*A yaodong (Chinese: 窑洞) or "house cave" is a particular form of earth shelter dwelling common in the Loess Plateau in China's north. They are generally carved out of a hillside or excavated horizontally from a central "sunken courtyard".

1.0 LOCATION

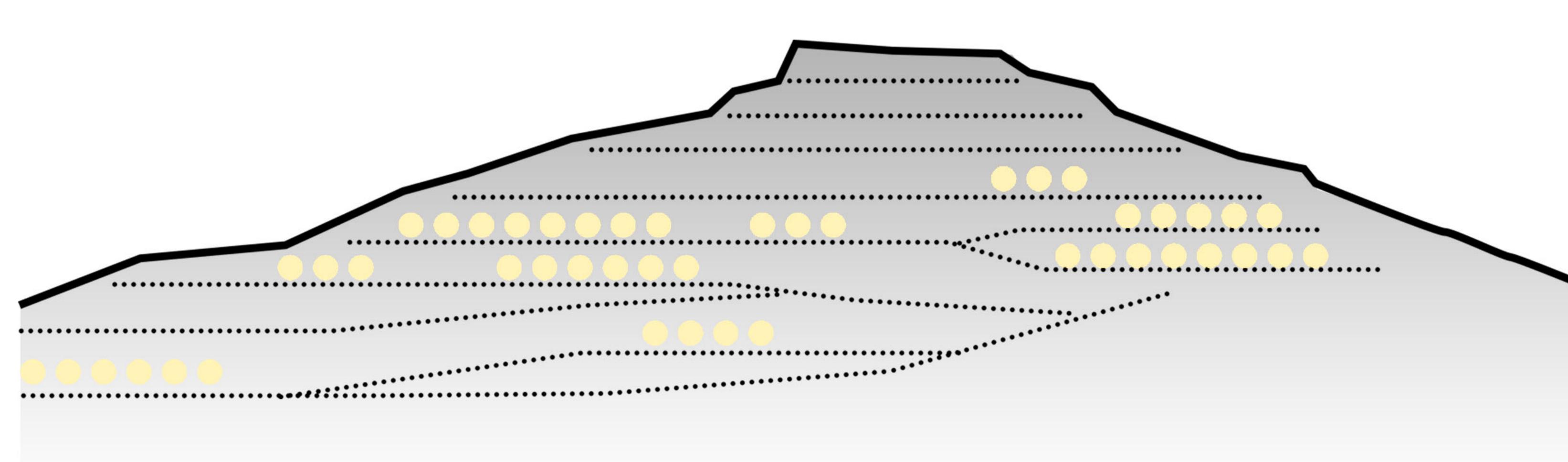


The Yaodong caves are widely spread among the Province of Shaanxi, which is located in the north of Chiana mainland.

2.0 LEOSS PLATEAU

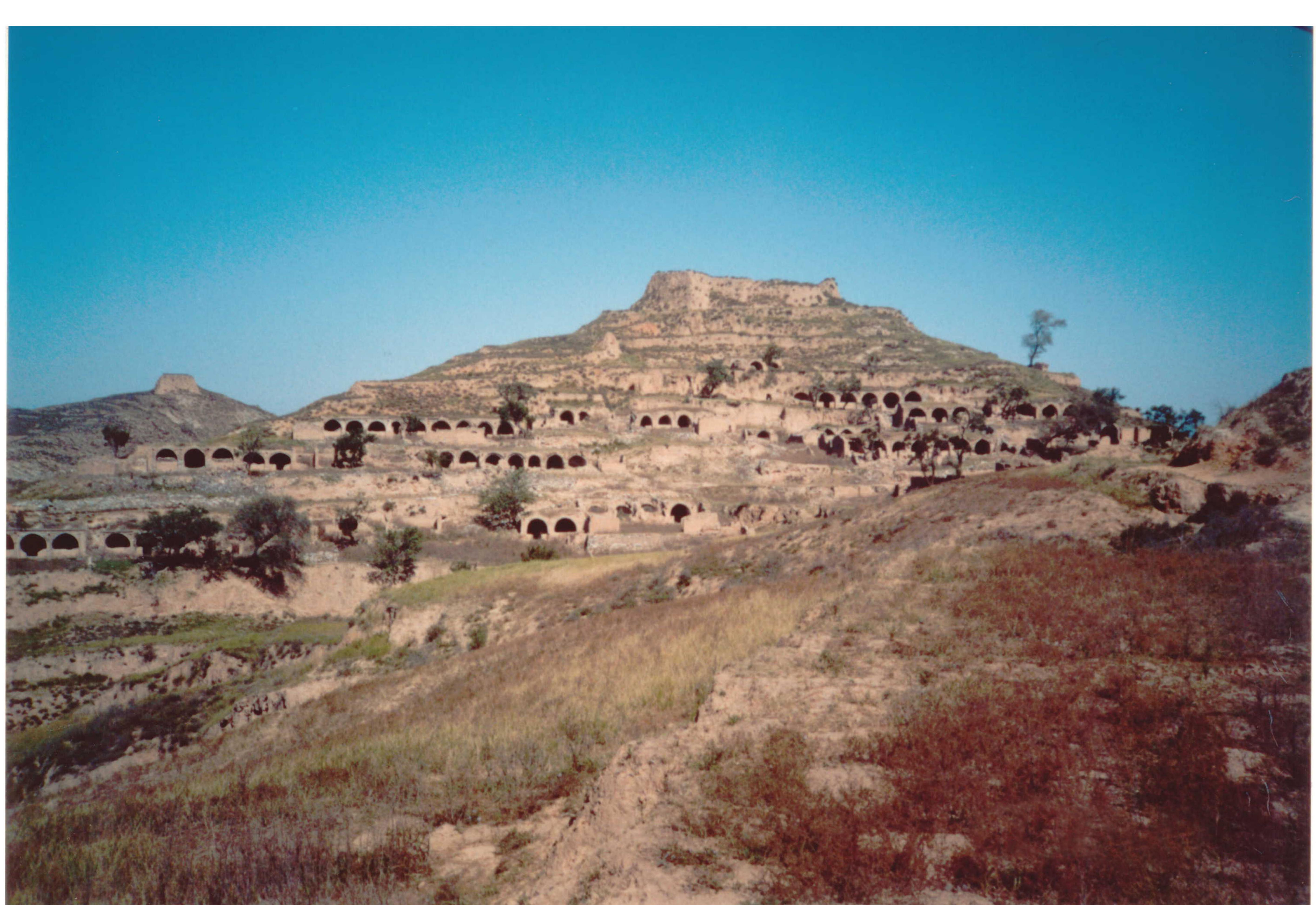


3.0 LAYER STRUCTURE

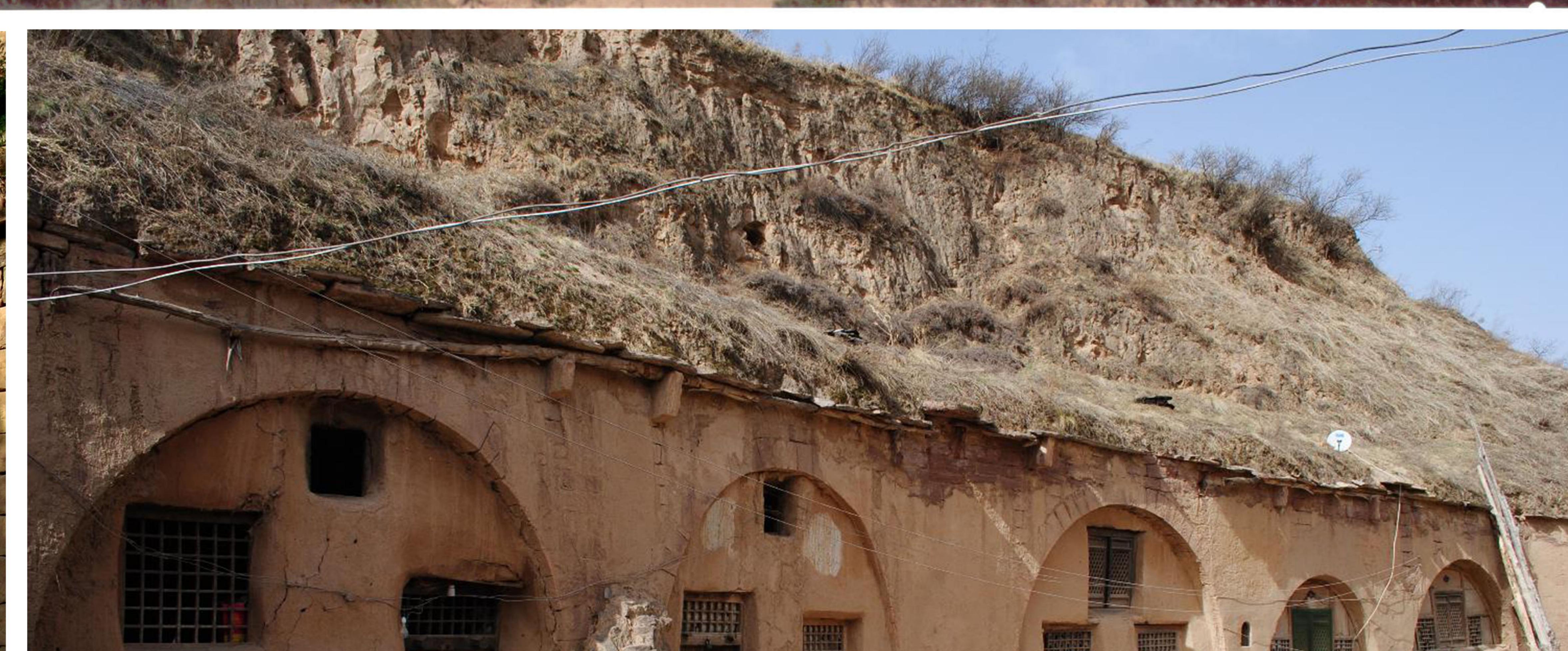


Yaodong caves are normally located on the slope of the mountain. The arrangement is not planed but according to the natural layer structure of the Leoss earth.





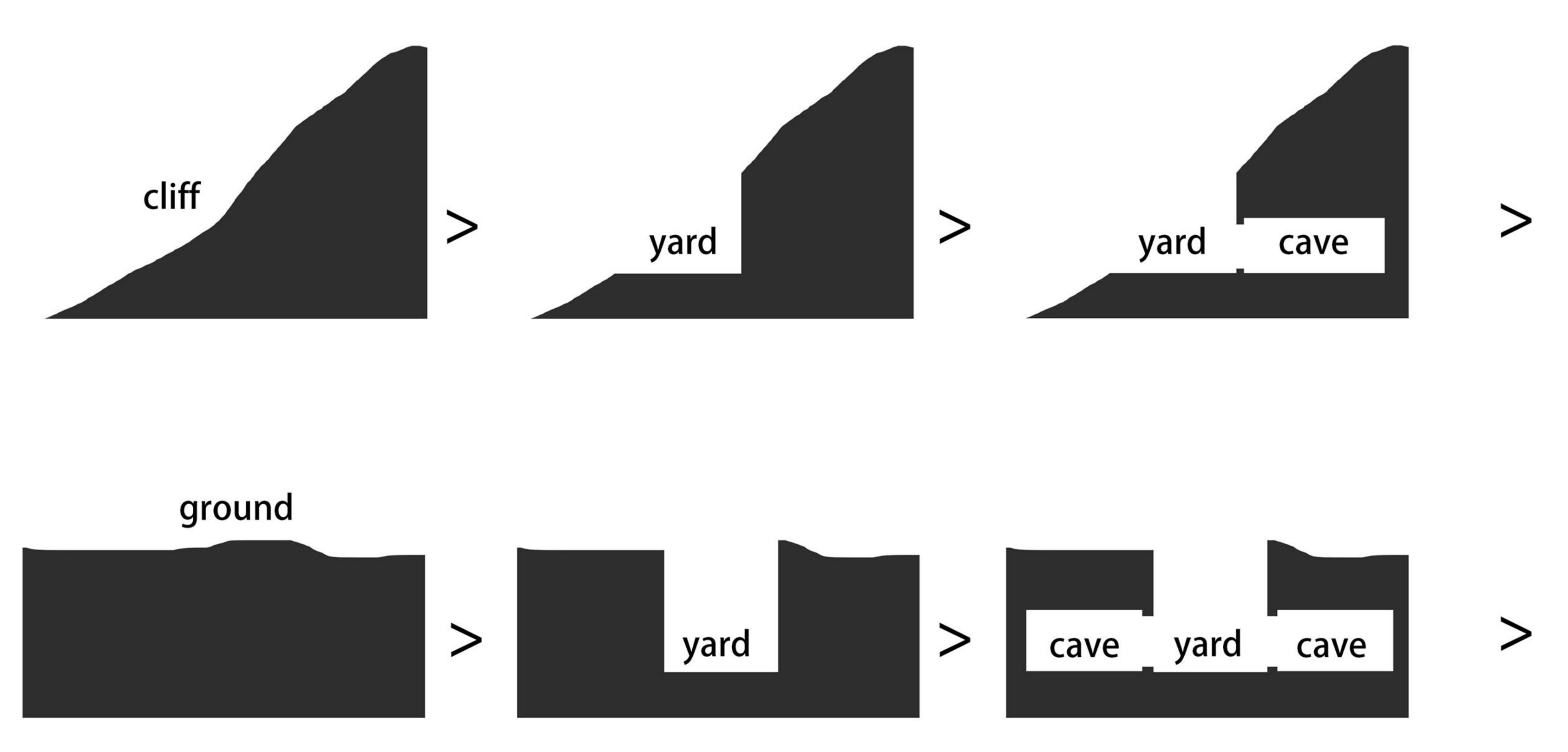




ANALYSIS ON YAODONG CAVE

THE RENOVATION OF TRADITIONAL CAVE HOUSING IN CHINA

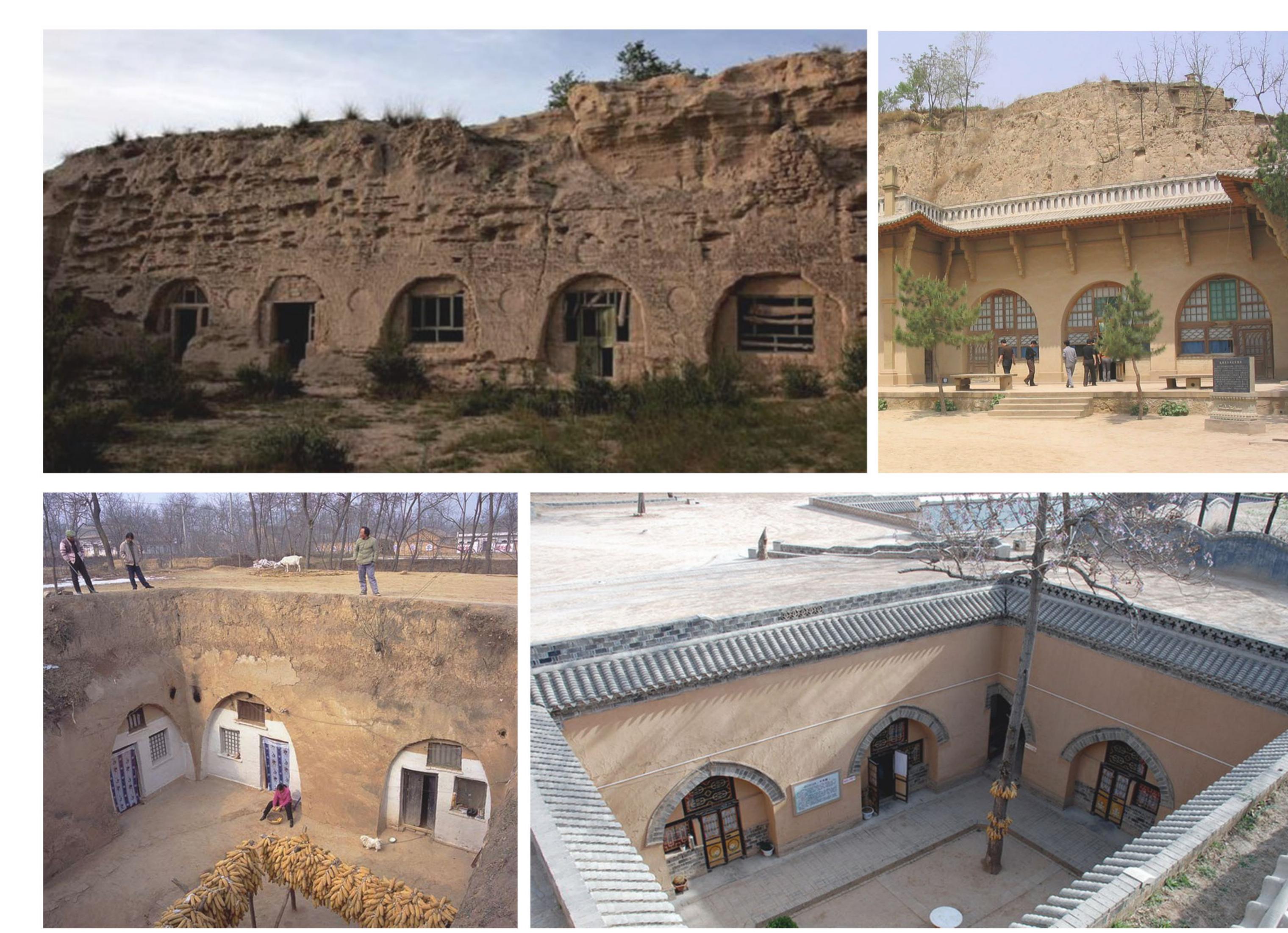
1.0 TYPOLOGY



1.1 THE CONSTRUCTION OF YAODONG CAVE

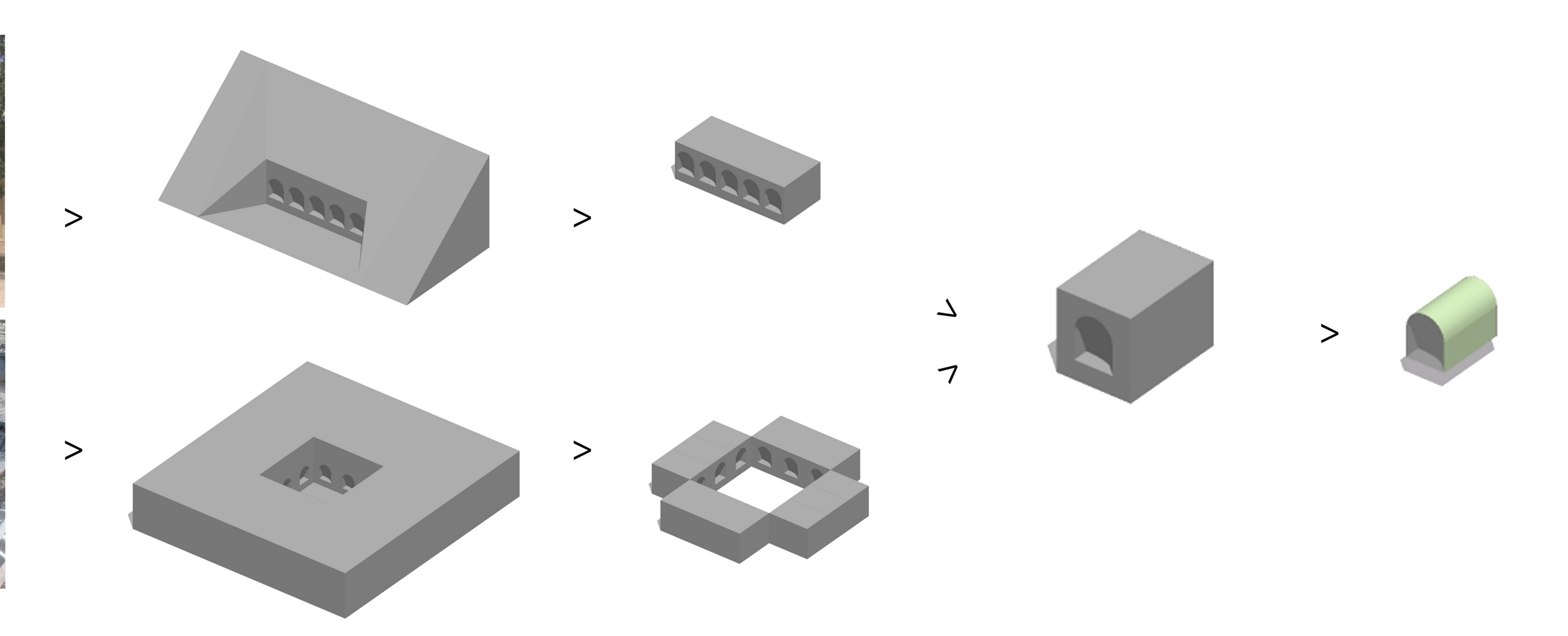
A traditional Yaodong cave is completely dug in the loess hill or just on the ground. The dwellings are hidden in the environment that not easy to find. Thus, it is said that "no house was seen in the whole village and no people was seen but the trees". In fact, the architecture of Yaodong village is not about to create but to subtract to the earth.

As a result, all the materials for building a Yaodong cave can be found in the local area. The construction of a traditional Yaodong merely produces waste to the environment. Everything is natural and from local, which makes Yaodong one of the most eco-friendly dwellings in China.



1.2 TWO MAIN TYPES OF YAODONG CAVE

- a. Cliff cave dwelling are those dug in loess cliffs, on the side of the valley: a typical example is the troglodyte city of Yan'an;
- b. Ground cave dwellings are those dug around an excavation conducted at the surface, serving as interior courtyard, called yaodong-well or sunken courtyard.



1.3 SIMPLIFYING YAODONG CAVE

1.4 UNIT OF YAODONG CAVE

The common feature of these two types is that both of them are built by digging from the earth, the Loess. Despite of the location of two types of Yaodong caves, it can be assume to be the same, with one façade open to the exterior environment and other five sides sheltered with earth.

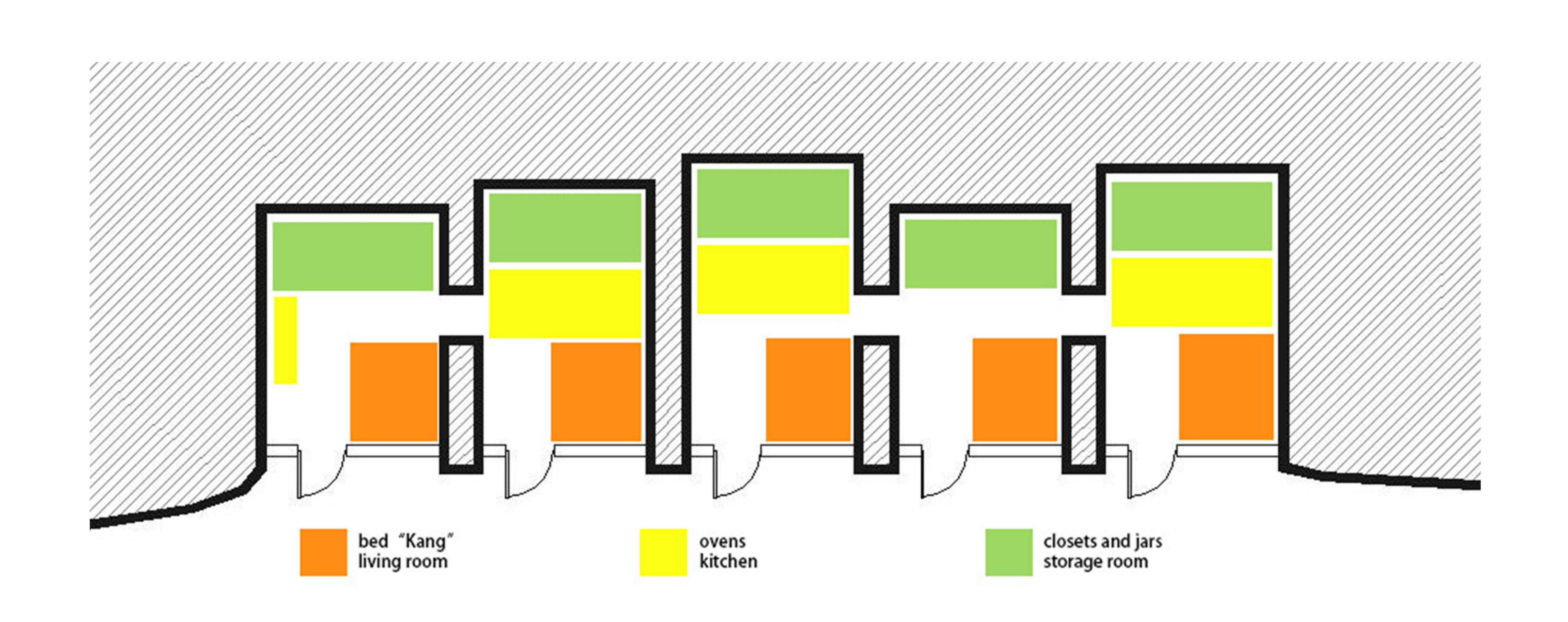
If we abstract a Yaodong cave into the simplest model, it is obvious that all the Yaodong caves are composed by a series of single caves. It is called "unit cave". In fact, Yaodong cave is the presentation of a few side by side "unit caves", thus the features and characteristics of "unit cave" is effective for the whole Yaodong cave.

2.0 FUNCTION

Here I would like to take an example of a real existing Yaoodng cave for illustrate the following issues.

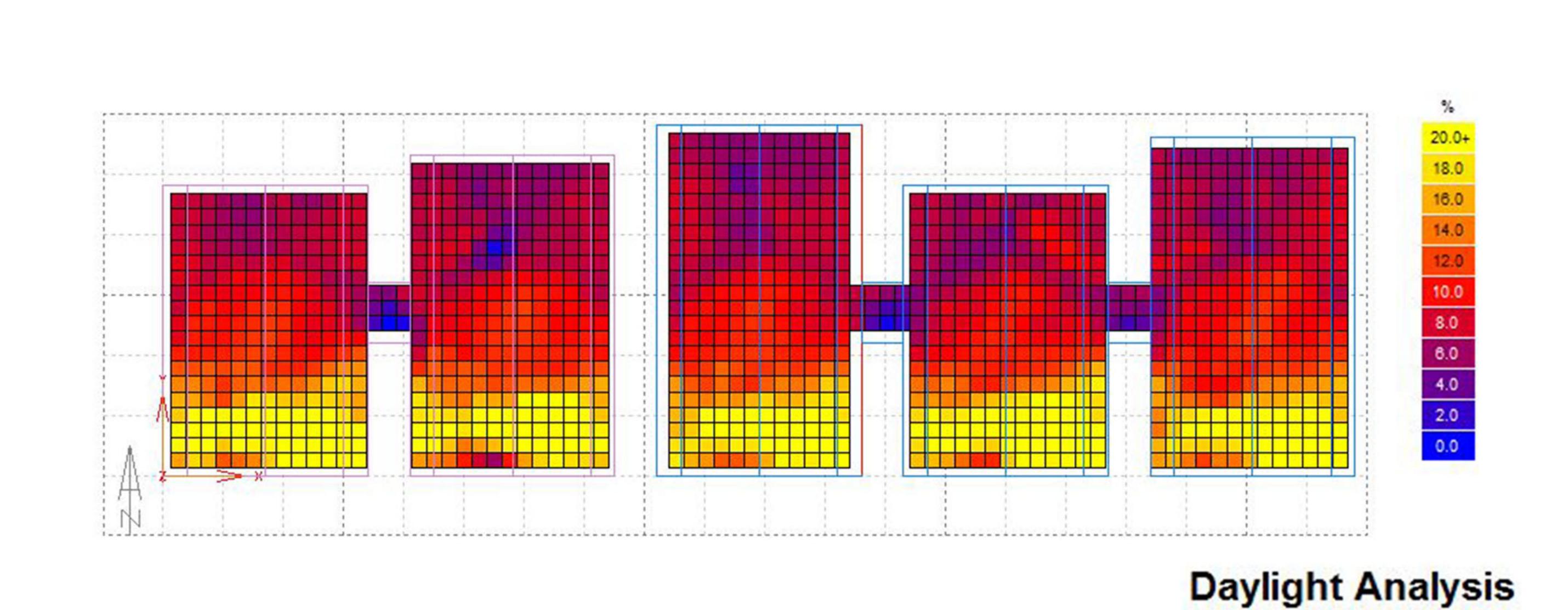
This Yaodong cave is a standard cliff Yaodong with five unit caves. It is abandonded yet the structure is quite complete without serious damage.





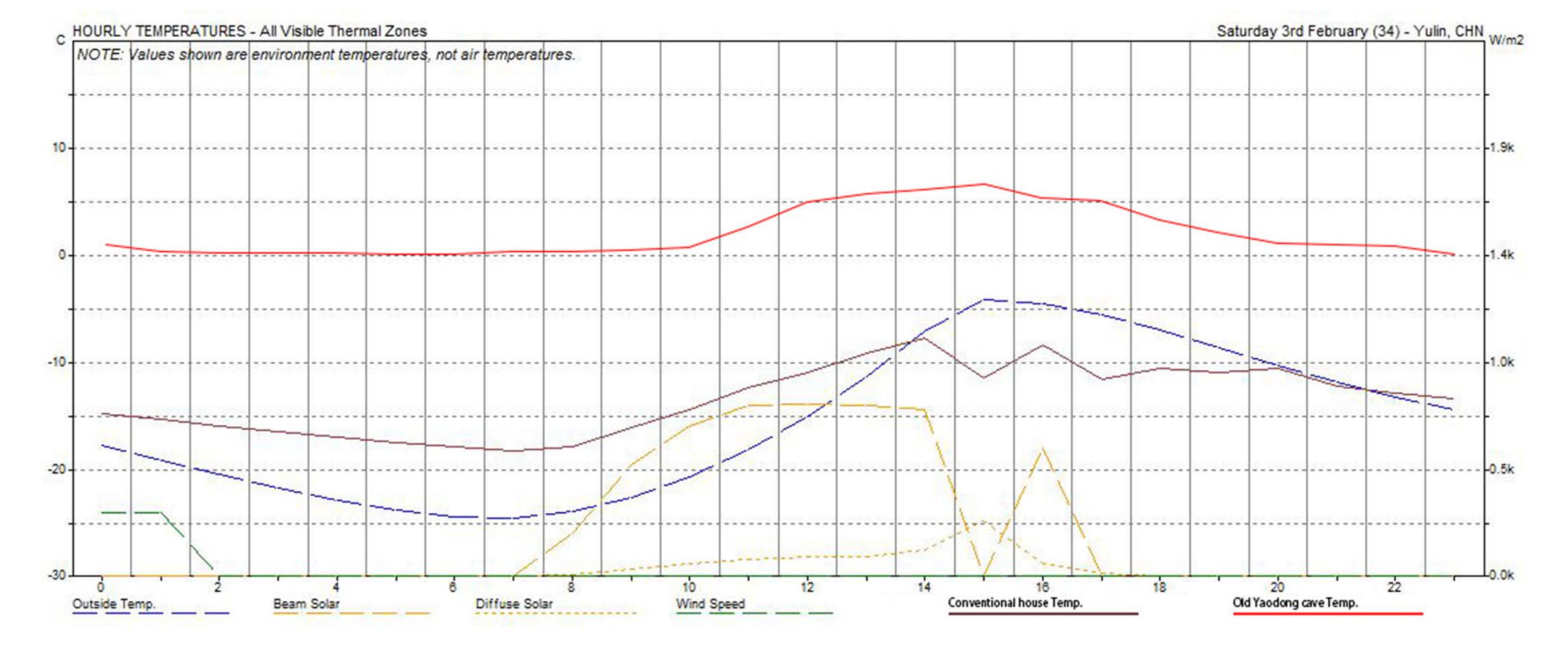
2.2 FUNCTION DISTRIBUTION IN YAODONG CAVE

3.0 PHYSICAL COMFORT



3.1 DAYLIGHT ANALYSIS

Due to the big openings of window on the façade, the natural lighting condition is quite good near the window. Less and less



3.3 HOURLY TEMPERATURE ON THE HOTTEST DAY OF THE YEAR



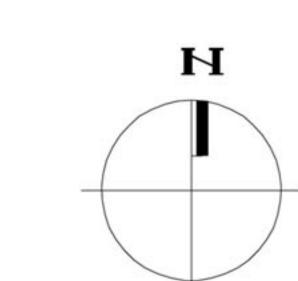
SUPERVISOR: PROF. ALESSANDRO ROGORA

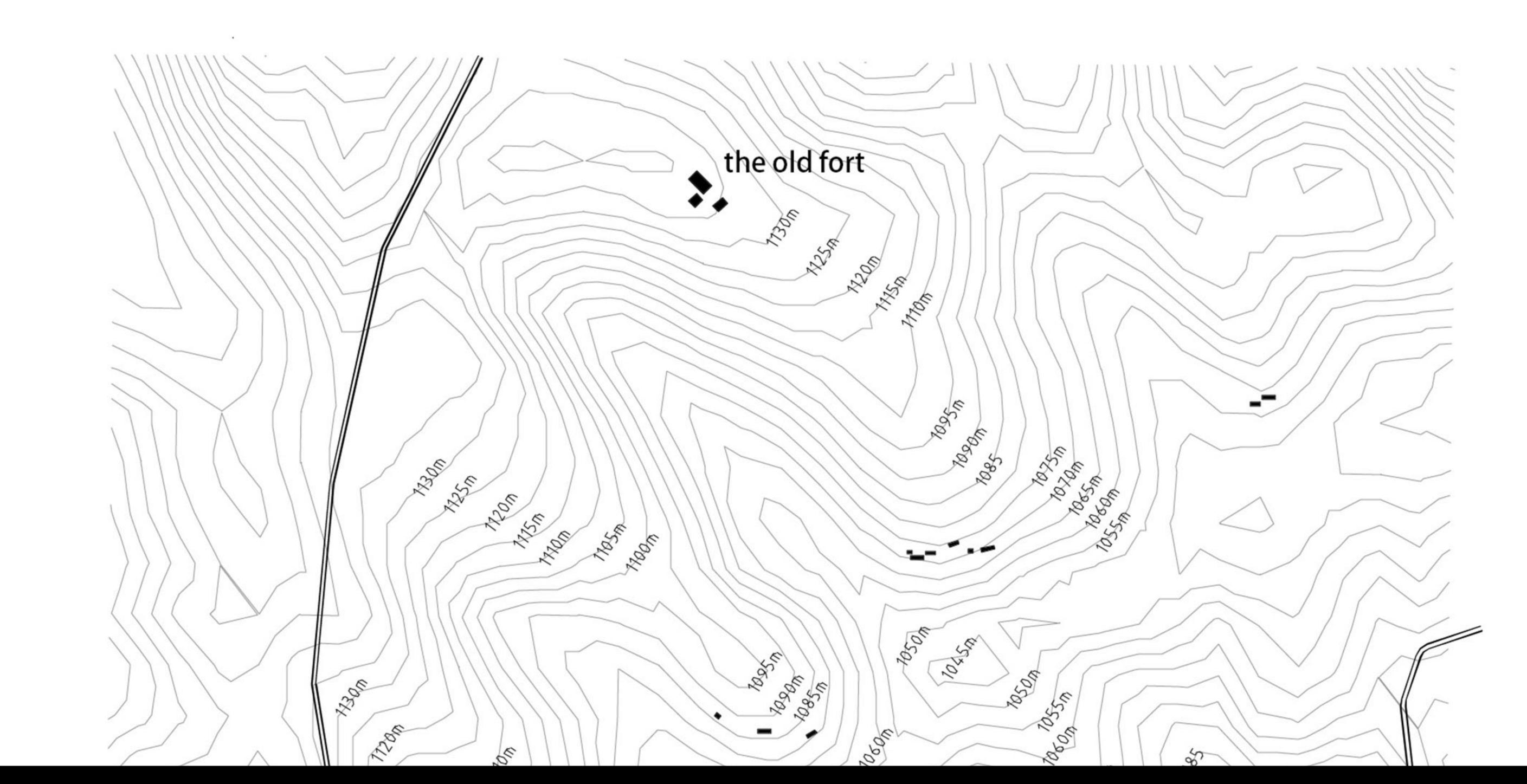
Yulin is a very famous historic town in the north edge of Shaanxi Province. 2000 years ago, the construction of the town started with the defensive wall. Other than the history of the town, Yulin is also the place where conserves the most quantity of Yaodong caves in China.

1.0 LOCATION



Lacking the control of building terms in history, the local government did not have the resources to analyze all the Yaodong caves and make the master plan of the location for each Yaodong cave. Since Yaodong caves were only caves in some point of view, they could not stand as properties for their owners or the government. No one took care for those abandoned Yaodong caves like they were never existed. It is quite common if some travelers go into the mountain area with a jeep, they would encounter hundreds of Yaodong caves which were not signed in the maps or navigators.





According to the development of local tourism business, it is believed that more and more people will come to Yulin and probably most of which are driving travelers. The Loess Plateau therefore is able to become the natural park for the tourists to experience the wild western China.

People from all over China come to see the Yaodong caves. However, despite of the most important caves, many other Yaodong caves are abundant in the wild. Thousands of Yaodong caves are sleeping silently in the Leoss mountains.

New road connecting Yaodang hotel neighborhoods Service spot located in every Yaodang hotel neighborhood walking path

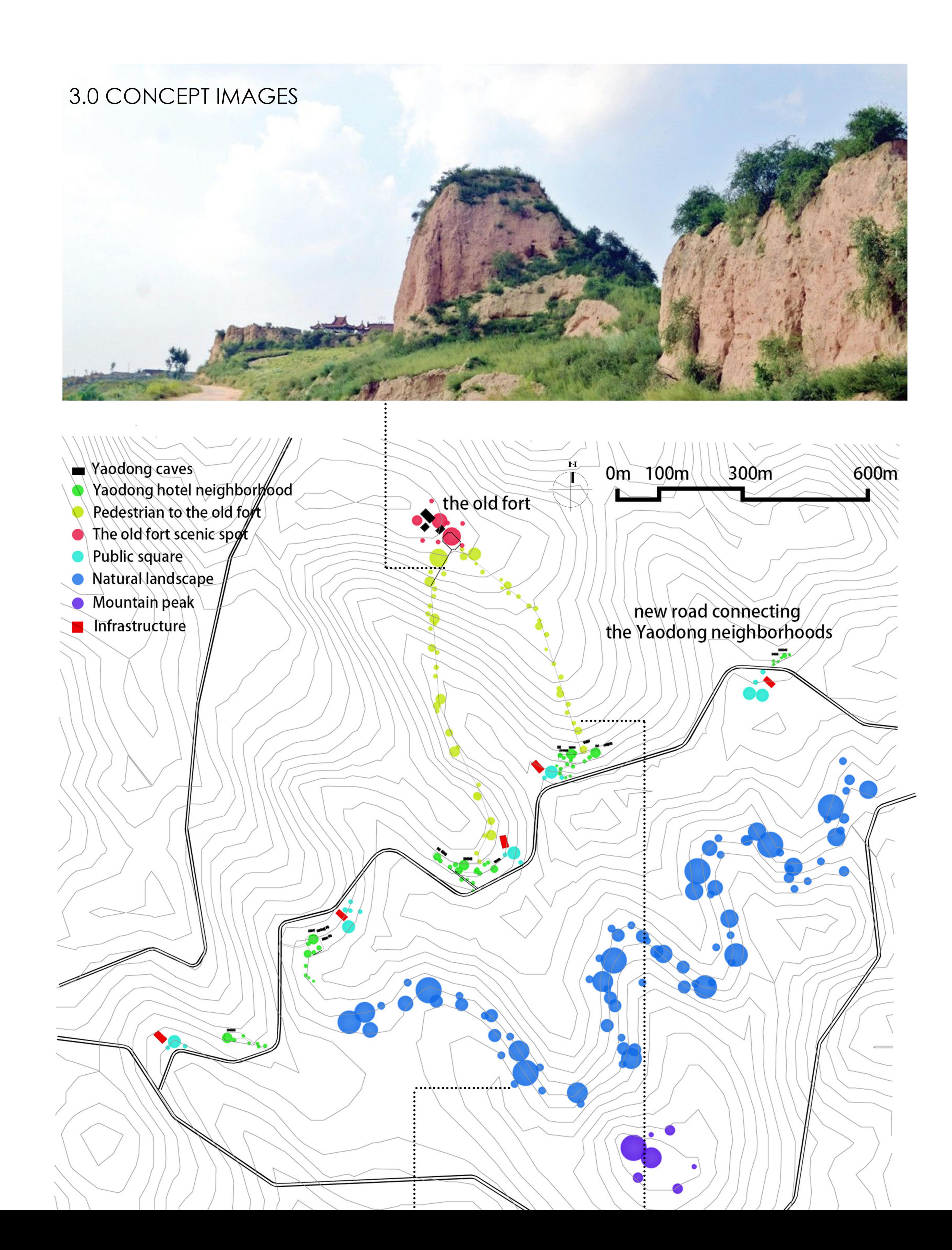
Since the old Yaodong caves are not suitable for modern living, family hotel might be a choice for renovation. Because of the tourism policies, more people would come to the town for the travelling. The demand for hotel will increase greatly. Thus, building more hotels is the proper choice to keep the balance between the need and demand.

Electric vehicle stops at

every Yaodong hotel neighborhood

Pedestrian path to


the old fort scenic spot

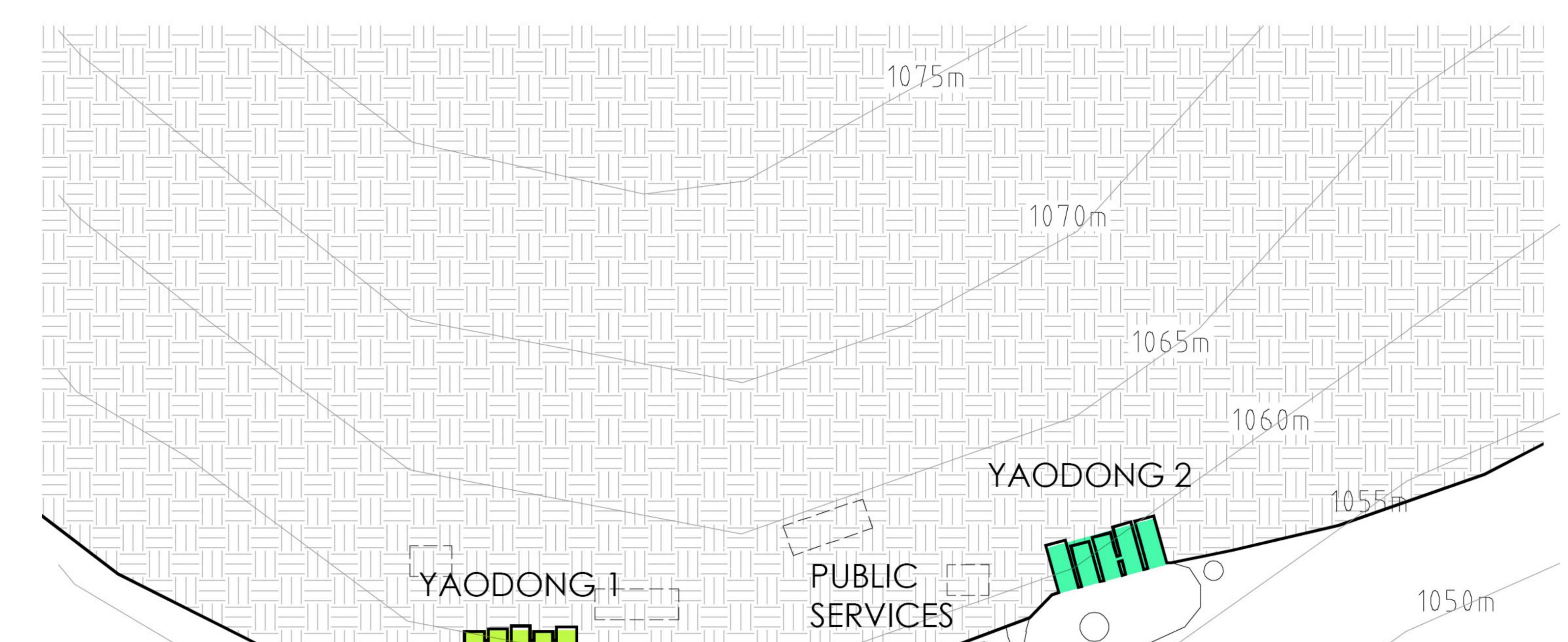


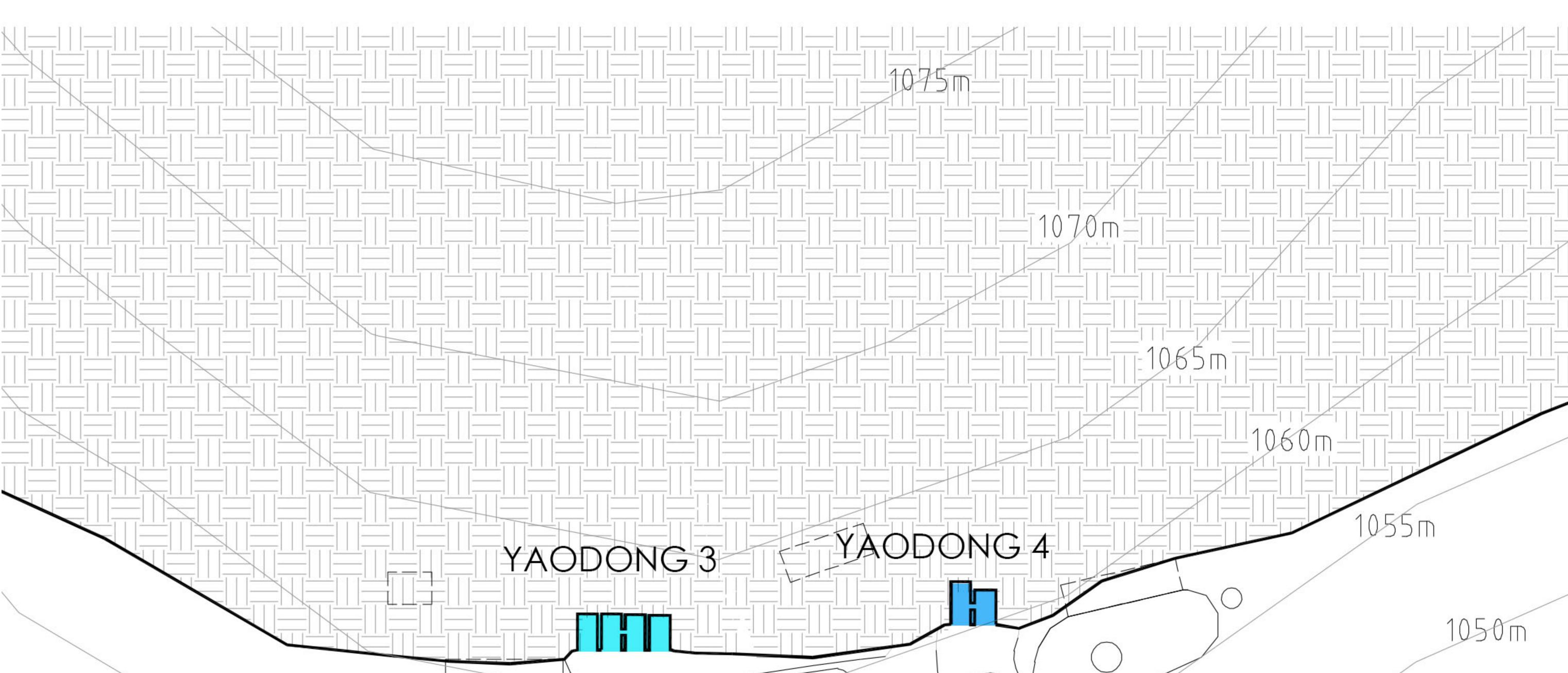
Back to the neighborhood of the Yaodong cave hotel, new public space is set providing multiple functions for the hotel use. The new yard which follows the old form represent the memory of old lives. Yet, with new pavement and green plantation, there will not be dusty areas in the yard. It is a place the travelers can enjoy the sunshine in winter days and watch the stars at summer nights.

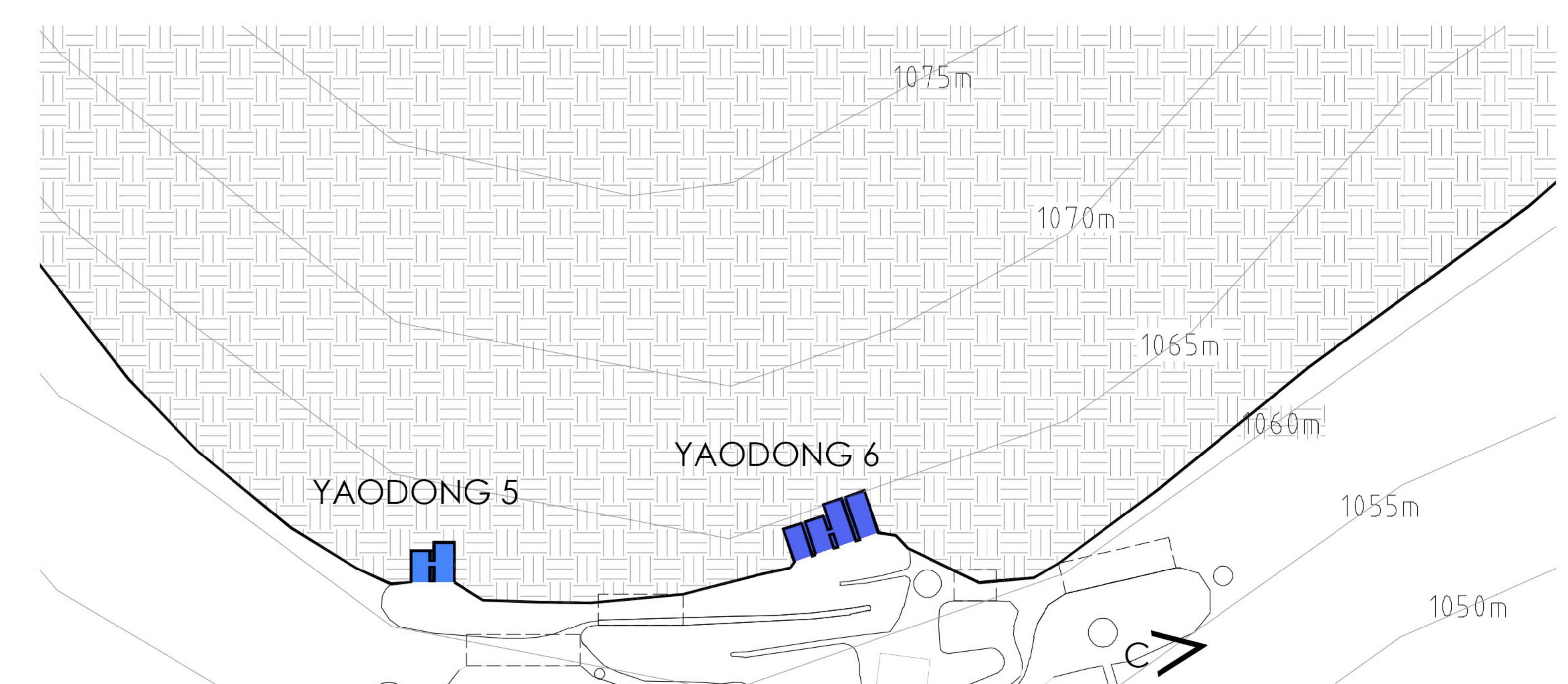


I choose the fourth neighborhood as the project one for further study. In this neighborhood, six Yaodong caves of different dimensions were located. These caves spread among the area spontaneously with multiple altitudes.









The intervention for the area started from the entrance to the yard, which was shared by all the Yaodong caves as public open space. The road to the vard is extended in order to keep the neigh-





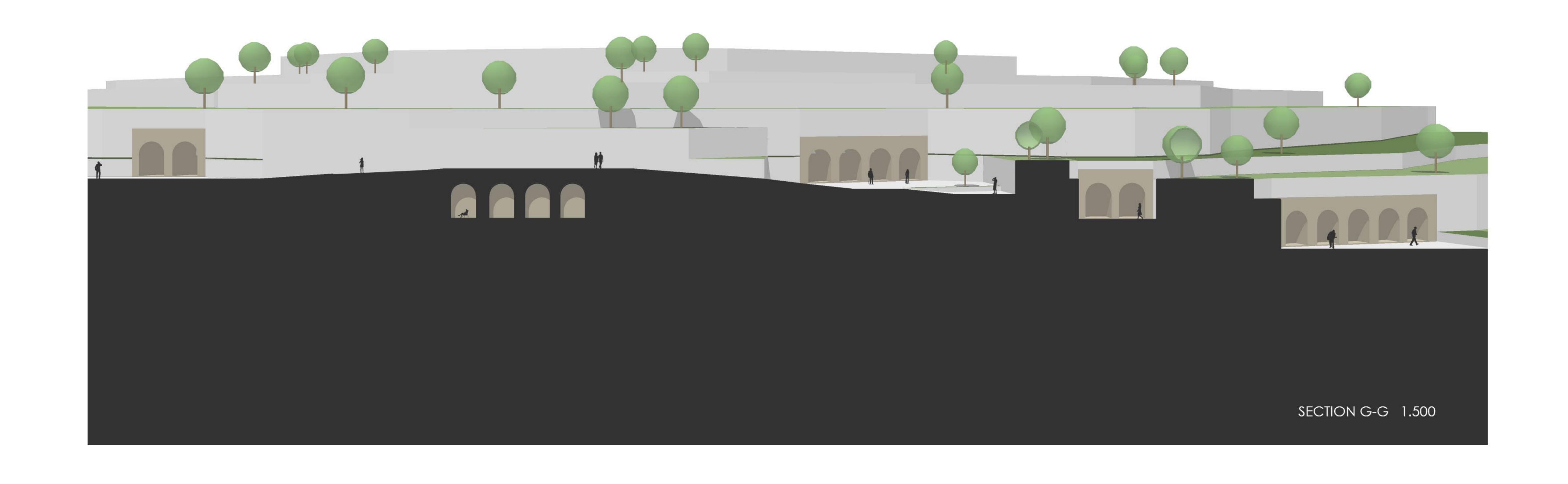








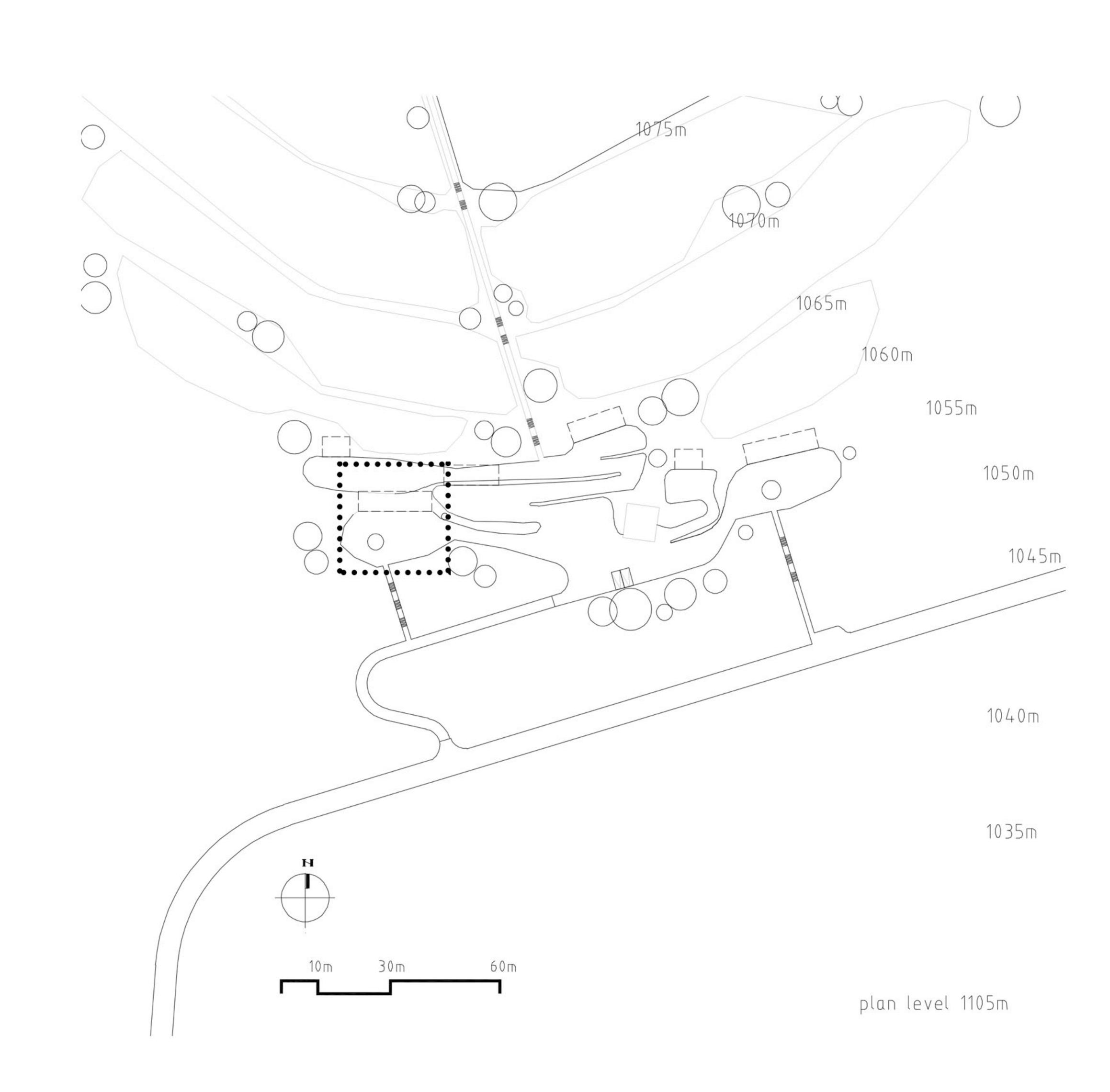


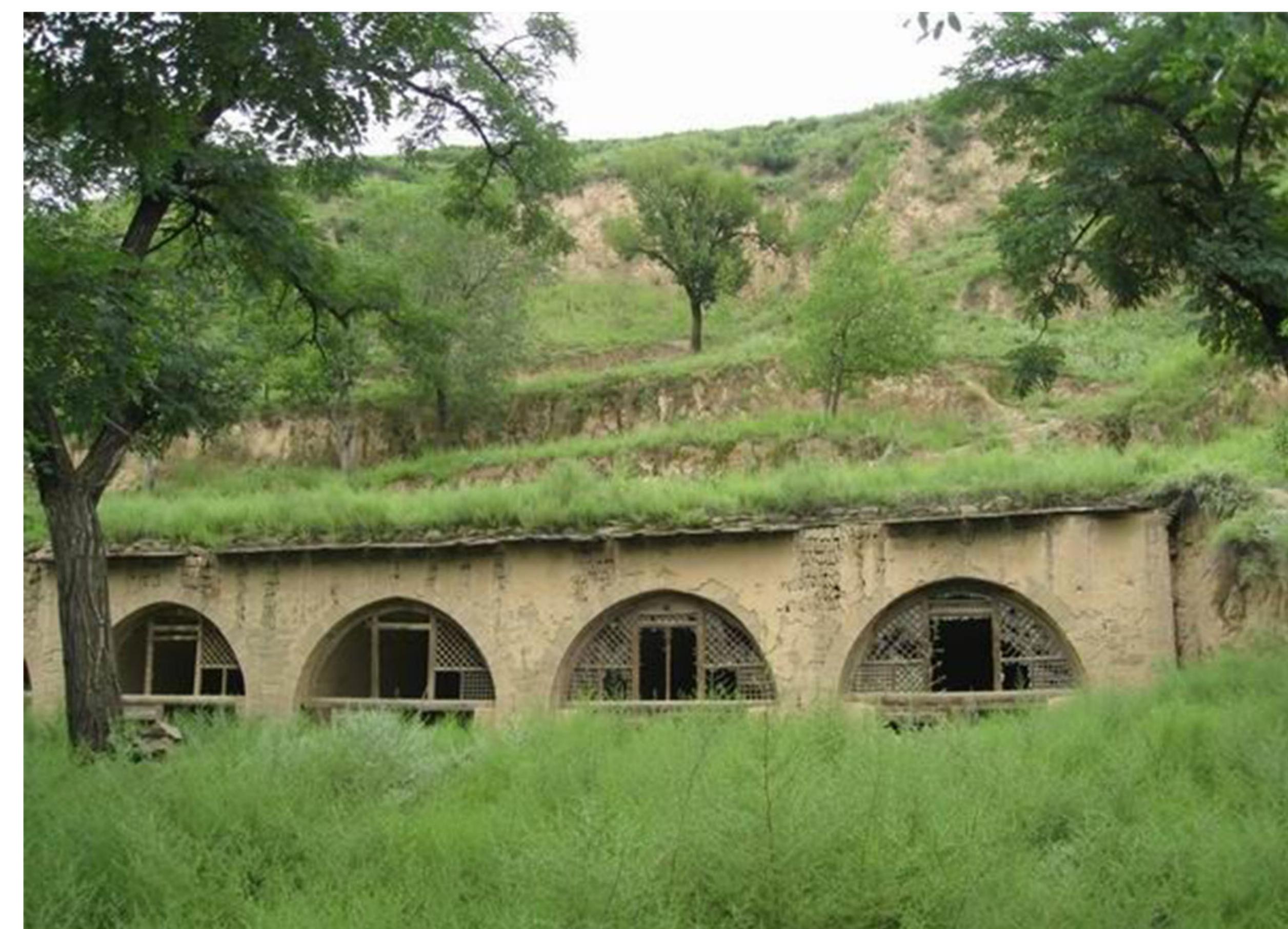


.APARTMENT

The Yaodong caves can be divided into several apartments due to the distribution. In this project, I would like to focus one of the biggest apartments which constituted with five unit caves.

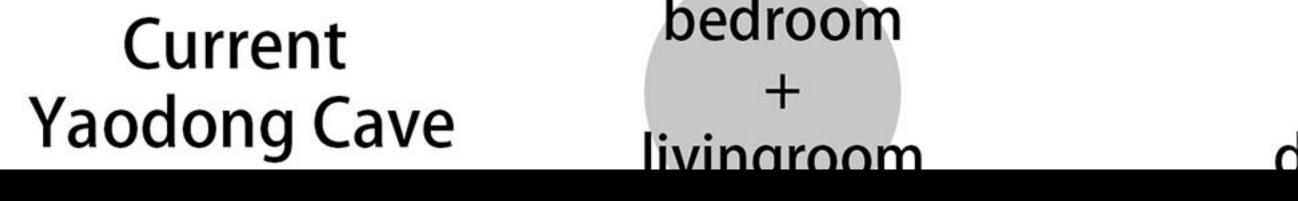
1.0 LOCATION





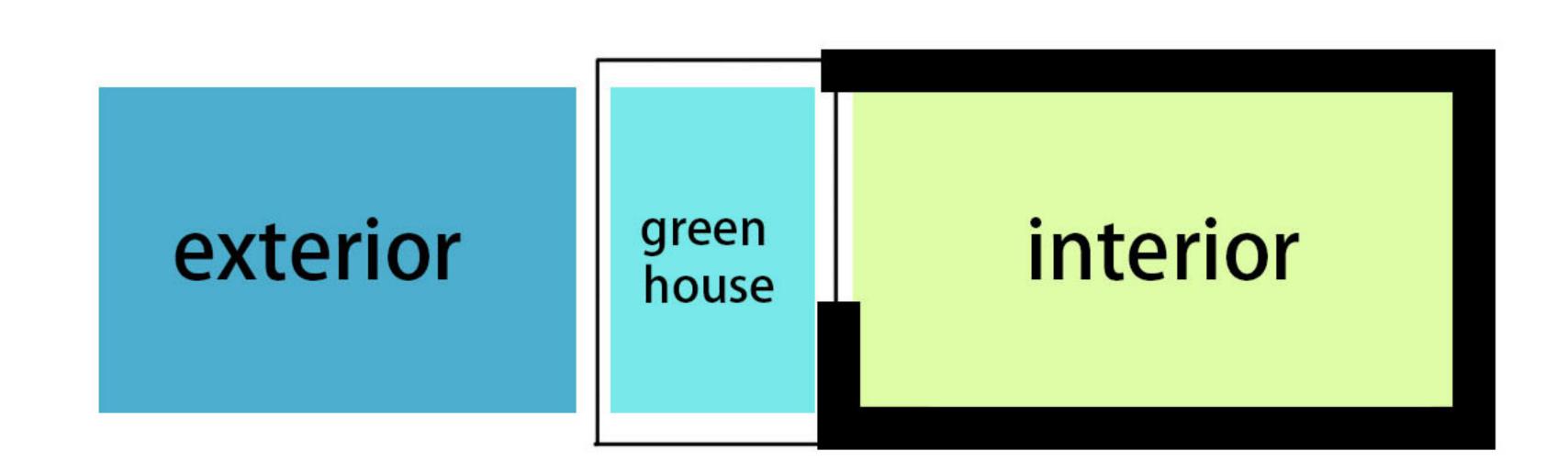
The projecti Yaodong cave is the same one in the previous chapter for the analysis.

2.0 PROPOSALS







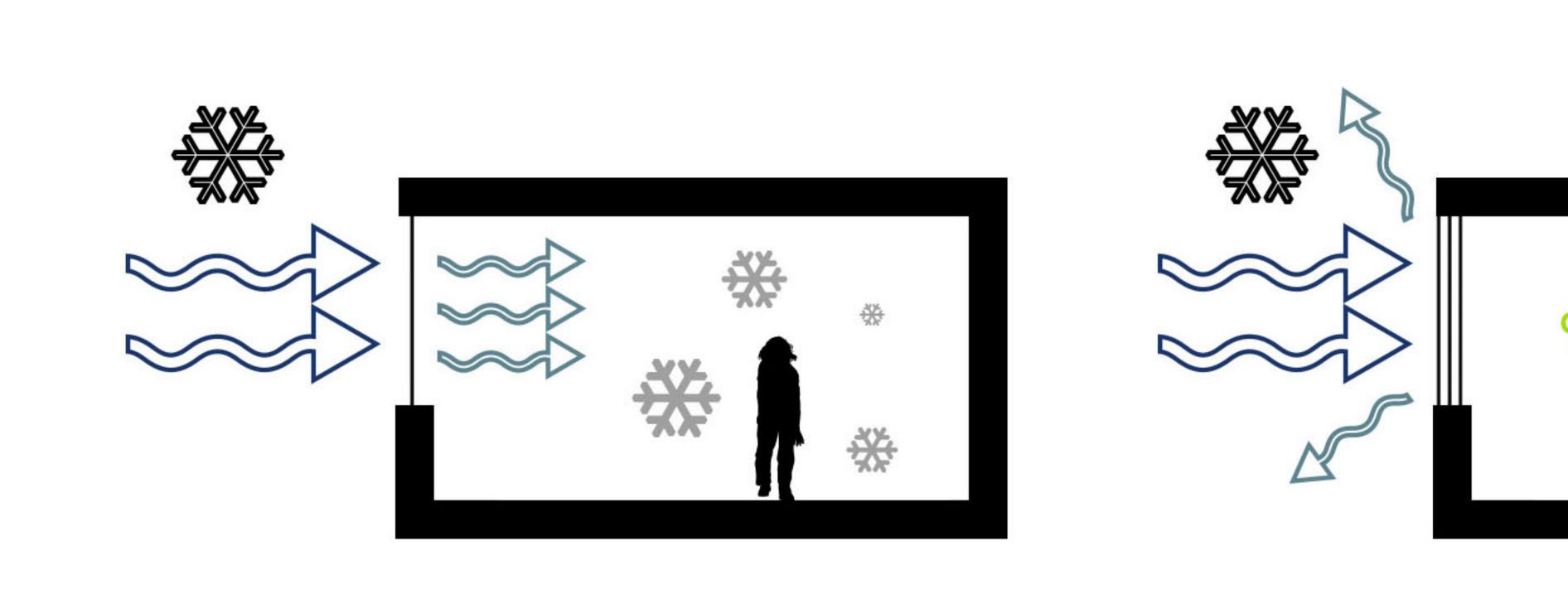


Greenhouse as An Intermediary

2.2 GREEN HOUSE

An additional solar greenhouse is attached to the Yaodong cave working as an intermediary. The solar green house is able to work as a direct gain buffer space in winter. In this space, the fresh air is heated by the sun radiation before comes in the cave.

The green house also provides the space for plantation.

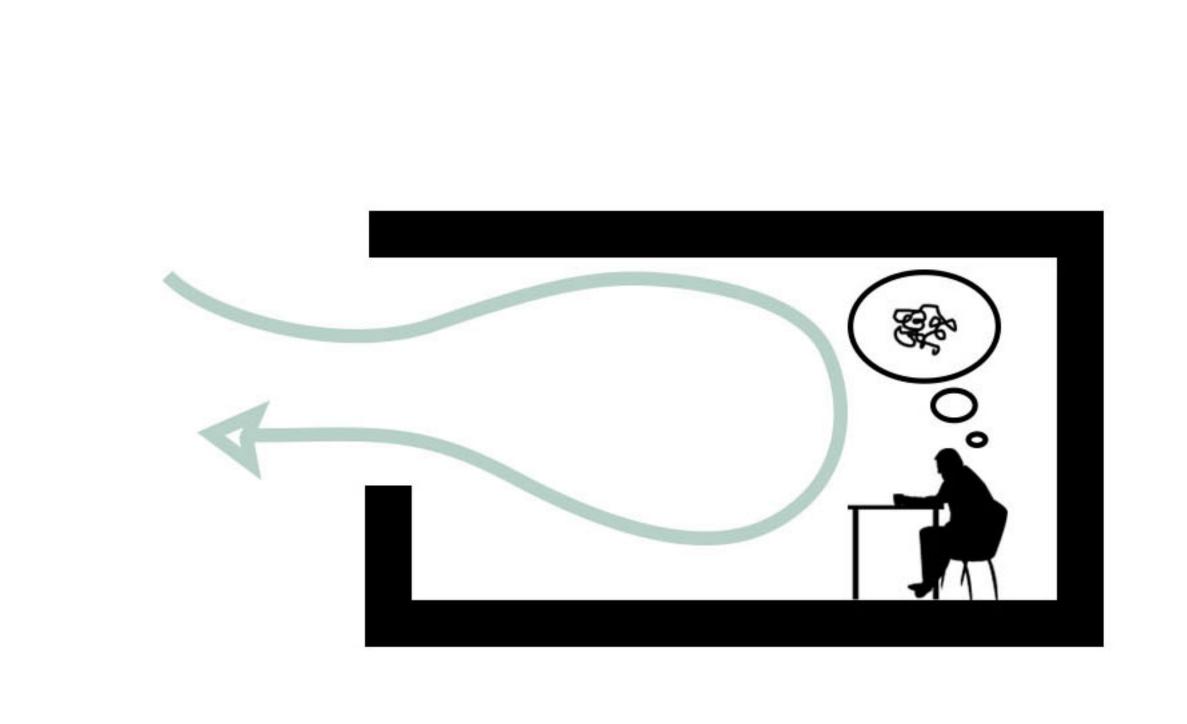


Current Yaodong Cave

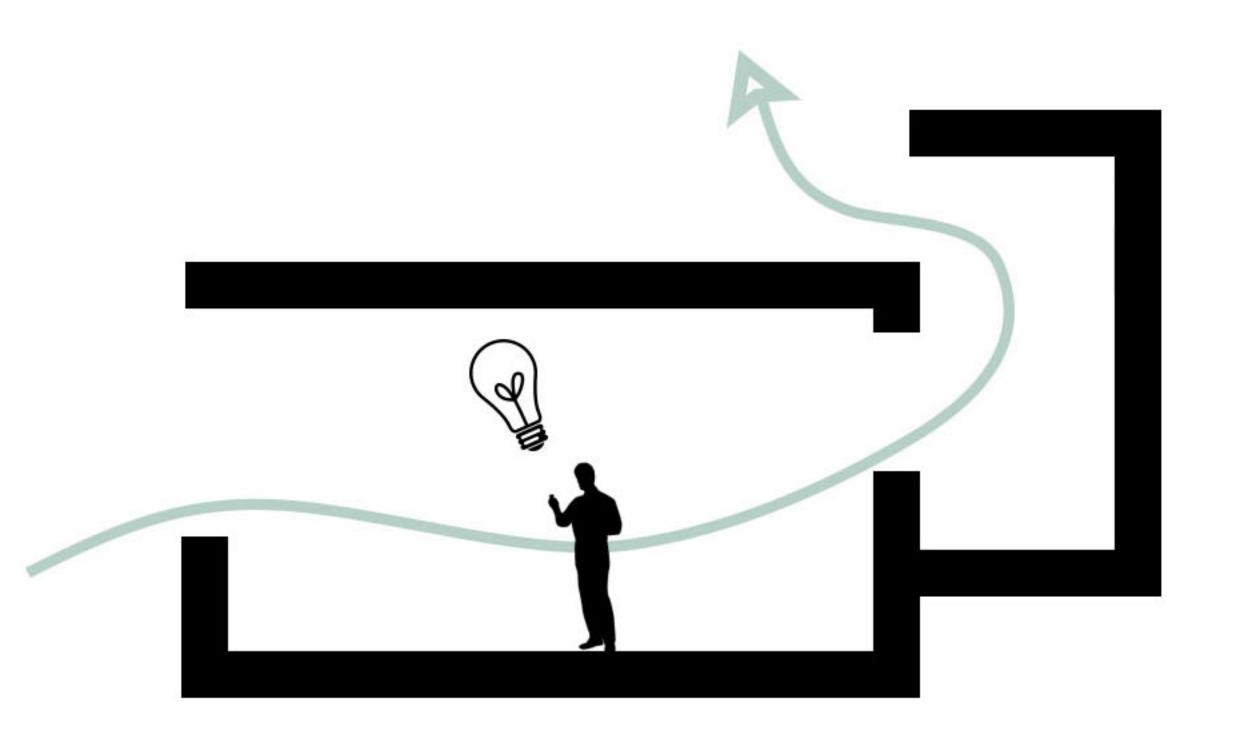
After Intervention

2.3 INSULATION

The insulating ability of a new type of window may be even better than an old wall. By simply replacing the new insulation windows to the old ones, the insulating ability can reach a considerable good value without compromising the passing of natural light.







After Intervention

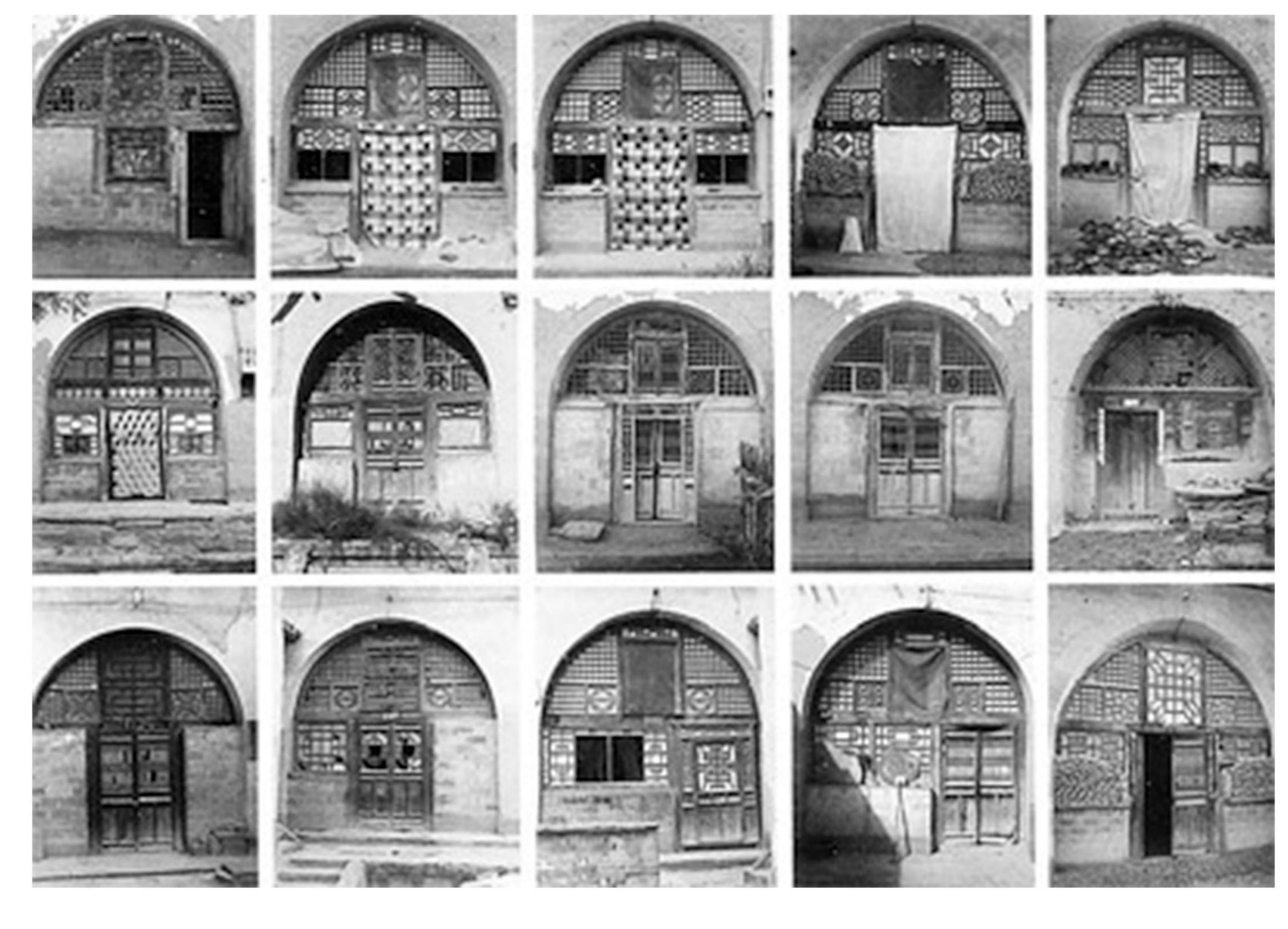
2.4 VENTILATION

To improve the ventilation, an extra window is designed on the deeper side of the cave. The level of the window is much higher than the windows on the façade referring the slope of the mountain. As a result, the former side ventilation becomes a cross ventilation which goes across the whole cave. The buoyancy driven airflow makes the fresh air coming from the façade's window and taking out the contamination to the high window. The effect can greatly improve the air quality in the cave as well as cool down the temperature inside in summer.

3.0 "FACE" OF YAODONG

The "face" is the only façade of Yaodong cave which expose to the exterior environment. Thus, the redesign of the "face" is critical for the renovation because it is the symbol or the initial image of a Yaodong cave inside people's mind.

3.1 FORMAL "FACE"



3.1 INFORMAL "FACE"



The two different types of "face" are the initial concept to design the new façade of Yaodong caves. In the hope of preserving the identity of Yaodong building, the position of substance and void remains almost the same. However, constructed with new insulation materials, the physical character for this façade is highly improved.

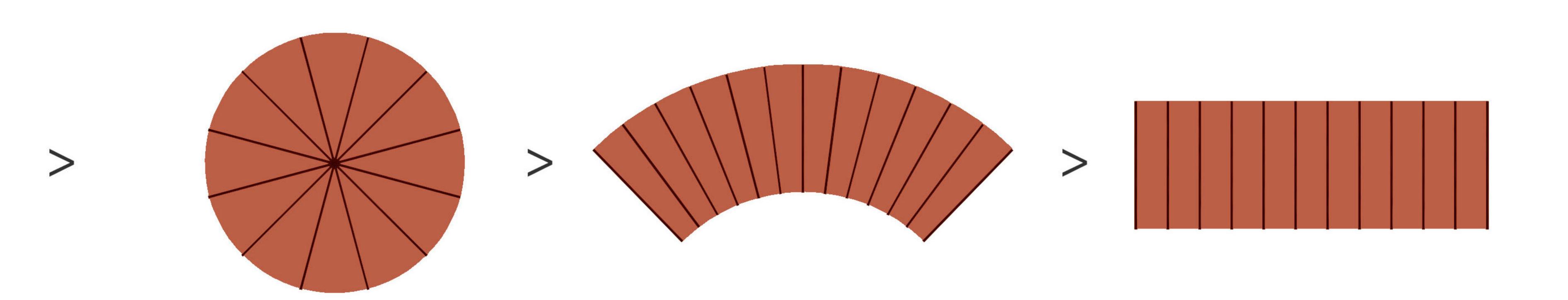


For the memory of the old window lattice, I take the main components of the wooden poles and re-design the pattern with fewer elements. The style of the lattice becomes more simple but symbolic. The wooden material and the crossing patterns tell the story of local culture in a graphic way. As a result, the new window keeps the old style of local tradition as well as improves the light transmission rate. Plus, the new structure makes it easier to maintain the integrity of the window, therefore enhances the insulation ability.

4.0 SHADING DEVICE



4.1 OILED PAPER UMBRELLA

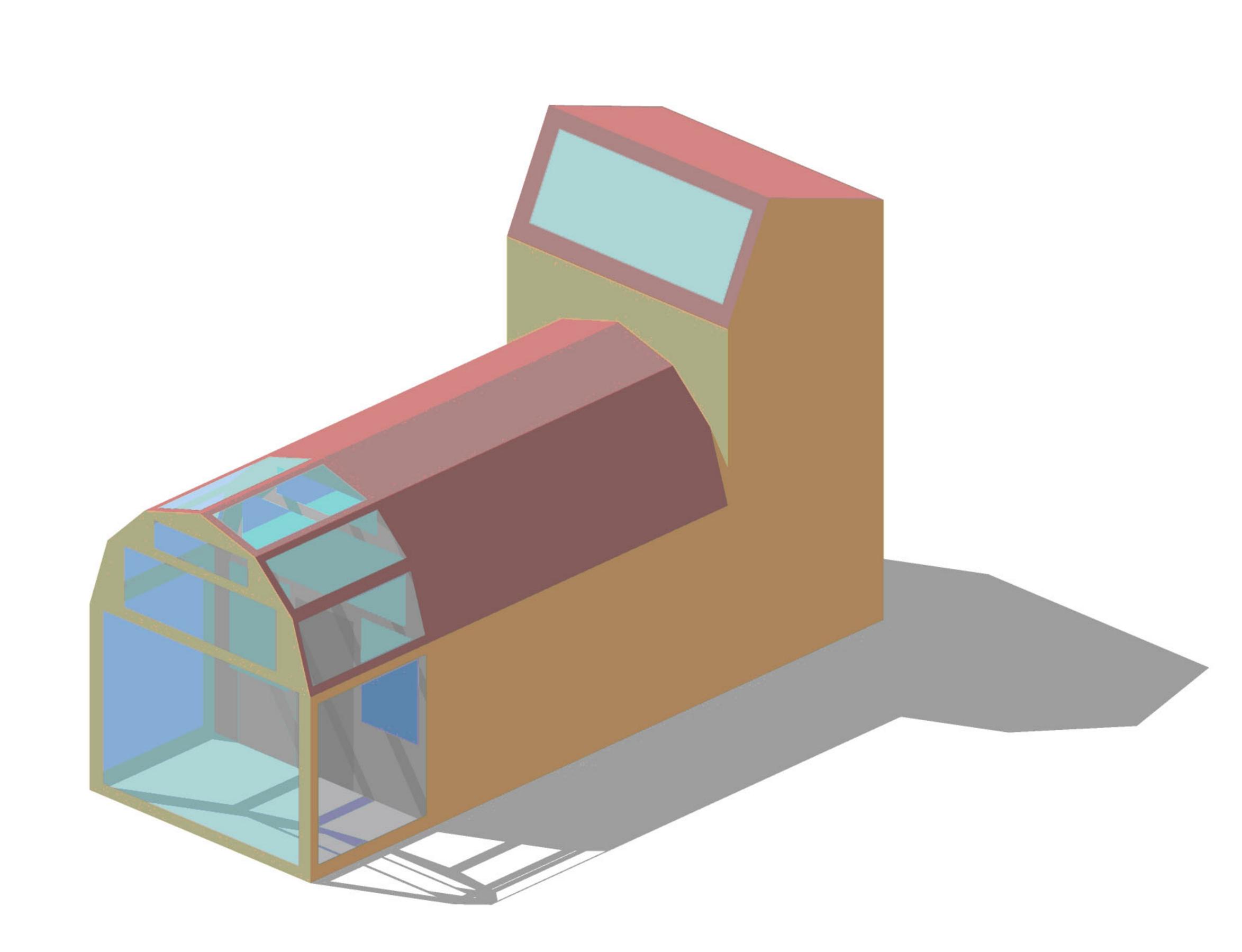


The traditional oiled paper umbrella is made of wood and paper which stained with oil. So that the cover of the umbrella is light as well as able to stop the rain drops. When paper was stained with colored oil, the umbrella became colored. In hot summer, people started to use colored umbrella to cast shadow, making cool area outdoors. The hand made oiled umbrella is even popular today by its character and art values.

THERMAL COMFORT

THE RENOVATION OF TRADITIONAL CAVE HOUSING IN CHINA

After the all renovation methods on the project Yaodong cave, it is necessary to reevaluate the thermal comfort condition in order to compare with the cave before intervention. As the same as the simulation made in the chapter seven, the work has been done in Energyplus software. With the same unit cave but different insulation materials and additional glass house, the result is going to be improved if the intervention is successful.



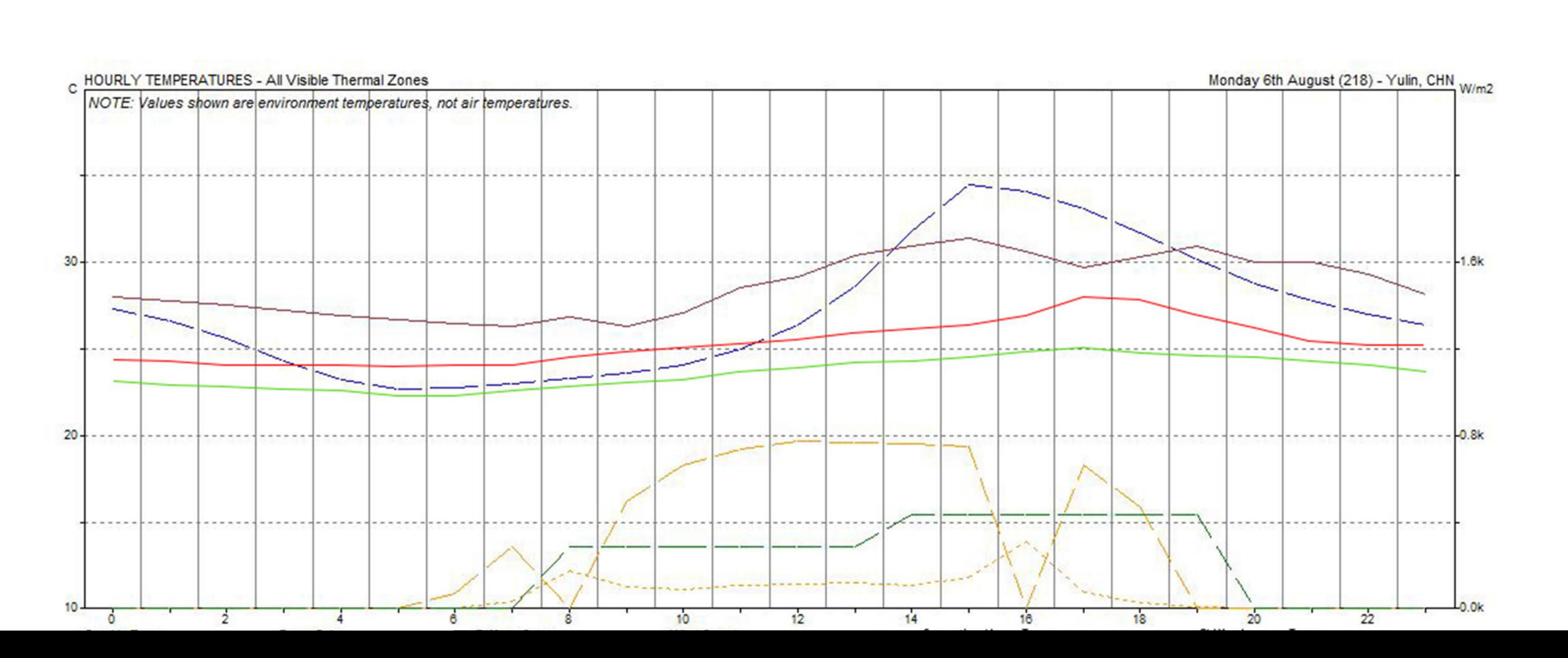
ENERGYPLUS MODEL

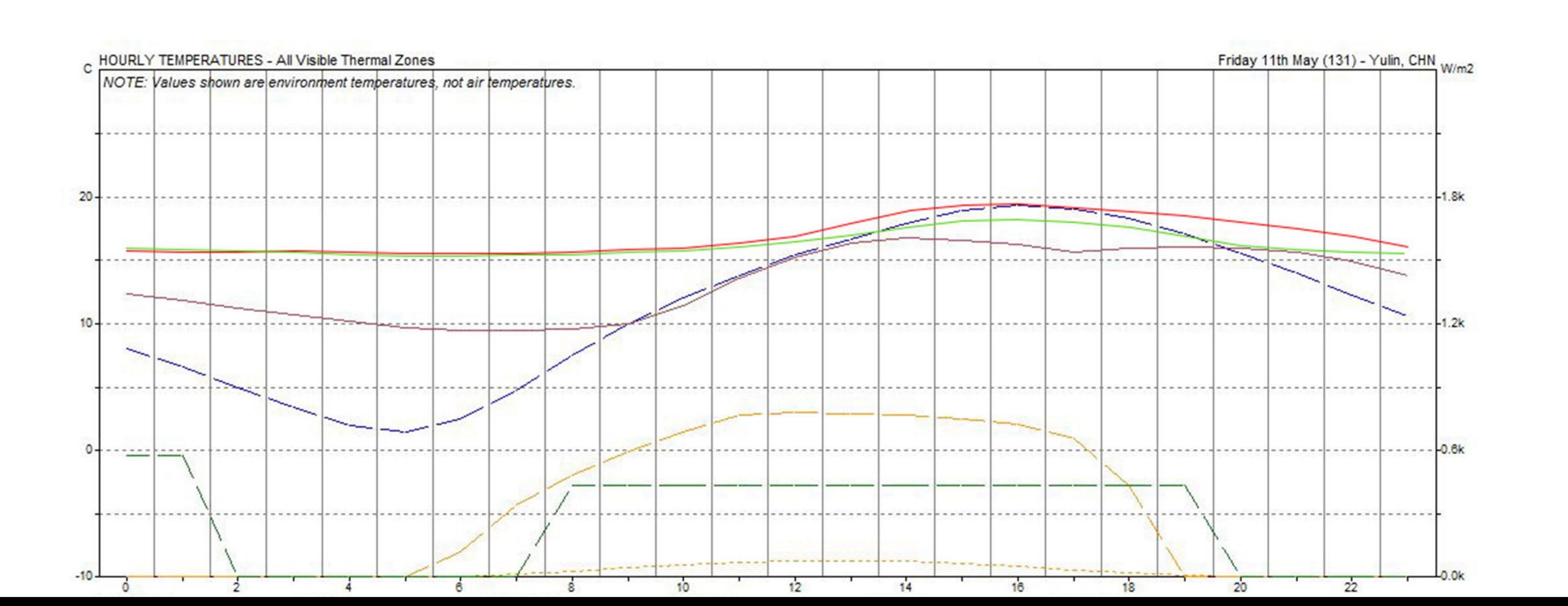
In order to find best approaches to maintain the thermal comfort in a nyaodong cave, different thickness of insulation boards are tested in the project.



Zone Mean Air Temperature

Date/Time	No Insulation	25mm Insulation Board	50mm Insulation Board
2013-2-3 1:00	3.25078014	4.211057617	4.626510914
2013-2-3 2:00	2.859786684	3.778275512	4.192888878
2013-2-3 3:00	2.592554058	3.46074777	3.875440372
2013-2-3 4:00	2.369478859	3.179938653	3.5927024
2013-2-3 5:00	2.139175311	2.893046425	3.29648274
2013-2-3 6:00	1.914130207	2.614786931	3.009457575
2013-2-3 7:00	1.7044335	2.354142602	2.740442717
2013-2-3 8:00	1.544264007	2.146329875	2.524198513
2013-2-3 9:00	2.063327163	2.604411346	2.972420961
2013-2-3 10:00	3.524842663	4.068388661	4.422487333
2013-2-3 11:00	5.42649861	6.084850615	6.406219971
2013-2-3 12:00	7.403210221	7.911992959	8.227914397
2013-2-3 13:00	8.898967065	9.416744088	9.722092218
2013-2-3 14:00	9.832130153	10.37820626	10.69177656
2013-2-3 15:00	10.26866599	10.89979939	11.22023156
2013-2-3 16:00	8.867576854	9.533698075	9.857660996



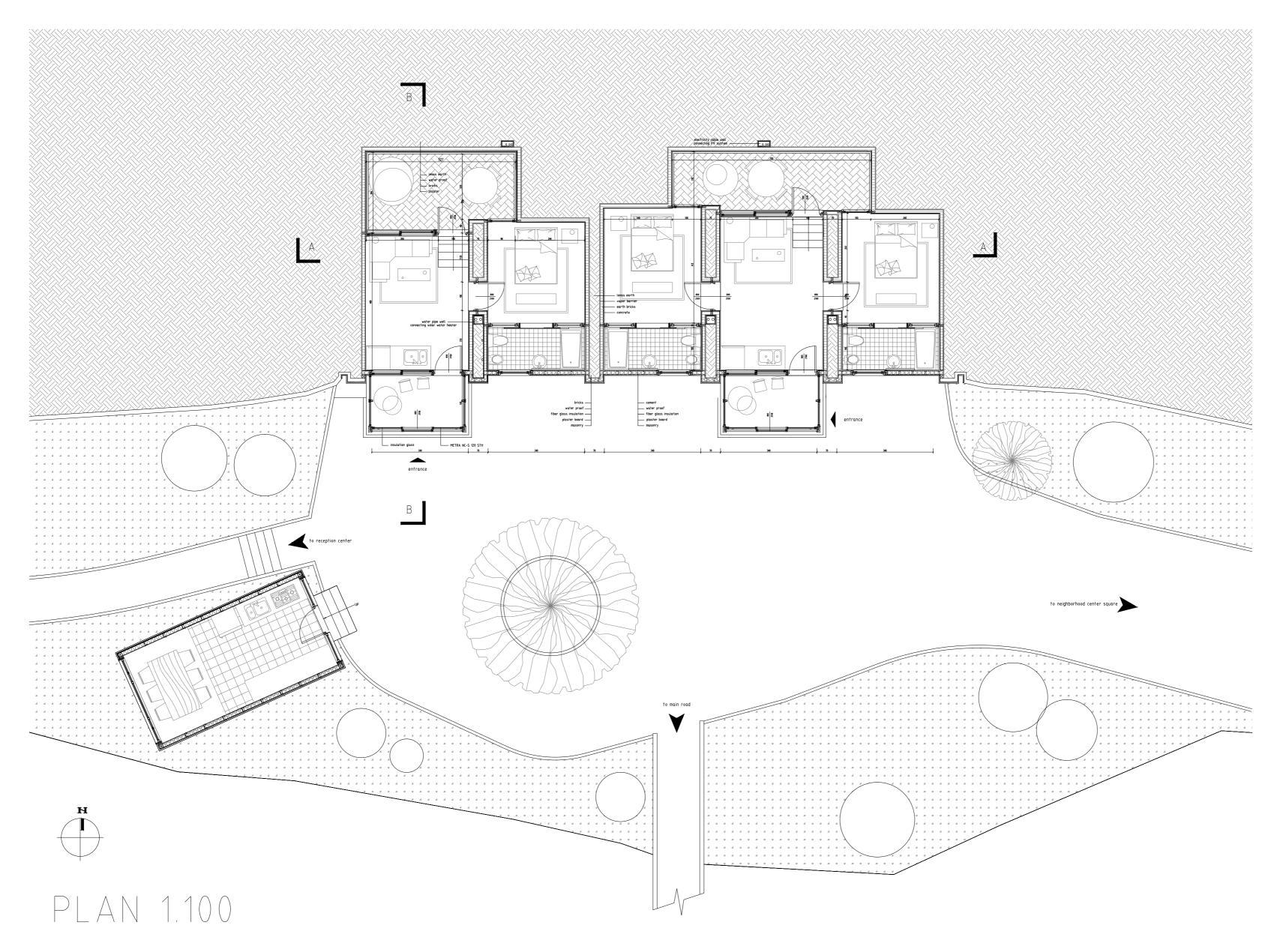


Insulation board improves the thermal comfort in winter. However in summer, the improvement is not so obviou. When testing with thickness of 25mm, the situation is even worse than the original cave. It is because the insulation somehow stops the geothermal effect from the earth shelter.



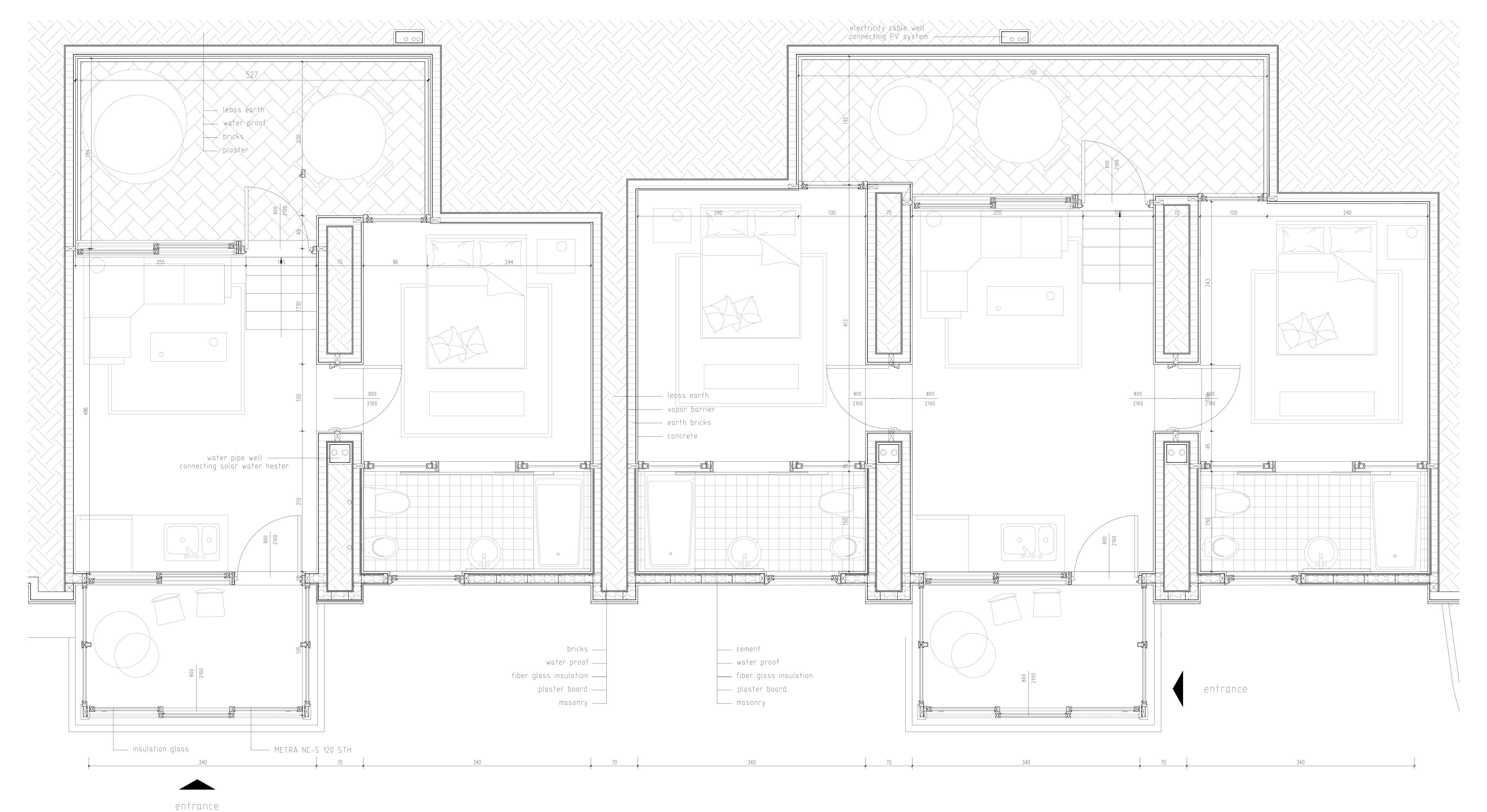
PERSPECTIVE VIEW 1





The Renovation of Traditional Cave Housing in China

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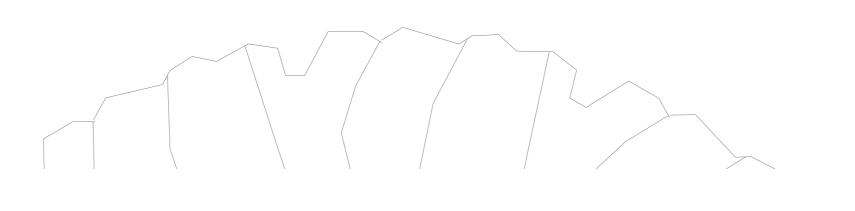
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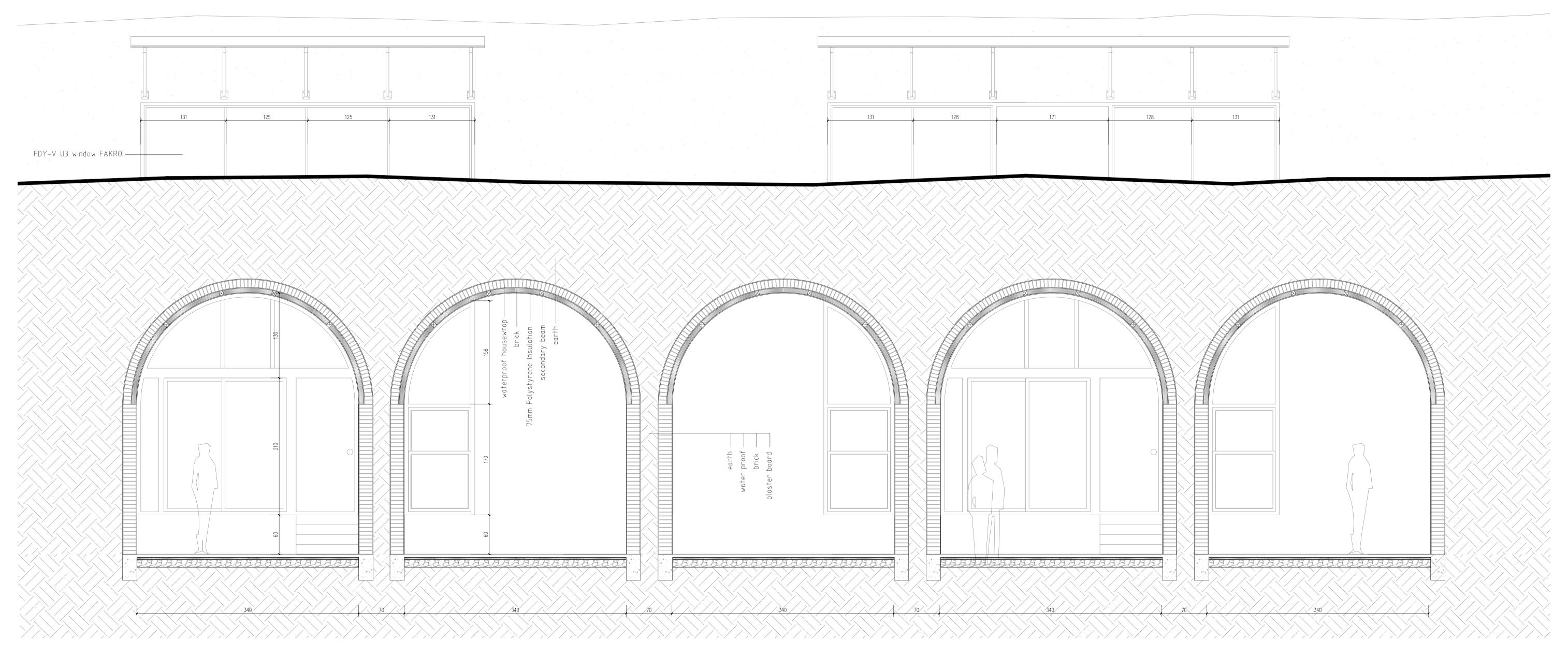
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SECTION A-A 1,30

The Renovation of Traditional Cave Housing in China

