Timing of the Ditrau alkaline intrusive complex (Eastern Carpathians, Romania)

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Abstract. On the basis of K-Ar and $^{39}Ar/^{40}Ar$ data, the following timing is suggested for the emplacement of the Ditrau Alkaline Intrusive Complex:

1) During Carnian (c.230 Ma), in the Middle-Triassic extensional stage a mantle derived gabbro-dioritic magma with mantle xenoliths was emplaced.

2) During Norian time (c.215 Ma) this gabbro-dioritic mass rose into the crust in a subsolidus stage and penetrated a crustal syenitic magma. Under these dynamic conditions, magma mingling and magma mixing occurred and a large variety of hybrid rocks formed.

3) During the Callovian-Oxfordian (c.160 Ma), in the Middle-Jurassic rifting (Civcin-Severin rift and spreading system), a mantle derived nepheline syenite magma that formed by partial melting intruded the Triassic Ditrau massif and veined all previously formed rocks. Mafic foid-rocks (ditro-essexite) formed by hybridization and partial metasomatic substitution. After this event, cooling below 300 °C lasted for 20-25 Ma, until the Berriasian stage (c.135 Ma). It was followed until 115 Ma by local hydrothermal alteration and mineralization.

4) During Aptian (c.115 Ma) the definitive closing of the Ar system is explained by tectonic uplift due to nappe transport.

Key words: Eastern Carpathians, Ditrau Massif, K-Ar and Ar-Ar data

Introduction

The Ditrau Alkaline Intrusive Complex (DAIC) occurs in the Romanian East Carpathians, near Gheorgheni, Lazarea and Ditrau. It cuts the Pre-Alpine metamorphic rocks of the Bucovinian nappe near the Neogene-Quaternary volcanic arc of the Harghita-Calimani Mts. Andesitic pyroclastics and basalt-andesite lava flows from these volcanoes unconformably overlay parts of the DAIC. The Ditrau massif is also covered by sedimentary lacustrine deposits which separated the volcanic arc from the East Carpathian land mass during Upper Pliocene and Pleistocene (Fig.1).

Pre-Alpine metamorphic rocks of the Bucovinian Nappe (uppermost Alpine unit including metamorphics) occur over a large area surrounding the DAIC. These metamorphics were involved in several nappe structures that are cut by the DAIC and were welded by its thermal contact aureole (Fig.2). Since the first radiometric data suggested a Jurassic emplacement (Bagdasarian, 1972; Streckeisen and Hunziker, 1974) the Ditrau massif was considered to be a stitching intrusion that proves Variscan staking of the aforementioned nappe structure in the metamorphic basement of Alpine nappes (Balintoni, 1981; Muresan, 1983).

The DAIC is characterized by a peculiar lithologic constitution and complicated internal framework. The petrographic complexity involves large series of ultrabasic to acid silica- versaturated and silica-undersaturated alkaline rocks of both, massive and oriented textures. Various concepts and petrologic models were advanced in the course of time, ranging from metasomatic to magmatic origin and from emplacement by a single magmatic intrusion, to multiple successive intrusions (for details see Streckeisen, 1952, Codarcea et al., 1958, Pál-Molnár, 1994, Kräutner and Bindea, 1995).

In this contribution a three stage model (Kräutner and Bindea, 1995) based on radiometric data is used to date DAIC emplacement. The proposed model is supported by relationships between the main rock and mineral associations observed in the field and under the microscope. It assumes that (Figs.3, 4):

1. Earliest DAIC components are gabbros and diorites of mantle origin, with xenoliths of olivine pyroxenites, partly or completely altered into hornblendites.

2. During their rise into the crust, these rocks (probably in a subsolidus stage) were partly mixed and mingled with a crustal syenitic magma. In this dynamic environment a part of the syenitic magma evolved towards:

- flow-oriented monzonitic components by mixing with the ascending basic rocks
- granitic melts by assimilation of quartz rich crustal rocks.

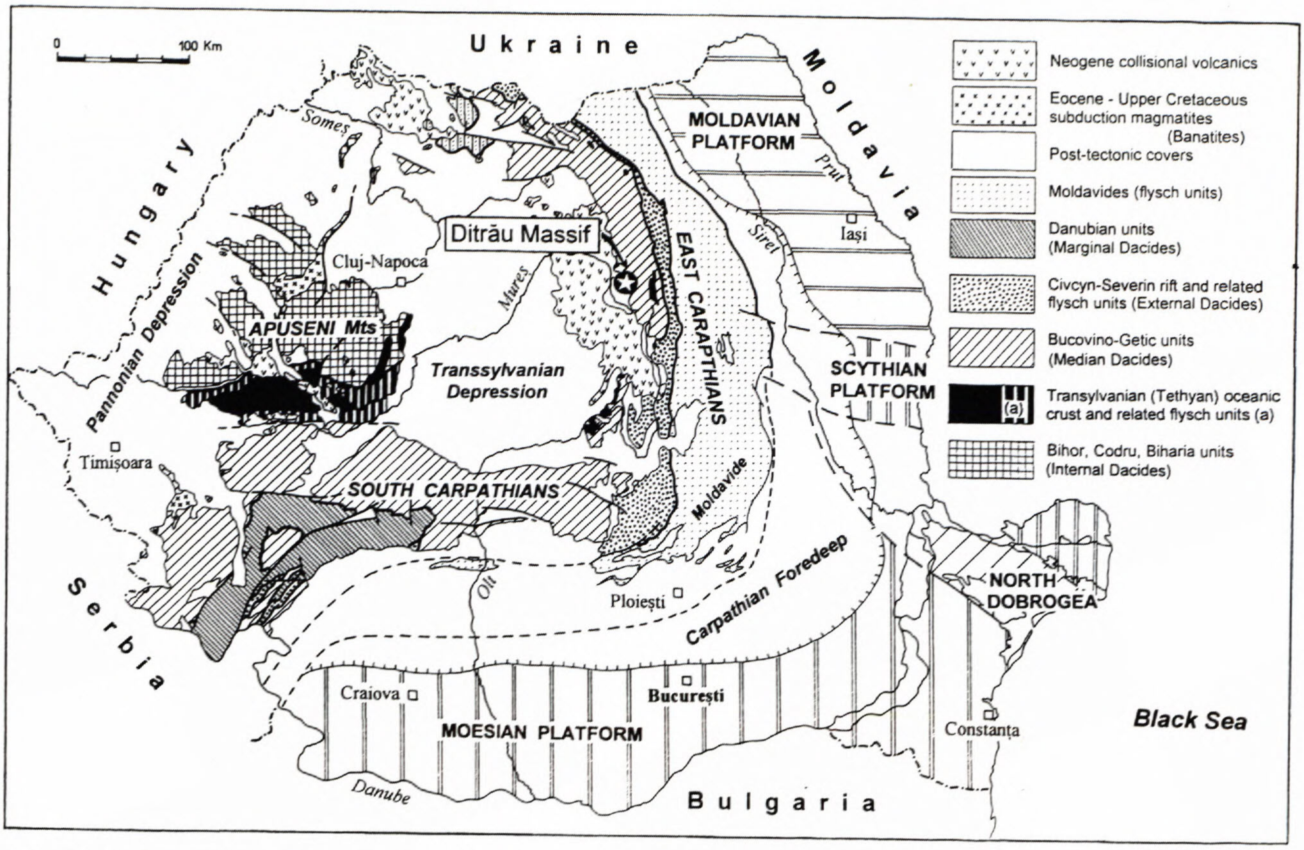

Fig.1 Position of the Ditrau Alkaline Intrusive Complex in the structural framework of the Romanian Eastern Carpathians.

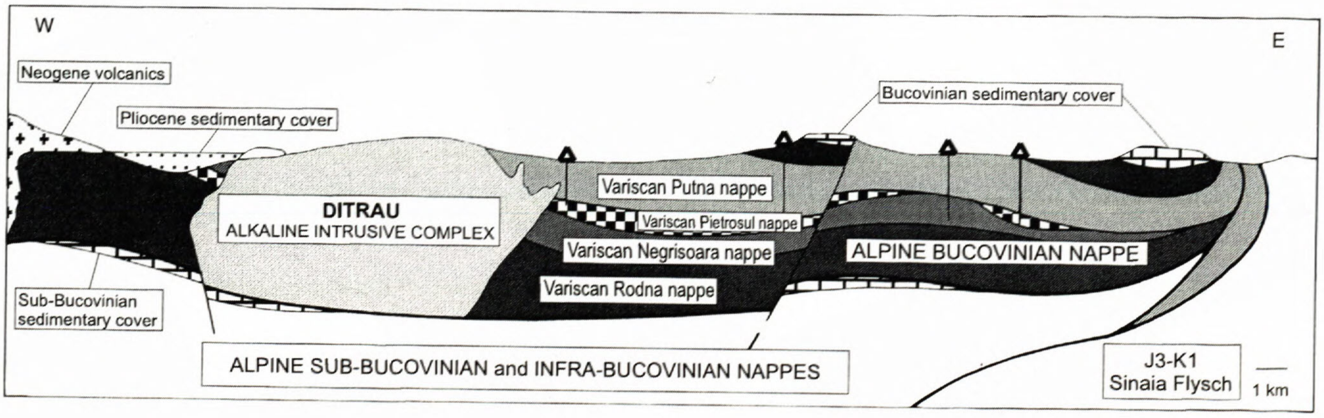

Fig.2 The Ditrau Massif is included in the Alpine Bucovinian nappe and cuts therein the Variscan nappe structure (Schematic geological profile through the Central Eastern Carpathians).

3. During a later stage a nepheline syenitic magma originated in the mantle by partial melting, intruded the aforementioned Ditrau rock associations. It produced in the previous DAIC rocks veining, hybridization and metasomatic alteration.

- In a late stage pegmatitic facies developed locally and sodalite and/or cancrinite bearing nepheline syenites formed
- tinguaite veins cut the whole structure
- a final hydrothermal stage associated with stockwork and vein mineralization concluded the development of the Ditrau complex,

4. During the first Alpine compressional stage the DAIC was involved in the Middle Cretaceous nappe system and was uplifted by tectonic transport.

Previous investigations

Various ages for the Ditrau Alkaline Intrusive Complex were assumed or inferred in early works ranging from Neogene to Paleozoic. Geologic relationships clearly show that the DAIC is younger than the surrounding Pre-Alpine metamorphic rocks and is considerably older than the Pliocene sedimentary cover.

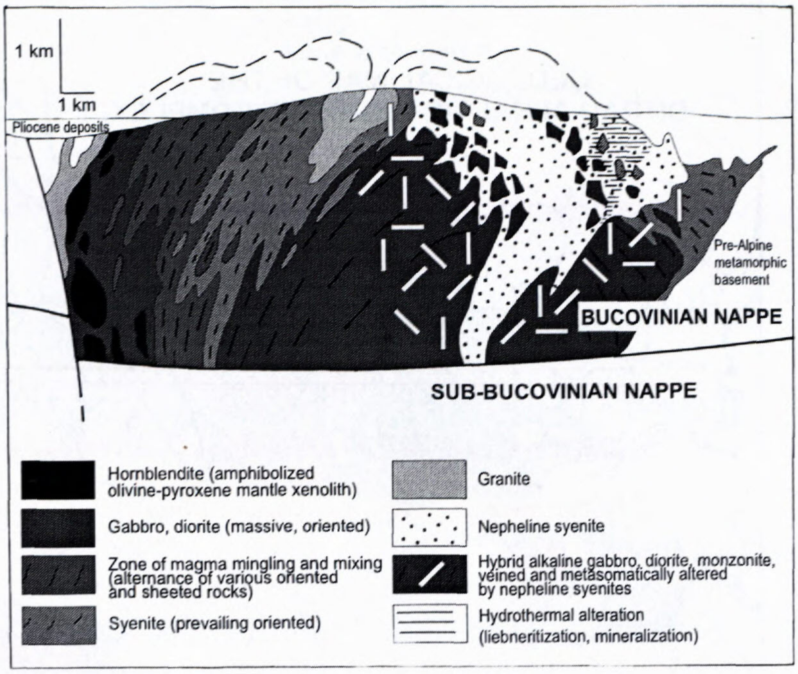

Fig. 3 Petrologic model for the internal structure of the Ditrau Alkaline Intrusive Complex.

Thus, a Mesozoic or younger age was considered by Mauritz and Vendl (1923) and a Post-Neocomian age was suggested by Reinhard (1911) and Földvári (1946), assuming genetic relations to the Neogene volcanics of the East Carpathians. Streckeisen (1931) suggested an intrusion in the Upper Cretaceous, while Ianovici (1938) envisaged a Jurassic age, because Liassic alkaline igneous rocks occur in the Brasov area. A Variscan emplacement was assumed by Pb-a ages of 297 Ma on zircon and 326 Ma on monazite (Ionescu et al., 1966).

Reliable estimates of the DAIC age appeared only since the first *K-Ar ages* were recorded. Bagdasarian (1972) suggested a Pre-Jurassic age (196 Ma) for hornblenditic rocks and an Upper Jurassic-Neocomian emplacement (140-120 Ma) of syenites and granites. More reliably, the nepheline syenites, tinguaites and the contact aureole were dated by Streckeisen and Hunziker (1974) at 160 Ma, with cooling below 300°C at 150 Ma. Between 1972-1981 Mînzatu et al. (1980,1981) recorded further K-Ar mineral and whole-rock ages ranging from 200 to 120 Ma. Based on isochron interpretations of the available K-Ar data, Kräutner et al. (1976) proposed an emplacement at 135 Ma and suggested cooling ages for the lower age values (122-115 Ma) and inherited Ar in rocks with higher age values (189-156 Ma). An *$^{40}Ar/^{36}Ar$-$^{40}K/^{36}Ar$ mineral isochrone* of 138.7±3 Ma for different DAIC biotites was also interpreted to indicate the closing age of the system (Mînzatu et al. (1981). A multistage evolution of the DAIC was proved by K-Ar dating since reliable Triassic K-Ar ages of 237-216 Ma (Pál-Molnár and Árva-Sós, 1995) and ^{40}Ar-^{39}Ar mineral plateau ages of 231-227 Ma (Dallmeyer et al., 1997) were recorded on hornblenditic and gabbroic rocks. A two stage model proposed by Pál-Molnár and Árva-Sós (1995) suggests a Middle Triassic-Lower Jurassic intrusion of hornblendites, nepheline syenites and granites, and a Middle Jurassic- Lower Cretaceous event that produced syenites, alkali-feldspar syenites and hybrid diorites.

Based on the first *Rb-Sr whole rock ages* Popescu (1985) inferred an ultrabasic intrusion at 200 Ma, followed by a syenite intrusion at about 160 Ma. A reinterpretation of these data and earlier K-Ar ages by Zincenco (1991) suggested the entering of the DAIC in the subsolidus stage at 171±3 Ma, ending of the pneumatolitic stage at 165±5 Ma and closing of the hydrothermal phase below 300°C at 154 Ma. Further Rb-Sr whole rock isochrone data were interpreted by Zincenco et al. (1994) in favour of a DAIC emplacement at 201±1 Ma, most probably in the Sinemurian. Based on a supplementary Rb-Sr isochrone of 231 Ma for ultrabasic rocks, Zincenco (1996, fide Postolache, 1997) suggested another age model involving the DAIC emplacement 231Ma ago, with the cooling of the marginal zones below 350°C at 201 Ma and the persistence of a central zone in a solid-liquid-gas stage until 123 Ma, when it pierced the solid cover zone. The system cooled below the hydrothermal stage at 116 Ma.

Interpretation of analytical data

K-Ar total gas ages and $^{40}Ar/^{39}Ar$ mineral plateau ages (Tables 1,2,3) recorded on Ditrau rocks in the course of time by different authors (Bagdasarian, 1972 were used to date the DAIC emplacement; Streckeisen and Hunziker, 1974; Mînzatu et al., 1980, 1981; Pál-Molnár and Árva-Sós, 1995; Dallmeyer et al., 1997). For stratigraphic time-scale the calibration of Gradstein et al. (1994) was used.

A rough statistic evaluation of all these data by histograms (Fig.5) indicates that age values cluster near two maximum domains, in which five secondary frequency peaks can be recognized at: ~235 Ma for hornblendite and gabbro-diorite ages; ~215 Ma for added granite ages, ~155 Ma, ~135 Ma and ~115 Ma for nepheline syenites and various pre-nepheline syenite rocks. This figure is compatible with our proposed petrogenetic model. It suggests (1) a Middle Triassic emplacement (~235 Ma) of gabbro-diorites with amphibolized mantle xenoliths, (2) followed in the Upper Triassic (~215) Ma by the crustal granitoids. (3) The nepheline syenite event appeared at the beginning of the Upper Jurassic (~160 Ma). It produced partial resetting of the Ar system in previously formed rocks. The continuously decreasing frequency of the age clusters at ~135 Ma and ~115 Ma, suggests a slow and long lasting cooling. During this period the late hydrothermal metasomatic activity and mineralization may bave taken place. Cessation of Ar loss at ~115 Ma fits well the suggested tectonic uplift by Alpine nappe transport during the Middle Cretaceous.

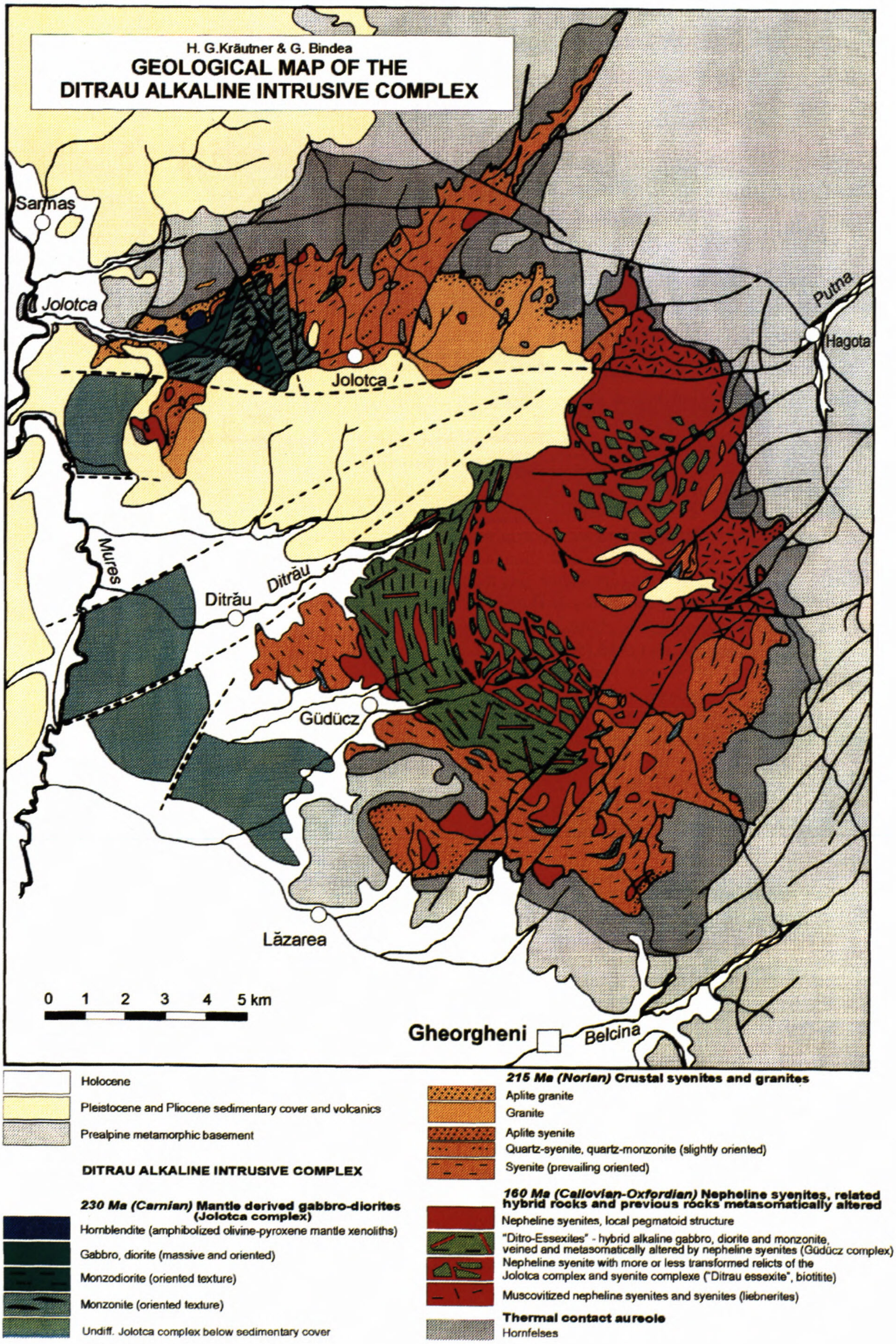

Fig.4 Geological map of the Ditrau Alkaline Intrusive Complex.

Table 2. *K-Ar ages of SYENITES and GRANITES from the Ditrau Alkaline Intrusive Complex recorded by Bagdasarian (1972), Ninzatu et al. (1980, 1981), Pál-Molnár and Árva-Sós (1995)*

Rock type	Locality	K-Ar total gas age				Sample	Source
		Biotite	**Muscovite**	**K-feldspar**	**Whole-rock**	Nr.	
Syenites (n=15)							
Syenite pegmatite	Hereb Valley, gallery 6		161,8±6,1			20	Mînzatu et al. (1981)
Pegmatoidic syenite (vein in hornbl.)	E confluence Teascului/Jolotca				143,5±0,5*(142±7)*	5137	Bagdasarian (1972)
Biotite-syenite (with titanite)	Ditrau-Tulghes road, km 11	139,3±5,1			136	2	Mînzatu et al. (1981, 1980)
Biotite-syenite	Ditrau Valley	134,3±4,8			131	3	Mînzatu et al. (1981, 1980)
Syenite	E confluence Simo/Jolotca				125,5±3*(128±3)*	5135	Bagdasarian (1972)
Syenite (folieted, vein)	Ditrau-Tulghes road				118±1*(121,5±0,5)*	5140	Bagdasarian (1972)
Biotite-syenite	Ditrau Valley	117			112		Mînzatu et al. (1980)
Biotite-syenite	Ditrau Valley, quarry	113,6±4,6				4	Mînzatu et al. (1981)
Syenite	Teascului Valley, gallery 19	107,6±4,1		182,7±6,9		6680	Pál-Molnar & Árva-Sós (1995)
Alkali feldspar syenite	Simo Valley	102,6±4,0		113,5±4,3		6679	Pál-Molnar & Árva-Sós (1995)
Granites, aplite granites (n=8)							
Granite	Török Valley	217,6±8,3		146,0±5,6		6677	Pál-Molnar & Árva-Sós (1995)
Granite	Teascului Valley	213,5±8,2		139,1±5,4		6703	Pál-Molnar & Árva-Sós (1995)
Granite	Naghag Valley	206,3±7,8		142,7±5,7		6704	Pál-Molnar & Árva-Sós (1995)
Aplite	Borehole 120, m 2				141,9±5,5	19	Mînzatu et al. (1981)
Leucogranite	Confluence Hompot/Jolotca				121,2±12*(125±10)*	5133	Bagdasarian (1972)

Calculated with constants recommended by Steiger and Jäger (1977), values from Bagdasarian (1972) recalculated by Zincenco et al. (1994) with constants recommended by Jäger and Steiger (1975); original published values in brackets

Table 1. *K-Ar and ^{40}Ar-^{39}Ar ages of HORNBLENDITES and GABBRO-DIORITES from the Ditrau Alkaline Intrusive Complex* recorded by Bagdasarian (1972), Ninzatu et al. (1981), Pál-Molnár and Árva-Sós (1995), Dallmeyer et al. (1997)

Rock type	Locality	K-Ar total gas age				^{40}Ar-^{39}Ar plateau age	Sample	Source
		Hornbl.	**Biotite**	**Plagioclase**	**Whole-rock**	**Hornblende**	Nr.	
Hornblendites (n=13)								
Hornblendite	Tarnita Valley	237,4±9,1					6546	Pál-Molnar & Árva-Sós (1995)
Pegmatoidic hornblendite	Tarnita Valley	234,7±10,8	162,4±6,1	161,3±9,8			6705	Pál-Molnar & Árva-Sós (1995)
			168,3±7,2				6705	Pál-Molnar & Árva-Sós (1995)
Hornblendite	Jolotca Valley, gallery 6	226,0±9,6					6548	Pál-Molnar & Árva-Sós (1995)
Hornblendite	Pietrarilor Valley	216,0±8,8					6547	Pál-Molnar & Árva-Sós (1995)
Hornbl. lense in oriented diorite	Confluence Tasok/Jolotca				195±8 *(196±6)*		5138	Bagdasarian (1972)
Hornblendite with plagioclase incl.	Ditrau-Tulghes road				174±1*(177±1)*		5139	Bagdasarian (1972)
Hornblendite (xenolith)	W confluence Halasag/Jolotca				159±12*(161±10)*		5134a	Bagdasarian (1972)
Hornblendite in oriented syenite	W confluence Simo/Jolotca				156±2*(161±2)*		5136a	Bagdasarian (1972)
Biotitite (biotitized hornblendite)	Jolotca Valley		161,0±6.3				22	Mînzatu et al. (1981)
Biotite-hornblendite	Jolotca Valley		134,5±5,2				21	Mînzatu et al. (1981)
Gabbro-diorites (n=8)								
Hornbllende-diorite	Ditrau-Tulghes road, km 7					231,5±0,1	2	Dallmeyer et al. (1997)
Gabbro	Jolotca Valley					227,1±0.1	1	Dallmeyer et al. (1997)
Diorite with feldspar aggregates	Teascului Valley	218,7±8,3		255,4±5,8			5667	Pál-Molnar & Árva-Sós (1995)
Meladiorite	Teascului Valley	208,3±8,3		138,2±5,8			6549	Pál-Molnar & Árva-Sós (1995)
Diorite	Teascului Valley	176,6±6,7		137,4±5,5			6550	Pál-Molnar & Árva-Sós (1995)

Calculated with constants recommended by Steiger and Jäger (1977), values from Bagdasarian (1972) recalculated by Zincenco et al. (1994) with constants recommended by Jäger and Steiger (1975); original published values in brackets.

Table 3. *K-Ar ages of NEPHELINE SYENITES, TINGUAITES and HORNFELSES from the Ditrau Alkaline Intrusive Complex recorded by Bagdasarian (1972), Streckeisen and Hunziker (1974). Ninzatu et al. (1980, 1981), Pál-Molnár and Árva-Sós (1995)*

Rock type	Locality	K-Ar total gas age			Sample	Source
		Biotite	**Nepheline**	**Whole-rock**	Nr	
Nepheline syenites (n=5)						
Nepheline syenite	Ditrau Valley	156±3*(153±3)*			1764	Streckeisen & Hunziker (1974)
Nepheline syenite	Comarnic	154±9*(151±9)*			429	Streckeisen & Hunziker (1974)
Nepheline syenite	Ditrau Valley		150,9±5,8		7	Mînzatu et al. (1981)
Nepheline syenite	Ditrau-Tulghes road			147±2*(152±1)*	5142	Bagdasarian (1972)
Pegmatoidic nepheline syenite	Ditrau Valley, quarry		116,1±4,4		9	Mînzatu et al. (1981)
Metasomatically altered nepheline syenites and syenites (n=7)						
Nepheline syenite with sodalite	Teascului Valley	182,4±6,9	232,7±8,8		6678	Pál-Molnar & Árva-Sós (1995)
Nepheline syenite with cancrinite	Ditrau Valley		147,4±6,0		8	Mînzatu et al. (1981)
Nepheline syenite with cancrinite	Ditrau Valley	136,9±5,1			5	Mînzatu et al. (1981)
Biotite-syenite with cancrinite	Csanod Valley	126,0±5,0			6	Mînzatu et al. (1981)
Syenite with sodalite (vein)	Ditrau-Tulghes road, km 7	120,0±4,5			1	Mînzatu et al. (1981)
Liebneritized nepheline syenite	Ditrau Valley		81,3±3,1		10	Mînzatu et al. (1981)
Tinguaites (n=5)						
Tinguaite	Confluence Aurora/Belcina			172,0±6,6	16	Mînzatu et al. (1981)
Tinguaite	Pricske			164±7*(161±7)*	835	Streckeisen & Hunziker (1974)
Tinguaite	Aurora Valley			159,3±6,1	17	Mînzatu et al. (1981)
Tinguaite	Csanod Valley.			159±6*(156±6)*	204	Streckeisen & Hunziker (1974)
Tinguaite	Csanod Valley			141,9±5,5	18	Mînzatu et al. (1981)
Hornfelses (n=4)						
Biotite hornfels	Aurora Valley, gallery 7			172		Mînzatu et al. (1980)
Biotite hornfels	Teascului Valley	152±6*(150±6)*			1195	Streckeisen & Hunziker (1974)
Phlogopit marble	Lazarea, borehole 141, m 137	156,8±5,9			24	Mînzatu et al. (1981)
Biotite hornfels	Aurora, borehole 144			138		Mînzatu et al. (1980)

Calculated with constants recommended by Steiger and Jäger (1977), values from Bagdasarian (1972) and Streckeisen and Hunziker (1974) recalculated by Zincenco et al. (1994) with constants recommended by Jäger and Steiger (1975); original published values in brackets.

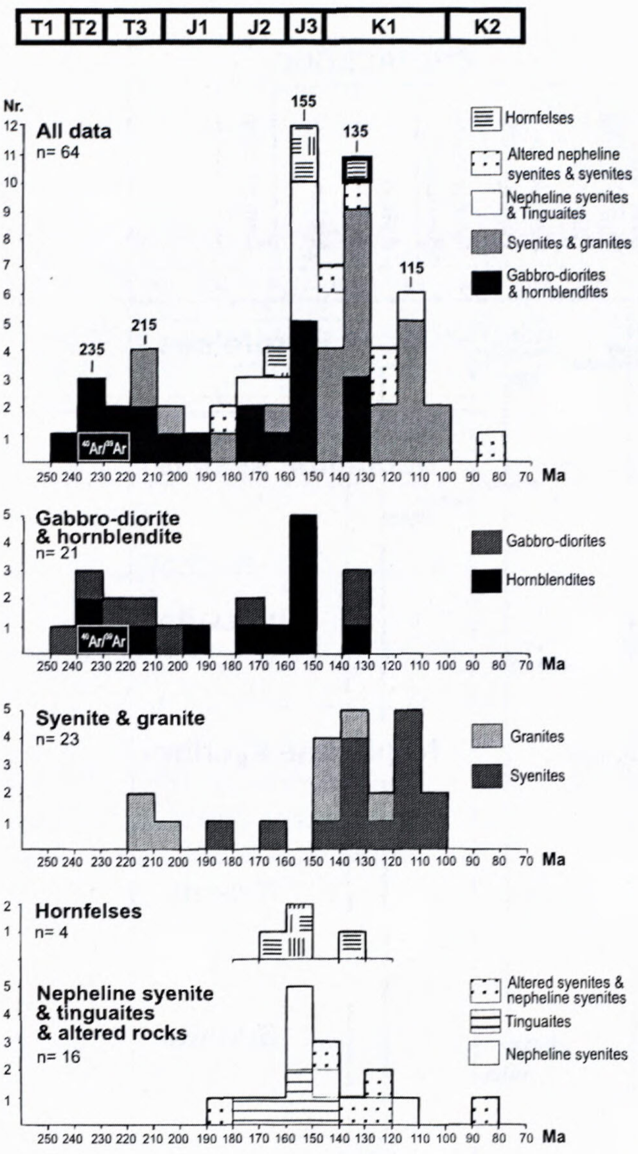

Fig. 5 Histograms with K-Ar total gas ages and $^{39}Ar/^{40}Ar$ mineral plateau ages from rocks of the Ditrau Alkaline Intrusive Complex. (Data from Bagdasarian, 1972; Streckeisen and Hunziker, 1974; Mînzatu et al., 1980,1981; Pál-Molnár and Árva-Sós, 1995; Dallmeyer et al., 1997)

A more detailed and reliable analysis, based on overlapping age intervals of error ranges (±) for individual samples (bars in Fig.6), suggests the following scenario:

(1) an early basic intrusion cooling below 500 °C between 231-227 Ma, as indicated by $^{40}Ar/^{39}Ar$ hornblende plateau ages from gabbro and diorite, as well as hornblende K-Ar total gas ages from hornblendite. Thus, conventionally, the *gabbro-diorite emplacement and accommodation of mantle xenoliths in these rocks occurred in the Carnian, at ~230 Ma,* as suggested by Dallmeyer et al. (1997). Recently, an age of 231 Ma was proposed by Zincenco (1996, fide Postoloache, 1997), on the basis of a Rb-Sr isochrone for ultrabasic rocks. Apparently, in hornblendites and gabbro-diorites argon systems of biotite-, plagioclase- and whole-rock were partly influenced by Jurassic heating, hybridization, metasomatic changes and recrystallization, produced by the penetrative nepheline syenite event. The rejuvenated biotite and feldspar K-Ar ages suggest tah the whole rock complex, a cooling below 300 °C between 160-140 Ma.

(2) For biotite from granites, an overlapping K-Ar age interval of 216-212 Ma may be considered, indicating cooling below 300 °C. Thus, conventionally, the *final emplacement stage of granitic- and associated syenitic granitoids can be assumed in Norian, at ~215 Ma.* A muscovite age of syenite-pegmatite suggests Jurassic partial heating over 400 °C at ~160 Ma, during the nepheline syenite event. A slow cooling of granites, syenites, gabbro-diorites and hornblendites down to 300 °C, until 135-130 Ma, is suggested by rejuvenated K-Ar ages of biotite from syenite and hornblendite, of feldspar from granites, gabbro-diorites and of whole-rock ages.

(3) The nepheline syenite emplacement was the last important thermal event in the DAIC, since the veining, hybridization and metasomatic influences nearly the whole massif. The best dating of this event may be inferred from tinguaite ages, as proposed by Streckeisen and Hunziker (1974). Tinguaites formed fast cooling veins in the final stage of the nepheline syenite intrusion. Overlapping whole-rock K-Ar ages of tinguaites are between 165-160 Ma. Biotite and nepheline ages of nepheline syenites cluster around 155 Ma. This age interval (165-155 Ma) complies with the aforementioned rejuvenated muscovite, biotite, feldspar and whole-rock K-Ar ages, recorded in syenites and hornblendites. Consequently the *emplacement of nepheline syenites may be inferred to be Callovian, with a possible extension into Lower Oxfordian, at 165-160 Ma.* In hornfelses, prevailing biotite ages mark this event.

(4) In metasomatically altered nepheline syenites, as well as in syenites, which are the most suitable rocks for the postmagmatic alteration, biotite-, feldspar- nepheline- and whole-rock ages cluster around 135 Ma and 115 Ma. We interpret the age of 135 Ma as a partial cooling below 300 °C and the end of high temperature metasomatic activity. The 115 Ma event probably marks the final stage of hydrothermal activity and definitive cooling due to tectonic uplift by nappe transport.

Proposed timing of the DAIC emplacement

Considering the above interpretation of analytical data and the proposed petrogenetic model the following timing is suggested for the DAIC emplacement (Fig.7):

c.230 Ma - Carnian *(231-227 Ma ^{40}Ar- ^{39}Ar Hornblende plateau ages and 235-225 Ma overlapping interval for K-Ar hornblende ages of gabbro and hornblendite).* On the South European passive continental margin a mantle derived gabbro-dioritic magma raised up due to mantle plume activity related to the Middle Triassic extensional stage (Dallmeyer et al., 1997). In the Bucovinian sedimentary cover this Middle Triassic extension is recorded by Ladinian radiolarites (Sandulescu, 1973) which cover the Anisian platform dolomites. The ascending magma contai-

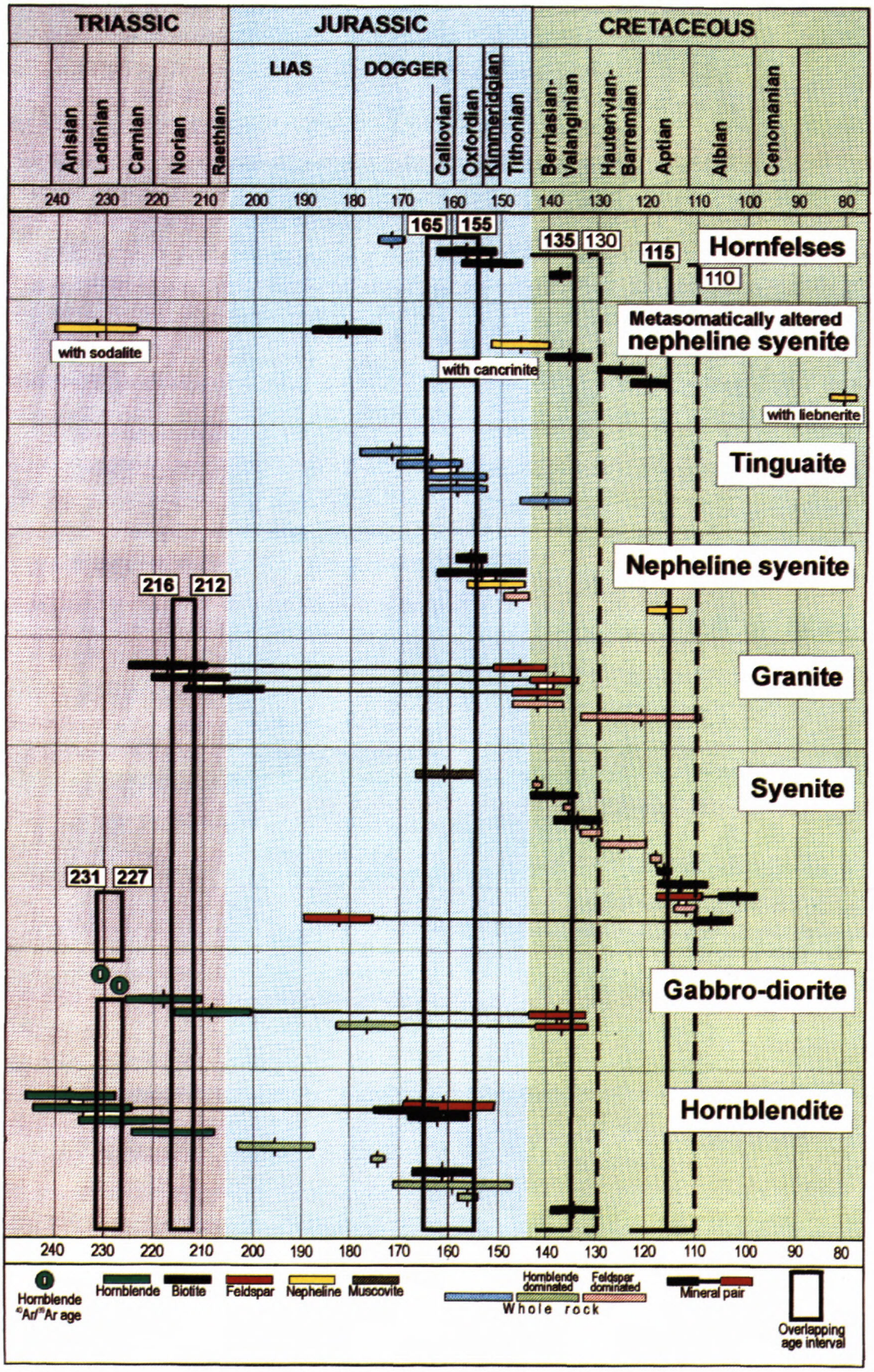

Fig.6 Overlapping intervals for error ranges of K-Ar total gas ages and $^{39}Ar/^{40}Ar$ mineral plateau ages from rocks of the Ditrau Alkaline Intrusive Complex. Bars indicate analyses with analytical error intervals. (Data from Bagdasarian, 1972; Streckeisen and Hunziker, 1974; Mînzatu et al., 1980,1981; Pál-Molnár and Árva-Sós, 1995; Dallmeyer et al., 1997)

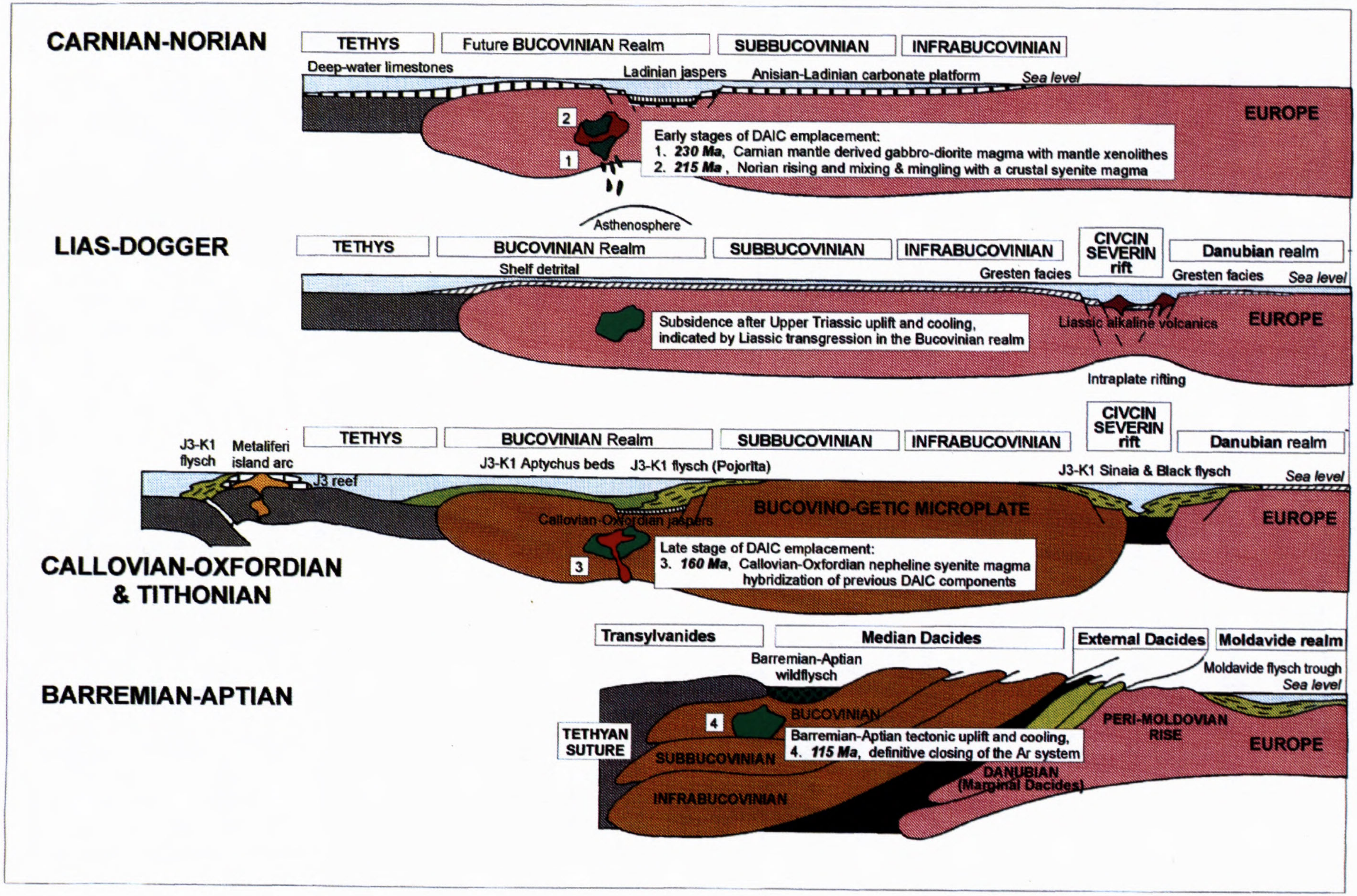

Fig 7 Plate-tectonic model for emplacement and timing of the Ditrau Alkaline Intrusive Complex.

ned ultramafic mantle xenoliths, represented by olivine bearing pyroxenites. These rocks were accommodated to crustal conditions by metasomatic changes with the gabbroic magma and by partial hydration; they were partially or completely transformed into hornblendites by „amphibolization“.

c.215 Ma - Upper Norian *(216-212 Ma overlapping interval of K-Ar ages for biotite of granites and for hornblende of hybrid gabbro-diorites, hornblendites).* The gabbro-diorite mass, probably in a subsolidus state, rose and penetrated the crustal syenitic magma in the crust. Under these dynamic conditions magma mingling and magma mixing produced a large variety of intermediary hybrid rocks. Prevailing oriented textures in most pre-nepheline syenite rocks are consistent with these dynamic conditions at a relatively deep crustal level. Sheeted structures and lenticular bodies of mafic rocks, enclosed in foliated syenitic rocks, strongly suggest a mingling of the two magma types. Magma mixing produced a continuous transition from alkali diorites to syenites. A large variety of foliated hybrid monzodiorites and monzonites occur in the transitional zone. Concomitant assimilation of quartz rich crustal rocks gave gradual transitions to quartz monzonites and quartz syenites. For granitic DAIC rocks that formed during this stage, a larger crustal assimilation beneath the actual intrusion level may be assumed. Veining by granite-aplitic rocks supports this interpretation.

c.165-160 Ma - Callovian-Oxfordian *(165-155-Ma overlapping interval of K-Ar whole rock ages of tinguaites with biotite and nepheline K-Ar ages from nepheline-syenites, muscovite, biotite and feldspar ages from syenites and hornblendites, biotite ages from hornfelses).* A mantle derived nepheline-syenite intrusion, formed by partial melting, intruded as a „central stock“, but also penetrated laterally towards marginal parts of the massif and veined all previously formed DAIC rocks. During late stages it developed locally to a pegmatoid facies. Mafic foid-rocks („ditro-essexite“, a comprehensive term for plutonic rocks of essexitic and theralitic chemistry, proposed by Streckeisen, 1952) formed through hybridization and partial metasomatic substitution of the previous gabbro-dioritic and monzonitic rocks with prevailingly oriented texture. The magmatic activity ended by late tinguaite veins. The nepheline-syenite event may be correlated with the Jurassic extensional stage that produced a separation of the Bucovino-Getic microplate from the European margin by the opening of the Civcin-Severin rift- and spreading-system (External Dacidic Rift acc. to Sandulescu, 1984). Inside the Bucovino-Getic microplate theses Jurassic extensional conditions are recorded in the Bucovinian sedimentary cover by Callovian-Oxfordian radiolarites. Later, the deeps were filled by Upper Jurassic - Lower Cretaceous flysch sequences. The nepheline-syenite emplacement ends subsequent to the Lias alkaline volcanism that was active to the south (Holbav), on the Bucovinian margin near the Civcin-Severin rift system.

Cooling up to c.135 Ma - Berriasian *(140-130 Ma frequency peak for biotite, feldspar, and whole rock K-Ar ages recorded in prevailing altered nepheline-syenites and syenites, but also in granites, gabbro-diorites, hornblendites and hornfelses).* A cooling period lasting about 20-25 Ma, supports the assumption of a deep crustal intrusion level. Late- and post-magmatic hydrothermal-metasomatic alterations produced peculiar varieties of nepheline syenites and pegmatites with cancrinite and sodalite („ditroit“, term proposed by Zirkel, 1866 for a variety of biotite-bearing nepheline syenite with cancrinite, primary calcite and sodalite along fractures).

Nappe transport and uplift up to c.115 Ma - Aptian *(120-110 Ma frequency peak for youngest biotite, feldspar, nepheline and whole rock K-Ar ages in nepheline-syenites and syenites).* A final closing of the Ar-system through cooling below Ar release temperatures is assigned to the tectonic uplift. It may be inferred that hydrothermal alteration (liebneritization) and mineralization developed before this time. A Meso-Cretaceous uplift of the DAIC is shown by its uppermost (Bucovinian nappe) position in the pre-Cenomanian nappe pile of the Central Eastern Carpathians.

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