The Kraishte magmato-tectonic zone (Western Bulgaria) — a review

A. Harkovska1, Z. Pecskaý2, M. Popov3


Abstract. The Kraishte magmato-tectonic zone (KMTZ) is the northernmost of the four NW-SE trending Paleogene linear magmato-tectonic zones cropping out in Western Bulgaria and referred, as second order structures, to the collision-related first order Macedonian-Rhodope-North Aegean magmatic zone (MRNAMZ).

The Kraishte volcanics (KV) are quite uniform dacites to rhyodacites of the calc-alkaline series. They were cooled at a shallow subvolcanic level and are affected irregularly by a low temperature hydrothermal alteration. Most of the KV bodies are conformable and concordant because their morphology is controlled mainly by the trust boundary between the Paleozoic rocks of the Penkyovtsi allochthonous unit and the Berriasian-Tithonian flysch of the Luzhnitsa-Tran unit. The presence of KV-epiclastics in the Gorna Glogovitsa and Sekirna grabens shows (in agreement with the available magnetometric data) that at least some of the KV-bodies have been exhumed before the Priabonian-Oligocene (?) sedimentation started. The projections of all of the new whole-rock K-Ar ages (47.4 - 42.2 ± 1.60-1.80 Ma) fall within a Pre-Priabonian (Lutetian — Bartonian) part of the Gradstein, Ogg’s (1996) geochronologic scale. The possible alternative suggestions about the age of the KV emplacement could be: a) the whole-rock ages reflect a long-term low temperature hydrothermal alteration of volcanic bodies, intruded before 47.4 Ma; b) the w. r. record is a complex combination of a polystage (?) Lutetian — Bartonian emplacement and of the related hydrothermal alteration processes, which caused a rejuvenation to a different extent.

The existing model for the KMTZ geodynamic position has obviously to be changed taking into account that: a) KMTZ differs from the other Paleogene magmato-tectonic zones in Western Bulgaria by the steeper NW-SE trend (150-160°), the calc-alkaline affinity of the KV, the older age and the absence of a base metal metallogenic specialization, typical for the magmatics from the other zones; b) in a regional scale KMTZ acts as a southern end of the more than 250 km long Late Alpine (Late Cretaceous — Early Tertiary) subduction-related magmato-tectonic structure, following the erosional front of Mid Cretaceous thrusts and described in Eastern Serbia as Ridanj-Krepolin belt and further to...

**Key words:** Palaeogene; Kraishte, Western Bulgaria; magmatism; tectonics.

**Introduction**

Four linear NW-SE trending Palaeogene magmato-tectonic structures crop out in Western and South-western Bulgaria extending across the state border on the territories of Serbia and Macedonia (Fig. 1, inset A). All of them as a rule are assigned to the Strouma area of the regional first-order Palaeogene Macedonian-Rhodope-North Aegean Magmatic Zone (MRNAMZ — Dabovski et al., 1989; Harkovska et al., 1998). They are traced by predominantly acidic magmatic bodies of different depth facies. The Kraishte magmato-tectonic zone (KMTZ — Kharkovska, 1984) is the northernmost of them.

The volcanics of KMTZ (Kraishte volcanics — KV) are known since the end of the 19th century (see the references in Йорданов, 1950). Their structural control by a set of NNW-SSE (150-160°) faults, interpreted as feeding structures, was suggested firstly by G. Bonchev (Bончев, 1934) and later confirmed many times (Kharkovska, 1984 and the references therein). The rather uniform acidic character of the KV and their calc-alkaline affinity were commented in a number of publications as their most important and distinctive petrologic features (Белев, 1960; Белев, Димитров, 1965; Белев, Радонова, 1970; Kharkovska, 1984; Божков и др., 1985), but for the time being no data on their minor-element composition have been reported. The morphology of the KV-bodies and their interrelations with the host rocks have been presented in different manner — e.g., compare the cross-sections drawn by Harkovska (Харковска, 1980) with those of Загорчев, Динкова (1991). The emplacement age of the KV bodies is still under discussion. Recently the KMTZ geotectonic position have been put under discussion as well (Harkovska et al., 2001).

In this paper, available and some recent data about KMTZ are summarized and discussed. New K-Ar age determinations of KV are presented and discussed and the first data on some trace element contents in KV are reported and interpreted in terms of the regional geotectonic setting of KMTZ.

1. **Regional geological setting of the KMTZ**

KMTZ consists of two subzones. The main, western subzone, comprises about 25 small (from some tens of m² up to 6-8 km²) bodies, cropping out as a discontinuous NNW-SSE...
Fig. 1. Sketch-map of the Kraishte magmato-tectonic zone (KMTZ); geological background after Zagorchev (2001), simplified:
la — Quaternary, 1b — Neogene; 2—3 — Paleogene: 2 — mainly terrigenous continental sedimentary rocks (Priabonian — Oligocene?); 3 — Kraishte volcanics (KV); 4 — Luzhnitsa-Trun unit; 5 — Penkyovtsi allochthonous unit; 6a — stratigraphic boundaries, normal and strike-slip faults; 6b — trust (erosional front); 7 — location of the radiometrically dated samples (for the respective numbers — see Table IV)
1 — Gorna Glogovitsa graben (GGg); 2 — Sekirna graben (Sg) of the Stanyovtsi graben complex.
Main KV bodies: G — Glavanovtsi laccolith-like (?) body — not studied in detail, R — Rouy body — not studied in detail, Y — Yarlovtsi cryptidome (dated sample N 1Zk), L — Leshnikovtsi laccolith(?), K — Klisoura dyke-like body, D — Dokyovtsi sills, Lr — Lyava reka laccolith (?), O — Odranitsa laccolith (dated sample N 4Zk), S — Shevarna laccolith (dated sample N 11Zk), Z — Zdravkovi sill (dated sample N 5Zk), T — Touton body (dated sample N 4Zk)
P — Polyana laccolith.
Inset B. KMTZ regional position (Harkovska et al., 2001) — according to the data of Grysh (1967), Dimitrievic (1995), Kharkovska (1984 and the references therein), Karamata et al. (1997 and the references therein) and interpreted map of Milovanović and Cirić (1968): black triangles — location of the KMTZ main volcanic bodies; empty triangles — location of the main magmatic bodies of the Ridanj — Krepolin belt; black points — location of the main plutonic bodies of the Moldova Nuova — Bocsha segment of the “Western banatitic zone”. The erosional front of the Mid-Cretaceous trusts (thrust piles, respectively) is shown.
(150-160°) trending strip between the village of Polyana (Pernik District) and the locality of Duschen kladenets on the Bulgarian-Serbian border (Fig. 1). Its length is about 30 km. The eastern subzone extends between Rouy Peak on the Bulgarian-Serbian border and the village of Eroul (Белев, 1960; Zagorchev et al., 1991).

The KMTZ is confined mainly by the Penkyovtsi thrust (Йорданов, 1950; Бончев и др., 1960), which is built of the allochthonous Penkyovtsi-Eleshnitsa Mid-Mesozoic terrain (Dabovski et al., 1989, 1991) = Penkyovtsi allochthonous unit and the Luzhnitsa-Tran unit (Zagorchev, 2001) — Fig. 1. The Penkyovtsi unit consists predominantly of Paleozoic (Ordovician — Devonian) very low to low grade metasedimentary rocks that host some small plutons of presumable Paleozoic age (Бончев et al., 1960; Zagorchev, 1995). The overlying Triassic sediments are of limited occurrence. The youngest rocks of the Luzhnitsa-Trun unit (Plate I-Ph. 1) and planar structures, marked by orientation of biotite flakes and/or small amygdal-like cavities (up to 0.5 x 2 cm in cross-section) with hydrothermal (zeolitic, calcitic, etc.) fill (Харковска, 1975, 1980). Rare magmatic folds with nearly horizontal axe planes and hinges are found in the apical parts of the Yarlovtsi cryptodome (Харковска, 1995; Plate I — Ph. 2). Linear orientation of hornblende phenocrysts is a common but not persistent flow structure (Plate I — Ph. 3). The magmatic striations on the contact surfaces of some bodies reflect local directions of the magmatic transport.

The primary jointing is of mixed type. A columnar-like to columnar type, coarse platy jointing and irregular blocky jointing are present. The irregular, 4-to 6-sided columns are of variable diameters (0.2-1.5 m) — Plate I — Ph. 4. Coarse blocky type jointing appears in the internal parts of some bodies instead of the coarse columnar one (Plate I — Ph. 5). An irregular blocky type of jointing occurs as a secondary structure as well. Irrespectively of their origin, the blocks are often affected by spheroidal weathering. (Plate II — Ph. 3).

The KV-texture is porphyritic with microholocrystalline (aplitic, micropoicilitic) and fine-grained felsitic to microfelsitic or granophyric groundmass, passing to hiallopilitic and microlitic in the narrow chilled endocontact zones only.

The KV bodies are hosted by both the Luzhnitsa-Trun unit (Plate II — Ph. 1) and the Penkyovtsi allochthonous unit (Plate II — Ph. 2). They cooled at a shallow subvolcanic level (Божков и др., 1985) reported that, near the village of G. Glogovitsa, a relic of KV flow and a small (10 x 15 m) neck of KV "lava-breccias" are exposed. Neither petrographic nor structural arguments are presented in support of this statement.

The morphology of the KV bodies is quite variable. Concordant and conformable bodies dominate — sills, sill-like bodies, symmetric and asymmetric flat laccoliths. Cryptodomes, dyke-like and stock-like bodies are rarely observed (Fig. 2A, 2F). Such a morphological variability is due to a combination of different types of host structures. The most important
host and screen structure for the larger igneous bodies (e.g. Lijva Reka, Odranitsa and Shevarna laccoliths — Fig. 2 — C, D) is the uneven, gently dipping thrust surface between the Eleshnitsa-Penkyovtsi and Luzhnitsa-Trun units. The bedding in the flysch sedimentary rocks served as a host structure of smaller bodies (e.g. Dokyovtsi sills — Fig. 2 — B, E). Steep to vertical faults of ENE-WSW (60-75°) and nearly longitudinal trends acted also as host structures (e.g. the southern contact of Shevarna laccolith), while NW-SE (140-150°) faults have to be regarded both as feeding and host structures.

The coincidence of the main strip of the KV-bodies with the present-day erosional front of the Penkyovtsi allochthon can be explained as follows: the KV bodies were formed at a subvolcanic level along the zones in

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1 In some of the previous publications of A. Harkovska (Харковская, 1980; Kharkovska, 1984) the importance of this structure was underestimated and some sills and/or laccoliths (e.g. Lyava Reka, Odranitsa) have been suggested to be stocks or stock-like bodies.
which the thrust surface was cross-cut by a set of NNW-SSE linear feeding faults. Later, when the territory was uplifted, the magmatic bodies acted as a factor, strengthening the erosional front of the thrust, because they were more resistant to the erosion than the hosting flysch sediments. It must be mentioned that the magmatic bodies of the Ridanj-Krepolin belt (Eastern Serbia) which is spatially interconnected with KMTZ, have the same structural position with respect to the erosional front of the Mid-Cretaceous thrusts or thrust pile (Fig. 1, inset B). Further to the North the same structural interrelations can be observed in the "Western banatitic zone" (SW Romania) — Fig. 1, inset B.

### Table I

**Selected analyses of the KMTZ volcanics**

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<th>10 (4Zk)</th>
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<td>0.03</td>
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<td>n.a.</td>
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<td>100.11</td>
<td>99.61</td>
<td>99.35</td>
<td>99.52</td>
<td>99.94</td>
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<td>99.68</td>
<td>99.56</td>
<td>99.65</td>
<td>100.04</td>
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1 — village of Yarlovtsi; 2 — hamlet of Valjavitsa (village of Divlya); 3 — "Touton I" peak; 4 — "Berainski goudel" locality; 5 — hamlet of Staro selo (village of Odranitsa); 6 — locality Ostri vruh (village of Lesnikovtsi); 7 — village of Odranitsa; 8 — village of Lyava Reka; 9 — hamlet of Zdravkovi (village of G. Glogovitsa); 10 — North of the "Touton I" peak; 11 — village of Divlya — (epiclastic boulder in the coarse basal Gg breccia-conglomerates);

Wet analyses: Nos, 2, 3, 4, 5, 7 and 8 (after Белев, Радованов, 1968; NN 1, 4 and 6 (after Белев, Димитров, 1965).

XFR analyses: Nos 2Zk, 4Zk and 5Zk (Geol. Inst. BAS, analyst — S. Stoyanov); n.d. — non-determined, n.a. — non-analysed.

### 3. Mineral and chemical composition

The composition of the KV bodies is quite uniform (Белев, Димитров, 1965; Белев, Радованова, 1970) and differs from those of the acidic Paleogene volcanics cropping out in the other linear Tertiary magmato-tectonic linear structures in West Bulgaria (Kharkovskaya, 1984).

3.1. Mineral composition. The KV-phenocryst association is not studied from the mineralogical point of view. It consists of biotite, needle-like (up to 6-10 mm long) hornblende (both together forming about 5-8% of the
Fig. 3A. TAS diagram (Le Maitre, 1989) for the KMTZ volcanics (black points - data of Kharkovska, 1984 and the references therein) and for the Priabonian-Rupelian igneous bodies of the neighbouring Rouen magmato-tectonic zone (crosses - data of Arnaudova, Ivanov, 1972; Arnaudova, 1973; Kharkovska, 1984).

Fig. 3B. K₂O/SiO₂ diagram: solid lines - after Peccerillo, Taylor (1976), dashed lines - modifications after Dabovski et al. (1989); black points - KV acc. to Table I; pointed circles - volcanics of the neighbouring subduction related Late Cretaceous Bourela volcanic complex (data of Baiparkrapova, 1989); crosses - Priabonian-Rupelian igneous bodies of the Rouen magmato-tectonic zone (references - as in Fig. 3A)
Fig. 4. Some KV trace-elements diagrams (see Table II)
rock), zoned plagioclase (An_{44,13}), subordinate strongly corroded quartz, very rare pyroxene (Белев, Радонова, 1970). The absence of K-feldspar phenocrysts, mentioned by the authors cited, is a typical KV feature, the only exception being reported for the Eroul body, in which the presence of rare microcline (phenocrysts or xenocrysts?) is mentioned (Белев, 1960). Two varieties are distinguished (Белев, Радонова, 1970): a biotite and a widespread hornblende-biotite one, respectively. Presumably, the biotite variety was formed as a later, more differentiated phase. Until now, however, no supporting field interrelations between the two varieties have been found.

Two types of biotite have been described. The primary green-brown biotite (flakes up to 3 × 2 mm in size) is the dominating or in some cases — the only mafic porphyric mineral. The second type of biotite is presented by brown to reddish fine flakes, which replace partially (up to 80%) to totally the hornblende phenocrysts. It is assumed to be product of a late magmatic or hydrothermal (?) processes. The total amount of accessories (apatite, zircon and magnetite) does not exceed 1%. Titanomagnetites with low Curie’s point (T_c = 325°C) have been determined in some of the volcanic bodies (Ножаров et al., 1984).

Nearly permanent occurrence of pyrite, formed as a result of irregular low-temperature hydrothermal alterations, is a typical feature but as a rule the pyrite is strongly to completely transformed into Fe-hydroxides. The very spectacular secondary concentric, sub-concentric and planar yellow-brown to dark brown mesostructures, presented on Plate II (Ph. 4, 5), are due to re-distribution and re-deposition of the Fe-hydroxides. Such structures are irregularly developed in all of the magmatic bodies. The abandoned quarries in the Leshnikovtsi body and at the right bank of Erma River (ENE of the village of Yarlovtsi) are typical examples. Chloritisation, sericitisation, argillisation, carbonatisation, albition and epidotisation are also related to the low-temperature hydrothermal alteration processes (Белев, Радонова, 1970; Божков и др., 1985). Zeolites and SiO_2 (quartz, chalcedony and opal) fill small-sized amygadal-like cavities and thin veinlets. Nozharov et al. (Ножаров и др., 1984) noted that the “chemical processes” in question strongly influenced the KV magnetic pattern.

3.2. Chemical composition. As it was mentioned in the literature, the KV major-element composition is an acidic one (strongly differentiated melts?). The available analyses (Table I) plot along the boundary between the dacitic and rhyolitic fields of the TAS-diagram (Fig. 3A) and in the rhyodacitic field of the K,O vs SiO_2 Peccerillo, Taylor’s diagram (Fig. 3B). The volcanics show a distinct calc-alkaline affinity, differing from the high-K calc-alkaline and shoshonitic affinity of the igneous rocks from the other Tertiary magmato-tectonic structures in Western Bulgaria (Белев, Радонова, 1970; Kharkovska, 1984). The only Late Alpine calc-alkaline igneous rocks in the region are the intermediate and acidic members of the Bourela complex, which belong to the neighbouring island-arc Late Cretaceous Western Srednogorie unit (Байрактаров, 1989; Fig. 3B). Such an affinity has been described for the acidic rocks of the Ridanj-Krepoline belt as well (Karamata et al., 1997).

The first information about some KV-trace element contents is presented in Table II and Fig. 4.

4. On the age of the KV-emplacement

4.1. Previous data. The KV Tertiary age was inferred firstly by Г. Бончев (1934) on the basis of some regional geological relationships, but different authors refer their emplacement to different parts of the Tertiary time-scale. Bonchev et al. (Бончев et al., 1960) suggested that the volcanics were formed as a result of a polystage (Priabonian, Oligocene and Miocene) magmatic activity. Бояджиев, Коста-

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Table II

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<th>Sr</th>
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<th>Rb</th>
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XRA — Geol. Inst. BAS, analyst — S. Stoyanov
PLATE I
Ph. 1. Nearly horizontal flow layers and vertical columnar jointing in the apical parts of the Yarlovtsi cryptodome (Garvanitsa peak)
Ph. 2. Magmatic fold with a horizontal axe plane; apical parts of the Yarlovtsi cryptodome (Garvanitsa peak)
Ph. 3. Linear arrangement of hornblende phenocrysts — Shevarna laccolith (near the hamlet of Shevarna)
Ph. 4. Nearly vertical irregular columnar jointing in the main Dokyovtsi sill-like body
Ph. 5. Coarse platy to blocky type jointing in the central parts of the Yarlovtsi cryptodome

PLATE II
Ph. 1. Uneven contact of the Odranitsa laccolith (2) and the Titonian-Berriassian flysch (1) NE of the village of Dokyovtsi (after Харковска, 1980).
Ph. 2. Detail of the upper contact of the Yarlovtsi cryptodome (2) with the Paleozoic host rocks of the Penkyovtsi unit (1) — village of Radovo (after Харковска, 1975).
Ph. 3. Spheroidal weathering in KV - Odranitsa laccolith (west of the hamlet of Poleto).
Ph. 4. Secondary yellow to dark brown "planar structures", marked by re-deposited Fe-hydroxides and formed obviously during the latest stages of hydrothermal alteration processes — abandoned quarry at the right bank of the Erma river.
Ph. 5. Picturesque secondary structures, coloured in light yellow to dark brown (see the explanation of Ph. 4 and in the text) — abandoned quarry at the right bank of the Erma river.
Ph. 6. Epiclastic KV boulder in the Paleogene breccia-conglomerates from the lowermost levels of the GGg section — South of Divlya (left slope of the Penkyovska river).

динов (1971) assigned them to the Priabonian-Oligocene time-span. A pre-Priabonian age was also suggested (Харковска, 1980; Харковска, 1984). According to magnetometric investigations, the intrusion of KV bodies took place before Priabonian (Ножаров et al., 1984). Determining the thermal remanent magnetisation of the best preserved KMTZ volcanics as normal, anomalous and inverse one, Nozharov et al. (Ножаров и др., 1984) concluded that such a magnetisation pattern can be explained by a polystage KV-intrusion within a relatively short time-span of about 1-2 Ma.

The first two K-Ar whole rock ages of the Odranitsa laccolith (38 Ma and 33 Ma) have been interpreted as Priabonian (Божков и др., 1985).

4.2. Discussion on the temporal interrelations of KV emplacement and the Paleogene stratified rocks from Gorna Glogovitsa graben (GGg). The following data are discussed be-

Table III
Genetic types of the volcaniclastics in the fill of the Paleogene Gorna Glogovitsa graben (literature data)

<table>
<thead>
<tr>
<th>Short description of the volcaniclastics</th>
<th>Age</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Unsorted &quot;basal conglomerates&quot; composed of well rounded clasts of &quot;rhyolites&quot; and of &quot;quartz-diorite porphyrites&quot;. The clasts are different in size. The conglomerates contain also clasts of low-grade Paleozoic metamorphics, quartz;</td>
<td>Presumed age of the sedimentary rocks - Priabonian-Oligocene;</td>
<td>Каратаев, Костадинов - in Божков и др. (1960)</td>
</tr>
<tr>
<td>b) KV - epiclastics in the middle level of the section</td>
<td></td>
<td>Харковска (1980)</td>
</tr>
<tr>
<td>&quot;Lahars and agglomeratic tuffs&quot;, formed of &quot;dacitic&quot; angular to semirounded clasts (1-2 cm) and blocks (up to 1-1.5 m); crystallo-lithoclastic unsorted &quot;tuffs&quot; with plagioclase ± quartz, hornblende and biotite crystalloclasts; metamorphic and volcanic (&quot;dacitic&quot;) microclasts;</td>
<td></td>
<td>Божков и др. (1985)</td>
</tr>
<tr>
<td>c) &quot;Ash tuffs&quot; and &quot;tuffaceous limestones&quot; with biotite, hornblende and quartz crystalloclasts.</td>
<td></td>
<td>Белсов, Радожовска (1970)</td>
</tr>
</tbody>
</table>
A. Harkovska, Z. Pecskay, M. Popov — The Kraishte magmato — tectonic zone...
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Table IV

New K-Ar ages of Kraishte volcanics

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Location of the dated samples</th>
<th>Dated fraction</th>
<th>K%</th>
<th>$^{40}$Ar rad (10$^6$)</th>
<th>K-Ar age (Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1Zk</td>
<td>Yarlovtsi cryptodome - village of Yarlovtsi, at 190 m SE (138°) from the water source “Bolyarka”</td>
<td>w.r.</td>
<td>1.94</td>
<td>77.1</td>
<td>3.224</td>
</tr>
<tr>
<td>4Zk</td>
<td>Odranitsi laccolith - at 650 m NNW (350°) of the “Touton I” peak</td>
<td>w.r.</td>
<td>1.52</td>
<td>84.7</td>
<td>2.570</td>
</tr>
<tr>
<td>5Zk</td>
<td>Zdravtchovs sill - at 700 m N (355°) from the church of the village of G. Glogovitsa</td>
<td>w.r.</td>
<td>1.83</td>
<td>72.9</td>
<td>3.283</td>
</tr>
<tr>
<td>11Zk</td>
<td>Shevarna laccolith - at 130 m ESE (110°) from the “Kalougerska mogila” peak</td>
<td>w.r.</td>
<td>1.49</td>
<td>76.1</td>
<td>2.665</td>
</tr>
<tr>
<td>4Zk$^c$</td>
<td>Touton body - at 170 m E (90°) of the “Touton I” peak</td>
<td>w.r.</td>
<td>1.65</td>
<td>74.7</td>
<td>3.073</td>
</tr>
<tr>
<td>2Zk</td>
<td>Epiclastic KV-boulder from the lowermost levels of the Paleogene section in the Gorna Glogovitsa graben - left bank of the Penkyovska river (South of Divlya)</td>
<td>w.r.</td>
<td>1.83</td>
<td>75.7</td>
<td>3.275</td>
</tr>
</tbody>
</table>

low: a) the contacts between KV-bodies and the sedimentary fill of the graben; b) the types of volcaniclastics in GGg.

Contacts. The GGg terrigenous sedimentary rocks are assigned to be of Priabonian-Oligocene age (Карагюлеева, Костадинов in Бончев и др., 1960; Zagorchev, Dinkova, 1991) but are not directly dated. The contacts of the KV bodies with them can be mapped along the western boundary of the graben only (Fig. 1), but they are not well exposed and are interpreted in rather different manners: e.g. as cross-cutting contacts (Бончев и др., 1960; Белев, Радонова, 1970), as tectonic contacts (Харковска, 1980) or as contacts between sedimentary rocks and synchronously erupted extrusive volcanics (Божков и др., 1985).

KV-volcaniclastics in the GGg Paleogene fill.

The available controversial information about the volcaniclastics is presented in Table III.

a) The coarse parallel-bedded “volcanogenic conglomerates,” described near the village of Divlya as basal levels of the GGg section, are typical KV epiclastics. The dominating clasts are well rounded to semirounded KV boulders (up to 1.2 m — Plate II — Ph. 6) and pebbles (0.5 — 20 cm). The KV clasts exhibit a felsitic to microgranular groundmass and contain plagioclase, biotite, quartz and hornblende phenocrysts. The age of one of these boulders was determined to be 45.4 ± 1.8 Ma (Table IV). The petrographic composition of the clasts in the irregularly distributed and poorly sorted psammitic to psephitic cement does not differ from that of the coarse clastic material.

A debris flow origin could be assumed for these sedimentary rocks, which show that the age of at least the biotite-hornblende KV-variety is relatively older than the age of the lowermost levels of the Priabonian-Oligocene (?) GGg section.

It must be pointed out that well rounded pebbles of the biotite-hornblende KV-variety occur also in the reddish polymictic conglomerates from the lowermost levels of the Paleogene section in the neighbouring Sekirna graben (Ск) (Fig. 1) — Kharkovska (1984).

b) Unsorted volcaniclastic deposits similar to the basal epiclastics are present in the middle levels of the GGg section near the hamlet of Dolchne (Харковска, 1980). They also consist mainly of KV-phenocrysts and angular or semirounded to rounded KV clasts (see also Table I—“a” in Божков et al., 1985) and do not contain any pyroclastic component (bombs, pumices, glass shards, etc.). Therefore, these rocks could hardly be interpreted to be of pyroclastic origin, e.g. cannot be regarded as genetically related to the sinsedimentary activity of a KV eruptive “center” and interpreted as “lahar deposits” or “agglomeratic tuffs” (Божков и др., 1985).

c) A pyroclastic origin has been suggested for the very fine-grained, not studied in detail crystalloclasts (plagioclase, biotite, rare quartz and fresh hornblende), dispersed in “tuffs” and in “tuffaceous limestones” (Бончев et al., 1960; Белев, Радонова, 1970). This crystalloclastic assemblage does not differ from the KV-phenocrysts assemblage, but it is not accompanied by vitroclastic components. The only volcaniclastic component in the rocks in question are presented by semi-rounded to well rounded small KV-lithic clasts. Therefore, for the time being, the pyroclastic origin...
Fig 5. Plots of the new w. r. K-Ar ages of KV on the geochronological time scale (Gradstein, Ogg, 1996) compared with the plots of whole-rock and sanidine ages of the magmatic bodies from the Rouen magmato-tectonic zone (RMTZ — after Harkovska, Pecskay, 1997) and Gorna Ribnitsa magmato-tectonic zone (GRMTZ — after Pecskay et al., 2001). The instrumental errors are given with arrows; for the location of the magmato-tectonic zones see the inset.

of these rocks and their genetic link with a suggested synsedimentary explosive volcanic activity in the confines of the KMTZ have to be considered as a hypothesis only.

The presence of KV-epiclastics in the GGg and Sg Paleogene deposits shows that the subvolcanic KV-bodies were exhumed before the beginning of the Priabonian — Oligocene (?) sedimentation.

4.3. New K-Ar ages — results and discussion. Five KV-samples with a weight of approximately 1 kg were prepared for w. r. radiometric dating (the chemical analyses of three of them are presented in Table I). After their crashing, sieving and washing carefully out the dust, the dried 0.6-0.2 mm-sized fractions were used for the analyses. One monomineral (biotite) sample was also prepared. It must be noted that it contained biotite of both the earlier and the late generations.

The details of the used analytical procedures are according to Balogh et al. (1985).

The K-Ar ages were calculated using the decay constants suggested by Steiger, Jagger (1977). The analytical errors are given with accuracy of ± 1σ. The information on the location of the dated samples and the K-Ar ages obtained is presented in Fig. 1 and Table IV.

The oldest age (47.4 ± 1.8 Ma) measured on sample K4p and the apparent ages of samples 5Zk, 2Zk and 11Zk are in accordance with each other within the analytical errors (Fig. 5). The differences between them could be explained with different intensity of their hydrothermal alteration which could partly rejuvenate the real age (like in the case, mentioned by Georgiev et al., 2001, p. 280). On the other hand, it cannot be completely excluded that the older age of K4p (Touton body), could record a relatively older phase of magmatic activity in the confines of the KMTZ. Such an explanation would be in agreement with the model of polystage magmatic evolution of KMTZ, based on the magnetometric data of
The gap between the relatively younger w. r. 4ZK age and the youngest age obtained (mixed primary and hydrothermal(?) biotite 4Zk) could be also referred to irregular hydrothermal alteration of the Odranitsa laccolith. However, this gap is too large and is inconsistent with the results of detailed and complex studies of some hydrothermal systems, which show (Marchev, Singer, 2000 and the references therein) that the hydrothermal activity follows closely the related magmatic events. In the case studied, these processes are separated by more than 4 Ma.

The pattern of the new K-Ar w. r. KV-ages indicates an about 5 Ma long time-span for the magmatic activity in the confines of KMTZ (from 47.4 to 42.2 ± 1.80-1.60 Ma). Based on the available information from other volcanic regions, and on the very uniform KV-petrographic features and chemical composition, such a long period cannot be accepted as a real time-span. The ages obtained could be explained: a) with a long-term low-temperature hydrothermal alteration of the volcanic bodies, intruded and cooled before or about 47.4 ± 1.8 Ma; b) with a complex combination of a relatively short-term processes of a Lutetian — Barthonian(? ) polystage (?) emplacement and the superimposed processes of a related low temperature hydrothermal alterations.

The magnetometric model (Hoxhov et al., 1984) of a polystage magmatic evolution of the KMTZ needs to be confirmed or rejected on the basis of detailed mineralogical and geochemical data (including the data on the hydrothermal alteration processes), which are not available now. Hence for the time being the only tentative conclusion is that all of new w.r. ages fall within a Pre-Priabonian interval (47.4 — 42.2 ± 1.60-1.80 Ma) on the Gradstein, Ogg’s (1996) geochronological scale (Fig. 5).

5. On the KMTZ metallogeny

The KMTZ metallogenic signature is unclear and the zone is considered to be practically a barren structure.

Insignificant hausmanite-magnetite veins with barite (± base-metal minerals) have been found in the confines of KMTZ. Small limonite (± hematite) caps, poorly preserved small sulphide (pyrite, arsenopyrite and chalcopyrite) occurrences (G. Sekirna, Stanyovtsi) and hematite mineralisations (veins and disseminations) crop out to the East and South-East of KMTZ. All of them are described as mineralizations of the Sekirna-Zemen ore zone (Kanurkov, 1988 and references therein), the limonite caps being interpreted as Fe-apo-sulphide (pyrite-base metals) occurrences with As, Zn, Ti, Ba (up to 0.08%) and Mn (up to 0.02%) as the more important elements. Both the primary sulphide and the iron-minerals occurrences are assumed to be of telethermal origin and of Oligocene or post-Oligocene age (Kanurkov, 1988).

Apart from them, small Hg-mineralisations of supposed Tertiary age are mentioned (Dokov et al., 1989). According to the same authors the barite veins, hosted in the Paleozoic rocks of Penkyovtsi unit, were formed also in Tertiary, while P. Dragov (personal communication) assigned their formation to Paleozoic time.

6. On the KMTZ geodynamic setting — a discussion

KMTZ was considered traditionally to be an integral part of the first order collision-related Paleogene Macedonian-Rhodope-North Aegean magmatic zone (MRNAMZ — Dabovski et al., 1991; Harkovska et al., 1998; Kamenov et al., 2000). Now, based on new data and on some regional correlations (Harkovska et al., 2001) this model has to be modified.

6.1. Regional position of the KMTZ. As shown in Fig. 1 (inset B), KMTZ forms the southern end of a regional, N-S to arch-like, more than 250 km long Late Alpine magmato-tectonic structure, interconnected with the erosional front of Mid Cretaceous single thrusts and thrust piles. The middle part of this structure (in Eastern Serbia) is marked by extrusive bodies and single hypabyssal plutons (Karamata et al., 1997 and the references therein) and its northern part (in the SW Carpathians — Romania) — by plutons (see the references in Ciobanu et al., 2002). The structure in question is described as western branch of the so called “Banatitic belt” and is interpreted in most of the geodynamic models as formed in a subductional setting (Ciobanu et al., 2002 and the references therein).

6.2. Some discrimination diagrams. The first discrimination diagrams for KMTZ igneous rocks (Fig. 6) are suggestive for their orogenic
6.3. Differences between KMTZ and the other linear West Bulgarian Tertiary magmato-tectonic structures, referred to the MRNAMZ:

Trend. The NW-SE KMTZ trend is “steeper” (150-160°) than the trends of the other Tertiary magmato-tectonic structures (135-140°) — Fig. 1, inset A.

Petrochemical affinity. The KV-affinity is a typical calc-alkaline one, while the igneous rocks of the other Tertiary West Bulgarian magmato-tectonic zones belong to the high-K calc-alkaline to/shoshonitic series (Figs. 3A and 3B; Kharkovska, 1984). The only calc-alkaline Alpine igneous rocks in Western Bulgaria are the intermediate and acid members of the Late Cretaceous Bourela volcanic complex (Western Srednogorie — Fig 3B), formed in an island-arc subduction setting (Байрактаров, 1989; Dabovski et al. 1989; Kamenov et al., 2000).

Age. The KV are older than the igneous rocks from the Rouen (Priabonian — Early Oligocene — Иванов et al., 1971; 31-30 ± 1,30 Ma — Harkovska, Pecskay, 1997) and Gorna Ribnitsa (32-30 ± 1.18-1.34 Ma — Pecskay et al., 2001) magmato-tectonic structures (N2 and N4 in Figs. 1 and 5).

Metallogeny. The metallogenic signature of KMTZ is unclear while the magmatism of the other Tertiary structures shows a typical base-metal metallogenic specialisation (Мьянков, 1984, 1988). By this reason the Kraishte region is not considered to be a part of the Rhodope Metallogenic Province (Dokov et al., 1989).

7. Conclusions

a) KMTZ consists of subvolcanic bodies cooled at shallow level. Their morphology is controlled mainly by the Mid-Cretaceous
thrust surface between the Luzhnitsa — Trun unit and the allochthonous Penkiovtsi unit;

b) KMTZ is a southern "fading out" termination of a regional, over 250 km long N-S to arch-like Late Alpine (Late Cretaceous — Early Tertiary) magmato-tectonic structure, marked in Eastern Serbia by the intermediate and acidic extrusive and single hypabyssal bodies of the Ridanji-Krepolin belt (Груюш, 1968; Karamata et al., 1997) and further to the North, in SW Carpathians (Romania) — by the basic and intermediate plutons of the "Western banatitic zone" (Ciobanu et al., 2002 and the references therein) — Fig. 1, inset B. The formation of this Late Alpine structure, which is closely interconnected with the erosional front of Mid Cretaceous single thrusts and thrust piles, is referred by the authors cited to a subductional environment.

c) The pattern of the new K-Ar whole-rock KV-ages could be explained alternatively: c) with a long-term low-temperature hydrothermal alteration of the subvolcanic bodies, intruded and cooled before or about 47.4 ± 1.8 Ma; c) with a complex combination of a relatively short-term processes of a polystage (?) pre-Priabonian (Lutetian — Barthonian?) emplacement and the superimposed processes of a related low temperature hydrothermal alterations. For the time being the most probable assumptions is that the KMTZ magmatic processes took place before 47.4 Ma.

The population of the new KV whole-rock ages is significantly older than the two so far reported K-Ar whole-rock ages (38-33 Ma — Божков и др., 1985). These ages are in agreement with the magnetometric age evidence (Ножаров и др., 1984) and with the presence of KV-epiclastics in the Priabonian-Oligocene (?) terrigenous sedimentary rocks of the Gorna Glogovitsa and Sekirna grabens. They show that the KMTZ igneous rocks are the oldest Tertiary volcanics, established so far not only in Western Bulgaria, but also across the whole Bulgarian territory (compare with the data of Янев et al., 1998).

d) The following differences between KMTZ and the other Tertiary (Priabonian — Early Rupelian) magmato-tectonic linear structures in West Bulgaria have to be noted: similar, but "steeper" NW-SE trend; pronounced calc-alcaline affinity of the magmatics; older age; absence of a base-metal metallogenic specialisation.

e) All data mentioned above show that KMTZ does not belong to the collision-related MRNAMZ. It may be suggested that the KMTZ acidic (strongly differentiated?) magmas have been generated either during the latest stages of the subductional processes responsible for the formation of the Late Cretaceous — Early Tertiary island-arc associations on the territory of the Balkan Peninsula, or in an environment, transitional to a collisional one. Such an assumption is in agreement with some metallogenic speculations, made years ago by Bogdanov (1977).

f) Additional data (mineralogical characteristics of the phenocrysts, supplementary trace-element data coupled with REE-analyses, high-resolution age determinations, Sr-isotopes data etc.) are needed to draw a real and comprehensive picture of the KMTZ melts genesis and to make a consistent discrimination of the geotectonic setting of the respective magmatics. Complex investigations (sedimentological, structural and volcanological) in the GG graben could help to solve the problems of the Tertiary evolution of the region under discussion.

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