GEODETIC EVIDENCE FOR SLOW INFLATION OF THE SANTORINI CALDERA

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Abstract

Santorini (Thera) is a volcanic island complex dominated by a partly submerged caldera defined by the islands of Thera and Therasia and the islet of Aspronisi. Santorini is the most important and most active volcano in the Aegean, famous for the Minoan (3600 years old) eruption which buried the ancient but very "modern" town of *Akrotiri*. Volcanic activity in Santorini was in many cases associated with ground deformations, subsidence and uplift, caused by magma flow at relatively shallow depths. Ground deformations therefore can be regarded as precursors of a future volcanic paroxysm.

A geodetic monitoring system aiming at an early identification of a future dilation of the caldera as a result of magma inflation was established in 1994, in the framework of an interdisciplinary project for the surveillance of this volcano. The geodetic monitoring system consisted of a radial EDM network with a central point at the Nea Kameni islet and 10 stations in the Thera and Therasia islands. Between June 1994 and October 2001 seven epochs of baseline measurements at a centimeter-level accuracy were made. A small-scale (up to 9.5cm), gradual inflation of the northern part of the caldera (between Nea Kameni and Therasia), possibly associated with magma ascent along a dike has been inferred from these epochs of measurements.

1. Introduction

Volcanic activity in Santorini was in many cases associated with ground deformations, coastal subsidence and uplift; the best examples were the formation of the intra-calderic islets of Nea Kammeni and of Palaia Kammeni in the historic times. Such ground movements are caused by magma flow at relatively shallow depths and can be regarded as precursors of a future volcanic paroxysm. For this reason, geodetic monitoring of the volcano was included in an interdisciplinary surveillance project started in 1994, in the framework of the European Union DG XII Environment Project and of the Institute for the Study and the Surveillance of the Santorini Volcano, succeeding earlier, smaller-scale projects. Initially, this project was limited to EDM measurements, but in October 2000 a GPS network was established on the same benchmarks. The results and conclusions from this geodetic subproject are the subject of this article.

2. Magma flow and surface deformations

Experience from numerous active volcanoes and theoretical considerations indicate that any upward or downward movements of magma in vents or chambers produce elastic stresses which are reflected in changes of the micro-topography and of horizontal distances and elevations of benchmarks around the volcanic centers (Fig.1); such topography changes may range from a few centimeters to several meters (Bonaccorso et. al, 1996; Mogi, 1958).

In the last thousand years the volcanic activity in Santorini was rather confined to the caldera (Druitt and Francaviglia, 1992; Fytikas et al., 1994) any magma movements would cause geodetically observable changes of distances among points of the caldera.

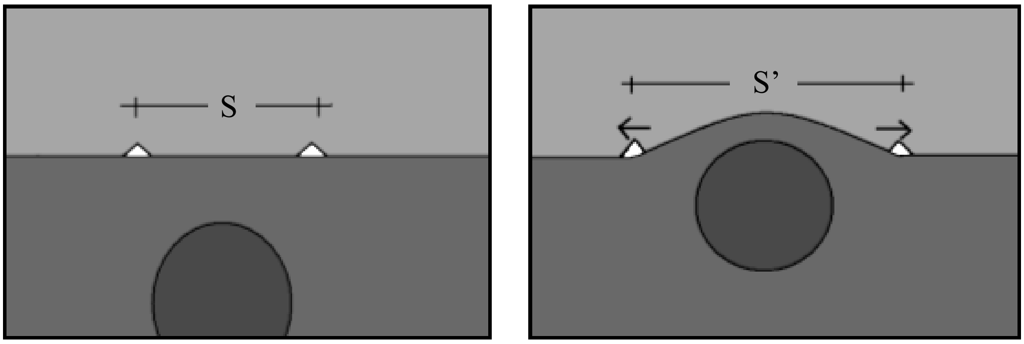

Figure 1: Topography changes as a result of magma chamber inflation.

3. Geodetic network

The topography of the Santorini island complex, a nearly circular caldera with subvertical walls with a radius of 3 - 6 km, was ideal for the establishment of a radial EDM geodetic network dedicated to the identification of baseline length changes. A central station was established at Nea Kammeni and 10 peripheral stations numbered 1 to 10 were established on the caldera walls in Thera and Therasia, with baselines numbered 1 to 10 (Fig. 1; Stiros and Chasapis, 2003). This network has a nearly uniform azimuthal distribution and can easily and unambiguously control baseline length changes which could reflect possible caldera inflation-deflation processes.

All stations of the network were selected among pillars of the National Triangulation Network established mostly in the 1960’s. Care was taken that pillars selected are founded on stable ground (consolidated pumice deposits, stable rock masses) so they are representative of kinematics and deformation of a wider area. Baseline lengths vary between 3.2 to 6.7km and because of the nearly uniform topography (steep cliffs of the caldera walls 100-300m above sea-level, central station on a peak) all baselines cross a nearly uniform medium, rather free of perturbation of the atmosphere close to the ground or the water (the raypath of all baselines is practically >100m above water/ground; Stiros and Chasapis; 2003; Fig. 3).

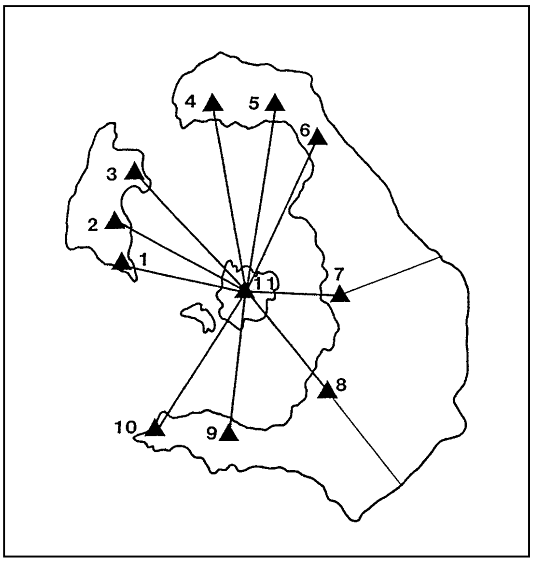

Figure 2: Baselines for the volcano geodetic monitoring EDM network.

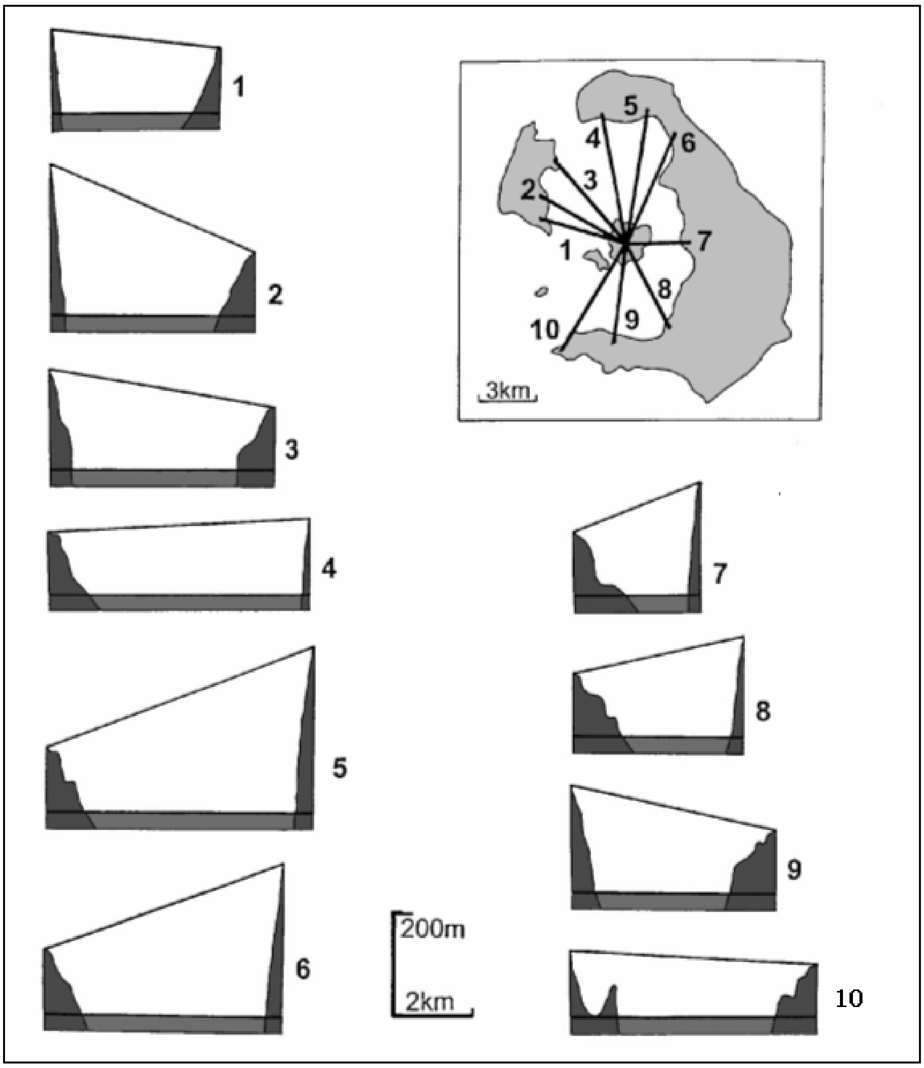

Figure 3: Raypath of the 10 baselines.

4. EDM Surveys and results

Between June 1994 and October 2001 seven epochs of measurements were made. Measurement procedure was nearly identical in all surveys: observations were made by the same surveying party, the same instrument, an AGA 6000 laser Geodimeter and the necessary accessories (centering plates, reflectors, thermometers, barometers etc), with methods permitting a typical accuracy of 1mm±1mm/km for each baseline (e.g. repeated measurements when wind was blowing and the atmosphere was uniform).

Baseline length changes of the seven surveys are summarized in Fig. 4. Among the 10 baselines, those between Therasia and Nea Kameni (baselines 1, 2, 3) show maximum cumulative changes between 6 and 9.5cm, while the changes of all other lines are up to ±2-3cm, and only in one or two cases up to 4.5cm. The observed length changes are systematic, and their amplitude higher than the corresponding uncertainly level at the 95% level, i.e. approximately 2cm.

In addition, local ground instability effects can be ruled out for most measurements, both on the grounds of field observations and on the pattern of the network. This indicates that there is evidence for a small-scale dilation of a part of the volcano, probably because of a minor inflation of a magma chamber; probably ascent of magma along a dyke.

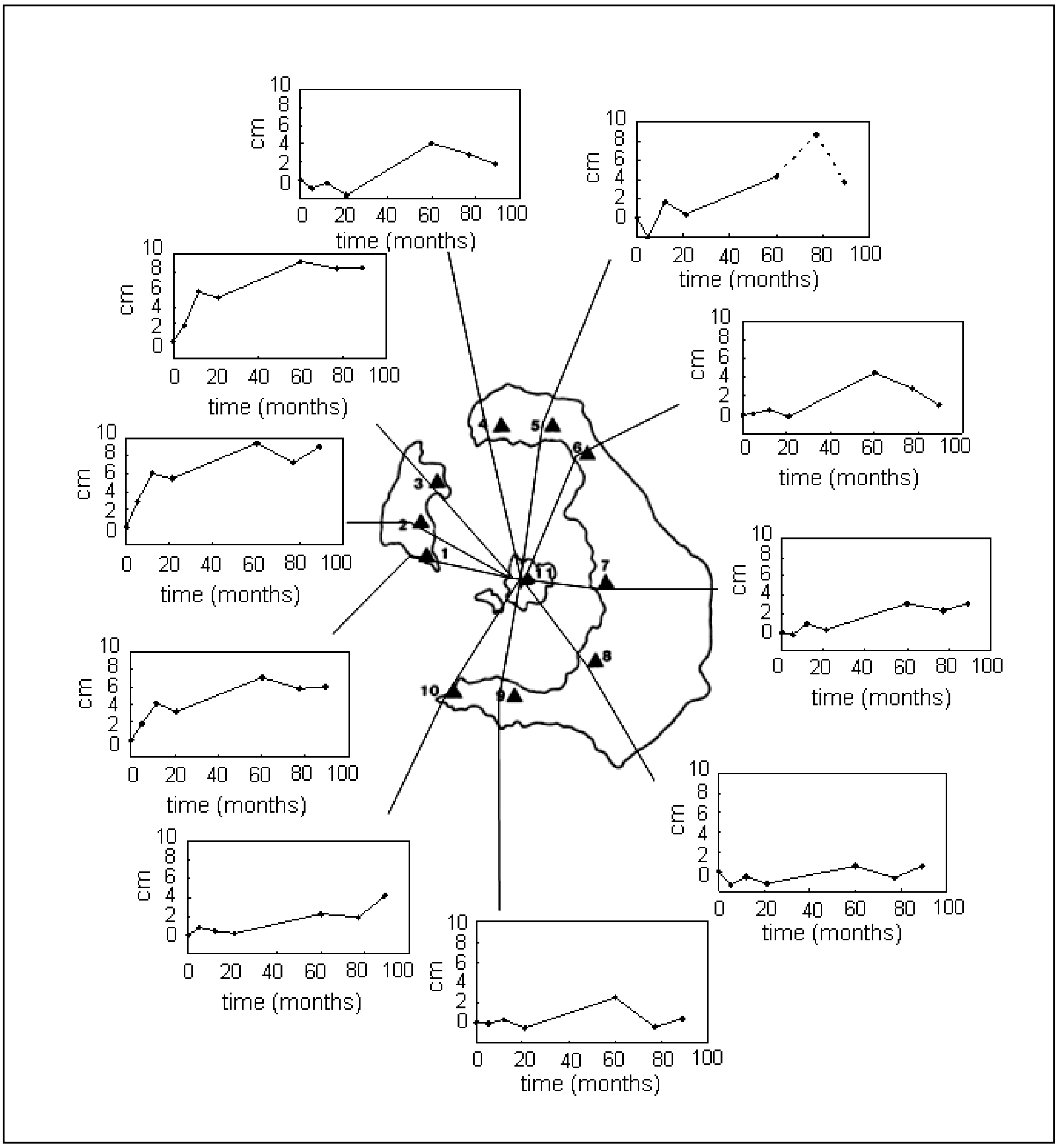

Figure 4: Summary of changes of baseline lengths between June 1994 and October 2001. Significant changes are confined to baselines of Therasia.

5. GPS Surveys

Since October 2000, the same network was measured by GPS, in combination with the EDM survey, in order to compare EDM and GPS data in the perspective of replacing EDM measurements by GPS. No significant differences in the coordinates of the GPS stations versus time was observed, in accordance with EDM data.

6. Conclusions

The EDM surveying data indicate a statistically significant, systematic increase in the length of baselines between Nea Kameni and Therasia, shortly after the first measurement, but definitely no changes in the southern part of the caldera (baselines 7, 8, 9, 10 in Fig.4). During the last years, however, no significant changes in the baseline lengths were observed. These results indicate an activity of the volcano feeding system. Whether such small-scale topography changes are premonitory phenomena of a near-future magmatic anomaly, is not possible for the moment to know.

Acknowledgements

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