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Fault-block rotations at the edge of a zone of continental extension; southwest Turkey

SIMON P. PRICE

Cambridge Arctic Shelf Programme, Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ, U.K.

and

BARRY SCOTT

Department of Geology, University of Leicester, University Road, Leicester LE1 7RH, U.K.

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Abstract—The NE–SW-trending Burdur, Acıgöl and Baklan basins of southwest Turkey are bounded by normal faults, which became active in Quaternary times. Prior to this a more widely spaced system of Pliocene basins had existed. Each of the Quaternary basins has a half-graben geometry with a major NW-dipping fault on its southeast side. Previous studies of the 1971 Burdur earthquake, caused by movement on the fault bounding the Burdur Basin, have shown this fault to flatten slightly at depth. Deformation in the hangingwall of the fault controlling the Pliocene basin in the Burdur region suggests a planar fault geometry. It is suggested that the Pliocene fault rotated to its present shallow orientation, then became inactive and acted as a detachment, at depth, for the more recent Quaternary fault. Quaternary faults bounding the Burdur, Acıgöl and Baklan basins have a sinistral strike-slip component, with slip vectors indicating extension in an NW–SE direction. This is at variance with regional N–S extension in western Turkey. A solution for this contrast is found by invoking block rotations about vertical axes in a deforming zone between the rapidly extending Aegean region to the west and the stable unstretched Anatolian Plateau to the east.

INTRODUCTION

CONTINENTAL extension has been widespread in the Aegean region since Late Miocene time and may have begun in Early Miocene time in some areas (McKenzie 1978, Seyitoğlu & Scott 1991). The Aegean extensional province (Fig. 1) covers an area of approximately 4 × 10^5 km^2. It is bordered to the south by the Hellenic Arc, where oceanic crust on the leading edge of the African plate is subducting northwards (McKenzie 1972, 1978). Its northern, western and eastern boundaries are relatively diffuse.

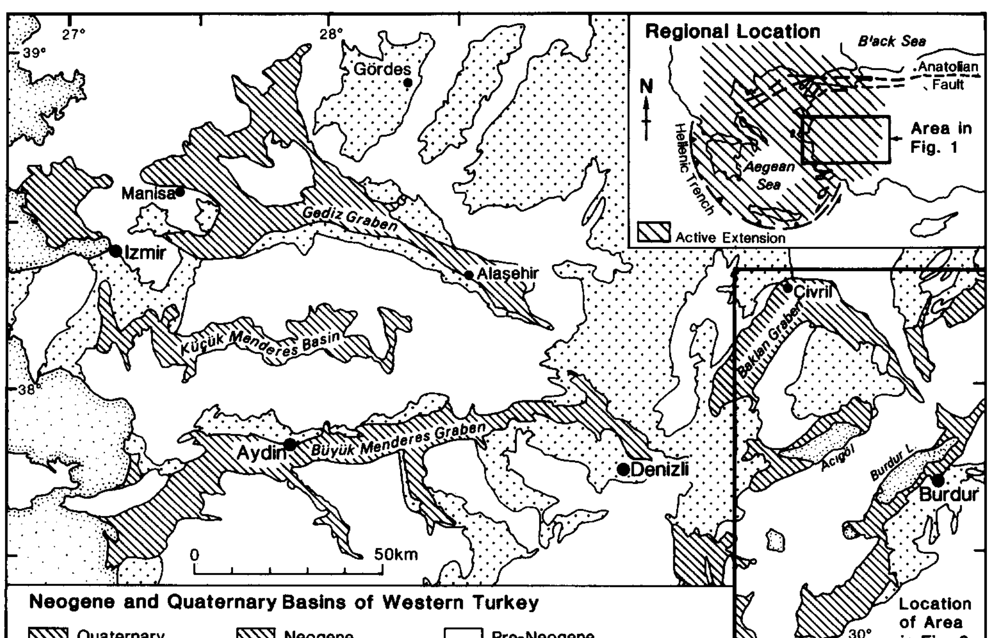

Fig. 1. Map showing the position of the study area in relation to the Aegean extensional province and Neogene and Quaternary basins in western Turkey.

Deformation in western Turkey is complex, with upper crustal fault-block rotations occurring about both horizontal and vertical axes. Rotations about horizontal axes are necessary for the upper crust to deform by pure shear during faulting (Jackson 1987). Rotations about vertical axes in western Turkey have been explained in the broken-slat model of Taymaz *et al.* (1991), where the whole of western Turkey is considered to rotate anticlockwise. However, palaeomagnetic data suggest that some areas of western Turkey have rotated clockwise, believed by Westaway (1990a) to be due to the frictional torque of adjacent, anticlockwise rotating blocks. In this paper we describe one such area, the Burdur region, which is situated at the eastern edge of the Aegean extensional province (Figs. 1 and 2) between the Aegean crust (22–32 km thick) and Anatolian crust (40–50 km thick) (Makris 1976, Makris & Vees 1977, Makris & Stobbe 1984, Mindavelli *et al.* 1989). Crustal-scale nor-

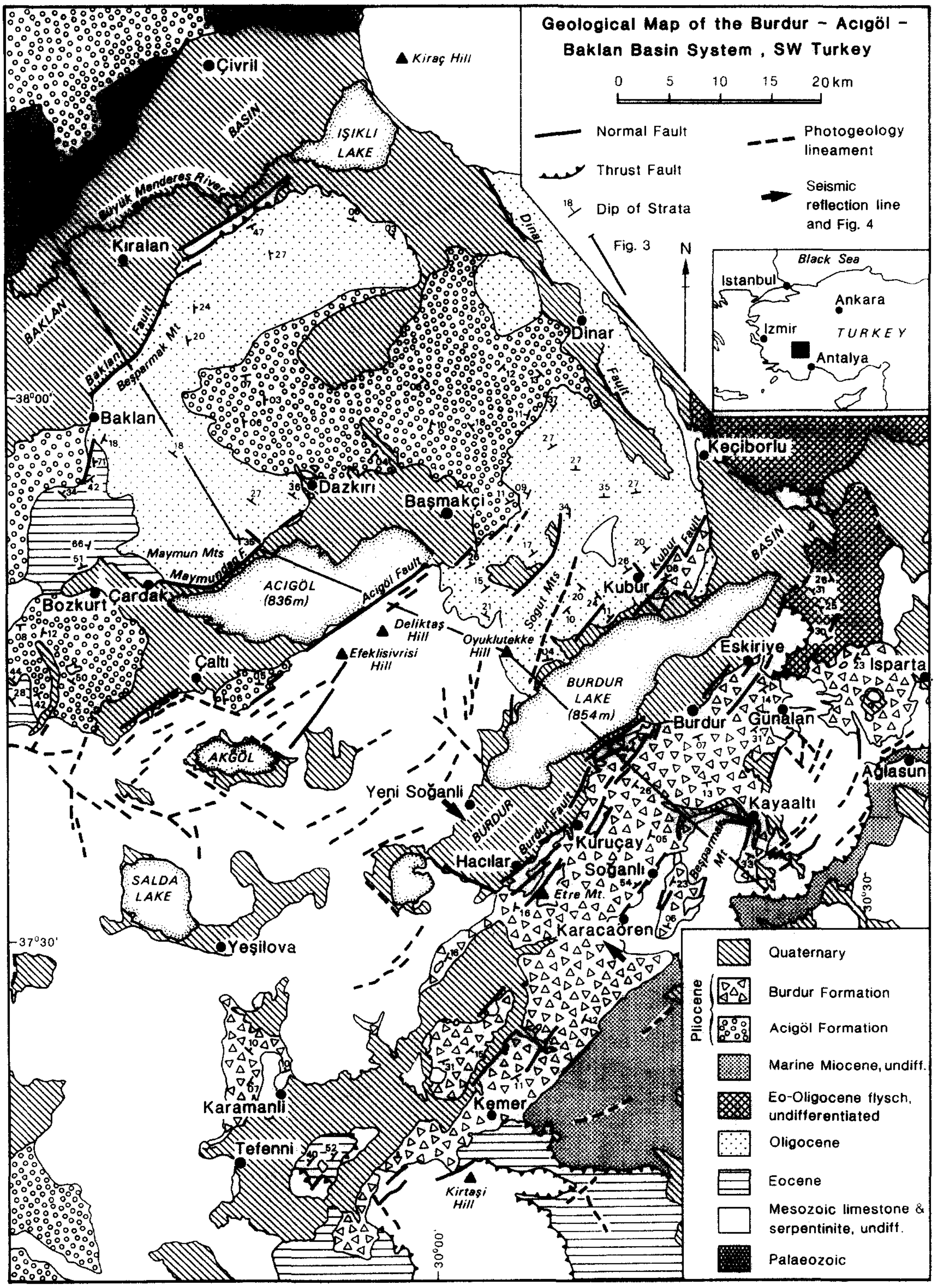

Fig. 2. Geological map of the Burdur, Acıgöl and Baklan basins. The positions of sections in Figs. 3 and 4 are shown.

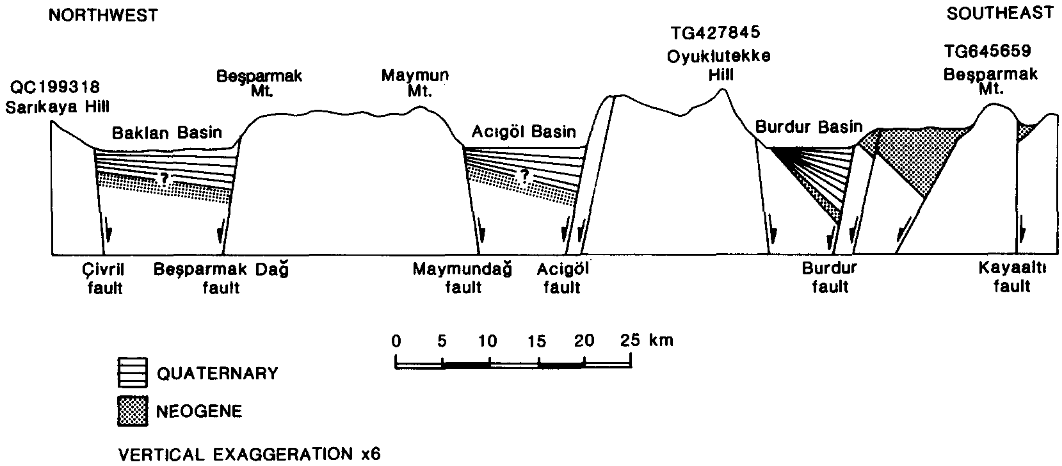

Fig. 3. Geological cross-section through the Burdur, Acıgöl and Baklan basins (located on Fig. 2).

mal faults in this region have a unique kinematic evolution which is explained as a diffuse boundary effect between these two different tectonic regimes.

BASIN STRUCTURE

Faults in the study area bound three narrow NE–SW-trending depressions; the Burdur, Acıgöl and Baklan basins (Figs. 2 and 3). These formed at the beginning of the Quaternary era, when a more widely spaced Pliocene fault-controlled 'saw-tooth' topography became gravitationally unstable and collapsed to give the more stable configuration of the present-day basin system (Price 1989, Taymaz & Price 1992). Quaternary faults controlling these three basins control topography and their slip planes are well exposed. Older Pliocene basin-bounding faults form the boundaries to the now inactive Pliocene basins. As most of these faults became buried at the end of the Neogene they are now poorly-exposed.

Burdur Basin

The segmented Burdur Fault crops out along the southeast margin of the basin (Wedding & Inque 1967, Karaman 1986a,b) (Figs. 2 and 3). This fault formed towards the end of the Pliocene, when faults controlling a single older Pliocene basin became inactive and faulting moved to the northwest, effectively dissecting the basin (Price & Scott 1989, 1991). Part of the Pliocene basinal succession (the Burdur Formation) was uplifted in the footwall of the Burdur Fault. The contents of the former basin are actively eroding into the present-day Burdur Basin. Continuous sedimentation across a single Pliocene basin is indicated by basal Pliocene conglomerates sitting unconformably upon serpentinite basement in the footwall of the Burdur Fault 7 km west-southwest of Burdur. These contain clasts of Oligocene conglomerates exposed on the northwest side of the Quaternary graben.

Figure 4(a) is a non-migrated seismic section from the southern end of the Burdur Basin, running perpendicular to the regional strike (Fig. 2). Strong SE-dipping reflectors at the northwest end represent the basin fill beneath the present-day Burdur Basin. These terminate 7 km to the southeast against a region containing no reflectors. This sub-surface termination can be correlated with a NW-dipping segment of the Burdur Fault at the surface (Fig. 2). There are no major reflectors below 2 s two-way time (which corresponds to a depth of about 2 km) because at this depth massive basement Mesozoic limestones without large velocity contrasts are reached. The southeast end of this section represents the uplifted succession of the Pliocene basin, southeast of Etre Mountain (Fig. 2). Here, large hyperbolic diffractions define a NW-dipping normal fault against which a series of SE-dipping reflectors terminate. The separation between these reflectors increases southeastwards.

The Pliocene–Quaternary boundary beneath the present-day Burdur Basin is taken at a depth of 450 m on the seismic section (Fig. 4b). This boundary appears to mark a minor unconformity, which may be associated with the gravitational collapse of the graben during the end of the Pliocene (Taymaz & Price 1992). However, mass balancing of the eroded Burdur Formation suggests that the depth of this boundary may be greater than 800 m (Price 1989).

Acıgöl and Baklan basins

Faults occur along both margins of the NE–SW-trending Acıgöl and Baklan basins (Erinç 1967, Bering 1971, Koçyigit 1984) (Figs. 2 and 3). Geomorphological evidence points to greater subsidence rates along the southeast margins of both basins. The size of the footwall scarp associated with the Acıgöl Fault on the southeast margin of the Acıgöl Basin (length 15 km—relief 1100 m) is much greater than that of the Maymundağ Fault along its northwest margin (length 6 km—relief 780 m). Also, the lake (Acıgöl) sits against the southeast margin of the basin (Fig. 2) and alluvial fans originating in the slope of the footwall of the Acıgöl Fault are poorly developed and of limited areal extent (less than 1 km^2). Blair & Bilodeau (1988) demonstrated that lakes respond more rapidly to subsidence than fans at the fault-controlled margins of sedimentary basins.

Also, a Quaternary erosion surface above deposits of the Pliocene Acıgöl Formation to the east-southeast of Çaltı (Fig. 2) has a shallow dip to the southeast. The Acıgöl Formation also has a general dip to the east-southeast further supporting a half-graben geometry with the major fault occurring on the southeast side of the basin. On the enhanced LANDSAT 5 TM image of the study area shown in Taymaz & Price (1992; their fig. 8) the Baklan Fault (Fig. 2) is clearly discernable as a lineament traceable for almost 15 km. The linearity of this margin of the basin compared with the opposite margin suggests faulting in recent times. Also, the Büyük Menderes River, which flows axially through the basin, occupies an asymmetrical meander belt with the abandoned part to the northwest of the active channel. The channels of meandering rivers in half-graben commonly move laterally towards the major basin boundary fault (e.g. the area of maximum subsidence) (Alexander & Leeder 1987).

FAULT GEOMETRY

Quaternary faults

The Burdur Fault (Fig. 2) is similar to faults described by Hancock & Barka (1987) from Yavansu, near Kuşadasi on the Turkish Aegean coast. Each individual segment is a slip plane against a basement topographic high. Slip planes are striated and overlie compact breccia sheets, which become increasingly degraded upwards. At 15 km, the Acıgöl Fault is the longest continuous fault segment in the study area. A layer of incohesive breccia, up to 15 m in width, occurs intermittently along the fault. This is underlain by a poorly exposed slip plane, which separates the breccia from well-jointed Mesozoic limestone. The Maymundağ Fault on the northwest side of the Acıgöl Basin, trends NE–SW at its northern end and ESE–WSE at its southern end (Fig. 2). There is no clear slip plane on this fault. The faults bounding the Baklan Basin are marked by a change in surface topography and slip planes of these faults are poorly exposed.

A large earthquake ($M_b = 6.0$; Ambraseys 1988) in the study area on 12 May 1971 caused ground rupture between the surface outcrops of the Burdur Fault in the vicinity of Hacilar (Erinç *et al.* 1971, Keightley 1975). Waveform modelling of the main shock of this event by Taymaz & Price (1992) suggested that the slip vector of the fault at the hypocentre plunged at 35° ± 5° towards 338. The average slip plunge taken from striations measured on the most reliable slip plane at the surface is 66°. Taymaz & Price (1992) took these observations to indicate that the Burdur Fault shallows at depth. No recent movements have occurred on other Quaternary faults in the study area.

Pliocene faults

Faults of undoubted Pliocene age are difficult to recognize and some of the Quaternary faults may represent older reactivated structures. The boundary fault to the Pliocene Burdur Formation is exposed at only two localities; 1 km northeast of Soğanlı and 1 km north of Karacaören (Fig. 2). At both localities Pliocene fluvio-lacustrine sediments are in contact with basement serpentinite. At the latter locality travertine and marls dip up to 25° away from the fault plane (to the northwest) which has a shallow dip of 47° to the northwest. At Soğanlı Pliocene fan delta sediments dip up to 30° away from the fault plane (i.e. to the northwest) which here has a dip of 47° to the northwest. The cessation of activity on this fault is shown by its degradation and overlap by hangingwall strata (Price & Scott 1991, their fig. 6). The dip of the sediments away from the fault plane at both localities is due to compaction against relatively rigid serpentinite basement in the footwall of the fault. This dip can also be seen on Fig. 4(a) as NW-dipping reflectors.

The sub-surface geometry of the Pliocene basin-bounding fault is investigated here by considering the geometry of the syn-rift Burdur Formation using the dip profile method of Roberts (1988). The Pliocene boundary fault is exposed at the southeast end of the Kuruçay–Güngörmez Tepe dip profile from the central part of the basin (Fig. 5). A clear decrease in SE dip occurs towards the fault until within 1 km of its location, where dips change direction. There are exceptions, as at 6 and 7.5 km, where frictional drag on synthetic faults in the hangingwall succession causes a local reversal of dips to the northwest. The increase in bedding dip away from the fault in this dip profile is indicative of sedimentation in the hangingwall of a rotating planar fault since listric faults always show the opposite relationship (Roberts 1988). Assuming the fault-block to have rotated in a coherent manner, Quaternary tilting will not affect the shape of the dip profile: SE dips will increase and NE dips decrease.

In order to produce a model dip profile for the Kuruçay–Güngörmez Tepe section the dip of the boundary fault at its southeast end, the amount of rotation since its formation and the depth of erosion (down to the profile level) in the hangingwall must be known (Roberts 1988). As already mentioned, the Pliocene boundary fault dips to the northwest at 47°. The base Pliocene reflector on the seismic sections from the southern part of the Burdur Basin dips to the southeast at 13° (Fig. 4b). Assuming this to be a pre-faulting horizontal datum this is the combined Pliocene and Quaternary rotation, which the fault has undergone since its formation, giving it an initial dip of 60°. Lignite from Sultandere mine 3 km south of Burdur has a calorific value of 16,700 kJ kg^{-1} (Wedding & Inque 1967). Comparison with established coalification curves (i.e. see Roberts 1988) suggests an approximate burial depth of 1000 m, giving a depth of erosion for the Burdur Formation.

Figure 5 shoes the synthetic dip profile from Roberts (1988) for a fault now dipping at 45°, which has been rotated through 15° as in the Kuruçay–Güngörmez Tepe section (within field measurement error). The model

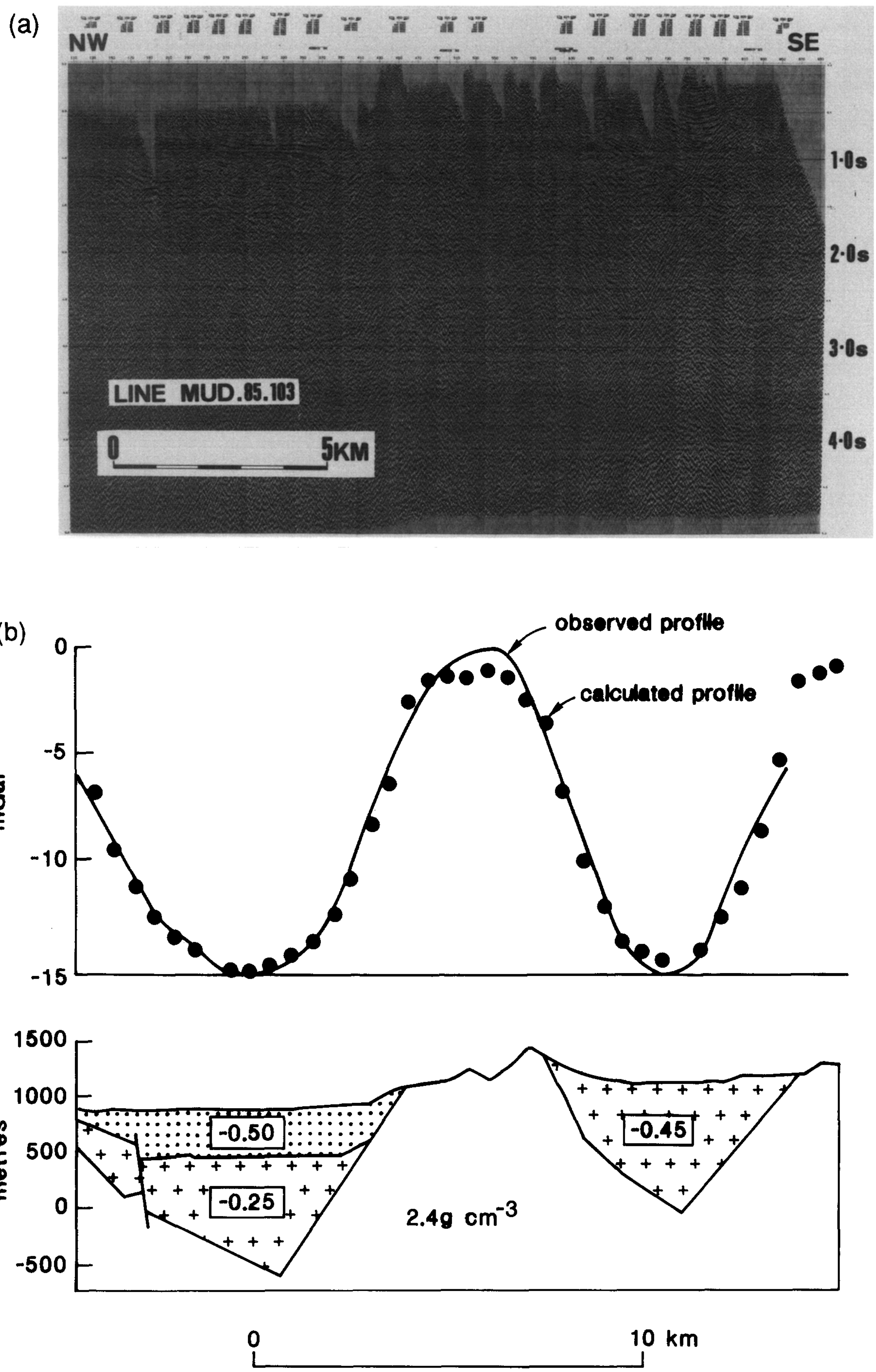

Fig. 4. (a) Unmigrated seismic section through the southern part of the Burdur Basin (located on Fig. 2). (b) Migrated depth–density model of (a). The dotted and crossed areas on the section are intepreted as Quaternary and Pliocene sediments, respectively. See text for discussion on the position of the boundary between the two.

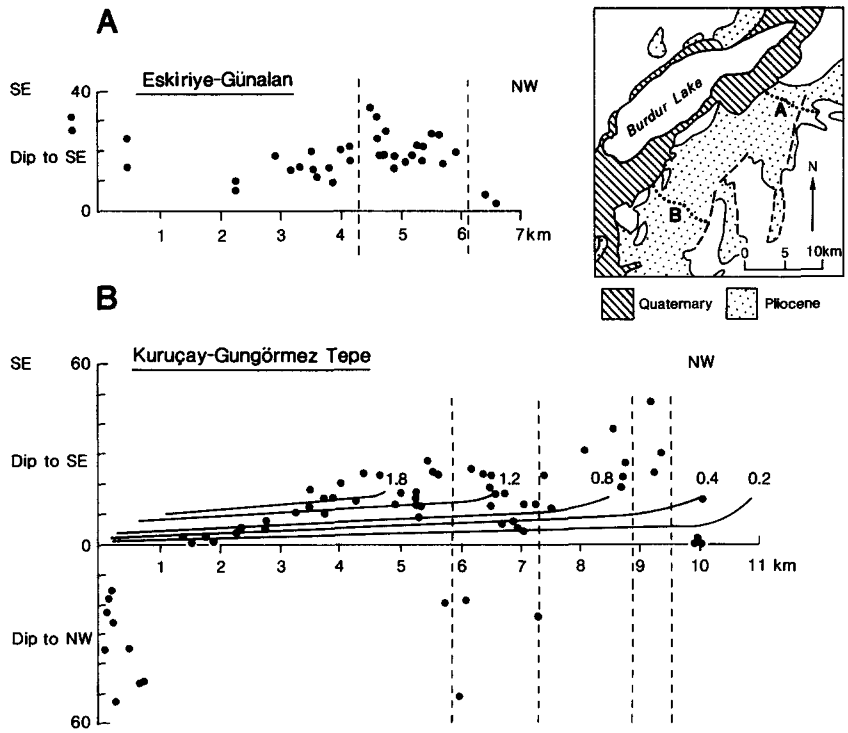

Fig. 5. Observed (dots) and synthetic (lines) dip profiles across the Pliocene Burdur Formation. The distance from the now buried basin-boundary fault is shown on the x-axis. the positions of faults within the Burdur Formation are shown as dashed lines. (See text for discussion of profiles.) The synthetic dip profiles are for a fault now dipping at 45°, which has been rotated through 15° (from Roberts 1988). Figures correspond to depth of erosion (in kilometres) in the hangingwall. A figure of 1 km is likely for Burdur (see text for discussion).

and observed dip profiles are in reasonable agreement. The observed profile shows a more rapid increase in bedding dip away from the fault than the model profile and the former also shows that near to the fault beds dip in the opposite direction (to the northwest, away from the fault). Both of these differences are considered to be caused largely by compaction, which will have the effect of reducing, or, as seen in Fig. 5, reversing the dip of the beds near to the fault plane and increasing their dip away from it. Compaction was not modelled by Roberts (1988). Also, as previously mentioned, Quaternary tilting will bring observed values above the modelled line.

In summary, a comparison of model and observed bedding dip profiles in the hangingwall of the Pliocene basin-boundary fault suggests a rotating planar fault geometry.

A model for fault evolution

The geometry of the Burdur Formation suggests a planar fault geometry in Pliocene time, whereas field observations and earthquake waveform modelling of the Quaternary Burdur Fault suggest some flattening at depth (Taymaz & Price 1992). Previous studies have shown that faults often reactivate pre-existing basement anisotropies (e.g. Şengör *et al.* 1985, Laubach & Marshak 1987). It is, therefore, possible that the geometry of the Burdur Fault was influenced at depth by the relatively shallow Pliocene fault.

Uncertainties in the exact geometries of both Pliocene and Quaternary faults prelude an accurate determination of upper crustal extension on geometrical grounds. If extension is accommodated on rotating planar faults then β, the factor by which extension increases, is related to the initial (60°) and final (47°) fault dips giving a value of 1.18 for the Burdur region (see Jackson & McKenzie 1983). However, this method will underestimate β if there is any curvature at depth on the fault. A fault dip of 35° at depth will increase β to 1.30 (see White 1988).

FAULT-BLOCK DEFORMATION

Graben orientation

A peculiarity of the basins in the region is their NE–SW orientation. West of the region are the Büyük Menderes, Küçük Menderes and Gediz graben, all E–W structures. However, as Fig. 1 shows, the Burdur, Acıgöl and Baklan graben have a similar orientation to the cross-graben north of the Gediz Graben. They may, therefore be genetically related to these structures, believed by Şengör *et al.* (1985) and Şengör (1987) to have formed as a result of differential stretching in the hangingwall of the Gediz Graben. A study of LANDSAT 5 images of the region, together with field mapping, show a distinct NE–SW joint pattern to the pre-Pliocene (largely Eocene–Oligocene and Mesozoic) basement (Price 1989). Such a fabric is not evident in the observed Pliocene sequences where the dominant trend is NNE–SSW. It is likely then that the NE–SW orientation of the graben in the Burdur region is an inherited feature, taking advantage of features in the palaeotectonic basement. Şengör *et al.* (1985) showed this for the Büyük, Küçük and Gediz graben and for the smaller cross-graben north of the Gediz Graben. The three main graben follow the general E–W-trending metamorphic fabric of the underlying Menderes Massif. Mindavelli *et al.* (1989) also suggest, from seismic studies in western Turkey, that azimuthal variations of Rayleigh and Love wave group velocities are consistent with velocities predicted by an anisotropic upper crust (to 20 km) in which vertical cracks are orientated in an approximate E–W direction. Parallelism of normal fault arrays with basement fabric has also been documented by Laubach & Marshak (1987) for the autochthonous Caledonian foreland of NW Scotland where post-Caledonian faults nucleated on a steeply-dipping basement fabric. As with Şengör *et al.* (1985) and Şengör (1987) they interpret faults which are orthogonal to the main trend to be due to break up of the hangingwall of the main faults, which have listric geometry.

Regional σ_3 orientation

Fault plane and slickenside lineation data are available for both Quaternary basin-bounding faults (Fig. 6) and faults within the Burdur Formation (Fig. 7). To avoid contamination of data by palaeotectonic (i.e. pre-rift) faults two criteria were used for selection. Faults chosen must be basin-bounding and must affect topography. The palaeostress determinations, shown on Figs. 6 and 7, were calculated using the method of Lisle (1987, 1988). The direction of least compression, σ_3, for all Quaternary basin-bounding faults is NW–SE (Fig. 6).

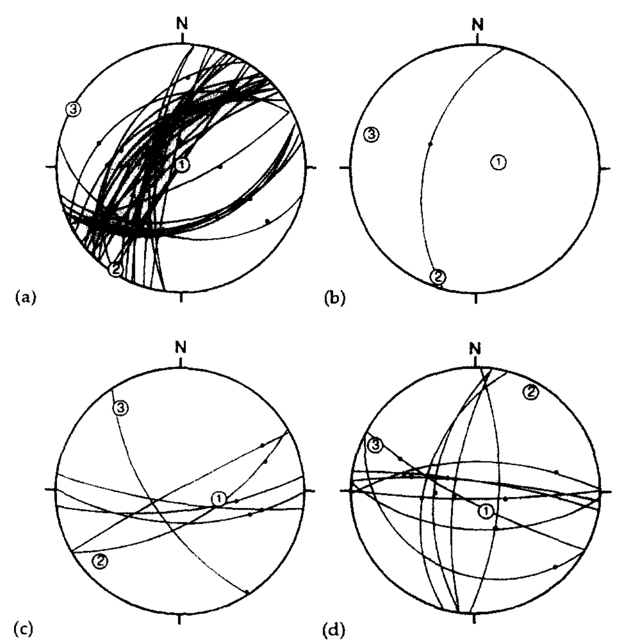

Fig. 6. Lower-hemisphere equal-area projections of slip planes and associated striations for (a) the Burdur Fault (projections for individual fault segments are given in Taymaz & Price (1992, their fig. 10)), (b) the Acıgöl Fault, (c) the Maymundağ Fault and (d) the Baklan Fault. 1, 2 and 3 are the principal stress axes (σ_1, σ_2 and σ_3, respectively) computed using the method of Lisle (1987). All faults have a normal dip-slip component.

The single slip plane for the Acıgöl Fault is the only reliable measurement. The pattern of faulting at Burdur shows that most measured faults dip to the northwest with some dipping to the southeast. This latter group are faults measured on the northwest side of the basin at Kubur (Fig. 2).

Data are also available for faults measured within the Pliocene succession of the Burdur Basin. In order to ascertain possible variation within this succession, data are grouped into seven sub-areas along its NW–SE strike (Fig. 7). The direction of least compression, σ_3, varies in orientation from NNW–SSW (area 7) to WSW–ENE (area 4) averaging approximately NW–SE. The spread of σ_3 may reflect irregular brittle deformation within the basinal succession.

Two important points arise from the above analysis. First, the data demonstrate that tectonic structure in the syn-rift hangingwall succession of major normal faults may not be useful in determining regional stress tensors. Secondly, the analysis for major basin-bounding faults shows a consistent NW–SE extension directly in the Burdur region which is in disagreement with the general N–S extension of the Aegean region of western Turkey shown both by palaeostress determinations (Angelier *et al.* 1981) and by earthquake focal mechanisms (McKenzie 1978, Jackson & McKenzie 1984). Figure 8 illustrates the regional N–S extension with discrepant E–W slip vectors on the eastern edge of the deforming zone. The study area lies at the eastern edge of the Aegean–Western Anatolian Extensional Province in the Transition zone of Şengör *et al.* (1985) and Lauer (1987) and this discrepancy in extension direction may be some kind of 'edge effect'. However, it must clearly be accounted for in any model concerning the evolution of the Burdur, Acıgöl and Baklan basins.

Block rotations

The tilts of syn-rift basinal sediments in the study area indicate rotation of fault blocks about horizontal axes. In addition, there is evidence for rotation about vertical axes in the study area. Large rotations about vertical axes in extending regions have become widely recognized in recent years, especially for the Aegean region (Laj *et al.* 1982, Kissel *et al.* 1984, 1985, 1986, Kissel & Laj 1988). Kissel & Poisson (1987) published palaeomagnetic data for Pliocene formations from the Antalya basin, to the south of the study area, and concluded that no significant rotations had occurred for at least 15 Ma. However, samples of volcanics from the Gölcük Member (4.5 Ma; Price & Scott 1989) at the northwest end of the Burdur Formation show a 12.5° (i.e. approximately 3° Ma^{-1}) clockwise rotation (Kissel *et al.* 1986). This locality is above the base of the Lycian nappes. Palaeomagnetic data from the Izmir region indicates an anticlockwise rotation of 29° (approximately 4° Ma^{-1}) (Kissel *et al.* 1986). Although the timing of this rotation is poorly constrained, a single K/Ar date of 7 Ma from a sampled lava near Izmir and the fact that block-faulting is generally post-Tortonian suggest that the rotations

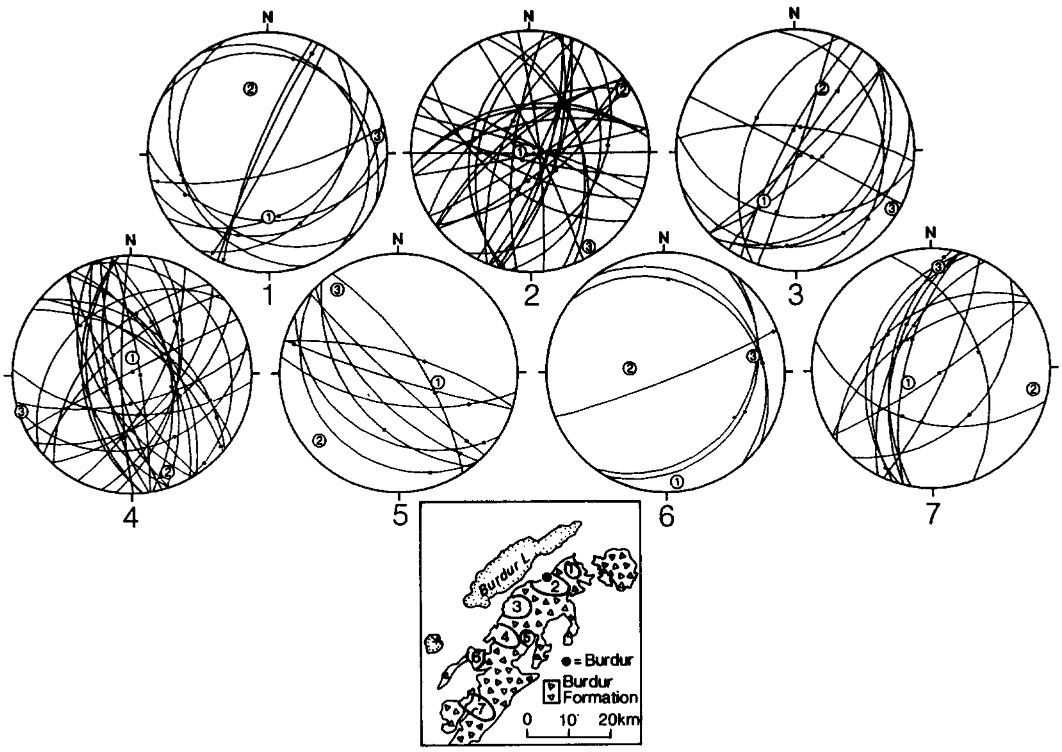

Fig. 7. Lower-hemisphere equal-area projections of slip planes and associated striations for faults within the Burdur Formation. The formation is divided into seven areas (inset map), each with a measured fault population. 1, 2 and 3 are the principal stress axes (σ_1, σ_2 and σ_3, respectively) computed using the method of Lisle (1987), for each fault system. All faults have a normal dip-slip component.

have occurred since this date (Kissel & Laj 1988). Kissel *et al.* (1986) suggest that anticlockwise rotations from the Izmir region are representative of the whole of western Turkey above the Lycian nappes. So, the local clockwise rotations near Burdur of approximately 3° Ma^{-1} oppose a proposed regional anticlockwise rotation of approximately 4° Ma^{-1}.

Deformational models

Any model describing active deformation for western Turkey must account for the discrepancy of σ_3 orientations between the study area and the area further to the west nearer to the Aegean coast, the basin orientation and geometry and the apparent clockwise rotations of crustal blocks. In the following section two basin evolution models, both potentially capable of producing the basin geometry of the region, are described.

It has already been mentioned that the three basins of the study area are parallel to the cross-graben north of the Gediz Graben and may therefore have formed in a similar manner. Şengör *et al.* (1985) and Şengör (1987) showed the faults controlling these graben to be controlled by cross-faults which accommodate differential stretching in the hangingwall of the main Gediz Graben Fault. Figure 2 shows that the three NE–SE-trending basins of the study area terminate in the northeast against the NW–SE-trending Dinar Fault. This fault was called the Çatma Daği Fault by Westaway (1990b). It may be a reactivated thrust as it is parallel and along strike from the Aksu Thrust which is a palaeotectonic structure overlain by Pliocene sediments and marks the base of the eastern flank of the Isparta Angle (Şengör & Yilmaz 1981). However, there is no doubt as to its present nature as a normal fault because at many localities along the mountain front northwest from Dinar (Fig. 2) slip planes can be observed with a normal dip-slip component. Additionally, footwall relief (i.e. uplift) of approximately 800 m associated with this structure suggests that it has had a relatively long history of footwall uplift. As such it is possible that the Dinar Fault is a major breakaway fault with the Burdur, Acıgöl and Baklan basins forming due to differential stretching of the hangingwall along cross-faults (as proposed by Westaway 1990b). This is further discussed below.

Several models have been proposed to explain fault-block rotations about vertical axes. A complex geometrical model involving strike-slip faults bounding an area deforming by rotations was proposed by Ron *et al.* (1984) and Garfunkel & Ron (1985). In this model surface area is conserved and stretching across the zone is balanced by shortening along strike. The two-dimensional model proposed by McKenzie & Jackson (1983, 1986) is simpler because the surface area increases within the deforming zone during extension and there is no shortening along strike. Therefore the motions of rigid plates bordering the deforming zone can more easily be related to deformation within the zone. This model bears a striking resemblance to the situation in the study area. Here, NE–SW-trending faults with approximately E–W slip vectors define clockwise-rotating blocks (Fig. 9). If the model fits, then the slip vectors on the faults define a N–S-trending deforming zone. The orientation of the faults dictates the velocity vector across this zone, which will have a dextral component with respect to the edge of the zone. Knowing the width of the deforming zone, the angle between the edge of the zone and the faults within it and the rate of rotation within the zone the model can be used to quantify the velocity vector across the deforming zone.

Geological data can be used to predict the width of the deforming zone. The zone will presumably incorporate all of the basement faults of the Burdur, Acıgöl and Baklan basins and with a N–S trend it must be at least 90 km wide. Figure 8 shows that to the east and west of the deforming zone Pliocene σ_3 determinations (from Angelier *et al.* 1981) indicate N–S extension. The stations where N–S extension was computed define a zone approximately 125 km wide. As the deforming zone is unlikely to have had its extremities at these stations a value somewhat less than this is likely and a value of 100 km is taken. It is interesting to note that Quaternary σ_3 determinations to the east of the deforming zone are E–W trending (Fig. 8), perhaps showing that the zone has extended eastwards in the last 5 Ma.

Assuming a N–S-trending deforming zone, the angle between the edge of the zone and the faults within the

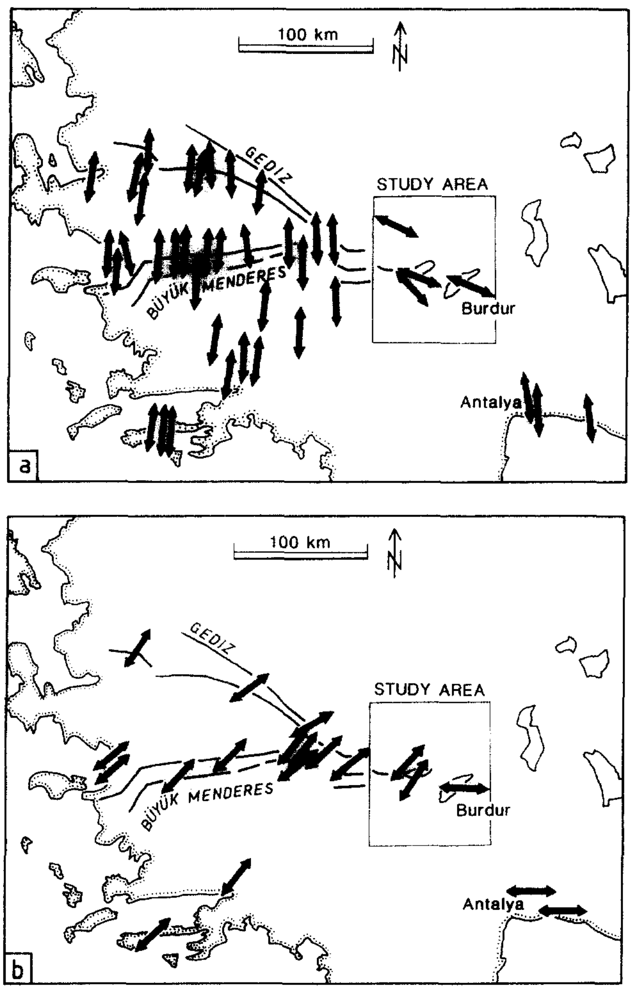

Fig. 8. (a) Regional σ_3 orientation for faults of Pliocene age in southwest Turkey. Note the change from N–S to NW–SE in the study area. (b) Regional s_3 orientation for faults of Quaternary age in southwest Turkey. (Both after Angelier *et al.* 1981.)

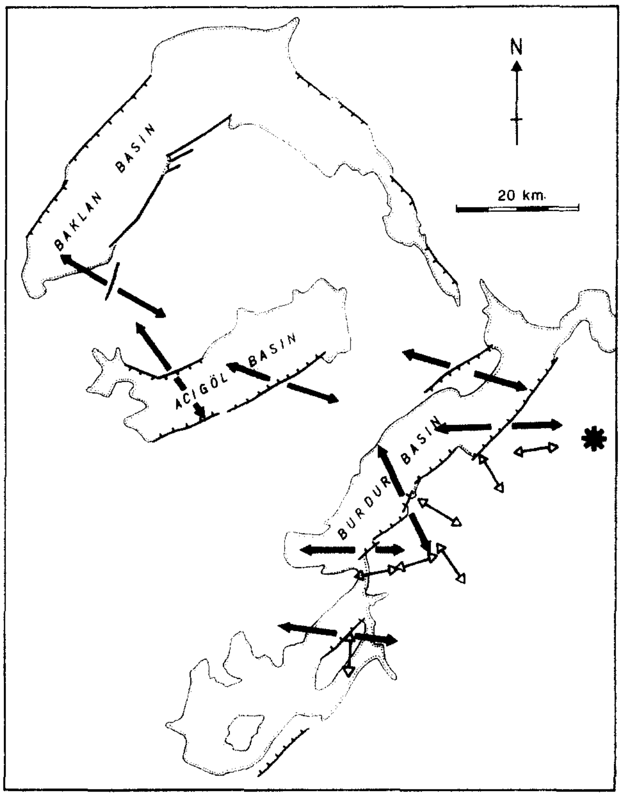

Fig. 9. Orientation of σ_3 in the Burdur, Acıgöl and Baklan basins. Black arrows indicate σ_3 orientation for Quaternary basin-boundary faults and small arrows for faults within the Burdur Formation. The star indicates the position of the palaeomagnetic determination in 4.5 Ma lavas undertaken by Kissel & Poisson (1986). Note the similarity between this figure and the pinned block model of McKenzie & Jackson (1986).

zone is about 45° (Figs. 2 and 9). This angle is consistent for the Burdur, Acıgöl and Baklan basins.

Palaeomagnetic data indicate a clockwise rotation rate of 3° Ma^{-1} within the deforming zone. This assumes that the local palaeomagnetic declination measured near to Burdur does not overprint the regional declination. The deforming zone rotates independently from any translation or rotation of the rigid boundary plates so there will be no overprinting.

Taking a deforming zone width of 100 km, a fault angle of 45° and a rotation rate of 3° Ma^{-1} gives a slip rate of approximately 0.7 cm a^{-1} across the zone (see McKenzie & Jackson 1986). This assumes that the blocks are pinned. If they are floating the value is halved. Previous applications of this model to deforming regions (e.g. McKenzie & Jackson 1983, Walcott 1984) favour the floating block model.

DISCUSSION

Several lines of reasoning suggest that the cross-graben model cannot account for the style of deformation seen in the study area. First, there is no evidence for a deepening of the 'cross-graben' towards the Dinar Fault. Indeed, the Quaternary Acıgöl Basin is not connected to the Dinar Fault (Fig. 2). This can arguably be explained by invoking strain heterogeneities within the hangingwall basement blocks. Secondly, although major earthquakes have occurred on the faults controlling the 'cross-graben' during the 20th century (Ambraseys 1975, 1988), there is no record of major earthquakes on the Dinar Fault. This is surprising as, according to Şengör (1987), the total theoretical seismic moment for the breakaway fault should be about 80% greater than that along the cross-faults. Thirdly, all the faults in the region are normal and dip in opposing directions. There are Pliocene tilts of about 13° in the Burdur region. So, if the Dinar Fault had a strike-parallel tilt of 10° one would expect some of the faults controlling the 'cross-graben' to have reverse attitudes, which they lack. Finally, and perhaps most convincingly, the fact that strata do not dip into the Dinar Fault but into the NE–SW-trending basin boundary faults suggests that extension in the Burdur region has been accommodated on the latter structures.

If the rotational block model is to be accepted, the N–S-trending deforming zone has to be interpreted in terms of the regional tectonic framework of the eastern Mediterranean. To the west of the deforming zone is the rapidly extending Aegean region with crustal thicknesses of 22–32 km and to the east the relatively stable Anatolian plateau with a crustal thickness of 40–50 km (Makris 1976, Makris & Vees 1977, Makris & Stobbe 1984, Mindavelli *et al.* 1989). The deforming zone is therefore a convenient boundary between these two regions of different tectonic character and crustal thickness. The dextral sense of motion of the velocity vector across the deforming zone also requires explanation. Recent models of deformation of the Aegean indicate opposed rotations on either side of the region, with central Greece rotating in a clockwise sense and western Turkey in an anticlockwise sense (e.g. Taymaz *et al.* 1991, Westaway 1991). The quantitative 'broken slat' model of Taymaz *et al.* (1991) reasonably mimics slip vectors, strain rates and rotations in the Aegean region. In this model the westward motion of Turkey is restricted by continental collision in Albania and NW Greece. This gives rise to E–W shortening in the Aegean, which causes a spreading out of continental crust over the free boundary of the Hellenic subduction zone. Rollback of this subduction zone accentuates N–S extension in the Aegean. The geometry of deformation was likened by Taymaz *et al.* (1991) to the behaviour of a system of broken slats attached to margins that rotate. On the margins of the deforming zone the slats are pinned at pivot points whose spacing remains fixed. At the eastern margin, ENE–WSW-trending slats rotate anticlockwise with rotation of individual slats increasing to the south. This results in a westward increase in N–S extension. Dextral strike-slip faulting is predicted between individual slats on the eastern margin. Such faulting is not observed in the Burdur region. We therefore propose a slight modification to the model of Taymaz *et al.* (1991) whereby anticlockwise rotation of the eastern margin of the Aegean region relative to stable Anatolia is accommodated by an approximately N–S-trending deforming zone, across which a dextral displacement occurs and within which NE–SW-trending fault-blocks rotate in a clockwise sense.

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