

Palaeogeographic and tectonic position of the Carboniferous rocks of the western Pontides (Turkey) in the frame of the Variscan belt

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Key words. – Late Palaeozoic, Carboniferous basin, Variscan chain, Black Sea, Palaeogeography, Palaeo-Tethys, Turkey.

Abstract. – The Carboniferous rocks situated between Istanbul and Zonguldak coal basin belong to a fragment of the Hercynian chain of problematic origin, known as the "Palaeozoic of Istanbul". The Carboniferous rocks of the "Palaeozoic of Istanbul" are part of a well-developed passive continental margin which is totally exotic with respect to the surrounding units in Turkey, but shows many similarities with the Palaeozoic sequence of the Moesian Platform and the European coal basins. It is suggested that the "Palaeozoic of Istanbul" was part of the East European Platform and has drifted southwards during the opening of the western Black Sea basin. The original position of this unit within the Hercynian chain is tentatively shown in a global reconstruction during Carboniferous.

Position tectonique et paléogéographique des formations carbonifères du NW des Pontides (Turquie) dans la chaîne hercynienne

Mots clés. – Paléozoïque supérieur, Bassins carbonifères, Chaîne hercynienne, Mer Noire, Paléogéographie, Paléotéthys, Turquie.

Résumé. – Les formations carbonifères situées entre Istanbul et le bassin houiller de Zonguldak appartiennent à un fragment de la chaîne hercynienne d'origine incertaine, connu sous le nom de « Paléozoïque d'Istanbul ». Les formations carbonifères de cette unité font partie d'une marge continentale passive, complètement étrangère aux unités avoisinantes en Turquie. Le « Paléozoïque d'Istanbul » présente par contre des affinités étroites avec les formations paléozoïques de la plate-forme moésienne et les bassins houillers européens. Ce fragment se serait séparé de la plate-forme est européenne lors de l'ouverture du bassin occidental de la mer Noire. Sa position présumée dans la chaîne hercynienne est indiquée sur une reconstruction globale au Carbonifère.

VERSION FRANÇAISE ABRÉGÉE

Au NW de la Turquie, les formations carbonifères situées entre Istanbul et Zonguldak (fig. 1) sont classiquement connues sous le nom de « Paléozoïque d'Istanbul » mais la place originelle de cette unité dans la chaîne hercynienne a toujours été problématique. L'examen des liens entre ces formations et celles connues au nord de la mer Noire montrera l'origine eurasiatique probable de cette unité (fig. 2). Aux environs d'Istanbul (fig. 3), au dessus d'un épais talus détritique ordovicien et d'une plate-forme carbonatée siluro-dévonienne, la séquence carbonifère débute par des cherts viséens reposant sur des calcaires noduleux pélagiques du Dévonien supérieur, et s'achève par un épais flysch d'âge viséen [Haas, 1968 ; Kaya, 1980]. L'ensemble est recouvert en discordance par des formations détritiques rouges attribuées au Trias inférieur. Plus à l'est, un socle gneissique non daté apparaît sous le Paléozoïque inférieur dans la région du Çamdağ [Aydt et al., 1987] et de Safranbolu-Araç [Arpat et al., 1978] (fig. 3), mais le Carbonifère est absent. Contrastant avec la région d'Istanbul, la région de Zonguldak-Amasra montre une puissante succession de carbonates nérithiques au Dévonien et au Dinantien [Dil, 1976]. Cette plate-forme carbonatée est surmontée par un bassin houiller productif au Namurien et au Westphalien (fig. 3), dont les flores sont typiquement eurasiatiques [Laveine et al., 1993], et dont le matériel silico-détritique proviendrait de la plate-forme européenne orientale [Kerey, 1985]. Les formations carbonifères de la région d'Istanbul font partie d'une marge continentale passive déformée au Carbonifère inférieur, comme en Europe de l'Ouest [cf. Franke et Engel, 1986]. Dans la région de Zonguldak par contre, la tectonisation majeure est nettement plus tardive (post-Stephanien), avec une vergence d'ensemble vers le nord-est (fig. 4) [Tokay, 1962]. L'unité « Paléozoïque d'Istanbul » est complètement étrangère aux unités avoisinantes en Turquie, dont elle est séparée tectoniquement, mais présente des affinités lithologiques et stratigraphiques étroites avec les formations paléozoïques des plates-formes moésienne et scythienne d'une part [Kozucharov et Savov, 1972 ; Oaie, 1986], et avec les bassins productifs d'Europe centrale et du Donetz d'autre part [cf. Izart et Vachard, 1994]. Les données géologiques, géophysiques et géomorphologiques régionales du pourtour de la mer Noire suggèrent que le « Paléozoïque d'Istanbul » se trouvait, au Carbonifère, le long du plateau d'Odessa, entre la Moésie et la Crimée. Au moment de l'ouverture du bassin occidental de la mer Noire, entre l'Aptien et l'Eocène inférieur [Finetti et al., 1988], ce fragment se serait déplacé vers le sud en suivant deux failles transformantes majeures [Okay et al., 1994]. La position probable du « Paléozoïque d'Istanbul » dans la chaîne hercynienne est figurée dans une reconstruction globale au Carbonifère supérieur (fig. 5), antérieurement à la fermeture de la Paléotéthys.

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Manuscrit reçu le 12 juin 1996 ; accepté après révision le 24 octobre 1996.

INTRODUCTION

The Carboniferous rocks cropping out between Istanbul and Zonguldak (fig. 1) belong to the northern part of the Pontides *sensu* Kettin [1966] or the Central Rhodope – Pontide fragment of Sengör and Yilmaz [1981] or the Istanbul Zone of Okay *et al.* [1994] (fig. 2). These formations are part of the classical “Palaeozoic of Istanbul”. The European affinities of the Upper Carboniferous floras of the Zonguldak-Amasra basin were recognized long ago [Zeiller, 1899; Charles, 1933] and their links with the Eurasian floras have recently been precised [Laveine *et al.*, 1992, 1993]. However, the original place of this unit within the Variscan framework is unclear, so that, most often, the “Palaeozoic of Istanbul” is omitted in the reconstructions of the Variscan chain. This unit consists of sedimentary rocks ranging in age from Ordovician to Upper Carboniferous [Tokay, 1962; Haas, 1968], and records the development of a south-facing Atlantic-type continental margin that was deformed during the Carboniferous with a north-northeasterly vergence [Abdüselamoğlu, 1977]. This unit is markedly different in many aspects from surrounding tectono-stratigraphic units in northern Turkey (fig. 2), but displays close stratigraphic similarities to the Palaeozoic rocks of the southern margin of Laurasia, cropping out in a belt between western Europe and the south Urals [Sandulescu, 1978; Zonenshain *et al.*, 1984; Matte, 1986; Okay *et al.*, 1994]. Initially, it was probably part of this large passive continental margin and later, between Aptian and middle Eocene, it moved south-

wards to its present location, coincident with development of the Black Sea back-arc basin [Görür, 1988; Okay *et al.*, 1994]. Detailed discussion on the mechanism and the timing of this event have already been published by three of the authors [Görür, 1988; Okay *et al.*, 1994]. The purpose of the present paper is to highlight the exotic nature of “the Palaeozoic of Istanbul” within the Pontides, and stress the comparisons that can be made with several units of south Laurasia, in order to replace this isolated fragment in the broader frame of the Variscan chain.

THE PALAEZOIC SEQUENCE OF ISTANBUL

This sequence is known from five areas (Istanbul, Çamdağ, Zonguldak, Amasra and Safranbolu regions) as described below (fig. 3).

Istanbul region (fig. 3)

In the Istanbul area, the lowest exposed Palaeozoic formations are coarse detrital sediments (Kurtköy Fm.) [Önal, 1982], consisting of more than 1000 m of conglomerate, arkosic sandstone and violet to pinkish mudstone, of alluvial fan origin. An Ordovician age is considered likely as the overlying fossiliferous sediments are lower Silurian [Abdüselamoğlu, 1977; Sayar, 1979; Önal, 1982]. Possible indications of cold climate, on the basis of the excellent preservation of feldspars, is consistent with the pro-

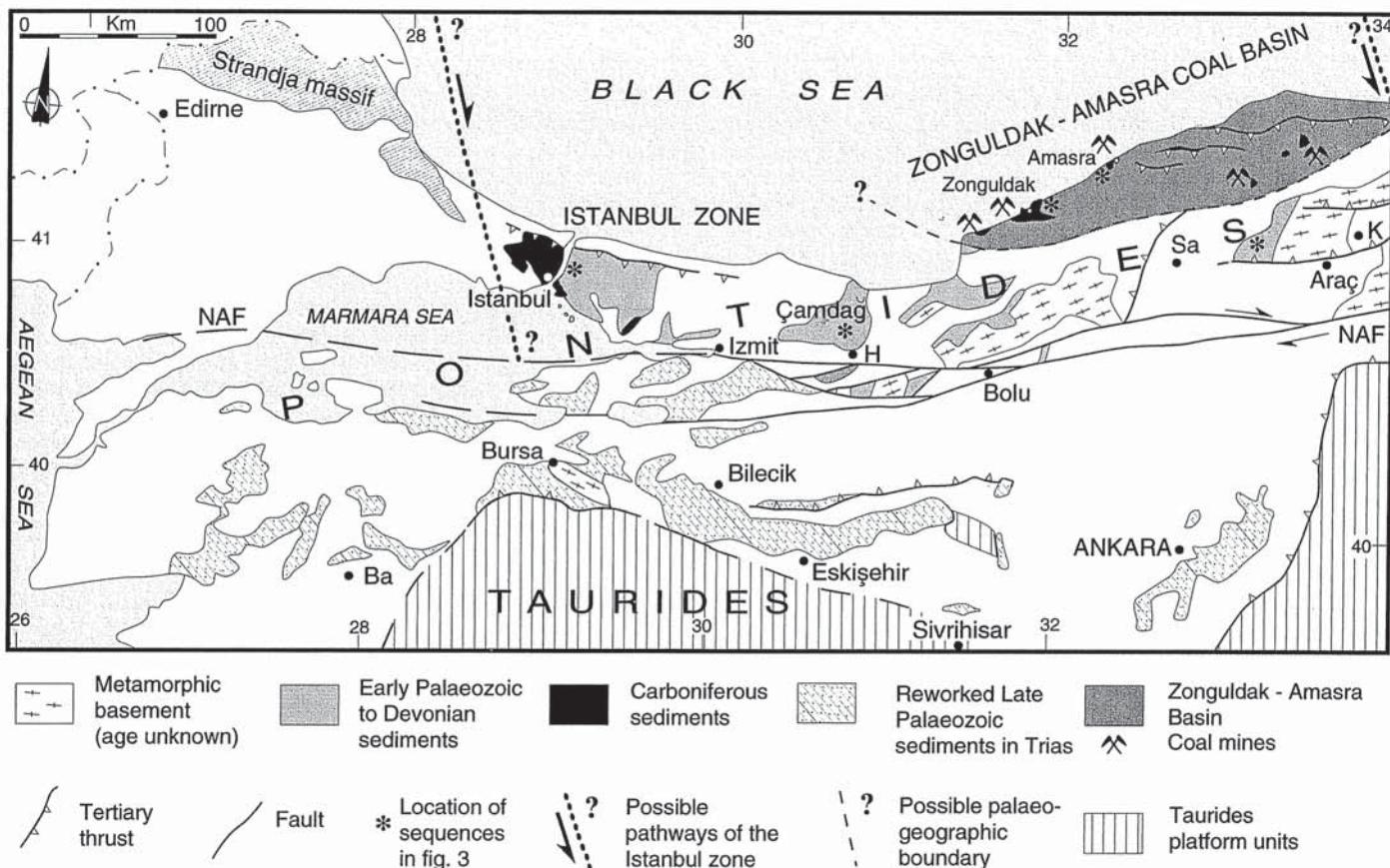


FIG. 1. – Outcrop map of the Carboniferous sediments and associated rocks in the western Pontides. A : Amasra ; Ba : Balikesir ; H : Hendek ; I : Istanbul ; K : Kastamonu ; Sa : Safranbolu ; Z : Zonguldak ; NAF : North Anatolian fault.

FIG. 1. – Carte d'affleurement des formations carbonifères et associées dans l'ouest des Pontides. A : Amasra ; Ba : Balikesir ; H : Hendek ; I : Istanbul ; K : Kastamonu ; Sa : Safranbolu ; Z : Zonguldak. NAF : faille nord anatolienne.

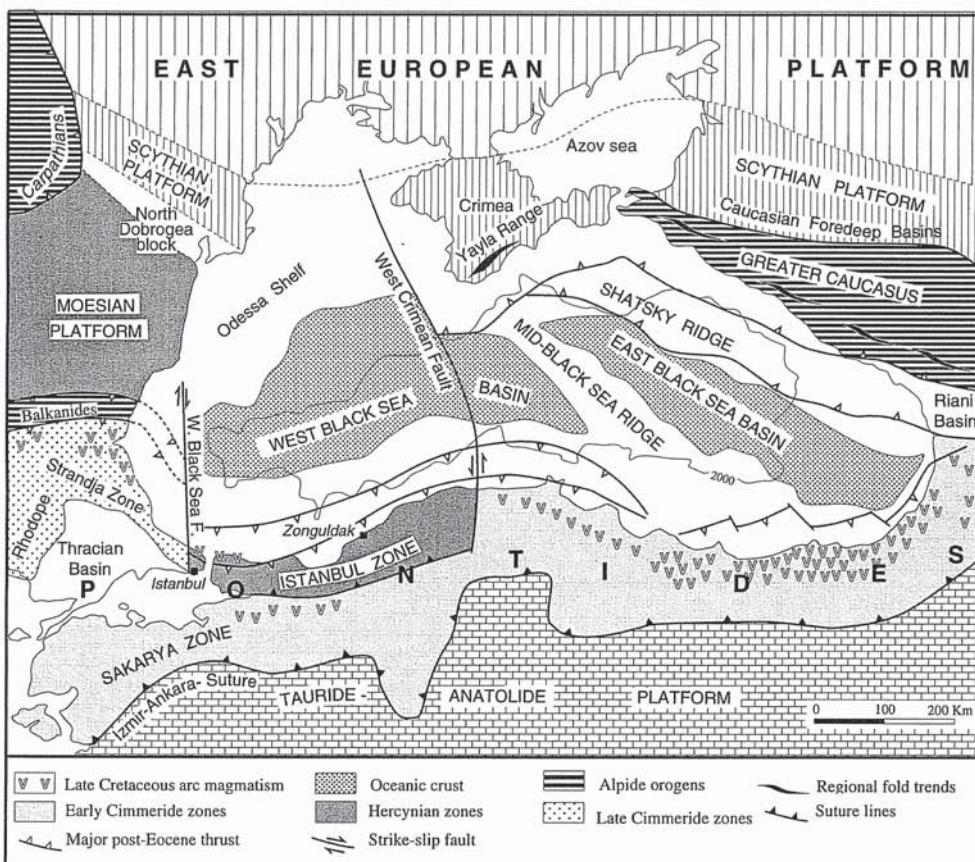


FIG. 2. – Tectonic map of the Black Sea region [after Okay et al., 1994].

FIG. 2. – Carte tectonique régionale de la mer Noire [d'après Okay et al., 1994].

ximity of the late Ordovician continental ice cap [Crowell, 1983].

The Kurtköy arkoses pass gradually upward into white to pinkish, cross-bedded, laminated quartz arenite with local burrows, worm trails and *Cruziana* sp. (Aydos Formation) [Önalan, 1982]. The quartz arenite, 150 to 300 m thick, is interbedded with greenish grey shale and was probably deposited in a tide-dominated shore environment. This facies is followed by a lagoonal unit (Gözdağ Formation) [Önalan, 1982], mainly interbedded shale, siltstone and sandstone with some bioclastic limestone beds in the upper part. Fossils found in both the clastics and the carbonates of this unit (1 in fig. 3) include brachiopods, graptolites, corals, crinoids, bryozoa, and ostracodes of early to middle Llandoveryan age [Yalçınlar, 1955; Arıç-Sayar, 1962 and 1969; Haas, 1968; Önalan, 1982]. This thick (250 m) fossiliferous unit provides an upper limit for the age of the underlying detrital formations, and passes locally through a white and cross-bedded subarkosic sandstone, into a 400 m thick carbonate sequence (Gebze Limestone) [Görür, 1982]. The subarkosic sandstone contains fossiliferous beds (2 in fig. 3) dominated by late Llandoveryan brachiopods [Haas, 1968; Ketin, 1983].

The Gebze Limestone is characterized by a variety of carbonate rocks, ranging from boundstone to mudstone. The basal part of the sequence is made of grey to pink, locally argillaceous and cross-bedded, echinodermal grainstone passing upwards into a massive coral packstone-boundstone. These light-coloured shoal limestones are followed by relatively deeper-water carbonates, represented by a

dark-coloured, thinly-laminated carbonate mudstone with slump structures at the base, and well-bedded wackestones at the top [Görür, 1982]. On the basis of brachiopods, corals, conodonts, and trilobites (3 in fig. 3), a late Silurian to early Devonian age is given to these carbonates [Haas, 1968; Önalan, 1982; Ketin, 1983]. They pass gradually through a nodular limestone facies into the overlying fossiliferous shale (4 in fig. 3) of early Devonian age [Önalan, 1982; Ketin, 1983]. This open-marine shale unit is followed by middle Devonian alternating calciturbidites and shales. Above, with an increasing frequency of limestone beds, the calciturbidites pass up into a typical, cherty and nodular deep-water micritic limestone of late Devonian age (5 and 6 in fig. 3) [Ketin, 1983].

Above the Devonian nodular limestone comes a thick Carboniferous flysch formation (Thracian flysch). At the base of the flysch lies a characteristic horizon of black radiolarites with radiolarians of early Visean age [Mc Callien, 1947; Abdüsselamoğlu, 1963; Kaya, 1973, 1980] which is intercalated with shales containing phosphatic nodules (Balataliman Fm) [Kaya, 1973]. These are succeeded by thick turbidites with alternating greywackes, siltstones and shales of the same age, (Trakya Fm) [Kaya, 1973]. The turbidites have a wide lateral continuity and show Tb-e, Tc-e, and Td-e Bouma sequences with well-developed sole marks. In the upper part of the Thracian flysch, limestone and conglomerate beds with plant remains are also found (7 in fig. 3) [Kaya, 1971]. In a few localities the latest turbidites are associated with shallow-marine bioclastic limestones (late Visean) which probably are olistoliths (Cebeciköy

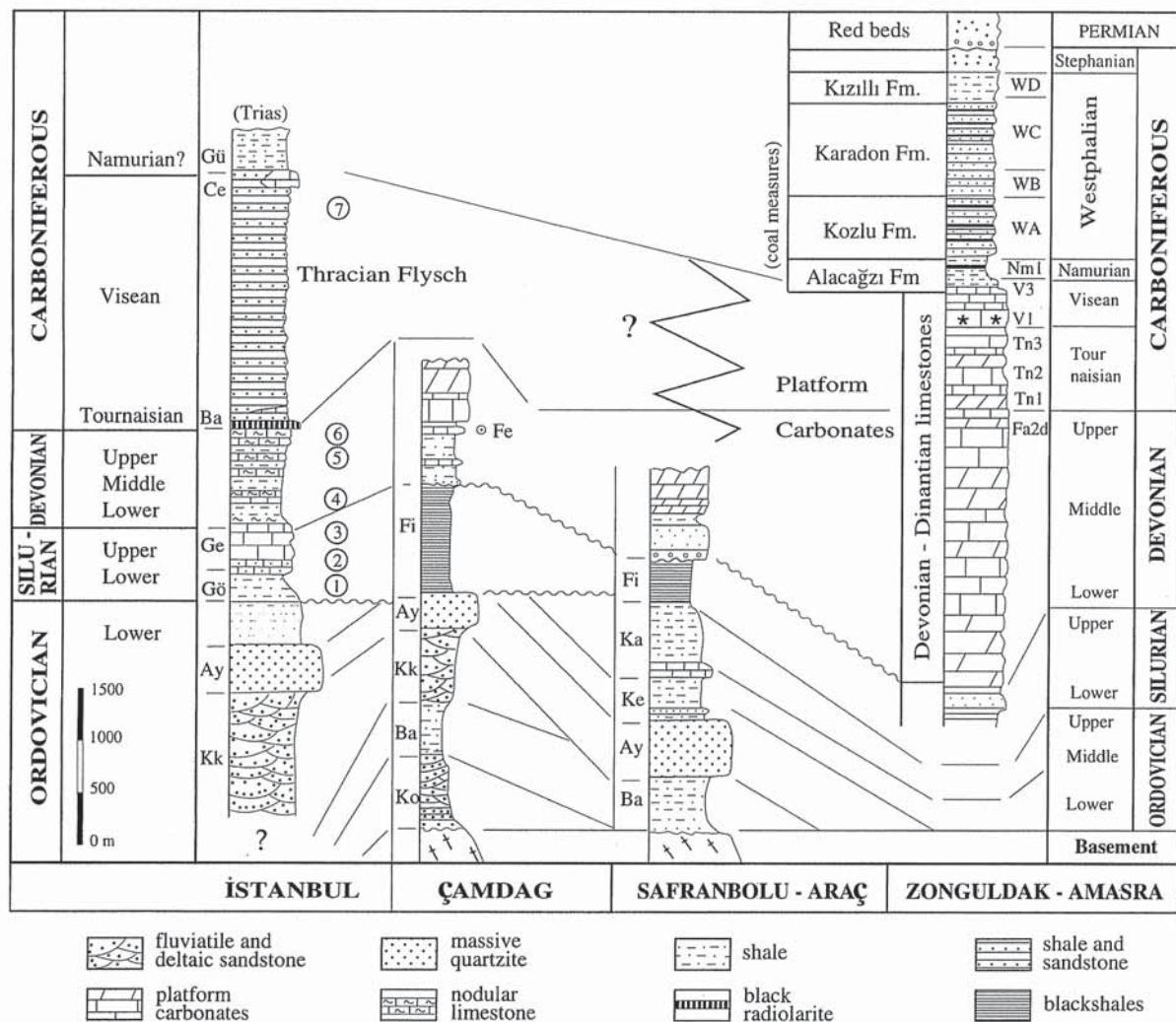


FIG. 3. – Four representative successions of the Palaeozoic formations in the western Pontides, from Istanbul to Amasra. Numbers 1 to 7 refer to faunal assemblages cited in the text and detailed hereafter.

FIG. 3. – Quatre successions stratigraphiques représentatives des formations paléozoïques des Pontides occidentales, entre Istanbul et Amasra. Les nombres 1 à 7 indiquent les assemblages cités dans le texte et détaillés ci-dessous :

- 1 : *Eoplectodonta* aff. *duplicata* (SOW.), *Katastrophomena scotica* (BANCROFT), *Resserella llandoveriana* WILLIAMS, *Leangella scissa* (DAVIDSON), *Hirnantia* sp.
 - 2 : *Stricklandia* lens (SOW.), *Pentamerus* aff. *oblongus* SOW., *Meristella* ? cf. *furcata* (SOW.).
 - 3 : *Dicoelosia biloba* (LIN.), *Dayia navicula* (SOWERBY), *Atrypa reticularis* (LIN.), *Spinatrypa* sp., *Alveolites lemniscus* SMITH, *Favosites gothlandicus* (LIN.), *Halisites* sp., *Spathognathodus steinhorrensis eosteinhorrensis* ZIEGLER, *Ancyrodelloides trigonica* BISCHOFF and SANNEMANN, *Icriodus latericrescens* PAECKELMANN, *Calymene arotia* HAAS, *Proteus barrangus* HAAS.
 - 4 : *Dalmanella circularis* (SOW.), *Brachyspirifer carinatus* (SEHNUR), *Fimbrispirifer trigeri* (VERNEUIL), *Pleurodictyum constantinopolitanum* ROEMER, *Parahomalodon* *gervillei* (VERNEUIL).
 - 5 : *Gyroceratites gracilis* BRONN, *Phacops turco praecedens* HAAS.
 - 6 : *Phacops turco turco* R. and E. RICHTER, *Phacops mastophthalmus* RICHTER.
 - 7 : *Lepidostrobus brownii* SCHIMPER, *Lepidodendron losseni* WEISS.
- Kk : Kurtköy Fm.; Ay : Aydos quartzite; Gö : Gözdag Fm.; Ge : Gebze Lst.; Ba : Baltaliman Lydite; Ce : Cebeciköy Lst.; Gü : Gümüşdere shales; Ko : Kocatongel Fm.; Ba : Bakacak Fm.; Ke : Ketencikdere Fm.; Fi : Fındıklı black shales.

Limestone) [Kaya and Mamet, 1971], but, as a rule the Thracian flysch is directly overlain by unconformable red sandstones of early Triassic age.

Çamdağ region (fig. 3)

Palaeozoic sediments crop out extensively in this region. North of Hendek, the oldest Palaeozoic rocks are represented by (?) Ordovician to (?) Silurian arkosic sandstones, succeeded with disconformity by Devonian carbonates and clastic rocks. North of Düzce and north of Yıldızca (Orhangazi), the Palaeozoic succession begins with reddish coarse

clastic sediments (? Cambrian to Ordovician) resting unconformably on a metamorphic basement [Kaya, 1982; Aydin et al., 1987]. The early Devonian rocks consist mainly of interbedded shales and dolomites succeeded by limestone, dolomitic limestone and dolomite of Middle Devonian age. The late Devonian is represented in this region by siltstone and arkosic sandstone. The Palaeozoic rocks are overlain with angular unconformity by Triassic continental clastic rocks [Kipman, 1974].

In contrast to the İstanbul region, the basement rocks of the Palaeozoic sequence are exposed in the Çamdağ area. Although less well known, the Palaeozoic sequence differs

from that in the Istanbul region through the presence of a disconformity between the Silurian and Devonian sequence, the abundance of dolomite in the early-middle Devonian rocks, the siliciclastic nature of the late Devonian deposits, and the absence of Carboniferous rocks.

Safranbolu-Araç region (fig. 3)

East of Safranbolu, in the Karadere valley, unmetamorphosed lower Palaeozoic formations resting unconformably on a gneissic basement were discovered by Arpat and others [Hamdi, 1975; Arpat *et al.*, 1978]. The Lower Palaeozoic sequence ranges from early Ordovician to middle Silurian [Dean *et al.*, 1995]. Ordovician rocks begin with red sandstones and mudstones containing acritarchs of probable Tremadoc age and continue with massive quartzites. Above, Arenig to Llanvirn siltstones with trilobites and graptolites alternate with quartzites and are followed by Caradoc too? Ashgill shales intercalated with black limestones with conodonts. Above, early Silurian (Llandovery) graptolitic black shales pass into grey to pink weathered mudstones with rare monograptids of Wenlock age. The Silurian shales are overlain with a weak unconformity by clastic sediments of Devonian age represented by conglomerates, quartzitic sandstones and shales, followed by brecciated dolomitic limestones at the top [Boztuğ, 1992]. Carboniferous and Permian strata are absent and the Devonian carbonates are directly overlain by upper Jurassic shallow-marine limestones.

Zonguldak region (fig. 3)

In the Zonguldak area, the Palaeozoic rocks comprise an Upper Devonian-Lower Carboniferous carbonate platform followed by a Middle to Upper Carboniferous coal-bearing succession. According to Dil [1976], the Upper Devonian limestones and shales (Fa2d) grade into Tournaisian dolomitic reef limestones (Tn1-Tn2), succeeded by lagoon micrites with cherts (Tn3-V1) and coral-bearing grainstone-packstones (V1b to V3b). The uppermost Visean (V3c) consists of alternating limestones and shales grading into Namurian black shales (Nm1). The overlying detritical suc-

cession is usually divided into four formations: Alacağzı Fm. (Namurian), Kozlu Fm. (Westphalian A), Karadon Fm. (WB and WC), and Kızılıl Fm (WD) [Kerey *et al.*, 1985]. The succession is marine at the base, whereas flood-plain, lacustrine, fluvial, and fan deposits are present in the middle and upper parts. The Alacağzı Formation is represented by dark grey to black shales at the base and coal-bearing shales, cross-bedded sandstones, and conglomerates at the top. These are succeeded by similar facies in the Kozlu Formation with 27 coal seams. The Karadon Formation is characterized by a thick sequence of conglomerates, coarse sandstones, and shales with coal beds and refractory clays ("Tonschiefer"). At the top, the upper part of the Kızılıl Formation consists of unfossiliferous red beds. As known since the early thirties, the megafloras show close affinities with those of the western European and the Donetz basins. However, unlike the western part of the Hercynian chain, siliciclastic materials were derived from a northerly source during the Namurian and Westphalian according to Kerey [1985], and were deposited in a large deltaic basin that was probably located on the southern margin of the Laurasian plate.

Amasra region (fig. 3 and 4)

The Palaeozoic sequence of this region starts with late Silurian to early Devonian dark red to green, ferruginous, and clayey sandstones, passing upwards into quartzites of the same age (Inkum Fm) [Tokay, 1955]. Towards the top, the quartzites become varicoloured and microconglomeratic and pass into dark-coloured and brecciated limestones with Emsian fossils. As in the Zonguldak area, these early Devonian limestones are succeeded by platform carbonates comprising mainly grey, cherty, and dolomitic limestones and dolomites of middle Devonian to early Carboniferous (Visean) age. The carbonate unit is followed by a thick clastic, coal-bearing sequence, ranging in age from late Visean to Stephanian, similar to the formations in the Zonguldak region [Tokay, 1955, 1962]. Unfossiliferous red beds (?Permian) rest on these clastics above an angular unconformity. Figure 4 is an interpretation of the pre-Cretaceous structures based on several wells, modified from Tokay [1962].

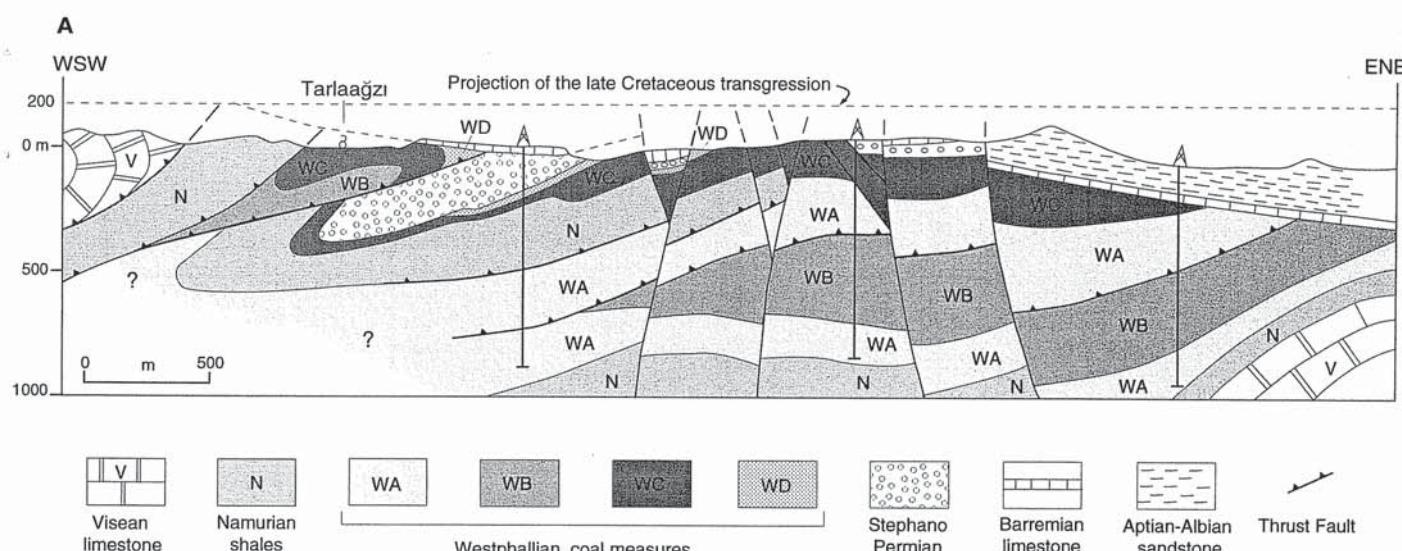


FIG. 4. – A structural interpretation of the pre-Cretaceous structures in the Amasra coal field, after Tokay [1962] modified.

FIG. 4. – Une interprétation des structures ante-Crétacé dans le bassin houiller d'Amasra, d'après Tokay [1962] modifié.

Circum-Black Sea region

Palaeozoic sediments crop out in various parts of the circum-Black Sea region, such as the Moesian and Scythian platforms, Krajstides (in western Bulgaria), North Dobrudja, and southern Urals [Garetskiy, 1970; Kozucharov and Savov, 1972; Sandulescu, 1978; Wagner and Higgins, 1979; Zonenshain *et al.*, 1984; Oaie, 1986]. In the Moesian Platform (fig. 2), ie. in Central Dobrudja, the basement for the Palaeozoic sequence is represented by Riphean schists which are unconformably overlain by quartzitic sandstones of Ordovician to Silurian age. In boreholes, siltstones, claystones, and clayey limestones with Silurian fossils are encountered above these sandstones. Borehole data reveal that the Devonian in western Romania consists mainly of black shales, quartzites and limestones at the base and limestones and dolomites with shale interbeds at the top [Garetskiy, 1970; Dachev *et al.*, 1988]. Similar but thinner coeval sediments also occur in Bulgaria. The Carboniferous in the Moesian block, in both the Romanian and Bulgarian parts, is represented mainly by dark grey shales, siltstones, sandstones, and conglomerates interbedded in part with marls, limestones, coal deposits, and tuffs. In Bulgaria, these sediments are 1 800 m thick and range in age from Upper Visean to Westphalian [Garetskiy, 1970]. In contrast, in North Dobrudja, the Lower Carboniferous is characterized by 1 100 m of red sandstones and conglomerates of alluvial origin [Oaie, 1986]. On the Moesian platform, the Carboniferous sediments are unconformably overlain by Permian terrigenous clastics.

In a recent synthesis, Şengör [1995] proposed a general structural frame of the Black Sea region from the Caucasus to Istanbul, and stressed the multiple tectonic events that affected the Zonguldak basin after the Hercynian orogeny. The Zonguldak region presents a much more complex structural evolution than the European coal basins which are lying on the stable Laurasiatic platform. Although still poorly understood in detail, the structure of the northern Pontide Chain implies a large southward backthrusting of Eocene age and a major decollement within the Mesozoic cover.

Correlations, discussion and suggestions

In the Istanbul region, after a long period of stability, the Palaeozoic sequence displays a deepening upward character from the middle or late Devonian to the early Carboniferous. During this interval, the depositional environment changed from a stepwise continental slope into a deeper basin. Following deposition of Visean black radiolarites, the basin was quickly filled with siliciclastic turbidites and became shallower. In contrast, east of the Istanbul region, the coeval late Palaeozoic sediments do not indicate such a change. On the contrary, in the Zonguldak-Amasra region, the Devonian and Visean limestones denote an uninterrupted shallow marine environment. This palaeo-bathymetric difference between west and east is most striking for the early Carboniferous : Visean turbiditic deposits in the west contrast with predominantly neritic carbonates deposited farther east.

As a whole, Palaeozoic sediments of the Istanbul region record the development of a south-facing Atlantic-type continental margin up to the late Devonian. The sediments accumulated during this period may represent the syn-rift deposits of the margin. Deposition of Visean radiolarites intercalated between deep water turbidites indicates that the rift basin turned into a larger and deeper, though not demonstrably oceanic, basin. The overlying thick turbiditic flysch of Visean age (Thracian flysch) probably indicates

the onset of Hercynian deformation of this margin, as in western Europe [Franke and Engel, 1986].

Deformations of Hercynian age in NW Turkey are insufficiently documented yet, owing to the multiple tectonic events that followed, and the loose age constraints. In the Istanbul region, the main Hercynian event took place during the early Carboniferous (late Visean to early Namurian) [Okay *et al.*, 1994], but significantly later in the Zonguldak-Amasra coal basins (Westphalian D to Stephanian or ?Permian) (fig. 4). In the Çamdag and Safranbolu areas, the lower Palaeozoic formations frequently exhibit steeply dipping fracture cleavage and widely open folds but an Hercynian age is uncertain as Carboniferous deposits are missing above. The Hercynian events were probably related to the closure of a part of the Rheic ocean located further south (fig. 5). As a result, the passive margin sequence was unconformably overlain by Lower Triassic sediments in the Istanbul region [Özdemir *et al.*, 1975], and undated red beds (?Permo-Triassic) in the Zonguldak-Amasra region (fig. 4).

The Palaeozoic sequence in the Istanbul region may easily be correlated with nearly identical Devono-Carboniferous sequences known from the southern side of the Hercynian chain in Spain (Cantabrian Mts), France (Montagne Noire, Pyrénées) or Sardinia (Iglesiente). Similar sequences have also been recorded in the Carnic Alps (Austria), the Krajstides (western Bulgaria), and the Moesian and Scythian Platforms (S and N Dobrougea). In the Zonguldak basin, the Visean carbonates and overlying coal measures of Namurian and Westphalian age may be compared with coeval formations in productive basins from northern to southeastern Europe (Wales, Belgium, Ruhr, Silesia, Donetz), and in the south Urals [Dil, 1976; Kerey *et al.*, 1985; Wagner and Higgins, 1979; Sandulescu, 1978; Zonenshain *et al.*, 1984; Izart and Vachard, 1994] which flank the Hercynian chain from Ireland to the southern margin of Laurasia.

In contrast with these closely related occurrences, the "Palaeozoic of Istanbul" appears as an exotic unit with respect to its presently surrounding tectonic units (fig. 2) [Okay *et al.*, 1994]. It is delimited to the west by the metamorphic rocks of the Strandja Massif, to the east by an accretionary mélange of Triassic to Liassic age, to the south by ophiolitic rocks of Cretaceous age, and to the north by the Black Sea Basin. Owing to an extensive Tertiary cover, its contact relationship with the Strandja Massif is not visible, but the other contacts show that the Palaeozoic of Istanbul is tectonically superposed on neighbouring units. This observation, along with its sharp lithologic contrast with the surrounding magmatic and metamorphic rocks, led some authors to consider the "Palaeozoic of Istanbul" as an allochthonous unit and to propose various hypotheses concerning its origin. Tollmann [1965 and 1968] suggested that it represents a remnant of a larger nappe which once overlaid the whole Western Pontides, including the Strandja Massif. Şengör [1984] named this the "Istanbul Nappe" and considered that it was originally located along the northwestern margin of Palaeo-Tethys and later, though before the Middle Jurassic, transform-faulted into the Pontides. In the Zonguldak region, Kerey [1985] suggested that the late Carboniferous deposits accumulated in a large basin developed on the southern margin of the Laurasian plate. He also indicated, following Brinkmann [1974], the former presence of a landmass in the Black Sea area which acted as a source for the Carboniferous sediments and persisted until late in the Mesozoic. Based on geophysical data on the Black Sea, Finetti *et al.* [1988] proposed that the western Pontides were initially situated directly south of the Moesian Platform and formed in the late Jurassic an active continental margin, facing the Neo-Tethys ocean in the

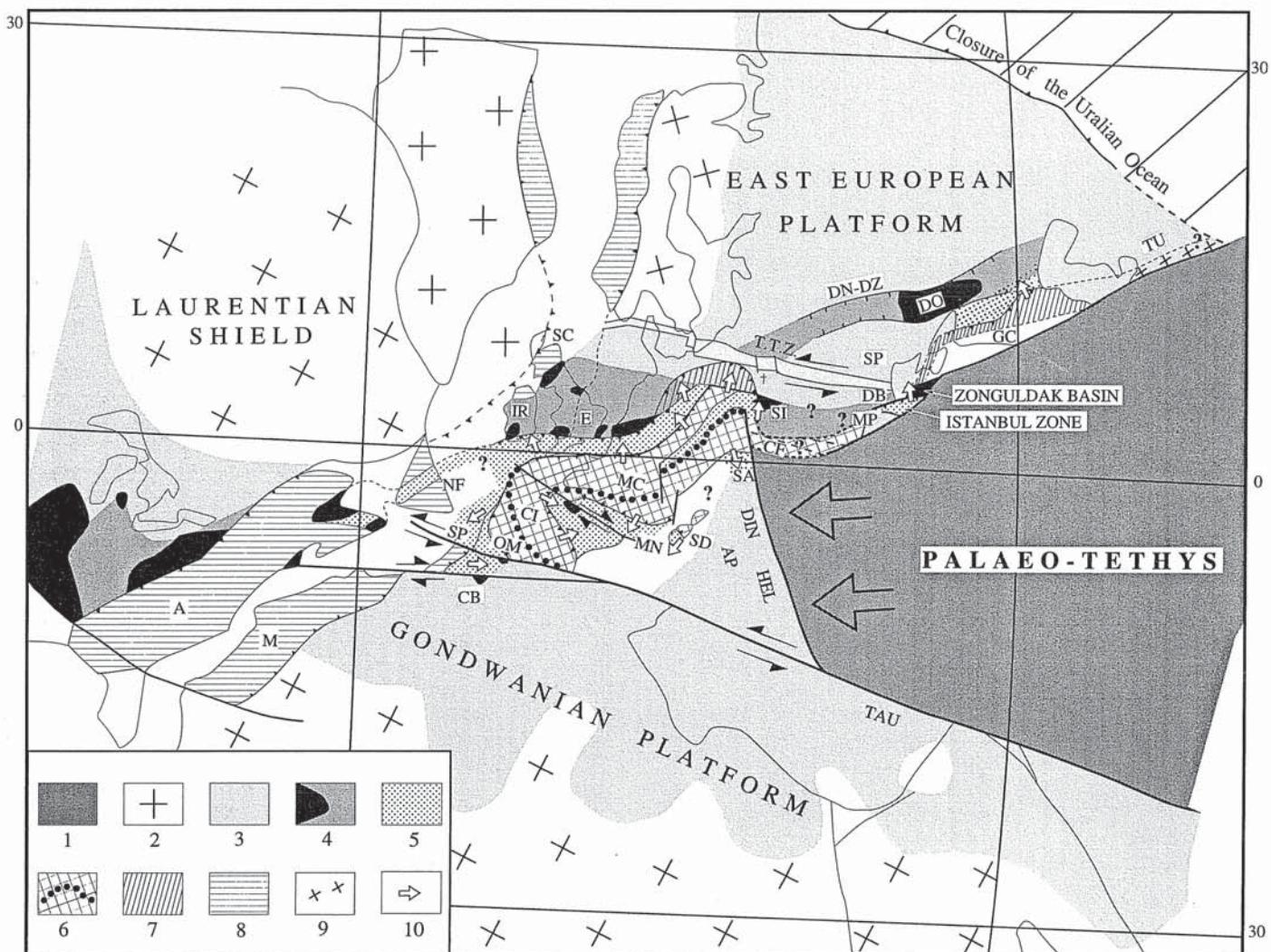


FIG. 5. – A sketch map of the Variscan chain during late Carboniferous showing the possible location for the “Palaeozoic of Istanbul” unit. This sketch emphasizes the contrast between the collided range in the west and the open Palaeo-Tethys ocean in the east. Owing to the important westward displacement of the northern part of Gondwana (arrows), part of the Variscan chain has been cut off along the southern border of the East European platform, leaving the “Palaeozoic of Istanbul” isolated from the inner parts of the chain that are now found fragmented in the Carpathians Mts. (CF). Legend : 1 : palaeo-Tethys oceanic crust ; 2 : shield ; 3 : shallow marine platforms ; 4 : molasse basins with coal (black) ; 5 : flysch zones (mainly lower Carboniferous) ; 6 : inner parts of the Variscan chain and trace of the oceanic closure (black dots) ; 7 : extension of the Hercynian deformation in the outer zones ; 8 : Caledonian and Caledono-Variscan orogen ; 9 : volcanic activity ; 10 : orogenetic vergence.

A : Appalachians. AP : Appenines. BF : border folds (SE Turkey). CB : Béchar. CI : Central Iberia. CF : Carpathian fragments. DB : Dobrogea. DN-DZ : Dniepr-Donetz basin. DO : Dombass basin. DIN : Dinaride platform. E : England. GC : Greater Caucasus. HEL : Hellenide platform. IR : Ireland. M : Mauritanides. MC : Massif Central. MN : Montagne Noire. MP : Moesian platform. NF : New Foundland. OM : Ossa Morena. SA : southern Alps. SC : Scotland. SD : Sardinia. SI : Silesia. SP : Scythian platform. TAU : Tauride platform. TU : Turkmenian zone. TTZ : Teyssiere-Tornquist Zone.

European part of the map according to Beauchamp *et al.* [1991], Edel & Weber [1995], Franke [1989], Guterch *et al.* [1994], Izart & Vachard [1994], Matte [1986], Okay *et al.* [1994], Sandulescu [1978] and Sengör [1995].

FIG. 5. – Carte schématique de la chaîne varisque au Carbonifère supérieur montrant la localisation possible du « Paléozoïque d'Istanbul ». Ce schéma montre le contraste entre la partie de la chaîne en collision à l'ouest et la Paléotéthys encore ouverte à l'est. Du fait du déplacement important vers l'ouest de la partie nord du Gondwana, une partie des unités varisques sont restées isolées le long de la bordure sud de la plate-forme est européenne, telles que le « Paléozoïque d'Istanbul » tandis que les parties plus internes de la chaîne se trouvent maintenant à l'état de fragments isolés dans les Carpates (CF).

Légende : 1 : croûte océanique de la Palaeo-Tethys ; 2 : boucliers ; 3 : plate-formes néréitiques ; 4 : bassins molassiques à charbon (noir) ; 5 : zones à flysch (surtout au Carbonifère inférieur) ; 6 : parties internes de la chaîne et trace de la fermeture océanique (points noirs) ; 7 : extension des déformations hercyniennes dans les zones externes ; 8 : orogène Caledono-Varisque ; 9 : activité volcanique ; 10 : sens de déversement orogénique.

A : Appalaches. AP : Appenines. BF : border folds (SE Turquie). CB : Béchar. CI : Central Iberia. CF : fragments carpathiques. DB : Dobroudjée. DN-DZ : bassin Dniepr-Donetz. DO : bassin du Dombass. DIN : plate-forme dinarique. E : England. GC : Grand Caucase. HEL : plate-forme hellénique. IR : Irlande. M : Mauritanides. MC : Massif central. MN : Montagne Noire. MP : plate-forme moésienne. NF : Terre-Neuve. OM : Ossa Morena. SA : Alpes du sud. SC : Ecosse. SD : Sardaigne. SI : Silesie. SP : Portugal. SP : plate-forme scythienne. TAU : plate-forme taurique. TU : zone turkmène. TTZ : Teyssiere-Tornquist Zone.

La partie européenne de la carte d'après Beauchamp *et al.* [1991], Edel & Weber [1995], Franke [1989], Guterch *et al.* [1994], Izart & Vachard [1994], Matte [1986], Okay *et al.* [1994], Sandulescu [1978] et Sengör [1995].

south. They pointed out that the opening of the Black Sea rifted them apart during the late early Cretaceous. In the same way, recent palaeomagnetic results from the western Pontides by H. Théveniaut [1993] have shown that this region was still part of the Moesian block at least from early Trias to late Jurassic. Ustaomer and Robertson [1993] suggested two alternative interpretations of the "Palaeozoic of Istanbul": (1) it was originally part of Gondwanaland and later united with Laurasia; (2) it formed part of the Laurasian margin until the back-arc opening of the Black Sea in the late Cretaceous. Recently, Okay *et al.* [1994] suggested that, before the Cretaceous, the "Istanbul Zone" was located along the Odessa Shelf between the Moesian Platform and the Crimea (fig. 5), and had drifted southwards along two major transform faults during the development of the western Black Sea Basin, between the Albian and early Eocene (fig. 2). Although this model seems compatible with existing geological and geophysical data, it nevertheless raises important questions, such as:

1) how well, and to what degree do the sequences of the western Pontide fragment and the Moesian Platform correlate in terms of detailed sedimentology, palaeontology, geochemistry, and structural geology?;

2) although the "Palaeozoic of Istanbul" contains two typical units of the external zones of the Variscan belt, no fragment of the more internal zones has been identified in NW Turkey. Where could they be? A tentative reconstruction of the Hercynian chain is presented on figure 5 where the Palaeozoic formations of Istanbul are situated along the southern border of the East European Platform, next to the Dobrodgea (DB) and Moesian Platform (MP). The map shows how the relative westward displacement of north Gondwana (arrows) may have isolated the Palaeozoic of Istanbul from the inner zones, which now are found as fragmented units (CF) in the eastern Carpathian Mountains [Ledru, 1996];

3) if the "Palaeozoic of Istanbul" was separate from the Pontide chain until the early Tertiary, we should find significant differences in the structure and stratigraphy of the

pre-Eocene formations of these two units. However, some pre-Eocene formations, such as the Inalti Fm (late Jurassic to early Cretaceous carbonates) seem to be present in both areas;

4) the transform faults which are supposedly located on the both sides of the "Palaeozoic of Istanbul" and have guided it to its present location in the south have been recognised in seismic sections off the Bulgarian and the Crimean shelves (fig. 2) [Dachev *et al.*, 1988; Finetti *et al.*, 1988; Okay *et al.*, 1994]. No data yet indicate that these structures actually come ashore in Turkey, though they could have been largely obliterated by the ubiquitous post-Eocene north-vergent thrusts around the Black Sea periphery.

Addendum

In a recent paper, Okay and Leven [1996] describe the late Carboniferous sequence of the Pulur region, near Bayburt in the eastern Pontides. Contrasting with the Zonguldak region, the late Carboniferous is marine and contains fusulinds of Kasimovian to early Gzelian age in alternating shales, sandstones and shallow-marine limestones with corals (Çatalçesme Formation, 1100 m). It is conformably overlain by arkosic sandstones (Hardisi Fm., 1000 m) attributed to latest Carboniferous and early Permian. This sequence probably overlies the high grade metamorphic rocks of the Pulur massif. The authors emphasize the analogies that can be drawn during Carboniferous between the eastern Pontides and the Caucasus realm, and compare the Pulur sedimentary sequence with the European molassic Rotliegende formation.

Acknowledgements. — The authors are indebted to TUBITAK for its support to this project in the frame of GloTek, and to W.T. Dean and Ian Metcalfe who suggested many improvements to the first draft, and to Ph. Matte and W. Franke who critically reviewed the manuscript. O.M. is grateful to P. Ledru and J.B. Edel for reading and discussion.

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