Activities of a Mine Surveyor and a Geologist at Design Bases in a Limestone Quarry

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Abstract. At the beginning of this article, the main historical milestones of Povážská cementáreň (cement plant) Ladce, a.s. (PCLA) are presented. The main parameters of the Butkov quarry are also specified (sources of the mineral resources) such as the size of the protected deposit area, the mining area, etc. Another part of the article is devoted to proposals for future mining process. There are two projects in connection with the basic investment plan for PCLA modernization. The first one is the preparation of the survey area for limestone - the stages above the current E15 and the other one is the preparation of the survey area for marl - the Moškové locality. Both of these projects were realized in association with Považská cementáreň, a.s., Ladce and VŠB - Technical University of Ostrava. An integral part of this article based on the project are also simulation of graphic models and diagrams. The last part of the article documents ways of the cooperation of Butkov Quarry and Považská cementáreň, a.s., Ladce with the public. The management of the Butkov Quarry and Považská cementáreň, a.s. have come to realize that their cooperation with the public on cultural and social activities helps both, the public and the quarry (include cement plant).

1. Introduction

This article provides basic information about the Butkov Quarry from historical, geological and also mining and technical points of view. The Butkov Quarry is interesting due to several facts. The vast majority of cement for construction purposes in Slovakia was mined in this quarry and produced in the cement plant. It is also worth mentioning that the management of the quarry and of the cement plant is actively involved in cultural events mainly in the quarry surroundings, but also in other regions. (Figure 1)

This article will, among other things, deal with the detailed description of extracted materials and their inclusion into technological groups for further processing according to their chemical composition, the proportion of minerals and the quality of the material. At the end of the article are tables, which indicate the composition of drilling flours from individual blasts in recent years.
In particular, this article will deal with two projects of further mining processes, which were created in cooperation between Považská cementáreň, a.s., Ladce and VŠB-TU Ostrava. The Ladce II mining area is a part of the reserved mineral deposit on Butkov Hill.

The main historical milestones and the main parameters of the Butkov quarry are currently listed in the following table 1 and table 2.

### Table 1. Main historical milestones.

| Historical milestone                                      | Year |
|-----------------------------------------------------------|------|
| quarry foundation                                         | 1889 |
| the first calculation of the reserves                     | 1966 |
| modernization of the ground facilities, new rotary kiln   | 1968 |
| extending the mining area from Ladce I to Ladce II        | 1985 |
| enlargement of the protected deposit area of Ladce II    | 2008, 2021 |
| extending the mining area Ladce II                        | 2016, 2021 |
| other cultural activities for the public                  | 2013 |

### Table 2. Main parameters at Butkov quarry.

| Parameter                                      | Unit         |
|-----------------------------------------------|--------------|
| the protected deposit area, Ladce II          | 1 482 653 m²  |
| the mining area, Ladce II                     | 1 102 651 m²  |
| the existing geological reserves of limestone Z1-Z3 | 365 296 000 t  |
| the existing geological reserves of marl Z1-Z3  | 56 720 000 t  |
| the average annual mining                      | 1 350 000 t   |
| max. height of Butkov Hill                    | +765 m a.s.l |

Figure 1. View of the Považská cement plant and the quarry [1]
2. The Butkov Quarry and its activities in the area of geological documentation

In the recent past, geological exploration has been realized in the area of the Butkov quarry. To achieve the objective of the geological task, a set of geological works (drilling, geological documentation, surveying work, sampling and laboratory work) were implemented between 2017 and 2021. These geological works were used to verify the cement raw material process for cement production at the Považská cement Plant Ladce, the central-eastern and central part, and the continuation of its balance development to the south of the Ladce Quarry [2].

For this purpose, the following geological works were used:

- archival research of geological work done so far in the proposed survey areas and in the vicinity
- search phase of geological survey
- tube sample boring of exploratory geological wells
- drill core evaluation collection
- mapping work
- partial reports from a geological survey
- final geological survey report

The specific objective was to confirm the qualitative and quantitative parameters of the limestone and marl structure for cement production - namely verification of 30 million tonnes of new balance reserves in the category Z-2 and with the quality of 76-78% of CaCO$_3$ content (up to 10% of marls), and verification of 30 million tonnes of new reserves in the Z-3 category and with the quality of 76-78% of CaCO$_3$ (up to 10% of marls). The planned reserves will represent an area of 0.12 km$^2$ with a minimum exploitable thickness of 300 m [2], see Figure 2.

3. Mined materials and their mining process in the near future

3.1. Classification of the reserves

Classification of the reserves of the exclusive deposits is regulated by Section 14 of Act No. 44/1988 Coll. as amended by Act No. 498/1991 Coll. and State Geological Authority (SGÚ) Decree No. 6/1992 Coll. on Classification and Calculation of Exclusive Deposit Reserves of the Slovak Republic.

According to the degree of exploration of the exclusive deposit or its parts and according to the degree of knowledge of its deposit conditions, quality, technological characteristics and mining and technical conditions, the exclusive deposit reserves are classified within the following categories: [4]

- Z-1 (verified reserves),
- Z-2 (probable reserves),
- Z-3 (expected reserves)

According to the suitability for economical use, the reserves are classified as:

- balance reserves,
- non-balance reserves.

3.2. Modules for preparation of raw material mixtures

- Lea and Parker SLP lime saturation module (degree of formation of C$_3$S and C$_2$S high-calcium compounds, their relative proportions) [1]

  \[ S_{LP} = \frac{100\%CaO}{2.80\%SiO_2 + 1.18\%Al_2O_3 + 0.65\%Fe_2O_3} \]  

- The silicate module M$_s$ (degree of clinker melt formation and thus the speed of sintering, dissolution, diffusion, nucleation - crystallization of the clinker phases, especially the basic clinker mineral alite C$_3$S) [1]
\[
M_S = \frac{\text{SiO}_2}{(\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3)}
\]

- **Aluminate module** \( M_A \) (degree of mutual ratio of resulting clinker minerals \( C_3A \) and \( C_4AF \) forming clinker melt – pervious mass between \( C_3S \) and \( C_2S \) or free lime \( \text{CaO}_{\text{free}} \)) [1]

\[
M_A = \frac{\text{Al}_2\text{O}_3}{\text{Fe}_2\text{O}_3}
\]

**Figure 2.** Proposal of the survey area in 2018 [1] certified by Milan Mikolas – main mine surveyor, issued by SBÚ – Slovak Mining Authority; ČBÚ – Czech Mining Authority

3.3. **Typology of limestones and marls at the Butkov Quarry**

During a few geological surveys carried out by the company GEOP in the past, a number of samples of four basic technological types of limestone from the Jurassic and Cretaceous period (as representative samples) and of marl from the Cretaceous period in the form of stone dust and for the preparation of raw materials were collected. These are the following types: [1]
• **Limestone T1** - it is a limestone of the highest class of the Early Cretaceous with intervention to the Middle Cretaceous - Urgonian, called white limestone. It consists of light grey to grey organogenic limestones, which are crystallized to a considerable degree. They are characterized by a high content of CaO and are interwoven with a CaCO$_3$ calcite network of up to a few millimetres. The content of harmful hornstone components is well below the specified conditions. It represents about 1.55% of the total amount of limestone reserves [1-3].

• **Limestone T2** - these are limestones of the transition phase between type I and type III limestones. Geologically (Barremian, etc.), radiolar limestone of the Cretaceous of dark grey to black in the Early Cretaceous (Neocomian) are in prevalence there, and they are represented by the so-called black limestone. They have a very variable chemical composition with frequent irregular SiO$_2$ balls and a thin network of calcite. It represents 11.5% of the total quantity of limestone reserves [1-3].

• **Limestone T3** - is the most widespread type of limestone in the deposit. These are marly limestones of the Early Cretaceous (Neocomian), so-called fair limestone, consisting of flesh-tinted, spotted and grey limestone with a relatively uniform distribution of alkaline components, but irregular occurrence of SiO$_2$ balls. Hornstones mainly occur in clusters. Continuous occurrence of hornstones was not detected. It represents 83.9% of the total quantity of limestone reserves. [1-3]

• **Limestone T4** – Malm Tithonian rocks with homogeneous composition represent it. It is made of pink, red and yellow-brown (Malm) limestone with a typical bulb-shaped structure. Of the total limestone reserves, they account for only 3.1%. [1-3]

• **Marlstones** - originated in the geological period of the Albian-Cenomanian. These are the calcareous marls of the Upper Albian and the Early Turonian. Their structure is finely layered with fine-grained layers alternating with layers containing coarser clastic admixtures or even sandstone layers. They represent 10% of the total reserves in the quarry. [1-3]

### 3.4. Qualitative characterization of the Ladce - Butkov deposit raw material base

The basic raw material component from the technological point of view are four raw material types of limestone (Table 3-7): [1]

- **Type 1** - light Urgonian limestones;
- **Type 2** - darker Urgonian limestones with hornstones;
- **Type 3** - grey Neokomian limestone;
- **Type 4** - red Malm limestone;
- **Correction** - Cenomanian lime clay, claystone and slate (Marls - marlstones).

#### 3.4.1. Limestone raw material type 1

They represent the supreme member of the Early Cretaceous - the coarse-grained organodetric limestone entangled with veins of white calcite. Depending on the chemical composition, these limestones are high percentage and have a stable chemical composition. The bulk density of white limestone - gravel limestone ranges from 2.66 – 2.70 g / cm$^3$, compressive strength reaches 1,820 – 2,000 kg / cm$^2$. [1-3]

**Table 3. Chemical composition of type 1.**

| SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | CaO | TiO$_2$ | P$_2$O$_5$ | MnO | Na$_2$O | MgO | K$_2$O | SO$_3$ | loss on ignition |
|---------|-------------|-------------|-----|---------|-----------|-----|---------|-----|-------|-------|-----------------|
| 8.55    | 1.9         | 1.17        | 47.82 | 0.16    | 0.12      | -   | 0.07    | 0.93 | 0.44   | -     | -               |

#### 3.4.2. Limestone raw material type 2

It forms radiolarian compact limestone and belemnite limestone with the positions of black hornstones. Besides calcite, they contain a clastic admixture of clay minerals. It is a compact fine-grained to microcrystalline rock with a conchoidal and partly sharp-angled fracture. The transition between hornstone black limestones and fair limestones is gradual and
characterizes their varying chemical composition. The density of these radiolarian limestones with hornstones is 2.45 – 2.7 g / m$^3$, compressive strength 400 - 1600 kg / cm$^2$. [1-3]

### Table 4. Chemical composition of type 2.

| SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | CaO | TiO$_2$ | P$_2$O$_5$ | MnO | Na$_2$O | MgO | K$_2$O | SO$_3$ | Loss on ignition |
|--------|-------------|-------------|-----|---------|-----------|-----|---------|-----|-------|--------|-----------------|
| 10.44  | 2.25        | 1.28        | 45.95 | 0.12    | 0.1      | 0.039 | 0.1    | 0.87 | 0.5 | 0.12 | 37.85          |

3.4.3. **Limestone raw material type 3.** They form marly limestone of the Early Cretaceous, which have a stable chemical composition and form a substantial part of the assessed raw material reserve. Early Cretaceous limestones have a typical mud structure. The bulk density is 2.64 - 2.68 g / cm$^3$, compressive strength 700 - 1000 kg / cm$^2$. [1-3]

### Table 5. Chemical composition of type 3.

| SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | CaO | TiO$_2$ | P$_2$O$_5$ | MnO | Na$_2$O | MgO | K$_2$O | SO$_3$ | Loss on ignition |
|--------|-------------|-------------|-----|---------|-----------|-----|---------|-----|-------|--------|-----------------|
| 12.14  | 2.55        | 1.42        | 45.03 | 0.14    | 0.1      | 0.12 | 0.89 | 0.57 | 36.72 |

3.4.4. **Limestone raw material type 4.** It forms red Tithonian limestone containing the clastic clay mixture and the topmost positions of bulb-structured limestones that protrude at the southern edge of the deposit in contact with the subsoil. The bulk density is 2.62 – 2.64 g / cm$^3$ [1-3].

**Figure 3.** Mining survey for the marl part of Moškové and limestone in the forefield of the quarry - survey boundaries marked in yellow [1]
Table 6. Chemical composition of type 4.

|  SiO₂ | Al₂O₃ | Fe₂O₃ | CaO  | TiO₂ | P₂O₅ | MnO  | Na₂O | MgO  | K₂O  | SO₃ | loss on ignition |
|-------|-------|-------|------|------|------|------|------|------|------|-----|-----------------|
| 6.25  | 1.73  | 1.00  | 49.99| 0.1  | 0.11 | 0.1  | 0.77 | 0.37 | 39.85|     |                 |

3.4.5. Correction. Cenomanian limestone clay, claystone and slate (Marls - marlstones). The marl deposit is made up of fine-grained sandstone positions with lime mastic. [1-3]

Table 7. Chemical composition.

|  SiO₂ | Al₂O₃ | Fe₂O₃ | CaO  | TiO₂ | P₂O₅ | MnO  | Na₂O | MgO  | K₂O  | SO₃ | loss on ignition |
|-------|-------|-------|------|------|------|------|------|------|------|-----|-----------------|
| 39.47 | 11.2  | 4.56  | 19.24| 0.59 | 0.15 | 1.02 | 2.03 | 2.56 | 18.55|     |                 |

3.5. Preparation of mining survey for marl - the part of Moškové locality limestone in the forecourt of the Butkov quarry.
Figure 3 shows the area of the limestone survey in the forefield of the quarry.

4. Cultural activities in Butkov Quarry and the region
The management of the Butkov quarry is not only innovative in terms of limestone mining and processing, but in their interest in the public, the environment and cultural events both near the quarry and in the whole region. In the years 2012-2018, the management of the cement plant participated in rare constructions within the quarry area, which are unparalleled in the European area.

4.1. Rock Sanctuary of Divine Mercy on Butkov Mountain
An example is the construction of the viewing terrace with a cross at 584 m - the 11th stage of the quarry in 2013. In 2015, the cross was joined by consecrated images - the memorials of St. John Paul II and St. Faustina, which contributed quite a lot to the fact that the viewing terrace became a place of pilgrimage in a very short interval, due to the increased interest of the public, gradually from around the world [4].

Figure 4. Construction of the cross [4, 5]
In 2016, a chapel for pilgrims was added to the cross and the monuments to St. John Paul II and St. Faustina, using natural materials and the artistic value of the ceramic paintings inside. (Figure 4)

Taking into account the unexpectedly high interest in this pilgrimage site and the safety of visitors, the quarry management built a cross path with stops for pedestrians, which leads outside the quarry area and reaches almost 1 km in length.

The most recent construction is the extension of the area with a 9 m high statue of the Virgin Mary and a relic of the saints, which were consecrated in May 2018.

Nowadays, this entire complex of buildings is called the "Rock Sanctuary of Divine Mercy on Mount Butkov".

More and more various meetings and events are taking place at this pilgrimage site, especially charitable ones, such as the Aleluja charity concert, which took place on 3 June 2017, arranged and financed by Považská cementáreň and featuring well-known singers such as Marie Rottrová, Jitka Zelenková and Helena Vondráčková. The financial proceeds from the voluntary collection of the concert participants were subsequently donated to a children's home [4].

Other activities include the bell tower of John Paul II, chapels with relics, the Detvian Cross, the entrance gate, sculptures of the Holy Family, St. Joseph, St. Anthony, a life-size statue of Christ and other buildings.

4.1.1. Partial depreciation of reserves. As the scenic terrace originally intended for the customers soon became the newest place of pilgrimage in Slovakia thanks to the construction of the cross and its blessing, this place of pilgrimage started to be visited by a large number of pilgrims. For this reason, the organization decided to propose the depreciation of the limestone reserves located in this part of the mining area. The main reason is the public interest and, in particular, maintaining safety and protection of life and health of visitors to this new place of pilgrimage located in the existing Ladce II mining area, who would be at risk due to mining of the reserves proposed for depreciation [1].

These were the reserves of the exclusive limestone and marl deposits in the Ladce II mining area, totalling 1,999,400 tonnes of limestone, classified as follows: [1]

**balance reserves of limestone - free** – 1,716,300 tonnes
Of which:
- In Z1 category reserve blocks amounting to 352,000 tonnes
- In Z2 category reserve blocks amounting to 786,400 tonnes
- In Z3 category reserve blocks amounting to 577,900 tonnes

**balance reserves of limestone - bound** – 283,100 tonnes
Of which:
- In Z1 category reserve blocks amounting to 0 t
- In Z2 category reserve blocks amounting to 166,900 tonnes
- In Z3 category reserve blocks amounting to 116,200 tonnes

Based on the results of the 2018-2020 prospecting survey, a reserve calculation for the exclusive deposit was approved by the Ministry of environment SR in 2021:
- Limestone reserves for chemical and technological processing: 365,296,000 t
- Reserves of clays for chemical-technological processing: 56,720,000 t
4.1.2. Reducing the mining area. Due to the importance of the public interest in the newly established place of pilgrimage and maintaining safety and protection of health and life of visitors to the place of pilgrimage, who would be at risk due to mining, the organization also decided to reduce the mining area.

The original Ladce II mining area covering 1,000,221 m² was reduced by an area of 17,659 m² to a total area of 982,562 m², and it forms an irregular geometric pattern with peak points 1 to 14 [1].

4.1.3. Authorisation of mining activities in the original mining area. In 2020, an opening, preparation and mining plan was submitted to permit mining activities until the reserves in the former mining area were extracted. Subsequently, in that year, the Prievidza district mining office issued a decision on the mining permit and a decision on the permit for blasting to replenish the reserves until 2103.

4.1.4. Change of the Ladce II Protected Deposit Area to the Hloža- Podhorie Protected Deposit Area. In 2020, a proposal was submitted in accordance with the applicable SR regulations for the amendment - extension of the protected deposit area Ladce II to the Hloža - Podhorie PPA (see Figure 5 - required mining survey documentation). After all the documentation was provided, the mining area was changed (extended) in May 2021 by decision of OBÚ Prievidza according to the original proposal.

![Figure 5. Ladce II Protected Deposit Area](image)

Legend: green - design of the boundaries of the protected deposit area Hloža – Podhorie; red – mining area Ladce II; 1-6, A-F, 13-1 - design of peaks of protected deposit area Hloža - Podhorie

4.1.5. Change of the Ladce II mining area to the Hloža - Podhorie mining area. In 2020, according to the current SR regulations, a proposal was submitted to change the extension of the Ladce II mining area to the Hloža - Podhorie mining area (see Figure 6 - necessary mining survey documentation). After
all the documentation was provided, the mining area was changed (extended) in May 2021 by decision of OBÚ Prievidza according to the original proposal.

**Figure 6.** Ladce II mining area

Legend: green - the boundaries of the protected deposit area Hloža – Podhorie; red – design of the new boundaries of the mining area Hloža – Podhorie; 1-16 - design of proposed peaks of mining area Hloža – Podhorie; A-F – peaks of the protected deposit area Hloža – Podhorie

5. **Conclusions**

This article shows how it is possible to combine the rational use of mineral resources for industrial production and sanctuary construction with intellectual property and the development of the local region.

There were about 100 participants at the beginning of the construction and consecration of the Divine Mercy Rock Sanctuary complex. Today, after 9 years of development of this complex, the number of pilgrims present during the annual pilgrimages in May and September averages 3000-4000 participants, only because of the limited space in the constructed complex. The complex was expanded in May 2018 to include a 9-meter statue of the Virgin Mary and other smaller structures in the vicinity. At the aforementioned benefit concert in June 2017, around 3500 people attended by invitation, while the interest was much higher; at the pilgrimage in May 2018, the number of participants exceeded 6000.

In addition to building this complex, it should be noted that the quarry and the cement plant fulfil their task in mining and the cement production very well; the last year’s production of extracted raw materials and subsequently produced cement exceeded 1.1 million tonnes, while ensuring the principles of occupational safety and safety of operation.
An integral part is the professional cooperation between the Faculty of Mining and Geology of VŠB – Technical University of Ostrava, the Povážská Cement Plant Ladce and since this year has expanded to include cooperation with the University of Žilina. The cooperation consists mainly in solving a complex of issues of mining, blasting, geodesy, mining surveying, and environmental protection as well as teaching specialists from the Cement Plant in this area in all forms of study.

References
[1] Internal documents of Povážská Cementárne Ladce a.s.
[2] B. NĚČ. Výzkum umisťování staveb a zařízení v dobývacích prostorech a chráněných ložiskových územích (Research on the placement of buildings and facilities in mining areas and protected deposit areas) [online]. VŠB-TUO, 2017 [Accessed 2018-01-17]. Dissertation thesis. VŠB – Technical University of Ostrava, (in Czech).
[3] J. Strigáč, J. Mikušinec, J. Strigáčová, and N., Štěvulová. The antifungal efficiency of carbide lime slurry compared with the commercial lime efficiency. IOP Conf. Ser.: Earth and Environ Science 92 (012058), 2017. doi:10.1088/1755-1315/92/1/012058.
[4] Ladce - church. Turistika.cz [online]. Praha: Turistika.cz, 2017 [Accessed 2018-01-17]. Available at: https://www.turistika.cz/mista/ladce-kostol-bozieho-milosrdenstva/detail. (in Czech).
[5] Butkov Cross [online]. Ladce: Nadace (Foundation) AGAPA, 2017 [Accessed 2018-01-17]. Available at: Kríž na hore Butkov - Kríž Butkov - Skalné sanktuárium Božieho milosrdenstva na hore Butkov. Available at: https://krizbutkov.sk. (in Slovak).