Δελτίο Ελληνικής Γεωλογικής Εταιρείας τομ. XXV/3, 135-145, 1991
Πρακτικά 5ου Επιστημονικού Συνεδρίου, Θεσσαλονίκη, Μάϊος 1990

Bulletin of the Geological Society of Greece vol. XXV/3, 135-145, 1991
Proceedings of the 5th Congress, Thessaloniki, May 1990

STRUCTURAL AND GEOMORPHOLOGICAL CHARACTERISTICS EXPRESSING STRIKE-SLIP MOTION ON THE CENTRAL PART OF THE NORTH ANATOLIAN FAULT ZONE AROUND NIKSAR, TURKEY

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ABSTRACT

The North Anatolian Fault is an active strike-slip fault which extends for about 1200 km from Karliova in the east to the gulf of Saros in the west along the Black Sea mountains, and has an extremely well developed surface expression.

Structural and geomorphological characteristics of the fault zone have been examined around the Niksar basin which is bounded by two major strike-slip faults associated with earthquakes in 1939 and 1942. The two master faults bounding the basin splay into several branches at the end of the fault rupture as a "horsetail structure". Related structures include linear fault valleys, elongated hills, fault scarps, offsets, depression zones, landslides, dammed streams and alluvium fans.

Types of strike-slip fault pattern in dextral (right-lateral) regimes that produces adjacent extensional sedimentary basins and compressional uplifted blocks are discussed with emphasis on examples from the Niksar region.

INTRODUCTION

The neotectonic framework of Turkey and its surrounding areas is outlined and defined by the complex of structures which resulted from the westerly movement of the Anatolian block. This movement was due in turn to the continued convergence of Eurasian and Arabian plates after the Middle Miocene (McKenzie,1972; Dewey & Sengor,1979; Sengor,1980) and was bounded by two conjugate strike-slip faults, the North Anatolian (NAF) and East Anatolian Faults (EAF). These two faults are respectively right-lateral (North Anatolian) and left-lateral (East Anatolian).

The study of the geometry and origin of the Neogene-Quaternary basins along the North Anatolian Fault Zone is important in understanding the kinematics of the fault zone. Recent studies of these basins have been undertaken by Barka (1984), Barka & Hancock (1984), Hempton & Dunne (1984), Hempton (1985), Sengor et.al.,(1985), Barka & Gulen (1989) and Kocyigit (1989), Tutkun & Hancock (1989), Tutkun & Kelling (1990).

In this paper, we shall discuss the structural and geomorphological features observed around the Niksar basin and adjacent areas based on field studies. The Niksar basin is located in the central part of the North Anatolian Fault Zone (Fig.1). It is bounded by the 1939 earthquake fault in the south and the 1942 earthquake fault in the north, and exhibits a pronounced "Z" shape (Mann et. al.,1983).

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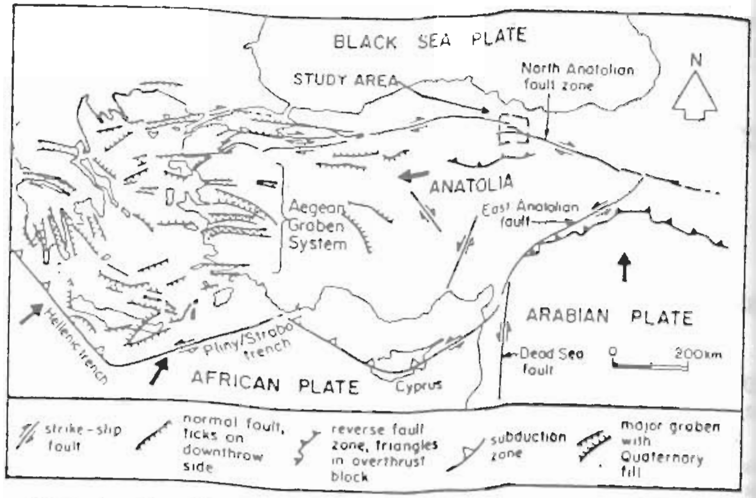

Figure 1 : Simplified neotectonic map showing the location of the study area and some of the major neotectonic features (after Sengor,1979; Hancock & Barka,1981).

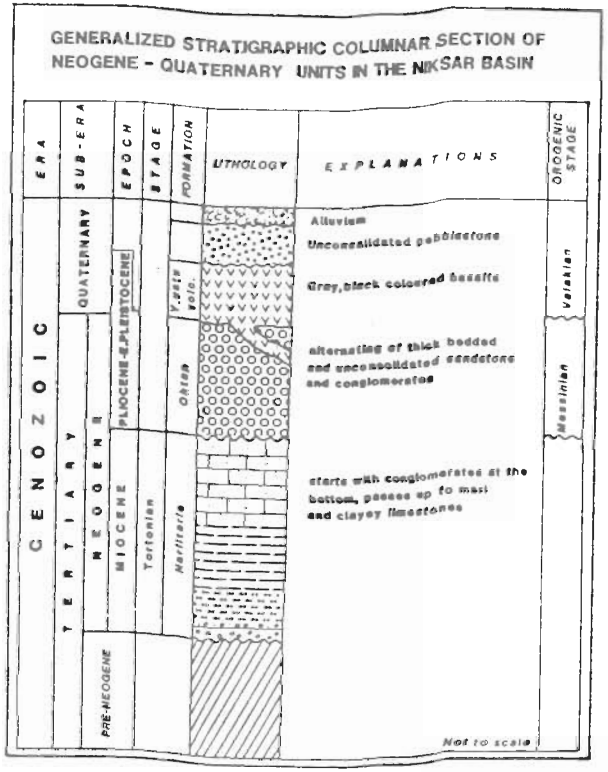

Figure 2 : Generalised stratigraphic columnar section of Neogene-Quaternary units in the Niksar basin (Revised from Tatar,1988; Temiz,1989).

STRATIGRAPHY OF THE NIKSAR BASIN

The Neogene-Quaternary stratigraphy of the basin consists of the Narlitarla formation of ? Tortonian age together with the Ohtap formation and the Yolustu volcanics of Pliocene-Early Pleistocene age. The youngest units in the basin are Holocene deposits and alluvial fans (Fig.2).

The basal units of the Neogene-Quaternary in the Niksar basin belong to the Narlitarla formation, starting with conglomerates at the bottom and passing upward into marl and clayey lacustrine limestones. They were first observed by Irrlitz (1968) and named the Narlitarla formation by Tutkun and Inan (1982). They are exposed at the southern margin of the basin (Fig.3).

After the Tortonian, during early Pliocene time, The fluvial Ohtap formation was deposited. Between the two formations, an angular unconformity of Messinian age has been recognized. Both the NW margin of the Niksar basin and the SE margin of the Erbaa basin are characterized by a series of conglomerates and sandstones which are fairly continuous laterally in the central part of the basin and dip gently (up to 10-15°) towards the N at the southern margin (Fig.3). This change in the depositional environment may show that strike-slip fault regime became active in this area during the early Pliocene (Fig.2). During the Upper Pliocene-Early Pleistocene, local basaltic-andesitic volcanism occurred at the eastern and western sides of the basin(Figs.2,3), probably related to local transtensional zones.

Holocene deposits consisting of unconsolidated conglomerate and sand occur over a large area in the Niksar basin, and are covered by alluvium and alluvial fan deposits.

GEOMORPHOLOGICAL CHARACTERISTICS OF THE NIKSAR BASIN

The Niksar basin (Fig.3) has a length of about 16 to 20 km and a width of 8-13 km, trending approximately NW-SE parallel to the North Anatolian Fault Zone.The northern and southern margin of the basin are bordered by the 1942 earthquake fault trending at 120°and the 1939 earthquake fault trending at 120-130°. These two main faults are regarded as Principal Displacement Zones. They have produced sharp, steep mountain fronts usually straight with numerous alluvial fans aligned along the margins of the basin. The slope of the alluvial fans is much steeper at the northern margin of the basin than the southern margin, and ranges between 600 m^2-1 km^2 indicating that recent uplift has been concentrated on the northern side. Both the southern and northern mountain fronts are dominated by slightly concave fault traces delineating scarps. The floor of the basin is about 300 m below sea level whereas the highest mountain peaks around the basin margins are 800-1200 m in height indicating a minimum net vertical displacement of about 1500 m.

Morphologically, the North Anatolian Fault Zone in the Niksar area is well defined as a narrow rift with numerous cut off, offset and dammed stream valleys. The country rocks generally exhibit some degree of fracturing and brecciation .The drainage system in the Niksar basin is consequent. A number of streams emanate from the highlands around the basin and flow transversely northward and southward into the basin. The main drainage system is dominated by the Kelkit and Canakci rivers, which have a fault- controlled valley character for most of their course and represent typical strike-slip fault valleys. The Kelkit River flows northwestwards through the fault-controlled valleys and joins the Yesilirmak River west of Erbaa.

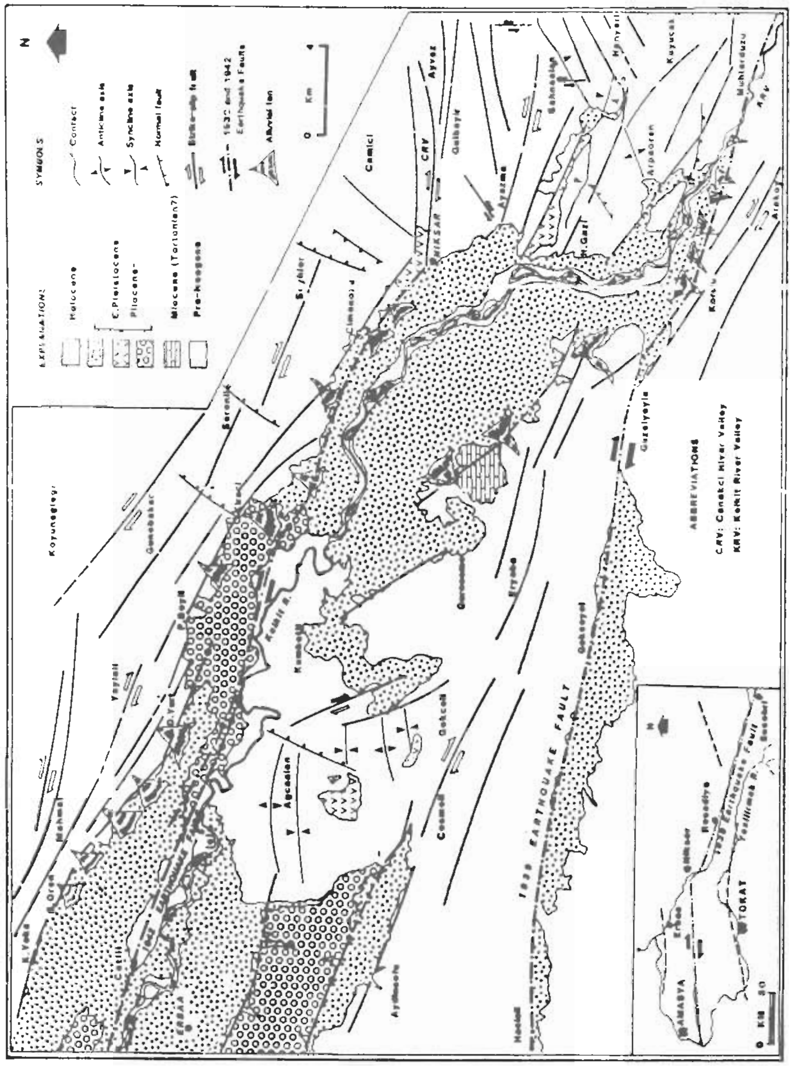

Figure 3 : Neotectonic map of the Niksar basin and adjacent regions.

The Kelkit valley, trending at 120° on the southeastern part of the basin, approximately parallel to the 1939 earthquake fault, shows a typical rift morphology and is bounded by a series of en-echelon faults. Along the southern margin of the valley, extremely well developed landslide surfaces, alluvial fans and brecciated zones have been observed.

The Canakci River valley is located on the northeastern side of the basin and trends approximately E-W , crossing the town of Niksar. The 1942 earthquake fault enters the valley around Niksar and splays into several branches (Figs.3,4). It exhibits features typical of strike- slip fault valleys including river offsets, elongated hills and various other surface expressions .

River Offsets.- Several streams on the northern and southern sides of the basin flow in a direction nearly perpendicular to the main fault zone, and are offset right laterally across the strike-slip faults. One of the clearest examples of offset drainages is observed around Niksar town (Fig. 5) where approximately 1825 m of displacement occurred in the Upper Jurassic-Lower Cretaceous limestones (Fig.6A).

The rivers are clearly deflected in a right-lateral sense, reflecting the sense of motion along the fault. Measured river offset values are 875 m, 530 m, 550 m, 550 m from west to the east on the same segment which displaced the formation boundary 1825 m.(Fig.5). In addition to these, 225 m and 875 m offsets in the courses of Ambarkaya and Suludere streams have been determined between the villages of Karabodur and Serenli as a seperate fault segment (Fig.5).

In the northwestern part of the study area, 8 km of Quaternary displacement is indicated by the arrangement of the courses of the rivers Yesilirmak and Kelkit where at their confluence they flow within an area of Quaternary deposits (Fig.6B). About 6 km of the displacement probably occured during the earlier Quaternary followed by an additional 2 km during the later Quaternary (Barka and Hancock,1984).

Depressions and landslide surfaces.- Depressed areas associated with strike-slip faults have been observed around the village of Kuyucak in the southeastern part of the study area where sag-ponds are situated along the faults. A small sag-pond caused by landslide activity has also been observed at the northern village of Şahnaalan.

Many landslides are located on both sides of the study area, e.g. around Niksar town in the Canakci river section . In some places, such as the villages of Gunebakan, P.Beyli, Ayan and Serenli, landslide formations are developed in unconsolidated and clastic units between pairs of faults.

FAULT PATTERNS

The simplified structural map of the study area in Fig. 3. shows that two main principal displacement zones following the 1939 and 1942 earthquake faults border the southern and northern margins of the basin. Between these two zones, lies a 11-15 km wide zone where secondary fault sets are developed.

The 1939 Earthquake Fault.- The 1939 earthquake fault, which trends at 120°, forms the southeastern margin of the Niksar basin. It follows the Kelkit valley in the E, but diverges from it to the W. It has a length of approximately 50 km within the study area. The epicentre of the 27 December Erzincan earthquake lies in the

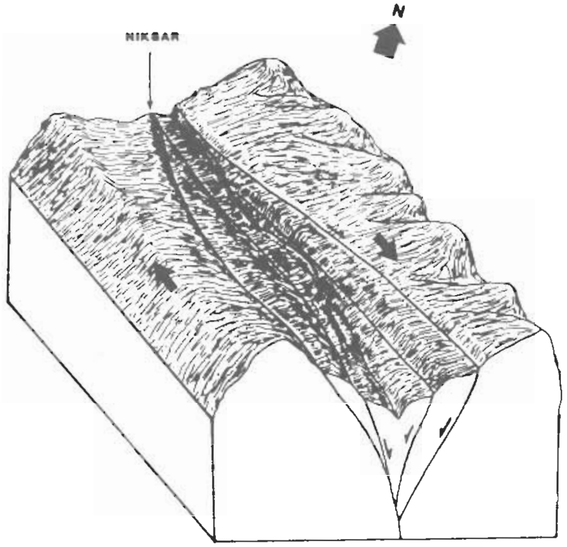

Figure 4 : Block diagram showing the negative flower structure in Canakci River Valley.

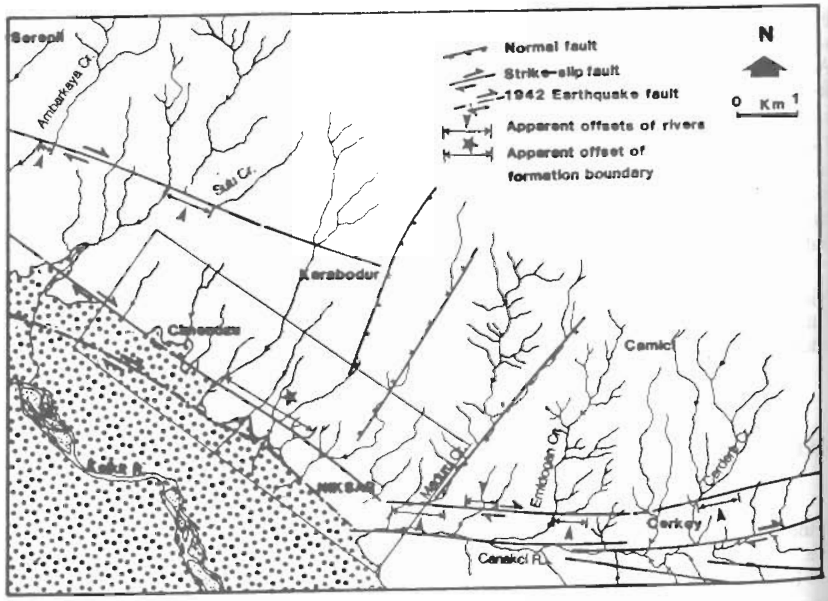

Figure 5 : Displacement estimates from measured stream offsets and a displaced formation boundary around Niksar town. The stippled area is Quaternary deposits

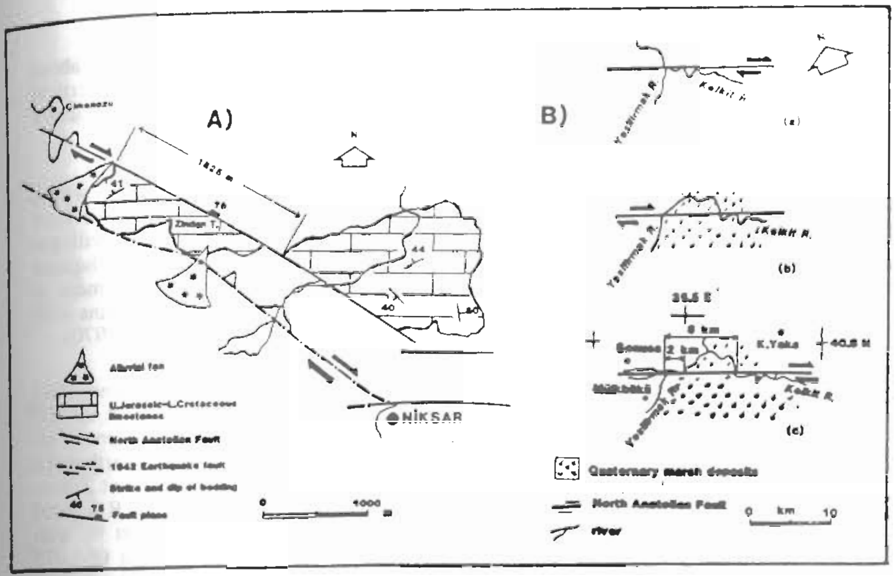

Figure 6 : A) Sketch map showing the 1825 m displacement of U.Jurassic-L.Cretaceous outcrop NW of Niksar town.

B) Displacement of the junction of the Yesilirmak and Kelkit Rivers.

(a) junction before the accumulation of Quaternary deposits;

(b) in the late Quaternary after 6 km of displacement;

(c) at the present day after 8 km of displacement (Barka & Hancock,1984).

southern part of the study area (Fig.3). The total length of the fault break was about 340 km. Along this fault , right lateral displacements of 1-2 m, and vertical displacements of 1.5-2 m. have been measured. NNW-SSE trending fracture systems were also observed (Ketin,1969).

The 1942 Earthquake Fault.- The 1942 earthquake fault is 40 km in length within the study area and trends at 120° between the towns of Erbaa and Niksar.The fault break trends WNW-ESE 12-15 km NE of the 1939 fault break, crossing the villages of Buzkoy, Tepekisla and Catili. The epicentre of the 20 December 1942 earthquake lies between the villages of Catili and Tepekisla. The right-lateral displacement in the Erbaa area was about 0.5 m. At the western end of the Erbaa basin, it joins with the 1943 earthquake fault break (Blumenthal,1943; Ketin,1969; Ambraseys,1970).

Secondary faulting.- Secondary faults in the region between the 1939 and 1942 earthquake faults, consist of four separate sets (Fig.7a). One set striking at 90-100° runs roughly parallel to the earthquake faults or Principal Displacement Zones (M-M'). The second set is interpreted as Riedel shears associated with the earthquake faults. The latter make an angle of 20-30° with the Principal Displacement Zones. Around the eastern part of Niksar town (Fig.3), conjugate Riedel shears (R1) trend at 005-010° with a left-lateral sense of motion, making an angle of almost 90° with the Principal Displacement Zone. Secondary synthetic faults (P) trend at 065-075° and make an angle of 20-30° with the Principal Displacement Zone (Fig.7b).

Brecciated zones.- Two main brecciated zones are developed along the Principal Displacement Zones following the 1939 and 942 earthquake faults. The first brecciated zone is located around the northwestern part of the Kelkit valley where Upper Jurassic-Cretaceous limestones and Palaeozoic low-grade metamorphics are crushed and brecciated. The width of the zone about 500 m- 1 km. The second main brecciated zone within the study area is located at the northwestern part of Niksar town. Its width ranges between 50-100 m, and occurs in the U.Jurassic-L.Cretaceous limestones.

TRANSTENSIONAL AND TRANSPRESSIONAL STRUCTURES

Important geometrical effects are produced by changes in direction of strike-slip faults (Reading,1980; Park,1988). As the two opposed blocks move past each other, local zones of convergence or divergence occur,which produce compressional and extensional effects respectively.The combination of folds and faults produced by these local zones of compression and extension have been termed flower structures by Harding and Lowell (1979). Positive flowers are uplifted zones with a compressional component across the strike-slip belt, and negative flowers are depressed zones with an extensional component.

Transtensional structures.- Transtensional transfer faults associated with strike-slip faults have been recognised around the Niksar basin. These transtensional transfer fault sets,which have a similar effect to releasing bends are important in controlling the geometry and evolution of the basin. Moreover the measurement of the displacements on the transfer faults can be used to estimate displacement on the main strike-slip fault. As seen in Fig. 3; the two main fault sets following the main trace of the 1939 and 1942 earthquake fault breaks appear to be oriented at 110-120°. In the eastern part of Niksar town; the fault set parallel to the 1942

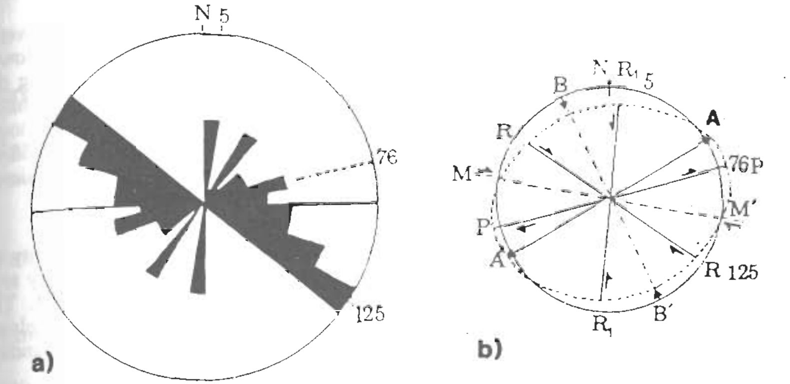

Figure 7 : (a) Rose diagram showing azimuths of strike-slip faults;

(b) Interpretation of the fault sets in terms of a strike- slip fault model: M-M', Principal Displacement Zone; R,Riedel shears; R', conjugate Riedel shears; and P shears.

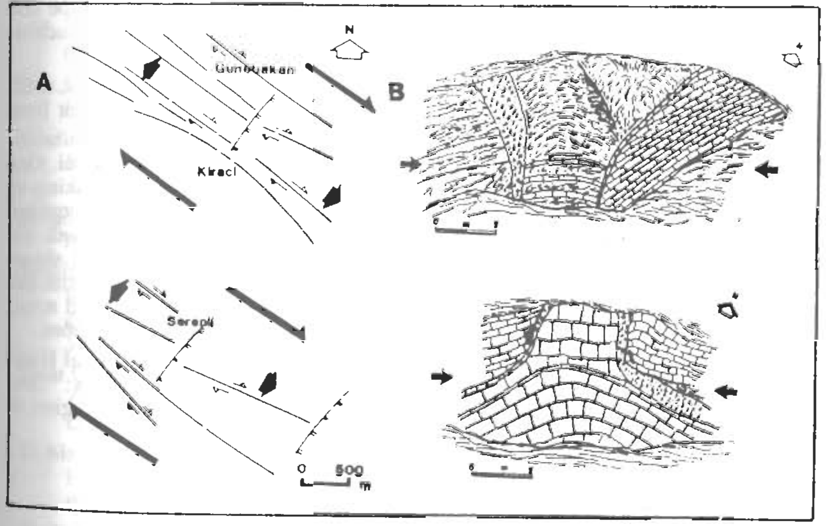

Figure 8 : A) Local extensional (transtensional) zones created by normal transfer faults perpendicular to strike-slip faults.

B) Positive flower structures associated with local transpressional zones in the northwestern of the study area.

earthquake rupture change its direction to approximately E-W, splaying into several branches as a horsetail structure. A local transtensional zone where negative flower structures illustrated in Fig.4 and considered to represent local divergent along the zone. Examples of transtensional transfer faults observed around the Niksar basin are given in Fig.8A. Such structures are seen in the northern part of Niksar town (Fig 3). Around the villages of Kiraci and Serenli, approximately 120-130° trending strike-slip faults are cut by NE-SW transfer faults, cause to local transtensional zones.

Transpressional structures.- Local transpressional zones occur in the vicinity of restraining bends and are observed mostly in the northwestern part of the study area around the village of Findicak. Two clear examples are shown in Fig.8B. The occurence of local transpressional zones in this part of the area is probably related to the restraining bend created by the change in orientation of the main boundary zone from NW-SE to nearly E-W.

CONCLUSIONS

1. Strike-slip fault movements commenced in the early Pliocene in the Niksar basin area with the deposition of the fluvial Ohtap formation.

2. The basin is essentially a fault overlap structure bounded by two principal displacement zones, the 1939 and 1942 earthquake faults. It has a "Z" shape and exhibits many geomorphological features typical of strike-slip fault zone, such as linear valleys, stream offsets, sag- ponds and landslides.

3. Available displacement estimates are 225-875 m from stream offsets; 1825 m from a displaced formation boundary and 8 km total Quaternary movement from the geometry of the confluence of the Kelkit and Yesilirmak rivers.

4. Secondary fault patterns are consistent with a dextral strike-slip model. One set is sub-parallel to the principal displacement zones (M-M'); a second, making an angle of around 20° clockwise of the principal displacement zones, are interpreted as synthetic Riedel shears (R); a third, making an angle of nearly 90° with the principal displacement zones, are interpreted as conjugate (antithetic) Riedel shears (R') and the fourth set making an angle of 20-30° anticlockwise of the principal displacement zones are regarded as secondary synthetic faults (P). Brecciated zones of about 500 m-1 km width are associated with the principal displacement zones.

5. Local extensional (transtensional) zones are created by transfer normal faults approximately perpendicular to the principal displacement zones and transpressional zones in the form of positive flower structures occur in the region of a restraining bend in a principal displacement zone.

ACKNOWLEDGEMENTS

We would like to thank to Professor G.Kelling and Res.Ass.U.Can Unlugenc for their assistance and useful recommendations in the field. The field work studies have been supported by Cumhuriyet University.

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