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SUMMARY: North-west Turkey encompasses two major tectonic units, the Pontides and the Anatolides, separated by the İzmir-Erzincan suture. The Anatolides, the metamorphosed northern extension of the Taurides, consist of several zones. The more southerly Afyon Zone is an Early Palaeozoic to Maastrichtian Tauride shelf-type sequence which rests on gneisses of the Menderes Massif. The Afyon Zone underwent greenschist facies metamorphism, gradually increasing in grade with depth, and overthrust by HP/LT metamorphic rocks and peridotites. A HP/LT metamorphic belt several hundred kilometres long constitutes the second Anatolide zone. There are two tectonic units in the blueschist sequence. A lower more recrystallised blueschist unit consists of a thick basal marble series overlain by meta-cherts, metabasites and meta-shales. An upper unit, with a wider distribution, shows only incipient HP/LT metamorphism, and consists of shales, radiolarian cherts, basic volcanic rocks, pelagic limestones and greywackes. The HP/LT rocks are tectonically overlain by a peridotite nappe, without HP/LT metamorphism. Steeply dipping major faults separate blueschists from the Inner Pontide sequence, which consists of a Permian-Triassic metamorphic basement overlain by carbonates and Upper Cretaceous flysch. Especially in the Ankara region, Upper Cretaceous flysch contains abundant ophiolitic olistoliths. Post-orogenic Palaeocene sediments are transgressive over the HP/LT metamorphic belt and the peridotite nappe. The blueschist sequence may have been the north-facing Anatolide/Tauride platform margin, subducted during the Late Cretaceous. Very fast uplift in the collision zone, aided by buoyancy of subducted continental crust, generated olistostromes in the Pontides and emplaced peridotite nappes over the Anatolide/Tauride platform.

The Alpine mountain chain was created by the collision of Eurasia and Gondwana during the Late Mesozoic and Tertiary. A broad zone of collision of the two megacontinents extends from the Apennines in Italy to the Taurides and Pontides in Turkey. This zone is marked by a pile of nappes, ophiolites, pelagic sediments and HP/LT metamorphic rocks. Regionally important HP/LT metamorphic provinces occur in three different parts of the Alpine chain: Western Alps, Cyclades in Greece and north-west Turkey. The aim of this paper is to give a general description of the least known of the three HP/LT metamorphic provinces. Long-standing problems of the formation and uplift of blueschists and the processes in collision zones are discussed in a regional geological framework. The description is based on the recent literature plus the author's own field-work, which together provide a general picture of much of north-west Turkey.

Geological setting

Major sutures can often be recognised by tectonic juxtaposition across narrow ophiolite zones of totally differing stratigraphies and faunal provinces. The suture representing the major oceanic area between Eurasia and Gondwana during the Mesozoic, and probably earlier, can safely be placed in Turkey in the İzmir-Ankara-Erzincan Zone (İzmir-Erzincan suture). During the Mesozoic, apart from a major İzmir-Erzincan ocean, there were also minor oceanic basins, for example separating the Apulia-Tauride microplate from Gondwana (Biju-Duval *et al.* 1977). However, these were narrow areas of oceanic crust probably of short duration, and the resulting microcontinents can be assigned to one of the megacontinents.

The İzmir-Erzincan suture divides Turkey into two major units: to the north the Pontides, and to the south the Taurides, and their metamorphosed equivalents, the Anatolides (Figs 1, 2 Ketin 1966). The İzmir-Ankara-Erzincan Zone of Brinkmann (1966) is a regional depression, where ultramafic and HP/LT metamorphic rocks, lying tectonically over the Anatolides, were preserved from erosion.

Palaeogeographically, the area south of the İzmir-Erzincan suture belongs to the Anatolide-Tauride Platform (Şengör 1979), which was linked to Gondwana. During the Mesozoic the area was a wide Bahamian-type continental platform (Bernoulli & Laubscher 1972). The Eurasian realm to the north of the İzmir-Erzincan suture was tectonically more active

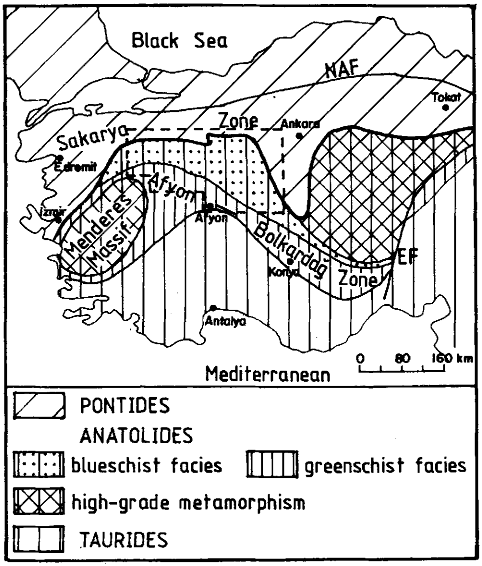

FIG. 1. Major tectonic units of western and central Turkey; only the Anatolide zones are differentiated. Area of Fig. 2 is indicated by dashed lines. NAF, North Anatolian Fault; EF, Ecemiş Fault.

during the Mesozoic, and characterized by important clastic sedimentation and basic volcanism (Fourquin 1975; Bergougnan & Fourquin 1980). North-west Turkey encompasses areas belonging to the Eurasian, the Sakarya Zone of the Pontides, and Gondwana realms, the Afyon Zone of the Anatolides, and with pelagic sediments, volcanic and ultramafic rocks recording an oceanic area separating the two continents.

Afyon Zone (Anatolides)

The Afyon Zone is a typical shelf-type Palaeozoic-Mesozoic sequence of the Taurides (Fig. 4). It covers large areas in Central Anatolia and extends as far east as the Bolkardağ region (Fig. 1); to the west it forms the cover of the gneisses of the Menderes Massif. The Afyon Zone can be correlated with the Bolkardağ Unit of Özgül (1976). Low-grade regional metamorphism, as well as its internal structural setting, places the Afyon Zone in the Anatolides (Ketin 1966).

At the base of the Afyon Zone is a thick sequence (>1500 m) of meta-sandstones, meta-siltstones and meta-quartzites with rare metabasite and recrystallised limestone horizons. Although the sequence is sparsely fossiliferous, Devonian fossils are found in the basal part of the clastic sequence in the Ilgın region

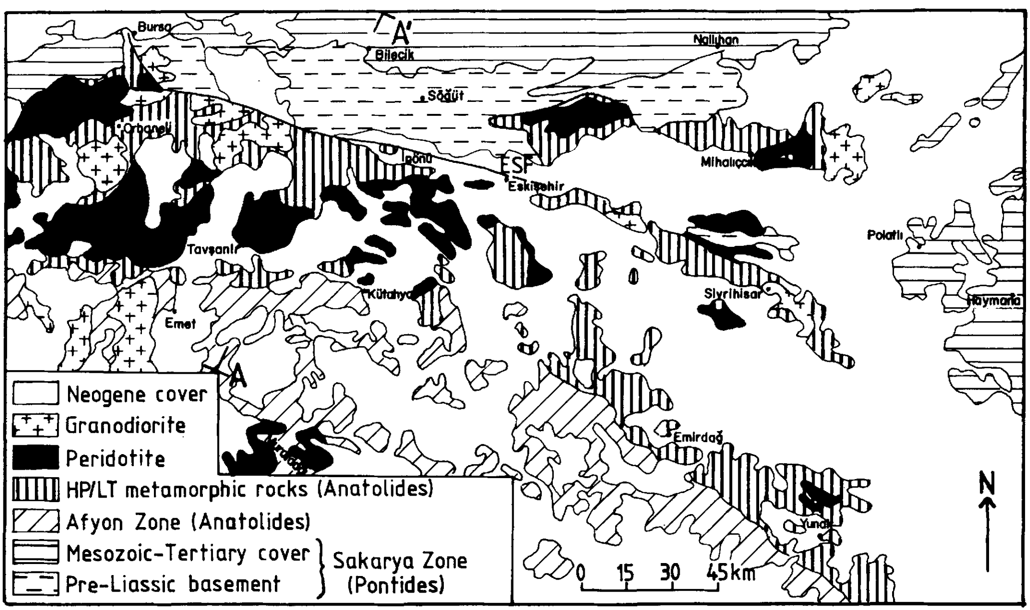

FIG. 2. Geotectonic map of north-west Turkey showing the tectonic units discussed in the text. ESF, Eskişehir Fault.

north of Konya (Niehoff 1964). The metaclastics pass up gradually into dark grey recrystallized limestones, which have yielded Carboniferous to Upper Permian fusulinids in the Afyon region (Erişen 1972). The Triassic sequence starts with a basal meta-conglomerate, consisting of meta-sandstones, meta-siltstones and intercalated algal limestones. The rest of the Mesozoic is represented by a thick sequence of platform carbonates, which extend to Maastrichtian (Fig. 4). The carbonates are locally overlain by an Upper Maastrichtian to Palaeocene 'wildflysch' comprising Permian, Jurassic and Cretaceous limestone olistoliths (Akdeniz & Konak, 1979; Konak, 1982). A strongly tectonised volcano-sedimentary complex with incipient HP/LT metamorphism and a periodotite nappe, lies tectonically over the carbonates and flysch (Fig. 3).

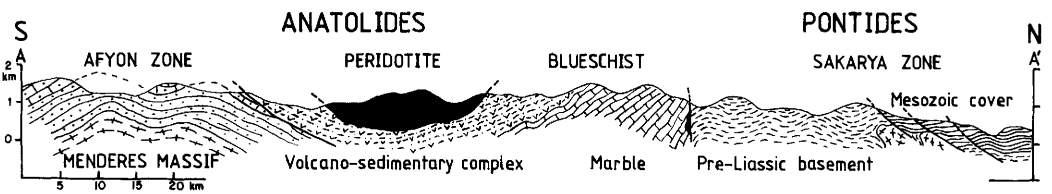

FIG. 3. Simplified structural section across north-west Turkey. The internal imbrication and faulting in the Afyon Zone and in the blueschist sequence are not shown. Line of section shown in Fig. 2 as A-A′.

Associated with the tectonic emplacement of the peridotites, the Afyon Zone was internally sliced and imbricated in post-Palaeocene time. South of İzmir the Mesozoic lithologies of the Afyon Zone rest directly on the gneisses of the Menderes Massif with a thin intervening tectonic slice of Palaeocene flysch (Başarır & Konak 1981). However, in some areas the thick basal clastic sequence of the Afyon Zone passes downward without tectonic break into the gneisses of the Menderes Massif. It seems likely that the gneisses of the Menderes Massif represent old (?Pan-African) metamorphic basement on which Palaeozoic and Mesozoic sequence of the Afyon Zone were deposited prior to the Alpine regional metamorphism (Dürr *et al.* 1978). The low-grade greenschist facies metamorphism, which has affected the Afyon Zone, shows a progressive increase in grade towards the deeper levels of the sequence. The Palaeozoic meta-clastics have the characteristic mineral assemblage: quartz + albite + phengite + chlorite ± biotite, whereas the Mesozoic carbonates and the flysch are little affected by the metamorphism and the carbonates are commonly fossiliferous.

HP/LT metamorphic belt (Anatolides)

Rocks affected by HP/LT metamorphism occupy an elongate WNW-ESE area in north-west Turkey, extending for over 350 km from the region of Orhaneli eastward to Yunak (Figs 1 & 2). The width of the blueschist belt increases towards the east: in the Tavşanlı region blueschists are 50 km wide; in the east the width of the blueschist belt is of the order of 100–130 km. The eastward extension of the blueschist belt is abruptly terminated by a poorly defined NNW-SSE trending major fault, which juxtaposes blueschists and the Upper Mesozoic-Tertiary sedimentary sequence of the Haymana basin (Fig. 2). Farther southeast, north of Konya (Bayiç 1968) and in the Bolkardağ region (Blumenthal 1955; Çalapkulu 1980) sodic amphibole-bearing meta-volcanic rocks are intercalated with recrystallized limestones and psammitic schists. It is not known whether they represent the southeastward continuation of the north-west Turkish blueschist belt or whether they are part of the Afyon Zone, which has undergone a high-pressure greenschist facies metamorphism in these regions.

In the south, rocks affected by the HP/LT metamorphism rest with a tectonic contact on the carbonates and flysch of the Afyon Zone. In the north, steeply-dipping faults juxtapose blueschists with the pre-Liassic basement of the Pontide sequence. The important Eskişehir fault (Fig. 2), marked by extensive brecciation and serpentinite lenses (Okay 1980c), is also characterized by sharp changes in gravity and magnetic anomalies. In a few places, such as south of Bursa (Lisenbee 1971), the basement rocks of the Pontide sequence lie with a low-angle tectonic contact over the blueschists. Blueschists are tectonically overlain by a peridotite nappe, which is now largely preserved in the regional depression between Bursa and Eskişehir.

Most of the rocks affected by the HP/LT metamorphism in north-west Turkey consist of

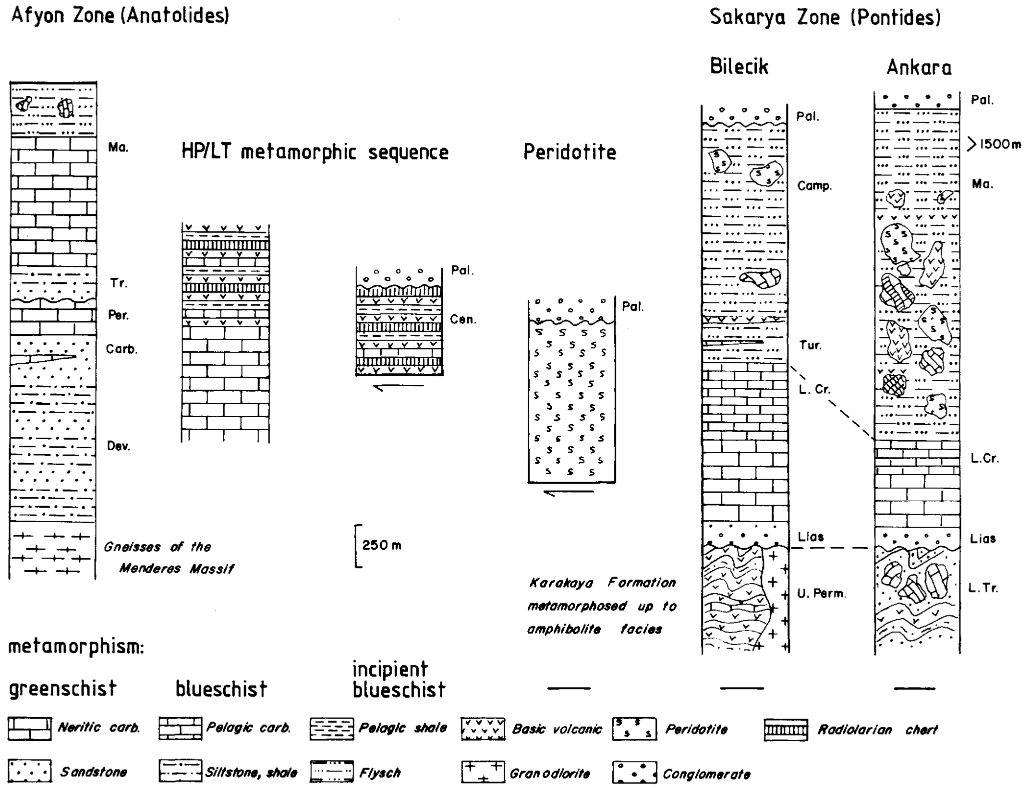

FIG. 4. Generalized synthetic stratigraphic sections of the tectonic units of north-west Turkey. The thicknesses of the HP/LT metamorphic sequences are very approximate. Dev., Devonian; Carb., Carboniferous; Per., Permian; Tr., Trias; Cr., Cretaceous; Cen., Cenomanian; Tur., Turonian; Camp., Campanian; Ma., Maastrichtian; Pal., Palaeocene; U., Upper; L., Lower.

a strongly tectonised volcano-sedimentary complex, which appears to be unmetamorphosed in the field but on careful examination reveals an incipient HP/LT metamorphism (Okay 1982). Completely recrystallized, schistose blueschists make up 30–40% of the 'blueschist' terrain. In this respect resemblance is striking to the Franciscan terrain in California, where most rocks also appear to be unmetamorphosed.

Incipiently metamorphosed volcano-sedimentary complex

These rocks occur as steeply-dipping imbricate slices underneath massive peridotites. They lie tectonically over the carbonates and the flysch of the Afyon Zone, or over the true blueschists. The rock-types in decreasing order of abundance are: pyroclastics, basic volcanic rocks, red and green pelagic shales, radiolarian cherts, pelagic limestones, greywackes, syn-sedimentary breccias, manganese deposits, keratophyres and neritic limestone olistoliths (Kaya 1972; Okay 1982). Penetrative deformation is absent in the sequence, and the rocks appear to be unmetamorphosed in the field. The characteristic feature of this complex is the close and repeated sedimentary intercalation of different rock types: a typical spilite-shale-chert sequence, for example, can occur 3–4 times over a 100 m wide section (Okay 1981, Fig. 4). Talc and serpentinite outcrops of various sizes mark numerous thrusts in the volcano-sedimentary complex. Tectonic slices of greenschist-facies metabasites are found in the volcano-sedimentary complex in the Tavşanlı region (Okay 1982). Much of the strong tectonism affecting this sequence was probably related to the emplacement of the peridotite nappe, and clearly post-dates HP/LT metamorphism.

Because of the strong tectonism, the thickness of the volcano-sedimentary complex is difficult to estimate. Minimum thicknesses range from 160 metres in the Orhaneli area (Lisenbee 1971) to 250 metres in the Tavşanlı area. Data on the age of deposition of the complex is sparse; pelagic limestones from the Muratdağı (Bingöl 1977) and east of Gediz (Akdeniz & Konak 1979) yield Cenomanian ages. Servais (1981) assigns a tentative Late Jurassic–Early Cretaceous age to the radiolarian cherts from the volcano-sedimentary complex south of İnönü.

A notable feature of this volcano-sedimentary complex is the presence of HP/LT minerals such as lawsonite and aragonite in the veins and amygdales in the volcanic rocks; calcite in pelagic limestones is recrystallized to coarse grains of aragonite. Associated with this incipient HP/LT metamorphism there has been extensive sodium metasomatism involving topotactic replacement of augite by sodic pyroxene in the volcanic rocks. The metamorphic conditons are estimated at 5–8 kb and 250–300°C (Okay 1982).

Blueschists

The rock types are similar to the volcano-sedimentary complex except that there is a thick basal marble unit but no ultramafic rocks.

White massive and locally cherty marble usually occurs as a several kilometre-thick unit beneath intercalated metabasites, meta-cherts and meta-shales. The contact between the marble and the meta-volcano-sedimentary sequence is primary as marble horizons and blocks are observed in the meta-volcano-sedimentary sequence near the marble contact (Çoğulu 1967; Yeniyol 1979; Okay 1980a, c). In some areas, such as in the Sivrihisar region, marble also occurs as several hundred metre-thick horizons within metabasites and meta-cherts. A foliation is generally well developed in all rock types in the glaucophane-lawsonite and glaucophane-epidote zones, where it is defined by the parallel orientation of mica and sodic amphibole grains. At least two phases of isoclinal folding are present in the glaucophane-lawsonite zone rocks (Okay 1980c). The thickness of the blueschist unit is difficult to estimate because of intense folding; apparent thicknesses of the meta-volcano-sedimentary sequence are ca. 1000–1500 m.

Lawsonite, glaucophane-lawsonite and glaucophane-epidote zones have been mapped in various parts of the Northwest Turkish blueschist belt (Çoğulu 1967; Okay 1980a, b; Kulaksız 1981). Typical mineral assemblages in the metabasites and meta-cherts from the Tavşanlı region are shown in Table 1. A characteristic feature of the north-west Turkish blueschists is the prograde nature of the mineral assemblages. The rocks generally do not exhibit the retrograde textures and minerals common in other terrains, so that prograde stages of metamorphism can easily be distinguished. The HP/LT metamorphism in north-west Turkey is characterized by an initial static metamorphic event with the development of a lawsonite + sodic pyroxene + chlorite assemblage in the basic volcanic rocks, where sodic pyroxene is pseudomorphous after augite. At this lawsonite zone stage the primary igneous texture was largely retained (Çoğulu 1967; Okay 1980b). This static recrystallization was followed by a second metamorphic event associated with the onset of penetrative deformation. Sodic amphibole formed at the expense of sodic pyroxene and chlorite during this second metamorphic phase. A late greenschist overprint, with development of epidote and calcic amphibole, is reported from the Mihaliççık (Çoğulu 1967) and Sivrihisar (Kulaksız 1981) areas.

Çoğulu and Krummenacher (1967) dated blueschists from the Mihaliççık region by the K/Ar method: phengites from two glaucophane schists gave ages of 65 and 82Ma. An upper age of blueschist metamorphism is given by Middle Palaeocene sediments unconformably overlying the volcano-sedimentary complex and peridotite in the Yunak (Yeniyol 1979) and Emirdağ (Umman & Yergök 1979) areas. Lower and Middle Eocene conglomerates and limestones are also transgressive over the peridotite and blueschist in the Tavşanlı, Yunak (Yeniyol 1979) and Simav (Akdeniz & Konak 1979) areas. Thus, the age of blueschist metamorphism is constrained to lie between Cenomanian and Middle Palaeocene. A further age constraint is given by abundant blueschist detritus in the Upper Campanian flysch of the Haymana basin (Batman 1978).

Eclogites

Eclogites are reported from the Mihaliççık and Sivrihisar areas. In the Mihaliççık region the supposed eclogites occur as tectonic inclusions in peridotite. However, chemical analysis of the eclogite (Çoğulu 1967) suggests that it may be an andradite-hedenbergite skarn rather than a true eclogite. In the Sivrihisar area, garnet-omphacite eclogites with minor glaucophane occur as small blocks along a major fault within the glaucophane-lawsonite zone blueschists (Kulaksız 1978).

Peridotite nappe

Peridotite forming the highest tectonic unit over both the blueschists and the low-grade

TABLE 1. *Progressive mineral changes in the Tavşanlı area, north-west Turkey (double lines, major (20%) mineral; single lines, minor mineral; dashed lines, sporadic occurrence)*

Metamorphic Zones	Incipient Metamorphism	Lawsonite Zone	Glaucophane-lawsonite Zone	
rock / mineral	Basic volcanic rocks			Chert
Sodic amphibole		dashed	double	single
Lawsonite	dashed	double	double	single
Sodic pyroxene	single	double	single	
Chlorite	double	double	single	dashed
Albite	double			
Quartz	dashed	dashed	dashed	double
Phengite		single		single
Alm. garnet			dashed	
Spess. garnet				single
Pumpellyite	single			
Epidote			dashed	
Sphene		single	single	
Magnetite			dashed	
Hematite			dashed	single
Aragonite	dashed	dashed	dashed	
Relict augite	double	dashed		

metamorphic rocks of the Afyon Zone is largely preserved in the regional depression between Orhaneli and Eskişehir, as a single massif over 4000 km^2 in area. In the east peridotite occurs as isolated klippen on the blueschists.

The dominant rock type is a spinel-bearing harzburgite/dunite tectonite (Çoğulu 1967; Lisenbee 1971; Okay 1980c). Serpentinization is not extensive except at the margins of the peridotite and along faults. Gabbro, occupying less than 2% of the surface area of the peridotite, occurs as small bodies a few hundred metres wide within the peridotites where it commonly shows compositional layering (Uz 1978; Tankut 1980). The common type is a pyroxene-olivine-plagioclase gabbro, with the pyroxene often uralitized and the plagioclase saussuritized.

The peridotite is cut by discontinuous microgabbroic dykes and stocks of variable width (0.2–5 m). The density of dykes is variable averaging 2–3 dykes per 500 metres horizontally. Dykes are commonly chilled against the peridotite, do not extend into the country rock, and like the gabbros, are affected by low-grade ocean floor-type metamorphism. Although the igneous texture survives, the primary plagioclase + augite assemblage in the microgabbros has been replaced by an albite + hornblende + pumpellyite assemblage (Lisenbee 1971; Yeniyol 1979; Okay 1980c). The mineral assemblages in the dykes and gabbros indicate that the peridotite unit has not undergone HP/LT metamorphism.

The upper parts of the ideal ophiolite sequence are apparently absent in north-west Turkey; this could be due to erosion, or it could be primary. It is significant that no complete ophiolite sequence has been described along the İzmir-Erzincan suture where peridotites are quite common.

There are no reliable isotopic or other data for the age of the peridotite; its emplacement over the volcano-sedimentary complex must be post-Cenomanian but pre-Middle Palaeocene.

Sakarya Zone (Pontides)

The Sakarya Zone corresponds approximately to the Mysisch-Galatische Scholle of Brinkmann (1966), to the Inner Pontides of Bergougnan and Fourquin (1980) and to the Sakarya continent of Şengör & Yılmaz (1981). In western Turkey the Zone occupies roughly the area between the North Anatolian Fault and the İzmir-Erzincan suture (Fig. 1). The Sakarya Zone consists of a pre-Liassic metamorphic basement and a cover of Mesozoic to Tertiary clastics and carbonates. The stratigraphy, which is completely different from the Afyon Zone, is well described in the Bilecik (Altınlı 1975; Saner 1980), and Ankara (Batman 1978; Akyürek 1981; Ünalan 1981) regions, and is summarized in two generalized stratigraphic sections in Fig. 4.

The basement of the Sakarya Zone consists of a thick, deformed, variably metamorphosed sequence of greywackes interbedded with basic volcanic rocks, shales and rare limestones. The upper parts of this sequence contain abundant olistoliths of Permian and Carboniferous limestone in a matrix of greywacke and shale. Small (<100 m), rare blocks of serpentinite are also reported (Yılmaz 1977). This Karakaya Formation of Bingöl *et al.* (1975) has a very wide distribution in the Pontides (Tekeli 1981), and extends from Edremit on the Aegean coast to the region of Ankara as the Dikmen greywackes, or the Dikmen melange of Özkaya 1982); and farther east to Tokat (Özcan *et al.* 1980) and the Ağvanis Massifs. In north-west Turkey the Karakaya Formation is best exposed in a 200 km long and 20 km wide, slightly arcuate metamorphic belt between Bursa and Nallıhan (Fig. 2). Here basic volcanic rocks are the main rock type with lesser amounts of greywacke, shale, limestone and chert. Around the town of Söğüt, Yılmaz (1977) differentiated four metamorphic zones with an increase in metamorphic grade to the north-west: spilites are progressively metamorphosed to amphibolites with garnet, barroisite and albite. Sodic amphibole in iron-rich meta-cherts and in some metabasites (Yılmaz 1977; Ayaroğlu 1979), and barroisite rather than hornblende in the amphibolites are indicative of high-pressure greenschist facies metamorphism. In the Sakarya region this sequence is intruded by a granite which has been dated as Early Permian (Çoğulu *et al.* 1965).

Data on the depositional age of the Karakaya Formation are scarce. Some of the intercalated limestones have yielded Late Permian ages in the Sakarya region (Sungur 1973) and Early Triassic (Scythian) ages north of Ankara (Akyürek *et al.* 1979). As the oldest sediments unconformably overlying the metamorphosed Karakaya Formation are of Middle to Late Triassic age (Bingöl *et al.* 1975; Servais 1981), metamorphism and uplift of the Karakaya Formation must have occurred during the Triassic (Tekeli 1981). However, the major marine transgression in the Pontides was at the beginning of the Liassic. In the Sakarya Zone the deformed and metamorphosed rocks of the Karakaya Formation are overlain by widespread Lower Liassic basal conglomerates. The conglomerate consists of well-rounded granite, schist and spilite fragments in a calcareous matrix. It passes upwards into sandstones and then into neritic carbonates of Middle to Late Jurassic age. The Early Cretaceous is represented by hemipelagic cherty limestones. In the Middle Jurassic–Early Cretaceous interval carbonate deposition is ubiquitous over the whole of the Pontides.

In the Sakarya region deposition of flysch with tuffaceous intercalations starts in the Cenomanian. The first serpentinite olistoliths in the flysch occur in the Campanian (Saner 1980). In the Palaeocene, molasse deposition starts with a gradual northward marine regression.

In the Ankara region the Late Cretaceous is represented by a chaotic sequence, locally over 2500 m thick, of serpentinite, basic volcanic rocks, exotic blocks of Permian, Jurassic and Lower Cretaceous limestones, radiolarian cherts, shales and volcanogenic sandstones (Çapan & Buket 1975; Batman, 1981). This sequence passes up gradually into regularly bedded flysch of Campanian age. The chaotic ophiolitic sequence, the Dereköy Formation (Ünalan *et al.* 1976), or Kırıkkale Mélange, (Özkaya 1982) is currently interpreted as a tectonized massive olistostrome deposit (Norman 1975; Batman 1981; Norman this volume). The Ankara Melange, as originally described by Bailey & McCallien (1954), includes both the partially metamorphosed pre-Liassic Karakaya Formation with abundant Permian limestone olistoliths, and an Upper Cretaceous ophiolitic mélange (Dereköy Formation).

Following deposition of the Dereköy Formation, a deep and relatively narrow intra-continental basin developed south-west of Ankara (Haymana basin) during the Maastrichtian. This received over 5000 m of flysch-type clastics between Maastrichtian and Lutetian times (Görür *et al.* this volume). Blueschist detritus, for example as grain-flows with glaucophane-lawsonite schist fragments, first occurs in greywackes of the Upper Campanian-Maastrichtian flysch (Batman 1978) and is common along with serpentinite detritus in the Palaeocene and Eocene clastics (Norman & Rad 1971).

Calc-alkaline plutonism and Neogene deposits

During the Early Tertiary important calc-alkaline plutonism affected the whole of north-west Turkey. Several individual stocks intrude peridotite, blueschist and the low-grade metamorphic rocks of the Afyon Zone (Fig. 2). The dominant plutonic rock-type is a hornblende—biotite granodiorite (Bürküt 1966). Age determinations on these granodiorites range from Early Palaeocene to Late Oligocene (Ataman 1974; Bingöl *et al.* 1982). Miocene conglomerates, commonly containing granodiorite fragments, are transgressive over the granodiorites. The calc-alkaline plutonism of north-west Turkey seems to be closely related to the uplift of the HP/LT metamorphic rocks, and may be the result of rapid near-isothermal decompression of the thickened continental crust of north-west Turkey.

The Palaeocene and Eocene was a period of uplift for much of north-west Turkey, so that sediments of this age are restricted. At the beginning of the Miocene the area was relatively stable with numerous lakes separated by highlands of peridotite and blueschist. Terrestrial and lacustrine Neogene sediments are widely distributed in north-west Turkey (Fig. 2), and consist largely of limestone, tuff, shale and lignite of Miocene and Pliocene age (Brinkmann 1976).

Discussion

The striking contrasts of stratigraphy in the Afyon and Sakarya Zones point to the existence of a major ocean in north-west Turkey in pre-Tertiary times. Evidence for the age of opening of this İzmir-Erzincan ocean in north-west Turkey, and indeed in the 1500 km-long suture separating the Pontides and Anatolides is very sparse. Continental margin sequences, which establish fairly accurately the age of initial rifting in areas such as the Antalya region (Marcoux 1976; Robertson & Woodcock 1981), have not been described along this major suture. It is still not clear whether the İzmir-Erzincan ocean represents one of the branches of Neotethys which opened during the Liassic (Şengör & Yılmaz 1981), or whether it is the original Tethys (Palaeotethys) which was in existence from the Mid-Palaeozoic onward, as implied by Biju-Duval *et al.* (1977). Although pre-Liassic thrusting and deformation have recently been described from the Taurides (Akay 1981; Monod & Akay this volume), the restriction of the Triassic orogeny, as represented by the metamorphosed and deformed Karakaya Formation, to the Pontides suggests that important differences between the Anatolide/Taurides and Pontides existed in pre-Liassic times. Triassic basic volcanics, tuffs and pelagic sediments in the Bozkır nappes north of the Tauride autochthon (Özgül 1976), also indicate that the opening of the İzmir-Erzincan ocean dates back to pre-Triassic times.

The structural position of the blueschists between the Afyon Zone and the peridotite nappe (Fig. 3) indicates that they belong to the Anatolide rather than to the Pontide realm. It is suggested that the blueschist sequence of north-west Turkey represents part of the northward-facing continental margin of the Anatolide/Tauride platform. The main evidence for this is the sudden passage from the thick platform carbonates to the pelagic sediments and volcanics in the blueschist sequence, which is interpreted as due to rapid foundering of a carbonate platform following rifting and establishment of a continental margin. The neritic carbonate olistoliths in the volcano-sedimentary complex of the Emirdağ and Tavşanlı regions may be another indication of block-faulting and foundering of a carbonate platform. Rapid submergence of shallow water platforms by synsedimentary normal faulting and the inception of pelagic conditions over large areas is characteristic of the early Mesozoic history of the Tethys, and generally indicates rifting preceding ocean floor speading (Bernoulli & Jenkyns 1974; Laubscher & Bernoulli 1977). The predominance of basic pyroclastic rocks in the blueschist volcano-sedimentary sequence of north-west Turkey could indicate proximity to a volcanic island. The oldest available ages from the volcano-sedimentary complex indicate a pre-Late Jurassic age for the platform carbonates of the blueschist unit (Servais 1981); accurate establishment of their age will probably solve the problem of the age of opening of the İzmir-Erzincan ocean.

Any plate tectonic model attempting to explain the formation and the present day tectonic position of the blueschists in north-west Turkey must take account of the following important features of the blueschists and related rocks:

(1) HP/LT metamorphic rocks are concen-

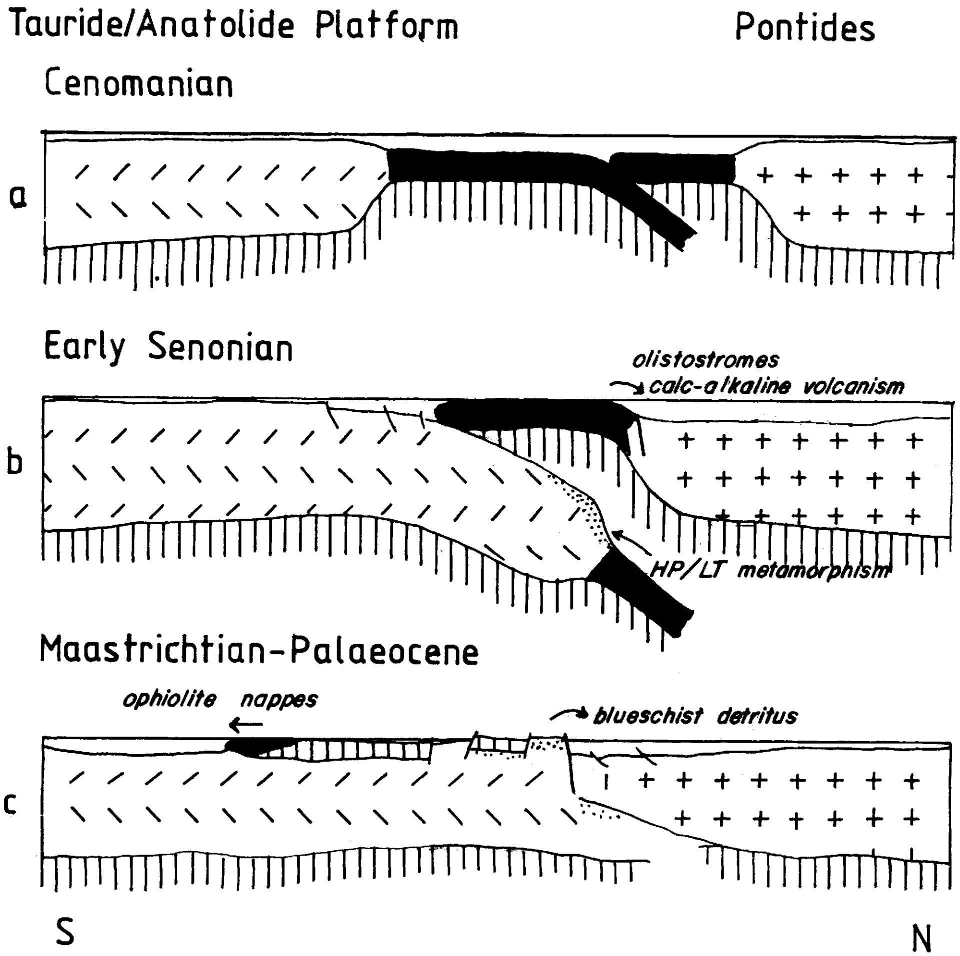

FIG. 5. Schematic sequence of N-S sections illustrating a possible model for the genesis of the north-west Turkish blueschists involving continent–continent collision. For explanations see the text.

trated in north-west Turkey, and do not occur regionally elsewhere in the İzmir-Erzincan suture.

(2) The blueschist sequences do not represent oceanic crust but may have been originally continental margin sequences.

(3) The peridotite nappe, which tectonically overlies the blueschists, has not undergone HP/LT metamorphism. A regular ophiolite sequence seems to be lacking in north-west Turkey.

It is believed that the available geological data and the inferences from these data can best be explained by invoking a northward dipping intra-oceanic subduction zone, and an irregularly shaped continental margin of the Anatolide/Tauride platform, with north-west Turkey forming a promontory during the Early Cretaceous (Fig. 5a). The consumption of the İzmir-Erzincan ocean eventually led to the subduction and HP/LT metamorphism of the north-west Turkish continental margin. The subduction of the buoyant continental crust of north-west Turkey caused uplift of the overlying oceanic crust and mantle at the same time (Fig. 5b). Deposition of flysch, calc-alkaline volcanism and huge olistostromes of ophiolitic material in the Sakarya Zone indicate that the subduction of the continental crust and uplift had already started in the Turonian. Blueschists must have been locally exposed by the Upper Campanian when detritus in the Pontide Haymana basin appears (Batman 1978). This is also an indication that the İzmir-Erzincan ocean was eliminated in north-west Turkey by the Maastrichtian (Fig. 5c). Continuing compression and strong uplift elevated the Sakarya Zone above sea level in the Palaeocene; at the same time in the south, huge ophiolite slices were detached from the uplifted oceanic crust and mantle and moved southward over the Anatolide/Tauride carbonate platform (Bozkır ophiolite nappes of Şengör & Yılmaz).

Uplift and exposure of blueschists implies several tens of kilometres of vertical upward movement relative to the rocks of Sakarya Zone. This uplift, must have been achieved along the major faults, which now juxtapose blueschists, formed at 30–35 km depth, and the Mesozoic sediments or the basement rocks of the Sakarya Zone. Another consequence is that most of the peridotites in north-west Turkey are preserved oceanic mantle rather than oceanic crust.

Uplift to the surface

A remarkable feature of the north-west Turkish blueschists is their rapid uplift to the surface. The youngest depositional ages from the HP/LT metamorphic rocks are Cenomanian. In the Upper Campanian and Maastrichtian blueschists were supplying detritus to the Haymana basin. Thus, the termination of the pelagic sediment deposition, HP/LT metamorphism and uplift to the surface must have occurred in less than 25 Ma (Cenomanian-Maastrichtian). The prograde nature of the HP/LT mineral assemblages and the general absence of a greenschist overprint also indicate very fast uplift.

The presence of aragonite, jadeite and lawsonite in the glaucophane-lawsonite schists gives a conservative pressure estimate of 10 kbar during the HP/LT metamorphism (Okay 1980c). As the blueschists occur as a coherent terrain and not as exotic blocks, a rock column 30–35 km thick must have been eroded during the Upper Cretaceous to expose the blueschists at the surface. Recent thermal modelling indicates minimum denudation rates of 1.4 mm/year or higher for the preservation of blueschists with no greenschist overprint (Draper & Bone 1981). Such a constant denudation rate gives a maximum total exhumation time of 20–25 Ma for blueschists formed at 30–35 km depth, which agrees well with the geological evidence.

As Draper & Bone (1981) point out, present day erosion rates are generally too low for the required unloading. They invoke tectonic and quasi-tectonic mechanisms, such as nappes or olistostrome flows, to achieve the necessary denudation rates. In north-west Turkey the unloading of the blueschists seems to have been achieved in two distinct ways. During the Late Cretaceous the erosion was aided by the formation of massive olistostromes which were deposited in basins in the north (Fig. 5b). Several thousand metre-thick chaotic deposits of ophiolitic material overlie carbonate platform rocks over large areas in the Central Anatolia. During the uppermost Cretaceous and Palaeocene, when the Sakarya Zone was also temporarily uplifted, the unloading was achieved by the detachment and southward movement of peridotite nappes, terminating sedimentation in the Afyon Zone (Fig. 5c).

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