# THE QUESTION OF THE MATERIAL ORIGIN OF THE WALLS OF THE SAQSAYWAMAN FORTRESS. CUZCO (PERU)

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*General view of the Saqsaywaman fortress. Cuzco Peru. (Photo by Patricia Awyan)*

This urgent problem, for a long time possesses the minds of many generations of the researchers. These cyclopean constructions puzzled humankind back to the times of the first conquistadors, who were the first to step on the lands of Terra Incognita. Masterly processed elements of the walls, fantastically exact adjustment of the block surfaces, the multiton megalithic blocks sizes – make everyone to admire the skill of ancient builders, until nowadays.

During the different times, absolutely independent researchers have studied the material, composing the blocks of the fortress walls of Saqsaywaman. It appeared to be a gray limestone, forming the surrounding geological formation. The fossil fauna, contained in this limestone, makes it equivalent to the Ayavkas limestone of the Lake Titicaca, related to the Aptian-Albian Cretaceous.

Blocks, making the wall, don't look like if they were cut off the rock (as many scholars prefer to say), or being cut off by some high-technology instrument. The way, these block are put together and adjusted to each other is much hard to achieve even by means of the modern machine technology. It is really very difficult, and sometimes impossible to get such fine non-gap joints, while working with the solid material, moreover in such a huge volumes.

*Fragment of the wall of the  Saqsaywaman fortress. Cusco. Peru. (photo by A. Veryanov)*

*Saqsaywaman fortress. Cuzco Peru. (Photo by Patricia Awyan)*

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*Masonry blocks of the first tier of the Saqsaywaman fortress. Cuzco Peru. (Photo by Patricia Awyan)*

So, what can we say about the ancient peoples, who in spite of the low-developed level of technology, were able to make all these truly incredible deeds?

According to the official historical version, these limestone blocks were cut off in the nearby quarry and then dragged to the place of construction, after what they were processed from all their sides by the primitive stone hand-tools, in order to be fitted to each other before the installation to the walls of the Saqsaywaman. All this deeds are assigned to ethnic peoples of Quechua (Inca) - the great Empire, which reigned in the South America in the XI-XVI centuries, until the times of conquistadors.

At this point, lets' mention that Incas could have inherited the knowledge of previous civilizations, which existed on the subordinated territories. Numerous archaeological studies of these areas, indicate the existence of more ancient pre-Inca cultures. These ancient cultures were the first founders of that very "base", on which the Inca Empire subsequently raised.

So, why should we regard these great megalithic Saqsaywaman building as the handiwork of the Incas, who, in their turn, could simply use the elder constructions of the previous civilization, which existed here long time before?

The Incas did not obtain any high-technology devices, by means of which they could perform the full range of works on the construction of such huge architect structures. No one archaeological studies confirm this fact.

Some explorers, are trying to explain the "way out" of the situation, even allowing factor extraterrestrial alien intervention. They say, that aliens arrived here, built all these impossible structures and flew away or disappeared, leaving no evidence or knowledge of the technologies,


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they used, while constructing this megalithic walls. What can we say about this? We shall say, that this question can be considered only after all the other possibilities, would be totally excluded. So, as long as these possibilities are not eliminated, we shall base our theory on real facts, logic and common sense.

The limestone blocks, forming the walls of the Saqsaywaman are so dense, that some explorers regard them as andesite, which is absolutely wrong. Moreover, this delusion, brings only misunderstandings and confusion in to the direction of further research.

The recent researches of the Saqsaywaman fortress, were provided by Russian scientists (Russian Academy of Sciences. Far Eastern Branch. Institute of Tectonics and Geophysics), together with (GEO y Asociados), who conducted the geo-radar research of the nearby area, in order to find the reason of destruction of the Saqsaywaman walls. This work was done for the Ministry of Culture of Peru. The results of this scientific research, together with geo-radar data, lightened the situation with the chemical composition of the material, forming the polygonal blocks of the fortress walls.

Below is an extract from the official report of the Institute of Tectonics and Geophysics FEB RAS, based on the results of X-ray fluorescence analysis of stone samples, taken directly from the place of study:

| Oxide / element | Quarry | Blocks of the fortress |
|---|---|---|
| $SiO_2$ | 13,20% | 13,36% |
| $TiO_2$ | 0,06% | 0,09% |
| $Al_2O_3$ | 0,56% | 0,90% |
| $Fe_2O_3$ | 1,11% | 0,94% |
| MnO | 0,07% | 0,07% |
| CaO | 69,86% | 70,15% |
| MgO | 0,70% | 0,65% |
| $K_2O$ | 0,35% | 0,68% |
| S | 0,05% | 0,04% |
| Cu | 0,01% | 0,01% |
| Pb | 0,00% | 0,00% |
| Co | 0,00% | 0,00% |
| Sr | 0,03% | 0,04% |
| V | 0,01% | 0,01% |
| Sc | 0,01% | 0,01% |
| Zr | 0,01% | 0,01% |
| Сумма | 86,04% | 86,98% |

As it seen from a composition, there is no any andesite at all. But the results show a high density of the limestone, forming the blocks. Also they show the absence of any organic fossils in the samples of material from the blocks, forming the fortress, as well as the presence of them in the samples, taken from the quarry.

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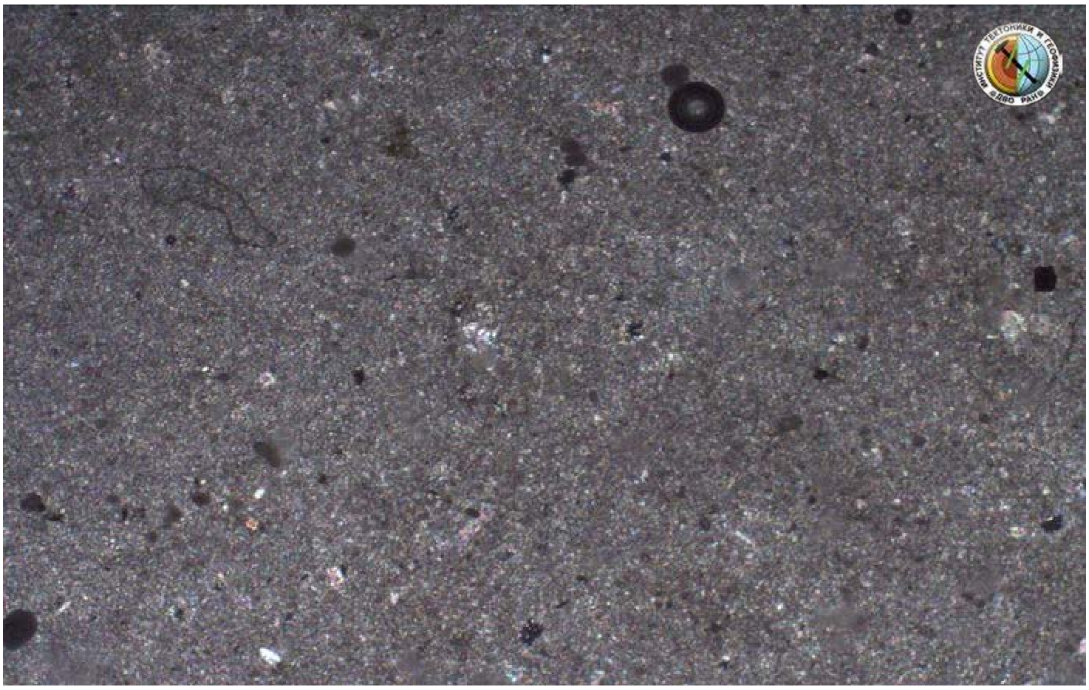
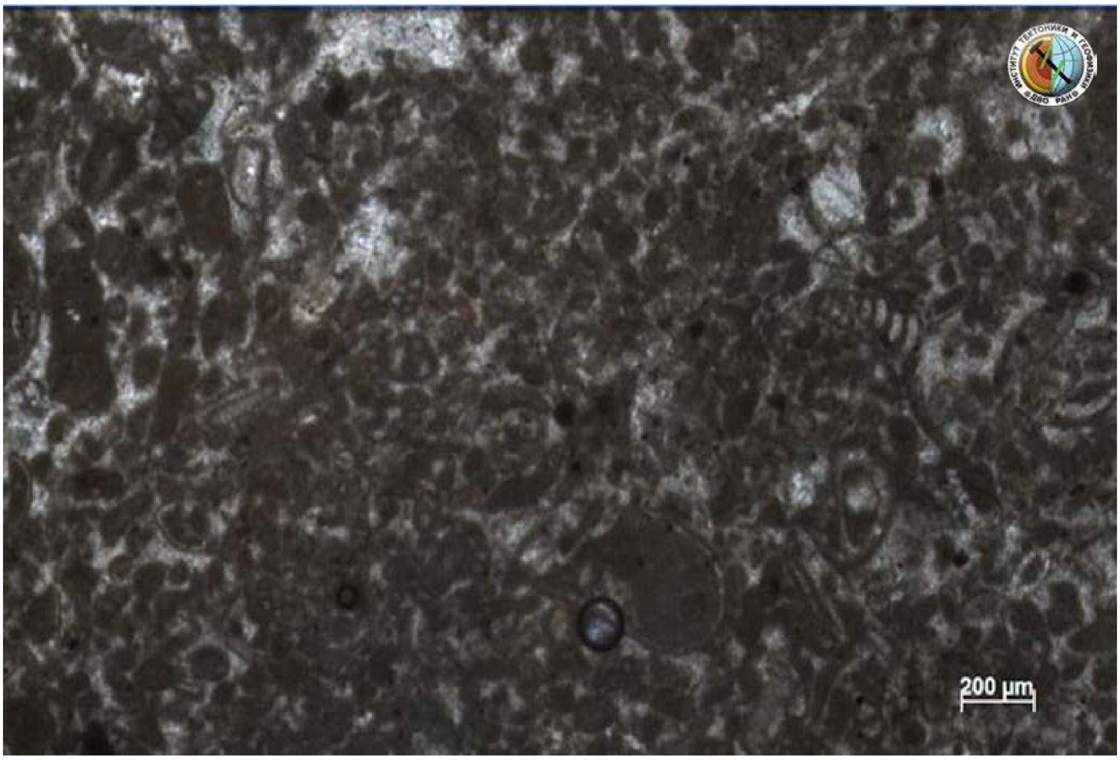
The microsection photo of the following sample, taken from the wall block, shows no obvious fossils and organic remains in it – but only clearly visible fine-grained structure.



In this case, it is probable to assume the chemogenic origin of the limestone, which is formed by the precipitation from solutions, and is usually represented by the oolitic, pseudo- oolitic, pelitomorphic and other geological fine-grained varieties. But we are not hurrying to make fast conclusion.

Along with the study of the microsection of the sample, taken from the wall block of Saqsaywaman fortress, a similar study of the microsection of the sample taken from the quarry, showed the clearly visible inclusions of organic fossil:



The analysis shows chemical similarity of the composition of the both studied samples, and at the same time difference in presence / absence of organic inclusions.

***The first preliminary conclusion:***

Limestone blocks tested some process, the consequences of which was the disappearance / dissolution of organic fossil. This process obviously happened, on the technological way between quarrying the block and putting it into the wall. Originally, "magical" transformation, which after considering all of the facts, really had happened!

Let’s consider carefully - what do we have on this point of research.

Actually, the composition of the samples indicates a direct analogy with the ***marly limestones***.

***Marly limestones*** – sedimentary breed of argillaceous - carbonate composition, where the concentration of CaCO3 makes 25-75%. The rest of the percentage is clay, fine sand and other impurities.

In our case, the presence of fine sand and clay is rather small. This fact is confirmed by the decomposition of the sample piece in the acetic acid. This experiment showed that the insoluble residue is represented by a very small amount of impurities. Therefore, the silicon dioxide, instead of the fine sand (which is insoluble in acetic acid) is represented by an amorphous silica and amorphous silex, once contained in the initial solution, along with the sediment calcium carbonate and other components.

*Photo of an experiment on the decomposition of limestone, taken from the blocks of the walls of the Saqsaywaman fortress, interacting with 70% acetic acid.*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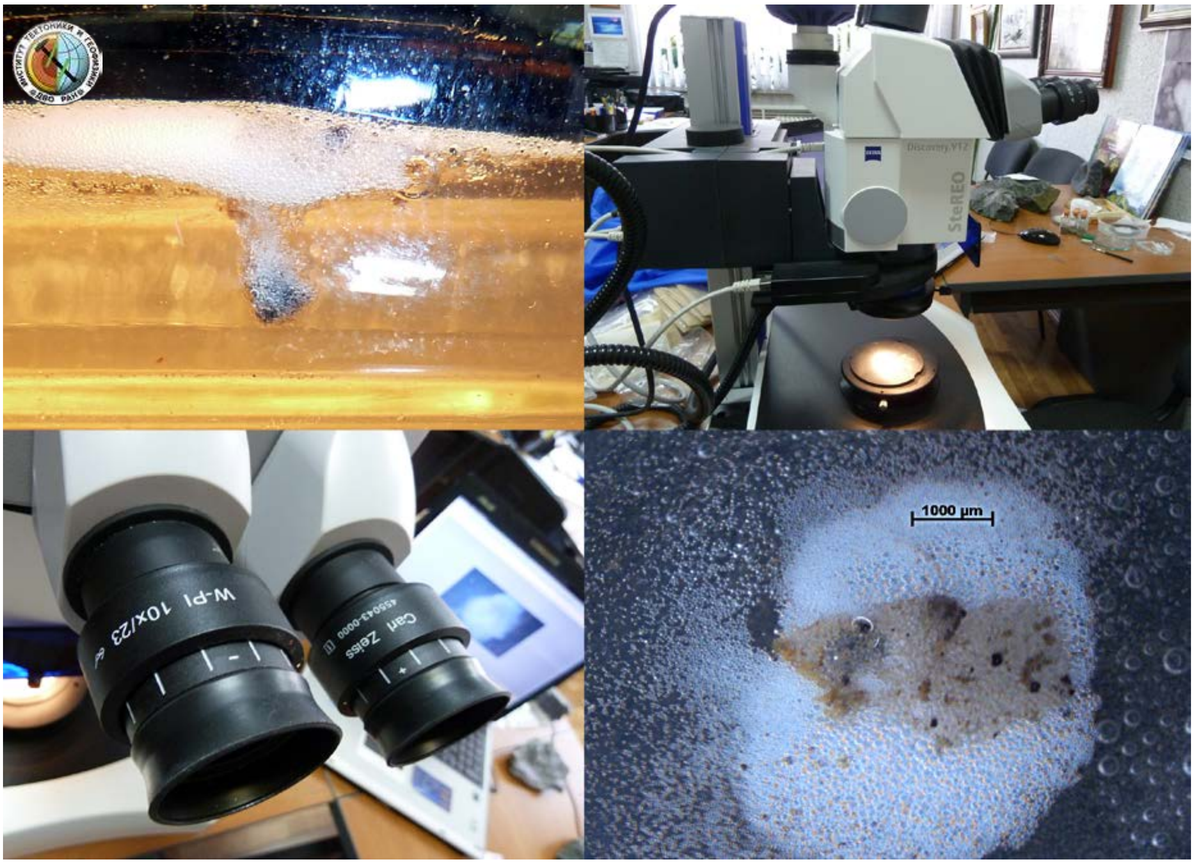


*Photo of an experiment on the decomposition of limestone, taken from the blocks of the walls of the Saqsaywaman fortress, interacting with sulfuric acid.*

It is well-known fact, that marl is the main raw material for the cement. So-called "marl - naturals" are used in producing of cement in its pure form without using any mineral supplements and additives, because all the necessary components are already present in its original composition.

Let's note, that the insoluble residue content of silica ($SiO_2$) in the conventional marls exceeds the number of sesquioxides in no more than 4 times. The marl, composed by the opal structures, with the silicate modulus (ratio of $SiO_2$: $R_2O_3$) more than 4 – is called "silica". In our case, the opal structures are represented by an amorphous silica - hydrate silica ($SiO_2 * nH_2O$).

*Opoka. Hydrated silica. Photo: (фото: Le.Loup.Gris Wikipedia)*

 

Opoka – is the hydrated silica (the old Russian name for it is - *siliceous marl*). Opoka – is a hard solid breed of rock, sonorous when struck. The last feature correlates with experiments on knocking on the blocks of the Saqsaywaman fortress for getting the sound. While knocking the blocks of the fortress wall with the help of a small stone, they produce a special “ringing” sound.

However, opoka – is a rock, composed mostly of silicon dioxide with minor inclusions of various contaminants (including CaO). It would be completely wrong to apply the classification of opoka to the limestones and the material of the Saqsaywaman walls, because the basic component, according to the analyzed samples, is just the calcium oxide (CaO).

**Calculation of the silica modulus (SiO2: R2O3):**

- According to the results of analysis of the sample from the quarry, it makes - 7.9 units. It means, that the studied sample can be applied to the group of "siliceous limestone";
- Material of the Saqsaywaman blocks makes - 7.26 units.

<u>Studying the stone breed, forming the blocks of the Saqsaywaman</u> fortress, it can be described as the "siliceous limestone" (according to the classification of G.Teodorovich), and as the "microsparite" (according the classification of R.Folk).

<u>The breed of the quarry</u> can be described as the "organogenic micrite" mixed with "pelmicrite" (according the classification of R.Folk).

Returning to the marl, lets note, that in addition to a raw materials for making cement, marl is also used for making a **hydraulic lime.** *Hydraulic lime* could be obtained after the process of burning the limestone marl at the temperature of 900 ° -1100 ° C, not allowing the composition get sintering (*it means, that in comparison with the production of cement, in this case, the clinker is absent*). While burning, the carbon dioxide (CO2) is being removed, forming a mixed composition of silicates: 2CaO * SiO2, aluminates: CaO * Al2O3 and ferrates: 2CaO * Fe2O3, which are bringing the special stability to the hydraulic lime in the moist environment, after its hardening and petrification. The main feature of the hydraulic lime - is its ability to petrify both in open air and in the water. It differs from the common lime by its greater ductility and toughness. Especially, this kind of lime is used in the areas subject to water or moisture.

The relation between the limestone and clay part, together with the oxides, affects the specific properties of such a composition. This dependence is expressed by the *hydraulic module*.

The calculation of the hydraulic module, according to the data, obtained from analyzes of samples, taken in the Saqsaywaman, is represented by the following results:

[ ***m*** = %CaO **:** %SiO2+%Al2O3+%Fe2O3+%TiO2+%MnO+%MgO+%K2O ]

- the sample, taken from the wall block of the fortress**:** ***m*** = 4,2;
- the sample, taken from the quarry: ***m*** = 4,35.

To determine the properties and classification of a hydraulic lime, the following ranges of the module are used:

- 1,7-4,5 (for strong-hydraulic lime);
- 4,5-9 (mild-hydraulic lime).

In this case, we have the absolute value = 4.2 (for the material of the wall block) and 4.35 (for the material of the quarry). The result can be described as the "medium-hydraulic" lime with a bias to the “strong-hydraulic”.

Hydraulic properties and the rapid increase of strength are typical for the strong-hydraulic lime. Then the value of the hydraulic module is higher, then faster the hydraulic lime is getting slaked. Then the module value is lower, then the reactions are less and the material could be defined as the mild-hydraulic lime.

In our case, we have an average module value, which means quite normal speed as for slaking, as well as for its hardening. This fact is appropriate for the complex of construction works of the Saqsaywaman walls, without using any high-technology tools and scientific researches.

While connecting the hydraulic quicklime (heat-treated limestone) with water ($H_2O$), the process of lime slaking gets started. This process can be described as the transformation of the anhydrous minerals, composing the material, into the hydroaluminates, hydrosilicates, gidroferrates, and as the result - the whole mass turns into a “lime paste”. The reaction of slaking of both common and hydraulic lime is exothermic. The hydrated lime, formed by this reaction $Ca(OH)_2$, reacts with $CO_2$ air (($Ca(OH)_2 + Co_2 = CaCO_3 + H_2O$)) and with the composition of the group ($SiO_2 + Al_2O_3 + Fe_2O_3$) * $nH_2O$. After the solidification and crystallization it forms a very strong and waterproof substance.

While slaking the hydraulic and common lime, depending on the slaking time, the quantitative composition of the water, and many other factors, a certain percentage of "outstanding" grains CaO, are still remaining in the lime mixture. These grains can be slaked with sluggish reaction during the long time after fossilization of material, forming microvoids and cavities, inclusions or individual globules, formed by the minerals, unrelated to the basic mixture of material. Particularly such processes are running in the subsurface geological layers, interacting with the aggressive external environment, such as water or moisture, containing various alkali and acids.

Presumably, such formations are caused by the quicklime grains of calcium oxide, which can be seen on the walls of the Saqsaywaman fortress as the white dots on a gray surface of the blocks:

*White dots on the grey blocks of the Saqsaywaman walls.*



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**The good hardness and moisture-resistance properties of the obtained substance** (without adding fine silica) were estimated **during the experiment** on mixing the quicklime with fine silica in the corresponding percentage, with the following slaking of it. After all, the soft substance was placed into the special forms, made for the solidification of samples.

The water resistance property prevents the adherence between the already hardened samples and newly prepared ones, thus providing the non-gap conjunction of the block surfaces. After the complete solidification, the samples can be easily detached from each other, thus showing that they do not run monolithic with the other blocks, being placed together in the wall construction. After the solidification, the surfaces of the samples become shiny, like if they have been polished. This fact could be explained by the presence of the amorphous silica, which after the interaction with $CaCO_3$ covers the blocks with a silicate “skin”.

***The second preliminary conclusion:***

The blocks of the Saqsaywaman walls are made of the *hydraulic lime*, obtained by applying a thermal effect on the Peruvian limestone.

It is well-known fact, that any quicklime (both hydraulic and common) has an ability to increase in its weight, while interacting with water. Depending on the composition of the substance, its volume can be increased in 2-3 times.

**The possible methods of thermal effect on a limestone.**

The temperature, required for the limestone burning is 900 ° - 1100 ° C. It can be obtained by the several available ways:

- Lava extrusion (in this case we assume a close contact of limestone formations with lava);
- Volcano eruption (when the minerals are burned and ejected to the atmosphere by means of the internal gas pressure);
- Human factor. (Technological way)

*10 meter lava fountain, Hawaii, USA. (photo: J.D. Griggs, Wikipedia.)*



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*Rodadero Formation. Cuzco (photo from the National Geographic archive. 1941)*

The researches, provided by the volcanologists, show us, that the temperature of lava, which is poured on the planet surface, makes 500 ° - 1300 °C. The enough temperature, good for the limestone burning is 800° - 900 °C. Lavas with such a temperature are foremost the silicon lavas. The content of $SiO_2$ in such lavas varies in the range of 50-60%. Lava gets more viscous with the increasing percentage of silica, and therefore its spreading on the surface is limited. While spreading on the surface it warms the contiguous geological strata in a close distance to the place of extrusion, thus contacting with the outer geological layers as well as with the underlying limestone mines.

The example is the "Inca throne," carved in one of the lava extrusion formation. This formation can also be represented as the silicified limestone with a high content of silica and alumina, or opoka. The process of crystallization, occurs here in a quite different way in comparison with the main rocky strata, covering the "Rodadero flows".  Of cause, this assumption requires more analysis and study of the described formation.

This geological formation is located not far from the Saqsaywaman fortress, and, by all its properties, could have been that very "fuser", that once has warmed the limestone strata up to the required temperature. After extrusion it has formed a bizarre hill, having cutting and scattering pre-heated fragments of limestone strata in the different direction from the point of injection.

According to some scientists data, this hill is represented by the augite-diorite porphyry, (which is based on silicon dioxide ($SiO_2$ - 55-65%)), which is a part of the plagioclase ($CaAl_2Si_2O_8$, or $NaAlSi_3O_8$). The basic role we shall assign to the plagioclase anorthite $CaAl_2Si_2O_8$, because the poured lava goes in the direct contact with the limestone layers, which are mostly composed of $Ca_2CO_3$.

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*Rodadero Formation. Cuzco*

The frozen "flows" of Rodadero extrusion are not limited by the only place of injection point. They continue their way under the planet surface, among the limestone geological layers of the area.

The study of this formation is not finished. It requires further research and analysis. But all the evidences of high temperatures effects (about 1000 °C) are still there.

So, the limestone, being heated and burned (thus transforming into the hydraulic slaked lime), reacts with the rainwater, hot spring, reservoir, or water vapor - immediately gets slaked, afterwards turning into a “lime paste”.

The crystallization and calcification occurs by the previously explained scenario. Moreover, in this case - the reaction with water turns calcined raw material into a fine mass (preliminary grinding the stone into a powder is not required here). The result of this reaction - is complete destruction of all the fossil and biogenic particles. Thus, we have that very "magical transformation", caused by the recrystallization of biogenic limestone into the microcrystalline one.

If needed, the lime paste can be stored for the years, if the air factor has being excluded.

A good examples of the frozen lime paste - are well-known "clay stones" with the typical artifacts on their surfaces. In some cases, these stones have the traces of removing their surface layer. This evidence fits the assumption of heating the entire mass of the "boulder", after what their surfaces, in comparison with the core, got much higher thermal stresses and could be easily processed. Apparently, this is the explanation for all these specific external artifacts, that we can watch on the surfaces of the “clay-stones”. The lime paste was taken from the heated soft surface layers of the limestone, until the deeper non-heated layers were approached. Thus we can watch the remaining “clay-artifacts” till our days.


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*“Clay-stone”. Photo by A. Verianov*

Another opportunity for making a lime paste, can provided by the volcanic ash. Its particle size and mineralogical composition differs, depending on the geological layers, forming the areas of volcanic activity. Then the ash particles smaller, then higher quality of the paste could be finally obtained; and consequently the process of crystallization and petrification would be completed with higher data. The fact is, that the ash particles can reach the size of 0.01 microns. In comparison with it, fine grinding of the particles of modern cement makes about 15-20 microns.

Fine particles of volcanic ash are forming a “mineral paste”, after interacting with water or moisture. This “mineral paste”, depending on its composition and conditions can spread over the ground, mixing with its layers, thus forming a fertile soil or solid rock surfaces of various forms, concentrating in rock crevices and lowlands.

The variety of artifacts, remaining on the surfaces of such geological formations, is revealing a variety of information, “pictured” there on the moment of solidification and crystallization of the stones. But in our case, the version of the volcanic ash, does not explain the presence of organic fossils in the sample of limestone, taken from the quarry.

*Footprints in the ashes of Tanzania. Laetoli*

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In addition to all the described versions, we must not forget the human factor (thermal processing of a limestone). The skillfully created bonfire can reach the temperatures of 600° -700 °C, and sometimes even 1000 °C.

The combustion temperature for the wood is about 1100 °C, for the coal is about 1500 °C.

In our case, it is necessary to build the special "ovens", which is not a great problem for the ancient peoples, as well as for the modern civilization.

## CONCLUSIONS

• During construction limestone blocks underwent a certain influence, the consequences of which was the disappearance / dissolution of organic remains on the way from the quarry up to the place of construction.

• The blocks of Saqsaywaman walls are made of hydraulic lime dough, obtained by thermal exposure on the Peruvian limestone.

* * *

Of course, we need more detailed researches and analysis, in order to estimate the real reason of thermal effects on the studied limestone. Whether it were human or natural factors, but the fact remains as the fact - recrystallization of biogenic siliceous limestone into a microcrystalline siliceous limestone. The result of this process we can see in the material, forming the wall polygonal blocks of the Saqsqywaman fortress. **In normal nature conditions - this process is absolutely impossible**.

Recrystallization process needs long-term temperature exposure up to of 1000 °C, followed by mixing the hydraulic quicklime analog with water, after what the slaked "lime paste" is formed.

According to all the facts, mentioned above, this "mysterious clayish paste", forming the polygonal blocks of the ancient megalithic walls of the Saqsaywaman fortress, and the technology of its construction doesn't leave any more doubts. The procedure of processing the raw "lime paste" (hydraulic lime) with its consequent mounting into the large blocks – doesn't sound impossible anymore, even for the ancient peoples.

So, the need in using of any fantastic high-tech equipment is completely eliminated, as well as the impossibly hard handwork on cutting and dragging the megalithic blocks to the place of construction.

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**REFERENCE:**

1. A. Verianov, N. Berdnikov. “Geo-radar and geo-chemical research of the Saqsaywaman fortress.” (GEO y Asociados & Institute of Tectonics and Geophysics. Russian Academy of Sciences. Far Eastern Branch. (FEB RUS).
2. Heinrich Gerth. “Der geologische Bau der sudamerikanischen Kordillere.” Gebrader Borntraeger,Berlin-Nikolassee, 1955
3. G.I. Teodorovich. “The Doctrine of the Sedimentary Rocks. Leningrad: Gostoptechizdat, 1958.
4. Jean Pierre Protzen. “Inca Quarrying and Stonecutting.” The University of California, Berkly.
5. Y.M. Bewt “The technology of cement and other cementation materials”. Stroiizdat, Moscow, 1976.
6. A.V. Storcheus. “To the question of the volcanic explosions mechanism”. Institute of Volcanology and Seismology FEB RUS, Petropavlovsk-Kamchatskiy, 2009.
7. FolkR.L. “Carbonate petrographic classification of limestones” Am. Ass. Petrol. Geol. Bull. 1959.
8. “Who left the footprints in Laetoli” http://www.chelovechectvo.ra/lyudi_niotkuda/kto_ostavil_sledy_na_peske_v_laetoli.html
9. Photo material is provided by Patricia Awyan, A.Verianov and Institute of Tectonics and Geophysics named after Academician Yu.A. Kosygin FEB RAS (http://itig.as.khb.ru)
10. Photo material, taken from the Internet resources:
http://dic.academic.ru/dic.nsf/rawiki/163207
http://commons.wikimedia.org/wiki/File:Opoka_rock_Saratov_2.jpg?uselang=ra

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