GEOLOGICA CARPATHICA, 54, 6, BRATISLAVA, DECEMBER 2003
377–384

SEDIMENTOLOGICAL, PALEONTOLOGICAL AND VOLCANIC RECORDS OF THE EARLIEST VOLCANIC ACTIVITY IN THE EASTERN PONTIDE CRETACEOUS VOLCANIC ARC (NE TURKEY)

CEMIL YILMAZ, CÜNEYT ŞEN and A. SIBEL ÖZGÜR

MMF Geological Engineering Department, Karadeniz Technical University, Trabzon, Turkey;
cyilmaz@ktu.edu.tr; csen@ktu.edu.tr; sozgur@ktu.edu.tr

(Manuscript received December 10, 2002; accepted in revised form June 23, 2003)

Abstract: This study deals with the volcanic blocks occurring within the Upper Coniacian-Santonian red limestone which crops out in the Maçka area (Trabzon, NE Turkey). The red limestones are thin to medium-bedded, and mostly consist of wackestones, rich in planktonic foraminifers with subordinate radiolarians and inoceramid bivalve fragments. In the upper part of the formation, volcanic blocks occur which consist of andesite to dacite and show microlitic-porphyritic texture with plagioclase and pyroxene as phenocrysts. Chemical data indicate that these volcanic rocks are calc-alkaline in character and show similar trace and rare earth element chemical signatures with those of arc related volcanics. The limestones and the volcanic blocks are discoloured in proximity of the boundary. The contact relationships suggest that the volcanic lava blocks were still hot when they fell on the unlithified pelagic limestone muds. These data emphasize that the earliest Cretaceous volcanism started at the Late Coniacian-Santonian boundary in the Eastern Pontide volcanic arc.

Key words: Cretaceous, Turkey, Pontide volcanic arc, volcanic rocks, pelagic limestone.

Introduction

The Northern part of Turkey is geotectonically known as the Pontide orogenic belt (Ketin 1966). Many studies carried out in this region concluded that the eastern part of the Pontides was a volcanic arc during Mesozoic and Cenozoic times (Tokel 1972; Gedikoğlu et al. 1979; Şengör & Yılmaz 1981; Bektaş 1984; Yalçınalp 1992; Robinson et al. 1995; Okay & Şahintürk 1997; Yılmaz et al. 1997). However, it remains a matter of debate whether the Eastern Pontides were the northern active continental margin of Gondwana (Dewey et al.1973; Bektaş et al. 1999) or the southern active continental margin of Eurasia during the Cretaceous (Şengör et al. 1981; Adamia et al. 1981). According to Bektaş et al. (1999), the Paleotethys ocean floor began to be consumed by southward subduction under the Pontides at the beginning of the Late Cretaceous and the subduction related calc-alkaline volcanic and associated pyroclastic rocks represent the northern edge of the Eastern Pontide magmatic arc. The volcanic activity was not continuous and it allowed sediment accumulations during the non-eruptive phases (Taslı et al. 1994; Yılmaz & Karslı 1997). Because the volcanic rocks have covered these sedimentary formations, smaller and discontinuous outcrops of sedimentary rocks are seen in the region. The lack of volcanostratigraphic, paleontological, sedimentological and petrological data have led to the volcanic rock often being ignored in many field studies conducted in the region. The data presented in this study will help to understand the age of the volcanic activity, and the evolution of the Eastern Pontide magmatic arc.

Geological setting

The Eastern Pontides can be divided into three lithologic assemblages corresponding to the northern, southern and axial zones (Bektaş et al. 1995, 1999). The northern zone consists of Mesozoic-Cenozoic volcanic rocks (Pontide magmatic arc) widespread along the Black Sea Coast. The southern zone includes the Hercynian granitic and metamorphic basement, Liassic rift related sediments, Middle Jurassic-Lower Cretaceous platform carbonates, Upper Cretaceous slope to basin sediments and Tertiary volcano-siliciclastic rocks. The axial zone or back-arc basin or Anatolids (Ketin 1966) consists of Alpine-type peridotites and metamorphic massifs.

The study area is located in the Northeastern Pontides, 30 km south of the city of Trabzon, around the town of Maçka (Figs. 1 and 2). Because of the destruction of the Cretaceous to Tertiary aged volcanic rocks (the Maçka volcanics), a single stratigraphic succession from bottom to top does not occur in the Maçka-Zigana area. Therefore, a composite section is presented which is based on some short sections (Fig. 3).

The stratigraphic succession in the study area ranges from Jurassic to Cenozoic. The Lower Jurassic Bürnük Formation at the base of the succession consists of thin to medium bedded tuffs intercalated with spilitic basalts. The Bürnük Formation is overlain by the İnaltı Formation (Ketin & Gümüş 1963), which is mainly represented by thick-bedded grey-coloured limestones interbedded with dolomites and dolomitic-limestones. On the basis of a scarce benthic foraminiferal assemblage the formation is referred to Middle Jurassic–Lower

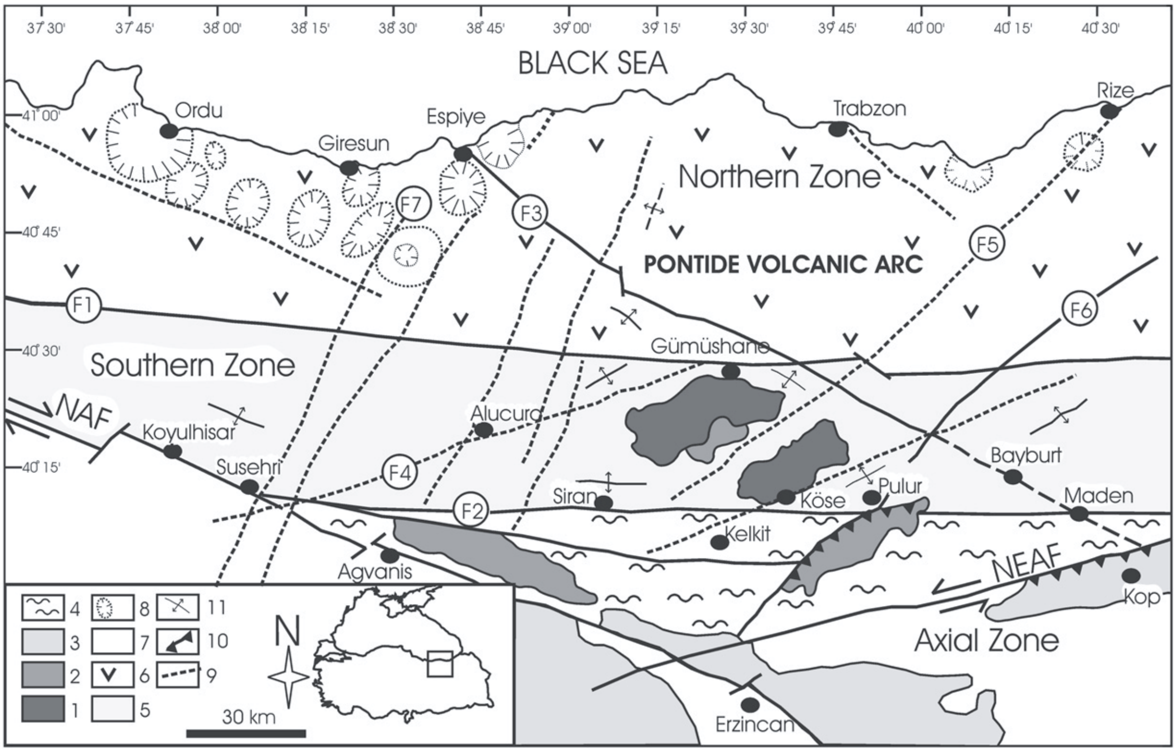

Fig. 1. Main tectonic features, tectonic zones of the eastern Pontides (Bektaş et al. 1999) and location of the study area. **F1** — Niksar-İspir fault; **F2** — Suşehri-Maden fault; **F3** — Espiye-Maden fault; **F4** — Suşehri-Gümüşhane fault; **F5** — Kırıklı-Rize fault; **F6** — Pulur fault; **F7** — Suşehri-Espiye fault. **1** — Paleozoic granites; **2** — Paleozoic metamorphic basement; **3** — serpentinite; **4** — Cretaceous ophiolitic melange; **5** — Mesozoic sedimentary rocks; **6** — Cretaceous and Eocene arc volcanics; **7** — undifferentiated Mesozoic and Cenozoic; **8** — caldera or dome; **9** — fault; **10** — thrust fault; **11** — orthogonal drape and drage folds. **NAF** — North Anatolian Fault; **NEAF** — North East Anatolian Fault.

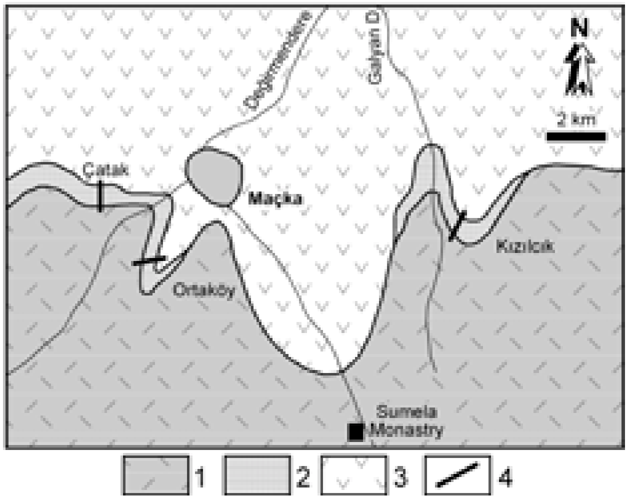

Fig. 2. Geographical location and geological map of the study area. **1** — Çağlayan Formation, **2** — Kapanboğazı Formation, **3** — Maçka Formation, **4** — Stratigraphic sections.

Cretaceous (Taslı 1984; Yalçınalp 1992). The Berdiga Formation horizontally and vertically passes into the Çağlayan Formation (Ketin & Gümüş 1963), which consists of megabreccias, calciturbidites, siltstones and marl-limestone deposited as a sedimentary prism on fault slopes derived from the Early Cenomanian tectonic deformation of the İnaltı Formation**.** In the upper part of the formation, marly limestones grade into thin to medium-bedded red coloured limestones, known as the Kapanboğazı Formation (Ketin & Gümüş 1963). The Upper Cretaceous-Cenozoic Maçka volcanics known as the Pontide arc volcanics (Yılmaz & Karslı 1997) consist of dacite, andesite and basalt and related pyroclastic rocks.

Lithofacies descriptions of the Kapanboğazı Formation

The Kapanboğazı Formation, about 20 to 45 m thick, mainly consists of thin to medium-bedded, red coloured limestones including at the top volcanic blocks with andesitic to dacitic in composition (Figs. 3 and 4). The red limestones are mostly wackestones, rich in usually well-preserved planktonic foraminifers (Fig. 3/3), with subordinate radiolarian and inoceramid bivalve fragments (Fig. 4D). The planktonic foraminifers include various species of Globotruncanidae and Heterohelicidae, such as *Marginotruncana coronata* Bolli, *Marginotruncana pseudolinneiana* Pessagno, *Hedbergella flandrini* Porthault, *Dicarinella concavata* (Brotzen), *Dicarinella primitiva* (Dalbiez), *Calcisphaerula innominata* Bonet, *Stomiosphaera sphaerica* (Kaufmann), *Maginotruncana* sp., *Heterohelix* sp., *Schackoina* sp., *Globigerinelloides* sp., *Dicarinella* sp., *Hedbergella* sp., *Radiolaria* sp., Globigerinidae, indicating a late Coniacian to Santonian age.

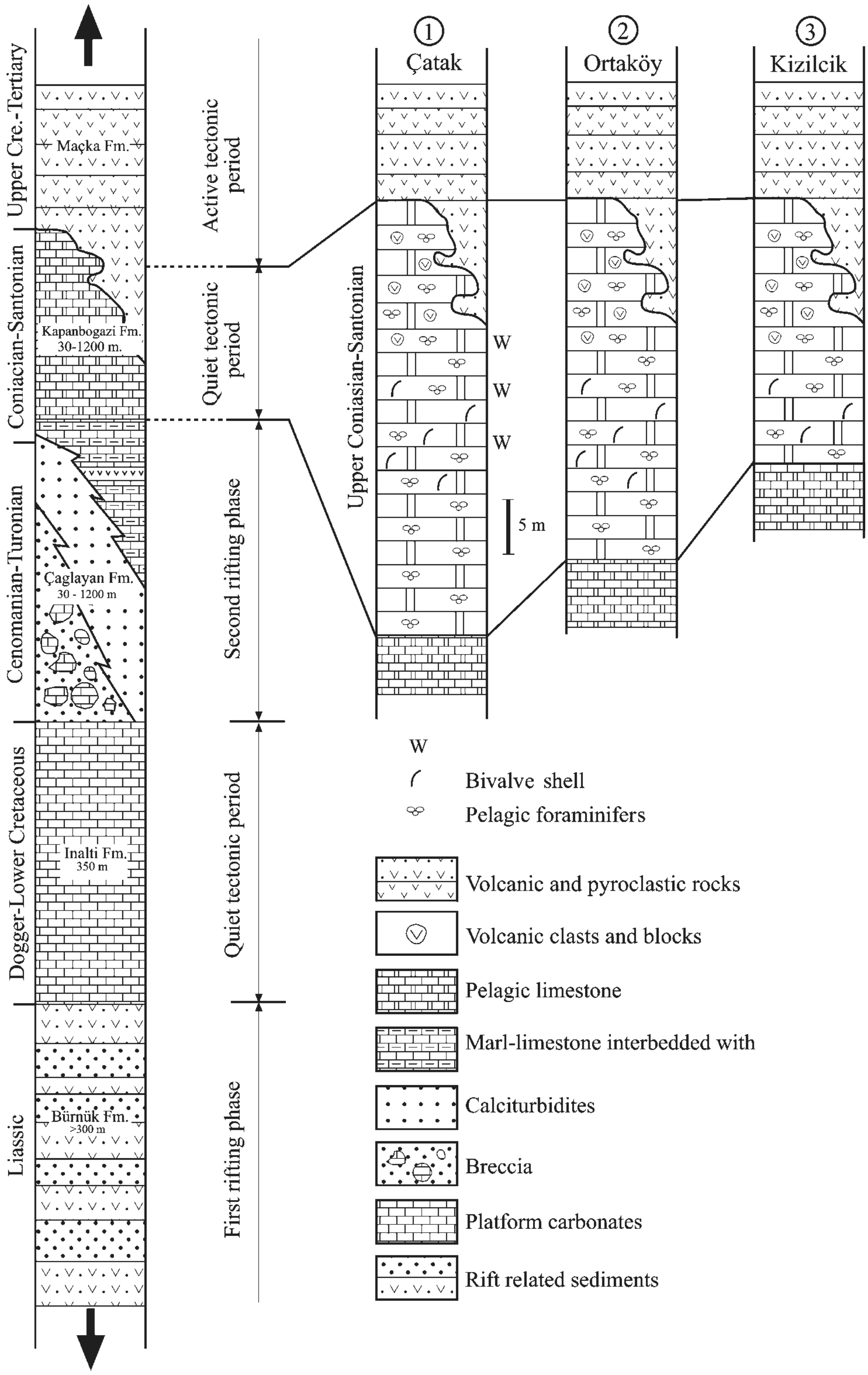

Fig. 3. General columnar section of the Maçka area and Çatak, Ortaköy and Kızılcık measured stratigraphic sections.

The matrix appears to be red to light brown in reflected light and mostly consists of micrite intimately mixed with fine fossil debris and some finely crystalline microspars. The volcanic rocks show microlitic-porphyritic texture with commonly altered andesine (An_{35-42}) and pyroxene phenocrysts. Macroscopically the green coloured matrix is made of microlithic plagioclase and some Fe-Ti oxides besides alteration products. The limestone and the volcanic blocks are discoloured to yellow in proximity of the boundary. In fact, the limestone-volcanic block contacts are burnt (Fig. 4B–C), because the limestone changes colour from red to dark brown up to almost black, while the andesite block boundaries are discoloured and they show a smaller size of the crystals. Furthermore, the contacts are also characterized by the occurrence of a microscopic

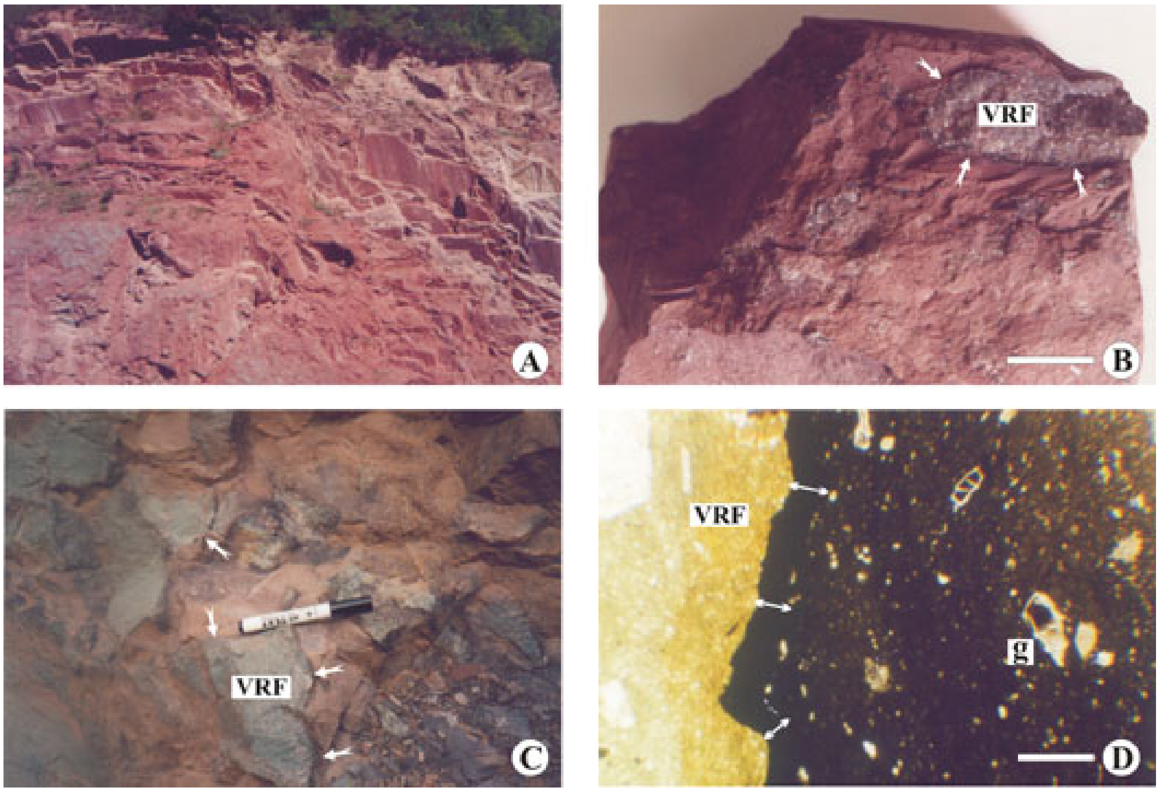

Fig. 4. Red pelagic limestone including andesitic blocks in the study area. **A** — Red pelagic limestone in the Çatak area. **B–C** — Volcanic rock fragments in the red pelagic matrix (scale bar is 2 cm in the B). **D** — Microscopic view of the samples B. **VRF** — volcanic rock fragment; **g** — *Globotruncana* sp. The arrows are marking cooked contact of the pelagic matrix and volcanic rock blocks (scale bar is 500 μm).

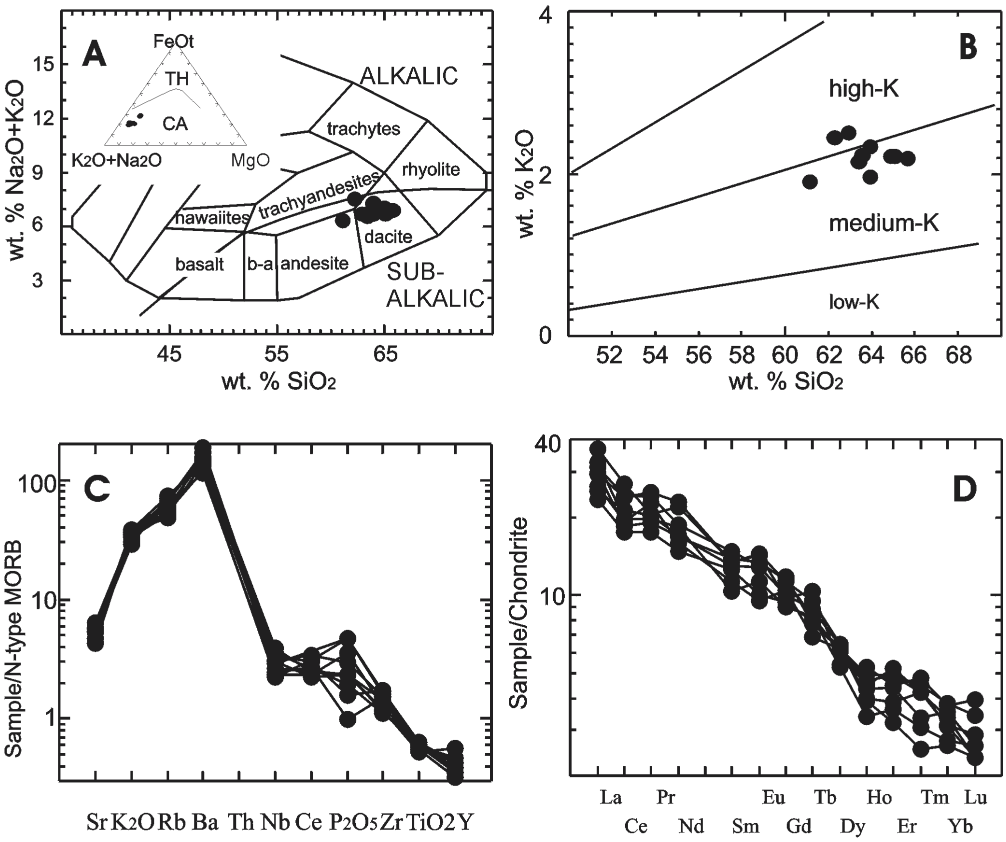

Fig. 5. Geochemical characteristics of the volcanic blocks (descriptions of the figures are given in the text).

darkened matrix with burnt pelagic microfossils and with pyrite crystals, which emphasize the destruction of the primary texture.

Geochemistry of the volcanic blocks in the Kapanboğazı Formation

Representative chemical analyses of the volcanic blocks are given in Table 1. All samples were analysed by ICP-MS at the ACME Chemical Laboratories, Vancouver British Columbia, Canada. The investigated fragments consist of medium to high-K calc-alkaline andesite and dacite normalized to 100 % on a water free basis (Fig. 5A,B; Irving & Baragar 1971; Peccerillo & Taylor 1976; Cox et al. 1979). Whole rock compositions range from 56.7 to 62.4 wt. % SiO_2, from 0.6 to 1.1 wt. % MgO, and from 1.8 to 2.3 wt. % K_2O (Table 1). Al_2O_3 concentrations are relatively constant near 14 wt. % over the entire investigated samples. Whole rock LOI contents vary from 3.7 to 7.7 wt. % and decrease with increasing size of the fragment (the sizes of investigated fragments are less than 20 cm with the exception of samples C9 and C10, their sizes are more than 75 cm). Incompatible element patterns normalized to n-MORB composition show typical arc characteristics (Fig. 5C normalization values from Sun & McDonough 1989). Fractionated trace element patterns show enrichment in LIL elements relative to the n-MORB and display slightly negative Nb and Ti anomalies. Chondrite normalized REE patterns are fractionated (Fig. 5D normalization values from McDonough et al. 1991). Step patterns have $(La/Lu)_N$ = 8–13 without pronounceable Eu anomaly.

Slighly different chemical compositions of fragments of the Kapanboğazı Formation show that Late Coniacian-Santonian submarine volcanic system has developed relatively large, shallow reservoirs that were capable of developing a compositional diversity. These chemical characteristics are in agreement with geotectonic models proposed by previous studies (i.e., Bektaş et al. 1999). However, both the age and chemistry of the earliest arc volcanics in the Eastern Pontides are presented in this study for the first time.

Table 1: Major (wt. %) and trace element (ppm) contents of volcanic rock inclusions in Kapanboğazı Formation.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
SiO_2	61.48	59.71	57.94	58.64	59.32	60.24	57.81	56.69	62.39	62.16
TiO_2	0.46	0.44	0.44	0.45	0.48	0.40	0.45	0.42	0.48	0.45
Al_2O_3	13.73	14.44	14.13	13.98	14.19	13.82	14.45	14.87	14.26	13.86
Fe_2O_3	2.53	3.13	2.28	2.73	3.04	2.38	2.86	3.09	2.78	2.48
MgO	0.67	1.12	0.60	0.84	0.98	0.75	0.67	1.06	0.68	0.64
MnO	0.24	0.26	0.23	0.28	0.22	0.18	0.23	0.18	0.28	0.17
CaO	8.01	7.86	10.18	9.45	8.73	9.45	9.24	10.29	8.27	9.24
Na_2O	4.37	4.41	3.85	4.07	4.20	4.62	4.68	4.08	4.59	4.23
K_2O	2.04	1.82	2.30	1.98	2.07	2.19	2.26	1.75	2.12	2.11
P_2O_5	0.05	0.12	0.12	0.08	0.10	0.12	0.15	0.24	0.24	0.18
LOI	6.10	6.40	7.70	6.90	6.20	5.80	6.80	7.20	3.80	3.70
TOTAL	99.68	99.71	99.77	99.40	99.53	99.95	99.60	99.87	99.89	99.22
Cr_2O_3	0.027	0.019	0.015	0.018	0.012	0.008	0.015	0.016	0.027	0.024
CO_2	1.45	1.49	1.91	1.52	1.38	1.68	1.56	2.40	0.80	1.08
Mg#	0.344	0.414	0.342	0.378	0.389	0.384	0.317	0.404	0.326	0.338
(ppm)										
Ba	1069	937	883	876	925	978	1159	834	759	721
Ni	18	11	9	18	19	12	8	14	11	14
Sr	510	506	482	479	578	527	483	470	385	420
Zr	112	107	89	128	83	89	115	120	124	95
Y	11	11	12	11	12	16	13	9	10	10
Sc	11	11	10	11	10	9	8	13	8	9
Nb	5.75	6.10	7.00	7.75	8.30	9.10	7.15	6.65	5.20	5.40
Hf	3.05	3.33	2.68	3.05	2.85	3.08	2.64	3.05	3.00	2.75
Th	3.12	2.96	3.25	3.20	3.00	3.47	3.28	2.85	2.94	3.20
Ta	0.72	0.82	0.67	0.74	0.65	0.72	0.55	0.65	0.84	0.74
Rb	37	39	40	29	33	36	27	41	29	35
La	9.20	11.90	8.60	10.80	9.60	9.70	13.50	12.90	11.50	10.90
Ce	20.30	18.90	16.80	22.80	22.99	18.40	25.60	18.65	23.15	17.60
Pr	2.80	2.70	2.40	3.40	3.10	3.10	2.82	3.00	3.30	2.60
Nd	12.00	13.05	10.50	16.30	10.80	11.30	15.60	12.00	13.20	11.90
Sm	3.00	2.40	2.90	3.10	2.50	2.60	3.10	3.50	3.40	3.20
Eu	1.11	0.98	0.87	1.26	0.85	0.83	1.24	0.87	1.23	1.17
Gd	3.06	2.75	2.86	3.45	2.98	3.19	2.98	2.26	3.60	3.48
Tb	0.51	0.48	0.46	0.55	0.50	0.40	0.60	0.40	0.45	0.48
Dy	2.44	2.01	2.37	2.45	2.24	2.36	2.05	2.40	2.35	2.30
Ho	0.37	0.29	0.33	0.34	0.31	0.42	0.45	0.34	0.40	0.38
Er	1.09	0.90	0.80	0.96	0.80	1.21	1.11	0.92	1.21	1.29
Tm	0.12	0.11	0.09	0.15	0.09	0.16	0.17	0.10	0.15	0.15
Yb	0.88	0.68	0.65	0.77	0.63	0.95	0.93	0.75	0.78	0.83
Lu	0.10	0.10	0.09	0.09	0.09	0.13	0.15	0.12	0.11	0.09

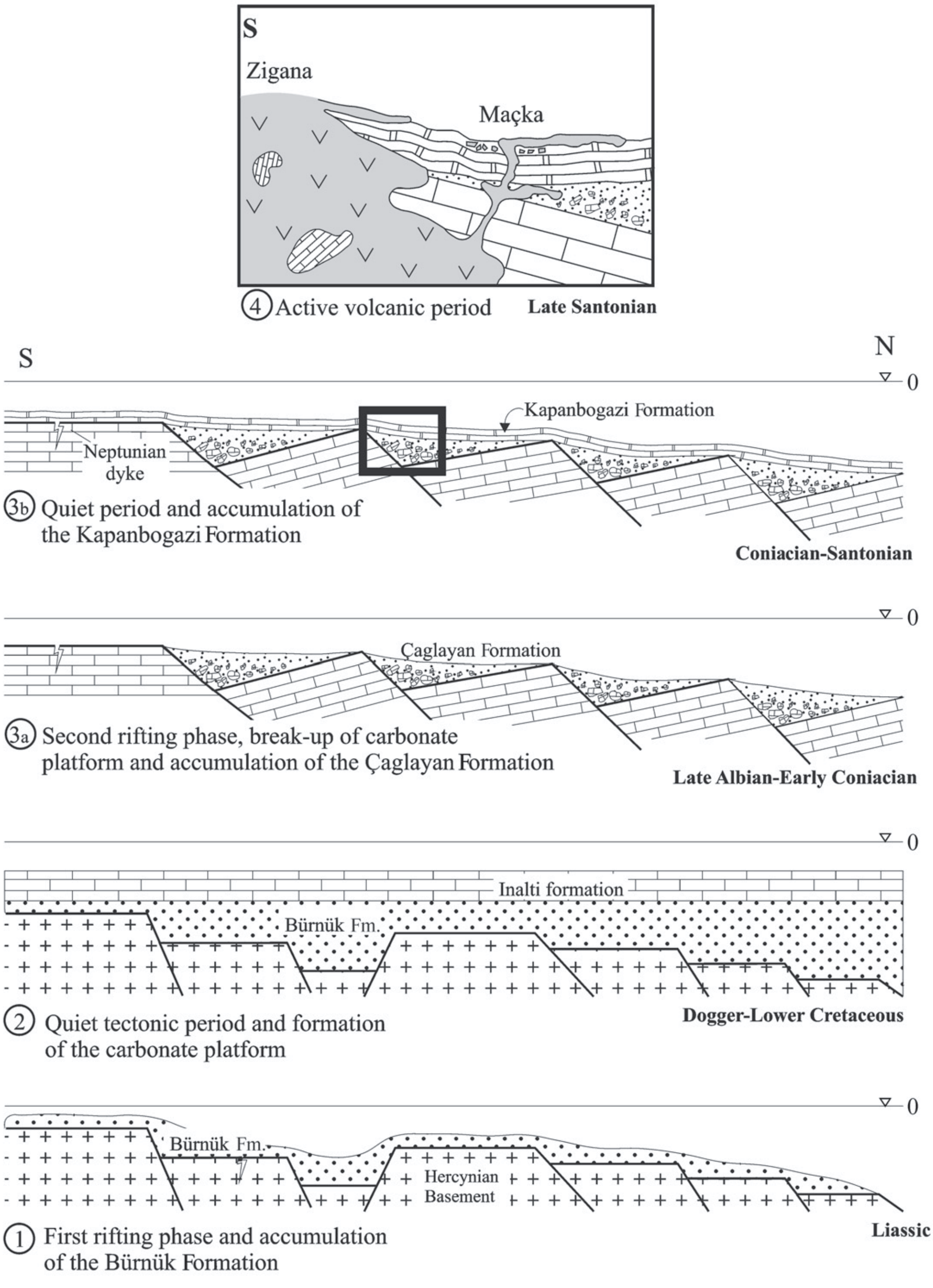

Fig. 6. Geodynamic evolution of the study area.

Discussion and conclusion

The relationship between the pelagic red limestones and volcanic blocks in the upper part of the Kapanboğazı Formation provide stratigraphic, paleontological and petrological information regarding the beginning of the volcanic activity in the Eastern Pontides. The contact relationships between volcanic blocks and limestones suggest that the volcanic lava blocks were still hot when they fell on the unlithified pelagic limestone muds. Therefore, biostratigraphic data obtained from pelagic limestones provide the age of the volcanic rocks. The beginning of the volcanism in the Eastern Pontide volcanic arc may thus be referred to late Coniacian–Santonian.

Many geotectonic models have been suggested to explain the interesting geological features of the Eastern Pontides (e.g. Bektaş et al. 1995; Yılmaz & Karslı 1997; Bektaş et al. 1999; Yılmaz & Korkmaz 1999; Yılmaz & Karslı 2000). Although the Jurassic to Early Cretaceous are clearly explained in these models, some Late Cretaceous tectono-stratigraphic events are not well documented. On the basis of previous studies (Yılmaz & Korkmaz 1999; Yılmaz & Karslı 2000) and of the data presented in this paper, a new model for the Maçka-Zigana area is proposed. Four distinct stages may be distinguished in the geotectonic evolution of the study area (Fig. 6):

1 — First Rifting Phase (Liassic): In this stage, under an extensional tectonic regime the Hercynian basement of the whole Eastern Pontides was rifted into asymmetrical sedimentary basins (Bektaş et al. 1995; Yılmaz 1997; Yılmaz & Korkmaz 1999). Volcaniclastic rocks accumulated in the grabens. The red nodular limestone developed "calcare ammonitico rosso" facies was deposited on the horsts and these condensed sediments made-up the pelagic carbonate platform (Santontonio 1993).

2 — Quiet Tectonic Period and Development of the Carbonate Platform (Dogger–Lower Cretaceous): After the extensional tectonic regime, a tectonically quiet regime prevailed from the Dogger to the Lower Cretaceous. Platform limestones (İnaltı Formation), widespread and deposited in shallow shelf conditions (Eastern Pontide Carbonate Platform, Yılmaz 2002) keep the geological records of the quiet period. Continuing extensional activity process resulted in normal faults causing crustal thinning and intense volcanism (Bürnük Formation).

3 — Second Rifting Phase, Break-up of the Carbonate Platform and accumulated Çağlayan and Kapanboğazı Formation: The quiet tectonic regime ended early in the Cenomanian and a newly extensional tectonic regime again become active. Those stresses broke up the carbonate platform and deepening basins occurred as a result of normal faults. In the fault slopes typical rift related sedimentary rocks (Çağlayan Formation) were deposited (Eberli 1987; Masse & Luperto-Sinni 1987; Santantonio 1993; Enos & Stephens 1993; Miller & Heller 1994; Rosales et al. 1994; Yılmaz 1997). At the same time interval, pelagic foraminifers bearing limestones (Kapanboğazı Formation) were deposited in the deep portion of the normal fault related sedimentary basins.

4 — Active Volcanic Period (Late Coniacian–Santonian): Volcanic inclusions present within the red pelagic limestones of the Kapanboğazı Formation indicate the beginning of the arc volcanism in the Eastern Pontides. That sub-marine volcanism continues to the end of the Tertiary. Geological records of those volcanics are seen in large outcrops through the Eastern Pontides and are known as the Pontide arc volcanics.

Acknowledgments: We thank D. Puglisi, J. Lexa and I. Haydoutov for their critical reviews and MTA Paleontology Service (Ankara) for the fossil determinations. We also thank L. Martire who improved the English of the text. This study was supported by funds from Karadeniz Technical University (Trabzon, Turkey) Research Grants 98.118.002.1 awarded to C. Yılmaz and 98.112.005 awarded to C. Şen.

References

Adamia S.A., Chkhotua T., Kekelia M., Lordkipanidze M., Shavishvili I. & Zahariadze F. 1981: Tectonics of the Caucasus and adjoining regions: implications for the evolution of the Tethys ocean. *J. Struct. Geol.* 3, 437–447.

Bektaş O. 1984: Upper Cretaceous shoshonitic volcanism in the Pontids and geotectonic implications. *KÜ Yerbilimleri Dergisi, Jeoloji* 3, 1–2, 53–62 (in Turkish with English abstract).

Bektaş O., Yılmaz C., Taslı K., Akdağ K. & Özgür S. 1995: Cretaceous rifting of the eastern Pontide carbonate platform, NE Turkey, the formation of carbonate breccias and turbidites as evidence of a drowned platform. *G. Geologia* 57, 1–2, 233–244.

Bektaş O., Şen C., Atıcı Y. & Köprübaşı N. 1999: Migration of the Upper Cretaceous subduction-related volcanism towards the back-arc basin of the eastern Pontide magmatic arc (NE Turkey). *Geol. J.* 34, 95–106.

Cox K.G., Bell J.D. & Pankhurst R.J. 1979: Interpretation of igneous rocks. *George, Allen and Unwin,* London.

Dewey J.F., Pitman W.C., Ryan W.B.F. & Bonnin J. 1973: Plate tectonics and evolution of Alpine system. *Geol. Soc. Amer. Bull.* 84, 3137–3180.

Eberli G.P. 1987: Carbonate turbidite sequences deposited in the rift-basin of the Jurassic Tethys ocean (eastern Alps, Switzerland*). Sedimentology* 34, 353–368.

Enos P. & Stephens B.P. 1993: Mid-Cretaceous basin margins carbonates, east-central Mexico. *Sedimentology* 40, 539–556.

Gedikoğlu A., Pelin S. & Özsayar T. 1979: Tectonic evolution of the eastern Pontide in Mesozoic. *Geocome-I, Abstr.* 68.

Irvine T.N. & Baragar W.R.A. 1971: A guide to the chemical classification of the common volcanic rocks. *Can. J. Earth Sci.* 8, 523–548.

Ketin İ. 1966: Tectonic units of Anatolia. *MTA Bull.* 66, 22–34 (in Turkish).

Ketin İ. & Gümüş A. 1967: The report on the geology of the Sinop-Ayancık region. (Part two: Jurassic-Cretaceous formations). *TPAO arşivi, report no 288* (in Turkish).

Masse J-P. & Luperto-Sinni E. 1987: A platform to basin transition model: the lower Cretaceous of the Gargano Massif (S-Italy). *Mem. Soc. Geol. Ital.* 40, 99–108.

McDonough W.F., Sun S., Ringwood A.E., Jagoutz E. & Hofmann A.W. 1991: K, Rb and Cs in the earth and moon and the evolution of the earth's mantle. *Geochim. Cosmochim. Acta*, Ross Taylor Symposium volume.

Miller R.P. & Heller P.L. 1994: Depositional framework and controls on mixed carbonate siliciclastic gravity flows: Pensylvanian-Permian shelf to basin transect South-Western Great Basin, USA. *Sedimentology* 41, 1–20.

Okay A.I. & Şahintürk Ö. 1997: Geology of the eastern Pontides. In: A.G. Robinson (Ed.): Regional and petroleum geology of the Black Sea and surrounding region. *AAPG Memoir 68*, 291–311.

Peccerillo R. & Taylor S.R. 1976: Geochemistry of Eocene calc-alkaline volcanic rocks from the Kastamonu area, northern Turkey. *Contr. Mineral. Petrology* 58, 63–81.

Robinson G.A., Banks C.J., Rutherford M.M. & Hırst P.P. 1995: Stratigraphic and structural development of the eastern Pontides, Turkey. *J. Geol. Soc.* 152, 861–872.

Rosales I., Fernandez-Mendiola P.A. & Garcia-Mondejar J. 1994: Carbonate depositional sequence development on active fault block: the Albian in the Castro Urdiles area, Northern Spain. *Sedimentology* 40, 1039–1067

Santontonio M. 1993: Facies association and evolution of pelagic carbonate platform-basin system: examples from the Italian Jurassic. *Sedimentology* 40, 1039–1067.

Sun S.S. & McDonough W.F. 1989: Chemical and isotopic systematics of oceanic basalts: Implications for mantle composition and process. In: Saunders A.D. & Norry M.J. (Eds.): Magmatism in ocean basins. *Geol. Soc. London, Spec. Publ.* 42, 313–345.

Şengör A.M.C. & Yılmaz Y. 1981: Tethyan evolution of Turkey: A plate tectonic approach. *Tectonophysics* 75, 181–241.

Şengör A.M.C., Yılmaz Y. & Ketin İ. 1981: Remnant of a pre-late Jurassic ocean in northern Turkey: Fragments of a Permian-Triassic Paleotethys. *Geol. Soc. Amer. Bull.* 91, 599–609.

Taslı K. 1984: Geology of the Hamsiköy (Trabzon) region. *KTÜ Dergisi, Jeoloji* 3/1–2, 69–76 (in Turkish).

Taslı K., Bektaş O. & Yılmaz C. 1994: Outcrops of the Upper Jurassic-Lower Cretaceous carbonate platform in the northern zone of the Pontids magmatic arc. *Bull. Geol. Congress, Turkey* 9, 56–61 (in Turkish).

Tokel S. 1972: Stratigraphical and volcanic history of the Gümüşhane region (NE Turkey). *PhD Thesis, Univ. College,* London, 1–198 (unpublished).

Yalçınalp B. 1992: Geology and geochemistry of the Porfiri Cu-Mo ore deposits in the Güzelyayla (Maçka-Trabzon). *Ph.D. Thesis, KTÜ, Fen Bil. Enstitüsü,* Trabzon, 1–173 (in Turkish).

Yılmaz C. 1997: Sedimentological records Cretaceous platform-basin transition Gümüşhane region (NE Turkey). *Geol. Mediterraneenne* 24, 1–2, 125–135.

Yılmaz C. 2002: Tectono-sedimentary records and controlling factors of the Mesozoic sedimentary basin in the Gümüşhane-Bayburt basin. *Geol. Bull. Turkey* 45, 1, 141–164 (in Turkish).

Yılmaz C. & Karslı O. 1997: Sedimentary records of the intra-arc basin during Upper Cretaceous in the Maçka-Zigana area. *Yerbilimleri* 30, 331–340 (in Turkish).

Yılmaz C. & Korkmaz S. 1999: Basin development in the eastern Pontides, Jurassic to Cretaceous, NE Turkey. *Zbl. Geol. Palaeont. Teil 1,* 1485–1494.

Yılmaz C. & Karslı O. 2000: Accumulation conditions Cretaceous roks in the Trabzon-Maçka area: sedimentary records of the opening the Black Sea. *TÜBİTAK-YDABCAG-596/G nolu Araştırma Projesi* 1–76 Trabzon (in Turkish).

Yılmaz Y., Tüysüz O., Yiğitbaş E., Can Ş.C. & Şengör A.M.C. 1997: Geology and tectonic evolution of the Pontides. In: A.G. Robinson (Ed.): Regional and petroleum geology of the Black Sea and surrounding region. *AAPG Memoir* 68, 183–226.