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Petrographic Observations of the Building Stones of the Great Pyramid of Giza

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Abstract: This article gives the readers an opportunity to look at the well-known archaeological monument in a different way. The Great Pyramid at Giza has in its four walls triangles that are made of different types of limestone compared the other parts. These triangles were made during the construction of the pyramid. On the top of the northern triangle used to be an entrance to the pyramid. These facts are presented and conscientiously proven in this article. A total of 12 samples from various rocks were taken from the Great Pyramid at Giza to conduct this research, and 13 samples were taken from the bedrock upon which the triangles had been built. This number includes also the samples from the rock in the quarry.

Key words: Giza, Pyramid, petrology, limestone, construction material.

1. Introduction

The limestone quarries were opened in each building site or in its immediate neighbourhood. Most of the material that was used to build the pyramids at Giza was extracted in the plateau.

Current investigations of the petrographic composition of the rocks used to build the pyramids as well as the conclusions related to the origin of the rock material are based on the not sufficient number of samples. These are just a few samples that were provided by the British Museum [1, 2] and the studies of Reisner and Klemm [3-5].

The Great Pyramid at Giza is the top achievement of the pyramid-builders epoch, both concerning the size and its meticulous construction. The mandator of the pyramid was Cheops, the king of the fourth dynasty of the Old Kingdom of Egypt. The plateau chosen by the king to build the pyramids was located on the edge of the desert on the western bank of the Nile River, today there exist the Cairo suburbs. The pyramid, the biggest one that has ever existed, was built on its north-eastern end (Fig. 1).

This ancient monument lasted for thousands of years. However, the civilization, technology and language of the ancient pyramid-builders of this miracle disappeared.

In 1925 J. H. Cole, employee of the Egyptian Survey Department, announced the results of the research made using the newest methods (at that time) and until today we derive data on the Great Pyramid at Giza from his measurements [6].

The height of the most studied and measured monument of the ancient Egypt probably was 146.73 meters. It is thought that at that time on its top stood pyramidion which crowned the construction. Present height of the pyramid is about 137.28 meters.

It is estimated that the four sides of the pyramid are of the following length:

- the northern side: 230 meters 25.5 centimetres;
- the southern side: 230 meters 45.3 centimetres;
- the eastern side: 230 meters 39.2 centimetres;
- the western side: 230 meters 35.9 centimetres.

All walls are oriented according to the cardinal directions. Each of them is sloping at the angle of about 51°52'. The area of its base is 5.3 hectares. About 2.3 million limestone blocks was used to build the pyramid.

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The average weight of each of them was 2.5 tonnes. [7-9].

The outer part of the pyramid—a stone cosmology, according to Herodotus looked as the following: “It is built of stone smoothed and fitted together in the most perfect manner, not one of the stones being less than thirty feet in length.” Because Herodotus visited Egypt in the fifth century B.C. and he saw the pyramid with its stone casing intact, he wrote that it had been built with smoothed stones. After conquering Egypt in 820 A.D. Arabs took the stone casing from the pyramid and they used it to build the city. It turned out that the pyramid had been built with the blocks. Their length reached even 3 meters, and their thickness depended on the layer of blocks in which they were placed.

We can only imagine how the pyramid looked like during the Herodotus times. We do not know if it had the signs on the polished structure of walls. Herodotus in his work writes that: “On the pyramid it is declared in Egyptian writing how much was spent on radishes and onions and leeks for the workmen, and if I rightly remember that which the interpreter said in reading to me this inscription, a sum of one thousand six hundred talents of silver was spent” [10].

Another person confirms this version. According to Abdela Latifa, the Arabic writer, the wall covering had hieroglyphic graffiti on its surface [11].

After more than one thousand years of destruction, caused by people and atmospheric conditions, not much of the casing has survived to the contemporary people to look at. Only a few blocks of the first layer on the northern wall, under the entrance to the pyramid has been preserved. As well as some blocks in the central part of the western and southern walls in the first layer are visible (Figs. 12 and 13). However, the last ones are badly damaged.

Present scholars focused on researching the other, untouched parts of the pyramid, which constitute its interior part. Not much has been discovered since the first opening of the pyramid in the 9th century A.D. by the Al Mamun’s people.

Only the airshafts and relieving chambers above the King’s chamber were found there. The last attempts at finding new rooms using the UPUAUT robot organized the National Geographic, under Dr. Zahi Hawas’s management, resulted in failure.

2. Geological Structure of the Giza Plateau

The area author interests is located between 29°30' and 30°30' of the north latitude and 30°30' and 31°30' of the east longitude. Fig. 1 shows the area, which adjoins to the Nile valley from the eastern and western side. From the northern side it is limited by the Nile Delta and from the southern side by the Faiyum Oasis. Almost all megalithic complexes of the Old Kingdom of Egypt are located in this area.

Morphological and geological structure of this region is the following:

The Nile valley and the Nile delta are filled with the alluvium. The rest of the area is visibly pleated due to the regional tectonic plates. The older sediments in this area are mainly built with the Oligocene and Eocene limestone. In some places they are cut by basalt and dolerite intrusions that occur in the south-western part up to the Faiyum Oasis region [12, 13]. More to the west is the area of about 15 × 10 km which is built with the Pliocene rocks. Next, towards the western direction there are the outcrops and the Miocene rocks and they continue till Libyan territories.

The south-western parts of the researched area are the Moqattam Hills and Maaditerritories. They are built with the Eocene limestone of the northern Galala Plateau [9]. In the region located south-eastern of Cairo, these formations are pleated and cut byfaults. Along the Nile valley is the Pliocene limestone zone which is 5 km broad and about 20 km long. Moqattam formations (Moq.) and Maadi (Ma.) are in the eastern bank of the Nile River and they are built with the Eocene sedimentary rocks. The ancient names of these quarries are Maadi and Tura and these are used in the historical and archaeological literature [14]. In this place, towards the north-southern direction, the fault

Fig. 1 The Great Pyramid at Giza, viewed from the western side.

goes through the ground. Thus, in this area the difference between morphological levels reaches more than 100 m in some places [15, 16]. In the fault zone the rocks section is well visible. From this place the ancient stonemasons began digging the limestone. Limestone in these quarries is dense and homogenous and of large thickness [17].

The whole researched area, its surface layers and those on the eastern and western banks of the Nile River are strongly damaged by aeolian and water erosion [1]. The valleys of dried rivers (wadi) have eroded the ground and its relative depth reaches even 70 meters [13]. This region may be specified as calm when considering tectonics.

The mineral composition of limestone from this region is quite diverse. It depends on the conditions of sediments formation: the distance from the seashore in the past, its depth, wind directions and thickness of the sedimenting layers.

The main mineral components of these rocks are: calcite, dolomite, fragments of organisms, opaque minerals, quartz, gypsum, as well as biotite and feldspar in trace amounts. Locally flintstones occur in the limestone. Fragments of various carbonate rocks are the additives [2, 18].

3. Research Material

The research source material consisted of 12 samples from the Great Pyramid at Giza blocks.

The localization of the samples taken to analysis is shown in Fig. 2.

Sample 04 01 WP b.: fragment of block made of the limestone rocks from the 1st layer of the south-western corner, about 10 m to the east from the corner.

Sample 04 02 WP b.: fragment of block from the 1st layer of the pyramid made of the limestone rock, it was taken about 20 m to the south from the north-eastern corner.

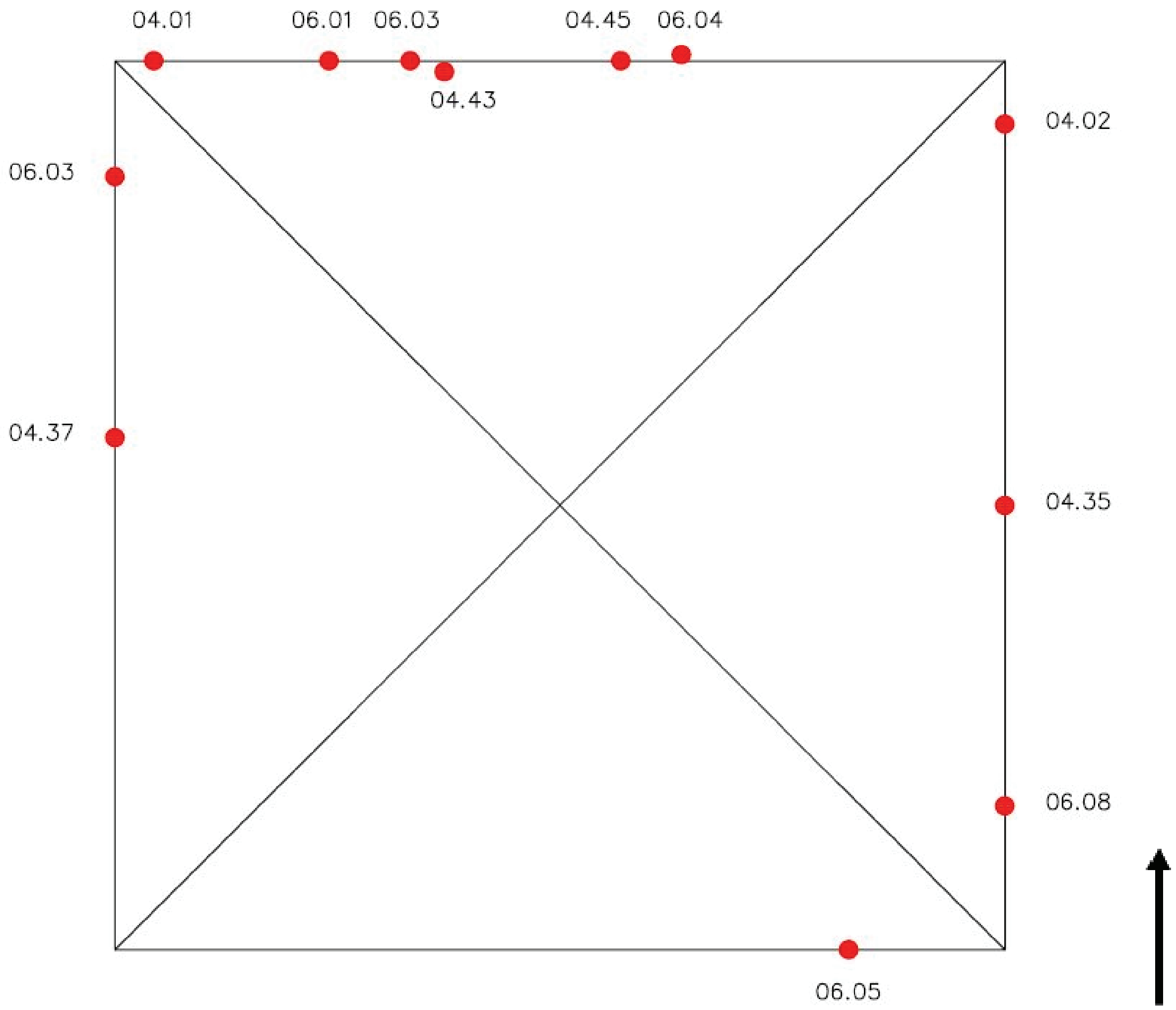


Fig. 2 Schematic drawing of the pyramid. Red dots indicate places of the samples collection and its numeration.

Sample 04 03 WP b.: fragment of block from the 1st layer from the limestone rock, it was taken from the western wall, 30 m to the south from the north-western corner of the pyramid.

Sample 04 35 WP b.: fragment of limestone block, taken from the 1st layer, from the central part of the eastern wall of the pyramid.

Sample 04 37 WP b.: fragment of limestone block, taken from the 1st layer, from the central part of the western wall of the pyramid.

Sample 04 43 WP b.: sample was taken in the 2nd layer of the central part of the northern wall of the Great Pyramid. This is the fragment of the casing block of the pyramid.

Sample 04 45 WP b.: fragment of limestone block, placed in the base of the pyramid (layer 0), from the central part of the northern wall of the pyramid. In this sample the remains of mortar are visible.

Sample 06 01 WP b.: fragment of block made of limestone rock taken from the 1st layer of its northern wall.

Sample 06 03 WP b.: fragment of block from the 1st layer of the base of the pyramid, it was taken from the central part of its northern wall.

Sample 06 04 WP b.: fragment of block taken from the 1st layer, the central part of the pyramid from the northern wall.

Sample 06 05 WP b.: fragment of block from limestone rock of the 1st layer, it was taken from the base of the pyramid, from its southern wall.

Sample 06 08 WP b.: fragment of block from limestone rock, it was taken from the 1st layer at the base of the pyramid level, from the eastern wall.

All 13 samples of the rocks from the quarries and natural openings localized in the Giza Plateau were also researched.

4. The Purpose and Methodology of the Research

The main purpose of this paper is to determine the mineral-petrographic composition of the blocks, which were used to build the pyramid. Due to the insufficient amount of the casing blocks, the study focuses on the stones, which were used to build the core of the pyramid.

Visual observations were made at different angles to the wall of the pyramid and their lightning at different times of day.

Macroscopic observations were made using Polish binocular PZO Mst 130 at a magnification from 10× to

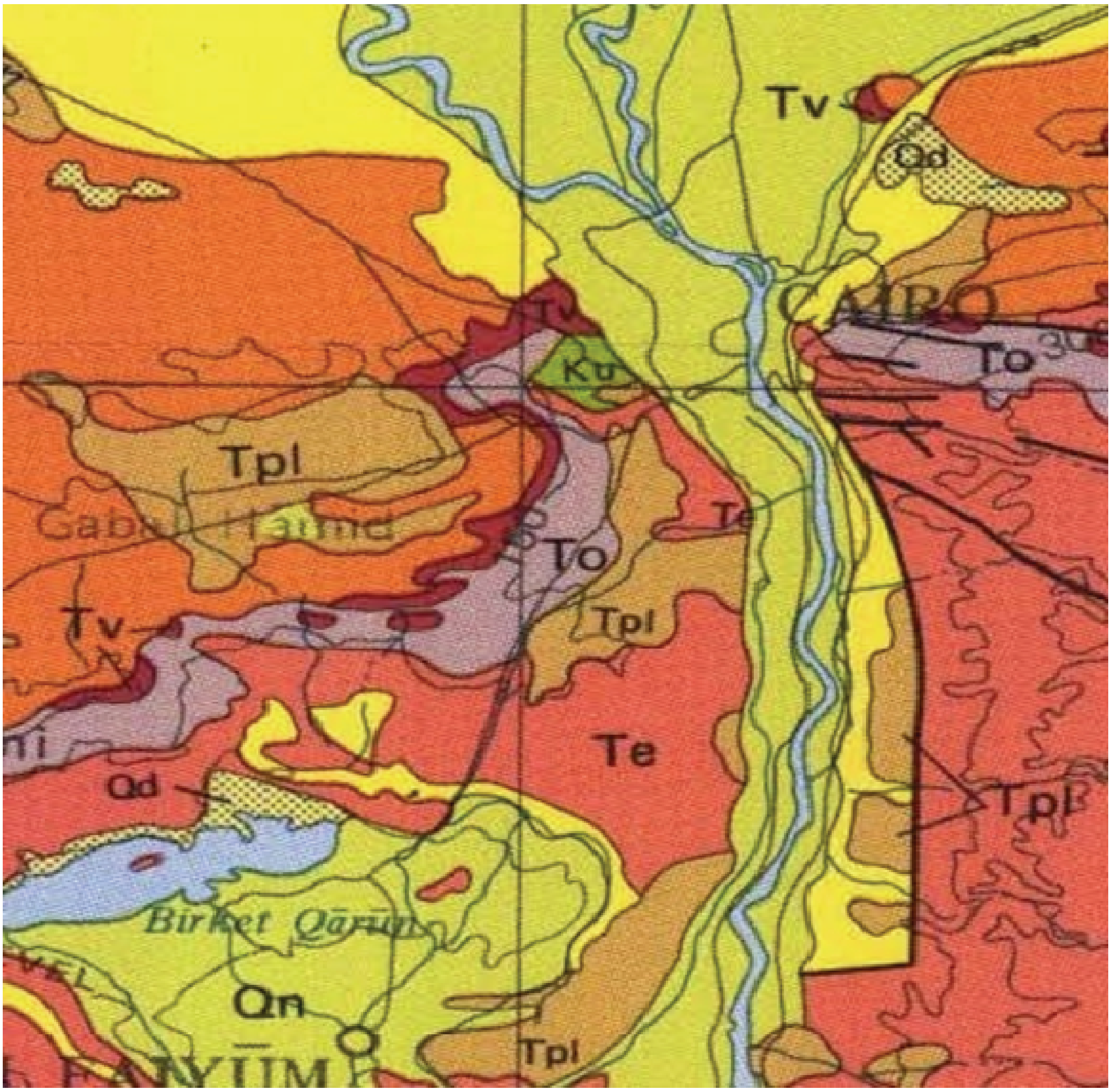


Fig. 3 Geologic map of Cairo. Egyptian Geological Survey 1981 [20].
Qd—sand dunes, Qn—Nile settelments, Tp—Paleocene, Te – Eocene, To—Oligocene, Tm—Miocene, Tpl—Pliocene, Tv—basalt intrusions, Ku—clastic phosphate and carbonate rocks from the Abu Rawash region.

25×. These observations constitute the preliminary phase of the investigation. After all, thin sections (polished thin section) of chosen samples were prepared.

Research used petrographic microscope: Petrographic microscope Carl Zeiss Jena with zoom up to 200× and microscope Nikon 120 with 500× zoom were used to more detailed observations.

Microphotographs of chosen fragments of microscopic sections were taken using digital camera Nikon, 100 ASA sensitivity.

The analysis of rock composition used quantitative microscope analysis (planimetric).

5. Results

Visual observations of the Great Pyramid at Giza at different angles of its natural lightning were conducted in the field.

During observations of the Great Pyramid at Giza differences in treatment, precision of positioning and colour of some blocks were noticed. After a detailed visual study it could be stated that some of them differ from the others not only in colour and precision of fitting, but also in the quality of the treatment.

Comparing Figs. 4 and 5 we can easily notice the difference in the precision of treating and fitting of the blocks. Blocks (Fig. 4) have irregular shapes. Their edges and corners did not preserve, the space between them is not always filled with mortar. However, fragments of limestone of different shapes and sizes are noticeable in mortar. In the central part of the wall of the pyramid (Fig. 5) all walls of the blocks (side, low and upper) are equal. All corners are at right angle. Spaces between the blocks are filled here with homogenous mortar.

Investigations conducted used petrographic microscope. Mineral-petrographic profile of samples was from the blocks of Great Pyramid at Giza.

Fig. 4 The photo presents the north-western corner of the Great Pyramid at Giza, from its western wall. Blocks are arranged irregular, not all spaces between the blocks are filled with mortar (Photo by K. Sołek).

Fig. 5 In the picture we can see the central part of the western wall of the Great Pyramid at Giza. In the foreground eroded casing blocks are visible. They were fitted in such a detailed way that it is difficult to see the joints between them. The blocks of the 2nd layer of the pyramid are precisely fitted, and the space between them is filled with mortar(Photo K. Solek).

Sample 04 01 WP b.: micrite limestone with single fragments of unidentified shells, micropore-mudstone.

Sample 04 02 WP b.: micrite limestone with single ostracods and pores filled with secondarily crystalized crystals of calcite-mudstone.

Sample 04 03 WP b.: micrite-sparite limestone, organodetritic. The remains of unidentified molluscs, echinodermata, foraminifera, postalgae structures and single grains of quartz are visible-wagkestone.

Sample 04 35 WP b.: micrite limestone with parallel structure of dark-yellow colour-mudstone.

Sample 04 37 WP b.: organodetritic limestone, full of foraminifera shells (mostly nummulite) and their fragments, as well as molluscs shells. Moreover, it contains sea urchin spines and other unidentified remains which are badly crushed. Only single grains of quartz are visible, the rock is slightly spongy and in its pores a microsite crystalized.

Sample 04 43 WP b.: mixed substance of coarse- and fine-grained, spongy with visible holes after air bubbles. The carbonate-gypsum mixture contains fragments of organodetriticlimestone, which have fragments of shells of unidentified molluscs, foraminifera, moss animals, echinoderms covered by hydroxides and iron oxides. It also contains small percentage of quartz and microcline grains. All of it is cemented by fine-crystalline gypsum.

Sample 04 45 WP b.: micrite limestone with single foraminifera and ostracods shells-mudstone.

Sample 06 01 WP b.: organodetritic limestone with the grains of intermediate size, carbonate joint of light bronze colour, probably with iron hydroxide. Limestone contains numerous foraminifera shells (probably nummulites) and other unidentified remains of molluscs, echinoderms and single grains of quartz. The material is slightly porous—grainstone.

Sample 06 03 WP b.: micrite limestone with single foraminifera shells—mudstone.

Sample 06 04 WP b.: micrite limestone with the remains of foraminifera and ostracods shells contains microcracks. Biomikryt mudstone.

Sample 06 05 WP b.: micrite limestone with single foraminifera shells—mudstone.

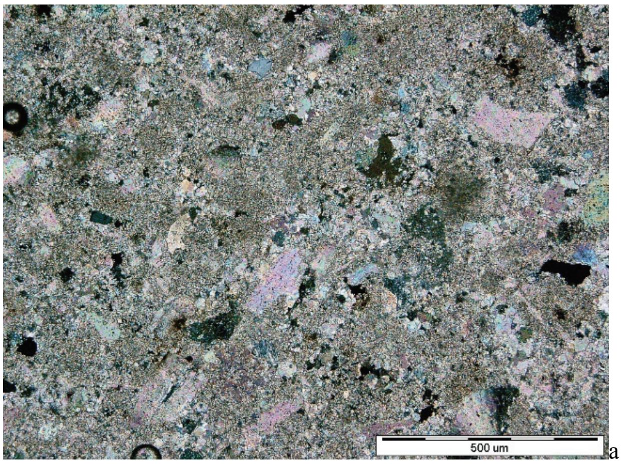
Sample 06 08 WP b.: marly limestone with the remains of foraminifera, molluscs and echinoderms shells. On one side, the sample has an isotropic-amorphous layer [19].

Samples analyses using the petrographic microscope with transmitting light have shown that the stone blocks of the pyramid differpetro graphically:

Micrite-sparitelimestones are built with micrite and sparite calcite in changing proportions with parallel texture (Fig. 6a).

Organogeniclimestone are cemented by micrite (Fig. 6a).

This is the Eocene organodetritic limestone with fragments of crushed molluscs shells supersaturated by calcite (Fig. 7a and 7b).



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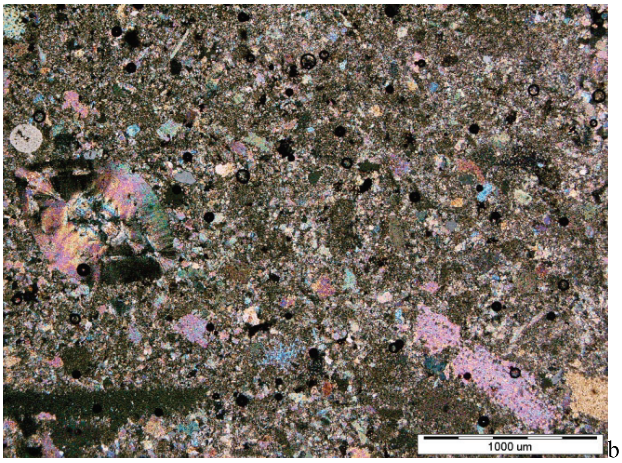
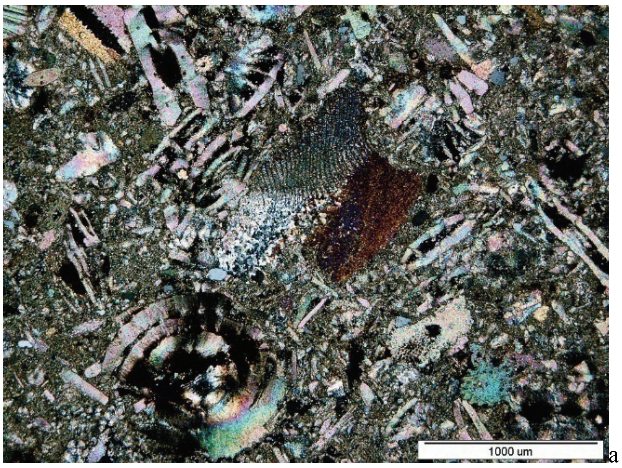


b

Fig. 6a Sample 04 03 WP b. micrite-sparite limestone, organodentritic. In this limestone there are visible remains of unidentified molluscs, echinoderms, foraminifera, postalgae structures, and single grains of quartz. Biospasparyt—wackestone.

Fig. 6b Sample 04 01 WP b. micrite limestone with single fragments of unidentified shells, the micropores are rarely visible. Biomicrite—mudstone.



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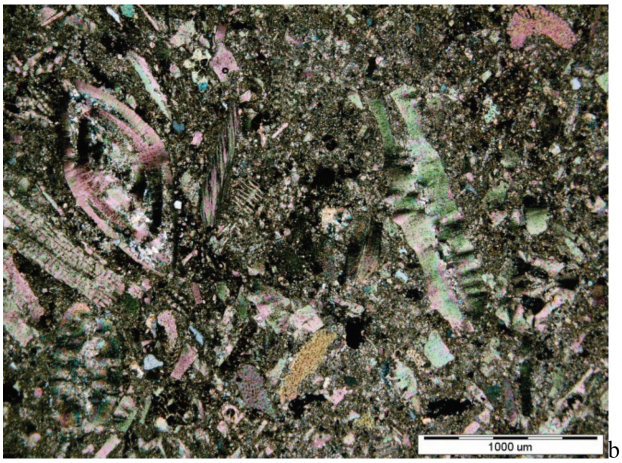


b

Fig. 7a Sample 04 37 WP b.: organodetriti climestone, filled with foraminifera shells (mainly nummulite), their non-lathed fragments, and molluscs shells. Moreover, it also contains sea urchins spines and other unidentified remains which are strongly crushed. Only single grains of quartz are visible, the rock is slightly porous, a micrite crystallized in pours. Biomicrite—grainstone.

Fig. 7b Sample 06 01 WP b.: organodetritic limestone with intermediate sized grains with carbonate joint of light bronze colour, probably with iron hydroxide. From numerous foraminifera shells (probably nummulites) and other unidentified remains of molluscs, echinoderms and single grains of quartz. The material is slightly porous. Biomicrite—grainstone.

Petrographic profile of the rocks from the Giza Plateau and pyramids bedrock:

Sample 04 41 EG: dolomitic limestone with the calcite joint, the remains of foraminifera, echinoderms and other unidentified fragments, as well as single grains of quartz. Rock is partly recrystallized. Single rhombohedral crystals of dolomite are visible. Rock is slightly porous.

Sample 04 42 EG: strongly porous dolomite, some dolomite crystals have holes or cracks in the central part of crystal. Inside the quartz grains are unidentified inclusions. It is strongly stained by a ferriferous substance.

Sample 04 46 EG: porous dolomite, some dolomite crystals have holes or cracks in the central part of crystal. In the rock shells of foraminifera (nummulites) and the remains of echinoderms armours are visible. Its surface rock has fragments of the isotropic-amorphous layer.

Sample 04 47 EG: organodetritic limestone with fragments of nummulites, clam or brachiopod. The rock is strongly dolomitised.Rhombohedra crystal of dolomite has losses in the central part of crystal. The isotropic-amorphous substance covers the border area.

Sample 05 01 EG: nummulite limestone, rock is built with the nummulite shells and it is joined with calcite. It contains single grains of gypsum, quartz, dolomite crystal; micropores are partly filled with opaque material.

Sample 05 02 EG: nummulite limestone, rock is built with the nummulite shells which are joint with calcite, it is considerably dolomitised, rhombohedral crystals of dolomite have losses in the central part of crystal. Rock contains single grains of gypsum and opaque minerals, which are located in the losses—wackstone.

Sample 05 03 EG: nummulite limestone, rock contains numerous foraminifera shells (nummulites) and other unidentified fragments of shells, the joint is dolomitised. Rhombohedral crystals of dolomite have losses in the central part of crystal. The isotropic-amorphous layer is visible on the edge of the sample.

Sample 06 01 EG: nummulite limestone, rock contains numerous shells of foraminifera (nummulites), sea urchin spines and other unidentified fragments of shells, the joint is dolomitised.Rhombohedral crystals of dolomite have losses in the central part of crystal. The isotropic-amorphous layer is visible in the edge of the sample.

Sample 06 03 EG: organidetritic limestone, rock contains numerous shells of foraminifera (nummulites), sea urchin spines and other unidentified fragments of shells, the joint is dolomitised. Rhombohedral crystals of dolomite have losses in the central part of crystal. The isotropic-amorphous layer is visible in the edge of the sample—wackstone.

Sample 06 07 EG: dolomite with fragments of shells, probably of molluscs, strongly porous, micropores are partly filled with opaque material. On one side of the walls, the sample contains isotropic-amorphous layer—dolomite.

Sample 06 09 EG: micrite limestone with the indications of dolomitisation process. In the limestone structure occur inclusions of the opaque material—mudstone.

Sample 06 10 EG: micrite limestone, rock built with coarse-grained calcite crystals and single dolomite crystals, strongly porous. In the pores walls the micritisation process is visible. Calcite crystals are subject of weathering in the surface area and they have microcracks. The whole rock is strongly ferrous. Single grains of quartz occur—wackstone.

Sample 06 33 EG: calcareous dolomite, it contains fragments of molluscs, echinoderms and foraminifera shells, and rock is slightly porous. Fragments of fauna are subjects of partial dolomitisation. Dolomite grains have holes in the central part of rhombohedron. Bigger crystals are parallelly cracked. The thin isotropic-amorphous layer—wackstone, covers part of the rock.

5.1 Results of Planimetric Analyses (Quantitative Microscope Analysis of Rocks)

Method of quantitative microscope analysis of rocks allows reaching percentage content of compounds in rock. Table 1 shows the results of planimetric measurements of samples from the Great Pyramid at Giza blocks. Table 2 shows the results of the analysis of samples of the rocks from the pyramid bedrock and the openings from the Giza Plateau.

Table 1 shows the results of measuring quantitative composition of compounds in the samples from the Great Pyramid at Giza blocks. Relatively large amount of fossils in the samples 04 37 WP b. and 06 01 WP b. are visible and it distinguishes them from the other samples. The sample 04 43 WP b. contains large amount of microcrystalline gypsum (11.5%) and fossils (16.4%), and this is the only sample, which contains the volcanic rocks minerals and salt. Also samples of the blocks 04 35 WP b. and 04 45 WP b. are distinguishing. They contain 88.4% and 99.8% of calcite as micrite formation in its composition. As we see in Table 2 all samples from the Giza Plateaucontain in its composition dolomite crystals or they are dolomites. They also contain a changing number of fossils, which are secondarily crystallised by dolomite. In some places they characterise in substantial porosity (which is included in the samples description).

6. Discussion

It was discovered that better-preserved blocks compose the central parts of the pyramid walls. The best-preserved blocks are observed in the first layer.

Table 1 Results of planimetric measurements of the quantitative composition (%) of the blocks from the Great Pyramid at Giza.

	04.01	04.02	04.03	04.35	04.43	04.45	04.37	06.01	06.03	06.04	06.05	06.08
	WP.b	WP.b	WP.b	WP.b	WP.b	WP.b	WP.b	WP.b	WP.b	WP.b	WP.b	WP.b
Calcite	86.1	93.4	79.1	88.4	59.6	99.8	53.7	50.1	94.3	88.1	91.3	80.6
Quartz	4.5	1.4	1.3	1.6	0.4	0.2	1	1.5	0.4	-	0.2	1.5
Fossils	9.1	5.1	18.5	8.3	16.4	-	43.6	44.6	0.7	3.2	2.8	14.7
Opaque minerals	-	0.1	0.4	1.7	0.2	-	0.3	3.1	0.9	0.8	3	0.1
Dolomite	-	-	-	-	-	-	0.2	-	1.6	-	0.3	-
Gypsum	0.3	-	0.7	-	11.5	-	1.2	0.7	2.1	7.9	2.4	3.1
Flint	-	-	-	-	-	-	-	-	-	-	-	-
Crushed feldspar	-	-	-	-	7.9	-	-	-	-	-	-	-
Biotite	-	-	-	-	0.1	-	-	-	-	-	-	-
Feldspar	-	-	-	-	0.2	-	-	-	-	-	-	-
Halite	-	-	-	-	3.7	-	-	-	-	-	-	-

Table 2 The results of the planimetric analysis of the quantitative amounts (%) of the composition from the pyramis bedrock and the opening in the Giza Plateau.

	04.41	04.42	04.46	04.47	05.01	05.02	05.03	06.01	06.03	06.07	06.09	06.10	06.33
	G.	G.	G.	G.	G.	G.	G.	G.	G.	G.	G.	G.	G.
Calcite	51.1	-	51.4	78.2	67.2	38.1	36.3	79.6	63	18.2	92.2	90.7	26.7
Quartz	0.3	0.8	0.8	1.2	0.6	0.5	0.7	-	2.4	1.8	-	-	-
Fossils	15	-	9.1	19.1	27.1	18.5	20.3	12.6	30	8.2	6.8	0.2	24.2
Opaque minerals	0.9	1.3	0.3	0.6	2.3	0.5	0.3	1.4	-	2.8	0.2	0.1	1.1
Dolomite	32.7	97.9	38.4	0.1	1.5	40.9	42.4	6.4	4.6	75	0.8	9	48
Gypsum	-	-	-	0.8	1.3	1.5	-	-	-	-	-	-	-
Flint	-	-	-	-	-	-	-	-	-	-	-	-	-
Crushed feldspar	-	-	-	-	-	-	-	-	-	-	-	-	-
Biotite	-	-	-	-	-	-	-	-	-	-	-	-	-
Feldspar	-	-	-	-	-	-	-	-	-	-	-	-	-
Halite	-	-	-	-	-	-	-	-	-	-	-	-	-

They lay in the distance of 40 m from the corners of the pyramid and they were put in the central part of the pyramid's foundation. In each subsequent layer their number is decreasing from the both sides. And thus, occurrence of this type of limestone ends up with the single block in the 19th layer (Fig. 8b, in circle), in the central part of the wall. These blocks are lighter in colour and precisely fitted. They arrange in a characteristic way and create a structure of a triangle shape (Fig. 4). The same elements are visible in the other three walls of the Great Pyramid at Giza.

It is hard to determine unambiguously the location of the apices of triangles. In the northern wall the apex was damaged during the opening of the original entrance to the Great Pyramid at Giza (Figs. 9a and 9b). In the photograph we can see that the original entrance to the pyramid was hidden behind the stone, precisely in the 19th layer.

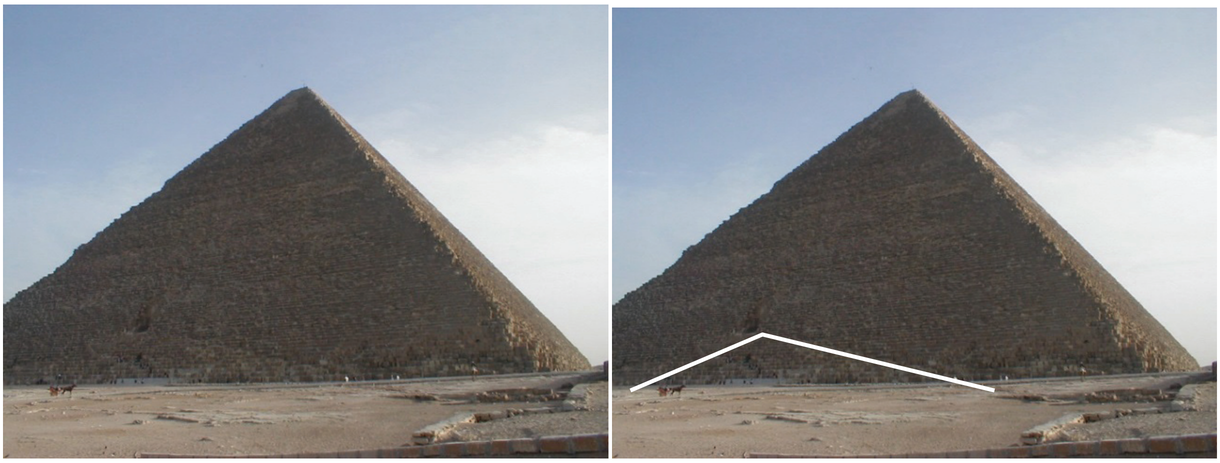
In the southern and eastern walls the apices of mentioned triangles are not visible.

The author's considerations about linking the triangle (α) with the location of the original entrance to the Great Pyramid at Giza are evident.

Even the ancient Greek geographer Strabo writes in his book *Geography* that "High up, approximately midway between the sides, it has a movable stoneand when this is raised up, there is a sloping passage to the vault". As it is visible in the Fig. 10 the entrance to the

a b

Fig. 8 The top of the Alpha triangle shown in the 19th layer of the western wall of the Great Pyramid at Giza (Photograph by the author).



a b

Fig. 9 The Great Pyramid at Giza, the northern wall with visible right side of triangle α and its apex destroyed while opening of the original entrance (Photograph by the author).

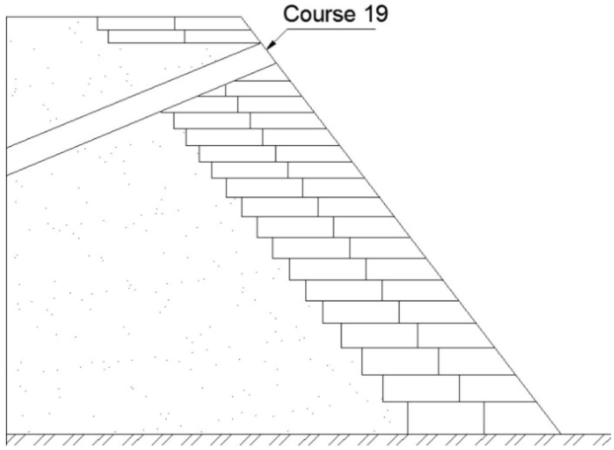


Fig. 10 Section N-S through the Great Pyramid at Giza (Drawing according to the F. Petrie measurements).

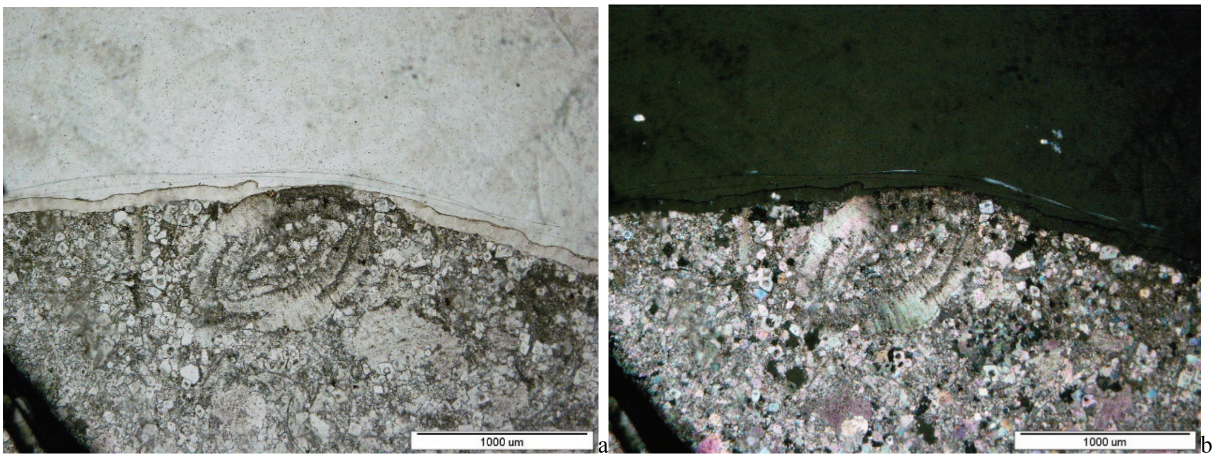


Fig. 11 Sample 04 47 EG 11a IN, 11b XN—Biomicrite—wackstone. Organodetritic limestone with nummulite fragments. Rock is strongly dolomitised. Rhombohedral crystals of dolomite have losses in the central part of crystal. The border area is covered by isotropic-amorphous layer. The isotropic-amorphous layer is a crytptocrystalline gypsum which covers the rocks in the Giza Plateau.

descending corridor, leading into the Great Pyramid at Giza, had to be located exactly in the 19th layer. This layer is considerably thicker than the neighbouring ones—it has 95 centimetres.

Thus, do we understand Strabo and his message correctly? Moreover, can we trust him when we study this issue?

Concluding, the triangles with the base in the foundation of the Great Pyramid at Giza and their sides in its walls (I name them Alpha triangles (α)) are visible in the four walls of the pyramid [21]. From mentioned triangles the most visible is the triangle located in the western wall, topped with a single stone. It is in the 19th layer of the stones, 16 m 65 cm high (Fig. 8b). According to the calculations the angle of all mentioned triangles in its top amounts 155°. The length of its base is about 150 meters [22].

German archaeologist Prof. Rainer Stadelmann, the researcher of Dahshur complex, writes in his works about the system of corridors in the Sneferu pyramids.

The king Sneferu (4th dynasty) built two pyramids in Dashur: The Red Pyramid and the Bent Pyramid. The southern pyramid of rhombic shape (the Bent Pyramid) has two entrances: the first one is the northern entrance with the system of corridors and chambers and the second entrance is located in its western wall. The second entrance has separate system of corridors. These corridors probably have never been connected [23].

Taking into account the statements of the ancient

Fig. 12 Western wall of the pyramid. Visible triangle sides (α) (arrows). (Photograph by the author).

Fig. 13 Western wall of the Great Pyramid at Giza. Strongly eroded casing blocks from the 1st layer and one side of α triangle are visible. The triangle in the western wall is topped with a single stone. It is located in the 19th layer of blocks, 16 m 65 cm high (Photograph by the author).

writers and the author's observations, which are proved by the laboratory analyses, we can assume that there is the second entrance to the Great Pyramid at Giza. It should be located in the 19th layer of the western wall of the pyramid.

It is also possible that the architect of the pyramid wanted to deceive all the unwanted guests and built the triangles in all walls of the pyramid.

Be as it may, the triangles exist in the four walls of the Great Pyramid at Giza. Why were they built? For the time being answering this question is the next mystery of the ancient pyramid-builders.

The triangle in the Great Pyramid at Giza is noticeable in many photographs from 19th and 20th centuries, which were made by various photographers. Why "α" triangles in the Great Pyramid have not been noticed till now? One explanation could be the fact that: what we know affects our visual perception of the world. A very good example of it is the "AERA" cover photo of the Annual Report 2010-2011.

In the western wall of the pyramid the "α" triangle is very well visible.

It is unknown whether this is the only pyramid with the triangles in its sidewalls that were built in the Old Kingdom of Egypt. The existence of such objects in other pyramids is also possible.

7. Conclusions

The research proved that:

The Great Pyramid at Giza is built with at least three types of limestone rocks:

(1) Micrite-sparite limestone with the carbonate joint with single remains of crustacean fossils (Wackestone);

(2) Micrite-sparite limestone with the carbonate joint and parallel texture(Mudstone);

(3) Organodetriti climestone with calcite filled with the fragments of crushed molluscs shells (grainstone).

Type 1 limestone (Fig. 6a) was used to build the core of the pyramid.

Type 2 limestone (Fig. 6b) was used to build the pyramid's cover.

And the limestone type 3 (Figs. 7a and 7b) was used to build the triangles in the wall of the Great Pyramid at Giza.

Table 3 Dunham 1962 Carbonate classification.

<table>
<tr><td colspan="4">Original components not bound together at deposition</td><td rowspan="4">Original components bound together at deposition. Intergrown skeletal material, lamination contrary to gravity, or cavities floored by sediment, roofed over by organic material but too large to be interstices</td></tr>
<tr><td colspan="3">Contains mud (particles of clay and fine silt size)</td><td>Lacks Mud</td></tr>
<tr><td colspan="2">Mud-supported</td><td colspan="2">Grain-supported</td></tr>
<tr><td>Less than 10% Grains</td><td>More than 10% Grains</td><td></td><td></td></tr>
<tr><td>Mudstone</td><td>Wackestone</td><td>Packstone</td><td>Grainstone</td><td>Boundstone</td></tr>
</table>

C. G. St. C. Kendall, 2005 (after Dunham, 1962, AAPG Memoir 1)

Table 3 [24] was used to classify the limestone. Polish naming was used in accordance with the Folk R. L. [25], classification [26].

The "Alfa" triangles located in the four walls of the pyramid are built with the 3rd type of limestone, the "grainstone" type. They have the same sizes and they are topped with a single stone in the 19th layer. As the petrographic analyses, shape and the accuracy of size of all triangles indicate, the triangles could not be placed in the pyramid by chance or due to the natural origin.

Limited amount of gathered and analysed samples from the Great Pyramid at Giza may be the only point to speculate.

Limestone from the Giza Plateau ate strongly dolomitised and such limestones were not discovered in the Great Pyramid at Giza.

The words of Egyptologist and geologist W. M. F. Petrie enhance the credibility of conclusions included in this paper: "Limestone from the western hills differs in the mineral composition from the limestone in the pyramid complex. The last one is more similar to the limestone from the eastern bank of the Nile River. Thus, we can assume that all this material was extracted from the steep cliffs of Tura and Maadi. From this place it was transported to the building site" [27].

These are the words of the prominent Egyptologist W. M. F. Petrie written in 1883.

References

[1] Aigner, T. 1983. "A Pliocene Cliff-Line around the Giza Pyramids Plateau, Egypt." *Palaeogeography Palaeoclimatology Palaeoecology* 42 (3): 313-22.

[2] Folk, R. L. 1962. "Spectral Subdivision of Limestone Types." *Amer. Assoc. Petrol. Geol. Met.* 1: 62-84.

[3] Klemm, R., and Klemm, D. D. 1993. *Steine und SteinbrücheimAltenÄgypten.* Berlin: Heidelberg.

[4] Klemm, R., and Klemm, D. D. 1999. "Die Integralrampe als Konstruktionselement großer Pyramiden." In Guksch *Stationen. Beiträge zur Kulturgeschichte Ägyptens Rainer Stadelmann gewidmet*, edited by H., Polz D., Mainz, pp. 87-94.

[5] Nicholson, P., and Shaw L. 2000. *Ancient Egyptian Materials and Technology*. Cambridge University press. pp. 5-103.

[6] Cole, J. H. 1952. *Determination of the Exact Size and Orientation of the Great Pyramid of Giza.* Cairo, Egypt: Government Press. pp. 6.

[7] Edwards, I. E. S. 1961. Piramidy Egiptu. przełożył Górski H. 1995. PIW Warszawa.

[8] Mencken, A. 1963. *Designing and Building the Great Pyramid.* Baltimore.

[9] Raynaud S., et al. 2008. "Geological and Geomorphological Study of the Original Hill at the Fourth Dynasty Egyptian Monuments."

[10] Herodotus. 1954. *The History of Herodotus, Books II, Dzieje, Przeł.* Z języka greckiego i opracował Hammer S.

[11] Arnold, D. 1988. "Manoeuvring casing blocks of pyramids." In *Pyramid Studies* and Other Essays presented to I. E. S. Edwards, edited by J. Baines et al. (eds.), London, p. 12-24.

[12] Harrell, J. A. 1992. "Ancient Egyptian Limestone Quarries: A Petrological Study." *Archaeometry. Oxford* 34: 195-211.

[13] Harrell, J. A., and Brown, V. M. 1995. "Topographical and Petrological Survey of Ancient Egyptian Quarries. Toledo."

[14] Badawy, A. 2005. "Present-Day Seismicity, Stress Field and Crustal Deformation of Egypt."

[15] Dunham, D. 1956. "Building an Egyptian Pyramid." *Archaeology* 9 (3): 159-65.

[16] Wells, A. J. 1962. "Recent Dolomite in the Persian Gulf." *Nature. V.* 194: 274-5.

[17] Fitzneer, B., et al. 2004. "Limestone Weathering on Historical Monuments in Cairo, Egypt."

[18] Gingerich, P. D. 1993. "Oligocene Age of the Gebel Qatrani Formation, Fayum, Egypt." *Journal of Human Evolution* 24: 207-18.

[19] Zalewski, F., and Pawlikowski, M. 2007. "Patina on the Bedrocks and Monumental Buildings of the Giza Region, Egypt." *Mineralogia Polonica-Special Papers* 28: 243.

[20] http://www.scirp.org/(S(lz5mqp453edsnp55rrgjct55))/reference/ReferencesPapers.aspx?ReferenceID=536206.

[21] Zalewski, F. 2004. Trójkąty-nowe spostrzeżenie w piramidzie Cheopsa. ArcheologiaŻywa.p. 5-7.

[22] Zalewski, F. 2006. "Petrographic Characteristics of Resources Used for Building the Great Pyramid of Giza, Egypt." *Geologo-mineralogiczeskijwestnik. Nr* 2: 12-3.

[23] Stadelmann, R. 1991. "Die AgyptischenPiramiden Von Ziegelbau zum Weltwunder." *Rhein von Zabern.* pp. 80-160.

[24] Dunham, R. J. 1962. "Classification of Carbonate Rocks According to Depositional Texture." In *Classification of Carbonate Rocks*, edited by W. E. Ham. Amer. Ass. Petrol. Geol. Met., 1: 108-21.

[25] Folk, R. L. 1959. "Practical Petrographic Classification of

Limestones." *Amer. Ass. Petrol. Geol. Bull.* 43: 1-38.

[26] Narkiewicz, M., and Śnieżek, S. 1981. "Dunhama klasyfikacja skał węglanowych: Propozycja polskiego nazewnictwa." *Przeg. Geol. Nr* 10: 536-7.

[27] Petrie, W. M. F. 1930. *The Building of a Pyramid, Ancient Egypt, Part II.* pp. 33-91.