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DINAR EARTHQUAKE (TURKEY, 1ST OCTOBER 1995) CORRELATION OF THE RECENT SEISMICITY DATA AND THE NEOTECTONIC SETTING IN SW TURKEY

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ABSTRACT

A magnitude (Ms) 6.1R earthquake occurred on 1st October 1995 close to Dinar city in northwest Turkey and caused the deaths of over 100 people together with severe damage to many thousands of properties. This earthquake was the last of a series of disastrous earthquakes that struck the region during the present century. All earthquakes were focused on northeast and northwest trending faults which form successive neotectonic horsts and grabens. Field observations carried out immediately after the tremor are totally in accordance with seismological data. Moreover, field observations and seismological data point out that during the last 100 years an east-west trending tensile stress field is dominant in the region.

KEY WORDS: Neotectonic, Seismotectonic, Dinar earthquake, Turkey

1. INTRODUCTION

On the 1st October 1995, an Ms=6.1 earthquake struck Dinar (SW Turkey) and the broader area (Fig. 1) causing many deaths and damages. Because of the earthquake, approximately 100 persons were killed and over 1,000 persons out of the 40.000 inhabitants were injured. In Dinar town, 2,050 buildings were totally destroyed, 4,400 suffered severe damage, while approximately 10,000 in the broader area were partly affected. The most significant damage was selectively observed in some parts of Dinar town and, according to the analysis (Carydis et al, 1995; Carydis & Lekkas, 1996), it was due to the geological, geotechnical and geomorphological conditions of the area.

Based on the data of the field survey which was collected within the framework of the Greek aid mission, instrument recordings of recent shocks and the data of the current century earthquakes, which struck the broader area of Dinar, an approach to the neotectonic setting and the evolving neotectonic processes of the area and SW Turkey will be hereby attempted.

2. SEISMICITY

The study of historical earthquake records (Ambraseys, 1975; Guidobani et al., 1994; Ambraseys & Finkel, 1995) reveals that the historical town of Dinar (Apemea) had been damaged several times: in 400 BC, 88 BC, and 53 AD. More recently, the 1875 earthquake ($I_o \cong$ IX-X), which affected a large area, caused damage in Dinar. On 7th August 1925, another earthquake ($I_o \cong$ VII-IX) occurred in the region, destroying about 2,500 residences and killing 330 people (Ambraseys, 1988). Ambraseys (1975, 1988) reported that both the 1875 and 1925 earthquakes occurred on the NE-SW trending Baklan fault (Fig. 2). However, Burdur earthquakes on 3rd October 1914 (Ms = 7.0, I_o=IX) and 12th May 1971 (Ms=6.2, I_o=IX) clearly occurred on the NE-SW trending Burdur fault zone. The 1914 earthquake has been associated with an approximately 20-kilometer long, normal, NE-SW trending fault rupture along the southeast coast of

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the Burdur lake, which is situated approximately 60 km from Dinar. In the 1971 earthquake 1,487 residences were destroyed in Burdur killing 57 people.

3. NEOTECTONIC SETTING

The broader area of Dinar - Isparta - Burdur - Baklan lies eastwards of the imaginary extrapolation of the Greek and Cypriot arc (**Fig. 1**). More specifically, it is situated at the north east of Pliny-Strabo zone, which is characterised by a mainly sinistral motion component, and at the north west of the Cyprus zone, which is characterised by a mainly dextral motion component.

A direct result of the macrostructure is the current neotectonic setting, which includes the study area of Dinar - Isparta - Burdur - Baklan. It is worth mentioning the large normal NE-SW and NW-SE trending fault zones with a slightly sinistral and a slightly dextral component respectively (Barka et al, 1995) that form neotectonic horsts and grabens with the same arrangement

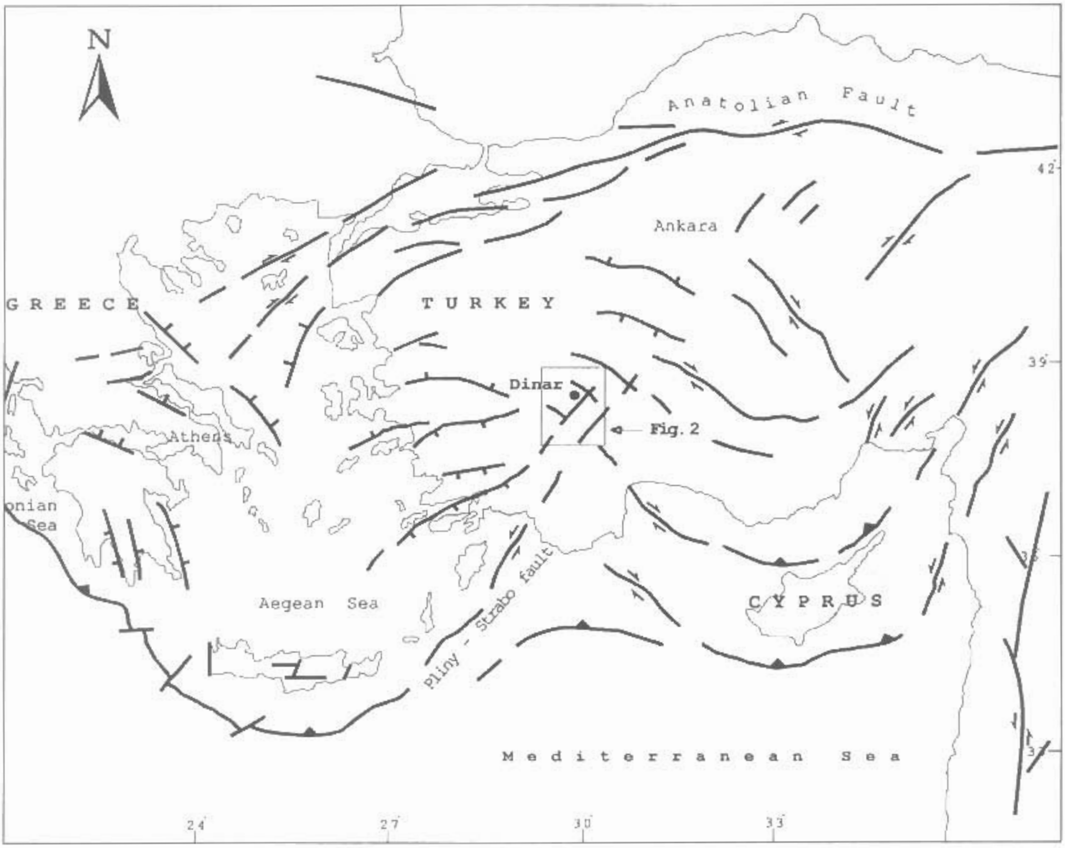

Fig. 1: Schematic tectonic map of the Aegean and Anatolia region. Bullet indicates the epicentre of the 1st October 1995 Dinar earthquake

In Burdur, Acigol, and Baklan, there are characteristic NE-SW trending grabens (Fig. 2) which are arranged parallel to each other. Towards SE these grabens are interrupted by the Dinar graben which has an oblique NW-SE strike. The occurrence of grabens is detected partly by the fault zones, but mainly by the occurrence of Plio-Pleistocene-Holocene formations within the morphological depressions, in contrast with the occurrence of Alpine formations on horsts.

The NE-SW tr... earthquakes in the past.

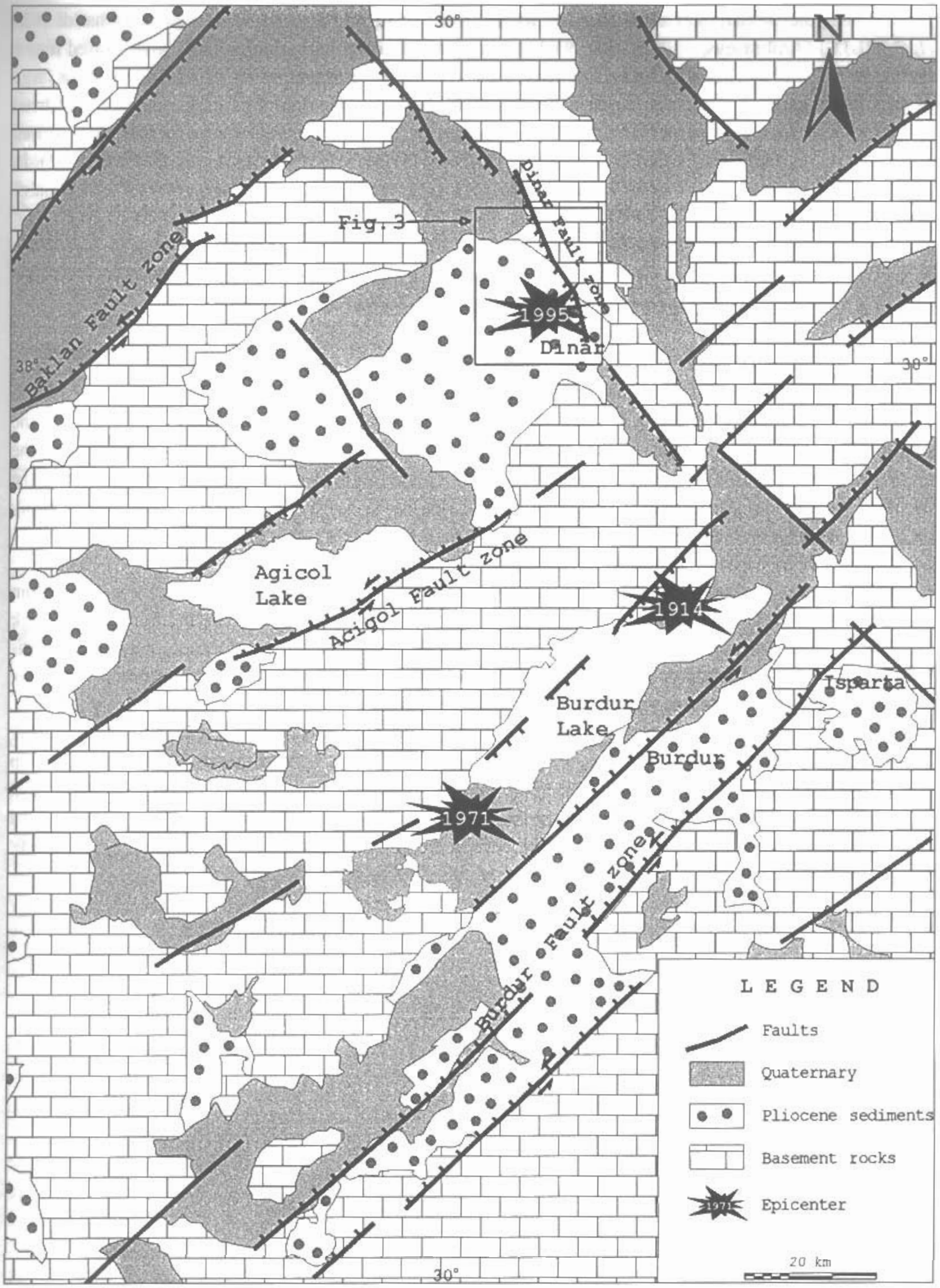

Fig. 2: Simplified neotectonic map of the Burdur-Isparta-Dinar-Baklan area, showing the two main fault systems of the area striking NE-SW and NW-SE respectively. The two main neotectonic grabens are confined by them. Stars indicate the epicenters of major shoc 1996 with modifications and additions).

For instance, the Baklan fault zone is related to the 1875 earthquake ($I_o \cong$ IX-X) as well as to that of 1925 ($I_o \cong$ VII-IX) (Ambraseys, 1975, 1988). Within the current century, the Burdur fault zone caused major earthquakes in 1914 (Ms=7.0) and 1971 (Ms=6.2). The 1914 earthquake was accompanied by a large surface occurrence of a NE-SW trending normal fault about 20 km long. The surface rupture occurred along the fault zone that borders the graben. Similarly, the 1971 earthquake was generated by a normal NE-SW trending fault with a slightly sinistral component (Erinc et al, 1971; Taymaz & Price, 1992). In addition, according to data of geographical positioning systems there is a 1.5-cm/yr respective motion of the fault blocks (Reilinger et al, 1995).

Despite its length and its significant role to the active neotectonic structure, the Dinar fault zone (Price & Scott, 1994) is considered to have been the less active among the Burdur, Acigol, and Baklan zones and it has not been reported to have generated major shocks (Sengor et al, 1985; Sengor, 1987).

4. SURFACE RUPTURE DATA

A fault rupture about 11 km long, extending from Dinar to Yapagli town, occurred on the surface during the 1st October 1995 shock (Fig. 3). The fault had a general NW-SE trend and in fact separated the flat surface of the approximately 800-1000 m high plateau which is situated to the SW, from the approximately 1000-1700 m high mountainous group which is situated to the NE. In essence, this was the marginal fault of the graben which separated it from the horst to the NE. The fault could not be easily defined to its full length prior to the earthquake because of successive talus cones in most sites.

The seismic fault can be divided into two parts:

- The first part is approximately 3 kilometers long, it strikes approximately N-S and it extends from Dinar town to Culpuk site. The maximum movement of its blocks was 15 cm and the western block has moved downwards in relation with the eastern. In some parts, especially where it bisects constructions, a slightly dextral component was observed (Fig. 4). It is worth mentioning that along fault ruptures, the damage was significantly increased (Fig. 5).
- The second part is approximately 8 kilometers long; it strikes 130-145° and it extends from Cupluk site to Yapagli town. The maximum movement of its blocks was approximately 30-40 cm and the dip of the fault plane is 70°-90° SW. The SW block had moved downwards in relation with the NE. In some sites SW of the main outcrop, up to 100 meters away from the fault surface, nearly parallel "antithetic" faults have occurred. In many sites, a slightly horizontal dextral movement component which did not exceed 5 cm, was observed, suggesting that it is a normal dip-slip fault.

It should be mentioned that to the north-west of Yapagli town, 5 km away of the imaginary extrapolation of the seismic rupture, a NW-SE mirror fault surface was observed but it didn't bear any reactivation traces, related to the shock in question.

5. SEISMOLOGICAL DATA

The Dinar earthquake (1st October 1995) was preceded by a series of foreshocks, which occurred the last 6 days prior to the mainshock and caused minor damage to some buildings. This seismic activity alerted the inhabitants and many of them had already left the town or moved outside their houses when the main shock struck.

The first foreshock with magnitude M_d=4.5 occurred on the 25th September (141 hours before the mainshock) and was widely felt by local people. On the whole, 35 foreshocks with magnitude M_d=3.0 were recorded. The foreshock activity ceased 51 hours prior to the mainshock. Two foreshocks with magnitude M_d=3.9 and M_d=3.5 occurred 13 hours and 39 minutes prior to the mainshock respectively. The foreshock activity occurred in Dinar town, which later became the epicentral area of the mainshock with Ms=6.1 magnitude (Eyidogan & Barka, 1996).

A number of automatic preliminary CMT solutions for Dinar earthquake have been reported by USGS-PDE and Harvard, USA; ERI, Japan; and EMSC, Germany (Table 1). The best double-couple fault plane solutions determined by the ... solutions show dominant normal faulting, the solution reported by USGS-PDE has a considerable strike-slip component. The focal depths relocated by the above data centres are found to have been too deep in comparison to a major fault scarp associated with the Ms=6.1 Dinar mainshock.

According to an analytical evaluation and process of recordings and macroseismic data, Eyidogan & Barka (1996) provided a version of the solution of the 1st October 1995 earthquake (Fig. 3) as well as a table with the main shock parameters (Table 1).

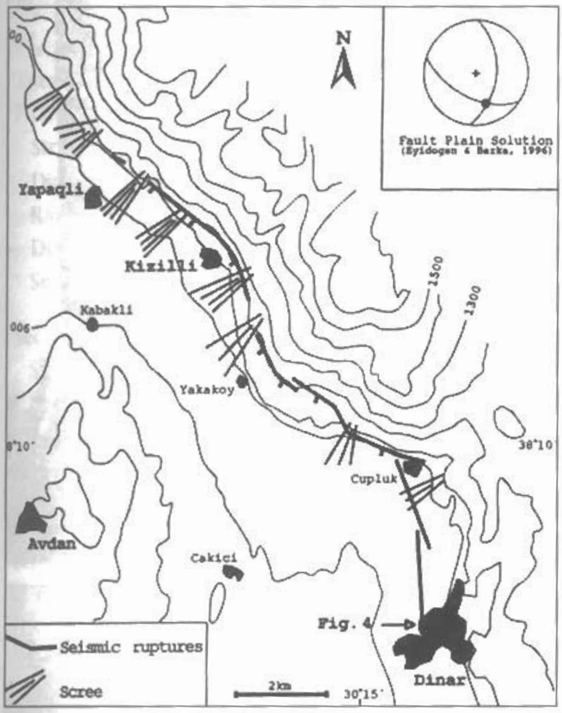

Fig. 3: Map of the surface rupture that followed the Dinar earthquake.

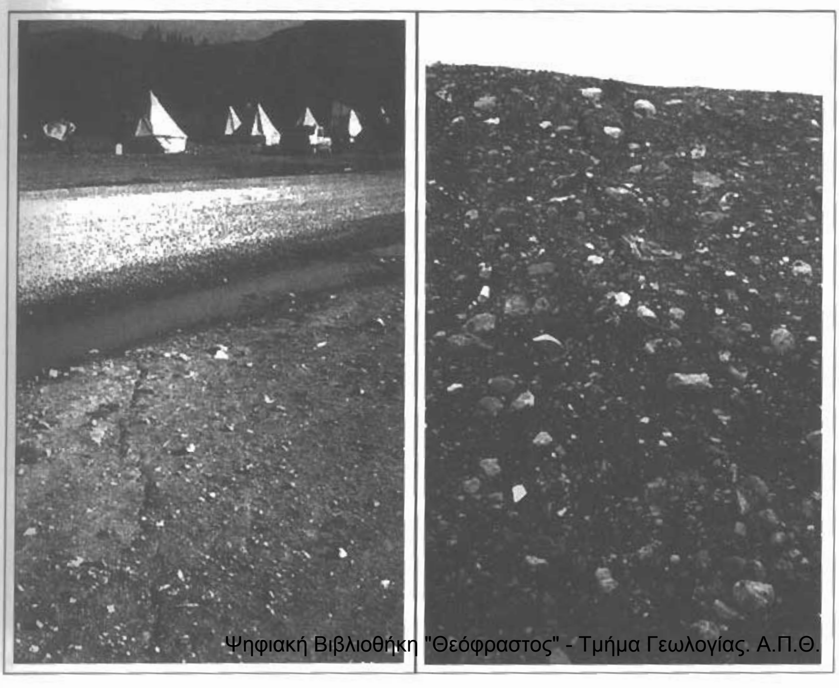

Fig. 4: View of the seismic rupture in the town of Dinar.

Fig. 5: Collapsed buil[illegible]ures.

Table 1

Source parameter	Value
Origin time	15:57:16 (GMT), 1 October 1995 (USGS-PDE)
Location	38.099° N-30.175° E (USGS-PDE)
M_s	6.1 (USGS-PDE)
m_b	5.7 (USGS-PDE)
M_w	6.2, 6.0 (USGS-PDE), 6.3 (HRV)
Total seismic moment	2.0 x 10^{18} Nm, 1.3 x 10^{18} Nm (USGS-PDE)
First sub-event	
Strike	135° (fixed)
Dip	40° ± 8°
Rake	255° ± 19°
Depth	8 ± 2 km
Seismic moment	0.38 ± 0.1 x 10^{18} Nm
Second sub-event	
Strike	135° (fixed)
Dip	62° ± 2°
Rake	221° ± 3°
Depth	12 ± 2 km
Seismic moment	± 0.2 x 10^{18} Nm

USGS-PDE = United States Department of the Interior Geological Survey, Preliminary Determination of Epicentres

HRV = Harvard University Determination

6. DISCUSSION AND CONCLUSIONS

Dinar mainshock (1st October 1995, Ms=6.1) in SW Turkey constitutes a snapshot of the geodynamic - neotectonic evolution of the area, which includes successive and characteristic evolution periods and is marked by geodynamic events, which are either older and can be studied by means of a geological - tectonic survey of the area, or are contemporary and can be studied by analysing instrument recordings of seismicity and surface macroseismic results of the earthquakes.

As it has already been mentioned, the area of Burdur-Isparta-Dinar-Baklan is characterised by the presence of NE-SW and NW-SE trending grabens bordered by fault zones of horsts with a respective trend. The grabens have been filled by Pliocene - Holocene formations in contrast to the horsts where Alpine formations occur.

Correlation of field data and instrument recordings regarding the 1st October 1995 earthquake, determines a NW-SE strike for the seismic fault and normal dip slip with a slight horizontal and dextral movement. These data pinpoint the fact that the area is dominated by a tensional stress field with a general ENE-WSW trend.

In addition, data analysis of the 1914 earthquake, (Ms=7.0) determined that the shock had been accompanied by a surface occurrence of a normal NE-SW trending seismic fault (approximately 20 kilometers long) of the Burdur fault zone. Moreover, analysis of the recordings of the 1971 Burdur earthquake, (Ms=6.2) determined a normal NE-SW movement with a slight sinistral component. This outcome is further supported by G.P.S. and field data. The above indicate a tensional field acting WNW-ESE.

The geometrical characteristics of the fault zones (NE-SW and NW-SE strike) are perfectly combined with trigger mechanisms and the surface data of contemporary earthquakes. Furthermore, the kinematic characteristics are also identical to those derived by the solutions of the focal mechanisms which, on the whole, point to normal dip-slip movements of the fault blocks with a slight sinistral movement on NE-SW trending faults and a slight dextral movements on faults normal to that.

Combination of both geometric and kinematic characteristics of the faults as well as the recent seismicity data of the Burdur - Isparta - Dinar - Baklan area, shows that a tensional stress field dominates the area and that strike alternates from ENE-WSW to WNW-ESE. The local stress field can be explained through a regional E-W tensional field, which is influenced by a less intense shear stress field. The combination of these stress fields forms grabens striking NW-SE, SW-NE and slight horizontal sinistral and dextral movement components which occur on the respective faults. The shear stress field appears to predominate up north in Central Turkey during Quaternary (Westaway, 1990a,b).

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