THE STRUCTURE OF THE RECSK PALEogene MAGMATITES FROM THE ASPECTS OF GEOPHYSICAL AND GEOLOGICAL DATA

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Abstract: The position of the intrusive bodies in the Recsk Paleogene magmatic system was well determined by airborne magnetic, radioactive spectrometry and EM geophysical surveys. The strong K-enrichment zone at Parádfürdő was also detected. The structural interpretations of the data given by the underground exploration of the Recsk Deeps confirm the former theory that the Paleogene magmatic intrusions were emplaced both along a previously existed anticline formed in Mesozoic sediments, and the fault systems parallel to this anticline’s axis. The examination of the fracture fillings show that there are moderate deviations in the structural directions formed in the Mesozoic and Paleogene formations. The recent structural appearance was determined by the youngest (Lower Miocene) lateral movements along the Darnó shear zone.

1. INTRODUCTION

The exploration of the Recsk Ore Complex was carried out in “reverse order”, compared to the general practice. The Recsk Deeps was discovered by drillholes based on mining data; and the general structural characteristics of the area were revealed after the drillcore interpretations. The geophysical background for the structural interpretations of the Recsk Deeps drilling project (Zelenka 1975, Zelenka and Földessy 1982) was based on gravity-, magnetic- and seismic data (Szalay, 1975). After the end of this active research period, there was an airborne-geophysical exploration program (Gulyás et al. 1994), which covered the whole area of the Recsk Ore Complex. This is the first study, which interpret these data combining geophysical and structural aspects. The structural data were produced by the drilling and drifting project in the late stage of the Recsk Deeps’ exploration and were discussed only in the project report (Baksa et al. 1988).
2. GEOPHYSICAL INVESTIGATIONS IN THE RECSK AREA

The re-interpretation of geophysical character of the Darnó zone has been carried out during the processing of airborne geophysical measurement data in the 1990s. In this airborne geophysical survey project a model area covering the 1:200,000 map sheet (Eger) has been selected and measured. Airborne magnetic, radioactive spectrometry and EM surveys have been carried out. The survey has covered both the Paleogene volcanic zone and the Darnó structure. The previous data sets have also been reprocessed and harmonized with the new results (Gulyás et al. 1994).

2.1. Gravity measurements

The results of gravity field measurements and the gravity data processing the Paleogene formations are bounded from SE by the Darnó shear zone, from SW by a NW–SE oriented structural zone (parallel with the range of the Eastern Mátra). The boundary of the Paleogene on the north is ill-defined.

On the filtered gravity map a centreline of an anticline structure between villages Recsk and Parád, clearly coincident with the known intrusive emplacements. The second order lithological changes alter the rocks of the basement because of the magmatism. The pre-Tertiary basement is located in 50–900 m depth and results the same gravity anomaly as Triassic outcrops near Sirok and the Darnó-hill.

On the gravity anomaly map you can see that the anticline structure is skewed (Fig. 1). The anticline is limited by a steeply dipping structure from East, which is the Darnó zone. There is a continuously dipping engrossment of the Paleogene formations on the southwest, which is limited by a supposed NW–SE structural line. The correct contouring of the Paleogene formations using the gravity measurements can not be done.

2.2. Magnetic field, EM measurements

The shallow rock alterations can be identified by their high apparent resistivity from the results of airborne electromagnetic measurements (Fig. 2, Table 1).

The Paleogene andesites and dacites in general appear in the magnetic anomaly map by low amplitudes anomalies, north from the Eastern Mátra. At the last stage of the volcanic activity (UA) the lavas have increased (and unaltered) magnetite content, in contrast to the highly altered volcanics of the previous
Fig. 1 Filtered gravity anomaly map with the results of boundary detection.

The structure of the Recsk Paleogene magmatites...
Fig. 2 Apparent resistivity map from the airborne measurements with the results of gravity boundary detection.
Fig. 3 Analytical signal map from airborne magnetic measurements with the results of gravity boundary detection (Kiss, 1995).
Table 1 Geological-geophysical model of the hidden intrusive centers (Szalay, 1975).

<table>
<thead>
<tr>
<th>Period</th>
<th>Lithology</th>
<th>( \sigma ) (g/cm(^3))</th>
<th>( \kappa ) (10(^{-6}) CGS)</th>
<th>( \rho ) ((\Omega)m)</th>
<th>( v ) (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holocene</td>
<td>Gravel</td>
<td>2.0 - 2.2</td>
<td>0</td>
<td>&gt;100</td>
<td>1700 - 2100</td>
</tr>
<tr>
<td>Pleistocene</td>
<td>Sand, clay</td>
<td>1.7 - 2.2</td>
<td>0</td>
<td>10 - 30</td>
<td>1700 - 2100</td>
</tr>
<tr>
<td>Pliocene</td>
<td>Volcanic tuff</td>
<td>1.7 - 2.6</td>
<td>&gt;1000</td>
<td>?</td>
<td>3700 - 4300</td>
</tr>
<tr>
<td>Miocene</td>
<td>Pyroxene andesite</td>
<td>1.7 - 2.6</td>
<td>&gt;1000</td>
<td>?</td>
<td>3700 - 4300</td>
</tr>
<tr>
<td>Oligocene</td>
<td>Sandstone</td>
<td>2.2?</td>
<td>0</td>
<td>50 - 150</td>
<td>2200 - 3000</td>
</tr>
<tr>
<td></td>
<td>Clay marl with tuff</td>
<td>0</td>
<td>6 - 25</td>
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<td></td>
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<tr>
<td>Eocene</td>
<td>A1 and UA andesite</td>
<td>2.2 - 2.6</td>
<td>0 - 500</td>
<td>3500 - 4400</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A1Q andesite, dacite</td>
<td>2.2 - 2.6</td>
<td>0 - 200</td>
<td></td>
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<tr>
<td></td>
<td>A2 andesite</td>
<td>2.2 - 2.6</td>
<td>0 - 150</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Diorite porphyry</td>
<td>2.2 - 2.6</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cretaceous</td>
<td>Basalt</td>
<td>2.7</td>
<td>&gt;1000</td>
<td>27 - 38</td>
<td>4400 - 4700</td>
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<tr>
<td>Triassic</td>
<td>Shale, chert</td>
<td>2.7</td>
<td>0</td>
<td>50 - 150</td>
<td>4300 - 5200</td>
</tr>
<tr>
<td></td>
<td>Limestone, dolomite</td>
<td>2.7</td>
<td>0</td>
<td>(\infty)</td>
<td>5100 - 6400</td>
</tr>
<tr>
<td></td>
<td>Hydrothermally altered limestone, silicified dolomite</td>
<td>&gt;2.7</td>
<td>0</td>
<td>?</td>
<td>4300 - 4800</td>
</tr>
<tr>
<td>Permian</td>
<td>shale</td>
<td>2.7</td>
<td>0</td>
<td>?</td>
<td>4700</td>
</tr>
<tr>
<td></td>
<td>limestone</td>
<td>?</td>
<td>(\infty)</td>
<td>5500 - 6100</td>
<td></td>
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</tbody>
</table>

stages. The subvolcanic emplacements of this late stage can be contoured by the ground and airborne magnetic measurements on both flanks and inside of the anticline structure. Since the best Au ores are preferably localized along the contacts of these unaltered late subvolcanic intrusives, this geophysical feature has strong significance. The analytical signal derived from the magnetic anomaly map emphasizes the places of the subvolcanic bodies (Fig.3).

2.3. Radioactivity survey

South of the Lahóca and Parád, on the eastern side of the Ilona valley a strong maximum of potassium content was identified by airborne radiometric
measurements. This is evidently connected to the adularia-sericite alteration known in the low-sulphidation epithermal mineralizations in this southern flank of the ore complex.

3. THE DARNÓ STRUCTURAL ZONE

The first recognition of the “Darnó Fault” was made by Rozlozslnik (1937) during the hydrocarbon exploration program in the Paleogene Basin. Since then, the “fault” has become an important regional structural zone of the Carpathian Basin. The dominance of this zone in the structure of the Paleogene formations in Recsk was first emphasized by Zelenka (1975) who introduced the concept of the Darnó Megatectonic Zone. He interpreted the ca. 10 km wide, NNE–SSW striking belt as a mobile zone embedding the Paleogene volcanic bodies. The original paleogeographic position of the Paleogene formations could have been along the Darnó-Balaton-Periadriatic lineament, SW of their recent location and the got their recent position in the Early Miocene.

4. STRUCTURAL EVOLUTION OF THE RECSK COMPLEX

4.1. Structural elements of pre-“Paleogene volcanic” origin

This kinds of elements were found during the shaft and drift explorations of the Recsk Deeps (Zelenka and Földessy, 1982). We can assume that, a previously existing, almost N–S striking anticline zone – also can be seen in the geophysical data – was the channel of the magma, the injection of which happened in multiple stages. The existence of this anticline is also supported by seismic- and drillhole data. The anticline is asymmetric; the thickness of the Triassic and Jurassic sedimentary sequences is different in the western and eastern wings. There could have been a significant strikeward movement along the axis of the anticline.

In some parts of the old Mesozoic formations overthrusted and overturned structural elements can be recognized. One of the underground outcrops of the overthrust was at the western wing of the anticline, in the Shaft No. 2, at the depth interval of 640–670 m. Here, in the underlying limestone block has 15–30° dipping to west, with slightly folded, bended layers, against to the overlying limestone block, which has steep, 30–60° dipping to west. This block is above the overthrusting plain. There are more parallel structural zones together, where
the intercalated competent limestone and incompetent shale layers are strongly folded. These tectonic surfaces are bended, sometimes strongly brecciated.

Overthrusting planes can be found at several levels in the limestone, at the 714–835 m depth interval of the Shaft No. 2 and in the shaft-connecting drift at -700 m and -900 m. The overthrusting planes generally have eastern vergency with 260/30° dipping. Supposibly, this is a lying wing of an overturned fold, which indicates a N–S striking overthrust zone with eastern vergency. The rocks of the overlying block are strongly foliated.

In the 20–40 m thick, strongly fractured zone striates can be recognized on the surfaces of the beds as a result of frequent lateral movement. The dip of these surfaces vary between 150–180/35–45°. The overthrust block can be followed in the -700 m drift level eastward, ca. 200 m long, in the direction of the dipping with small folds and flexures. These beds are strongly folded, with steep dipping, 290/50–85° in the last 20 m close to the underlying block. After this, there is a brecciated zone (Fig.4). There is a compressive, brecciated zone at the axis of the folded, underlying block. The rocks have 235–240/30–40° dipping in the
underlying beds below the overthrust bed. The enclosed, 100 m thick limestone has 180/40° dipping.

4.2. Structural evolution contemporaneous with the Paleogene volcanism

The injection of the magma could have happened in multiple stages along the axis of the almost N–S striking anticline. The axis of the anticline turns to SW–NE at the southern part of the area, and the emplacement of intrusive bodies follows the turning of the axis. There are brecciated, compressed intrusive zones formed without movement, because of the stretching and melting effect of the magma intrusion. The fragments in the breccia are always from the non-brecciated hostrock, and are cemented with infiltration veins of the intrusive material. This was observed in the 515–520 m depth interval of the Shaft No. 1, where the sometimes open, steep 60–90° faults are filled with intrusive breccia in a thickness of 0.5–2 m. Hydrothermal alterations are also observed near the above mentioned elements. The fracture frequency of the basement and the overlying sequences are significantly different (overlying sequences: 1.26 piece/m, basement: 0.55 piece/m) based on experience.

38% of the fractures are open now, and there are water and hydrocarbon migration along the structure. These are dominantly northern (NE–N–NW) dipping fault zones. The rest of the fractures are filled by sulphide, clay-minerals, quartz and cemented hostrock breccia where the matrix has fluidised texture (Table 2).

4.3. Structural evolution following the ore formation

These late structural elements can be mainly observed in a NNE–SSW strike along the Darnó shear zone. Parallel structures occur in a zone of almost 10 km in width. These structures are shown by all drillhole-, gravity-, seismic-, radiometric- and electromagnetic data. These structures have been also observed in the Paleogene ore body, as lateral, strikeward shear and movement zones.

The structures can be also recognised underground (depth interval 715–775 m, Shaft No. 1), where strong brecciation occurs along several parallel fault plains and the faults are dipward- and strikeward curved. The original ore body is altered and rolled along these zones (depth interval 120–170 m, drift No. 41, -700 m level, where the fault planes dip to 130/85–150/70°). The sinistral direction of the movement is recorded in the frequent fault striates.
**Table 2** Directional and frequency distribution of the fracture filling types in different rock formations.

<table>
<thead>
<tr>
<th>Direction</th>
<th>NNW</th>
<th>NW</th>
<th>WNW</th>
<th>W</th>
<th>S</th>
<th>SSE</th>
<th>SE</th>
<th>ESE</th>
<th>ENE</th>
<th>NE</th>
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<tbody>
<tr>
<td>Water</td>
<td>5</td>
<td>3</td>
<td>11</td>
<td>12</td>
<td>31</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
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<td>1</td>
<td>1</td>
<td>1</td>
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<td>1</td>
<td>1</td>
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<td>1</td>
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<td>1</td>
</tr>
<tr>
<td>Andesite</td>
<td>14</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>2</td>
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<td>1</td>
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<td>1</td>
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<tr>
<td>Quartz</td>
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<td>Clay</td>
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<tr>
<td>Breccia</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Sulfide</td>
<td>11</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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</tr>
<tr>
<td>Number of Structural Elements</td>
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<td>19</td>
<td>14</td>
<td>5</td>
<td>6</td>
<td>31</td>
<td>14</td>
<td>11</td>
<td>28</td>
<td>14</td>
<td>15</td>
<td>11</td>
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</table>

**Volcanic sequences**

- water
- hydrocarbon
- andesite
- carbonate
- quartz
- clay
- breccia
- sulfide
- number of structural elements
4.4. Structural elements in the different rock formations

In the Paleogene stratovolcanic andesite the oldest fault directions can be observed in open pits and underground drifts (A1, A1Q andesite, Etelka-pit; Shaft No. 1; and A1 andesite of the Lahóca Hill). These oldest elements are fault plains with strikes of ESE–WNW, dipping to 195–199/65° and 12/85°. Lateral movements with NE–SW strike, dipping to 110–130/60–63° and 305–325/70–85° also occur.

In the overlying Oligocene and Miocene sediments (marl at Mátraderecske and conglomerate on the Darnó Hill), fault plains with strikes of E–W, dipping to 180/40–50° and fault plains with N–S strike, dipping to 268/80° can also be visible.

The hydrothermal breccia containing adularia and jarosite at Parádfürdő-Ilona Valley is connected to this kind of structure.

Fault plains with NW-SE strike, dipping to 45–50/55–85°, 72/65° and 230/50° can be found in all kinds of rocks – including the fresh, youngest andesite bodies.

The youngest movements were re-activations along the previously formed fracture plains. These movements strongly influenced the recent morphology of the Paleogene andesite bodies. However, in the southern foreground of the Mountains, the Miocene volcanism displays a near E–W structural vergency.

Acknowledgement

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