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Testing of Permian-Lower Triassic stratigraphic data in half-graben/tilt-block system: evidence for the initial rifting phase in Antalya Nappes

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ABSTRACT

Testing of Middle Permian-Lower Triassic stratigraphic data from the Antalya Nappes in a half- graben/tilt-block system has revealed the presence of episodic rifting events separated by periods of tectonic quiescence. Following a period of uplift during the Permian (late Artinskian to Roadian), the basement rocks have been activated by displacement faults and several depocenters in half-graben like asymmetrical basins began to be filled with Roadian to Wordian continental clastic deposits intercalated with coal and marine rocks. The early Capitanian time was a period of tectonic quiescence. The second event occurred in middle to late Capitanian times and produced basaltic volcanic rocks intercalated in the shallow marine fossiliferous carbonate successions. Following the Lopingian (Wuchiapingian and Changhsingian) and Permian-Triassic boundary interval representing a long tectonic quiescence, the last rifting episode started with an abrupt facies change in the late Griesbachian. Variegated shales, limestones, volcanics, talus breccia and debris flow deposits were laid down in a half-graben/tilt-block system. As normal faulting has become active the deposition continued on the subsiding hanging wall side. The stratigraphic gap increased in magnitude as the erosional truncation has incised deeply the footwall side. This initial rifting phase in the Antalya Nappes is prior to the onset of a stronger and more continuous rifting event which occurred in the Anisian-Carnian interval including a variety of deep water clastic and carbonate deposits, radiolarites containing sometimes blocks and clasts derived from the basin margins and volcanic rocks carrying intra-oceanic setting character.

Keywords

Rifting, Stratigraphy, Permian-Early Triassic, Antalya Nappes, Turkey

Introduction

Studies in the last 50 years have shown that lithospheric extension is characterized by a distinctive development of tilt blocks and half-grabens bounded by major normal faults (Mckenzie 1978; Şengör and Burke 1978; Şengör 1995; Şengör and Natal'in 2001; Wernicke and Burchfiel 1982; Jackson et al. 1982a, b; Brun and Choukroune 1983; Gibbs 1984, 1987; Bosworth 1985; Lister et al. 1986; Barr 1987; Leeder and Gawthorpe 1987; Dewey 1988; Ingersoll 1988; Schlische 1991; Ziegler and Cloetingh 2004; Merle 2011, Franke, 2013). In the western Tethyan belt, many of the rifted margins formed by lithospheric extension are found in orogenic belts; they are highly disrupted, pervasively deformed or rarely preserved due to subsequent orogenic deformation. Although these rifted margins carry crucial information on continental break-up mechanisms, particularly their initial phase remains poorly understood and thus receives less attention in the picture of the process of rifting.

There are two fundamental approaches for the study of rifts in orogenic belts. In volcanic associated rift systems geochemical evidence plays an important role in determining the tectonic setting of rift-related rocks. However, the whole configuration of the rift system can only be understood with high resolution stratigraphic/structural data which would constitute the basis of possible rift models.

The main purpose of this contribution is to focus on the timing of the early rifting phase in one of the complicated orogenic belts in Turkey known as Antalya Nappes, based on several stratigraphic sections measured in Permian-Lower Triassic successions. In order to understand the early phase of the continental rifting, tectonosedimentary facies models for extensional basins of several authors (Ahr 1973; McIlreath and James 1978; Read 1982, 1985; Leeder and Gawthorpe 1987; Gawthorpe and Leeder 2000; Bosence 2005; Cross and Bosence 2008; Dorobek 2007; Jerram et al. 2016) have inspired us to analyse the critical position of rift-related facies and their relation with the underlying pre-rift rocks. We have adopted the highly simple and practical tectonosedimentary facies model for coastal/shelf basin with carbonate facies of Leeder and Gawthorpe (1987) which has been elaborated and enriched by Gawthorpe and Leeder (2000) and Cross and Bosence (2008). In the model of Leeder and Gawthorpe (1987), within a characteristic half-graben/tilt-block system generated by extensional tectonism, facies mosaics are greatly controlled by tectonically induced slopes resulting from hanging wall downtilting and footwall uplift. In the studied sections covering the interval from Permian to Lower Triassic we have detected several rock relationships and facies indicating the particular characteristic features of this tectonic environment.

Regional Geological Setting and previous studies on rift-related successions in the Antalya Nappes

The Tauride Block, known as a distinct tectonic entity within the Late Paleozoic – Mesozoic geological history of Turkey, comprises an autochthonous belt ranging in age from Cambrian to Eocene and the nappes composed of oceanic and platform margin-slope deposits derived from both the north and the south of the platform (Özgül 1976, 1984a, 1997; Şengör and Yılmaz 1981; Altiner and Özgül 2001). In the Central and Western Taurides, this autochthonous belt is represented by three distinct units, namely Geyik Dağı, (restricted only to the Anamas-Akseki belt in this study, see also Şahin et al. 2012), Karacahisar and the Beydağları (Fig. 1). Allochthonous units are basically divided into two groups. Northern allochthons comprise Aladağ, Bolkar Dağı, Bozkır and Lycian Nappes, and the southern ones consist of Antalya and Alanya Nappes.

Among the allochthonous units of the Tauride Belt, Antalya Nappes (Lefèvre 1967; Brunn et al. 1971; Gutnic et al. 1979), known also as 'Antalya Complex' (Woodcock and Robertson 1977; Robertson and Woodcock 1981a,b,c; Waldron 1981,1984a,b; Yılmaz 1984; Robertson et al. 2003) or 'Antalya Unit' (Özgül 1976, 1984a) constitute a regionally important allochthonous rock assemblage of Paleozoic and Mesozoic age widely exposed within the Isparta Angle, around the City of Antalya (Fig. 1). Although the same tectonic units within the Antalya Nappes have been classified under different nomenclature by several authors (see references in Şahin et al. 2012) it was Brunn et al. (1971) who recognized for the first time the fundamental subdivision of the Antalya Nappes. According to their nomenclature, the lower nappe consists of an Upper Triassic to Upper Cretaceous sedimentary rock succession and is capped by a Campanian-Maastrichtian flysch containing blocks. The middle nappe is composed of Mesozoic deep-water clastics and carbonates, radiolarites associated with submarine basic volcanics and ophiolitic rocks while the upper nappe is represented by Paleozoic and Mesozoic platform-type deposits.

Antalya Nappes constitute a good example for understanding rift settings and continental breakup mechanisms in the eastern Mediterranean (Şengör and Yılmaz 1981; Yılmaz 1984; Robertson 2002, 2007; Robertson et al. 2003, 2012). Robertson (2002, 2007) and Robertson et al. (2003, 2012) stated that pre-Triassic rift volcanics are insignificant as evidence for rifting in the eastern Mediterranean and an extensional setting is inferrred to have existed throughout much of the northern Gondwana region during Middle-Late Permian time. Although this statement is correct in a very general context the recent discovery of basaltic rocks of Capitanian age intercalated within the shallow marine carbonate successions in the Antalya Nappes by Şahin et al. (2012) contradicts this generalization because it reveals the presence of rift-associated volcanism in the Permian. More recently, Tekin et al. (2016) and Sayit et al. (2017) questioned the Permian age of the volcanic rocks prefering to assign them a Triassic age. However, the volcanic rocks are clearly intercalated with Permian (Capitanian) shallow marine limestones containing basalt fragments, which demonstrates their Permian age. Permian rifting, based on widespread tectonic subsidence and marine transgression, is documented in many areas including onshore Levant (Garfunkel and Derin 1984; Garfunkel 1998, 2004; Gardosh et al. 2010), within the Antalya Nappes (Poisson 1977, 1984; Robertson and Woodcock 1982) and the central Taurides (Monod 1977; Özgül 1984a, 1997; Altiner et al. 2000; Mackintosh and Robertson 2012).

Triassic rifting is documented throughout the eastern Mediterranean region, and the best-documented example is from the Antalya Nappes (Marcoux 1970, 1974; Robertson et al. 2012). As one of the earliest evidences of rifting, Özgül (1984a) mentioned about the rift basins as early as middle Anisian in the Triassic stratigraphy of the Antalya Nappes based on the presence of olistoliths and debris flows derived from the older rocks of their own stratigraphy. Particularly within the middle nappe, thrust sheets include Triassic slope to basin siliciclastics, radiolarites and carbonate sedimentary rocks intercalated with volcanic rocks (Juteau 1980; Poisson 1977; Robertson and Woodcock 1982). Robertson and Waldron (1990) studied these Triassic lavas and reported that they range from within-plate, to transitional and mid-ocean ridge-type basalts. They interpreted these extrusions as products of the rifting of the northern margin of Gondwanaland in Early Triassic time. Varol et al. (2007) studied the basalts of Carnian age from the Antalya Nappes and reported that they are very similar to oceanic island basalts. In a recent study, Maury et al. (2008) studied the Carnian basalts belonging to the Karadere-Sayrun unit of the Middle Antalya Nappes and noted their emplacement in an intra-oceanic setting. The upper nappe represented by a carbonate platform (Tahtalıdağ unit) developed on one or several rifted continental fragments, surrounded by these slope sediments associated with volcanics (Robertson 1993, 2007; Robertson and Woodcock 1982; Robertson et al. 2012, 2013).

Study areas and Permian-Lower Triassic stratigraphy

Seven areas have been studied from the Antalya Nappes displaying different aspects of the Permian-Lower Triassic stratigraphy (Fig. 1). Three of these areas, Adrasan, Gedelme and Üçoluk, are located to the west and southwest of the City of Antalya, in the southwestern sector of the Antalya Nappes largely exposed between the Mediterranean Sea and the Beydağları Autochthon. The Koçular area is located to the north of the City of Antalya, where the Antalya Nappes expose at around and to the south of the Eğirdir Lake. The other three areas, Güzelsu, Demirtaş and İnceğiz, are located in the eastern sector of the Antalya Nappes to the east of the City of Antalya. In this sector, the Antalya Nappes crop out under the tectonic cover of the Alanya Nappes (Fig. 1).

The Middle-Upper Permian sequence constitutes the main part of the studied succession and was calibrated by a recent biozonation comprising 10 biozones (Py1-Py10) introduced by Altiner and Şahin (2012) and Şahin et al. (2012) along a thick carbonate section fully exposed in the eastern Taurides. With a slight modification, this zonation purely based on foraminifera is as follows: Roadian to Wordian (Py1 zone: unnamed zone); upper Wordian (Py2 zone: primitive *Dunbarula* zone); lower Capitanian (including the Wordian-Capitanian boundary beds) (Py3 zone: *Eopolydiexodina-Rugososchwagerina* zone); lower to middle Capitanian (Py4 zone: *Chusenella* gr. *conicocylindrica-Skinnerella* zone); upper Capitanian (Py5 zone: unnamed zone; Py6 zone: *Shanita* zone; Py7 zone: *Necdetina taurica* zone); lower Wuchiapingian (Py8 zone: *Paraglobivalvulina mira-Reichelina* zone); upper Wuchiapingian (Py9 zone: *Louisettita elegantissima* zone) and Changhsingian (Py10 zone: *Paradagmarita monodi* zone). Biozones are shown in the measured sections and important markers of these zones are illustrated in Fig. 2.

Adrasan area

In the Adrasan area, located 32 km south of the Town of Kemer, two main rock assemblages have been recognized belonging to middle and upper Antalya Nappes (Fig. 3A and 4). Two stratigraphic sections have been measured in the upper nappe in order to understand the evolution of the Permian-Lower Triassic stratigraphy. The

Olimpus-1 section has been measured in two of the tectonic slices and consists of three stratigraphic portions (a, b, c) delimited by faults (Fig. 3A, 5 and 6A). The part of the section (a) belonging to the lower tectonic slice is made up of Wuchiapingian and Changhsingian limestones rich in crinoids, brachiopods, *Bellerophon*-type gastropods and foraminifera. The Wuchiapingian has been calibrated by the Py8 (samples 74-83) and Py9 (samples 84-89) zones whereas the Changhsingian corresponds to the Py10 zone (samples 90-100) of Altiner and Şahin (2012). The continuation of the section in the second slice is interrupted with a normal fault (b and c portions) (Fig. 3A and 6A). The lower portion (b) is composed of algal and foraminiferal limestones of middle to late Capitanian age and is equivalent of the Py4 (samples 101-103), Py5 (samples 104-107) and Py6 (samples 108-109) zones, whereas the upper portion (c) comprises both the uppermost Permian (Changhsingian) Py10 zone (samples 110-116) and the base of the Akıncıbeli Formation of Demirtaşlı (1987) consisting of variegated shales intercalated with *Postcladella*- and *Spirorbis*-bearing clayey limestones of late Griesbachian age (samples 117-118). The succession studied along the Olimpus-2 section in the Adrasan area (Fig. 3A, 5 and 6A) is similar to the upper portion (c) of the Olimpus-1 section. Limestones containing chert nodules represent the Changhsingian Py10 zone (samples 122-127) and are unconformably overlain by the upper Griesbachian basal layers (samples 128-137) of the Akıncıbeli Formation.

The Permian to lowermost Triassic succession in the Adrasan area is incomplete. Available stratigraphic data indicate that the Permian carbonates are nearly continuous from mid-Capitanian to Changhsingian. However, the Roadian-Wordian to lower Capitanian part of this formation is missing because of tectonic repetitions in the area. The most critical stratigraphic information in the Adrasan area comes from the Permian-Triassic boundary beds. Paleontological data indicate that the boundary corresponds to an unconformity. The Griesbachian Kokarkuyu Formation of Altiner (1981) and the top of the Changhsingian stage are missing in the succession and the upper Griesbachian basal layers of the Akıncıbeli Formation rest on the eroded Changhsingian beds of the Permian Çukurköy Formation.

Gedelme area

Located 8 km to the west of the Town of Kemer and approximately 40 km southwest of the City of Antalya, the Gedelme area displays highly different aspects of the Permian-lowermost Triassic stratigraphy (Fig. 3B). Despite the presence of a fault between Permian and the Triassic successions the Kesmeboğazı section displays the most complete Permian stratigraphy in the area (Fig. 3B and 7). The Roadian-Wordian portion of the section measuring more than 70 m in thickness consists of sandstones, shales, bituminous clayey limestones and rests unconformably on the Upper Silurian-Lower Devonian limestones and quartz sandstones (samples 55-67) (Fig. 7). This poorly fossilifeous interval corresponds to the Py1 and Py2 zones of Altiner and Şahin (2012). Capitanian starts with dominantly occurring fossiliferous limestones rich in algae and foraminifera. The first two zones are the equivalents of Py3 (samples 68-89) and Py4 (samples 90-103) zones. Despite the absence of the markers of the upper zones Py5-Py7 (e.g. *Shanita* or *Necdetina*) the interval corresponding to samples 104-107 in the section has been assigned to the upper Capitanian. The upper limestones in the Kesmeboğazı section belong to the Lopingian Series. The lower part is Wuchiapingian in age and corresponds to the Py8 and Py9 zones (samples 108-110) whereas the upper part belongs to the Changhsingian Py10 zone (samples 111-121). The base of the Akıncıbeli Formation of late Griesbachian age rests on the Changhsingian carbonates at a faulted contact.

The other two sections, Beşiktaşalanı and Sumakseniri, measured in the southern part of the Gedelme area, are mainly Capitanian in age (Fig. 3B and 7). The Beşiktaşalanı section starts with questionable Wordian sandstones (Py2? zone, samples 119-120) at the tectonic contact between the middle and upper Antalya Nappes and continues upwards with the lower to middle Capitanian Py3 and Py4 zones (samples 121-138). The continuation of the Py4 zone entirely composed of limestones has been measured in the Sumakseniri section (samples 158-171). In this section an important part of the Permian carbonates corresponding to upper Capitanian (Py5-Py7 zones), Wuchiapingian (Py8-Py9 zones) and Changhsingian (Py10 zone) and the Griesbachian Kokarkuyu Formation seem to have been truncated by an erosion surface and the base of the Akıncıbeli Formation unconformably overlies the lower-middle Capitanian of the Çukurköy Formation.

The Sapandere section, located 1.5 km to the north of the Kesmeboğazı section, displays another interesting stratigraphic relation with the underlying basement rocks (Fig. 3B and 7). This time a Capitanian succession, corresponding to Py3 (samples 184-185), Py4 (samples186-193) and Py5 (samples 194-199) zones with an alternation of limestone, quartz sandstone, shale and a distinct basaltic lava layer, directly rests on the Devonian sandstones .

The Permian-lowermost Triassic stratigraphy in the Gedelme area displays very interesting rock relations within a few km^2 large area. Despite the presence of a faulted contact at the top of the Changhsingian beds the Kesmeboğazı section represents a nearly full record of the Çukurköy Formation consisting of Roadian-Wordian clastics at the base and a carbonate dominated succession from Capitanian to Changhsingian in the upper part of the section. However in the southern part of this area a deep incision, down to the Capitanian stage, is observed below the upper Griesbachian strata of the Akıncıbeli Formation. In the northern part, another remarkable stratigraphic relation is the absence of Roadian-Wordian clastics above the basement rocks where the Capitanian stage directly rests on the Devonian clastics.

Üçoluk area

This area is located 15 km northwest of the Kemer Town and 35 km southwest of the City of Antalya and is entirely composed of a rock succession of the upper Antalya Nappes (Fig. 3C). Three stratigraphic sections have been measured in the upper nappe. In the Belendere section Permian rocks rest unconformably on the Devonian clastics dated as Strunian (late Famennian) based on palynology and starts at the base with a nearly 60 m thick clastic succession composed of quartz sandstones, siltstones, pyritic shales and coal (Fig. 6B and C, 8). Below the Capitanian carbonates these clastics are most probably Roadian to Wordian equivalent of the Py1and Py2 zones (samples 27-34) of Altiner & Şahin (2012). Overlying Capitanian composed of sandy limestones, limestones and shales most probably belongs to the Py3 zone (samples 35-39) (Fig. 6D and 8).

The Çürükdağ section displays an excellent Permian-Triassic boundary succession and mass extinction record. The section has been extensively studied in order to describe the boundary events and different fossil groups (Lys and Marcoux

1978; Altiner et al. 1980; Marcoux and Baud 1986; Baud et al. 1989, 2005; Crasquin-Soleau et al. 2002, 2004a,b; Angiolini et al. 2007; Kershaw et al. 2011). Only the uppermost part of the Changhsingian stage (Py10 zone, samples 1-10) consisting of algal limestones capped by an oolitic limestone level has been studied from the Permian (Fig. 6E and 8) and this succession is overlain by the Kokarkuyu Formation composed of cyclic rock packages made up of stromatolitic, micritic and oolitic limestones (samples 141-171) (Fig. 6E and F). The presence of *Postcladella kalhori* and *P. grandis* has allowed us to assign a Griesbachian age to the formation. Kokarkuyu Formation is sharply overlain by the Akıncıbeli Formation composed of variegated shales, clayey limestones and thin-bedded limestones rich in gastropods, thin-shelled bivalves and intraformational flat pebbles (samples 172-183). Containing still the Griesbachian fossils, these basal layers of the Akıncıbeli Formation include also some volcanoclastic tuffaceous levels indicating the onset of volcanic activity in the region.

In the Armutgözlek Tepe section the Permian is characterized by recrystallized limestone layers corresponding to the Py10 zone (sample 90-96) of the Changhsingian stage (Fig. 6G and 8). The Permian is directly overlain by the Akıncıbeli Formation; the underlying Kokarkuyu Formation of Griesbachian age was truncated by erosion. Following a bauxitic level accumulated over the unconformity surface, basal layers of the Akıncıbeli Formation start with variegated shales and clayey limestones containing *Postcladella* (samples 97-101). These levels are intercalated with a basaltic lava flow (Fig. 6H and 8) which seems to have formed contemporaneously with the tuffaceous layers observed in the Çürükdağ section.

Koçular area

Located 10 km to the south of the Eğirdir Lake (Fig. 1), the Koçular area consists mainly of rock units of the upper Antalya Nappes thrusted by an ophiolite unit (Fig. 3D). Two stratigraphic sections, Barak-1 and -2, have been measured in this area in order to understand the stratigraphic order in the uppermost Permian and Griesbachian units. In the Barak-1 section, a limestone section more than 80 m thick rich in algae and foraminifera corresponds to the Changhsingian Py10 zone (samples 1-14) of Altiner and Şahin (2012) (Fig. 8). Following an observation gap of 2 m the Changhsingian is overlain by laminated (stromatolitic) limestones (samples 15-19). Although the characteristic fossil groups of the Griesbachian substage have not been found and the Permian-Triassic boundary is not well exposed in this section we consider this part of the section as the Kokarkuyu Formation of Griesbachian age. Very close to the Barak-1 section the Kokarkuyu Formation is well exposed to the south of the Barak village along the Barak-2 section (Fig. 8). The formation contains a Griesbachian fossil assemblage including *Postcladella* (samples 26-22) and exhibits a very clear boundary with the overlying Akıncıbeli Formation consisting of variegated shales or mudstones intercalated with clayey limestone beds (Fig. 9A). The top of the Kokarkuyu Formation is subaerially exposed and capped by an iron-oxide rich crust (Fig. 9B). Transgressive Akıncıbeli Formation directly overlies this boundary.

Güzelsu area

The study area is located in the eastern sector of the Antalya Nappes, 45 km northeast of the Manavgat Town (Fig. 10A). Studied by Monod (1977), Demirtaşlı (1987), Şenel et al. (1998) and more recently by Şahin et al. (2012) it constitues an important part of the Güzelsu Corridor and comprises three main tectonic units (Fig. 1

and 10A). These are from north to south, the middle Triassic-middle Eocene Anamas-Akseki Autochthon which constitues a part of the Main Limestone Axis of the Taurides (l'Axe Calcaire du Taurus, Ricou et al. 1975), the Antalya Nappes and the Alanya Nappes which are made up of a metamorphosed Cambrian to Upper Cretaceous rock assemblage consisting in itself of different tectonic slices or units (Özgül 1984a,b; Okay and Özgül 1984; Çetinkaplan et al. 2016). The Antalya Nappes in the Güzelsu Corridor consist of three different slices (Çataltepe, Alakırçay and Tahtalıdağ nappes according to Şenel et al. 1998) and the rock composition and structure of these slices are highly comparable with lower, middle and upper subdivisions of the Antalya Nappes in the type region (Brunn et al. 1971; Gutnic et al. 1979; Şahin et al. 2012) exposed between Kemer and Beydağları (Fig. 1).

In the Güzelsu area three stratigraphic sections have been measured in the upper Antalya Nappes. Along the Çukurköy section, the Çukurköy Formation measures 425 m in thickness (Fig. 10A, 11). It unconformably overlies the Ordovician siltstones and shales and consists of an alternation of sandstone, siltstone, shale, coal and clayey limestone at the base (Fig. 9C and 11). This succession belongs to the Py1 and Py2 zones (samples 594-585; 375-391) of Altiner and Şahin (2012) and is Roadian to Wordian in age. The fusuline- and algae-rich limestone unit at the base of the Capitanian stage belongs to the Py3 zone (samples 392-395). Upwards in the section these fossiliferous limestones intercalated sometimes with quartz sandstone and shale constitute a thick succession corresponding to the Py4 zone (samples 396-452) of the Capitanian. The uppermost part of the Çukurköy Formation composed of dolomites and rarely of limestones is still dated as Capitanian (Py5-Py7 zones, samples 453-460). The

Lopingian of the Çukurköy Formation and the Kokarkuyu Formation of Griesbachian age were eroded in this section and the base of the Akıncıbeli Formation consisting of variegated shales and clayey limestones of latest Griesbachian age directly rests on the Capitanian carbonates (Fig. 9D and E).

The other two sections have been measured in the east of the study area, close to the Karadere Village. (Fig. 10A) The Karadere section has been measured in an important part of the Kızılbağ Formation, a pervasively dolomitized unit in this part of the study area (Fig. 11) The formation unconformably overlies the Devonian rocks and is composed of dolomites and dolomitic limestones at the base probably corresponding to the Py3 zone (samples 581-584). It continues upward with limestones containing chert nodules and corals (Waagenophyllidae) (Fig. 9F), shale interbeds, a rather thick quartz sandstone unit (Fig. 9G) and basaltic pillow lavas (Fig. 12A) described by Şahin et al. (2012). The basaltic volcanism corresponds to the upper part of the Capitanian Py4 zone (samples 234-239; 173-175; 320-350). Overlying the volcanic interval, the rest of the Capitanian section consists again dominantly of dolomites and dolomitic limestones and belongs to the Py5-Py7 zones (samples 351-358). The upper part of the Kızılbağ Formation in the Karadere section is incomplete because of tectonic complications. Only the lower part of the Wuchiapingian stage (Py8 zone, samples 359-371; 177-178) has been recognized consisting of limestones with shale and mudstone interbeds.

Close to the Karadere section, the Mezarlıkdere section measured in the Kızılbağ Formation reveals also the presence of basaltic lava layers in the Capitanian (Fig. 11 and 12B). The carbonates in this section intercalated with basaltic pillow lavas, mudstones or shale belong to the Py4-Py7 zones (samples 174-190) of the Capitanian stage.

Demirtaş area

Demirtaş area is located in the eastern sector of the Antalya Nappes, 10 km to the northeast of the Demirtaş Town (Fig. 10B). In this area, the upper Antalya Nappes consisting of Paleozoic and Triassic rocks appear in a tectonic window under the metamorphic Alanya Nappes (Özgül 1976, 1984a,b; Okay and Özgül 1984). The Tırlar section has been measured in the uppermost part of the Permian corresponding to the Changhsingian stage, the entire Kokarkuyu Formation of Griesbachian age and the Akıncıbeli Formation of latest Griesbachian to Dienerian age (Fig. 13). The Changhsingian part belongs to the Py10 zone (samples 194-216) consisting entirely of limestones rich in foraminifera, algae and fragments of crinoids and brachiopods with rare shale interbeds. Overlying the Permian-Triassic boundary the Kokarkuyu Formation starts with stromatolitic limestones at the base and continues with oolitic and dolomitic limestones toward the top (samples 217-231). The subaerially exposed and intensely karstified surface capped by an iron oxide crust defines the boundary between the Kokarkuyu and the Akıncıbeli formations. Consisting of variegated shales and clayey limestones at the base, the Akıncıbeli Formation is characterized upwards by mass flow deposits consisting of blocks, boulders and pebbles derived from the underlying Griesbachian Kokarkuyu Formation and the Permian carbonates (Fig. 12C,D and 13).

İnceğiz area

Located 8 km to the north of the Gazipaşa Town, the rock succession of the upper Antalya Nappes in the İnceğiz are exposed under the tectonic cover of the Alanya

Nappes (Fig. 10C). Two sections have been measured in order to understand the anatomy of the Upper Permian (Lopingian) and Lower Triassic stratigraphy. In the Örçün section from the north of the study area (Fig. 10C, 13), the Permian is dominated by algal and foraminiferal limestones with some episodic shale and quartz sandstone intercalations. This succession belongs to the Wuchiapingian (Py8 zone, samples 499-502 and Py9 zone, samples 503-504) and Changhsingian (Py10 zone, samples 505-507). The top of the Permian section is faulted and the base of the Akıncıbeli Formation of latest Griesbachian age (samples 558-559) directly rests on the Changhsingian carbonates.

The Asartepe section (Fig. 13) reveals the characteristic geologic events occurred during the Early Triassic in the study area. The Changhsingian carbonates with rhytmic shale interbeds (Py10 zone, samples 464-471) are overlain by the Griesbachian Kokarkuyu Formation composed of recrystallized stromatolitic and oolitic limestones (samples 472-473). Overlying a subaerially exposed karstic surface at the top of the Kokarkuyu Formation the upper Griesbachian to Dienerian (Induan) succession of the Akıncıbeli Formation (Fig. 12E and F) composed of bituminous clayey limestones, quartz sandstones, variegated shales or mudstones (samples 474-498) grades upward into a mass flow deposit containing several blocks, boulders and gravels derived from the underlying Griesbachian Kokarkuyu Formation and the Permian Çukurköy Formation (Fig. 12G, H and 13). This chaotic succession probably continues into the lower Middle Triassic (Anisian) in the region reflecting the onset of the major rifting phase in the Triassic.

Discussion

Permian of the Antalya Nappes within the broad paleogeographic framework of Turkey

As described in Altiner et al. (2000), the similarity between biofacies characteristics of Middle to Upper Permian blocks of the Karakaya Orogen (Şengör & Yılmaz 1981) in North Turkey and those of Middle-Upper Permian successions in various tectonic units of the Taurides, and the clear evidence proving the lateral continuity of inner platform deposits of Southern Biofacies Belt to outer platform-platfom margin deposits of Northern Biofacies Belt in the Permian paleogeography of the Taurides (Altiner et al. 2000) lead to reconstruction of one single carbonate platform model, comprising all Middle and Upper Permian marine sedimentary deposits exposed in Turkey (Fig. 14). This vast carbonate platform was appearently facing a trough or a basin (most probably Paleotethys) to the north, the evidence for it is the pelagic Permian blocks discovered in the Karakaya Orogen (Kozur and Kaya 1994; Okay and Mostler 1994; Göncüoğlu et al. 2004) and some Permian slope facies discovered in the Bursa region (Altiner et al. 2000).

To the south, the Permian carbonate platform was connected to the North Africa-Levant-Arabia Permian System. In our carbonate model, the East-West trending pelagic basin in the eastern Mediterranean Sea region previously introduced by Robertson et al. (1991, 2012, 2013) based on conodont- and radiolaria-bearing pelagic successions in Crete (Krahl et al. 1983; Kozur and Krahl 1987, Robertson 2008) and Sicily (Kozur 1993), is inferred to have been located to the south of the depositional setting of Antalya-Alanya nappes, between North Africa-Levant-Arabia and the Taurides (Fig. 14).

As was previously pointed out by Altiner et al. (2000), the provisionally named ‘North African Biofacies Belt’ of Altiner et al. (2000) extending from Tunisia through Sicily, South Italy, southern Greece and the southern Greek islands and finally to Cyprus shows a remarkable coincidence with the Permian rift basin of Robertson et al. (1991) and areas of early rifting of the southern Neotethys (Stampfli et al. 1991). If this coincidence is true the ‘North African Biofacies Belt’ of Altiner et al. (2000) would have constituted margins and slopes of this pelagic basin.

In the reconstructed Permian carbonate platform model of Altiner et al. (2000), Middle-Upper Permian deposits rest on a tectonically disturbed basement, probably activated in Devonian and Carboniferous times and reactivated during the late Early Permian. The presence of a non-depositional area represented by a structural high (Beyşehir-Akseki-Hadim High), probably reactivated during the Late Paleozoic, areas of incomplete Late Paleozoic sedimentation in the Geyik Dağı Autochthon/Parautochthon, Bolkar Dağı and Antalya nappes (Brunn et al. 1971; Özgül 1976, 1984a,b, 1997, Özgül et al. 1973, 1991; Monod 1977; Marcoux 1979; Gutnic et al. 1979; Zaninetti et al. 1981; Altiner 1984; Altiner and Özgül 2001; Altiner and Şahin 2012; Demirtaşlı 1984; Şenel et al. 1983, 1998; Şahin et al. 2012) and the nearly complete sedimentation from Upper Devonian through Carbonifeorus to Asselo-Artinskian in the Aladağ Nappe (Özgül 1976, 1984a, 1997; Monod 1977, Argyriadis 1978; Altiner 1981, 1984; Altiner and Özgül 2001; Kobayashi and Altiner 2008a,b, 2011) all suggest that the basement was most probably rifted during pre-Middle Permian times to give rise to different stratigraphic sequences in linear depositional belts in the Tauride Belt.

Within this paleogeographic configuration, the Permian of the Antalya nappes, as part of the Southern Biofacies Belt, is located to the south of the Karacahisar Unit which was probably bordering the Beyşehir-Akseki-Hadim High to the South (Fig. 1 and 14). In addition to several stratigraphic evidences, the absence of Middle-Upper Permian deposits in the İnce Dere Block of the Karacahisar Unit is a strong evidence to consider this unit as the continuation of the Beyşehir-Akseki-Hadim High. On the other hand, the presence of marine Carboniferous beds in the Eldere-Dede Göl Block of the Karacahisar Unit partly correlatable with the marine Lower Carboniferous recognized in the tectonic slices of the Antalya Nappes suggests that the Upper Paleozoic stratigraphy of the Antalya Nappes was in continuation with that of the Karacahisar Unit. As has been previously suggested by Şengör and Yılmaz (1981), Şengör (1990) and Özgül (1984a) the Alanya Unit was located further to the south of the depositional belt of the Antalya Nappes in this transect. Despite intense metamorphism, Permian-Triassic sections reveal that the Permian of the Alanya Nappes was part of the Southern Biofacies Belt and, further to the south, it was probably facing the North African Permian Rift Basin whose margins were rimmed by limestones of the 'North African Biofacies Belt' of Altiner et al. (2000).

Permian-Early Triassic initial rifting phase in the Antalya Nappes

As mentioned previously in this paper, it is rather difficult to bring evidence for the ancient rifting processes in the Tethys since many of the paleorifts are found today in pervasively deformed orogenic belts and the collisional processes destroy the order of occurrence of the facies mosaic within the rift system. This is even more difficult when one studies the initial rifting phase including only episodic pulses of continental break-up mechanism because the continental margins are not yet formed during this phase. In the case of Antalya nappes, rifting occurred mainly in two discrete phases. The initial rifting phase, from mid-Permian times to Early Triassic, was more episodic with pulses separated by intervals of tectonic quiescence. However the second phase from Anisian to Carnian was stronger and continuous with a variety of deposits developed in different steps of rifting including slope facies consisting of mass flow deposits with rock falls and turbidities, radiolarites, basinal pelagic limestones and shales and finally basaltic volcanic rocks carrying the signals of ocean floor character (Marcoux 1979; Özgül 1984a; Robertson 2007).

According to Leeder and Gawthorpe (1987) and Gawthorpe and Leeder (2000) tilt-block/ half-graben structures are considered to be bounded by single normal faults which penetrate to mid-crustal levels. As the hanging wall basement detaches from the footwall an asymmetrical basin progressively develops above the hanging wall. Therefore, by the combination of footwall uplift and hanging wall subsidence the steeper footwall scarp slopes are produced. In this model, the footwall area is the main sediment source for the adjacent basin. When activated by fault motion a talus margin and scarp slope deposits with rock falls, slumps and debris flows, derived from the footwall, accumulate on the subsiding hanging wall side. However, on the opposite side of the half graben system because of footwall uplift an important shallowing then subaerial exposure occurs leading to intense karstification in the carbonate deposits with important gaps in the stratigraphic record.

In the Permian-Lower Triassic stratigraphy of the Antalya Nappes the shallow marine carbonates are episodically interlayered with volcanic rocks. Those in the Middle

Permian of the Kızılbağ Formation in the Güzelsu area have been previously described by Şahin et al. (2012) and interpreted as rift volcanics. This Capitanian volcanism is nearly contamporenous with one of the large igneous provinces of Wignall (2001), Emeishan Large Igneous Province from southwestern China. The presence of basaltic layers alternating with carbonates containing keriothecal fusulinoideans from the Makou Formation in southwestern China, as reported by Jin and Shang (2000), indicates the fact that Emeishan volcanism started to outpour in the Capitanian in an interval of time nearly coeval with the volcanism in the Antalya Nappes. These volcanics in the Antalya Nappes, intercalated with carbonates should have filled episodically rift-controlled asymmetrical basins very similar to the mechanism proposed recently by Jerram et al. (2016). In the Lake Erhai section of southwestern China submarine basaltic pillow lavas and hyaloclastites spread over the block-faulted graben- or half graben-like structures developed in the shallow-water carbonates of the Makou Formation.

In the Antalya Nappes episodic rifting events separated by times of tectonic quiscence can be summarized as follows:

Roadian-Early Capitanian

Following a period of uplift during pre-mid Permian times (probably during late Artinskian to Roadian) the basement rocks of the Antalya Nappes have been affected by numerous small displacement faults and the subsidence started in these areas by the activity of growing normal faults. Thus, several isolated depocenters in these asymmetrical basins began to be filled with clastic deposits intercalated with coal, clayey limestones and marls containing marine fossils (Fig. 15a). These deposits seem to be cyclic reflecting distinct transgressive-regressive sequences. Such depocenters have been detected in the Kesmeboğazı (Gelendere area), Belendere (Üçoluk area) and Çukurköy (Güzelsu area) sections.

Following the Roadian-Wordian clastic sedimentary episode the regional Capitanian transgression started and both clastics in the depocenters and the pre-mid Permian basement either on the uplifted footwall or directly on the horsts were covered by the lower Capitanian carbonates. In the Gedelme area, the Roadian-Wordian clastics pinch out along the boundary with the basement rock within a maximum 2 km distance and lower Capitanian rocks in the Sapandere section directly rest on the basement rocks (Fig. 15a). We consider such kind of diachronism in the Middle Permian related with the tilted block geometry during the early rifting phase of the Antalya Nappes.

The early Capitanian time was a period of tectonic quiescence since no particular facies change has been observed in the carbonates which represent a distinct horizon levelling the Permian stratigraphy.

Middle-Late Capitanian

Following the tectonic quiscence period during the early Capitanian the second rifting event occurred in the middle to late Capitanian times in the Antalya Nappes and this is best observed in the Güzelsu area (Şahin et al. 2012). In this area, the lower Capitanian carbonate deposition was suddenly interrupted by the deposition of a distinct quartz sandstone succession corresponding to the lower part of the Py4 zone both visible in the Çukurköy and Karadere sections (Fig. 15b). The rapid invasion of quartz sandstone into the region has been interpreted as a forced regressive event caused by a tectonic uplift, which was accompanied by an eustatic sea-level fall (see Haq and Schutter 2008). In the middle to late Capitanian time, the platform started to collapse under tensional forces, thus rifting started (Fig. 15b). Basaltic volcanism probably fed by feeder dyke systems was injected either along the fault planes or by cutting the basement of the subsiding basin as it is shown by Jerram et al. (2016) in southwestern China where block-faulted grabens or half grabens in the Makou Formation are randomly cut by feeder dyke systems. The main lithological differentiation between the Çukurköy and Kızılbağ formations probably started in this time interval since the volcanism intensely dolomitized the Kızılbağ Formation.

Apart from the Güzelsu area, the Sapandere section (Gelendere area) also displays a prominent basaltic layer in its middle to upper Capitanian succession. We note here that both Karadere and Sapandere sections containing volcanic rocks start directly with Capitanian rocks overlying the uplifted footwall side of the tilted blocks during the Roadian-Wordian rifting (Fig. 15a and b). The Olimpus-1 section (Olimpus area), Beşiktaşalanı and Kesmeboğazı sections (Gelendere area) and the Çukurköy section (Güzelsu area) do not directly contain basaltic layers, however geological and geographical proximity to sections containing lava flows suggest that they were probably close to the outpouring lava centers during the middle to late Capitanian times.

Lopingian

Lopingian was a time of tectonic quiescence, a pause in rifting in the Antalya Nappes (Fig. 15c). Consisting entirely of shallow water wackestones rich in foraminifera, algae (mostly *Mizzia* and gymnocodiacean algae), *Bellerophon*-type gastropoda, brachiopod fragments interbedded with mudstones, both Wuchiapingian and Changhsingian stages of the Lopingian Series consistently display a more or less uniform facies and constitute again a distinct choronostratigraphic horizon leveling the

Permian stratigraphy. Nearly in all study areas stratigraphic sections partly or wholly traverse across the Lopingian Series. When Lopingian is totally absent, like in the Çukurköy section or in the Sapandere section where the base of the Akıncıbeli Formation of late Griesbachian age directly rests on the Capitanian carbonates, the gap is due to the erosion truncating the whole Lopingian and an important part of the Griesbachian substage below the late Griesbachian unconformity. In places where this erosional relief is not so deep in the Permian only the top of the Changhsingian is eroded like in the Olimpus sections.

Permian-Triassic boundary beds (Changhsingian-Griesbachian)

The pause in rifting continued during the deposition of Permian-Triassic boundary beds corresponding to the uppermost Changhsingian limestones and the Griesbachian Kokarkuyu Formation (Fig. 15d). The remarkable persistence and continuity of the Permian-Triassic boundary beds with a marker oolitic limestone level less than 1m thick capping the uppermost Changhsingian and the stromatolitic and oolitic levels in the lowermost Griesbachian are well known from the Southern Biofacies Belt of Taurides (Altiner et al. 2000) including the successions described from the Arabian platform (Fontaine 1981; Köylüoğlu and Altiner 1989; Gaillot and Vachard 2007) and from the Aladağ Nappe (Özgül 1976; Monod 1977; Altiner 1981, 1984; Altiner and Zaninetti 1981; Altiner and Özgül 2001; Ünal et al. 2003; Groves et al. 2005; Payne et al. 2007), Geyik Dağı Autochthon/Parautochthon (Özgül 1976; Zaninetti et al. 1981; Altiner and Şahin 2012), Antalya and Alanya Nappes from the Taurides. Although the Permian-Triassic boundary beds are fully recorded in the Çürükdağ, Demirtaş and İnceğiz areas in the Antalya Nappes the biostratigraphical studies reveal that this stratigraphy is sometimes incomplete due to the late Griesbachian erosional truncation. In the Adrasan sections, Sumakseniri section from the Gedelme area and Çukurköy section from the Güzelsu area the Akıncıbeli Formation rests on the Permian carbonates with an erosional relief of different magnitude.

Late Griesbachian-Dienerian

After a long tectonic quiscence period, active block faulting started again during the late Griesbachian-Dienerian times (Fig. 15e). Following a short period of uplift in the latest Griesbachian the top of the Kokarkuyu Formation was totally exposed and immediately after, as normal faulting has become active, the hanging wall basement of the rifted segments detached from the footwall and asymmetrical depocenters developed on the subsiding hanging wall side. The sea advanced onto the depressed basements of the hanging wall side and the first layers of the Akıncıbeli Formation were laid down terminating laterally at their depositional limits toward the uplifted footwall side (Fig. 15e). The footwall area remained subaerially exposed and became the main source area of the adjacent basin. As fault motion has been activated, a talus margin and scarp slope deposits consisting of rock falls and debris flow deposits accumulated on the hanging wall side of the asymmetrical basins. Such deposits containing Griesbachian and Changhsingian blocks, pebbles and clasts were laid down in the Asartepe and Tırlar sections in the eastern sector (east of the City of Antalya) of the Antalya Nappes. As the strata of the Akıncıbeli Formation have progressively accumulated, they started to onlap the differentially eroded footwall side. For example, the Capitanian was directly overlain by the upper Griesbachian-Dienerian Akıncıbeli Formation in the Çukurköy (Güzelsu area) and Sumakseniri (Gedelme area) sections.

However, in the Olimpus 1-2 (Adrasan area) and Armutgözlek Tepe (Üçoluk area) sections the partly eroded Changhsingian limestones are overlain by the Akıncıbeli Formation (Fig. 15e). In the Armutgözlek Tepe section, bauxite accumulated at first as the product of a karst residue over the eroded Changhsingian on the footwall side and this level was transgressively covered by the Akıncıbeli Formation containing basaltic interlayers possibly fed by a dyke system. Permian-Triassic boundary beds have been preserved in the Barak 1-2 (Koçular area) and the Çürükdağ (Üçoluk area) sections because they were located on the subsiding hanging wall side of the half-grabens. In the Çürükdağ section (Üçoluk area) tuffaceous volcanoclastic layers intercalated in the Akıncıbeli Formation are probably coeval with the basaltic layers found in the Armutgözlek Tepe section (Üçoluk area). Permian-Triassic boundary beds were also fully preserved in the Tırlar and Asartepe sections located on the subsiding hanging wall side of the asymmetrical basin whereas on the footwall side which was being uplifted, boundary beds and an important part of the underlying Permian were truncated by an active erosional agent.

Conclusions

Since this study has been carried out in an once-active extensional setting destroyed later by collisional processes it has not been possible to detect the fault trends formed during rifting. Therefore, after gathering the stratigraphic data based on a highly refined biostratigraphy we tried to show how the Permian-Lower Triassic stratigraphy could be tested and interpreted within a rifting scenario of extensional half-graben/tilt-block system. Depicting mainly the initial rifting phase, this scenario has put forward that the rifting occurred in episodic pulses interrupted by periods of tectonic quiescence during the Middle Permian-Early Triassic interval. This phase is clearly different than the stronger and more continuous phase of rifting which occurred during the Anisian-Carnian period and led to an oceanization stage in the Triassic paleogeography of the Antalya Nappes.

The initial rifting scenario in the Antalya Nappes helped us to understand the possible configuration of facies mosaic developed in asymmetrical basins controlled by block-faulting, diachronic relations of Permian facies with the basement rocks and the significance of stratigraphic gaps basically formed by differential erosion. The basaltic volcanism discovered both in the Capitanian and Lower Triassic needs to be documented by geochemical studies in order to complete and enrich this scenario.

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Figure captions

Fig. 1 Map showing the distribution of tectonic units in the area between western and central Taurides (modified from Özgül 1984). White rectangles are the locations of study areas and listed names are the measured stratigraphic sections.

Fig. 2 Main foraminiferal species used in the Middle-Upper Permian and Lower Triassic biostratigraphy. 1. *Paraglobivalvulina mira* Reitlinger; 2. *Globivalvulina vonderschmitti* Reichel; 3. *Globivalvulina graeca* Reichel; 4. *Labioglobivalvulina* *baudi* Gaillot and Vachard; 5. *Retroseptellina decrouezae* (Köylüoğlu and Altiner); 6. *Septoglobivalvulina distensa* (Wang); 7. *Dagmarita chanakchiensis* Reitlinger; 8. *Louisettita elegantissima* Altiner and Brönnimann; 9-10 *Paradagmarita monodi* Lys; 11. *Paradagmarita planispiralis* Gaillot and Vachard; 12. *Endothyra* sp.; 13. *Neoendothyra* sp.; 14. *Reichelina* cf. *changhsingensis* Sheng and Chang; 15-16. Primitive *Dunbarula* sp.; 17. *Neofusulinella* cf. *rara* (Sheng); 18-19. *Neofusulinella giraudi* Deprat; 20. *Neofusulinella pseudogiraudi* (Sheng); 21. *Neofusulinella* sp.; 22. *Kahlerina* sp.; 23. *Minojapanella* sp.; 24. *Chusenella sinensis* Sheng (=*C*. gr. *conicocylindrica* Sheng); 25, 27. *Eopolydiexodina* sp.; 26. *Skinnerella* gr. *elliptica* (Sheng); 28. *Necdetina taurica* Altiner, Groves and Özkan-Altiner; 29. *Sphaerulina* cf. *zisongzhengensis* Sheng; 30. *Midiella* ? *reicheli* (Lys); 31. *Multidiscus padangensis* (Lange); 32. *Multidiscus* sp.; 33. *Glomomidiellopsis lysitiformis* Gaillot and Vachard; 34-35.Unknown cornuspirid form; 36. *Shanita amosi* Brönnimann, Whittaker and Zaninetti; 37-38. *Postcladella kalhori* (Brönnimann, Zaninetti and Bozorgnia); 39. *Postcladella grandis* Altiner and Zaninetti; 40. *Rectostipulina quadrata* Jenny-Deshusses; 41. *Rectostipulina pentamerata* Groves, Altiner and Rettori; 42. *Pseudovidalina* sp.; 43. *Altineria alpinotaurica* (Altiner); 44. *Nestellorella dorashamiensis* (Pronina); 45. *Protonodosaria* sp.; 46. *Nodosinelloides sagitta* (K.V. Miklukho-Maklay); 47. *Frondina permica* Sellier de Civrieux and Dessauvagie; 48. *Ichthyofrondina* cf. *guangxiensis* (Lin); 49. *Ichthyofrondina* cf. *latilimbata* (Sellier de Civrieux and Dessauvagie); 50. *Robuloides lens* Reichel; 51 *Robuloides gibbus* Reichel; 52. *Geinitzina* sp.; 53. *Pseudotristix* sp.; 54-55 *Aulacophloia martiniae* Gaillot and

Vachard; 56. *Polarisella elabugae* (Cherdyntsev); 57. *Pachypholia schwageri* Sellier de Civrieux and Dessauvagie; 58. *Pachyphloia ovata* Lange; 59. *Pachyphloia robusta* K.V. Miklukho-Maklay; 60. *Pseudolangella fragilis* Sellier de Civrieux and Dessauvagie; 61. *Langella cukurkoyi* Sellier de Civrieux and Dessauvagie; 62. *Langella perforata langei* Sellier de Civrieux and Dessauvagie. 1: Oimpus-1 84; 2,58: Kesmeboğazı 90; 3: Kesmeboğazı 100; 4: Olimpus-1 95; 5,9: Olimpus-1 90; 6: Barak-1 12; 7: Çukurköy 453; 8,14,29: Kesmeboğazı 120; 10: Çürükdağ 5; 11: Olimpus-1 94; 12: Kesmeboğazı 84; 13: Sapandere 191; 15: Çukurköy 392; 16: Sumakseniri 159; 17: Beşiktaşalanı 128; 18: Kesmeboğazı 71; 19: Beşiktaşalanı 127; 20: Karadere 235; 21: Kesmeboğazı 68; 22: Kesmeboğazı 91; 23: Çukurköy 413; 24: Katran Tepe 877 (equivalent of the Capitanian of Belendere section); 25: Çukurköy 397A; 26: Çukurköy 437; 27: Çukurköy 440; 28: Mezarlık 184; 30. Olimpus-1 107; 31: Çukurköy 397B; 32: Karadere 374; 33: Kesmeboğazı 119; 34: Beşiktaşalanı 129; 35: Kesmeboğazı 60; 36: Capitanian of the Demirtaş area 1-2; 37: Çürükdağ 9; 38: Çürükdağ 144; 39: Çürükdağ 175; 40,41,48,52,60: Kesmeboğazı 115; 42: Karadere 238; 43: Karadere 373; 44: Tırlar 216; 45: Kesmeboğazı 60; 46: Tırlar 215; 47: Asartepe 505; 49,53: Kesmeboğazı 116; 50. Mezarlık 188; 51,59: Olimpus-1 98; 54: Kesmeboğazı 112; 55: Olimpus-1 116; 56: Tırlar 203; 57: Kesmeboğazı 86; 61: Sumakseniri 165; 62: Çukurköy 387. Scale bar: 0.1 mm.

Fig. 3 Geological maps of Adrasan (A), Gedelme (B), Üçoluk (C) and Koçular (D) areas. For legend see Fig. 4.

Fig. 4 Legend for geological maps and measured stratigraphic sections.

Fig. 5 Olimpus-1 and Olimpus-2 sections from the Adrasan area. For legend see Fig. 4.

Fig. 6 A. Olimpus-1 and Olimpus-2 sections in the Adrasan area. Notice that the Olimpus-1 section consists of three portions delimited by faults; B. Roadian-Wordian basal clastic layers of the Çukurköy Formation unconformably overlying the Upper Devonian (Strunian). Belendere section, Üçoluk area; C.Bituminous shale and coal intercalation in the quartz sandstone succession of Roadian-Wordian age. Belendere section, Üçoluk area.; D. Capitanian transgression over the Roadian-Wordian clastic sequence. Belendere section, Üçoluk area; E. Permian-Triassic boundary in the Çürükdağ section, Üçoluk area. Top Permian is capped by a 60 cm thick oolitic limestone which is overlain by stromatolitic limestones of Griesbachian age. Notice the boundary has been displaced by a normal fault; F. Domal stromatolites at the base of Griesbachian. Çürükdağ section, Üçoluk area; G. The unconformity between the Akıncıbeli Formation of late Griesbachian age and the Changhsingian of the Çukurköy Formation. Armutgözlek Tepe section, Üçoluk area; H. Basaltic volcanics intercalated in the variegated shales of late Griesbachian age. Armutgözlek Tepe section, Üçoluk area.

Fig. 7 Kesmeboğazı, Sapandere, Beşiktaşalanı and Sumakseniri sections from the Gedelme area. For legend see Fig. 4.

Fig. 8 Belendere, Çürükdağ and Armutgözlek Tepe sections from the Üçoluk area and Barak-1 and Barak-2 sections from the Koçular area. For legend see Fig. 4.

Fig. 9 A. The late Griesbachian unconformity between the Kokarkuyu and Akıncıbeli formations. Barak-2 section, Koçular area; B. Close-up view of the late Griesbachian unconformity. Barak-2 section, Koçular area; C. Coal and bituminous shale deposits in the Roadian-Wordian of the Çukurköy Formation, Güzelsu area; D. Varicoloured shales, marls and clayey limestones of late Griesbachian age (Akıncıbeli Formation) unconformably overlying the Capitanian dolomites and dolomitic limestones of the Çukurköy Formation. Çukurköy section, Güzelsu area; E. Close-up view of the unconformity between Permian and Triassic deposits. Çukurköy section, Güzelsu area; F. A coral colony in growth position in the limestones intercalated with basaltic lava layers. Karadere section, Güzelsu area; G. Main quartz sandstone level underlying limestones intercalated with basaltic lava layers. Karadere section, Güzelsu area; H. A limestone breccia level indicating probably the flow occurred during active faulting. Karadere section, Güzelsu area.

Fig. 10 Geological maps of Güzelsu (A), Demirtaş (B) and İnceğiz (C) areas. For legend see Fig. 4.

Fig. 11 Karadere, Mezarlıkdere and Çukurköy sections from the Güzelsu area. For legend see Fig. 4.

Fig. 12 A. The Capitanian limestone layer intercalated within basaltic pillow lavas. Karadere section, Güzelsu area; B. Capitanian limestones overlying basaltic pillow lavas. Mezarlıkdere section, Güzelsu area; C. Lopingian and Griesbachian limestone blocks within the Akıncıbeli Formation of late Griesbachian-Dienerian age. Tırlar section, Demirtaş area; D. Close-up view of the Griesbachian block composed of stromatolitic limestones. Tırlar section, Demirtaş area; E. The boundary between the Kokarkuyu Formation of Griesbachian age and the Akıncıbeli Formation of late Griesbachian-Dienerian age. Asartepe section, İnceğiz area; F. Akıncıbeli Formation of late Griesbachian-Dienerian age composed of clayey limestones and fine siliciclastic rocks. Asartepe section, İnceğiz area; G. Large Griesbachian block and clasts in the Akıncıbeli Formation of late Griesbachian-Dienerian age. Asartepe section, İnceğiz area. H. Permian-Griesbachian clasts in the Akıncıbeli Formation. Asartepe section, İnceğiz area.

Fig. 13 Tırlar section from the Demirtaş area and Asartepe and Örçün sections from the İnceğiz area. For legend see Fig. 4.

Fig. 14 Hypothetical reconstruction of the Middle-Late Permian carbonate platform (modified from Altiner et al. 2000) and the position of the Antalya Permian within this paleogeography.

Fig. 15. Testing of the Middle Permian-Lower Triassic stratigraphic data from the Antalya Nappes in a half-graben/tilt-block system.

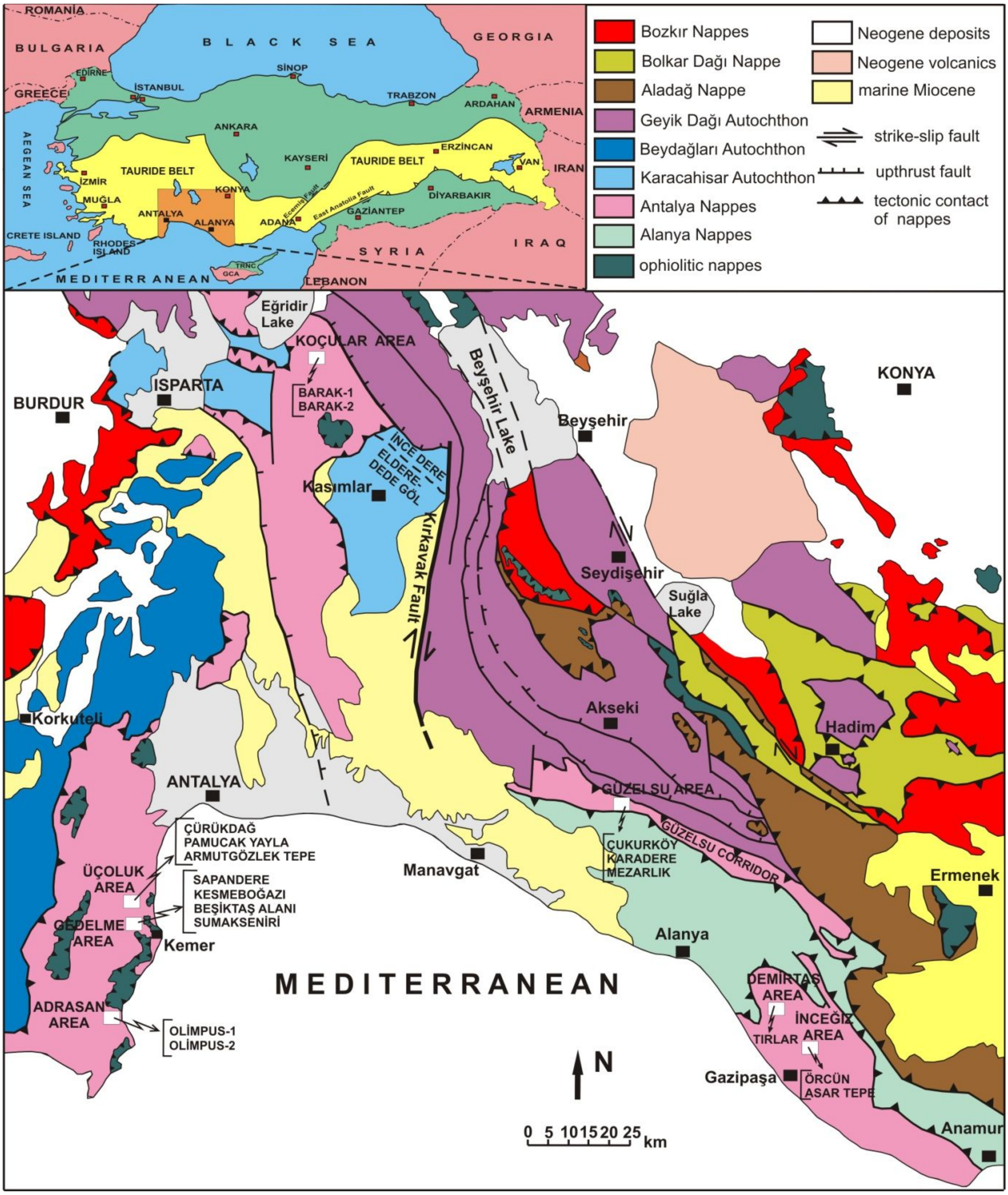
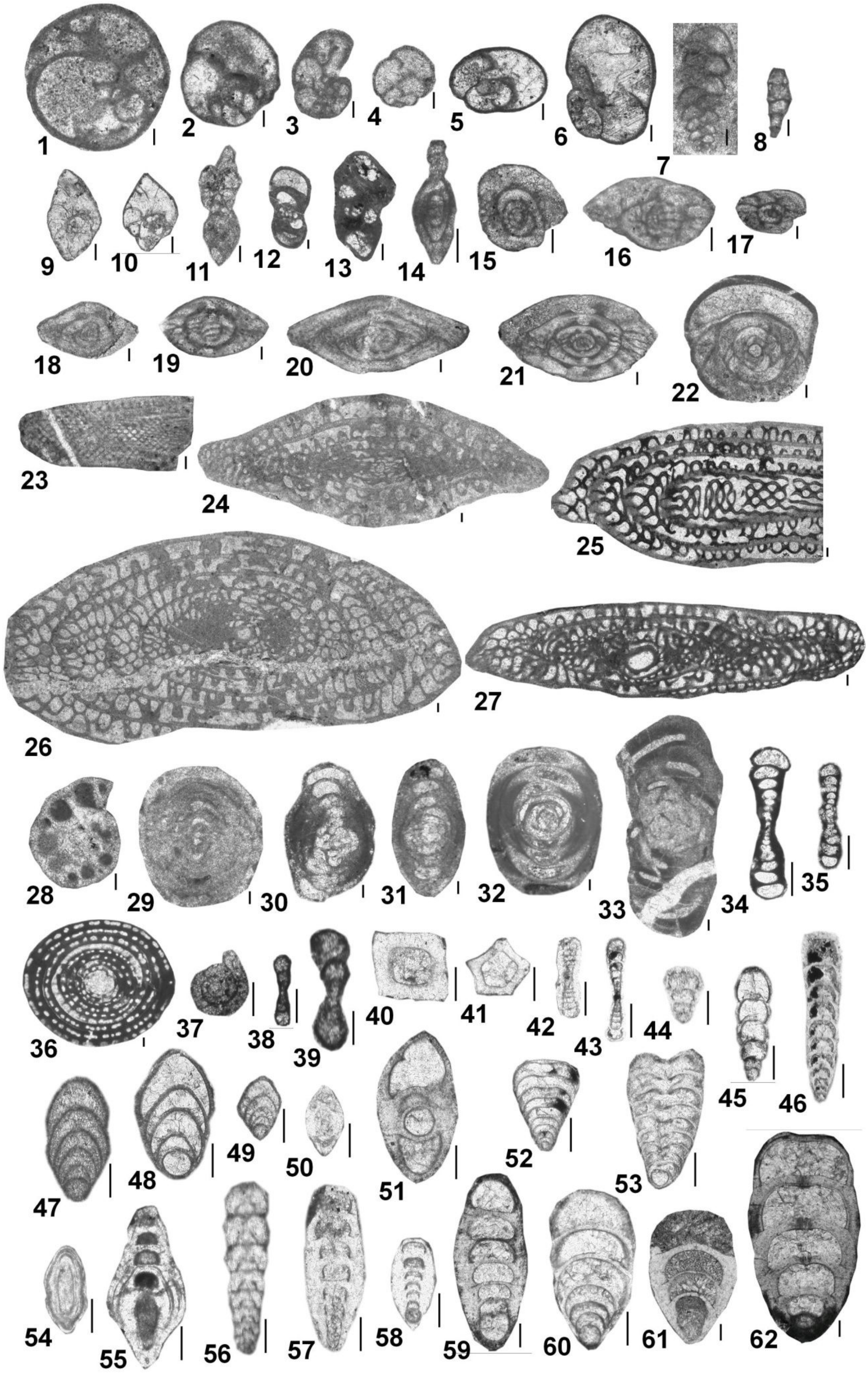

Bozkır Nappes
Bolkar Dağı Nappe
Aladağ Nappe
Geyik Dağı Autochthon
Beydağları Autochthon
Karacahisar Autochthon
Antalya Nappes
Alanya Nappes
ophiolitic nappes
Neogene deposits
Neogene volcanics
marine Miocene
strike-slip fault
upthrust fault
tectonic contact of nappes
ROMANIA
BULGARIA
BLACK SEA
GEORGIA
GREECE
EDİRNE
İSTANBUL
SİNOP
TRABZON
ARDAHAN
ARMENIA
ANKARA
AEGEAN SEA
TAURIDE BELT
KAYSERİ
ERZİNCAN
VAN
IRAN
İZMİR
KONYA
MUĞLA
DİYARBAKIR
ANTALYA
ALANYA
ADANA
GAZİANTEP
CRETE ISLAND
RHODES ISLAND
SYRIA
IRAQ
MEDITERRANEAN
LEBANON
Eğridir Lake
KOÇULAR AREA
BARAK-1
BARAK-2
Beyşehir Lake
Beyşehir
KONYA
BURDUR
ISPARTA
İNCE DERE
ELDERE
DEDE GÖL
Kasımlar
Kırkavak Fault
Seydişehir
Suğla Lake
Akseki
Hadim
Korkuteli
ANTALYA
GÜZELSU AREA
GÜZELSU CORRIDOR
ÇÜRÜKDAĞ
PAMUCAK YAYLA
ARMUTGÖZLEK TEPE
ÜÇOLUK AREA
SAPANDERE
KESMEBOĞAZI
BEŞİKTAŞ ALANI
SUMAKSENİRİ
GEDELME AREA
Kemer
Manavgat
ÇUKURKÖY
KARADERE
MEZARLIK
Ermenek
Alanya
MEDITERRANEAN
DEMİRTAŞ AREA
İNCEĞİZ AREA
TIRLAR
ADRASAN AREA
OLİMPUS-1
OLİMPUS-2
N
Gazipaşa
ÖRCÜN
ASAR TEPE
Anamur
0 5 10 15 20 25 km

Fig. 1


1
2
3
4
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6
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21
22
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42
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58
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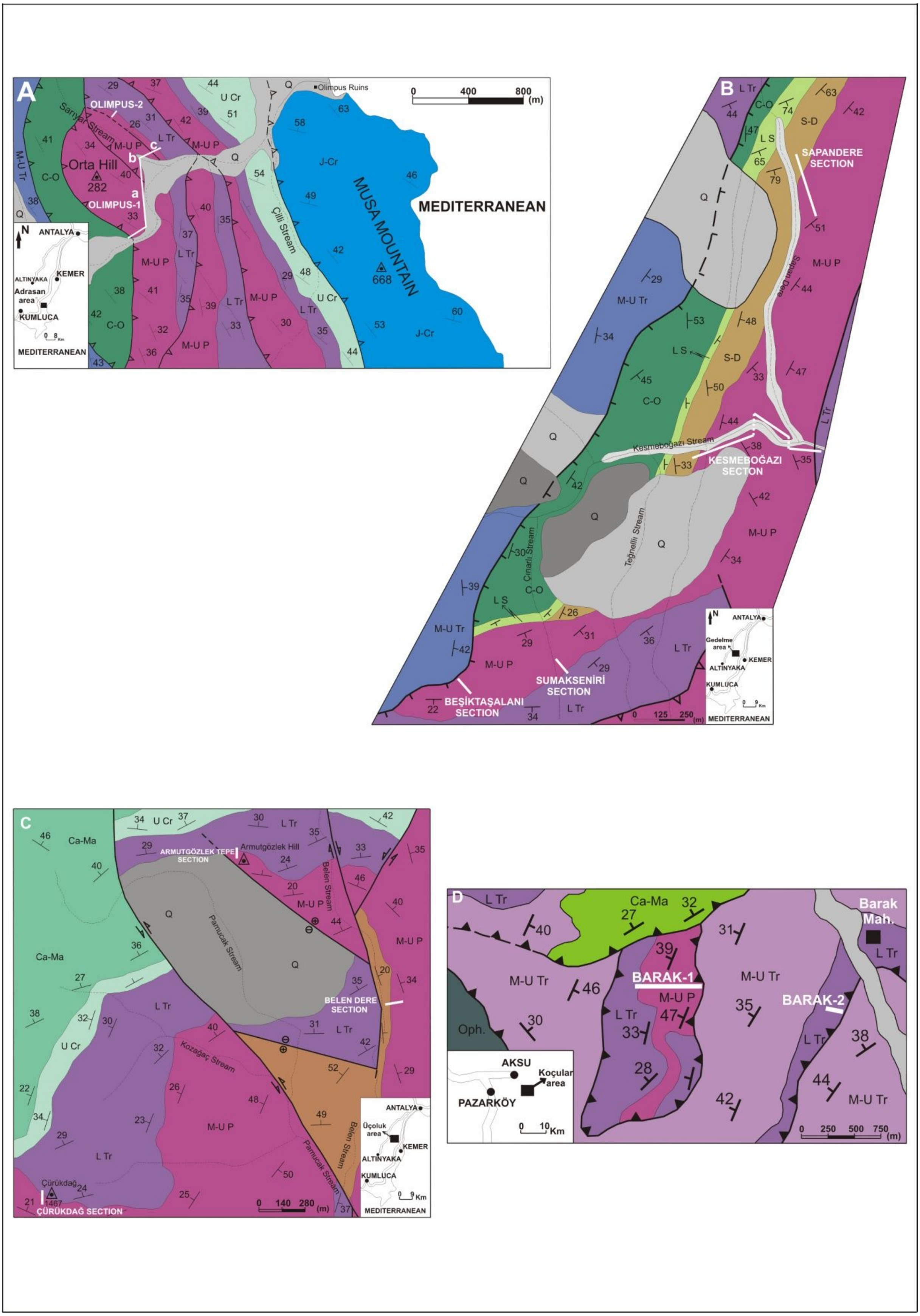
60
61
62

Fig. 2



A
OLIMPUS-2
OLIMPUS-1
Orta Hill
282
Sarıyar Stream
Çiçili Stream
Olimpus Ruins
MUSA MOUNTAIN
668
MEDITERRANEAN
M-U Tr
C-O
M-U P
L Tr
U Cr
J-Cr
Q
ANTALYA
KEMER
ALTINYAKA
Adrasan area
KUMLUCA
MEDITERRANEAN
B
SAPANDERE SECTION
KESMEBOĞAZI SECTION
Kesmeboğazı Stream
Teğnelli Stream
Çınarlı Stream
Sapan Dere
BEŞİKTAŞALANI SECTION
SUMAKSENİRİ SECTION
S-D
L S
Gedelme area
C
ARMUTGÖZLEK TEPE SECTION
Armutgözlek Hill
Belen Stream
Pamucak Stream
Kozağaç Stream
BELEN DERE SECTION
ÇÜRÜKDAĞ SECTION
Çürükdağ 1467
Ca-Ma
Üçoluk area
D
BARAK-1
BARAK-2
Barak Mah.
Oph.
AKSU
PAZARKÖY
Koçular area

Fig. 3


Geological maps
Stratigraphic sections
Q
Quaternary (travertine)
Q
Quaternary (alluvium or scree deposit)
Ca-Ma
Campanian - Maastrichtian
U Cr
Upper Cretaceous
J-Cr
Jurassic - Cretaceous
M Tr-Cr
Middle Triassic - Cretaceous
M-U Tr
Middle - Upper Triassic
L Tr
Lower Triassic
M- U P
Middle - Upper Permian
M- U P
Kızılbağ Fm .
Çukurköy Fm .
M. U. Permian
S-D
Upper Silurian - Lower Devonian or Devonian
L S
Lower Silurian
M O
Middle Ordovician
C-O
Cambrian - Ordovician
Upper Antalya Nappes
Middle Antalya Nappes
Lower Antalya Nappes
Anamas - Akseki Autochthon
Alanya Nappes
Dip and strike of bedding
Reverse fault
Thrust fault
Normal fault
Strike - slip fault
Stratigraphic contact
Measured stratigraphic section
Triangulation point
Town or village
Basaltic volcanics
Volcanoclastic deposit
Bauxite
Coal
Bituminous shale
Variegated shale
Shale
Shale or mudstone
Mudstone
Marl
Siltstone
Quartz sandstone
Cross-bedded sandstone
Sandy limestone
Limestone with thin lenses of quartz sandstone
Algal and foraminiferal limestone
Oolitic limestone
Limestone with chert nodules
Dolomitic limestone
Dolomite
Bituminous clayey limestone
Domal stromatolite
Stratiform stromatolite
5
Sample number

Fig. 4

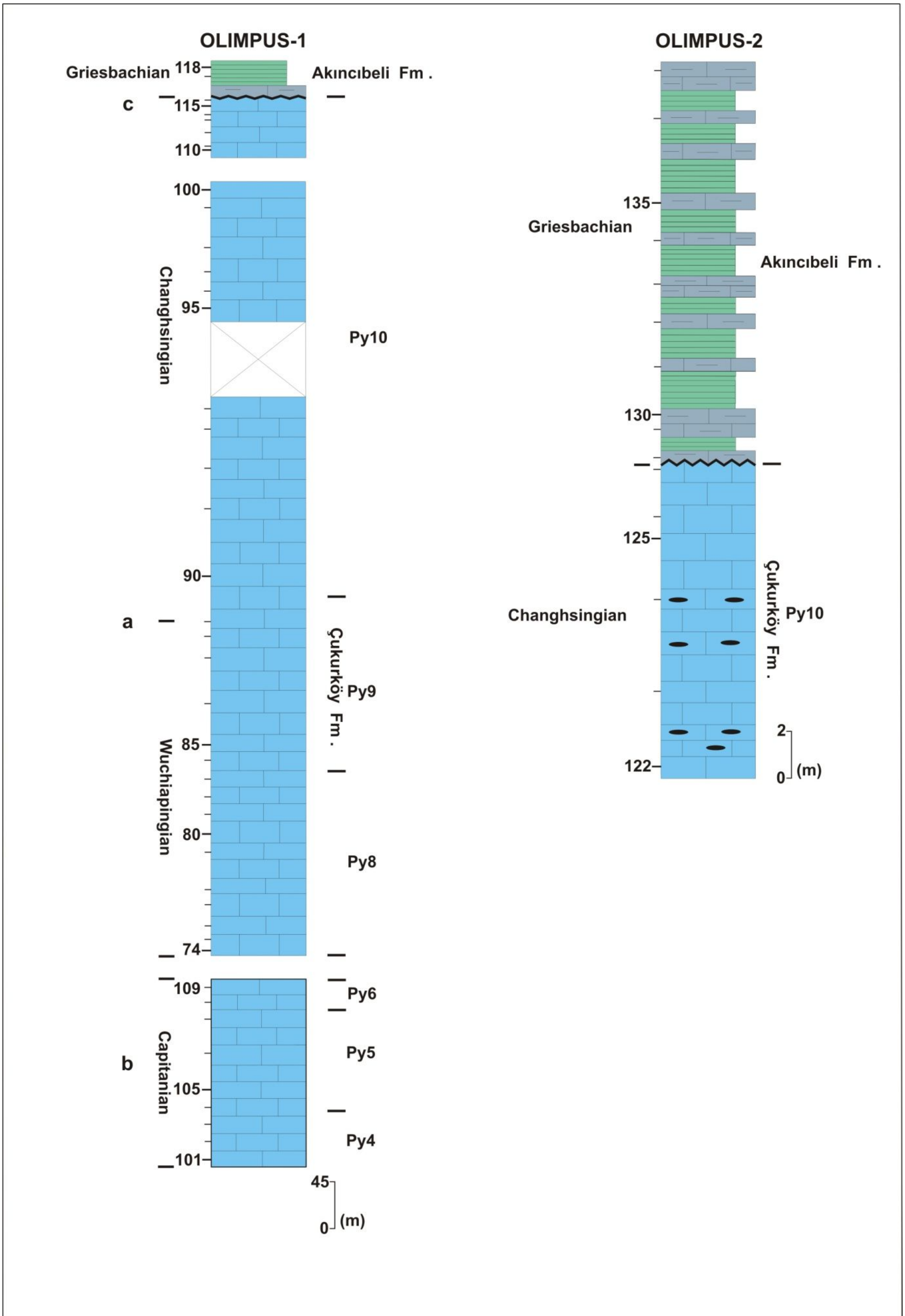

OLIMPUS-1
Griesbachian
118
Akıncıbeli Fm .
c
115
110
100
Changhsingian
95
Py10
90
a
Çukurköy Fm .
Py9
85
Wuchiapingian
80
Py8
74
109
Py6
b
Capitanian
Py5
105
Py4
101
45
0
(m)
OLIMPUS-2
135
Griesbachian
Akıncıbeli Fm .
130
125
Changhsingian
Çukurköy Fm .
Py10
2
122
0
(m)

Fig. 5

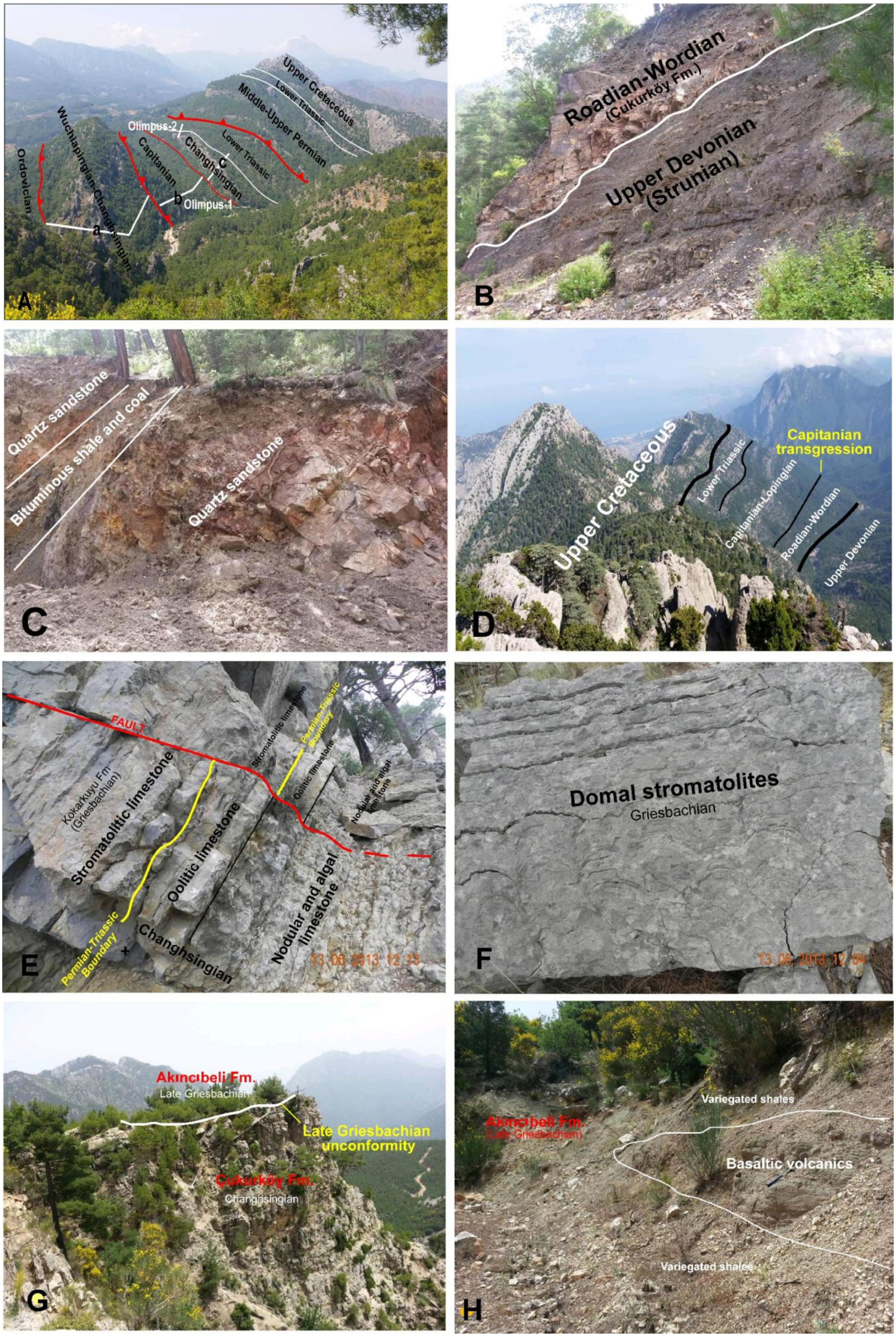

Ordovician
Wuchiapingian-Changhsingian
Olimpus-2
Capitanian
Changhsingian
Olimpus-1
Lower Triassic
Middle-Upper Permian
Lower Triassic
Upper Cretaceous
a
b
c
A
Roadian-Wordian
(Çukurköy Fm.)
Upper Devonian
(Strunian)
B
Quartz sandstone
Bituminous shale and coal
Quartz sandstone
C
Upper Cretaceous
Lower Triassic
Capitanian-Lopingian
Capitanian transgression
Roadian-Wordian
Upper Devonian
D
FAULT
Kokarkuyu Fm
(Griesbachian)
Stromatolitic limestone
Oolitic limestone
Permian-Triassic Boundary
Changhsingian
Nodular and algal limestone
Stromatolitic limestone
Permian-Triassic Boundary
Oolitic limestone
E
Domal stromatolites
Griesbachian
F
Akıncıbeli Fm.
Late Griesbachian
Late Griesbachian unconformity
Çukurköy Fm.
Changhsingian
G
Akıncıbeli Fm.
(Late Griesbachian)
Variegated shales
Basaltic volcanics
Variegated shales
H

Fig. 6

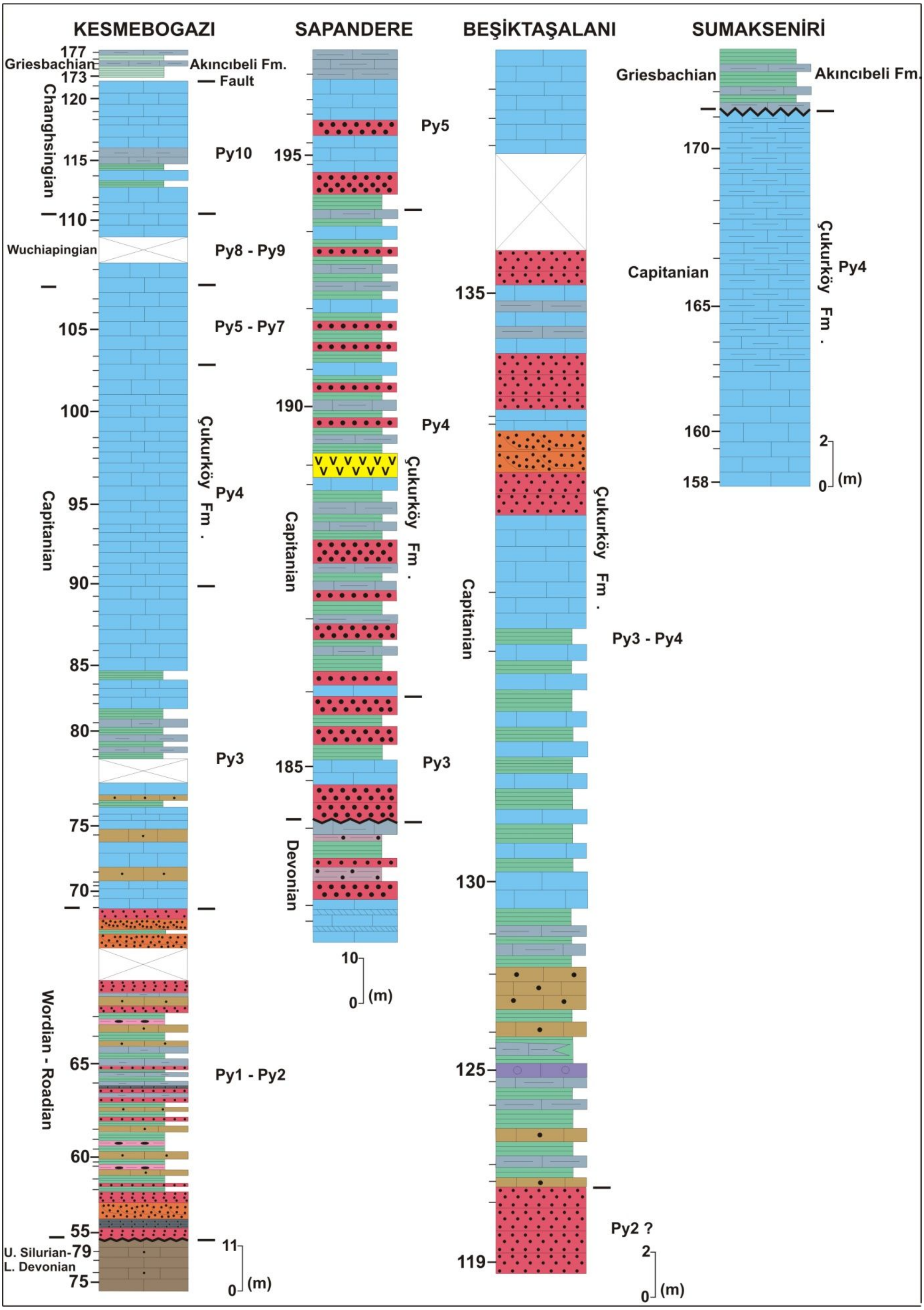

KESMEBOGAZI
SAPANDERE
BEŞİKTAŞALANI
SUMAKSENİRİ
Griesbachian
Akıncıbeli Fm.
Fault
Changhsingian
Wuchiapingian
Capitanian
Wordian - Roadian
U. Silurian-
L. Devonian
Çukurköy Fm .
Py10
Py8 - Py9
Py5 - Py7
Py4
Py3
Py1 - Py2
Py5
Py3 - Py4
Py2 ?
Devonian
(m)

Fig. 7

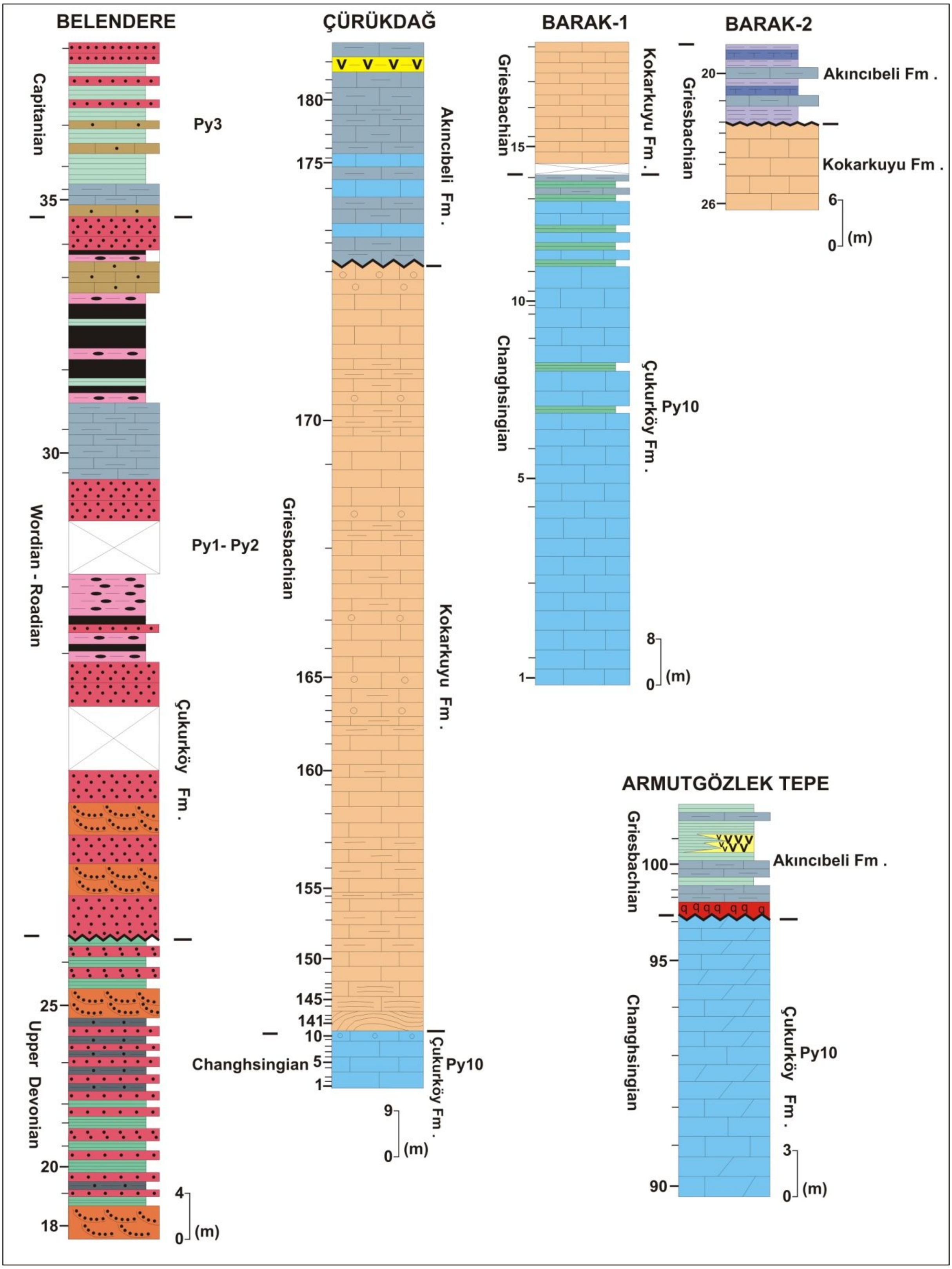

BELENDERE
ÇÜRÜKDAĞ
BARAK-1
BARAK-2
ARMUTGÖZLEK TEPE
Capitanian
Wordian - Roadian
Upper Devonian
Py3
Py1- Py2
Çukurköy Fm .
Akıncıbeli Fm .
Kokarkuyu Fm .
Griesbachian
Changhsingian
Çukurköy Fm .
Py10
(m)

Fig. 8

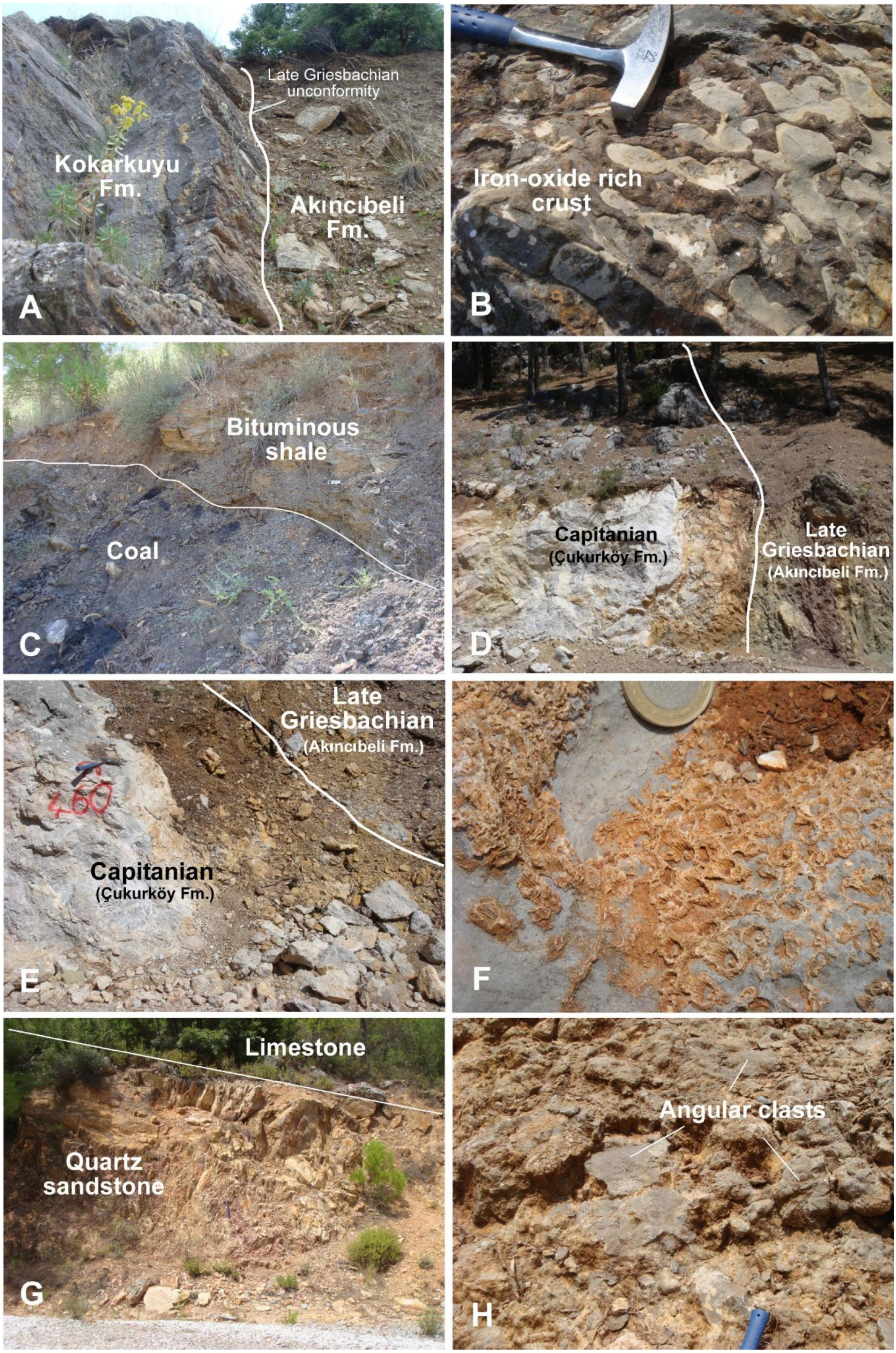

Late Griesbachian
unconformity
Kokarkuyu
Fm.
Akıncıbeli
Fm.
A
Iron-oxide rich
crust
B
Bituminous
shale
Coal
C
Capitanian
(Çukurköy Fm.)
Late
Griesbachian
(Akıncıbeli Fm.)
D
Late
Griesbachian
(Akıncıbeli Fm.)
Capitanian
(Çukurköy Fm.)
E
F
Limestone
Quartz
sandstone
G
Angular clasts
H

Fig. 9

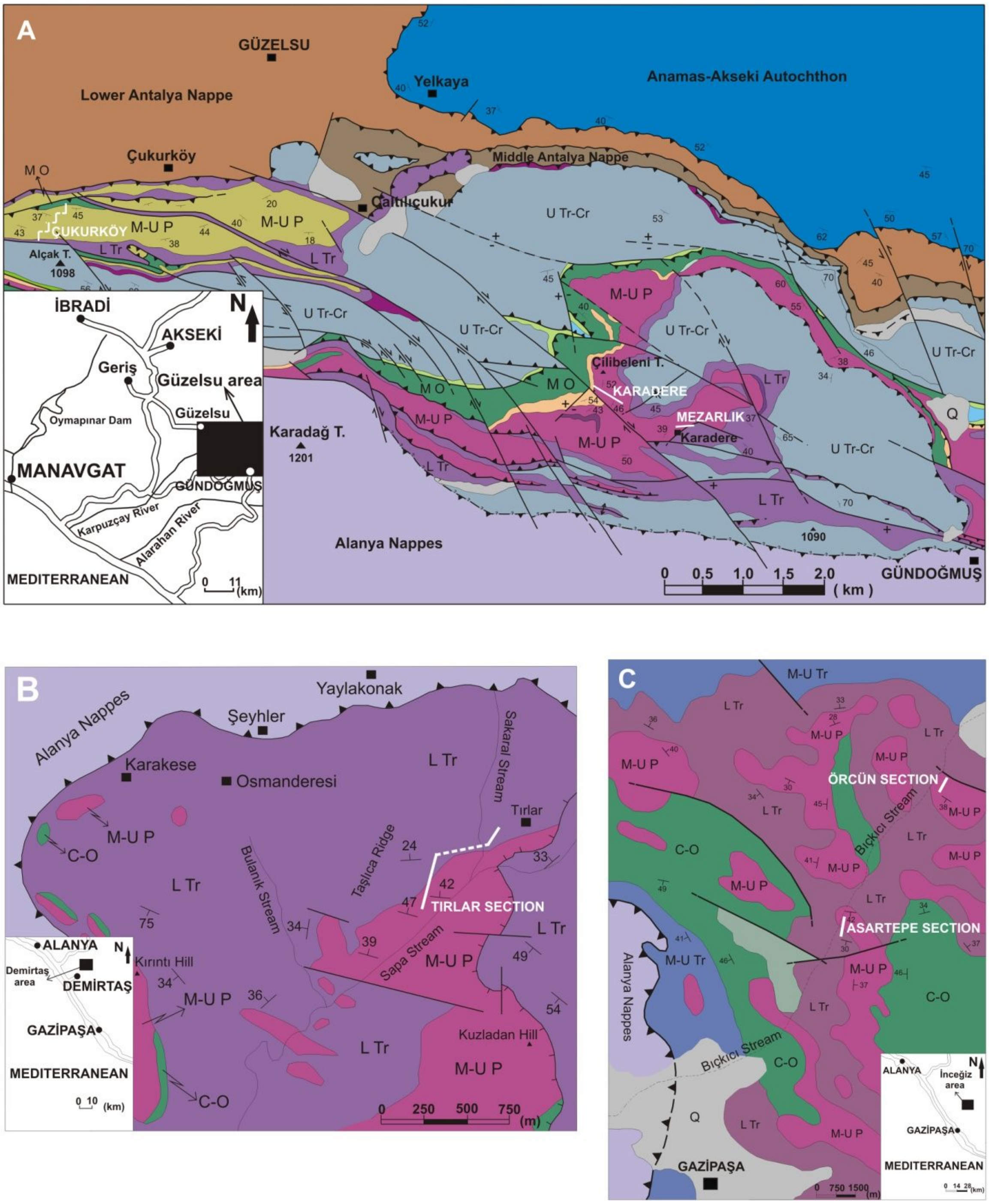

A
GÜZELSU
Lower Antalya Nappe
Yelkaya
Anamas-Akseki Autochthon
Middle Antalya Nappe
Çukurköy
M O
ÇUKURKÖY
M-U P
L Tr
Çaltılıçukur
U Tr-Cr
Alçak T.
1098
Çilibeleni T.
KARADERE
MEZARLIK
Karadere
Karadağ T.
1201
Alanya Nappes
Q
1090
GÜNDOĞMUŞ
0 0,5 1,0 1,5 2,0 (km)
İBRADİ
AKSEKİ
Geriş
Güzelsu area
Güzelsu
Oymapınar Dam
MANAVGAT
GÜNDOĞMUŞ
Karpuzçay River
Alarahan River
MEDITERRANEAN
0 11 (km)
B
Alanya Nappes
Yaylakonak
Şeyhler
Karakese
Osmanderesi
Sakaral Stream
Tırlar
L Tr
M-U P
C-O
Bulanık Stream
Taşlıca Ridge
TIRLAR SECTION
Sapa Stream
Kırıntı Hill
Kuzladan Hill
0 250 500 750 (m)
ALANYA
Demirtaş area
DEMİRTAŞ
GAZİPAŞA
MEDITERRANEAN
0 10 (km)
C
M-U Tr
L Tr
M-U P
C-O
ÖRCÜN SECTION
Bıçkıcı Stream
ASARTEPE SECTION
Alanya Nappes
Q
GAZİPAŞA
0 750 1500 (m)
ALANYA
İnceğiz area
GAZİPAŞA
MEDITERRANEAN

Fig. 10

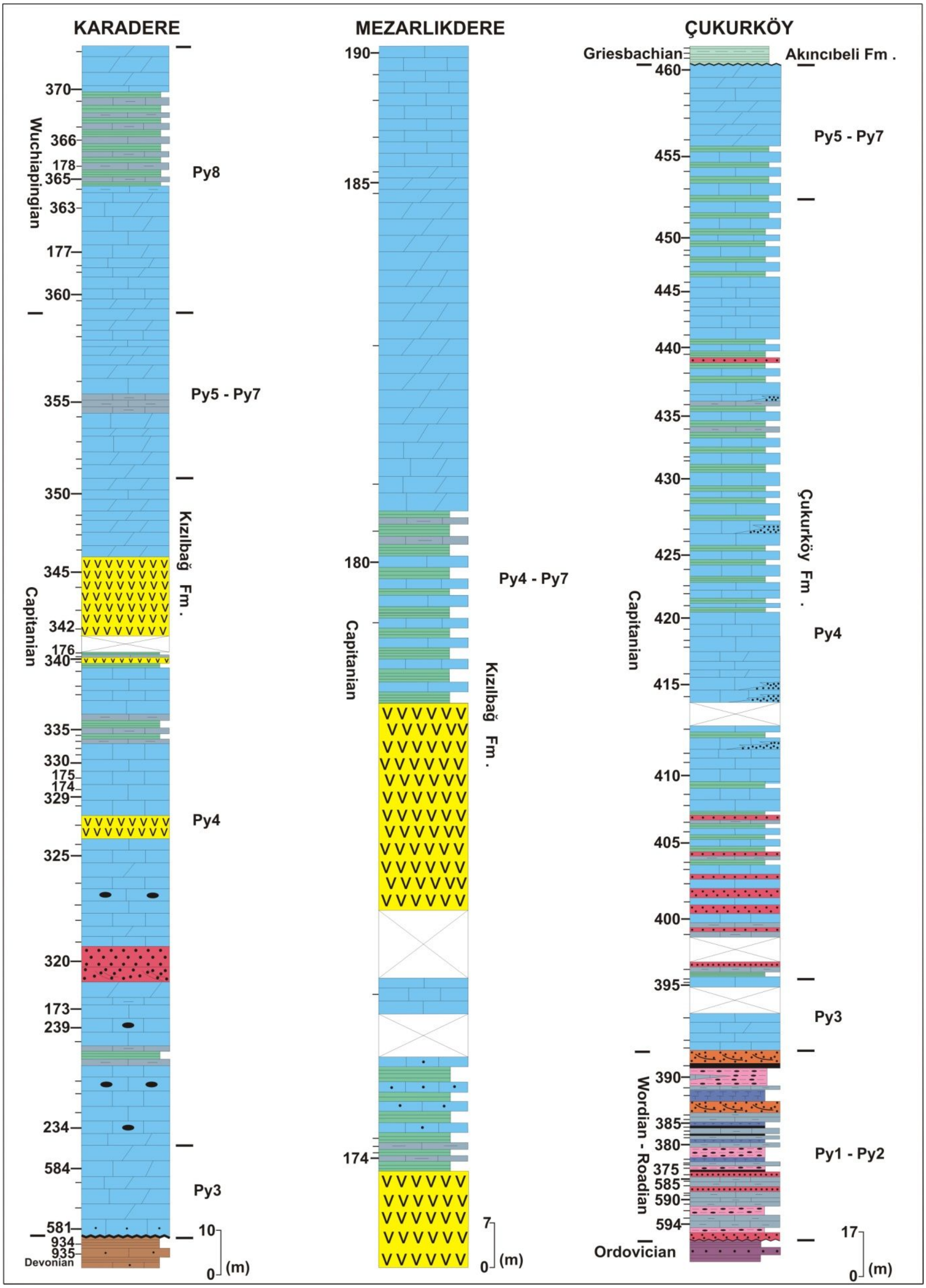

KARADERE
MEZARLIKDERE
ÇUKURKÖY
Wuchiapingian
Capitanian
Py8
Py5 - Py7
Kızılbağ Fm.
Py4
Py3
Devonian
Py4 - Py7
Griesbachian
Akıncıbeli Fm.
Çukurköy Fm.
Wordian - Roadian
Py1 - Py2
Ordovician
(m)

Fig. 11

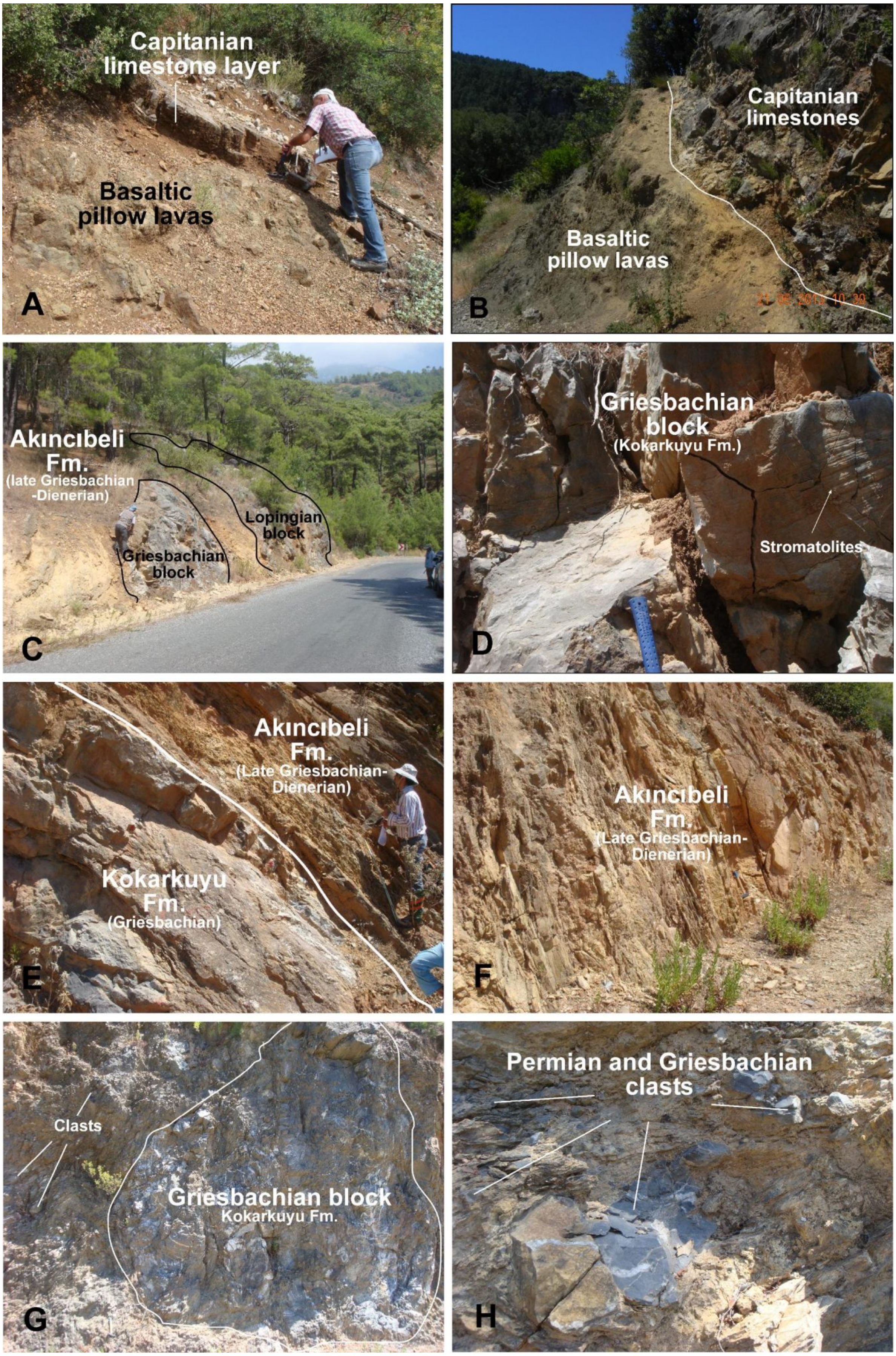

Capitanian
limestone layer
Basaltic
pillow lavas
A
Capitanian
limestones
Basaltic
pillow lavas
B
Akıncıbeli
Fm.
(late Griesbachian
-Dienerian)
Lopingian
block
Griesbachian
block
C
Griesbachian
block
(Kokarkuyu Fm.)
Stromatolites
D
Akıncıbeli
Fm.
(Late Griesbachian-
Dienerian)
Kokarkuyu
Fm.
(Griesbachian)
E
Akıncıbeli
Fm.
(Late Griesbachian-
Dienerian)
F
Clasts
Griesbachian block
Kokarkuyu Fm.
G
Permian and Griesbachian
clasts
H

Fig. 12

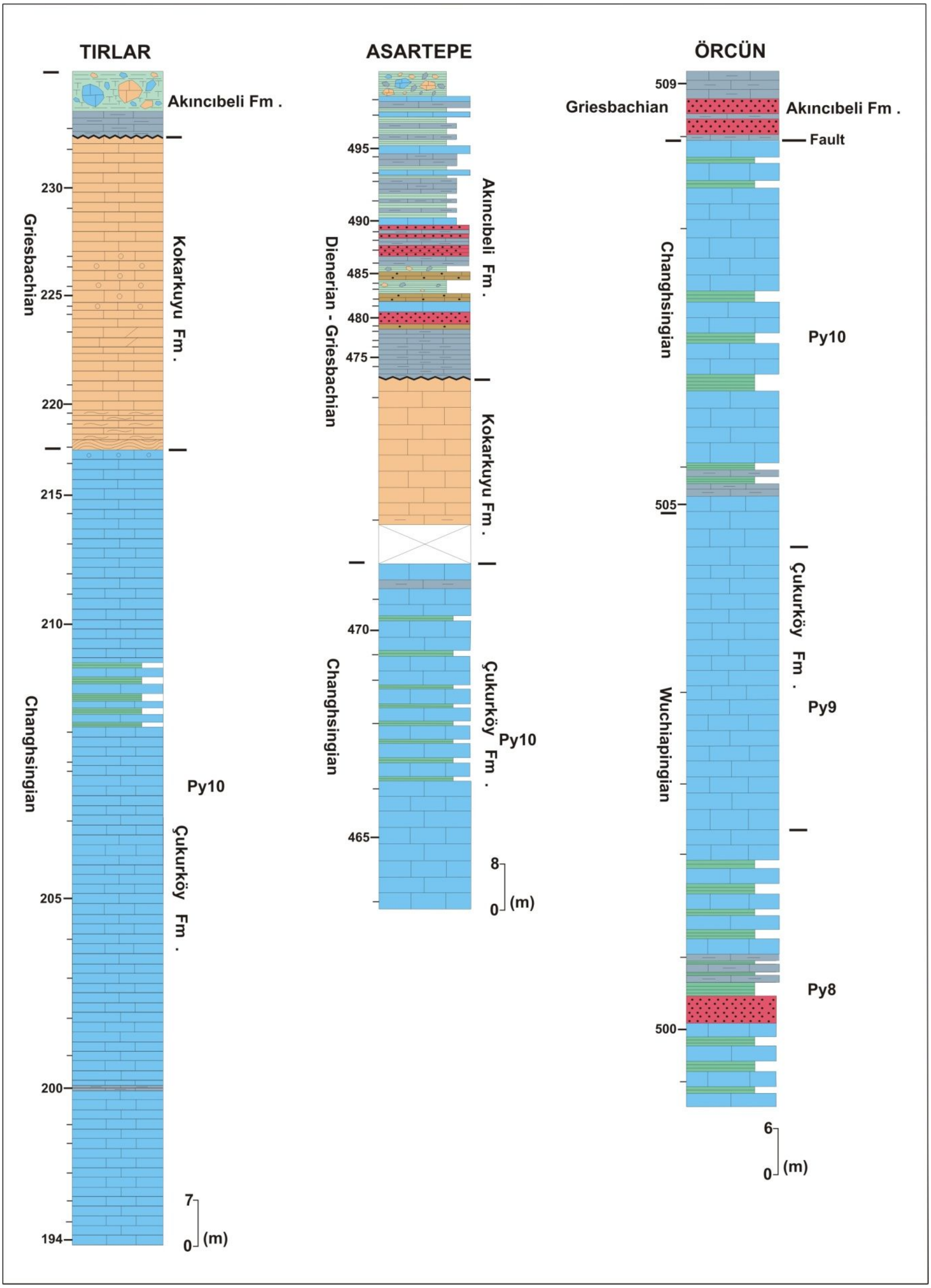

TIRLAR
Akıncıbeli Fm .
Kokarkuyu Fm .
Griesbachian
Changhsingian
Çukurköy Fm .
Py10
ASARTEPE
Akıncıbeli Fm .
Dienerian - Griesbachian
Kokarkuyu Fm .
Changhsingian
Çukurköy Fm .
Py10
ÖRCÜN
Griesbachian
Akıncıbeli Fm .
Fault
Changhsingian
Py10
Wuchiapingian
Çukurköy Fm .
Py9
Py8
(m)

Fig. 13

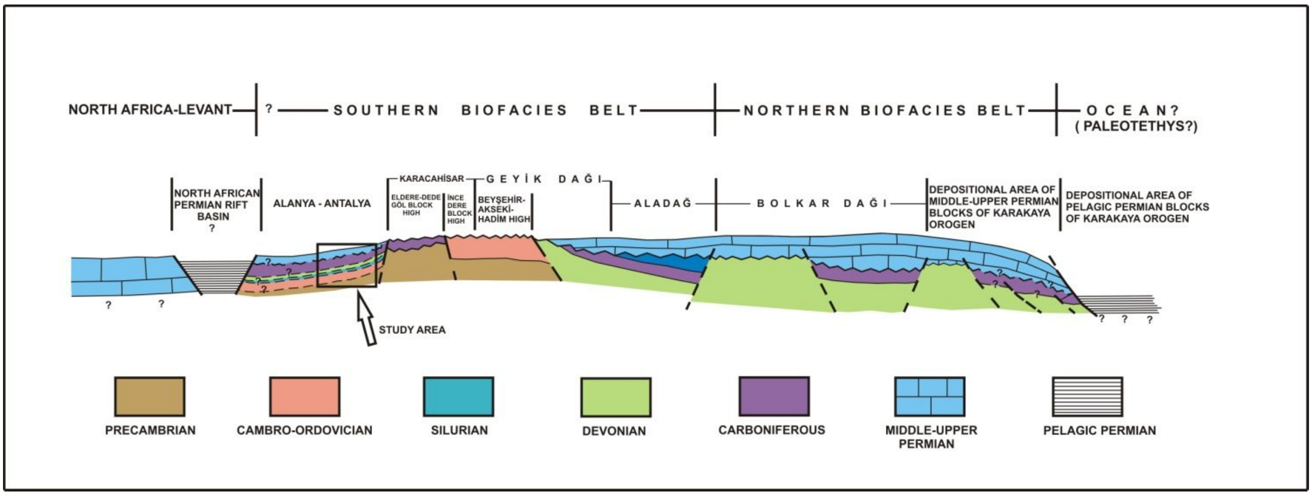

NORTH AFRICA-LEVANT
SOUTHERN BIOFACIES BELT
NORTHERN BIOFACIES BELT
OCEAN? (PALEOTETHYS?)
NORTH AFRICAN PERMIAN RIFT BASIN ?
ALANYA - ANTALYA
KARACAHİSAR
GEYİK DAĞI
ELDERE-DEDE GÖL BLOCK HIGH
İNCE DERE BLOCK HIGH
BEYŞEHİR-AKSEKİ-HADİM HIGH
ALADAĞ
BOLKAR DAĞI
DEPOSITIONAL AREA OF MIDDLE-UPPER PERMIAN BLOCKS OF KARAKAYA OROGEN
DEPOSITIONAL AREA OF PELAGIC PERMIAN BLOCKS OF KARAKAYA OROGEN
STUDY AREA
PRECAMBRIAN
CAMBRO-ORDOVICIAN
SILURIAN
DEVONIAN
CARBONIFEROUS
MIDDLE-UPPER PERMIAN
PELAGIC PERMIAN

Fig. 14

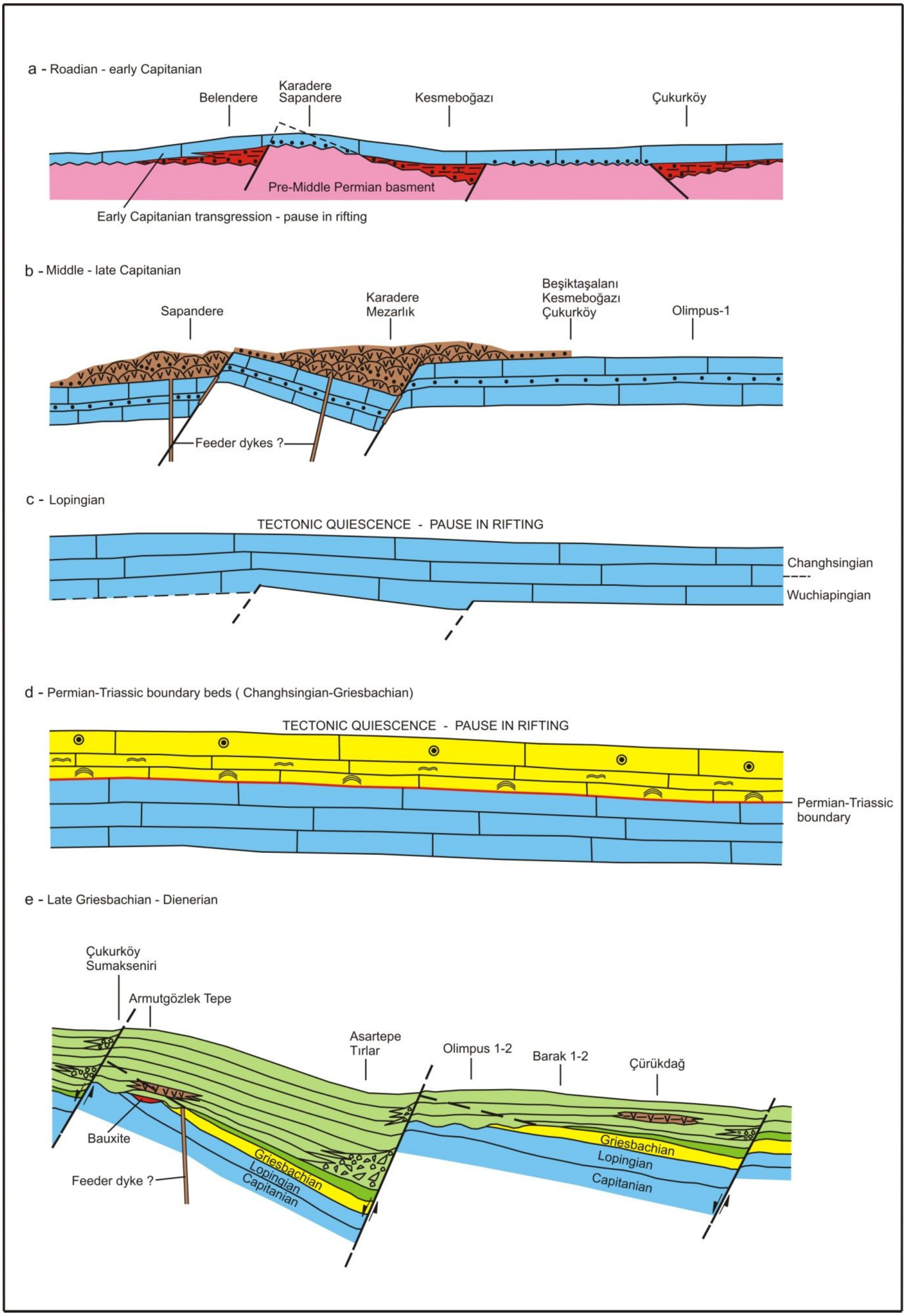

a - Roadian - early Capitanian
Belendere
Karadere
Sapandere
Kesmeboğazı
Çukurköy
Pre-Middle Permian basment
Early Capitanian transgression - pause in rifting
b - Middle - late Capitanian
Sapandere
Karadere
Mezarlık
Beşiktaşalanı
Kesmeboğazı
Çukurköy
Olimpus-1
Feeder dykes ?
c - Lopingian
TECTONIC QUIESCENCE - PAUSE IN RIFTING
Changhsingian
Wuchiapingian
d - Permian-Triassic boundary beds (Changhsingian-Griesbachian)
TECTONIC QUIESCENCE - PAUSE IN RIFTING
Permian-Triassic boundary
e - Late Griesbachian - Dienerian
Çukurköy
Sumakseniri
Armutgözlek Tepe
Asartepe
Tırlar
Olimpus 1-2
Barak 1-2
Çürükdağ
Bauxite
Feeder dyke ?
Griesbachian
Lopingian
Capitanian
Griesbachian
Lopingian
Capitanian

Fig. 15