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The Fira fault (Santorini, Greece) from the French "Expédition de Morée (1829-38)" to modern scientific approach

Pavlides, Spyros (1), Chatzipetros, Alexandros (1)

(1) Department of Geology, School of Geology, Aristotle University of Thessaloniki, Greece, [pavlides, ac]@geo.auth.gr

Abstract: *Fira fault is a syndepositional normal fault that deforms volcanics (lava layers and pyroclastic flows) of the volcanic complex of Santorini Island. This fault is classified as active, as documented by the microseismicity pattern, during the 2011-2012 crisis. The fault has been a prominent feature of Fira cliff and it has been described since the early "Expédition de Morée" survey. Although volcanic material near the uppermost part of the fault appears undeformed, a prominent scarp of the same strike modifies the relief at the fault-line.*

Keywords*: Santorini, normal fault, volcanic complex*

Santorini is a volcanic island of the South Aegean Active Volcanic Arc. It consists of several volcanic centres and lava - pyroclastic layers, as well as domes, dykes and palaeo-calderas. The surficial soft tuff-pumice materials (1 to 40 m thick) are products of the well-known late Bronze age (Minoan) enormous volcanic eruption of the 17th c. BC, that shaped the island complex of Thera/Santorini. The island basement has few outcrops and consists of the Cycladic blueschist Unit, overthrusted by crystalline limestone

Many papers have dealt with the physical volcanology and the evolution of the Island, as well as the volcanic rocks and especially of the prehistoric enormous eruption of the 17th century B.C., but only a few for the structural features of the island (e.g. Mountrakis et al., 1996, Fig. 1) and none with the Fira active fault.

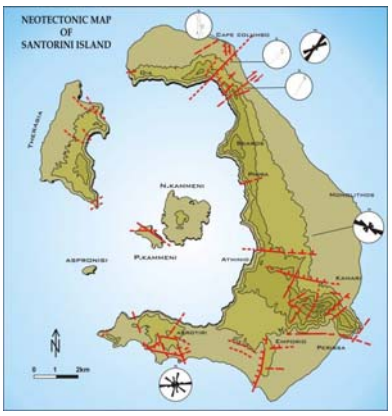

Figure 1: Neotectonic map of Santorini Island group (Mountrakis et al., 1996).

The French Morea expedition (Expédition Scientifique de Morée) is the name given to the land intervention of the French Army in the Peloponnese between 1828 and 1833, at the time after the Greek War of Independence. This mission was linked to the scientific fields of geography and geology, natural history, cartography, archaeology, (Leader: Bory de Saint Vincent, Blouet and Ravoisié, 1831; Bory de Saint-Vincent et al., 1834). In the first volume and the chapter of Geology a sketch clearly shows a discontinuity of the lava and pyroclastic layers (Fig. 2).

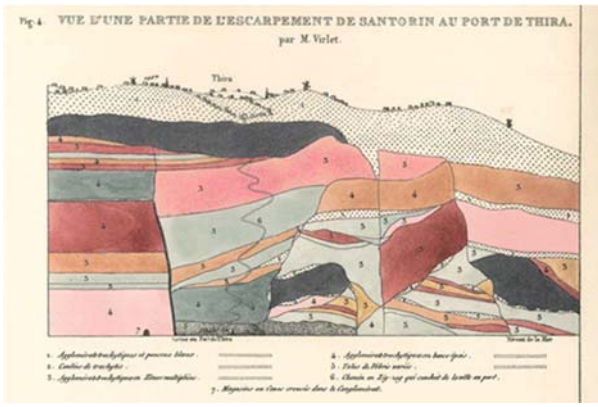

Figure 2: Detail from the first volume of Expédition Scientifique de Morée, where Fira fault is clearly been sketched.

Fira fault is a normal 7Fault trending ENE-WSW (N60°E) with a right lateral oblique slip sense of movement. It shows gradually smaller displacement from the see level to top lava layer (Nomikos Conference Center) (Fig. 3). It affects all the layers from the sea level up to the last volcanic flow, which is 40.000 - 60.000 years old, where typical cooling fractures and tectonic open joinst have been observed. A non-typical fault scarp on the surface volcanics is also observed. It runs subparallel to a longer "fault zone", including the known volcanic centres, known as Kamenes and the 1956 earthquake M7.5 great Amorgos-Santorini fault zone. The Santorini-Amorgos area is a zone of crustal weakness in an overall right-lateral transtensional regime. It represents a major structural boundary.

Figure 3: Overview of Fira cliff and fault.

Figure 4: Colour view of the 3D model of Fira fault outcrop that was constructed using photogrammetry. The fault displacement decreases towards the top.

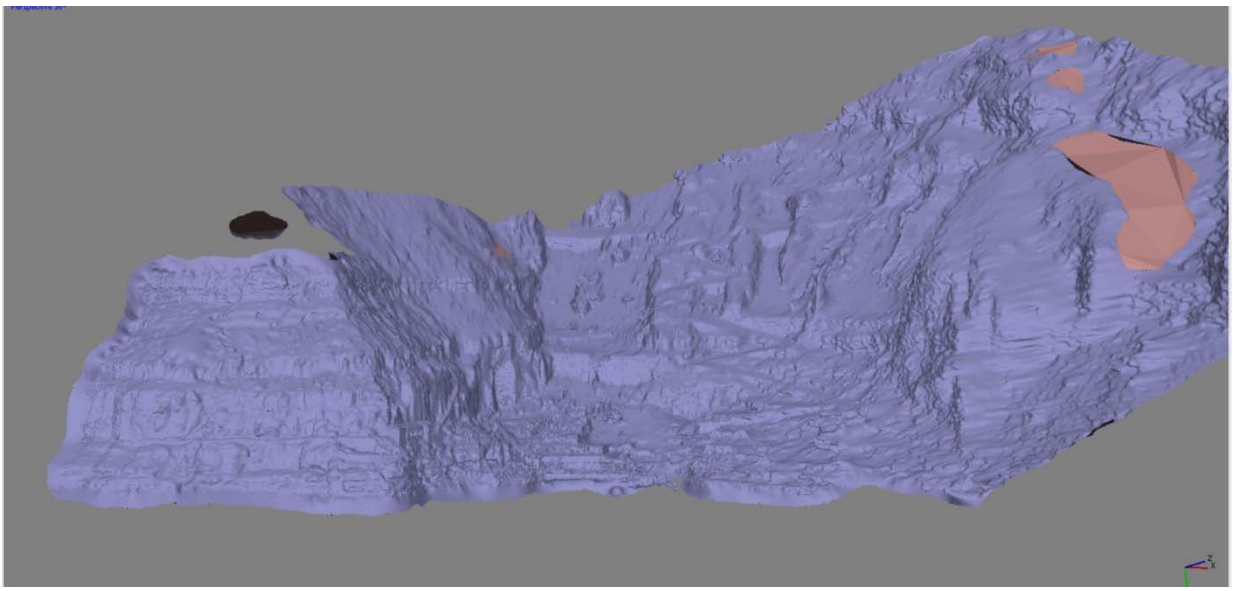

Figure 5: Shaded 3D model of Fira cliff.

The stress regimes in the broader area imply that the Amorgos-Santorini line is attributed to the tectonic stresses related with the well-established Aegean motion towards SSW, whereas the Fira fault, which gives rise to recent microseismicity of the area, is due to a local stress regime attributed to buoyancy forces relating the magmatic processes of the area.

The combination of two stress regimes reflects the competition between the tectonic (lithospheric) and magmatic (local volcanotectonic) forces, in a fault-dynamic regime that could be characterized as an extensional-transtentional field.

During the 2011-2012 volcano-seismotectonic crisis the Kamenes volcanic line - Fira Fault was activated by a series of minor earthquakes M 2.0 to 3.5. The Fira fault segment that was activated during the 2011-2012 crisis is about 6 km long, so its maximum potential magnitude calculated from the empirical relationships (Wells & Coppersmith 1994; Pavlides & Caputo 2004) is less than 5.5.

3D Model

To better understand the geometry and the gradual displacement of the fault, a 3D model was constructed using photogrammetric methods. A set of more than 50 photos was aligned and paired using specialized software. The paired photos were then used to extract a dense point cloud (ig. 4), which in turn was used to construct a uniform 3D model (fig. 5). This can be used to apply quantitative analytic methods to quantify the syndepositional behaviour of the fault.

The 3D model shows that there is a gradual decrease to the fault displacement from 22 m to its lowermost part (where visible) to 0 next to the surface. The decrease gradient is not smooth, but it shows an episodic pattern, which can be interpreted as intermittent periods of activity, possibly related to the volcanic activity rather than the structural pattern.

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