

c) The "Dome" by night with a blue glowing in the new vent while combustion of gas forms flames as seen fig d) (photos taken August 29th, 2011).

e) New hydrothermal vent formed in August 2011.

Seismic activity

Since 2008, recorded Volcano Tectonic earthquakes (VTs) showed (*Fig. 5*) low activity at the end of 2008 that amplified conspicuously in January 6th, 2009, with a peak on January 8th 2009 followed by 3 months of seismic activity too high to be counted. Only the most representative ones are shown in *Figure 5*. This activity is associated to the Cinchona earthquake, M_w6.2, which occurred on January 8th, 2009, 4 km east of the active crater of Poás at a depth of 7.1 km (*Pacheco et al.*, 2009). This earthquake might correspond to a tectonic event associated to a dextral strike-slip motion of the neotectonic Angel fault in an extensional context (*Montero et al.*, 2010).

No recent volcano-tectonic activity has been noticed; however technical problems prevented the collection of seismic data between December 21st, 2010 and January 31st, 2011, and again between April 6th and June 30th 2011 due to lightning strike. Long Period earthquakes (LPs) instead present an increase of activity from May to November 2010, then again since July 2011 at least, which matches fairly close with the observation of numerous phreatic eruptions for the periods June-December 2010, February-June 2011, and with the general increase in temperature of the "Dome" observed since June 2009. This superficial seismic activity is associated to the motion of fluids in the hydrothermal system.

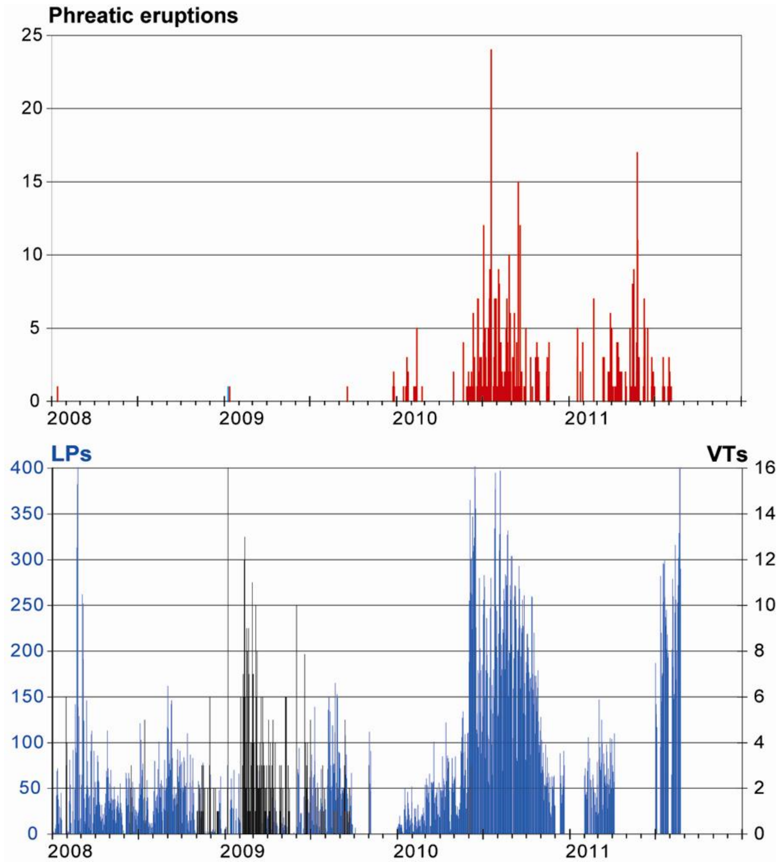
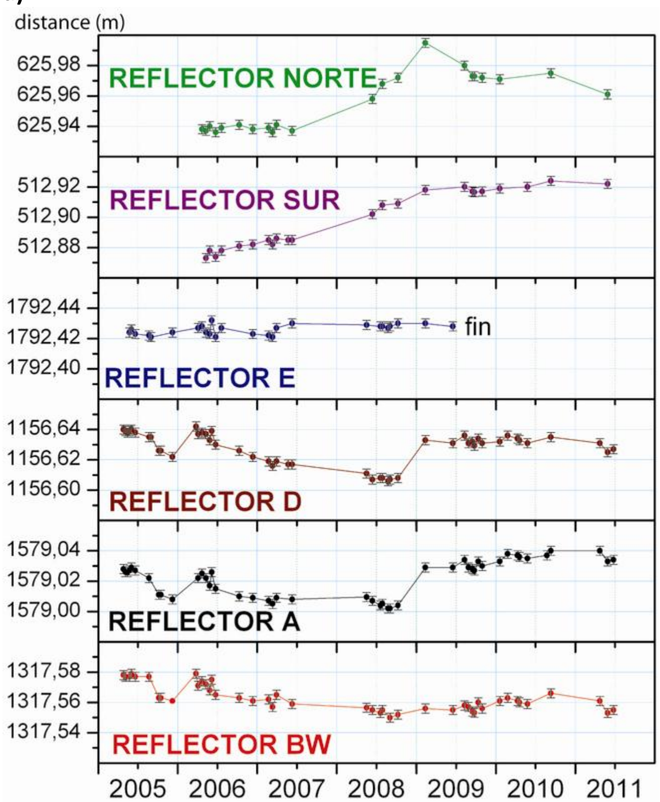


Figure 5: Daily counting of VT and LP recorded since 2008, and phreatic eruptions witnessed by the park rangers of Poás Volcano National Park and OVSICORI staff.

Deformation by EDM

The ground deformation at Poás is mostly monitored by leveling along the access road to the crater and regular EDM measurements from the overlook (Mirador) which is 700m (horizontal distance) south of the "Dome" (*Fig. 6*). Five fixed reflectors are spread around the active crater, 2 at the bottom south of the "Dome" ~250m lower in elevation than the overlook (reflectors "norte" and "sur"), and 3 on the other side of the crater 150 to 180m lower in elevation than the overlook (reflectors A, D and BW). This monitoring shows (*Fig. 6a*) a general relative increase of the distance with the reflectors along a north-south direction (norte, sur and A) and a slow relative shortening trend with the others (D and BW). The leveling shows (*Fig. 6b*) a fluctuation in 2006 and a loss of 20 mm over 15.8m since 1991, which represents a flattening of ~39 µrad in 20 years. The Cinchona earthquake (January 8th, 2009) is noticeable by a sudden increase of the distance with almost all the reflectors. The 2005-2006 drop of distance (~2cm = 0.0012-0.0017%) noticed with the reflectors A, D and BW (around the crater) is also noticeable by a sudden flattening of the leveling profile. This deformation matches with the sudden increase of the lake temperature and the beginning of the decrease of its pH and volume. However, only a minor shortening of the distance (~4 mm) with the same array of reflectors seems to match with the recent apparent change of activity at Poás.

a)



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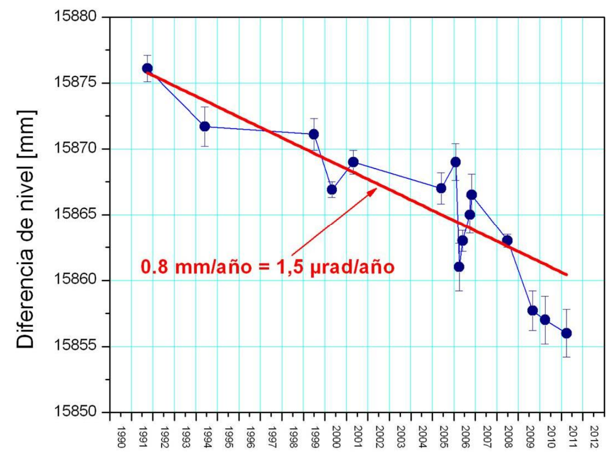

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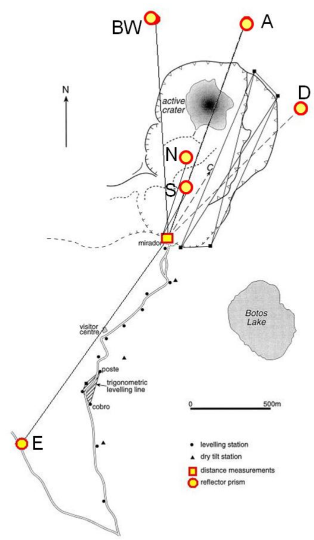

Figure 6:

a) EDM measurements since 2005 from the overlook (Mirador).

b) Leveling along the access road since 1991.

c) Map of the network.

III_ Interpretations

The change of activity recently observed can be compared with previous events at Poás, when incandescence on the "Dome" was visible in 1981. A maximum temperature of 1020°C was measured with a thermocouple on April 28th, 1981 (*SEAN*, 1981). This high fumarolic activity on the dome was followed by a decrease in the level of the lake until its disappearance in 1989 generating vigorous degassing and ejection of sulfurous solid material with a strong impact on the environment (*Barquero and Fernández*, 1990; *Locke et al.*, 2003; *Rymer et al.*, 2005).

According to our previous observations, if the shortening of the distance is confirmed by further measurements it could possibly be correlated to an increase of activity in the lake and the dome which would suggest a depressurization of the hydrothermal system. However the relationship between the ground deformation and the volume of the lake is not well defined and conclusions should be taken with care. The volume dropped by ~94% since August 2005 and gravitational collapses are now visible around the lake as erosion applies, forming steps sometimes confused with fractures. Such a change of volume in the lake is likely to correspond to a significant unload of the water table in the volcanic edifice that may affect our interpretation of the deformation data.

Moreover, the seismic recording does not show any volcano-tectonic activity suggesting that the system is open and recording of long period seismicity and low amplitude tremors confirms the strong degassing activity observed either way in the lake (punctuated by phreatic eruptions) or the “Dome” (corresponding to an increase of temperature of the fumaroles).

Based on micro-gravity measurements, *Rymer et al*. (2009) concluded that a magmatic intrusion might have occurred west and east of the “Dome” around 2002, perturbing the hydrothermal system under the lake. The resulting unbalance of the thermal budget would be responsible for the decrease of its volume. The shifting of locus of fumarolic vents between the lake and the “Dome” was interpreted in terms of convection under the crater with up-welling in the west and down-welling in the north over a 5-10 year periodicity (*Rymer et al.*, 2005).

Such an interpretation of the recent change of activity at Poás cannot be excluded, however there is no evidence of magmatic intrusion at this stage of observations. Considering that the lake and the “Dome” are coupled (each phreatic eruption is followed by a vigorous degassing on the “Dome” within seconds to minutes), the simplest hypothesis would be a change in the plumbing system that shifted the locus of degassing discharge from the lake to the “Dome”. However, the causes of such a sudden change are still to be defined.

IV_ Conclusions

The lake has accelerated its loss of volume since April 2011 and is now ~76,000 m^3. If it follows this tendency it might disappear by the end of the year with significant impact on the environment as the lake-hydrothermal system behaves like a buffer that absorbs a large part of the volatile and particle emission. Nevertheless, the lake activity seems to have decreased since July 2011 and after a few dry months the rain is expected to increase with the hurricane season which may modify this tendency. Moreover, the “Dome” shows an increase of activity with visible incandescence by day since July 2011 but up to now there is no evidence of a magmatic intrusion and this observation may be due to a spatial shift of locus of main fumarolic vents from the lake toward the “Dome”.

Acknowledgements

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