PERMIAN-PALEOGENE PALEOGEOGRAPHY ALONG THE EASTERN PART OF THE INSUBRIC-PERIADRIATIC LINEAMENT SYSTEM: EVIDENCE FOR CONTINENTAL ESCAPE OF THE BAKONY-DRAUZUG UNIT

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The Drauzug appears as a foreign body in Paleozoic and Triassic paleogeographic reconstructions. The distribution of Permian and Upper Triassic facies zones in the Transdanubian Central Range (Bakony s.l.) (Western Hungary) made it possible to fit the latter unit in the place of the former one. A series of paleogeographic sketches from Late Permian through Late Triassic, Early Jurassic, Early Cretaceous, Late Cretaceous to Middle Eocene illustrates the consequences of this reconstruction.

Due to the northward motion of Apulia, an eastward directed continental escape took place following the Mesoalpine tectogenesis. The Bakony-Drauzug unit shifted about 450 km to the east in about 22 million years, from the Middle Eocene to Late Oligocene. A 35° counterclockwise rotation in the Miocene, connected with the folding of the Outer West Carpathians, completed the emplacement of the Bakony.

The Bakony-Drauzug fragment is a separate unit of the Alpine edifice between the Eastern and Southern Alps (Kovács, 1983). Its borders are the DAV (Defereggental-Anterselva-Valles)–Rába Lineament to the north and the Gailtal–Balaton Lineament to the south.

Le Drauzug est apparamment un corps étrange dans les réconstructions paléogéographiques dans le Paléozoique et dans le Triassique. La distribution des zones de faciès dans les Montagnes Centrales Transdanubiennes (Bakony s.l., Hongrie de l'Ouest) nous a rendu possible d'ajuster cet unité à la place du précédent. Les conséquences de cette réconstruction sont illustrées sur une série de schèmes paléogéographiques, complétés dans le Permien supérieur, le Triassique supérieur, le Jurassique inférieur, le Crétacé inférieur et supérieur et l'Éocène moyen.

Suivant la tectogénèse Mésoalpine, c'était le mouvement d'Apulie dirigé vers le Nord, qui était la cause d'un échappement continental dirigé vers l'Est. L'unité de Bakony-Drauzug se déplacait de 450 km environ, vers l'Est. Tout ceci se déroulait pendant les 22 millions années entre l'Eocène moyen et l'Oligocène supérieur.

Une rotation de 35° dans sens inverse des aiguilles d'une montre dans le Miocène, qui était reliée au plissement des Carpathiens de l'Ouest extérieurs a complété l'emplacement du Bakony.

Le fragment de Bakony-Drauzug est une unité séparé de l'édifice Alpine, coïneé entre les Alpes de l'Est et ceux du Sud (Kovács, 1983). Ces bordures sont le linéament DAV (Defereggental-Anterselva-Valles) — Rába par le Nord, et le linéament de Gailtal-Balaton par le Sud.

Keywords: Permian, Mesozoic, Paleogene, paleogeography, Southern Alps, Eastern Alps, Hungary, tectonics, lineament

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Introduction

The Insubric Lineament, which was site of significant horizontal and vertical movements following the Mesoalpine tectogenesis, according to Trümpy (1973), bifurcates at the western end of the Drauzug (Fig. 1). Its northern branch, the DAV (Defereggental-Anterselva-Valles) Lineament divides rocks affected by Alpine metamorphism to the north from formations not affected by it to the south (Ahrendt, 1980). The southern branch corresponds to the Periadriatic Lineament s. s. (Gailtal Lineament). Both have an eastward continuation into Hungary: the northern one is the Rába Lineament (Kovács, 1983), the southern one is the Balaton Lineament ("Balaton Crystalline-Metamorphic Zone" of Majoros [1980, Fig. 4]). The Drauzug unit enclosed by the two lineaments is considered to be a foreign body in Paleozoic and Triassic paleogeographic reconstructions (Schönlaub and Prey, in Oberhauser, 1980, pp. 9–13, 26–29, 70–77) (Fig. 2), but its Triassic facies are closely related to those of the western end of the Northern Calcareous Alps (Bechstädt, 1978). In this paper an attempt is made to demonstrate that the Permian–Paleogene facies zones of the Transdanubian Central Range in Hungary (Bakony unit) can be fitted in between the Southern and Eastern Alps, in the place of Drauzug. We show the timing and tectonic characteristics of the emplacement (continental escape) of the Bakony-Drauzug unit into its present-day position, connected with Mesoalpine tectogenesis.

The Insubric Lineament and its bifurcated branches, the DAV-Rába and the Gailtal–Balaton Lineaments are considered as former strike-slip faults. Along these faults the Bakony-Drauzug unit can be "pushed back" from its present position to the original one.

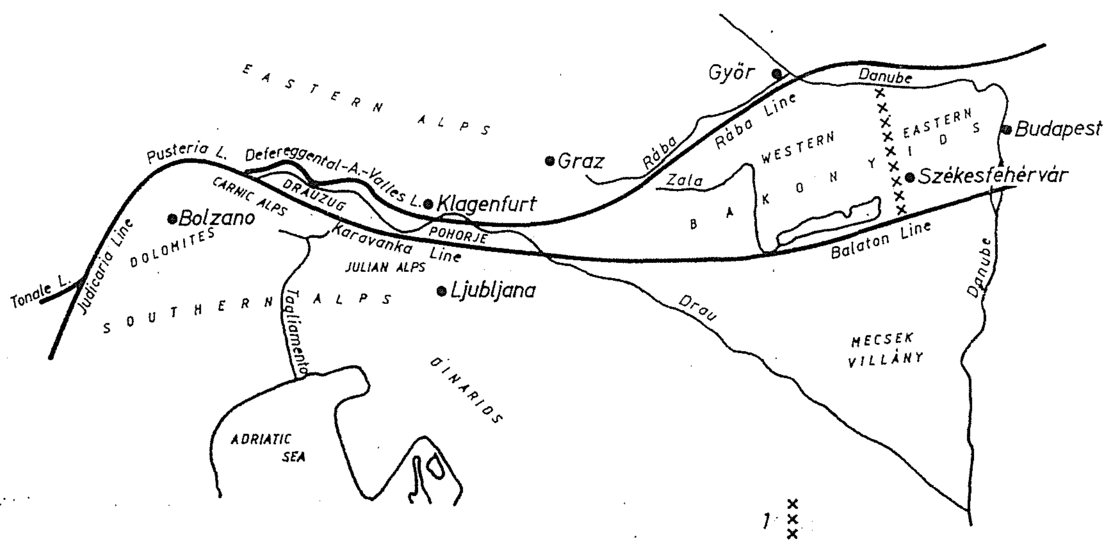

Fig. 1. The Bakony-Drauzug unit. 1. Paleogeographic boundary between Western and Eastern Bakony unit

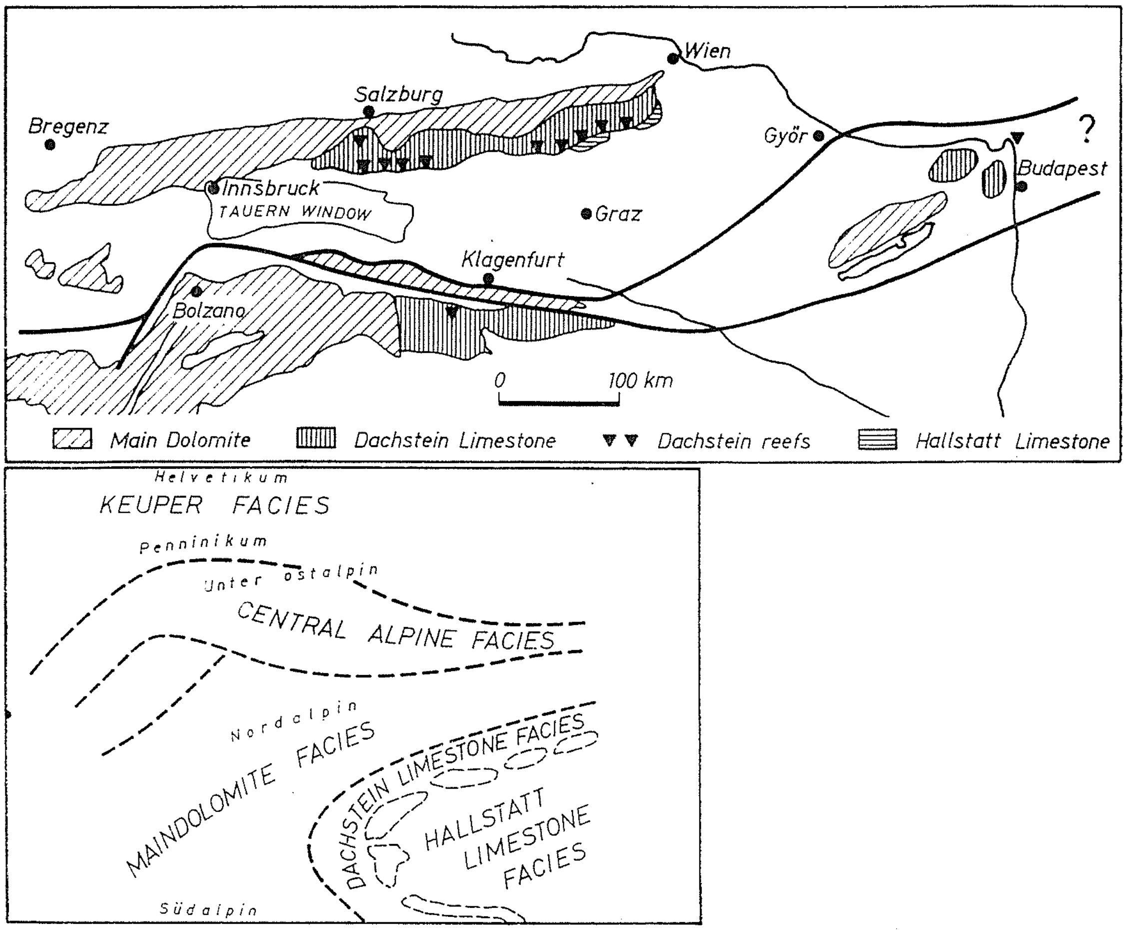

Fig. 2. The Bakony-Drauzug unit is a foreign body in Late Triassic facies reconstruction (after Prey, 1980, completed)

The Bakony unit is divided to an eastern and a western part on paleogeographic grounds. The boundary between them (indicated by a line of crosses in all figures) appeared in several stages and seems to be a constant factor in the paleogeographic evolution of the Bakony. If "pushed back" to its original position, it coincides with the complex zone between the Trento platform and the Belluno trough.

Due to space limitations, facts and hypotheses are shortly reviewed in this paper; detailed discussion of the problems will be published elsewhere.

Fitting of displaced paleogeographies across strike-slip faults

Recognition and fitting of displaced isopic zones across strike-slip faults is a common method for determining the dimensions of displacement. The best results could be achieved where the boundary between different facies zones forms a right angle with the fault, and can be traced to the immediate vicinity of that, either in surface or in subsurface exposures. Several kinds of facies boundaries can be used for this purpose: boundary between terrestrial and marine sediments (P_3), between terrigenous clastics and carbonates (K_1), between intertidal carbonates and non-deposition on a drowned submarine platform (J_1), etc. Late Permian, Late Triassic, Early Jurassic and Early Cretaceous paleogeographic situations discussed in this paper are shown as examples.

Paleogeographic schemes

1. Late Permian (Fig. 3)

The Late Permian transgression in the Southern Alps and Bakony took place approximately from east to west. This resulted in the deposition of the Bellerophon Formation, containing a basal evaporitic member (Südalpin: Fiammazza facies; Bakony: Tabajd evaporites) and a higher algal limestone and dolomite member (Südalpin: Badiota facies; Bakony: Dinnyés Dolomite). The evaporitic environment reached the western proximity of the Dolomites. Farther to the west mostly continental sedimentation (Südalpin: Gröden-type Beds; Bakony: Balaton Sandstone) persisted till the end of Permian.

The approximately N-S facies zones of the Southern Alps and Bakony turn to nearly E-W direction in the Northern Calcareous Alps (Nordalpin). South of the mostly continental Permoscythian red beds an evaporitic formation (Haselgebirge) was deposited (Buggisch et al., 1978; Majoros, 1980, 1983; Schönlaub, 1979 and in Oberhauser, 1980).

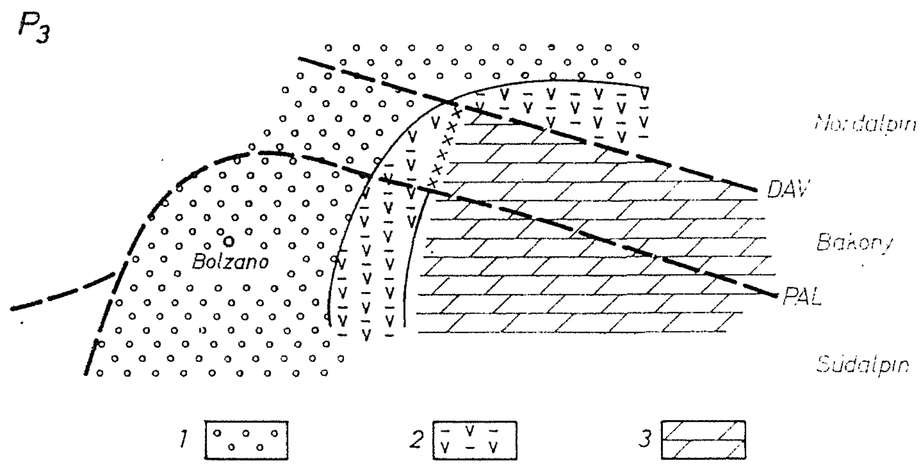

Fig. 3. Late Permian paleogeographic scheme: terrestrial vs. marine sediments. DAV = DAV-Rába Lineament; PAL = Gailtal–Balaton Lineament (part of the Periadriatic Lineament) (both for orientation only). 1. terrestrial Gröden Beds; 2. evaporites; 3. marine Bellerophon dolomite and limestone

2. Late Triassic (Norian) (Fig. 4)

Prey (in Oberhauser, 1980) has shown that the facies boundary between the Main Dolomite (Hauptdolomit) and the Dachstein Limestone lies in a N-S direction in the southern part of the Northern Calcareous Alps and in the Southern Alps (Fig. 2). He recognized also that the Drauzug is a foreign

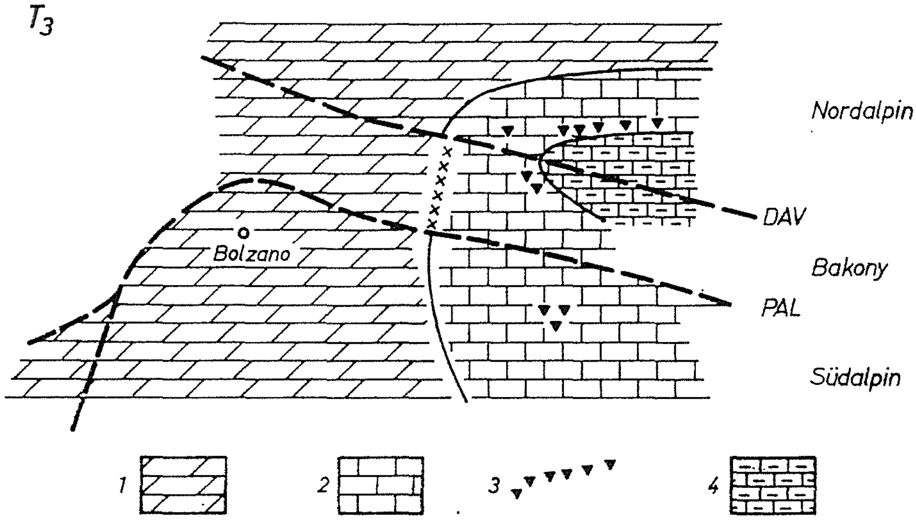

Fig. 4. Late Triassic (Norian) paleogeographic scheme: Main Dolomite vs. Dachstein Limestone. 1. Main Dolomite; 2. Dachstein Limestone; 3. Dachstein reefs; 4. Hallstatt Limestone

body in its present position, since its exclusive Hauptdolomit facies transects the facies boundary mentioned above.

The Hauptdolomit–Dachstein Limestone boundary of the Bakony-Drauzug unit lies about 450 km to the east (Fig. 2). If "pushed back" to its original position, the comprehensive picture of Fig. 4 can be drawn on the Norian paleogeography of the eastern part of the Alps. The marine character of the sediments increases eastward (restricted lagoonal Hauptdolomit—open lagoonal Dachstein Limestone reefs on platform margin—pelagic Hallstatt Limestone) (Gaetani, 1979; Kovács, Krystyn and Lein, in press; Prey, in Oberhauser, 1980; Végh-Neubrandt, 1972, 1982).

3. Early Jurassic (Hettangian–Sinemurian) (Fig. 5)

The fragmentation of the huge Upper Triassic carbonate platform began during the Hettangian. The characteristic facies of the different zones recognized by Aubouin (1963) are as follows:

Lombardian basin: siliceous limestones in Südalpin.

Trento platform: lagoonal carbonate sedimentation: Südalpin: Calcari

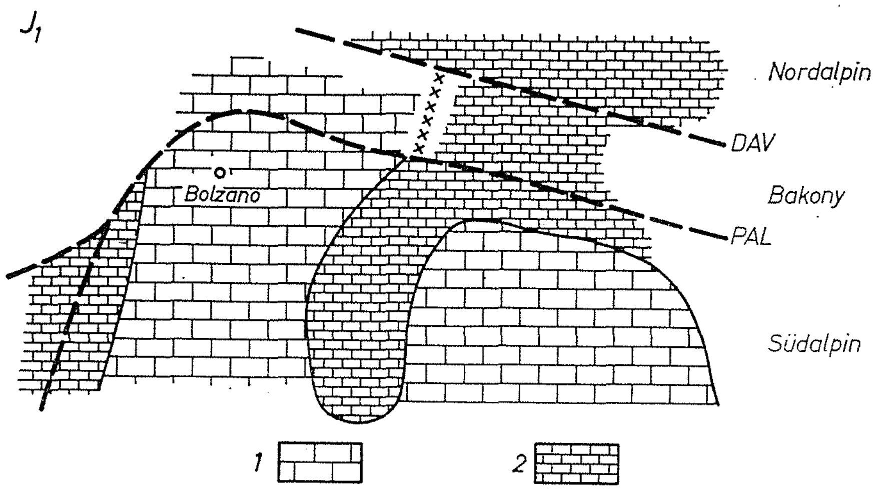

Fig. 5. Early Jurassic (Hettangian–Sinemurian) paleogeographic scheme: shallow vs. deep-marine limestones. 1. white, neritic limestone; 2. red, thin-bedded limestone

Grigi; Western Bakony unit: Dachstein-type Liassic limestone; Nordalpin, western and middle sector: Rhaeto-Liassic reef limestones and associated lagoonal sediments.

Belluno trough: Südalpin: starved depression with anoxic carbonate mudstones (Soverzene Formation); Eastern Bakony unit: no sedimentation and subsolution during Early Hettangian, thin beds of Ammonitico Rosso from Middle Hettangian onwards; Nordalpin, eastern sector: Ammonitico Rosso-type Adneth Limestone.

Friuli platform: lagoonal Calcari Grigi. This zone does not extend to the north beyond the Southern Alps.

(Aubouin, 1963; Bosellini et al., 1981; Flügel, 1981; Fülöp, 1968, 1971, 1976; Plöchinger, in Oberhauser, 1980; Winterer and Bosellini, 1981.)

4. *Early Cretaceous (Valanginian–Hauterivian)* (Fig. 6)

Most of the discussed area is covered by pelagic limestones made of coccoliths: Südalpin: Maiolica and Biancone; Western Bakony unit: Biancone or Mogyorósdomb Formation; Nordalpin, western and eastern sectors: Schrambach Beds. One exception is the reef and back-reef sedimentation of the Friuli platform. Another exception is the Berzsek Marl of the Eastern Bakony unit and the Rossfeld Beds of the middle sector of Nordalpin. These are flysch-like, turbiditic sediments with olisthostromes. The western boundary of this flysch basin is a reliable fitting point for the Bakony unit and the Nordalpin (Aubouin, 1963; Bosellini et al., 1981; Faupl, 1979; Fülöp, 1958, 1964; Plöchinger, in Oberhauser, 1980).

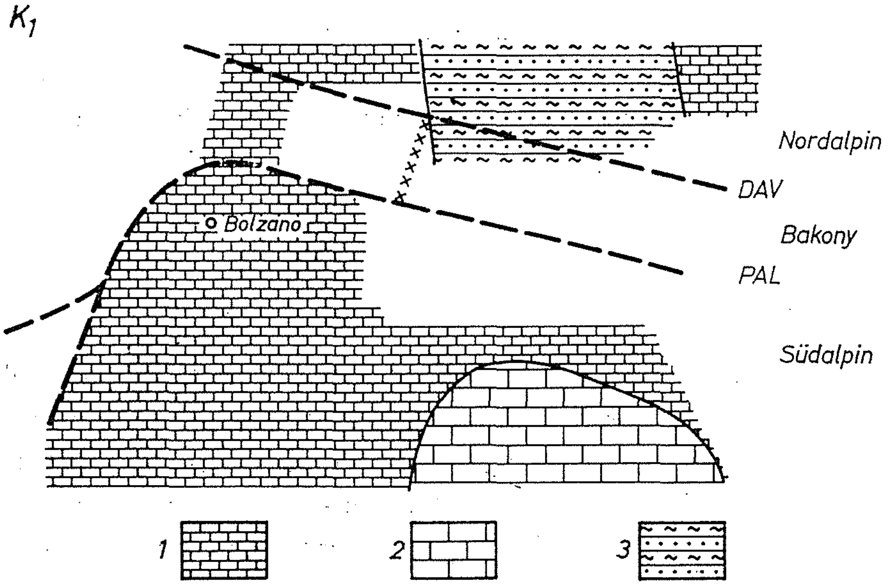

Fig. 6. Early Cretaceous (Valanginian–Hauterivian) paleogeographic scheme: biancone vs. turbidites. 1. Biancone and Schrambach Beds; 2. neritic limestones on Friuli platform 3. Rossfeld Beds and Bersek Marl ("flysch");

5. *Late Cretaceous (Campanian–Maastrichtian)* (Fig. 7)

The Lombardian basin of the Southern Alps is filled by flysch. The Trento plateau is covered by a condensed sequence of pelagic Scaglia Rossa, while the Belluno basin contains a more complete and thicker sequence. The Friuli platform is characterized by rudistid reefs. The Scaglia Rossa of the Belluno basin extends far to the north and merges into the Inoceramus–

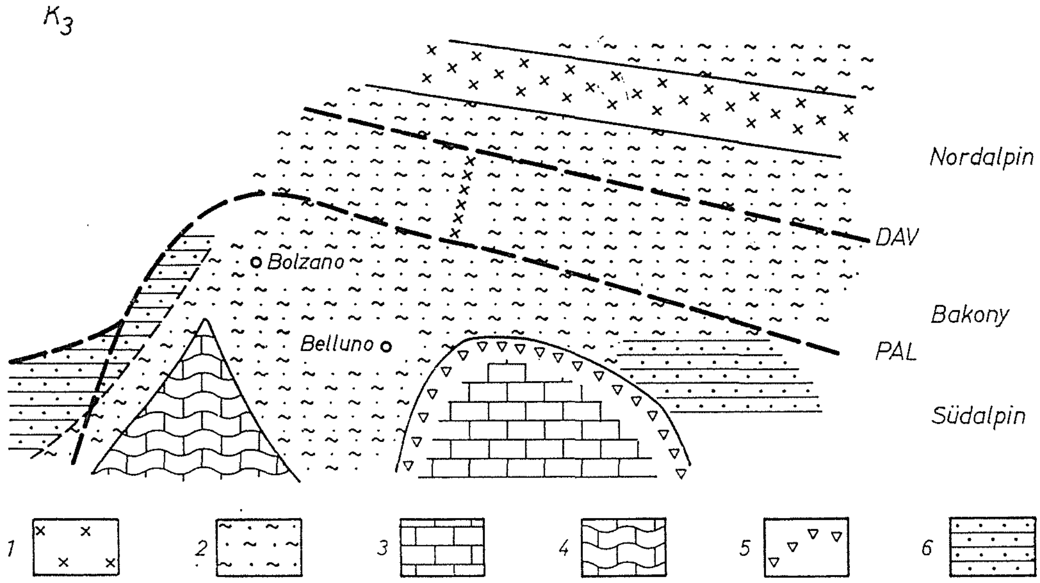

Fig. 7. Late Cretaceous (Campanian–Maastrichtian) paleogeographic scheme: southward deepening basin. 1. crystalline mainland; 2. (hemi)pelagic marls; 3. neritic carbonates; 4. condensed pelagic carbonates; 5. rudistid reefs; 6. flysch

Globotruncana marls (Polány Formation) of the Bakony, then into the Nierental Beds of Austria. The percentage of terrigenous material increases northwards. The Alpine mainland, which separated the southern and northern Gosau basins, closed the Late Cretaceous sea northwards (Haas, 1981; Massari et al., 1983; Oberhauser, 1968).

6. *Middle Eocene (Lutetian)* (Fig. 8)

Pelagic Scaglia Cinerea covers the Lombardian basin. The Trento platform extends far to the north and can be connected to the southern part of Bakony unit. It is covered by neritic, nummulitic-algal limestones. Its NE and SE extensions enclose the Belluno trough which contains flysch with resedimented carbonate breccias. The flysch basin—similar to the present-day Tongue of the Ocean—extends towards the Slovenian flysch. As terrigenous content of sediments increase northwards, the neritic carbonates of the Trento platform merge into the neritic marls and sandstones of the Bakony unit, and extends northward to Guttaring (Carinthia). The Alpine mainland forms the northern shore of the Mediterranean Middle Eocene sea.

Transcurrent faulting has just began along the Gailtal–Balaton and DAV–Rába Lineaments, forming the strike-slip basins of the Transdanubian Central Range (Bakony unit). These initial movements finally led to the continental escape of the Bakony–Drauzug unit (Cita, 1965; Drobne, 1979; Dudich and Kopek, 1980; Gnaccolini, 1968; Hinte, 1963).

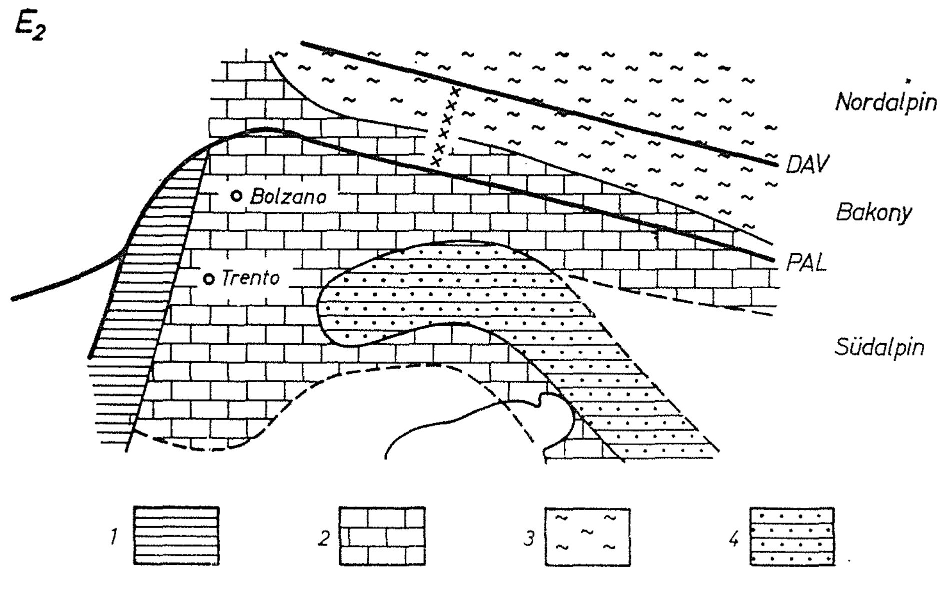

Fig. 8. Middle Eocene (Lutetian) paleogeographic scheme: Shelf vs. flysch trough. 1. pelagic marl (scaglia); 2. neritic limestone; 3. neritic marl; 4. flysch

7. *Early Oligocene (Early Kiscellian)* (Fig. 9)

The continental escape of the Bakony-Drauzug unit continues. The dimensions of the movement (≈130 km) can be determined by the fitting of the western paleogeographic boundaries of two anoxic basins: the Tard Clay

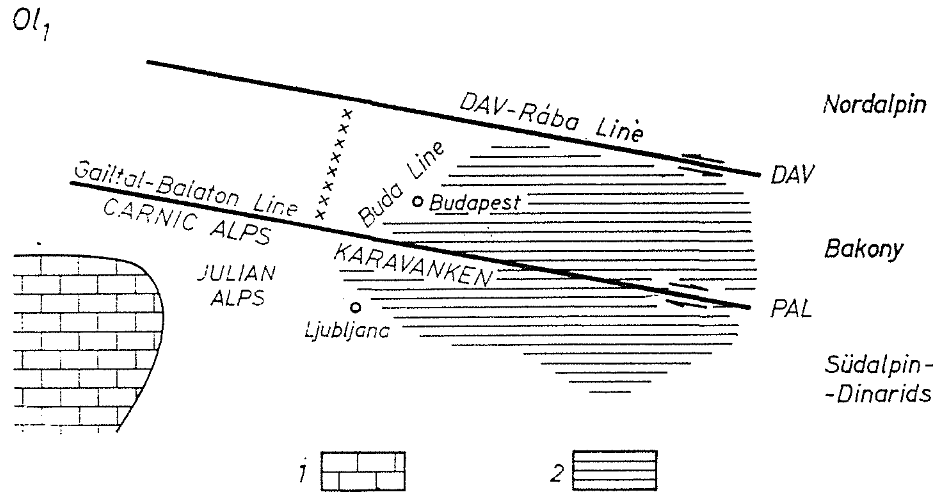

Fig. 9. **Early Oligocene (Early Kiscellian) paleogeographic scheme: mainland vs. anoxic basin. 1. neritic limestone of the Castelgomberto shelf; 2. laminated clay of the anoxic basin**

Sea of the Bakony unit and the Fischschiefer Sea of Slovenia. The connection to the neritic carbonates of the Castelgomberto shelf has been barred by the Eocene folding and subsequent uplift of the Dinarids (Báldi, 1983; Burchfiel, 1980; Kuščer, 1967).

8. *Late Oligocene (Egerian)* (Fig. 10)

The continental escape ended not later than Late Oligocene. A new, neotectonic basin was formed subsequently, during Eggenburgian times. This basin transects the DAV–Rába Lineament, excluding the possibility of post-Oligocene transcurrent faulting (Báldi, 1982).

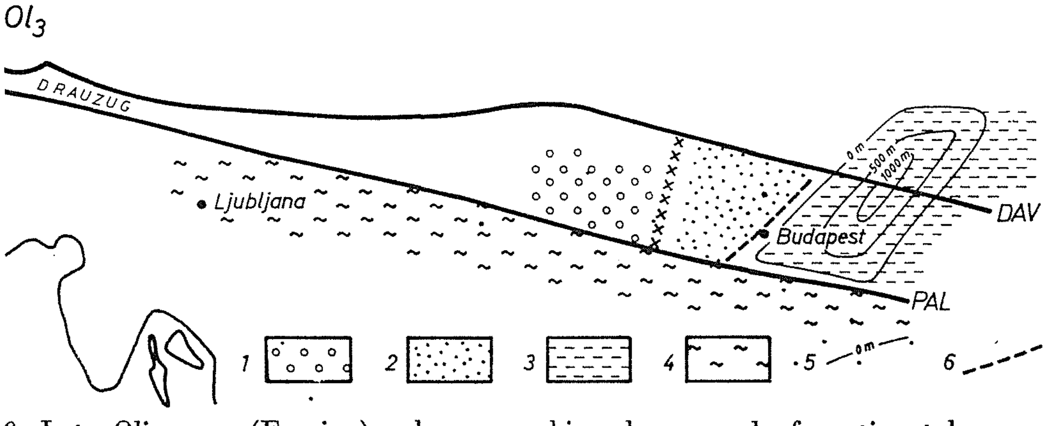

Fig. 10. Late Oligocene (Egerian) paleogeographic scheme: end of continental escape and initiation of neotectonic extension. 1. terrestrial gravel (Csatka Fm.); 2. brackish and marine sand (Mány Fm.); 3. marine clayey aleurite (schlier); 4. marine clay and sand; 5. contours of the Lower Miocene extensional basin; 6. Buda Fault

9. Middle Miocene (Badenian) (Fig. 11)

After Egerian (Ol_3) and before Badenian (M_4) a 35° counterclockwise rotation occurred, as can be deduced from paleomagnetic investigations. This rotation bended the Bakony-Drauzug unit and formed its present-day curved shape. The space necessary for the rotation was provided by the contempo-

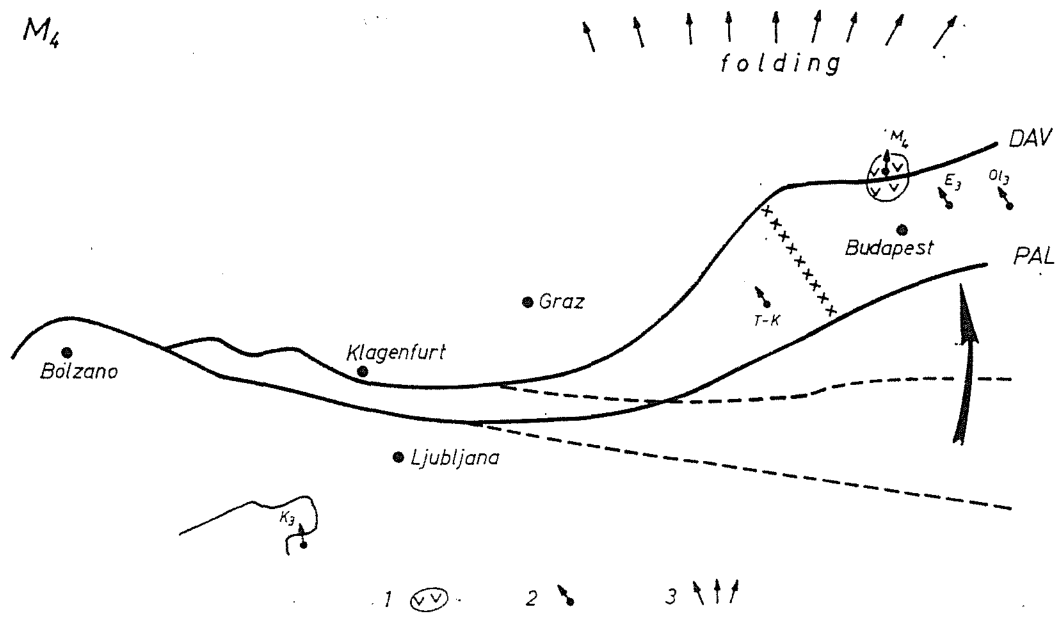

Fig. 11. Middle Miocene (Badenian) paleogeographic scheme: after rotation. 1. the Börzsöny andesite volcano; 2. observed paleomagnetic north; 3. Early–Middle Miocene folding in the Outer West Carpathians

raneous folding of flysch and molasse in the Outer West Carpathians (Balla and Márton-Szalay, 1980; Jiríček, 1979; Márton and Veljović, 1983; Márton P., 1983, pers. comm.).

Continental escape

The Middle Eocene–Late Oligocene horizontal displacement of the Bakony Drauzug unit (about 450 km in about 22 million years) can be interpreted as a continental escape caused by the northward motion of Apulia (Kovács, 1983; Kázmér, 1984). This motion formed an integral part of the Mesoalpine orogeny. The elongated wedge of the unit shifted eastward, toward the pressure shade of the Pannonian region. This displacement generated secondary dextral faults (Mészáros, 1980) in the Bakony unit forming acute angles with the main transcurrent faults (Tapponnier et al., 1982). The zigzag shape of the northern border of Drauzug can be explained by similar secondary

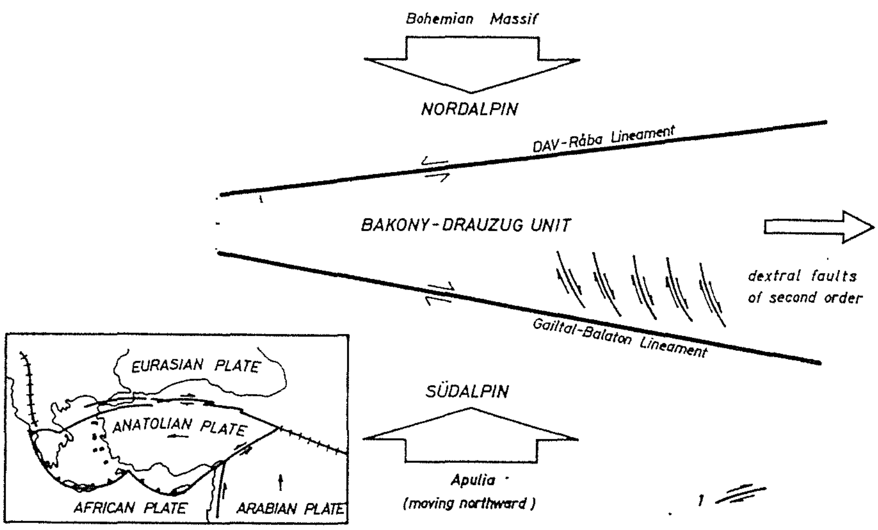

Fig. 12. Continental escape of Bakony-Drauzug: a model (inset after Hempton, 1982). 1. Dextral faults of second order

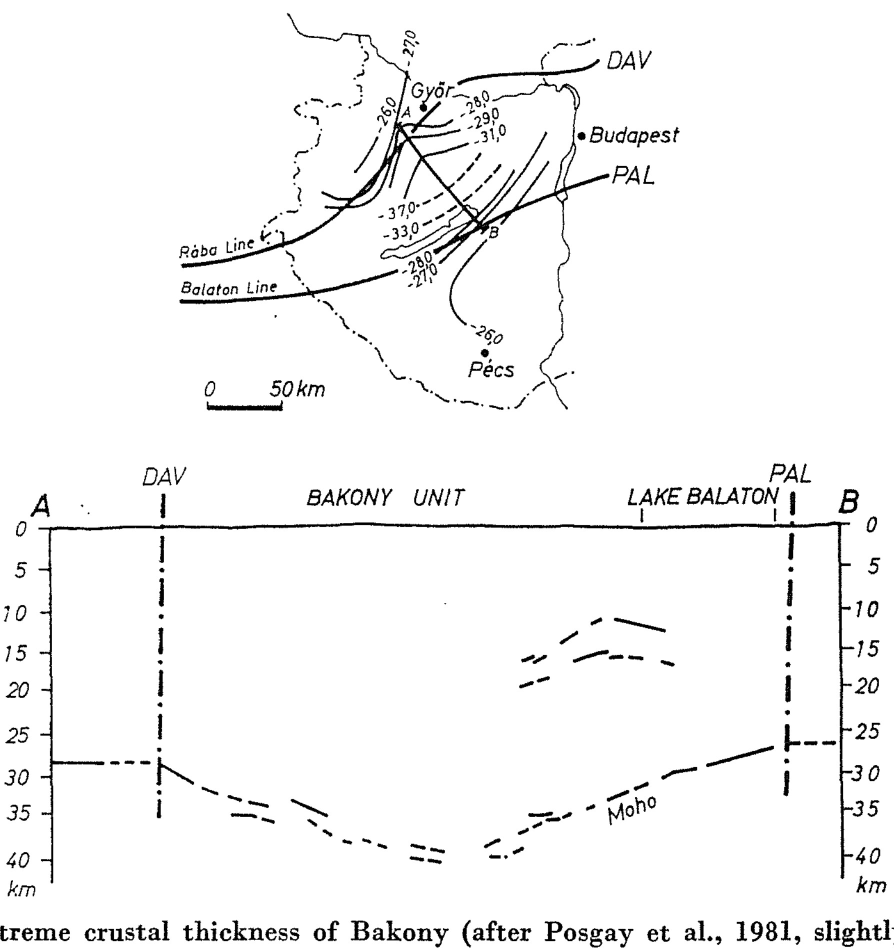

Fig. 13. Extreme crustal thickness of Bakony (after Posgay et al., 1981, slightly modified)

fault systems, which caused the blockwise movement shown by Rathore and Heinz (1980). The Neogene–Quaternary westward continental escape of the Anatolian plate (McKenzie, 1972; Hempton, 1982) has been used as an analogue for the tectonic interpretation.

The syntectonic sedimentation of the Bakony unit was that of a complex strike-slip zone (Reading, 1980), dissected by swarms of oblique-slip faults.

The boundary lineaments of the escaping Bakony-Drauzug wedge cut through the whole crust as can be postulated from the extreme crustal thickness of the unit, compared to its immediate vicinity (Fig. 13).

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