GEOLOGICKÝ ZBORNÍK — GEOLOGICA CARPATHICA, 39, 1, BRATISLAVA, FEBRUARY 1988, Pp. 99—108

MIROSLAV BIELIK*

ANALYSIS OF THE STRIPPED GRAVITY MAP OF THE PANNONIAN BASIN

(Figs. 2)

Abstract: The stripped gravity map of the Pannonian Basin was constructed to obtain a better understanding of the anomalous gravity effects of the pre-Tertiary basement of this region. The paper deals with brief characterize of the gravity field of this map and geological and geophysical interpretation of the source of the most important gravity anomalies. The image of the gravity field of the stripped map of the Pannonian Basin can be divided into two mainly parts: the north--western one and south-eastern one. The significant vertical and/or deep density boundaries (linear zones of disturbed character of gravity field) observable mainly in the NE-SW to ENE-WSW, NW-SE and N-S directions were specified.

Резюме: Для более глубокого понимания аномального еффекта гравитационного поля дотретичного фундамента паннонского бассейна была построена открытая карта силы тяжести этой области. Представлена краткая характеристика поля силы тяжести и геологическо-геофизическая интерпретация причин основных аномалии поля силы тяжести. Характер поля открытой карты силы тяжести можно в принципе разделить на две главные части: северозападную и юго-восточную. Выделены также и выразительные вертикальные и наклонные границы плотностных контрастов (зоны линейных возмущений поля силы тяжести), проявляющихся главным бразом, в направлениях СВ-ЮЗ вплоть до ВСВ-ЗЮЗ, СЗ-ЮВ и С-Ю.

Introduction

In general, a stripped gravity map represents Bouguer's anomalies corrected by the gravity effect of near-surface inhomogeneities, i.e. it shows the effects of anomalous masses located deeper.

The construction of the stripped gravity map of the Pannoniam Basin (the procedure is elaborated in detail in the paper by Bielik, 1986) was stimulated by the fact its basement is almost completely covered with Tertiary sediments the thickness of which reaches even 7,000 m in certain places. The map of Bouguer's anomalies was corrected by the gravity effect of Tertiary sedimentary-volcanic complexes. In the region of the Vienna Basin only by the Neogene sediments because its basement is made of the Inner as well as Outer Carpathians. The relative density according to which the differential densities were computed was 2.67 Mgm^{-3}. The scheme of the result stripped gravity map of the Pannonian Basin is shown in Fig. 1. The Yugoslav part is not incorporated into this map because no sufficient quality and quantity gravimetric data were available from this part of the Pannonian Basin. However, the gravity effect of the sedimentary filling was computed from the whole territory of the Pannonian Basin (Bielik, l. c.).

* RNDr. M. Bielik, Institute of Geophysics of the Centre of Geoscience Research, Slovak Academy of Sciences, Dúbravská cesta 9, 842 28 Bratislava.

It is only natural that the construction of the stripped gravity map required rather extensive work. The degree of knowledge of the structures and density conditions of the Tertiary is substantially different in various parts, and consequently, this means the final map has a different accuracy degree in various zones. Despite all this we are convinced the stripped map of the gravity field of the Pannonian Basin will be a contribution to the research of the structure and development of this important Inner Carpathian region. The knowledge gained from the analysis of the gravity field of the stripped map supplements and enriches the results of the geologic and geophysical interpretations of the Pannonian Basin published in the papers of Stegena (1964), Renner—Stegena (1965), Stegena—Géczy—Horváth (1975), Boccaletti et al. (1976), Maheľ (1978), Ibrmajer (1978), Sclater et al. (1980), Horváth—Royden (1981), Balla (1982, 1984), Čech (1982), Royden—Horváth—Rumpler (1983), Pospíšil—Vass (1983), Meskó (1983), Horváth (1984), Nikolayev (1984), Stegena—Horváth (1984), Čech—Zeman (1985), Fülöp et al. (1968) and many others.

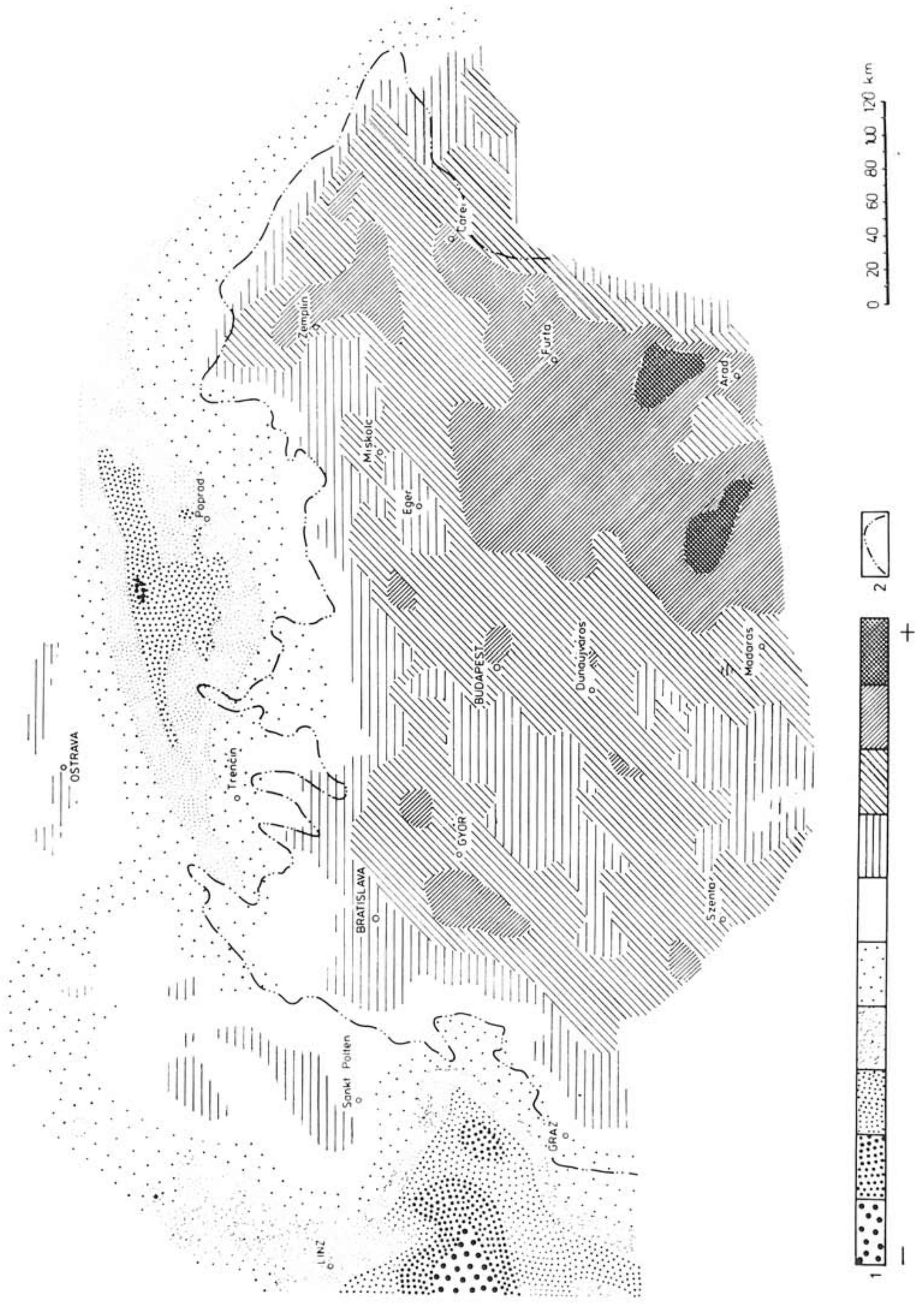
Anomalous gravity zones

The obtained results are summarized into the scheme of basic structures of the gravity field of the Pannonian Basin and its vicinity (Fig. 2).

The whole area of the Pannonian Basin is characterized by a significant gravity field. Its values are within the range of 0 to 1,000 μms^{-2}. The maximum is achieved roughly at the boundary among Hungary, Roumania and Yugoslavia. North to it the so called West Carpathians minimum (reaching even —600 μms^{-2}) and westwards the zone of negative anomalies (to —900 μms^{-2}) lie. A belt of rather insignificant positive anomalies (+250 μms^{-2}) stretching from Sankt Pölten to Ostrava is wedged between them. All zones are mutually separated by zero isoanomalies.

The image of the gravity field of the stripped map of the Pannonian Basin can be divided into two parts from the regional point of view: the north-western one and south-eastern one. The north-western one spreads north-westwards from the Central Hungarian line (defined according to Brezsnyánszky and Haas, 1986) and reaches the fringe of the Eastern Alps and West Carpathians. Its north-eastern end is in the area of the Slánske vrchy Mts. The gravity mean values are substantially lower compared to the south-eastern part. The south-earstern part lies to the south-east from the mentioned Central Hungarian line. In the east it is demarcated with the East Carpathians and Apusens. Besides the anomalies in the directions of NE-SW and ENE-WSW anomalies with their axes oriented NW-SE and N-S can be observed there.

Fig. 1. Scheme of the stripped gravity map of the Pannonian Basin.
Explanations: 2 — boundary between the stripped gravity map and Bouguer's anomalies.


OSTRAVA
Trenčin
Poprad
Zemplin
Carei
Furta
Arad
Miskolc
Eger
BUDAPEST
Dunaujvaros
Madaras
GYOR
BRATISLAVA
Szenta
Sankt Polten
GRAZ
LINZ
0 20 40 60 80 100 120 km
1
2
+
−

With respect to the gravity character further partial (local) anomalous zones can be specified in both of them. In general they are characterized by relatively positive or negative values of the gravity field. The notions relative positive (negative) values of the gravity field designate such values that are higher (lower) than the mean value of gravity in the area of the Pannonian Basin. This value is approx. 500 μms^{-2}. Their probable cause will be explained later.

The north-western part

Two relatively positive and two relatively negative anomalous zones appear as two separate local areas of the gravity field of the north-western part:

The first — relatively positive — one extends roughly on the territory of the Danubian Basin and Kisalföld Lowland. It may be demarcated with the contour line running approximately over Körmend—Györ—Pukanec—Trenčín—Bratislava. The anomaly direction is NE-SW and the amplitude of the gravity field achieves the values of approx. 700 μms^{-2}.

The other — relatively negative — one is again oriented NE-SW. Its location is in a good compliance with the mountain ranges of Bakony, Vertés, Gerecse, Pilis, Borzsóny. The gravity values are within the interval of approx. 250—450 μms^{-2}.

The third — relative gravity depression — one spreads approximately in the territory demarcated by Gyöngysö, Tokaj, Zemplín and Šafárikovo. Two minimums may be specified in it. The first one lies in the zone of Eger, the second one 10 km from Zemplín, i.e. in the places neovolcanites emerge to the surface in the Bük and Mátra, Zempléni-Hegység Mountains respectively. Both are separated with a positive gravity saddle probably caused by thicker Middle to Upper Triassic shallow water carbonate formations in the zone of Bük.

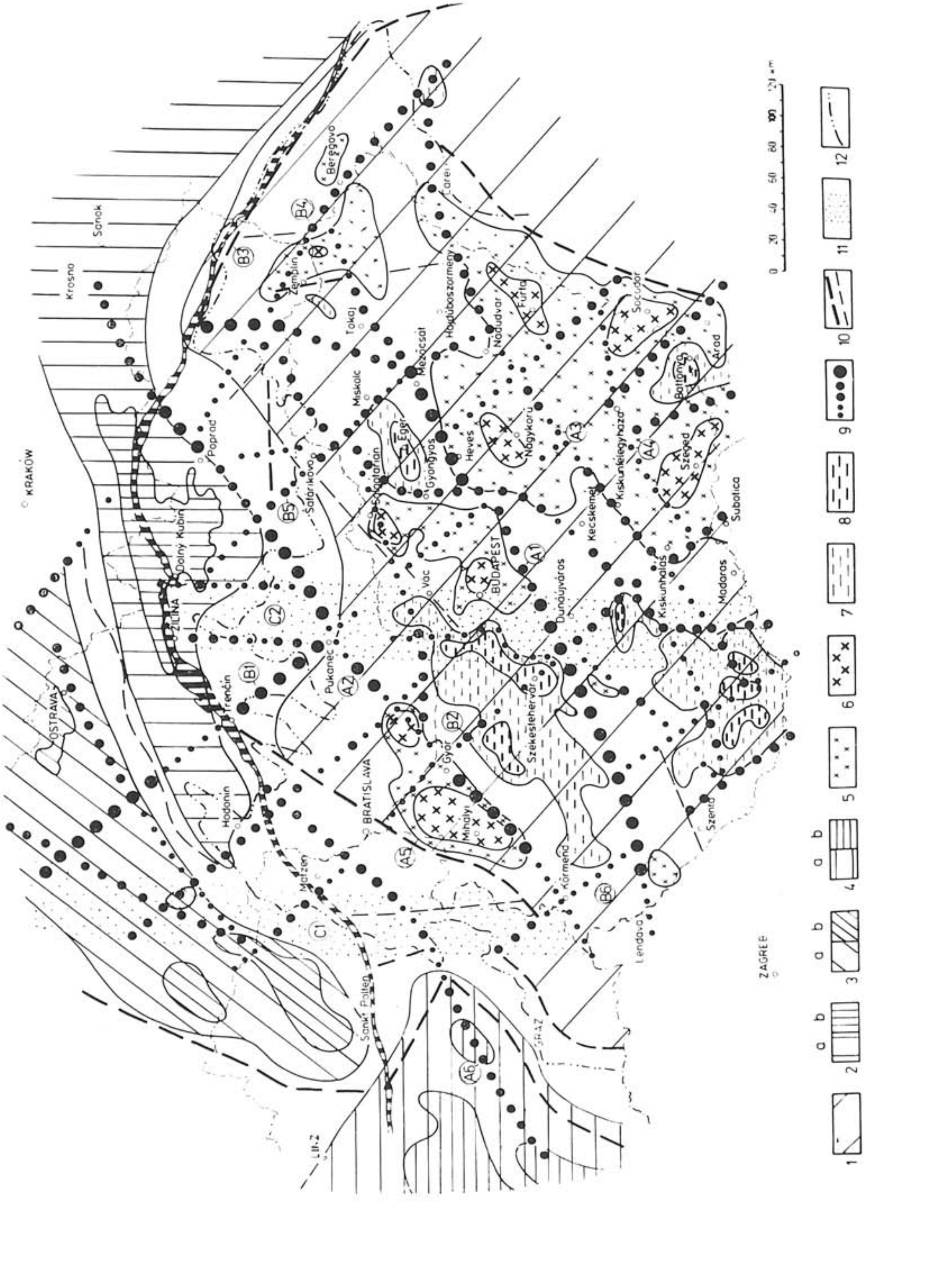
The fourth — rather insignificant gravity elevation — one with two maximums achieving more than 600 μms^{-2}. Demarcated roughly with the isoanomaly 550 μms^{-2}.

The south-eastern part

Three local zones are distinguished in it. The first one is made of the relative depression of the gravity field (200—500 μms^{-2}) spreading over the area among the communities of Madaras, Kecskemét, Dunaujváros and Szenta.

Fig. 2. A scheme of essential structures of stripped gravity map of the Pannonian Basin.

Explanations: 1 — gravity elevation of the Pannonian Basin; 2 — West Carpathian gravity low; 3 — positive anomalies of the south-eastern part of Bohemian Massif; 4 — gravity depression of the Eastern Alps; 5 — relative elevations of the gravity field in the Pannonian Basin; 6 — maximums of the relative elevations of the gravity field in the Pannonian Basin; 7 — relative depression of the gravity field in the Pannonian Basin; 8 — minimums of the relative depression of the gravity field in the Pannonian basin; 9 — density boundaries; 10 — zones of maximum gravity gradients; 11 — zones where the character of anomalous field is disturbed; 12 — boundary between the stripped gravity map and Bouguer's anomalies.


KRAKÓW
OSTRAVA
Krosno
Sanok
Poprad
Dolny Kubin
ZILINA
Trenčin
Hodonin
BRATISLAVA
BUDAPEST
Miskolc
Tokaj
Eger
Gyöngyös
Heves
Nagykörü
Kecskemét
Dunaújváros
Székesfehérvár
Győr
Mihályi
Körmend
Szeged
Subotica
Kiskunhalas
Madaras
Arad
Battonya
Lendava
ZAGREB
Vác
Pukanec
Beregovo
Zemplín
Mezőcsát
Nádudvar
Furta
Kiskunfélegyháza
Szentó
GRAZ
LINZ
Sankt Pölten
A1
A2
A3
A4
A5
A6
B1
B2
B3
B4
B5
B6
C1
C2
1
2
3
4
5
6
7
8
9
10
11
12

Its centre is approximately between the Mecsek and Villány Mts. and the axis has an approximately N-S direction from the Yugoslav—Hungarian border. However, it should be noted the isoanomalies turn into NE-SW to W-E direction in the northern fringe of the zone.

The second zone is the most significant and typical anomalous zone covering the largest area in the specified eastern part of the gravity field. Besides this it represents the "most intensive" gravity elevation in the territory of the whole Pannonian Basin. An evidence of this are the gravity values achieving almost 1,000 μms^{-2}. Its major part extends in the southern part of Hungary reaching also the territory of Roumania and Yugoslavia. It may be divided into two sub-parts: the northern and southern ones. In the northern one the anomalies have an exclusively NE-SW (and/or ENE-WSW) direction while in the southern one it is NW-SE.

The third — relatively positive anomalous zone — covers the territory of the Transcarpathians Depression. The direction of the anomalous zone is NW-SE. Two separate maximums can be distinguished. The first one (700 μms^{-2}) is at the border of the ČSSR and Hungary. The other one (having a smaller area) can be observed north to Beregov. Its amplitude is 650 μms^{-2}.

Linear fault zones of the gravity field

According to Plančár et al. (1977) the linear fault zones of the gravity field represent vertical and/or skew density boundary in different depths. They are manifested either by the zones of maximum gradients or the zones of disturbed character of field. The boundaries may characterize fault systems as well as neotectonic joints of various geologic formations with different density or geologic structure.

In the studied zone of the Pannonian Basin and its wider vicinity linear fault zones observable mainly in the NE-SW to ENE-WSW direction (designated with the letters (A), NW-SE (B) and N-S (C) in the work) were specified. The manifestation of density boundaries in various other directions is not so significant and frequent.

Fault zones in the NE-SW and ENE-WSW direction

The Al linear fault zone forms a significant density boundary between the NW and SE part of the Pannonian Basin. It extends approximately from Lendava along the southern fringe of the Balaton Lake towards Mezöcsát and it is in a very good compliance with course of the line designated as the Central Hungarian Structure Zone by Brezsnyánszky and Haas (1986). Its eventual continuation in the NE direction from Mezöcsát is not clear for it is shielded by a significant gravity elevation extending from the territory of the East Slovakian Lowland.

A significant A2 density boundary runs across Hungary, Czechoslovakia and Poland. In the territory of Hungary it may be observed along the Rába river, in Czechoslovakia it extends over Kolárovo, Pukanec, Poprad and continues over the villages of Krosno and Sanok in Poland. In the territory of Hungary it runs in the territory of the Rába fault line. In the ČSSR it may be observed in the territory interpreted by Fusán—Ibrmajer—Plančár (1979) as the Vepor deep-seated fault. The manifestation of this zone is made more complex due to the presence of the Kolárovo gravity anomaly in the Danubian Lowland.

In the south-eastern part of the Pannonian Basin the A3 zone turning gradually in the W-E direction in its northern part can be observed. The A4 linear fault parallel with it is probably the reflection of the Békés fault line.

The north-western fringe of the basin is demarcated by a significant zone of the maximum gradient (A5). In the zone of Trenčín it joins the klippen zone. In the south-western direction it continues to the Dinaride zone. To the north--west of it another A6 linear zone manifested by a significant damage of field character extends.

Linear fault zones in the NW-SE direction

When analyzing the density boudaries of the given direction by means of the stripped gravity map their manifestation was more significant compared to the map of Bouguer's anomalies.

The B1 and B2 zones run across the whole territory. i.e. they can be observed not only in the Pannonian Basin zone but also in the West Carpathians with a continuation to the Bohemian Massif. The B1 failure manifestation is observable very well in the area demarcated with the Štiavnica—Přerov deep--seated fault and its most southern part where it forms a significant density boundary between the gravity elevation at Socodor and the depression with a center at the village of Battonya. Its effect is even more hidden approximately between the A1 and A2 transverse fault lines. The B2 zone extending at the connecting line roughly from Matzen along the Danube through Székesfehérvár to Subotica is observable very well.

The B3 zone is accompanied with the significant maximum gradient of a substantial width. Its axis extends approximately in the area the klippen zone. It forms the NE boundary of the Pannonian Basin. The B4 zone runs in parallel with it. In the zone of the East Slovakian Lowland its manifestation is superimposed with a significant gravity elevation.

Other two linear elements of the field of the NW-SE direction run through Miskolc (B5) and Körmend (B6).

Linear fault zone of the N-S

This direction of fault zones in the stripped gravity map is made of wide belts (up to 50 km) of field character damage. The first of them (C1) runs from the eastern part of the Bohemian Massif to the Vienna Basin and continues along the joint of the Pannonian Basin with the Eastern Alps further to the south up to the Körmend area.

The second one (C) extends from the klippen zone between Žilina and Dolný Kubín to Hungary and probably continues further to Yugoslavia. Its manifestation is more significant in the area of the Pannonian Basin than in the West Carpathians. Its existence is probably the cause of the Danube stream direction change not only at Vác but also in the territory of Hungary and the northern part of Yugoslavia.

The linear element of the N-S direction is also visible in the section of surface emergence of neovolcanites of the Slánske vrchy Mts. In the area of the eastern fringe of Zempléni-Hegysék neovolcanites it has already a SWS-NEN direction and farther it links to the Al line. The specified density boundary is in a very good coincidence with the course of the Slánsky deep-seated fault (Fusán—Ibrmajer—Plančár, 1979).

Generalizing knowledge

Some generally valid knowledge can be derived from the analysis of the stripped gravity field map of the Pannonian Basin and other geophysical and geologic data:

— The gravity effects of the sedimentary filling reaches even some —500 μms^{-2} in some zones.

— The whole territory of the Pannonian Basin represents a significant gravity elevation. Its values reach almost 1,000 μms^{-1}, this being a substantial difference compared to the Bouguer's anomalies map. The explanation should be sought after in the deep seated structure of the Pannonian Basin. Probably, it is a manifestation of crust high density masses and the upper mantle the presence of which is at substantially lower depths than in the surrounding mountain belts ranges. Their smallest depth is assumed in the SE part of the Pannonian Basin.

— The effect of the deep-seated structure on the gravity field of the stripped map is dominant compared to the effect of the direct structure of the pre--Terciary basement.

— The values of the gravity field drop in the direction towards the mountain belts of the Eastern Alps, West and East Carpathians and this is probably caused by a gradual immersing of heavy masses deeper. This subsidence and/or the section of the greatest inclination of the immergence of these masses is accompanied by a substantial horizontal density gradient as far as the size and width are concerned. The surrounding mountain belts are, on the contrary, characterized by negative anomalies of the gravity field which are believed to be the reflection of the upbuilding of the masses of earth crust upper part due to their nappe structure.

— The knowledge the gravity field of the Pannonian Basin can be divided into two main parts is in a very good compliance with the latest geologic results published in the work of Breznyánszky—Haas (1986).

— In the north-western and south-eastern part several local relatively positive and negative anomalous zones can be observed as already mentioned. The source of the positive zones is probably the presence of masses with higher densities (basic? ultrabasic? rocks) in the pre-Terciary basement. On the other hand, the cause of the relatively negative anomalous zones are the rocks with lower density compared to the assumed basic or ultrabasic rocks. Out of these especially the granitoide and crystalline schist complexes should be mentioned. However, Mesozoic complexes rank here, too.

— A valuable finding is the observation the largest partial depressions (as far as the depth and range are concerned) of the pre-Terciary basement of the Pannonian Basin are characterized by maximum values of the gravity field. The zones of Danubian and Kisalföld Lowlands, Transcarpathian Depression and the Great Hungarian Lowland are concerned. The Vienna Basin makes a certain exception. This is one of the reasons for the question whether it is a part of the Pannonian Basin. The presence of high density rocks with their apical components in the basement of these depression is an evidence of a probably significant effect of high density masses on their formation.

— The most important density boundaries in the studied zone are especially in the NE-SW, NW-SE and N-S directions. Compared to the map of Bouguer's anomalies especially the two last directions are better observable. Boundaries characterize mainly the fault systems. It is believed the faults of these three main directions were playing the main role in the formation of the Pannonian Basin as a significant intra-mountaineous geotectonic structure.

Conclusion

At present the gravimetric study of the Pannonian Basin is continuing. A stripped gravity map of the whole territory is being finished. The result of this is the analysis of the gravity field will be gradually supplemented and precised.

REFERENCES

BALLA, Z., 1982: Development of the Pannonian basement through the Cretaceous—Cenozoic collision: A new synthesis. Tectonophysics (Amsterdam), 88, pp. 61—102.

BALLA, Z., 1984: The Carpathian loop and the Pannonian Basin: A kinematic analysis. Geophysical Transactions (Budapest), 30, 4, pp. 313—353.

BIELIK, M., 1986: Konštrukcia odkrytej tiažovej mapy panónskeho bazénu. Contributions of the Geophysical Institute SAS (Bratislava), 18. In print.

BOCCALETTI, M. et al., 1976: The Tyrrhenian and Pannonian basins: A comparison of two mediterranean interarc basins. Tectonophysics (Amsterdam), 35, pp. 45—69.

BREZSNYÁNSZKY, K. — HAAS, J., 1986: Main features of the pre-Tertiary basement of Hungary. Geol. Zbor. Geol. carpath. (Bratislava), 37, 3, pp. 297—303.

ČECH, F., 1982: Ložiská palív — vzťah k hlbinnej stavbe panónskej panvy a karpatského oblúka. Geol. Inst. D. Štúr, Bratislava, 146 pp.

ČECH, F. — ZEMAN, J., 1985: Genéza a dynamika medzihorských panví v alpínskej mobilnej Európe. Zbor. geol. Vied, Západ. Karpaty (Bratislava), 10, pp. 197—210.

FUSÁN, O. — IBRMAJER, J. — PLANČÁR, J., 1979: Neotectonics blocks of the West Carpathians. In: Geodynamic investigations in Czechoslovakia. VEDA, publ. SAV, Bratislava, pp. 187—192.

FÜLÖP, J. et al.: Precenozoic basement map of Hungary. 1 : 500 000. Edition of the Hungarian Geol. Inst. Budapest. In print.

HORVÁTH, F., 1984: Neotectonics of the Pannonian basin and the surrouding mountain belts. Alps, Carpathians and Dinarides. Annales Geophysical (Gauthier-Villars), 2, 2, pp. 147—154.

HORVÁTH, F. — ROYDEN, L., 1981: Mechanism for the formation of the intra-Carpathian basins. A review. Earth Evol. Sci., 1, 3—4, pp. 307—316.

IBRMAJER, J., 1978: Tíhové mapy ČSSR a jejich geologická interpretace. Ph. D. Thesis. Archive of the Faculty of Natur. Sci. of Charles Univ., Prague, 240 pp.

MAHEĽ, M., 1978: Geotectonics position of magmatites in the Carpathians, Balkan and Dinarides. Zbor. geol. Vied, Západ. Karpaty (Bratislava), 4, 173 pp.

MESKÓ, A., 1983: Regional Bouguer gravity maps of Hungary. Acta Geodaet. Geophys. et Montanist. Hung. (Budapest), 18, 1—2, pp. 187—200.

NIKOLAYEV, V. G., 1984: Sootnošenije neovulkanitov s glubinymi razlomami v pannonskom basejne. In: Blokovoje strojenije i razlomy geosynklinaľnych oblastej. Izd. Bolg. akad. nauk (Sofija), pp. 23—34.
PLANČÁR, J. et al., 1977: Geofyzikálna a geologická interpretácia tiažových a magnetických anomálií v Slovenskom rudohorí. Zbor. geol. Vied, Záp. Karpaty (Bratislava), 2, pp. 7—144.
POSPÍŠIL, L. — VASS, D., 1983: Vplyv stavby litosféry na vznik a vývoj vnútrohorských a tylových molasových panví Karpát. Geol. Práce, Spr. (Bratislava), 79, pp. 169—184.
RENNER, J. — STEGENA, L., 1965: Gravity research of the deep structure of Hungary. Ann. Univ. Sci. (Budapest), 8, pp. 153—159.
ROYDEN, L. — HORVÁTH, F. — RUMPLER, J., 1983: Evolution of the Pannonian Basin system 1. Tectonics, 2, 1, pp. 63—90.
SCLATER, J. G. et al., 1980: The formation of the intra-Carpathian basins as determined from subsidence data. Earth Planet. Sci. Lett. (Amsterdam), 51, pp. 139—162.
STEGENA, L., 1964: The structure of the Earth's crust in Hungary. Acta geol. Acad. Sci. hung. (Budapest), VIII, pp. 413—431.
STEGENA, L. GECZY, B. — HORVÁTH, F., 1975: Late Cenozoic evolution of the Pannonian Basin. Tectonophysics (Amsterdam), 26, pp. 71—90.
STEGENA, L. — HORVÁTH, F., 1984: Review of the Pannonian Basin. Acta Geodaet. Geophys. et Montanist. Hung. (Budapest), 19, 1—2, pp. 153—160.

Manuscript received August 17, 1987.