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Neotectonic map of Syria and some aspects of Late Cenozoic evolution of the northwestern boundary zone of the Arabian plate

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Abstract

The neotectonic map of Syria, 1:500,000, was compiled by the authors in 2003–2004. The map shows tectonic features formed or continued to develop during the Neogene and Quaternary in Syria and adjacent territories, including the Mediterranean realm. The neotectonic structure of the region was formed as a result of three phases of deformation. During the Early Miocene first phase, the Arabian plate moved along the Dead Sea–Jordan segments of the Levant (Dead Sea) transform fault zone, Roum fault and its continuation in the continental slope of the Mediterranean. The chain of the coastal anticlines in the “Arabian” side of the transform zone and the Lattaqie oblique (sinistral-thrust) boundary fault zone in the north were formed under the NNW-trending compression. The Lattaqie zone continued by the Cyprus arc in the west and by the Taurus (Bitlis) thrust in the east and further by the Main Thrust of the Zagros. After “quiet” (for Syria) epoch of the Middle Miocene when the Arabian plate moved to the NE, during the Late Miocene second phase of deformation, the Arabian plate moved again to the NNW along the same transform boundary. But a part of the Late Miocene plate motion (up to 20 km) resulted by shortening in the Anti-Leban–Palmyride fold-thrust belt that separated the Aleppo block from the main part of the Arabian plate. During the Pliocene–Quaternary third phase of deformation, the recent structural pattern of the Levant zone was formed in Lebanon and the northwestern Syria. At the same time, the Serghaya and smaller sinistral faults branched out the Levant zone and the system of the W–E-trending convex to the south dextral faults ruptured the Palmyrides and the stable part of the Arabian plate. The total Pliocene–Quaternary sinistral offset on the young Levant zone segments and the associated faults has reached 35–40 km, like on the Dead Sea–Jordan segments of the Levant fault zone. The faults, demonstrating the Pliocene–Quaternary activity are still active now and represent the main seismic zones in Syria. Offsets on them are mostly a cumulative effect of strong earthquakes.

Keywords: Neotectonic structure and phases of deformation in Syria; Active faults

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1. Introduction

Late Cenozoic structure and tectonic development of the western and northwestern margins of the Arabian plate have been subjects of intensive studies for last several decades, because these areas are important both for understanding general regularities of plate interaction and seismic hazard assessment in the region. All investigators consider the Levant fault zone (Dead Sea Transform, DST) by the western recent boundary of the plate. Structural pattern of the zone (en echelon mutual position of its segments, pull-apart basins between them, manifestations of the shortening component of motion in the Yamunneh, Lebanon, segment where the zone turns to the NE 30° from the general N–S trend) certainly indicates the sinistral sense of motion. The Late Quaternary left-lateral offsets found in the Aqaba, Dead Sea and Jordan segments of the zone (Zak and Freund, 1965; Garfunkel et al., 1981; Klinger et al., 2000; Zilberman et al., 2000) as well as in the Lebanon (Quennell, 1984) and Syrian (Trifonov et al., 1991, 2002; Meghraoui et al., 2003) segments. The segments were renewed during the historical and recent (post-1900) earthquakes (Ambraseys and Jackson, 1998). The Late Quaternary and recent offsets correspond to focal mechanisms of earthquakes (Ioffe and Garfunkel, 1987).

The data on the older history of the Levant zone were obtained in its southern (Dead Sea–Jordan) half. The investigators (Quennell, 1959; Freund et al., 1968, 1970; Garfunkel, 1981; Walley, 1988; Darkal et al., 1990) grounded the total offset on the zone to about 105 km and attributed 35–40 km of it to the Pliocene and Quaternary. Although their proofs were called in question (Mart, 1991; Sneh, 1996), such a big offset seems to be very probable. The youngest formation affected by the offset is the 24–20 Ma old Red Sea dike system and the oldest sediments in the Dead Sea and Sea of Galilee are dated by 18–17 Ma (Garfunkel and Ben-Abraham, 2001; Hurwitz et al., 2002). So, the Levant zone has been developed since ∼20 Ma. The history of lateral slip on the zone was correlated with the history of the Red Sea rift opening (Kaz'min, 1974; Kaz'min et al., 1987). Its total magnitude up to 300 km and magnitude of the Pliocene–Quaternary spreading to 75 km approximately correspond to the Miocene and Pliocene–Quaternary slip on the transform (Izzeldin, 1987; Garfunkel and Ben-Abraham, 2001). The data on the transform slip sense and rates since 5 Ma correspond satisfactory to the calculated present-day kinematics of the Middle East and the eastern Mediterranean; the calculation has given the 7 ± 0.5 mm/a left-lateral slip rate on the transform (Westaway, 1994).

While the data on the structural position, amount of motion and history of the southern segments of the Levant zone between the Aqaba and Hula pull-apart basins correspond to each other, its northern continuation is a subject of discussion. Freund et al. (1970) advance reasons for 70–80 km sinistral offset of the Neo-Tethys ophiolite nappes on the Yammuneh, Lebanon, and El Ghab, Syria, segments of the Levant zone. Resting on the Freund's reasons, Garfunkel and Ben-Abraham (2001) reckon that most of the transform motion continued along these faults. Additional argument in favour of this notion is more evident shortening on the Taurus thrust zone to the E of the Levant zone, than to the W of it.

But other investigators (Girdler, 1990; Butler et al., 1997) think that significant and probably larger part of the motion was realized on the Roum fault that branched out the Levant zone in the western side of the Hula pull-apart basin and extended to the Mediterranean. Walley (1988) turned attention to absence of field evidence to support not only 70–80 km or larger total offset on the Yammuneh fault, but even 40 km of the Pliocene–Quaternary displacement (Dubertret, 1970) and proposed a "braided" strike-slip model for the northern continuation of the Dead Sea–Jordan part of the fault zone. According to the model, the motion is transmitted along a number of faults, joined into the Yammuneh–Serghaya fault system. Chaimov et al. (1990, 1992) showed by analysis of the 1:200,000 scale geological maps of Syria, seismic reflection and well data that the southwestern Palmyride fold-thrust belt had been shortened to ∼20 km and the shortening, decreasing to the NE (McBride et al., 1990; Brew et al., 2003) could also absorb a part of the transform motion.

The diversity of notions on the northern half of the transform is caused by a lack of data on the Late Cenozoic slip and its structural distribution in Syria. The previous studies of the Late Cenozoic tectonics had not been provided for all territory of Syria, whereas available neotectonic data on the separate regions were fragmental and not enough for understanding the geodynamic evolution of the main structural elements. So, the purpose of this paper is to sum up the data on neotectonics of Syria and try to use them for review of the Late Cenozoic history of the northwestern margin of the Arabian plate and development of the transform.

We used for the analysis the published data including the former authors' papers as well as unpublished authors' data obtained by field observations, interpretation of space images and studying seismic reflection and

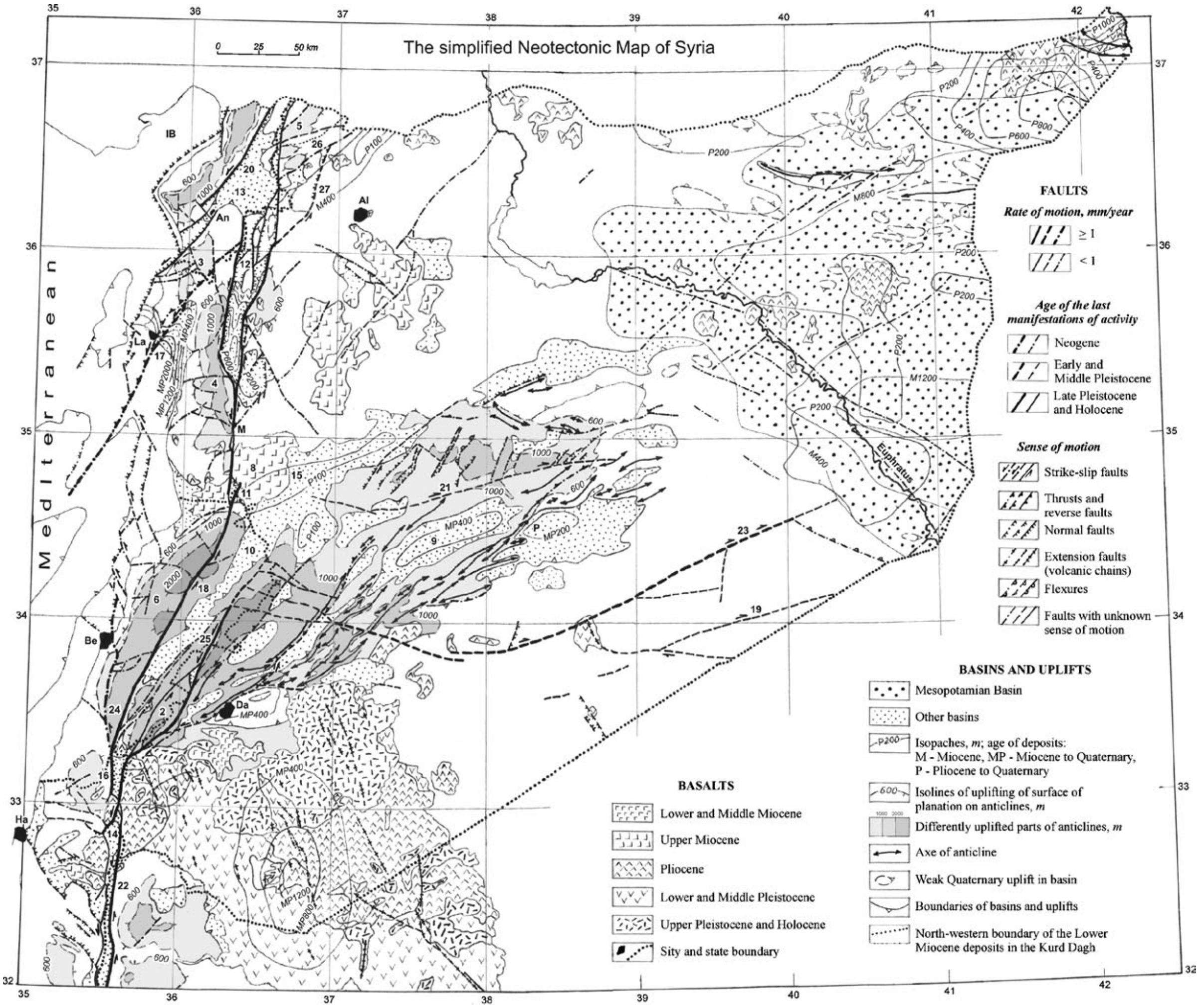

Fig. 1. Simplified neotectonic map of Syria. *Anticline ridges*: (1) Abdel Aziz, (2) Anti-Leban, (3) Bassit, (4) Coastal, (5) Kurd Dagh, (6) Leban. *Volcanic plateaus*: (7) Jebel Arab, (8) Shin. *Basins*: (9) Ad Daw, (10) Bekkaa Valley, (11) Bokaieh, (12) El Ghab, (13) Amik, (14) Galilean Lake, (15) Homs, (16) Hula, (17) Nahr El-Kabir, (18) Yammuneh. *Faults*: (19) Akfan, (20) Amanos, (21) Jhar, (22) Jordan River, (23) Olab, (24) Roum, (25) Serghaya, (26) Aafrin, (27) St. Simeon. Al, city of Aleppo; An, city of Antakia; Be, Beyrouth; Da, Damascus; Ha, city of Haifa; IB, Iskenderun Bay; La, city of Lattaqie; M, town of Myssiaf; P, town of Palmyra.

well sections collected in the Syrian Petroleum Company. A result of our analysis was compiling of the neotectonic map of Syria and Lebanon, 1:500,000 (Fig. 1). According to the Russian geological terminology, we understand neotectonics as tectonics of the Oligocene to Quaternary time (Trifonov, 1999). Because the Syrian Oligocene uses to continue the Eocene sections without unconformity and the essential deformation took place later, we have limited the neotectonic epoch for Syria and correspondingly our analysis by the Neogene and Quaternary.

2. Principles and a legend of the neotectonic map

The neotectonic map of Syria and Lebanon, 1:500,000 (Fig. 1), was compiled in 2003–2004 by the authors under leadership of M. Rukieh (Editor-in-Chief), V.G. Trifonov (Editor, Responsible Executor) and A.E. Dodonov and H. Minini (Deputies of the Responsible Executor). The map is based on the data of geological mapping of Syria in scales 1:200,000 and 1:500,000 (Geological Map of Syria, 1964; Ponikarov et al., 1967) as well as tectonic mapping (Leonov, 1989; Barazangi et al., 2001), publications (Ammar, 1993; Brew et al., 2001, 2003; Chaimov et al., 1990, 1992; Devyatkin et al., 1997, 2000; Gomez et al., 2001, 2003; Knipper et al., 1988; Kopp et al., 1994; McBride et al., 1990; Meghraoui et al., 2003; Rukieh, 1997, 2000, 2001; Sharkov et al., 1994, 1998; Trifonov et al., 1991, 2002; Walley, 1988), isopach maps of the Miocene, Pliocene and Quaternary, compiled by T. Zaza and A. Yusef with using the data of the Syrian Petroleum Company, results of interpretation of Space Image Atlas of Syria (1996) and Topographic Map of Syria (1971), and field investigations carried out by the authors. Parts of the map covering the adjacent territories were made by using the published data (Adiyaman and Chorowicz, 2002; Butler et al., 1997; Carte Geologique du Liban, 1955; Dubertret, 1970; Garfunkel, 1981; Garfunkel and Ben-Abraham, 2001; Geological Map of Turkey, 1989; Perinçek and Çemen, 1990; Ron, 1987; Walley, 1988; Westaway, 2004; Yürür and Chorowicz, 1998), results of interpretation of space images and data on bottom bathymetry of the Levantine Sea (Hall et al., 1994).

The map shows tectonic features formed or continued to develop during the Neogene and Quaternary. They are faults, basins, folds and uplifts as well as volcanic formations, all of which reflect different phases of neotectonic development. The main features of recent topography (Fig. 2) were created for the same epoch.

The faults are differentiated by: (1) *age of the last geological and/or geomorphologial manifestations of activity*—the Neogene, Early–Middle Pleistocene and Late Pleistocene–Holocene; (2) *intensity of the Pliocene and Quaternary*

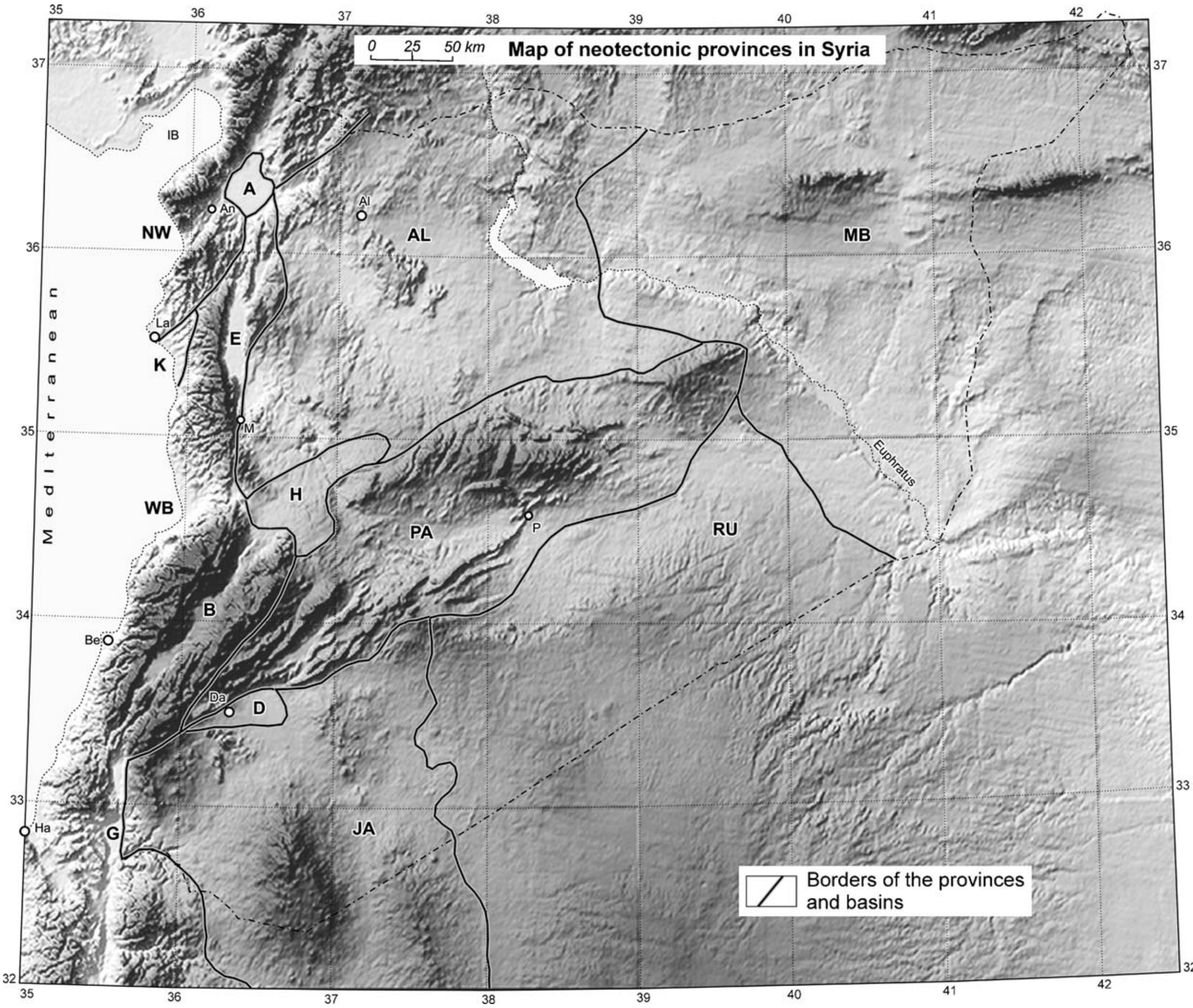

Fig. 2. A model of topography and boundaries of the neotectonic provinces in Syria and Lebanon. *The provinces*: (WB) the western boundary zone between the Arabian and African plates; (NW) the northwestern boundary zone between the Arabian and Anatolian plates; (JA) the Jebel Arab volcanic province; (PA) the Palmyrides; (AL) the Aleppo Plateau; (MB) the northwestern termination of the Mesopotamian basin; (RU) the stable part of the Arabian plate (the Rutbah province). *Basins*: (A) Amik; (B) Bekkaa valley; (D) Damascus; (E) El Ghab; (G) Galilean Lake; (H) Homs; (K) Nahr El-Kabir; (IB) Iskenderun Bay. *Sities*: (Al) Aleppo; (Be) Beyrouth; (Da) Damascus; (Ha) Haifa; (La) Lattaqie.

motion—faults with average rates of motion ≥1 and <1 mm/a; we have not been able to calculate the rates of the Miocene motion on the faults and have used the same symbols to separate main and secondary ones; (3) *sense of motion*—thrusts or reverse, strike-slip, normal and extention faults, flexures and faults with unknown sense of motion.

The Mesopotamian Basin and other basins of different genesis have been designated. To demonstrate the structure of basins, their boundaries and isopachs of the Late Cenozoic sediments and basalts are shown. The isopachs are signed by the age symbols of the formations: M, Miocene; MP, Miocene and Pliocene–Quaternary; P, Pliocene–Quaternary.

Neotectonic uplifts are bounded and their structure is demonstrated by isolines of rise of surface of planation (major anticlines like Leban and Anti-Leban) and/or by axes of folds (the Palmyrides). The magnitude of uplift is designed by different intensity of grey color. Boundaries of weak Quaternary uplifts that can correspond to structures perspective for oil and gas concentration are shown by special symbol.

For representation of the neovolcanic formations and structural elements, the basaltic fields of different age (Early and Middle Miocene, Late Miocene, Pliocene, Early and Middle Pleistocene, Late Pleistocene and Holocene) as well as volcanic chains, individual volcanoes and directions of the lava flow are shown.

3. Neotectonic provinces

Neotectonic provinces of the region differ by sense, intensity and age of the Late Cenozoic processes (Fig. 2). The provinces are seen in the neotectonic map because of differences of style and pattern of their individual structures. The neotectonic provinces are the following.

The western boundary zone between the Arabian plate and the northern part of the African plate (the latter is represented by the Levantine Sea of the Mediterranean) occupies the continental slope and coastal area including big anticline uplifts of the Coastal and Leban Ranges, the Bekkaa Valley syncline and the Anti-Leban Range. In the Late Cenozoic structure, the latter is also the marginal anticline of the Palmyrides, although it differs from the Palmyride folds by peculiarities of the previous development (Dubertret, 1970; Walley, 1998). All folds of the western boundary zone are ruptured by faults. The largest one is the Levant sinistral active fault zone. It is composed by several en echelon segments known as the Jordan, Yammuneh and El Ghab faults (Garfunkel and Ben-Abraham, 2001). The Galilean Lake, Hula, Bokaieh (Qalaat Al Hosn) and El Ghab pull-apart basins are situated between them. The Levant strike-slip zone has usually the N–S trend and smaller normal component of motion, the eastern side in the N and the western side in the S being subsided. But the Yammuneh segment of the zone strikes to the NNE–SSW and has reverse component of motion. Pull-apart basins are not characteristic for it. One of structures of this type is the small Yammuneh Basin near the village with the same name (18 in Fig. 1). The Levant zone is complicated by the Serghaya and several smaller associated sinistral faults branched to the NE out the zone (Walley, 1988). Another fault system is the Roum sinistral fault (Girdler, 1990; Butler et al., 1997) and its northern continuation in the continental slope. The latter is formed by combination of normal and sinistral faults. The reverse faults (perhaps, with strike-slip component) bound the Bekkaa Valley. A lot of smaller faults cut the Coastal and Leban Ranges.

The northwestern boundary zone between Arabian and Anatolian plates is represented by southwestern termination of the East Anatolian fault zone (EAFZ), nappes and ophiolites of the Bassit, Kurd Dagh and Amanos Ridge to the east of the Iskenderun Bay. All major faults strike to the SW–NE. The EAFZ is a system of oblique (sinistral and reverse) faults, such as: the Yakapinar-Göksun fault onshore of Iskenderun Gulf, the Amanos fault to the SE of the Amanos Ridge and the East Hatay fault eastward. They generated structures corresponding to shortening and sinistral slip. In consequence, the Amanos Ridge has to be regarded as an anticline and the Karasu valley to the SE of it as a syncline (Lyberis et al., 1992; Adiyaman and Chorowicz, 2002).

The ophiolite zones of the Bassit and Kurd Dagh had been thrusted in the Maastrichtian (Knipper et al., 1988). But the nappes control recent topography of the Bassit and Kurd Dagh that reasons into their the Late Cenozoic renewing. The nappes are offset by the E-trending dextral faults. The southeastern boundary of the Bassit part of the province is represented by the Lattaqie oblique (sinistral-thrust) fault zone (Ponikarov et al., 1967; Trifonov et al., 1991) that limits the Nahr El-Kabir Neogene Basin from the NW. The fault zone demonstrates several episodes of motion and deformation. The first of them produced thrusting of ophiolites in the Maastrichtian, when the Neo-Tethys was closed. The second episode took place in the Lower Miocene (see below). Later the fault zone served by the northwestern boundary of the marine sedimentation in the Nahr El-Kabir Basin during the all Neogene and the Early Pleistocene.

Structural difference of the Middle and Late Pleistocene terraces on the fault zone sides proves continuation of the activity. On the surface of abrasion marine terraces of the northwestern fault side in and near city of Lattaqie, only scattered marine pebbles can be observed. In the southeastern side of the fault zone, the terraces are composed by several metres of marine sands, sandstones and sandy limestones with lenses of gravel and pebbles. The correlation of the lower (Late Pleistocene) terraces in both sides of the fault zone shows decrease of their levels in the southeastern side from 41 up to 27–34 m and from 20 up to 17–20 m.

The Lattaqie zone is cut and offset by the Dead Sea (Levant) transform and continues to the NE of the El Ghab Basin by the fault that we called by the Aafrin lineament (Trifonov et al., 1991). This Aafrin fault separates the Kurd Dagh thrust-fold structure and the Neogene Basin that could continue the Nahr El-Kabir Basin to the NE. The fault is exposed near the village of Kara-Bash as the 150-m wide zone with several parallel ruptures and tectonic lense of the Paleogene limestone dipped 60° NW. The ruptures cut the Lower Miocene limestones and marls and are complicated by carst cavities near the land surface. Two ruptures are filled by tectonic breccia 0.3 m thick and demonstrate vertical offset of the Late Quaternary colluvium to 0.4 and 0.25 m. So, the weak activity of the Aafrin fault as well as the Lattaqie one continues up to the Late Pleistocene and perhaps the Holocene. Unlike the Lattaqie zone, the Aafrin fault does not limit the Lower Miocene deposits; they continue ∼10 km northward the fault and are limited by small faults within the Kurd Dagh.

The Levant active fault zone is limited by the faults of the EAFZ. The western strand of the Levant zone, bounding the El Ghab Basin from the west is identified in the Amik Basin as a small scarp on the surface of the Upper Quaternary deposits (Adiyaman and Chorowicz, 2002) and does not continue northward the Amanos fault. The strand which bounds the El Ghab Basin from the E continues further to the north and terminates against the East Anatolian zone near town of Narli (Perinçek and Çemen, 1990). The eastern St. Simeon strand, which branches from the eastern side of the El Ghab Basin to the NE is limited by the Aafrin fault.

The Jebel Arab volcanic province occupies all the southern part of Syria and continues to Jordan. It is the great basin overfilled by basaltic flows with volcanic cones and chains. Thickness of basalts attains 1200 m (Ammar, 1993). Average altitude of the volcanic plateau is about 800 m with highest volcanoes more than 1000 m. Age of the basalts is ranged from the Early Miocene (Sharkov et al., 1994, 1998; Devyatkin et al., 2000; Rukieh, 2000) up to the historical time (Trifonov et al., 1991). Big part and, perhaps, majority of the basalts were erupted from volcanic chains concentrated on the NW-trending extension faults. Unlike basaltic eruptions in the oceanic spreading zones, for example the rift zones of Iceland (Trifonov, 1978), the Jebel Arab extension faults erupted lava during long time, and volcanoes with ages from the Pliocene up to the Late Pleistocene could be located on the same faults.

The Palmyrides is the ENE-trending en echelon row of the NE-trending linear asymmetric anticlines with steeper and thrusted southeastern sides. The anticlines are composed by the Cretaceaus and Paleogene sediments and some of them have diapiric cores of the Triassic evaporites. The intensity of folding reduces to the NE. The anticlines are manifested in topography by ridges, but their steep slopes are sometimes eroded and the highest altitudes correspond to the northwestern slopes. General altitudes reduced from 3000 m in the Anti-Leban, composed mostly by the Jurassic and Cretaceaus carbonates, up to 600–700 m in the eastern termination of the folded system. The syncline basins between the anticlines have irregular contours and are filled by the Neogene and Quaternary continental terrigeneous deposits. The biggest is the Ad Daw Basin. The northern Palmyrides are characterized by the peculiar tectonic style. It is really a single major gentle anticline, the northeastern part of which is separated out the bigger southwestern part by a chain of the WNW-trending steep small anticlines and thrusts. The bigger southwestern part of the gentle anticline is cut by the NNE-trending grabens, bounded by normal faults or flexures and partly filled by the Upper Pliocene (?) and Quaternary sediments.

The Aleppo Plateau is the northern stable block of the Arabian plate with the almost horizontal sedimentary cover, the Neogene (and rare Quaternary?) basaltic flows and small magnitude faults of the northeastern and rarer northwestern strikes.

The northwestern termination of the Mesopotamian Basin is differentiated to the folded northern and undeformed and deeply subsided southern parts. The folded subzone continues the zone of the Marginal Folds of Turkey and analogous folds of the Zagros. All anticlines are asymmetric: a slope, looking to the undeformed part of the basin is steeper, than another slope and is often ruptured by thrust or reverse fault. Unlike them, the Abdel Aziz anticline in the southern part of the subzone is characterized by the contrary asymmetry. The Pliocene–Quaternary syncline basin separates the Abdel Aziz and more northern anticlines of the subzone. The undeformed subzone of the Mesopotamian Basin has the step-like southwestern side corresponding to the Euphratus buried fault zone.

The stable part of the Arabian plate (the Rutbah province) occupies the southeastern part of the country named by the Syrian Desert. It is covered by thick undeformed Phanerozoic sedimentary rocks.

4. Azonal neotectonic features

Two elements of the neotectonic structure have transzonal distribution.

Firstly, there are basins with triangular or irregular countours in junction of three provinces. They are the *Amik Basin* in junction of the El Ghab pull-apart graben and intermountain Karasu Basin in front of the Amanos Ridge (i.e. between the western and northwestern boundary provinces and the Aleppo Plateau); the *Nahr El-Kabir Basin* between the western and northwestern boundary provinces and the Levantine Sea; the *Homs Basin* between the Aleppo Plateau, western boundary province and the Palmyrides; the *Damascus Basin* between the Palmyrides, the western boundary and Jebel Arab provinces (Fig. 3).

Secondly, there is a system of the W-E-trending dextral faults convex to the S. The system is represented by Jhar, Olab and Akfan faults and several smaller ruptures of the same trend. The *Jhar* fault delimits the southern and northern Palmyrides and is lost in the Homs Basin. The largest *Olab* fault cuts the all northern part of the Rutbah province and the Palmyrides and joins with the northern termination of the Serghaya fault. The southern *Akfan* fault is observed more or less continuously only in the eastern part of the Rutbah province. Westward it is represented by fragments, the western of which joins with the Damascus fault of the southwestern Palmyrides.

4.1. Basalts

The most complete section of the Neogene–Quaternary basalts is observed in the Jebel Arab Plateau. In other provinces, only some parts of the section are present. Ages of the basalts were determined by analysis of their stratigraphic position and K–Ar dating (Fig. 4). Detailed location of the dated basalts and their chemical composition are described in the previous publications (Sharkov et al., 1994, 1998; Devyatkin et al., 2000). The Miocene basalts are known in the western part of the country. They include the Lower Miocene (pre-Helvetian) lavas with the K–Ar age of about 20 Ma in the western part of the Aleppo Plateau, the western slope of the Jebel Arab Plateau and adjacent part

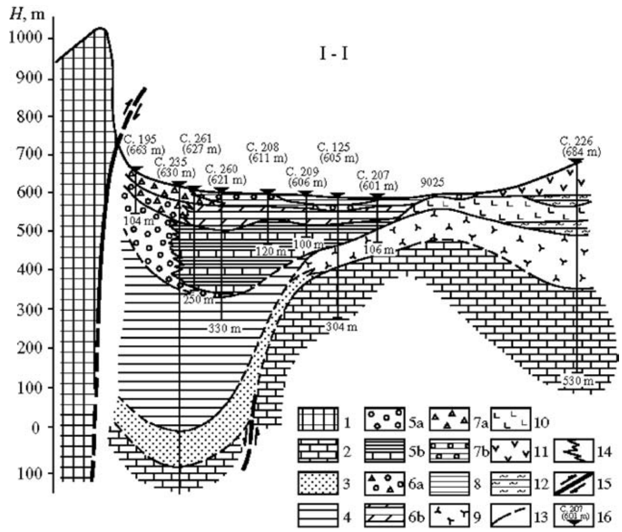

Fig. 3. Geological profile across the Damascus Basin (Devyatkin et al., 2000), with using the drilling data provided by *Lengiprovodkhoz* (Water Resources Management Institute, St.-Petersburg); line of the profile is shown in Fig. 4. (1) Palmyride fold zone; (2) Paleogene undeformed marine sediments; (3) Early Miocene continental sands; (4) Early Pliocene lacustrine clays, marls and sands; (5) Late Pliocene–Early Pleistocene red alluvial-proluvial conglomerates (a) and lacustrine clays and limestones (b); (6) Middle Pleistocene proluvial and alluvial pebbles, boulders and debris (a) and lacustrine clays, marls, and sands (b); (7) Late Pleistocene proluvial pebbles (a), sands and clays (b); (8) Holocene lacustrine sands and clays; (9–11) basalts: (9) Miocene, (10) Pliocene, (11) Quaternary; (12) Miocene and Pliocene sedimentary and eluvial clays; (13) stratigraphic boundary; (14) facies boundary; (15) fault and direction of movements; (16) drill hole (number and well head elevation above sea level).

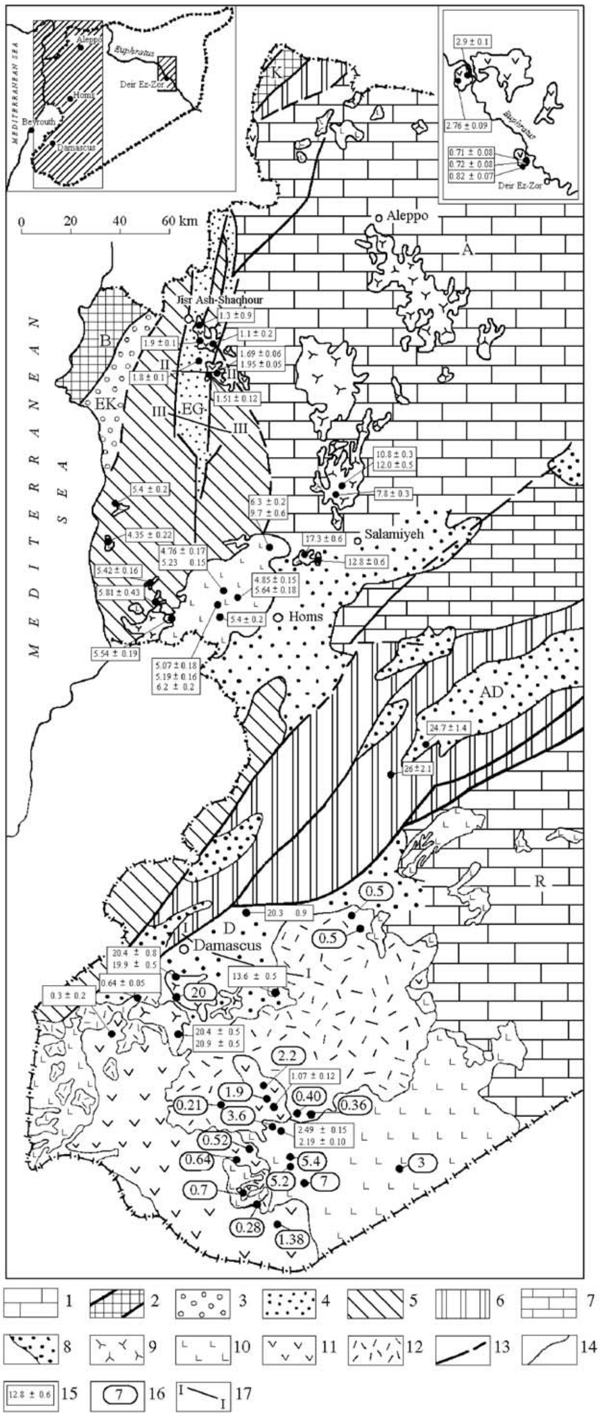

Fig. 4. Map of the western Syria showing geochronological units of Late Cenozoic basalts and major tectonic elements (Sharkov et al., 1994, 1998). (1) Platform blocks: A, Aleppo; R, Rutbah; (2) platform margins including the Neo-Tethys ophiolites: B, Bassit; K, Kurd Dagh; (3) Miocene El-Kebir Basin (EK); (4) Pliocene-Quaternary El Ghab graben (ED); (5) major anticline uplifts; (6) the southern Palmyrides, deformed and presumably detached sedimentary cover; (7) the northern Palmyrides, poorly deformed sediments; (8) inner and peripheral (piedmont) molasse basins: D, Damascus; AD, Ad Daw; (9–12) Late Cenozoic basalts: (9) Miocene, (10) Pliocene, (11) Quaternary and (12) Holocene (?); (13) faults; (14) geological boundaries; (15 and 16) K–Ar ages of basalts, Ma: (15) authors' data and (16) data borrowed from Giannérini et al. (1988); (17) geologic section line (Figs. 3 and 9).

of the Levant fault zone. The basalt flow with the K–Ar age of 24.7 ± 1.4 Ma was found in the southwestern side of the Ad Daw Basin in the central Palmyrides. Eastward, in the Mesopotamian Basin, only the Pliocene and Quaternary basalts are known. Basalts of the El Ghab graben belong to the Late Pliocene and Early Quaternary generation. Basalts of the same age were described in the junction of the El Ghab segment and the EAFZ (Yürür and Chorowicz, 1998).

5. Neotectonic evolution of Syria and adjacent areas

The northern and northeastern convergent boundary zones of the Arabian plate contain fragments of the Neo-Tethys ophiolite suture. They were covered by the Upper Maastrichtian in the Bassit and Kurd Dagh zones (Knipper et al., 1988) and by the Oligocene in the Zagros. So, all basins related to the Neo-Tethys were closed during the early collision epoch that finished in the end of the Eocene. After it, the late collision (neotectonic) epoch has begun and continues up to present time.

Three stages of neotectonic evolution were identified in the active zones surrounding the Arabian plate. According to the analysis of oceanic paleomagnetic anomalies (Savostin et al., 1986), data on evolution of the Aden–Red Sea rift system (Kaz’min, 1974) and structural data on the convergent plate boundaries (Trifonov, 1999), those stages were characterized by different direction of the plate motion and its pressure to the adjacent zones. For the first stage (Oligocene–Early Miocene), the Aden–Red Sea rift system progradated to the NW and correspondingly its eastern part extended more intensively, than the western one. As a result, the Arabian plate moved to the NNW and produced shortening in its northwestern margin. After interruption of rifting and volcanism 20–15 Ma, for the second stage (Middle Miocene), the Red Sea rift extended more intensively and the plate moved to the NE. Collision movements on the Main Thrust of Zagros was a result. Acceleration of tectonic movements took place for the third stage (Late Miocene–Quaternary) in the Aden–Red Sea rift system as well as in the convergent and transform plate boundaries. It probably depended on a break of the continental crust and beginning of spreading in the Aden–Red Sea rift system (Kaz’min, 1974; Izzeldin, 1987). The break happened in the Aden rift earlier, than in the Red Sea one. Because of it, shortening in the convergent plate boundaries was directed to the NNW–SSE in the Late Miocene. In the Pliocene–Quaternary, the spreading began in the Red Sea rift also. It caused the northern drift of the Arabian plate and the recent N–S shortening in its convergent boundaries.

The changes of the general dynamic situation are manifested in Syria by three phases of the neotectonic deformation (Fig. 5).

The first pre-Helvetian phase, corresponding to the first stage of the Aden–Red Sea rift opening, is represented by NE-trending folds and thrusts in the Bassit block and its Kurd Dagh continuation. It is spectacularly manifested by sharp unconformity (up to 90°) between the Paleogene and Helvetian, observed in the Lattaqie area, and presence of very coarse material in the bottom of the Helvetian strata (Fig. 6). These outcrops represent the northwestern side of the Lattaqie thrust zone between the area of deformation and the undeformed Miocene strata in the Nahr El-Kabir Basin, where the pre-Helvetian unconformity is not distinguished and the Lower Miocene (Aquitanian and Burdigalian) and Oligocene limestones are present. This allows supposing significant convergence of the structural zones on the Lattaqie thrust. The Oligocene is often eroded in Syria. But its existing fragments are represented mainly by the shallow-water carbonate formations without signs of regression. So, the first phase of deformation took place later, in the Lower Miocene. The Lattaqie thrust zone continues to the SW up to the continental slope southward Cyprus (Ponikarov et al., 1967). It could be continued to the east by the southern strand of the Bitlis Thrust and the Main Zagros Thrust (Fig. 7).

During the first phase of deformation, the coastal ranges developed as anticline zone, manifested in palaeotopograpy. It is proved by the fact that southward town of Missyaf the Late Miocene–Early Pliocene (10–4.85 Ma) (Adjamian and Jamal, 1983; Sharkov et al., 1994, 1998) Shin Plateau basalts cover the Jurassic limestones near the axial part of the Coastal anticline to the west of the El Ghab segment of the Levant fault zone and the Cenomanian carbonates in the anticline slope to the east of the fault zone. Perhaps, the Palmyride anticlines rose also that is demonstrated by weak unconformity between the Paleogene and Miocene deposits. At the same time, manifestations of the anticline erosion are absent in the Palmyride sedimentary basins (Devyatkin et al., 2000). The future anticlines could form very gentle uplifts that limited areas of lacustrine and alluvial sedimentation represented by white quartz sands (Fig. 5a). The latter were a product of long transportation probably from the southwestern crystalline part of the Arabian plate. In the eastern part of the Aleppo Plateau and in the Euphratus Valley, the first stage of deformation is manifested by absence of the Lower Miocene and often the Oligocene in the sections, although angular unconformity has not anywhere been registered between the Paleogene and Middle Miocene.

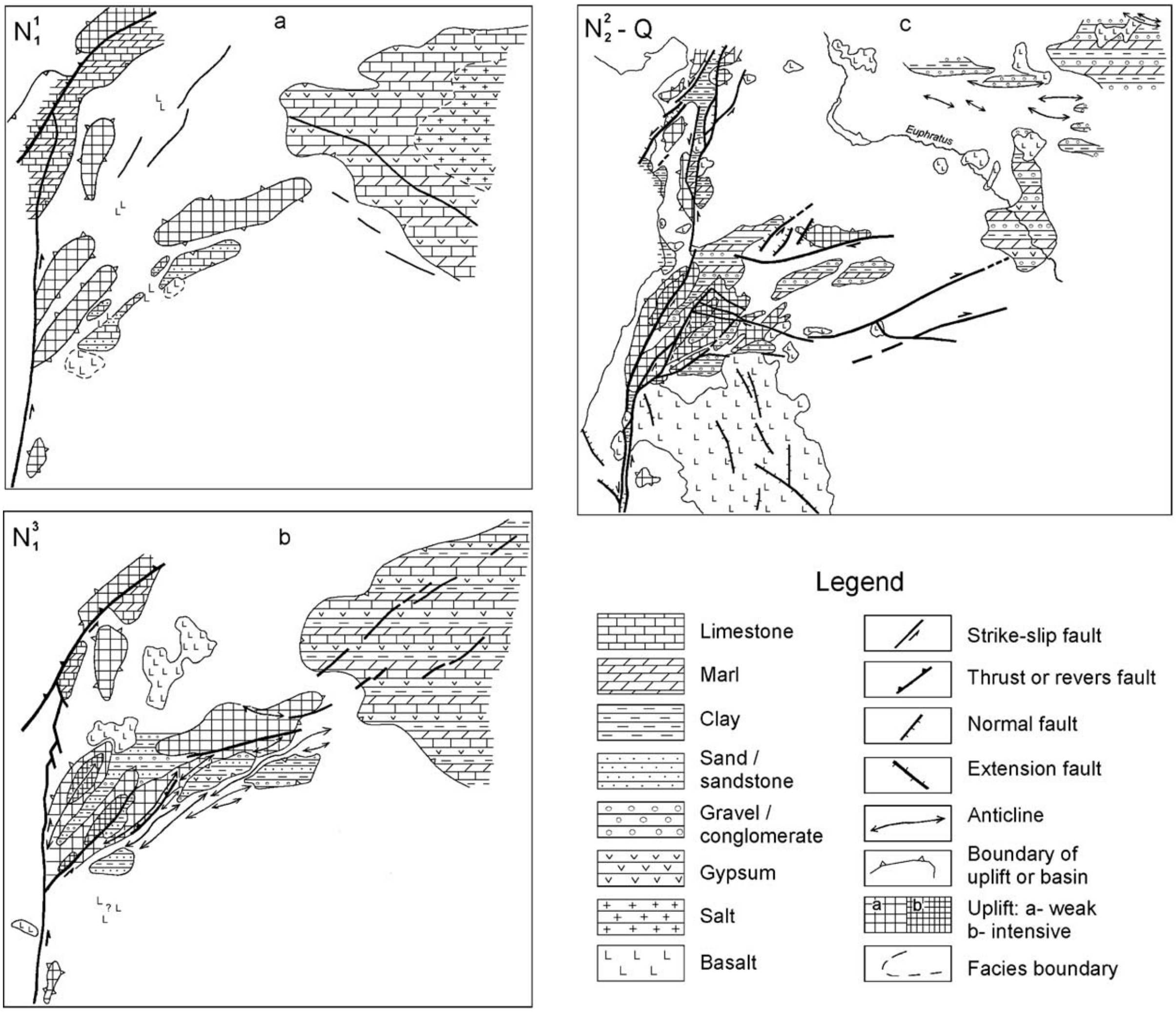

Fig. 5. Schematic maps of the geodymamic and palaeogeographic situation during three phases of the neotectonic deformation in Syria: (a) Early Miocene; (b) Late Miocene; (c) Pliocene to Quaternary. The palinspastic reconstructions were carried out to estimate mutual position of the structural elements in maps (a and b).

The first phase of deformation in Syria, like in the Aden–Red Sea rift system, was probably characterized by falling down the volcanic activity. The available K–Ar dates represent the time intervals 26–20 Ma (8 samples) and 13.6–4.35 Ma (24 samples) and only two probes give the age 17.3 ± 0.6 and 15.42 ± 0.16 Ma (Fig. 8). If number of dates approximately manifests (after correction to the representativity of the data) the intensity of volcanism, two other epochs of falling down the volcanic activity may be identified in the Fig. 8: between the Middle and Late Miocene (8–9 Ma) and in the Early Pliocene (4.5–3.5 Ma). They correlate to the younger phases of deformation.

The Middle Miocene and the beginning of Late Miocene, corresponding to the second stage of the Aden–Red Sea rift opening, were the tectonically quiet time in Syria. It was characterized by shallow-water marine sedimentation in the northwestern Syria changed by continental sedimentation in the Palmyrides and lagoon paleoenvironment accompanied by evaporite accumulation in the Mesopotamian Basin.

The second (Late Miocene) phase of deformation (Fig. 5b), corresponding to the first part of the third stage of the Aden–Red Sea rift opening, is manifested in the Palmyrides by unconformities at the base of the Upper Miocene and the Pliocene. Flint gravel and pebbles derived from the Cretaceous and Paleogene limestones are characteristic for the Upper Miocene sandstones of the Palmyride Basins while the Pliocene is represented mostly by coarse conglomerates composed by products of local material erosion (Devyatkin et al., 2000). So, the Palmyride folds were

Fig. 6. The coastal outcrop of unconformity between the almost horizontal Helvetian strata and steeply dipped Eocene limestones in the southern side of city of Lattaqie. The basal layer of the Helvetian contains blocks and big boulders of the eroded Paleogene. Photo by V.G. Trifonov.

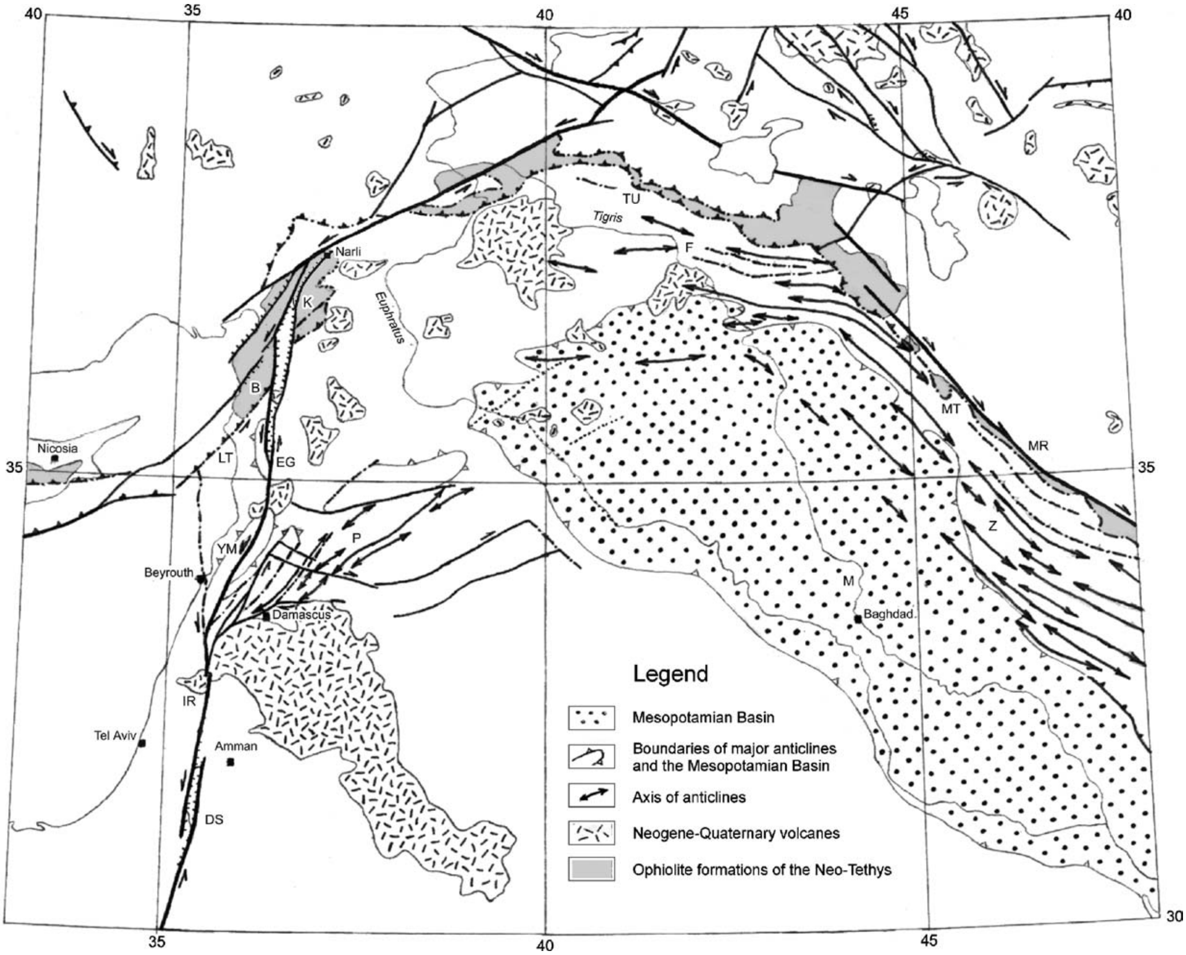

Fig. 7. Schematic map of the main neotectonic features in the convergent and transform boundaries of the Arabian plate. Segments of the Levant fault zone: DS, Dead Sea; JR, Jordan River; YM, Yammuneh; EG, El Ghab. Other fault zones: LT, Lattaqie fault; MR, main recent fault of Zagros; MT, main thrust of Zagros; TU, Taurus (Bitlis) thrust. Folded and thrusted belts: B, Bassit; F, marginal Folds of Turkey; K, Kurd Dagh; P, Palmyrides; Z, folded Belt of Zagros; M, Mesotopamian Basin. Symbols for faults are explained in Fig. 1.

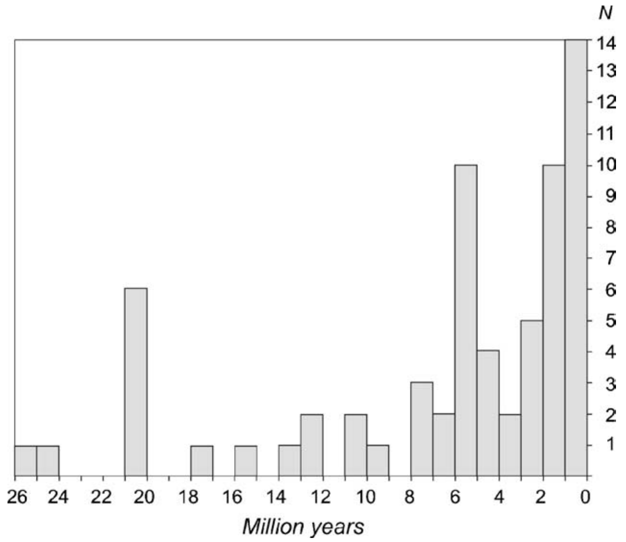

Fig. 8. Histogramme of age distribution of the available K–Ar dates of the Syrian basalts, by the data in (Adjamian and Jamal, 1983; Sharkov et al., 1994, 1998). *N* is number of the dates.

manifested in palaeotopography in the Late Miocene and they were subjected to additional vertical motion during the Pliocene, probably, as a result of compensation of the isostatic disbalance caused by processes of erosion and sedimentation.

For the first and second phases of deformation, the Yammuneh and El Ghab segments of the Levant fault zone did not exist. It proves by the fact that the Shin Plateau basalts cover the fault zone and the centres of eruption were not controlled by it. The Dead Sea–Jordan River segments of the zone continued from the Hula Basin to the N by the Roum Fault and its northern offshore continuation in the continental slope of the Mediterranean where these faults joined with the Lattaqie fault zone. So, the Leban and Coastal Ranges were the anticlines in the Arabian plate and its western flank was uplifted relative to the adjacent part of the African plate, like it took place in the Jordan part of the plate boundary.

During the third (Pliocene–Quaternary) phase of deformation (Fig. 5c), the recent pattern of the Yammuneh and El Ghab segments of the Levant sinistral zone was formed. The beginning of the third phase is controlled by two dates: 4.85 ± 0.16 Ma – age of the youngest basalts of the Shin Plateau (Sharkov et al., 1994, 1998) and about 3.5 Ma – age of the oldest sediments found within the fault zone graben near town of Missyaf (Trifonov et al., 1991). The faults cut the eastern slopes of the Leban and Coastal Ranges. The Galilean Basin was deepened (Hurwitz et al., 2002) and Hula (Garfunkel and Ben-Abraham, 2001), Bokaieh and El Ghab (Fig. 9) pull-apart basins were formed in en echelon junctions of the fault zone segments. Probably at the same time, the Serghaya and smaller young faults branched to the NE out the Levant zone and the system of the W–E-trending convex to the south dextral faults was formed. Magnitude of dextral offset of the Palmyride folds reaches 2.5 km on the largest Olab fault. Two major dry valleys of tributaries of the Euphratus River are offset to the same distance (2.5–3 km). Basalts in the top of the upper terrace of the Euphratus River were dated by 2.76–2.9 Ma. So, the Euphratus valley started to develop in the Pliocene and we dated its major tributaries hypothetically by the Late Pliocene (about 2.5–2 Ma). It gives the average rate of slip on the Olab fault 1.2–1.5 mm/a. The western terminations of the Olab and adjacent dextral faults join with northern termination of the Serghaya fault and the latter does not continue northward the junction.

The southwestern termination of the EAFZ probably was also formed during the third phase of deformation (Yürür and Chorowicz, 1998), although Westaway (2004) supposes its generation in the Late Miocene, $\sim$7 Ma BP. Since the end of Miocene, the anticlines in the northern part of the Mesopotamian basin have been uplifted and have begun to be eroded. It is fixed by unconformities to 10–15° between the Upper Fars (Upper Miocene) and Bakhtiary (Pliocene) formations and up to 10° between the Bakhtiary and the Quaternary basalts and by local source of the Bakhtiary conglomerates, although the anticlines could start to arise still in the Miocene. During the third phase, the intensive basaltic eruptions took place on the central and eastern rupture zones of the Jebel Arab Plateau. Volcanism occupies

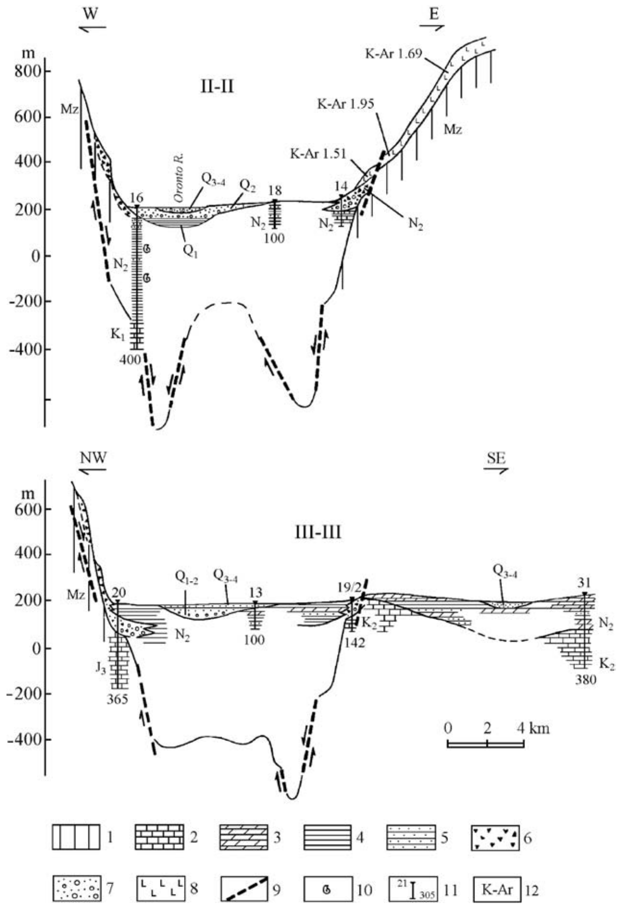

Fig. 9. Geological profiles (based on the bore-hole and geophisical data) across the central and southern parts of the El Ghab pull-apart basin; lines of the profiles are shown in Fig. 4. (1) Mesozoic and Paleogene rocks; (2–8) Pliocene–Pleistocene deposits: (2) limestones, (3) marls, (4) clays, (5) sandstones and sands, (6) breccias and conglomerates, (7) shingles with gravel and sands, (8) basalts; (9) faults; (10) shells of molluscs; (11) wells, their numbers and depths (in m); (12) K–Ar dates.

the eastern part of Syria, while it concentrated along the young segments of the Levant zone in the western boundary province.

6. Offsets on the northern segments of the Levant fault zone

The data on magnitudes of sinistral slip on the Yammuneh segment of the Levant zone are insufficient for the slip-rate estimation. Walley (1988) reported that the Litani River valley is dispaced by 4 km and there are several small and young pull-apart basins up to 7 km long associated with a leftward stepping of the fault. Sinistral displacement for the period of the basin formation cannot exceed their length (Garfunkel and Ben-Abraham, 2001). Ron (1987) suggested the 7–10 km offset by correlation of similar topographic features on the fault sides. Walley (1998) supposed the total sinistral motion up to 47 km by offset of the Syrian Arc structures that had been formed by two-stage deformation of the Senonian and Late Paleogene age. The last stage probably corresponds to the first phase of the neotectonic deformation in Syria.

The data on the El Ghab segment sinistral offsets seems to be more imformative. The northern margin of the Shin basaltic plateau is offset to 10–12 km (Trifonov et al., 1991; Rukieh, 1997). Since the youngest lava flow is dated by 4.85 Ma, the slip rate cannot be less, than 2–2.5 mm/a. Two estimates can be received by comparison of the Bassit and Kurd Dagh ophiolitic sections and their southeastern boundaries. The correlation of the Lattaqie fault zone and the Aafrin fault gives the offset on the El Ghab segment to ∼15 km. The correlation of the Lattaqie zone and the northwestern boundary of the Lower Miocene deposits in the Kurd Dagh increases the offset up to 25–30 km. Perhaps, the first value characterizes the Late Pliocene and Quaternary offset on the El Ghab fault zone and the second value characterizes the Pliocene–Quaternary offset. If it is true, both values give the average slip rate on the El Ghab segment ∼6 mm/a.

The left-lateral offset of the old aqueduct on the main strand of the El Ghab segment near village Al Harif (5 km northward town of Missyaf) is principal for estimating the recent slip rate on the fault. The offset was discovered by Adjamian and Trifonov (Trifonov et al., 1991). Meghraoui et al. (2003) calculated the offset by 13.6 ± 0.2 m and dated it by first century A.D. These authors included to the value not only offsets on the fault branches, but also the aqueduct bend, although it could exist before the displacement. We limited ourselves by the fault slip only and received 9-m main offset and offsets to 1 and 0.75 m on two small accompanied faults (Fig. 10). So, the total offset of the aqueduct reaches 10.5–11 m and gives the average slip-rate ∼6.0 mm/a.

According to the published data (Gomez et al., 2001, 2003) and our observations, offsets of similar Late Pleistocene and Holocene elements of drainage system on the Serghaya fault are essentially smaller, than on the El Ghab segment of the Levant zone. Gomez et al. (2003) estimate the Holocene slip rate on the Serghaya fault by ∼1.5 mm/a. So, the total offset on the both faults together with the smaller associated faults can reach 35–40 km in sum, i.e. it can approximately coincide with the Pliocene–Quaternary offset on the Dead Sea–Jordan River segments. This conclusion is supported by results of the GPS observations around the DST (McClusky et al., 2003). According to these data, the slip rates on the southern part of the DST increase to the north from 5.6 to 7.5 (±1) mm/a and grades from pure sinistral slip with increasing transpression; on the Yammuneh segment, the motion is partitioned between 6 ± 1 mm/a left-lateral motion parallel to the fault trace and 4 ± 1 mm/a fault-normal shortening. The older displacement on the Dead Sea–Jordan River segments (estimated by 60–65 km) could continue for the first and second phases of deformation on the Roum fault and its offshore continuation and in the Palmyrides.

To explain generation of the Palmyride structure, we have taken into account the following considerations. (1) The Palmyride fold-thrust belt branches out the Levant fault zone to the NE of the Hula Basin, where trend of the coastal ridges changes from the N–S to the NE–SW. So, formation of the Palmyrides is caused by peculiarities of the transform motion geometry in the western boundary of the Arabian plate and the Palmyrides should have the sinistral component of motion along the zone (Walley, 1988). (2) The Palmyride fold-thrust belt was formed partly before and mostly for the first and second phases of deformation in the region, when the axis of compression was directed to the NNW–SSE (almost normally to the Palmyride folds and thrusts). (3) Territory of the Palmyrides and Anti-Leban coincides with the area of the thickened Triassic evaporites (Fig. 11). It gave a possibility to suppose detachment of the folds along the evaporites and participation of diapirism in their formation (Lovelock, 1984; data of M.L. Kopp and Yu.G. Leonov in Devyatkin et al., 2000). The detachment surfaces under the evaporites were interpreted by analysis of seismic reflection data (Chaimov et al., 1990). So, the observed surficial structure of the Palmyrides contains a lot of secondary elements, caused by diapirism and probably does not coincide with the deeper structure. The most intensive folding and thrusting is fixed in the southeastern side of the thickened evaporite area that corresponds to asymmetry of the folds and dip of majority of the thrusts to the NW. Chaimov et al. (1990) estimated the NW–SE minimum shortening of the Palmyride Mesozoic and Cenozoic deposits by 20 km. To the NE, the intensity of shortening decreases and the detachment is not fixed in the seismic reflection sections (McBride et al., 1990; Brew et al., 2003).

We agree with the Kopp and Leonov's (Devyatkin et al., 2000) interpretation of the Palmyrides as the zone of sinistral simple shear branched out the southern part of the Levant zone. At the same time, the southern Palmyride thrusted folds form en echelon row that can be interpret as a result of dextral, but not sinistral shear. We explain the row as a system of the sinistral R-shears, which arose under sharp angle to the row axis (Hancock, 1985) and had the reverse or thrust component of displacements in conditions the NNW-trending compression. The R-shears transformed into the complex folds thrusted to the SE in the detached Mezozoic and Cenozoic cover under diapirism.

The detachment does not except shortening of the Palmyride crust under the horizon of detachment. It is possible to estimate it presumably by the Earth's crust thickening during the folding. Now its thickness is about 40 km in the Palmyrides (Moho Map of the Middle East, 2003). From the Late Paleozoic (Permian?) up to the Early Cretaceous, the Palmyrides developed under lateral extension as the rift-type trough and their crust was probably thinned. They started to rise later, only with beginning of the collision (McBride et al., 1990; Brew et al., 2003). So, we can suppose that before the Late Cenozoic folding, the Palmyride crust was similar with or thinner than the crust in the adjacent parts of the Arabian plate (∼35 km), i.e. the Palmyride crust thickness increased to 5–10 km (to 15–30%) during the folding.

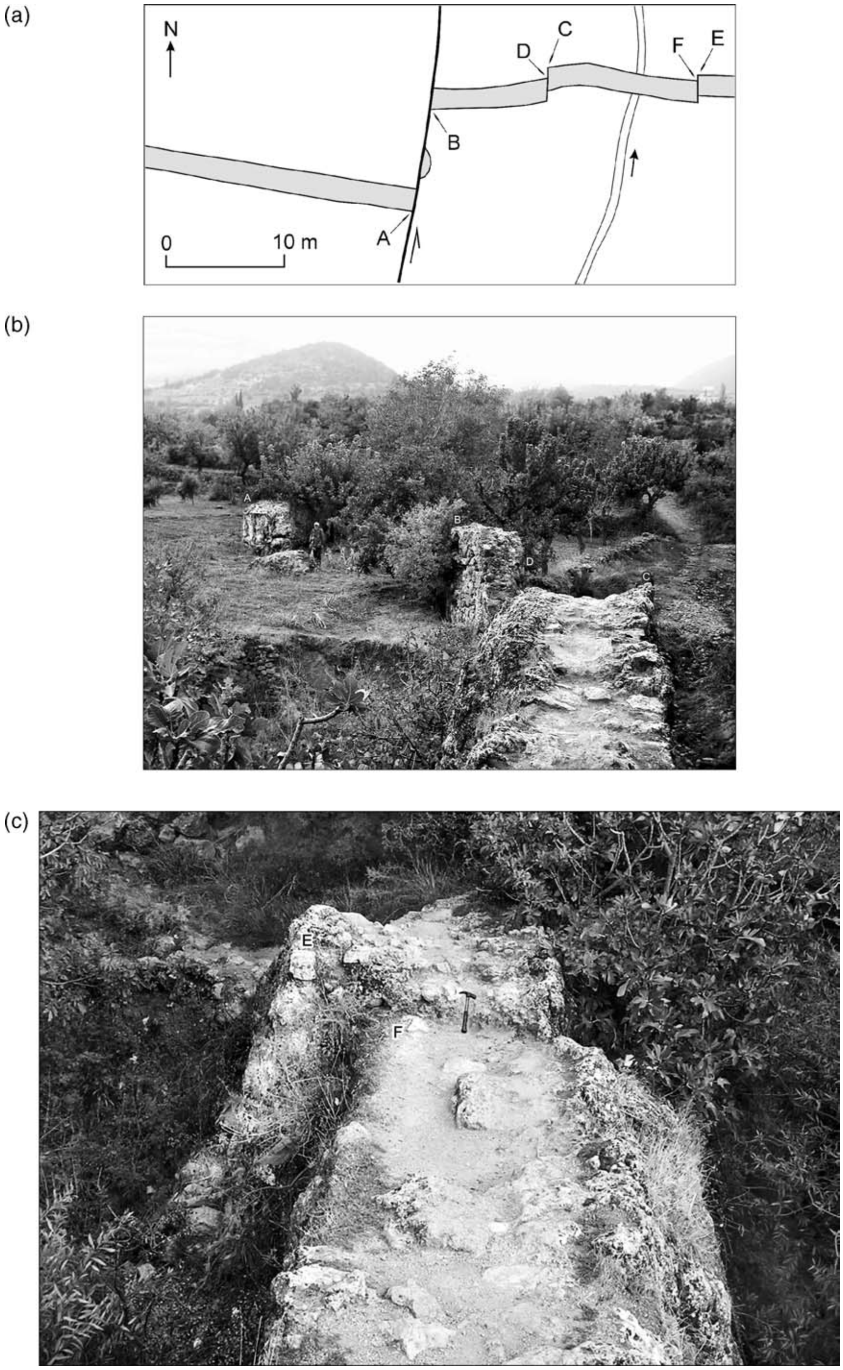

Fig. 10. Offsets of the Roman aqueduct on the Levant fault zone near village of Al Harif: (a) position of the offsets, after (Meghraoui et al., 2003) with additions; (b) offset to 9 m (AB) on the main fault strand and to 1 m (CD) on the associated fault; (c) offset to 0.75 m (EF) on the associated faults. Photos by A.E. Dodonov.

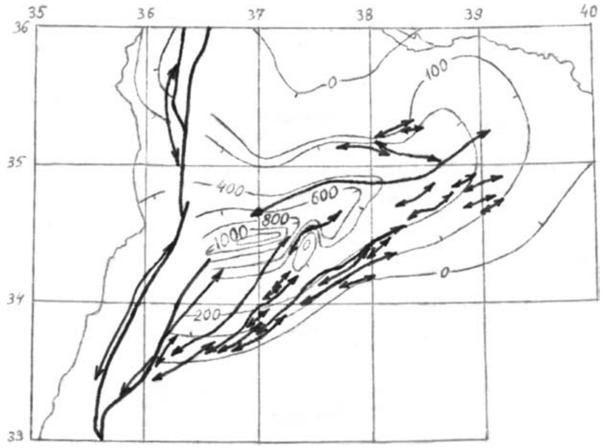

Fig. 11. Correlation between the fold structure of the Palmyrides (Fig. 1) and thickness of the Triassic evaporite-containing strata of the Kurashina Anhidrite Formation, compiled by the data of the Syrian Petroleum Company.

The recent width of the Palmyrides is 50–80 km. So, the increase of the crust thickness corresponds to the collision of the Aleppo Plateau and the Rutbah part of the Arabian plate up to 15–30 km. This value characterizes approximately a contribution of the Palmyrides formation to the total displacement on the western transform boundary of the Arabian plate. The other part of the supposed Miocene displacement (∼35–45 km) could be realized by motion on the Roum fault zone and its offshore continuation.

The particular problem is a transmission of the Late Cenozoic sinistral motion along the western flank of the Arabian plate into the southeastern flank of the Anatolian plate. According to the Westaway's (2004) modelling, the transition from rather diffuse fault geometry to the present localized geometry of the junction of the DST and the EAFZ occurred in the Late Miocene, ∼7 Ma BP. Westaway estimates total left-lateral slip on the southwestern termination of the EAFZ as at least ∼65 km, partitioned with ∼45 km on the Amanos fault, ∼10 km on the East Hatay fault and ∼10 km on faults farther east. The Pliocene–Quaternary slip rate on the southwestern termination of the EAFZ is estimated as ∼8 mm/a, partitioned between localized left-lateral slip at ∼2 mm/a on the Yakapinar-Görsun fault onshore of Iskenderun Bay (Westaway, 2004), 1–1.7 mm/a on the Amanos fault (Yürür and Chorowicz, 1998; Yurtmen et al., 2002; Westaway, 2004) and 2.5–4.3 mm/a on the East Hatay fault (Westaway, 2004). The slip had essential reverse component (Lyberis et al., 1992; Adiyaman and Chorowicz, 2002). These values correspond to the results of the GPS measurements around the EAFZ. Reilinger et al. (1997) estimated sinistral slip rate on the EAFZ as 11 ± 1 mm/a, but later this estimate was reduced up to 9 mm/a (McClusky et al., 2000). The motion and deformation are dispersed within the 100-km wide zone and only 4–8 mm/a are localized on the main strands of the EAFZ.

7. Active faulting

As it was decided for compiling the World map of major active faults (Trifonov and Machette, 1993), we understand them as faults with manifestations of the Late Pleistocene and Holocene motion. All major active faults in Syria and adjacent territories (Fig. 12) have been characterized by inherited development during the third phase of deformation (Pliocene and Quaternary). The main faults are concentrated in the Levant and Serghaya zones.

Like the southern (Dead Sea–Jordan) segments of the Levant zone, the El Ghab segment is usually marked by a valley where the Bokaieh (Qalaat Al Hosn) and El Ghab pull-apart basins are separated by the Missyaf saddle with relatively thin Pliocene–Quaternary fill. Although the saddle is narrow, it is usually composed by several (as minimum, two in cross-sections) longitudinal fault strands situated en echelon to each other. We studied in details the sinistral offsets of the drainage system in the 26 km part of the Missyaf saddle between villages of Sakhlieh and El Beida (Fig. 13). The Late Quaternary ravines and valleys crossing the fault strands were distinguished by their size and working up into three generations that we presumably dated by early and late parts of the Late Pleistocene and the

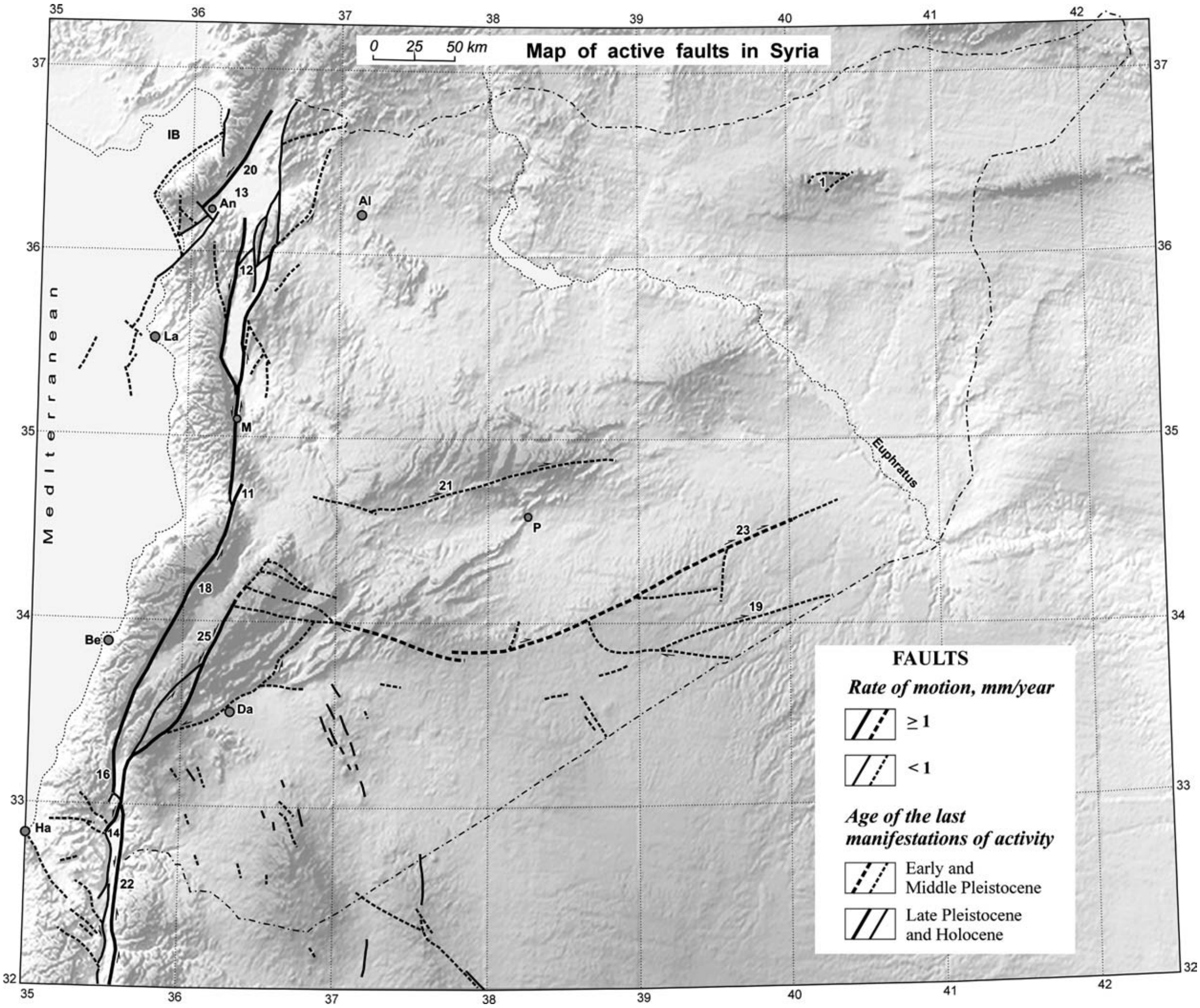

Fig. 12. Active faults in Syria and adjacent territories. Numerals of the faults and basins are the same as in Fig. 1.

Holocene. In the north of the studied segment, the drainage features are systematically offset to 400–450, 60–70 or 30–40 m on the western strand and 130, 75–80 (one site) or 13–20 m on the eastern strand. The offsets to 30–40 and 13–20 m were attributed to the Holocene drainage elements, while the larger offsets were attributed to the older ones. A sum of the Holocene offsets on the both strands is about 50 m. The offsets decrease to the south on the western stands and are not more, than 25 m near El Beida. On the eastern strands, the offsets of the same geomorphic features increase in the southern direction up to 150–175 and 34–40 m. So, the motion on the fault zone has been transmitted from the western strands to the eastern ones, but the total displacement on the strands has been invariable. Its Holocene rate is more than 5 mm/a.

Trenching of the main strand of the Levant zone near village of Al Harif showed that the Roman aqueduct offset had been a cumulative ground effect of three strong earthquakes in the fault zone (Meghraoui et al., 2003). Similar values of the sinistral slip rate were calculated by using the Late Holocene aqueduct offset, the total Holocene displacement near town of Missyaf, and estimates of the total Quaternary and Pliocene–Quaternary offsets on the El Ghab segment. It is a base to suggest the predominant role of strong seismic pulses in motion on the El Ghab segment during the all third phase of deformation. The same cumulative effect of strong earthquakes can be supposed on the Serghaya fault (Gomez et al., 2003). Lots of strong historical earthquakes were registered in and near the El Ghab segment and the Serghaya fault (Ben-Menahem, 1991). Some of them had produced seismic ruptures (Ambraseys and Jackson, 1998).

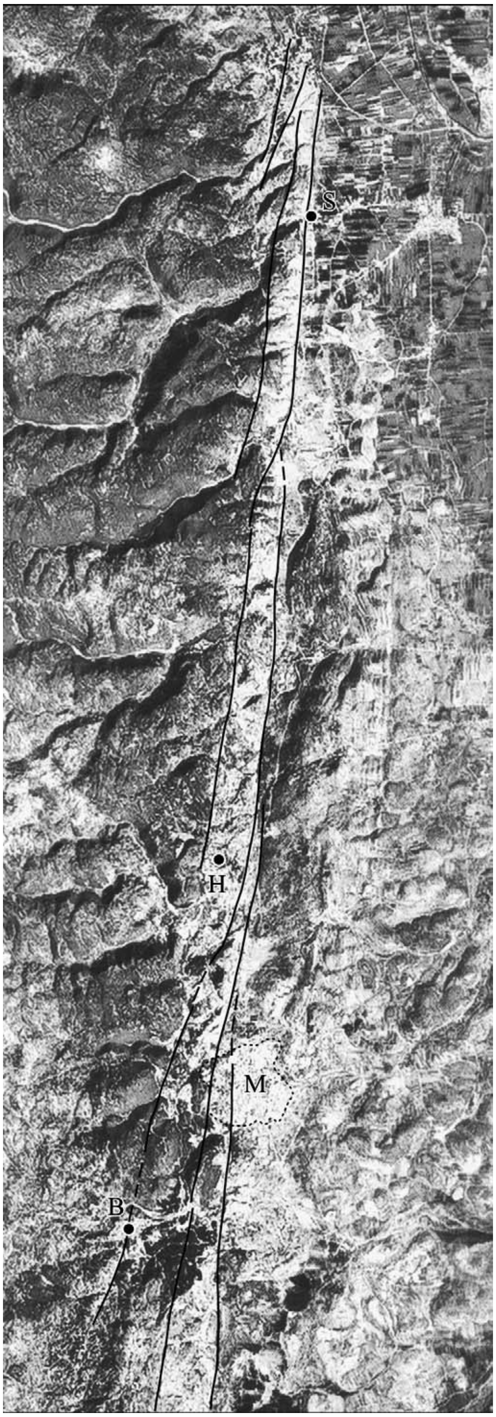

Fig. 13. Space imagery (Space Image Atlas of Syria, 1996) and interpreted active faults of the Levant fault zone segment near town of Missyaf. B, El Beida; H, Al Harif; M, Missyaf; S, Sakhlieh.

But the XX century was characterized by abatement of seismicity (Garfunkel et al., 1981). Perhaps, it depends on its cyclic recurrence (Trifonov et al., 1994). The Serghaya fault is linked with the system of the W–E-trending dextral faults, convex to the south and cutting the Palmyrides and adjacent part of the Arabian plate. These faults have also to be taken into account for seismic hazard assessment in the region. Weak manifestations of the Late Quaternary activity have been fixed in the Lattaqie-Aafrin fault zone

8. Conclusion

The compiled neotectonic map of Syria, 1:500,000, can be used as a tool to separate active faults as probable seismic zones in the country and to solve some problems of the Late Cenozoic structure and evolution of the northwestern margin of the Arabian plate. Position, structure and tectonic activity of the margin changed for the Neogene and Quaternary.

During the first phase of deformation, in the Early Miocene, the Arabian plate moved to the NNW along the Dead Sea–Jordan segments of the Levant transform fault zone, Roum fault and its continuation in the continental slope of the Mediterranean. The chain of the longitudinal coastal anticline uplifts arose in the “Arabian” side of the transform zone. In the north, the transform boundary joined with the Lattaqie oblique (sinistral-thrust) boundary fault zone that striked from the southern slope of the Cyprus arc to the NE, where continued by the Taurus (Bitlis) Thrust and further to the SE by the Main Thrust of the Zagros.

The Middle Miocene, when the Arabian plate moved to the NE, was the tectonically quiet epoch in Syria, but it was a time of the most intensive development of the Main Thrust of the Zagros. During the second phase of deformation, in the Late Miocene, the Arabian plate moved again to the NNW along the Dead Sea–Jordan segments of the Levant transform fault zone, Roum fault and its offshore continuation. But at the same time, a part of the plate motion resulted in formation of the Anti-Leban–Palmyride fold-thrust belt. It arose as en echelon row of the R-shears and was transformed in the Mesozoic and Cenozoic part of the sedimentary cover into the system of thrusted anticlines. The transformation was caused by detachment of that part of the cover along the Triassic evaporites and by their diapirism. Formation of the Palmyrides isolated the Aleppo stable block out the other part of the Arabian plate. About 20 km of the Miocene transform motion on the western boundary of the Arabian plate was realized by the Palmyride folding and faulting. Other 35–45 km could result in slip on the Roum fault and its offshore continuation.

During the third phase of deformation, in the Pliocene and Quaternary, the recent structural pattern of the Levant zone was formed in Lebanon and the northwestern Syria. At the same time, the Serghaya and smaller sinistral faults branched out the Levant zone and the system of the W–E-trending convex to the south dextral faults ruptured the Palmyrides and the northern part of the stable Rutbah block of the Arabian plate. The total Pliocene–Quaternary sinistral offset on the young Levant zone segments together with the Serghaya and smaller strike-slip faults has reached 35–40 km and approximately corresponds to the Pliocene–Quaternary offset on the Dead Sea–Jordan segments of the Levant transform. These young faults are still active and represent main sources of strong earthquakes dangerous for the western Syria.

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