CAVE DWELLING (YAODONG), XI'AN, CHINA

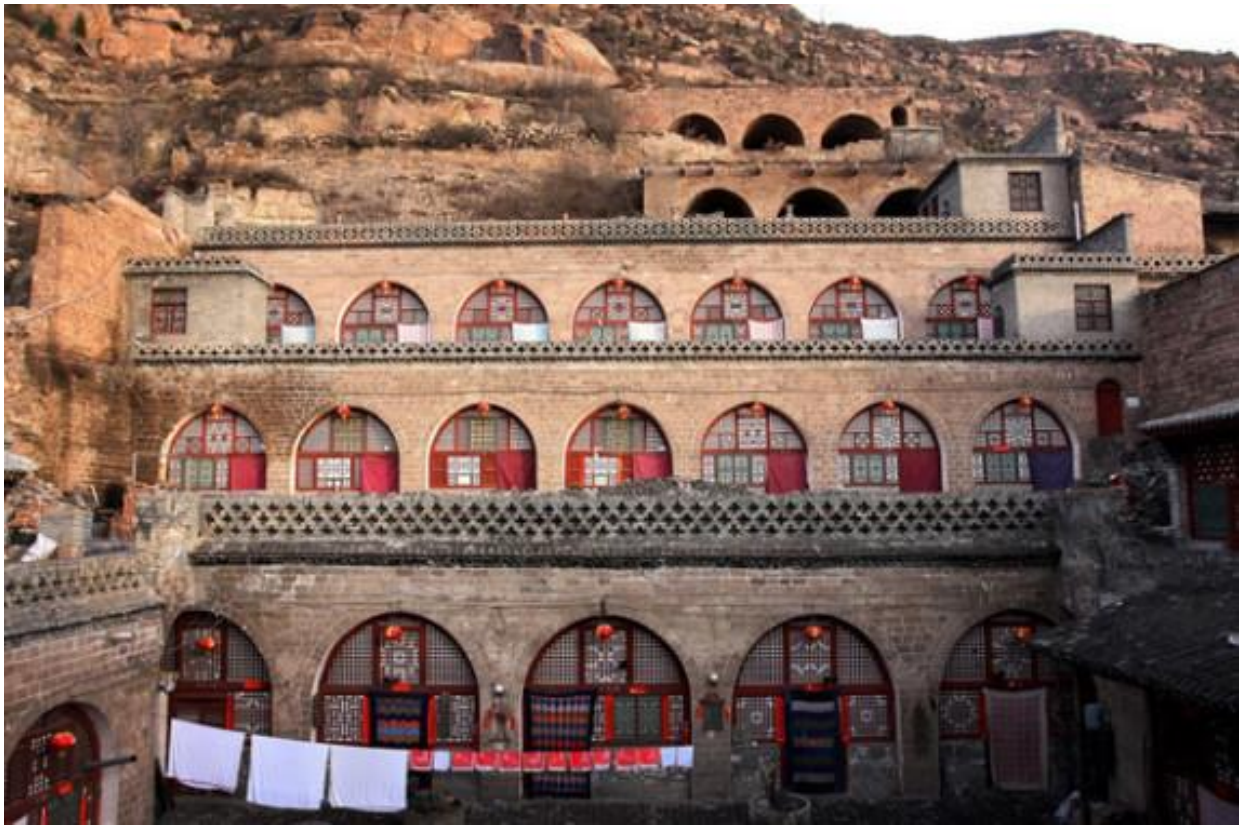

Image 1. Yaodong, Xi'an, China[1]

Introduction

Found in China's northern provinces, including (perhaps most famously) Shaanxi. Multiple dwellings are built adjacent to and on top of one another and together make up a tiered village, often for a single clan or extended family.[2]

1. Provide a brief overview of location and climate.

[1] http://www.thesilkroadchina.com/photo-p255-v49-cave-dwelling-shaanxi.html
[2] http://ignition.eg2.fr/2016/04/30/ephemeral-buildings-perpetual-architecture-shanxi-yaodong/

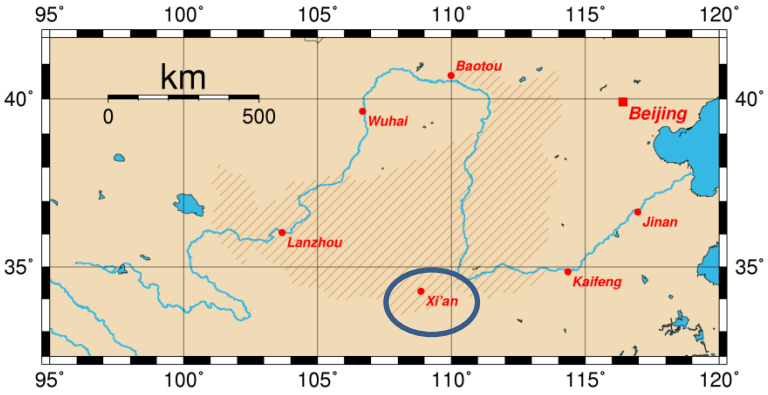

Image 2. The Loess Plateau in northern China (hatched area) and the valley of the Yellow River[3]

The yaodong homes are common on the Loess Plateau of China in the North and are found mainly in four provinces: Gansu, Shanxi, Henan, and the Hui Autonomous Region of Ningxia.

In the Qingyang region especially, the ratio of cave dwellers to non-cave dwellers is the highest found anywhere in China.[4]

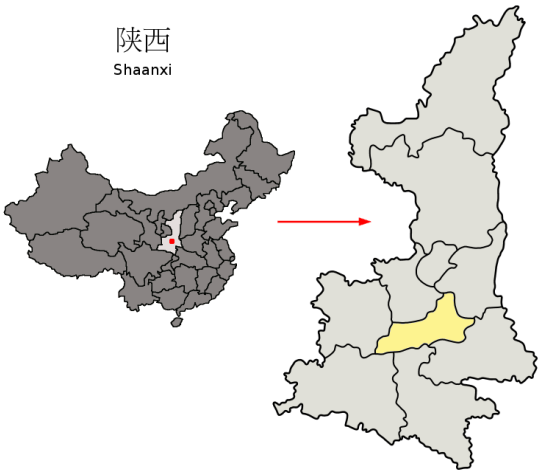

Image 3. Location of Xi'an(marked in yellow)[5]

Xi'an is the capital of Shaanxi Province, People's Republic of China. It is a sub-provincial city located in the center of the Guanzhong Plain in Northwest China

[3] https://en.wikipedia.org/wiki/Yaodong
[4] https://en.wikipedia.org/wiki/Yaodong
[5] https://en.wikipedia.org/wiki/Yaodong

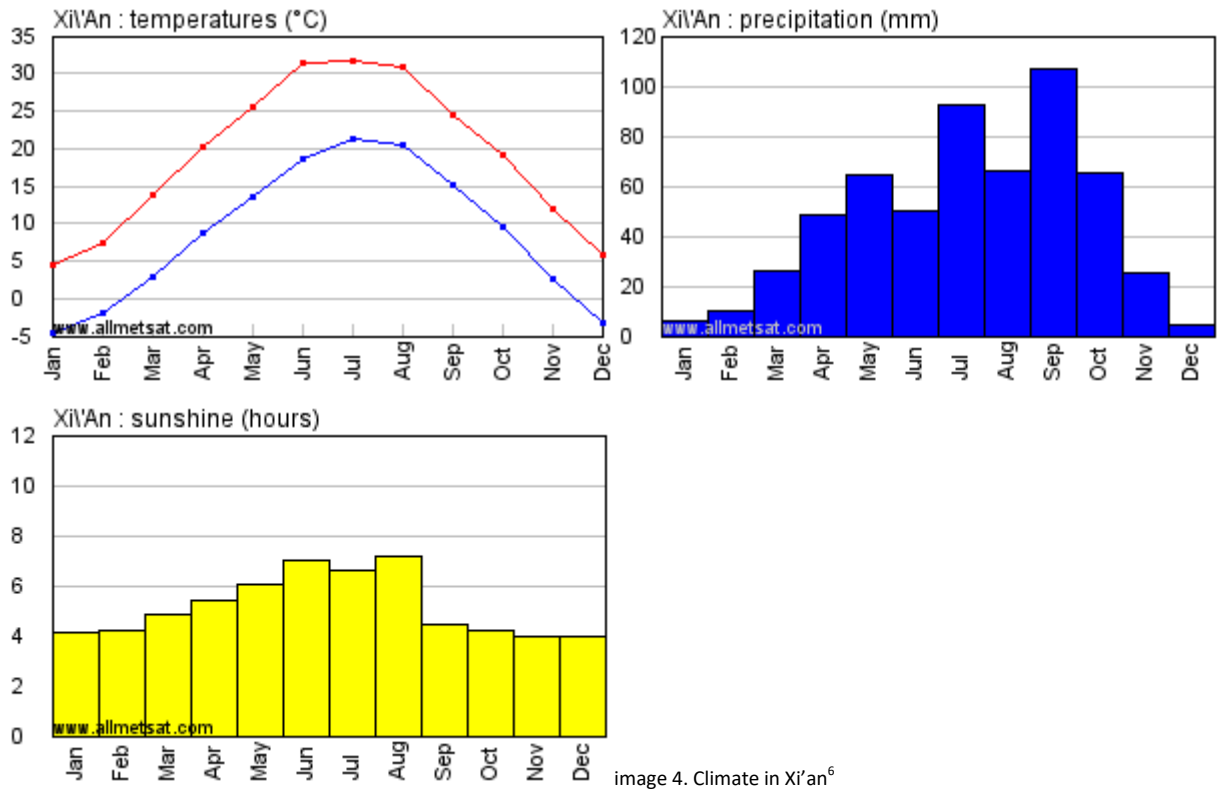

image 4. Climate in Xi'an[6]

Xi'an has a temperate climate that is influenced by the East Asian monsoon, classified under the Köppen climate classification as situated on the borderline between a semi-arid climate (BSk) and humid subtropical climate (Cwa). The Wei River valley is characterised by hot, humid summers, cold, dry winters, and dry springs and autumns. Most of the annual precipitation is delivered from July to late October. Snow occasionally falls in winter but rarely settles for long. Dust storms often occur during March and April as the city rapidly warms up. Summer months also experience frequent but short thunderstorms. The monthly 24-hour average temperature ranges from around the freezing mark in January to 27.0 °C (80.6 °F) in July, with an annual mean of 14.08 °C (57.3 °F). With monthly percent possible sunshine ranging from 31 percent in December to 47 percent in August, the city receives 1,536 hours of bright sunshine annually. Extremes since 1951 have ranged from −20.6 °C (−5 °F) on January 11, 1955 to 41.8 °C (107 °F) on June 21, 1998. A highest record of 42.9 °C (109 °F) was registered in another station on June 17, 2006.[7]

[6] http://www.eldoradocountyweather.com/climate/china/Xi%27An.html
[7] https://en.wikipedia.org/wiki/Xi%27an#Climate

Climate data for Xi'an (normals 1981–2010, extremes 1951–2013) [hide]													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	17.0 (62.6)	24.1 (75.4)	31.3 (88.3)	34.9 (94.8)	38.6 (101.5)	41.8 (107.2)	41.0 (105.8)	40.0 (104)	38.5 (101.3)	34.1 (93.4)	24.5 (76.1)	21.6 (70.9)	41.8 (107.2)
Average high °C (°F)	5.1 (41.2)	8.9 (48)	14.4 (57.9)	21.5 (70.7)	26.6 (79.9)	31.4 (88.5)	32.4 (90.3)	30.3 (86.5)	25.6 (78.1)	19.3 (66.7)	12.4 (54.3)	6.3 (43.3)	19.5 (67.1)
Daily mean °C (°F)	0.3 (32.5)	3.6 (38.5)	8.7 (47.7)	15.4 (59.7)	20.5 (68.9)	25.3 (77.5)	27.0 (80.6)	25.1 (77.2)	20.3 (68.5)	14.1 (57.4)	7.2 (45)	1.5 (34.7)	14.1 (57.4)
Average low °C (°F)	−3.3 (26.1)	−0.4 (31.3)	4.1 (39.4)	10.3 (50.5)	15.1 (59.2)	19.9 (67.8)	22.3 (72.1)	21.0 (69.8)	16.5 (61.7)	10.2 (50.4)	3.2 (37.8)	−2.2 (28)	9.7 (49.5)
Record low °C (°F)	−20.6 (−5.1)	−18.7 (−1.7)	−7.6 (18.3)	−4 (25)	3.5 (38.3)	9.2 (48.6)	15.1 (59.2)	12.1 (53.8)	4.8 (40.6)	−1.9 (28.6)	−16.8 (1.8)	−19.3 (−2.7)	−20.6 (−5.1)
Average precipitation mm (inches)	6.7 (0.264)	9.8 (0.386)	27.1 (1.067)	37.5 (1.476)	54.9 (2.161)	64.5 (2.539)	97.5 (3.839)	78.6 (3.094)	94.1 (3.705)	61.7 (2.429)	21.5 (0.846)	7.3 (0.287)	561.2 (22.093)
Average precipitation days (≥ 0.1 mm)	3.4	4.0	6.4	7.8	8.2	8.8	9.9	10.0	11.6	9.9	5.5	3.6	89.1
Average relative humidity (%)	65	62	64	64	65	61	68	75	77	76	73	68	68.2
Mean monthly sunshine hours	88.4	96.1	116.6	142.8	169.5	179.7	181.1	168.1	121.0	98.9	92.4	81.0	1,535.6
Percent possible sunshine	32	34	33	38	40	43	44	47	34	32	32	31	37
Source: China Meteorological Administration,[34] all-time extreme temperature[33]													

image 5. Climate in Xi'an[8]

2. Describe the design intent and building environmental design strategies/features in the building. Identify how each environmental design strategy affects the heat flow equation in the building.

Heat Flow equation in building

Q = + Solar ± Conduction ± Ventilation ± Infiltration ± Evaporation + Internal Gains + ...

Solar Radiation

"Warm in winter; Cool in Summer." The thick earth separates the indoor space and outdoor, serves as an effective insulator that keeps the inside of a yaodong warm in cold seasons and cool in hot seasons. Consequently, very little heating is required in winter, and in summer, it is as cool as an air-conditioned room. It is a very good example for sustainable lifestyle for modern architecture design. The building units are carved into a hillside or dug into the ground to create a sunken dwelling, which could block the solar radiation. And the windows are not very big. As it is hot and humid in summer of Xi'an, it is a good idea to block the solar radiation.

Conduction

[8] http://www.eldoradocountyweather.com/climate/china/Xi%27An.html

The yaodong, or cave houses, use earth from the hillside as insulation to regulate temperature in harsh winters and summers. They can be carved into a hillside, dug into the ground to create a sunken dwelling, or built standalone by packing earth on top of a brick frame. The R-values of the massive ground and bricks provide good performance of conduction. And the only one side towards the air brings down the surface area which is a good way to affect conduction in order to have a better indoor environment.

Ventilation

In the case of yaodong carved into a hillside, wind comes from only one side of the building. As it is cold and dry in winter, it is a good idea to reduce the effect of air flow.

Infiltration

As there is only one side against the air flow, the pressure difference between indoor and outdoor is relatively high which provides more opportunities for infiltration.

3. Describe what would you have changed if you were in charge of the project.

1. Yaodong is very fragile to earthquake or geology instability (landslides, etc.). I would like to have some more new materials used in the project, for example, steel
2. With only one side possible for a window, Lighting of Yaodong is not very good. People might feel depressed inside. I would like to design some more holes on the façade to bring sufficient light inside