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THE RODIA FAULT SYSTEM: AN ACTIVE COMPLEX SHEAR ZONE (LARISSA PLAIN, CENTRAL GREECE)

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ABSTRACT

The detailed morphological and tectonic study carried out and here presented allows to better define the geometry and the kinematics of one of the major shear zones bordering the actually subsiding Tirnavos Low (northern Larissa plain,). The Rodia Fault System is composed of several segments characterized by different directions and ages here described and tentatively analysed. The complementary use of already existing data for the Pliocene-Quaternary stratigraphy enables also an attempt of aging single segments of the fault and even an estimate of the Late Pleistocene-Recent slip-rate along some of the segments. The whole set of data and its analysis bring to the conclusion that the fault may be active in the future and consequently the seismic risk for the densely inhabited area may be high.

INTRODUCTION

Recent tectonic and morphotectonic studies of Thessaly (Central Greece) allowed to map for the first time several faults with evident features of recent reactivations (Caputo, 1990). One of these is the Rodia Fault System (RFS). It is one of the few major structures of a larger system of faults which is performing the present-day subsidence of the Tirnavos Low (Caputo, 1990; Demitrack, 1986) interacting and partly superimposed on the NW-SE trending (Pliocene-Early Pleistocene) Larissa Basin (fig. 1; Caputo & Pavlides, 1991).

The fault zone has a general E-W to ESE-WNW direction and bounds to the north the Tirnavos Low; there the Palaeozoic substratum is in direct contact with Pliocene and mainly Quaternary deposits (fig. 2).

The Pliocene sediments of the Rodia Formation are restricted to the eastern sector of the area and should probably represent an old delta getting southwestwards into the now extinct Larissa Lake. Schneider (1968) supposes that during Late? Villafranchian lacustrine and brackish sedimentary conditions persist. Micropaleontological dating of some samples collected in the northern Larissa plain confirms that age for the higher lacustrine layers (Daniela Esu, written comm.). Only in Middle Pleistocene the environmental conditions became typically subaerial. During Late Pleistocene and Holocene several episodes of deposition have been distinguished (Demitrack, 1986). They formed different and sometimes overlapping generations of scree cones and flood-plain deposits and they were alternated to periods of pedogenesis during which different and characteristic soils formed (fig. 2).

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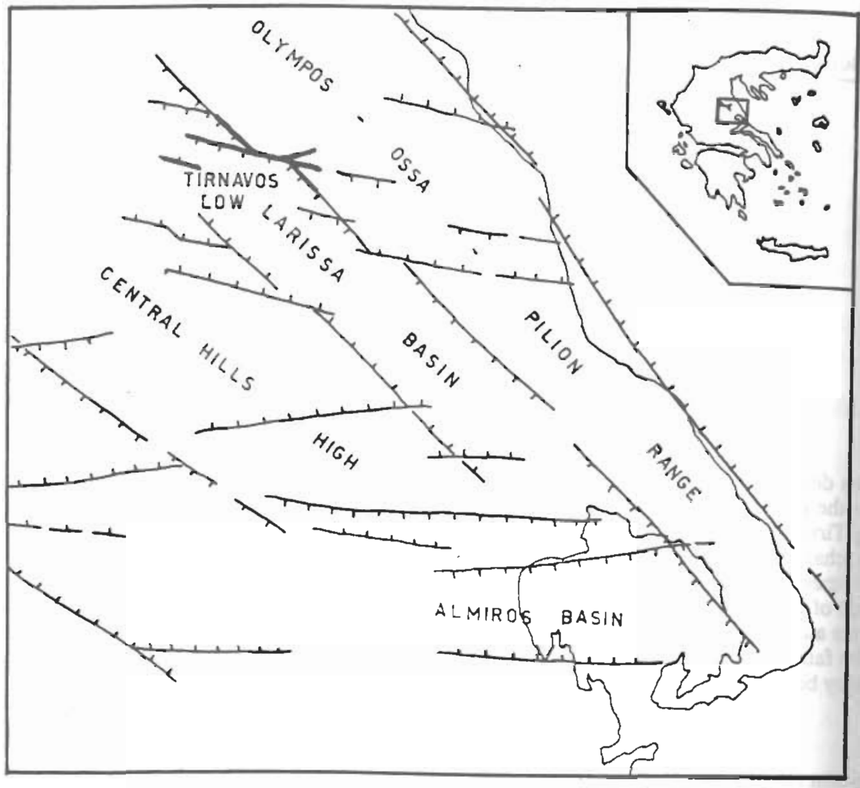


Fig. 1: Tectonic sketch of eastern Thessaly where the Pliocene and Quaternary major structures are shown.

GEOMETRY AND KINEMATICS OF THE RFS

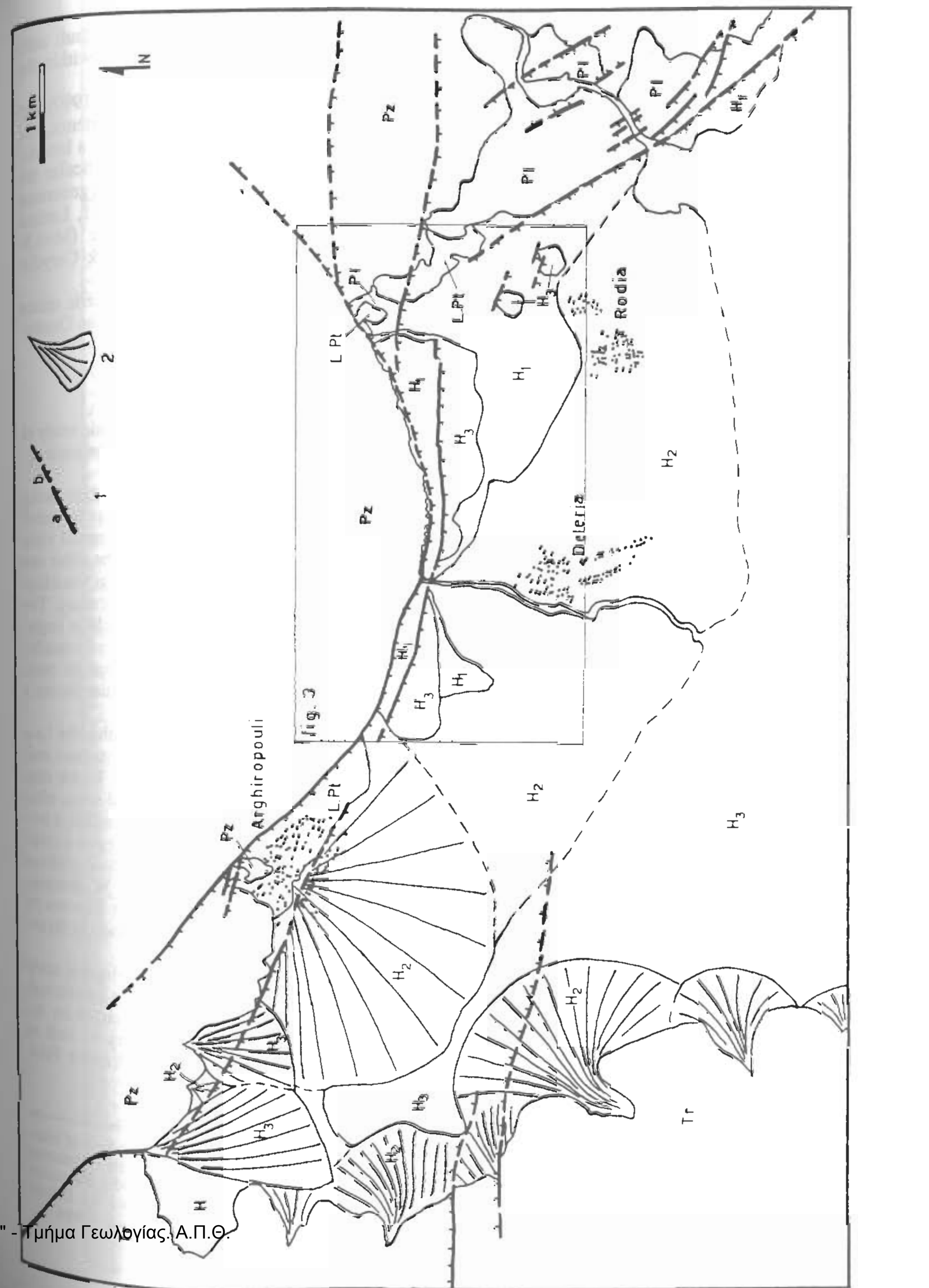
Although the general trend of the RFS is E-W to ESE-WNW, this shear zone is made of a composite and complex system of faults of different directions (from NE-SW, through E-W to NW-SE) and partly of different ages (at least from Pliocene to Recent).

The kinematics observed along the fault is slightly variable. Nevertheless everywhere a strong normal dip-slip component of movement is always measurable. Some segment of the RFS may show oblique-slip kinematics either with a sinistral component, as along the strand N of Arghiropouli, or with a dextral component, as along the NE-SW trending segment N of Rodia.

The structural analysis carried out along the structure (Caputo, 1990) clearly shows that the RFS has been involved by two distinct tectonic phases. The first phase occurred during Pliocene (-Lower Pleistocene?) and is characterized by a NE-SW direction of extension. During this phase, the eastern NW-SE trending sector of the fault was certainly active as some syn-sedimentary faulting clearly suggests. The segment N of Arghiropouli with a similar direction was also probably active.

The second phase shows a roughly N-S direction of extension. It involves Late Pleistocene and

Fig. 2: Geological map of the RFS (simplified from original mapping at scale 1:5.000). Pz = metamorphic schists (Palaeozoic); Tr = limestones (Triassic); Pl = Rodia Formation (Pliocene); L.Pt = New Red Fan alluvium (Late Pleistocene); H3 = Rodia alluvium (Early Holocene); H2 = Deleria alluvium (Middle Holocene); H1 = Pinios alluvium (Latest Holocene); 1 = alluvial cones; 2 = a) faults, b) presumed or buried. Quaternary stratigraphy modified from Demitrack (1986).



Holocene deposits and activated the southernmost ESE-WNW trending segments of the fault zone along the actual Palaeozoic-Quaternary contact as well as along a new fracture system within the younger deposits (see fig. 2 and later on).

A comparison with the Neogene-Quaternary tectonic evolution of Thessaly (Caputo, 1990) and of the whole Inner Aegean Region (*e.g.* Mercier *et al.*, 1987; 1989) confirms the existence, the direction and the age of both phases. This brings to the conclusion that the RFS is part of a broader fault system and it is related to a regional and more or less uniform stress field. In particular the younger N-S direction of extension has been largely proved to be still active all around. It generated several earthquakes in the surrounding areas the more important of which are the 1941, Larissa earthquake (M=6.1; Ambraseys & Jackson, 1990), the 1957, Velestino earthquake (M=6.8; Papazachos *et al.*, 1982) the 1978, Thessaloniki earthquake (M=6.5; *e.g.* Papazachos & Carydis, 1983), the 1980, Volos earthquake (M=6.5; Papazachos *et al.*, 1983).

A part of the main and conterminous system of faults, SW of Arghiropouli two antithetic minor faults exist. Both of them are nearly E-W and involve either the Triassic limestones and the Quaternary alluvial cones. Kinematically they show an almost pure dip-slip normal movement.

MORPHOTECTONICS OF THE RFS

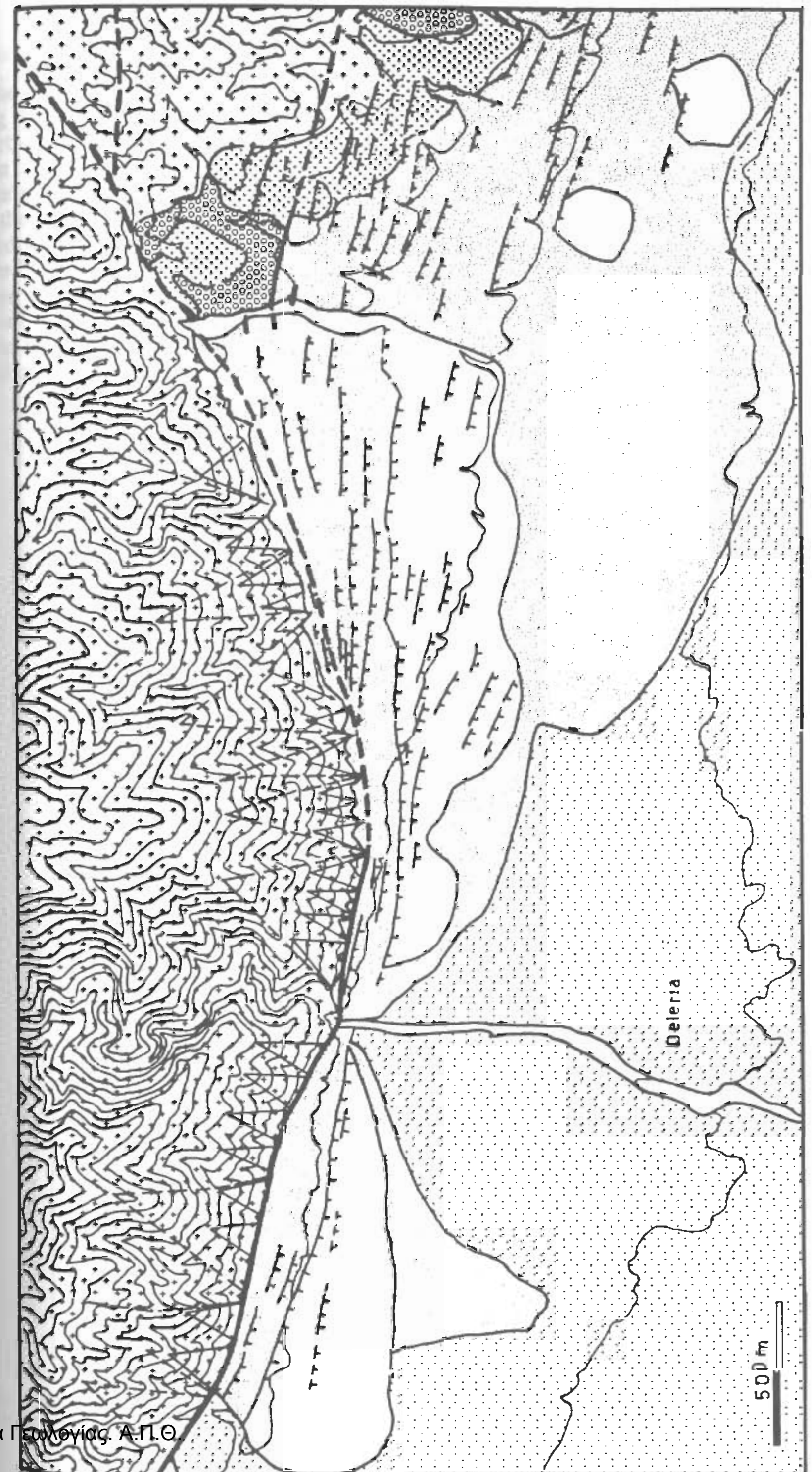
A specific mapping at the scale 1:5.000 permitted to carry out a detailed morphotectonic study of the area. Indeed, several morphological features are conclusive indicators of very recent tectonic activity along the fault zone.

An impressive morphotectonic feature along the fault is a system of triangular facets being characteristic of the central sector of the RFS (fig. 3). In plan view from the analysis of aerial photographs (provided by the Greek Geographical Military Service) as well as from frontal view (fig. 4) three generations of these morphostructures are recognizable. The largest set is the older one and consequently the features are nowadays the less preserved and the more difficult to visualize. The slope angle they define is quite small because of the retreat and erosion of the fault scarp. The intermediate set of triangular facets is certainly the better defined and shows a larger slope angle. Contrary to the two previous sets, formed in the metamorphic Palaeozoic rocks the third and smaller set involves Late Pleistocene deposits too. Although these features are certainly the younger ones, the higher erodibility of these poorly consolidated materials with respect to the substratum causes a quicker evolution of these tectonic morphologies.

In the central and eastern sectors, south to the main substratum-alluvium contact, within the Late Pleistocene and Holocene deposits, many morphological scarps exist. They have been mapped and, all along their length, the height has been measured. Both set of data are shown in fig. 3. In this map is possible to observe that some of the scarps is in continuity with Quaternary faults and some other even dislocates and separates Quaternary deposits of different ages. At least for these scarps a tectonic origin must be claimed (see fig. 2). For the remaining ones several parameters suggest a common and similar tectonic genesis. Indeed their linearity, their considerable length, their uniform height all along, their sharp profiles, the parallelism among them and their mainly E-W direction strongly support this hypothesis. Nevertheless, a different origin for some of the scarps may not be completely discarted. Only trenching across them will permit to unequivocally and definetely distinguish between morphotectonic features and not.

Concerning the two antithetic faults, it must be noted that all along a clear morphological scarp exists. It has a similar shape in both the strong lithology of the substratum (*i.e.* Triassic limestones) as in the poorly consolidated recent deposits. A strip of colluvium and denser vegetation on the downthrown block is also a characteristic feature. The same kinematics and geometry as well as very similar morphologies, have been observed just 10 km to the south along the Tirnavos Fault (Caputo, 1992) one of the major structures bordering the Tirnavos Low (fig. 1).

Fig. 3: Geological and morphotectonic map of the central sector of the RFS. Three generations of triangular facets exist and are represented with dashed lines. In the minor and younger family Late Pleistocene deposits are involved too (see also fig. 4). 1 = metamorphic schists (Palaeozoic); 2 = Rodia Formation (Pliocene); 3 = New Red Fan alluvium (Late Pleistocene); 4 = Rodia alluvium (Early Holocene); 5 = Deleria alluvium (Middle Holocene); 6 = Pinios alluvium (Latest Holocene); 7 = faults; 8 = morphological scarps.



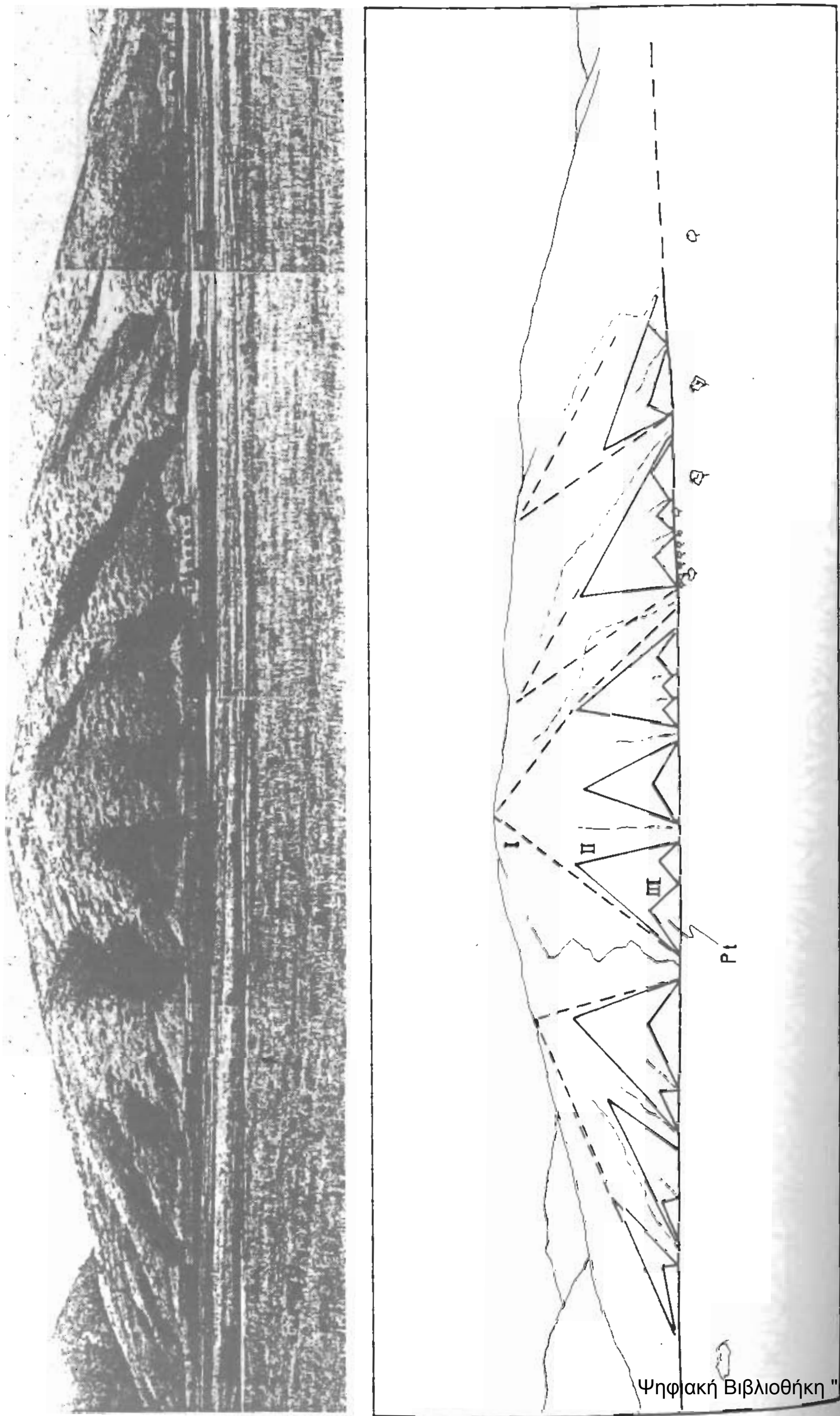


Fig. 4: A frontal view of the three-generations system of triangular facets.

AGE OF FAULTING

The RFS is composed of several segments showing a different and partially indipendent history. Aging the evolution of each single segment is probably beyond the limits of the present knowledge. Nevertheless, for some of them it is possible to establish a relative chronology and age boundaries for the last slip events.

For example the NW-SE trending set (A in fig. 5) developped in the eastern sector strongly affects the Pliocene Rodia Formation. Along some of the faults an intraformational breccia has been formed whereas some of these structures are clearly growth faults. Indeed this set of faults was undoubtedly active during the Pliocene and probably later (Early Pleistocene?) as far as the southwestern outcropping limit of the Rodia Formation corresponds to a fault. The NW-SE trending segment N of Argiropouli (G in fig. 5) probably has a similar age but it was certainly reactivated after of the deposition of the New Red Fan alluvium (Late Pleistocene). On these deposits rests a conoid belonging to the younger Deleria Fan alluvium (Early Holocene) which is cut by the segment

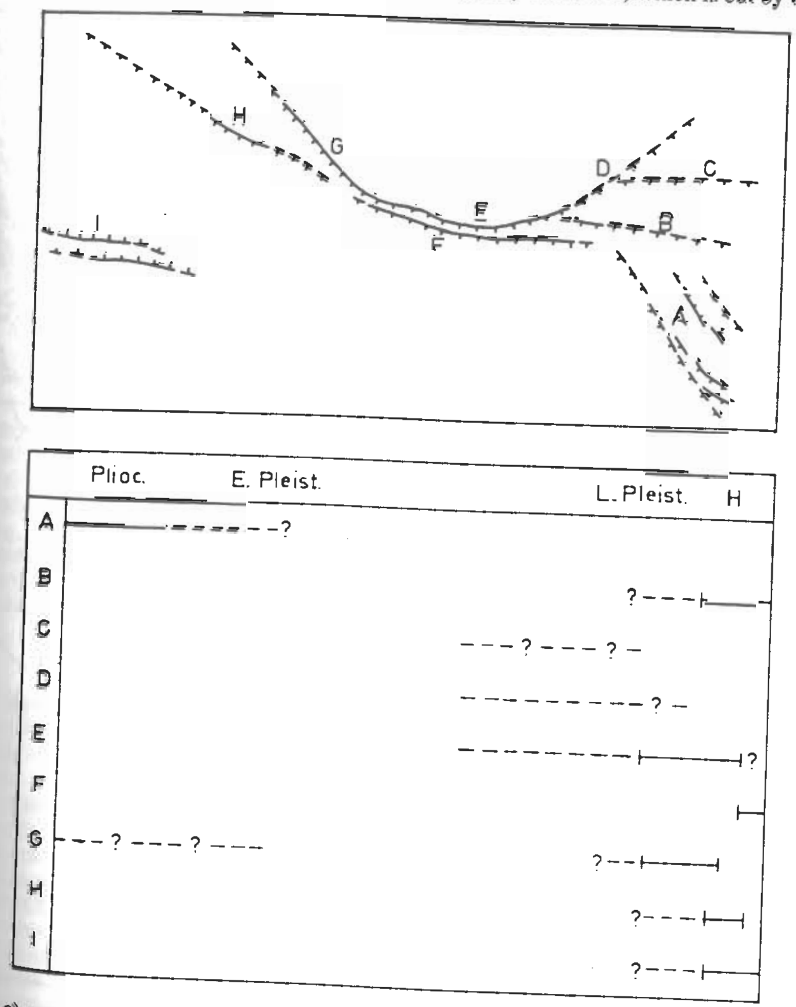


Fig. 5: a) tectonic sketch of the major segments belonging to the RFS and b) their possible time-span of activity (stratigraphy of faulting).

H (fig. 5). Coeval deposits are also involved by the two antithetic faults (I in fig. 5). Thus they predate faulting. Unfortunately, upper age boundary is available only for the segment H. Indeed, two scree cones of the Pinios alluvial deposits partly cover it and do not show any tectonic deformation. Lower but not upper age boundary is also available for segment B (fig. 5) the Rodia Fan alluvial sediments are deformed.

Both central segments of the fault system involve Quaternary materials. The northern one (E in

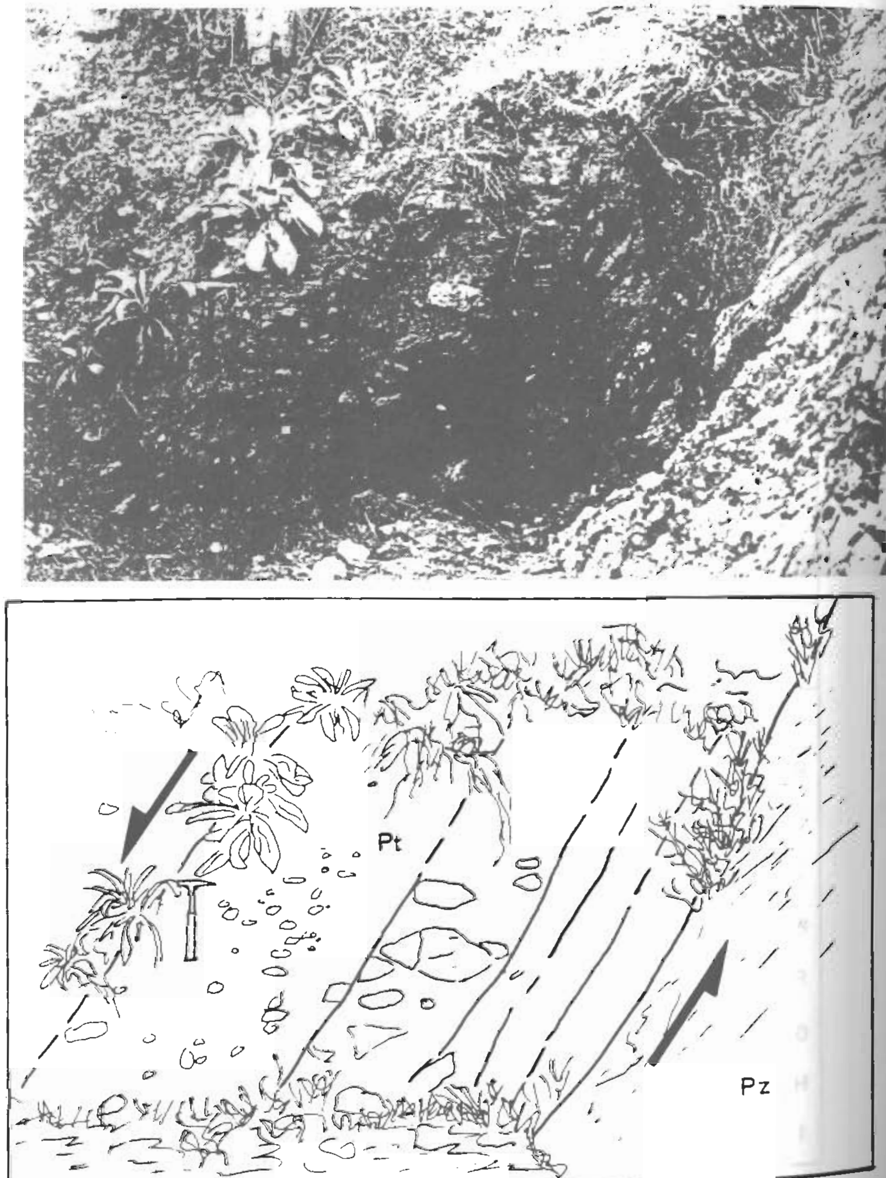


Fig. 6: The wide shear zone between the Palaeozoic substratum (right) and the Late Pleistocene deposits (left) along the segment E in the central sector of the RFS. Hammer for scale.

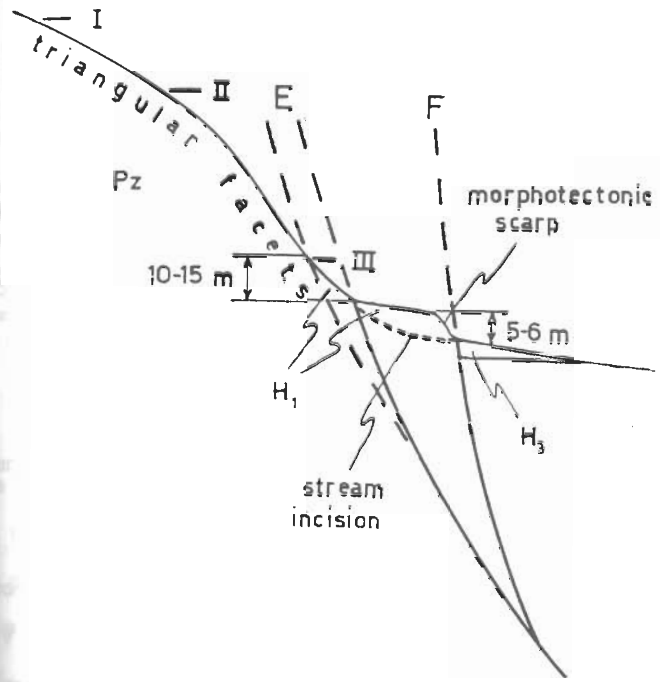


Fig. 7: Schematic cross-section of the central sector of the RFS. I, II and III refer to the three generations of triangular facets. E and F are the two segments of the central sector (see fig. 5a). Other symbols as in fig. 3. See text for further explanations.

fig. 5) corresponds to the substratum-alluvium contact. The important system of triangular facets clearly indicates a quite large amount of movement in relatively recent times. The fact that the lower set of these morphologies involves Late Pleistocene deposits proves that some faulting is certainly younger while the other two sets suggest that faulting is probably also older.

Finally segment F (fig. 5) is probably the most recent one because it deformes the Late Holocene Pinios alluvial deposits which are the younger ones affected by the RFS.

Condensing we may assess two things: first, E-W segments are commonly younger than NW-SE trending ones and, second, there is a general basin-ward migration of faulting. This latter phenomenon is quite common for normal faults and described in similar tectonic environments (*e.g.* Stewart & Hancock, 1990). If this is the case, activity on segment F possibly post-dates faulting on segment E. In fig. 5b is summarised and represented the stratigraphy of faulting.

DISCUSSION

For the displacement occurred along the RFS there are three major evidences of large cumulative amounts. First is the tilting of Quaternary and Pliocene sediments towards N and NE, respectively (the latter up to 30-40 degrees). Second is the huge shear zone (1-2 meters) along the contact between the substratum and the Late Pleistocene deposits (fig. 6). Third is the previously described system of triangular facets.

According to the age of the involved materials, all these features quantitatively indicate some tens of meter of displacement since Late Pleistocene and some hundred since Pliocene. A deformation that is representative for the whole shear zone. In the Tirnavos Low, Doutsos (1980) suggests a compatible thickness of Pliocene-Quaternary sediments with a maximum of probably more than 500 m for the centre of the basin. On the other hand, each single segment of the fault system may behave differently and separately as discussed when aging the fault evolution.

What we may tentatively do more is to estimate a slip-rate during the Late Pleistocene-Recent tectonic activity at least for the central sector of the RFS. The Late Pleistocene Rodia Fan alluvium deposits lying in the footwall block of segment E and forming the younger set of triangular facets (fig. 4) are at 10 to 20 m higher than the corresponding downthrown sediments. The same deposits have been upthrown of about 5-6 m by segment F as localized erosion down to the new relative base-level of some stream indicates (fig. 7). According to these minimum amounts of cumulative displacement and the maximum time-span of activity, the average slip-rate for the whole central sector is in the order of few mm per year. Similar values have been suggested for other recent and active faults of Thessaly (Tirnavos Fault, Caputo, 1992); Nea Anchialos Fault Zone, Caputo, 1990) as worldwide (*e.g.* Cabrera *et al.*, 1987; Bell and Katzer, 1990).

As mentioned above all the surrounding regions show a diffuse seismicity and a strong activity. In the frame of the actual regional stress field characterized by a N-S direction of extension, the RFS contains geometries that are mechanically perfectly suitable for future slips. According also to the Late Pleistocene and Holocene tectonic evolution described and outlined in the present paper, the seismic potential is quite high. If we consider the dense population living in the Larissa plain and the soft materials on which most of the buildings stand on it is clear that the seismic risk generated by the RFS is slightly high. Future investigations to understand the palaeoseismic evolution of the area are of scientific primary importance but especially from a socio-economical point of view.

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