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# Tectonic implications of the Neogene stratigraphy of the Çankırı basin with special reference to the Çandır locality (North-Central Anatolia, Turkey)

With 15 figures

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Abstract

The Çankırı Basin is straddled between the Sakarya continent of the Pontides in the north and the Kırşehir Block of Taurides. It includes Neogene units more than 1 kni in thickness. Eight Neogene formations and two distinct tectonic regimes are identified. The formations were dated using rodent fossils. They were mapped by remote-sensing techniques and their depositional environments and tectonic settings were established by field studies. l'he early and middle Miocene sediments were deposited in an extensional tectonic regime, which replaced the pre-Neogene thrust regime. The late Miocene to Pliocene age sediments were deposited in a compressional tectonic regime which gradually changed its character to regional transcurrent tectonics which has been operating in much of Turkey ever since.

**Keywords:** Çandır Formation, Miocene, Deformational History, Chronostratigrapliy

Zusammenfassung

Das Çankırı-Becken erstreckt sich zwischen dem Sakarya-Kontinent der Pontiden im Norden und dem Kırşehir-Block dcr Tauriden. Es umfasst Neogen-Einheiten von über einem Kilometer Machtigkeit. Acht Neogenformationen und zwei unterschiedliche tektonische Systeme lassen sich unterscheiden. Die Formationen wurden anhand von Nagerfossilien datiert und mit Fernerkundungssystemen kartiert; Ablagerungsmilieu und tektonische Bedingungen wurden durch Feldstudien erfasst. Die früh- und mittelmiozanen Sedimente lagerten sich in einem expandierenden tektonischen System ab, das das vorneogene Bruchsysteni ablöste. Obermiozäne bis pliozäne Sedimente kamen in einem kompressionstektonischen System zur Ablagerung, das seinen Charakter schrittweise zu einer regionalen Überschiebungstektonik änderte, die in der Turkei seither wirksam ist.

**Schlüsselwörter:** Çandır-Formation, Miozän, Verformungsgeschichte, Chronostratigraphie.

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## Introduction

The Neogene tectonics of the Çankırı Basin (Figures 1 & 2) are characterized by a complex deformational history that is distinguished by lateral changes in type, style, and trends of the structures which are developed within the Neogene units (Figure 3). Therefore, the establishment of the stratigraphy for the Neogene units is very important if the tectonic events that occurred in this time period are to be time constrained.

After termination of marine conditions in the middle Eocene, the evolution of the Çankırı Basin continued under continental settings and resulted in red clastics characterized by conglomerates, sandstones, and siltstones and widespread evaporates. Current studies of Neogene rodents in Turkey, in general, and Çankırı region, in

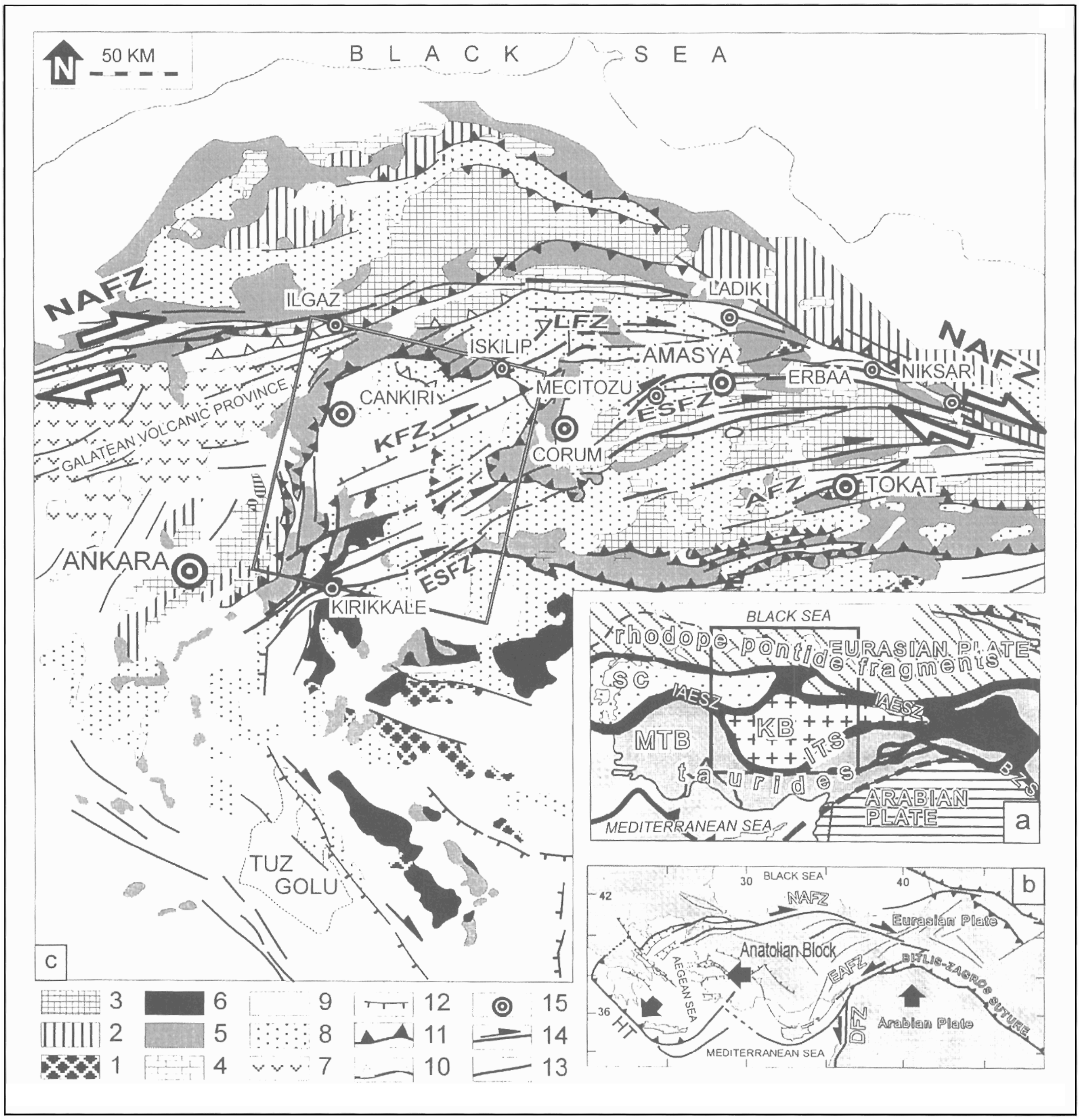


**Fig.** 1: a) Inset map showing the geological outline of Eastern Mediterranean area (Modified after ŞENGÖR et al. 1984). BSZ: Bitlis-Zagros Suture, IAESZ: Izmir-Ankara-Erzincan Suture Zone, ITS: Intra-Tauride Suture, KR: Kýrţehir Block, MTR: Taurus-Menderes Block, SC: Sakarya Continent. b) tectono-stratigraphical map of central Turkey, box shows the location of the study area.
1. Pre-Late Cretaceous metamorphic basement of the Kırşehir Block, 2. Pre-Jurassic metamorphic basement of the Sakarya Continent, 3. Triassic Karakaya Complex, 4. Jurassic-Cretaceous platform carbonates on the Sakarya Continent. 5. Pre-Paleocene Granitoids of the Kırşehir Block, 6. Late Cretaceous (?) ophiolites and ophiolitic melanges, 7. Paleocene carbonates, 8. Early Tertiary units (mainly marine), 9. Neogene Cover.

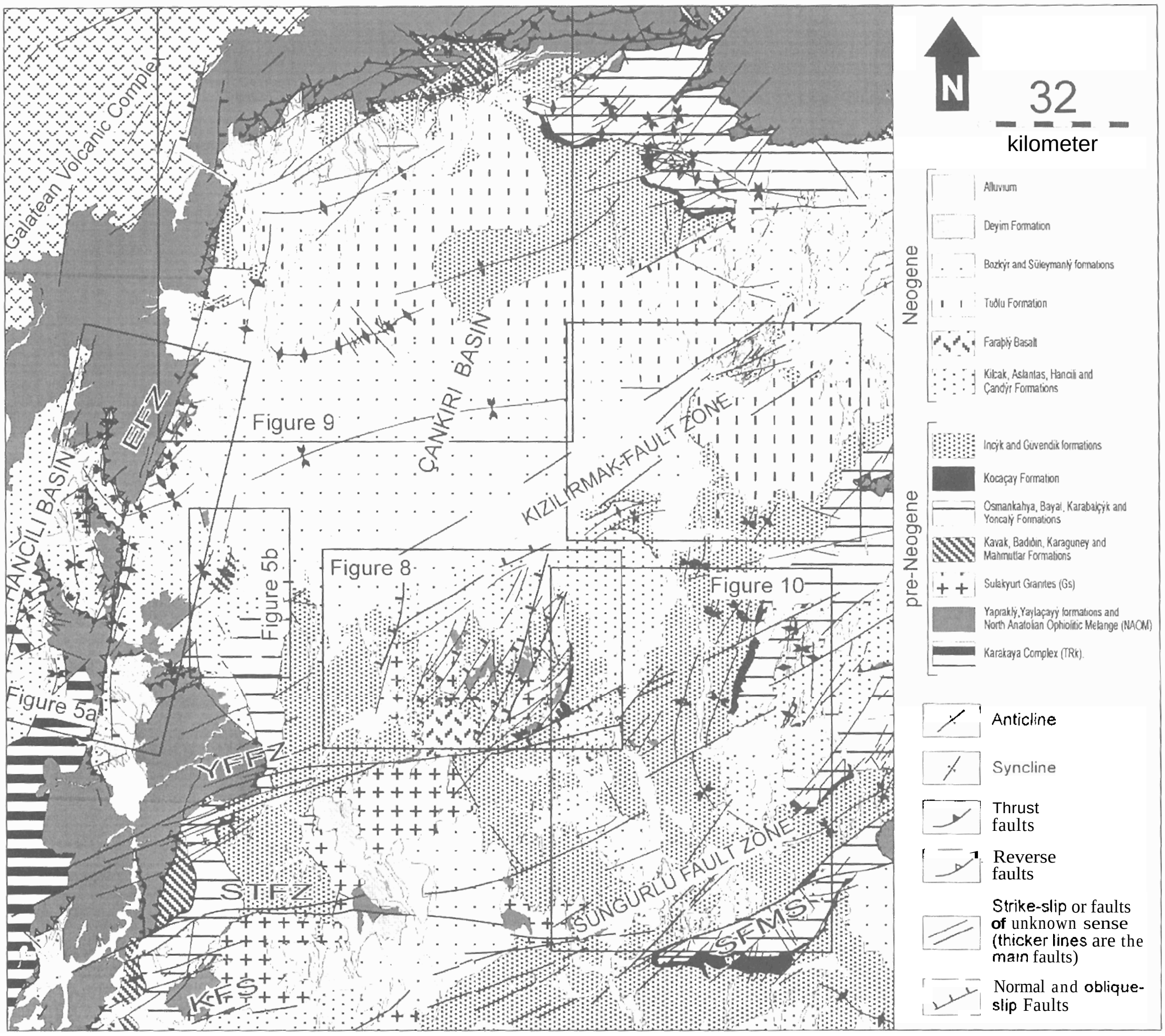


**Fig. 2:** Geological map of the Çankırı Basin

particular, in combination with radiometric and paleomagnetic studies have contributed to the establishment of a Neogene stratigraphy in Turkey (DE BRUIJN & SARAÇ 1992, DE BRUIJN et al. 1992, 1993, DE BRUIJN & KOENIGSWALD 1994, ÜNAY 1994, KRIJGSMAN 1996, KRIJGSMAN et al., 1996, KRIJGSMAN, this volume). In this context, we aim at establishing and describing the Neogene stratigraphy of the Çankırı basin (Figures 1, 2 & 3) and to use it to temporally constrain the tectonic development of the Çankırı Basin during the Neogene. For the purpose of this paper the main stratigraphic units in the Çankırı Basin are subdivided into the Neogene and pre-Neogene. (Figure 3). The description of the pre-Neogene units is given in KAYMAKCI et al. (1999a) and is summarized in Figure 3. Although, the region was previously mapped and a number of lithostratigraphic units were established, the ages of those units were based on superposition and most of the units are intermixed up with each other (see Figure 4). This study has re-mapped and established a higher resolution stratigraphy of the Çankırı Basin and adjacent Hancılı Basin.

## Methods

The ages suggested for the various formations are based on biostratigraphic correlations of the succession of rodent faunas of Anatolia with the European MN zonation. In this chapter we focus on geology of the Çandır Formation in the western section of the Çankırı Basin and the adjacent Hancılı Basin, with sediments of similar age (Figure 5). The Çandır Formation (Figure 6) was informally named by TEKKAYA (1975) who suggested a late Miocene age for the unit. It was later modified by KOÇYIĞIT et al. (1995), however, their age interpretation is not correct (A. KOÇYIĞIT and G. SARAÇ 1997, personal communication). In the map and the columnar sections of

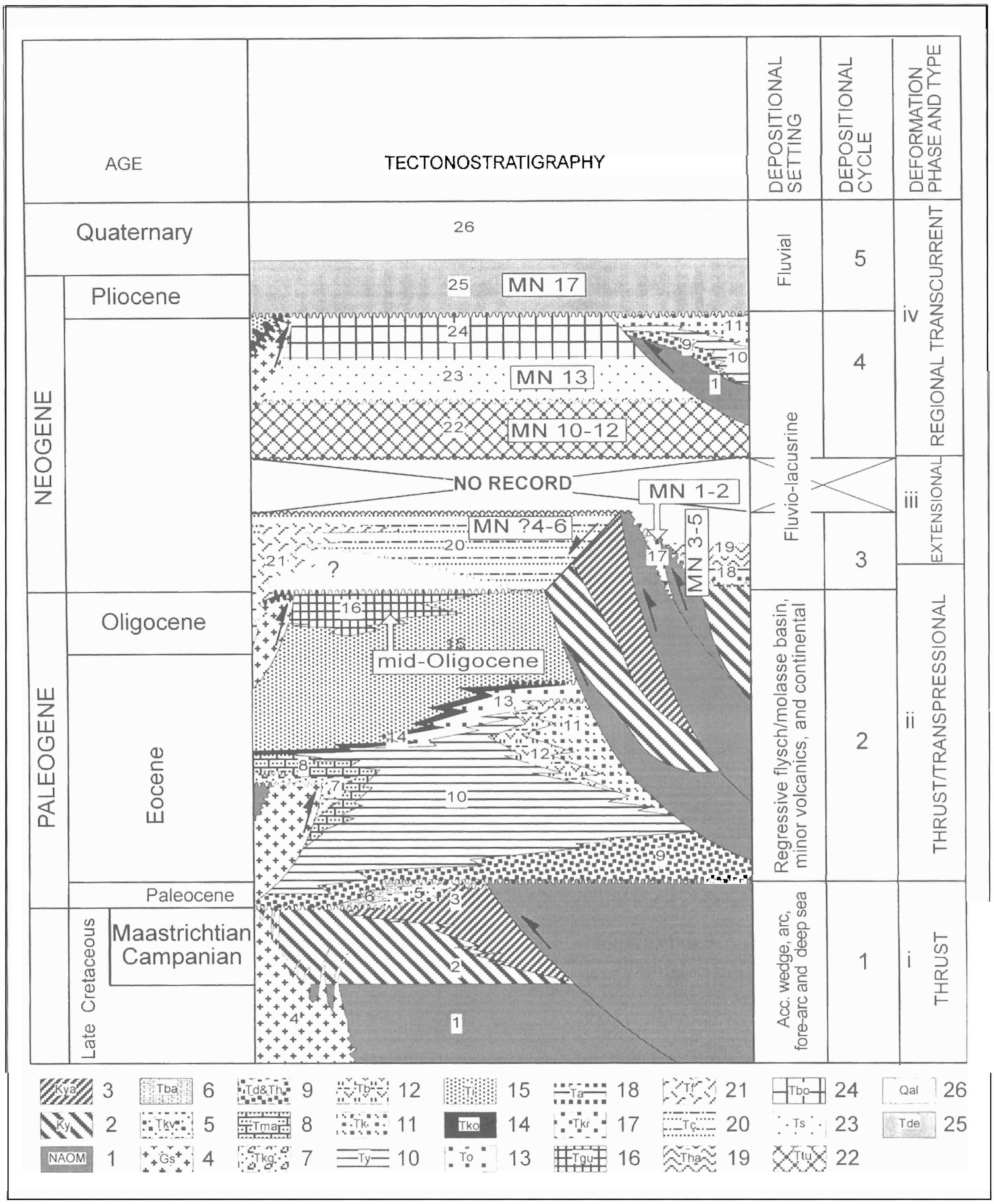


**Fig. 3:** Generalized tectono-stratigraphic column of the units exposed in and around the Çankırı Basin. 1. North Anatolian Ophiolitic Melange-NAOM, 2. Yaylaçayı Formation (distal fore-arc sequence), 3. Yapraklı Formation (proximal fore-arc facies), 4. Sulakyurt Granites of the Kırşehir Block that intruded in pre-Paleocene, 5. Kavak formation (red clastics and carbonates), 6. Badiğin Formation (neritie limestones), 7. Karaguney Formation (clastics derived mainly from the Kırşehir Block) 8. Mahmatlar Formation (clastics derived from Sulakyurt Granite), 9. Dizilitaşlar and Hacıhalil Formations (mainly turbiditic clastics and intercalated limestones), 10. Yoncalı Formation (Eocene Hysch), 11. Karabalçık Formation (distributary channel conglomerates and sandstones with coal seams), 12. Bayat Formation (Eocene volcanics and volcanoclastics), 13. Osmankahya Formation (mixed environment clastics and red beds), 14. Kocaçay Formation (Middle Eocene nummulitic lirnestonc covering both basin in-fill and the granites. 15. İncik Formation (continental red clastics), 16. Guvendik formation (evaporites), 17. Kılçak and Altıntaş formations (fluvial red clastics exposed only in the Hancılı Basin), 18. Hancılı Formation (Lacustrine deposits exposed only in the Hancılı Basin, 19. Çandır Formation (fluvio-lacustrine sediments). 20. Tuğlu formation (evaporates and lacustrine shale/marl), 21, Suleymanlı Formation (fluvio-lacustrine red clastics), 22. Bozkır Formation (evaporites), 23. Deyim Formation (fluvial clastics), 24. Alluvium. (See KAYMAKCI et al. 1999a for the description of pre-Neogene units).

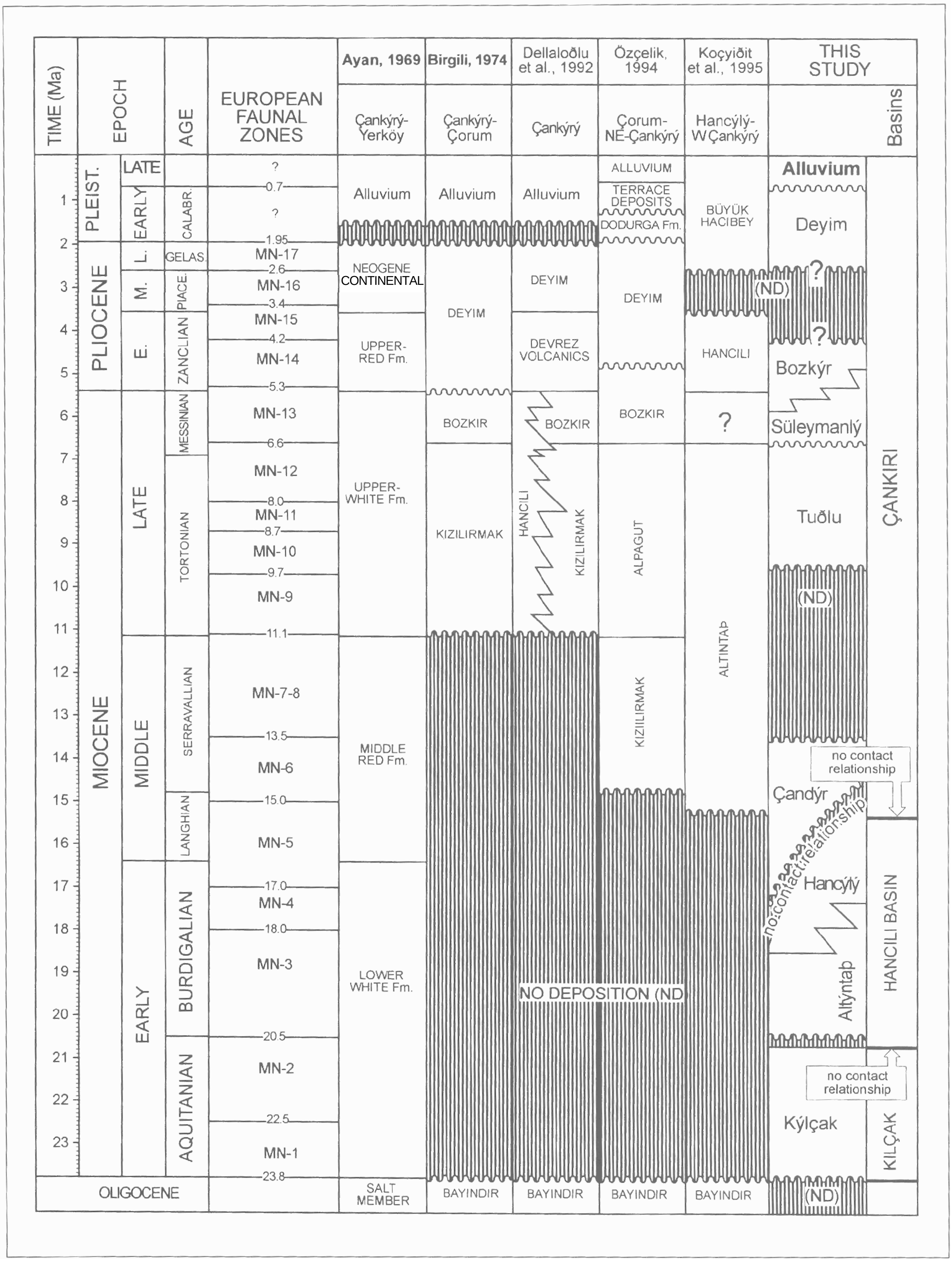


**Fig.** 4: Correlation chart illustrating the relative ages of the units in the Çankırı and Hancılı basins and comparison of previous studies with this study. Correlation of the standard time units and mammal zones is after STEININGER (1999).

KOÇYIĞIT et al., (1995) the Çandır, Altıntaş, and Hancılı formations (see Figure 4) are represented as different facies of the same unit, the Çandır Group (KOÇYIĞIT et al., 1995). However, each of these units has different physical characteristics, age, tectonic and depositional settings. In this study we have separated and re-mapped these units (Figure 2 and 5). The Çandır unit is one of the best known and contains some of the richest fossil localities in Turkey (SEN et al. 1998) we maintain the name as Çandır Formation as suggested by TEKKAYA et al. (1975) although the age they suggested is wrong. Although the local Miocene succession is well established and allows dependable correlations within Anatolia based on the grade of evolution of the dentition in a number of murid genera (i.e. Cricetodon. *Spanocricetodon, Democricetodon*, and *Mirebella*), the correlation of the early Miocene part of the local zonation with the MN zonation remains uncertain due to fauna dissimilarity and the limited number of available magnetostratigraphic and radiometric ages of mammal bearing deposits (KRIJGSMAN et al. 1996).

## Results and discussion

### Neogene stratigraphy

The oldest Neogene unit in the study area is the Kılçak Formation of Aquitanian age, it is followed by the Altıntaş Formation of Burdigalian age, Hancılı Formation of Burdigalian to Langhian age, Çandır Formation of Burdigalian? to Serravalian age, Tuğlu Formation of Tortonian age, Sűleymanlı and Bozkır formations of Messinian to Pliocene? age, Deyim Formation of Galesian age, and recent alluvium (Figure 3).

### The Çandır Formation (Tç)

The Çandır Formation unconformably overlies the pre-Neogene units and is unconformably overlain in places by the Sűleymanlı and Bozkır formations. It is also tectonically overlain by the NAOM (North Anatolian Ophiolitic Melange).

The type section of the Çandır Formation is 1 km north of the village of Çandır (Figure 5). In the lower part of the type section, the Çandır Formation is composed of an alternation of red to pink, buff to creamy white pebbly mudstone, clayey limestone, siltstone, matrix supported conglomerate intercalated with white, limy marl, thin silty-limestone, oolite bearing limestone, clayey limestone, and very thin organic rich layers (Figure 6). Above this level is the alternation of red to pink sandy-silty mudstone, loose matrix supported conglomerate, clayey sandstone, siltstone intercalated with caliche limestone, paleosol horizons with carbonate concretions and cross bedded sandstone and conglomerates locally discordant with these horizons. At the top are the pink sandy, limy concretions bearing mudstone, clayey porous limestone, siltstone, silty-limestone, white to creamy white marl, greenish shale alternations and clayey- pebbly-sandstone intercalation. It becomes finer and thinner towards the top and to the north-east. The upper levels of the Çandır Formation are characterized by inter-fingering of fluvial and lacustrine sequences. Lateral variation of the Çandır Formation in various reference sections is illustrated in Figure 7.

In Mahmatlar section (Figure 7 & Mh in Figure 5), it is composed of alternation of red clastics, including mainly red sandstone and shale intercalated with matrix and grain supported conglomerates, and creamy white to buff, pale brown to pinkish sandstone, shale/marl, sandy limestone, marly limestone, and very thick varve-like sandy-mudstones (Figure 7). In the area between Dağhalilince to İnelgazili villages (Figure 8a) the Çandır Formation is composed predominantly of red to dark greenish brown conglomerate, planar and trough cross-bedded sandstones (Figure 8b & c), grains of which are derived from underlying pre-Neogene units including NAOM and the Sulakyurt Granite. The section displays fining and thinning upwards. The Çandır Formation in this part of the basin (Figure 8a) is also characterized by a very well developed cyclicity and decimetre scale color banding. Overall color of the unit changes gradually towards the top. At the bottom it is brick red to magenta to purple and dominated by conglomerates (x in Figure 8b & c), in the middle part it is dark greenish purple to gray and dominated by cross-bedded sandstones (y in Figure 8b & c) and towards the top it is buff to yellowish and dominated by sandstone, siltstone and shale alternations. (z in Figure 8b & c).

In the Akçavakıf reference section (Av in Figure 9a) the Çandır Formation is composed of alternation of matrix supported red to pinkish to buff conglomerate, clayey sandstone and sandy mudstones (Figure 7). In the Derekutuğun section (Dk in Figure 9a), the Çandır Formation is exposed within an asymmetric anticline. In this section, it is composed of alternation of brick red to pinkish conglomerates, pebbly sandstones and red mudstone (Figure 7). The pebbles of conglomerates are ellipsoid and sub angular, and the largest clast size is around 20 cm. They are derived mainly from igneous and limestone blocks within the NAOM. The facies in this section display a very large-scale lensoid pattern. This distribution and the presence of sub-angular pebbles indicate close proximity to the source. West of Derekutuğun village (Figure 9a) limestone bearing facies dominate and the matrix of the conglomerates and the sandstones are constituted by limestone. In the Sarıyaka section, in the south-east of the Çankırı basin (Sy in Figure 10a), it is dominated by alternation of gray, green, greenish-gray shale, mudstone, beige to white marl, limy-marl, marly limestone alternation and intercalation of organic material rich horizons and lenses of immature to moderately mature lenses of conglomerate and cross-bedded sandstones (Figure 7).

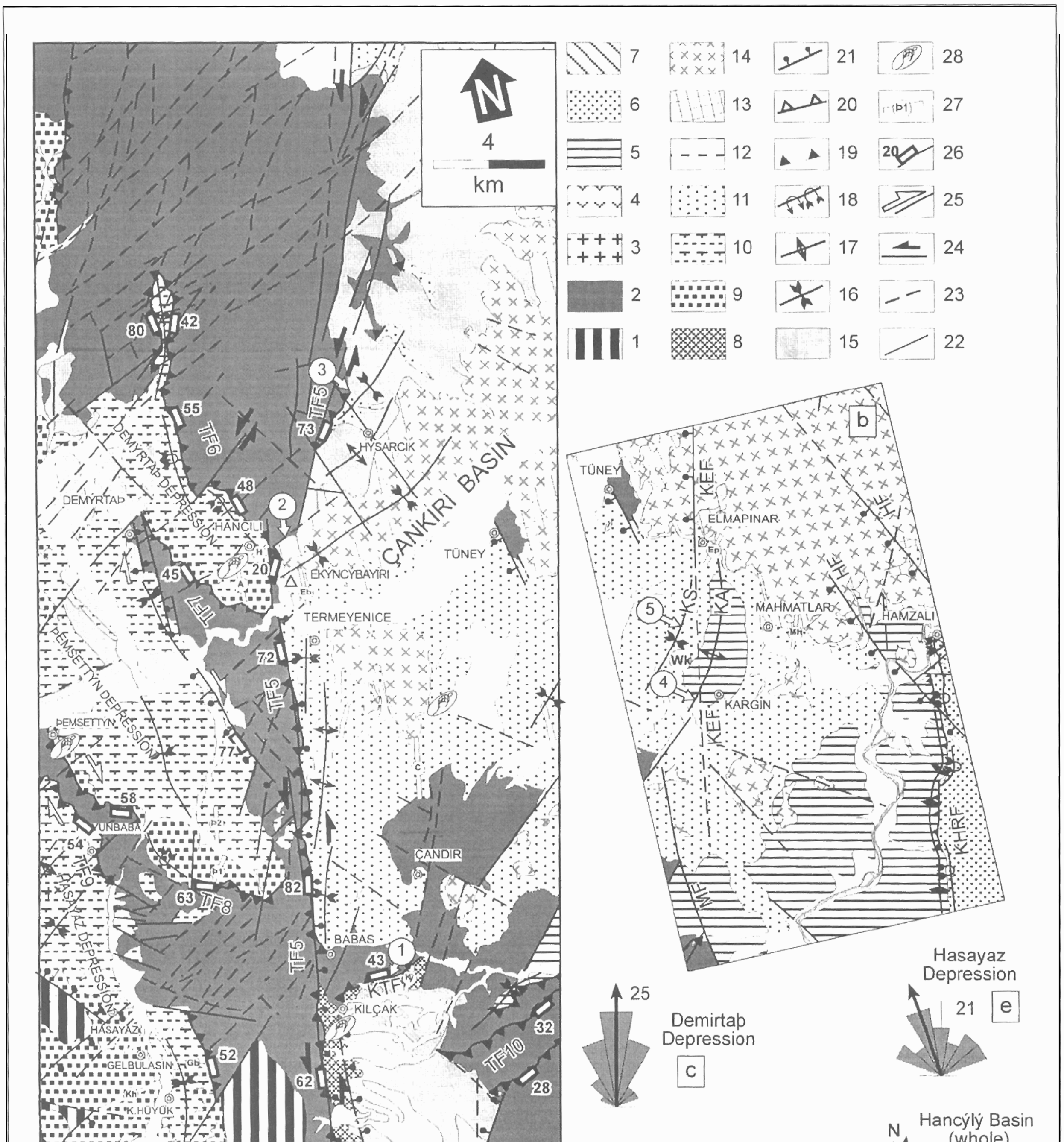


**Fig.** 5: Geological map of the western part of the Çankırı Basin around Hancılı and Çandır. 1. Karakaya Complex, 2. Late Cretaceous units, 3. Sulakyurt Granite, 4. Galatean Volcanic Province (GVP), 5. Early Tertiary units, 6. İncık Formatıon, 7. Giivendik formation, 8. Kılçak Formation, 9. Aslantaş Formation, 10. Hancılı Formation, I I. Çandır Formation, 12. Tuğlu Formation, 13. Süleymanlı Formation, 14. Bozkır Formation, 15. Deyim Fonnntion, 16. syncline, 17. anticline, 18. overturned folds, 19. thrust fault, 20. reverse fault, 21. normal fault, 22. strike-slip and faults with unknown sense of movement, 23. photo lineaments, 24. sinistral sense of movement, 25. dextral sense of movement, 26. dip of fault scarp where it is best exposed, 27. line of measured section, 28. Rodent fossil locality.

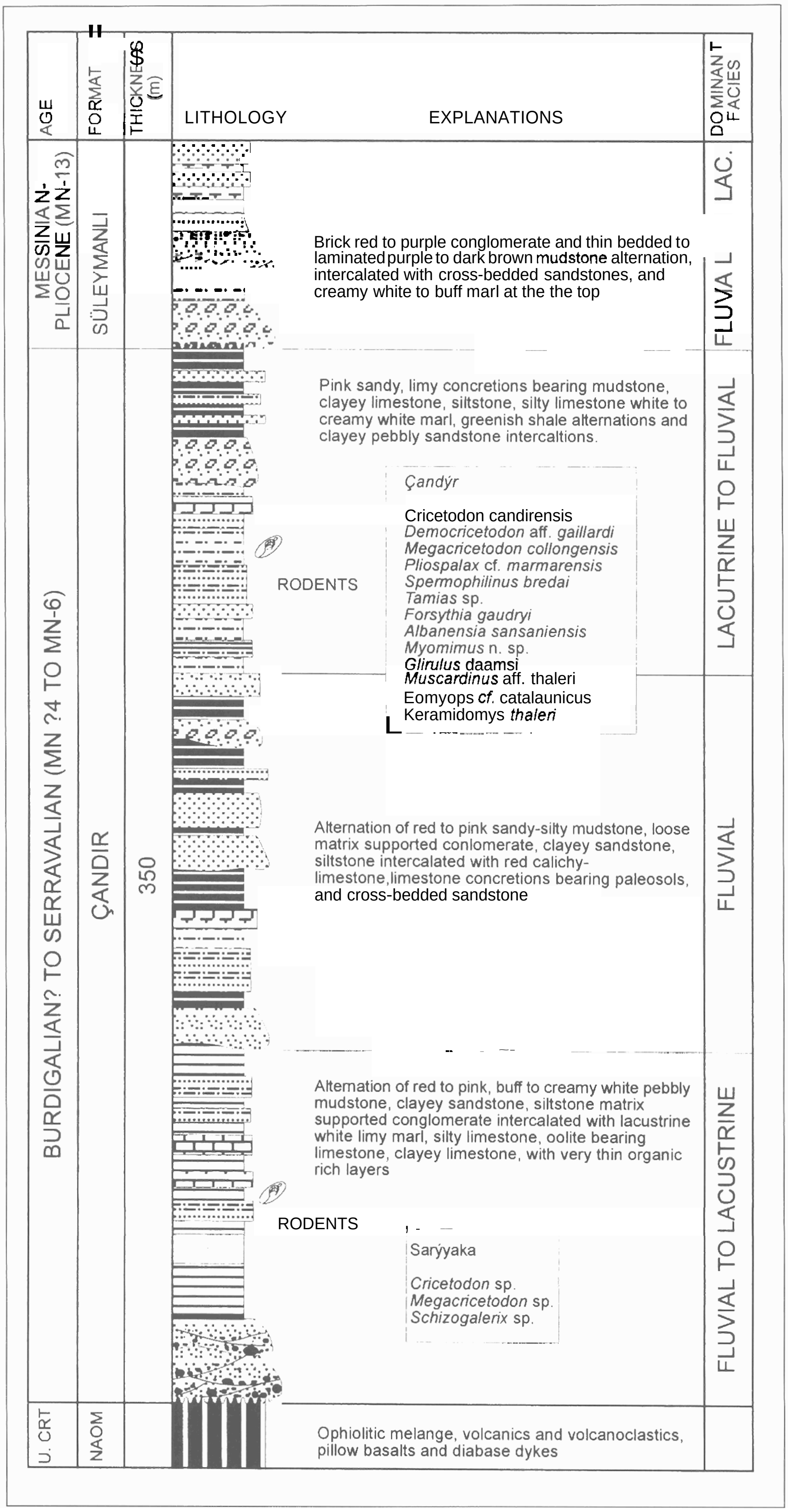


**Fig. 6:** Generalized columnar section of the Çandır Formation (fossil lists are from Çandır and Sarıyaka locations, see Figures 5 & 10 for the sample locations).

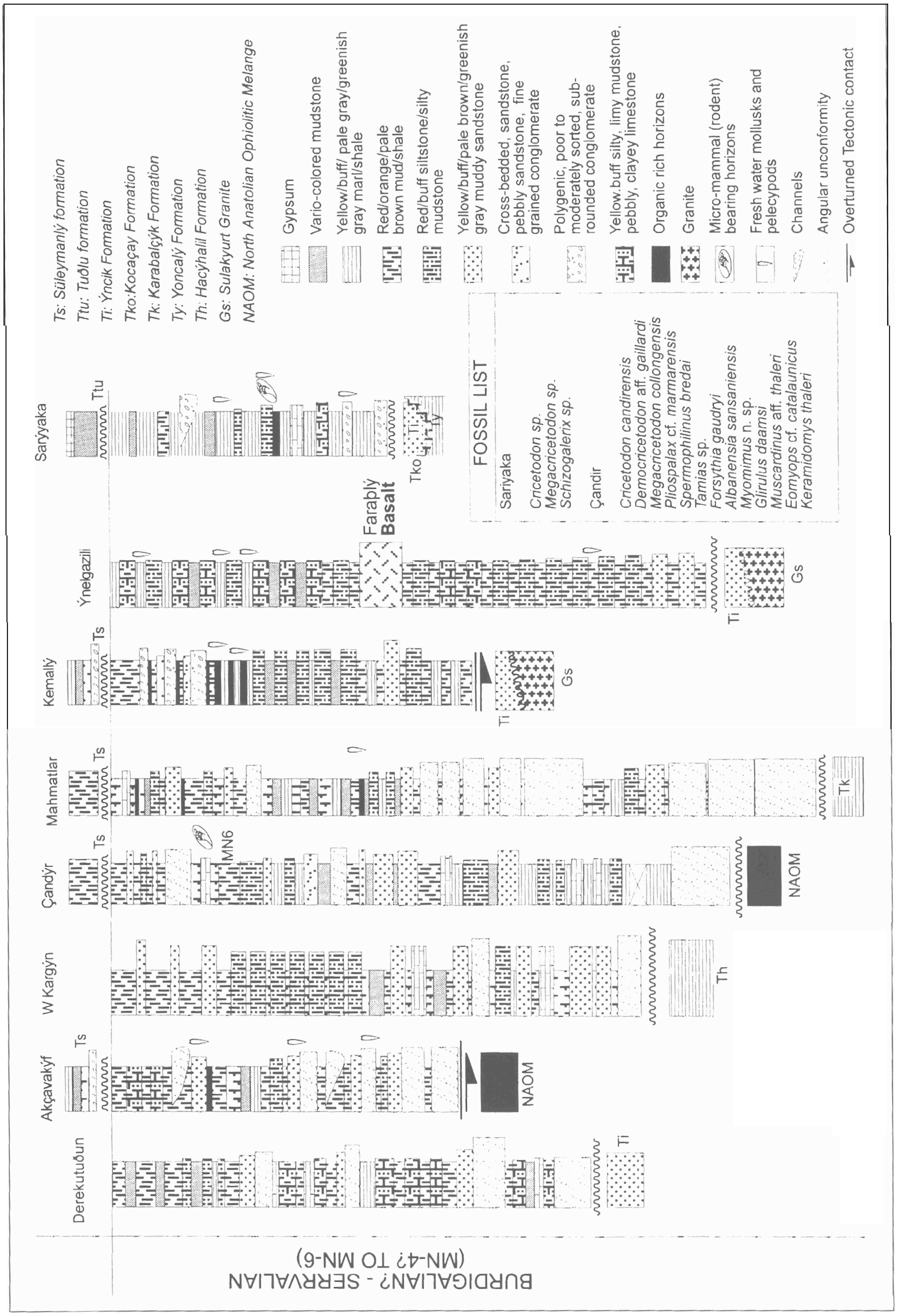


**Fig.** 7: Correlation chart of the measured sections of the Çandır Formation (see Figures 5, 8, 9, and 10 for the locations of the sections).

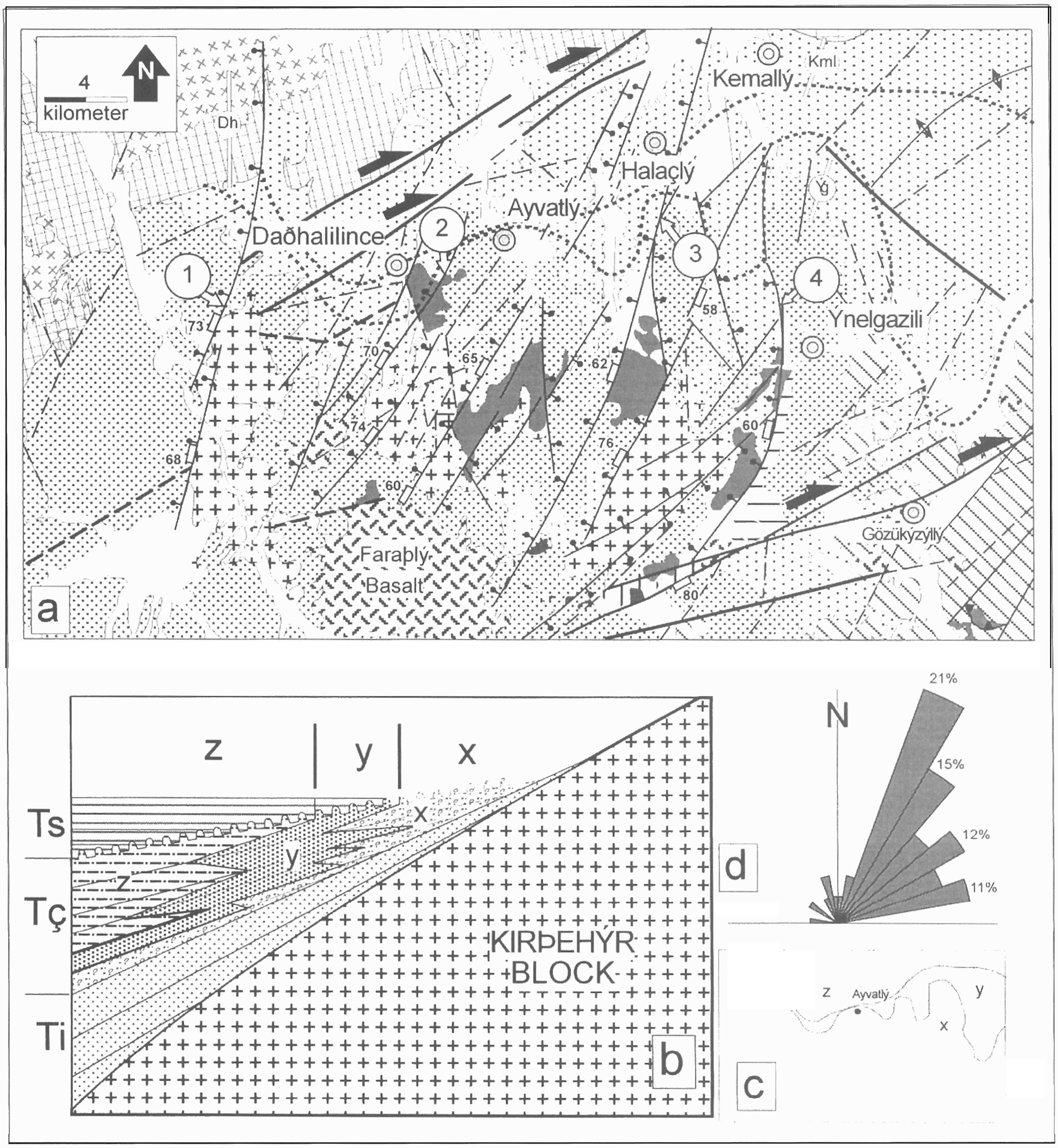


**Fig. 8:** a) Geological map of the central part of the Çankırı Basin. b) simplified map of the facies belts of the Çandır Formation, c) schematic illustration of the interpreted cross-section of facies belts of the Çandır Formation, d) length weighted rose diagram of the faults that are displacing the granitic basement and the Çandır Formation, percentages indicate the length frequency of the faults (see Figure 5 for the explanation of the symbols).

In the Çandır micromammal fossil locality (indicated with rodent sign in Figure 5) following rodents have been recognized; *Cricetodon candirensis, Democricetodon* aff. *gaillardi, Megacricetodon collongensis, Pliospalax* cf. *marmarensis, Sperrnophilinus bredai, Tamias* sp., *Forsythia gaudryi, Albanensia sansaniensis, Myomimus* n. sp., *Glirulus daamsi, Muscardinus* aff. *thuleri, Eornyops* cf. *catalaunicus, Kerarnidornys thaleri* (see de Bruijn et al., this volume). In the samples collected from the Sarıyaka locality *Cricetodon* sp.. *Megacricetodon* sp., and *Schizogalerix* sp. are present. The correlation of Çandır assemblage to the MN scheme is complex because it contains a number of species of differing ages in the European record (see de Bruijn et al., this volume), although all occur between MN-4 and MN-7/8. Magnetostratigraphical results are also ambiguous, but

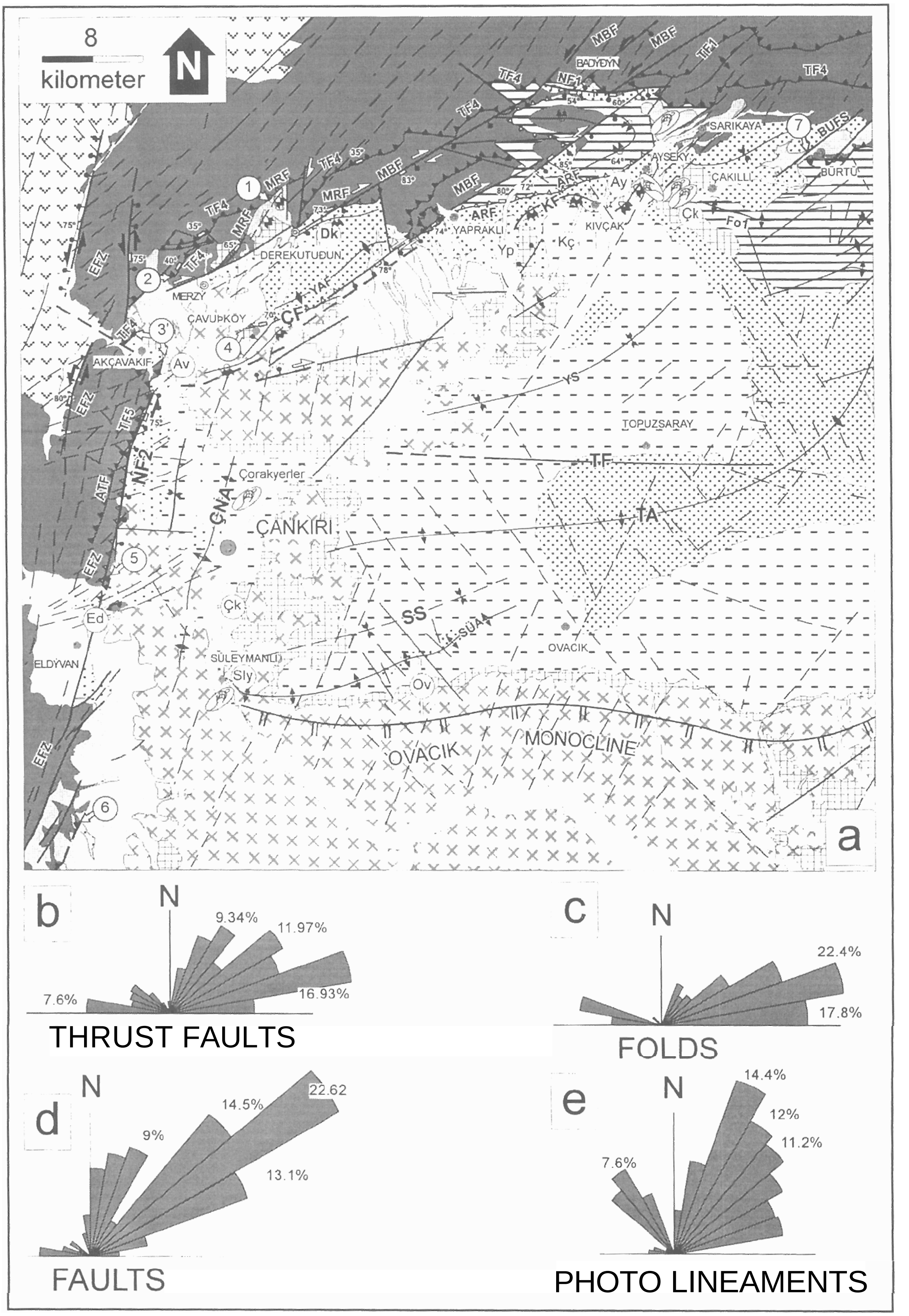


**Fig. 9:** a) Geological map of the north-western part of the Çankırı Basin (see Figure 5 for the explanation of the symbols). b-e) length weighted rose diagrams of the structures.

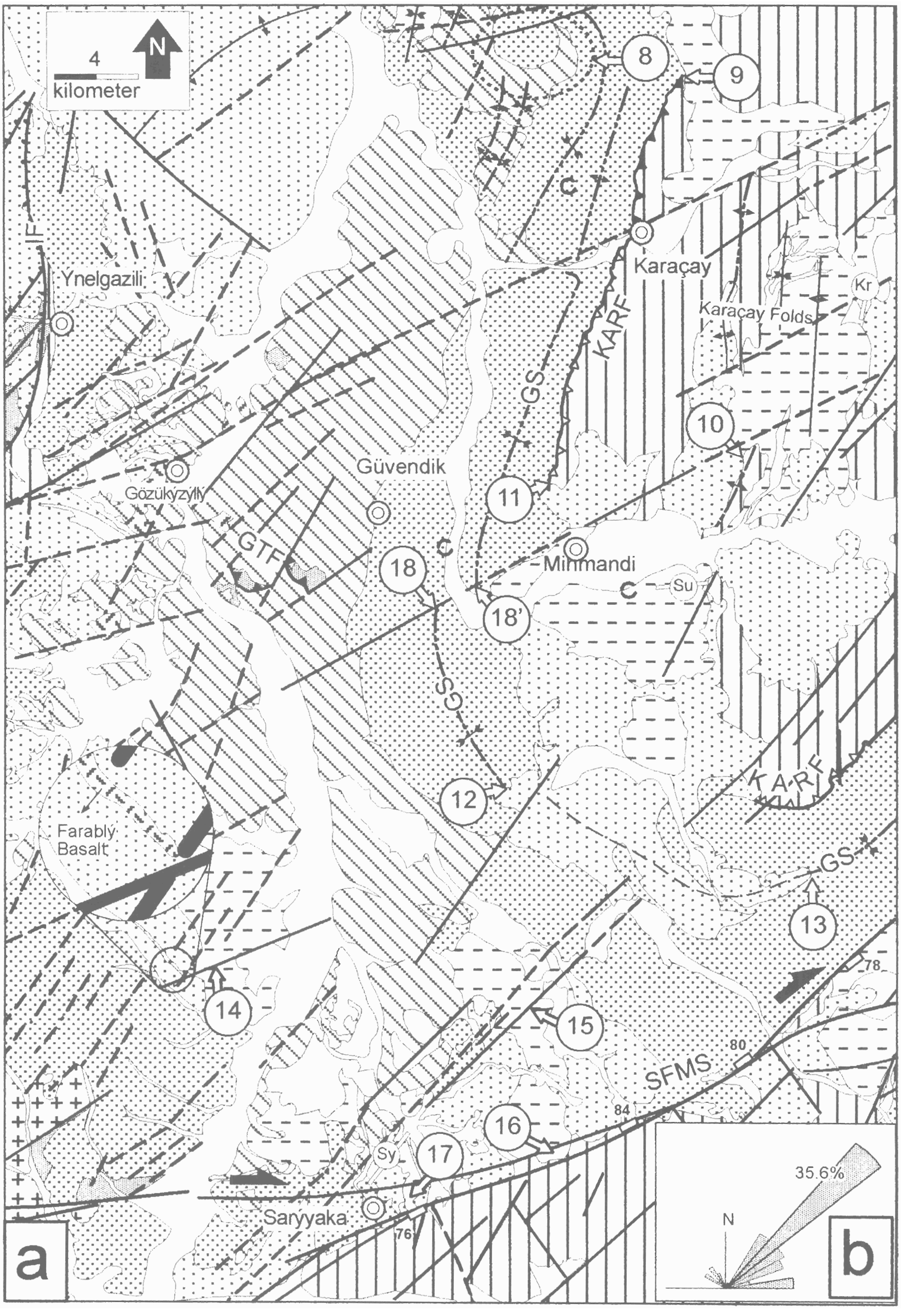


**Fig.** 10: Geological map of the eastern margin of the Çankırı Basin (see Figure 5 for the explanation of the symbols).

are consistent with a best fit for the fossiliferous level at either 16.3-16.5 Ma or 13.5-14.1 Ma. (MN-5 & MN-6), depending on presence and duration of gaps in the paleomagnetic section (KRIJGSMAN, this volume) and the age of MN 5-MN 6 (BEGUN et al., this volume). These results are consistent with the biostratigraphical correlations, and help to constrain the middle Miocene age of the Çandır Formation (see also BEGUN et al., this volume). The *Cricetodon* specimens from Sarıyaka locality seem to represent the same species as the one in the assemblage from the Hancılı Formation, suggesting a correlation with MN-4. Therefore, the Çandır Formation apparently encompasses MN-4 to MN-5 or 6 (Burdigalian'? to Langhian or mid-Serravalian). The main rodent locality from Çandır, and the stratigraphically close main large mammal locality (Loc. 3) are most probably in the middle of this range.

## Neogene Tectonics

In this section, the deformation style and tectonic relationships of the Neogene units with each other and with the structures developed in the Çankırı Basin and adjacent Hancılı Basin is given (Figure 5). In Figure 11 various boundary relationships of the units in relation to the faults developed in the western part of the Çankırı Basin are illustrated. Figure 12 depicts the temporal relationships between the basin in-fill and the structures developed in the Hancılı Basin and the western part of the Çankırı Basin.

The thrust faults developed within the Hancılı Basin overlay the Hancılı Formation, of Langhian age (Figure 4) and are locally covered by the MN-17 Deyim Formation. Therefore they are between post-Langhian and pre-Galesian in age. The age of the Kılçak Thrust Fault (KTF) is not constrained precisely because of lack of its relation between other Neogene units. It postdates underlying Kılçak Formation of Aquitanian age and predates Deyim Formation of Galesian age (Figures 11a & 12). The Kazmaca-Hamzalı Reverse Fault (KHRF) is covered by the Suleymanlı Formation and developed in the early Tertiary. It is interpreted to be pre-Aquitanian based on sources information discussed elsewhere (KAYMAKCI et al. 1999a, b, c & d). In addition, the Kargın Anticline and Syncline (KA and KS, 4 and 5 in Figure 5b) are parallel to the KHRF. The strikes of the beds of the Dizilitaşlar and Çandır formations are parallel to each other on either limb of the anticline. Unfolding of the Dizilitaşlar Formation according to dip amount of the Çandır Formation indicates that this structure has two episodes of coaxial folding. The earlier phase developed prior to the deposition of the Çandır Formation in Burdigalian? to

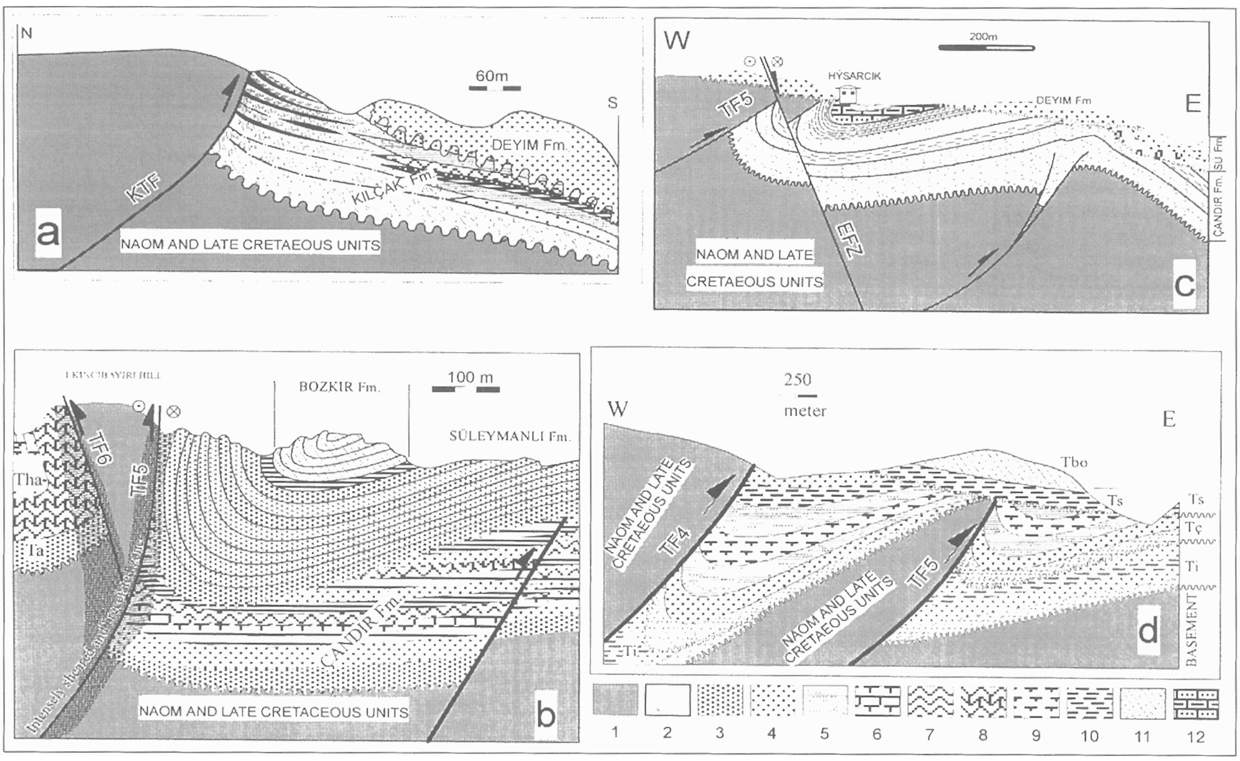


**Fig. 11:** Schematic illustration of various tectonic relationships between a) NAOM, Kılçak and Deyim formations (locality is 1 in Figure 5. view to East). b) NAOM, Altıntaş, Hancılı, Çandır, Suleymanlı and Bozkır formations. Note overturning of the Bozkır Formation (locality is 2 in Figure 5, view to north). c) NAOM, Çandır Formation, Suleymanlı and Deyim formations. Note that Deyim Formation overlies the thrust contact (locality is 3 in Figure 5). d) NAOM, İncik, Çandır, Suleymanlı and Bozkır formations. Location is near Akçavakıf village (3 in Figure 10, view to N).

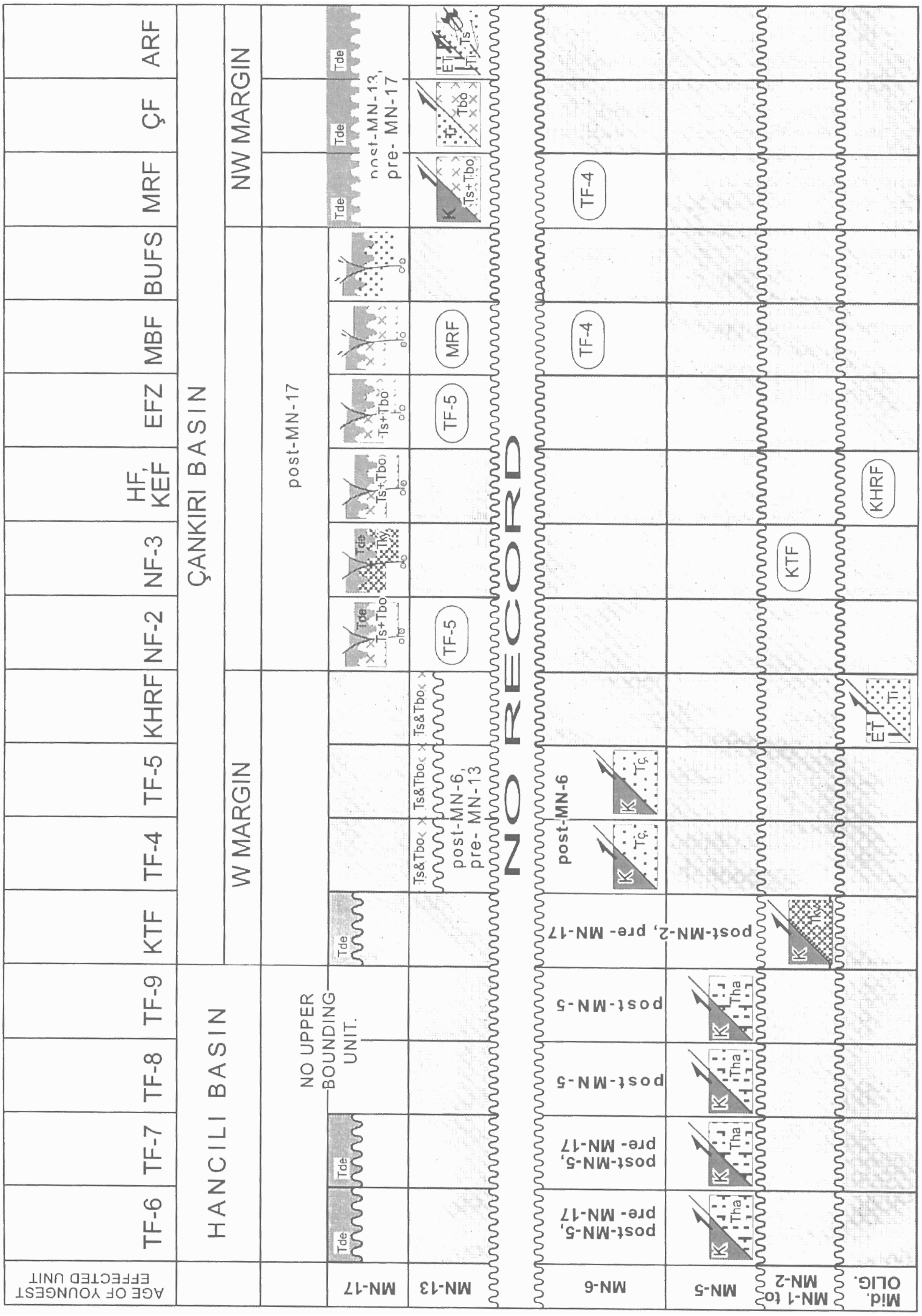


**Fig.** 12: Temporal relationships between various structures developed in the western and north-western part of the Çankırı Basin (see Figure 3 for the abbreviations of the units). The faults indicated in ellipses are displaced by the faults in the top row.

Serravalian (Figure 13). Together with the information discussed in the KAYMAKÇI et al. (1999a), this relation indicates presence of a compressional deformation prior to Aquitanian.

The reverse faults developed in the western margin of the Çankırı Basin overlay the Çandır Formation and are covered by the Suleymanly and Bozkır Formations and are therefore of post-Serravalian age (Figure 11b-c & 12). The youngest reverse faults in the Çankırı Basin are developed in the north-western corner of the basin. These reverse faults overlay the Suleymanlı and Bozkır Formations and are covered by the Deyim Formation and are thus of post-Messinian and pre-Galesian age (Figure 12). The youngest structures developed in the Çankırı Basin are the strike-slip faults. They have displaced most of the thrust and reverse faults and the Deyim Formation of Galesian age. In Figure 12 temporal relationships of some the most prominent of these strike-slip faults are illustrated. Among these the Eldivan Fault Zone (EFZ in Figure 9a) defines the western boundary of the Çankırı Basin and it includes a number of 15 km to few meters long faults oriented about NNE-SSW. The Merzi-Badiğin

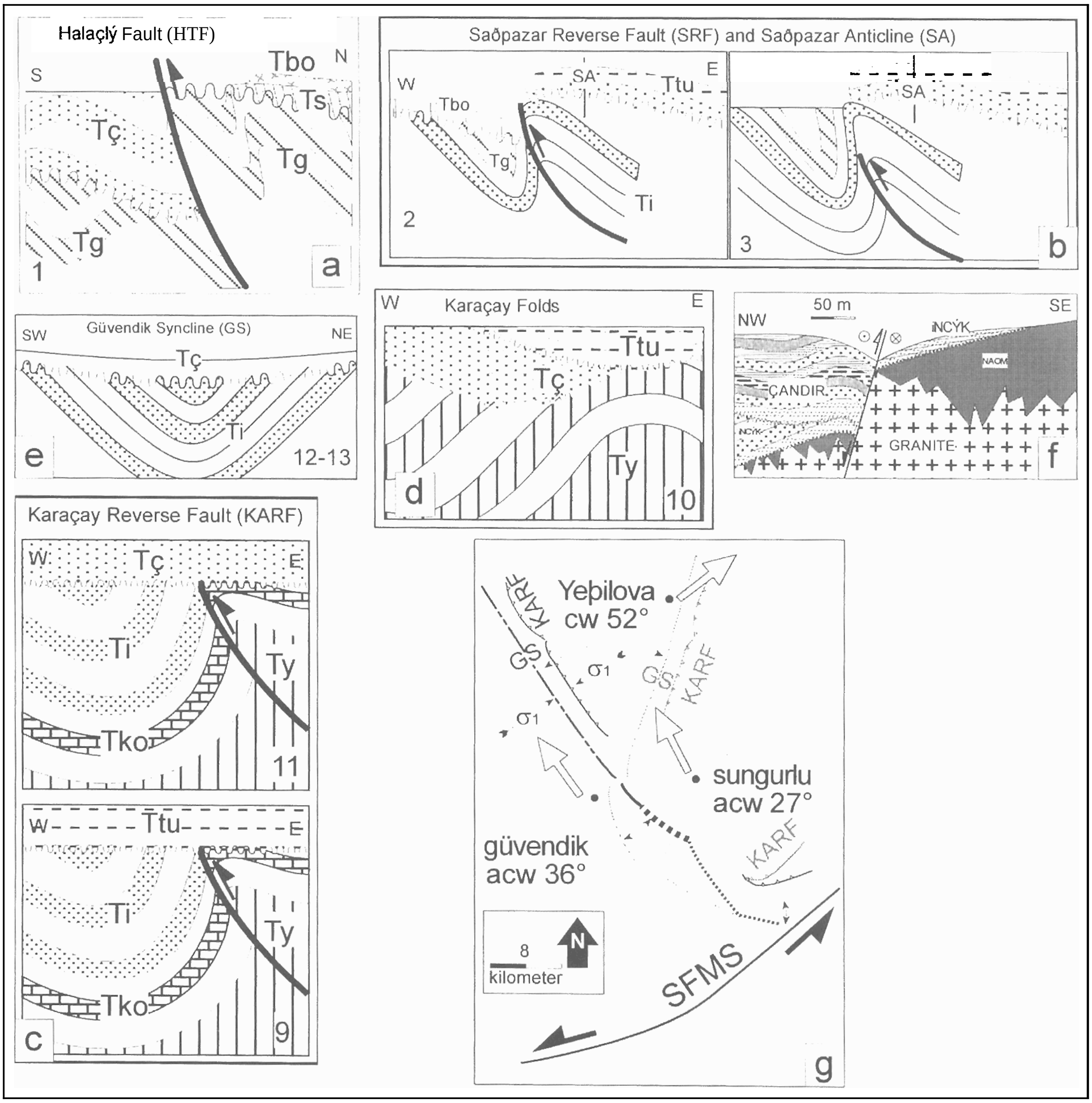


**Fig.** 13: Schematic illustration of various tectonic relationships between different Neogene units (Numbers are the locations of sketches in Figures 11 & 13). Note emergent and blind nature of the SRF. f) Cross-section depicting an inverted normal fault near Dağhalilince village (see its location in Figure Xa). Note inverse dragging and normal separation that is still preserved and also to the on-lap unconformities between the basement and the İncik Formation. View to N. The down going arrow indicates normal faulting and up going arrow indicates reverse faulting due to inversion.

Fault set (MBF in Figure 9a) includes some NE-SW oriented strike-slip faults about 30 km long and delimits the NW corner of the Çankırı Basin (Figure 9).

In the Hancılı Basin, two sets of folds have developed (Figure 5). One set is oriented approximately NW-SE parallel to the thrust faults and the horst-like blocks that separate the Hancılı Basin into 3 separate depressions. This relation implies that these folds are developed under the same tectonic regime that resulted in the thrust faults developed in the Hancılı Basin (TF-6 to TF-9). The other set of the folds are developed in the Hasayaz Depression and are oriented NE-SW. The folds in the western part of the Çankırı Basin are oriented generally in two directions. The folds developed within the Çandır Formation are oriented about NNE-SSW. Except for the Çankırı Anticline (ÇNA in Figure 9) the folds developed within the late Miocene units (Tuğlu, Suleymanlı and Bozkır Formations) are oriented NE-SW. Starting from the Ovacık Monocline (Figure 9) and moving towards the north-west the major folds (the Suleymanlı Anticline (SUA) and Syncline (SS), the Topuzsaray Anticline (TA), the Yőrűk Syncline (YS), the Kývçak (KF) and the Yapraklı folds (YAF)) change their orientation gradually from about E-W to NE-SW. The tightness of the folds is higher in the NW (KF and YAF) and in the south (Ovacık Monocline and SUA). These relations are interpreted to be the response of the more deformable basin in-fill material caught within a wedge shaped are defined by the reverse faults in the NW corner of the Çankırı Basin and the Kırşehir Block in the south.

The folds developed in the western margin of the Çankırı Basin are oriented into two directions (Figures 5 & 9). The folds developed in the Çandır Formation are oriented NNE-SSW while the ones developed in the Suleymanlı and Bozkır Formations are oriented NE-SW. The folds in the restrained areas tend to become parallel to the restraining bend (BIDDLE and CHRISTIE-BLICK 1985). The orientation of the folds in the Sűleymanlý and Bozkir Formations may be explained by this relation. The other explanation is the simple shear deformation that causes progressive rotation of the folds such that as the deformation progressed the earlier formed folds tend to become parallel to the main displacement zone; which is the Eldivan Fault Zone (EFZ), while the later ones make higher angles.

In the previous sections it is documented that the pre-Neogene of the Çankırı Basin is characterized by generally E-W oriented compression and beginning of the Neogene in the Çankırı and Hancılı basins are accompanied with extensional deformation (Figures 18 & 20). This phase of compression and thrusting is also discussed in KAYMAKÇI et al. (1999a, b, c & d).

Considering all the information documented above, a model is proposed for the Hancılı Basin and the western margin of the basin (see Figure 14). During the latest Oligocene the western margin of the Çankırı basin was dominated by an approxiinately E-W oriented thrusting with 2 sets of tear faults oriented NW-SE and ENE-WSW, respectively (Figure 14a & b). During this period, the İncik Formation of Middle Eocene to Middle Oligocene was deposited coeval with thrusting (see also KAYMAKCI et al. 1999a). By the beginning of the Neogene, the region is dominated by extensional deformation (Figure 14c & d) and Altıntaş and Hancılı Formations were deposited in the Hancılı Basin (Figure 14) while in the Çankırı basin, Kılçak and Çandır Formations were deposited. Similar relations are also observed in the central parts of the basin that is dominated by normal oblique-slip faults oriented in NNE-SSW directions (Figure 8).

In post-MN-6 (possibly Tortonian to present) the extensional regime is replaced by approximately NW-SE oriented compression (Figure 12).

The beginning of the extensional tectonic regime in the Çankırı Basin is in Aquitanian (23.8 Ma). SEYITOĞLU et al. (1992) and BOZKURT & PARK (1997) proposed that beginning of the extensional regime in western Anatolia is Early Miocene. Therefore, it can be concluded that the eastern continuation of the extensional regime in the western Anatolia can be extended at least up to the Çankırı Basin. The North Anatolian fault Zone (NAFZ) is the major structure that controls the post-Late Miocene tectonics of Turkey. The Master strand of the Sungurlu Fault Zone (SFMS) is the sub-strand of the Ezinepazarı-Sungurlu Splay of the NAFZ. The Kızılırmak Fault Zone (KFZ) is the western continuation of the Laçin Fault Zone (Figure 15a). Presently, these faults have dextral strike-slip sense of movement while the Eldivan Fault Zone (EFZ) has sinistral strike-slip sense of movernent. Its orientation and sense of movement indicates that EFZ is the r'-shear of the NAFZ (Figure 15b & c). The orientations of the $\sigma_1$ that is discussed in KAYMAKCI et al. (1999b & c) are in good agreement with the P&T axes obtained from seismic fault plane solutions (Figure 15). It is proposed that all of these faults including the NAFZ, its splays in the Çankırı Basin, EFZ, and other structures discussed in previous sections can be explained by riedel pattern of deformation. Therefore, it can be concluded the latest compressional deformation recognized in the Çankırı Basin is not a local phenomenon but it fits well into the overall regional trancsurrent tectonics in the eastern Mediterranean area that resulted in the development of the NAFZ.

In conclusion, eight different Neogene stratigraphic units are differentiated and mapped in the Çankırı Basin. These units are dated using rodent fossils. The age of the units in which no rodents were found in the field are constrained by their superposition with respect to well-dated units. The Kılçak Formation is characterized mainly by fluvio-lacustrine clastics and it is the oldest Neogene unit in the Çankırı Basin and it is of Aquitanian age (MN-1 to MN-2 Mammal Zones). The Altıntaş Formation is characterized mainly by red clastics and it is of Burdigalian in age. The Hancılı Formation is characterized mainly by lacustrine deposits and of Burdigalian to Langhian in

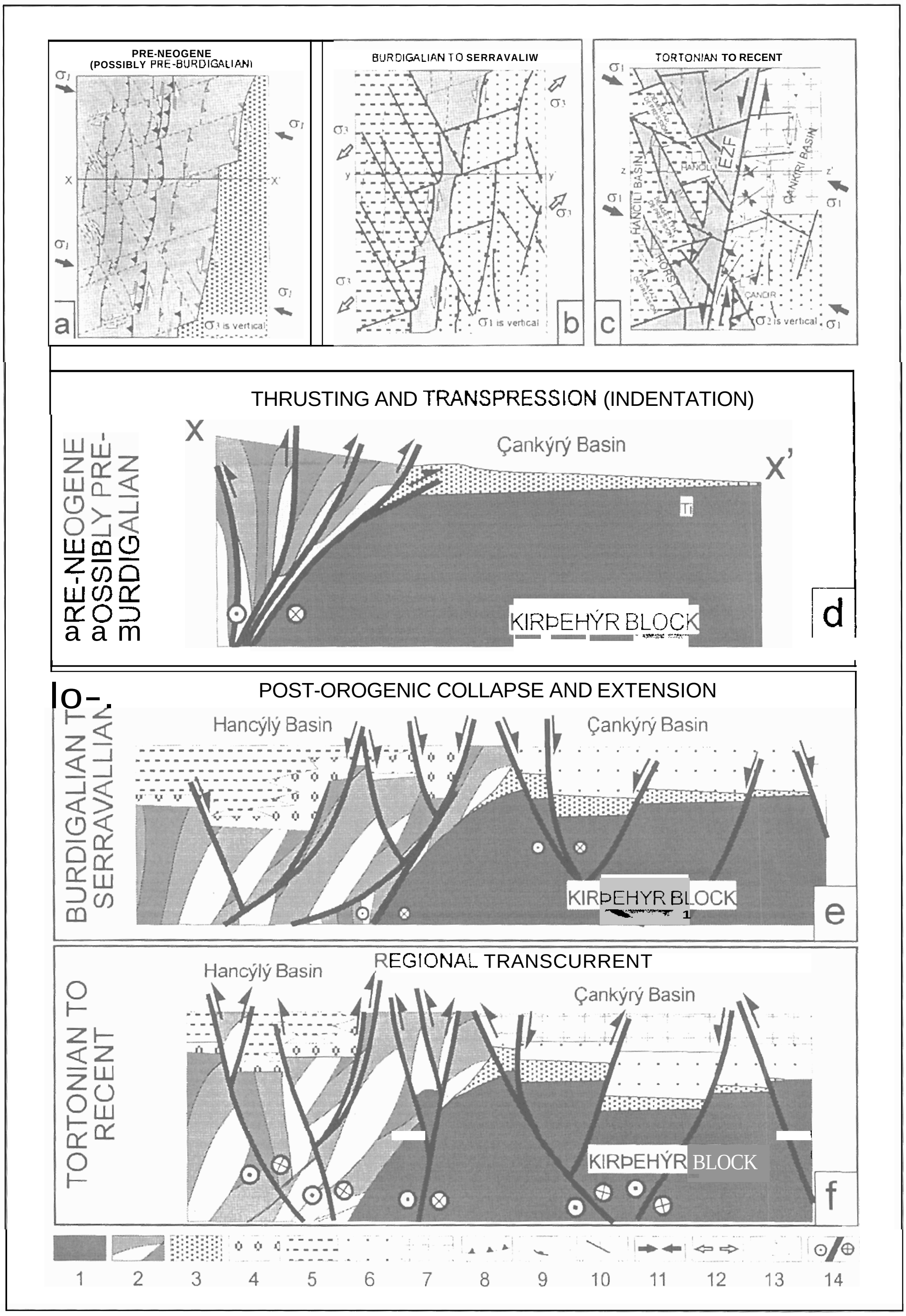


**Fig.** 14: a-c) Cartoons illustrating tectonic evolution of the western parts of the Çankırı Basin. d-f) schematic cross-sections along imaginary E-W lines. (a & d) Phase of thrusting in pre-Neogene. Note the orientations of tear fault sets. (b & e) normal faulting and extensional phase in Early to Middle Miocene Note reactivation of tear faults into normal faults in this period. Note also that deposition in the Hancılı Basin and the Çankırı basin is isolated from each other. (c & f) phase of Neogene compression that commenced in Tortonian. Note that most of the normal faults are inverted into reverse faults and they have strike-slip components. 1. pre-Neogene, 2. Incik Formation (Ti), 3. Altıntaş (Ta) and Hancılı (Tha) formations, 4. Çandır Formation (Tç), 5. Suleymanlı ('74) and Bozkır (Tb) formations. 6. thrustireverse fault, 7. normal fault. 8. transpressional faults, 9. compression direction, 10. extension direction.

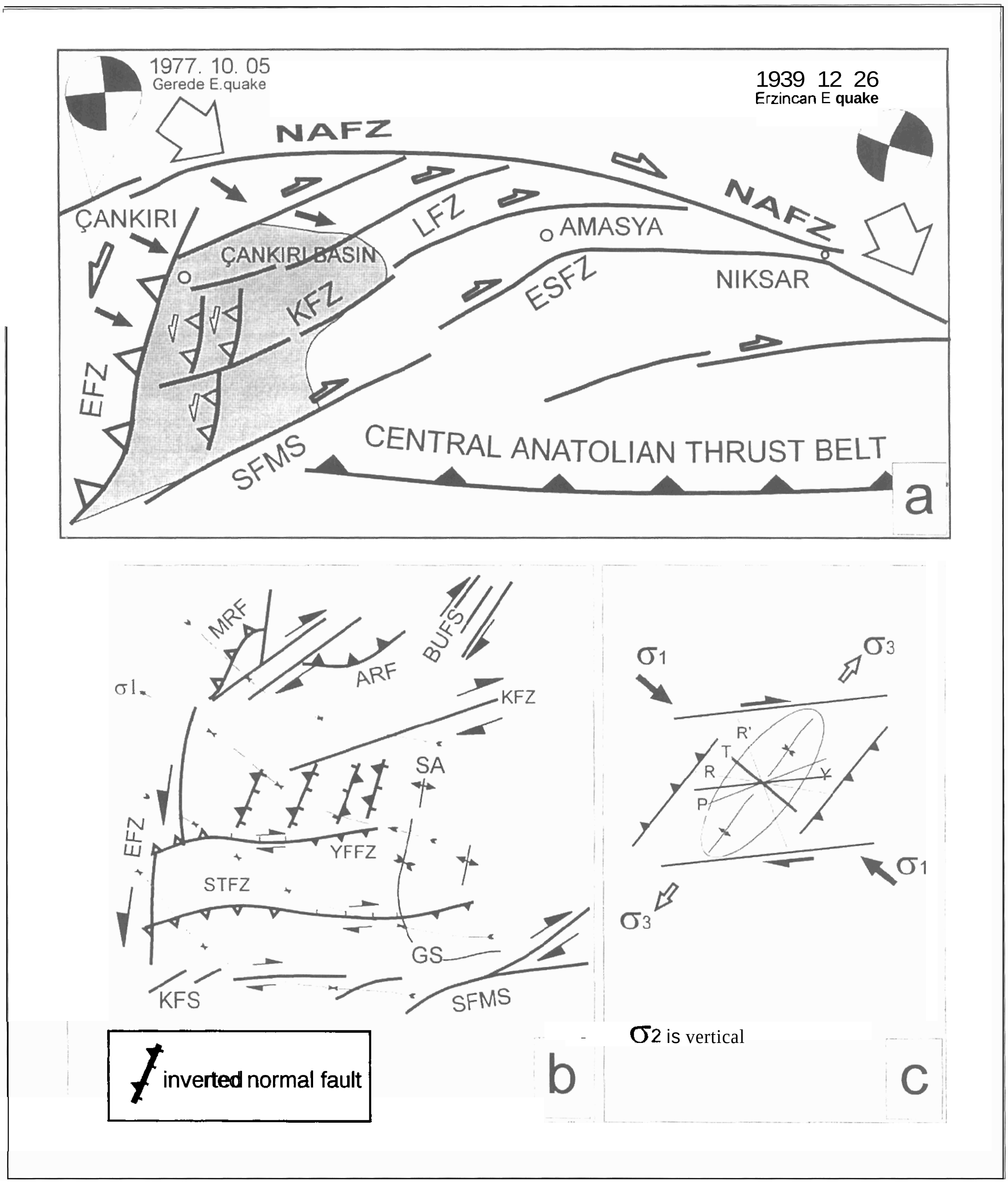


**Fig.** 15: Simplified tectonic map of the active faults in the north central Turkey. EFZ: Ezinepazarı-Sungurlu Fault Zone, KFZ: Kızılırmak Fault Zone, LFZ: Laçin Fault Zone, NAFZ: North Anatolian Fault Zone, SFMS: Master Strand of the Sungurlu Fault Zone (partly modified after BARKA & HANCOCK 1984, ÖZÇELIK 1994. KAYMAKCI & KOÇYIĞIT 1995, fault plane solutions are after JACKSON & MCKENZIE 1984, the location of the 1939 event is approximately 300 km east of the map area, near Erzincan). b) simplified structural map of the Çankırı Basin area. ARF: Ayseki reverse fault, BUFS: Burtü Fault set, EFZ: Eldivan fault Zone, GS: Güvendik Syncline, KFS: Kyrikkale Fault set, MRF: Merzi Reverse Fault, STF: Sivritepe Fault Zone, YFFZ: Yağbasan-Faraşlı Fault Zone. c) riedel pattern of deformation proposed for the structures developed in the latest phase of deformation (Tortonian to recent) in the Çankırı Basin area.

age. The Çandır Formation is characterized by fluvio-lacustrine clastics and carbonates and it is of Burdigalian to Serravalian in age. The Tuğlu Formation is characterized mainly by evaporites and it is of Tortonian in age. The Suleymanly Formation is of Messinian to Pliocene in age and characterized mainly by fluvio-lacustrine red clastics. The Bozkır Formation is of Messinian to Pliocene in age and characterized by thick evaporites. The Deyim Formation is of Galesian in age and characterized mainly by fluvial clastics.

Two different tectonic regimes were recognized in the Neogene. The earlier regime commenced in Aquitanian (23.8 Ma) and characterized by extensional deformation in which Kılçak, Altıntaş, Hancılı, and Çandır formations were deposited. The second regime is characterized by regional transcurrent tectonics and commenced in Tortonian (9.7 Ma) in which Tuğlu, Suleymanly, Bozkır and Deyim formations were deposited. In the latest tectonic regime early-formed structures, both in the Hancılı and in the Çankırı Basin, are inverted into transpressive Faults. The latest tectonic regime in the Çankırı Basin is implemented by the same tectonic regime that resulted in the development of the North Anatolian Fault Zone and it is current active.

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