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Discovery of Middle Permian volcanism in the Antalya Nappes, southern Turkey: tectonic significance and global meaning

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Detailed stratigraphic studies on the Middle-Upper Permian rocks of the Tahtalıdağ nappe (Antalya Nappes), largely exposed along the Güzelsu Corridor in central Taurides, have revealed the presence of basaltic volcanic rocks intercalated within the shallow-marine fossiliferous carbonate successions. Vitrophyric basaltic extrusions producing distinct pillows in the Kızılbağ Formation severely dolomitized the associated carbonate rocks.The coeval Çukurköy Formation, devoid of volcanic layers, is also exposed in the same corridor and was probably representing a part of the carbonate platform bordering this volcanic activity. The Middle-Upper Permian successions of the Kızılbağ and Çukurköy Formations have been calibrated based on a foraminiferal zonation and a Capitanian age has been assigned to the basaltic interval. Basalts are also chronostratigraphically located just below a horizon interpreted as the mid-Capitanian mass extinction event. Based on these data, two fundamental conclusions can be driven from this study. The discovery of basaltic volcanism brings a strong evidence for a much longer history about the rift-associated volcanic events in the Antalya Nappes. The Capitanian volcanic rocks are contemporaneous with the Emeishan Large Igneous Province in South China which is linked to the mid-Capitanian mass extinction event.

Keywords: Middle Permian; Capitanian; basaltic volcanism; rifting; Antalya Nappes; mid-Capitanian Mass Extinction Event

1. Introduction

Antalya Nappes (Brunn et al., 1971; Gutnic, Monod, Poisson, & Dumont, 1979; Lefèvre, 1967), known also as ‘Antalya Complex’ (Robertson, Poisson, & Akıncı, 2003; Waldron, 1984; Woodcock & Robertson, 1977; Yılmaz, 1981, 1984) or ‘Antalya Unit’ (Özgül, 1976, 1984), constitute a regionally important allochthonous rock assemblage of Paleozoic and Mesozoic age widely exposed within the Isparta Angle, around the City of Antalya. These nappes were basically recognized as a pile of thrust sheets in the region. The lower nappe introduced for the first time by Brunn et al. (1971) has also been named as the Çataltepe unit by Poisson (1977), Dereköy unit by Marcoux (1978), northern Kumluca zone by Yılmaz (1984) and Çataltepe nappe by Şenel, Serdaroğlu, Kengil, Üniverdi, and Gözler (1983). It consists of an Upper Triassic to Upper Cretaceous sedimentary rock succession and is capped by a Campanian–Maastrichtian flysch containing blocks. This nappe is structurally interpreted to be the lowest in position.

Brunn et al. (1971) defined the middle nappe of Antalya Nappes as consisting of clastics associated with submarine basic volcanics and ophiolitic rocks. Clastics and associated volcanics have been defined as the Ispartaçay Formation by Poisson (1977). Some authors, Robertson and Woodcock (1980, 1981a, 1981b, 1982, 1984), Şenel et al. (1983), Şenel (1986), Yılmaz (1981) and Yılmaz, Maxwell, and Muehlberger (1981), considered the ophiolitic rocks as a separate unit, different from the middle nappe. Later, Şenel et al. (1983) named this unit as the Alakırçay nappe, a term already used as the Alakırçay unit by Marcoux (1977, 1979) for the Triassic sedimentary rock assemblage.

Brunn et al. (1971) defined the upper nappe as a succession composed of Paleozoic and Mesozoic platform-type deposits. The same rock assemblage has been named as Dulup sequence near Eğirdir Lake (Dumont & Kerey, 1975). Marcoux (1977, 1979) recognized three distinct slices in this tectonostratigraphic unit comprising Bakırlıdağ, Kemer and Tahtalıdağ. Monod (1977) introduced the Katrandağı unit as the upper nappe. Şenel et al. (1983) and Şenel (1986) used the Tahtalıdağ nappe term for the upper nappe and recognized many variations in its stratigraphy, such as the presence of pelagic Ladinian-Norian sequences associated in places with volcanics or the absence of Middle and Upper Triassic deposits. A fourth nappe is tectonically imbricated with the three previous units. It is entirely ophiolitic and known as the Tekirova opholitic nappe widely exposed along the coasts of the Antalya Bay.

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This article was originally published with errors. This version has been corrected. Please see Erratum (http://dx.doi.org/10.1080/09853111.2014.890343)

Antalya Nappes (~Antalya Complex) constitute a good example for understanding of rift settings and continental break-up mechanisms in the eastern Mediterranean (Robertson, 2002, 2007; Robertson, Parlak, & Ustaömer, 2012; Robertson et al., 2003; Şengör & Yılmaz, 1981; Yılmaz, 1984). 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 inferred to have existed throughout much of the northern Gondwana region during Mid-Late Permian time. Permian rifting, based on widespread tectonic subsidence and marine transgression, is documented in many areas, including onshore Levant (Garfunkel, 1998, 2004), within the Antalya Nappes (Poisson, 1977, 1984; Robertson & Woodcock, 1982) and the central Taurides (Altıner, Özkan-Altıner, & Koçyiğit, 2000; Mackintosh & Robertson, 2012; Monod, 1977; Özgül, 1984, 1997). In contrast to pre-Triassic times, 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). Particularly within the middle nappe, thrust sheets include Triassic slope to basin siliciclastic and carbonate sedimentary rocks intercalated with volcanic rocks (Juteau, 1975, 1980; Poisson, 1977; Robertson & Woodcock, 1982). 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 & Woodcock, 1982; Robertson et al., 2012, 2003).

The main aim of this paper is to report the discovery of Middle Permian (Capitanian) basaltic volcanism in the Antalya Nappes, define its stratigraphic position within the biostratigraphic frame of Middle-Upper Permian carbonate deposits of the Tahtalıdağ unit and discuss its significance in relation with the opening history of the Antalya Ocean. To fulfill this purpose, two stratigraphic sections have been measured in the Permian of the eastern sector of the Antalya Nappes exposed in a narrow belt between the towns of Güzelsu and Gündoğmuş, east of the City of Antalya. Among these chronostratigraphically equivalent shallow-water carbonate successions, one of them displays volcanic rocks intercalated within the carbonate rocks. The petrography of volcanic rocks is given briefly in the paper; however, the geochemistry of basalts is left out of the scope for a further study. The interval of the Capitanian volcanism in the Antalya Nappes is partly coeval with the onset of eruption of the Emeishan Large Igneous Province in southwestern China and coincides with the Capitanian mass extinction including fusulinoidean foraminifers, important groups of brachiopods and corals. With the data available from the studied successions, a discussion on the global significance of Capitanian volcanism is also given in the paper.

2. Geological setting and the Permian in the Güzelsu Corridor

The Tauride Block, known as a distinct tectonic entity within the Late Paleozoic–Mesozoic geological frame of Turkey, is characterized, in general, by an autochthonous belt ranging in age from Cambrian to Eocene and the nappes comprising the oceanic and platform margin-slope material derived from both the north and the south of the platform (Özgül, 1976, 1984, 1997; Şengör & Yılmaz, 1981). In the Central and Western Taurides, the autochthonous belt is represented by three distinct units, namely the Geyik Dağı Unit (restricted only to the Anamas-Akseki belt in this study), Karacahisar Unit and the Beydağları Unit (Figure 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.

Within the Isparta Angle, Antalya Nappes are exposed in three distinct sectors in the Central and Western Taurides (Figure 1). To the west of the City of Antalya, the exposures between Kemer and Beydağları constitute N-S trending structures and are often referred as the type of Antalya Nappes. The second large exposure is around the Eğirdir Lake and extends to the south toward the Sütçüler area and disappears under the Miocene cover of the Antalya area. Antalya Nappes also crop out to the east of the City of Antalya under the cover of the Alanya Nappes. Exposures to the south of the Town of Akseki, known as the Güzelsu Corridor, and the exposures around the Town of Gazipaşa extending to the south of the Town of Anamur represent the eastern sector of the Antalya Nappes (Figure 1).

The study area is located in the eastern sector of the Antalya Nappes, more precisely in an area between the towns of Güzelsu and Gündoğmuş. It is easily accessible from the main highway connecting Antalya via Manavgat to Akseki (Figure 2). Two principle roads bifurcating from the Akseki highway in the direction of the towns of Güzelsu and Gündoğmuş reach the study area.

The study area constitutes an important part of the Güzelsu Corridor (Figure 3) and comprises three main tectonic units. These are, from north to south, the Anamas-Akseki Autochthon (Geyik Dağı Unit), Antalya Nappes and the Alanya Nappes. Antalya Nappes consist of three distinct slices (Çataltepe, Alakırçay and Tahtalıdağ nappes of Şenel et al., 1998) in this region and the rock composition and structure of these slices are quite comparable with lower, middle and upper subdivisions of the Antalya Nappes in the type region (Brunn et al., 1971; Gutnic et al., 1979) exposed between Kemer and Beydağları, west of the City of Antalya.

Although the Tahtalıdağ nappe in the Güzelsu Corridor is characterized by different types of successions (Katrandağı, Kavzandağı and Gündoğmuş sequences of Şenel et al., 1998), the fundamental stratigraphic frame of the nappe consisting of Paleozoic and Mesozoic rocks

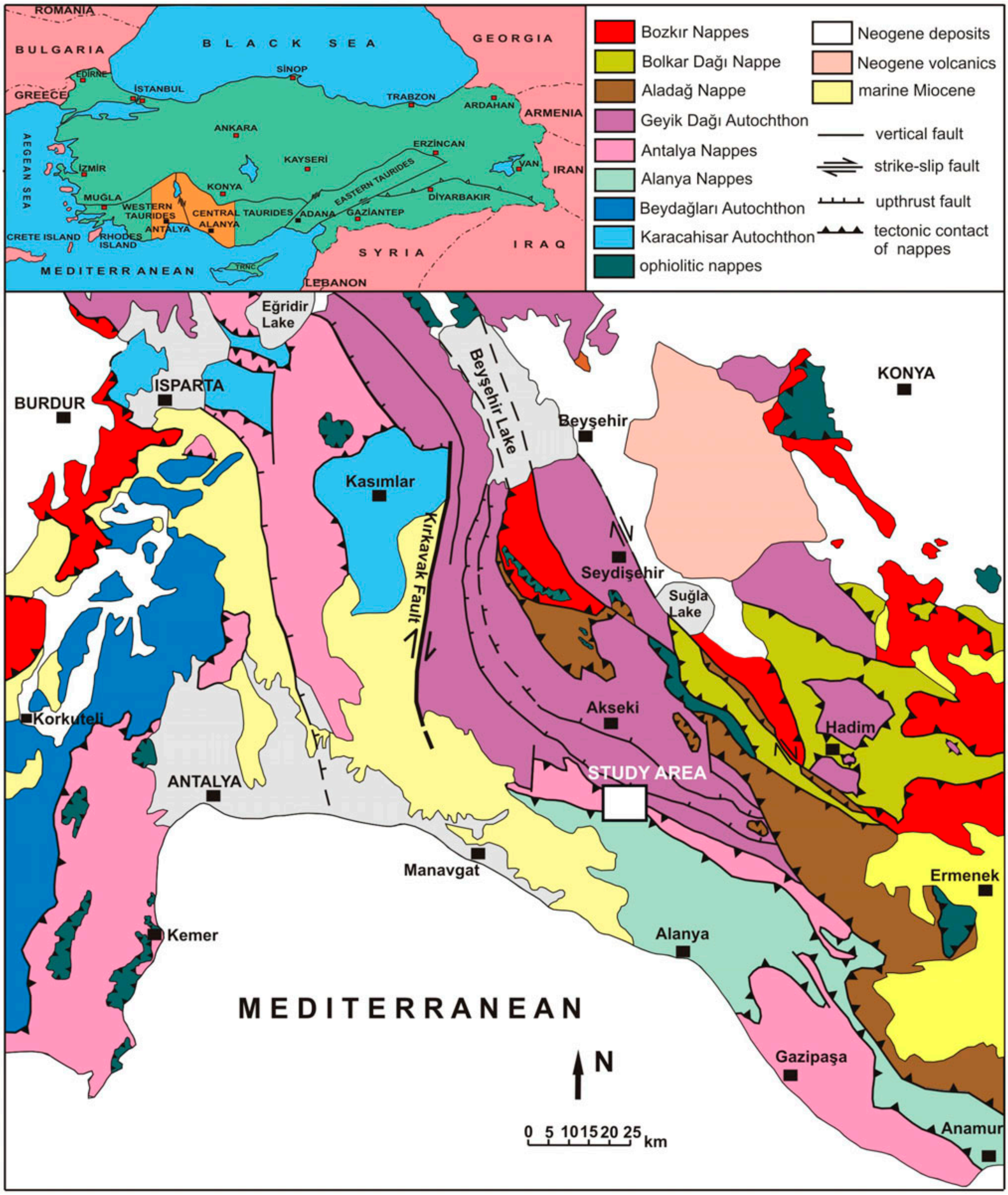

Figure 1. Map showing the distribution of tectonic units in the area between western and central Taurides (modified from Özgül (1984)). The area indicated by the white rectangle is the location of the study area.

is more or less uniform. The oldest rock formation is the Upper Cambrian–Ordovician Seydişehir Formation (Blumenthal, 1947; Monod, 1967), which is basically made up of siltstones and shales. The succession continues upward with graptolithic shales and sandstones of Silurian age (Bozsenir Formation; Şenel et al., 1992) and dolomites, limestones, shales and sandstones of early to middle Devonian age (Güneyyaka Formation, Demirtaşlı,

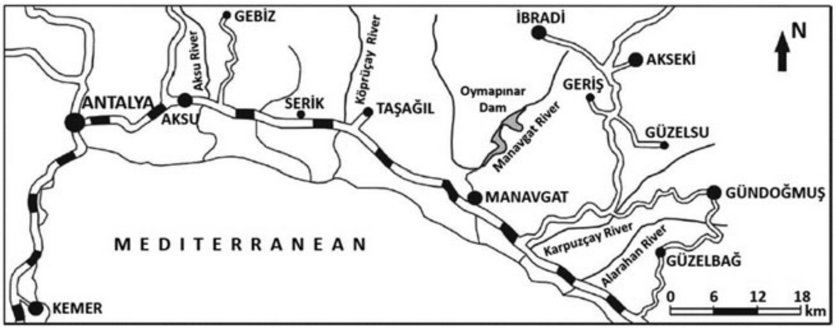

Figure 2. Geographic setting and the accessibility of the study area.

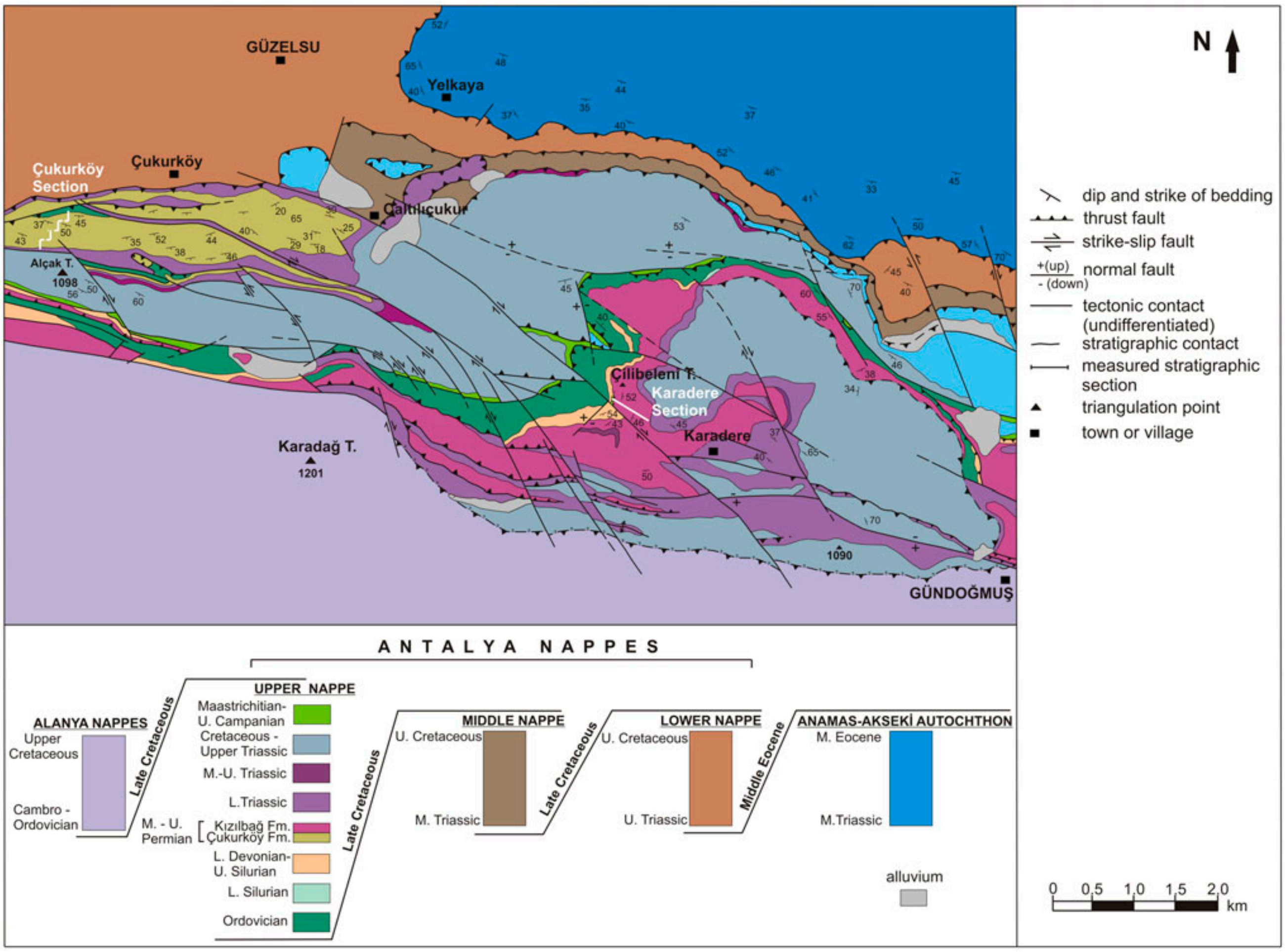

Figure 3. Geological map of the study area (simplified and modified from Şenel et al. (1998)) and the location of Çukurköy and Karadere köyü sections.

1987). The youngest rock units in the Paleozoic are the unconformably overlying Middle-Upper Permian Çukurköy Formation (Şenel et al., 1992) consisting of sandstones with coal layers, shales, clayey limestones and thick carbonates and the coeval Kızılbağ Formation (Demirtaşlı, 1987) made up of dolomites intercalated with thin limestone layers. Unconformably overlying the Permian rocks in the area, the Mesozoic starts with varicolored shales and marls of Scythian–Anisian age (Akıncıbeli Formation; Demirtaşlı, 1987). Thin-bedded limestones containing thin-shelled bivalves of Ladinian to Norian age (Günlük Formation; Şenel et al., 1992) are followed upwards either with Rhaetian–Cenomanian neritic limestones (Katrandağı Limestone; Monod, 1977) or the coeval dolomites intercalated with limestone layers (Kavzandağı Formation, Demirtaşlı, 1987) or a Dogger-Malm succession made up of conglomerates, bauxitic levels and dolomites in the lower part and limestones in the upper. The top of the Tahtalıdağ succession is capped by an upper Campanian–Maastrichtian flysch containing blocks of various lithology of Antalya Nappes including ophiolites (Keçili Formation; Juteau, 1975).

The investigation of the Permian rocks was started mainly because of coal in the Güzelsu Corridor. Ziegler (1938–1939) discovered the coal layers in the Çukurköy area at the base of limestones containing fusulines and *Fenestella*. Barutoğlu (1940) considered the coal beds as Carboniferous in age. However, Nebert (1963, 1964), after studying the coal layers in the Çukurköy area, described a succession of Permian age starting with quartz arenites at the base and continuing upwards with carbonates containing abundant *Bellerophon*. Nebert noticed, as described earlier by Blumenthal (1951), the tectonically complicated nature of the area. He recognized that the Permian sequences were transported and emplaced into the region from south to north by gravitational sliding mechanisms. According to him, Upper Permian units were later fragmented by tectonic movements and thrusted onto the Cretaceous sediments. Monod (1979) in his map illustrating the area between Çukurköy and Güzelsu recognized the Upper Permian limestones containing algae, fusulines and brachiopods and the overlying Lower Triassic made up of marls and limestones. However, he included doubtfully the Permo-Triassic succession at the base of his lower nappe which is basically represented by the Güzelsu Formation containing sandstones with plant remains intercalated with pillow lavas, *Halobia* limestones and reefal limestone blocks. Demirtaşlı (1987) considered the lower and upper nappes of the Antalya Nappes as olistoliths in a wild flysch of Maastrichtian age (Çukurköy Formation) in the Güzelsu Corridor. However, he recognized a stratigraphy from Ordovician to Cretaceous in the upper nappe and introduced the Kızılbağ Formation for the Upper Permian rocks due to the presence of extensive dolomitization in the succession. Finally, Şenel et al. (1998) studied the stratigraphy of the region and recognized the Permian rocks containing coal deposits as a formation different than the Kızılbağ Formation of Demirtaşlı (1987). Thus, the Permian rock units in the region were divided into two formations; while the lithological character of the Kızılbağ Formation was being described as dominated by dolomites, the Çukurköy Formation was introduced for a succession starting at the base with shales, quartz sandstones, siltstones and clayey limestones including coal layers and the succeeding thick limestone succession intercalated with distinct shale layers. According to Şenel et al. (1998), the Çukurköy Formation is overlain with an unconformity by the varicolored marls of the Akıncılar Formation of Scythian age.

3. Measured stratigraphic sections

3.1. Çukurköy section

This section has been measured on the northern slopes of the Alçak Tepe located 1.5 km SW of the Çukurköy village (Figure 3). Because of intense tectonics in the region, several lateral shifts were made in order to avoid folds and faults.

The Çukurköy Formation, fully exposed and measuring 477 m in thickness along the section (Figure 4), overlies unconformably the Ordovician siltstones and shales of the Seydişehir Formation (Figure 5(a)) and starts at the base with a distinct transgressive–regressive cycle (samples 594–585; Figure 4). Over the unconformity surface, the cycle starts with gray to beige or dark green colored quartz sandstones and continues upwards with shales containing thin layers of coal and bituminous clayey limestones or marls (Figure 5(b)–(d)). Clayey limestones and marls are usually rich in marine fossils including foraminifera, gastropods, brachiopods and crinoids. This cycle is abruptly truncated by a quartz sandstone layer defining the base of the following cycle, which exhibits a succession similar to the underlying cycle (sample 375–387; Figure 4). The sandstone layer is followed upwards at first by shales with coal layers and bituminous limestone or marl intercalations and then by bituminous clayey limestones or marls containing marine fossils. The overlying deposits upwards in the section are still cyclic in nature but different in lithological character (samples 388–391). Cross-bedded light-colored quartz sandstones intercalated with marls and limestones rich in foraminifera, gastropods and crinoids are capped at the top by a thin coal layer. These three distinct cycles measure 51 m in thickness, and the succession continues upwards with again a distinct quartz sandstone level and thin-, medium- to thick-bedded, gray to dark colored fossiliferous limestones intercalated with quartz arenitic levels (Figure 5(e)) and shales (samples 392–407; Figure 4). Limestones in this interval, 74 m in thickness, are rich particularly in foraminifera, gastropods, algae (*Ungdarella*, gymnocodiacean algae), crinoids and brachiopods and contain the first appearance of the famous fusuline *Eopolydiexodina* in the lower levels (samples 392–395). Upwards in the section, the succession is dominated by a 47-m-thick fossiliferous limestone rarely intercalated with shale layers (sample 408–412; Figure 4) and then by a shaly interval measuring 10 m and including thin limestone layers, which contain schwagerinid-type fusulines (sample 413; Figure 4). The succession passes upwards to medium- to thick-bedded, dark gray colored limestones rich in fusulines, gymnocodiacean algae and crinoids (samples 414–420; Figure 4). Measuring 35 m in thickness, this limestone level is followed upwards with a 98-m-thick limestone interval (samples 421–438 m; Figure 4) containing small pockets of quartz sand and distinct shale layers (Figure 5(f)). Upwards, following a shaly interval measuring 17 m (samples 439–440; Figure 4), the succession continues with a 35-m-thick limestone (Figure 5(g)) containing

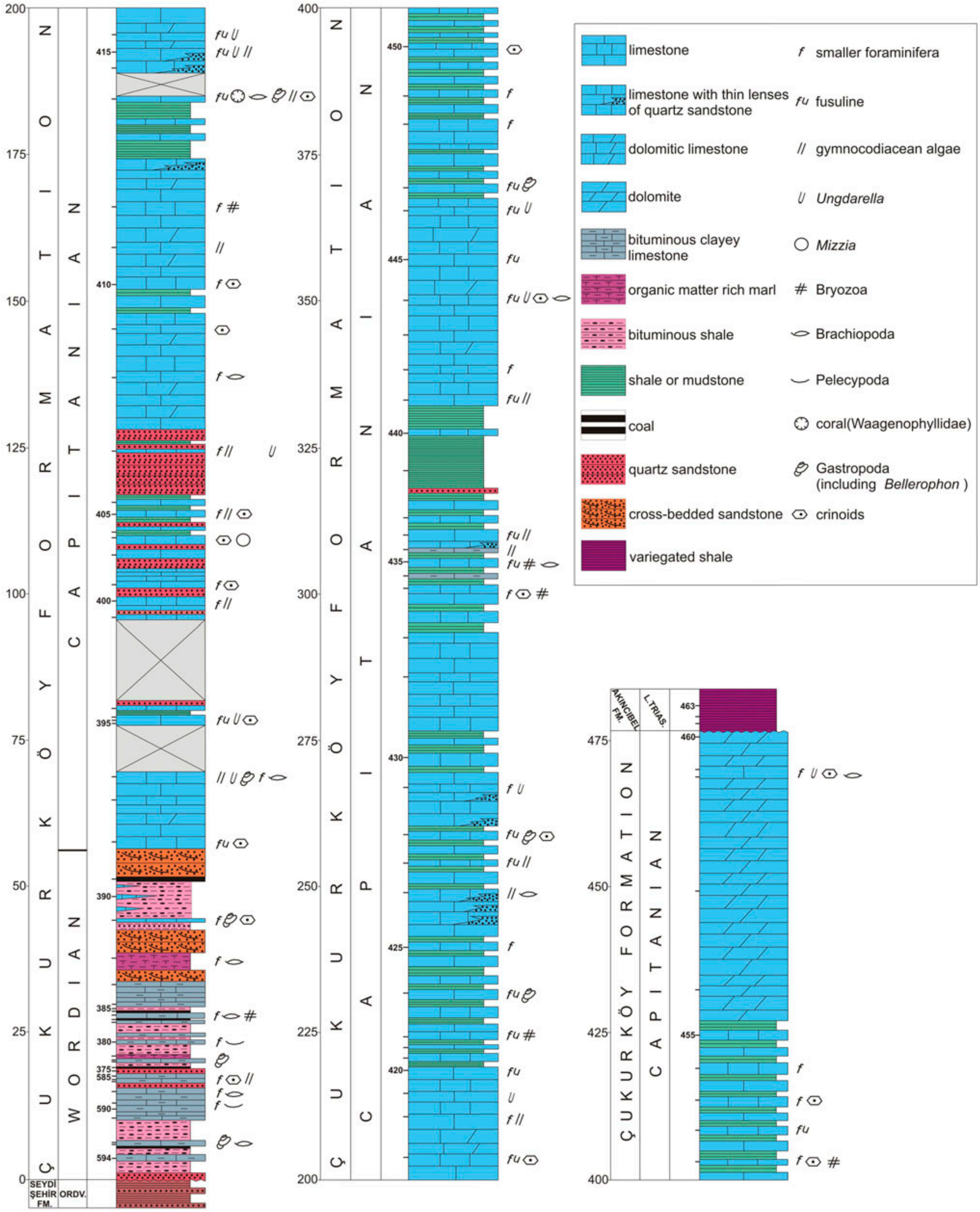

Figure 4. Çukurköy Formation in the Çukurköy measured section.

several levels with large fusulines (samples 441–446; Figure 4). The upper part of the Çukurköy Formation consists of a limestone-shale alternation (samples 447–455; Figure 4) measuring 60 m in thickness and the succeeding medium- to thick-bedded, light gray dolomites containing rare limestone or dolomitic limestone levels (samples 456–468; Figure 4). The dolomitic interval measuring 60 m in thickness is truncated at the top by an erosion

Figure 5. (a) The stratigraphic contact between the Ordovician shales and siltstones of the Seydişehir Formation (ORD) and the lower levels of the Çukurköy Formation (M. PERM). (b) Bituminous clayey limestone or marl layers in the lower levels of the Çukurköy Formation (samples 589–588 in Figure 4). (c) Bituminous clayey limestone rich in foraminifera, *Bellerophon*, gymnocodiacean algae, crinoids, brachiopods and ostracoda (sample 587 in Figure 4). (d) Bituminous clayey limestone or marl layers (BCL) intercalated with 1 m thick quartz sandstone (Q) (samples 588–586 in Figure 4). (e) The contact between quartz sandstone (Q) and limestone (LMST) just below sample 403 in Figure 4. (f) Limestone-shale alternations in the Çukurköy Formation (sample 438 in Figure 4). (g) Well-bedded limestone layers in the Çukurköy Formation (sample 442 in Figure 4). (h) Permian-Triassic boundary in the Çukurköy section. Note the Lower Triassic (possibly Dienerian) varicoloured shales, marls and clayey limestones of the Akıncıbeli Formation (TR) unconformably overlying the dolomites or dolomitic limestones of the Çukurköy Formation (PERM) (samples 460–462 in Figure 4).

surface and the Lower to Middle Triassic Akıncıbeli Formation overlies unconformably the Çukurköy Formation (Figure 5(h)).

Based on foraminifers (Plate 1), the Çukurköy Formation at its type-locality has been assigned to two Middle Permian stages, Wordian and Capitanian. Three

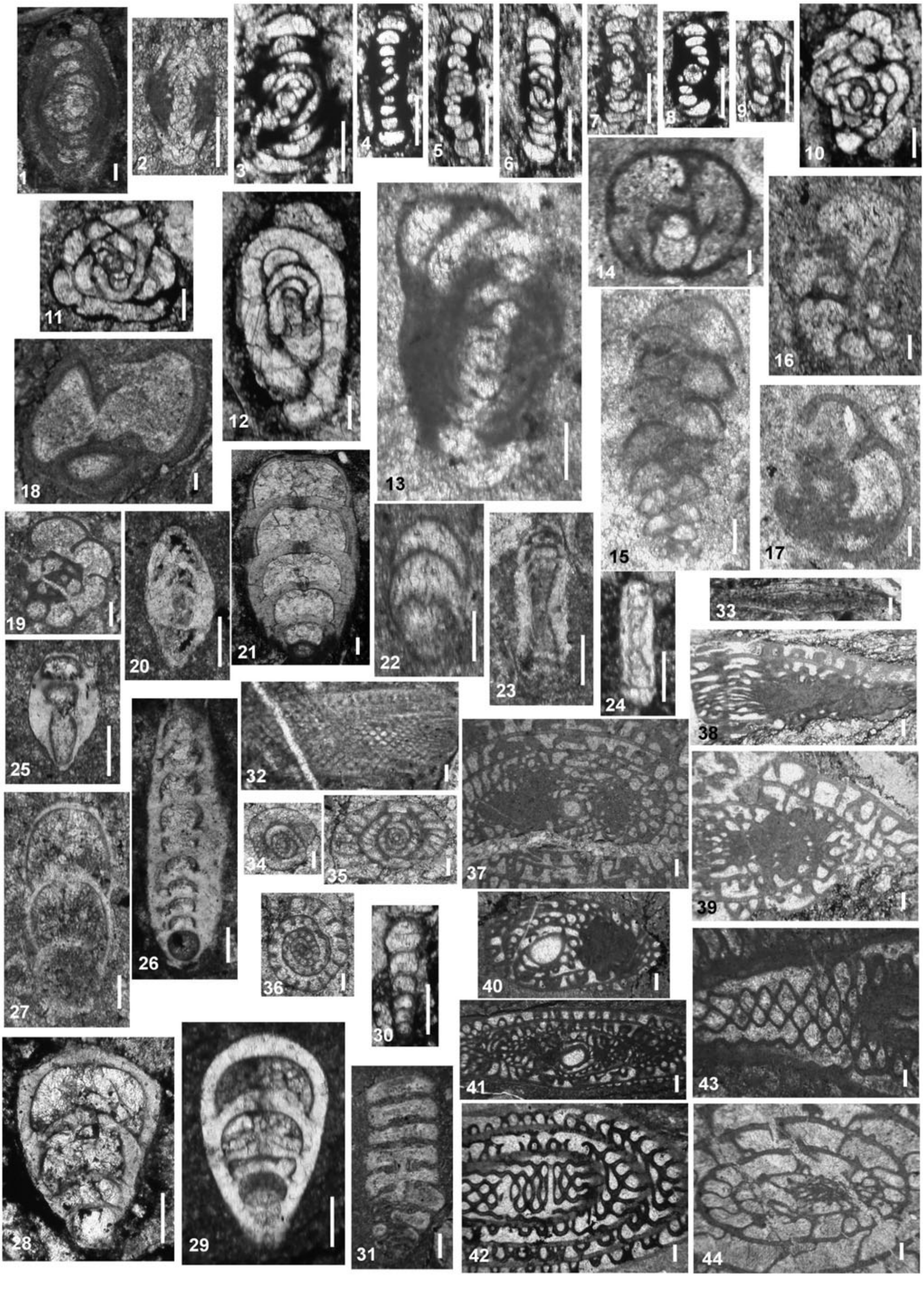

Plate 1. Foraminifera from the Çukurköy Formation. 1. *Multidiscus padangensis* (Lange); 2. *Multidiscus* sp.; 3. *Hemigordius ovatus* Grozdilova; 4. *Hemigordius permicus* Grozdilova; 5–6. *Hemigordius* sp.; 7–8. *Hemigordius longus* Grozdilova. 8 is considered an atypical individual of *H. longus*, not a *Midiella*. 9. *Hemigordius irregulariformis* Zaninetti, Altiner and Çatal; 10. *Hemigordiellina regularis* (Lipina); 11. *Hemigordiellina* ? or a new genus ?; 12. *Agathammina pusilla* (Geinitz); 13. *Midiella* sp.; 14. *Retroseptellina decrouezae* (Köylüoğlu & Altiner); 15. *Dagmarita chanakchiensis* Reitlinger; 16. *Globivalvulina graeca* Reichel; 17. *Endoteba controversa* Vachard & Razgallah; 18. *Globivalvulina vonderschmitti* Reichel; 19. *Endothyra* sp.; 20. *Robuloides lens* Reichel; 21. *Langella perforata langei* Sellier de Civrieux & Dessauvagie; 22. *Frondina permica* Sellier de Civrieux & Dessauvagie; 23. *Pseudo-vidalina involuta* Zaninetti, Altiner and Çatal; 24. *Pseudovidalina ornata* Sosnina ?; 25. *Pachyphloia ovata* Lange; 26. *Pachyphloia schwageri* Sellier de Civrieux & Dessauvagie; 27. '*Protonodosaria' globifrondina* Sellier de Civrieux & Dessauvagie; 28. *Langella conica* Sellier de Civrieux & Dessauvagie; 29. *Langella cukurkoyi* Sellier de Civrieux & Dessauvagie; 30. *Protonodosaria* sp.; 31. *Climacammina valvulinoides* Lange; 32. *Minojapanella (Wutuella)* cf. *wutuensis* Kuo; 33. Boultoninae (a transitional form between *Boultonia* and *Russiella* ?); 34. Schubertellidae gen. and sp. indet. (see Kobayashi & Altiner, 2011); 35–36. *Dunbarula protomathieui* Kobayashi and Altiner; 37. *Parafusulina* gr. *elliptica* Sheng; 38–39. *Chusenella* spp.; 40–42. *Eopolydiexodina* sp.; 43. *Parafusulina* sp.; 44. *Rugososchwagerina* sp. 1, 19: 397B (for samples see Figure 4); 2: 442; 3–5, 7–8: 589; 6, 11–12, 21, 30: 387; 9: 588; 10: 586; 13: 446; 14–15: 453; 16: 400; 17, 32: 413; 18: 449; 20, 22, 25: 431; 23: 418; 24: 386; 26: 444; 27: 425; 28: 585; 29: 451; 31:433; 33: 438; 34–36: 392; 37: 437; 38: 415; 39: 396; 40, 42: 397A; 41: 440; 43: 436; 44: 445. Scale bars: 100 µ (2–17; 20, 22–30); scale bars: 200 µ (1, 18–19, 21, 31–36); scale bars: 300 µ (37–44).

transgressive–regressive and coal-bearing cycles at the base (samples 594 to 391; Figure 4) belong to the Wordian stage, and the rest of the formation comprising limestones and dolomites occasionally intercalated with quartz sandstones and shales (samples 392–460) are assigned to the Capitanian.

The foraminiferal biostratigraphy of the Southern Biofacies Belt of Altıner et al. (2000) comprising mainly the Middle-Upper Permian deposits of the Arabian Platform (southeast Anatolia) and the Geyikdağ Autochthon, Aladağ and Antalya Nappes from Taurides in Turkey has been recently restudied by Altıner and Şahin (2012) on a thick carbonate section fully exposed in the Geyik Dağı Autochthon in the eastern Taurides. The previously introduced zonal schemes suggesting a fourfold subdivision in the Middle-Upper Permian deposits (Altıner, 1981, 1984; Altıner et al., 2000; Köylüoğlu & Altıner, 1989; Zaninetti, Altıner, & Çatal, 1981) have been highly improved in the Köserelik Tepe section of the Yığılıtepe Formation with 10 biozones (Py1–Py10) from Wordian to Changhsingian (Figure 6). In the Middle Permian section of the Çukurköy section, we recognized four main intervals all correlatable with the biozonation scheme proposed by Altıner and Şahin (2012).

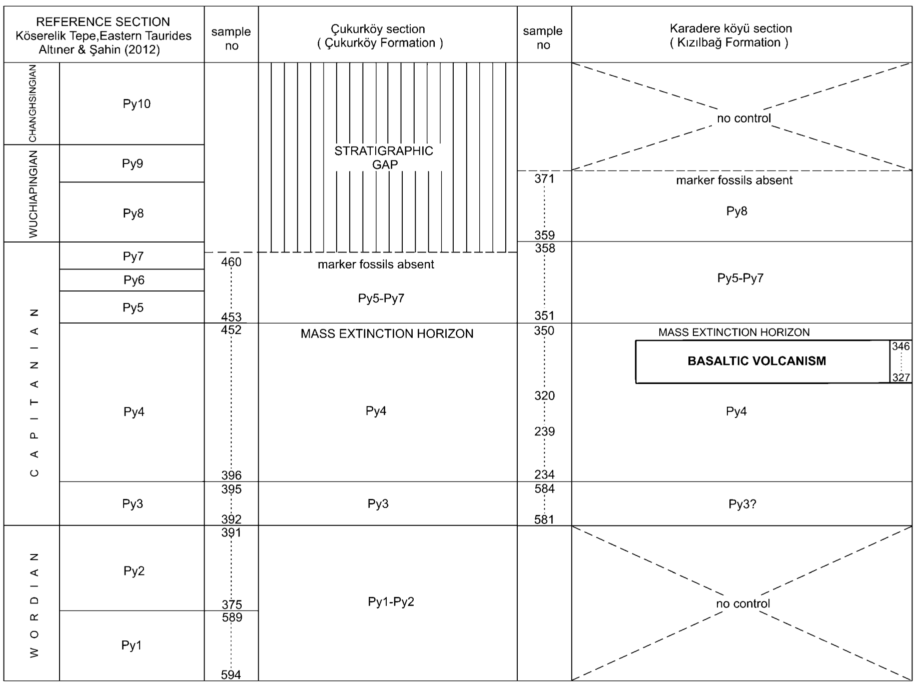

Figure 6. Biostratigraphic calibration of Çukurköy and Karadere köyü sections (Py1–Py10: foraminiferal zones) and the chronostratigraphic position of the basaltic volcanism.

The lower part of the Çukurköy succession assigned to the Wordian stage (samples 594–391; Figure 4) belongs to Py1–Py2 zones (Figure 6). Particularly marls, bituminous clayey limestones and bituminous wackestones to packstones containing gastropods, brachiopods, pelecypods, ostracods and crinoids have yielded a rather well-diversified foraminiferal assemblage comprising primitive *Dunbarula* sp., *Globivalvulina* sp., *Langella perforata langei*, *L. cukurkoyi*, *L. conica*, *Cryptoseptita* sp., *Pseudolangella* sp., *Protonodosaria* sp., *Pseudovidalina* sp., *Hemigordius longus*, *H. permicus*, *H. ovatus*, *H. schlumbergeri*, *H. irregulariformis*, *H.* sp., *Glomomidiella* sp., *Agathammina pusilla*, *A.* sp., *Cornuspira* sp., *Hemigordiellina regularis*, *Palaeonubecularia* sp. and *Baisalina*-like forms. An important part of this interval (samples 589–391) corresponds to the Py2 zone of Altıner and Şahin (2012). However, the base of the formation between samples 594 and 590 is nearly unfossiliferous and has been tentatively assigned to the Py1 zone.

The interval between samples 392 and 395 is characterized by algal (gymnocodiacean algae and *Ungdarella*), crinoidal and foraminiferal wackestones and packstones and assigned to the Py3 zone (base Capitanian) (Figure 6). In addition to the foraminifera list given above, the following foraminifers are recognized for the first time: *Eopolydiexodina* sp., *Parafusulina* (*Skinnerella*) sp., *Dunbarula protomathieui*, *D.* sp., *Globivalvulina* ex gr. *cyprica*, *G. graeca*, *Multidiscus* sp. Among these forms, *Eopolydiexodina* is a typical genus widespread at the Wordian–Capitanian boundary in the peri-Gondwana terranes (Altıner & Şahin, 2012; Gaillot & Vachard, 2007; Şengör, Altıner, Cin, Ustaömer, & Hsü, 1988; Ueno, 2003).

An important part of the Çukurköy Formation (samples 396–452; Figures 4 and 6) belongs to the Py4 zone of Altıner and Şahin (2012) and the lime mudstones to wackestones, crinoid-, fusuline- and algae (*Ungdarella*, gymnocodiacean algae)-rich wackestones, packstones and grainstones contain a highly diversified association of foraminiferal fauna including *Parafusulina* gr. *elliptica*, *Parafusulina (Skinnerella)* spp., *Chusenella* spp., *Rugososchwagerina* sp., *Eopolydiexodina* sp., other Schwagerinidae, *Minojapanella* (*Wutuella*) cf. *wutuensis*, transitional forms between *Boultonia* and *Russiella* ?, *Dunbarula protomathieui*, D. sp., *Nankinella* sp., *Staffella* sp., *Necdetina* ? sp., *Neoendothyra* sp., *Endothyra* sp., *Endoteba controversa*, *Globivalvulina vonderschmitti*, *G. graeca*, *G.* ex gr. *cyprica*, *G.* sp., *Retroseptellina decrouezae*, *Dagmarita chanakchiensis*, *Climacammina valvulinoides*, Palaeotextulariidae, *Langella ocarina*, *L. perforata*, *L.* sp., *Pseudolangella fragilis*, *P.* sp., *'Protonodosaria' globifrondina*, *Nodosinelloides* sp., *Frondina permica*, *Frondinodosaria* sp., *Geinitzina* sp., *Ichthyofrondina* sp. ? sp., *Pachyphloia ovata*, *P. schwageri*, *P. pedicula*, *Robuloides lens*, *Xingshandiscus alpinotauricus*, *Pseudovidalina involuta*, *P. ornata* ?, *Rectostipulina* or *Syzrania* sp., *Hemigordius irregulariformis*, *H.* sp., *Neohemigordius* sp., *Neodiscus* sp., *Multidiscus* sp., *Glomomidiella nestellorum*, *Hemigordiellina regularis*, *Agathammina pusilla* and *Cornuspira kinkelini*. This zone constitutes an important part of the Capitanian stage and is characterized at its lower boundary by the diversification of schwagerinids including *Chusenella*. The upper boundary corresponds to a global event coinciding with the extinction of all keriotheca-bearing schwagerinids in the mid-Capitanian (Bond, Wignall, et al., 2010; Wignall et al., 2012; Wignall, Sun, et al., 2009) (Figure 6).

The rest of the Çukurköy Formation in the Çukurköy section still belongs to the Capitanian. Although foraminifers are relatively rare in this intensely dolomitized interval (samples 453–460; Figure 4), the presence of *Charlilella rossae*, *Dunbarula* and *Ungdarella* even in the last levels of the formation indicates a chronostratigraphy not younger than the Guadalupian. We, therefore, place this interval within the Py5–Py7 zones of Altıner and Şahin (2012) and, above the mid-Capitanian extinction horizon, position the upper boundary arbitrarily in the upper Capitanian (Figure 6). Below the variegated shales of the Akıncıbeli Formation assigned tentatively to the Dienerian substage (upper Induan) of the Lower Triassic, an important stratigraphic gap is then present in the section between the Çukurköy Formation and the Akıncıbeli Formation comprising the interval from latest Capitanian to early Induan (Griesbachian).

3.2. *Karadere köyü section*

This section is located 2 km NW of the Karadere village and has been measured on the southwestern slope of the Çillibeleni Tepe. Measuring 280 m in thickness, it consists of an important part of the Kızılbağ Formation associated with volcanic rocks. Due to tectonic complexity, neither the base nor the upper part of the formation could be examined in the measured section.

The Kızılbağ Formation overlies with a tectonic contact a thin sliver of Upper Cretaceous rock resting on the Lower-Middle Devonian rocks in the section and starts at the base with 24 m thick, gray or dark gray colored, medium- to thick-bedded dolomites, sandy dolomites and dolomitic limestones (samples 581–584; Figures 7 and 8(a)). The lithology changes upwards in the section and 9 m thick, dark gray, medium-to thick-bedded limestones appear in the succession containing chert nodules and abundant corals (Waagenophyllidae, Figure 8(a) and (b)), foraminifers, crinoids and algae (samples 234–237; Figure 7). The section continues with 20-m-thick shales, organic matter-rich clayey limestones, chert-bearing limestones and dolomites (samples 238–372), and finally, this carbonate-dominated succession is overlain with a sharp contact by 22 m thick, reddish to yellowish, sometimes cross-bedded quartz sandstones (sample 320; Figures 7 and 8(c)). Overlying lithology in the section is a 23-m-thick carbonate succession consisting of dark gray to gray colored, medium- to thick-bedded limestones, dolomitic limestones and

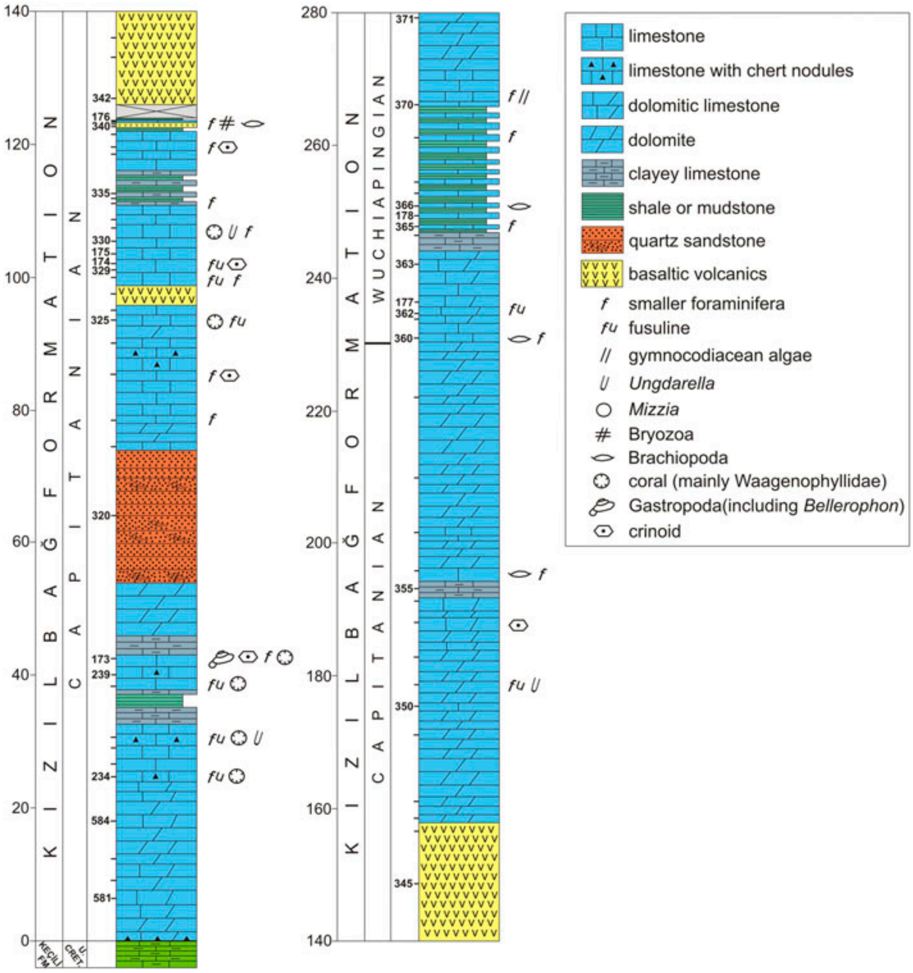

Figure 7. Kızılbağ Formation in the Karadere köyü measured section.

dolomites sometimes rich in corals, fusulines and crinoids (samples 321–326; Figure 7). The following layers are composed of a 3 m thick highly altered, brownish volcanic rock (sample 327; Figure 7) intercalated within the carbonate rocks. Volcanic rock layers appear again in the section (sample 340) following a 24-m-thick limestone succession rich in *Bellerophon*, foraminifers, crinoids and corals (Waagenophyllidae, Figure 8(d)) containing in the middle some mudstone layers probably of volcanic origin (samples 328–339; Figure 7). The volcanic rock at level 340 measuring 7 m in thickness is a typical vesicular vitrophyric basalt coming from a pillow-lava layer (Figure 8(e) and (f)). Under the microscope, lath-shaped plagioclase crystals and clinopyroxenes are visible in a glassy groundmass. Plagioclase crystals often show bending indicating rapid cooling, and the vesicles of varying size are calcite-filled (personal communication: Dr Fatma Toksoy-Köksoy, Middle East Technical University). Following a 40-cm-thick limestone layer (sample 341; Figures 7 and 8(e) and (f)) containing basalt and limestone clasts (Plate 2, 40–41) in a fossiliferous packstone displaying flow structures, the succession continues this time with a thicker basaltic succession measuring 36 m in thickness (sample 342–346; Figure 7). Samples collected from this interval are again of vitrophyric basalt type containing sometimes large calcite-filled vesicles on pillows (Figure 8(g)). Plagioclase microliths are randomly oriented in the samples indicating absence of oriented lava flow. Apart from the presence of usual clinopyroxene occurrences, sample 343 contains titaniferous augite mineral, indicating the basaltic layers in this level were in close proximity to a dyke system feeding the basaltic volcanics (personal communication: Dr Fatma Toksoy-Köksoy, Middle East Technical University). Overlying this important basaltic interval, the Kızılbağ Formation continues upwards with 75 m thick gray to dark gray, medium-bedded dolomites intercalated with dolomitic limestones and rare limestones (samples 347–359; Figure 7). Dolomites are usually very friable and smell oil. In the overlying levels, the succession is made up of dark gray colored, medium- to thick-bedded dolomitic limestones measuring 12 m in thickness (samples 360–363) and then a 20-m-thick clayey limestone and shale alternation rich in productid brachiopods in the lower levels (samples 364–369; Figure 8(h)). The succession terminates with a 5-m-thick limestone interval rich in algae and foraminifera and 7-m-thick dolomites (samples 370–371).

Figure 8. (a) Lower part of the Karadere köyü section. Dolomites (Dol) (samples 581–584, Figure 7) and the overlying limestones (LMST) containing chert nodules and abundant corals in the Kızılbağ Formation (samples 234–237, Figure 7). (b) Compound corals (Waagenophyllidae) in the lower part of the Karadere köyü section (sample 234, Figure 7). (c) The main quartz arenitic sandstone level in the Karadere köyü section (sample 320, Figure 7). (d) Corals (Waagenophyllidae) in the limestones intercalated with basaltic lava layers (sample 331, Figure 7). (e) Highly weathered basaltic pillows (BP) and the overlying 40 cm thick limestone layer (LMST) (sample 341, Figure 7). (f) Close-up view of basalt-limestone contact (sample 341, Figure 7). (g) Vesicular basaltic pillows in the Kızılbağ Formation (sample 345, Figure 7). (h) Productid brachiopods in the upper levels (Wuchiapingian) of the Karadere köyü section (sample 366, Figure 7).

Based on foraminifers, Capitanian and Wuchiapingian stages of the Permian System have been recognized in the Karadere köyü section (Plate 2). Because of tectonic complexity, the Wordian portion of the formation is entirely missing at the base of the section (Figures 6 and 7). The section was divided into four biostratigraphic intervals (Figure 6). The lower part consisting of dolomites and quartz-rich sandy and silty dolomites (samples 581–584; Figures 6 and 7) is unfossiliferous and has been tentatively assigned to the Py3 zone of

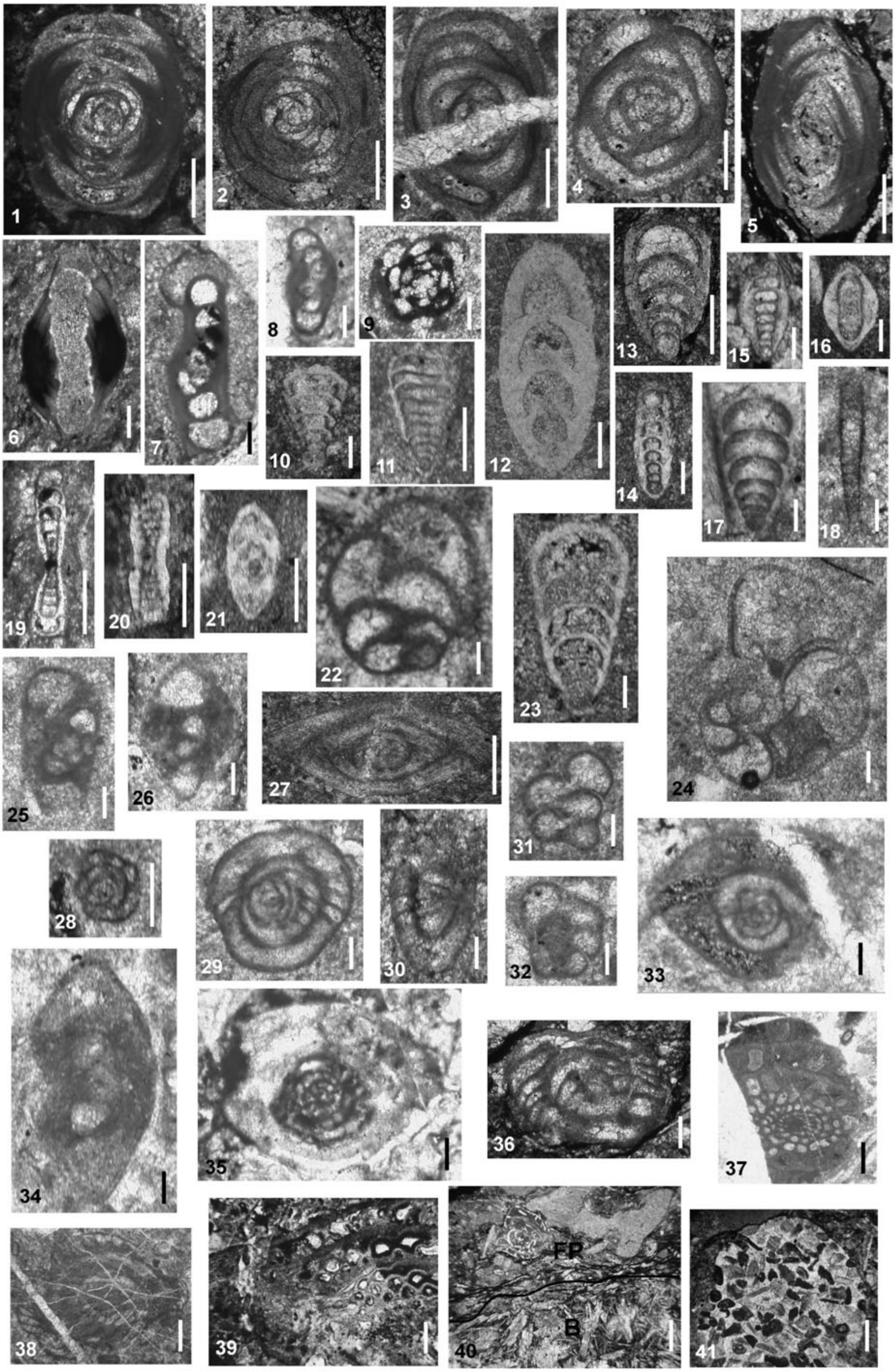
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Plate 2. Foraminifera from the Kızılbağ Formation. 1–2. *Multidiscus* n. sp.; 3–4. *Neodiscus milliloides* A. D. Miklukho-Maklay; 5. *Multidiscus* sp.; 6. *Multidiscus arpaensis* Pronina; 7. *Neodiscopsis* sp.; 8. *Midiella zaninettiae* (Altiner); 9. *Glomomidiella nestellorum* Vachard, Rettori, Angiolini & Checconi; 10. *Nestellorella* ? sp.; 11. *Geinitzina* sp.; 12. *Langella ocarina* Sellier de Civreux & Dessauvagie; 13. *Langella perforata* (Lange); 14. *Pachyphloia schwageri* Sellier de Civreux & Dessauvagie; 15–16. *Pachyphloia ovata* Lange; 17. Lagenid genus indet.; 18. *Earlandia* sp.; 19. *Xingshandiscus alpinotauricus* (Altiner); 20. *Pseudovidalina* sp.; 21. *Robuloides lens* Reichel; 22. *Globivalvulina* ex gr. *cyprica* Reichel; 23. *Pseudolangella fragilis* Sellier de Civreux & Dessauvagie; 24. *Globivalvulina graeca* Reichel; 25–26. *Neoendothyra* spp.; 27. *Schubertella* sp.; 28. *Streblospira* sp.; 29. Schubertellidae gen. and sp. indet. (see Kobayashi & Altiner, 2011); 30. *Reichelina* sp.; 31–32. Globivalvulinidae gen. and sp. indet.; 33. *Dunbarula* sp.; 34. *Neoendothyra permica* (Lin); 35–36. *Dunbarula* spp.; 37. Schwagerinidae (*Parafusulina* ? sp.); 38. *Yangchienia* sp.; 39. Schwagerinidae (*Chusenella* sp.); 40. Fossiliferous packstone (FP) containing basalt clast (B); 41. Limestone clast (grainstone) in fossilifeorus limestone. 1: 174 (for samples see Figure 7); 2, 4: 323; 3, 32: 328; 5, 40–41: 176; 6, 19: 373; 7–8, 14: 368; 9, 23: 339; 10, 30: 359; 11, 34: 237; 12, 27, 29: 235; 13: 335; 15, 36: 338; 16, 21: 178; 17, 33: 332; 18, 24, 28: 173; 20, 26: 238; 22: 236; 25, 37: 330; 31: 326; 35, 39: 350; 38: 333. Scale bars: 100 μ (6–11, 14–26, 28–36); Scale bar: 200 μ (12); Scale bars: 300 μ (1–5, 13, 27); Scale bars: 400 μ (37–41).

Altıner and Şahin (2012). The overlying thick interval (samples 234–239; 320–350; Figure 6) containing also volcanic layers consists mainly of foraminifera-bearing wackstones or packstones usually rich in *Tubiphytes*, *Ungdarella*, *Pseudovermiporella*, crinoids, corals, gastropods and brachiopods. In places, these levels display current-oriented allochems and are usually silicified and dolomitized. All this succession placed in the Py4 zone (Figure 6) of Altiner and Şahin (2012) contains a rich association of foraminiferal fauna including Schwagerinidae, *Chusenella* ? sp., *Yangchienia* sp., *Necdetina* ? sp., Staffellidae, *Nankinella* sp., Schubertellid gen. and sp. indet., *Schubertella* sp., *Dunbarula protomathieui*, *Dunbarula* sp., *Dagmarita chanakchiensis*, *Retroseptellina decrouezae*, *Globivalvulina vonderschmitti*, *G. graeca*, *G.* ex gr. *cyprica*, *G.* sp., Globivalvulinidae gen. indet., *Charliella* sp., Palaeotextularidae, *Palaeotextularia* sp., *Climacammina valvulinoides*, *Endothyra* sp., *Neoendothyra permica*, *N.* sp., *Langella ocarina*, *L. perforata*, *L.* sp., *Pseudolangella fragilis*, *P.* sp., *Pachyphloia ovata*, *P. schwageri*, *P. pedicula* ?, *P.* sp., *Frondina permica*, *Nodosinelloides* sp., *Tauridia* sp., *Geinitzina postcarbonica*, *G.* sp., *'Protonodosaria' globifrondina*, *P.* sp., *'Nodosaria'* sp., *Robuloides lens*, *Pseudovidalina* sp., *Xinshandiscus alpinotauricus*, *Syzrania* sp., *Glomomidiella nestellorum*, *Multidiscus* n. sp., *M. arpaensis*, *Neodiscus milliloides*, *N.* sp., *Hemigordius ovatus*, *H. permicus*, *Hemigordiellina* sp., *Streblospira* sp., *Agathammina pusilla*, *A.* sp. The upper boundary of the zone coincides with the mass extinction horizon of schwagerinid foraminifera and also of a group of brachiopods and corals (Waagenophyllidae) as was also recorded in the Çukurköy section (Figure 6). The Middle Permian basaltic volcanism corresponds to the upper part of this Capitanian foraminiferal zone. The basaltic interval from sample 327 to 346 is located just below the mass extinction horizon in the Capitanian.

Although marker fossils are absent, the overlying biostratigraphic interval (samples 351–358; Figures 6 and 7), located between Py4 and Py8 zones, correlates with the Py5–Py7 zones of Altıner and Şahin (2012) (Figure 6) and still belongs to the Capitanian stage. Clayey limestones with pyrite framboids and dolomites contain rare foraminifers including *Paraglobivalvulina* ? sp., *Langella* sp., *Pseudolangella* sp. *Pachyphloia ovata*, *P.* sp., *Robuloides lens* and *Hemigordius* sp. The last biostratigraphic interval in the Karadere köyü section (samples 359–371; Figures 6 and 7) correlates with the Py8 zone of Altıner and Şahin (2012) and is assigned to the Wuchiapingian stage. Clayey lime mudstones with packstone lenses rich in coral fragments and brachiopod-rich packstones contain the following foraminiferal assemblage: *Reichelina* sp., *Neoendothyra* sp., *Palaeotextularia* sp., *Earlandia* sp., *Nestellorella* ? sp., *Pachphloia schwageri*, *Geinitzina* sp., *Frondina permica*, *Calvezina* sp., *Nodosinelloides* sp., *Midiella zaninettiae*, *Hemigordius guvenci*, *Neodiscopsis* sp. and *Agathammina pusilla*. In the Karadere köyü section, the upper part of the Lopingian could not be identified because of tectonic complexity. However, it is very probable that the succession continued up to Permian-Triassic boundary.

4. Permian rift volcanism in the Antalya Nappes

In recent studies, Permian rifting has generally been recognized as a widespread tectonic subsidence and marine transgression within the Antalya Nappes (Robertson, 2007; Robertson et al., 2012). In the shallow-water shelf carbonates of Middle to Late Permian, no evidence of volcanism has been documented up to now. Initial tuffaceous rift volcanism has been reported from Early-Middle Triassic accompanied by subsidence and extensional faulting. Olistoliths and debris flow deposits derived from the adjacent margins and volcanics alternating with radiolarites, and other pelagics in the Anisian to Ladinian of the Alakırçay nappe (middle nappe) are related to this rifting event (Özgül, 1984). Finally, all these drastic organizations representing this rift phase were followed by continental breakup and were accompanied by the extrusion of volcanic rocks during the Late Triassic (Carnian) time (Robertson, 2007). The Carnian time is also represented by a thick turbiditic sandstone deposition which comprises debris flows and huge blocks up to several km in size, belonging to Lower Paleozoic, Permian and Lower-Middle Triassic formations (Özgül, 1984).

Discovery of the basaltic volcanism in the Middle-Upper carbonate succession (Kızılbağ Formation) belonging to the upper nappe (Tahtalıdağ Nappe) of the Antalya Nappes in the Güzelsu Corridor brings a very strong evidence that rift-associated events in the region have a much longer history. Overlying a peneplain topography on the Lower Paleozoic rocks of the upper nappe (Tahtalıdağ Nappe), the Middle Permian transgression started in the region with cyclic deposits consisting of quartz sandstones, coal-bearing shales and bituminous clayey limestones and marls (Figure 9(a)). The sea-level was oscillating markedly at that time and depositing bituminous limestones and marls over nearby areas covered by coastal plain deposits with coal-rich swamps. Because of tectonic complexity, the Wordian consisting mainly of these coal-bearing and bituminous levels could not be recognized at the base of the Kızılbağ Formation. However, considering the distance between the Çukurköy and Karadere Köyü sections, it is very probable that the Kızılbağ Formation is underlain by a similar coal-bearing succession of Wordian age. Overlying the coal-bearing sediments, the main Capitanian transgression bringing large fusulines invaded the area (Figure 9(b)). Corals (mainly Waagenophyllidae) started to concentrate in the areas where the future volcanism of the Kızılbağ Formation would activate. Organisms preferred these sites because sea water was probably being geothermally heated from fissures at the basement and the environment was becoming biologically more productive. The 'early' Capitanian carbonate sedimentation was later suddenly interrupted by the deposition of a distinct quartz sandstone level both visible in the Çukurköy and Karadere köyü sections. The rapid invasion of quartz arenites into the region probably occurred due to a forced regressive event caused by a tectonic uplift, which was accompanied by a eustatic sea-level fall (Figure 9(b)). In the 'middle-late' Capitanian time, the platform started to collapse under tensional forces, thus rifting started (Figure 9(c)). Basaltic volcanism was probably fed by a dyke system injected along the fault planes formed during block faulting. The main lithological differentiation between the Çukurköy and Kızılbağ Formations started in this time interval. Intensely dolomitized carbonates, probably largely affected from volcanism, were named as the Kızılbağ Formation by Demirtaşlı (1987), whereas less dolomitized limestone successions underlain by coal-bearing lithologies were introduced as the Çukurköy Formation by Şenel et al. (1998). According to the Karadere köyü section, the Upper Permian (Lopingian) carbonates (at least Wuchiapingian) deposited over the Capitanian volcanics and carbonates in the region. By considering also the stratigraphic contact between the Çukurköy Formation and the Akıncıbeli Formation (Figure 9(d)), it can be concluded that the true gap in the successions of the Güzelsu Corridor occurred at some time between post-Wuchiapingian and pre-late Induan (Dienerian) interval. This gap, however, increased in magnitude when the erosional truncation became more active on the underlying rocks. In the Çukurköy section, the youngest levels of

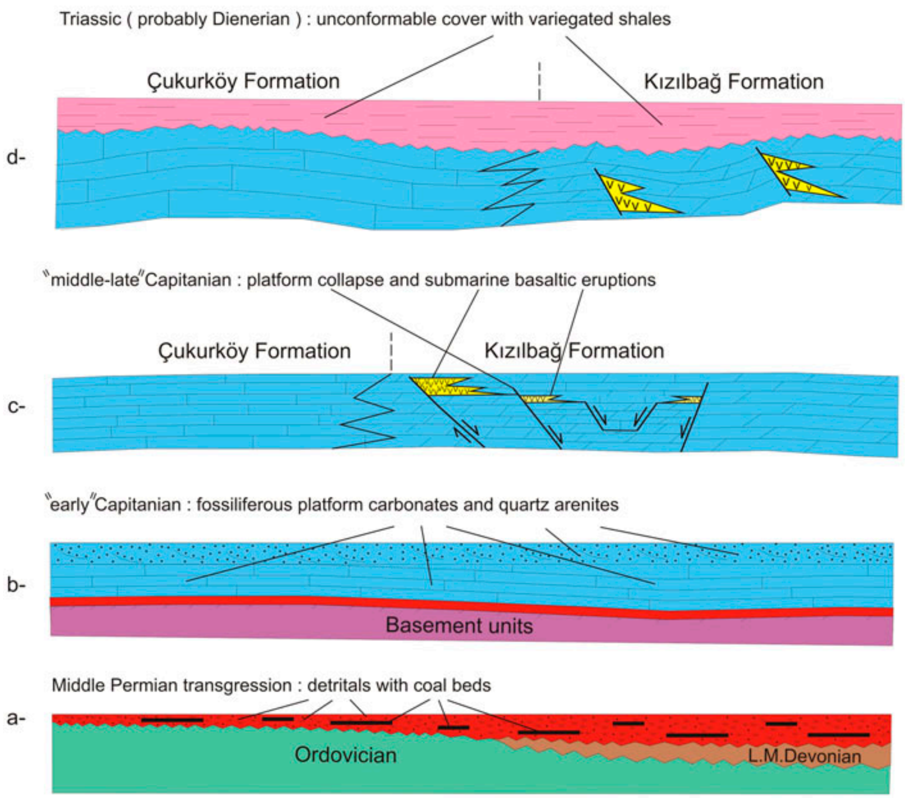

Figure 9. Rift-associated events in the Permian successions of the Güzelsu Corridor.

the Çukurköy Formation below the unconformity surface are Capitanian in age, meaning that an important part of the formation was truncated by the erosion surface.

5. Global meaning of the mid-Capitanian volcanism in the Antalya Nappes

As it has been already reported, large igneous provinces are usually associated with main Mass Extinction Events in the Phanerozoic history of the earth (Wignall, 2001). Recent detailed studies have revealed that mass extinction crisis for many groups of organisms in the mid-Capitanian is strongly linked to a volcanic province or traps in southwestern China, more precisely, Emeishan Large Igneous Province (Bond, Hilton, et al., 2010; Bond, Wignall, et al., 2010; Shen & Shi, 2009; Wang & Sugiyama, 2001; Wignall, 2001; Wignall et al., 2012; Wignall, Sun, et al., 2009; Wignall, Védrine, et al., 2009). In the shallow-marine warm-water taxa, the extinction losses were considerable by that time and many groups of organisms like larger fusulines, corals, brachiopods, alatoconchid bivalves and calcareous algae suffered from this extinction. It has been proven that mid-Capitanian volcanism has also strongly affected the plant communities on land, for example, there was a strong reorganization of plant communities in South China with a 24% species loss (Bond, Wignall, et al., 2010).

In southern China, the lavas of the Emeishan flood basalts rest on Middle Permian carbonates (the Maokou Formation), and they are directly overlain by Upper Permian and locally Lower Triassic marine strata (Chung & Jahn, 1995; Wignall, 2001; Yin et al., 1992). However, Jin and Shang (2000) have reported the presence of fusulinid foraminifera from shallow-marine limestones interbedded with basaltic lava flows (see also Wignall, 2001). More recently, Wignall, Sun, et al. (2009), Wignall, Védrine, et al. (2009) and Bond, Hilton, et al. (2010) studied the Maokou and Wuchiaping formations of south China and reported that the carbonates of the Maokou Formation are intercalated with the volcanic succession of the Emeishan Large Igneous Province. According to these authors, the extinction record marked by the loss of keriothecal-walled fusulinoideans corresponds to the base of the oldest record of volcanism from the mid-Capitanian *Jinogondolella altudaensis* conodont zone.

In the Antalya Nappes, basaltic volcanism corresponding to the upper part of the Capitanian Py4 foraminiferal zone of Altiner and Sahin (2012) (Figure 6) seems to be coeval with the Emeishan volcanism in South China. These volcanics alternate with shallow-water limestones containing keriothecal-walled schwagerinids which became extinct just above the uppermost basaltic layers in the Karadere köyü section (see Figure 6, mass extinction horizon coinciding with the upper boundary of the Py4 zone). Although this data seem to be slightly diachronic when it is compared with the conclusion of Bond, Hilton, et al. (2010) who reported the extinction level coinciding with the oldest record of volcanism in the Capitanian of South China, the presence of basaltic layers alternating with carbonates containing keriothecal fusulinoideans from the Makou Formation, as reported by Jin and Shang (2000), indicates the fact that Emeishan volcanism started to outpour maybe slightly earlier than the mid-Capitanian Mass Extinction Event. Thus, considering the stratigraphic position of the basaltic volcanism in the Antalya Nappes, we reach the conclusion that the volcanism in both regions started nearly at the same time. Although the paleogeographic and tectonic settings of the Antalya area and the South China are entirely different in the mid-Permian world, it is amazing to see this synchroneity in the oldest record of Capitanian volcanism. This coincidence could be explained by its link to the mid-Capitanian Mass Extinction Event. The volcanism in the Antalya Nappes, possibly much smaller in volume, might have contributed in a way to the extinction event in the mid-Capitanian. Particularly, the keriothecal fusulinoideans harboring symbiotic algae, calcareous algae and corals were affected from the volcanogenic kill mechanism events (cooling and acid rain caused by SO_2 and sulfate aerosol formation, Wignall, Sun, et al., 2009). However, it is difficult to determine the degree of the impact of the basaltic volcanism in the Antalya Nappes on the mid-Capitanian extinction event without knowing its distribution and the volume in the region.

6. Conclusions

Middle-Upper Permian measured stratigraphic sections from the upper nappe (~Tahtalıdağ nappe) of the Antalya Nappes in the Güzelsu Corridor (Central Taurides) reveal the presence of basaltic volcanic rocks intercalated within the shallow-marine carbonates. This discovery adds a remarkable data to the history of rift-related volcanic events in the Antalya Nappes. In previous studies, an extensional setting has been inferred to have existed throughout much of the northern Gondwana region in Mid- to late Permian times, and the widespread tectonic subsidence and marine transgressions have been explained as a result of rifting in the region. Mid-Permian (Capitanian) volcanism associated with a carbonate rock succession in the Antalya Nappes clearly exhibits the outlines of a scenario related with the rupture of a carbonate platform under an extensional regime and the penecontemporaneously generated volcanic rocks intercalated within the carbonate rocks. However, because of the presence of stratigraphic gaps and the tectonic complexity in the region, it is not certain yet whether this volcanism continued up to the end of the Permian and had a link with the Triassic volcanism, which is known to have been active from Early to Late (Carnian) Triassic.

The Capitanian volcanic event in the Antalya Nappes, calibrated by using foraminiferal biostratigraphy, coincides with the onset of eruption of the Emeishan

Large Igneous Province in southwestern China which is thought to have been the main cause of the mid-Capitanian extinction event involving the loss of keriothecal fusulines and important groups of corals and brachiopods. Although Antalya region and southwestern China were belonging to entirely different paleogeographic settings during mid-Permian times and the volcanism in Antalya Nappes was probably much smaller in volume, this coincidence evokes the fact that mid-Capitanian extinction event might have been related to the activity of several volcanic centers on the earth surface.

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