

AGS (HK) Technical Seminar

2025-09-25

Engineering Geological and Geotechnical Challenges

of Lin Ma Hang Lead Mine Revitalization –

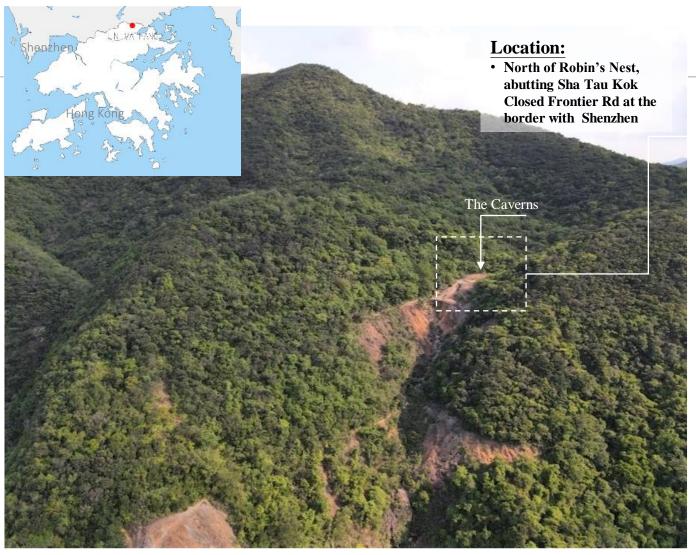
A Unique Community-based Educational Mining Heritage Project

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& K L Lo

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History:

- Operated mid 19th century to 1962 by various operators
- Series of adits with >2130m tunneling
- Excavated at different levels with multiple adits/shafts



Geology:

- Coarse ash crystal tuff of Tai Mo Shan Formation, Mid-Jurassic, subject to low grade regional (& some contact) metamorphism
- Ore vein dipping 15° to vertical, from cm to several metres in width



Ore Minerals:

- Galena main economic ore sphalerite (Zinc) secondary
- Ore containing 10% lead
- Estimated 16,000 tons of lead & 10,200 kg of silver
- Iron Pyrite (Fools Gold)
- Magnetite (Iron)



Ecology:

- SSSI for important bat roosting site
- >10 species in the caverns & adits



Meinhardt was appointed by CEDD of HKSAR Government to provide professional services to revitalize the existing Lin Ma Hang Lead Mine cavern, complete natural terrain hazard studies to make the accessible area safer for the public & create an open museum as proposed by AFCD.



Panoramic View of Lin Ma Hang Main Cavern (before works)



Some successful revitalized caverns elsewhere...



Mammoth Cave System in Kentucky, USA (Palmer, 2016)

- carbonate rock



Cappodocia in Central Anatolia -Turkey (Erguvanli & Yüzer, 1978)

- soft pumice & volcanic tuff

Essential components to consider for revitalization

- The revitalization works shall pose <u>minimum</u> <u>damages</u> to the heritage.
- Maintain authenticity of heritage

Heritage Protection Geotechnical Safety Minimal geotechnical works for the cavern – in general unlined for landscaping reason

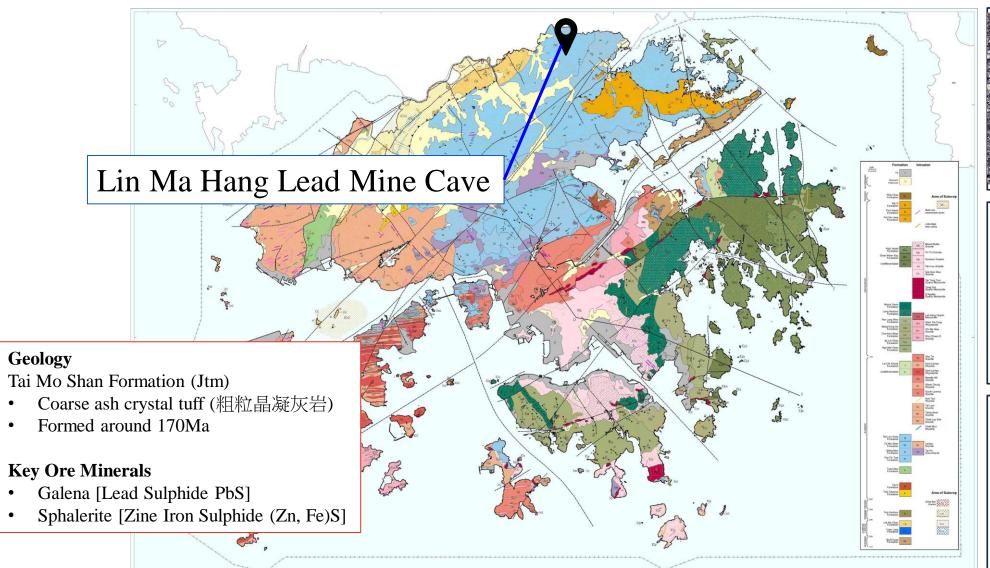
 As an open museum exhibiting the <u>mining</u> history of Hong Kong

Educational Elements

Ecological Sensitivity

- Located in proximity to SSSI
- Important <u>bat roost</u> in Hong Kong



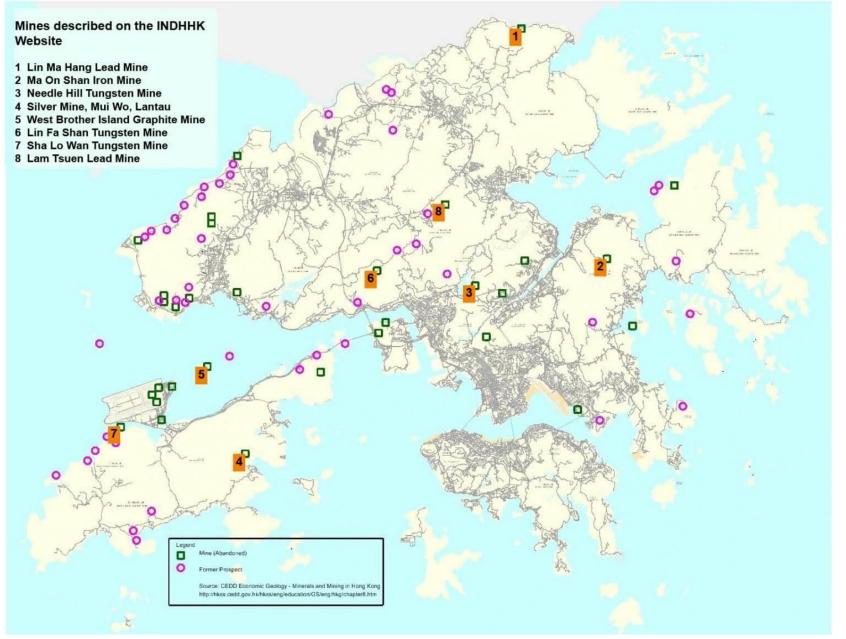




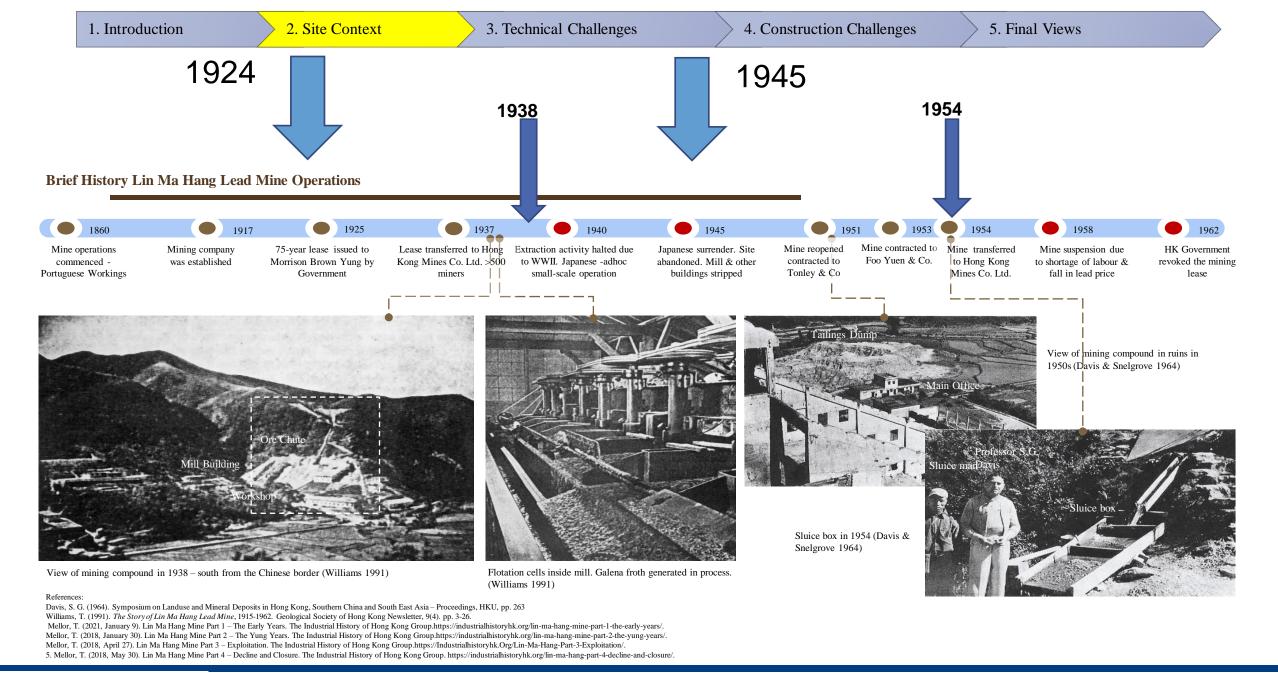








Sewell RJ et al, Hong Kong Geology: A 400-million year journey, CEGG, Gov of HKSAR, 2009. Chapter 8, Economic Geology – Minerals and Mines in Hong Kong.



Education Panel erected on site



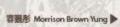
1860 蓮麻坑礦場開始有採礦活動 Signs of mining operation commenced.

1917 採礦公司正式成立。吉席、保羅、遮打爵士去信工 務署申請許可證,於沙頭角礦區開採石灰、黃金和 煤炭。

> The official establishment of the mining company. Sir Catchick Paul Chater wrote to the Director of Public Works for the application of a prospecting license for lime, gold and coal in Sha Tau Kok Mining District.

1925 首位受過西方教育培訓的華人礦務工程師容觀形, 率先引入現代技術開採鉛礦,並擴展蓮廳坑礦山, 以商業模式變運

> Morrison Brown Yung, the first western trained Chinese Mining Engineer, was the first to expand the Lin Ma Hang mine into a commercial operation through the introduction of modern methods to extract lead ore.





1936至1939年是礦場的鼎盛時期,每年平均出產超過3,000 · 順精鉛及6萬安士(即約1,700公斤)銀· 而灃礦廠亦於1937年 10月建成、最初每日可處理50噸礦石,期後增至225噸。

1938年初,礦場約有500多名工人,當中300多人於地下工 作。隨著礦場蓬勃發展,礦工數目亦陸續增加,直到1939年 10月高峰時,礦場有近2,000名工人。

1936 to 1939 was the heyday of mining, with an average annual output of more than 3,000 tonnes of refined lead and more than 60,000 oz (i.e. 1,700 kg) of silver. With booming development of the

mine, ore concentrator was built in October 1937, which initially processed 50 tonnes of ore per day and subsequently increased to 225 tonnes. At the beginning of 1938, there were about 500 miners at the Lin Ma Hang Mine, of which more than 300 worked underground. The mine reached its most prosperous time, with over 2,000 miners In October 1939.

> 1938年的潜礦廠 ▶ Mill Building in 1938





1950年代的漢碼藥 Mill Buildings in 1950s

3.000 職tonnes

1941 二戰爆發,當時政府為準備戰事,徵用礦場的採礦設 備以建設防空洞,加上日軍封領華南地區海域,對香 港的航運造成重大影響。礦產不能出口外地。其後。 日軍操控礦場·更強迫附近村民採礦。

When WWII broke out, the government requisitioned mining equipment from the mines to build air raid shelters in preparation for the war. Additionally, the Japanese forces blockaded the coastal waters of South China, significantly impacting shipping in Hong Kong, which disabled the export of minerals to other regions. The Japanese then took over the mine and forced villagers to work there.

1945 蓮庭坑村的抗日村民與游擊隊成功擊退日軍並阻止福 場運作。礦場荒廢。

> Lin Ma Hang villagers joined forces with the Anti-Japanese guerrillas. They successfully drove away the Japanese and damaged the mine. The mine was abandoned.

The miners were mainly from the Shandong Province, but there are also villages from the Halda villages next the mines, such as Lin Ma Hang Village and Houng Yaser Wai Village. The mine operated in three eight-hour shifts, allowing the mine to word 24 hours a day la the past, the Lin Ma Hang Mine employed a large number of labourers, which alleviated the unemployment problem in Hong Kong at that time.

1951 礦場重新由承辦商 Tonley & Co. 運作, 出產的精鉛銳

Mine reopened and was contracted to Tonley & Co. Production of refined lead was drastically reduced to 176 tonnes.

1958 因佔港日軍於二戰期間過度開採礦場的礦柱,令礦 場場陷風險大大增加。與此同時,國際鉛價下跌 工潮等負面因素,令其後接手的香港礦業公司缺乏 資金修復礦場,最終決定停止營運,並只僱用3名守 衛看守確場。

> The risk of collapse at the top of the mine increased as the Japanese over-exploited the ore in the pillars. At the same time, as the price of lead fell and workers went on strike. Hong Kong Mines Co. Ltd, the mining company that subsequently took over, lacked sufficient fund to repair the mine. They finally decided to close the mine, which was then guarded by only 3 watchmen.

1962 香港礦業公司無力重啟礦場運作,礦場繼續荒廢 政府決定撤銷採礦租約,提早收回礦場。

> Hong Kong Mines Co. Ltd. was unable to restart the mine. The mine was continued to be abandoned. The government decided to cancel the mining lease and take back the mine.

1860-1920s

鉛精磷最高每年產量

Maximum Annual Production of Lead Concentrate

1927

450噸tonnes

1930-1940s

3,600 witonnes

1941-1945

00000000000000000000 _____

1941

1950-1962

1952

752 witonnes



香港岩土及岩土環境工程專業協會 ASSOCIATION OF GEOTECHNICAL &

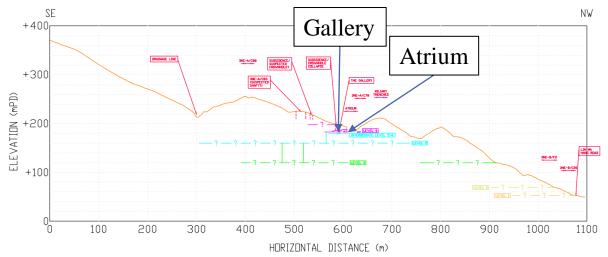
Before Works







Atrium







Main Features & Some Mine Hazards to the Public



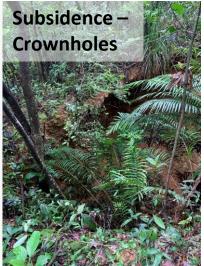








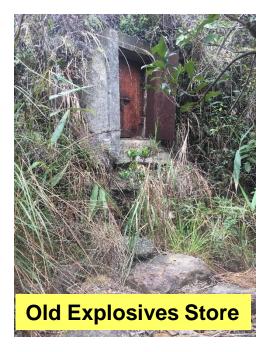
















The Cavern Gallery

Adverse weather





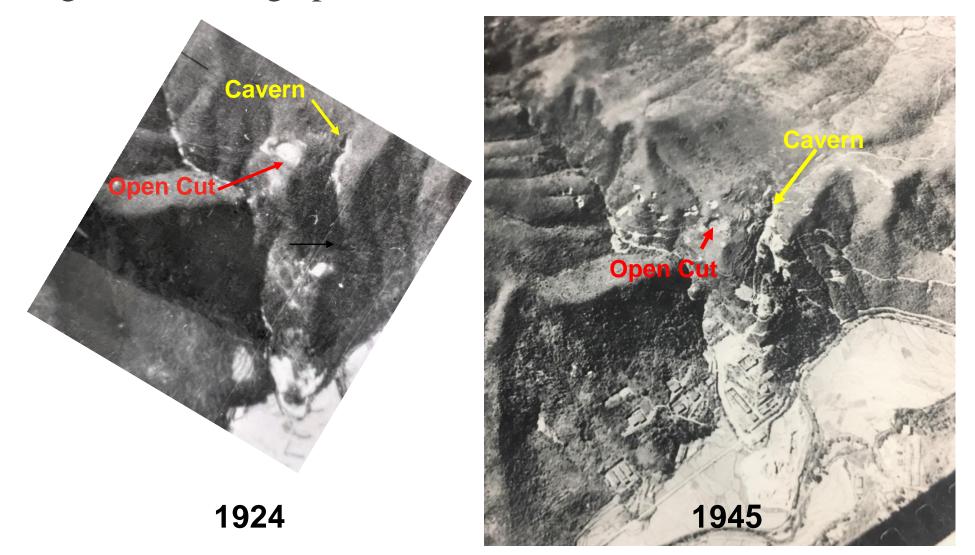


View from Inside Adit 2 Grille into the Gallery

Keyed Access through the Grilles

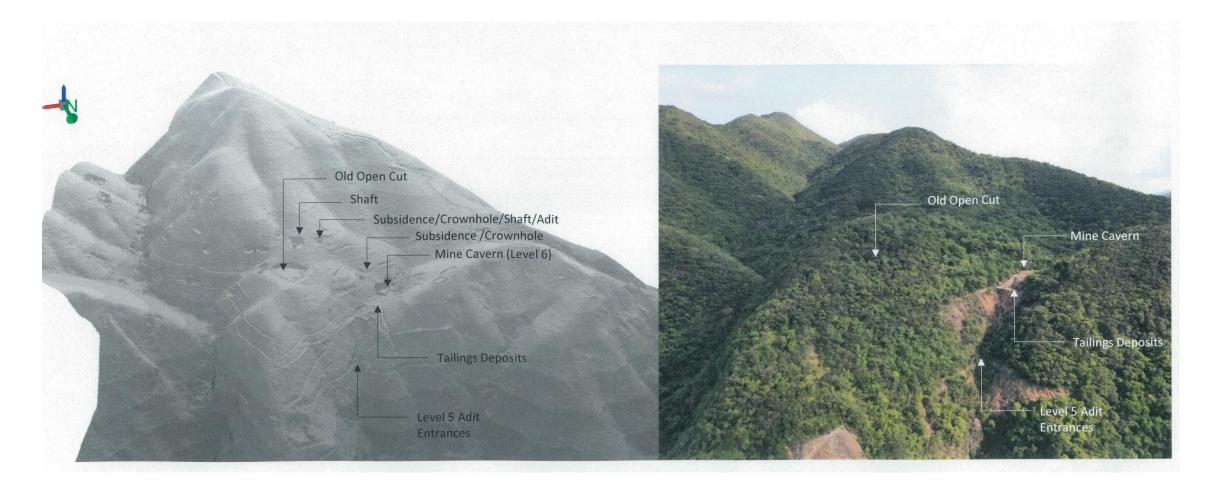


Exciting Aerial Photographs in 3D – 1924 & 1945

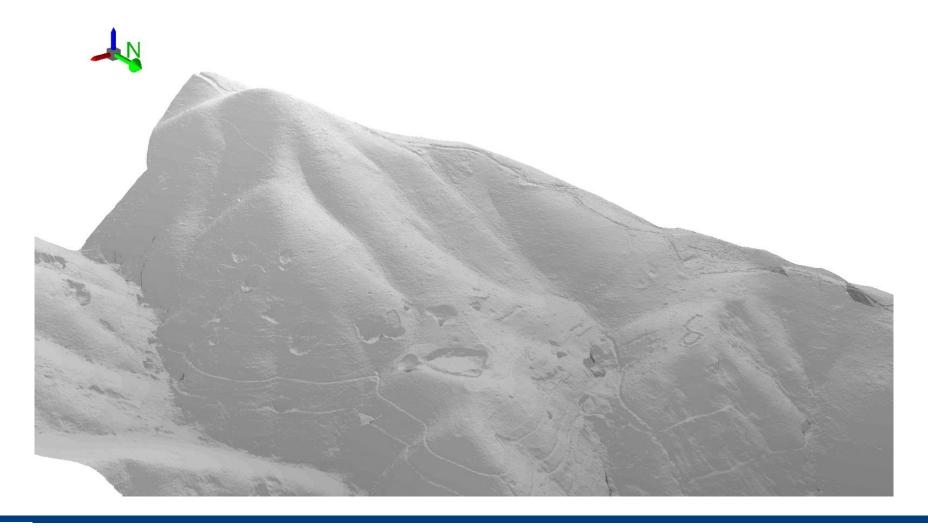




Comparison 2021 Colour 3D & 3D LiDAR

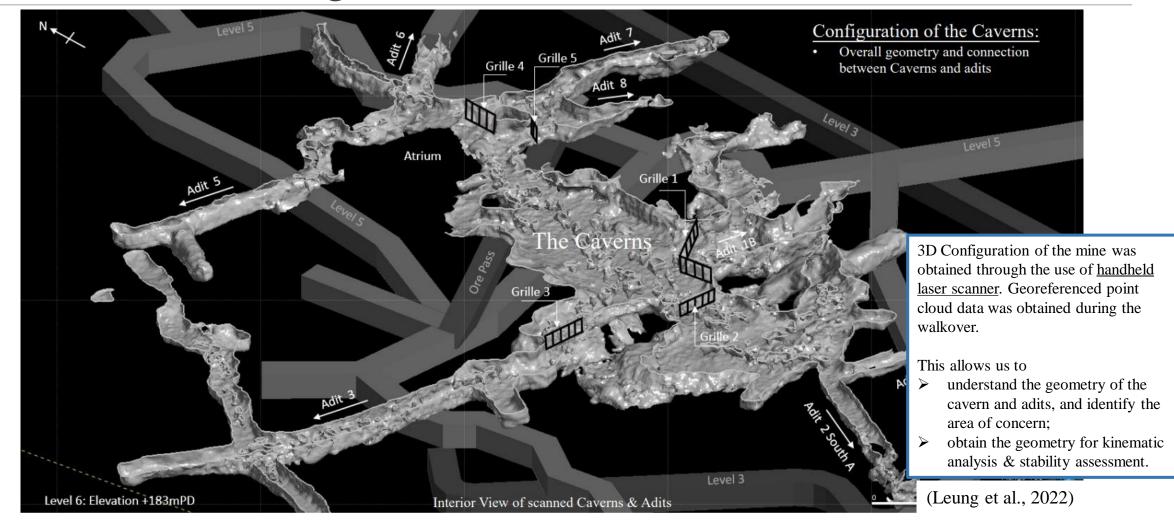


Full 3D Lidar





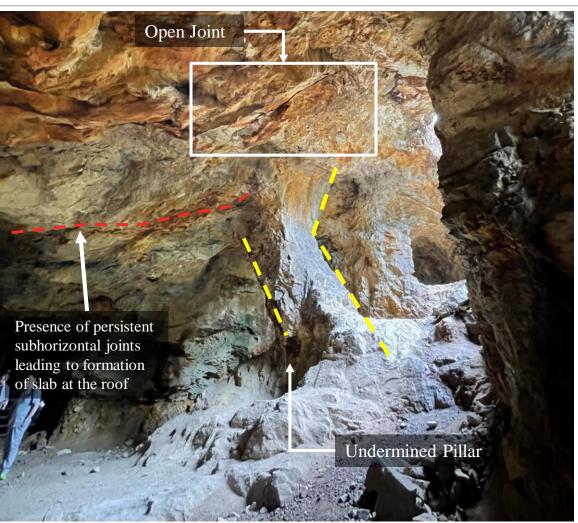
3D LiDAR Configuration of Cavern, Atrium & Adits





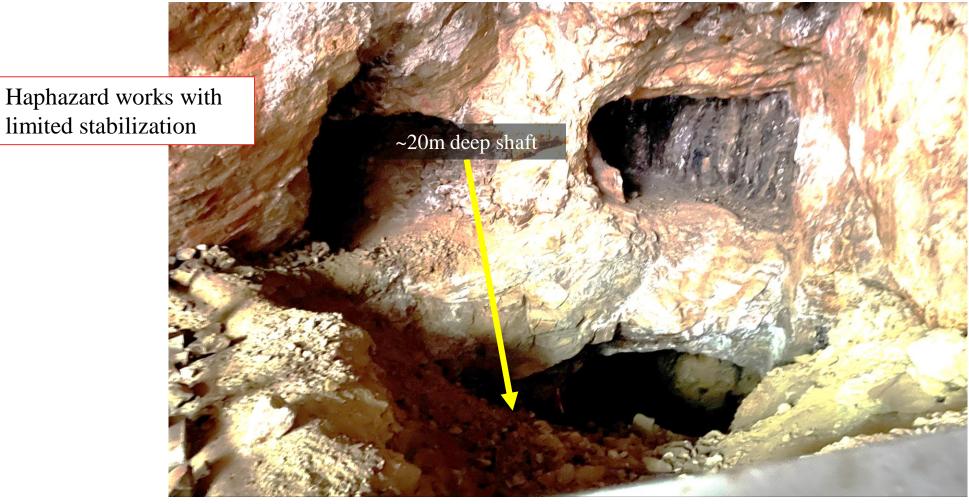
Rock Condition in Cavern

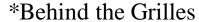






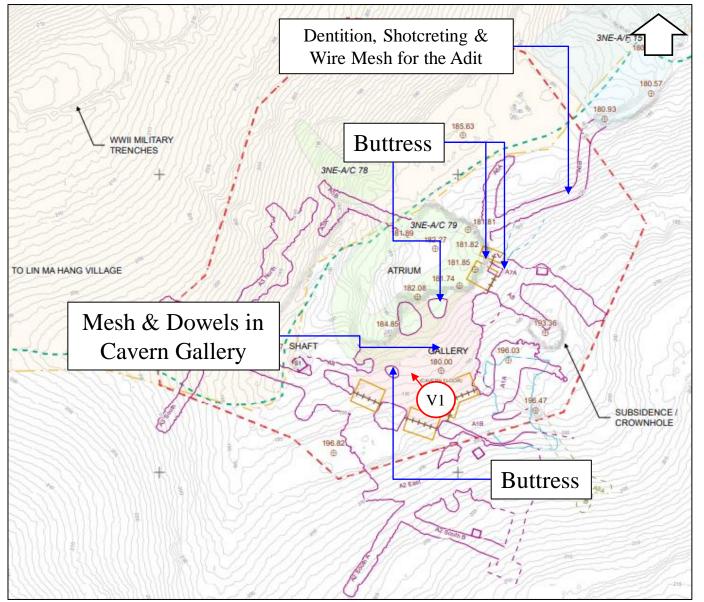
Other Features in Cavern







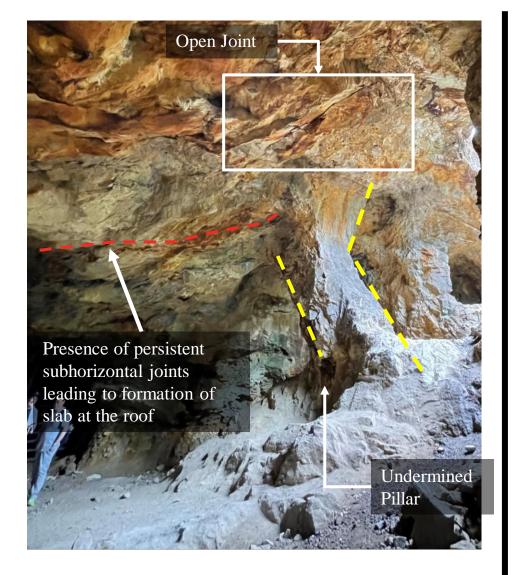
As-built Precautionary & Mitigation Measures for the Cavern & Adit





Cavern Gallery (View V1)

Major Adopted Mitigation Measures against the Identified Risks







Buttress



Rock Dowels

Wire Mesh

Challenges

Lin Ma Hang, as located in a remote and ecological sensitive area, multiple <u>technical challenges</u> and <u>construction challenges</u> have been encountered in different stages of the project.

Technical Challenges	Construction Challenges
Assessment for rock stabilization	Logistics
Balancing robust geotechnical works with resultant visual impact	Dowel Installation in proximity to Site of Special Scientific Interest (SSSI)
	Maintain authenticity of heritage



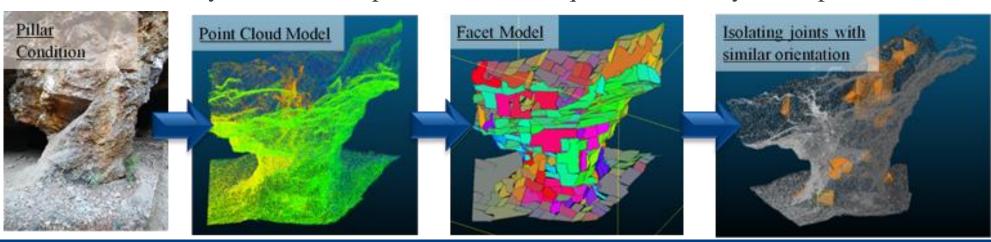
Technical Challenges - 1

- 1) Assessment for rock stabilization
 - 8m high & 19m wide with limited access to rock face during initial investigations

Solution

1. Introduction

- Adopted NGI Q System (NGI, 2022) for rock mass assessment & pattern rock dowels
- Additional spot dowel & verification of pattern dowel locations during construction to cater for local instability
- Innovative use of hand-held laser scanner technology to capture geometry for stability assessment, i.e. kinematic analysis for roof & pillar + Limited Equilibrium Analysis for pillars





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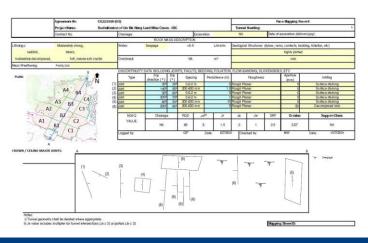
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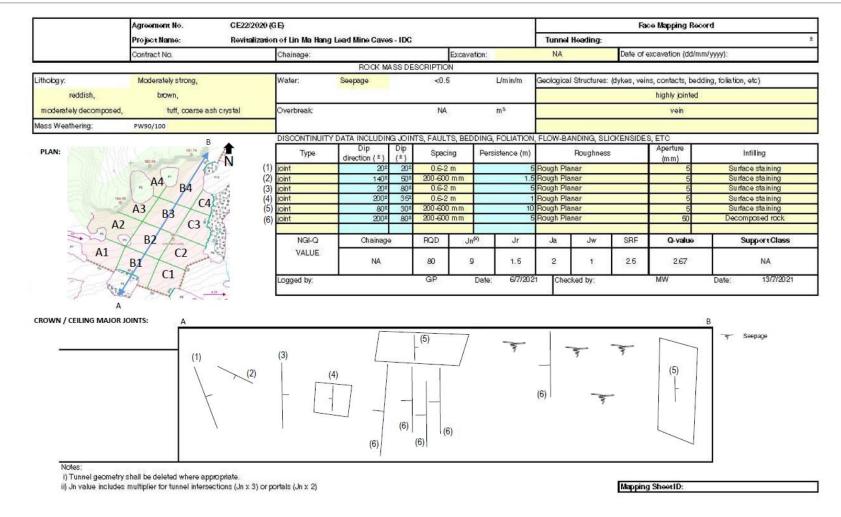








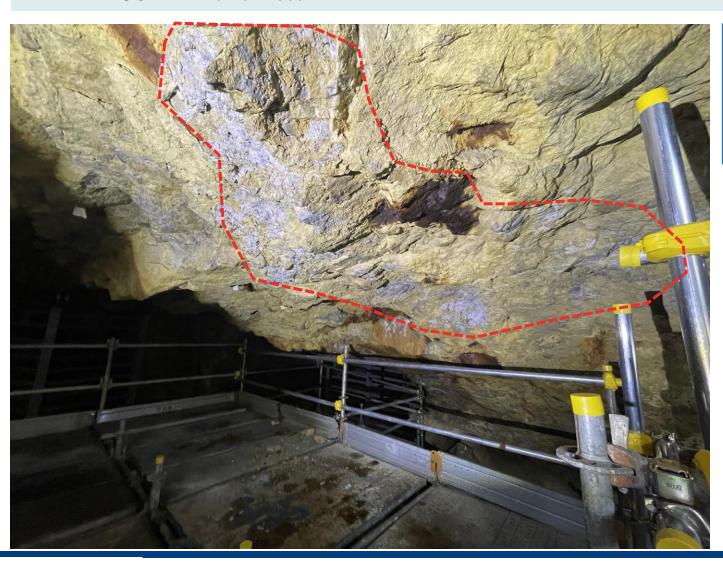
Technical Challenges - 1





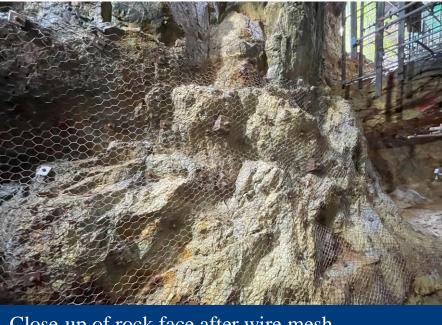
1. Introduction

Locally persistent discontinuities near southern portion of main cavern in which no rock-wall contact recorded & infill >50mm in thickness



Appeared intact & strong at distance, but easily crumbled by hand

- Solution: required protection with wire mesh shotcreting not preferred option for landscaping reason



Close-up of rock face after wire mesh



Technical Challenges - 2

- 2) Balancing robust geotechnical works with resultant visual impact
 - Neither concrete or shotcrete lining utilized to maintain authenticity of mine appearance

Solution

- Provision of **suitable rock coloured pigments** to rock dowel head & wire mesh to blend in with the rock colour
- Provision of artificial rock cladding for concrete surfacing works





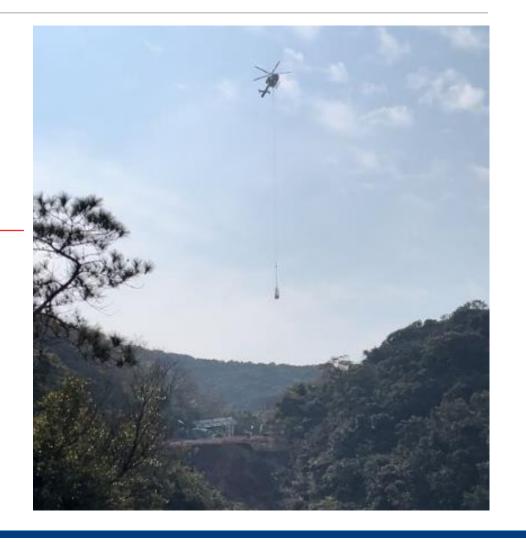
Construction Challenges - 1

1) Logistics

"998 STEPS" without vehicular access to reach site at
 +181mPD

> Solution:

- Deployed airlift operations by helicopters for material/machinery delivery & removal of construction waste





- 2) Dowel Installation in proximity to Site of Special Scientific Interest (SSSI)
- Unique & important habitat for bats with great ecological value in Hong Kong







中華菊頭蝠 Chinese Horseshoe Bat



南長翼蝠 Bent-wing Bat







Construction Challenges - 2

2) Dowel Installation in proximity to Site of Special Scientific Interest (SSSI)

I. Coring

- Utilize electrical coring machine with water flushing, enclosed by tarpaulin sheeting for noise & dust reduction
- \rightarrow Minimize disturbance to bat populations



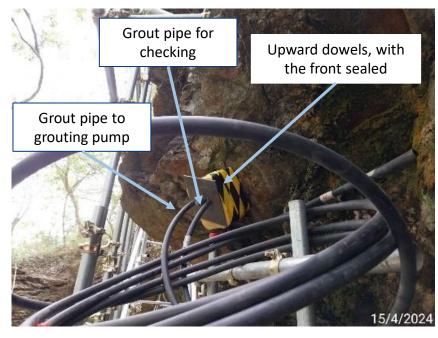


Construction Challenges - 2

2) Dowel Installation in proximity to Site of Special Scientific Interest (SSSI)

II. Grouting

- Presence of interconnected joint networks & blast-induced open apertures create difficulties in grouting
- ∘ → Multi-stage grouting procedure
 - i. Using more diluted grout at beginning to seal joints & cracks
 - ii. Using typical cement-water ratio grout for grouting dowels
- → Additional benefit: Reduction of water ingress into the Caverns Gallery



Grouting works in progress



- 3) Maintain authenticity of heritage
- Exposed concrete surface
 inharmonious & damages to
 original mine heritage appearance





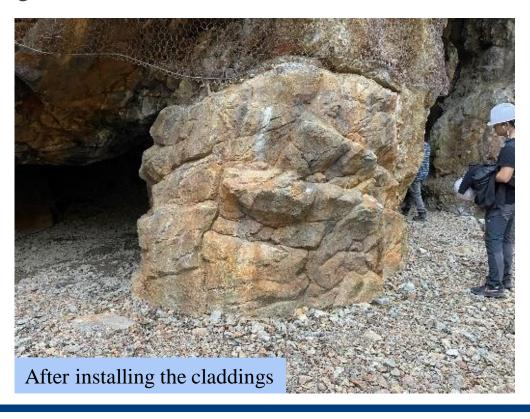
- 3) Maintain Authenticity of Heritage
- **Solution**
- Holistic finishing & landscaping
- I. Brown pigments for **dowel heads & wire mesh**
 - i. to blend in with the rock colour of weathered tuff in association with iron staining





- 3) Maintain Authenticity of Heritage
 - II. Artificial Rock Cladding for Concrete Surfacing Buttress B1







- 3) Maintain Authenticity of Heritage
 - II. Artificial Rock Cladding for Concrete Surfacing Buttress B2







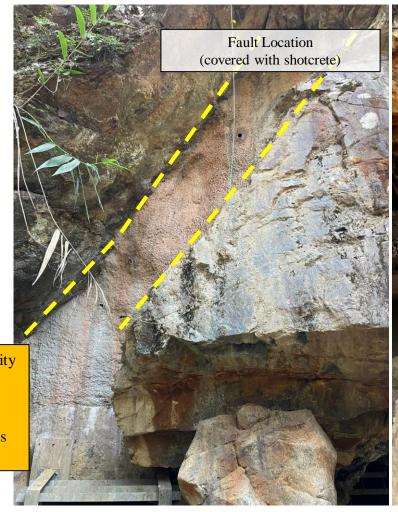


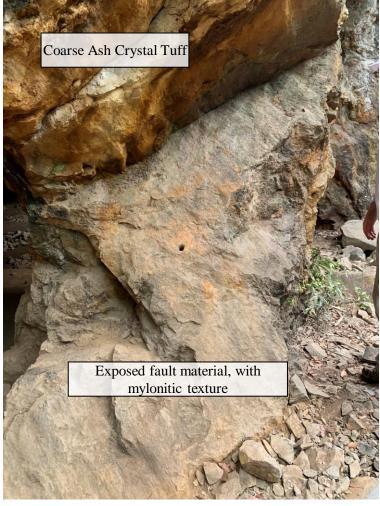
Construction Challenges - 3

- 3) Maintain Authenticity of Heritage
 - III. Preservation of GeologicalFeatures of Special Interest –Faulting Mylonite Zone

As the fault zone is almost <u>1m wide</u>, it poses threat to stability of the overlying material. Therefore, shotcrete is applied on its surface to prevent further erosion and deterioration.

- Buttress has also been constructed to support the rock mass at the footwall.







View along Strike



Side View





Summary

Project Team overcame Technical Challenges & Construction Challenges leading to successful completion

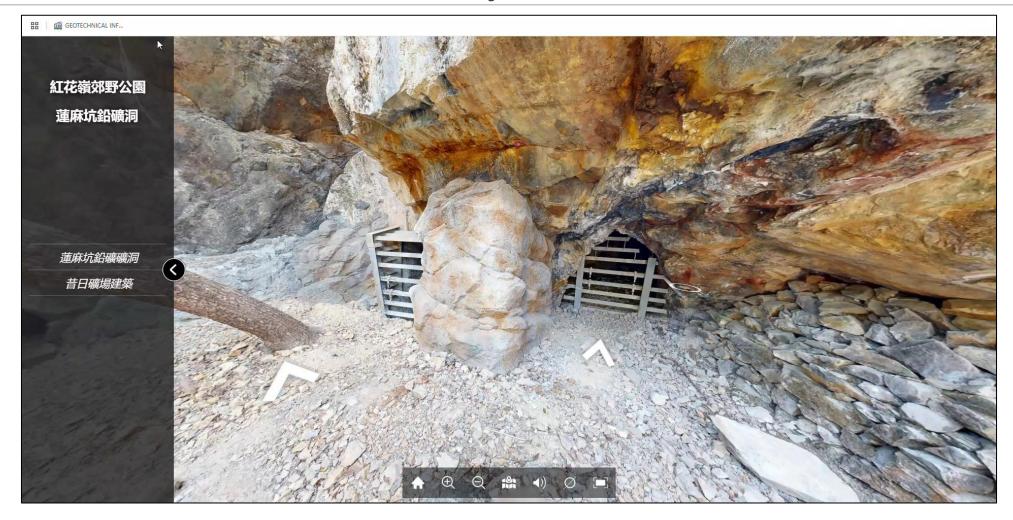
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Major works completed <u>two months</u> earlier than contract completion date & opened 30 December 2024



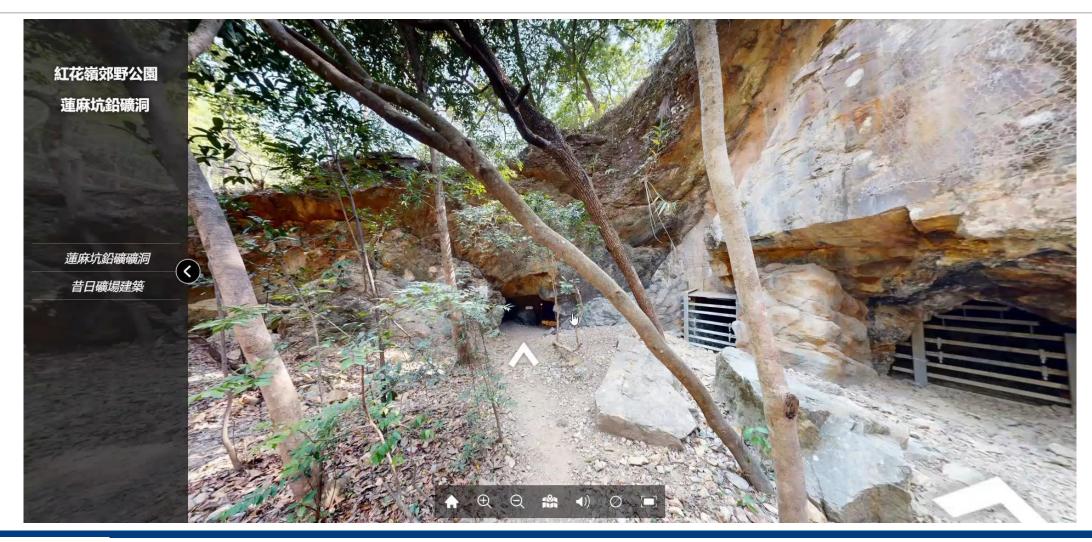


Final Views – Cavern Gallery & Atrium





Final Views – Adit A6B





Acknowledgements

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