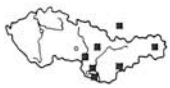
GEOLOGICKÝ ZBORNÍK — GEOLOGICA CARPATHICA, 34, 4, BRATISLAVA, AUGUST 1983,
Pp. 411—422

DIONÝZ VASS⁺ — FRANTIŠEK ČECH⁺⁺

SEDIMENTATION RATES IN MOLASSE BASINS OF THE WESTERN CARPATHIANS

(Figs. 7, Tabs. 7)



A b s t r a c t: During the formation of Alpine molasses in the Western Carpathians, the subsidence was most rapid in the period of the main molasse (Eggenburgian — Sarmatian, 23 — 10.5 m. y.) in longitudinal intramountain basins where the subsidence rate attains 10.9 cm/100 yr. The slowest one was that of the early molasse (Upper Carboniferous — Egerian, 70 — 23 m. y.) in the back-deep — the rates vary within the range 0.14 — 2.5 cm/100 yr. In the course of the late molasse development (Pannonian — Pliocene, 10.5 — 1.8 m. y.) the back-deep subsidence was the most intensive — average 2—6 cm/100 yr.

Р е з ю м е: Во время формирования альпийских моласс в Западных Карпатах наиболее быстро проходило оседание в периоде основной молассы (эгенбург — сармат, 23 — 10,5 млн. лет) в продольных внутригорных бассейнах, где скорость оседания достигает 10,9 см/100 лет. Оседание ранней молассы прошло наиболее медленно (верхний мел — эгер, 70—23 млн. лет) в задней глубине — скорости колеблются от 0,14 до 2,5 см на 100 лет. В процессе развития поздней молассы (панон — плиоцен, 10.5—1.8 млн. лет). задняя глубина оседала наиболее интенсивно — средние скорости 2—6 см/100 лет.

Introduction

Molasse-forming epoch is an important tectonogenetic period in the development and formation of folded mountain complexes. It is connected with important magmatic activity, but also intensive subsidence in the way that the thickness of molasse complexes very often exceeds maximal accumulations of flysch troughs in certain mountain complexes (cf. A u b o i n, 1964).

Molasses in folded mountain complexes, i. e. also in the Western Carpathians, can be, on the basis of several tectonogenetic features, divided into outer, inner and back molasses (areally) and early, main and late molasses — with regard to time (V a s s, 1981).

The intensity of subsidence is one of important features by which molasses are distinguished from each other as far as time and area are concerned. Subsidence directly indicates synsedimentary tectonics. It was only until recently that it could be fully applied in discussing the tectonic activity because the quantification of subsidence was a problem. Data on the thickness of molasse complexes are mostly well-known today and they have been synthetized deep bore-holes. These data were synthetized towards the close of the 70-ies Západné Karpaty 11 (1969). Certain data were corrected with regard to new discoveries (R u d i n e c, 1978; V a s s et al., 1979 and others).

⁺RNDr. D. V a s s, CSc., Dionýz Štúr Geological Institute, Mlynská dolina 1, 809 00 Bratislava.
⁺⁺Prof. RNDr. F. Č e c h, DrSc., Department of Mineral Raw Materials, Faculty of Sciences, Žižkova 2, 801 00 Bratislava.

Another feature for quantificating the subsidence, i. e. numerical identification of time, was provided by modern radiometric and magnetostratigraphic scale (for Neogene areas of Parathetys Vass and Bagdasarjan, 1978, for Paleogene Pomerol, 1978; Handerbol—Bergren, 1978; Odin et al., 1978; Cretaceous van Hinte, 1978).

Before analyzing the sedimentation rate, the facts need to be mentioned that there are several factors which cause the decrease of values determined from present thickness of fossil sediments. They manifest as follows:

— The reduction of original sediment thickness during its consolidation and compaction (the ratio 1:2 to 1:3, Bouček — Kodym, 1954; Pautot and Le Pichon, 1973 suggest 20—30 % reduction of thickness due to compaction).

— The fluctuation of subsidence in time, i. e. the existence of longer periods of fading of subsidence and corresponding fading sedimentation rates, and/or the stop of sedimentation, and/or syngenetic washing out of sediments without distinct features of erosion (hidden gaps).

— The shortening of thicknesses of layered complexes in postdepositional time (gaps).

The subsidence of the early molasse (Upper Cretaceous — Egerian)

It seems a difficult task to reconstruct the subsidence of the early molasse, since, especially in the Inner Western Carpathians, only denudation relicts of sediments in the early molasse have been preserved. Until now the most total profile of the early stage of the early molasse is buried under the volcanoclastics of the Krupinská planina mountains (the main molasse). It was intercepted by the bore-hole GK-4 near Bzovík. The thickness of sediments of the early stage of the early molasse (see Vass et al., 1979) is 540 m. The time interval, when the sediments originated, corresponds to the uppermost Cretaceous (Campanian—Maastrichtian) to Eocene, i. e. in the period which can be chronometrically quantificated as the time interval between 70—33 m. y. The average sedimentation rate was 0.14 cm/100 yr (Table 1).

With regard to lithological development of the lower part of the sequence with thickness about 500 m — even coarse-detrital, with features of rapid sedimentation, it can be assumed that these sediments accumulated much more rapidly. Nevertheless, the subsidence rate of coarse- detrital layers can not be quantificated since data for precise biostratigraphic identification of the sequence are missing.

It should be mentioned that within the Western Carpathian and Pannonian area, during the period of early molasse formation, the sedimentation took place also in the flysch trough (the Outer Carpathians, Inner Carpathian Podhaľský flysch, the Szolnok trough), where the sedimentation rate was higher than that of the early stage of the early molasse.

For reconstruction of sedimentation rate in the period of late stage of the early molasse (Kiscellian—Egerian), the Buda paleogene basin (Ipeľská kotlina depression being its part) can serve as the object of the consideration. In this depression, the thickness of sediments of the late stage early molasse attains 1100 m, from this amount 400 m corresponds to Kiscellian and 700 m to Egerian. The numerical age of Kiscellian is 6 m. y. (33—27 m. y.), that of Egerian is 4 m. y. (27—23 m. y.). The subsidence rate of Rupelian is 0.8 cm/100 yr, Egerian 1.3 cm/

Table 1

Sedimentation rate in Ipeľská kotlina depression (culmination stage of early and main molasses) and in Bzovík depression (early stage of early molasse)

Molasse		Age	m. y. 13.3	Maximal thickness (in m)	Sedimentation rate cm 100 yr
Main		Badenian	16.5	700	2.2
		Karpatian	19.0	250	1.0
		Eggenburgian-Ottnangian	23.0	450	1.1
Early	culm.	Egerian	27.0	700	1.3
		Rupelian	33.0	400	0.8
	early	Uppermost Cretaceous — Eocene	70.0	540	0.14

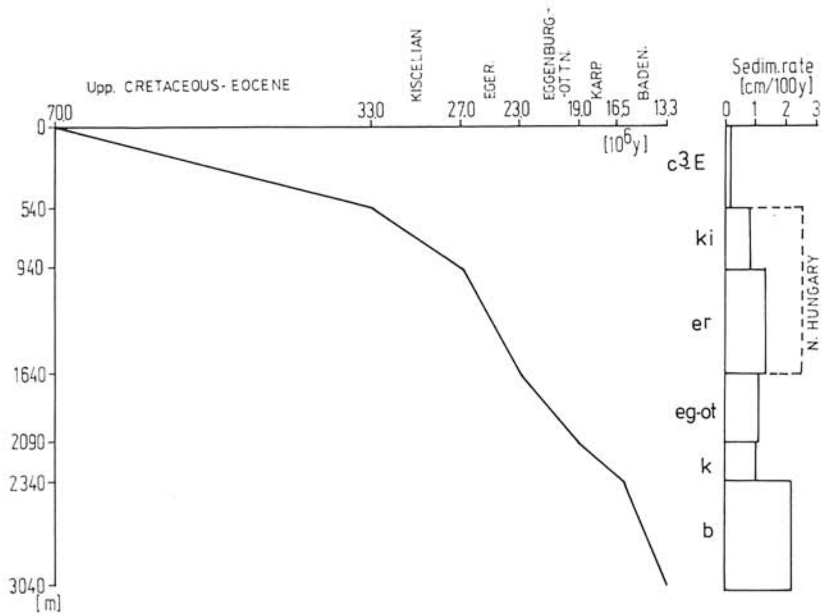


Fig. 1. Rate of molasse deposition in Ipeľ basin.

100 yr. Since the thickness of Rupelian and Egerian in the northern Hungary is higher (their mutual thickness reaches even 2500 m), therefore, also maximal rates of subsidence are higher (2.5 cm/100 yr).

It seems that the sedimentation rate culminates in the late stage of the early molasse and it is related to the backdeep of the Carpathians.

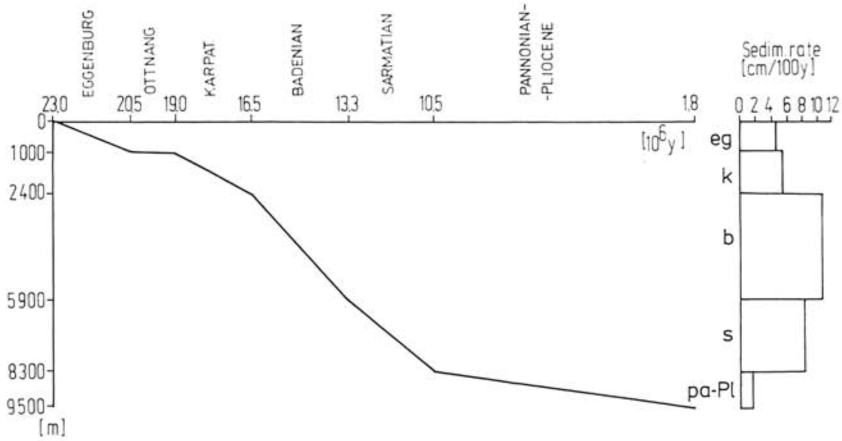


Fig. 2. Rate of molasse deposition in E. Slovakian basin.

Subsidence of the main molasse (Eggenburgian — Sarmatian)

During the development of the main molasse, sedimentation was the most intensive and rapid in longitudinal intramountain basins. The filling of these basins, namely that of the Vienna basin and East-Slovakian basin, represents the thickest accumulations of the Alpine molasses in the Western Carpathians, attaining several 1000 m (6000 to 7000 m). These accumulations are thicker than those originated in flysch trough during Cretaceous and Paleogene and which form the substance of nappes in outer part of the Western Carpathians.

The sedimentation of the main molasse increases in time. It is lower than that in the early stage of the main molasse (Eggenburgian—Karpatian). In the Galanta basin the sedimentation took place only in its northern part (Bánovce kotlina depression, Horná Nitra kotlina depression) and maximal accumulations of Eggenburgian to Karpatian reach approximately 800 m (in Bánovce kotlina depression, Brestenská in Seneš et al., 1978). That is witnessed by sedimentation rate 1.2 cm/100 yr. In East-Slovakian basin in Eggenburgian there have originated approximately 1000 sediments (bore-hole Prešov-1) at sedimentation rate 4.3 cm/100 yr. In Ottnangian there was no sedimentation, and/or there are no Ottnangian sediments preserved. In Karpatian there is a layered complex of approximately 1400 m thickness and the sedimentation rate was 5.6 cm/100 yr. An exception to this is the Vienna basin where namely in the Karpatian there was the most intensive subsidence and there have originated approximately 2000 m of sediments which is in correspondence with sedimentation rate 8 cm/100 yr (the maximal one in the Vienna basin, Table 3).

Table 2

Sedimentation rate in the East Slovakian basin

Molasse	Age	m. y.	Maximal thickness (in m)	Sedimentation rate cm/100 yr
		1.8		
Late	Pannonian-Pliocene		1200	1.4
		10.5		
Main	Sarmatian		2400	8.6
		13.3		
	Badenian		3500	10.9
		16.5		
	Karpatian		1400	5.6
		19.0		
	Ottnangian		0	0
		20.5		
	Eggenburgian		1000	4.6
		23.0		

Subsidence and sedimentation rates reach the maximum in the culmination period of the main molasse forming, i. e. in Badenian and Sarmatian. In the Galanta basin the thickness of Badenian and Sarmatian reaches 3000 m and sedimentation rate is 5 cm/100 yr (From that amount in Badenian even 7.8 cm/

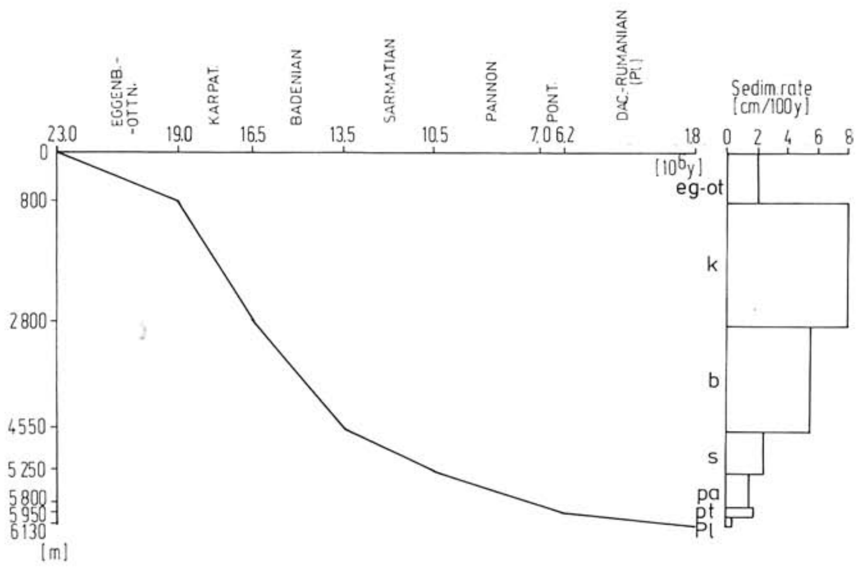


Fig. 3. Rate of molasse deposition in Vienna basin (cs. part).

Table 3

Sedimentation rate in the Vienna basin

Molasse	Age	m. y.	Maximal thickness (in m)	Sedimentation rate cm 100 yr
		1.8		
Late	Dacian — Roumanian		180	0.6
	Pontian		150	
		7.0		
	Pannonian		550	1.6
		10.5		
Main	Sarmatian		700	2.5
		13.5		
	Badenian		1750	5.5
		16.5		
	Karpatian		2000	8.0
		19.0		
	Ottnangian Eggenburgian		800	2.0
		23.0		

Table 4

Sedimentation rate in the Galanta basin

Molasse	Age	m. y.	Maximal thickness (in m)	Sedimentation rate cm 100 yr
		1.8		
Late	Dacian — Roumanian		200	0.6
		5.2		
	Pontian		200	1.1
		7.0		
	Pannonian		1000	2.8
		10.5		
Main	Sarmatian		600	2.1
		13.3		
	Badenian		2500	7.8
		16.5		

/100 yr, Table 4). In the East-Slovakian basin during the Badenian period there have originated complexes of thickness to 3500 m and sedimentation rate attained 10.9 cm/100 yr. Sarmatian sediments have thickness around 2200 m and sedimentation rate was 8.6 cm/100 yr.

In the Vienna basin, as already mentioned above, subsidence culminates in Karpatian. Maximal thicknesses of Badenian reach 1750 m, sedimentation rate 5.5 cm/100 yr. Sarmatian maximal thickness values are 700 m, sedimentation rate 2.5 cm/100 yr.

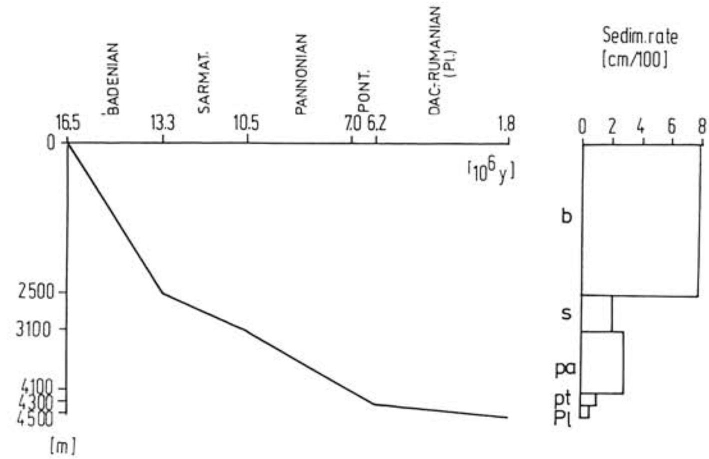


Fig. 4. Rate of molasse deposition in Galanta basin.

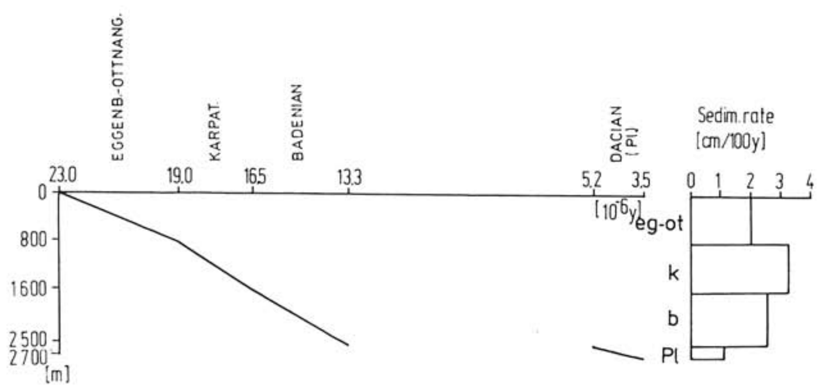


Fig. 5. Rate of molasse deposition in W. Carpathians fore-deep (cs. part-Moravia.)

A similar trend of subsidence and increase of sedimentation rate in time can be observed also in inner depressions where total thickness of main molasse sediments is lower and then also maximal sedimentation rate does not reach values stated in longitudinal basins.

Sedimentation rate culminates also here in Badenian and Sarmatian: sedimentary complex thick about 1500 m (e. g. in Turčianska kotlina depression) is in correspondence with the rate 2.5 cm/100 yr.

Sedimentation rate of the main molasse in the back-deep was connected with totally different tectonic conditions. In episodical basins of the back-deep, small accumulations of sediments (in hundreds of meters) have originated. Sedimentation rates during Eggenburgian—Badenian, for example in Ipeľská kotlina

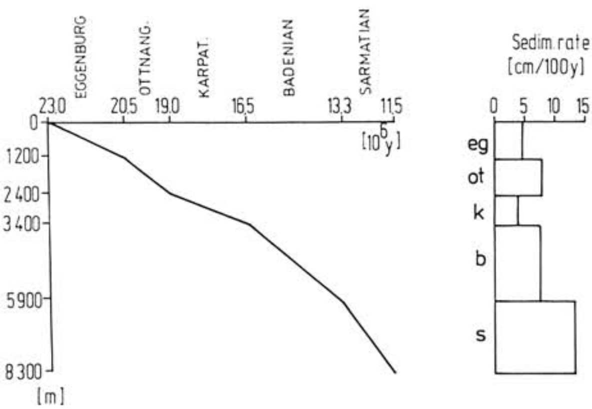


Fig. 6. Rate of molasse deposition in W. Carpathian fore-deep (Poland).

basin, reach values 1.0 to 2.2 cm/100 yr. Sedimentation in episodical basins was not continuous and sedimentation centres migrated in the area. Larger accumulations of molasse complexes originated only in cooperation with volcanism. This type of accumulation is represented for example by accumulations in volcano-tectonic zones in Hungary where the thickness of the main molasse reached 2000—3000 m.

Sedimentation in the Czechoslovak part of the foredeep (the fore-deep not folded into the flysch nappes, i. e. the outer fore-deep), was lower in comparison with longitudinal intramountain basins. The thickness of layered complexes within individual geological periods attains hundreds of meters. Maximal thickness of Eggenburgian and Ottnangian is approximately 800 m, sedimentation rate being 2.0 cm/100 yr. The thickness of Karpatian is also around 800 m (Cicha and Krystek in Seneš et al., 1978 recently reported even 1200 m) and sedimentation rate was 3.2 cm/100 yr (4.8 cm/100 yr respectively). Maximal thickness of Badenian reaches 800—900 m and sedimentation rate was 2.5 cm/100 yr (Table 5).

It seems that the subsidence of the main molasse in the Polish fore-deep was larger and the sedimentation rate increased in time. Maximal sedimentation rate was in Middle and Lower Sarmatian, their assumed total thickness reaches 2400 m and sedimentation rate was 13.3 cm/100 yr (Table 6). The fact needs to be mentioned that direct comparison of subsidence and sedimentation rate in the Polish fore-deep and in intramountain basins, and/or in basins of the back-deep is out of the question since thicknesses of the Polish deep are

Table 5

Sedimentation rate in the Czechoslovak fore-deep of the Carpathians

Molasse	Age	m. y.	Maximal thickness (in m)	Sedimentation rate cm/100 yr
		3.5 (?)		
Late	Dacian		200	1.1
		5.2		
		13.3		
Main	Badenian		900	2.5
		16.5		
	Karpatian		800 (1200)	3.2 (4.8)
		19.0		
	Ottnangian- -Eggenburgian		800	2.0
		23.0		

In the fore-deep, Badenian is represented mainly by Lower Badenian-Moravian. On the condition that Lower Badenian lasts 1 m. y. and Moravian thickness in the fore-deep is 800—900 m, sedimentation rate during Moravian reaches 9 cm/100 yr.

Table 6

Sedimentation rates of the main molasse in the Polish fore-deep (thicknesses assumed, according to N e y et al., 1974. Figs. 3—9)

Age	m. y.	Maximal thickness (in m)	Sedimentation rate cm/100 yr
	11.5		
Sarmatian		2400	13.3
	13.3		
Badenian		2500	7.8
	16.5		
Karpatian		1000	4.0
	19.0		
Ottnangian		1200	8.0
	20.5		
Eggenburgian		1200	4.8
	23.0		

only assumed, originally they should be according to N e y et al. (1974, Figs. 3—9), whereas the sedimentation rate in other molasse basins was determined on the basis of investigated thickness of sediments. Their original thickness was probably larger.

Table 7

Sedimentation rate in the Gabčíkovo basin (the late molasse)

Age	m. y.	Maximal thickness (in m)	Sedimentation rate cm 100 yr	Average sedimentation rate cm 100 yr
Quaternary		400	2	
	1.8			
Dacian—Roumanian		2250	6	4
	5.2			
Pontian		500	3	
	7.0			
Pannonian		1600	4	
	10.5			

Subsidence of the late molasse (Pannonian — Roumanian)

The subsidence during the sedimentation of the late molasse was less intensive. Relatively strongest subsidence happened to occur in the back-deep. Gabčíkovo basin can serve as a typical example of subsidence in the back-deep. The average sedimentation rate from the basis of Pannonian until now (including

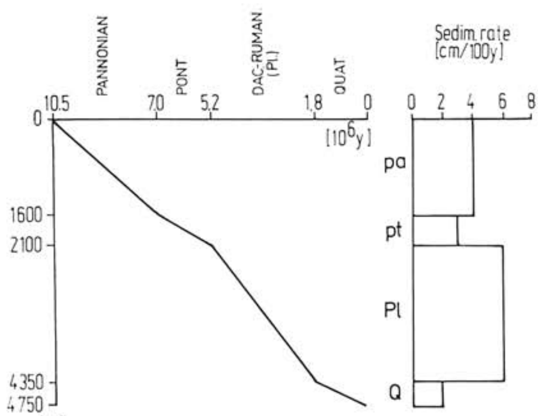


Fig. 7. Rate of molasse deposition in Gabčíkovo basin.

Quaternary), i. e. in the time period reaching 10.5 m. y. into the past, at maximal thickness of sediments 4700 m, is 4 cm/100 yr. A similar subsidence rate was calculated for Pannonian (Table 7) — that is the period between approximately 7 to 10.5 m. y., when within the Gabčíkovo basin there has accumulated

1600 m thick sequence of sediments. The subsidence seemed to fade in Pontian (3 cm/100 yr). The fading out correlates with the origin and development of Pontian coal series. Later on in Pliocene (Dacian—Roumanian) the subsidence rate of the late molasse culminated in time interval 3.4 m. y. (from 1.8 to 5.2 m. y.) and in Gabčíkovo basin there originated a layered complex of thickness to 2250 m and sedimentation rate reached 6 cm/100 yr. During the Quaternary subsidence again was weaker.

Sedimentation of the late molasse was considerably slower in intramountain basins. Within the East-Slovakian basin the average subsidence rate within Pannonian—Roumanian (including the latter one) attains only 1.4 m. y. In the Vienna basin the average sedimentation rate in exactly the same period is represented by the value 1.1 cm/100 yr. Sedimentation rate decreases in time, whereas in Pannonian this rate reached 1.6 cm/100 yr and in Pontian to Roumanian only 0.6 cm/100 yr.

Conclusions

Discussion about the subsidence during the formation of the Alpine molasses within the Western Carpathians can be closed with the statement that the highest thicknesses of sediments originated at the most rapid sedimentation in the period of main molasse within longitudinal intramountain basins where the sedimentation rates range from 0.14 to 2.5 cm/100 yr (data on thicknesses of the early molasse are relatively least total). Sedimentation was slow also in episodical basins of the backdeep in the time of the main molasse formation (1.1 to 2.2 cm/100 yr in Ipeľská kotlina depression).

In the development of late molasse in the back-deep sedimentation was relatively rapid — 2—6 cm/100 yr, but it did not reach the rate of the main inner molasse. Within intramountain basins sedimentation of the late molasse was considerably slower, with values 0.6 to 2.8 cm/100 yr.

It is not negligible that the area of maximal subsidence of molasse sediments migrated both in time and space.

In the period of the early molasse, maximal subsidence was observed in the back-deep. The main part of subsidence activity passed to intramountain basins in the period of the main molasse. Within the late molasse period the substantial part of subsidence activity again was back in the back-deep (Vass, 1981).

The analysis of sedimentation rate of molasse sediments, changes of its intensity in time and area represent a new element in synthetizing conceptions on the tectonics of molasse-forming period. Correlation of knowledge about sedimentation rate (and its changes) with volcanic activity, disintegration of crust in tafrogene processes, with tangential pressures and their consequences, allow to develop a new view on the processes of earth's crust formation and of mountain complexes and during their elevation.

Translated by H. Budajová

REFERENCES

AUBOIN, J., 1964: Réflexion sur le problème des Flyschs et des Molasses: Son aspect dans les Hellénides (Gréce). Eclogae geol. Helv. (Basel), 57, 2, pp. 451—496.

BOUČEK, B. — KODYM, O., 1954: Geologie I, všeobecná geologie. Nakl. ČSAV, Praha. 559 pp.
HANDERBOL, J. — BERGGREN, W. A., 1978: A new Paleogene numerical time scale. In: Contributions to the Geologic Time Scale. (G. V. Cohee et al editors). Amer. Assoc. Petrol. Geologists Bull. (Tulsa), pp. 213—234.
NEY, R. et al., 1974: Zarys paleogeografii i rozwoju litologicznofacjalnego utworow miocenu zapadliska przedkarpackiego.
ODIN, G. S. — CURRY, D. — HUNZIKER, J. C., 1978: Radiometric dates from NW European glauconites and the Palaeogene time-scale. J. Geol. Soc. (London-Edinburgh), 135, 5, pp. 481—497.
PAUTOT, G. — LE PICHON, X., 1973: Resultats scientifiques du programme JOIDES. Bull. Soc. géol. France (Paris), 7-e série 15, pp. 403—425.
POMEROL, CH., 1978: Critical review of isotopic dates in relation to Paleogene stratotypes. Contributions to the geologic time scale. (Edit. G. V. Cohee et al.). Studies in Geology 6. Amer. Assoc. Petrol. Geologists Bull. (Tulsa), pp. 235—245.
RUDINEC, R., 1978: Paleogeographical, lithofacial and tectonogenetic development of the Eastern Slovakia and its relation to volcanism and deep tectonics. Geol. Zborn. — Geol. carpath. (Bratislava), 29, 2, pp. 225—240.
SENEŠ, J. et al., 1978: Correlation tables, first working version. IG CP 25. Manuscript, Geol. ústav SAV, Bratislava.
VAN HINTE, J. E., 1978: A Cretaceous Time Scale. In: Contributions to the geologic time scale. (Edit. G. V. Cohee et al.). Studies in Geology 6. Amer. Assoc. Petrol. Geologists Bull. (Tulsa), pp. 269—287.
VASS, D. — BAGDASARJAN, G. P., 1978: A radiometric time-scale for Neogene in the Paratethys region. In: Contribution to the Geologic Time Scale. (Edit. Cohee G. V. et al.). Studies in Geology 6. Amer. Assoc. Petrol. Geologists Bull. (Tulsa), pp. 179—203.
VASS, D. — KONEČNÝ, V. — ŠEFARA, J. et al., 1979: Geologická stavba Ipeľskej kotliny a Krupinskej planiny. Geol. ústav D. Štúra, Bratislava. 280 pp.
VASS, D., 1981: Alpínske molasy Západných Karpát. Doktorská dizertačná práca. Manuskript. Archív Geol. ústav D. Štúra, Bratislava.

Review by J. SENEŠ Manuscript received July 16, 1982