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

**by**

**Zhong-qi Quentin Yue**

Civil Engineering Department, The University of Hong Kong, Hong Kong, P.R. China

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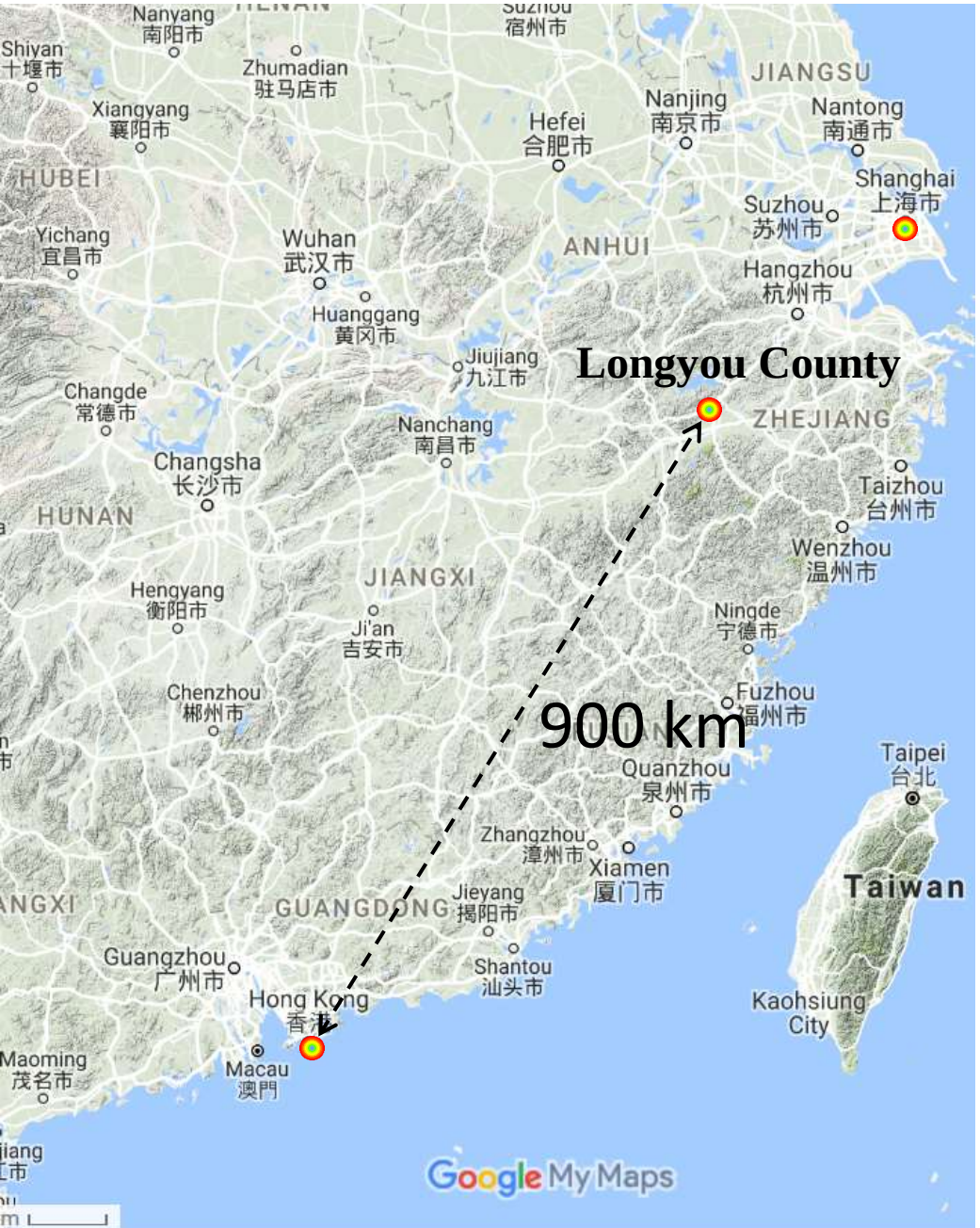
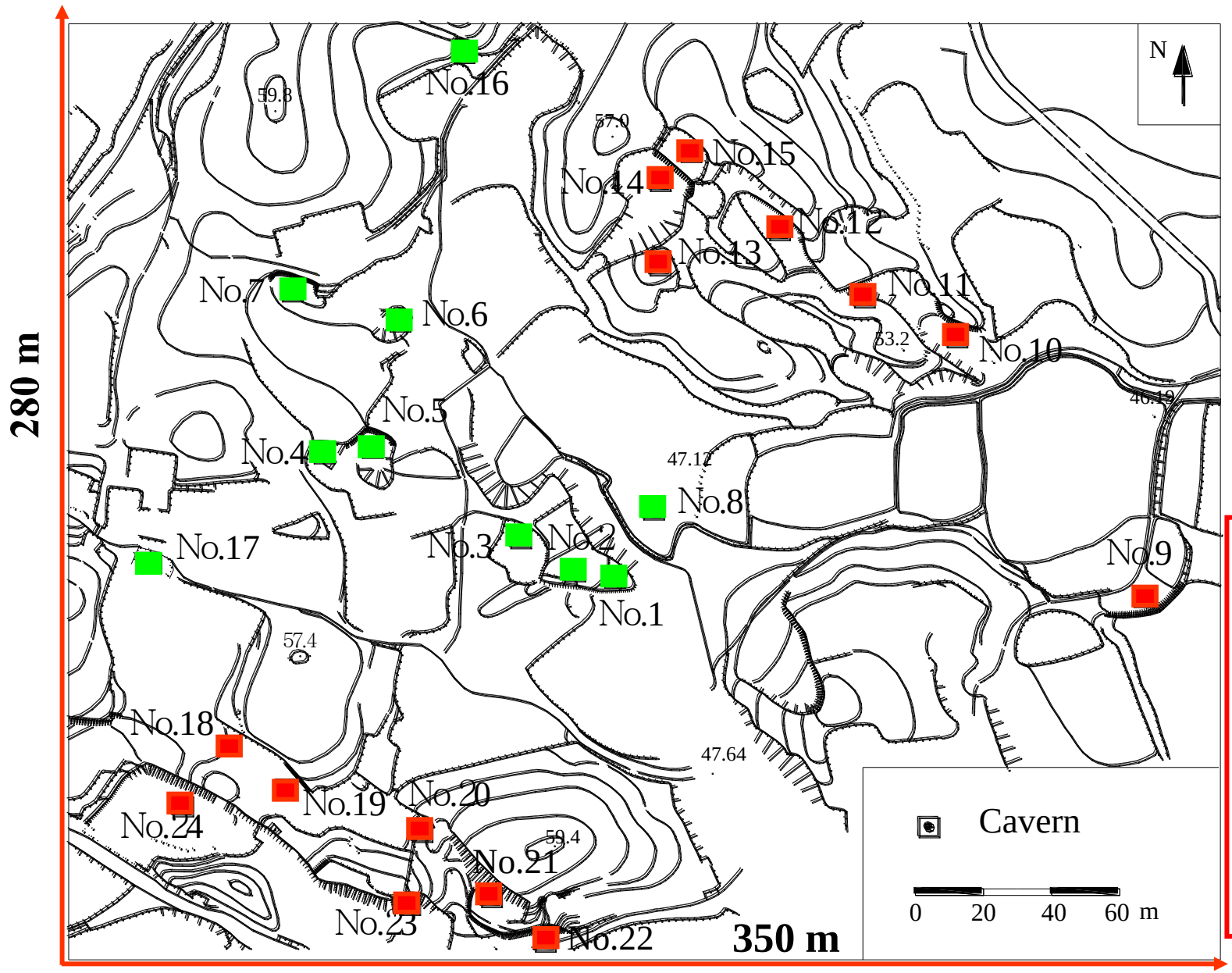
# Location and Histroy of Large Longyou Caverns





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 10 Complete Caverns



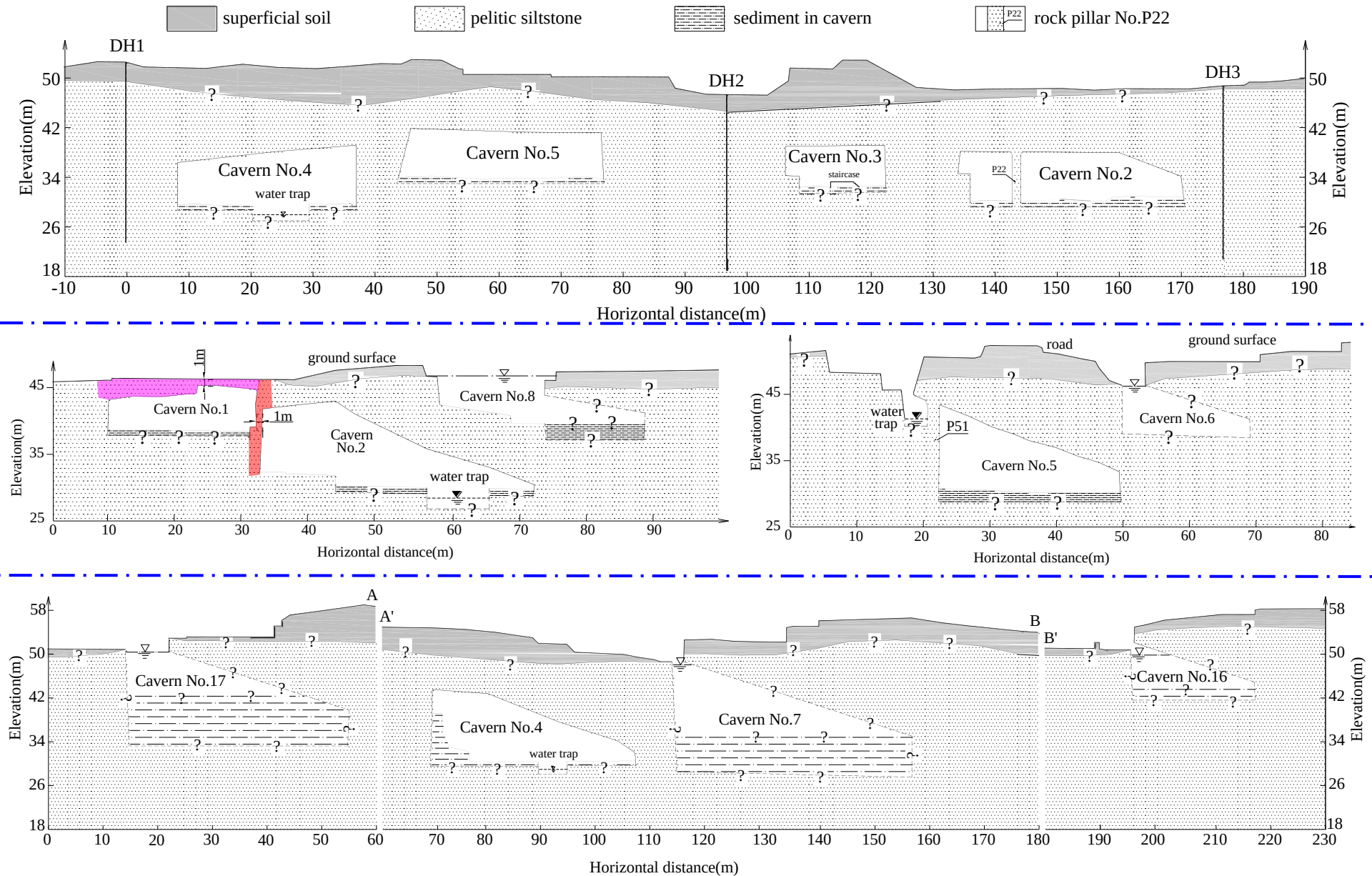




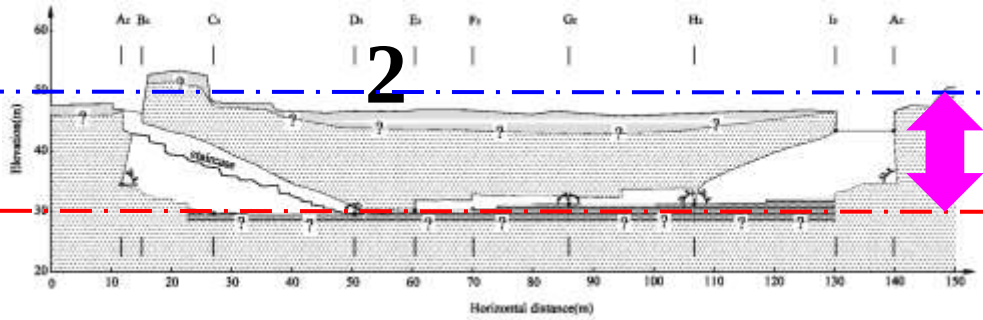




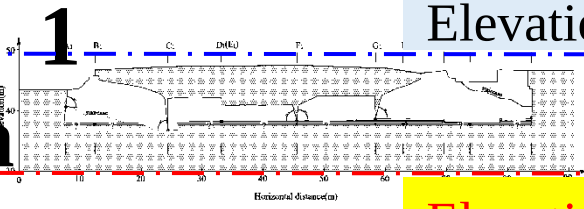
# Cross-sections of the 10 Complete Caverns



# Wall Profiles of 10 Complete Caverns



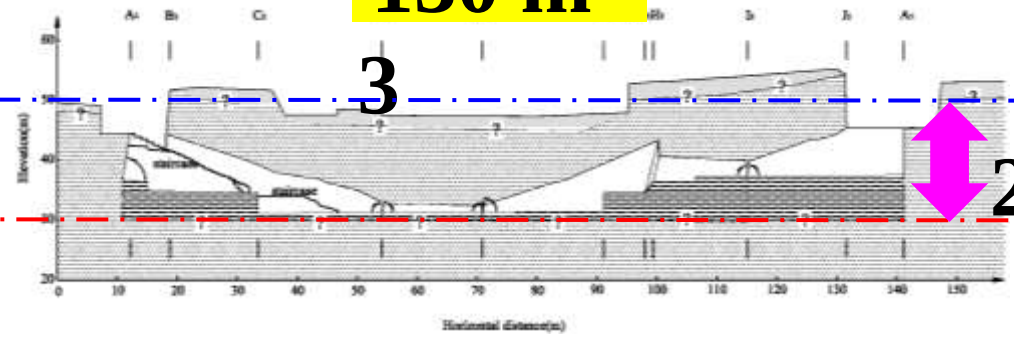

20 m



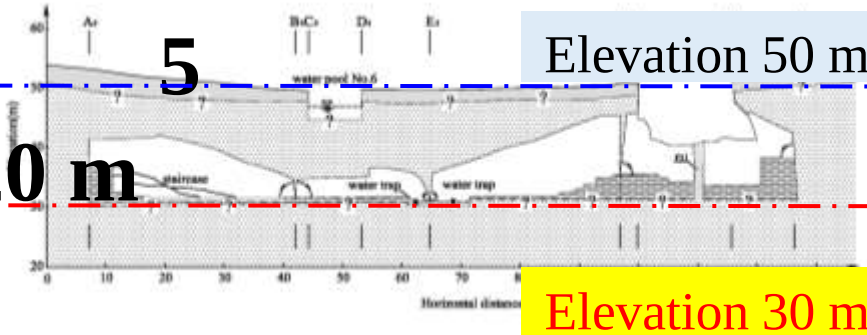

Elevation 50 m

Elevation 30 m

130 m

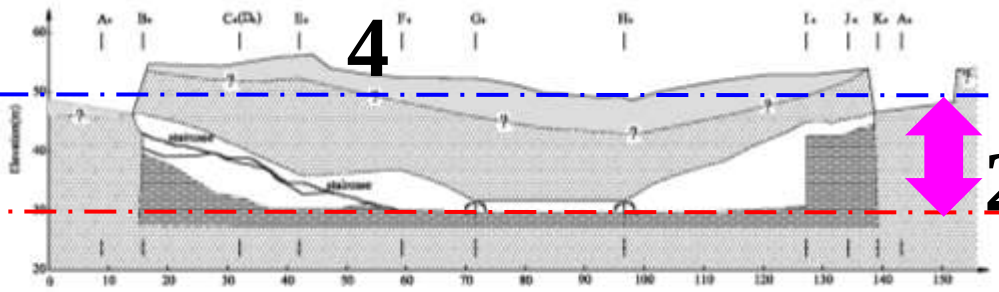



20 m




Elevation 50 m

Elevation 30 m




20 m

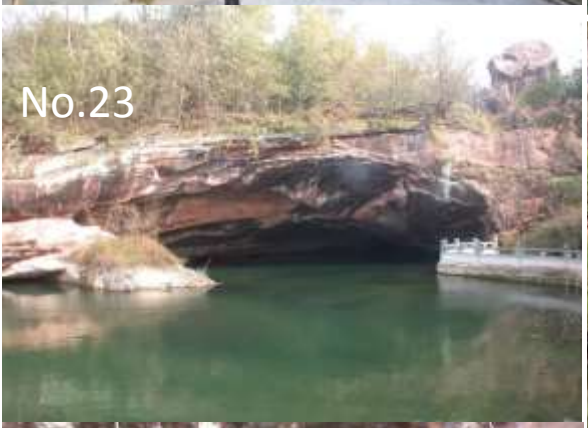
Elevation 50 m

Elevation 30 m

The caverns have large spans and are in shallow depths!

# 14 Partly or Completely Failed Caverns






# 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




# Properties of Argillaceous Siltstone

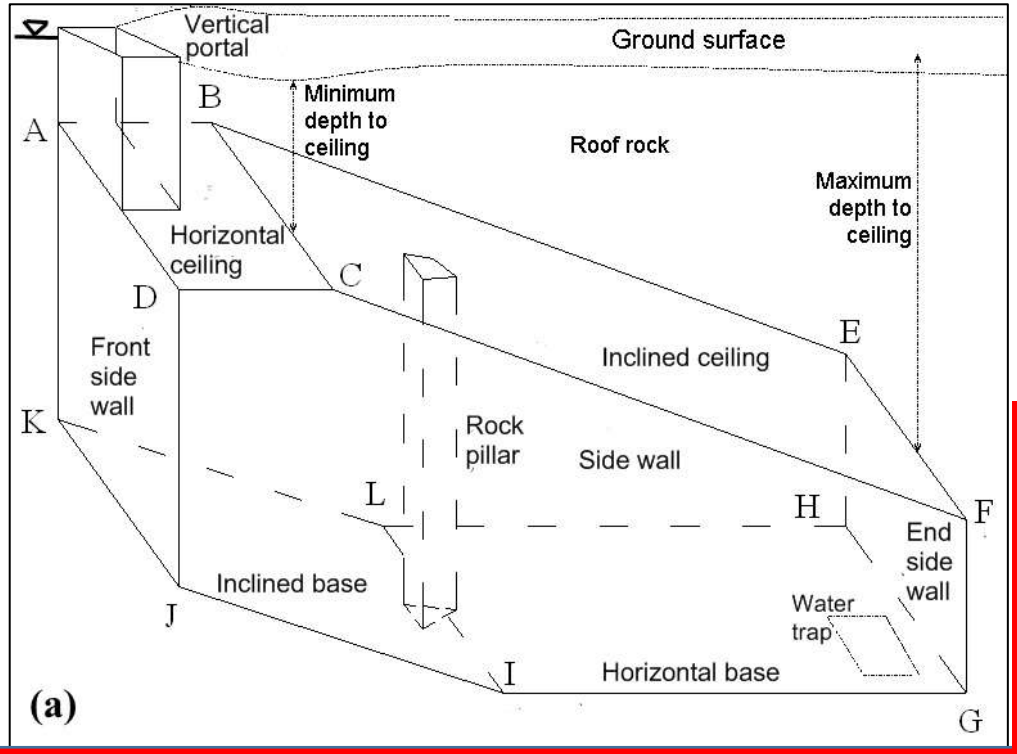
The large amount of manual carving demonstrate that the rocks are not hard & strong, and not soft & poor.

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

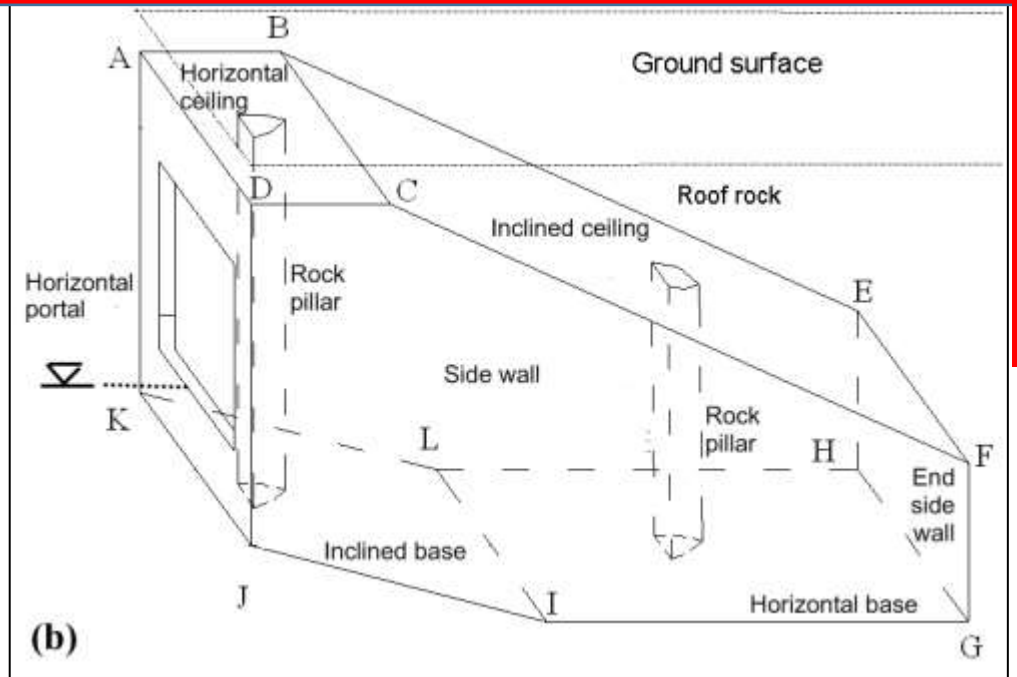
The rock minerals are
quartz, plagioclase feldspar, calcite, chlorite, illite and montmorillonite.

**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**



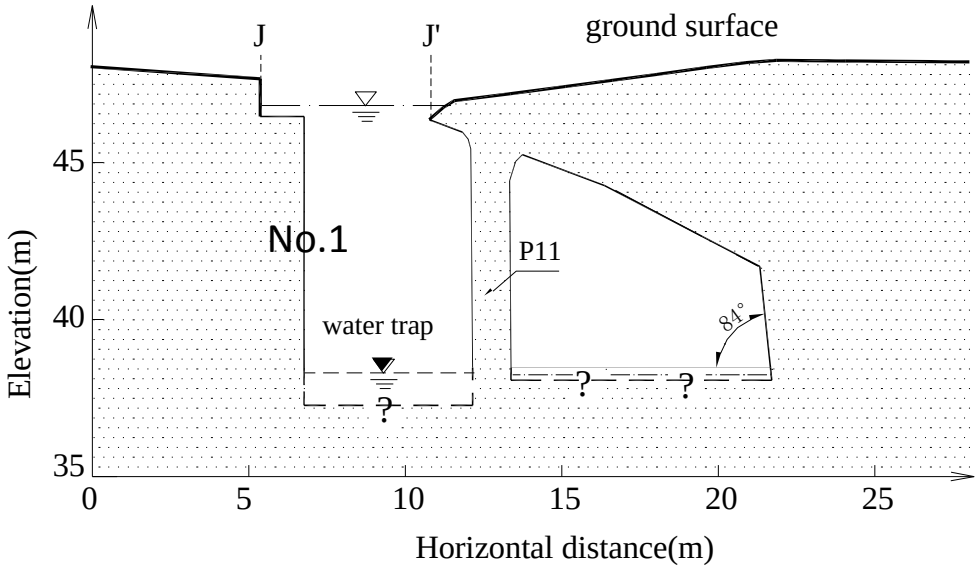

**Each failed rock cavern has a horizontal portal entrance**

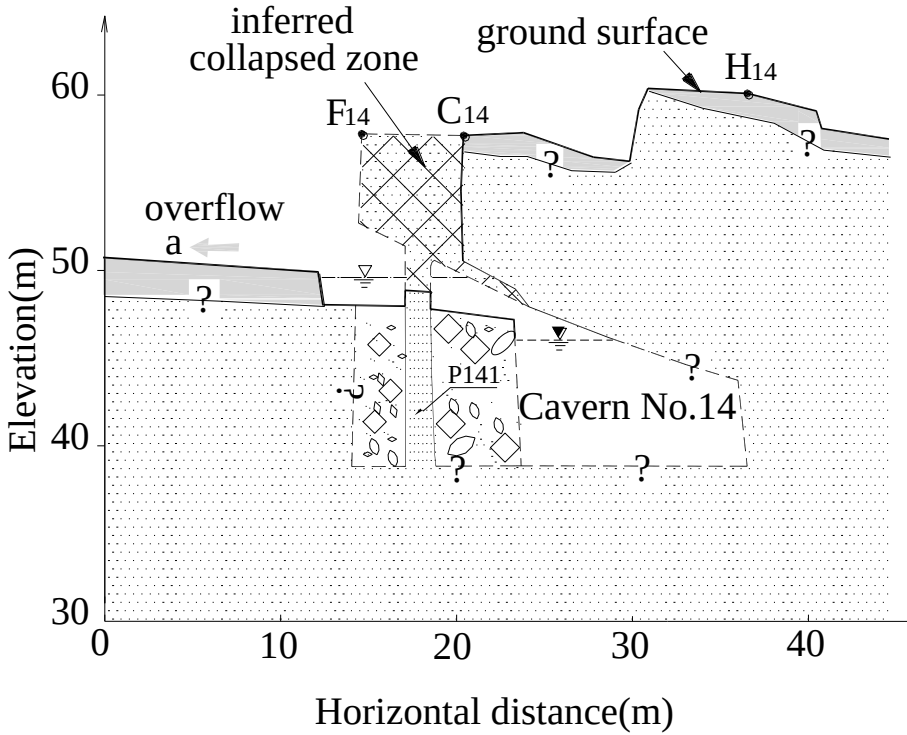



**They are the major difference between the complete and the failed rock caverns**

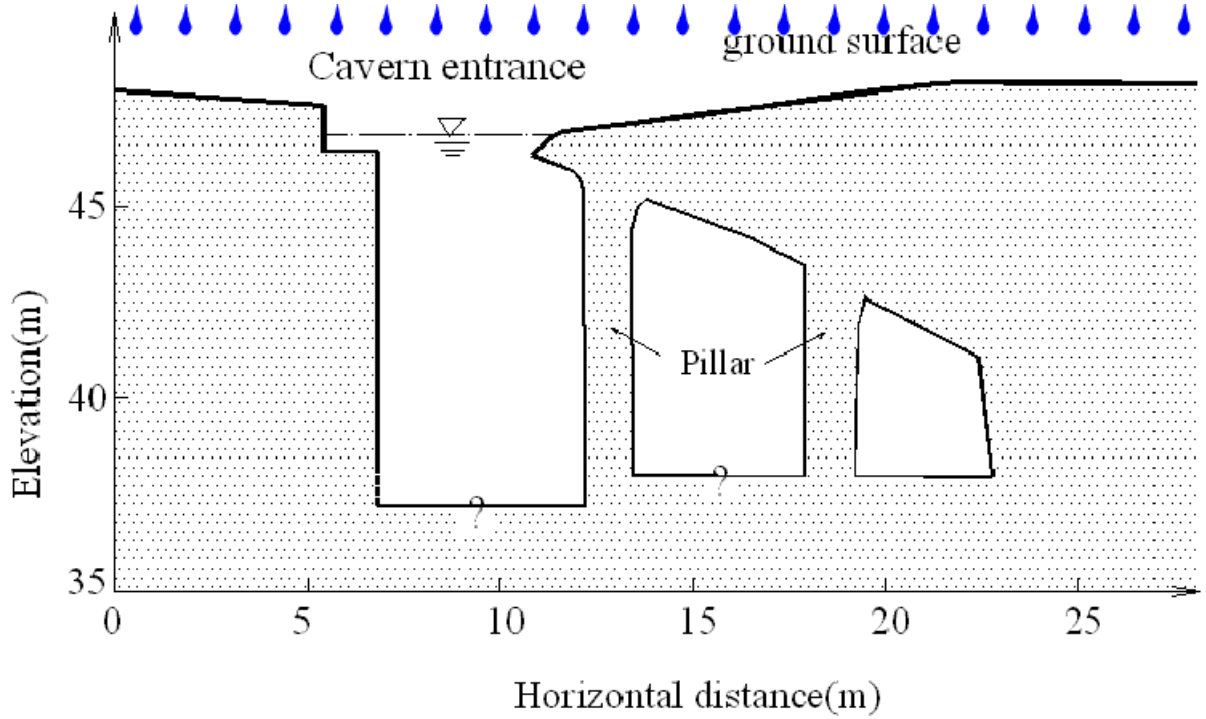
# The Major Difference between Complete & Failed Caverns



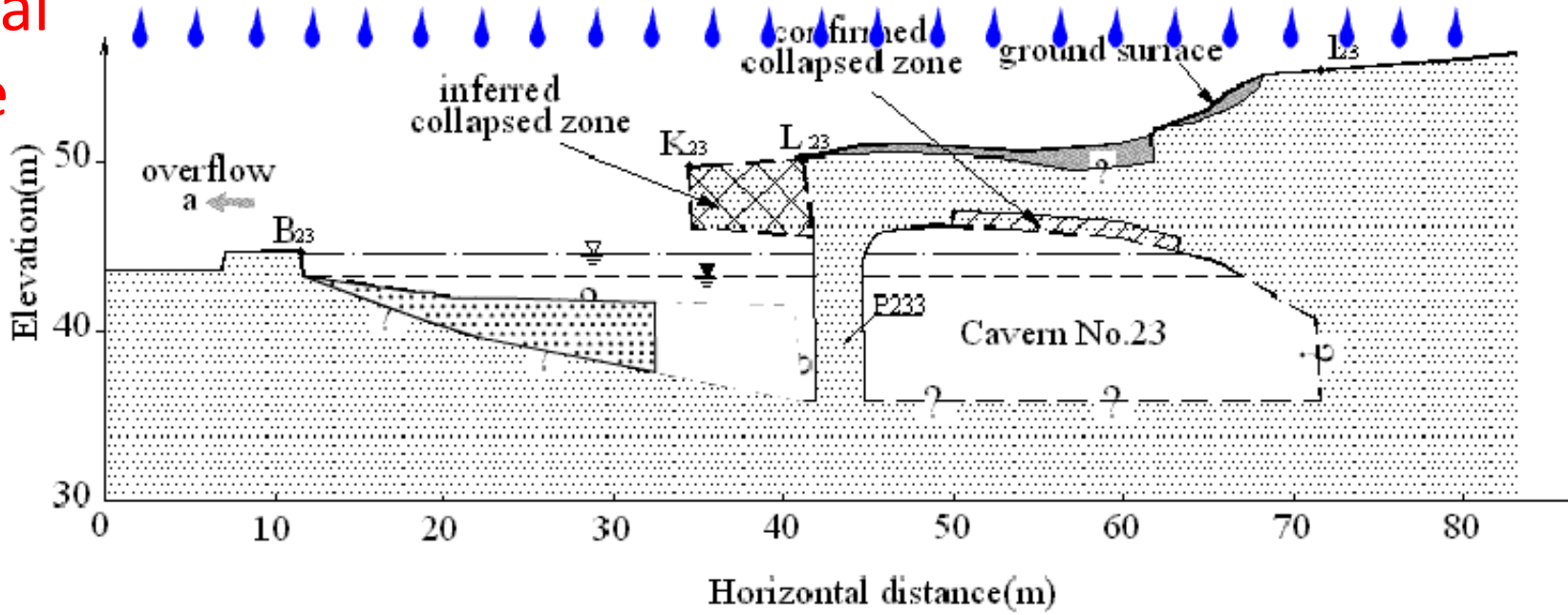


Vertical entrance cavern

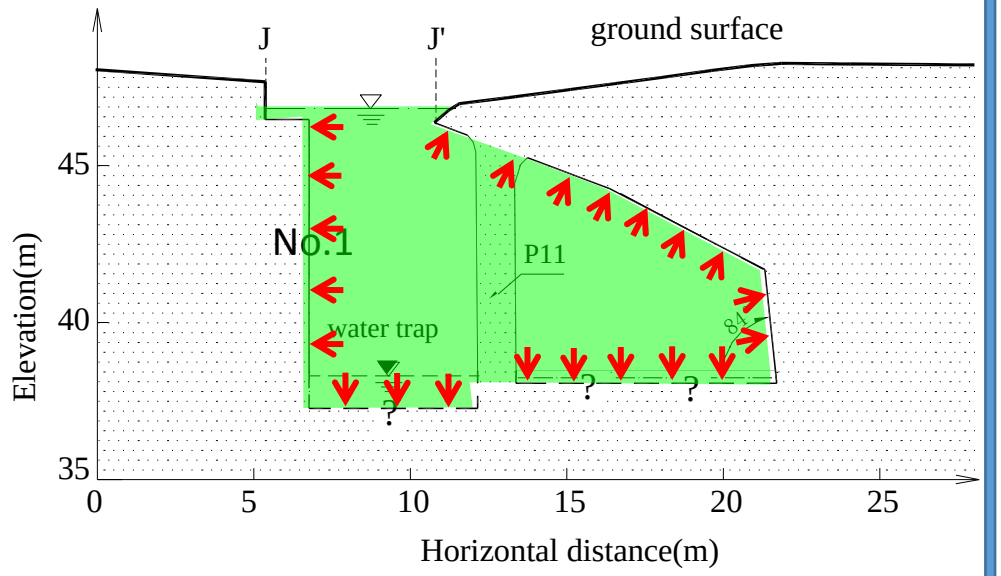


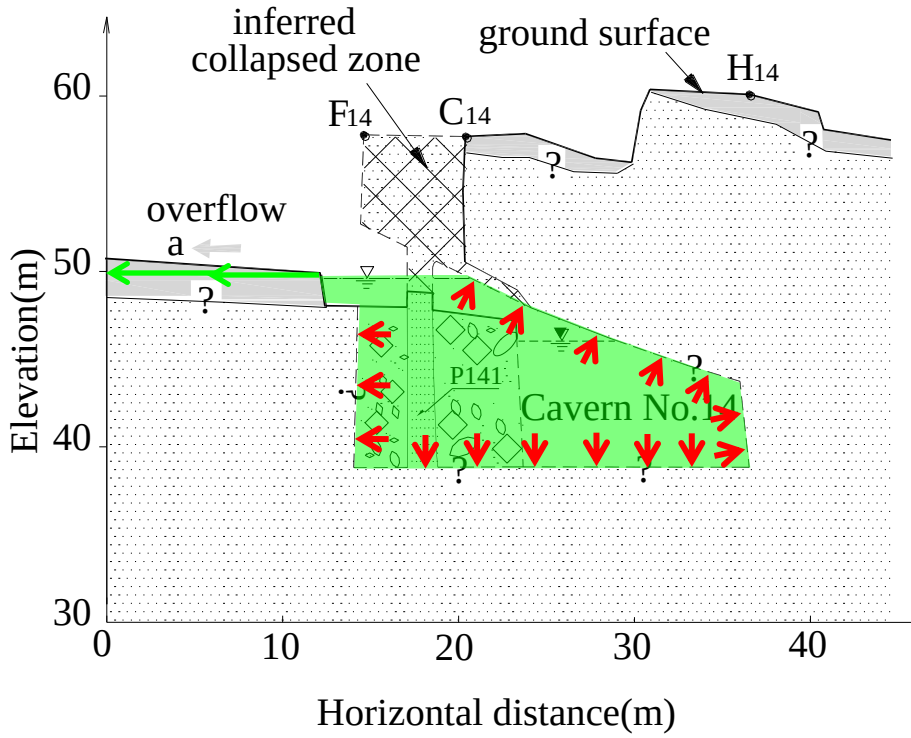

Horizontal entrance cavern



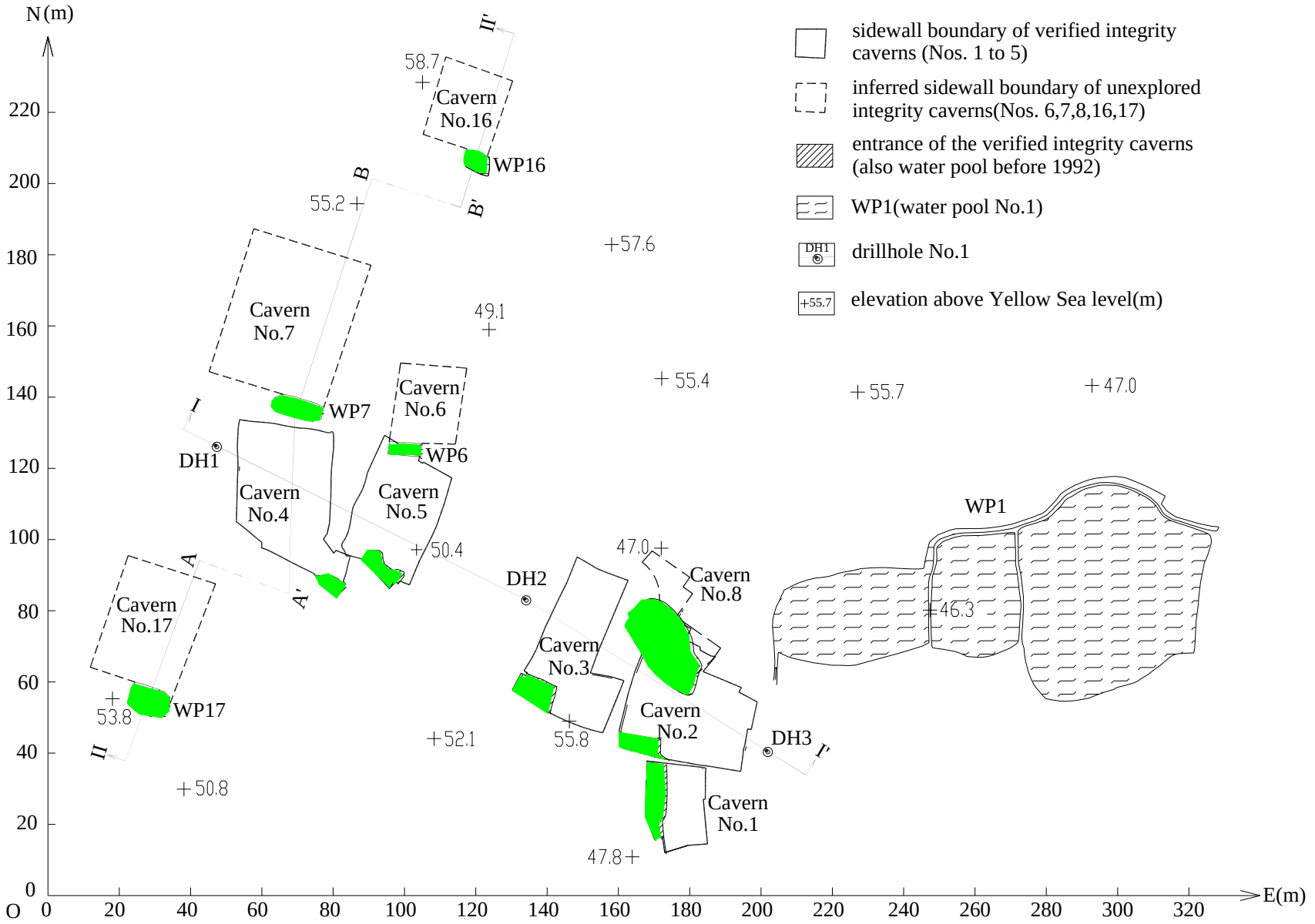
# The Major Difference between Complete & Failed Caverns





# 10 Pools for Vertical Entrances of 10 Complete Caverns



# 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

New calcareous sinter in new cracks

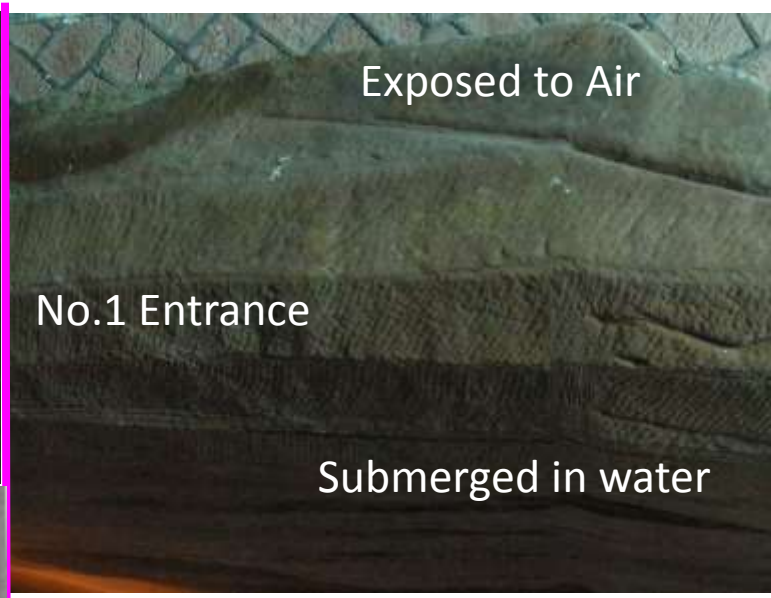
- The water in the caverns has **pH** values lower than 7.
- The surrounding rock has **pH** values greater than 7.
- So, the **alkali rock** and the **acidic water** would reacts chemically and generate **new minerals** such as calcite.
- With time, more and more new minerals can **infill cracks** and 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

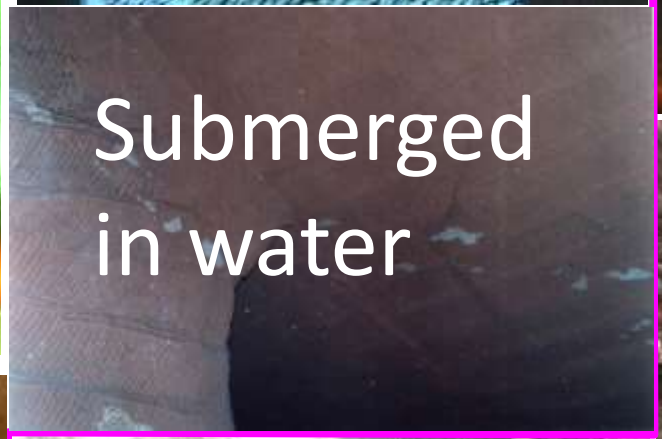
The argillaceous siltstone has
the ability of self-healing of its cracks in natural acidic water !

# Fine or Weathered Caving Imprints and None Cracks

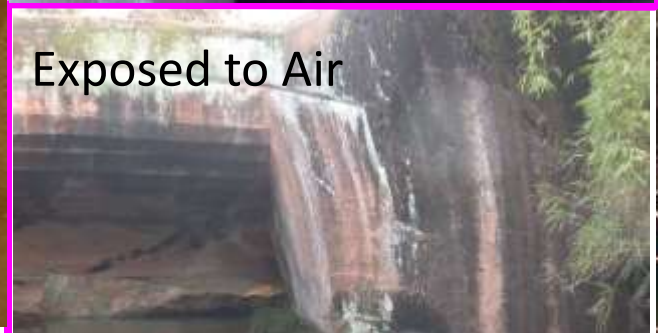










# Take home message

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

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