ROTATION ALONG TRANSVERSE TRANSFORMING ORAVA STRIKE-SLIP FAULT IN THE LIGHT OF GEOMORPHOLOGICAL, GEOPHYSICAL AND PALEOMAGNETIC DATA (WESTERN CARPATHIANS)

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Abstract: Morphostructure pattern suggests rotation of Orava Block along Orava transforming transversal fault. The shortening of the Western Carpathians during their shift to the north on N-S direction is well know, but the press in between Bohemian Massifs and Ukrainian Shield caused also substantial shortening on W-E direction. The crucial role for such tectonic processes was played by transversal Orava fault and Orava Block rotation. Paleomagnetic preliminary results and geophysical data seem to confirm such hypothesis.

Key words: horizontal rotation, paleomagnetism, gravimetric anomalies, magnetotelluric profil, Neogene Orava Basin, Tatra Mts

Orava transverse fault seems to be very important tectonic zone of the Western Carpathians. It is rather young fault transforming main morphostructures from western side Velka Fatra, Cho◊, Skoru✶ina Inner Flysch syncline, Orava Basin and Babia Góra range (Magura Outer Flysch) and from east Nizke Tatry, Liptov Basin, Tatra Mts, Podhale Inner Flysch syncline and Gorce Mts (Magura Flysch)(fig. 1). In result of this activity Orava Basin have got pull-apart formation. The opening of Orava Basin started ca 14 Ma ago (Baumgart-Kotarba 2001). The uplift from 5 km depth of Tatra Mts is very young, 10-15 Ma according fission track methods in comparison to Nizke Tatry 52,9 Ma (Burchart 1972, Kova◊ et all. 1994). It was also a period of thrusting and pushed to north sub-Silesian, Silesian, fore-Magura and Magura tectonic units on foredeep marine sediments Middle Badenian in age documented in Zawoja borehole (Oszczypko 1997).Such activity seems to be prolonged to Quaternary, because the NE part of Orava Basin along the Domański Wierch fault is infill with 110-128 m. of fluvial/fluvioglacial sediments laying directly on Magura units,without Neogene deposits (Baumgart-Kotarba, Dec, Ślusarczyk 2001).The aim of this short paper is to prove a rotation of so-called Orava Block (Baumgart-Kotarba 1992, 2001) along central part of this long transversal fault crossing West Carpathian from the Pliocene volcanic system (Polana) on the south to Mszana tectonic window on the north. The rotational features have the following location

- fault extended from Kralovany to Ru□omberok (Vah gorge)
- arch shaped fault bordering from south Cho◈ Mts, (Prosiek fault)
- fault bordering Tatra Mts from west passing through Oravice village and crossing Inner Flysch between Skoru✶ina and Podhale regions,
- fault zone of Domański Wierch (uplifted Pliocene molasse), near Ludźmierz village changing direction from 45^{o} NE to NNE along Lepietnica valley (Magura Outer Flysch). Also the area on the east side of Lepietnica fault is more uplifted (Gorce Mts)

Probably rotated Orava Block from the east is limited by fault zone of Skawa Valley (Figs.3 and 4).

Morphostructural and geological data

Looking on geological maps the characteristic pattern of Klippen Belt morphostructure (Zazriva-Parnica sigmoid), double structure of Magura Oravska ranges and fault within Skoru✶ina flysch in contact with Cho◈ Mesozoic rock near Kubin could be interpreted as pattern related with shortening of tectonic units in the zone of hinge due to compression made between rotated to NW Orava block and stopped Mala Fatra block (Geological Map 1:200 000, ed. M. Mahel 1962). Sigmoid shape is also discernible on the shape of Cho◈ Mts in its SW part along Wag gorge from Kralovany to Ru□omberok and along S fault of Cho◈.Even the shape of the front of tectonic Krynica unit (Mk) within Magura unit reflects this rotation of Orava block to NW. On the boundary between Magura and Silesian nappe the shape of Żywiec tectonic window and course (shape) of isoline 1,5 km of depth to crystalline basement (Geophysical Map of the Western Outer Carpathians 1:500 000, Geological Atlas 1987) seem to be influenced by the same rotation. The front of Magura nappe changes his course from NE to NEE direction near Żywiec and follows this direction up to Skawa valley fault line.

Quaternary activity of the Orava fault is evidenced not only by the young infill of NE part of Orava depression but also by system of faults crossing Pliocene sediments of Domański Wierch hill. There are flower structures significant for strike-slip motions (Baumgart-Kotarba, Dec, Ślusarczyk 2001). The present day earthquakes (Baumgart-Kotarba 2001) manifest tectonic activity also.

Paleomagnetic data

The first results of paleomagnetic study (E.M·rton, G.Imre) seem to confirm the activity of Orava fault during Sarmatian and Pliocene time. At Miętustwo village in

2001 were sampled Sarmatian (Birkenmajer 1978) fluvial sediments gentle sloping to the north. The results of mean paleomagnetic direction Dc =28^o and Ic = 53 indicate clockwise rotation on the east of Orava transforming fault during last 10 Ma. It is interesting that Grabowski (2000) paleomagnetic results from Triassic and Jurassic strata from the Tatra Mts indicate also clockwise rotation.

The second new samples were collected near Lipnica 20 km on the west of Orava fault from young fluvial sediments. According to palynological analysis carried by prof. L.Stuchlik (Institute of Botany, Pol. Acad. of Sci., grant No 6PO4E02008, Committee for Sci. Res.) this sediments are Pliocene/Quaternary in age (2.5–2 Ma). The new results from Lipnica sediments indicate counterclockwise rotation (Dc=344^o, Ic= 64^o). This is preliminary result, but seems indicate the rotation of Orava block ca 16^o to NW. Rotation with counterclockwise direction started earlier in Vah Block on Eggenburgian (42^o) and Karpatian (37^o) marine deposits of piggy-back basins (Kova◊ et al.1989). This was interpreted as stopping role of rigid Bohemian Massif during general shift of Carpathian to the north (Kova◊ et all. 1989, Baumgart-Kotarba 1996)

The results from the Tatra Mts (Grabowski 2000): Dc : 23^o , 34^o (Bobrowiec – NW Tatra Mts) and 40^o(Havran – NE Tatra Mts) seems to be in opposition to the results publicised from Paleogene Inner Flysch of Podhale and Levo Basins by M·rton et all. (1999). The mean direction from 6 localities from Podhale is Dc=298^{0,} Ic= 53^0 (Fig.1) The data from Levo Basin and Podhale are in good agreement. The preliminary opinion is that the clockwise directions obtained by Grabowski (2000) from the Tatra Mts are comparable with young rotation documented in Miętustwo. The explication of such coincidence is not easy. But it is possible that young uplift of Tatra massif was related with some horizontal clockwise rotation and this uplift was related with whole shift of Tatra Block, together with Magura Flysch in compressional regime and with Neogene deposits in Nowy Sącz basin.

Interpretation of geophysical data

Two kinds of geophysical measurements are considered in the paper. First are results of magnetotelluric sounding (MTS) along profile “Chyżne-Spytkowice” (Królikowski et all, 2000). Five parts in electrical cross-section obtained from those data can be distinguished. Coming from the north, the first 15 km (Fig.2), is not disturbed in deep structure by Carpathian movements and represents a style of foredeep. In the second part (II) to Sucha borehole, low resistivity masses are push into space between top high resistivity basement and also high resistivity 55 km deep layer. In third part (III), between Sucha borehole and Babia Gora foreland all structural elements in the upper part of cross-section are dipping intensively to south, and further 15 km to the south, there is break in continuity of all upper layers in fourth part of profile (Fig.2, IV). Low resistivity masses filled all cross-sections. Finally, at the south end of profile high resistivity block appears again (part V). Close to Chyżne village the top of crystalline block is sloping to the south.

It seems, that rigidity of masses can influence a resistance of rock masses against their rotation. From this point of view the border between part III and IV in MTS profile is also a border between rigid and soft masses. The second important boundary concerning the deep structure is the boundary between part I and II (Fig. 2).

Results of other geophysical measurements, two gravitational maps, were used for location of this border in area of investigations. One of them (Fig.3) was the original gravitational map and second was result of its transformation. The intensive trend in gravity field, its decrease in south direction caused, that structure of field can't be recognised properly. Second map (Fig. 4) is result of elimination of trend by subtracting from each gravity value in grid constructed along S-N and W-E direction the mean value calculated along W-E lines. The structure of map can be divided into three parts. The north part of maps consists intensive anomalies, showing directions NW-SE, which are characteristic for stresses in Bohemian Massif. The south part consists anomalies oriented in W-E directions (Tatra direction). The middle part, having in the Fig.4 rather low differentiation in gravity data, can be correlated with the III and IV parts in the MTS profile. That correlation allows us to construct a potential border of rotated masses on the distance of 10 km to NE sub- parallel to the Skawa valley as it is shown in Fig.4. Another interesting line cross Outer Carpathians on prolongation of the Orava rotational fault to north from east side of Mszana tectonic window to Kraków. Near Kraków this line divides from the west the system of horst and graben, so called Brama Krakowska unit and from the east Sandomierz fore-Carpathian Depression.

Final remark

The Orava transversal transforming fault probably is related to very deep geological structures. According to magnetotelluric profile (Fig.2) this rotation could be stimulated by structures which are deeper than 60 km. The value of shortening in W - E direction can be evaluated as twice (100 km to 50 km). The lenght of rotational fault from Kralovany to Mszana tectonic window is ca 100 km and the width of Magura unit between Żywiec tectonic window and hypothetical east limit of rotation close to Sucha village is 50 km.

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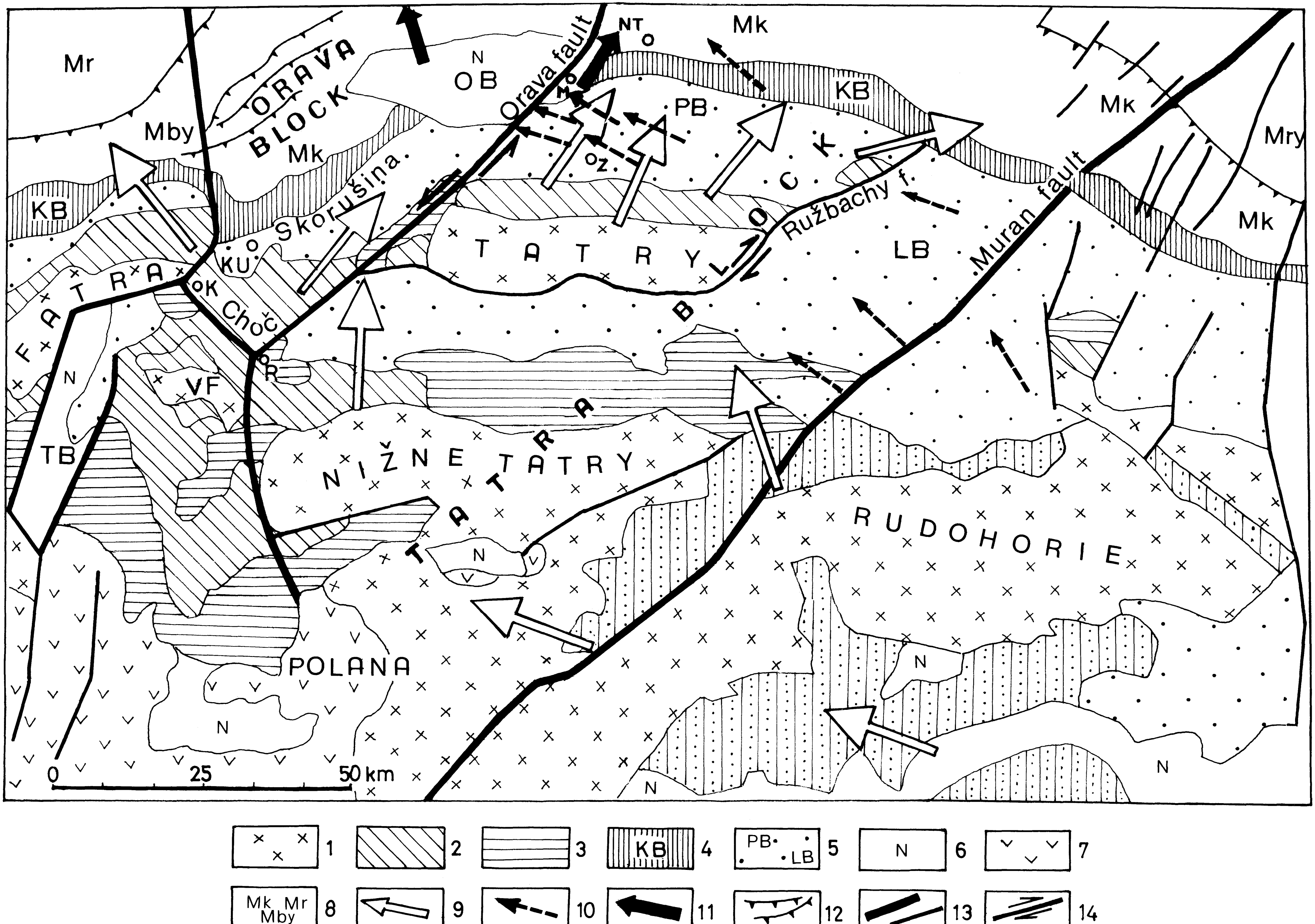
Fig.1. Paleomagnetic directions on the structural map of Western Carpathians according to Grabowski (2000)-(9) and Marton et all.(1999)-(10) with new paleomagnetic data from Neogene sediments evidenced opposite rotations (11) along Orava fault.1 – crystalline rock, 2 – Kri na unit, 3 - Cho◊ unit, 4 –Klippen Belt, 5 – Podhale and Levo Inner Flysch, 6 – Neogene sedimentary infill, 7 – Neogene volcanics, 8 – Magura Outer Flysch (Mk –Krynica unit, Mr - Ra a unit, Mby-Bystrzyca unit), paleomagnetic direction: 9- according to Grabowski (2000), 10 – according to Marton et all.(1999), 11 – samples collected in 2001 by authors, 12 - front of thrust, 13 – important faults, 14 – strike-slip Orava and Ru bachy faults.

Fig. 2. Magnetotelluric profile Chyżne-Spytkowice (location on fig. 4) according to Królikowski et all. (2000). Resistivity in Ωm.

Fig. 3. Gravitational map (Bouger's anomalies) based on data from Polish State Geological Institute (1984/85). 1 – important fault, 2 – secondary fault, 3 – front of thrusts, M – Magura unit, Mk – Krynica unit, S – Silesian + Subsilesian + Skole units, 4 – axis of gravitation minimum (mg), 5 – Klippen Belt, 6 – Orava-Nowy Targ Basin, 7 – rotational Orava fault, 8 – magnetotelluric profile Chyżne-Spytkowice (I-V parts). All structural features according to Geological Atlas of the Western Outer Carpathians (1988-89)

Fig. 4. Transformed gravitational map. BG – Babia Góra summit, ŻW – Żywiec tectonic window, MW – Mszana tectonic window, P.FL – Podhale flysch.



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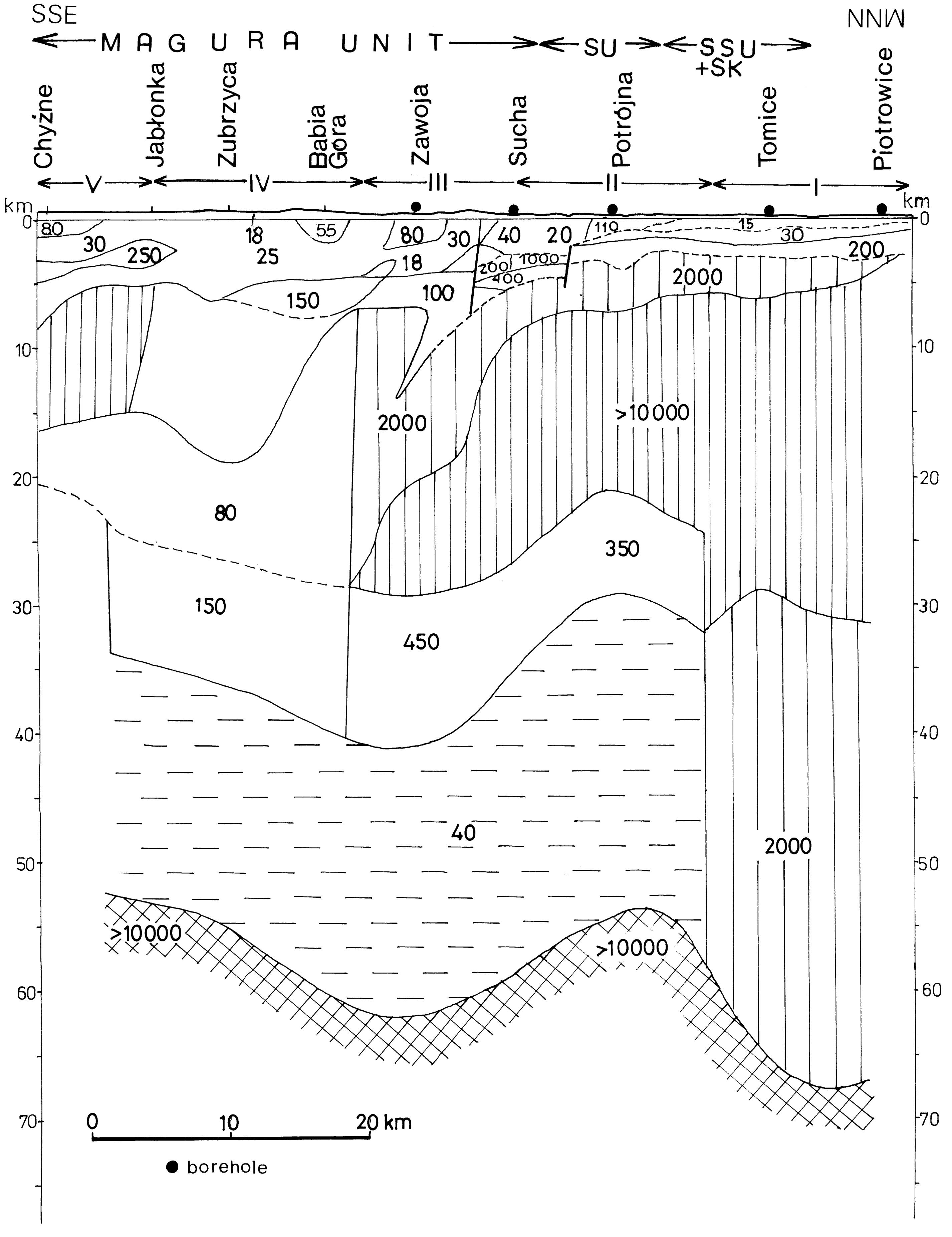

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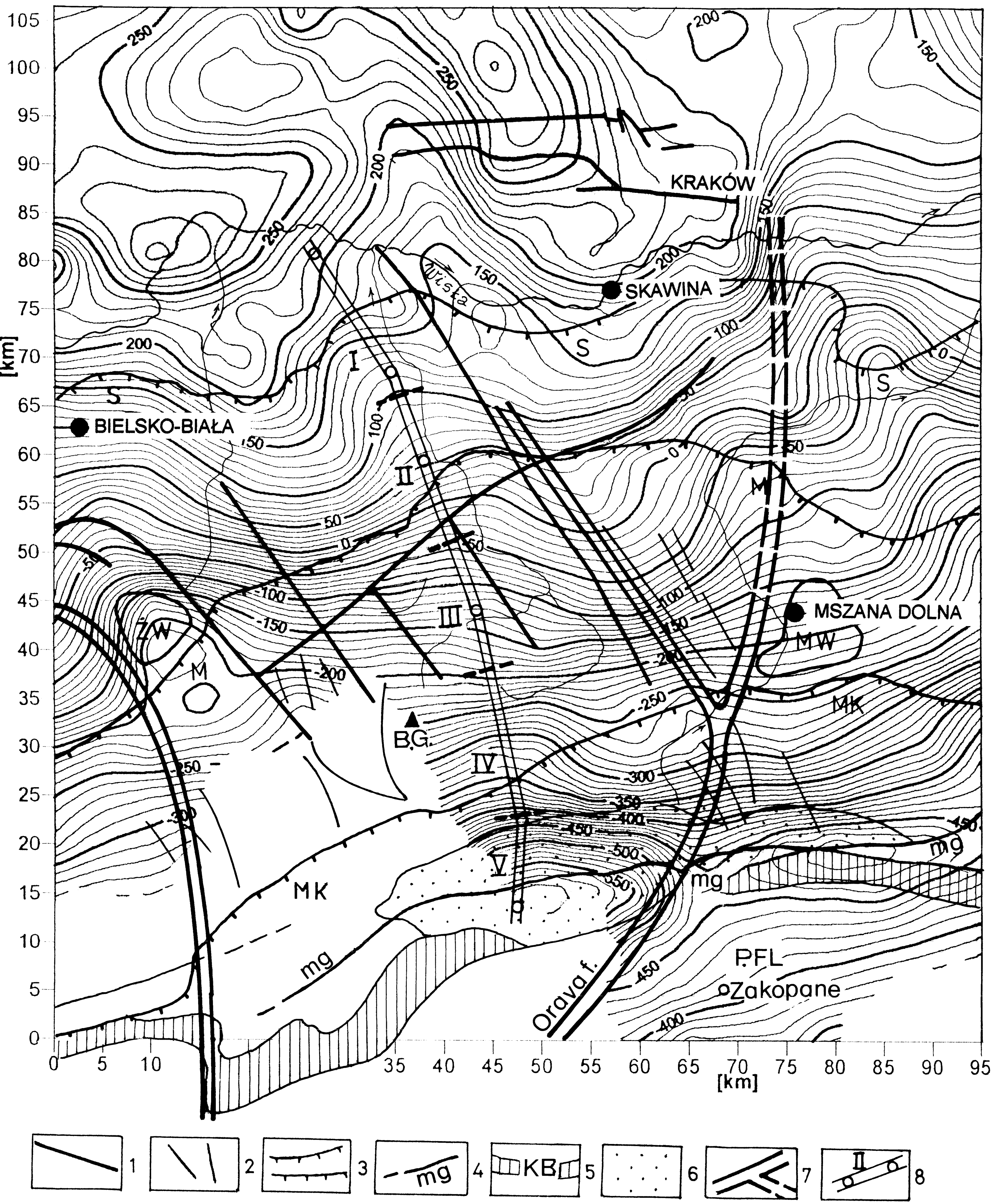

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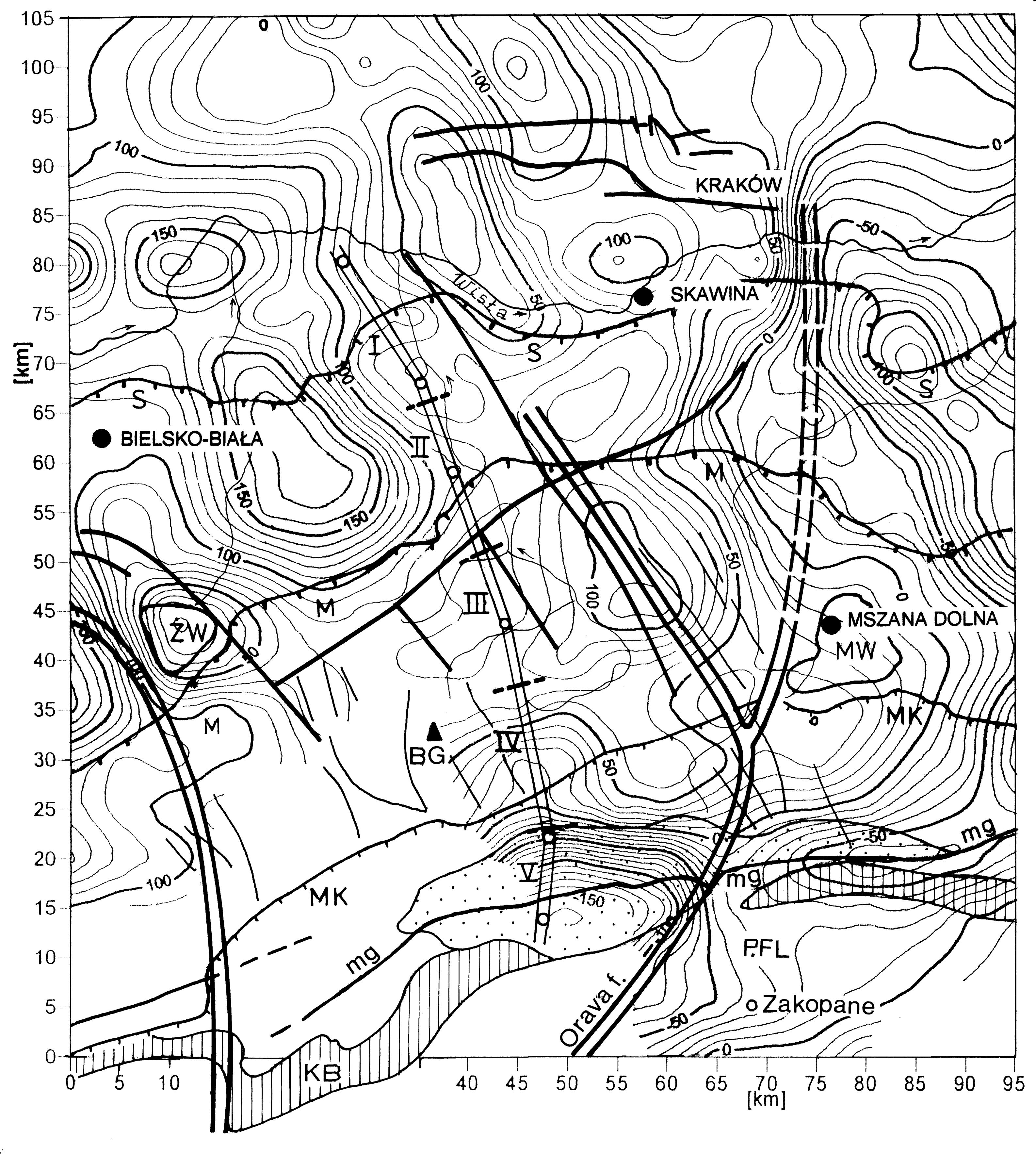

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