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Active faulting in the north-eastern Aegean Sea Islands

A. Chatzipetros [a,*], A. Kiratzi [b], S. Sboras [a,d], N. Zouros [c], S. Pavlides [a]

[a] Department of Geology, Aristotle University of Thessaloniki, 54124, Greece
[b] Department of Geophysics, Aristotle University of Thessaloniki, 54124, Greece
[c] Department of Geography, University of the Aegean, Mytilene, 81100, Greece
[d] Department of Earth Sciences, University of Ferrara, via Saragat 1, 44100 Ferrara, Italy

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ABSTRACT

The distribution of seismicity, faulting pattern and its effect on local geomorphology is examined for the islands of Lemnos, Aghios Efstratios, Lesvos, Chios, Samos and Ikaria of north-eastern Aegean Sea, Greece. The main active faults on each island are described in terms of their geometrical characteristics and geomorphology. Faults that comply with specific criteria (geological age, effect on relief, their geometrical relationship to the active stress field) have been characterized as active. We evaluated and reviewed published information, augmented with new field data for onshore faults, while the effects of faulting on the seafloor and their probable association with recorded earthquakes were used to determine offshore faulting. The relation of active faulting to the stress pattern has been examined as well. It is shown that as the deformation changes gradually from transtensional in the north to extensional in the south, so does the active faulting pattern. The effect of the westernmost splays of the North Anatolian Fault Zone, the largest of which is the ~300 km long, North Aegean Trough, is profound due to their close vicinity, causing shearing in good agreement with the modeled principal displacement zone deformation pattern. Faulting in the area is controlled by the distance from the main dextral principal displacement zones: the northern part of the area is directly affected by the North Anatolian Fault Zone and its splays, while this effect gradually weakens in the central and southern areas. The geomorphology responds to this faulting, causing the formation of fault-parallel gulfs near Lesvos and Lemnos and fault-defined shorelines in the rest of the islands. Ikaria exhibits a notable fault-controlled tilted topography as the result of footwall uplift.

1. Introduction

It is well known that the active stress field in any given area affects pre-existing faults and creates new ones. In both cases, the resulting deformation on the active faults variously affects the morphological relief, usually by causing local or regional uplift or subsidence. This effect, as well as the faulting pattern (i.e. sense of movement, strike and dip of active faults), changes gradually as the local geotectonic setting changes itself. In this paper we attempt to identify the change of active faulting pattern in northeastern Aegean islands (Greece), in relation to the main structural features of the area. We also examine their impact on geomorphology, especially along the island shorelines. To this end, we reviewed and evaluated published data and complemented them with new fieldwork. Recorded seismicity and related fault plane solutions also provide information regarding the seismic behaviour of fault zones, especially useful when offshore faults are concerned.

The Aegean Sea and surrounding lands is a region characterized by diffuse seismicity (Fig. 1) and complex tectonics controlled by interplay of moving plates in the broader area. The distribution of shallow ($h \leq 40$ km) earthquake focal mechanisms (Fig. 1) indicates that the accumulated deformation is partially taken up by earthquakes, whose type of faulting briefly are as follows: a) low angle thrust and steeper reverse faulting along the Hellenic trench accommodates the Aegean–Nubia (Africa) convergence; b) ~E–W normal faulting along mainland Greece, the back-arc Aegean area and western Anatolia; c) ~N–S normal faulting along the Hellenic Mountain Range and the overriding Aegean plate, approximately south of the volcanic arc and d) strike–slip faulting in the Northern Aegean Sea and western Greece (Ionian Islands and western Peloponnese).

Kinematic and dynamic models attempt to explain the observed pattern of deformation. During the last decades the results from GPS campaigns have repeatedly refined the kinematics of the region. The kinematic models for the Aegean area clearly show the westward extrusion of the Anatolian plate and the rapid escape of the Aegean lithosphere towards SW (e.g. Armijo et al., 2004; Delikaraoglou et al., 2006; Flerit et al., 2003, 2004; Kahle et al., 1998; Kreemer and Chamot-Rooke, 2004; Kreemer et al., 2004; McClusky et al., 2003). They also suggest that deformation is confined to narrow strips between

* Corresponding author. Tel.: +30 2310998512; fax: +30 2310998482.
E-mail addresses: ac@geo.auth.gr (A. Chatzipetros), kiratzi@geo.auth.gr (A. Kiratzi), ssmporas@auth.gr (S. Sboras), nzour@aegean.gr (N. Zouros), pavlides@auth.gr (S. Pavlides).

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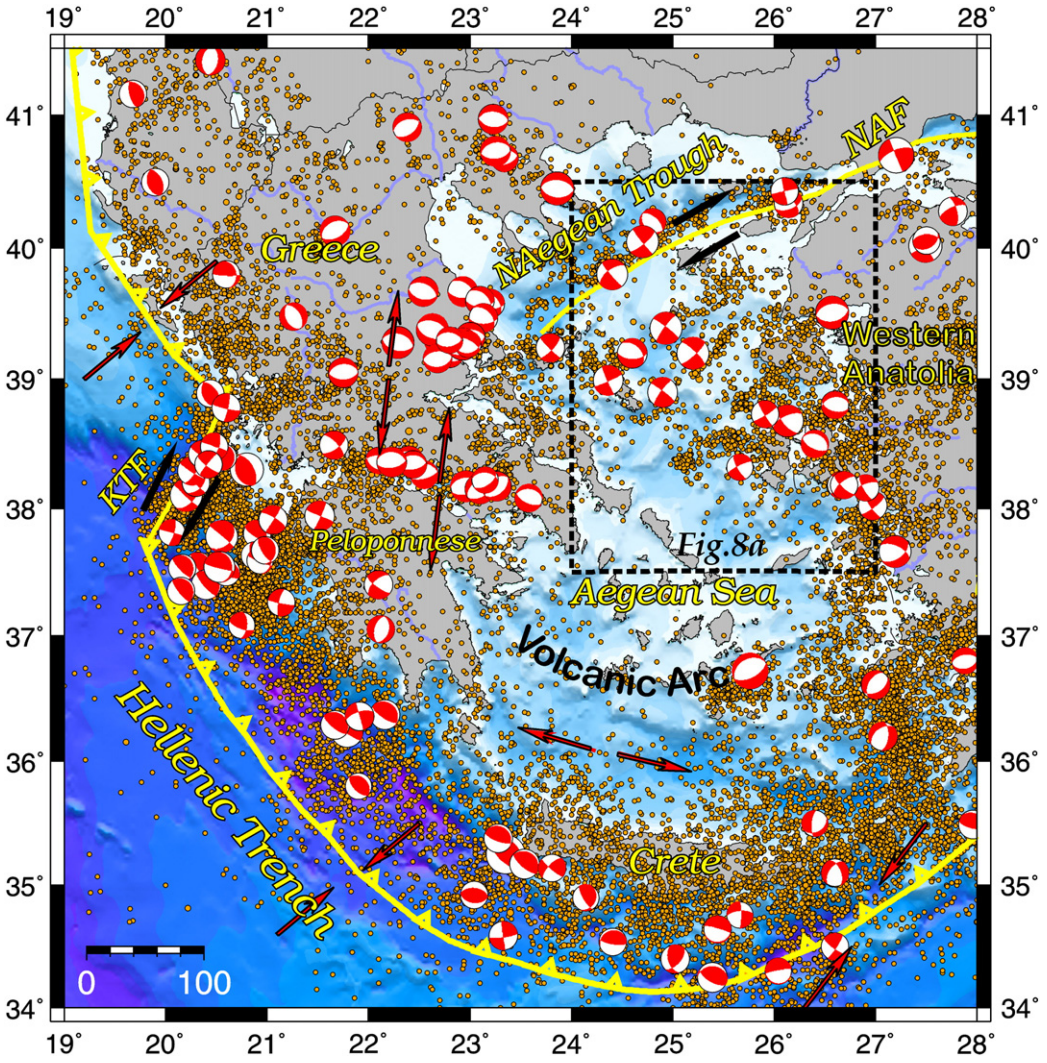

Fig. 1. The east Aegean Sea islands studied here (dotted rectangle) within the seismotectonic framework of the broader Aegean Sea and the surrounding lands. The distribution of seismicity (circles denote shallow earthquakes with $M \geq 4.0$ of the period 1964 onwards) is the studied area depicts some well defined NE–SW trending strands connected to the North Anatolian Fault (NAF) Zone. The distribution of the strongest ($M \geq 5.5$) shallow ($h \leq 40$ km) earthquake focal mechanisms (beach-balls) indicates that the accumulated deformation is partially taken up by: a) low angle thrust and steeper reverse faulting along the Hellenic Trench accommodating the Aegean–Nubia (Africa) convergence; b) ~E–W normal faulting along mainland Greece, the back-arc Aegean area and western Anatolia; c) ~N–S normal faulting along the Hellenic Mountain Range and the overriding Aegean plate, approximately south of the volcanic arc and d) strike–slip faulting in the Northern Aegean Sea, in the Ionian Islands and western Peloponnese (KTF: Kefallinia Transform Fault zone).

rigid rotating blocks, compatible with plate tectonics (e.g. Goldsworthy et al., 2002; Le Pichon and Kreemer, 2010; Le Pichon et al., 1995; Nyst and Thatcher, 2004; Reilinger et al., 2006). The Anatolia westward extrusion is facilitated by the ~1200 km long, dextral strike–slip North Anatolian Fault (NAF) and its strands that enter into the Aegean Sea. A broad shear zone is formed between western Anatolia and central Greece where mainly strike–slip faulting, at times combined with a normal component, form linear strands in the Aegean Sea, also depicted in the distribution of the seismicity (Fig. 1a). Paleomagnetic data from Cenozoic rocks reveal strong variation in the rotational vectors in central Aegean Sea. At the North Aegean Trough a 25° dextral rotation is evident in the last 17 Ma. (Kondopoulou, 2000). Regarding the eastern Aegean Sea and the western Anatolia, bordering blocks show different magnitudes as well as sense of rotation: Lesvos Island and Biga peninsula show zero rotation, Karaburun peninsula shows intense clockwise rotation, while Izmir and Chios areas show chaotic counterclockwise rotation since Middle Miocene (Kondopoulou et al., 2011).

These models are very successful in describing the gross characteristics of the kinematics; however, they are less successful in explaining the diffuse distribution of seismicity between the narrow deforming zones. Models that address the dynamics of the region, that in turn control the kinematics, are based on a variety of forces which indicatively include: Arabia push, slab rollback, asthenospheric driving forces, forces derived from gradients in the gravitational potential energy, forces associated with slab detachment and gravitational collapse (e.g. Özeren and Holt, 2010 and references therein).

Despite the overall satisfactory modeling of the kinematic deformation in the area, not much are known about the geometry, kinematics and activity of specific faults in the study area.

The purpose of the present paper is to study the active faulting of the eastern Aegean Sea Islands (Fig. 1) which lie in the shear zone between western Anatolia and central Greece. Previous studies indicate diversity in fault trending and character (e.g. Armijo et al., 2004; Flerit et al., 2004; Kiratzi, 1991; Kiratzi and Louvari, 2003; Kiratzi et al., 1991; Koukouvelas and Aydin, 2002; Kreemer et al., 2004; Papanikolaou et al., 2006; Papazachos and Kiratzi, 1996; Ten Veen et al., 2009). More specifically we study the islands of: Lemnos, Aghios Efstratios, Lesvos, Chios, Samos and Ikaria. We focus on their main active structural characteristics, assess their geomorphologic signature and examine how the style of faulting, as well as its effect on relief, varies between the islands, and hence spatially with respect to the North Anatolian Fault. We show that there is a clear differentiation in the geomorphologic signature of these islands: while Lemnos forms very long shorelines, the other islands show a regular shape with long, rather straight shoreline