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Contemporary Tectonic Deformation in the Santorini Volcanic Complex, Greece.

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Tectonic deformation is difficult to study in the Santorini Volcanic Complex which comprises a cluster of small and awkwardly shaped islands covered by pyroclastic deposits: seismicity is generally absent and tell-tale markers of tectonic activity are swiftly erased by surface processes. We address the problem by combining geophysical exploration methods to assess the long-term effects of tectonic deformation and time-lapse Differential GPS (DGPS) and kinematic modelling to directly evaluate present-day deformation. 3-D modeling of gravity data is used to strip the gravity effect of pyroclastic and extrusive volcanic formations, reconstruct the morphology of the Alpine basement and delineate markers of tectonic activity such as fault steps, grabens and horsts. Spatial analysis of magnetotelluric data is used to map *epiphenomenal* conductivity anomalies generated by thermal fluid circulation along active faults. Finally, the DGPS observations span the period 1994–2005 during which the SVC was in repose and no volcanic activity whatsoever was reported before, during and immediately after the measurements. These measurements are used to resolve relative displacements (deformation) of the surface with nearly sub-millimetric precision, while their numerical modeling determines the nature and kinematics of the active fault zones generating this deformation. The following active fault configuration was determined:

The **Trans-Santorin Divide** (TSD) develops lengthwise of the line joining the areas of Vlychada/Cape Exomytis, the Kammeni islets and the Oia – Therassia strait. In the topography of the Alpine basement it appears as a series of dents and depressions aligned in an approximately N330° direction (Fig.1a, 1b). At depths greater than 500m, it is collocated with a major sub-vertical conductivity apparently associated with fluid circulation interface and defined by the current concentration pointed to by the real induction vectors and the mutual configuration of the maximum electric field polarization state (Fig. 1a). Contemporary deformation identifies the TSD as an aseismic segmented right-lateral dislocation surface that splits the SVC into NE and SW halves (Fig. 1c). Faulting with analogous geometrical characteristics may also exist in eastern Thera as well as along the caldera wall between Mts. Mikros Prof. Elias and Megalo Vouno where they and may be associated with the extrusion of Peristeria Volcano lavas: the deep dent in the Alpine basement at that location is thought to represent the volcanic vent.

The **Columbo Fault Zone** (CFZ) develops in a NE-SW direction between Mts. Mikros Prof. Elias and Megalo Vouno at north Thera and terminates on the TSD. It comprises a pair of parallel sub-vertical south-westerly dipping normal-sinistral faults (Fig. 1c): the Cape Columbo Fault (CCF) to the north and the Mikros Prof. Elias fault (MPEF) to the south. CFZ may be associated with thermal fluid injection into the shallow crust, possibly occurring at depths of 2-3 km via a TSD-like fissure beneath the coastline (caldera wall) and the pipe of the Peristeria Volcano. Onshore, it does not have a clear signature in the gravity field; offshore, it appears to have formed a significant NE-SW depression beneath the North Basin that terminates against the TSD (Fig. 1a-1c). The CFZ also appears to have limited effect on the electrical conductivity of the SVC crust (Fig. 1a).

The **Anhydros Fault Zone** (AFZ) is a very significant NE-SW system forming the NW flank of the Santorini–Amorgos Ridge; it has been detected off the northeast coast of Thera Island and is thought to traverse the SVC. On Thera, its presence is confirmed by its footprint on the Alpine basement, where it is seen to comprise a set of parallel, north-westerly dipping faults located between the Athinios–Monolithos line and Fira (Fig. 1a-1c). The morphological characteristics of the Alpine basement in the area of the Akrotiri Volcano indicate that AFZ may have had a role in the extrusion of the Akrotiri lavas (Fig. 1a-1c). The AFZ does not appear to affect electrical conductivity structure, meaning that it is *not* associated with active circulation (Fig. 1a). It also appears to insignificantly contribute to the observed horizontal displacement field, which can be entirely explained by the TSD and CFZ faults. These observations indicate that the AFZ may not have been particularly active in the recent geological past.

The CFZ and AFZ have antithetic throws and generate a graben-like structure that contains the Kammeni Line and the volcanic centre of the Kammeni islets. Given the observed kinematics of the TSD and CFZ, it can be safely concluded that the AFZ, as well as *any* NE-SW fault in the vicinity of the SVC, can only have *left-lateral* heave.

The arrangement of NNW-SSE right-lateral (TSD) and NE-SW normal left-lateral faults (CFZ) can be explained *only* if the NNW-SSE faulting direction comprises the synthetic (dextral) Riedel-R shear and the NE-SW direction the antithetic (sinistral) Riedel-R′ shear. This configuration can only be generated by N-S σ_1 and E-W σ_3 principal stress axes (Fig. 1c), therefore *secondary* E-W compressional and N-S extensional failure is also expected.

The strain field computed from GPS observations indicates E-W extension lengthwise of a zone stretching from Cape Exomytis to Athinios port and along the east flank of the caldera, up to Imerovigli. The same computations indicate NNE-SSW compression at south Thera and along the Akrotiri peninsula. The footprint of the caldera on the Alpine basement is a parallelogram with N-S long side and WNW-ESE short side. All this evidence indicate that the east flank of the caldera may have formed by collapse along secondary westerly dipping N-S normal faults and the WNW-ESE short side of the parallelogram by collapse along WNW-ESE “inverse faults”.

The observed configuration of active faulting and associated principal strain/stress axes can only be driven by NW-SE right-lateral shearing of the broader SVC area, the exact geographical extent of which as well as its role and contribution to the regional tectonic and kinematic setting of the south Aegean Sea cannot be determined with the present data.

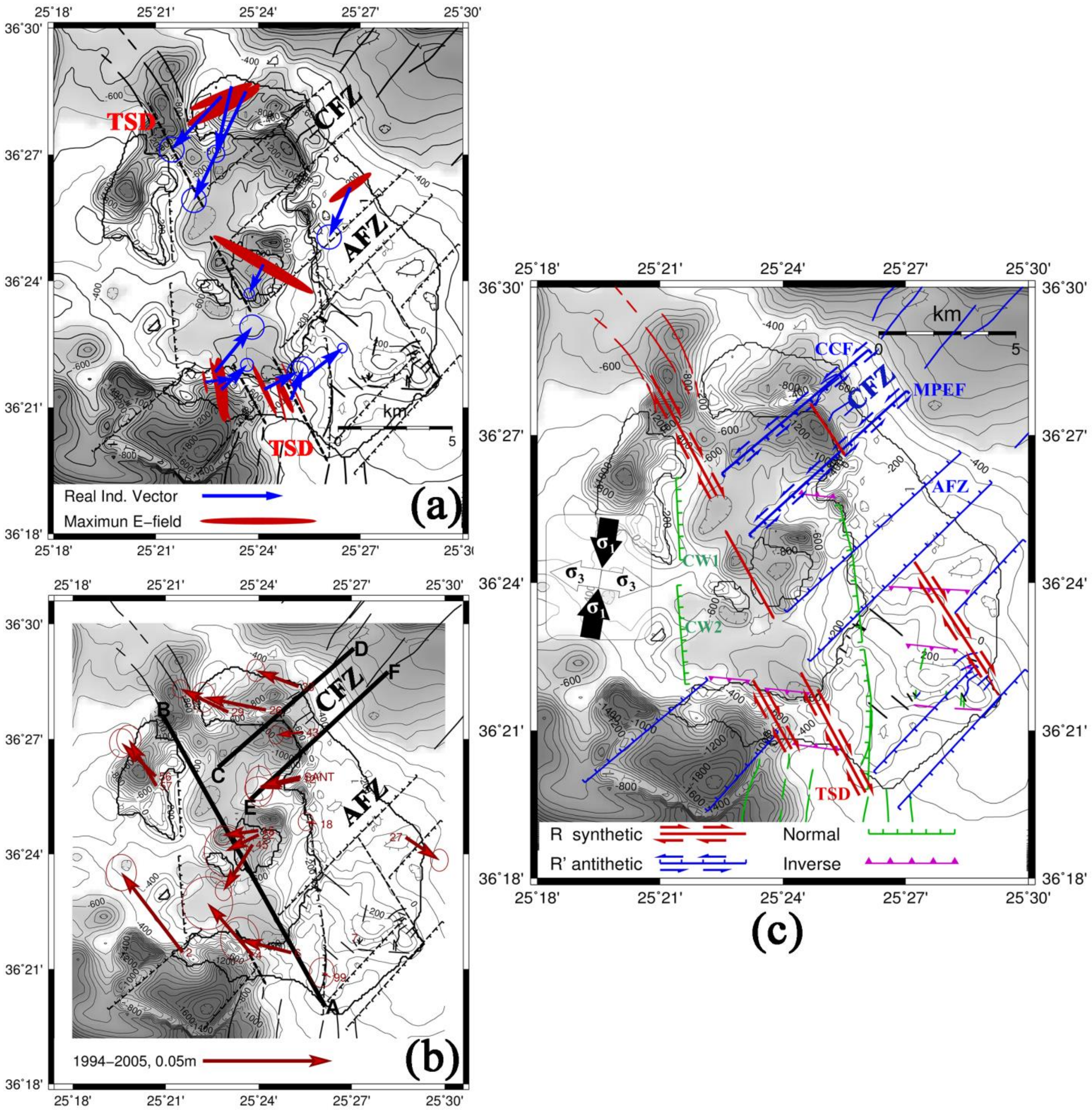

Figure 1. (A) Polarization of the maximum electric field (red ellipses) and the Real Induction Vectors (blue arrows); both are shown as averages over the bandwidth 1–100s and are superimposed on the model of the Alpine basement. (B) Aggregate horizontal displacement vectors relative to Station 7, measured over the periods 1994-2005 and superimposed on the model of the Alpine basement. AB, CD and EF are the surface traces of the model faults used in modelling the surface deformation sensed by the GPS data; they represent the TSD, the CCF and the MPEF respectively. Solid black lines indicate the traces of known faults and dashed lines the traces of inferred faults; throw/dip direction is shown whenever possible. (C) The horizontal stress axes σ_1, σ_3 and the principal (R/R′) and secondary (normal/inverse) tectonic and kinematic elements in the SVC. They are all superimposed on the model of the surface of the Alpine basement.

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