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EVALUATION OF TERRAIN SUBSIDENCE IN RELATION TO THE ENGINEERING-GEOLOGICAL ZONES IN A TERRITORY OF THE OSTRAVA-KARVINÁ DISTRICT AFFECTED BY MINING**

1. Introduction

The study deals with the evaluation of terrain subsidence caused by mining activities in the selected time chronology, in relation to the existing built-up area and planned built-up area according to the land-use plan. The evaluation was also related to the engineering-geological zones, such as the representatives of localities with similar geological structure in connection with the foundation engineering. All the mentioned information should become an integral part of land-use planning and vital information for building offices and future engineering-geological and geotechnical surveys.

A tool that would permit a mutual comparison of such information was the Geographic Information Systems by means of overlay analyses. However, before that it was necessary to vectorize all the required information on the basis of earlier registered map documentation and aerial photos using the absolute methods, or relative positions. All this was complemented by field and archive study of selected sites where information had to be updated or verified on the grounds of previous circumstantial evidence with ambiguous identification of particular parameters.

The case study was implemented in the cadastral district of the town of Orlová (partly of Dětmarovice, Doubrava, Rychvald and Karviná), which is in terms of mining activities located in the Karviná section of the Ostrava-Karviná District, where black coal is extracted in Karviná Mine, which was established having merged the former ČSA Mine and Lazy Mine as of 1 April 2008. The Plant ČSA is situated in two allotments of Doubrava and Karviná

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Doly I. The Plant Lazy is found in the south-western part of the Karviná partial basin. The allotment of the Plant Lazy is in the cadastres of the municipalities of Orlová and Karviná.

As for geology, the interest area is located on the contact of two geological units of the Bohemian Massif, in the Upper-Silesian Basin of the Moravia-Silesian Region, and the Carpathian Fore-deep of the Western Carpathians. The Quaternary is formed by a varied range of different genetic types with significant representation of anthrogenous sediments. As for geomorphology, the territory falls in the complex of the Ostrava Basin and the district of Orlovská Plateau and Ostravská Bottomland.

2. Evaluation of Changes in Declines

The part of the declines evaluation concerned the evaluation of the overall interest area. In this area the sizes of declines were evaluated (provided by the company of OKD) caused by the extraction of black coal in Karviná Mine (Plant ČSA, in the former Doubrava Mine, Doubrava allotment) of OKD. The declines were observed in four time periods — 1983–1990, 1983–1995, 1983–2000, 1983–2005 (fig. 1, 2, 3). The study also comprises an assessment of forecast subsidence by 2010 (2003–2010), which is not stated in this initial chapter as it was not compatibly evaluated with the four afore mentioned time periods. Seven intervals were selected for the purposes of uniformity and possible good comparison of subsidence value results (territory without declines, up to 50 cm, 50–100 cm, 100–200 cm, 200–300 cm, 300–500 cm, 500–1200 cm). All relevant partial values were assigned into the given intervals.

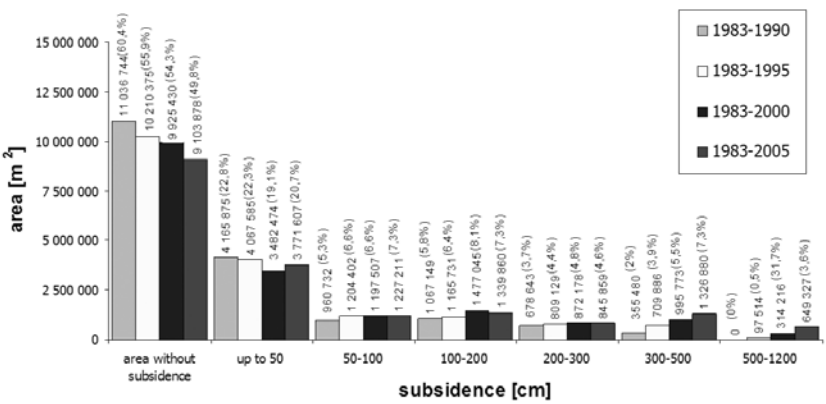

Fig. 1. Changes in the areas of declines in the interest area (map sheet 15 44 02) in the individual time periods

A characteristic feature of the interest area is the possibility to compare localities without any impacts of undermining (extensive area without declines) with localities where their manifestations are unambiguous with a gradual transition from small to more prominent declines. Such a territory is situated north-westwards from the considered diagonal running in the direction south-west-north-east in the observed area. In the course of the monitored periods the areas dropped from the original 60.43% (11.04 km^2) to 49,84% (9.1 km^2) out of the total area (fig. 1). Almost one fifth of the area (22.8%, 22.3%, 19.1%, 20.7%) produced declines up to 50 cm during all the four monitored time periods (4.17 km^2, 4.07 km^2, 3.48 km^2, 3.77 km^2). This interval of declines represents the second most frequent group of the evaluated territories in terms of subsidence in the area. The following 3 intervals (50–100 cm, 100–200 cm, 200–300 cm) are quite balanced groups in which no prominent fluctuations in the values occur in the course of the monitored time periods. On the contrary, a growing trend in the size of the areas of declines in time can be observed in the last two intervals (300–500 cm and 500–1200 cm). There is a reversed trend there than in the case of the first interval, i.e. an increase in the areas in time where for the interval 300–500 cm between the first and fourth time period the area grew by 365% (from 2% to 7.3% of the total area). In the last interval a change from zero value to an area corresponding to 3.6% (0.65 km^2) was registered. A territory with the largest value of declines is found near the town quarter Orlová-město, by the most direct route it is north-eastwards about one kilometre from the Old

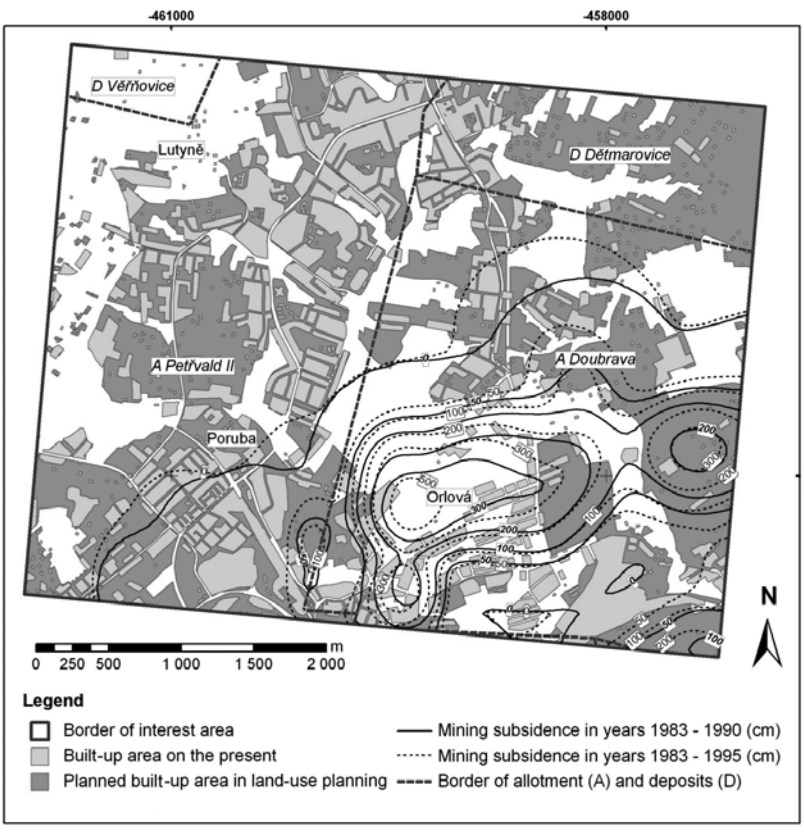

Fig. 2. Map of isocatabases in the years 1983–1990 and 1983–1995 overlaying the current built-up area, planned built-up area and the borders of allotments

Square between the streets of Dr. M. Tyrše and Bezručova. The original value, which was over 470 cm in the first time period 1983–1990, rose to over 700 cm in the course of the years in the last time period 1983–2005.

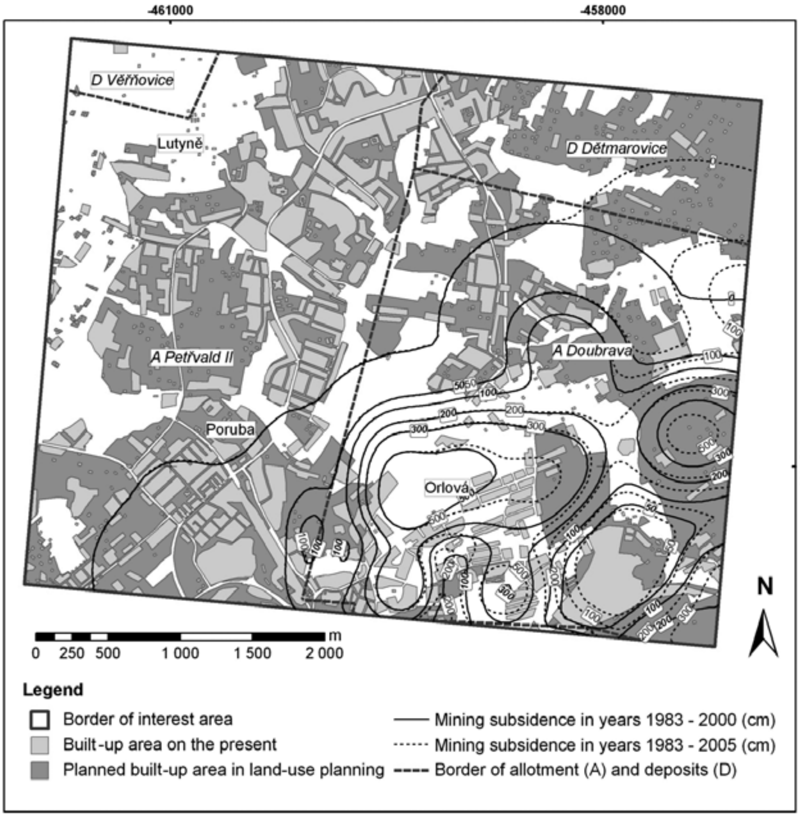

Fig. 3. Map of isocatabases in the years 1983–2000 and 1983–2005 overlaying the current built-up area, planned built-up area and the borders of allotments

The interest area has been affected by the former *Doubrava Mine*, *which currently makes part of Karviná Mine* (*Plant ČSA*) in the Doubrava allotment.

The negative impacts of undermining in the interest area are the consequences of mining activities in the *former Doubrava Mine*, which at present belongs to *Karviná Mine* (Plant ČSA, Doubrava allotment).

In Plant ČSA, Karviná Mine has an annual production of about 2.8 million tons (allotment area of about 26 km^2), in Plant Lazy about 1.9 million tons (allotment area of about 6 km^2). Doubrava Mine as a part of Plant ČSA participates on the daily production with 5000–5200 tons within the allotment area of about 9.5 km^2).

The biggest absolute depth in Plant ČSA is in the return shaft Doubrava III in the locality Doubrava — 1176 m. At the altitude above the sea level it opens at 281 m and reaches as deep as 895 m below the sea level. The mean depth of extraction in Plant Lazy ranges around 852 m below the surface. The deepest workings are as deep as 970 m below the surface.

In terms of the mining and driving technology in Plant ČSA the prevailing volume of length is driven by drilling machines in the implementation of mine openings in the seams. In crosscutting and ripping the associated rocks, jumbos combined with loaders are used. The basic mining method is outbye longwall caving along the strike. Coal getting in the overall volume is implemented from coalfaces equipped with mechanical advancing supports and power loaders.

As for the history, the Mine of Czechoslovak Army (ČSA) was established on 1 July 1995 merging two originally independent mines of ČSA and Doubrava. However, its history is much longer and it dates back to the very beginnings of mining in the Karviná Region. It is probably the place from where the first reports on the discovery of black coal originated in the 18th century in the locality called Kamienčok. In 1780 prospecting work was begun by Count J. E. Larisch-Mönnich. In 1856 the local shafts were joint into one company which is considered the start of the existence of the nowadays ČSA Mine. The family of Larisch-Mönnich owned the local mines till the dispossession in 1945. In 1951 a state company Velkodůl Čs. armády was established there and extensive reconstruction followed [12].

There is an also long history of mining in the locality of Doubrava. Doubrava Mine was the oldest from the existing mines in the regions of Orlová, Poruba, Doubrava and Lazy. The reference to the beginning of mining in the cadastre of Doubrava municipality dates back to 1822 when Baron Anton Mattencloit built a shaft "Versuch" on the hill "U havírny". In 1836 shallow shafts helped to create a mining company that was collectively owned by Mattencloit and Larisch-Mönnich. In 1854 the test pit No. 1 was deepened to 152 m and was called "Eleonora"; In 1855 the shaft Versuch was deepened as deep as 120,8 m and renamed to "Bettinaschacht".

The first electricity in the district was introduced in 1896 and in a wider scale used to power pumps, screening plant, chain creeper and lifts. At the turn of the century, the technical development accelerated and pneumatic rock drills were used there as first in 1905. The pit Bettina was then the second mine in the district.

In 1914 the pits Bettina and Eleonora were combined into one complex "Pits of Bettina and Eleonora of the Vítkovice coal mines". This merger laid foundations for the Doubrava Mine that later was and remained till the merger with ČSA Mine a medium-sized mine within the OKR. In 1949 in Doubrava Mine the first ever full inertization of a closed mine was applied using nitrogen produced directly on the mine surface.

The lowest seams of the Karviná Formation were mined of the thickness from 1.0 to 6.5 metre situated lying with the inclination from 5° to 25° towards the north-west in the depth around 700 to 1000 m. The relief of the Carboniferous began in the pit locality „Do I" in the depth of 10 m below the surface. The relief of the Carboniferous fell sharply towards the north into the Dětmarovice pothole. The depositing of the seams was flat with the prevailing dip from 0 to 10°. Behind the Doubrava Fault the productive Carboniferous is situated by 350 to 450 m deeper. With regard to this division, dips about 25° can be expected, the direction of the beds is undulated and the average dip is towards the north-east.

A part of the mining area at the contact of the Miocene-Carboniferous is covered by a water and gas bearing horizon. It is situated on the Carboniferous hillside from the contour –500 m, so the area of this detrital territory covered around 21% of the allotment.

In terms of the reached depth of extraction, Doubrava Mine was the deepest mine in the Karviná section and the main hoisting shaft „Do I“ had its lowest, tenth hoisting level as deep as 930 m below the surface. However, it was deepened with respect to filling the production equipment below the level of the 10^{th} level below the depth of 1000 m. The mine belonged to medium-sized mines in OKR with daily production of 5000 to 5200 tons [16].

The second part of declines evaluation focused on the evaluation ***in relation to the current built-up area***. Similarly to the case of the overall interest area the evaluation was carried out in four time periods (1983–1990, 1983–1995, 1983–2000, 1983–2005) in 7 intervals of declines (localities without declines, up to 50 cm, 50–100 cm, 100–200 cm, 200–300 cm, 300–500 cm, 500–1200 cm).

A larger proportion of the current built-up area is in a territory without any manifestations of declines (fig. 4). In spite of the fact that the area decreased in the course of the monitored periods from 58.94% (2.62 km^2) to the final 51.62% (2.29 km^2) out of the total area, the territory without any declines constitutes a larger part of the built-up area. In the second interval (up to 50 cm) similar values can be observed for the first two time periods –29.4% (1.31 km^2) and 30.1% (1.34 km^2), followed by a slight drop down to the values of the last two periods 25 m 7% (1.14 km^2) and 24.6% (1.1 km^2). This drop is caused by the redistribution of the area of the interval for the benefit of the following intervals. There is an almost 100% increase in the built-up area in the third interval of 50–100cm, where in the first time period the built-up area took up 3.1% (0.14 km^2) of the area, in the third it was even 6.4% (1.31 km^2) and in the last period, similarly to the second period it was 5.9% (0.26 km^2) out of the total area. A similar course occurred in the interval of 100–200 cm, where the values move from the original 3.6% (0.16 km^2) via 2.8% (0.13 km^2) to 5.7% (0.25 km^2), and finally, they levelled off at 4.9%

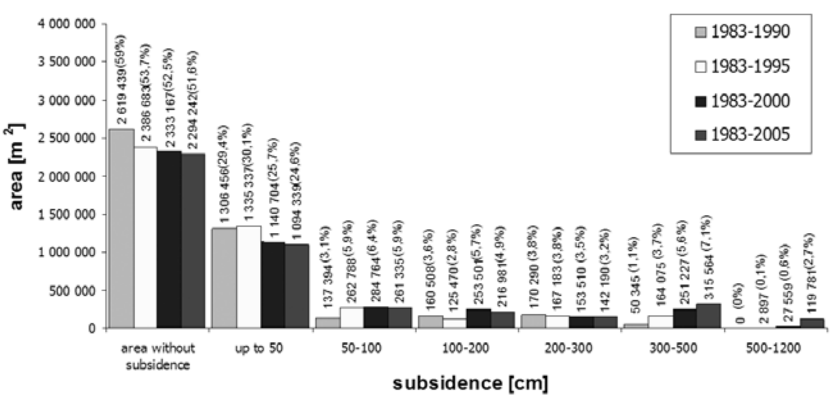

Fig. 4. Dependence of the current built-up area in the selected intervals of subsidence values in the individual time periods

(0.22 km^2) of the built-up area. The following interval of 200–300 cm shows rather balanced values in the course of the years as they range from 3.2% (0.14 km^2) to 3.8% (0.18 km^2). In case of the declines value of 300–500 cm there was a sharp rise in the built-up area that comparing the first and fourth time period reaches almost 650%, i.e. from the original 1.1% (0.05 km^2) to 7.1% (0.32 km^2). During the years, the built-up area erected on the declines of 500–1200 cm grew from zero value to 2.7% (0.12 km^2) out of the total built-up area.

The third part of the evaluation of subsidence concerned the evaluation in relation to the future development according to the land-use plan. An overlay analysis in the interest area identified a mutual relation between the forecast subsidence for 2003–2010 and the land-use plans of the municipalities reaching into this territory.

It was discovered that planning the future development (fig. 5) the impacts of declines in the territory have been considered only partially. The planned built-up area is mostly (56.68%, 3.79 km^2) placed in the localities without any subsidence. However, 17.44% (1.17 km^2) of new development is planned on the subsided territories up to 50 cm and almost one tenth (9.56%, 0.64 km^2) should be erected on the declines in the interval of 50–100 cm. According to this analysis, the third largest area of the built-up area (12.25%, 0.82 km^2) should be built on the declines in the interval 100–200 cm. From this point, the area of the land-use plan distribution has a falling character: 200–300 cm (3.26%, 0.22 km^2), 300–500 cm (0.73%, 0.05 km^2) and mere 0.09% (0.006 km^2) in the most prominent declines of this map sheet 500–1200 cm.

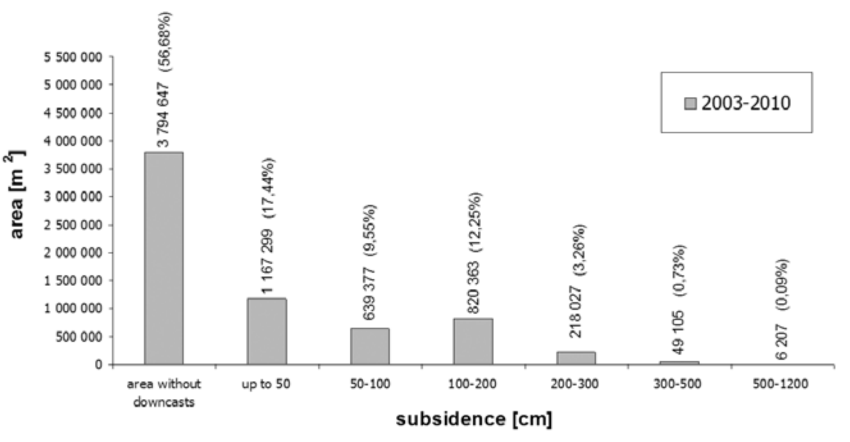

Fig. 5. Dependence of the future development in the interest area on the forecast subsidence intervals between 2003–2010

In terms of the evaluation of the conditions for the future development in the landscape affected by mining, we are interested in the relation of engineering-geological zones found within the reach of influence of certain values of subsidence caused by undermining (forecast subsidence 2003–2010). The spatial distribution of the individual engineering-geological zones in relation to the selected ranges of subsidence values is apparent from figure 6.

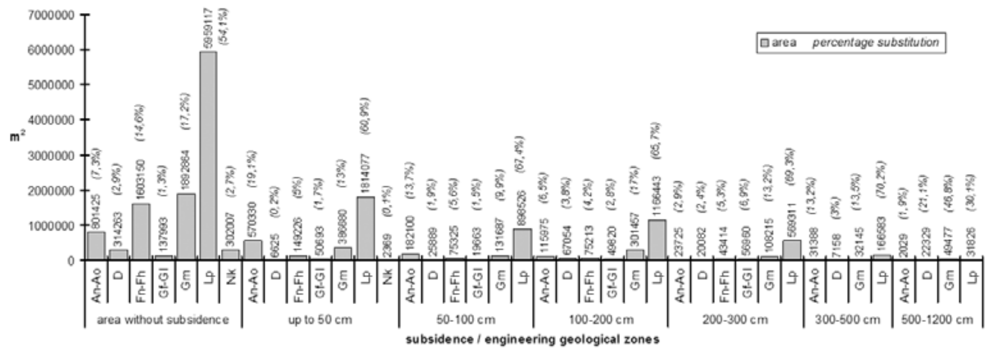

Fig. 6. Dependence of the dominant engineering-geological zone distribution on the forecast subsidence value intervals (2003–2010)

An *example of the evaluation of such an impact* is an area with the highest value of declines (500–1200 cm). It is the zone of moraine sediments G_m (46.8%) that has the largest distribution. According to the grain-size distribution and the character of plasticity there are clays with low to medium plasticity, uniquely at higher proportion of coarser clastics there are gravely clays. Their geotechnical characteristics depend on the specific consistency that is stiff to solid. The second most wide-spread zone is the zone of polygenetic loess sediments L_p (30.1%). Cohesive soils of this zone are the most wide-spread in the interest area, even in the localities affected by mining. At stiff to solid consistency they represent medium-bearing and medium-compressible foundation soils that were used, for example, for the construction of a new quarter in Karviná and the town of Havířov. With true loess their ability to subside cannot be excluded. As a rule, they are free of ground water. The third most important zone is the zone of deluvial sediments *D* with an area of 21.1%. The geotechnical characteristics of the soils in the zone are very variable and can be determined only on the basis of the results of tests and analyses directly in the locality in question. Seasonally, ground water may run through this geological environment on the ground of their pore permeability, which may influence slope movements in a more inclined terrain. The smallest area (1.9%) is taken up by the zone of spoil banks, stock piles and dumps A_n, and the zone of settling basins and waste dumps A_o. The zone A_n is represented by Carboniferous waste rock, slag and fly ash and the zone A_o constitutes anthropogenic deposits, rubble and solid municipal waste.

3. Conclusions

Evaluating the study of the interest area it can be stated that the carried out case study is a very good demonstration example for land-use planners and pedagogic opportunities to observe territories with the impacts of undermining on the current and future built-up area according to the land-use plan. It is possible to observe manifestations of a territory without any impacts of mining whose area significantly decreased in the course of the years from the original 60.43% to 49.84%. It is situated in the north-western direction from the considered diagonal south-westwards off the studied area with the manifestations of undermining. What is typical for territories with the impacts of mining activities is the possibility to observe their manifestations in the subsidence basin with the transition from small declines to more prominent ones based on the course of isocatabases.

As mentioned above, the identified trends confirmed the fact that along with time the territory that was not affected by any impacts decreased at the expense of an expanding subsidence basin. Therefore, redistribution of the impacts in the interest area occurred. It is necessary to point out that the evaluation of the factor is significantly influenced by time changes. It is the consequence of black coal mining in Karviná Mine (Plant ČSA, former Doubrava Mine, Doubrava allotment).

The growing trend of mining activity impacts was apparent also in terms of the evaluation of the manifestations of subsidence in relation to the current built-up area. The current built-up area was more and more affected by negative impacts of undermining in the course of the monitored period. Nevertheless, at present there is still over 50% of the built-up area that has not been affected by the black coal mining in the locality.

The future development was assessed by means of overlay analyses with the land-use plan. It proved that, for example, the planned built-up area on the most affected intervals of 300–500 cm and 500–1200 cm falls in the category U_V_1, while it is a functional area of the land-use plan, such as the zone of small-scale production, warehouses and technical equipment. This example confirms the fact of ignoring the geofactor of undermining by authorized land-use planners.

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