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THE EXISTENCE OF THE EARLY TO MIDDLE JURASSIC AND EARLY CRETACEOUS METAMORPHIC EPISODES OBTAINED BY K-Ar GEOCHRONOLOGY IN THE DADAY-DEVREKANİ MASSIF AND SURROUNDINGS, KASTAMONU REGION, NORTHERN TURKEY

DADAY-DEVREKANİ MASİFİ VE ÇEVRESİNDE (KASTAMONU, KUZEY TÜRKİYE) K-Ar JEOKRONOLOJİSİ İLE BELİRLENEN ERKEN-ORTA JURASİK VE ERKEN KRETASE YAŞLI METAMORFİZMALAR

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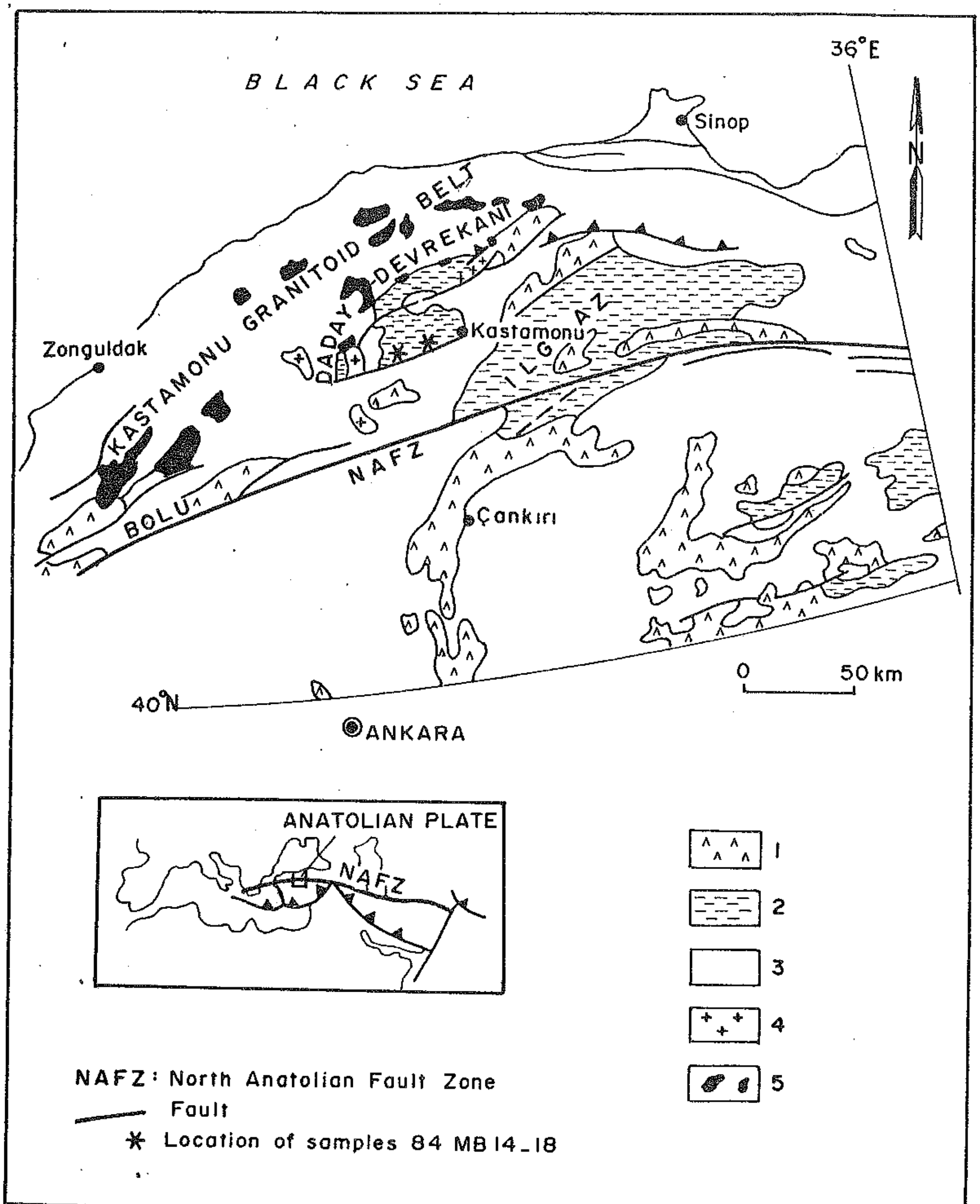
ABSTRACT: Daday-Devrekani massif and surroundings are composed of different tectonostratigraphic units constituting an imbrication structure in the central-western Pontides. These units are of Precambrian Daday-Devrekani metasedimentary group, Paleozoic Ilgaz metasedimentary group, pre-Lower Jurassic Çangal metaophiolite associated with some blue schists, Early Jurassic Börümce formation, Middle Jurassic Kastamonu granitoid belt, Middle Jurassic Göynükdağı contact aureole, and some dynamically metamorphosed rocks derived from all the units mentioned above during Early Cretaceous time. Mineralogical-petrographical and geochemical studies have concluded that there were different metamorphic units metamorphosed under different conditions in different geodynamics during different time spans. K-Ar datings, carried out in the hornblendes, biotites, muscovites, wholerocks and fine-grained fractions from these different tectonostratigraphic units, have revealed that two metamorphic episodes have affected this imbrication structure. The first metamorphic episode is of LP/MT in character which has occurred during Early to Middle Jurassic time. The cooling age of the plutons from the Kastamonu granitoid belt is also synchronous with this Early to Middle Jurassic metamorphic event. The second metamorphic episode, possessesing a HP/LT nature, has occurred during Early Cretaceous time. This Early Cretaceous high-pressure metamorphism seems to create the glaucophane schists in the Çangal metaophiolite, ultramylonites from the Daday-Devrekani metasedimentary group, mylonitic granites from the Kastamonu granitoid belt, and mica-schists in the Ilgaz metasedimentary group. From the geodynamic point of view, the first metamorphic episode, associated also with the cooling age of the Kastamonu granitoid belt, seems to be related to the subduction-collision system of the paleo-Tethyan oceanic realm. As for the Early Cretaceous second metamorphic episode, it is considered to be associated with the juxtaposition of the Anatolides and Pontides.

Key Words: Daday-Devrekani Massif, K-Ar Dating, Western Pontides, Kastamonu Granitoid Belt, paleo-Tethyan.

ÖZ: Orta-Batı Pontidlerde yüzeylenen Daday-Devrekani Masifi ve yakın çevresi, imbrikasyon yapısı gösteren çeşitli tektonostratigrafik birliklerden oluşmaktadır. Bu birlikler Prekambriyen yaşlı Daday-Devrekani metasedimanter grubu, Paleozoyik yaşlı Ilgaz metasedimanter grubu, Alt Jurasik öncesi yaşlı Çangal metaofiyoliti ve ilgili mavişistler, Erken Jurasik yaşlı Börümce formasyonu, Orta Jurasik yaşlı Börümce formasyonu, Orta Jurasik yaşlı Kastamonu granitoyid kuşağı, Orta Jura yaşlı Göynükdağı kontakt metamorfiti ve ERken retase yaşlı dinamik metamorfizma sonucu yukarıda sayılan tüm bu birimlerden itibaren türemiş olan kataklastik kayaçlardan meydana gelmektedir.

Mineralojik-petrografik ve jeokimyasal çalışmalar sonucunda, imbrike yapı gösteren bu birliklerin; değişik jeolojik zamanlarda, farklı jeodinamik ortamlarda ve metamorfizma koşullarında etkin olan farklı metamorfik olaylarla meydana geldikleri belirlenmiştir. Hornblend, biyotit, muskovit, tümkayaç ve kilboyu fraksiyon üzerinde yürütülen K-Ar radyometrik yaş tayini çalışmaları, bu imbrikasyon yapısının iki farklı metamorfizmadan etkilendiğini ortaya koymuştur. Birinci metamorfik olay Erken-Orta Jurasik döneminde gerçekleşmiş olup düşük basınç/orta sıcaklık karakteri sergilemektedir. Kastamonu granitoyid kuşağının soğuma yaşı da aynı zamanda bu metamorfizma ile eşzamanlılık göstermektedir. İkinci metamorfik olay ise Erken Kretase döneminde etkin olmuştur ve yüksek basınç/düşük sıcaklık karakteri göstermektedir. Erken Kretase yaşlı bu yüksek basınç/düşük sıcaklık karakteri göstermektedir. Erken Kretase yaşlı bu yüksek basınç metamorfizması, aynı zamanda, Çangal metaofiyolitindeki glokofan şistleri, Daday-Devrekani metasedimanter grubundaki ultramilonitleri, Kastamonu granitoyid kuşağındaki milonitik granitleri ve Ilgaz metasedimanter grubundaki mikaşistleri de meydana getiren metamorfizma olarak değerlendirilmektedir. Jeodinamik konum bakımından irdelendiğinde, Kastamonu granitoyid kuşağının soğuma yaşıyla da birlik oluşturan Erken-Orta Jurasic yaşlı birinci metamorfizmanın paleo-Tetis okyanusal alanının dalma-batma / çarpışma sistemiyle; Erken Kretase yaşlı ikinci metamorfizmanın ise Anatolid-Pontid kenetlenmesiyle ilgili olabileceği ileri sürülebilmektedir.

Anahtar kelimeler: Daday Devrekani Masifi, K-Ar yaşı, Batı Pontidler, Kastamonu Granitoyid kuşağı, paleo-Tetis.



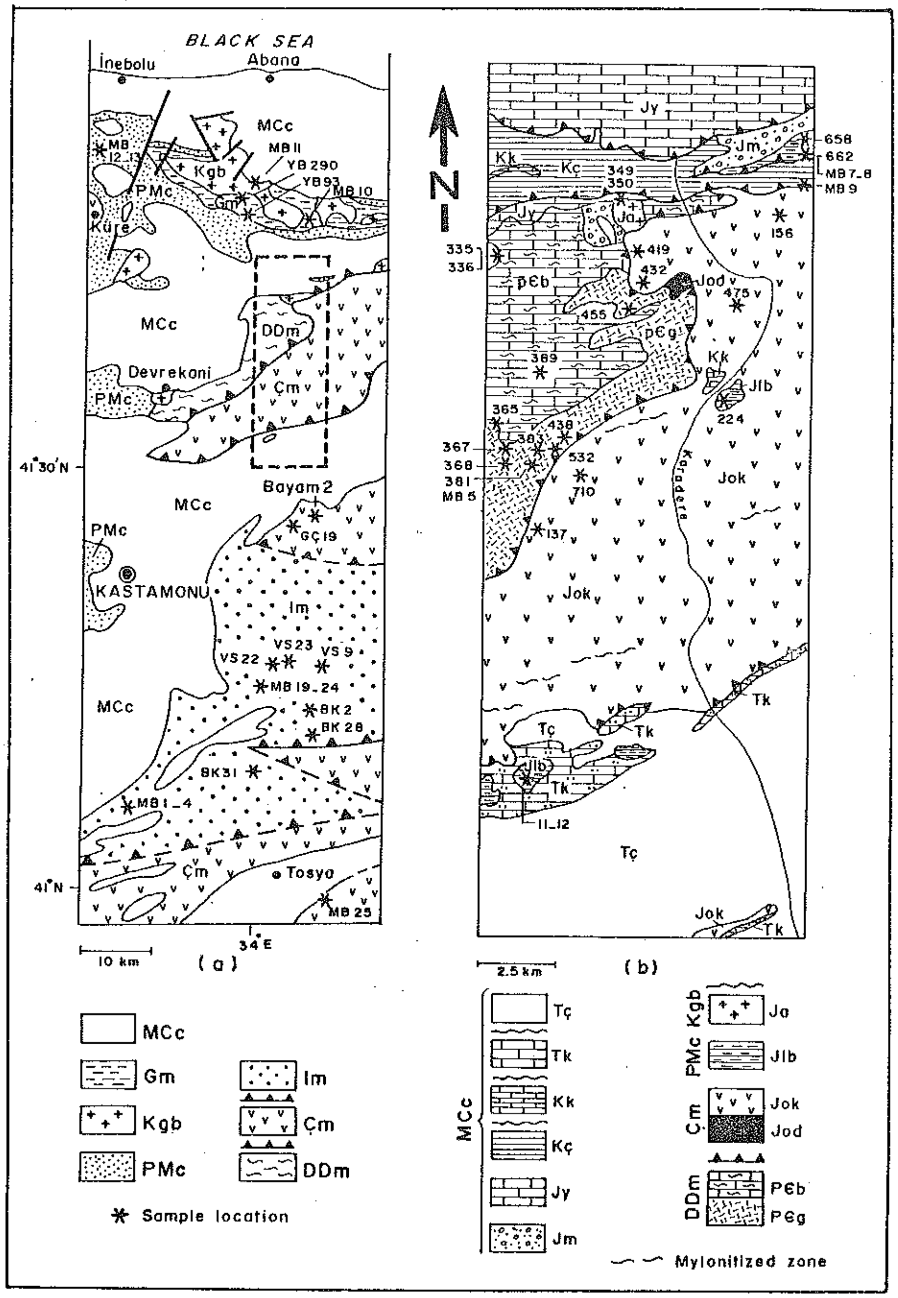
Şekil 1. Merkez Batı Pontidlerin taslak jeolojik-yapısal haritası (Yılmaz ve Boztuğ 1986 tarafından yapılan harita temel alınmıştır). Dikdörtgen şekil 2 a'nı lokasyonlarını göstermektedir.
1. Ofiyolitik, metaofiyolitik birlikler Ofiyolitik tektonik melajlar; 2. Paleozoyik metamorfikler; 3. Paleozoyik - Mesozoyik (Erken Jurasik) ankimetamorfik örtü ve Senozoyik diyajenetik örtü; 4. Prekambriyen metamorfikleri; 5. Orta Jurasik yaşlı Kastamonu Granitoyid kuşağı plütonları.

Figure 1. Sketch geologic-structural map of the North-Central Turkey, based upon Yılmaz and Boztuğ (1986). The rectangle indicates the location of Figure 2a.
1.Ophiolitic, metaophiolitic assemblagesand ophiolitic tectonic melanges; 2. Paleozoic metamophics; 3. Plaezoic-Mesozoic (Early Jurassic) anchimetamorphic cover and Cenozoic diagenetic cover; 4. Precambrian metamorphics; 5. Plutons of the Middle Jurassic Kastamonu granitoid belt.

Table 1. Rock type, HT mineral assemblages and geographic coordinates of the studied samples.
Tablo 1. Çalışılan örneklerin kayaç tipleri, HT mineral toplulukları ve coğrafik koordinatları.
Açıklamalar: qu, kuvars, pl, Pljiyoklaz; bi, biyotit; hb, hornblend, cc, kalsit; di, diyopsit; ep, epidot; zr, zirkon; tur, turmalin; ap, apatit; mu, muskovit; sph, sfen; ser, serisit; sil, sillimanit; gar, granat; ch, klorit, op, opak mineral; tr/act, tremolit/aktinolit.

Samaple	Rock type/HT mineral assemblage	Geographic coordinate
Daday-Devrekani Metasedimentary Group (DDm)		
Gneisses		
OY-365	Quartz-feldspar gneiss/qu±pl±kf±bi	34°00'E, 41°38'N
OY-3671	Calc-silicate gneiss/hb±cc±di±ep±pl	34°00'E, 41°38'N
OY-368	Quartz-feldspar gneiss/ kf±bi±qu±zr±tur±ap	34°00'E, 41°38'N
OY-381	Quartz-feldspar gneiss/qu±kf±pl±mu±zr	34°01'E, 41°38'N
OY-3832	Hornblende gneiss/ hb±bi±qu±pl±ch±ep±zr±ap	34°01'E, 41°38'N
OY-389	Amphibolite/hb±pl±sph±ap±tur	34°01'E, 41°39'N
OY-4382	Hornblende gneiss/hb±bi±qu±pl±sph±ep±ser	34°01'E, 41°38'N
Y-455	Garnet-sillimanite-bi°tite gneiss/qu±sil±gar±bi±mu±ch	34°03'E, 41°40'N
OY-532	Mica gneiss/qu±kf±pl±bi±mu±zr±ap±°p	34°01'E, 41°38'N
Ultramylonites	84 MB 6 Ultramylonite	34°03'E, 41°38'N
Ilgaz Metasedimentary Group (Im)		
Schists		
84 MB 1	Micaschist	33°48'E, 41°05'N
84 MB 2	Micaschist	33°48'E, 41°05'N
84 MB 3	Micaschis	33°48'E, 41°05'N
84 MB 4	Micaschist	33°48'E, 41°05'N
BK-2	Micaschist/qu±mu±ch±°p±ap±tur	34°06'E, 41°13'N
BK-28	Micaschist/qu±mu±ch±bi±ap±tur±°p±zr	34°04'E, 41°10'N
BK-31	Micaschist/qu±mu±ch±bi	34°04'E, 41°26'N
VS-9	Micaschist/mu±bi±qu±ch±cc	34°07'E, 41°16'N
VS-222	Calc-schist/cc±qu±mu±ch±°p±tur	34°03'E, 41°16'N
Red Argillites		
84 MB 19	Red argillite	34°00'E, 41°15'N
84 MB 20	Red argillite	34°00'E, 41°15'N
84 MB 21	Red argillite	34°00'E, 41°15'N
84 MB 22	Red argillite	34°00'E, 41°15'N
84 MB 23	Red argillite	34°00'E, 41°15'N
84 MB 24	Red argillite	34°00'E, 41°15'N
Çangal Metaophiolite (Çm)		
Radiolarites		
84 MB 14	Radiolarite	33°06'E, 41°14'N
84 MB 15	Radiolarite	33°06'E, 41°14'N
84 MB 16	Radiolarite	33°06'E, 41°14'N
84 MB 18	Radiolarite	33°25'E, 41°16'N
Metabasites		
OY-475	Metabasite/hb±pl±qu±ep	34°05'E, 41°40'N
Glaucophane-schists		
VS-23	Lawsonite-glaucophane schist	34°03'E, 41°16'N
Orthophyllonites		
84 MB 25	Orthophyllonite	34°07'E, 40°59'N
GC-191	Orthophyllonite/ser±ch±qu	34°04'E, 41°26'N
OY-137	Orthophyllonite/qu±pl±mu±ch	34°01'E, 41°37'N
°Y-156	Orthophyllonite/mu±ch±qu±op	34°06'E, 41°42'N
°Y-4193	Orthophyllonite/qu±ser±pl±ch±ep±cc	34°03'E, 41°41'N
°Y-432J	Orthophyllonite/ser±ch±ep±qu±tr/ac±op	34°03'E, 41°41'N
°Y-710	Orthophyllonite/qu±ch±pl±ser	34°02'E, 41°37'N
Börümce Formation (Jlb)		
Sandstones		
84 MB 7	Sandstone	34°07'E, 41°43'N
84 MB 8	Sandstone	34°07'E, 41°43'N
Argillites		
84 MB 12	Argillite	33°44'E, 41°52'N
84 MB 13	Argillite	33°44'E, 41°52'N
OE-90	Argillite	33°58'E, 41°46'N
OY-12	Argillite	34°01'E, 41°32'N
OY-224	Argillite	34°05'E, 41°39'N
OY-658	Argillite	34°07'E, 41°43'N
OY-662	Argillite	34°07'E, 41°43'N
Sericite schist		
OY-11	Sericite schist/ser±ch±qu±pl±bi±mu±cc	34°01'E, 41°32'N
Kastamonu Granitoid Belt (Kgb)		
Diorites		
OY-335	Diorite/pl±hb±bi±ch±ser±qu±op	34°00'E, 41°41'N
OY-336	Diorite/pl±hb±bi±ch±qu±ser	34°00'E, 41°41'N
OY-349	Di°rite/pl±hb±sph±ser±ch±op	34°03'E, 41°42'N
Pegmatites		
84 MB 5	Pegmatite/kf±qu±mu	34°01'E, 41°38'N
84 MB 11	Pegmatite/kf±qu±mu	33°59'E, 41°50'N
Mylonites		
OY-350J	Diorite myl°nite/hb±tr/act±pl±ch±bi	34°03'E, 41°42'N
Göynükdağı Contact Metamorphics (Gm)		
Phyllites		
84 MB 10	Phyllite	34°05'E, 41°48'N
YB-290	Phyllite/ser±ch±qu±mu±bi±pl	33°58'E, 41°49'N
Sericite schists		
YB-93	Sercite schist/ser±ch±mu±bi±qu±op	33°58'E, 41°48'N

Explanation: qu, quartz; pl, plagioclase; kf, K-feldspar; bi, biotite; hb, hornblende; cc, calcite; di, diopside; ep, epidote; zr, zircon; tur, turmaline; ap, apatite; mu, muscovite; sph, sphene; ser, sericite; sil, sillimanite; gar, garnet; ch, chlorite; op, opaque mineral; tr/act, tremolite/actinolite.



Şekil 2. Çalışma alanının basitleştirilmiş jeoloji haritası (Mevki için şekil 1'e bakınız) 2.b Şekil 2a'daki küçük bir alanın detay jeoloji haritası. Ddm, Daday Devrekani metasedimenter grubu; Çm, Çangal metaofiyoliti; Im, Ilgaz metasedimenter grubu; Pmc, Paleozoyik-Mesozoyik (Erken Jurasik) ankimetamorfik-sedimenter örtü; Kgb, Kastamonu granitoyid kuşağı; Gm, Göynükdağı kontakt metamorfikleri, Mcc, Mesozoyik-Senozoyik sedimenter örtü; pєg, Gürlevik gnaysı; pєb, Başakpar metakarbonatı; Job, Dibekdere meta ultramafikleri; Jok, Karadere metabaziti; Jlb, Börümce formasyonu; Ja, Asarcık diyoriti; Jm, Muzrıp formasyonu; Jy, Yukarıköy formasyonu; Kç, Çatak formasyonu; Kk, Kirensökü-sü formasyonu; Tk. Kayaardı formasyonu, Tç, Çünür formasyonu.

Figure 2. Simplified geoloic map of the study area (see Figure 1 for the location); 2b. Detailed geological map of the dashed area in Figure 2a. DDm, Daday-Devrekani metasedimentary group; Çm, Çangal metaophiolite; Im, IFlgaz metasedimentary group; PMc, Paleozoic-Mesozoic (Early Jurassic) anchimetamorphic-sedimantary cove; Kgb, kastamonu granitoid belt; Gm, Göynükdağı contact metamorphics; MCc, Mesozoic-Cenozoic sedimentary cover; pєg, Gürleyik gneiss; pє b, Başakpinar metacarbonate; Jod; Dibekdere metaultramafics; Jok, Karadere metabasite; Jlb, Börümce formation; Ja, Asarcık diorite; Jm, Muzrup formation; Jy, Yukarıköy formation; Kç, çatak formation; Kk, Kirensöküsü formation; Tk, Kayaardı formation; Tç, Çünür formation.

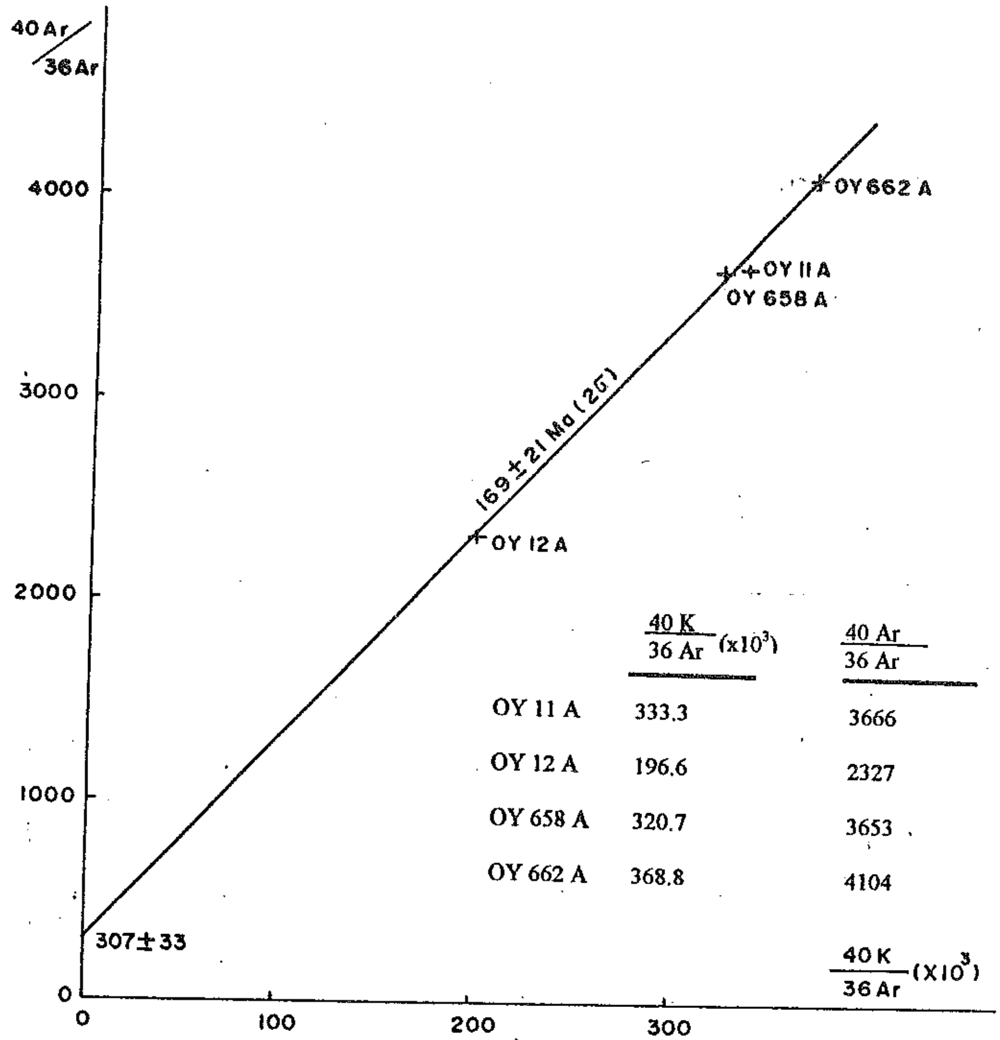
Table 2. Metamorphic history of the Daday-Devrekani massif and surroundings, Kastamonu region, central-western Pontides, northern Turkey.

Tablo 2. Daday Devrekani masifi ve yakın çevresinin (Kastamonu bölgesi, Orta Batı Pontidler ve Kuzey Türkiye) metamorfik tarihçesi.

Diğer açıklamalar için Şekil 1, 2 ve metne bakınız.

Group name	Initial age	Rock type before metamorphism	Type of metamorphism	Ages of metamorphism	Rock type after main metamorphism	Geodynamics
DDm	Precambrian	Pelitic to marly calcareous sediments	HT/MP amphibolite facies; general overprint of greenschist facies issued in a subduction-collision system	Amphibolite facies: Precambrian; Greenschist facies: early to Middle Jurassic	K-feldspar-sillimanite gneiss; biotite-hornblende gneiss; calc-silicate gneiss; diopside marble; calc-silicate marble	Continental crust forming the southernmost part of Eurasian plate
Im	Paleozoic	Pelitic to calcerous	L-MT/LP greenschist facies sediments	Early to Middle Jurassic issued in continental crust by subduction-collision system	Micaschist, calc-schist, marble	Epicontinental to epiophiolitic sedimentary cover
Çm	Paleozoic	Typical middle - upper part of oceanic crust	LT/LP greenschist to epidote amphibolite facies of ocean floor metamorphism; probable overprint of subduction-collision system metamorphism	Upper Paleozoic to early Mesozoic; later overprint of subduction-collision system occurred Early to Middle Jurassic	Typical metaophiolite (serpentinite, metagabbro, metadiabase, metaspilite, metaporphyrite)	Well-preserved remnants of the paleo-Tethys oceanic crust
PMc	Upper Paleozoic to Early Mesozoic	Limestone, typical flyschoidal sequence	Very low-grade metamorphism induced by the subduction-collision system(anchimetamorphism)	Early to Middle Jurassic	Recrystallized limestone, argillite, slate	Epicontinental to epiophiolitic sedimentarycover
Gm	pre-Middle Jurassic	All rock units of pre-Middle Jurassic age	Albite-epidote to hornblende hornfels facies	Middle Jurassic	Spotted hornfels, spotted schist, micaschist, phyllite, marble	Contact aureole around Kastamonu granitoid belt formed by the subduction-collision system
	pre-Early Cretaceous	Mainly crystalline rocks of pre-Early Cretaceous age	LT/HP dynamic metamorphism	Early Cretaceous	From DDm: Ultramylonite From Çm: Glaucophane schist, orthophyllonite, anthopylite schist From Im: Micashist From Kgb: Mylonite	Juxtaposition of the Eurasian plate and Anatolides during the final stages of subduction-collision system

See Figs. 1, 2 and text for other explanations.



Şekil 3. Börümce formasyonu 84 MB 8 nolu örneğinde iri taneli muskovit örneğindeki yelpaze şekilli büyümenin görünümü; a. düşük büyüme; b. a zonunun daha yüksek büyümesi.

Figure 3. Coarse detrital muscovite of sample 84 MB 8 from the Börümce formation showing the progressive fan out of its edges; a. low magnification; b. higher magnification of zone a.

INTRODUCTION

There are various tectonostratigraphic units constituting the paleo-Tethyan imbrication system in the Daday-Devrekani massif and surroundings in the outer zone (Adamia et al., 1980) of the central-western Pontides (Ketin, 1966) in northern Turkey (Figure 1). These constituents, ranging from Precambrian to Early Cretaceous in age, are composed mainly of hihg/medium-grade crustal metasediments, low-grade metasediments and anchimetamorphic/diagenetic epicontinental/epiophiolitic cover, metaophiolitic assemblage associated with blue schists, subduction and collision related granitoid plutons, and mylonitic rocks derived by the later ductile and sometimes brittle deformation from all these units mentioned above (Yılmaz and Boztuğ, 1986; Boztuğ and Yılmaz, 1995). These different tectonostratigraphic units, studied in detail, have been called Daday-Devrekani metasedimentary group (Yılmaz, 1979, 1980, 1981; Boztuğ, 1988, 1992), Ilgaz metasediments (Yılmaz and Boztuğ, 1986), Samatlar group (Boztuğ, 1992, 1989a), Çangal metaophiolite (Yılmaz, 1983a,b), Kastamonu granitoid belt formed by the subduction (Yılmaz and Boztuğ, 1986) and collision (Boztuğ et al., 1995) related granitoid plutons, Göynükdağı contact metamorphite

Table 3. K-Ar isotopic data of mineral and wholerock samples from the Daday-Devrekani massif and surroundings, central-western Pontides, Turkey.

Tablo 3. Daday-Devrekani masifi ve yakın çevresindeki Merkez Batı Pontidler'den alınan minerale ve tüm kayaç örneklerinin K-Ar izotop verileri.

Açıklamalar: WR, Tüm kayaç; At, attapulgit; I60±Ch40, %60 illit +% %40 klorit; I± Ch, İllit-klorit karışmı; C-S, Klorit - simektit karışımı; Gla, glokonit; S, Simektit; C-V klorit - vermikülit karışımı. *az **bol ***çok bol. diğer simgeleri için tablo 1'e bakınız.

Sample	Mineral	K_2O(%)	$^{40}Ar_{rad}/^{40}Ar_{tot}$ (%)	$^{40}Ar_{rad}$(nl/g)	t(Ma±2σ)
Daday-Devrekani Metasedimentary Group (DDm)					
Gneisses					
OY-365	Bi	5.82	(I) 87.8	31.8	162±5
			(II)89.7	32.1	163±5
OY-367$_I$	Hb	1.51	(I) 82.7	9.9	196±6
			(II)92.0	10.04	195±6
OY-368	Bi	8.26	(I) 93.3	50.0	179±5
			(II)95.0	50.0	179±5
OY-381	Mu	7.91	94.0	45.0	168±4
OY-383$_2$	WR	4.00	96.0	22.9	169±5
	Bi	6.22	94.6	35.8	170±4
OY-389	Hb	0.456	77.2	2.73	177±8
OY-438$_2$	Bi	5.05	94.6	25.66	151±4
	Hb	1.01	80.0	5.66	166±6
OY-455	Bi	4.70	90.4	23.64	149±4
OY-532	Bi	9.41	96.7	48.9	154±4
Ultramylonites					
84 MB 6	At*** ±I**	2.54	62.1	9.08	107±6
Ilgaz Metasedimentary Group (Im)					
Schists					
84 MB 1	$I_{60}\pm Ch_{40}$	5.21	85.6	22.16	127±6
84 MB 2	$I_{70}\pm Ch_{30}$	5.84	93.1	22.66	116±5
84 MB 3	$I_{75}\pm Ch_{25}$	6.28	91.4	27.5	131±5
84 MB 4	$I_{60}\pm Ch_{40}$	5.30	96.3	24.4	137±6
BK-2	Mu	3.83	88.2	14.63	115±3
BK-28	$I_{60}\pm Ch_{40}$	4.11	53.4	13.05	96±5
BK-31	$I_{70}\pm Ch_{30}$	5.51	81.9	20.25	110±3
VS-9	$I_{70}\pm Ch_{30}$	4.73	82.6	14.03	90±3
VS-222	I_{100}	5.72	76.2	37.5	192±6
Red Argillites					
84 MB 19	$I_{60}\pm Ch_{40}$	2.175	87.2	11.80	161±7
84 MB 20	$I_{70}\pm Ch_{30}$	2.29	74.0	11.31	147±7
84 MB 21	$I_{45}\pm Ch_{55}$	2.98	84.7	16.36	162±7
84 MB 22	$I_{75}\pm Ch_{25}$	3.32	73.4	17.61	157±7
84 MB 23	$I_{50}\pm Ch_{50}$	1.816	89.8	20.37	166±8
84 MB 24	$I_{75}\pm Ch_{25}$	3.50	91.9	17.95	152±7
Çangal Metaophiolite (Çm)					
Radiolarites					
84 MB 14	WR	0.179	66.4	0.986	163±13
	$I^{*}\pm Ch^{**}\pm$(C-S)	0.503	37.90	2.54	150±12
84 MB 15	WR	0.964	76.7	5.11	157±7
	$I_{40}\pm Ch_{60}$	1.314	73.7	8.00	180±8
84 MB 16	WR	0.240	60.0	1.174	146±8
84 MB 18	$I_{80}\pm Ch_{20}\pm$(I-S)	4.43	85.7	20.37	137±6
Metabasites					
OY-475	Hb	0.138	45.4	0.710	153±16
Çangal Metaophiolite (Çm)					
Glaucophane schists					
VS-23	Hb	0.219	55.5	0.793	109±9
	Gla(a)	0.241	57.7	0.896	112±9
	Gla(b)	0.347	56.1	1.237	107±7
	Gla (c)	0.681	76.9	2.591	114±5
Orthophyllonites					
84 MB 25	$I_{30}\pm Ch_{70}$	1.358	54.3	3.37	75±5
GC-191	$I_{60}\pm Ch_{30}\pm S_{10}$	5.73	84.4	23.5	123±4
OY-137	$I_{80}\pm Ch_{20}$	4.36	87.3	18.33	126±4
OY-156	Inm±Chnm	0.677	57.5	2.48	110±5
OY-4193	$I_{70}\pm Ch_{30}$	4.14	86.6	15.93	115±4
OY-432J	WR	2.98	89.6	13.01	130±4
OY-710	$I_{70}\pm Ch_{30}$	5.45	73.1	26.2	143±4
Börümce Formation (Jlb)					
Sandstones					
84 MB 7	Mu	9.40	94.3	108.7	367±16
84 MB 8	Mu	8.27	95.9	113.9	341±15
Argillites					
84 MB 12	$I_{30}\pm Ch_{70}\pm$(I-S)	2.55	91.1	17.61	202±5
84 MB 13	$I_{65}\pm Ch_{35}$	4.83	93.5	29.8	182±4
oE-90	$I_{50}\pm Ch_{50}\pm$(I-S)	2.83	89.2	23.8	243±11
OY-12	$I_{70}\pm Ch_{30}$	4.98	87.3	28.5	169±5
OY-224	$I_{80}\pm Ch_{20}$	6.90	93.9	41.7	178±5
OY-658	$I_{70}\pm Ch_{30}$	6.03	91.9	35.0	171±5
OY-662	$I_{60}\pm Ch_{40}$	4.92	92.9	28.1	169±5
Sericite schist					
OY-11	$I_{75}\pm Ch_{25}$	5.53	91.9	31.0	166±4
Kastamonu Granitoid Belt (Kgb)					
Diorites					
OY-335	Hb	0.697	79.4	3.42	146±6
OY-336	Hb	0.832	70.9	4.98	176±7
	Bi	4.10	87.3	22.47	162±5
OY-349	Bi	5.51	89.7	29.9	161±4
Pegmatites					
84 MB 5	Mu	11.05	82.7	58.6	157±7
84 MB 11	KF	16.04	98.8	71.8	134±6
	Mu	11.13	93.7	103.4	267±12
Mylonites					
OY-350$_J$	Hb	0.457	(I)50.4	1.589	105±6
			(II)69.1	1.774	116±6
Göynükdağı Contact Metamorphics (Gm)					
Phyllites					
84 MB 10.	$I_{70}\pm Ch_{30}\pm$(C-V)	5.22	88.1	32.0	180±8
YB-290	$I_{75}\pm Ch_{25}\pm$(C-V)	3.20	90.3	27.1	245±11
Sericite schists					
YB-93	$I_{75}\pm Ch_{25}\pm$(C-V)	3.57	91.8	24.1	204±9

Explanation: WR, wholerock; At, attapulgite; I60 ± Ch40, 60 % illite ± 40 % chlorite; I±Ch, illite-chlorite mixed-layer; C-S, chlorite-smectite mixed layer; I-S, illite-smectite mixed layer; Gla glauconite; S, smectite; C-V, chlorite-vermucilite mixed layer; *scarce; **abundant; ***very abundant. See Table 1 for other abbreviations of minerals.

(Yılmaz and Boztuğ, 1985, 1987a), and cataclastic rocks formed along some major thrust zones (Yılmaz, 1979; Boztuğ, 1988; Boztuğ and Yılmaz, 1995).

This paper deals mainly with the existence of two metamorphic episodes, based on K-Ar datings, which have affected some of these different units. As clearly seen from the data given above, these tectonostratigraphic units are composed of different lithology and mineral assemblages. That is why some different minerals and/or mineral associations have been analysed to get correct and utilizable results with the K-Ar dating technique.

SAMPLING AND ANALYTICAL PROCEDURES

As weathering processes in northern Turkey may reach locally up to several decameters in some units, fresh outcrops are scarce and can only be found along new road cuts and in deep valleys. All geochronological samples (Table 1) were carefully collected from these fresh outcrops and selected after thin section control and wholerock X-ray diffraction examination. Mineral separations include HT igneous and metamorphic minerals and fine-grained fractions finer than 2 m, i.e. clay minerals. Untransformed hornblendes, muscovites, biotites and glaucophanes were carefully selected and purified before being regarded as convenient for K-Ar analysis. X-ray diffraction analysis of fine fraction was performed on untreated, glycolated, and heated oriented samples. K_2O content of each sample was obtained through acid dissolution of 30 mg aliquots by atomic absorption (AAS) analysis. The precision of the K_2O content is estimated at + 2% (1σ). Argon concentration was determined through isotopic dilution using a 6 cm radius mass spectrometer in the static mode. The atsmospheric argon ratio of the machine is 40Ar / 36 Ar = 295.6 ± 0.7 (1σ). The argon content of the Glo standard was measured as 24.86 ± 0.19 (1σ) nl/g in agreement with the recommended value which is of 24.86 nl/g (Odin, 1982). Numerical dates of the geological time scale refer to Odin (1982), Palmer (1983) and Hag et al. (1987). Age calculation use the constant recommended by Steiger and Jager (1977). Error calculations follow the method proposed by Mahood and Drake (1982), and isotopic lines are best-fit lines calculated after Williamson (1968).

All the analytical studies were carried out at the laboratories of the Institut Dolomieu in Grenoble, France.

GEOGOLICAL SETTING

As mentioned above, the Daday-Devrekani massif and surroundings, taking place in the outer zone of the central-western Pontides, seem to be a part of an imbrication structure derived by the thrust tectonic regime related to the evolution of the paleo-Tethyan system (Şengör et al., 1980; Şengör and Yılmaz, 1981; Yılmaz and Boztuğ, 1986; Şengün et al., 1990; Boztuğ and Yılmaz, 1995). Some mineralogical-petrographical and geochemical-petrological studies (Yılmaz, 1979, 1980, 1981, 1983a, 1983 b, 1984, 1988; Boztuğ, 1983, 1987, 1988, 1989a, 1989b, 1992; Yılmaz and Boztuğ, 1984, 1985, 1986, 1987a, 1987b; Boztuğ and Yılmaz, 1983, 1985, 1987, 1989, 1991a, 1991b, 1995; Bonhomme and Yılmaz, 1984; Boztuğ et al., 1984, 1995;) carried out in the Daday-Devrekani massif and surrounding parts of this imbrication system, permit better to define the different metamorphic rock units on the basis of (1) their initial source and geodynamic environments, (2) their relative ages, and (3) the various metamorphic P/T conditions (Table 2). The main geological features of different tectonostratigraphic units, constituting this imbrication system, can be summarized, from bottom to top, as follow:

Daday-Devrekani Metasedimentary Group (DDm): This group has been firstly identified as Precambrian in the northeastern part of the Daday-Devrekani massif (Fig. 2) by Yılmaz (1979, 1980). It represents the basement crustal metamorphic rocks in the studied area. These high- to medium-grade crustal metasediments, overlain by fossiliferous Lower to Middle Paleozoic sedimentary-anchimetamorphic units, are also exposed in the soutwestern part of the Daday-Devrekani massif (Boztuğ, 1988, 1989a, 1989b, 1992). The index metamorphic minerals observed in the DDm (Table 1) indicate that it was submitted to a HT/MP type metamorphic event locally reaching partial melting (Yılmaz, 1981, 1984). This result suggest that the DDm would be part of the southernmost edge of the Eurasian continent. On the other hand, a LP/L-MT retrograde metamorphism was superimposed upon the whole DDm. Apart from this latter retrograde event, some ultramylonites with very low-grade retrograde metamorphic mineral assemblages can be observed in some shear zones developed during the final stages of collision, i.e. juxtaposition of this Precambrian crustal metasediments with the pre-Lower Jurassic Çangal metaophiolite (Fig.2).

The Ilgaz Metasedimentary Group (Im): It consists of Paleozoic metasedimentary rocks metamorphosed during the Early Alpine period. It involves metamorphic rocks in the greenschist facies (Table 1).The Im has been affected by a HP/LT dynamic metamorphism similar to that of the Çangal metaophiolite.

The Çangal Metaophiolite (Çm): The pre-Lower Jurassic Çangal metaophiolite is a well-preserved fragment of the paleo-tethyan oceanic crust. This sequence outcrops between the DDm and the Im as a tectonic slab (Figs. 1,2). The typical mineral assemblages of the Çm represent the metamorphic facies from LP/LT greenschist to epidote-amphibolite. These assemblages are believed to have been formed by in-situ ocean floor metamorphism (Yılmaz, 1983, 1988, Yılmaz and Boztuğ, 1986). After this in-situ ocean floor metamorphism, the Çm probably was metamorphosed in the deepermost parts of the subduction zone, as it yields some glaucophane-schist and eclogitic rocks in the Elekdağ region, some 50 km northeast of Kastamonu city (Fig.1). The Çm has also been metamorphosed under the low-grade retrograde cataclastic metamorphic conditions along some shear zones developed during the final stages of collision, i.e. juxtaposition with the DDm (Yılmaz and Boztuğ, 1986).

Börümce Formation (Jlb): The Lower Jurassic, probably Triassic-Lower Jurassic Börümce formation consists typically of black colored flyschoidal rocks composed of sandstone-siltstone-claystone alternation. The Börümce formation can also be regarded as an anchimetamorphic unit according to clay mineralogy and illite crystallinity index studies (Ataman et al., 1977; Boztuğ and Yılmaz, 1985). All the rock types of the Börümce formation, e.g. the sandstones, claystones and siltstones represent a good slaty oriented groundmass consisting of sericite and chlorite under the microscope. The rocks of the Börümce formation are locally cut by some plutons of the Kastamonu granitoid belt forming some contact aureoles among which the most typical one is called Göynükdağı contact metamorphics in the Göynükdağı-Bozkurt region, nort of Kastamonu city (Yılmaz and Boztuğ, 1985; 1987a).

Kastamonu Granitoid Belt (Kgb): Some granitoid plutons, belonging to the Middle Jurassic Kastamonu granitoid belt of Northern Turkey (Yılmaz and Boztuğ, 1986), cut the DDm, Çm and Jlb units (Figs. 1,2). Among these plutons, the Asarcık diorite is seen to intrude both the DDm and Çm (Fig. 2). Some plutons of the Kgb, e.g. the Asarcık diorite, Ağlı-Şenlikköy and Sallamadağ plutons, are depositionally covered by the Middle-Upper Jurassic Muzrup formation (Fig.2) indicating a pre-Middle Jurassic age for these plutons. On the other hand, a HP/LT dynamic metamorphism has also affected the plutons of Kgb that produced some granite mylonites. This dynamic metamorphism can also be related to the juxtaposition of crustal and oceanic assemblages.

Göynükdağı Contact Metamorphics (Gm): The most spectacular one of the contact aureoles developed around the plutons of the Kastamonu granitoid belt is the Göynükdağı contact aureole. This contact aureole, consisting mainly of spotted slates, spotted schists, phyllites, spotted hornfelses and knotted hornfelses (Yılmaz and Boztuğ, 1985, 1987a; Boztuğ, 1987), has been developed by the Ahiçay-Elmalıçay pluton intruding the Börümce formation in the Göynükdağı region of the Bozkurt-Kastamonu area (Fig. 2). The thickness of this aureole can attain up to 600 meters in some localities.

EARLY TO MIDDLE JURASSIC METAMORPHIC EPISODE

The Daday-Devrekani metasedimentary group, red argillites from the Ilgaz metasedimentary group, radiolarites and metabasites of the Çangal metaophiolite, black argillites in the Börümce formation, and phyllites of the Göynükdağı contact aureole seem to have been affected by this metamorphic episode (Table 3). On the other hand, some hornblendes and biotites extracted from the unmetamorphosed and fresh dioritic rocks of the Asarcık diorite (Yılmaz, 1979, 1981; Boztuğ et al., 1995) belonging to the Kastamonu granitoid belt also yields the K-Ar cooling ages which are synchronous with this metamorphic episode (Table 3). Such a contemporary relation between the igneous and metamorphic units reveals that the igneous and metamorphic events must be associated with each other, at least, in space and time, whatever the mechanism of the igneous or metamorphic petrogenesis. The K-Ar ages determining this metamorphic episode and cooling age of the plutons, depending on the nature of the units, can be briefly summarized as follow.

Daday-Devrekani Metasedimentary Group: At a first approach, the K-Ar amphibole and biotite ages of this unit range from 196 to 166 Ma, and from 179 to 149 Ma, respectively. The muscovite gives an age around 168 Ma. As for the wholerock K-Ar age in the Daday-Devrekani metasedimentary group, it determines an age of 169 Ma (Table 3). These data clearly show that an Early to Middle Jurassic metamorphism has affected these high- to medium-grade crustal metasediments. On the other hand, one can easily notice that the apparent ages of the amphiboles and muscovites are the oldest, and the biotites being slightly younger. There should be two explanations for such a context, either the crystallisation or neoformation, or the so-called argon loss until the blocking temperature is reached (Dodson, 1973; Purdy and Jager, 1976). Whatever the mechanism, the minimum temperature required is 400 to 450 °C. Such a temperature already corresponds to lower greenschist to upper epidote-amphibolite facies (Miyashiro, 1973). The younger biotite ages may thus be related to the temperature cooling after the metamorphic climax whose age is given by amphiboles and muscovites. Amphibole, extracted from OY-367 sample, is significantly older than the other amphiboles. It contains a small amount of diopside visible in thin section. As pyroxenes generally contain excess argon (Tougarinov, 1965); this result may be regarded as erroneous. In these conditions, the metamorphic climax should be set at the latest at the date defined by amphiboles and muscovites, or at a slightly older date, i.e. 170±10 Ma.

The Daday-Devrekani metasedimentary group is stratigraphically older than the Early Paleozoic as it is overlain by an Early to Medium Paleozoic fossiliferous anchimetamorphic to sedimentary sequence (Boztuğ, 1988, 1989a, 1992). Thus, the metamorphic event dated here at 170±10 Ma can not be the first structuration metamorphism. The K-Ar apparent ages of all HT minerals correspond to an argon total loss related to this secondary event, i.e. the Early to Middle Jurassic metamorphic episode.

Ilgaz Metasedimentary Group: The Ilgaz metasedimentary group consists of schists, phyllites and red argillites. Schists and red argillites were selected for the K-Ar geochronology. Schists yield some scattered ages ranging from 192 to 90 Ma both on muscovite and fine fractions (Table 3), however, most of the samples determine the Early Cretaceous age (see further). Apart from the schists in the Ilgaz metasedimentary group, a suite of red argillites have been sampled around Akkaya village, between Kastamonu and Tosya (84 MB 19 to 24) (see Fig. 2), for the K-Ar dating. Fine-grained fraction ages of these red argillites range from 166 to 147 Ma. The X-ray diffractograms show that the youngest samples display the worst crystallized illites. A possible interpretation of the apparent age variations is a partial loss of radiogenic argon related to this mineralogical partial alteration of the illites connected to the younger event (see further). Thus, a Middle Jurassic tectono-thermal event seems to be responsible for the neoformation of the fine-grained mineral association of the red argillites in the Ilgaz metasedimentary group.

Çangal Metaophiolite: The radiolarite and metabasite types of rocks of the Çangal metaophiolite yield some apparent K-Ar ages sometime around Early to Middle Jurassic, whereas the blue schists and orthophyllonites determine a clear Early Cretaceous age. Wholerock and fine-grained fraction K-Ar ages of four radiolarite sample, taken from the Araç district in Kastamonu region (Table 1), are widely scattered, from 180 to 137 Ma (Table 3). The mineralogy helps in understanding these data as the amount of interlayered minerals (illite-smectite and chlorite-smectite) is higher in the youngest samples, i.e. in the 84 MB 14 and 18 samples. This means that these samples were slightly weathered, and that their K-Ar apparent ages are no more geologically significant. In addition to the radiolarites, a metabasite sample from the Çangal metaophiolite has also been studied for the K-Ar dating (Table 1). The green hornblendes, extracted from this metabasite sample OY-475, has also yielded an age of 153 Ma, i.e. Middle Jurassic (Table 3). The most striking meaning of these data obtained from the Çangal metaophiolite that this Early to Middle Jurassic metamorphic episode must have been active after the ophiolite obduction, since it has affected already obducted ophiolitic slabs, both of the metabasites and initial epiophiolitic cover.

Börümce Formation (Jlb): The Lower Jurassic Börümce formation is made up of marly black shales, argillites, sandstones and siltstones. Among these lithologies, some argillites and sandstones have been analysed for the K-Ar geochronological study (Table 1). Detrital coarse muscovites, extracted from two sandstone samples in the Börümce formation, determine some old ages of 367 and 341 Ma (Table 3). These ages may be either the true age of detrital material of Variscan origin, or the partially reset ages of old muscovites, perhaps of Upper Precambrian origin. Some Variscan units are known around the region studied. They are the Arda granitoids in the South Bulgaria (Durand-Delga et al., 1988), the Sakar granitoids in the Rhodope massif in Greece (Ivanov, 1988), and other plutons in the eastern Pontides (Bergougnan, 1987). There are also some Precambrian medium to high-grade metasediments, containing muscovite minerals, just in the Daday-Devrekani massif (Yılmaz, 1980, 1981; Boztuğ, 1992), in the Bitlis massif (Yılmaz et al., 1981) and in the Apulo-Anatolian micro-continent. Then, such an origin is possible for these large detrital muscovite flakes in the sandstones of the Börümce formation. SEM observations of muscovite flakes show that these minerals are partially opened and fan out on their borders. This might have induced a partial isotopic opening up. Then, the more likely origin for the detrital muscovites present in the Börümce formation sandstones is to be tought in Precambrian rocks of the surrounding area. As for the K-Ar ages of the argillitic rocks of the Börümce formation, the oldest age has been obtained from the sample OE-90 which is of 243 Ma (Table 3). This age is also considered to reveal a significant contribution of detrital clays, or better, of detrital very small (finer than 2 m) muscovites or sericites. Other argillitic samples, e.g. samples OY-11, OY-12, OY-658, OY-662 all have the same conventional ages, nearly 170 Ma (Table 3). In a 40 Ar/36 Ar vs 40 K/ 36 Ar diagram, the fine-grained fractions of these four samples, sampled from the same location, define an isotopic line with the following characteristics: age is 169 ± 21 Ma (26), (40Ar/36Ar)o is 307 ± 33 (26) (Figure 3). Their age being younger than the time of deposition (170 Ma instead of ca 200 Ma) (Hay et al., 1987) is more likely to correspond to a diagenetic recrystallization, as indicated by the crystallinity index. Incidentially, this diagenetic event has exactly the same age as the diagenetic event recorded in the Upper Triassic and Early Jurassic of southeastern France (Bonhomme and Millot, 1987).

Kastamonu Granitoid Belt: The plutons of this belt intrude the Daday-Devrekani metasedimentary group, the Çangal metaophiolite, the Triassic limestones and the Börümce formation. It is therefore younger than 200 Ma. It is overlain by the Middle-Upper Jurassic conglomerate Muzrup formation. It is thus older than ca 160 Ma. The K-Ar isotopic ages of various minerals from the belt range from 267 to 134 Ma, however, most of the ages determine an age of approximately 170 Ma (Table 3). In particular, the muscovite of the pegmatite 84 MB 11 has an apparent age of 267 Ma. However, considered together, the muscovite-alkali feldspar pair of this sample yields an age of isotopic internal redistribution of 120 Ma, very close to the age of the high-pressure metamorphic episode (see further), similar to that of sample OY-350J (Table 3). The hornblendes, extracted from sample OY-336 show an age of 176 Ma. This age is nearly the same as that obtained from the amphiboles of the Daday-Devrekani metasedimentary group. Two biotite fractions, concentrated from the samples of

OY-336 and OY-349, also yield some ages similar to those of the biotites in the Daday-Devrekani metasedimentary group (Table 3). One can easily imagine that these two results are the consequence of a partial reset at ca 120 Ma of minerals which have already crystallized at ca 170 Ma. Then, the most probable age for the Kastamonu granitoid belt seems to be sometime around 170 Ma, in agreement with the stratigraphy.

Göynükdağı Contact Metamorphics: Two phyllites and one sericite schist samples (Table 1) from the Göynükdağı contact aureole have been analysed for the K-Ar ages. As seen from Table 3, the K-Ar ages of these contact aureole rocks determine some ages ranging from 180 to 245 Ma. These K-Ar ages have also been interpreted as the mixed ages due to inherited detrital very small micas (Boztuğ and Yılmaz, 1989b, 1991b), probably similar to that argillite sample OE-90 in the Börümce formation (see above). Thus, these types of inherited muscovites did not allowed for a precise dating of the contact metamorphism.

EARLY CRETACEOUS METAMORPHIC EPISODE

This metamorphic episode has been spectacularly noticed in the mylonitic and phyllonitic rocks derived from all the tectonostratigraphic units constituting the imbrication structure in the Daday-Devrekani massif and surroundings. Moreover, the finding of this metamorphic event in the glaucophane schists derived from the Çangal metaophiolite has evidently supplied that the Early Cretaceous metamorphism must have been a high-pressure dynamic metamorphism which can be induced by the collision or juxtaposition of different units. The Early Cretaceous K-Ar ages obtained from the dynamically metamorphosed rocks can be briefly summarized as follow.

Ultramylonites from the Daday-Devrekani Metasedimentary Group: Some parts of the Daday-Devrekani metasedimentary group apparently seems to be affected by the dynamic metamorphism which formed some ultramylonites along some shear zones (Yilmaz, 1979, 1980). Sample 84 MB 6 was taken from one of these shear zones within the gneisses of the Daday-Devrekani metasedimentary group (Table 1). The fine-grained fraction has been extracted from this sample which has given a K-Ar age of 107 Ma (Table 3). Despite careful sampling, the fine-grained fraction contains attapulgite, with some illites. SEM observation shows that this attapulgite is fibrous and stays in sample open fractures (Fig. 5). Attapulgite is generally poor in K2O content (Trauth, 1977). It occurs either as massive clay horizons deposited in magnesian sedimentation (Trauth, 1977; Thiry, 1981) or as a part of weathering related with calcrete and silcrete formations (Truc et al., 1985; Menillet, 1987). In the case of sample 84 MB 6, the field observations show that it obviously results from current weathering. Thus, its age must be very young. Therefore, by all means, the argon contribution of the attapulgite component is probably unsignificant as compared with that of the illite. The measured age, i.e. 107 Ma, is the illite's age. But, this illite must be regarded only as a residue of the original sample. Thus, its age has to be suspected of being lowered through argon partial loss, and is therefore only a minimum age for the shearing event.

Schists from the Ilgaz Metasedimentary Group: As pointed out earlier, the schists from the Ilgaz metasedimentary group mainly determine some early Cretaceous K-Ar ages. Four samples (84 MB 1 to 4), collected from the same outcrop (see Table 1), give some ages ranging from 137 to 115 Ma (Table 3). The fine-grained fraction mineralogy of these four particular samples shows that for a similar illite/chlorite repartition, the youngest sample is the more aluminous and the best crystallized, while the oldest is the more ferro-magnesian and the worst crystallized. This suggests a secondary transformation of the fine-grained fraction for a more aluminous and better crystallized illite type. This occurred either at nearly 116 Ma, if this transformation of sample 84 MB 2 was complete, or at less than 116 Ma, if this transformation was unable to reset sample 84 MB 2 completely.

Orthophyllonites and Glaucophane Schists from the Çangal Metaophiolite: The dynamically metamorphosed rocks of the Çangal metaophiolite display two types of formations, viz., (1) wide shear zones in which the original mineralogy is transformed into fine-grained phyllosilicates (Yılmaz, 1988), and (2) between the shear zones, more massive phacoid inliers, in which hornblende is progressively altered into glaucophane with tremolite-actinolite. Fine-grained fractions from these orthophyllonites, taken from the shear zones within the Çangal metaophiolite, were extracted for the K-Ar analysis (Table 1). K-Ar respective apparent ages range from 143 to 110 Ma (Table 3). On the other hand, only one sample, 84 MB 25, taken from the North Anatolian Fault Zone around Tosya town of Kastamonu city (Table 1), determines an age of 75 Ma (Table 3) (see further). One of the sampled metabasites from the more massive phacoid inlier within the the Çangal metaophiolite, sample VS-23, includes both the green amphiboles and glaucophanes (Table 1). In particular, the green hornblende-glaucophane suite of sample VS-23 was separated into four magnetic fractions (Table 1). K-Ar apparent age of green hornblende is of 109 Ma, whereas that of glaucophanes ranges from 114 to 107 Ma in this sample (Table 3). These K-Ar ages, clearly representing the Early Cretaceous time obtained from the sample VS-23, are, therefore, considered to be the age of the transformation of green hornblende into glaucophane under high-pressure metamorphic conditions. As the conventional K-Ar ages of both glaucophanes and some fine-grained fractions of the orthophyllonites are very close to each other, and as they appeared in the same conditions, it is concluded that both materials were altered or recrystallized enough to lose all previously accumulated radiogenic argon. However, some fine-grained fractions, and one analyzed wholerock sample were not completely reset, as they show apparent ages slightly or significantly older. This discussion leads to the conclusion that the Çangal metaophiolite was submitted to a high pressure event at nearly 120 Ma.

Mylonites from the Kastamonu Granitoid Belt: As mentioned earlier, the shear zones also cut through the plutons of the Kastamonu granitiod belt. A granitic mylonite sample, OY-350J has been taken from one of these shear zones within the Asarcık diorite (Table 1). Two fractions of hornblendes, extracted from this sample, determine the ages of 105 and 116 Ma (Table 3), clearly representing Early Cretaceous time for the mylonitization of diorites along shear zones which is definitely synchronous with the formation of the glaucophane schists. On the other hand, the K-feldspar minerals concentrated from sample 84 MB 11 pegmatite also yield an age of 134 Ma which may reflect high-pressure event. So that, the dynamic metamorphism of 120 Ma has caused either radiogenic argon loss and partial or total age reset, or local isotopic internal reequilibration as in sample 84 MB 11 in the plutons of the Kastamonu granitoid belt.

GEODYNAMIC DISCUSSION OF TWO METAMORPHIC EPISODES

The metamorphic event of Early to Middle Jurassic in age, affected the Daday-Devrekani metasedimentary group, Ilgaz metasedimentary group and Çangal metaophiolite, is synchronous with the cooling age of the Kastamonu granitod belt. Thus, this confirms that these two events can be regarded as geodynamically connected (Yılmaz and Boztuğ, 1986). The Kastamonu granitoid belt is regarded as a calk-alkaline suite formed by subduction- and collision-related magmatism induced by the northward subduction of the oceanic floor of the paleo-Tethys beneath the southern tip of Eurasia (Boztuğ et al., 1984; Yılmaz and Boztuğ, 1986; Boztuğ et al., 1995). At the same time, the Daday-Devrekani metasedimentary group, Ilgaz metasedimentary group and already obducted Çangal metaophiolite was submitted to a greenschist to epidote-amphibolite facies (LP/L-MT) metamorphism. Moreover, some plutons from the Kastamonu granitoid belt, e.g. the Asarcık diorite and Karaman microgranite, are exposed to intrude the already obducted ophiolitic slabs of the Çangal metaophiolite. Yılmaz and Boztuğ (1986) has suggested a special type of ophiolite obduction, i.e. something like the fingering type of obduction while the subduction was continuing and producing arc magmatism which was intruding the already obducted ophiolitic slabs by fingering type of obduction mechanism, to explain this geologic context. By taking care all these data one can suggest that the emplacement of the Asarcık diorite from the Kastamonu granitoid belt and synchronous Early to Middle Jurassic metamorphism can be related to a subduction-collisional event due particularly to the intruding of this dioritic pluton into the already subducted ophiolitic slab of Çangal metaophiolite. This imbrication system outcrops today as a whole after isostatic uplifting.

Regionally, ages of 170±10 Ma range were already determined in Greece and in Yugoslavia (Lanphere et al., 1975; Okrusch et al., 1978; Roddick et al., 1979). Most of these age determinations were performed by Rb-Sr and K-Ar methods on metamorphosed ophiolitic material, using mainly amphiboles, muscovites and paragonites. In the same way, a plagiogranite cutting through the ophiolitic suite near Lake Sevan in the Caucasus was dated at 168 ± 8 Ma, using K-Ar method on muscovite and biotite (Gasanov, 1979; in Bergougnan, 1987). Delaloye et al. (1982) has also pointed out a K-Ar biotite age of 162 Ma on the Gümüşhane granite in Northeastern Turkey which is exactly similar to that of other biotites of various units dated in the present work.

The second metamorphic episode, dated here at nearly 120 Ma, corresponds to a HP/LT dynamic metamorphic event. It should be related to compressional forces which may be induced by the later stages of the collision, i.e. the juxtaposition of Pontides and Anatolides. Although collision and shearing are generally not contemporaneous, the K-Ar ages obtained in the Daday-Devrekani massif and surrounding in Kastamonu region give the same result for both metamorphic minerals (glaucophanes) and shearing zone material.

Another expression of this shearing component is the North Anatolian Transform Fault which limits to the south the studied area (Şengör, 1979), and which is still active today. A sample (84 MB 25) was collected from this mylonitic system just in the south of the Tosya town of Kastamonu city (Figs. 1, 2, Table 1). The K-Ar age of fine-grained fraction of this sample is 75 Ma (Table 3). This age corresponds to the cooling of nearly 200 °C, as the fine-grained fraction is constituted of diagenetic illite. This date is, thus, the time at which this particular structure cooled down under the limit of 200 °C.

During the time interval from 120 to 75 Ma, i.e. from the Early Cretaceous to the Maastrichtian, no sedimentary record is known in the studied area. This might suggest that the shearing event was going on along the North Anatolian Transform Fault Zone under relatively hot conditions, during the duration of nearly 50 Ma.

As a concluding remark, the K-Ar geochronology studies have distinguished two different metamorphic episodes in the Daday-Devrekani massif and surroundings in the Kastamonu region of Northern Turkey. One of them is related to subduction-collision dated back at 170±10 Ma. The second metamorphic event is of a high-pressure type of metamorphism, i.e. dynamic metamorphism, occurred at 120 ±10 Ma which is thought to be related to the final stages of the collision, i.e. the juxtaposition stage. Shearing began immediately after and lasted under hot conditions until 75 Ma. Finally, from 75 Ma ago until present time, the geodynamic setting moved to a purely sliding system. Such being the case, this event succession suggests that the collisional angle between the two micro-plates North and South of the future North Anatolian Transform Fault Zone decreased progressively to generate first a subduction-collision system, then a juxtapositional system, and finally, after shearing, a pure sliding system.

CONCLUSIONS AND SUGGESTIONS

The geological, mineralogical-petrographical and geochemical-petrological stüdies, already carried out by various authors, basically by the first two authors of this paper in the Daday-Devrekani massif and surroundings in the central-western Pontides since 1977, have concluded that there are different metamorphic units metamorphosed under different conditions in different geodynamic environments during different times. After these results, some absolute age datings are needed to clarify some of these metamorphic events. Therefore, some K-Ar isotopic datings have been performed to get the absolute ages of the young tectono-thermal events, i.e. late metamorphic episodes in the Daday-Devrekani massif and surroundings in central-western Pontides. These K-Ar datings have revealed that there were two metamorphic episodes in this region. The first dated metamorphic event is a lower greenschist to epidote amphibolite facies metamorphism at 170±10 Ma. It involves almost all the tectonostratigraphic units constituting the imbrication structure in the Daday-Devrekani massif. The cooling age of the Kastamonu granitoid belt is also synchronous with this metamorphic episode. The second metamorphic event is a high-pressure, relatively low-temperature event at 120±10 Ma. The fine-grained fractions newly formed in the accompanying shearing zones are of the same age. From a geodynamic point of view, it seems that the whole structure played first a subduction-collison system at 170 Ma, then as a high pressure sytem due to juxtaposition at 120 Ma, and, finally, as a purely sliding system since 75 Ma.

In addition the K-Ar datings presented here, some other absolute age datings such as Rb-Sr, Nd-Sm and Ar40/Ar39 techniques are suggested to carry out to get the initial metamorphic ages and later polymetamorphic episodes in the Daday-Devrekani massif and surroundings in the central-western Pontides in northern Turkey.

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REFERENCES

Adamia, S.A., Bergougnan, H., Fourquin, C., Haghipour, C., Lordkipanidze, M.D., Özgül, N., Ricou, L.E. and Zakariadze, G.S., 1980, The Alpine Middle East between the Aegean and Oman traverses: International Geol. Congr., 26 th, Colloque C5, Geology of the Alpine Chains Born of tethys: Mém. du BRGM, no. 115, p. 122-136, Paris.

Ataman, G., Yılmaz, O. and Ertürk, O., 1977, Diyajenez-ankimetamorfizma geçişinin illit kristallik derecesi ile araştırılması (Batı Pontidlerde bir deneme). Yerbilimleri, 3, 1-2, 145-160, Ankara.

Bergougnan, H., 1987, Etudes géologiques dans l'est Anatolien. Thése d'Etat, Univ. Pierre et Marie Curie, Paris 6, 606 p.

Bonhomme, M.G. and Millot, G., 1987, Diagénése généralisée du Jurassique moyen (170-160 Ma) dans le bassin du Rhone inférieur jusqu a la bordure des Cévennes, France. Datations K-Ar d'argiles du Trias et du Lias inférieur. C.R. Acad. Sci., Paris, t. 304, Série, II, no. 9, 431-434.

Bonhomme, M.G. and Yılmaz, O., 1984, First K-Ar data from the Daday-Devrekani and Ilgaz massifs and the Kastamonu granitoid belt, northern Turkey. Terra Cognita, 4, 2, 199-200.

Boztuğ, D., 1983, Daday-Devrekani masifi kuzeyindeki Büyükçay-Elmalıçay granitik sokulumu. Yüksek Müh. Tezi, Hacettepe İniv., Ankara, 149 p, (yayınlanmamış).

Boztuğ, D., 1987, Petrology of spotted rocks from the Göynükdağı contact aureole, Kastamonu province, northern Turkey. EUG-IV, 13-16 April 1987, Strasbourg-France, Progr. Suppl., p.13.

Boztuğ, D., 1988, Daday-Devrekani masifi güneybatı kesiminin mineralojik-petrografik ve jeokimyasal incelenmesi. Doktora Tezi, Hacettepe İniv., Ankara, 232 s., (yayınlanmamış).

Boztuğ, D., 1989a, Alt-Orta Paleozoyik yaşlı Samatlar grubu (Karadere-Araç/Kastamonu) ve Mesozoyik örtüsünün kil mineralojisi ve vitrinit yansıması yöntemleriyle incelenmesi. IV. Ulusal Kil Sempozyumu Bildiriler Kitabı, Cumhuriyet Üniversitesi, Sivas, 147-173.

Boztuğ, D., 1989b, Clay mineralogy and vitrinite reflectance of the Paleozoic and Mesozoic shales forming the epicontinental cover of Eurasian plate in Kastamonu region, western Pontides, Turkey. Terra Abstracts, 1, 311.

Boztuğ, D., 1992, Lithostratigraphic units and tectonics of the southwestern part of the Daday-Devrekani massive, Western Pontides, Turkey. Bull. Of the Mineral research and Exploration, Ankara, 114, 1-22.

Boztuğ, D., Debon, F., Le Fort, P. and Yılmaz, O., 1984, Geochemical characteristics of some plutons from the kastamonu granitoid belt, northern Anatolia, Turkey. Schweiz. Mineral. Petrogr. Mitt., 64, 389-403.

Boztuğ, D. and Yılmaz, O., 1983, Büyükçay-Elmalıçay granitoyidi (Kastamonu) ve çevre kayaçlarının mineralojik-petrografik ve jeokimyasal incelenmesi. Yerbilimleri, 10, 71-88.

Boztuğ, D. and Yılmaz, O., 1985, Göynükdağı (Kastamonu) yöresinde benzer görünümlü Jura ve Kretase yaşlı birimlerin kil mineralojisi ve illit kristallik derecesi yöntemiyle incelenmesi. II. Ulusal Kil Sempozyumu Bildiriler Kitabı, Hacettepe İniv., Ankara, 27-38.

Boztuğ, D. and Yılmaz, O., 1987, Distinction of the Jurassic and Cretaceous formations by means of clay minerals in Göynükdağı-Kastamonu area, northern Turkey. EUG-IV, April 13-16, 1987, Strasbourg-France, Progr. Suppl., p.15.

Boztuğ, D. and Yılmaz, O., 1989, First K-Ar results of the Göynükdağ contact aureole, Kastamonu region, Western Pontides, Turkey: A mixed age due to inherited muscovite. Terra Abstracts, 1, 354.

Boztuğ, D. and Yılmaz, O., 1991a, Metamorphism and geological evolution of the southwestern part of Daday-Devrekani massif, Western Pontides, Kastamonu province, Turkey. Terra Abstracts, 3, 323.

Boztuğ, D. and Yılmaz, O., 1991b, K-Ar geochronology of the fine fractions from the Göynükdağı contact aureole: A mixed age due to inherited muscovite, Kastamonu, North Turkey. Mahmut sayın Clay Minerals Symposium, Proceedings, 2-4 may 1991, University of Çukurova, Adana, 74-86.

Boztuğ, D. ve Yılmaz, O., 1995, Daday-Devrekani masifi metamorfizması ve jeolojik evrimi, Kastamonu bölgesi, Batı Pontidler, Türkiye. Türkiye Jeoloji Bülteni, 38/1, 33-52.

Boztuğ, D., Debon, F., Le Fort, P. and Yılmaz, O., 1995, High compositional diversity of the Middle Jurassic Kastamonu plutonic belt (Northern Anatolia, Türkiye). Turkish Journal of Earth Sciences, 4, 67-86.

Delaloye, M., Çoğulu, E, and Chessex, R., 1982, Etude géochronométrique des massifs cristallines de Rize et de Gümüşhane, Pontides orientales, Turquie. C.R. Soc. Phys. Hist. Nat. Genéve, 7, 43-52.

Dodson, M.H., 1973, Closure temperature in cooling geochronological and petrological systems. Contrib. Min. Petrol., 40, 259-274.

Durand-Delga, M., Clément, B. and Ferriére, J., 1988, Compte-rendu de la reunion extraordinaire de la Société géologique de France en Bulgarie, 16-27 September 1985, Bull. Soc. Géol. France, t. 4, no. 2, 201-225.

Hag, B.U., Hardenbol, J. and Vail, P.R., 1987, Chronology of fluctuating sea levels since the Triassic. Science, 235, 1156-1167.

Ivanov, Z., 1988, General framework of the Rhodope massif geological and structural development in the Balkanides setting. Bull. Soc. Géol. France, t. 4, no. 2, 227-240.

Ketin, İ., 1966, Anadolu'nun tektonik birlikleri. MTA Dergisi, 66, 20-34.

Lanphere, M.A., Coleman, R.G., Karamata, S. and Pamic, J., 1975, Age of amphibolites associated with Alpine peridotite in the Dinaride ophiolite zone, Yugoslavia. Earth Planet. Sci., Letters, 26, 271-276.

Mahood, G.A. and Drake, R.E., 1982, K-Ar dating of young volcanic rocks: A case study of the Sierra La Primavera, Jalisco, Mexico. Geol. Soc. Amer. Bull., 93, 1232-1241.

Menillet, F., 1987, Les meuliéres du bassin de Paris, France et les faciés associés. Thése d'Etat, Univ. Lois-Pasteur, Strasbourg, 536 p.

Miyashiro, A., 1973, Metamorphism and metamorphic belts. George Allen and Unwin Ltd., London, 492 p.

Odin, G.S., 1982, Numerical dating in stratigraphy. Wiley, New York, 1041 p.

Okrusch, M., Seidel, H., Kreuzer, H. and Harre, W., 1978, Two types of island arc tholeiites in Japan. Earth Planet. Sci., Letters, 39, 291-297.

Palmer, A.R., 1983, Geologic time scale. Geology, 11, 503-504.

Purdy, J.W. and J(ger, E., 1976, K-Ar ages on rock-forming minerals from the Central Alps. Mem. Inst. Geol. Mineral. Univ. Padova, Vol. 30, 32 p.

Roddick, J.C., Cameron, W.E. and Smith, A.G., 1979, Permo-Triassic and Jurassic Ar40/Ar39 from Greek ophiolites and associated rocks. Nature, 279, No.5716, 788-790.

Steiger, R.M. and J(ger, E., 1977, Subcommission on geochronology: Convention on the use of decay constants in geo- and cosmochronology. Earth Planet. Sci., Letters, 36, 359-362.

Şengör, A.M.C., 1979, The North Anatolian transform fault: Its age, offset and tectonic significance. Jl. Geol. Soc., London, 136, 269-282.

Şengör, A.M.C., Yılmaz, Y and Ketin, İ., 1980, Remnants of a pre-Late Jurassic ocean in northern Turkey: Fragments of Permian-Triassic paleo-Tethys?. Geol. Soc. Amer. Bull., 91, 599-609.

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

Şengün, M., Keskin, H., Akçören, F., Altun, İ., Sevin, M. Akat, U., Arman, F. and Acar, Ş., 1990, Kastamonu yöresinin jeolojisi ve paleo-tetisin evrimine ilişkin sınırlamalar. Türkiye Jeoloji Bülteni, 33, 1-16.

Thiry, M., 1981, Sédimentation continentale et altération associés: Calcitisations, ferruginisations et silicifications. Les argillites plastique du Sparnacian du bassin de Paris. Sci. Géol. Mém. 64, Strasbourg, 173 p.

Tougarinov, A.I., 1965, The geological age of the ancient formations of the USSR based on the comparative Pb-U and K-Ar age determinations. In Géochronologie Absolue, Colloque CNRS, No. 151, 205-208.

Trauth, N., 1977, Argiles évaporitiques dans la sédimentation carbonatée continentale et épicontinentale Tertiaire. Bassins de Paris, de Mormoiron et de Salinelles, France et Jbel Ghassoul, Maroc. Sci. Géol. Mem. 49, Strasbourg, 195p.

Truc, G., Triat, J. M., Sassi, S., Paquet, M., and Millot, G., 1985, Caractéres généraux de l'épigénie carbonatée de surface, par l'altération météorologique lieé a la pédogenése et par l'alteration sous converture lieé a la diagenése. C. R. Acad. Sci., Paris, t. 300, serie 2, No. 7, 283-290.

Williamson, J.M., 1968, Least-squares fitting of a straith line. Can. J. Phys., 46, 1845-1847.

Yılmaz, O., 1979, Daday-Devrekani masifi kuzeydoğu kesimi metamorfitleri. Doç. Tezi, Hacettepe İniv., Ankara, 243 s., (yayınlanmamış).

Yılmaz, O., 1980, Daday-Devrekani masifi kuzeydoğu kesimi litostratigrafi birimleri ve tektoniği. Yerbilim leri, 5-6, 101-135.

Yılmaz, O., 1981, Daday-Devrekani masifi Ebrek metamorfitinin petrografisi ve tümkayaç kimyası. Yerbilimleri, 8, 71-82.

Yılmaz, O., 1983a, Çangal metaofiyolitinin mineralojik-petrografik incelenmesi ve metamorfizma koşulları. Yerbilimleri, 10, 45-58.

Yılmaz, O., 1983b, Mineralogical-petrographical study of the Çangal metaophiolite and its metamorphism conditions. In Ophiolites: Oceanic Tectonics and Metamorphism, Meeting of Working Group on Mediterranean Ophiolites, 2nd, Florence, Italy, Ofioliti, 8, (suppl.), p.67.

Yılmaz, O., 1984, Petrography and wholerock chemistry of the Precambrian(?) Daday-Devrekani metasedimentary group (Province of Kastamonu, Turkey). Intern. Geol. Congr., 27th, Moscow, Abstracts, 2, p. 409.

Yılmaz, O., 1988, L'ensemble ophilitique de Çangal, Turquie du Nord: mise en évidence d'un métamorphisme océanique et d'un rétrométamorphism cataclastique tardif. Géologie Alpine, 64, 113-132, Grenoble.

Yılmaz, O. ve Boztuğ, D., 1984, İllitin kristallik derecesi yöntemiyle Büyükçay-Elmalıçay granitik sokulumundaki dokanak (kontakt) metamorfizmasının incelenmesi. Doğa Bilim Dergisi, B-8, 3, 261-268.

Yılmaz, O. and Boztuğ, D., 1985, Göynükdağı metamorfiti. TUBİTAK Projesi Raporu, TBAG-569, 121 s., 1 Ek, (yayınlanmamış), Ankara.

Yılmaz, O. ve Boztuğ, D., 1986, Kastamonu granitoid belt of northern Turkey: First arc plutonism product related to the subduction of the Paleo-Tethys. Geology, 14, 179-183.

Yılmaz, O. ve Boztuğ, D., 1987a, Göynükdağı (Kastamonu) yöresinin jeolojik ve mineralojik-petrografik incelenmesi. Doğa TU Müh. Çev. Dergisi, 11,1, 91-114.

Yılmaz, O and Boztuğ, D., 1987b, Petrography, petrochemistry and solidification sequences of the Ağlı pluton from the Kastamonu granitoid belt, northern Turkey. Yerbilimleri, 14, 91-107.

Yılmaz, O., Michel, R., Vialette, Y. and Bonhomme, M.G., 1981, Réinterprétation des données isotopique Rb-Sr obtenues sur le métamorphites de la partie méridionale du massif de Bitlis, Turquie. Sci., Géol. Bull., 34, 59-73, Strasbourg.

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