volume 53, special issue september 2002

GEOLOGICA CARPATHICA

Internatipnal Geological Journal

VEDA
PUBLISHING HOUSE OF THE SLOVAK ACADEMY OF SCIENCES

KINEMATICS OF ACTIVE FAULTS IN LOKRIS, CENTRAL GREECE — BLOCK ROTATION WITHIN A CRUSTAL-SCALE SHEAR ZONE?

H.D. KRANIS[1]

[1]University of Athens, Department of Dynamic, Tectonic & Applied Geology, GR 15784 Panepistimioupoli, Athens, Greece; hkranis@geol.uoa.gr

Abstract: The kinematics of active faults in central-eastern mainland Greece suggests that the range-bounding faults are oblique-normal, rather than purely dip-slip. The tectonic fabric can is consistent with elongated block rotation, which can be controlled by a NE-SW, 30 km wide crustal scale shear zone that may accommodate the westward extrusion of the Anatolian plate into the Aegean.

Key words: Greece, Lokris, Aegean, active faulting, block rotation, kinematics.

Introduction

Lokris is a part of central-eastern mainland Greece (Fig. 1), an area characterized by intra-plate extension since the Pliocene, which has resulted in graben formation, controlled by active faults. We focus on the southern margin of the Northern Gulf of Evoia (NGE) (Fig. 2), which is controlled by E-W to WNW-ESE faults. The aim of this paper is to present the kinematics of a range-bounding series of fault zones and to place them in a regional geodynamic context.

Faults and fault zones

The Arkitsa-Longos fault zone (ALFZ) consists of four segments (Fig. 2) arranged in relay fashion. An impressive variety of well-preserved kinematic indicators are found on the recently-exposed Arkitsa fault plane including striations, corrugations, pluck holes, tool marks and debris streaks. All of them are consistent with oblique-normal movement: dip slip accounts for 75 % and strike-slip (left-lateral) for 25 %. The mean displacement vector is oriented N30W on a mean fault plane 67/018. NNW-oriented are also the striations on the middle segment of the ALFZ.

To the west of the ALFZ is the Agios Konstantinos f.z. (AKFZ) (Fig. 2), the two f.z's overlapping for approximately 2.5 km. The AKFZ begins with am E-W segment at its eastern end and through small NNW-SSE transfer faults bends to NW-SE, which is its

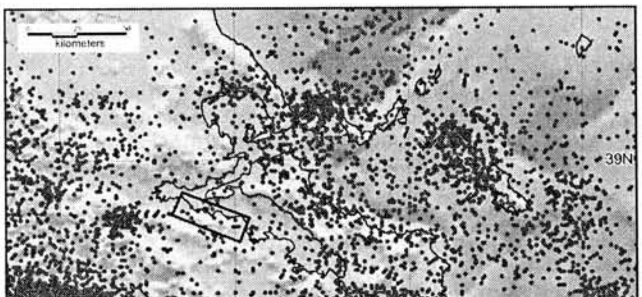

Fig. 1. Location and seismicity map of central Greece. The rectangle shows the location of Fig. 2.

dominant strike. The major peculiarity of the AKFZ lies in that its NW-SE western segment has very low dips (35-38°) all along its exposure. This has been discussed by Kranis (1999, 2000) and has is attributed to the block-rotation that the core of Mt Knimis has undergone since the Early Pleistocene. Well-preserved striations and plod marks were also found on the AKFZ, especially on its western segment. All of them have a steady N to NNW trend.

The impressive mountain front of Mt Knimis at Kamena Vourla is the result of the occurrence of the Kamena Vourla f.z. (KVFZ) (Fig. 2), which consists of three relay segments. The faults here are very steep (dips generally greater than 60°) and strike E-W to ESE-WNW. No kinematic indicators were found on the eastern segment; notwithstanding, the central (mainly) and western segments bear striations, pluck holes, comb fractures and tension gashes. On the former there are two sets of striations, one with NNE and one with NW trend, almost equally abundant. As Kranis (1999) showed these two sets develop on different "faces" of the fault plane, which has a step-like trace. The NNE-trending striations develop on the ENE-WSW striking faces and the NW-trending striations develop on the NW-SE ones. Even so, the mean slip vector on the central segment is 40/348.5, which means that is also NNW-trending. As for the western segment, where previous research had suggested that kinematic indicators should trend NE (Roberts 1996a,b), my investigations showed that again the striations trend NW to NNW.

Further to the west, and after the termination of the Knimis range, occurs the Molos f.z. (MOFZ), which has uplifted the Lokris basin (which can thus be considered as a footwall basins for the MOFZ and also a hanging-wall basin for the Kallidromo f.z. (Figs. 2, 3). MOFZ consists of two left-stepping segments, but no direct, fault-plane kinematic indicators were found on either of these faults.

Summing up the aforementioned observations, we can see that the kinematic indicators along the Knimis northern front trend NNW, with a mean slip vector trending N15W.

Certain peculiarities are present, as the low dips of the Agios Konstantinos fault and can be attributed to footwall block rotation; the latter has been facilitated by the occurrence of a complex fault zone that forms the SW and southern boundary of Mt Knimis, the Kainourio-Trano Livadi f.z. (KTLFZ) (Kranis 1999).

Discussion and conclusions

All the above show that the entire mountain front is controlled by oblique-normal faults with almost invariably NNW-oriented kinematic indicators. This well-established sinistral component of movement is also consistent with the observed displacement on the trace of the adjacent Atalanti fault during the 1894, where Skuphos (1894) documented a significant left-lateral component on the scarps produced by the large earthquake. If we also take into account that the Kallidromo fault zone (Fig. 3), which lies to the

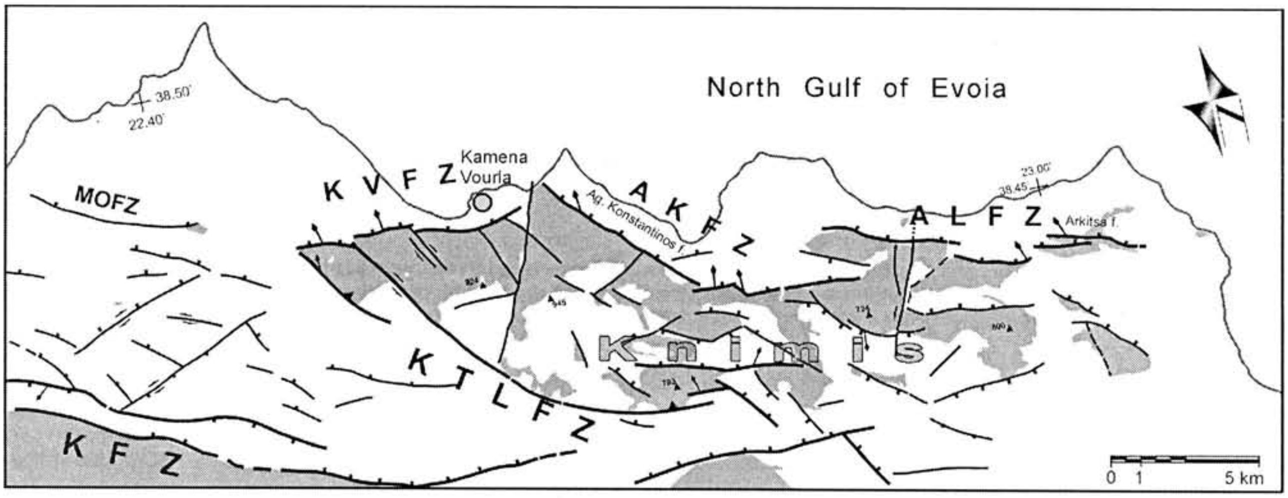

Fig. 2. Tectonic map of the study area. Grey shading is for alpine rocks. Hachure is on the downthrown block of normal faults. The mean slip vector is show with the diamond-edged arrow. Split arrows show the component of strike-slip on normal faults, where it was determined indirectly. Notice the consistency of slip vector all along the coastal faults.

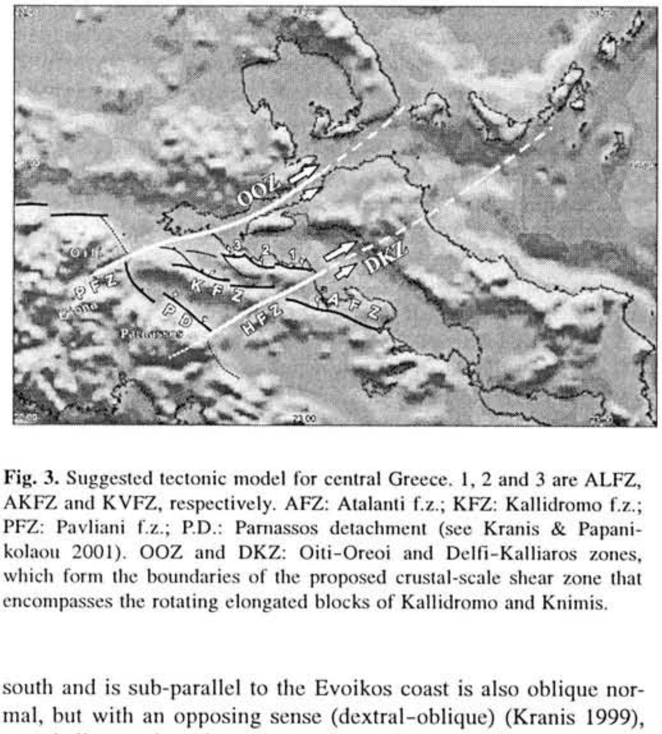

Fig. 3. Suggested tectonic model for central Greece. 1, 2 and 3 are ALFZ, AKFZ and KVFZ, respectively. AFZ: Atalanti f.z.; KFZ: Kallidromo f.z.; PFZ: Pavliani f.z.; P.D.: Parnassos detachment (see Kranis & Papanikolaou 2001). OOZ and DKZ: Oiti-Oreoi and Delfi-Kalliaros zones, which form the boundaries of the proposed crustal-scale shear zone that encompasses the rotating elongated blocks of Kallidromo and Knimis.

south and is sub-parallel to the Evoikos coast is also oblique normal, but with an opposing sense (dextral-oblique) (Kranis 1999), we shall see that these two sub-parallel range-bounding fault zones impose a vertical rotation axis on their footwall blocks. In other words, there are two elongated blocks (Mt. Knimis — including its adjacent mountains — and Mt Kallidromo) that rotate around vertical axes. The concept of rotating elongated blocks has been analyzed by various researchers so far (such as Westaway 1991; Taymaz et al. 1991; Jackson 1994) and it has been placed in the framework of a deforming zone between two plates with different sense or magnitude of relative movement. It is, so to speak a shear zone that includes rigid or semi-rigid blocks that respond two the stress distributed within the zone. The next plausible question is whether such a zone exists and if so, what are its boundaries. On this subject Kranis (1999), Kranis & Lekkas (2000) and Kranis et al. (2001) have suggested that there are two distinct features that may function as the boundaries to a crustal-scale shear zone. The two boundaries trend NE-SW and define a 33 km wide deforming zone (Fig. 3) are: (i) the Oiti-Oreoi zone, which consists of the Pavliani fault zone an active, oblique-normal fault zone that bounds Mt Kallidromo from the NW and separates Mt Oiti on the north (which is outside the deforming zone) and Mt Giona on the south. The NE prolongation of the Pavliani fault zone lies within the Oreoi straits which is an active NE-SW graben. (ii) The Delfi-Kalliaros zone that includes the Hyambolis fault zone (Kranis et al. 2001), which is a series of NE-SW to ENE-WSW, left-stepping faults that constitute a ~2.5 km wide deformation zone, of 17 km visible length. The overall pattern of the faults within the deformation zone is representative of a structure that accommodates considerable proportion of strike-slip offset, of course along with dip-slip as well. The DHK zone may extend offshore in the Evoikos Gulf and further to the NE, where it coincides with the ENE-WSW neotectonic fault proposed by Fytrolakis et al. (1988).

It is therefore reasonable to suggest that the aforementioned structures accommodate a part of the westward extrusion of the Anatolian plate, which is expressed in the form of ENE-WSW asymmetric graben in the northern Aegean, but within mainland Greece its fading (?) effect interacts with the upper Tertiary and Quaternary extensional tectonic fabric.

References

Fytrolakis N., Alexouli-Livaditi A., Livaditis G. & Kyroussis J. 1988: Geomorphological study and observations on the hydrogeology and pollution of surface and subterranean waters in the Kireas and Nileas basins (N. Evia). *Bull. Geol. Soc. Greece* XX/III, 115-132 (in Greek).

Jackson J. 1994: Active Tectonics of the Aegean region. *Ann. Rev. Earth Planet. Sci.* 22, 239-271.

Kranis H.D. 1999: Neotectonic activity of fault zones in Lokris, central-eastern mainland Greece. *PhD. Thesis, University of Athens*, 234 pp.

Kranis H.D. 2000. Geometry and kinematics of fault zones in Lokris, Eastern Mainland Greece: Implications for multi-block rotation. *Proc. IESCA 2000, 25-29.9.2000*, (Abs.) p. 47.

Kranis H.D. & E.L. Lekkas 2000: The Pavliani fault zone: Evidence for westward propagation of the North Anatolian Fault Zone in Eastern Mainland Greece. *Proc. IESCA 2000, 25-29.9.2000*, (Abs.) p. 48.

Kranis H.D. & Papanikolaou D.I. 2001: Evidence for detachment faulting on the NE Parnassos mountain front (Central Greece). *Bull. Geol. Soc. Greece* XXXIV/1, 281-287.

Kranis H.D., Palyvos N., Livaditis G. & Maroukian H. 2001: The Hyambolis Zone: geomorphological and tectonic evidence of a transverse structure in Lokris (Central Greece). *Bull. Geol. Soc. Greece* XXXIV/1, 251-257

Lemeille F. 1977 : Etudes néotectoniques en Grèce Centrale Nord-orientale

(Eubée Centrale, Atiique, Beotie, Locride) et dans les Sporades du Thèse, Univ. Paris XI — Centre d' Orsay, 173 pp. Nord (île de Skiros).

Philip H. 1974 : Etude néotectonique des rivages égéens en Locride et Eubée nord-occidentale (Grèce). *Thèse doc. sp., Acad. de Montpelier*, 86 p.

Roberts G.P. 1996a: Variation in fault-slip direction along active and segmented normal fault systems. *J. Struct. Geol.* 18, 835-845.

Roberts G.P. 1996b: Seismological segmentation in the Gulfs of Corinth and Evia fault systems: models of fault growth. *Workshop: Natural and anthropogenically induced hazards: large earthquakes in the geological record, Corinthos, May 1996*, Poster present.

Skuphos T. 1894: Die zwei grossen Erdheben in Lokris. *Sond. Z. Ges. Er.*, Berlin, XXIX, 409-474.

Taymaz T., Jackson J. & McKenzie D. 1991: Active tectonics of the north and central Aegean Sea. *Geophys. J. Int.* 106, 433-490.

Westaway R. 1991: Continental extension on sets of parallel faults: observational evidence and theoretical models. In: Roberts A.M., Yielding G. & Freeman B. (Eds.): The Geometry of Normal Faults. *Geol. Soc. Sp. Pub.* 56, 143-169.4.