Correlation of the Alpidic geotectonic features in the Eastern Mediterranean

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Abstract

A survey on the main Alpidic geotectonic structures, their genesis and correlation in the Eastern Mediterranean is given, useful for the understanding of the principal types and phases of ore mineralization.

Zusammenfassung

Ein Überblick über die Hauptzüge der alpidischen tektonischen Strukturen des östlichen Mediterran-Gebietes, über deren Genese und Korrelation wird vorgelegt, mit dem Zweck, das Verständnis für die grundlegenden Typen und Phasen der alpinen Erzlagerstättenbildung dieser Region zu fördern.

Content

1. The significance of the tectonic events for metallogeny

After more than hundred years of intensive geological investigations in the Eastern Mediterranean realm the structure of this region is now known in its princi-

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pal features. Of course still a lot of questions concerning the correlation of the different units of the individual sectors of this mountain chain remains to be clarified.

During the last years new methods like paleomagnetic investigations, radiometric dating etc. and new concepts like the plate tectonics brought light into some genetic problems.

Important phases of geotectonics in the Alpidic era, connected with metallization, are the following events:

1. The attenuation of the earth crust and somewhat later the rifting and opening of first rift-systems: This first step began in the region mentioned during the Permian (attenuation) and the lower Middle Triassic (first rifting) by a progressive division of Pangea into two supercontinents on both sides of the scissorlike opening Tethys. During this phase particulary the stratiform ore deposits of sulphides of Pb, Zn, Fe, Cu, Sb and Hg have been formed.

2. The formation of wide true ocean-floors with thick ophiolite sequences followed during Jurassic and (Lower) Cretaceous time, combined with island-arc volcanism. Magmatic ultramafic to mafic and volcano sedimentary types of ore deposits prevailed in this phase with metals like Fe, Cu, Ni, Cr, Co, Zn, Mn.

3. By the Upper Triassic to Liassic Cimmerian (-Indosinian) phase in the eastern part of the northern branch of Tethys and by a sequence of Alpidic orogenic phases since the Lower Cretaceous (since the Austroalpine phase in the Hauterivian-Barrémian) in the entire Tethys began the subduction of the margins of the great plates, began the orogenesis with nappe formation and an calcalcaline volcanism with andesitic to dacitic magmas. It was connected with the formation of porphyry copper ores, and with deposits of Mo, Au, Pb, Zn etc. This type of volcanism and also a granodioritic plutomism lasted still until the younger phases of the orogenetic development in Miocene time, accompanied or followed by hydrothermal ore deposits (Pb, Zn, Sb, Mo, Hg, As etc.).

2. The main features of the Alpidic paleogeography of the Eastern Mediterranean

The attenuation of the crust in the Eastern Mediterranean realm began with the birth of the Tethys during Permian time, when the Mediterranean region was invaded by the sea, coming from the east and advancing towards west. The formation of this Permo-Mesozoic Tethys was totally independent of older Mediterranean oceans, like the extremely broad Hercynic "Prototethys" in Central Europe. This Alpidic Tethys was formed completely discordant above the eroded Hercynian mountain system, as well as above the northernmost part of the old socle of the Afro-Arabian block.

The advance toward west of the Tethys in Permian time reached the Carnian Alps, Sicily and Tunisia, in Triassic time (with the Sephardic facies as marginal sea) the Betic Cordillera and the Rif, in Jurassic time by opening of the Tethyan Atlantic, the region of Middle America.

Starting already in Permian time, a characteristic subdivision of the Tethys area into three longitudinal zones is recognizable, remaining with somewhat changing details also during the Mesozoic era:

a) A northern trough of the Tethys sea above an attenuated crust received a thick sequence of neritic sediments during Permian time. Here the rifting of narrow channels with oceanic floor with ophiolites, pillow lavas and radiolarites had started since the earlier Middle Triassic: in the Western Carpathians since the Middle Triassic (Meliata series), in the Eastern Carpathians (Transsylvanian nappe) and in the Dobrodgea since the Lower Anisian. The eastern prolongation of this northern channel from Crimea to Caucasus and a parallel secondary rift system in Northern Anatolia (Karakaya Marginal Sea Belt) have been closed during Upper Triassic time by the Cimmerian orogenesis. But under a somewhat changed shape the northern branch of the Tethys sea had regenerated since the Lower Jurassic.

b) A median rise, formed by a long, later divided microcontinent with thick crust, named Kreios. This broad geoanticline sometimes was flooded by shallow sea, bearing typical alpine-mediterranean macro- and microfaunas, or fell dry, forming gaps of different extent in the corresponding series or showing masses of detritic material. The flora of this microcontinent formed – e. g. during the Ladinian/Carnian time – a separate Mediterranean phytogeographic region with mixed northern (Laurasia) and southern (Gondwana) types of flora (N. PANTIĆ et al., 1983, p. 6). The position of this median rise as a middle ridge yet in Permian time was pointed out by I. ARGYRIADIS (1975, p. 60, p. 95 ff.; 1980), and in Triassic time and later by A. TOLLMANN (1978, p. 341: "Kreios").

c) The southern trough also was marked by a thick series of neritic sediments during the Permian. In Triassic time the rifting of the crust had begun here since the Middle or Upper Anisian by the opening of a series of parallel narrow troughs: The longest external deepwater basin with pelagic sediments, flysch and lavas in Middle Triassic time represents the Budva-Cukali-Pindus zone in the Dinarides and Hellenides, Cyprus and an equivalent in the Taurus of Antalya. Further internal rifting zones in Triassic time were mentioned by G. KAUFFMANN (1976) from Greece. During the Jurassic and the Cretaceous a broad ocean formed in the eastern prolongation of the southern Mediterranean branch of the Tethys in Zagros and in Oman.

3. Some remarks on regional tectonics

a) The northern branch of the Alpine orogenetic system

The northern branch of the Eastern Mediterranean comprises the Eastern Alps, the Carpathians, the Balkan chain and the Pontides in Anatolia, moreover also a spur running from the Dobrodgea to Crimea and Caucasus.

The connection of the nappe system of the Eastern Alps and Western Carpathians was established in a satisfactory manner by D. ANDRUSOV (1960, 1968), A. TOLLMANN (1960, 1969, 1975), M. MAHEL (1979) et al. For details see their publications: As equivalents of Flysch, Helvetides, Penninic, Lower-, Middle-and

Upper-Austroalpine nappe systems of the Alps one can recognize Flysch, Pienides, Tatrides, Vysoká and Krížna, Veporides (with Föderata- and Velký Bok-series) and Choč-Strážov-Gemerides in the Carpathians. The Meliata unit and the Südbükkschiefer unit represent a new Carpathian element above the oceanic crust (H. KOZUR & R. MOCK, 1973; K. BALOGH et al., 1984). In general one can not agree with the ideas of B. LEŠKO & I. VARGA (1980) about the tectonic correlation based on some geophysical data: The Penninic zone of the Alps shurely does not reappear in the Klippenbelt, the Veporides and Gemerides.

The great break between the Transdanubian Mts. and Western Carpathians on the one hand and Tisia and Eastern Carpathians on the other hand is explained by H. P. LAUBSCHER (1971, Fig. 2), B. GECZY (1973, p. 426), F. HORVATH et al. (1977, p. 210, Fig. 1), S. KOVÁCS (1980, Fig. 5; 1982, Fig. 1) et al. as a considerable transverse strike-slip fault along the Tisia block, including the Bihor autochthonous in the east, which was transported from the outer zone of the Carpathians (marginal Gresten facies today in the south in Mecsek, Villany and Bihor!) to an inner position. The opinions about the timing of this shift vary from Lower Cretaceous to Lower Tertiary. The north facing nappe system of the Apuseni Mts. therefore is considered as the displaced prolongation of the nappe system of the Western Carpathians, supported also by the facies sequence within this nappe pile (M. BLEAHU, 1976).

The correlation of the tectonic units of the Eastern and Southern Carpathians has been given in 1969 by A. TOLLMANN (map Fig. 1) and in excellent manner in recent time – including the Kraistides and the Balkan chain – by M. SANDULESCU (1975, Figs. 2, 3, 16, 17, 26, 30) and M. BLEAHU et al. (1974), so that it is sufficient to draw the attention to these publications.

The nappe structure in the area of the Paring window with a sequence of Danubian (below), Severin-, Getic- and Supragetic nappe can be traced to the Balkanides (tectonic division cf. E. BONČEV et al., 1974): The Pre-Balkan corresponds with the external Danubian, the Stara Planina nappe with the internal Danubian, the Srednogora nappe with the vast Getic nappe (M. SANDULESCU, 1975, Fig. 16).

The problematic structure of the (Sakar-) Strandsha zone in the eastern part of the Srednogorie unit is either explained as a tectonic window with metamorphic Triassic and Jurassic (A. TOLLMANN, 1965; 1968, p. 59; P. BECK-MANNAGETTA et al., 1978, map: "Thrakian window") or as a fault trough (graben) with a metamorphic Lower Paleozoic and also Mesozoic series (I. NATSCHEW et al., 1979) or as an anticlinorium with metamorphic Triassic-Jurassic in local synclines (S. SAVOV, 1962; S. SAVOV et al., 1971).

The movements of the Balkanide nappes doubtlessly are directed towards north. A nappe structure is evident. Therefore we can not agree with the hypothesis of a slightly folding without any southward dipping subduction zone in the sense of E. AIELLO et al. (1977, Fig. 3) or K. HSÜ et al. (1977, Fig. 5).

Recently even the idea arised that the vast Srednogorie nappe has been thrusted as a whole above the Rhodope massif, which was interpreted as a tectonic window (P. BECK-MANNAGETTA & W. MEDWENITSCH, 1978, Nebenkarte 1 : 9,000.000).

The prolongation of the main northern branch of the Mediterranean orogen runs eastwards to the Pontides in northern Anatolia. A new synthesis of A. ŞENGÖR & Y. YILMAZ (1981) gives a pretty survey including a lot of details on the Tethyan evolution of Turkey in space and time. In Permotriassic time two ocean channels of the northern branch of the Tethys acted as mobil zones: The Crimea-Caucasus-Mashad trough in the north and the Karakaya Marginal Sea as a narrow channel south of the Pontides. By the Cimmerian orogenesis in the Upper Triassic both areas have been reduced, the southern one was totally closed. After A. ŞENGÖR et al. (1981, p. 210 ff. and Fig. 6B) two new ocean channels were formed in northern Anatolia during Early Jurassic time: the Intrapontic branch and – divided by the Sakarya microcontinent – the Izmir-Ankara channel. Since the Middle Jurassic the sea has again invaded a broad area of northern Turkey ("Vardar ocean") north of the central Anatolian platform. The alpine orogenesis in this region began with the subduction north of the Pontides island arc during Mid Cretaceous time, continued with ophiolite obduction (Bozkir ophiolite nappe) in Late Cretaceous and was finished mainly in Mid-Eocene – much sooner than in the southern branch of the Tethys in this country. A. ŞENGÖR et al. (1981) think about north dipping subduction zones beneath the European continent and Sakarya island and therefore a southward facing of nappe structures in the Pontides, still has not been proved sufficiently (cf. I. KETIN, 1956, Fig. 1).

b) The southern branch of the Alpine orogen

Concerning the tectonic correlation of the units in the southern branch of the eastern Mediterranean realm we can be brief with regard to some recent papers, summerizing our knowledge from the region of Dinarides-Hellenides. After the "classic" papers of L. KOBER (1952) and K. PETKOVIĆ (1958) about the great tectonic lines of the Dinarides we mention at least the articles by J. AUBOUIN (1963, 1973), J. AUBOUIN et al. (1970), M. HERAK (1986), W. MEDWENITSCH (1956), W. MEDWENITSCH & B. SIKOŠEK (1965), J. PAMIĆ (1984 a, b), B. SIKOŠEK (1974), B. SIKOŠEK & W. MEDWENITSCH (1965) as some reviews about the structure of the Dinarides and the papers by J. AUBOUIN et al. (1970, 1976), D. BERNOULLI et al. (1972, 1974), V. JACOBSHAGEN et al. (1976, 1978), J. CADET et al. (1980), M. BONNEAU (1984), R. HALL et al. (1984), A. POISSON (1984) about the Hellenides and their correlation to the Taurides. The article by R. BLANCHET & J. MERCIER (1978) and the volume by J. DIXON & A. ROBERTSON (1984) summarizes all important facts about the whole region.

As summary of all these papers results: From the external side in the west, from the foreland Apulia, with thick neritic sediments of Triassic and Jurassic we meet prograding towards East, towards the internal region, however, the following facies zones (respectively nappes in later time):

1. The Adriatic-Ionien Zone, a miogeosynclinal trough zone, with neritic series up to the Middle Liassic, covered by a pelagic sequence. This zone is relatively autochthonous, with Schuppen structure, detached in the Triassic gipsum level.

2. The Dalmato-Gavrovo-Tripolitza Zone, a miogeosynclinal shallow platform, rich in reef-buildups, only in Crete allochthonous.

3. The Budva-Cukali-Pindus Zone, an eugeosynclinal deep water trough with abundant pelagic series including radiolarits and basic lavas from Triassic to Eocene time, finally transported as a cover nappe far towards the West.

4. The Karst-Parnass Zone, a platform with thick neritic series mainly from Triassic to Upper Cretaceous, namely in the High- and Pre-Karst. Nappe structure.

5. The Bosnian-Grammos-Beotian Zone, a trough with pelagic sediments from Triassic to Jurassic and a flysch of the Cretaceous. The facies corresponds in best manner with that of the Pindus Zone.

6. The Serbo-Subpelagonian Zone, a deep trough during Upper Jurassic and Lower Cretaceous with masses of ophiolites and radiolarites, covered by neritic series of Higher Cretaceous. Transported as a nappe system (Merdita-, Durmitor-nappe etc.) with rests of a sole of Paleozoic (in Yougoslavia) and Triassic formations.

7. The Golija-Korab-Pelagonian Zone, a ridge with a neritic Triassic and Jurassic series covered by a sheet of ophiolites and a gap up to the Upper Cretaceous. This unit was transported as a nappe system (Korab-Perister nappe etc.) with a socle of crystalline basement and granites. In the eastern part of this zone and its eastern prolongation we find the windows of Olympus, Attica, Eubea, the Cyclades and Menderes. The units 5–7 have been summarized by L. Kober (1952) as "Extern Radiolarite-Ophiolit Zone" = "ERO".

8. The Vardar Zone ("IRO-Zone" L. Kober), the innermost trough zone in front of the Serbo-Macedonian hinterland (9), is characterized by masses of ophiolites and radiolarites (diabase-hornfels formation) in the Upper Jurassic, deposited on neritic Triassic-Jurassic limestones. Three phases of flysch(oid) formations (boundary Jurassic/Cretaceous, Middle and Upper Cretaceous) follow.

In a comprehensive manner we can group the units 1–2 into the relative autochthonous miogeosynclinal external area, the unit 3–8 into the allochthonous eugeosynclinal internal area. The distances of the nappe transport of these inner units exceed about hundred, probably in some examples also two hundred kilometers. The formation of nappes took place essentially during the Lower Cretaceous and the Late Eocene (D. Bernoulli & H. Laubscher, 1972). As an indicator for the wandering of movements from the inner to outer zones we can – as usually – utilize the beginning of the flysch formation. According to J. Aubouin (1964) and particularly D. Richter (1976, 1978 a, b) we find the oldest flysch (1) of Dogger age in the inner Vardar Zone (Svoula flysch), then (2) the Eohellenic flysch of Upper Jurassic to Lower Cretaceous in the Vardar- and Pelagonian zone, followed (3) by the main flysch stage of the inner zones (Pelagonides, Parnass, Pindus) from the end of the Cretaceous to the Upper Eocene, and finally (4) the main flysch stage of the outer zones (Gavrovo, Ionian zone) from Upper Eocene to Lower Miocene, terminated by a L./M. Miocene flysch of the outer fold zone.

The metamorphosis began in the inner region, the Vardar zone, after a first precursor of the Upper Jurassic ophiolite phase in the Midcretaceous before the sedimentation of the Albian flysch.

The correlation from the Aegean region to Anatolia and to the Taurides was stated by papers of W. E. PETRASCHECK (1960), J. AUBOUIN et al. (1976), D. BERNOULLI et al. (1974), R. BRINKMANN (1976), J. BRUNN et al. (1976), J. DIXON & A. ROBERTSON (1984), L. MOUSSOULOS et al. (1977), O. MONOD (1977) etc.

In the Taurides of southern Anatolia the rifting of the crust started in Upper Anisian to Ladinian time with production of radiolarites, tuffites, pelagic limestones, turbidites, slumpings and olistholits. A second phase in Carnian time brought up to 600 m of pillow lavas, of ophiolites, accompanied by radiolarites, pelagic and turbiditic sediments (TH. JUTEAU, 1970, 1979; J. MARCOUX, 1974; O. MONOD et al., 1974). This deep ocean channel can be traced since the Triassic from the Antalya nappes regions across Bitlis to the Zagros, with the maximum of tectonic activity in Upper Cretaceous (L. RICOU, 1971, Fig. 1). The maximum of the oceanic stage in the Taurides was attained in Early Cretaceous. Since Midcretaceous time here the orogenesis started along a north dipping subduction zone, forming the pile of Lycian nappes in the region of Antalya (I. KETIN, 1960; E. BINGÖL, 1974; J. BRUNN et al., 1972, 1974; J. MARCOUX & A. POISSON, 1972; L. RICOU et al., 1974, 1975, 1979; J. DIXON et al., 1984; R. MALL et al., 1984; A. ŞENGÖR et al., 1984).

4. Review about the great steps of Alpidic evolution

The formation of the Mediterranean Tethys began by the—above mentioned—attenuation of the Hercynian crust during Permo-Skythian time as the result of the start of the scissorlike meridional drifting of the two supercontinents. Since the Lower Anisian the first oceanic rift channels opened in the northern and southern branch of the Tethys. The attenuation of the crust continued. The facies of the sediments is also dictated by eustatic see level movements (Lower Carnian event etc.). The Jurassic evolution is controlled by the transversal drifting of Africa from Northern America: By this rifting broad oceans opened in the Penninic area in échelon pattern. The attenuation and rifting of the crust rise up to its maximum during the Upper Jurassic with its ophiolite-radiolarite formations in the northern and southern branch of this sector of the Tethys and with formation of grand gravity sliding nappes of the Hallstatt zone in the northern branch. The main subduction by a convergent drifting of the supracontinents started in both branches of the Tethys by the Austroalpine phase of Hauterivian-Barrémian (130—125 million years ago), followed by the first metamorphic processes. The nappe formation realized during Midcretaceous and Lower Tertiary, followed the advance of the subduction front from the inner to the outer zone in both branches. In younger time great block movements along transverse faults interferred with the overthrust tectonics. The ore mineralization during the whole Alpidic era was corresponding with these tectonic events, as outlined in the first chapter.

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