Long-term Performance of Large Longyou Caverns Manually Carved in Argillaceous Siltstone Ground

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The caverns were manually carved in argillaceous siltstone ground hundreds or thousand years ago.
24 Rock Caverns & Their Long-term Performance

10 stable and integrate caverns
Currently flatter ground

14 partly or completely failed caverns
Currently hilly ground
The caverns have large spans and are in shallow depths!
14 Partly or Completely Failed Caverns

Roof collapsed

No.14

No.23

Roof collapsed
Question

Why do the 24 rock caverns have two groups of totally different performances over past hundreds or thousands years?!
Profiles of the Argillaceous Siltstone

Thick seam on collapsed cliff

Man-cut profile on road

Thin seams for failed cavern roof

Thin seams for complete cavern roof
Properties of Argillaceous Siltstone

The large amount of manual carving demonstrate that the rocks are not hard & strong, and not soft & poor.

Unit weight = 22 (dry) and 23 (saturated) kN/m$^3$
Modulus = 4.5 (dry) and 3.0 (saturated) GPa
UCS = 31.6 (dry) and 18.1 (saturated) MPa
Split tensile strength = 1.6 MPa

The rock minerals are quartz, plagioclase feldspar, calcite, chlorite, illite and montmorillonite.

The rock has low-medium strength & stiffness. When wetted, its stiffness and strength can be reduced significantly.
Each complete rock cavern has a vertical portal entrance.

Each failed rock cavern has a horizontal portal entrance.

They are the major difference between the complete and the failed rock caverns.
The Major Difference between Complete & Failed Caverns

Small vertical entrance

Large horizontal entrance

No. 1

Inferred collapsed zone

Ground surface
Vertical entrance cavern

Horizontal entrance cavern
The Major Difference between Complete & Failed Caverns

Water can be full & stable

Water flows out
10 Pools for Vertical Entrances of 10 Complete Caverns

- sidewall boundary of verified integrity caverns (Nos. 1 to 5)
- inferred sidewall boundary of unexplored integrity caverns (Nos. 6, 7, 8, 16, 17)
- entrance of the verified integrity caverns (also water pool before 1992)
- WP1 (water pool No. 1)
- drillhole No. 1
- elevation above Yellow Sea level (m)
The Answer to The Question

• The full water in a cavern functions as a completely flexible support material to its surrounding rock and largely reduces its stresses and deformation.

• It offers a sealed and stable environment against the rock physical and chemical weathering.

The full water occupation is the natural factor that has made the rock caverns stable and kept them integrity for over hundreds years!
Further Answer to The Question

- The water in the caverns has pH values lower than 7.
- The surrounding rock has pH values greater than 7.
- So, the alkali rock and the acidic water would react chemically and generate new minerals such as calcite.
- With time, more and more new minerals can infill cracks and then heal the submerged rock.
- So, the complete caverns had no old cracks when they were discovered in 1992.

Weak alkali rock + Weak acidic water → New Minerals

The argillaceous siltstone has the ability of self-healing of its cracks in natural acidic water!
Exposed to Air
Fine or Weathered Caving Imprints and None Cracks
No.4 roof
No.3 pillar
No.3 roof
No.1 Entrance
Exposed to Air
Submerged in water
Exposed to Air
Submerged in water
Exposed to Air
Take home message

Longyou rock caverns give us the evidence of long-term performance of rock caverns

Fully filling of water in rock caverns can make them stable and integrity for many years

References


