Carpathian Journal of Earth and Environmental Sciences, August 2012, Vol. 7, No. 3, p. 109 - 117

THE REVALUATION OF THE DRILLINGS OF THE MANGANESE MINERALIZATION IN EPLÉNY (HUNGARY)

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Abstract: During our work, the layers of 233 drillings that were made in order to explore manganese ore (79 deep drillings and 154 drillings that were in the mine) have been revaluated. These drillings became deeper between 1949 and 1975 as a result of the mining that was running in these times. Fortunately, then the data remained complete and in this way facilities were provided to revaluate them lithologically as well as stratigraphically. The footwall formations constitute a continuous sedimentary sequence with the overlying Úrkút Manganese Formation in the area of Eplény-basin. In the studied area the primary oxidized manganese ore is the most characteristic, while towards to W radiolarian clayey marl occurs. In the Eplény-basin the manganese ore reaches its maximum thickness (21 m) at the intersection of tectonic lines. Although the low-grade carbonate manganese ore appears in some drillings, however according to quantity and quality, the high-quality oxidized manganese ore was mined (~28 w/w% Mn, ~8-9 w/w% Fe, Si, and ~0.2 w/w% P). As a result of our investigation the high quality, boulderly, coarse oxidized manganese ore occurs at the bottom of the manganese ore deposit, while towards the younger layers the Mn concentration decreases. In the Early Cretaceous and in the Middle Eocene the manganese sequence was redeposited which is spatially separable. While the Albian redeposition is in the southern part of the Eplény-basin, the Eocene redeposition is characteristic in the entire basin. This work is the first one that integrates the formations that were intersected by the drillings in Eplény into litostratigraphic units and preserves the archive drilling information in the standard drilling database.

Keywords: manganese ores, Upper Lias, Transdanubian Central Range, Eplény-basin, Hungary

1. INTRODUCTION

In Eplény (Transdanubian Range, Bakony Mountains, Hungary), the investigation with drillings began in 1949 and it lasted until the closure of the mine, in 1975. In 26 years' time 79 (signed with E) deep drillings and 154 (signed with EB) mine drillings deepened, so 233 drillings were available. These drillings hold important information about the structure of the manganese basin; the processing and revaluation of them are the first steps towards making a geological model. The main aim of this work is the revaluation of these drillings, but the digital archiving of this data is also an important task. The revaluations of the stratigraphic units were based on the revaluation of the formations that are intersected along the drillings. So, the formations that are intersected in the drillings were estimated, and then integrated into stratigraphic units. This provides facilities to characterize certain formations (especially the formations that are parts of the Úrkút Manganese Ore Formation) more specifically and to analyze their regional spread. This work is the first one that integrates the formations that are intersected by the drillings in Eplény into litostratigraphic units.

2. GEOLOGICAL BACKGROUND

The manganese mineralization (Eplény-basin) is in the Transdanubian Range, Bakony Mountains. In geological terms, it belongs to the Alps-Carpathians-Pannonian-Dinarides region (Haas et al. 2000; Fig. 1).

The manganese ore group of beds appears in an absolutely different way according to evolution in Eplény, than in Úrkút. While in Úrkút 4 beds can be divided (carbonated main bed, radiolarian clayey marl, manganese-carbonated clayey marl [II. bed]), in Eplény the 3 beds appear usually with sharp boundary, in reduced thickness (oxidized manganese ore, radiolarian clayey marl, manganese-carbonated clayey marl [II. bed]). Of course, in every region the deposit appears differently according to evolution and thickness. Usually the manganese ore group of beds, after hiatus, settle to Lias Hierlatz-type limestone, and part of it to Middle-Lias cherty limestone. The original size of the occurrence could be 1.0 km^2 at a maximum.

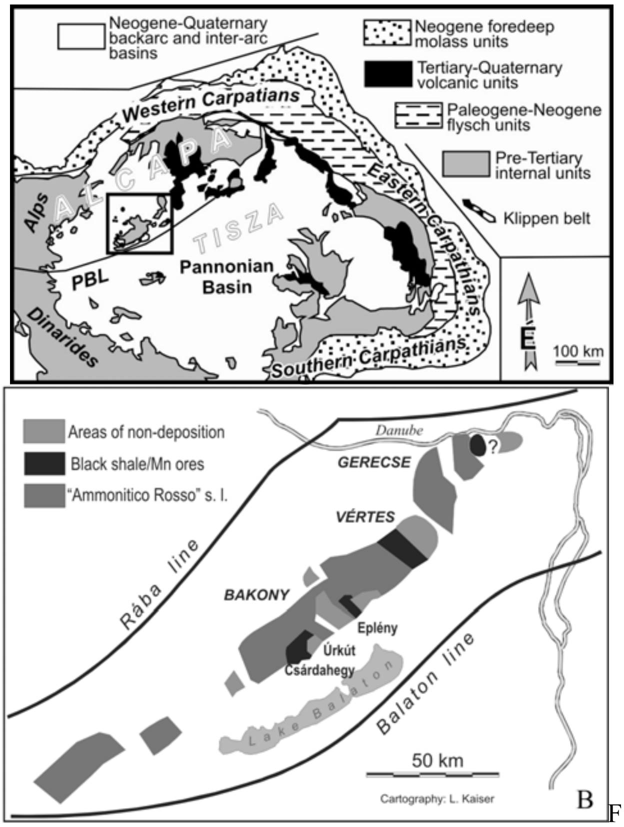

Figure 1. Location of Jurassic manganese deposits (A), and indications in the Transdanubian Range, Central Europe. (B). Early Toarcian palaeogeographical sketch map modified from Vörös and Galácz (1998); PBL – Periadriatic-Balaton Line, DKH - Transdanubian Central Range

Firstly, the circumstances and characteristic features of the mineralization were summarized by Sikabonyi (1954), after him by Szabóné Drubina (1955, 1959, 1966), then by Cseh Németh (1967), Cseh et al., (1971), Grasselly (1968), Grasselly et al., (1969), Greguss (1974), Szabó (1982), Polgári et al., (eds) (2000), and Szabóné Drubina (2002).

The Jurassic layers in the Eplény-Lókút (W from Eplény-basin) region are surrounded by Triassic formations laying on the surface. The Jurassic series usually pinches out to SE with a peneplain surface; its dip shows a NW orientation. So if we head SW along it, younger and younger formations appear. The Jurassic layer is covered with Cretaceous sediment in the NW, while the NE part of the region is covered with Eocene and Oligocene formations (Szabó 2006).

The Jurassic manganese ore mine was really poor according to production and resources. It opened during World War I. and the Great Depression. The development of mining was until the end of World War II, its flourish was in the 1950s and 1960s. Its decline began in 1968 with the introduction of the new economic mechanism, then in 1975 the production was put an end. The mine was closed completely in 1989 (Szabó 2006).

3. DATA AND METHODS

The aim of the work was to revaluate 233 drillings (79 deep drillings that are signed with E and 154 drillings that are signed with EB) made in the mine depositionally and stratigraphically. With the help of the original drilling records (Szabó 1976) the depositional descriptions were revaluated, and as a result of that the formations could be integrated into stratigraphic units. The basis of the litostratigraphic processing of the drillings in the 1980s was the litostratigraphic classification that was accepted by the Hungarian Commission on Stratigraphy (Bérczi & Jámbor 1998, Császár 1997). Of course, on the basis of the descriptions only, a certain formation could not be obviously classified. Knauer (1996) who in certain cases mentioned certain drillings of Eplény in the detailed descriptions of certain formations, which could be compared with the original descriptions of the drillings. The analyzed data of the samples taken during drillings (Mn, Fe, Si and P) has also been used in order to characterize the manganese ore group of beds.

According to the Úrkút Manganese Ore Formation we can divide the formations into two groups: footwall and hanging wall formations. In the case of footwall formations we do not have to talk about thickness or thickness maps, because the drillings processing are now (signed with E and EB) explorer drillings. It means that if manganese ore was found, they stopped after drilling through the whole ore, and if they found nothing, they did not drill through the older formations.

Footwall formations are the depositional units of Upper-Triassic and Upper-Lias. In the maps of these formations, we illustrated the depositions directly laying the manganese ore. Of course, classifying them stratigraphically can be inaccurate to a certain extent, because certain Low-Jurassic formations are different from each other according to quantity, so their classification is not an easy task (on the basis of Knauer & Végh 1969). However, this information cannot be used to make thickness maps.

In cases of the hanging wall formations, thickness can hold important information, so in the descriptions of certain formations the maximum and average thickness counted by the use of the drillings can be given. The deep drillings (E) usually intersect along the whole hanging wall drillings, but in cases of the drillings made in the mine (EB), not all of them do. Because of that, while making thickness maps, in cases of deep drillings we need to take into consideration 0 m thickness, but in the other case we do not have to. It means that if an EB drilling does not intersect a hanging wall formation, it still can be there, while in cases of E drillings they did not appear in the point of EOV Y, and EOV X. However, there are certain EB drillings that drill through formations older than manganese ore. Of course, in this case thickness can be taken into consideration according to the certain formation. While demonstrating the thickness maps we illustrated the formation thicknesses in the region of where manganese ore appeared, because only in this region was the drilling network dense enough to estimate the rack thicknesses.

As the result of the revaluation, a standard database is available and in that the most important parameters of the drillings (name of drillings, coordinates of EOV Y, EOV X, Z, its depths, the intersected formations, their depths, ages, furthermore the litostratigraphic units) can be found. It also contains the thin section of the digitalized rocks assigned to certain drilling samples. In this way any type of query could be easily done with the database.

4. RESULTS

4.1. Footwall formations

While making the relief model of the footwall, the already-existing footwall map was digitalized (Szabó, 1976) and was made on the basis of the observations of the drillings. In order to be clearer, the formations intersected by the drillings were also illustrated on the footwall map as well as the spread of certain formations on the surface (Fig. 2).

Among the Upper-Triassic formations, the Hauptdolomite Formation and the Dachstein Limestone Formation can both be found in the region. While two drillings (E-40, E-75) intersected the Dachstein Limestone Formation, the Hauptdolomite in the drillings did not; they appear only in the surface. These two formations appear on the surface only in the NE and the S.

The first part of the Lower-Jurassic is the Dachstein-type Lias limestone, with white oolites. It is a crystallised limestone (Kardosrét Limestone Formation) that appears only in the drillings on the E part of the NW-SE tectonic line (Géza-fault) of the Eplény-basin. On the Kardosrét Limestone Formation, pink, well-layered, crinoidal, brachiopod limestone (Hierlatz Limestone Formation) can settle as well. These two formations can be found on the whole region of the basin, on the surface as well as in the drillings.

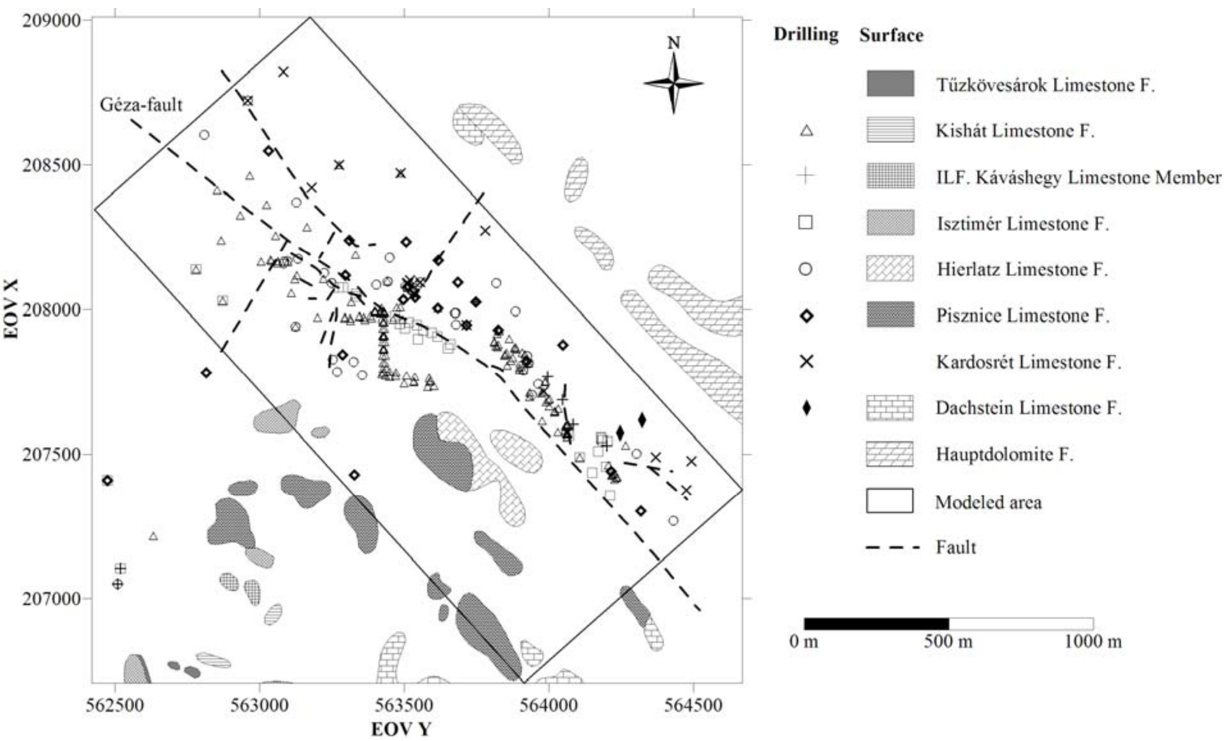

Figure 2. The morphology of the direct footwall of the manganese ore in Eplény-basin with the formations, and with its surface occurrences

The grey, red, cherty limestone (Isztimér Limestone Formation) appears in the region of manganese ore, along the main NW-SE tectonic line (Géza-fault). In some drillings the cherty limestone dominated by red cherty layers (Káváshegy Limestone Member) also appears. It appears on the surface mainly in the SW part of the region. The "ammonitico rosso"-type, tuberous limestone evolved from the Tűzkövesárok Limestone Formation appears only in one drilling (E-67) and on the surface, in the S border of the region. The pink, crinoidal**,** tabular limestone (Kishát Limestone Formation) can also be found in the tectonic zone that is in the NE-SW axle of the basin, directly as a footwall formation.

4.2. Manganese Ore Formation of Úrkút and hanging wall formations

The "in situ" manganese ore (Úrkút Manganese Ore Formation (Fig. 3) can be found in a well-delineated region, in the NW-SE tectonic trench. The SE edge of the trench reaches the manganese ore its thickest development (E-15: 21.3 m). On the lifted parts and heading to the border of the basin it becomes slighter and slighter, around 5 m (Table 1). It appears only in the drillings, not on the surface.

The posidoniceous, tuberous, cherty calcareous marl (Eplény Limestone Formation) is in the NW part of the basin (in the region of the trench) and its average thickness is 40 m. It appears on the surface in the SW part of the region, on the side of Kávás Mountain. From the formation, the cherty limestone, radiolarite (Lókút Radiolarite Formation), developed gradually. It can be found in the same region, like the Eplény Limestone Formation in its hanging wall, above the NW trench, and its thickness is about 80 m. On the surface it appears in the E-SE part of the region, but it also appears on the side of Kávás Mountain. In the hanging wall of the radiolarite there is pink, saccocomaceous, "ammonitico rosso"-type, tuberous limestone (Pálihálás Limestone Formation) that evolved in the region of the NW trench and its thickness is about 13 m. On the surface it does not appear. In the hanging wall of this formation there is majolica facies, tabular, cherty-lanced limestone, calcareous marl (Mogyorósdomb Limestone Formation). It also appears in the NW part of the region, in the surroundings of the trench, and its average thickness is about 11 m. The terrestrial, varicoloured clay, clayey marl limestone (Tés Clay Formation) appears in the Eplény-basin only in the drillings, and it is mainly in the NW part of the region.

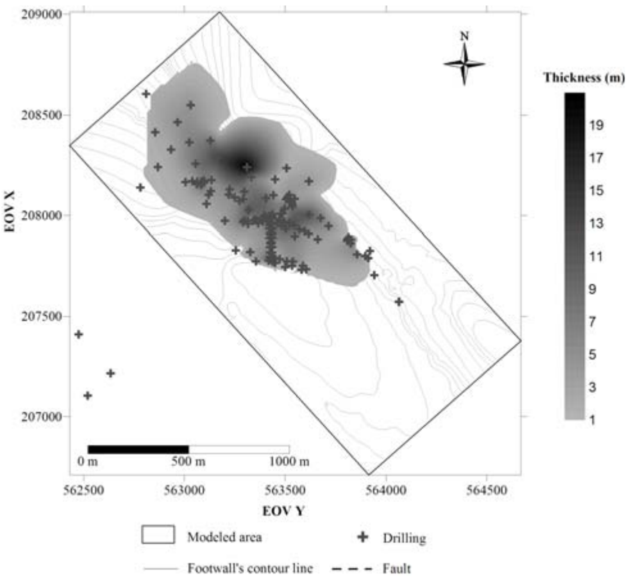

Figure 3. The thickness map of Úrkút Manganese Ore Formation

Table 1. The maximum and average thickness of the hanging wall formations

Formation	Drilling No. (E, EB)	Max. thickness (m)	Average thickness (m)
Úrkút Manganese Ore F.	110	21.3	5.4
Eplény Limestone F.	31	62.3	39.6
Lókúti Radiolarite F.	26	115.2	70.3
Pálihálás Limestone F.	12	25.6	13.3
Mogyorósdomb Limestone F.	6	18.4	10.9
Tés Clay F.	25	59.8	32.0
Tés Clay F. Kepekő Member	58	12.0	3.0
Zirc Limestone F.	14	52.0	25.1
Gánt Bauxite F.	25	7.5	2.0
Kisgyón F. Szarvaskút Member	46	78.9	40.0
Csatka F.	54	135.0	41.4

In the area of the above-mentioned trench heading NW it reaches its maximum thickness, which is about 60 m. Its layers containing redeposited, weathered cherties and redeposited manganese ore (Kepekő Member) are in the most important part of the region, along the faults, but especially in the surroundings of the main NW-SE tectonic line and their thickness is about 3 m. In the hanging wall of the Tés Clay Formation there is rudistid, tabular, tuberous limestone (Zirc Limestone Formation), which is also in the NW part of the region, and its thickness increases when heading N. It appears on the surface in the NW part of the region as well. The average thickness of this formation is about 25 m.

Cherty debris, nummulitic, sandy limestone containing redeposited manganese ore (Kisgyón Formation, Szarvaskút Member, in Gyalog & Budai, 2004) appears in the NW-SE direction of strike, mainly in the surroundings of the Géza-fault, but in the lifted area that is E from the fault they appear in greater thickness. They appear only in drilling, and their average thickness is 40 m.

The youngest formation (Oligo-Miocene) is the Csatka Formation containing clay, sand and gravel. It gradually reaches its maximum thickness (135 m) when heading E; its average thickness is only 41 m. Its occurrence on the surface is significant.

4.3. The lithology of Úrkút Manganese Ore Formation

The manganese ore formation was divided into 32 lithology types that can be organized in the following groups:

Primary deposit:

- Boulderly oxidized manganese ore
- Coarse oxidized manganese ore
- Radiolarian clayey marl
- Manganese carbonated clayey marl
- Cherty band

Secondary deposit:

- Radiolarian clay
- Banded oxidized manganese ore
- Brown clay
- Manganiferous clay
- Manganiferous limestone

The lithology types of the primary deposit did not go through any alteration, while the lithology of the secondary deposit modified after a while. It means that they oxidized and the group of beds was redeposited. However, the lithology that only oxidized can be considered as part of the Úrkút Manganese Ore Formation. The redeposited manganese ores are parts of the Kepekő Member of Tés Clay Formation and the Kisgyón Fomation Szarvaskút Member (Middle-Eocene). The lithology of the group of beds on a higher surface went through oxidation (carbonated ore and follower rocks) on the basis of the following (Polgári et al., (eds) 2000):

Primary deposit → Oxidation → Secondary deposit:
(1) Radiolarian clayey marl → Radiolarian clay
(2) Manganese carbonated clayey marl → Banded oxidized manganese ore

The lithology of the primary deposit is along the faults (Fig. 4), but mainly in the surroundings of the main, NW-SE tectonic line (Géza-fault). However, the coarse oxidized manganese ore is in the main parts, while the boulderly oxidized manganese ore is in the surroundings of the faults. There is much more boulderly and coarse oxide manganese ore in the bottom of the group of beds, than manganese carbonated clayey marl (II. bed) that is in the upper part of the ore deposit. This is probably genetic rather than caused by erosion.

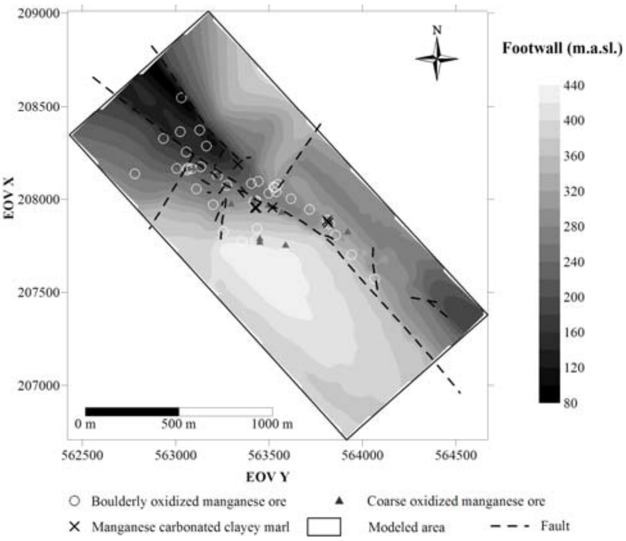

Figure 4. Regional spread of the lithology types of the primary deposit (1)

The radiolarian clayey marl belonging to the primary deposit (Fig. 5) also appears along the Géza-fault, on the main part of it, in the same region as the coarse oxidized manganese ore. In the W of the Eplény-basin, in the Lókút area, only this lithology appears from the Úrkút Manganese Ore Formation. The manganese ore did not develop. The cherty band closing the primary oxide ore was found only in some drillings. Where the primary oxide ore did not develop, only manganiferous limestone can be found, and this lithology is mainly in the NW part of the region.

The lithology, having gone through oxidation, can be found along the banded oxidized manganese ore faults, on the main parts, and the radiolarian clay is in the same region as primary boulderly oxidized manganese ore. Secondary lithologies appear in the surroundings of the faults or on the upper parts of the layers where the oxidation was influential. The different clay types (manganiferous, brown) can be found in all of the drillings, so it appears in the whole region, because of its clayey fine-grained compound of deposit.

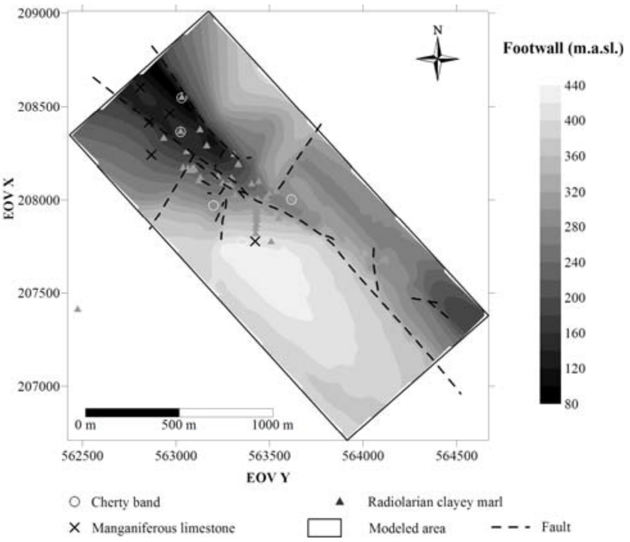

Figure 5. Regional spread of the lithology types of the primary deposit (2)

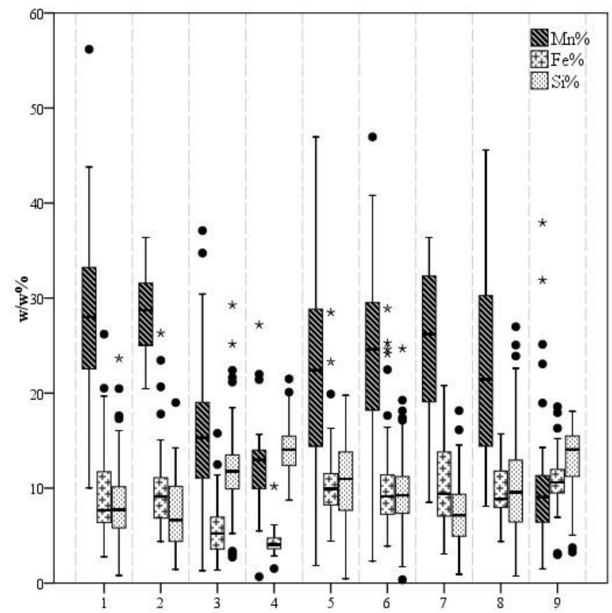

Figure 6. The box-plot diagram of the Mn, Fe, Si concentration of the depositional types. Notation: 1. Boulderly oxidized manganese ore, 2. Coarse oxidized manganese ore, 3. Radiolarian clayey marl, 4. Manganese carbonated clayey marl (II. bed), 5. Redeposited oxidized manganese ore (Tés Clay Formation, Kepekő Member), 6. Radiolarian clay, 7. Banded oxidized manganese ore, 8. Secondary oxidized manganese ore, 9. Manganiferous clay.

The lithology can be characterised not just territorially, but on the basis of the Mn, Fe, Si and P concentration (Fig. 6). The number of the chemical analysis was the following: Mn: 1128; Fe: 1129; Si: 1121; P: 1030 (Laboratory of Eplény, data obtained by wet chemical method).

It can be seen in the above figure that the boulderly and the coarse oxidized manganese ore have the highest Mn concentration – these are the primary manganese ore. The Mn concentration of them is ~28 w/w%, while their Fe and Si concentration is 8-9 w/w%. Surprisingly, the Mn concentration of the radiolarian clayey marl is higher on average (and its Si concentration is less) than the manganese carbonated clayey marl developed from this lithology. However, both lithologies are low quality manganese ores.

The Mn concentration of the secondary oxidized manganese ore (redeposited, banded oxidized manganese ore) and radiolarian clay is higher than 20 w/w% on average, and their Fe and Si concentration is less than 10 w/w%. On the basis of this data they can be considered good quality manganese ore on average.

Among the manganiferous clay there are high quality manganese ores, since its Mn concentration can be even ~38 w/w%.

The spatial distribution of the concentrations can give more information than the box-plot diagram above (Fig. 6). The regional spread of certain elements shows well where good quality manganese ore can be found. Of course, we cannot demonstrate the vertical spread of the concentration on the map, which is why during making the maps we considered the maximum element concentration at a certain drilling point (Figs. 7-10).

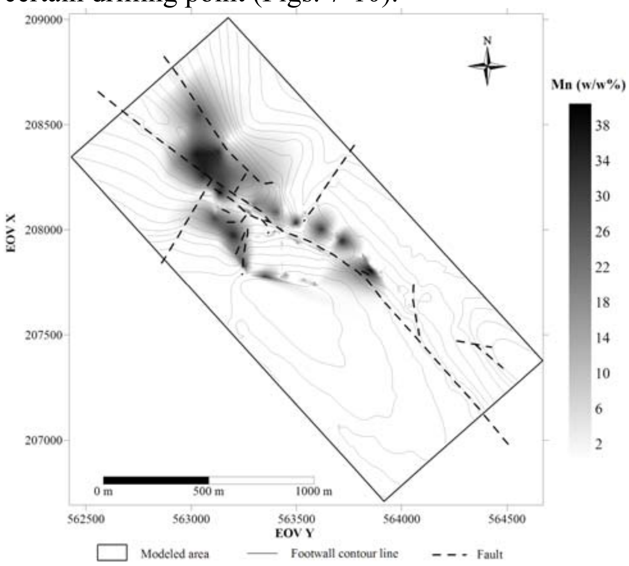

Figure 7. The regional distribution of the maximum Mn concentration of Úrkút Manganese Ore Formation

It can be seen in the figures that good quality manganese ore (Mn > 20 w/w%) appears along the faults, but mainly in the NW part of the region, in the graben. On the basis of the thickness map of the formation (Fig. 3), the manganese ore deposit becomes thicker here (almost 10 m).

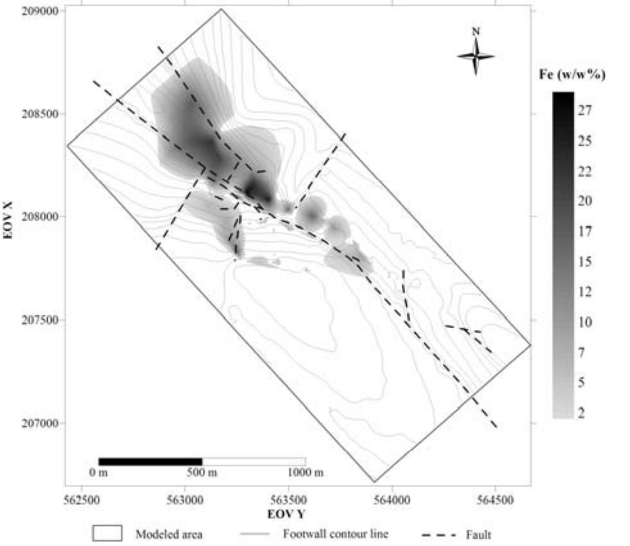

Figure 8. The regional distribution of the maximum Fe concentration of Úrkút Manganese Ore Formation

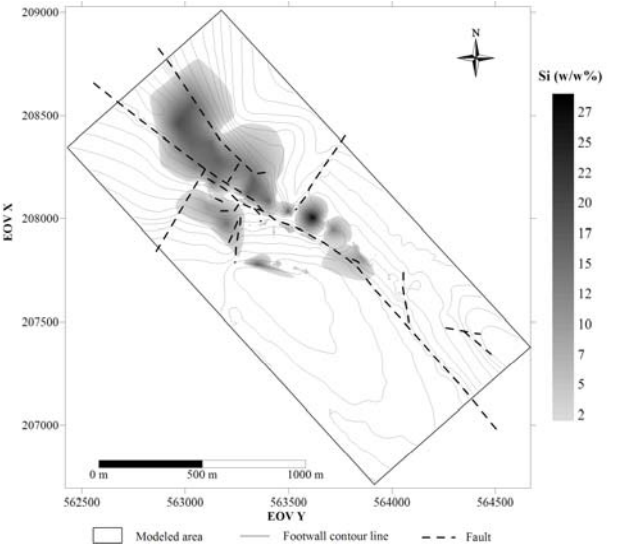

Figure 9. The regional distribution of the maximum Si concentration of Úrkút Manganese Ore Formation

The Fe concentration also reaches its highest value in the region of the graben, but it is higher in the lifted areas than in the deeper ones.

The Si concentration of it is similar; in other words, it can exceed the value of 10 w/w% in the region of the NW graben. It is likely to be possible because of the cherty, clayey composition of the deposit.

In the case of P, fewer analyses are available than in the above mentioned 3 elements cases, which is why a smaller region can be characterised. On the basis of these in the region of the NW graben its concentration is above 0.3 w/w%.

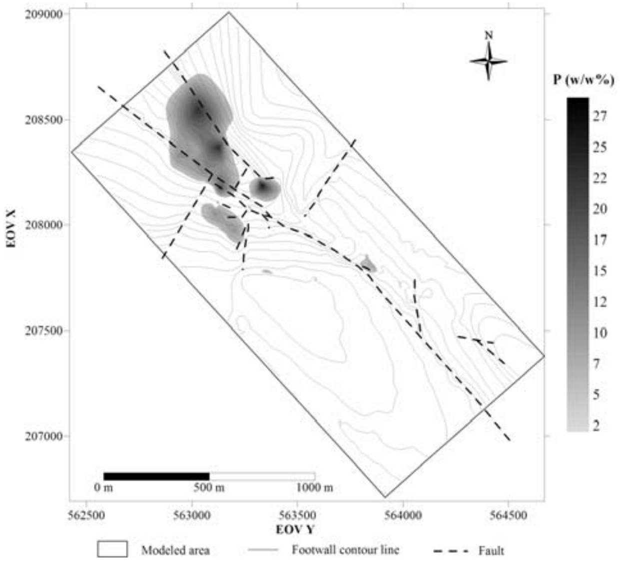

Figure 10. The regional distribution of the maximum P concentration of Úrkút Manganese Ore Formation

5. DISCUSSION

The hanging wall formations of Úrkút Manganese Ore Formation have concordant Lower-Jurassic layers. These layers begin with the oldest (Hettangian) Kardosrét Limestone Formation and end with the Upper-Lias manganese ore. While the Pisznice Limestone Formation and Hierlatz Limestone Formation usually appear in the whole area (the two formations usually interfingering with each other), the Isztimér Limestone Formation and Kishát Limestone Formation mainly appear along the main tectonic lines.

The Upper-Lias manganese ore is the thickest in the graben developed along the Géza-fault; in the SE end of the graben, it appears at the crossing of the faults. In the Middle-Upper-Jurassic thickness maps it can be seen that the younger and younger formations become thicker and thicker towards the NW (so it is likely that the formations blow in a NW direction). This tendency can be observed in cases of Middle-Cretaceous formations as well (Tés Clay Formation, Zirc Limestone Formation).

It is different in cases of tertiary formations. While the Mesozoic formations reach their highest thickness towards the NW in the region of the graben, in cases of tertiary formations the direction is E. Of course, there is a big difference between the formations of the two periods according to maximum thickness.

The thickness map (Fig. 11) of the whole hanging wall of the manganese ore deposit holds important information. Whole hanging walls are those that can be found between the ore and the surface. It can be seen on the thickness map (Fig. 2) that principally the region of the graben having a NW-SE direction of strike is filled with hanging wall formations (maximum thickness: ~300 m). It follows that the graben developed before Middle-Cretaceous is not completely filled with the manganese ore deposit, since the hanging wall formations appearing in the region are really thick. If the manganese deposit filled the graben, the hanging formations would appear with the same thickness in the region.

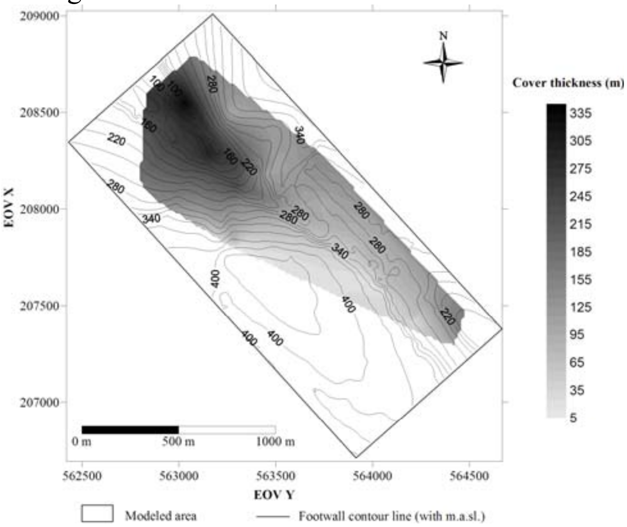

Figure 11. The thickness of the whole hanging wall with the hanging wall morphology

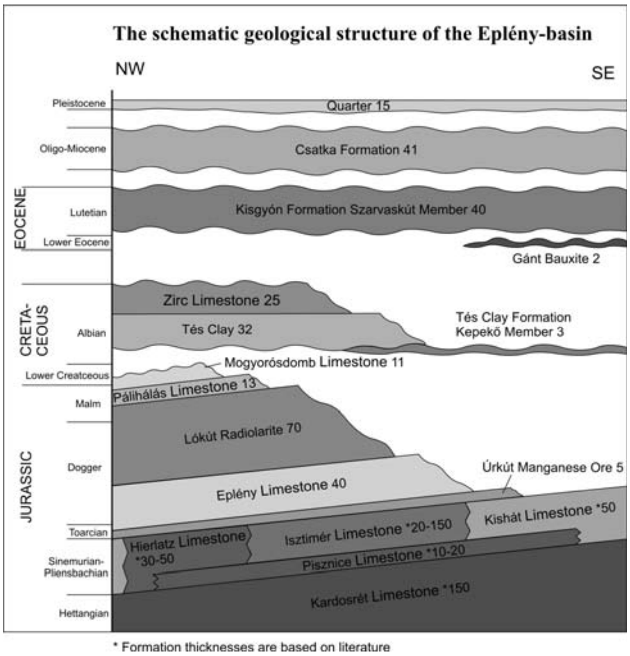

Figure 12. The schematic geological structure of the Eplény-basin

The distribution of the lithology types of Úrkút Manganese Ore shows the spread of the high quality manganese ores well. The distributional maps of the lithology types (Figs. 4-5) are consistent with the element concentration maps (Figs. 7-10). This means that the boulderly, coarse oxidized manganese ore that is at the bottom of the manganese ore deposit is high quality ore, while as the layers of deposit become younger and younger, the Mn concentration decreases. Of course, other lithology types may contain a higher Mn content because of the bulk analysis, for example clays may contain small manganese oxide particles.

A revaluation as a result of drillings figure 12 shows the schematic geological structure of the Eplény-basin.

ACKNOWLEDGEMENT

Thanks to Dr. Zoltán Szabó (retired senior engineer, Úrkút) for helping process the drillings of Eplény.

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Received at: 06. 01. 2012
Revised at: 04. 04. 2012
Accepted for publication at: 23. 04. 2012
Publised online at: 25. 04. 2012