TECTONIC FACTORS INFLUENCING KARST DEVELOPMENT AND THE LIMESTONE SILICICLASTIC CONTAMINATION. CASE STUDY: MATEIAŞ LIMESTONE, JURASSIC, ROMANIA

BELEŞ Daniela, HOSU Alexandru

Abstract. The long and complex depositional and tectonic history of the Getic Carpathian Nappe has erected folded and faulted carbonate rocks, sandstones, shales and tectonic breccias (leaving aside the metamorphic core). In Hulei quarry, located close to Campulung city, the complex tectonic setting, mainly wrench faulting, with fault planes and especially share zones has induced an irregular spatial distribution of the contaminated zones of industrial limestone. In case of sections with tectonic breccias and then the faulted planes with an active water circulation and respectively their associated breccia, the contamination is represented by gray-greenish clay and sandstone karst infillings. The spatial distribution of limestone contamination shows the role of two main processes: the fault pattern and various phases of karstification.

Keywords: wrench faulting, siliciclastic contamination, limestone, Jurassic.

Rezumat. Factori tectonici cu influenţă în dezvoltarea carstului şi a contaminării siliciclastice a calcarului. Studiu de caz: Calcarul de Mateiaş, Jurasic, România. Evolutia depoziţională şi tectonică lungă şi complexă a Pânzei Getice a condus la fracturarea şi ridicarea unor serii de roci carbonatice, gresii, şisturi şi brecii tectonice (lasând la o parte masa centrală a suitei metamorfice). În cariera Hulei-Mateiaş, aflată în apropierea oraşului Câmpulung, contextul tectonic complex, fracturările prin forfecare, cu planuri de falii, dar în mod special zonele de forfecare, au determinat apariţia unei distribuţii spaţiale neregulate a zonelor de contaminare a calcarului industrial. În cazul secţiunilor cu brecii tectonice şi respectiv a planurilor de falie, facilitând o circulaţie activă a apelor meteorice, contaminarea este reprezentată prin umpluturi de carst, argile şi gresii cenuşiu-verzui. Distribuţia spaţială a modelului de contaminarie a calcarului subliniază rolul a două procese dominante: modelul de fracturare şi respectiv diversele faze de carstificare.

Cuvinte cheie: sisteme de fracturare prin forfecare, contaminare siliciclastică, calcare, Jurasic.

INTRODUCTION

The quality management of limestone deposits is always a challenging task, especially in case of sensitive industrial applications with particular quality requirements. The main elements affecting the quality of a high grade limestone deposits are karstification and tectonic processes, changing the primary chemical or mechanical properties of the rock. Exposed to weathering processes, limestone is a sensitive material, being affected in the upper section and/or sometimes even deeper by karstification processes, erosion, dissolution followed by siliciclastic infillings. Therefore in most of the cases, dozens of meters in the upper part of the deposit are largely contaminated by coloured (red, yellow, green, gray, etc.) siliciclastic rocks (sand and clay).

An intensive set of tectonic processes will modify a massif and homogenous limestone into a fragmented, brecciate mélange with fault planes or share zones with direct impact on granulometry of the mined material. In the same time, these strongly fractured areas facilitate the chemical weathering processes and karst development.

The limestone deposit mined in Hulei – Mateiaş area supplies several applications for construction industry, like cement, filler and lime for which the chemical or granulometric constrains are critical. In this situation the evaluation of the deposit in term of siliciclastic contamination and tectonic imprint are very important.

Geological setting

Limestone deposit Hulei-Mateiaş is located in the northeastern area of Câmpulung Muscel, Argeş County. The two limestone massifs belong to Dâmbovicioara area, on the eastern side of the Southern Carpathians. From the geological point of view, the limestone formation of the area concerned (Mateiaş Limestone, Kimmeridgian-Tithonian) represents the eastern ending of Getic Nappe, a tectonic unit of Median Dacides (Fig. 1), overthrusted and emplaced in the "Senonian", during the Late Cretaceous phase of deformation ("Laramic").

Due to a long subaerial exposure, involving intensive erosional processes, large parts of the Getic Nappe and especially the sedimentary rocks, have been eroded. Therefore, sedimentary patches of this large nappe can be recognized only in few areas, one of the most important being Braşov-Dâmbovicioara area.

Lithological units

A detailed geological mapping of the industrial limestone deposit from Hulei Hill-Mateiaş area identified and described the following lithological units (Fig. 2).

The metamorphic basement consists of greyish-greenish chloritic schist; it crops out both in the NW and the SE parts of the studied area. In the NW part, metamorphic rocks crop out along the access road to Hulei area and along the creek that starts from the spring located between Hulei and Mateiaş Hills. This basement was intercepted in different boreholes, which described and confirmed its nature and extension, as well as its relationship with the sedimentary cover. On the SE side of the area, the metamorphic basement crops out along the European road and along the road connecting the Mausoleum with Piatra village. As in the case of the NW area, numerous fragments, centimetre to sub-centimetre in size, of schists and quartzite are present on the surface.

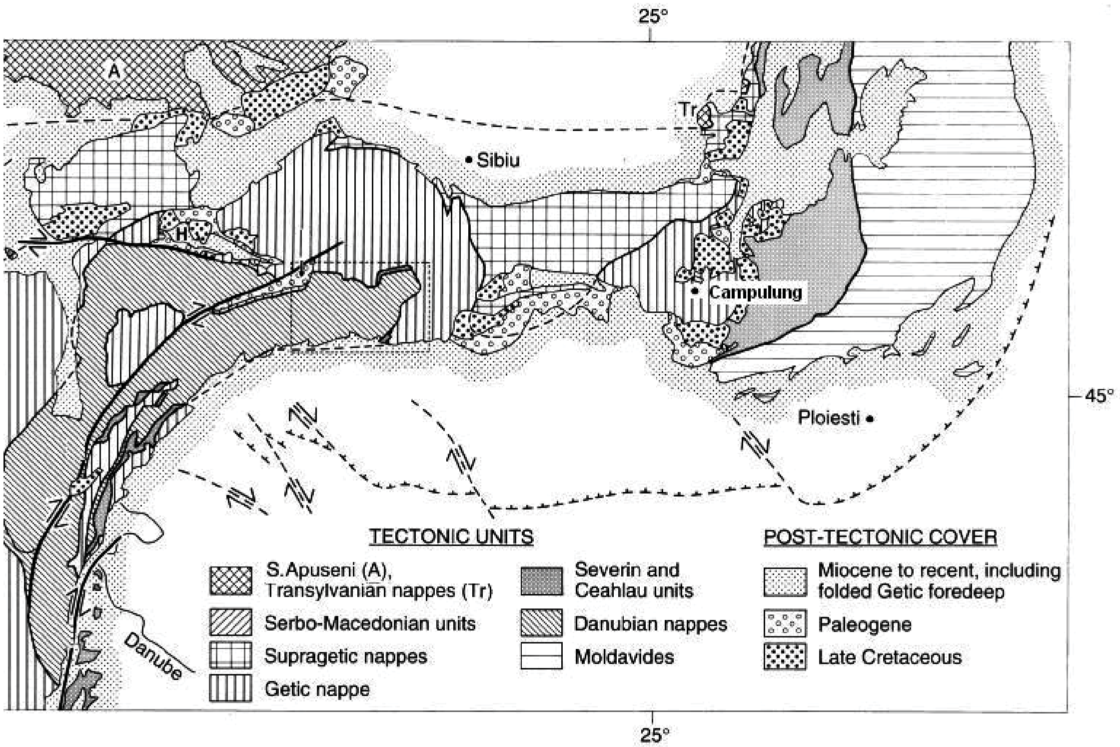

Figure 1. Tectonic map of the Southern Carpathians, based on the geological map of Romania, 1:1,000,000 (SĂNDULESCU *et al*., 1978) and on a tectonic map by BALINTONI *et al*., 1994. Structures in the Getic Foredeep.
Figura 1. Harta tectonică a Carpaţilor Meridionali, pe baza hărţii geologice a Romaniei 1:1,000,000 (SĂNDULESCU *et al*., 1978) şi a hărţii tectonice elaborată de BALINTONI *et al*., 1994 (in BERZA *et al*., 1994). Structura Avanfosei Getice (după MATENCO *et al*., 1997).

The Jurassic "reef" deposits represent the dominant lithological unit in Hulei-Mateiaş area and they are well-evidenced in both outcrops, as well as in the geological survey works. In the southwestern areas of both Hulei and Mateiaş Hills, blocks of reef limestone are caught within the finely-stratified limestone beds (Fig. 3). The blocks vary in size from m^3 to hundreds of m^3.

Geological processes responsible for limestone contamination

The finely-stratified limestone (turbiditic and hemipelagic deposits with silica nodules) are present in both Hulei and Mateiaş Hills being represented by, often folded, cm- to dm-thick beds of carbonate turbidites with frequent silica nodules. Compared with the reefal, massive facies, the turbiditic succession represents the only one sequence of the deposit with structural elements offering confident information concerning bedding, hence their spatial position. In Hulei Hill, these limestone facies are strongly deformed and folded, cropping-out along the road leading to the upper benches of the quarry, with a maximum development in the southern area of the quarry. In the southern part of Hulei quarry the elementary bedding is in the range of 10-20 cm thick, the succession passing gradually to coarser bedding towards NW, up to 50 cm thickness. This trend represents a general feature of turbiditic deposits. Diagenetic silica is better represented in the finely-stratified layers; its participation gradually decreases towards NW. In Mateiaş Hill, the finely-stratified limestone is less-developed as compared to Hulei Hill, but they are still present in the SE part of the area where the bed thickness is around 10-20 cm (ŞTEFĂNESCU & ŞTEFĂNESCU, 1985).

Cretaceous carbonate and siliciclastic conglomerates were identified in small basins developed in-between Mateiaş and Măgura peaks. On the outcropping areas, these *in situ* deposits occur most of the time as isolated blocks. These types of conglomerates contain well-rounded clasts of Jurassic limestone, and subordinately rounded clasts of metamorphic schists and quartzite are also present. The matrix is arenitic. This unit was intercepted in boreholes as well. Siliciclastic conglomerates were identified in the NE part of Mateiaş area and they consist of rounded clasts of metamorphic schists and quartzite. This unit is present only at the topographic surface level and it is delimited into three distinctive patches preserved on the plateau of Mateiaş Hill.

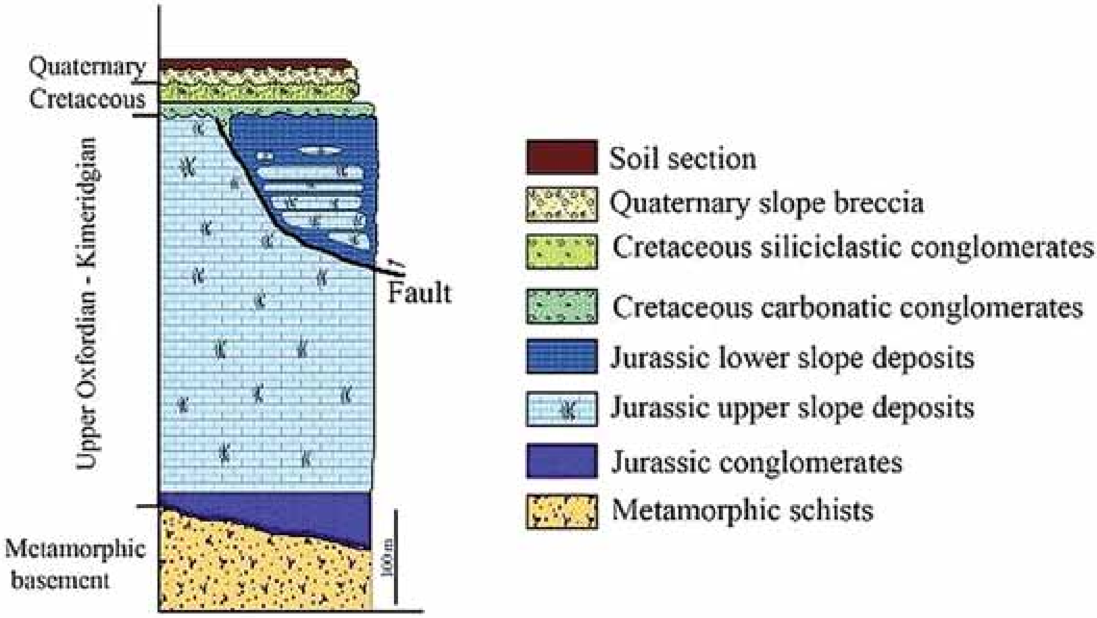

Figure 2. Synthetic litho-stratigraphic column of the limestone deposits in Hulei-Mateiaş area, Câmpulung.
Figura 2. Coloana lito-stratigrafică sintetică a depozitelor carbonatice din zona Hulei-Mateiaş, Câmpulung (original).

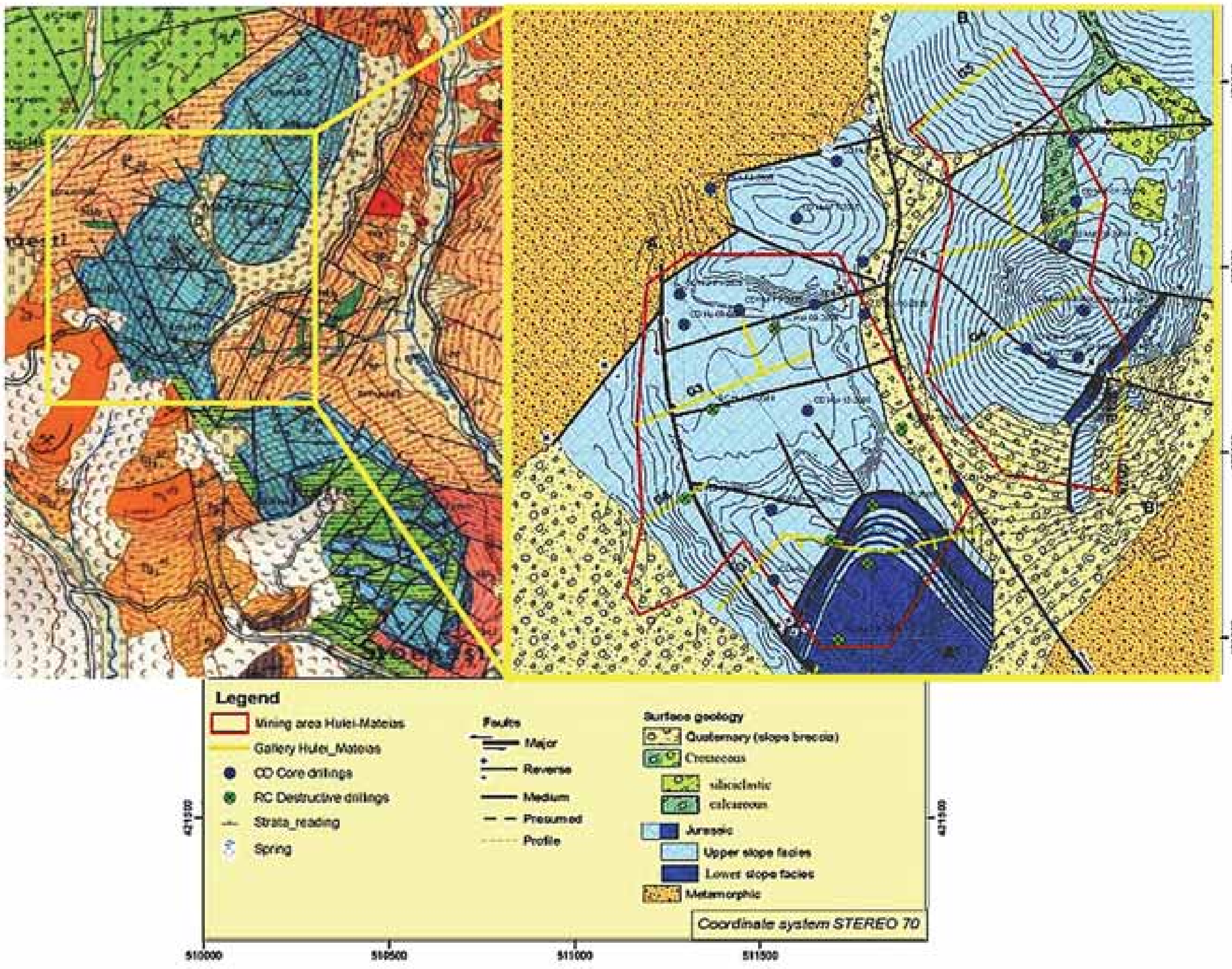

Figure 3**.** Geological map of Hulei Mateiaş area 1:50.000, sheet 128a - Câmpulung Muscel.
Figura 3. Harta geologică a zonei Hulei-Mateiaş 1:50.000, foaia 128a - Câmpulung Muscel (ŞTEFĂNESCU *et al*., 1983).

Quaternary deposits are represented by paleosoils and calcareous breccia accumulated at the slope toes (scree).

These sedimentary deposits have been affected by two tectogenetic phases. The first phase was pre-Albian when Getic realm overthrust movement was initiated, corresponding to the first Getic phase and the age of the first superposition being recorded between the Early and Late Aptian (SĂNDULESCU, 1994).

The second Getic phase, representing the main "Laramic" overthrusting event took place in the Late Cretaceous, when the Getic Nappe covered the Danubian units.

With the progress of geochronology, it has been established that many karstic systems in carbonate deposits are older than it had been thought. Karstification and tectonics have a parallel history. Thus, one can determine causal relations over time. Tectonic events such as strike-slip faults or earthquakes modify the endokarstic morphology and the fillings (QUINIF & VANDYCKE, 2001).

Tectonic processes: strike-slip and oblique-slip tectonics, flower structures

Strike–slip faulting is a common mode of tectonic deformations in Hulei-Mateiaş limestone deposit and occurs at a wide range of scales. Strike slip systems are relatively narrow and sub vertical **wrench zones** along which two adjacent blocks move sideways, horizontally, parallel to the strike of the fault zone. The transtensive strike-slip duplexes outline the following characteristics: fan-like architecture, rather steep faults converge at depth into a single and sub vertical fault, the deep main fault (the **stem**) is sub vertical, normal and reverse offsets along a single fault plane often result from inversion of the relative movement on the fault. This upward splay shape of subsidiary faults is termed a **flower structure** (Fig. 4).

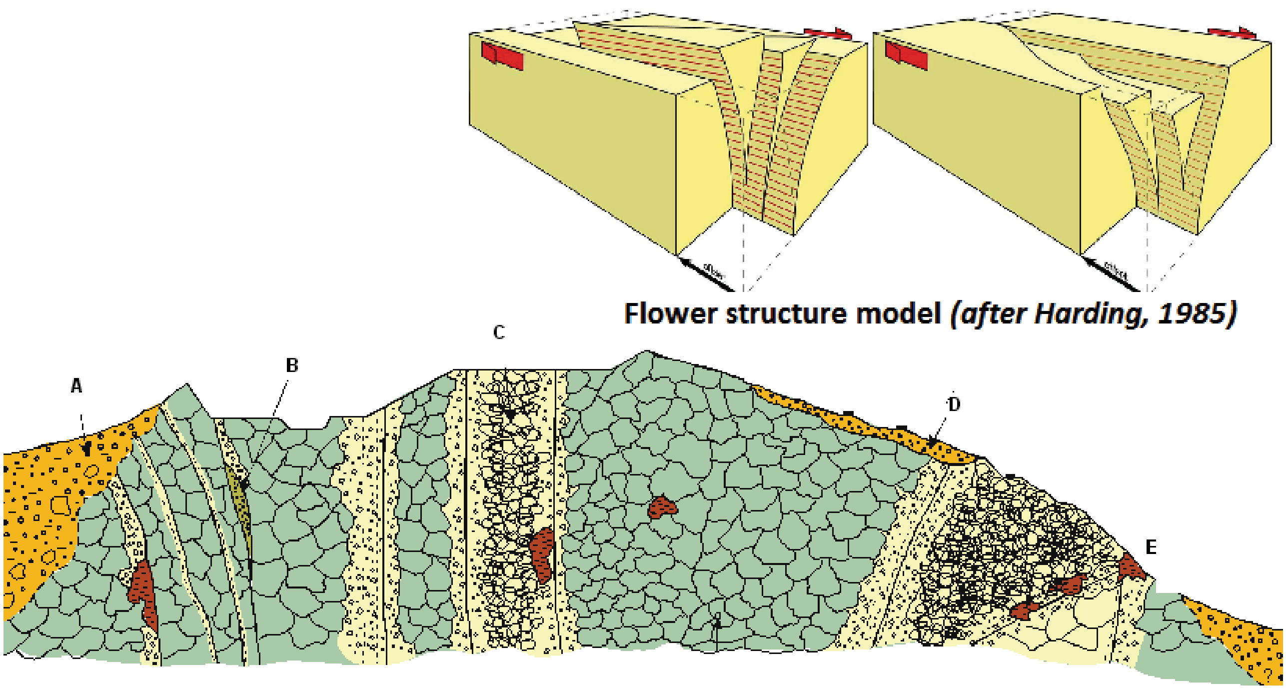

Figure 4. Flower structures recognized in Hulei quarry, outlining the distribution and types of tectonic/karst sediments contaminating the limestone deposit: A - scree talus, B - tectonically injected lens of sandstone and clay, C - strongly fractured limestone impregnated by clay and sandstone, D - pockets of surface scree, E - karst cavity in filled by sandstone, conglomerate and clay.
Figura 4. Structura tectonică de tip floare dezvoltată în cariera Hulei, subliniind distribuţia şi tipurile de sedimente tectonice/carst care contaminează zăcământul de calcar: A - detritus de taluz, B - lentile de gresii şi argilă injectate tectonic, C - calcar puternic fracturat impregnat cu argilă şi nisip, D - buzunare superficiale cu detritus, E - cavitate carstică umplută cu gresii, conglomerate şi argile.

The limestone cropping out in Hulei quarry is much more infilled by Cretaceous clastics, and this infill is linked to numerous faults (Fig. 4). The result of this geological process is a heavily deformed/fragmented limestone (Plate I, Fig. 2), therefore contaminated by sandstone, clay and conglomerates to various degrees (Plate I, Fig.1). This contamination is obviously linked to the faults and shows its largest concentration always along the fault planes, which can be 5 m to 40 m wide. All the karst holes are equally filled by clastic rocks. The model also implies that the limestone is contaminated at all elevations and that the contamination is not only a surface effect. Mining at greater depth will, therefore, not improve this situation.

Karst processes: endokarst and exokarst

There are two primary reasons that can be concerned with fractured and karst rock. The first one is structural integrity and the second one is ground water flow (which may be of concern as a ground water resource or as a pathway for contaminant transport, or in the case of an earthen dam may affect structural integrity of a site). Generally the karst includes surface and subsurface features, which are the result of dissolution enlargement of soluble rocks (and also mechanical enlargement by erosion and strain).

During the Early Cretaceous, Mateiaş Limestone which belongs to the front of the Getic Nappe, have been pushed to the south of the Southern Carpathians. Most probably the limestone became exposed to subaerial weathering and was karstified. At Lower/Upper Cretaceous boundary karst infill with clastic sediments took place, mainly green-gray sandstone and clay, but also conglomerates. This infill was accompanied or followed by a further tectonic phase, mainly wrench faulting, which smeared the clastic sediments into the faults (Plate II, Fig. 4). The near vertical position of the faults and the observed slickensides on fault planes corroborate this interpretation.

Finally there exists also a sub recent karstification, which created further caves. These caves, as long as they occur close to the present surface, are filled by various clastic materials (Plate II, Fig. 3), specifically a brown to red mass of clay and limestone fragments.

Siliciclastic contamination defined based on geochemical data

In order to evaluate the level of contamination of the limestone deposit developed in Hulei and Mateias areas, a geological survey based on drill-holes was conducted. Two types of drilling methods have been used: continuous core drilling and reverse circulating drilling. The thickness of the investigated section was between 50 m to 200 m.

The samples collected, 3 kg to 5 kg each, represent 2 m to 2.5 m length of borehole in homogenous sections or each type of material in case of sections with relevant lithological changes. In case of core drilling the sample represents half of the core, which has been split in two parts, one crushed and reduced with a splitter and the other one kept in the raw material storage. In case of reverse circulating method, the drilling chips and dust collected after the cyclone was reduced with the splitter up to 3-5 kg the rest being kept to the storage area. The level of contamination was evaluated as well by statistical analysis of the data resulted from the geological and chemical survey of the deposit (Fig. 5).

The high grade limestone (HGL) is characterized by very low levels of siliciclastic components respectively SiO_2 and Al_2O_3 and very high levels of the CaO as autigenic component.

In the case of normal karst infillings or tectonic injected lenses, the values of SiO_2 and Al_2O_3 are very high, indicating the large input of siliciclastic materials, sand and/or clay. As an intermediate situation, the highly fractured limestone and tectonic breccias impregnated with clay and sand present relevant values of siliciclastic components SiO_2 and Al_2O_3 balancing the CaO, as autigenic carbonate component.

CONCLUSIONS

During the Early Cretaceous, Mateiaş Limestone located in front of Getic Nappe, have been pushed to the south of the Southern Carpathians. Throughout the overthrusting processes the limestone units have been strongly tectonically deformed, being exposed to a subaerial weathering as well and consequently karstified. Later on, the karst infill with clastic sediments took place, mainly green-gray sandstone and clay, but also conglomerates. The spatial distribution of limestone contamination shows the role of two main processes: the fault pattern and to various phases of karstification.

This siliciclastic infill was accompanied or followed by a further tectonic phase, mainly wrench faulting, which smeared the clastic sediments into the faults. Consequently Mateiaş Limestone contains considerable amounts of clay and sandstone contaminations, although the limestone itself mainly reefal facies is of the highest purity. The limestone is heavily fractured as a result of tectonic movements. Finally there exists also a sub recent karstification, which created further caves. These caves, as long as they occur close to the present surface, are filled by various clastic materials, namely a brown to red mass of clay and limestone fragments. The contamination is not limited to zones close to surface but concerns the whole volume of the limestone

Geostatistical analysis can discriminate between different contamination patterns. In case of high grade limestone (HGL) the siliciclastic components respectively SiO_2 and Al_2O_3 are at very low levels but CaO as autigenic component indicates very high values.

In the case of normal karst infillings or tectonic injected lenses, the values of SiO_2 and Al_2O_3 are very high, indicating the large input of siliciclastic materials, sand and/or clay.

As an intermediate situation, the highly fractured limestone and tectonic breccias impregnated with clay and sand presents relevant values of siliciclastic components SiO_2 and Al_2O_3 balancing the CaO, as autigenic carbonate component.

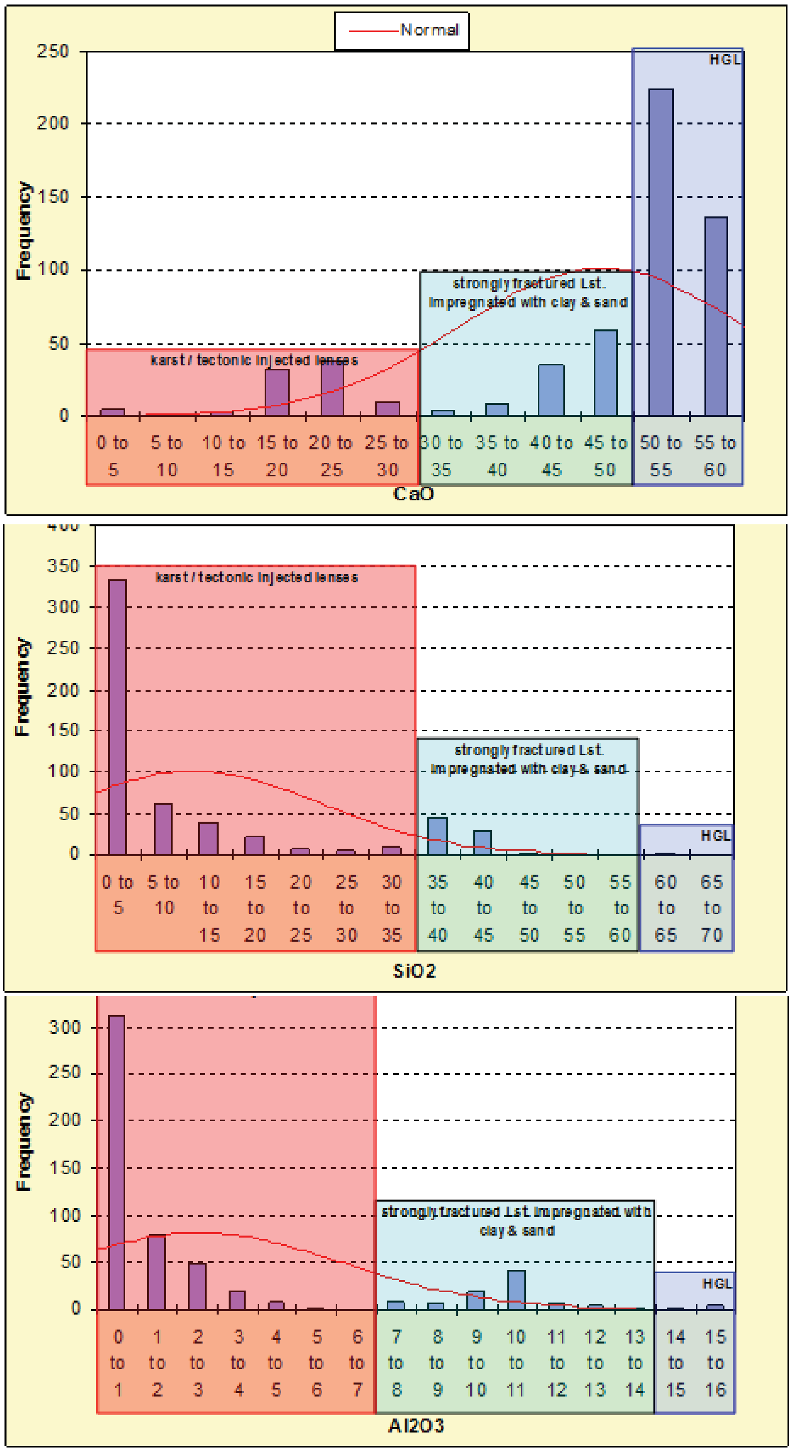

Figure 5. Distribution of CaO, SiO_2 and Al_2O_3 per type of material: HGL – high grade limestone, strongly fractured limestone and karst / tectonic injected lenses. / Figura 5. Distribuţia CaO, SiO_2 şi Al_2O_3 pe tipuri de materiale: HGL – calcar de mare puritate, calcar paternic fracturat şi contaminat şi respectiv lentile carstice sau injectate tectonic (original).

REFERENCES

BERZA T., BALINTONI I., IANCU V., SEGHEDI A. HANN H. P. 1994. *South Carpathians.* Romanian Journal of Tectonics and Regional Geology. (Supplement 2: ALCAPA II Field Guidebook). **75**: 37-49.

HARDING T. P. 1985. *Seismic characteristics and identification of negative flower structures, positive flower structures, and positive structural inversion.* Bulletin of the American Association of Petroleum Geologists. Edit. AAPG. Tulsa. **69**(4): 582-600.

QUINIF & VANDYCKE. 2001. *"Karst and tectonics"- Preface* . Geologica Belgica. University Liege. **4**(3-4): 3.

MATENCO L., BERTOTTI G., DINU C., CLOETINGH S. 1997. *Tectonic evolution of the region between the South Carpathians and the Moesian platform (Romania).* Tectonics. Edit. AGU. Washington. **16**. 896 pp.

SĂNDULESCU M., KRAUTNER H., BORCOŞ M., NĂSTĂSEANU S., PATRULIUS D., ŞTEFĂNESCU M., GHENEA C., LUPU M., SAVU H., BERCEA I., MARINESCU F. 1978. *Geological map of Romania, 1:1,000,000.* Institutul de Geologie şi Geofizică. Bucureşti.

SĂNDULESCU M. 1994. *Overview on Romanian geology.* Romanian Journal of Tectonics and Regional Geology, (Supplement 2: ALCAPA II Field Guidebook) Edit. Academiei. Bucureşti. 75: 3-15.

STEFĂNESCU M., GHENEA C., DIMITRESCU R., MIHĂILESCU N., DINCĂ L., GHEUCA I., MĂRUNŢEANU M., GHENEA A., STEFĂNESCU M., ANDREESCU I., MIHĂILĂ N. 1983. *Harta geologică scara 1:50000, foaia 128a (Câmpulung Muscel)*. Institutul de Geologie şi Geofizică. Bucureşti.

ŞTEFĂNESCU M. & ŞTEFĂNESCU M. 1985. *Stratimetry and structure of the Mateiaş Limestone*. Dări de seamă ale Institutului de Geologie şi Geofizică. Bucureşti. **69**(5)/1982: 109-115.

Beleş Daniela
Babes-Bolyai University
Str. Fantanele 30, Cluj-Napoca, Romania
E-mail: daniela.beles@holcim.com

Hosu Alexandru
Holcim Romania SA
Floreasca 169A, Bucuresti, Romania
E-mail: alexandru_hosu@yahoo.com

Received: March 28, 2012
Accepted: June 20, 2012

PLATE I / PLANŞA I

Limestone contamination - tectonic imprints / Calcar contaminat – influenţa factorului tectonic

Figure 1. Strongly fractured limestone including some sandstone and clay contamination.
Figura 1. Calcar intens fracturat contaminat cu gresii şi argile (original).

Figure 2. Apparent stratification; in fact it is all fracturing.
Figura 2. Structuri cu aspect de stratificaţie; în relitate sistem de fracturi (original).

PLATE II / PLANŞA II

Limestone contamination - karst infilling / Calcar contaminat – umpluturi carstice

Figure 3. Massive contaminations by green-gray sandstone (exokarst).
Figura 3. Contaminare masivă a clacarului cu umpluturi de gresii verzui cenusii (exocarst) (original).

Figure 4. Smeared the clastic sediments into the faults with green clay (endokarst).
Figura 4. Contaminarea fracturilor din calcar cu umpluturi carstice de argile verzi (endocarst) (original).