THE STONE LAB

Digital Application of Ancient
Armenian Stone Masonry for
Rural Development of Shikahogh

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Abstract

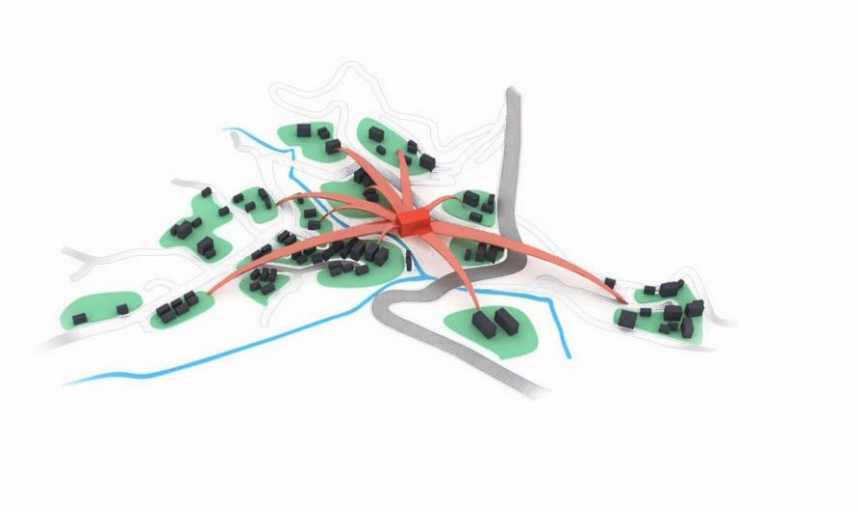
"Digital applications of ancient Armenian stone carving techniques for rural development of Shikahogh" is an innovative action research, with a real time application of a "Stone Lab" in a remote village of Shikahogh in Armenia.

The petroglyphic and traditional stone masonry heritage presents the contextual substance, whereas underneath this layer, a deeper and more spiritual metamorphoses of belonging and identity preservations manifest.

Shikahogh is a post USSR village where a steady population deterioration is observed. It is also a historic cradle of ancient Khachkars (traditional stone crosses) of which no prior study has been made.

The "Stone Lab" will employ a hybrid approach of the experimental archaeology and digital reconstruction to unveil the hidden inscriptions of these Khachkars as well as the functions and technological processes behind their creation.

Thus the "Stone Lab" is the development catalyst, a seed of change and the outcomes of its deployment are largely unpredictable.



Stone lab : the impact diagram

Literature review

2.1 Shikahogh (Armenia)

2.2 Stone Masonry

2.3 Digital Reconstruction

Context

Identity. Land. Stone.

As a crossroad connecting Europe and Asia, Armenia was relentlessly caught between empires, mainly Persian, Ottoman and Russian.

Thus the current size of the country (11490 square miles) represents only the fraction (about 10%) of what was used to be the Greater Armenia. Throughout the history, this small nation has been fighting for its survival and for the preservation of its national identity. The deeply rooted land conciousness is a strong representation of the centuries of struggle trapped between the three empires. Stone is closely linked to the notion of the national identity preservation on many levels. It was not only the building material, and the tool, but also the carrier of the first Armenian petroglyphs which then turned into the hieroglyphs which later eveloved into the modern Armenian language of today. The language, the cultural rituals and folklore was preserved throught the stone inscriptions. The stone has an absolute unique role in the conciousness of the nation as the vehicle of their message pouring from the ancient world through to the 21st century, transfering and transcending the wisdom of the old world.

The strategic location of Shikahogh is what makes it so significant, as Syunik province in general is a rather fragile region, where both borders with the neighboring Turkey and Azerbaijan are shut and are under the surveliance of Armenian and Russian armed forces. Being rather remote and detached by series of mountains, the region and Shikahogh village in particular are difficult to reach and less progress is made here. As the preservation of the land is so crucial and very little is done in this region, the stone lab will be restating the vital concept through studying the unresearched stone relics of the Shikahogh village.

This is where the meetings and gatherings would take place, themed around the communist propaganda, here we see a rise of a different kind of socio-political agenda. The communist ideology was disseminated and re-enforced via these centres.

The shift finds its reflection on the architectural solutions, on the use of the materials and utilasiation of the stone masonry techniques as well. The traditinal elements, the stone masonry technologies that took centuries to develop, where still implemented, however the spiritual aspect was made obsolete, in favour to utilitarian, cooperative design. With the emergence of the soviet regime, the ornamental design was abandoned, along with the underlying meaning. The utilitarian outlook was about sameness and simplicity, no more differentioations and individuality, which is in complete opposition of the core phylosophy of the Khachkar- that is the individual mediator between an individual human being and God. In fact God was made obsolete during the USSR realm. In the same time, the Khachkar crafting suffered a decline in popularity, since the spiritual practices were discouraged by the communist propaganda. Only after the world war two, the architects and stone masons utilised the opportunity of raising World War two memorials in towns and villages across the country, by crafting them into new types of memorial Khachkars.

This view point, however has changed once more, after the USSR collapse in 1991, creating a mix environment, that is trapped within the remains of the soviet structure, but where the effort is to resurrect the rich cultural heritage, whilst trying to address newly emerging practical and sustainable requirements.

Armenia 2nd century BC

Armenia 3rd century AD

Armenia 7th century AD

Armenia 10th century AD

Armenia current territory 2013

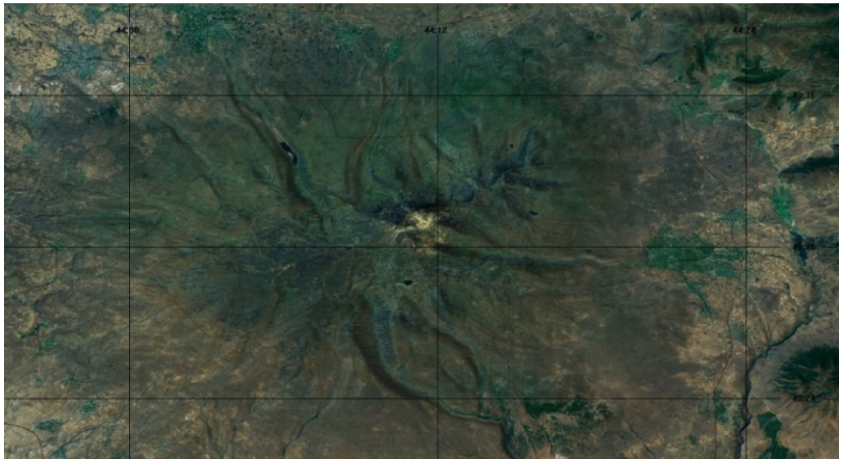
Context

The legends and the volcanic origins

The vast majority of stones in Armenia are of igneous origin and there are seven active and extinct volcanos on the current territory of Armenia; Ara, Aragats, Alages, Arteni, Gegham, Porak and Tskhouk-Karchak . Most of these mountains are surrounded by legends and myths, passed upon generations through folklore tales and music.

The mount Ara is called after Armenian King Ara Geghetsik (Armenian translation Ara the Handsome). According to the legend during the war against Assyrian queen Shammuramat King Ara arranged his army at the foot of mount Ara, and the queen - on the slope of Hatis. Unfortunately the king fell in the battle and the mountain is said to be the body of Ara.

to shed light on him.



Mt Aragats, sattelite view

Mt Aragats

Armenians thus believe that the Illuminator's lantern is still there, and only those pure in heart and spirit can see the eternal lantern - the symbol of hopes and dreams of the nation.

Located in southern Armenia on the western slopes of Vardenis volcanic ridge, south of Lake Sevan, Alages is perhaps the youngest of all the volcanos, with the last eruption registered in 1340 and to this date, the mountainous area is prone to destructive earthquakes (on average one every 50 years), with occurrences at >7 Richter. This means that when a strong earthquake occurs, damage will be considerable in ordinary buildings.

The Geghama Rindge is of volcanic origin including many extinct volcanoes. The range has 70 km length and 48 km width, stretching between Lake Sevan and the Ararat plain. Initial explosive eruptions at the Gegham Ridge volcanic field were followed by the extrusion of rhyolitic obsidian lava domes and flows. This obsidian revolutionised and accelerated the ancient technological advancement; it was sharper and more resiliant than any other material used prior. It is, therefore, not surprising that a great number of petroglyphs have been found in the area of Geghama Mountains dating back to around 7000 and 9000 BC.

Porak is a mid-Pleistocene stratovolcano located in the Vardenis volcanic ridge about 20 km South East of Lake Sevan at the border of Armenia and Azerbaijan, hence the lava flows extend into both countries. Fifth century BC petroglyphs found in the area were interpreted to depict volcanic eruptions. Porak volcano is referred to in a famous cuneiform inscription as Mount Bamni, and stratigraphic and archaeological evidence indicates that an explosive eruption also producing a lava flow occurred at the time of a military battle dated to 782-773 BC.

A group of pyroclastic cones is located in the central part of the Syunik volcanic ridge along the Armenia/Azerbaijan border about 60 km south east of Lake Sevan. The Tskhouk-Karckar volcano group was constructed within offset segments of the major Pambak-Sevan strike-slip fault trending South East from Lake Sevan. Abundant petroglyphs, burial kurgans, and masonry walls were found in nearby area of the mountain. Lava flows from cinder cones of the Tskhouk-Karckar volcano group overlie petroglyphs dated to the end of the 4th millennium and beginning of the 3rd millennium BC and are themselves used in gravesites dated at around 2720 BC. Following these eruptions, the area was not repopulated until the middle Ages.

We see that the concentration of the petroglyphs around these mountains was due to the abundance of both tools and materials used by the early stone artists. The petroglyphs in turn tell the legends and myths of the mountains.

Context

The Stone

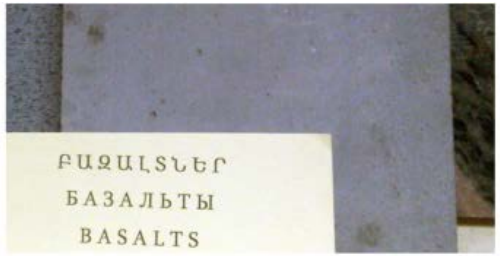
types and qualities

Volcanos and earthquakes not only shaped the topology of the land, but played a significant role in predefining the path of the cultural and the technological advancement, since people were confined with the tools and materials that the natural phenomena made available to them. Depending on the mineral composition and the setting of the stock, the formation method of the rock can vary slightly. After a violent volcanic eruption, volcanic ash, frothy magma, dust and fine rock particles settle and build up on the land surface.

The ejected particles form a rock with a soft, porous texture. The particles may eject from the main volcanic vent or may escape through cracks in the walls of the volcano, called fissures. These fissures are often smaller than the central vent but extend from the magma chambers toward the land surface. The magma and rock particles that settle from the volcanic eruptions can form tuff rocks in several ways. Some tuff rocks form when the particles become buried under layers of other rock and harden into stone through compaction. Alternatively, the particles can form a rock through cementation, typically when calcite or quartz in solutions precipitates and glues the particles together into a rock. Sometimes, a welded tuff is formed, as the temperature of the rock particles are very high.

Since Caucasus region and Armenia in particular is prone to earthquakes, it is not surprising that tuff and other similar deposits are abundant in this area, as most of these stones are an extrusive igneous rocks that form after volcanic activities.

Amongst other igneous rocks, Armenian highland holds enormous stocks of tuff, which is an easily cut resilient type of stone.



The Stone museum in Yerevan, Armenia

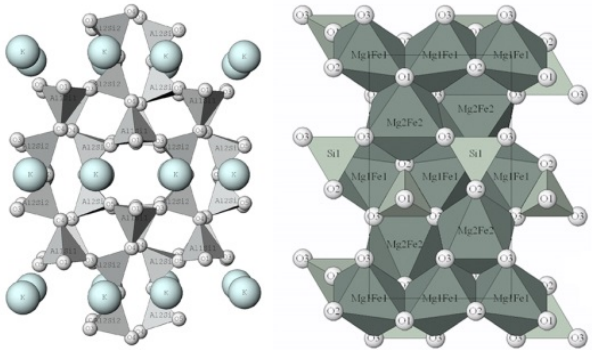
Context

The Stone

Geometries

Located around 30 km on the East of Yerevan, a curious volcanic basalt patterns can be found around the Garni Gorge. These are natural formations (“the Symphony of Stones”) comprising of columns of various sizes which are mostly hexagonal in shape, even though squares, pentagons, heptagons, octagons and other geometrical shapes are common too.

The origins of these structures are of volcanic eruptions, with particular cooling and solidifying processes of the boiling lava, which gave these almost perfect geometric forms and hanging columns a distinct appearance. The rocks have multiple layers unveiling how the lava solidified, shrunk and formed these shapes over long periods of time. While a flow can shrink in the vertical dimension without fracturing, it can't easily accommodate shrinking in the horizontal direction unless cracks form; the extensive fracture network that develops results in the formation of columns. The topology of the lateral shapes of these columns can broadly be classed as a random cellular network. The size of the columns depends on the rate of cooling; very rapid cooling may result in very small



Volcanic rock formation and crystalline structure

Garni Gorge volcanig columns

Geghard cave detail

CNC manufacturing

Context

Petroglyphs

From 15000 BC the petroglyphs have recorded not only the story of the evolution of the tools and technologies, the craftsmanship and lifestyle in Armenia, but the path that the language has undergone. From the early carved petroglyphs on the cave walls to the 5th century AD Khachkars with inscriptions, the native language has survived throught transformation and due to being embedded in stone.

There are exceptionally rich centres of rock carvings in historic Syunik, more than 2000 decorated rocks were discovered at Oughtassar. The carvings are graphic and volumous and have been represented horizontally or vertically on the flat, brown and black rock- fragments, amounting several hundred patterns. The depth of their cutting is 2-6 mm, while the width is 2-21 mm. The themes vary from most animals, to scenes representing hunters and hunting objects.

Petroglyphs from Ughtasar

Petroglyphs from Syunik

The petroglyphs effectively communicate the information on the activities, mode of life, production ways and means, animal husbandry and farming, ancient legends and myths, natural phenomena and general trends of the past generations.

The main features of the technical and stylistic execution of rock carvings:

The late neolithic-iron age art of rock carvings portrays figures which were carved out on comparatively smooth surfaces of basalt rock fragments by means of various hand-size stone swingels and obsidian cutters, substituted, later on by metal ones.

There were several carving techniques such as the “point beat”(this required hundreds and thousands of beats of the stone swingel to cover 1-3 cm of the artwork) and the linear (which had a limited development).

Armenian petroglyphs continually evolved fo over four thousand years. Through ages constantly changing and becoming more complex: based on the productive, religious, and ideological norm shifts of early farming, hunting gathering, herding etc stages.

Diverse forms of hunting were depicted from bare hands, to the ropes, clubs, traps, hollows, nets etc. Hunting done by the means of the bow and arrow , spears and hatches for example was aimed at preserving the communal herd from beasts of prey. The bezoar goat was the first animal to be domesticated. Incidentally, this particular species is now extinct, only few reside in the Shikahogh natural preserve.

From these petroglyphs we learn that the ancients concieved the universe to be divided into three horizons (upper , middle and lower), which formed one indissoluble unity and did not differ essentially from each other. They believed that the upper horizon- the sky was inhabited with birds and celestial bodies. This three layered distinction is then translated into later Khachkars as well.

A vast number of the Syunik petroglyphs display, in various relations, Gods of neolithic and early iron age and although they are anthropomorphic, their large dimensions with exaggerated iconographic details and functions differ sharply from the pictures of ordinary men and hunters. Their apperance often is associated with the celestial symbols, emphasizing the extraordinary heavenly origin of these supernatural creatures.

These petroglyphs can be treated as written monuments, laying at the origin of all subsequent writing and scripture, which are based on the pictures of objects. Pictographic, hieroglyphic and ideographic characters originate in early Bronze Age, entering into Urartian (pre historic Armenia) culture and presumably changing into stylized scripts.

Context

Khachkar

Khachkar (Armenian - cross stone, a stone that bears a cross, a cross shaped stone etc.) is an absolutely essential component in the development of Christianity, education, arts, crafts and architecture in Armenia since 4th century AD. According to the evidence presented in the "History" by Agatangeghos, the first cross-bearing steles and temple appeared in the centre of the capital of Armenia as a result of a miracle. The Khachkar, thus, aimed to give holiness to an open air, the secular territory, which was in interesting contrast to temple- a non-secular, holy territory of the temple.

The main components of Khachkar are the central cross and other illuminated symbols, the decor elements (triangles, stairs, rosette etc.), birds and other figurative reliefs, cornice, inscriptions etc.

Khachkar is a common model of Armenian world and the tradition of erecting the stele is still kept intact in modern Armenia. The main stimuli for Khachkar placement was an anticipation or a goal, which can be described as a holy attribute directed towards the future.

Throughout Armenian history, Khachkar played a role of a temple, a gravestone, a book. The making of the cross-stone, was considered a serious and prestigious profession, since most of the master Khachkar makers were well travelled and had a thorough understanding of not only sketching and carving, but also sculpting, construction and architecture. These craftsmen were referred to as inventors, decorators, painters, sculptors, masters, etc.

Khachkar inceptions starts with the choice of the material and the quarry. The sourcing of the right stone was of paramount importance, people would often cover great distances, leaving their natural habitats for days and nights in search for a particular stone. Older Khachkar inscriptions give a detailed story of the great difficulties and torments one went through obtaining the stone, such as this extract carved on an old Khachkar from Syunik:

" I, Sargis of village Koghq, went through endless pain and had to employ wit and craft to possess this stone to make it into khachkar".

The beneficiary of the khachkar or the khachkar artist would have a vision or a dream about the location of this particular stone that was destined to become a khachkar. An inscription on one of the stones from Artsakh reads:

The transportation and installation of the Khachkars was a laborious task, requiring constant perfection of the technical solutions. The khachkars themselves tell the story through their additional structural elements, that had no conceptual or ornamental bearings. These elements are for example the protrusions on the back and the sides of the cross-stones. Khachkars from earlier period (before 8th century) also include holes in them, for the ropes to go through for lifting and transportation.

The creation process:

After the volumetric treatment (the blocking out of the main body and bringing it to some degree of standard geometric shape) the frontal surface was chosen for further polishing. Once completed, the khachkar artist would then spend time "conversing with the stone".

The artist would juggle with many fragile components; he had to be well versed in mathematics and geometry to produce the symmetries ,but also contrast it with his depth of knowledge of limitations of the stone. Lastly and most importantly he had to give due space to the spiritual symbolism and the depiction of divinity that knows no limits.

Tuff Khachkars (5th – 6th Century AD)

Khachkar studio in Yerevan

Methodologies

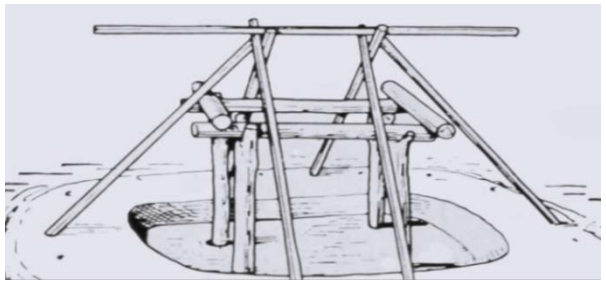
Experimental Archaeology

The preliminary fieldwork I have conducted in Summer 2013 revealed a great number of Khachkars in Shikahogh, that have not been researched and nothing is known of their origin or purpose. Like most other cross-stones, these Khachkars might have had unique significance in the past. Moreover, it is possible that studying these Khachkar may lead towards new discoveries about the village itself. During my month and a half intensive research in Armenia, most efforts to reveal the history of the village were futile. The investigations in local and national libraries and museums provided no leads; it was next to impossible to discover any recorded evidence that went further than 18th century.

The methods of experimental archeology and digital reconstruction will be employed to regenerate the Khachkars and decipher the semantics.

The experimental archaeology cluster of the stone lab attempts to exercise a hypotheses, by replicating or rather reenacting the ancient methods of stone carving. The Shikahogh Khachkar will be the archeological source material and various methods, techniques, analyses, and approaches will be practiced to understand these artifacts.

Jomon settlement footprint



Reconstruction drawing

Jomon hut full reconstruction

During my interview with Khachkar artist Varazdat Hambardzumyan, he said that the majority of Armenian Khachkars were destroyed , left behind during the 1915 Armenian genocide. His team put together a studio, collecting data such as old photography (mostly saved by the Armenians of diaspora) that will enable them to ressurrect / replicate these lost relics. The digital application methods could vastly accelerate the process of repairing, replicating and restoring the Khachkars.

Such projects are undertaken by New Jersey based non profit atelier called The digital Stone, with comprehensive collection of CNC mills and lathes, used exclusively in service of Arts since 1990. Their process is a hybrid between the digital and analogue. In the example of the restauration of New York City's Tweed Courthouse, the survived architectural elements were laser-scanned so that exact replicas could be made to replace those lost or ruined over the years.

Many works executed on the computerized equipment are rescaling and material realizations of works otherwise created by traditional or "analog" means. The original piece is laser scanned, creating a three-dimensional electronic model that could be used by CNC machines. Once the stone is selected, the digital carving process first blocks out, then refines the surface, however the finer details are hand carved.

The hybrid flow of the "man and machine" unity, each performing their part, creates a less time consuming and economic model.

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The hybrid flow of the "man and machine" unity, each performing their part, creates a less time consuming and economic model.

Methodologies

Digital Reconstruction

With Khachkar we have seen that the volumetric treatment was done by the new disciplies and did not explicitly represent a worthwhile stage for the main artist-the master, to be involved in. Modern khachkar studios in yerevan continue this tradition. What digital stone project did is replace this less significant but most laborious stage with the digital counterpart to speed up the process. The Stone lab will investigate both into the potential of the hybrid modes of working as well as use the digital tools to re-invent the process.

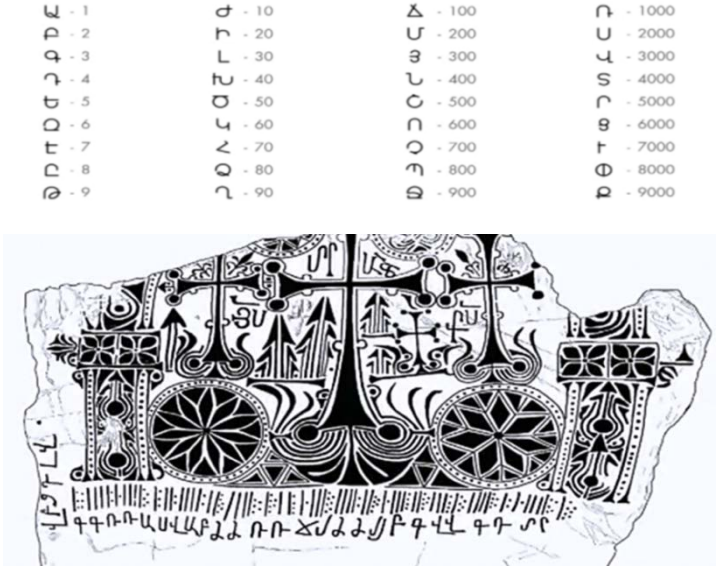
Khachkar- blocking out

Robotic arm- blocking out

Digital applications will also assist in decifering the Khachkar inscriptions. With these cryptograms rather elaborate encrypting techniques were used, based on mathematical sequences where a letter was assigned a number, or a line and a dot.

One of the methods is created upon four columns where each letter was assigned a number and on the Khachkar each number was represented as a combination of a vertical line and series of dots. Upon discovering the hidden numbers, the corresponding letters were recognised and the message is revealed. There are hundreds of variations of these encrypted Khachkar messages, which are majorly under-researched. With digital application introduction, it may be possible to implement a computational pattern recognition code that can authomate and speed up the process, as well as use sophisticated mathematical models to recover the corrupt data.

Khachkar inscription



Khachkar cryptograms

Fieldwork

Shikahogh

When driving from Yerevan to Shikahogh village, one can observe the soil gradually turning from earth brown to red tinted. The name Shikahogh (orange earth or red, heated soil) comes from the orangey, fiery red colour of soil in the area. Scientists say the ten thousand hectares of forest help to moderate hot winds blowing from desert plains in Iran to the south. The vegetation is also influenced by air from the Caspian Sea to the east. These climatic conditions have created a mix of flora and fauna unique to the region. The oldest parts of the forests in Shikahogh are thousands of years old. The growth is so thick in places it blocks out almost all sunlight, so that deep in the forest even the brightest days can seem dark. The local ecosystem has been kept intact largely because of the region's remoteness.

Shikahogh is one of the five villages within Kapan municipally in Syunik province, along with Chakaten, Srashen, Nerkin Hand and Tsav. It is surrounding the Shikahogh Natural Preserve, which is one of Armenian's largest natural reserves. The Shikahogh preserve is a home for many indigenous species, such as the Bezoarian Goat and the Armenian moufflon (a species of wild sheep), as well as between five and eight Asian Panthers - an endangered species of which there are only 20 in the greater Caucasus.

In the village, the main economic determinant is projected upon farming, agriculture as well as a group of villagers are employed at the Preserve.

A two week trial fieldwork was conducted in the village during August 2013, where I had interviewed the local residents, the governor and the head of the natural preserve. It was a unique opportunity to immerse into the day to day village life, with its breath taking surroundings, to synchronise with the schedule with which the locals operate and build a comprehensive understanding of the joys and the impediments of farming, agriculture and the village life in general, as seen from the residents perspective.

In recent years, a number of young representatives were promoted to the governing roles in the village, who are eager to enrich the village life and incentivise the growth of population. However this is not an easy task to accomplish; the village is facing a number of deep rooted difficulties, of which the deterioration of population, the lack of job opportunities, the infrastructural and facilitative defects being the most pressing.

Shikahogh (Syunik region, Armenia)

Fieldwork

Khachkar workshop

The village population was 189 in 2010 (accoridng to Armstat) and a steady deterioration of numbers is observed every year. In his interview, the governor Jirayr Patvakanyan admits “In the next few years our population might see a drop in numbers by around 40% as over 60% of the current population are elderly people above the age of 75”.

The only jobs are to be found in the small hydro-electric plant, where around 15 villagers are currently employed. Many others have left to the nearest towns and cities to work in the Kapan or Kajaran mines. During the last two years, 20 families have already packed and left Shikahogh.

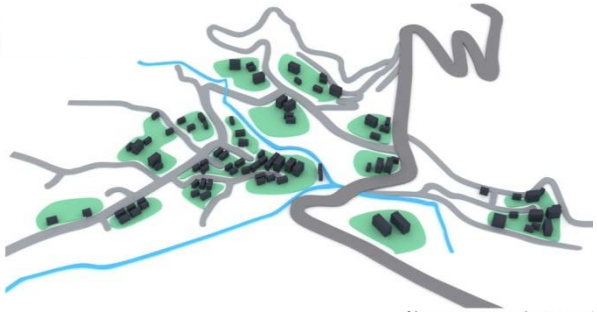
The situation regressed further after the World Wildlife Fund conducted a sutdy in the Preserve and errected fences around the forest, prohibting villagers any access. Most importantly villagers were refused permissions for cutting any trees, which used to be the main fuel material for harsh winters in the village. One of the villagers, grandma Coghik says “The trees have more value than us humans. This isn’t

Analysis

After the trial research in Shikahogh village, the main growth impediment was identified as the population decline. Therefore, upon returning to the capital city Yerevan, I have conducted a small sample questionnaire to start constructing some clues around what the city dwellers think about the rural settlements.

A total of 38 participants of 18-36 age group volunteered for interviews and written questionnairs under the wider pretext “what would incentivise you to relocate to a village?” . Around 42% admitted that they would not consider the possibility, no matter what the circumstances, another 40% could see themselves relocating, provided the right job opportunities were available, whereas the rest of the participants had contradicting views and were generally uncertain.

Since a big number of participants hinted on that “in new 21st century, the concept of the traditional village is obsolete



“No interference“

“Smart Village“

“Automated Village“

The first consideration was the "no interference" mode, where no project will be implemented and it is assumed that the population will continue to shrink.

Next was the scenario of the "smart village“, which would provide answers for all the village issues observed during the fieldwork. Those include the redesign of the irrigation system, the street lamps, establishment of three workshops(ceramics, carpet making and stone working) etc; a complete renovation and rebranding of the village, with an intent to create a model that can be transferred and adopted by other rural dwellings.

Then I have investigated into the notion of the "automated village“ that would acknowledge that there must be a reason why the village population decreases and thus instead of fighting something that can be an evolutionary modification, we embrace and prepare for the change. Automated village would assume no human habitation but simply the continuation of village as a mechanism that provides farming and agricultural produce with a remote control in place.

What the “no interference” and the “automated village” fail to address is the importance of the land preservation and hence the ideas were disregarded. On the other hand the “smart village” was recognised as too broad a pursuit for the specific time horizon of this particular research.

Thus the "stone lab“ stood out as the most efficent scenario, which would also utilise a portion of the “smart village”, enabling the villagers to study the stone masonry technique and to venture into archaeological journey of the ancient Khachkars in the village of which no information is available. This is an attempt to raise the sense of community and belonging, and to let the locals know that the government does care about them. The stone lab will not only provide some work opportunities along the way, but will allow an experimental hybrid model studies of ancient techniques translated and transformed with modern tools.

Conclusion

The outcomes of the Stone lab trial are largely impossible to predict and that is the intriguing aspect of the research. As a catalyst, reiterating the symbolism of the stone masonry tradition it can hugely impact the village lifestyle from practical and spiritual point of view. Only after its installation the true influence on the village community can be observed.

The workshop, exploring the unresearched Khachkars, might give birth to new discoveries that will play a role in constructing the history of the village and the province, decoding the Khachkar inscriptions, a new chapter in the language and alphabet development might arise. A great contribution to knowledge would be the resurrection and reenactment of these techniques alone, that might attract a wider audiences of archeologies and historians. The new digital methodologies used in the lab might enable new ways of thinking amongs the Khachkar artists and stone masons, that are rather sceptical about the new tools and technologies.

Grandma Coghik, Shikahogh

Iran-Armenia highway, Shikahogh

Books

Abeghyan Artashes. Volcanos and earthquakes. Elektrasharj publishers. Tbilisi. 1909.

Abgaryan M. A. Assistance to a stone mason. Alexander Myasnikyan publishers. Yerevan. 1983.

Abrahamyan Levon, Nancy Sweezy. Armenian Folk Arts, Culture and Identity. Indiana University Press. USA. 2001.

Aghathov E. G. Armenian groundworkers: A project in one village. AGBU publications. Paris. 1926.

Aghayan Tsatur. A visual reference of the Armenian history. Hayastan publishers. Yerevan. 1989.

Amoroso Nadia. Digital Landscape Architecture Now. Thames and Hudson. UK. 2012.

Ananyan Levon. Fiery mountains. HGM. Yerevan. 2003.

Ananyan Vakhtang. The familiar mountains. Haypethrat. Yerevan. 1963.

Arakelyan Vazgen. An active Volcano: Hovhannes Shiraz. Noyyan Tapan. Yerevan. 2008.

Asaturean Jacob. A history of stone and soil. Atlas Publishers. Beyrut. 1969.

Avakian Arra. Armenia: A Journey through History. The Electric Press. USA. 2008.

Ayvazyan Argam. Petroglyphic heritage of Nakhijevan. Gasprint. Yerevan. 2004.

Azarev I. Mnjoyan K. From the experiments of Artik Tuff. Haypethrat. Yerevan. 1956.

Aziz Sartaj. Rural Development: Learning From China. The Macmillan Press. Hong Kong. 1980.

Baghdasaryan A. A. Tuff quarries of Armenia. Hayastan publishers. Yerevan. 1968.

Balasanyan A. E. Mineralogy. YSU. Yerevan. 1981.

Baqshi Kim. Destiny and stone. Soviet writer publishers. Moscow. 1985.

Brumfield William Craft. A history of Russian Architecture. Cambridge University Press. 1993

Chaszar Andre. Blurring the Lines. Wiley Academy. USA. 2006.

Chiras Daniel. The Natural House. Green Books. USA. 2000

Corner James. Taking Measures across the American Landscape. Yale University Press. New Haven and London. 2000.

Davtyan Robert. Avetiq Isaakyan on architecture and arts. Voskan yerevantsi publishers. Yerevan. 2005.

Dernie David. New Stone Architecture. Laurence King Publishing. London. 2003.

Dunn Nick. Digital Fabrication in Architecture. Laurence King Publishing. London. 2012.

Ernst Bruno. The Magic Mirror of M. C. Escher. Tarquin Publications. England. 1985.

Evans Robin. The Projective Cast: Architecture and Its Three Geometries. The MIT Press. London. 2000.

Feireiss Lukas, Oosterhuis Kas. Game set and match 2: The Architecture co-laboratory. Episode Publishers. Rotterdam. 2006.

Gabrielyan H. K. The weathering processes of the volcanic regions of Armenian SSR. YSU. Yerevan. 1962.

Ghukasyan Margo. Stone made miracles. HGM. Yerevan. 2005.

Gink Karoly, Gombos Karoly. Armenia: Landscape and Architecture. Corvina Press. Hungary. 1974.

Glynn Ruairi, Sheil Bob. Fabricate: Making Digital Architecture. Riverside Architectural Press. Canada. 2011.

Goodwin Godfrey. A history of Ottoman Architecture. Thames and Hudson. London. 1971.

Grigoryan Grigor. Armenian lithography. Zangak-97 publishers. Yerevan. 2000.

Harutyunyan Varazdat. The history of Armenian architecture. Luys publishers. Yerevan. 1992.

Hasratyan M. M. Syunik architecture of 17-18th centuries. Arm SSR Publishers. Yerevan. 1973.

Hatsagorcyan Z. A. The catalogue of Armenian stones. Kazmtechshinnyut. Yerevan. 1968.

Heller Mark. The ontology of physical objects: four-dimensional hunks of matter. Cambridge University Press. 2008.

Heruni Paris. Armenians and the ancient Armenia. Anahit. Yerevan. 2006.

Hillis William Daniel. The Pattern on the Stone. Basic Books. NY. 1998.

Hoveyan Hovik. Petroglyphs. HGM publishers. Yerevan. 2003.

Hovhannesyan Mamikon. The industry of stone. Hayastan publishers. Yerevan. 1976.

Husted Steven, Melvin Michael. International Economics. Pearson. England. 2013.

Hutt Antony, Harrow Leonard. Iran: Islamic Architecture Vol. 2. Scorpion Cavendish. London. 1978.

Ignatieff Michael. For most of it I have no words: Genocide: Landscape: Memory. Dewi Lewis Publishing. England. 1998.

Isabekyan Hrayr. Armenian renaissance architecture. Hayastan publishers. Yerevan. 1990.

Iwamoto Lisa. Digital fabrications: Architectural and Material Techniques. Princeton Architectural Press. New York. 2009.

Kant Immanuel. Prolegomena to any future metaphysics (edited by Beryl Logan). Routledge. London. 1996.

Kapadia R., Andersson G. Statistics Explained. Ellis Horwood ltd press, England. 1987.

Karakhanyan G. H. Safyan P. G. Syunik petrogplyphs. GA publishers. Yerevan. 1970.

Krikorian Robert, Masih Joseph. Armenia: At the Crossroads. Harwood Academic Publishers. The Netherlands. 1999.

Leatherbarrow David. Uncommon Ground: Architecture, Technology and Topography. The MIT Press. London. 2002.

Littlefield David. Space craft: developments in architectural computing. RIBA. 2008.

Liu Yu Tung. Defining digital architecture: 2001 FEIDAD award. Taiwan. 2001.

Liu Yu Tung. Developing digital architecture: 2002 FEIDAD award. Taiwan. 2002.

Liu Yu Tung. Distinguishing digital architecture: 6th FEIDAD award. Taiwan. 2007.

Liu Yu Tung. Diversifying digital architecture: 2003 FEIDAD award. Taiwan. 2003.

Liu Yu Tung. The tectonics: Towards a new theory of digital architecture. Taiwan. 2009.

Lockwood Arthur. Diagrams. Studio Vista. London. 1969.

Lunkevich V. earthquakes and volcanic mountains. Martirosyants publishers. Tbilisi. 1897.

Martirosyan H. A. Geghama ridge petroglyphs. GA publishers. Yerevan. 1981.

Melqonyan Zareh. Mountains on the slopes. Soviet writer publishers. Yerevan. 1984.

Melqumyan Alexander. In the world of the Armenian stones. Soviet writer. Yerevan. 1986.

Mirzabekyan H. Cave working hygiene. Haypethrat. Yerevan. 1956.

Mnatsakanyan S. Armenian Rural Architecture. Arm SSR publishers. Yerevan. 1956.

Mogel Lize, Bhagat Alexis. An Atlas of Radical Cartography. Journal of Aesthetics and Protest Press. CA. 2007.

Musheghyan Gevorg. The application of the seismic principles in Ancient Armenian architecture. Science Academy publishers. Yerevan. 2005

Novello Adriano Alpago. Armenians: 2000 years of art and architecture. France. 1995.

Papukhyan N. Ts. Folk Architecture of Syunik. Arm SSR Publishers. Yerevan. 1972.

Paul Coates. Programming Architecture. Routledge. USA. 2010.

Petrosyan Hamlet. Khachkar: the origins, symbolism and applications. Printinfo publishers. Yerevan. 2008.

Petrosyan Suren. Armenian petroglyphs. Yegea publishers. Yerevan. 2005.

Pickover A. Clifford. Mazes for the Mind: Computers and the unexpected. St. Martin's Press NY. 1992.

Qalantaryan Ashkharhabek. Armenia from stone to medieval ages. Science publishers. Yerevan. 2007.

Qaramyan Martin. The native mountains. Georgia SSR publishers. Tbilisi. 1953.

Sahinyan A. A. Garni and Geghard. Soviet writer publishers. Yerevan. 1978.

Sardaryan Sandro. Armenia: the cradle of civilization. YSU. Yerevan. 2004.

Sardaryan Sandro. Armenian Petroglyphs from stone to bronze ages. YSU. Yerevan. 2010.

Sauer Christian. Made of: New Materials Sourcebook for Architecture and Design. Die Gestalten Verlag. Berlin. 2010.

Sebastaci Ghukas. The story of David Bek. Arevik publishers. Yerevan. 1988.

Shahinyan Samvel. Armenian caves. GAA. Yerevan. 2005.

Shakhyan Garnik. Architectural and Construction Activities of Armenia in 8-9th Centuries. Anahit Publications. Yerevan. 2004.

Shirinyan K. G. The volcanic tuffs and tuff-lavas of Armenia. SSR GA publishers. Yerevan. 1961.

Souto De Moura Eduardo. Stein Element Stone. Birkhauser. Germany. 2003.

Spiller Neil. Cyber Reader. Critical Writings for the Digital Era. Phaidon Press. London. 2002.

Tadevosyan Tadevos. The stones and the cities. Hayastan Publishers. Yerevan. 1990

Terzidis Kostas. Algorithmic Architecture. Architectural Press. USA. 2009.

Toramanyan Toros. Building materials and applications in Ancient Armenia. Melqonyan fund publishing. Yerevan. 1932.

Toramanyan Toros. The history of materials in Armenian Architecture. Armenian SSR Science Academy publishers. Yerevan. 1948.

Ursprung Philip. Herzog & De Meuron: Natural History. Lars Muller Publishers. Canada. 2002.

Walter Benjamin. Illuminations. Pimlico. London. 1999.

Wells David. The Penguin dictionary of curious and interesting geometry. Penguin. 1997.

Yarbrough Beth, Yarbrough Robert. The World Economy: Trade and Finance. South Western. USA. 2006.

Zellner Peter. Hybrid space: new forms in digital architecture. Thames & Hudson. 2000.

Electronic resources

Akhundov Faud, “Why are there no old cities in Yerevan?”, Vestnik Kavkaza, 13 March 2012, http://vestnikkavkaza.net/articles/society/24114.html, (17 February 2013).

Bressan David, “Paleoseismology of the Anatolian and Caucasus Region”, History of Geology Blog, 24 October 2011, http://historyofgeology.fieldofscience.com/2011_10_01_archive.html, (12 February 2013).

Dutch Steven, “Igneous Rocks”, University of Wisconsin - Green Bay, 18 September 1997, https://www.uwgb.edu/dutchs/EarthSC202Notes/igneous.htm, (15 May, 2013).

Emmer Michele, “From Topology to Virtual Architecture”, Mathland, http://www.generativeart.com/on/cic/papersGA2004/17.htm, (2 February 2013).

Jrbashyan R., “Geology of Meso-Cenozoic Basins in Central Armenia”, 2011, http://www.searchanddiscovery.com/documents/armenia/, (21 April, 2013).

Karakhanyan A., “Holocene-historical volcanism and active faults as natural risk factors for Armenia and adjacent countries”, Journal of Volcanology and Geothermal Research- Science Direct, 15 March 2012, http://www.sciencedirect.com/science/article/pii/S0377027301002645, (24 February 2013).

Stone E. Michael, “The New Armenian Mosaic from Jerusalem”, Armenian Studies: The Hebrew University of Jerusalem, http://unixware.mscc.huji.ac.il/~armenia/newmos.html, (18 April, 2013).

Vardanyan Gurgen, “Karahunj Observatory”, Petroglyphs of Ughtasar, http://uxhtasar.com/carahunge.htm, (22 March, 2013).

“5 Axis Milling”, CNC Toolkit- Multi-axis Creative machining, http://www.cnc-toolkit.com/cnc_5axisMill.htm, (2 February 2013).

“An introduction to hexagonal geometry”, The Global hexagonal Awareness Project, 16 April 2010, http://hexnet.org/content/hexagonal-geometry (20 March 2013).

“Armenian Literature”, Armenian Research Centre- University of Michigan-Dearborn, 29 August 2005, http://www.umd.umich.edu/dept/armenian/literatu/index.html, (7 April 2013).

“Armenian petroglyphs”, http://barevarmenia.com/travelblog/armenian-rock-art/, (1 March 2013).

“Christian Youth Mission for Armenia and Fuller Centre for Housing Armenia Build Hope for a Homeless Family”, http://hetq.am/eng/news/18632/ (20 March 2013).

“Company registered in UAE to build Armenia-Iran railway”, News AM, 18 January 2013, http://news.am/eng/news/136415.html, (7 April 2013).

“Complex and Systematic study of Armenian Stone Art”, http://armrockart.nt.am/index.htm, (2 April 2013).

“Conchoidal Fracture”, Sandatlas, 5 March 2013, http://www.sandatlas.org/2013/03/conchoidal-fracture/, (16 May 2013).

“Crystal Structures”, http://staff.aist.go.jp/nomura-k/english/itscgallary-e.htm, (1 May, 2013).

“Dar-Alages Volcano”, Volcano Discovery, http://www.volcanodiscovery.com/dar-alages.html, (12 April 2013).

“Digital Stone Exhibition”, Autodesk, http://usa.autodesk.com/adsk/servlet/index?id=11915550&siteID=123112, (30 April, 2013).

"Evolution of the Armenian Alphabet", Middle East Armenian Portal, 8 November 2006, http://www.azad-hye.net/news/viewnews.asp?newsId=267skz73, (6th March, 2013).

"Geghard Monastery Architectural Complex", Armenica: History of Armenia, http://www.armenica.org/cgi-bin/armenica.cgi?24122452902705=2=ba=4====baz0019===, (20 February, 2013).

"Habitat for Humanity in Armenia", Habitat for Humanity, http://www.habitatforhumanity.org.uk/Armenia?gclid=CLWtz63Zs7YCFZDKtAodqmAAAA, (19 March, 2013).

"Kapan-Meghri Motorway", Shikahogh State Reserve, http://www.shikahogh.am/nature_eng.html, (12 march, 2013).

"Mortuary landscapes", The Vorotan Project: Southern Armenia, 27 November 2006, http://proteus.brown.edu/11/90, (12 May, 2013).

"Open Sesame: Volcanic caves of Armenian plateau", Mysteries of Armenia, 6 September, 2009, http://wowarmenia.com/?p=646, (23 March 2013).

"Overview of Geologic Fundamentals", USGS, 11January 2013, http://3dparks.wr.usgs.gov/nyc/common/geologicbasics.htm, (24 March 2013).

"Palu Village Houses", Ottoman Armenian Village house Reconstruction Project, http://www.houshamadyan.org/en/mapottomanempire/vilayetdiyarbekir/palu/local-characteristics/house-and-architecture.html, (5 May 2013).

"Shikahogh Reserve and Zangezur Sanctuary", Caucasus Nature Fund, http://caucasus-naturefund.org/our-program/our-parks/shikahogh-reserve/, (28 April 2013).

"Shikahogh Reserve saved", Armenian Forests, 27 June 2005, http://www.armenianforests.am/news2005.html, (16 February 2013).

"Stone Quarrying in Armenia, Virtual Ani, 18 March 2004, http://www.virtualani.org/quarry/, (23 February 2013).

"Stones. Squares. Uncertainties", 14 June 2012, http://iheartuniquenessiheartinfinity.com/tag/stone/page/2/, (28 April 2013).

"The Ancient Armenian Kingdom", http://ancientweb.org/index.php/explore/country/Armenia, (5 March 2013).

"The origins of Khachkar", Khachkar, http://www.khachkar.am/en/origins/, (2 March 2013).

Magazines

AA projects review. Protoarchitecture: AA publications. 2002..

Building Bulletin 74. A school for Armenia. HMSO Publications. London. 1991.

Neoplasmatic Design. Architectural Design magazine September/October 2008.

Protoarchitecture: Analogue and digital hybrids. Architectural Design magazine July/August 2008

Videos

A compelling documentary on the Armenian genocide. Director Laurence Jourdan. 52min + 46min interview with Dr Yves Ternon.

Deformography - The surreal poetics of cybridised architecture. Neil Spiller. Professional lecture filmed on 26th October 2005.

Shikahogh: treasures of reserve. 2011. OOO IFAM. 30 mins.