Limestone in V4 countries

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The article is dealing with the issue of limestone in V4 countries, in the countries, Slovakia, the Czech Republic, Poland and Hungary. The limestone is intensely mined because it has a multilateral use: it serves as gravel, building stone, peculiarly coloured varieties are used as a decorative stone; the largest quantity is consumed in the production of cement and lime. In the metallurgy, limestone (high percentile) is an important slag-forming additive; in confectionery is the source of necessary CO_2. At the beginning of the article, are analysed the general properties, formation and composition of limestone. It is followed by mining and preparation and processing of limestone. In the part of the article dealing with production, are parts focused on the production of V4 countries, but also part dealing with the production of concrete products and their use in the industrial sectors. Data collected about export and import of the limestone led to the acquisition of business analyses and the creation of maps for better visualisation of acquired knowledge. In the article are processed data of limestone, its production in V4 countries and export and import, which were statistically processed and evaluated by the test Wilcoxon / Kruskal-Walis. As can be seen from the collected data and its processing, the business has a local character. The biggest producer is Poland, followed by the Czech Republic, Slovakia and Hungary. Biggest exporter of the limestone is Poland; the biggest importer is the Czech Republic.

Keywords: *limestone, V4 countries, production of limestone, export, import, cartographer, Wilcoxon / Kruskal-Walis Tests*

Introduction

Limestone is sedimentary carbonate rock of the pre-amber and recent age, which forms about 15% of the sedimentary lithosphere. Limestone is present in almost all sedimentary geological formations around the world. The major rock component is calcium carbonate (CaCO3) - most often as calcite, rarely aragonite. Limes are often coloured with various admixtures (limonite, hematite, serpentine, organic material, clay minerals). Depending on the method of formation, limestone deposits are divided into sedimentary sea deposits (detrimental, chemogenic, organogenic limestone) and freshwater sedimentary deposits (travertines and sinter). The limestone often occurs along with the dolomite, and it can be a part of this rock. Based on the ratio of calcite and dolomite minerals, respectively clay is classified as limestone, dolomitic limestone or clay-limestone (Petránek, 2018). We analysed limestone in the countries of V4, which are Slovakia, Czech Republic, Poland and Hungary. We took into consideration the geology of limestone in countries, production of limestone, and exploitation of limestone, processing and trade of limestone in the V4 countries. We have been studied trends and possibilities of using raw materials as it is mentioned by (Kogło et al., 2017) and analysed the potential deficit of minerals as it can be seen in (Witkowska-Kita et al., 2017). Mineral industries are well described by (Steblez, 2004).

It is important to take in consideration that non-metallic raw materials are mainly local players, as for example kaolin, like (Lopes et al., 2018) wrote. The theory is support by other authors, (McDaniel et al.,2015).

The utilisation of limestone is in several industries. With industries are connected economic activities, as it was written by (Dikshit, 2014). Processing and finishing of the goods are well described by the authors (Hoda et al.,2013).

As we mentioned above, limestone is used mainly in countries where it is mined or is exported or imported for short distances (Straka et al, 2018). With a similar topic is dealing (Soleimani, 2018). We are in the article dealing with the V4 countries, but good inspiration for us was (Dolia, 2017), describing the situation about raw materials and economy in Ukraine.

The processing of limestone and its utilisation in industries are well written by the author (Baláž, 2006) and (Baláž et al., 2014).

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Material and Methods

We have proceeded in this chapter as follows. We have divided the methodology into the following processes, as can be seen in Figure 1.

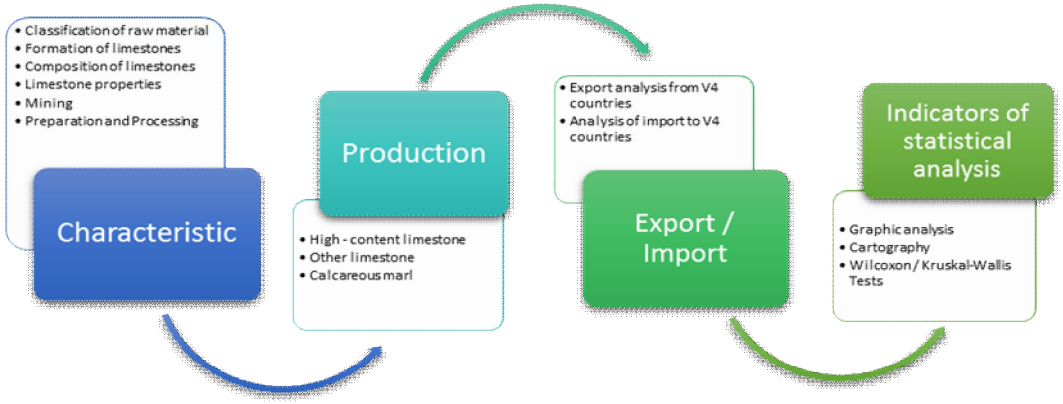


Fig. 1. Methodology and its visualisation (own processing).

We have described individual variables, characteristics, production, export/import and indicators of statistical analyses of the raw material, which is in our case the limestone, through their most important features and processes.

In the text below one can find the facts. Data were processed by statistics methods. We have made nonparametric tests. Nonparametric tests are useful when the usual analysis of variance assumption of normality is not viable. The Nonparametric options provide several methods for testing the hypothesis of equal means or medians across groups. Nonparametric multiple comparison procedures are also available to control the overall error rate for pairwise comparisons. Nonparametric tests use functions of the response ranks, called rank scores. See (Hajek, 1969) and (SAS Institute Inc., 2017).

Note the following:

For the Wilcoxon, test, if the X factor has more than two levels, a chi-square approximation to the one-way test is performed. Performs a test based on Wilcoxon rank scores. The Wilcoxon rank scores are the simple ranks of the data. The Wilcoxon test is the most powerful rank test for errors with logistic distributions. If the factor has more than two levels, the Kruskal-Wallis test is performed. The Wilcoxon test is also called the Mann-Whitney test.

Classification of limestone

Limestone is sedimentary rock forming together with dolomites four-fifths of all sediments on the Earth's surface. It consists of calcium carbonate ($CaCO_3$) (over 80 %), whether in the form of calcite or aragonite. Admixtures are dolomite, siderite, quartz, clay minerals and fragments of fossils. Pure limestone is white (called chalk), various admixtures colours them in grey, red.

According to the place of origin, limestone is divided into:

- Shallow sea limestone occurs rarely. Sediments are composed of limestone sand formed from fragments of shells, which are associated with limestone mud.
- Deep-water limestone is divided into two groups:
  1. Turbid limestone
  2. Pelagic limestone

Turbid limestone is not very widespread; they are known from older formations. They occur at the mainland coasts, where the undersea sediments are merged into the sea and processing by the turbulent current.

The sedimentary environment of pool limestone is in deep ocean basins, where limestone sludge is deposited in the depth of 2,000 to 3,600 m. At greater depths (over 4,000 m) the lime sludge dissolves again.

Limes associated with evaporating - small accumulations of limestone also occur when evaporating temporary lakes in desert areas. The layers of these rough, uneven layers are called caliber and calcretes. The auxiliary minerals are evaporated, especially gypsum and anhydrite.

Freshwater limestone is created in lakes in the form of lake chalk, which is actually a clay lime sediment. Another type of freshwater limestone is oncoids produced by algae with a strong porous texture. The last type is travertine, which is formed by precipitation from thermal sources.

Eolic limestone is created when developing humid fragments from coral reefs on the shores of the seas and subsequent formation of solid layers, which are also called eolianites.

The process of limestone formation is multiple and takes place in different environments from the surface to the depth. During the conversion of mud to limestone, six basic processes are in progress: cementation, micritisation, neomorphosis, dissolution, compacting and dolomitization.

The formation of limestone

Limestone is an organogenic sedimentary rock formed from calcareous shells of living organisms. The shells of marine animals and their skeletons contain calcium that has been extracted from the seawater during their lifetime.

Limestone was created from:

- shellfish,
- the shells of other microscopic organisms,
- Coral shelves.

Shells of dead corals create under living corals layers of hundreds of meters. The shells of dead molluscs are gathered in the shallow seas. The shells of unicellular organisms (plankton) accumulate at the bottom of deep seas.

Composition of limestone

Limestone is a solid sedimentary rock, which is predominantly composed of calcium carbonate. It accounts for more than 80 %; the remaining part is less than 20 %, for example, dolomite, siderite, quartz, clay minerals and fragments of fossils. Limestone rock is forming together with dolomites four-fifths of all sediments on the Earth's surface.

Limestone contains calcite grains and admixtures of clay or organic substances. We know more species of limestone according to the composition. The limestone can be, for example:

- Lumachel limestone - formed mainly from the shells of molluscs,
- Limestone - formed from microscopic organisms,
- Coral limestone - formed from coral.

Changes begin immediately after storage or even during storage, and may take place both in the marine and terrestrial environment. The absolute majority of limestone is of biochemical or organic origin.

Cementation and micritisation occur on the seabed, where cementation is more characteristic of the active environment and micritisation for the seawater. At higher depths, dissolution of calcite occurs. Dissolution depends on the degree of water saturation by calcite, while in cold waters this saturation is smaller. Thus, with decreasing depth, it decreases. It is caused by fresh water, while dissolvation, cementation and soil producing happen. Overlapping with other sediments - compacting (limiting) of the limestone layers happens by mechanical grain saturation in the structure or by chemical reactions. The limes are predominantly composed of calcite, alternatively of aragonite. Calcite is involved in the composition of primary and secondary limestone components.

If the rock-forming organisms make their shells of calcite, it is quite pure, and in the case of aragonite, there are magnesium compounds. If they are high (more than 4-mole percentage $MgCO_3$), we talk about high-magnesia calcite. However, high Mg content is unstable in calcite, therefore older, low algal limestone has low magnesium content. High-magnesia calcites are used for shells, for example, cephalopods and corals.

Aragonite is also unstable, changing to calcite, so it only contains recent limestone. Dolomite in limestone is not primarily present; it is only a result of later metasomatic processes. Siderite is a rare addition to limestone. It occurs in formations in which limestone and siderite iron ores are associated. Of the accessory minerals, which is present in the form of chalcedony spherolites, is of greater importance.

Kaolinite and feldspar are presented from other silicates. Other minerals (phosphates, glauconitic, gypsum) are not a common accessory, and their occurrence is due to specific sedimentation conditions.

Features of limestone

Limestone is polygenetic rocks. A large part was originally mechanically moved and deposited similar to other classical sediments; others were chemically precipitated from water. That is why their textural characters are different. The first group has hydrodynamic textures, while the other is very specific and depends on the environment.

The textures formed by the hydrodynamic model are the same as in the classical sediments - sloping layers, gradation layering, and features on the surface. Paleocarous surfaces are formed by dissolution with bottom water. Irregular shapes, cavity surfaces with cavities are formed. The fenestral texture is a generic name for carbonate cavities, filled with sparites).

Stromatakis is formed in shallow waters and has large irregular cavities. Tuber textures are created in shallow water limestone - they are actually traces of animal bruising. The limestone has approximately the same hardness, good acid solubility in the release of CO_2.

It also dissolves in water, which contains CO_2 to form calcium bicarbonate ($Ca(HCO_3)_2$). This phenomenon is the cause of karst phenomena such as caves, slopes and others. Karst is the name for a limestone area, where erosion factors have occurred to remove the humidified shell and depletion of rock massifs. Due to the chemical exfoliation, the original geological structure and the formation of typical karst formations are disturbed here. These are divided into primary and secondary.

The quality of the limestone found in the deposit depends on its long-term development and the surrounding environment. These features affect the amount of non-carbonate minerals (impurities such as clay, quartz sand, etc.) in the sediment. When the limestone reaches the earth's surface, it can contain impurities from rainwater. Earthquakes and other natural phenomena cause rifts in the limestone and by these can get inappropriate minerals into it and remain there forever.

Within a single quarry, limestone layers may have very different properties and changes in the course of the deposit.

Colour: Limestone can be white, grey, dark, and sometimes red.

Exploitation of limestone

There are several activities at the same time.

Blasting works are planned on the basis of a mining plan - it determines where, when and what methods can be used. If necessary, it is possible to carry out selective blasting or, conversely, mix the material from the blasts in different areas. It is necessary to ensure responsible use of inventories and at the same time satisfy customer requirements.

Mining usually begins with drilling and blasting, followed by loading and transporting the ground rock into the primary crusher. The quality and the enormous amount of stone needed for the treatment in the processing plant is ensured by a carefully designed blasting program. This is an essential step in the process.

In the quarries where blasting is used, the drilling rig drills holes for explosives. Non-crushed stone is commercially utilised in another way or used to fill the pit and reclamation the site after the quarry has been closed.

Preparing and processing of limestone

Stone adjustment consists of primary and secondary crushing. The product is then classified by a fraction. If necessary, washing of the stone can be done with recycled water, usually obtained from settling tanks. After crushing, the stone is placed on the deposition area to ensure a constant supply of stone for subsequent processes.

For lime and dolomite lime production, rock fractions greater than 20 mm are usually sent to blast furnaces. Limestone which is not intended for industrial calcination is usually modified for further applications.

During the production of limestone with a high content of calcium for the chemical industry or dolomitic limestone for industrial use, the rock either mills or dries and mills, thus obtaining the purity and desirable characteristics of the markets, whether in the form of stones or milled products.

The core of the transformation is the kiln, that can transform the crude carbonate rock on lime oxide or dolomite lime, which offers a wide range of usable properties.

Chemical transformation requires a considerable amount of energy and these large industrial facilities. Different types of technologies are used especially rotary and vertical furnaces.

Rotary furnaces produce lime with controlled reactivity and provide complete decarbonisation with very low residual CO_2. These furnaces are capable of providing products with the particular specification, for example, lime with low sulfur or special reactive lime and also dolomite lime. This helps improve resource efficiency.

Once the lime is pulled out from the kilns, it should be sorted and stored according to the particle size, residual CO_2 content and other physical and chemical properties determined by the laboratories. Classification is carried out using conveyor belts, elevators, crushers and sorters. According to particle size, lime is divided into three main categories: pieces crushed and ground lime.

Lime can be further processed to obtain new features and meet the needs of the latest applications. There are three main processes for lime processing:

1. CRUSHING AND MILLING - Lime is crushed in the following types of mills equipped with graders: hammer mills, rotary ball mills, vertical pendulum mills and pelvic mills.
2. HYDRATION - forms dry powder - calcium hydroxide $Ca(OH)_2$. The hydrator consists of one, two or three hydrating chambers and a mixer where the water starts to react with the starting line. Excavated lime is distributed by particle size and stored in strength.
3. PRODUCTION OF LIME MASH - Lime milk is industrially produced in stirred reactors, either from burned or slaked lime, in the presence of more water. The final product is slurry of lime.
4. According to usability is limestone and cement materials divided into:
   - o High-content limestone ($CaCO_3$ content> 97%), or high-grade limestone
   - o Another limestone,
   - o Calcareous marl.

High-content limestone is a material used in:

- Metallurgy (agglomeration);
- Chemical industry (production of cellulose, chlorine lime, soda, carbide),
- Rubber industry,
- Food industry,
- Glass and ceramics industry (filler, enamel flux, glaze preparation)
- Building industry (production of lime and some types of building materials).

Limestone with less quality is used in:

- Agriculture (soil limestone - a reduction of acidity, fertilisation, production of compound feed)
- Building industry (building and decorative stone, building materials).

Limestone is mainly used for the production of a cement material (Petránek, 2007).

The limestone is intensely mined because it has a multilateral use: it serves as gravel, building stone, peculiarly coloured varieties are used as a decorative stone; the largest quantity is consumed in the production of cement and lime. In the metallurgy, limestone (high percentile) is an important slag-forming additive, in confectionery is the source of necessary CO_2 etc.

Limestone material is not recycled, respectively. Is recycled secondary to some products (glassmaking, building industry, etc.). in agriculture limestone can be replaced by dolomites, burnt lime, etc. Various carbonates and their mixtures can be used in the case of desulphurization of the gases.

Limestone and dolomites replace each other by neutralising acidic waters, soils, gases, or they can be replaced by natural and synthetic zeolites or anaerobic bacteria (biological technologies).

In some industries, however, there is no adequate substitution for limestone (production of cement, lime, production of blast furnace raw iron) (Petránek, 2007).

Results

Production in the Slovak Republic

Limestone belongs to the most used raw materials in Slovakia. The consumption of limestone is covered entirely by domestic mining, which exceeds 7 million tons per year, of which about 40% are high-percentage limestone. The most important producers of high-grade limestone are Holcim, JSC (Deposit Vajarská) and Carmeuse Slovakia, Ltd. (deposit Slavec - Gombasek). In the mining of another limestone, the leading position belongs to Carmeuse Slovakia, Ltd. (deposit Vļeláre). Other important producers are also Dobývanie, Ltd. (StráŘavy) and Povaġská cementárŘa, JSC (Ladce). Limestone is mainly used as a material for the production of cement and lime. Cement is the most important Slovak export commodity based on a mineral base. Limestone mining is maintained at a relatively stable level (Baláġ, 2006).

In 2016, the limestone material, cement materials and dolomite reached the second highest revenue per employee. Labour productivity and efficiency are one-third higher than the average for total mining. The share of enterprises classified in the CZ-NACE B division, Mining and quarrying of raw materials is about 40% in this material measured by the share of revenues. According to the assessment of absolute indicators, it is a medium significant material in the number of organisations and revenues. According to other absolute indicators,

limestone is less important raw material. Between 2012 and 2016, most of the absolute indicators have improved to added value.

According to relative indicators, limestone is rather a low evaluated material. However, the value of the revenue per employee indicator, due to the link with non-taxed businesses is significantly above average. In terms of dynamics between 2012 and 2016, relative indicators are declining in practice. In 2013, there was a significant decline and growth in 2014 (Starý J. et al., 2017).

Production in Poland

Limestone with a content of $CaCO_3$ above 90% is a mineral used in lime. Variants that have other criteria are used in the chemical industry, metallurgy, sugar industry for lime meal production, including sorbents for flue gas desulphurization. Limestone as a material is used on a cement clinker product that requires the addition of raw materials from the clay. Limestone and spittle are minerals that are only useful in the cement industry. The $CaCO_3$ content may be significantly lower in this case (less than 80 %). However, the content of other chemical constituents and the proportion of their percentages is important (Brzezinski D., 2013).

Production in the Czech Republic

Limestone in the Czech Republic is industrially very important, whose reserves seems to be large, but in fact they are heavily limited by the fact that a significant part of their reserves are located in protected areas (for example the Bohemian Karst, Moravian Karst) or areas thanks to large morphological clusters of landscape, botanical or zoologically attractive. Sources of limestone can be found in many places in the Czech Republic. The most significant areas are Devon Barrandien, the most important and largest bearing area of the Czech Republic with deposits, Konoprusy, Kozolupy-stains in the structure, Kosor-Hvíz̦alka, further Moravian devon, as the most important area in Moravia with deposits, for example, Mokrá pri Brne, Hranice-Ľ̦ernotín; other important deposits are Prachovice, Vitoġov-Lesnice, Vtramberk and Úpohlavy (Starý J., Kavina P., Vaneļek M., 2009).

Resources of limestone in the category of industrial sources reach about 150 yearly life at the current level of mining, which traditionally represents about 10 to 11 million tons per year, resulting in that limestone is being the most widely used raw material. The mining of limestone and cement raw materials are generally directly linked to the processing industry, which has a long tradition in the territory of the Czech Republic (lime and cement in particular). These investment units have been in the past an important item of Czech foreign trade and have been successfully delivered to many Third World countries.

Due to this tradition, the early 1990s, the rapid and successful privatisation of Czech prosperous businesses happened, which were also taken by German and French investors as well as a well-studied raw material base. Also, a significant Swiss investment was made in the Czech Republic for the mining and processing of super pure calcite suitable for microfilm for the production of fillers. In the last decade, the decline in the production of ground limestone for agricultural purposes has been observed, due to a lack of funds for agro-technical purposes (MPaO, 2012).

Production in Hungary

Hungary is also known for its limestone quarries, most of which are located in mountainous areas like in the Bükk and Upponyi Mountains, in Bélapátfalva, Bükkzsérc, Cserépfalu, Eger, Egerszalók, Felsőtárkány, Miskolc-Diósgyőr, Miskolc-Omassa, Miskolc -Tapolca, Mónosbél and Szilvásvárad, in the Pilis and Budai Mountains (Budlakalász, Budapest III.ker., Kesztölc, Pilisjászfalu, Pilisszántó, Remeteszőlős, Sóskút), Velencei and Szabadbattyáni-rög (Polgárdi) (Csövár, Keszeg, Vác), Gerecse (Bajna, Csolnok, Dorog, Héreg, Lábatlan, Tardosbánya, Tatabánya), Mátra (Eplény, Hárskút, Sümeg, Tapolcafő, Ugod) Sirok), Mecsek (Pécs, Pusztakisfalu, Versend), Villányi (Beremend, Csarnóta, Nagyharsány, Siklós - Máriagyűd, Villány) (Nagy, 2018).

The Komarnian region is known mainly for the exploitation of red marble, basalt, coal mines and limestone quarries. Marble and limestone mines on the western side of the Gerecse Mountains in the eastern Komarno are known for centuries. Limestone material extracted from this area is a solid and hard limestone that is suitable for treating. Between years 1850-1855, the stone material was transported to the fortification of the Komárom castle; and later in the imperial palace in Vienna, where the entire basement from top to bottom consists of stones carved in Hungary. Marble and limestone materials were also transported to state buildings in the countryside; specifically for the construction of the church of St. Stephen in Budapest, New House, Harbor Bridge, the church of Budin and the building of the Ministry of Finance. In the area of Tardos and Dunaaaslm, there are limestone quarries where there is an average of 200 workers and where the production is about 1500-1800 m^3 per year (Borovszky, S., 2010).

Limestone is used in various forms in the metallurgical, agricultural and sugar industries. The limestone meal is used in the agricultural industry and contains minerals that improve soil properties (Dömsödi, 2010).

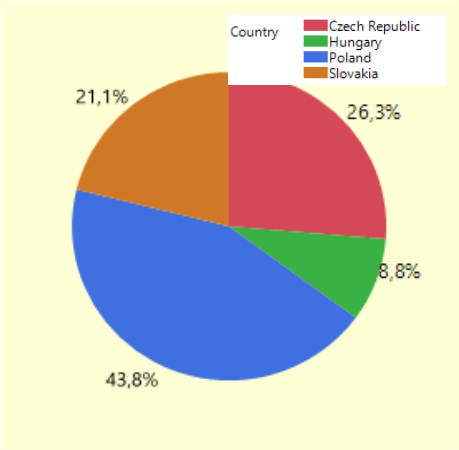
The limestone mining in Hungary from 2003 to 2013 had a decreasing trend. While in the year 2003 ï 2008 was mined 500 thousand tons of limestone, which represented a constant value. However, since 2009, mining has declined. In 2010 mining fell to almost half (less than 260 thousand tones), in 2013 it was less than 200 thousand tons per year.

One of the reasons for the decline in mining and production is the non-renewable of limestone deposits, as well as the replacement of limestone with other materials. Hungary has high-quality mineral resources, mainly building materials, but the building industry has not experienced any major boom in recent years, and for this reason, also the mining of construction materials has declined significantly in recent years (Horn, J., 2013).

Production in V4 countries

By analyzing the production of limestone in the V4 countries in 10 years it is possible to sort the countries according to the importance of the rate, the biggest producer is Poland, which produces 43 % of the raw material, the Czech Republic and Slovakia produce over 20 % of the raw material and the lowest volume of production up to 10 % is Hungary, see Figure 2. Within 10 years, there may be a slight decline in production in the V4 countries (Fig. 3), but this does not affect the long-term.

Structure of V4 production



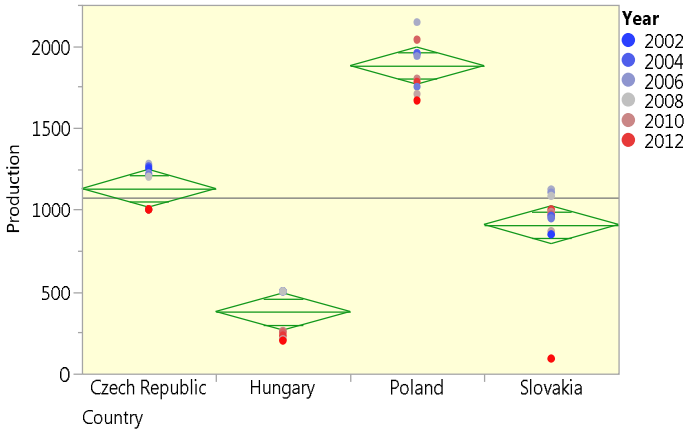


Fig. 2. Structure of limestone production in V4 countries. *Fig. 3. One-way analysis of limestone production for 10 years.*

(Own processing according to www.indexmundi.com, both figures Fig. 2 and 3.)

Analysis of limestone sales prices

Following the analysis of the production of limestone in the V4 countries and then the analysis of import and export in volume units (tones), the development of these indicators was evaluated with regard to the sales prices of the raw material, which has an impact on the economic balance of individual countries.

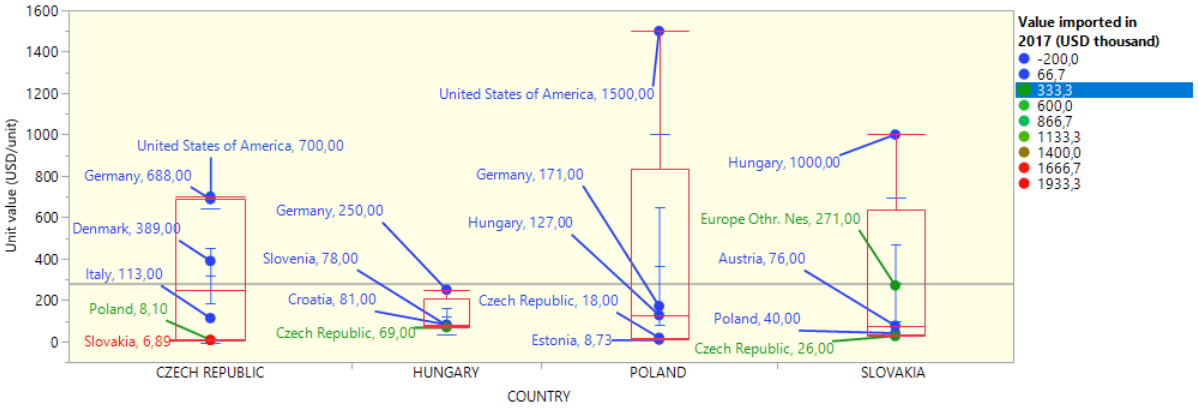
- The sale and purchase price of limestone has a large spread, ranging from $ 6.89 / ton up to $ 1,500 / ton for imports and a range of $ 5.9 to $ 3000 / ton for exports (see Table 3). The price level of this raw material is derived from several variables, e.g.:
- quality
- utilisation,
- quantity.

Tab. 1. Overview of limestone prices in the international trade for 2017 in the V4 countries (own processing according to www.indexmundi.com and www.trademap.org)

Country	Export		Import	
	Min	Max	Min	Max
Czech Republic	19	667	6,89	700
Hungary	186	214	69	250

Country	Export		Import	
	Min	Max	Min	Max
Poland	6,78	1000	8,73	1500
Slovakia	5,9	3000	26	1000

The observed variance of values in the raw material price levels was analysed by the Wilcoxon / Kruskal-Walis Tests, where we examined the price variability of the importing country. The test results did not confirm the statistically significant variability in import prices due to the landscape (Fig. 4).

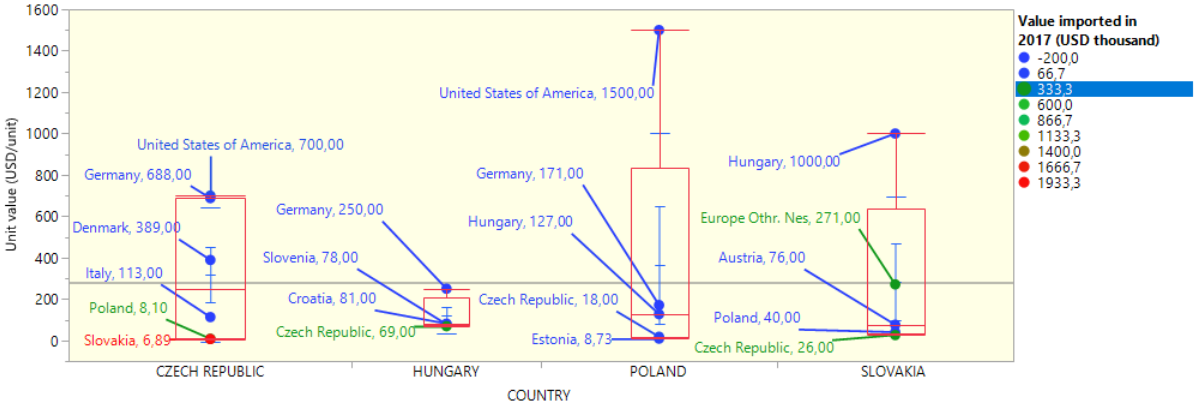


Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
ČR	6	66,000	60,000	11,0000	0,482
HUNGARY	2	31,000	20,000	15,5000	1,395
POLAND	7	61,000	70,000	8,7143	-0,718
SLOVAKIA	4	32,000	40,000	8,0000	-0,750

1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
2,9707	3	0,3962

Fig. 4. Analysis of Import Price Variability in V4 Countries (own processing according to www.indexmundi.com and www.trademap.org).



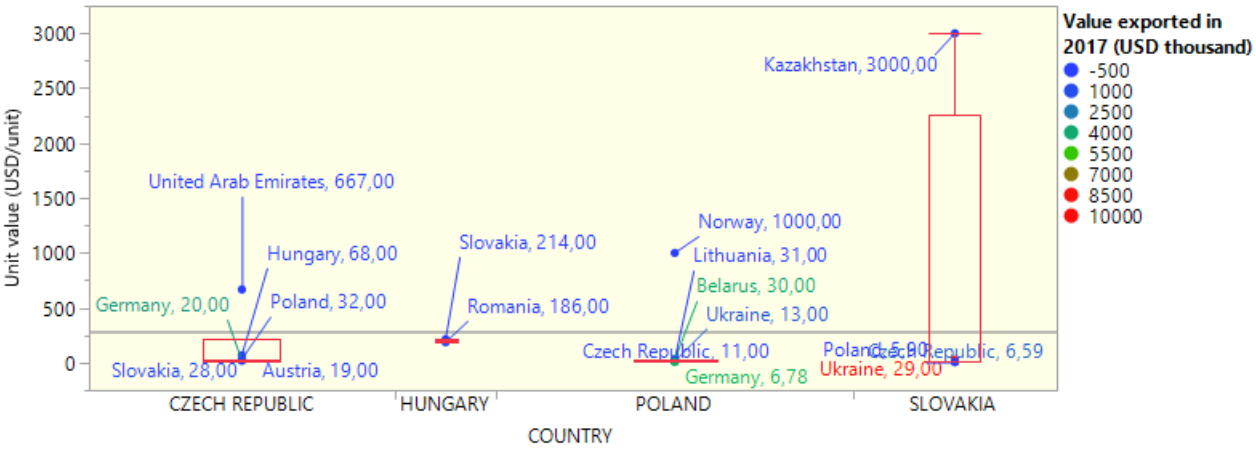
Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
CZECH REPUBLIC	6	65,000	63,000	10,8333	0,124
HUNGARY	4	40,000	42,000	10,0000	-0,142
POLAND	5	52,000	52,500	10,4000	0,000
SLOVAKIA	5	53,000	52,500	10,6000	-0,000

1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0,0505	3	0,9970

Fig. 5. Analysis of export price variability in V4 countries (own processing according to www.indexmundi.com and www.trademap.org).

Through the Wilcoxon / Kruskal-Walis Tests, price variability in the exporting country was also analysed. The test results, as in the previous case, did not confirm the statistically significant variability in export prices due to the landscape (see Figure 5). It cannot be said that any of the countries would have significantly lower / higher prices for exporting/importing limestone.



Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
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HUNGARY	2	31,000	20,000	15,5000	1,395
POLAND	7	61,000	70,000	8,7143	-0,718
SLOVAKIA	4	32,000	40,000	8,0000	-0,750

1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
2,9707	3	0,3962

Fig. 6. Analysis of import price variability in V4 countries (own processing according to www.indexmundi.com and www.trademap.org).

Foreign trade - limestone and cement

The groups of non-metallic materials, which are imported and exported in significant quantities, also include limestone and semi-products made of limestone - cement and lime. One of the main reasons for the import and export of these commodities in recent years has not been such a shortage or surplus of commodities, rather than economic reasons. In the case of limestone, cement and lime, to a certain degree of simplification, it was true, that cheaper Slovak or Polish production (alternative) was delivered to the Czech market, while somewhat more expensive Czech production was offered to German, the Austrian market.

The quantity of limestone import shows significant fluctuations in recent years - only between 2001 and 2011 ranged from 170 to 570 kt per year.

The characteristic feature of imports of raw materials is that 99.9 % come from Slovakia and the average import price is significantly lower than the prices for which limestone from the Czech Republic are exported. Exports of limestone have been long in the range of 85 to 270 kt. per year with a value of 40 to 110 million CZK and are mainly exported to Germany, Poland, Austria and other countries.

The quantity is an even more significant item of cement, whose import reach an average of 0.7 to 1.3 million tons worth of 1.3 - 1.9 billion CZK per year. Until 2002, imports of cement from Slovakia were completely dominated; in recent years imports of cement from other neighbouring countries - Germany and Poland - have also increased. Cement exports from the Czech Republic are currently about 0.6 to 1.7 million ton per year, which is significantly less than in 1999 when exports reached three times more. Cement exports are mainly to Germany, less to Poland, Slovakia and Austria. In the case of cement, it is not surprising that the import prices of cement are lower than export prices, due to the fact, that the German import prices of German cement are relatively high.

The default lime trade has similar properties to limestone - most of the lime is imported from neighbouring Slovakia in volumes ranging from 100 to 120 kt. per year for an average of 10 to 20 % below the average export prices of 150 to 200 kt. limes that are used in the Czech Republic. Export is mainly directed to Germany and in a significantly smaller amount back to Slovakia. In financial terms, the export volume is approximately 250-300 million CZK per year. In 2009, foreign trade of lime was lost on both sides (imports of about 90 kt, export of about 125 kt.), which indicates a decrease in demand. In the years 2010-2011, the volume of LU with lime returned to the range usual in recent years (2010: about 105 kt., 150 kt., Exports: 105 kt., 180 kt. (MPaO, 2012).

The result from analysing of limestone import to the V4 countries

In the analysis of the imported volume of limestone in tones, the quantity of imported limestone was assessed in the countries of V4 - Czech Republic, Slovakia, Poland, and Hungary in 2017. We recorded the largest volume of imports in the Czech Republic with a volume of 708 231 tones and the smallest in Hungary

with a volume of 12 742 tones (Tab. 2). The import of this raw material in the V4 countries is provided in the closer territory mostly from the neighbouring countries as seen in Fig. 7. In the Czech Republic, 70 % of imports are provided by Slovakia, followed by Poland, Germany and Italy. The Hungarian, Polish and Slovak imports mostly cover the Czech Republic, which covers 50-90 % of these countries' imports, followed by Germany, Austria and other countries.

Tab. 2. Overview of Limestone Import in the V4 countries in 2017 (own processing according to www.indexmundi.com and www.trademap.org).

	Imported volume of limestone in tones 2017			
COUNTRY	**Sum**	**Mean**	**Min**	**Max**
CZECH REPUBLIC	354116,00	59019,33	54,00	293110,00
HUNGARY	6371,00	1592,75	12,00	5951,00
POLAND	14734,00	2455,67	0,00	7249,00
SLOVAKIA	22482,00	4496,40	13,00	20527,00

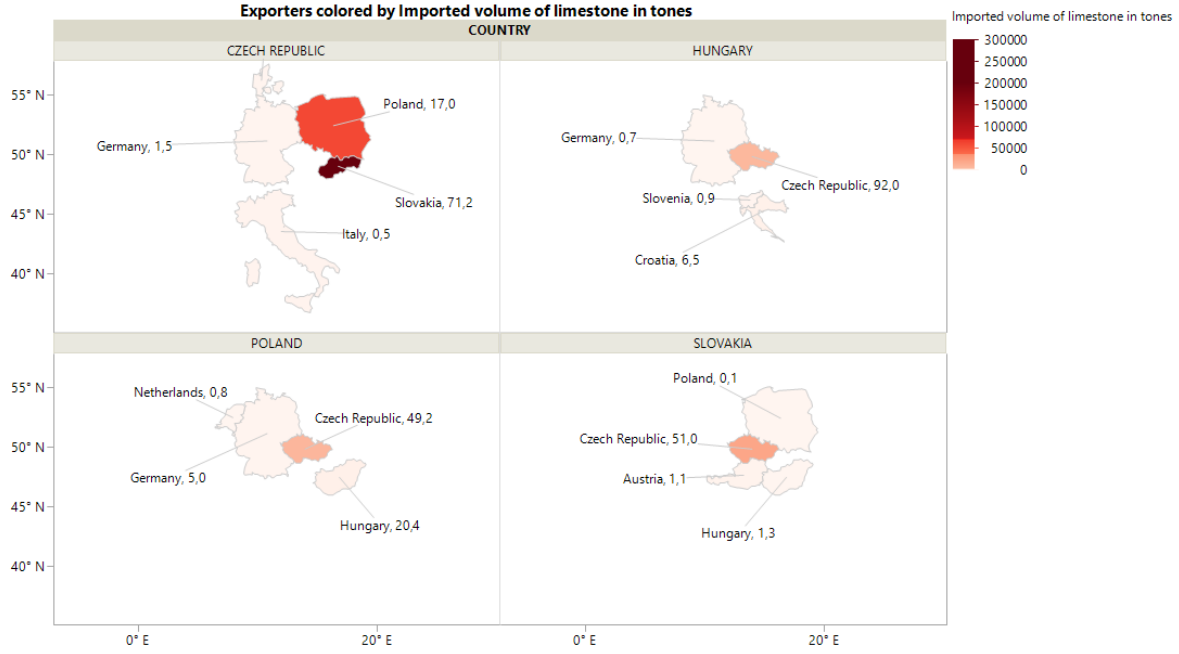

Fig. 7. Cartographer of the Limestone Exporter to the V4 countries in 2017 (own processing according to (www.trademap.org)).

The result from Analysing of limestone export from V4 countries

In the analysis of the Limestone export in tones, the quantity of exported limestone from the V4 countries in 2017 and the routing of this raw material was assessed. The largest volume of exports was recorded in Poland with a volume of 1 830 404 tones and the smallest in Hungary with a volume of 265 tones (Tab. 3). Exports of this raw material from the V4 countries are re-directed to nearby locations mostly in neighbouring countries as shown in Figure 8. The Czech Republic exported almost 70 % to Germany, the rest of the exports to Slovakia, Poland, Hungary and Austria. Poland has two major importers of limestone Germany and Belarus, which covers 80 % of Poland's exports. Slovakia is the country with the 2 largest exports of limestone in V4 at 1 289 589 tones, with up to 84 % of this raw material being directed to Ukraine and 16 % by the Czech Republic.

Tab. 3. Overview of limestone exports from the V4 countries in 2017 ((own processing according to www.indexmundi.com and www.trademap.org).

	Exports of limestone in tonnes			
COUNTRY	**Sum**	**Mean**	**Min**	**Max**
CZECH REPUBLIC	233168,00	38861,33	3,00	182733,00
HUNGARY	132,00	66,00	14,00	118,00
POLAND	915202,00	130743,14	16,00	627135,00
SLOVAKIA	644795,00	161198,75	1,00	352970,00

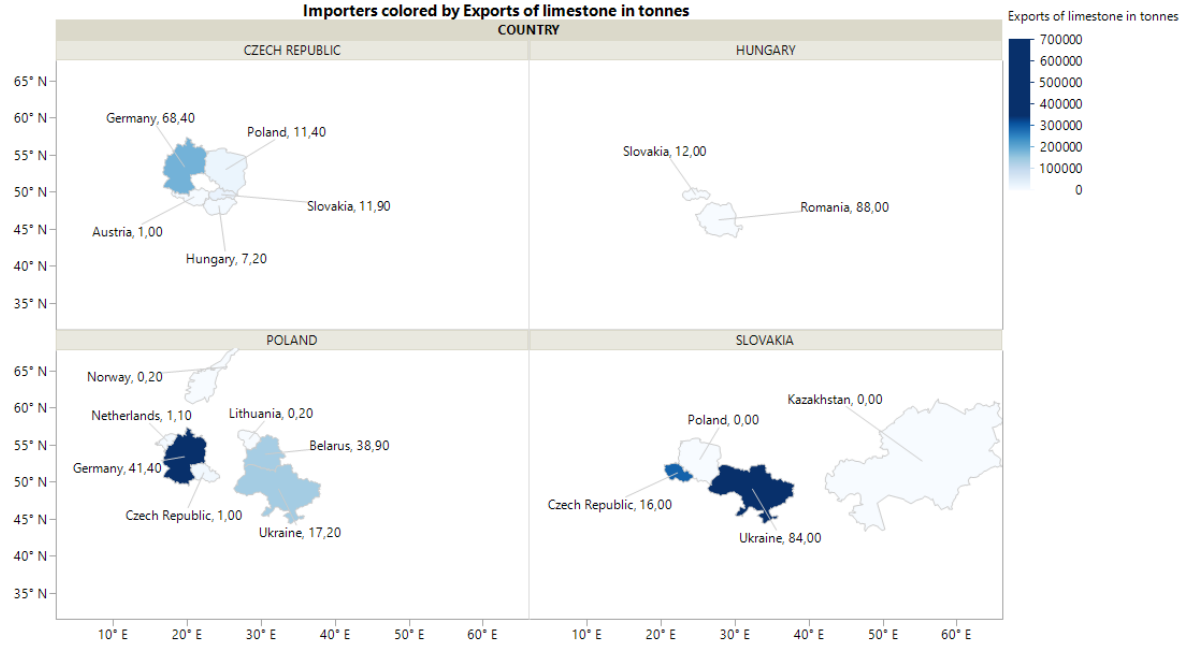

Fig. 8. Cartographer of limestone importers from the V4 countries in 2017 own processing according to (www.trademap.org).

Conclusion

We have chosen the limestone issue in V4 because it is the raw material that is used in many industries and as such is irrecoverable in many processes.

It is also a mineral raw material which is mined and processed in all four of V4 countries.

For analysis through production and export and import, we have decided for data availability and the possibility of comparing them. However, we also consider the processing of the problem in terms of four key factors, characteristic of limestone, limestone production, limestone import and export, and the development of indicators for statistical analysis.

Analysis of the production of limestone in the V4 countries and then the analysis of import and export in volume units (tones), the development of these indicators was evaluated with regard to the sales prices of the raw material, which has an impact on the economic balance of individual countries. By analyzing the production of limestone in the V4 countries in 10 years it is possible to sort the countries according to the importance of the rate, the biggest producer is Poland, which produces 43 % of the raw material, the Czech Republic and Slovakia produce over 20 % of the raw material and the lowest volume of production up to 10 % is Hungary.

The groups of non-metallic materials, which are imported and exported in significant quantities, also include limestone and semi-products made of limestone - cement and lime. One of the main reasons for the import and export of these commodities in recent years has not been such a shortage or surplus of commodities, rather than economic reasons. In the case of limestone, cement and lime, to a certain degree of simplification, it was true, that cheaper Slovak or Polish production (alternative) was delivered to the Czech market, while somewhat more expensive Czech production was offered to German, the Austrian market.

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