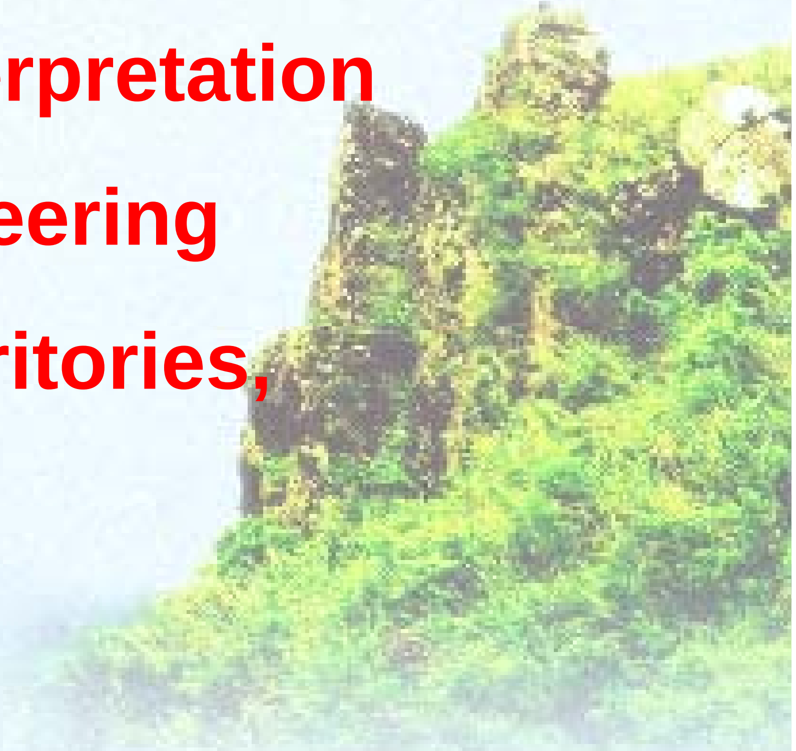
Influence of Geological Interpretation on Geotechnical Engineering in the Northwest New Territories, Hong Kong



Lai Kuen-wai

(A Talk in HKIE on 30 June 2010)

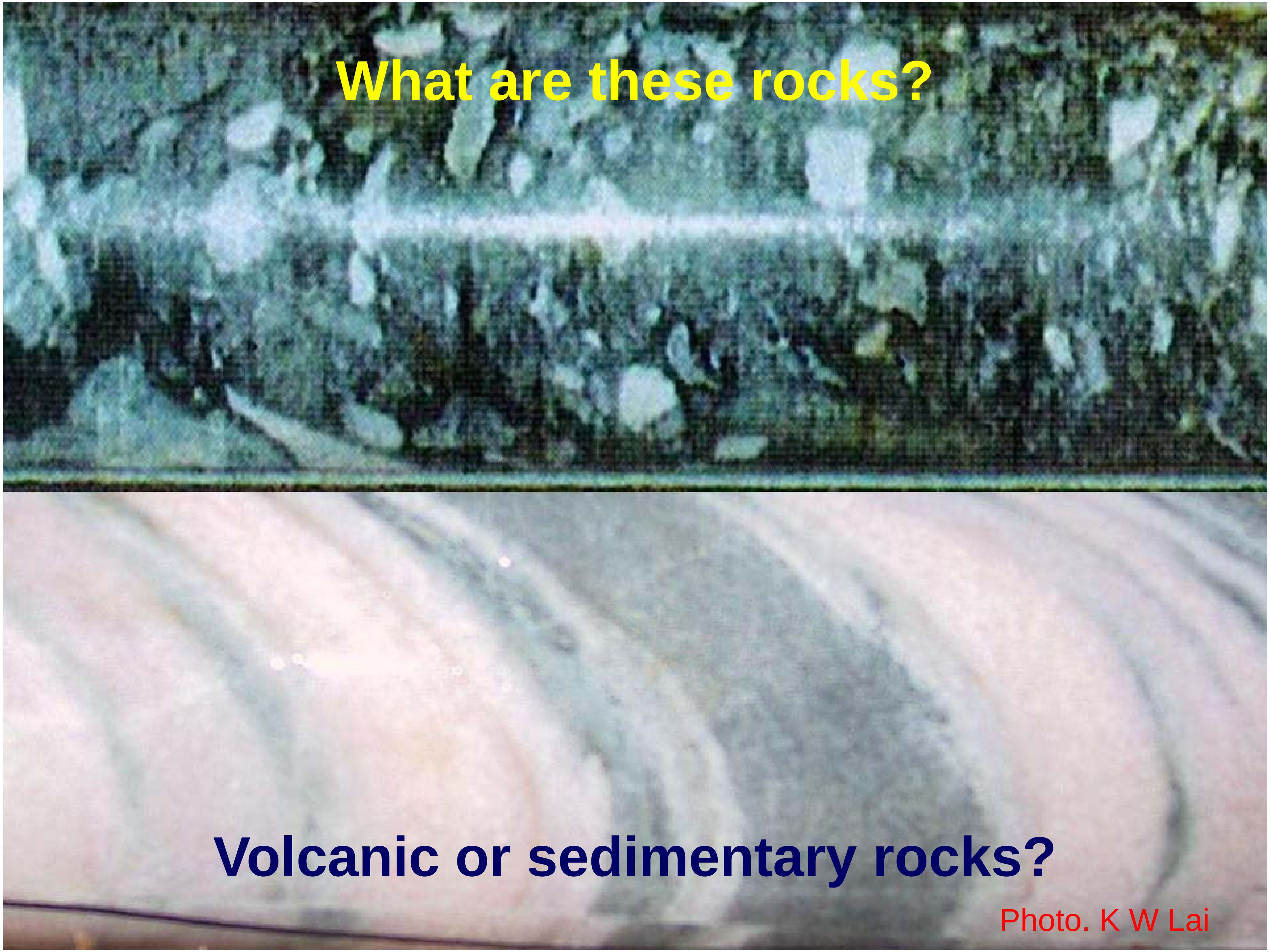
Outline

- Importance of accurate rock identification ?
- Inaccuracies of rock identification in borehole logs and geological reference materials
- Research into the Tuen Mun Formation
- Evidence of palaeovolcanic plug in the Tsing Shan area
- Evidence of stratovolcanic deposits in Ling To Monastery area
- Rock strength properties and their geotechnical engineering significance
- Accurate geological interpretation provides the correct geological model

Why this Question Must be Asked?

1. Plenty of pyroclastic rocks belonging to the Tuen Mun Formation in the borehole logs were previously identified as sedimentary rocks.

2. Differing descriptions occurs in some published geological reference materials.


What are these rocks?
Volcanic or sedimentary rocks?
Photo. K W Lai

Incorrect description of borehole logs

“metasiltstone with marbles”

Photo. K. W. Lai

The marble clasts-bearing tuff breccia was misidentified as marble in borehole logs

Inaccuracies in Borehole Logs

- Fine-grained andesite/tuff as siltstone
- Tuff breccia as conglomerate
- Marble clasts-bearing tuff breccia as siltstone interbedded with marble

Inaccuracies
in Geological Reference Materials

- The “Pre-Quaternary Geology of Hong Kong” is an excellent geological reference. More than 20 geologists made significant contributions to the project from 1982 to 2000.

- Minor problems of the descriptions which could be improved upon are:

  a) Use of the outdated information to show the geology of Tin Shui Wai area; and

  b) Application of obsolete data to describe the geology of Tsing Shan area.

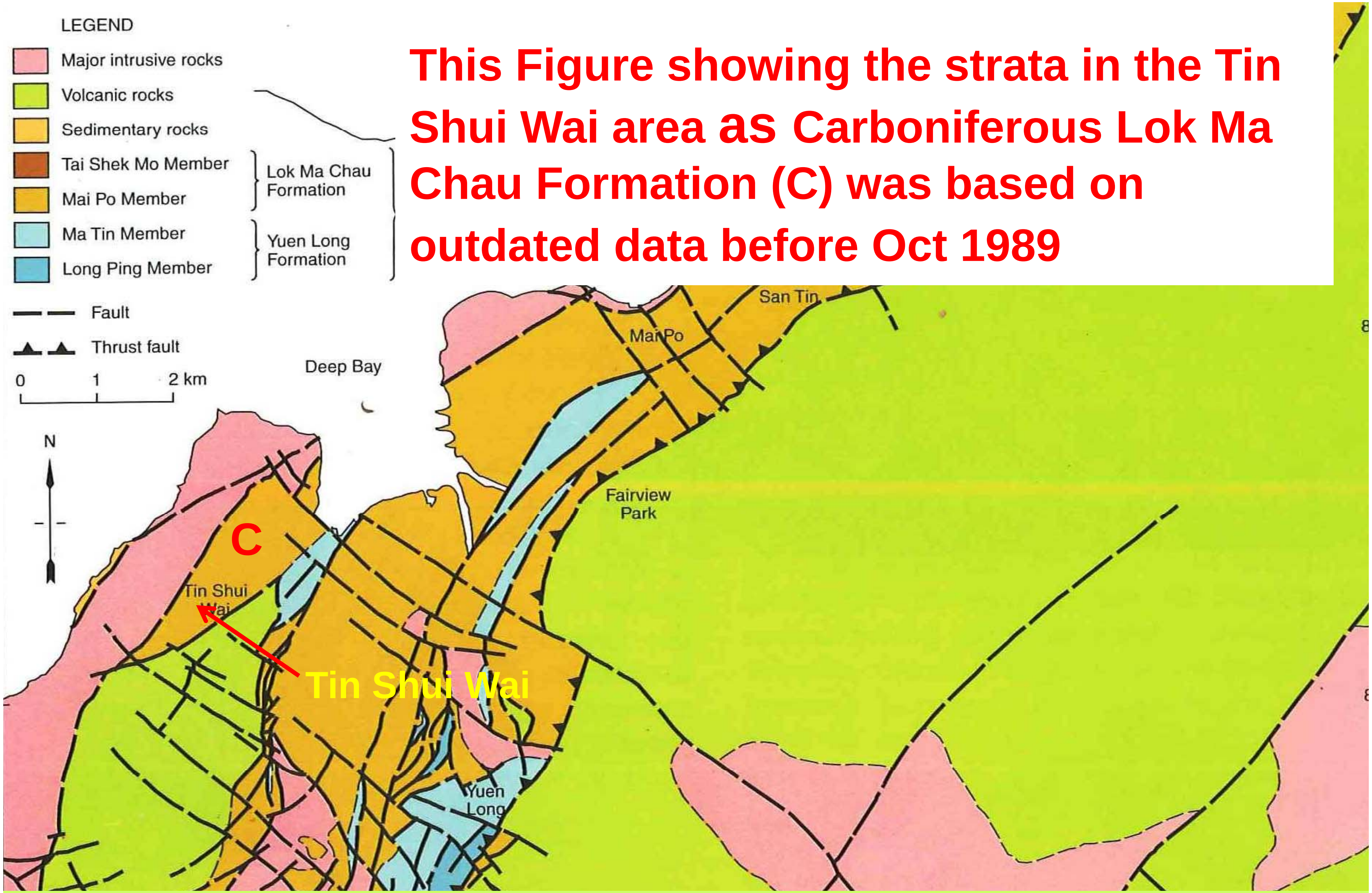
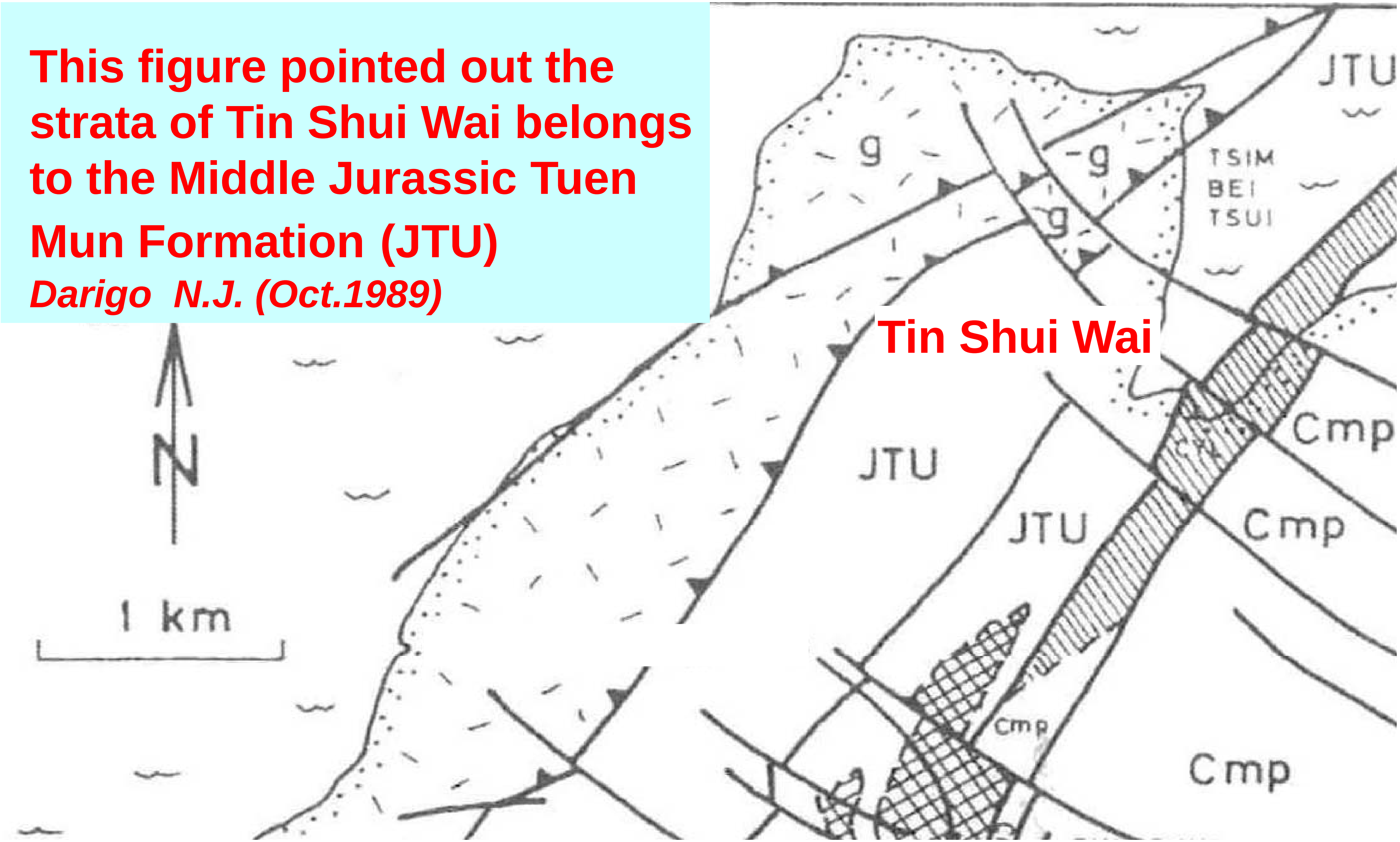


Figure 3.5 - The Pre-Quaternary Geology of Hong Kong (Sewell R.J. *et al* 2000)

This figure pointed out the strata of Tin Shui Wai belongs to the Middle Jurassic Tuen Mun Formation (JTU)

Darigo N.J. (Oct.1989)



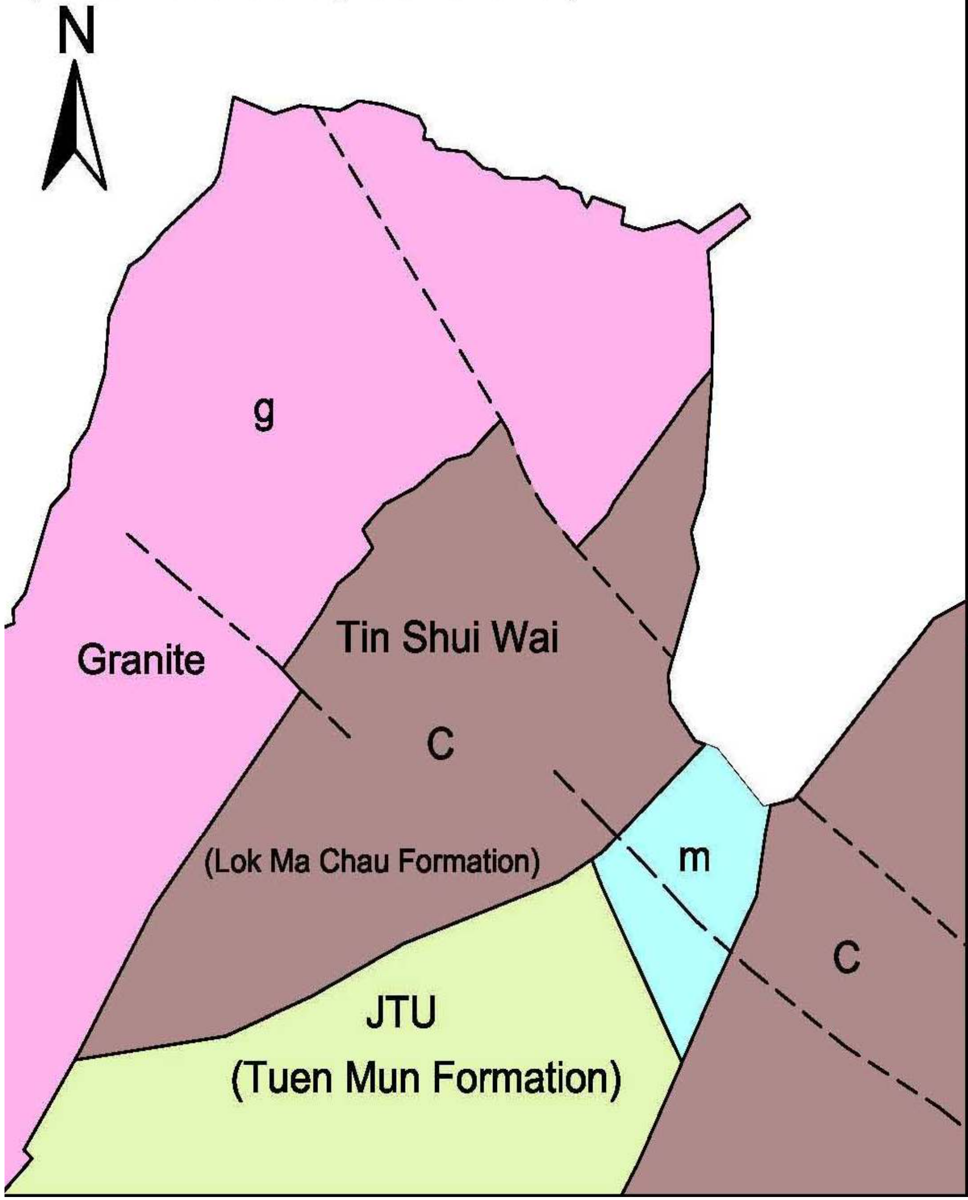
This figure was also published in:

- *Frost D.V. (1989)*

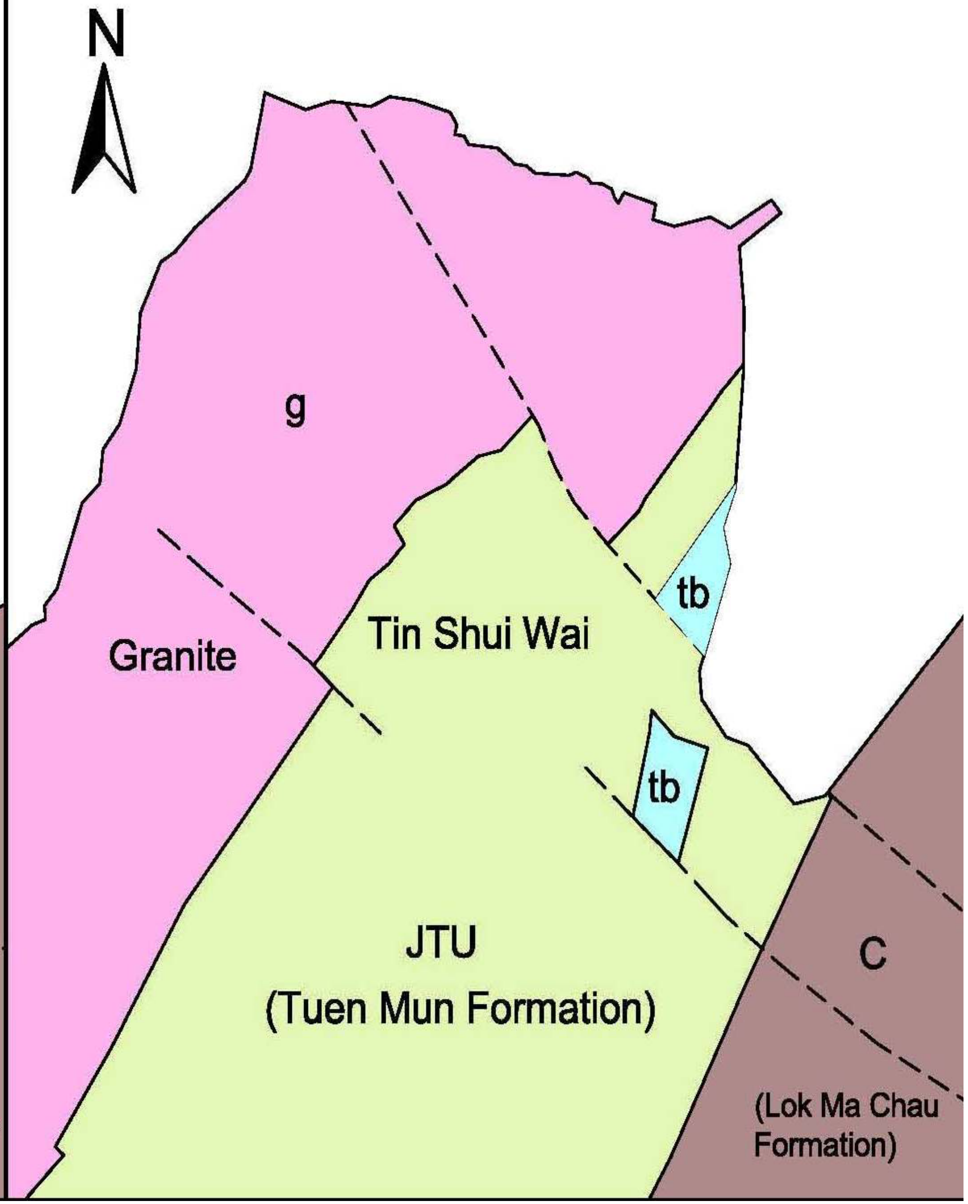
- *GCO Publication No. 2/90 (Irfan T.Y.ed.1990)*

Comparison of the 1994 and 2000 Geological Mapping of Tin Shui Wai

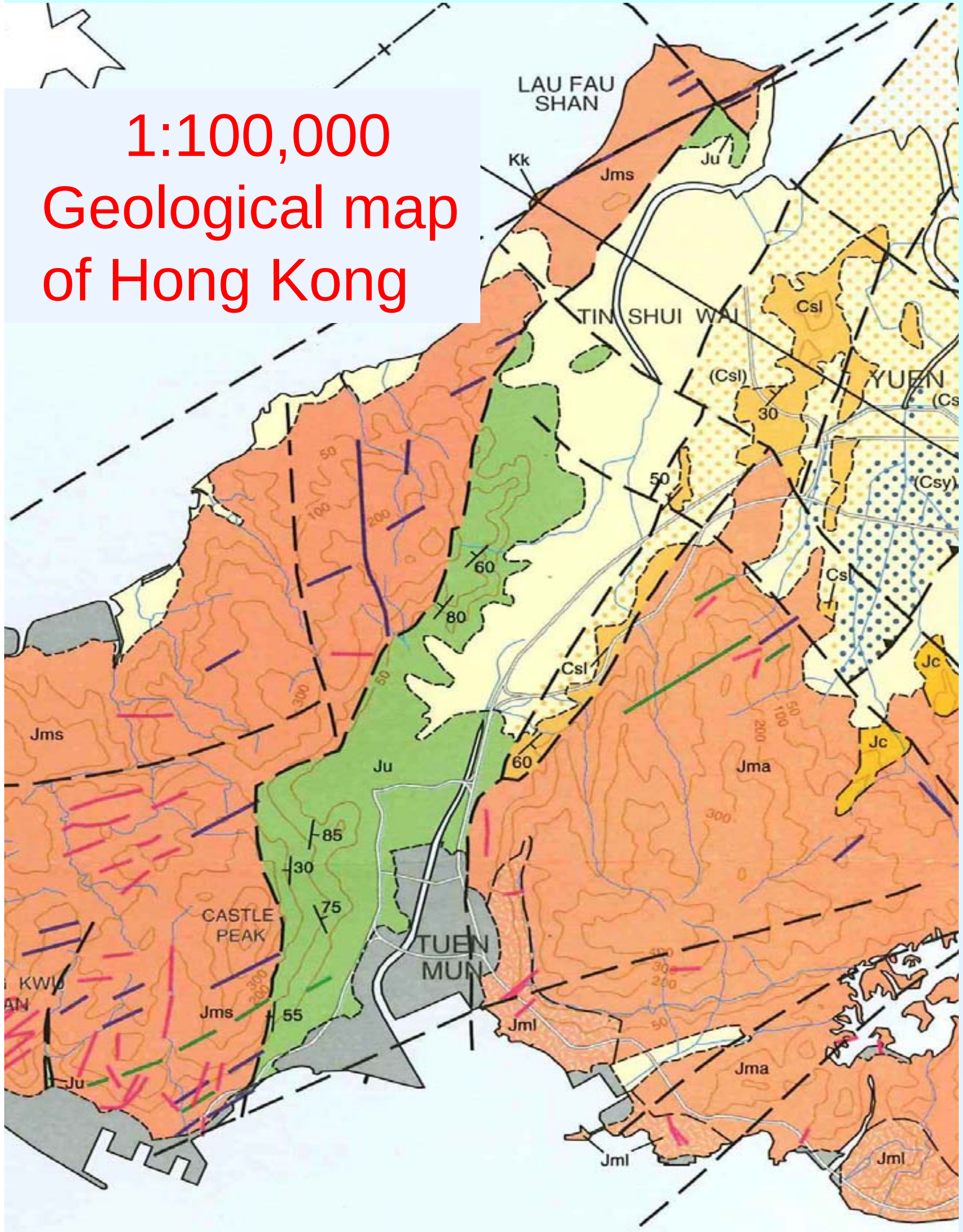
Pre-Quaternary Geology of Hong Kong. Figure 3.5
(GEO 2000. ed. by Sewell *et al*)



Solid Geological Map of San Tin 1:20,000
(GEO 1994 compiled by Lai. *et al*)



1:100,000 Geological map of Hong Kong



The Lok Ma Chau Formation of the Tin Shui Wai area shown in Figure 3.5 is also contradicted those strata in 1:100,000 geological map of Hong Kong

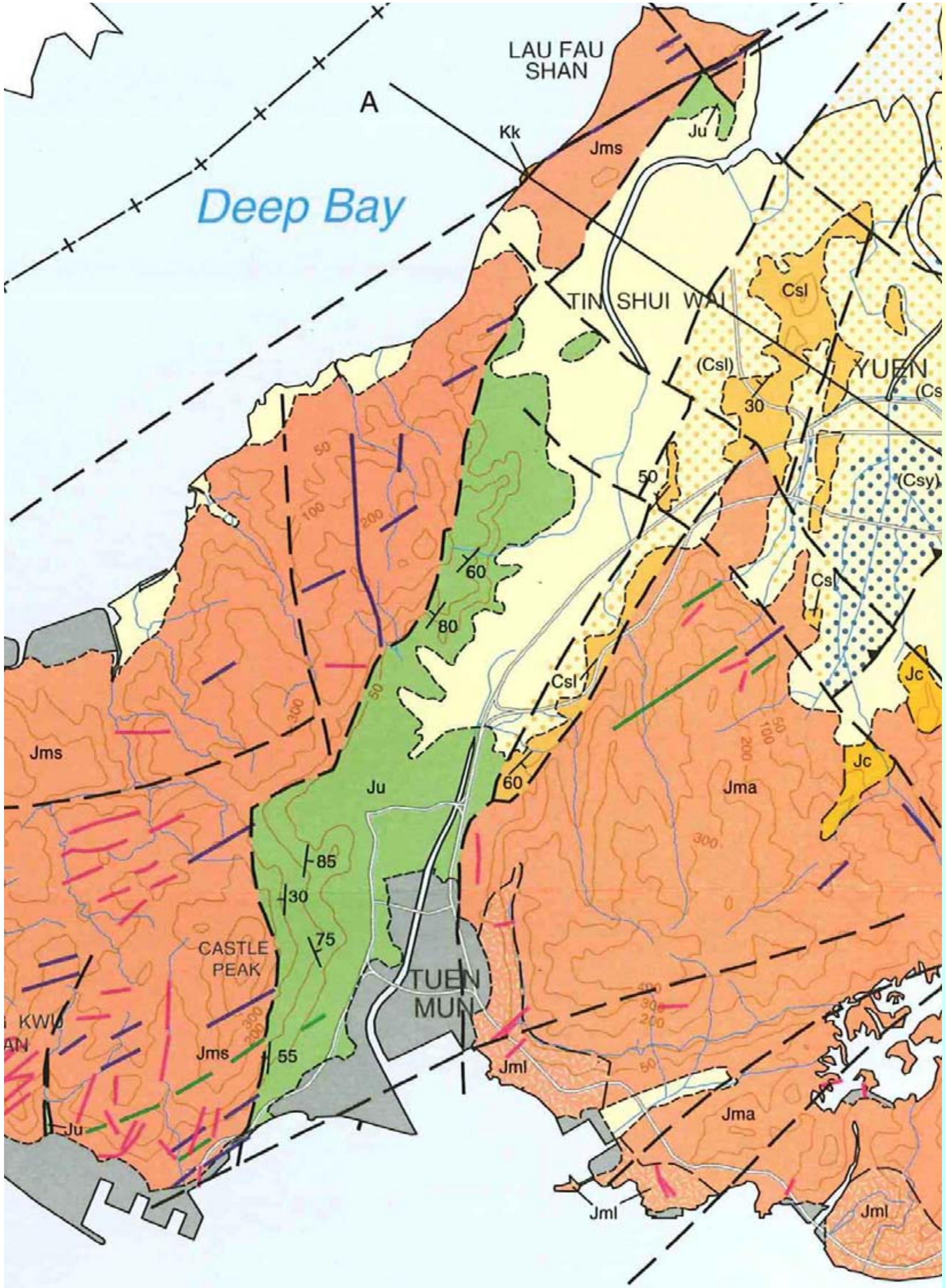
(GEO 2000. compiled by Kirk, P.A. *et al*)

Description of the Tuen Mun Formation used outdated data from the obsolete Tsing Shan Formation *(Sewell et al 2000)*

Page 69 of The Pre-Quaternary Geology of Hong Kong *(Sewell et al. 2000)* states the lower part of Tuen Mun Formation in the west of the Tuen Mun area comprising **quartzite, sandstone metasiltstone and phyllite predominate, with subordinate tuff, tuffite and conglomerate.**

The Contradiction between Geological Report and related Geological Maps

The description of the Tuen Mun Formation of Tsing Shan area in page 69 (Sewell *et al*. 2000) did not agree with the geological map at scale 1:100,000 (GEO 2000. compiled by Kirk, P.A. *et al*) and the facts



Geological Map of Hong Kong

(1:100,000 GEO 2000 ed. by Kirk.P.A. et al)

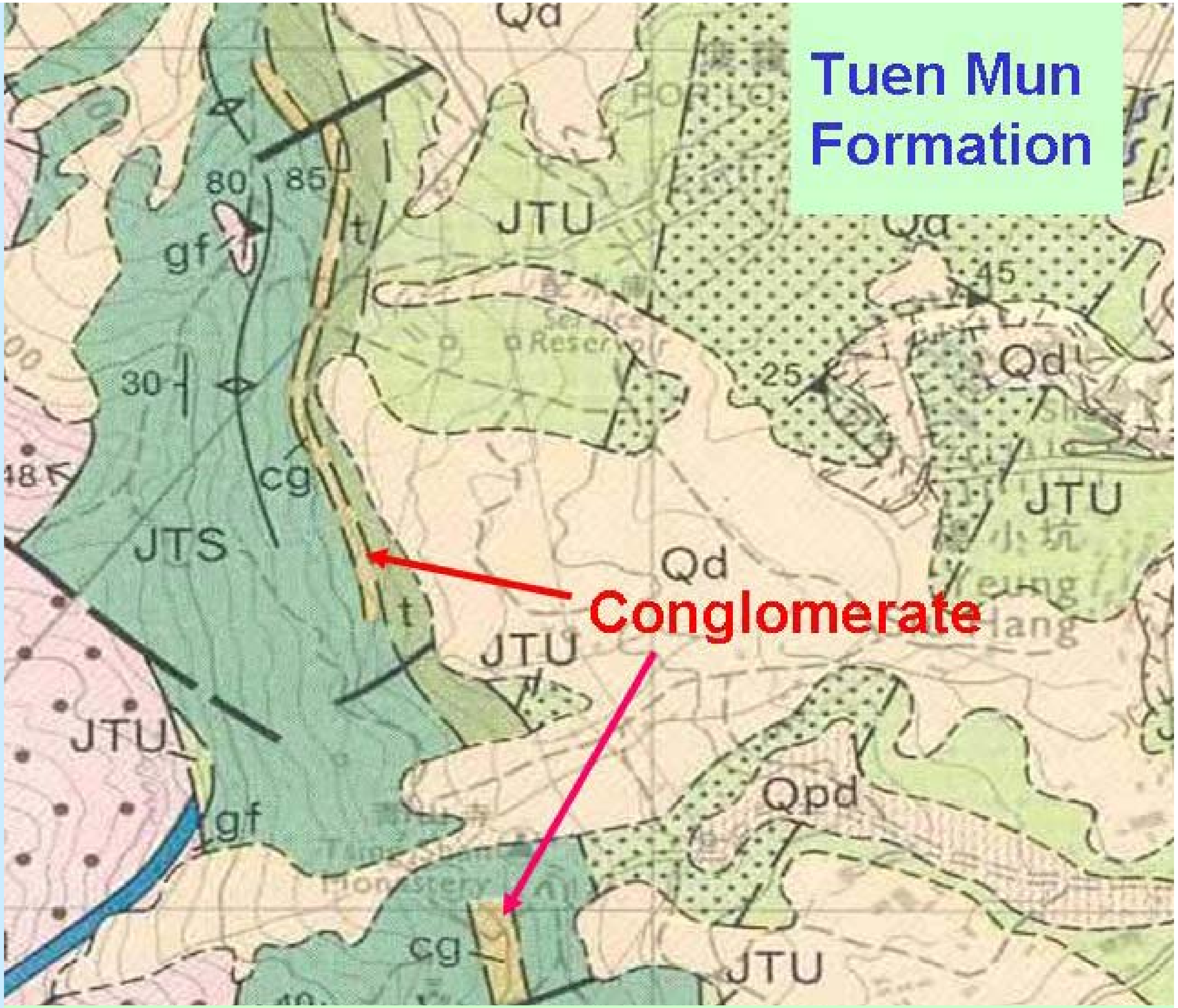
The description of Tuen Mun Formation:

Andesite lava and lapilli lithic-bearing fine ash crystal tuff with intercalated tuff breccia

Geological Map of Tuen Mun

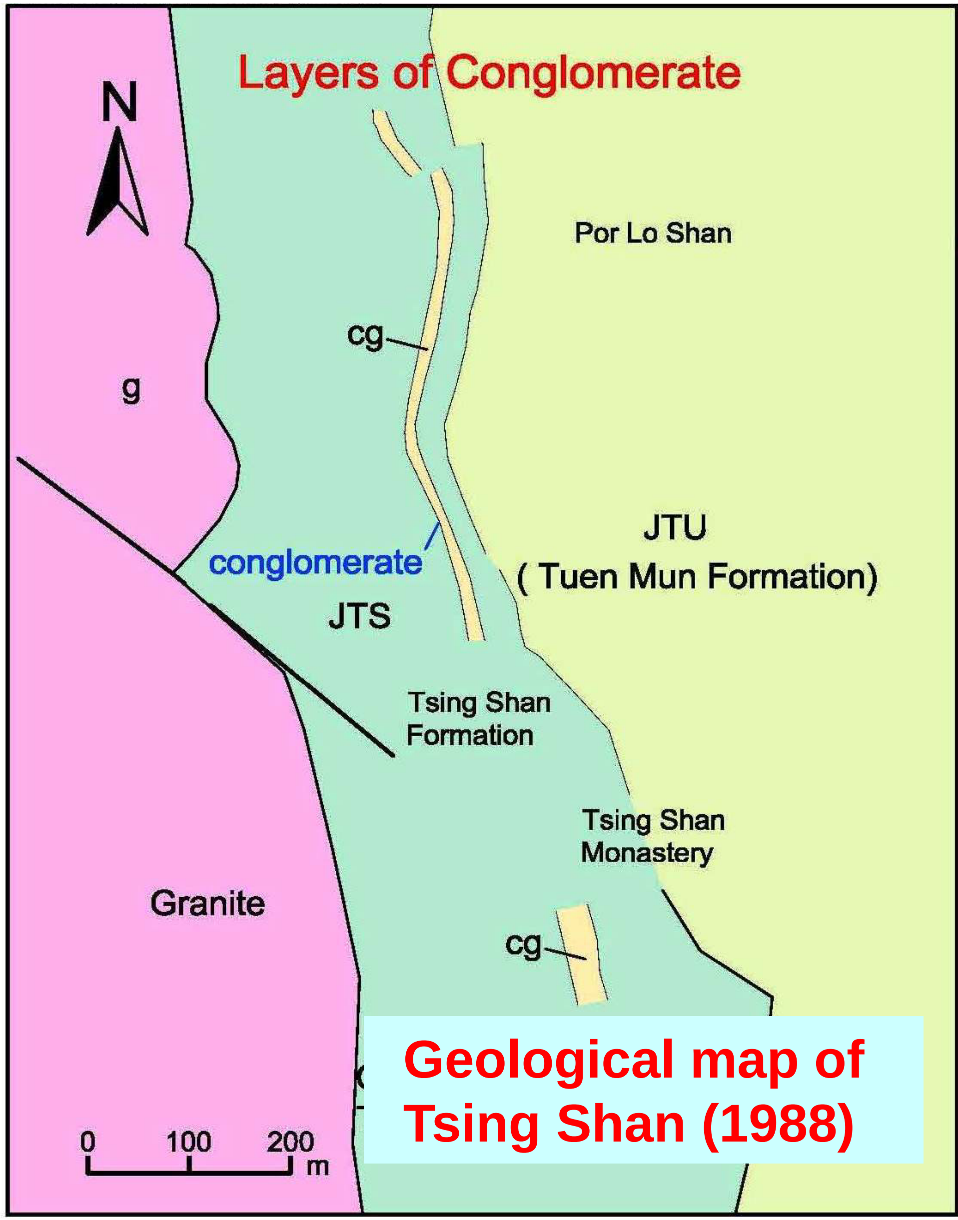
(1:20,000)

1988 edition

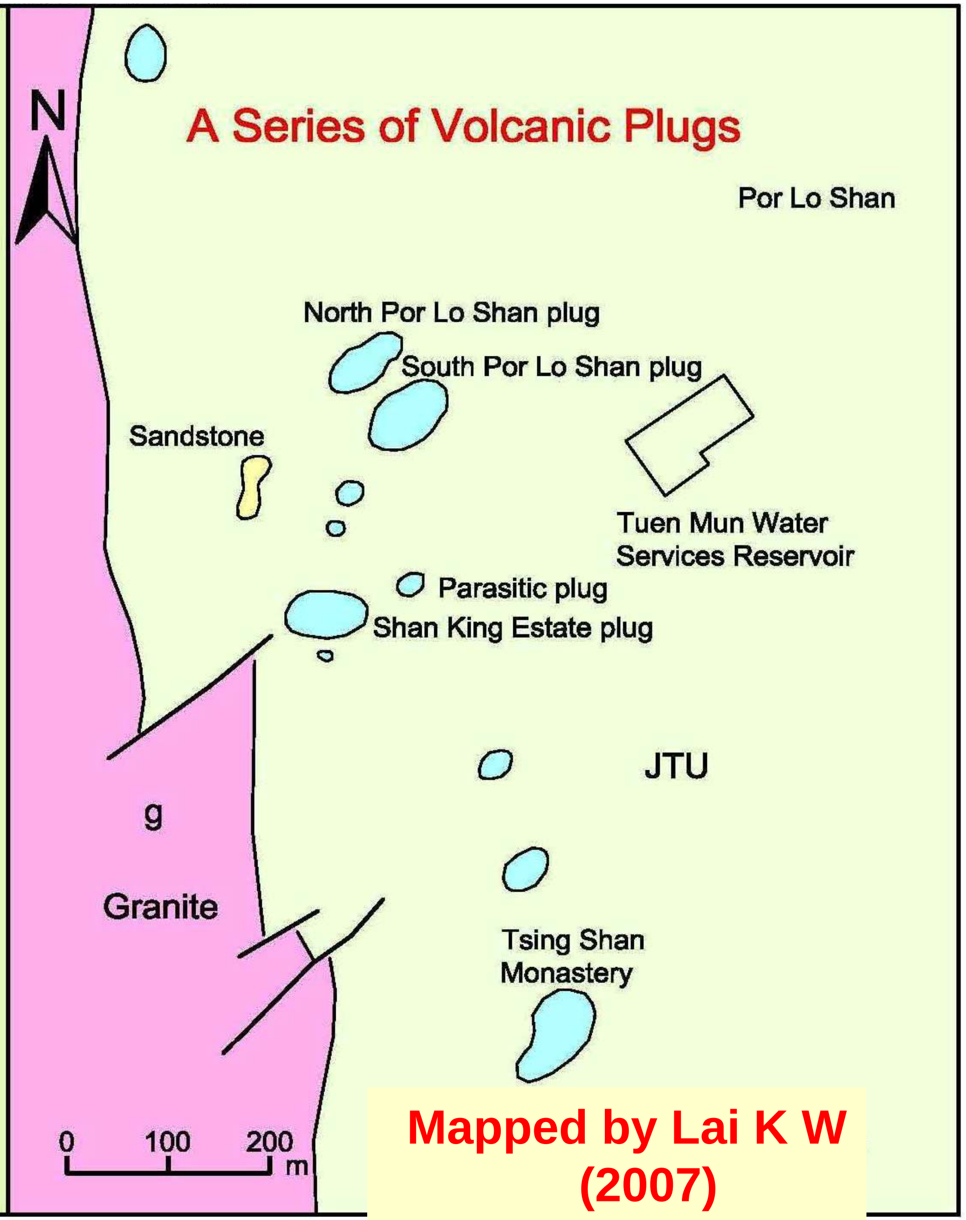


The obsolete Tsing Shan Formation has been merged into the Tuen Mun Formation *(Hong Kong Geological Map 1: 100,000 compiled by Kirk P.A. et al. 2000)*

Comparison of **1988 and 2007 G**eological Mapping of Tsing Shan Area



Geological map of Tsing Shan (1988)



Mapped by Lai K W (2007)

Misinterpretation of the Tuen Mun Formation in publications after 2000

- The Pre-Quaternary geology of Hong Kong
  (Sewell *et al*. 2000) p38 & p69
- Engineering Geological Practice in Hong Kong
  (GEO 2007) p35, p75, p105 and p140
- Hong Kong Geology Guide Book (in Chinese)
  (香港地質考察指引)
  (GEO 2007) p48-55. Chapter 8
- Hong Kong geology guide book
  (GEO 2008) p52-60. Chapter 8

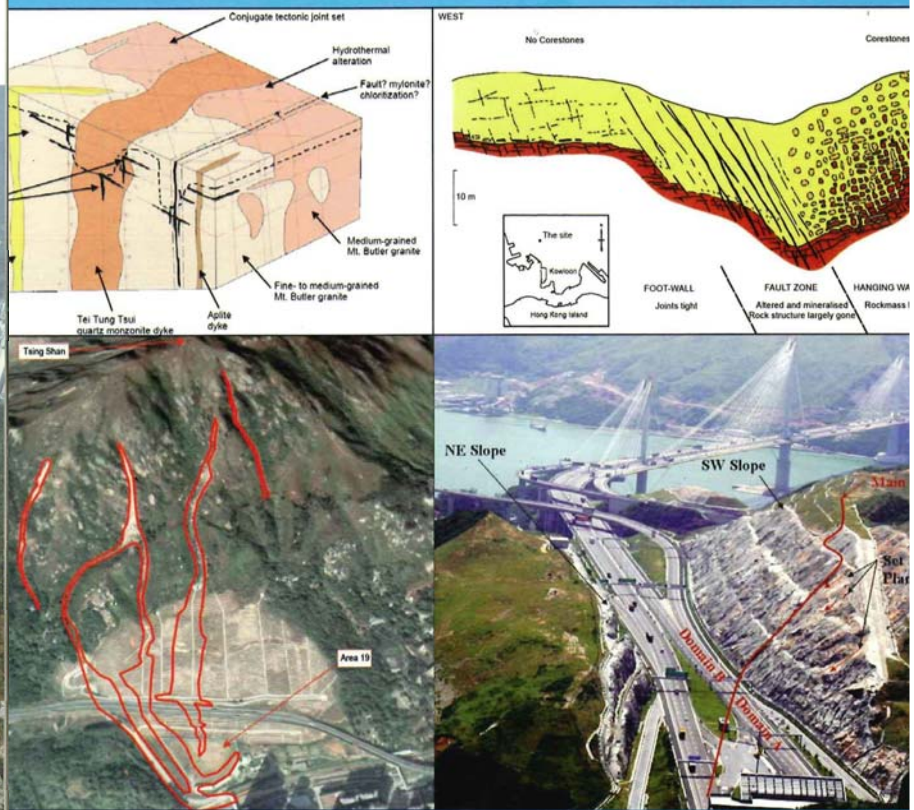
The Pre-Quaternary Geology of Hong Kong

Hong Kong Geological Survey
Geotechnical Engineering Office
Civil Engineering Department
The Government of the Hong Kong SAR

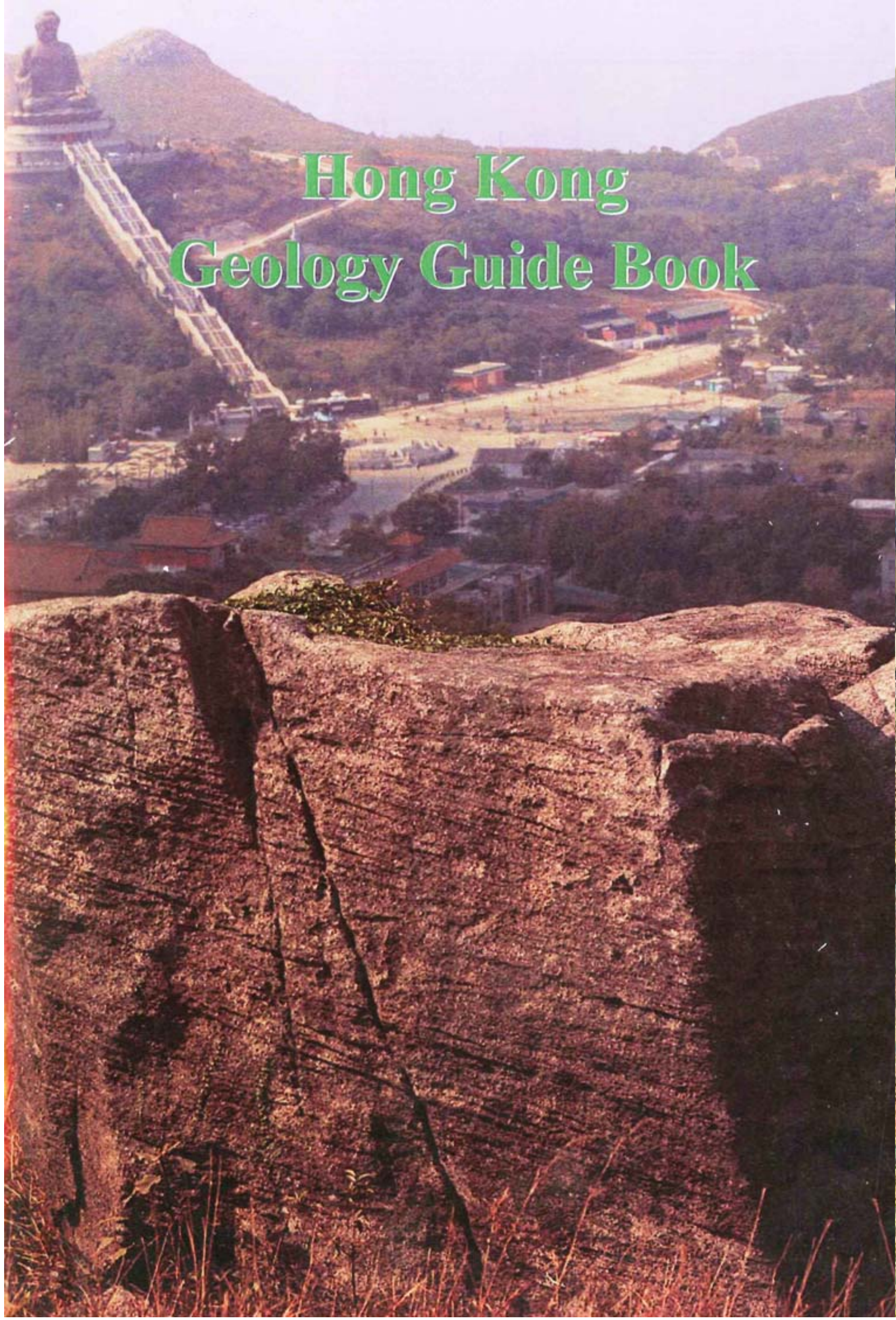
August 2000

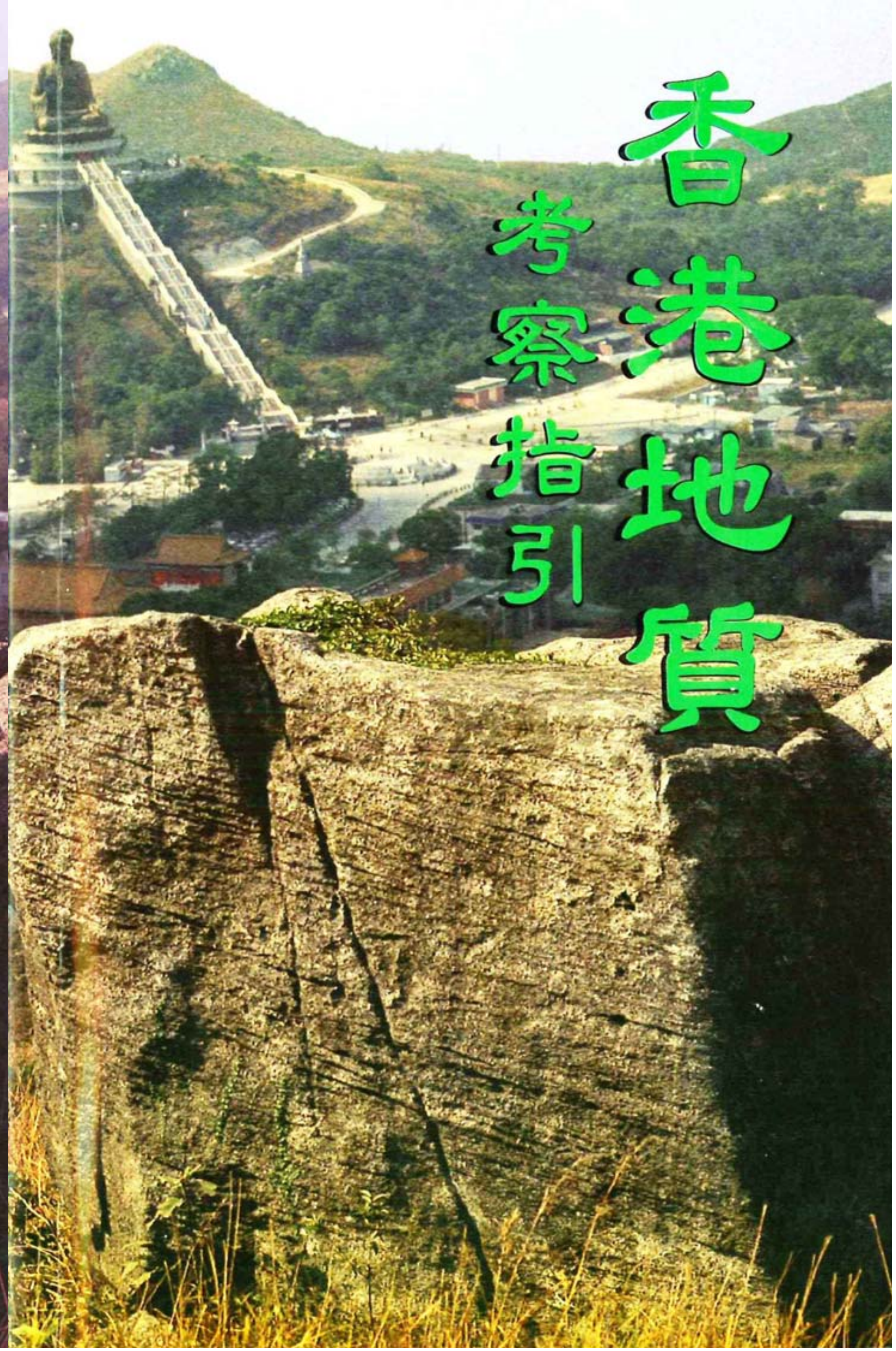
GEO PUBLICATION No. 1/2007

ENGINEERING GEOLOGICAL PRACTICE IN HONG KONG



EOTECHNICAL ENGINEERING OFFICE
ivil Engineering and Development Department
he Government of the Hong Kong
pecial Administrative Region


Hong Kong
Geology Guide Book

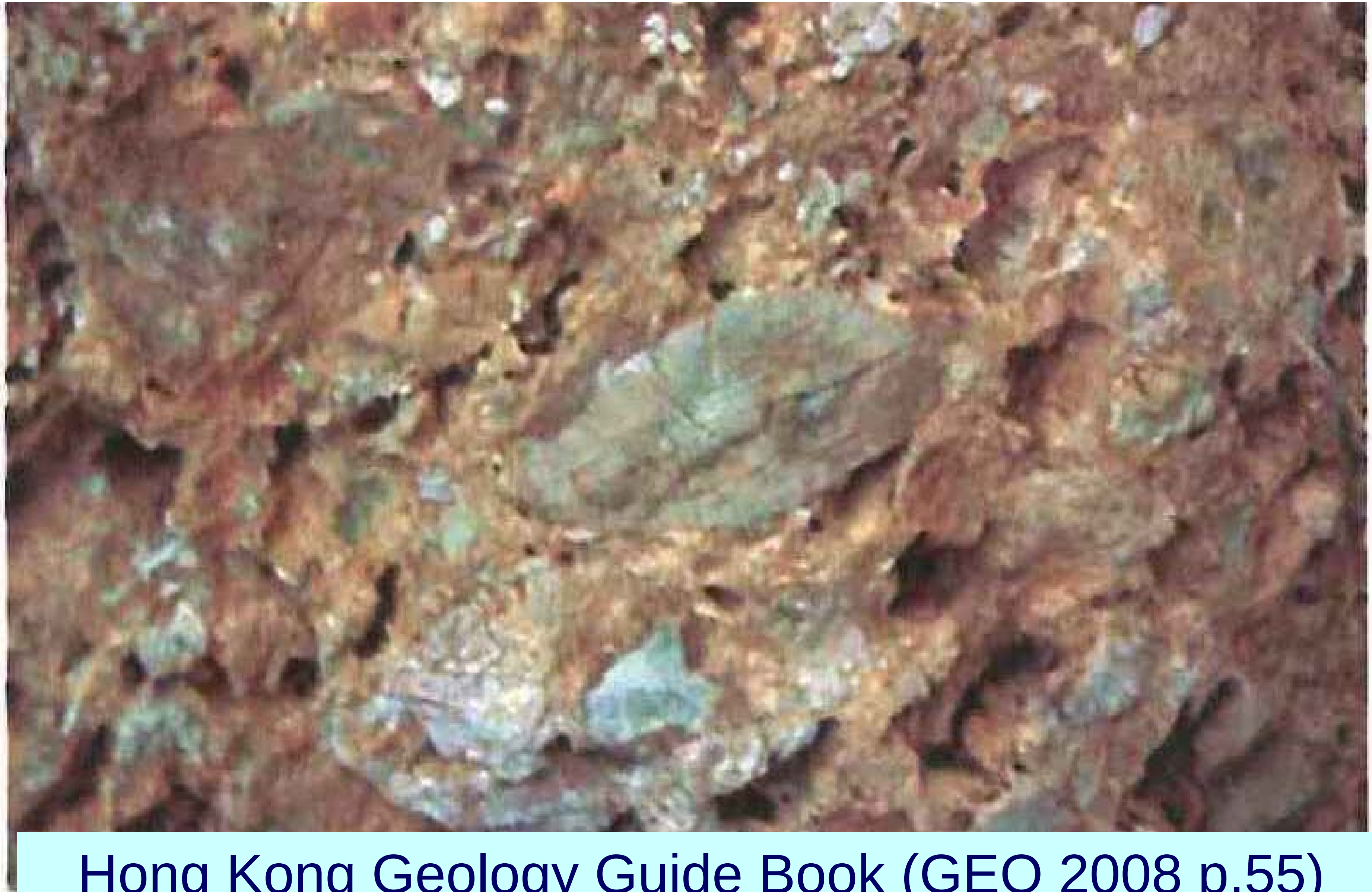

香港地質
考察指引

Geological Misinterpretation

Chapter 8 of the Hong Kong Geology Guide Book

- "The rocks at Tsing Shan Monastery consist of a variety of conglomerates and breccias"

- "These rocks may have formed following the collapse of a volcanic edifice, or by fluvial activity on the margin of a crater lake" (*Page 55*)



Hong Kong Geology Guide Book (GEO 2008 p.55)

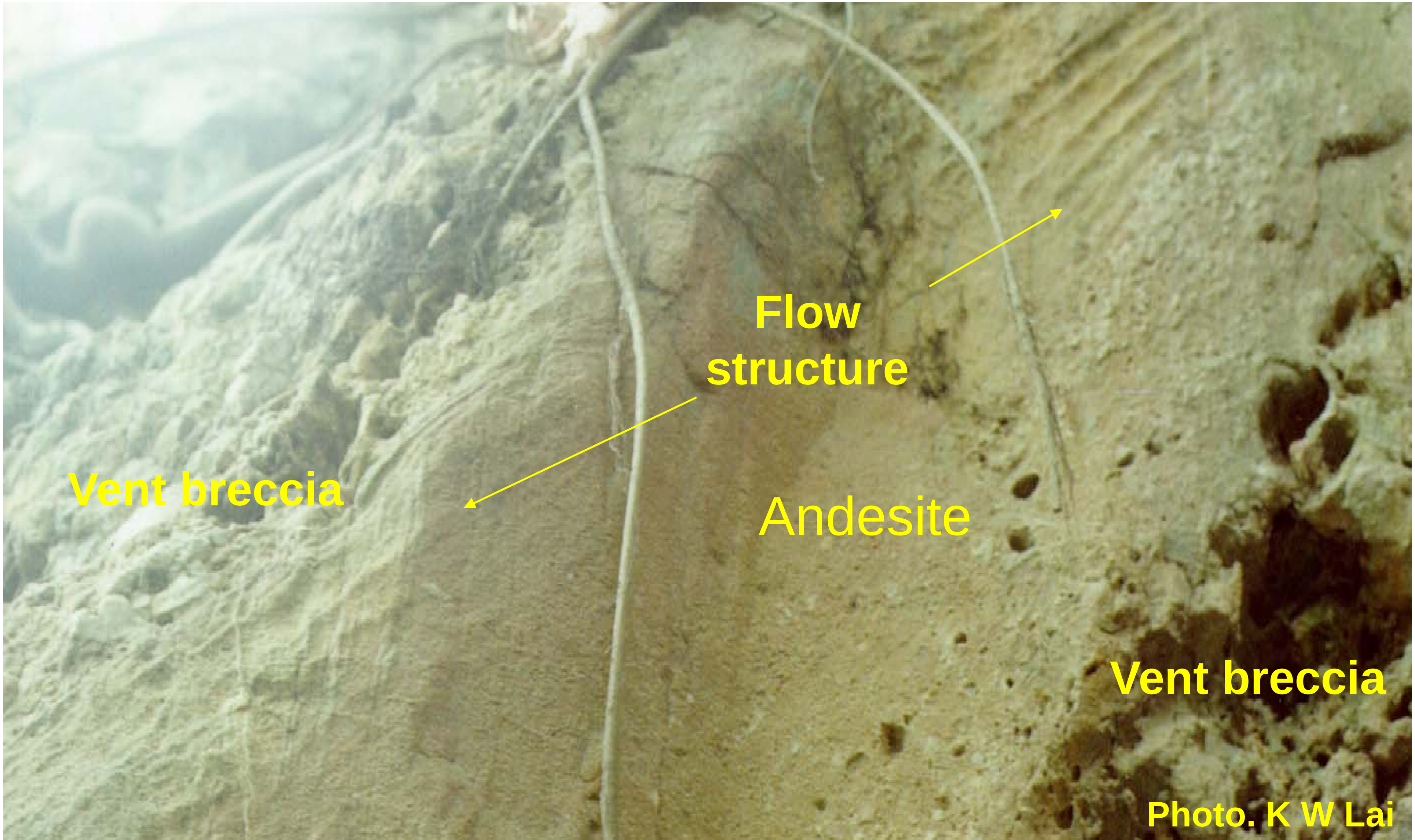
Conglomerate in Tsing Shan Monastery

These rocks are vent breccia cemented by andesite within a volcanic plug, not conglomerate

(Photo taken in the same location in Tsing Shan Monastery)

Hong Kong Geology Guide Book (GEO 2008 p.56)

Fine-grained banded strata between breccia/conglomerate

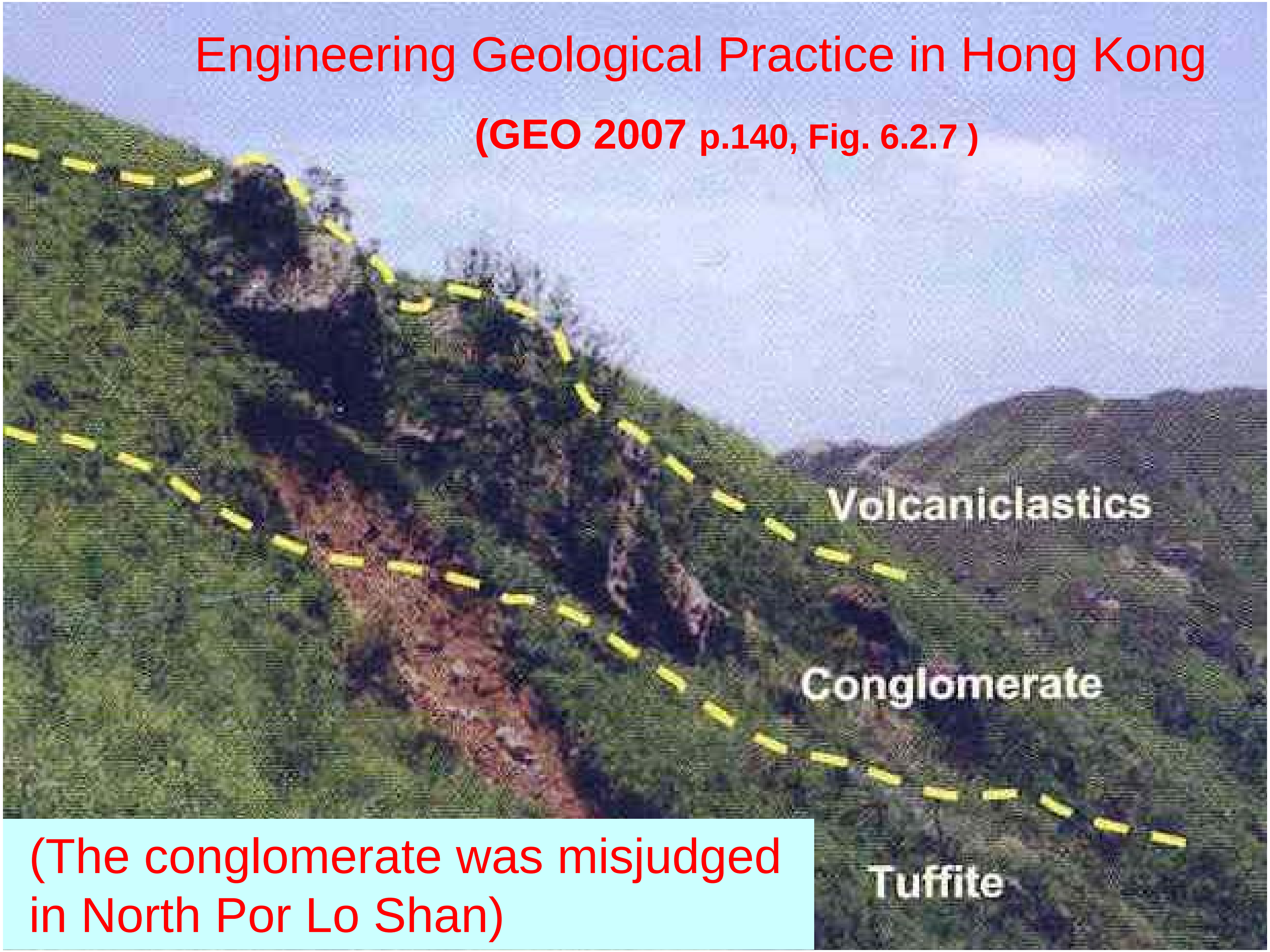


These rocks occur in a volcanic plug with lava flow structure, they can't formed by volcano collapse or fluvial activity

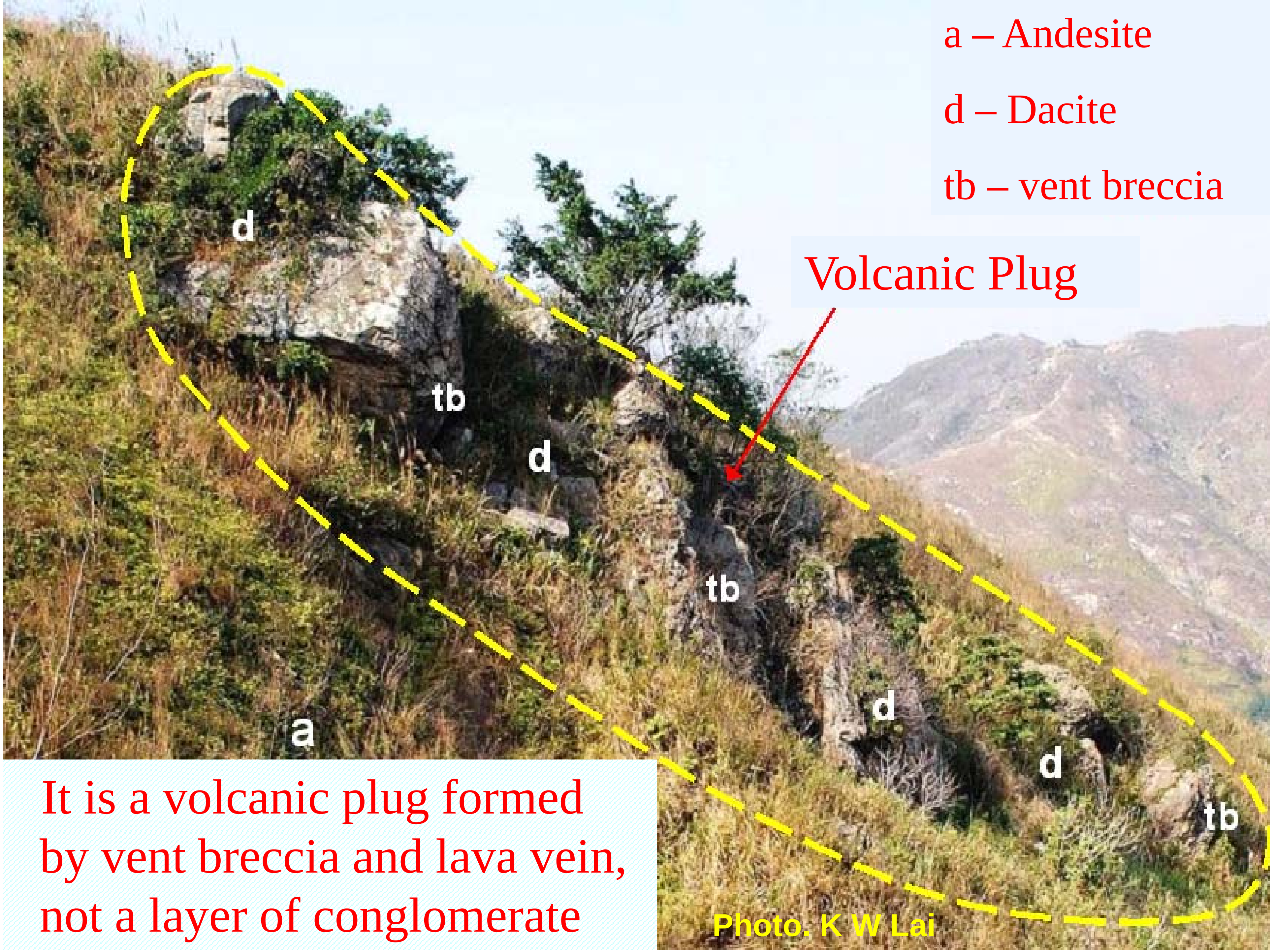
(Photo taken in the same location in Tsing Shan Monastery)

Engineering Geological Practice in Hong Kong

(GEO 2007 p.140, Fig. 6.2.7)



(The conglomerate was misjudged in North Por Lo Shan)



It is a volcanic plug formed by vent breccia and lava vein, not a layer of conglomerate

Reason for Misinterpreting of Conglomerate

- There are bedding and graded bedding, some clasts are transported by fluvial processes
- Some lithic clasts are rounded to subrounded
- Lithic clasts are reworked or redeposited
- Pyroclastic rocks also can form rounded clast and bedding

Rounded clasts and layers of a stratovolcano, Iceland

Consequences of Misinterpreted Rock Types

- Erroneous ground investigation results
- Generates inaccurate geological model which can significantly affect the foundation and engineering design
- Increases development cost dramatically
- Prolongs construction programme

Discussion on the Tuen Mun formation has been addressed in following publications

- Lai K W *et al* (2004)
- Lai K W (2005)
- Chan S H M (2005)
- Chan J *et al* (2005)
- Lai K W *et al* (2006)
- Chan S H M & Kwong A K L (2009)
- Lai K W (2009)

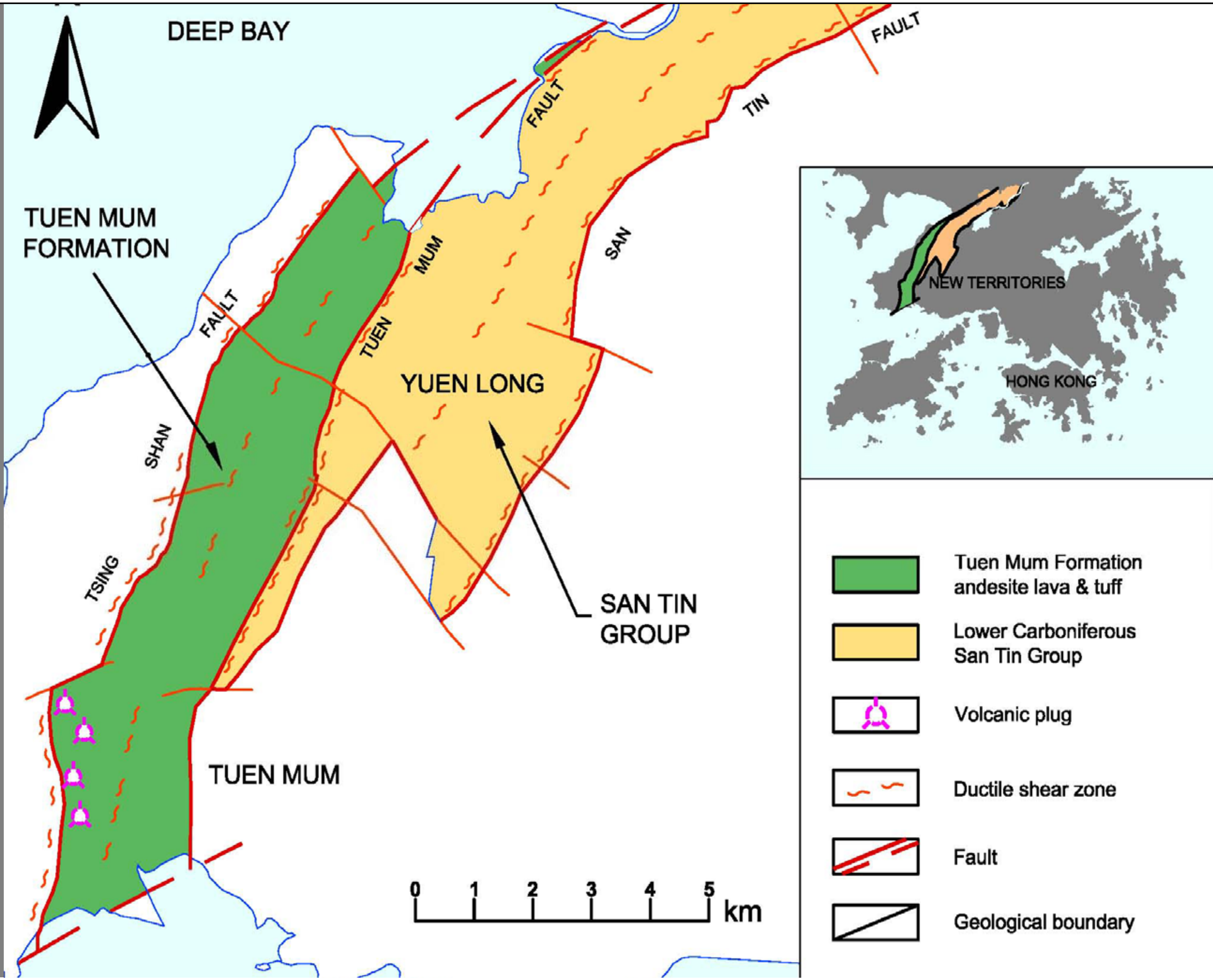
What We Have Done in the Research of the Tuen Mun Formation (TMF)

- Re-mapped the geology of TMF from Tuen Mun to Shenzhen area
- Visited and studied more than 20 volcanoes in the world to compare with those rocks in TMF
- Collection of 180 volcanic rock samples & identification of 105 thin sections from TMF
- Checking of more than 1,000 borehole logs
- Sent 20 samples for chemical analysis

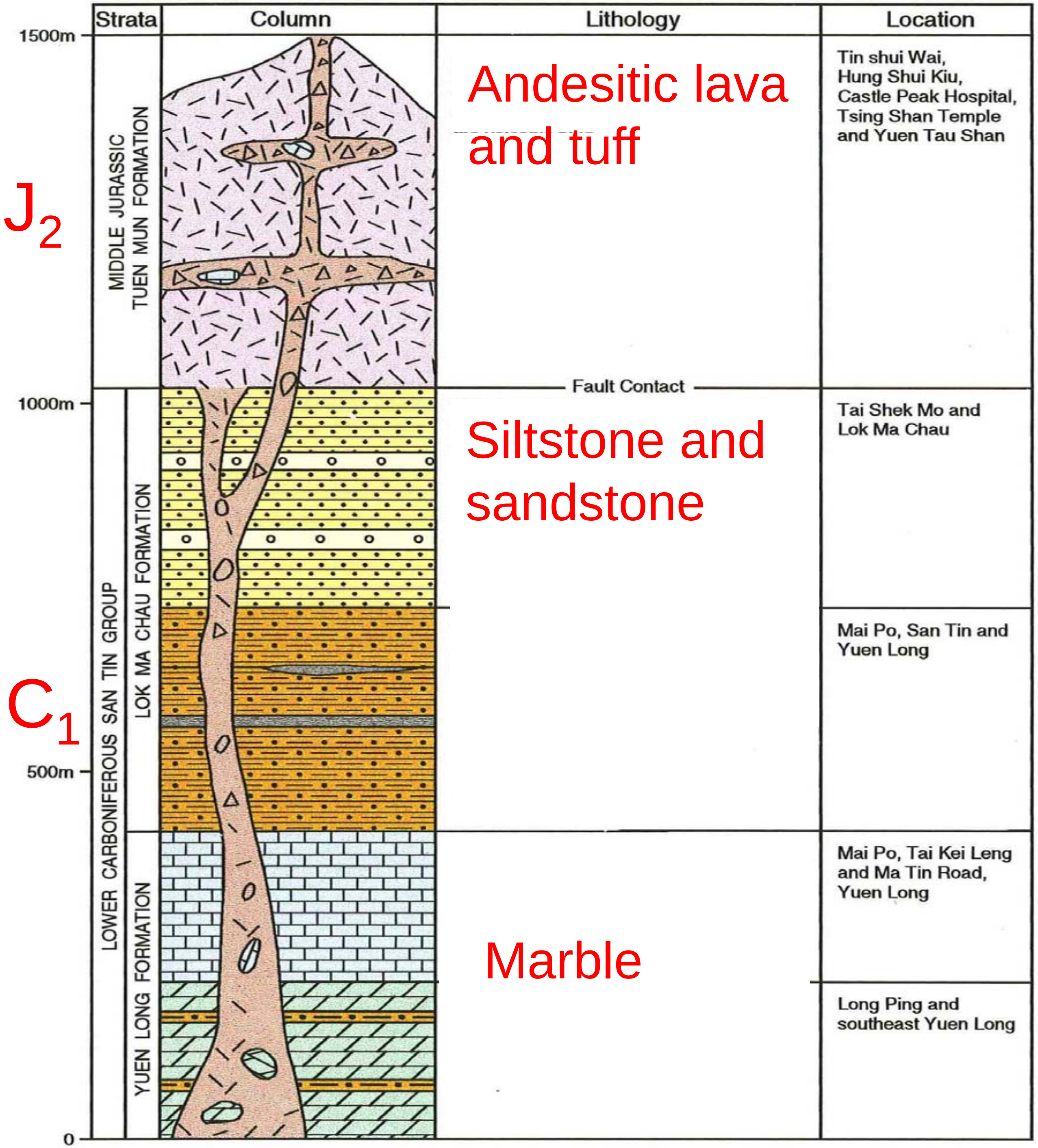
Palaeovolcano Group in Tuen Mun Formation

- Palaeovolcanoes occurred from Tsing Shan Monastery to Por Lo Shan area
- Discovery of palaeovolcanic plugs and their surrounding stratovolcanic deposits
- Composed of basaltic andesite, dacite lava, vent breccia and tuff
- A series of volcanoes was controlled by the Tuen Mun – Lo Wu Fault. Zone

Geology of Tuen Mun – Tin Shui Wai Area



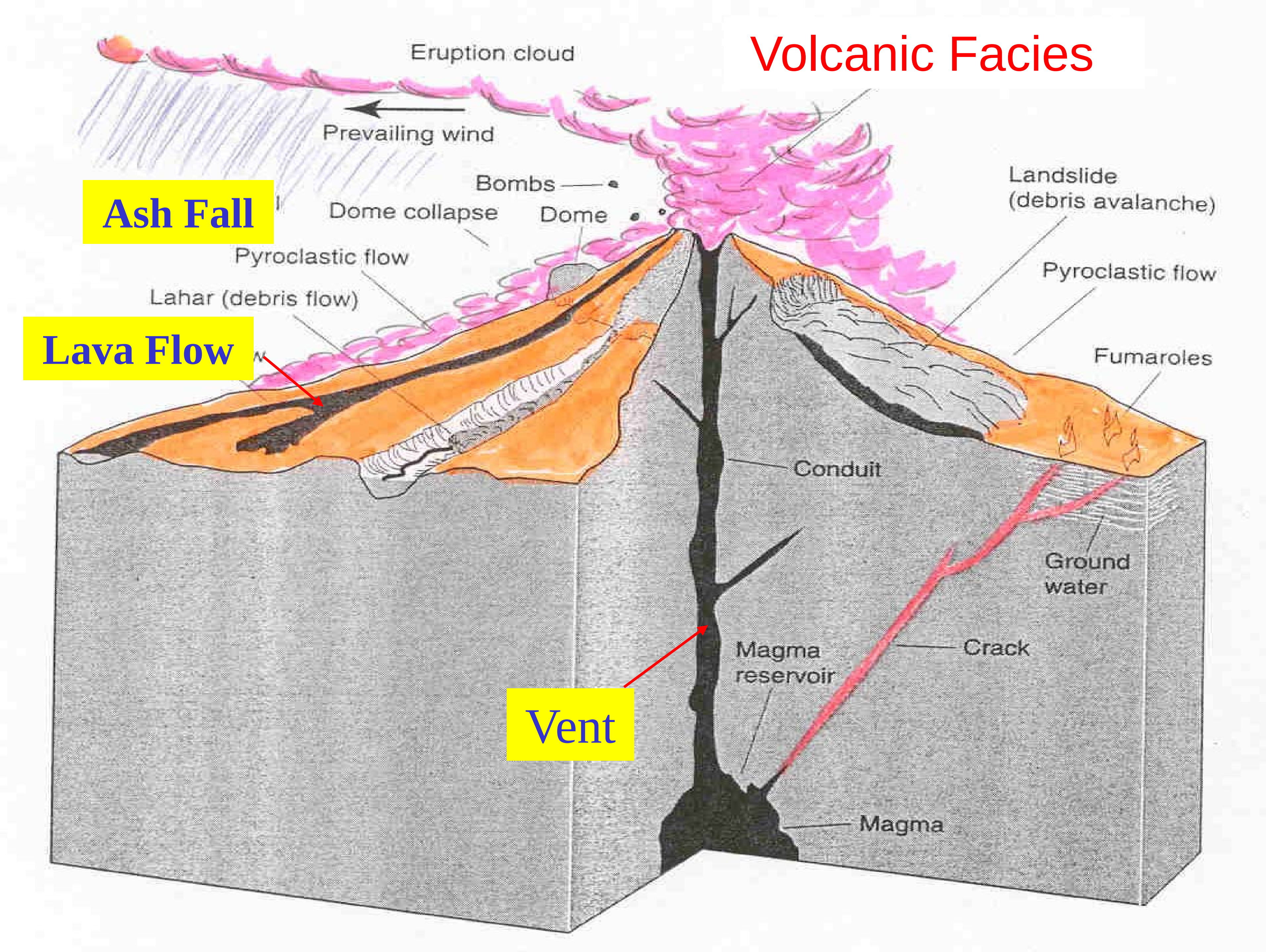
Stratigraphic Column of North West New Territories



Volcanic Facies of Tuen Mun Formation

- Effusion Facies : lava flow
- Air Fall Facies : tuff and tuff breccia
- Pyroclastic Flow Facies: tuff and lapilli tuff
- Surge Facies : fine ash tuff
- Vent Facies : vent breccia and brecciated lava
- Eruption-Sedimentary Facies: tuffaceous siltstone/sandstone

Volcanic Facies



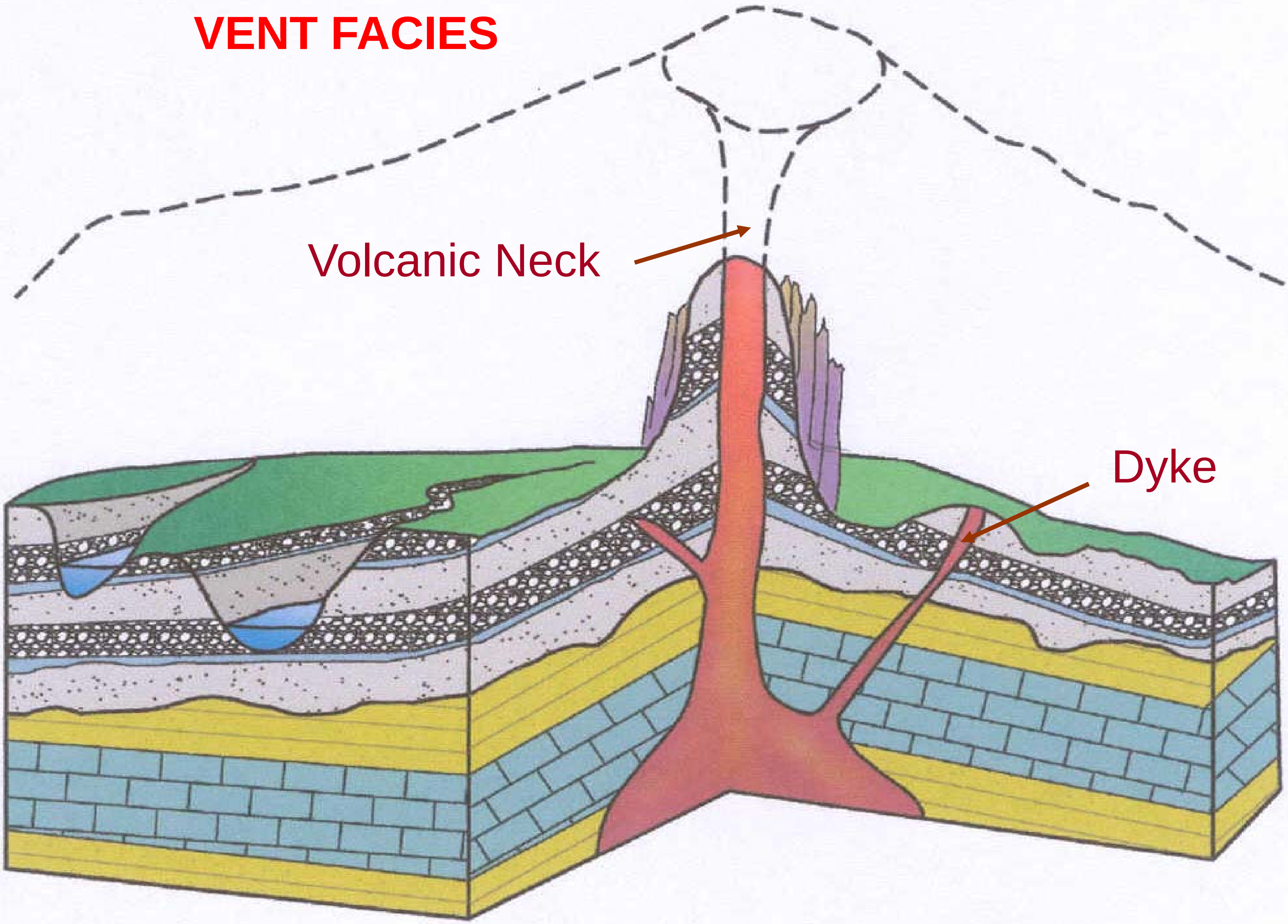
Evidences of Palaeovolcanic Plug

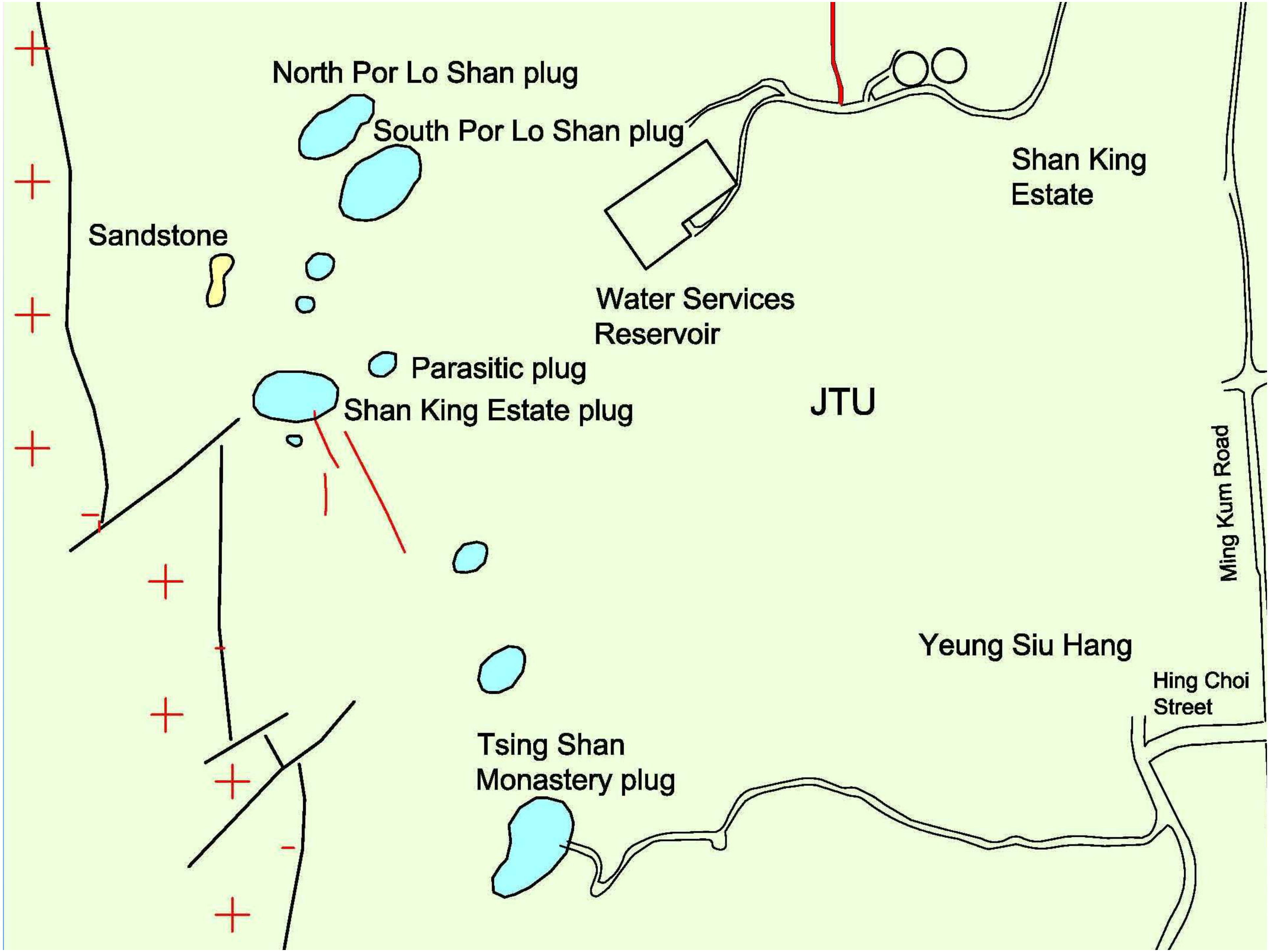
1. Mode of occurrences
2. Rock composition
3. Chemical and mineral composition
4. Alteration
5. Lava flow
6. Degassing structure and
7. Joint type

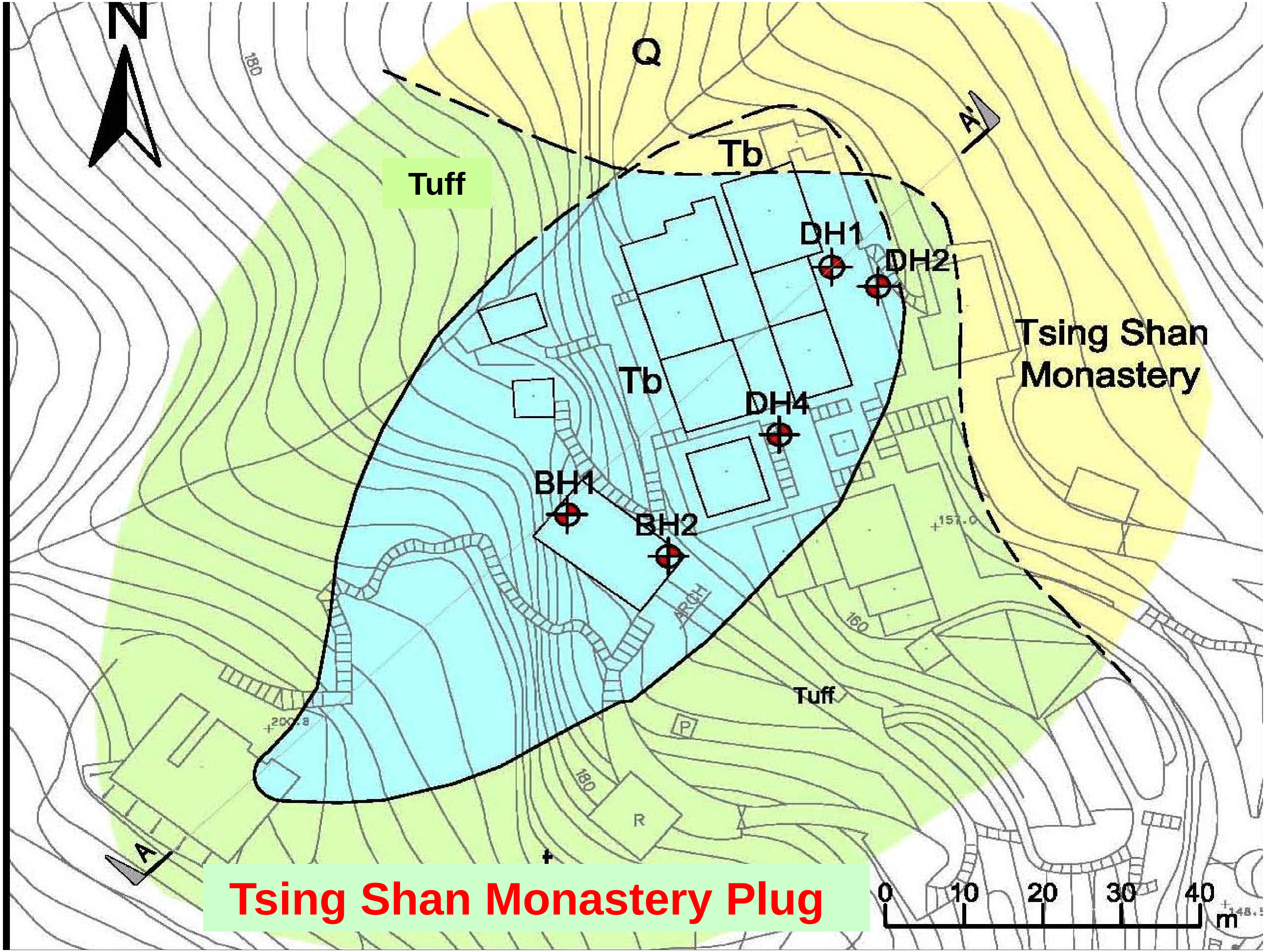
Evidence 1
Mode of Occurrences

- Plane – Circular, Elliptic and Rain drop shape
- Cross Section – Cylinder
- Forming a series of volcanoes

VENT FACIES

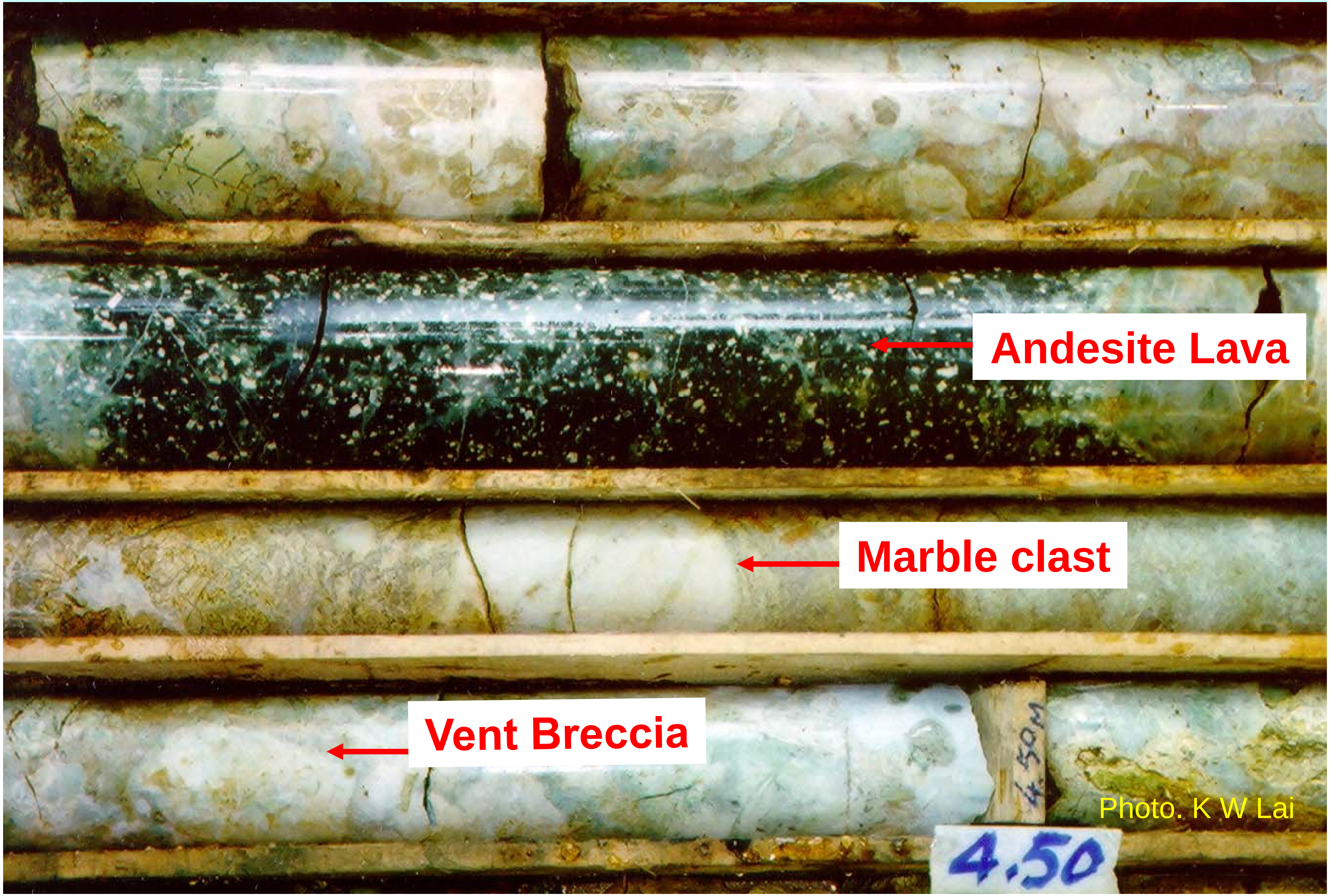



North Por Lo Shan plug
South Por Lo Shan plug
Shan King
Estate
Sandstone
Water Services
Reservoir
Parasitic plug
Shan King Estate plug
JTU
Ming Kum Road
Yeung Siu Hang
Hing Choi
Street
Tsing Shan
Monastery plug

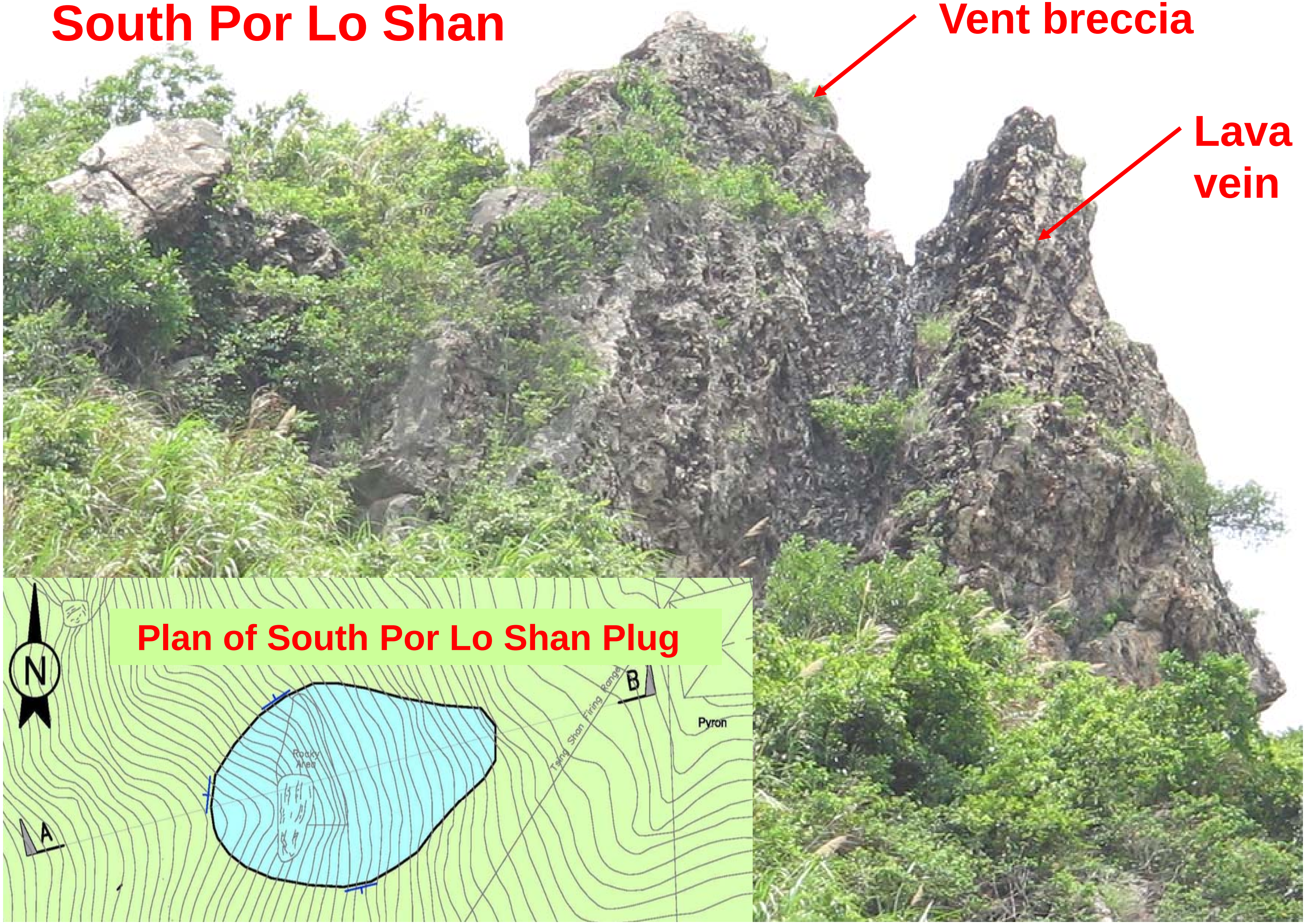


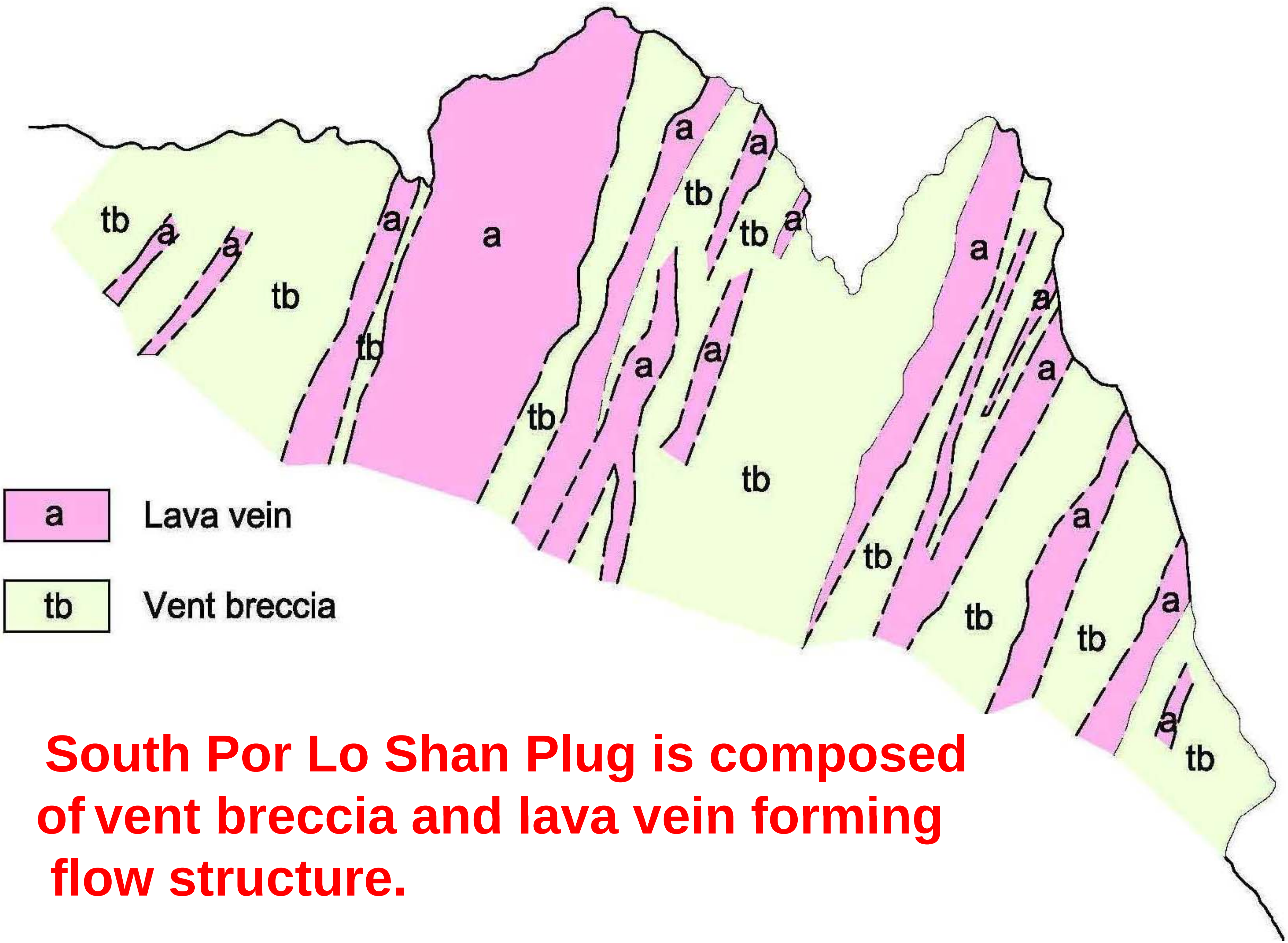
Tsing Shan Monastery Plug

Rock Cores of Tsing Shan Monastery



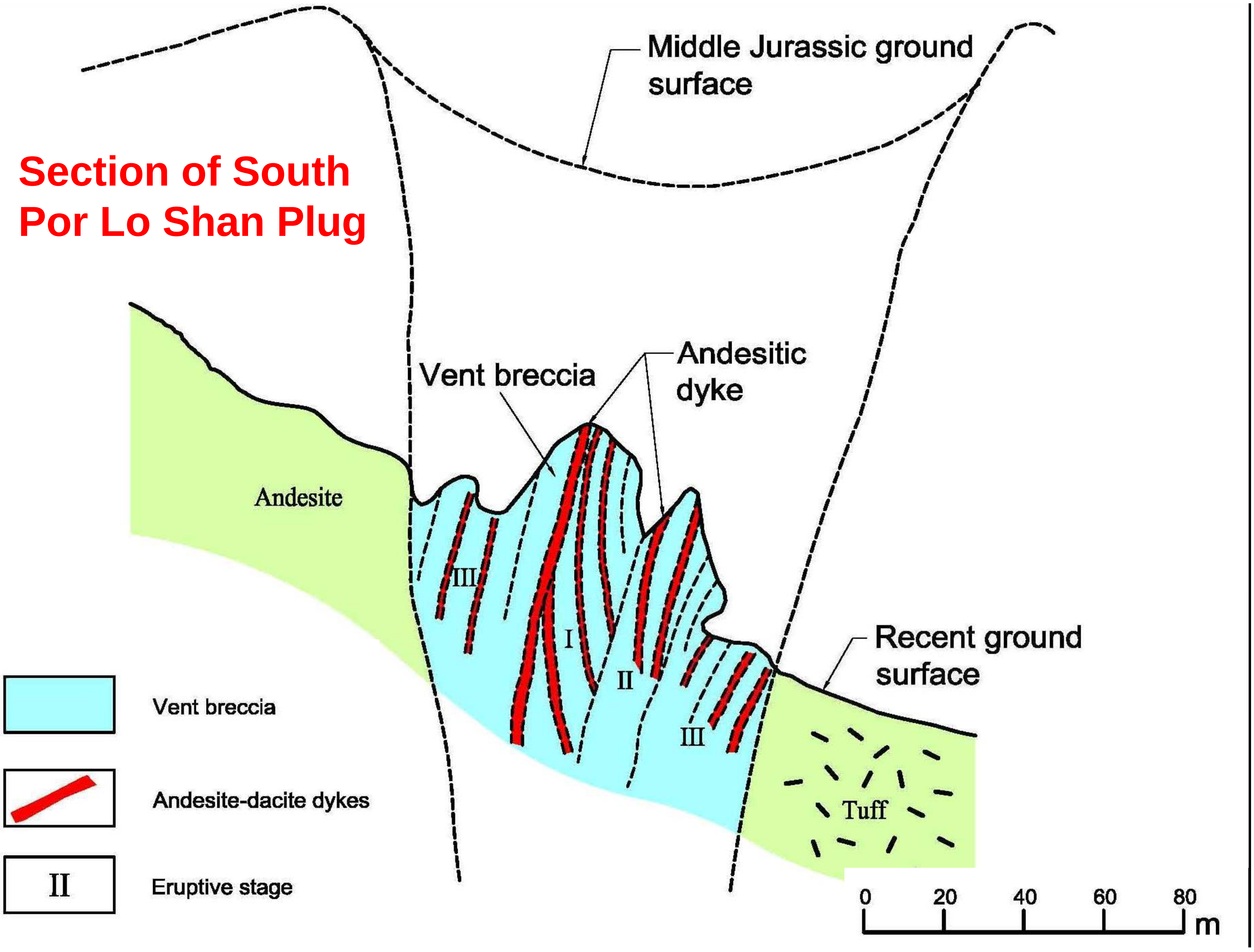
South Por Lo Shan



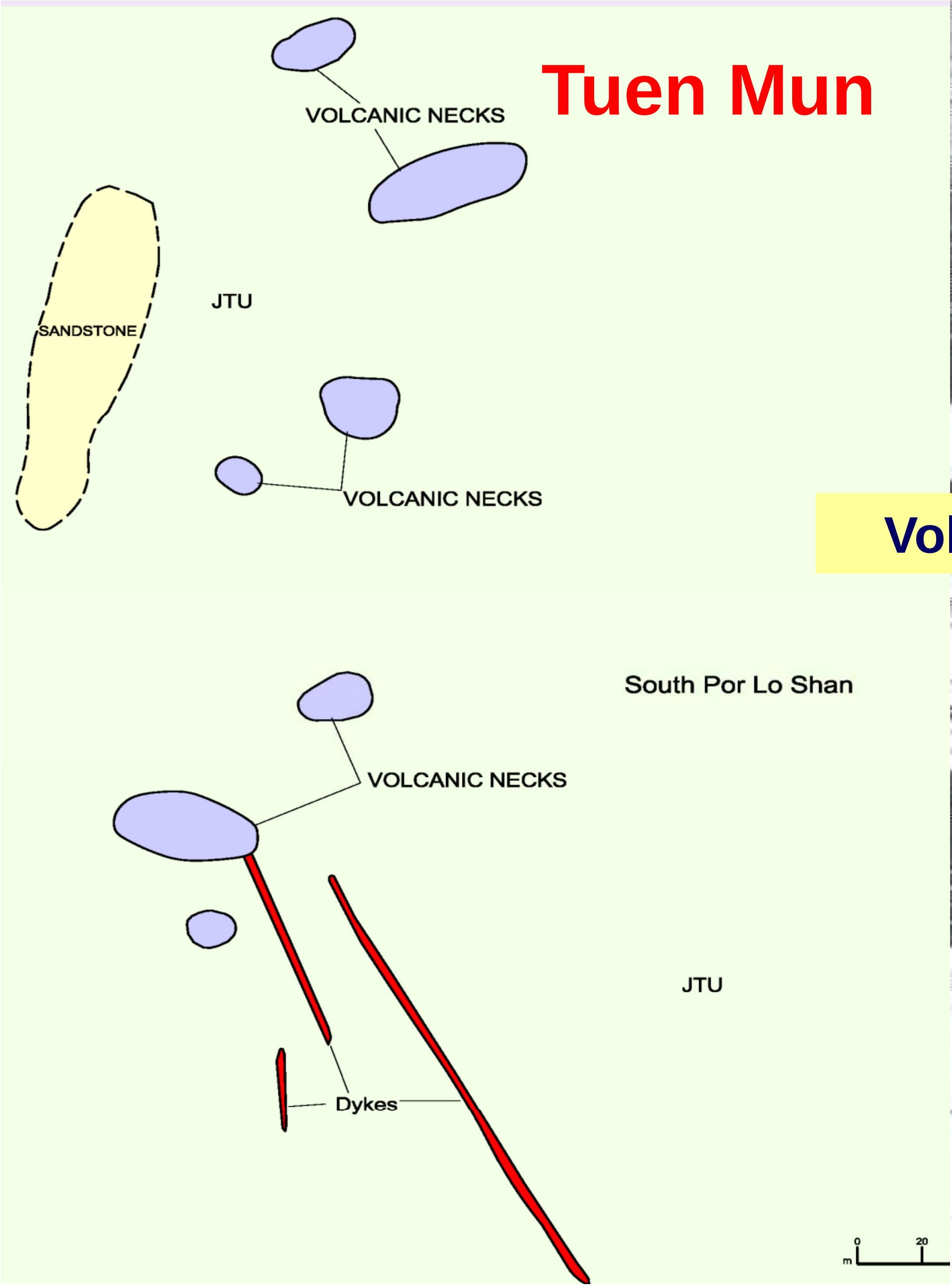


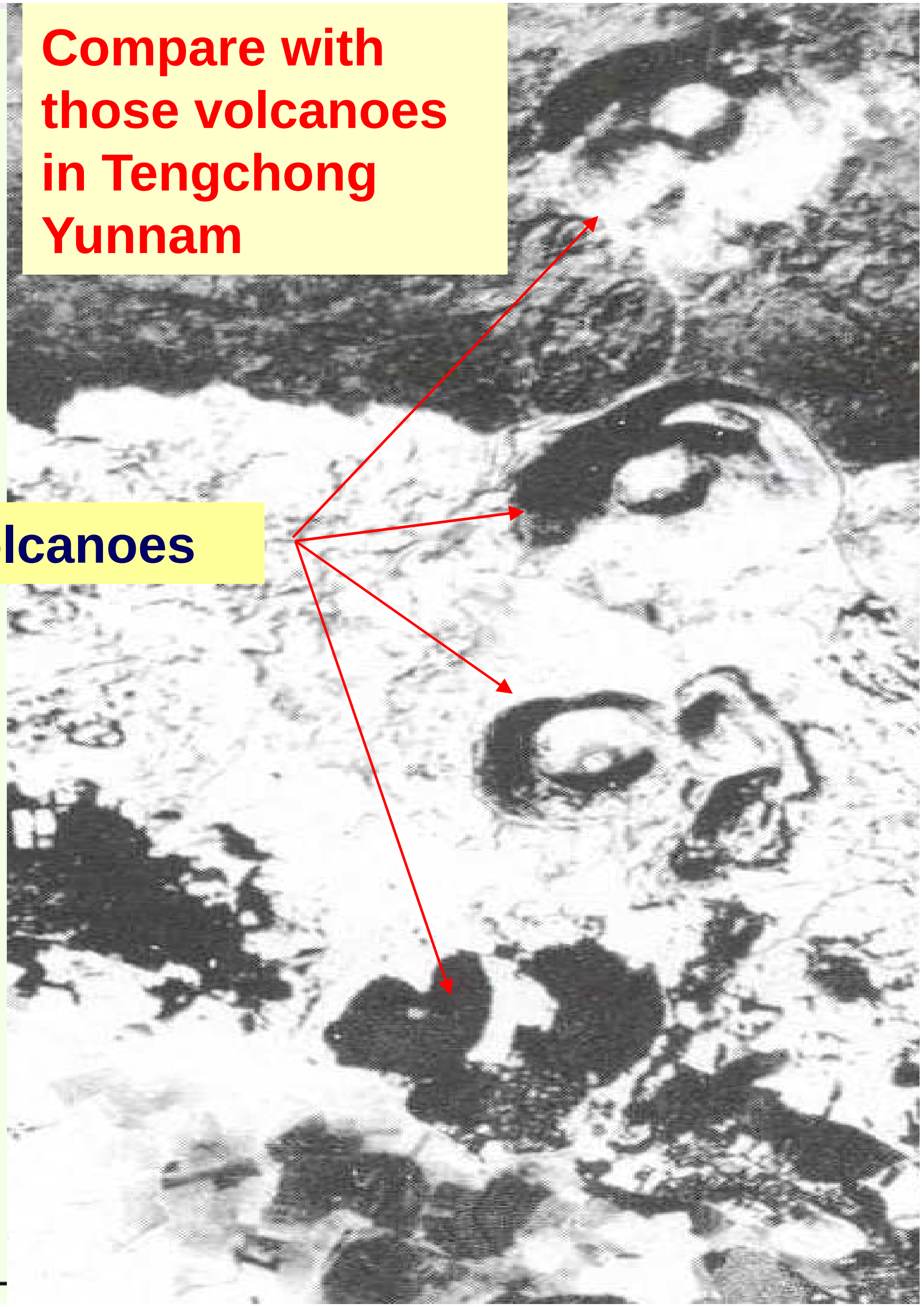
South Por Lo Shan Plug is composed of vent breccia and lava vein forming flow structure.

Section of South Por Lo Shan Plug



Forming a Series of Volcanoes

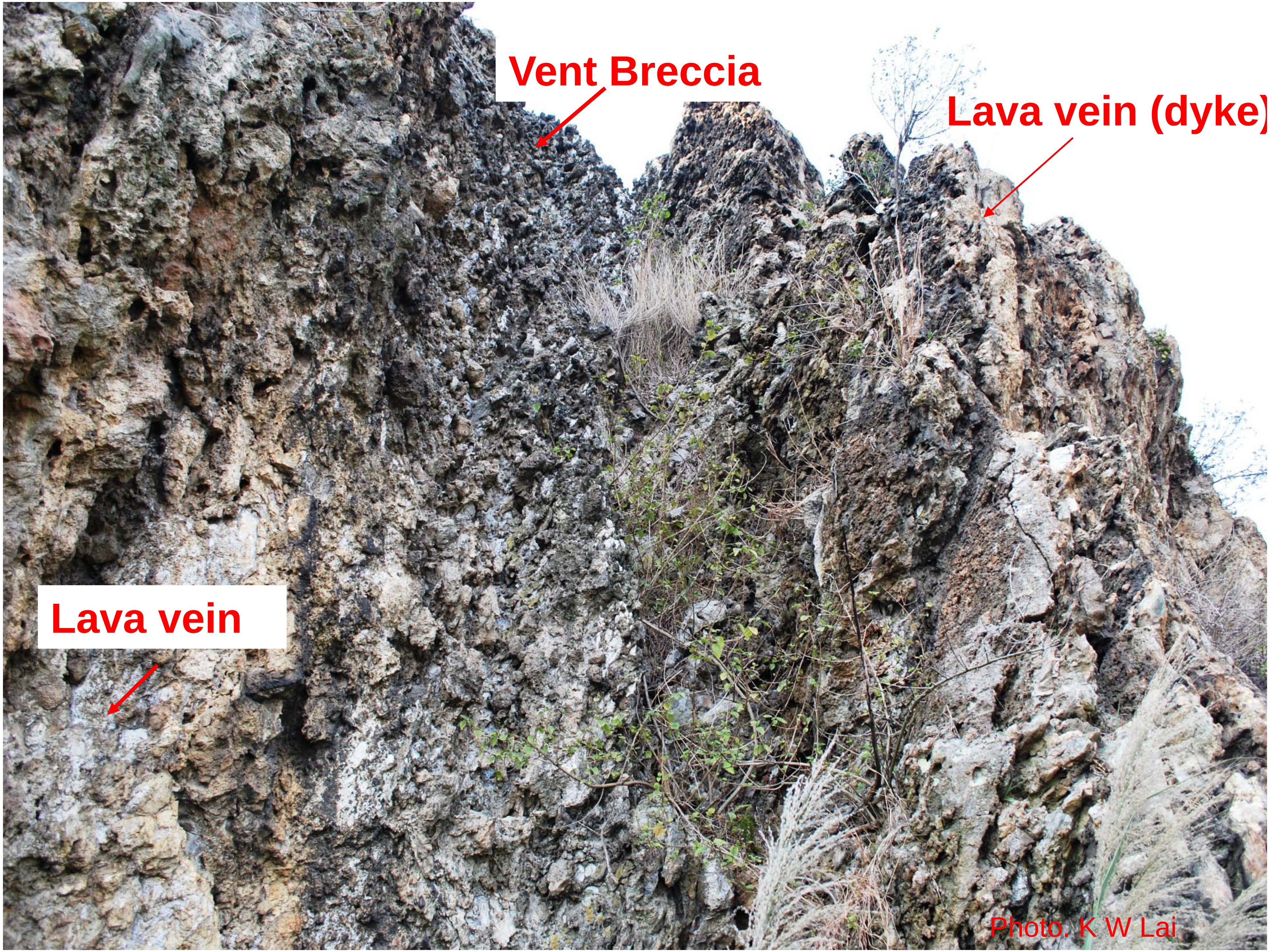


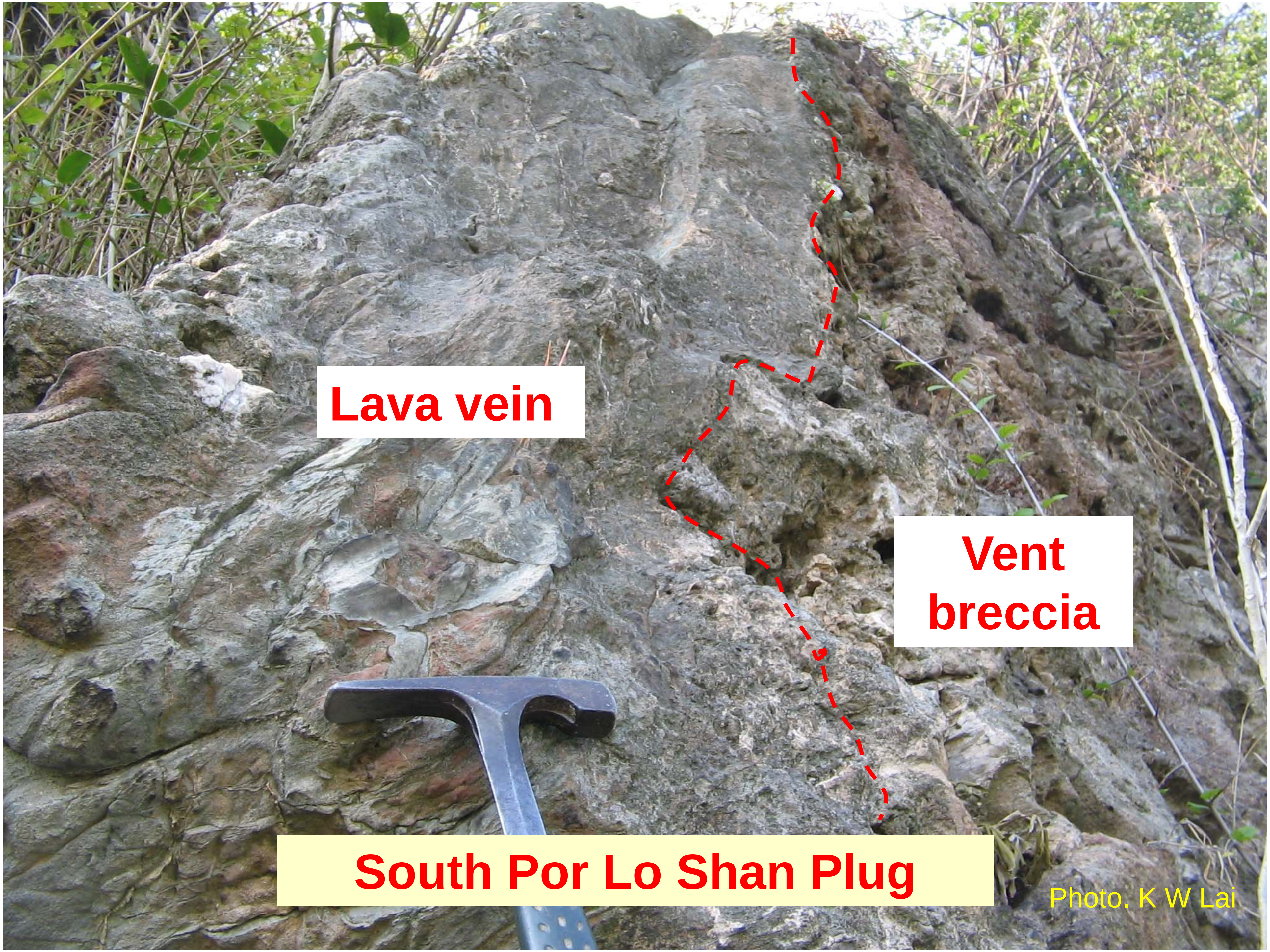


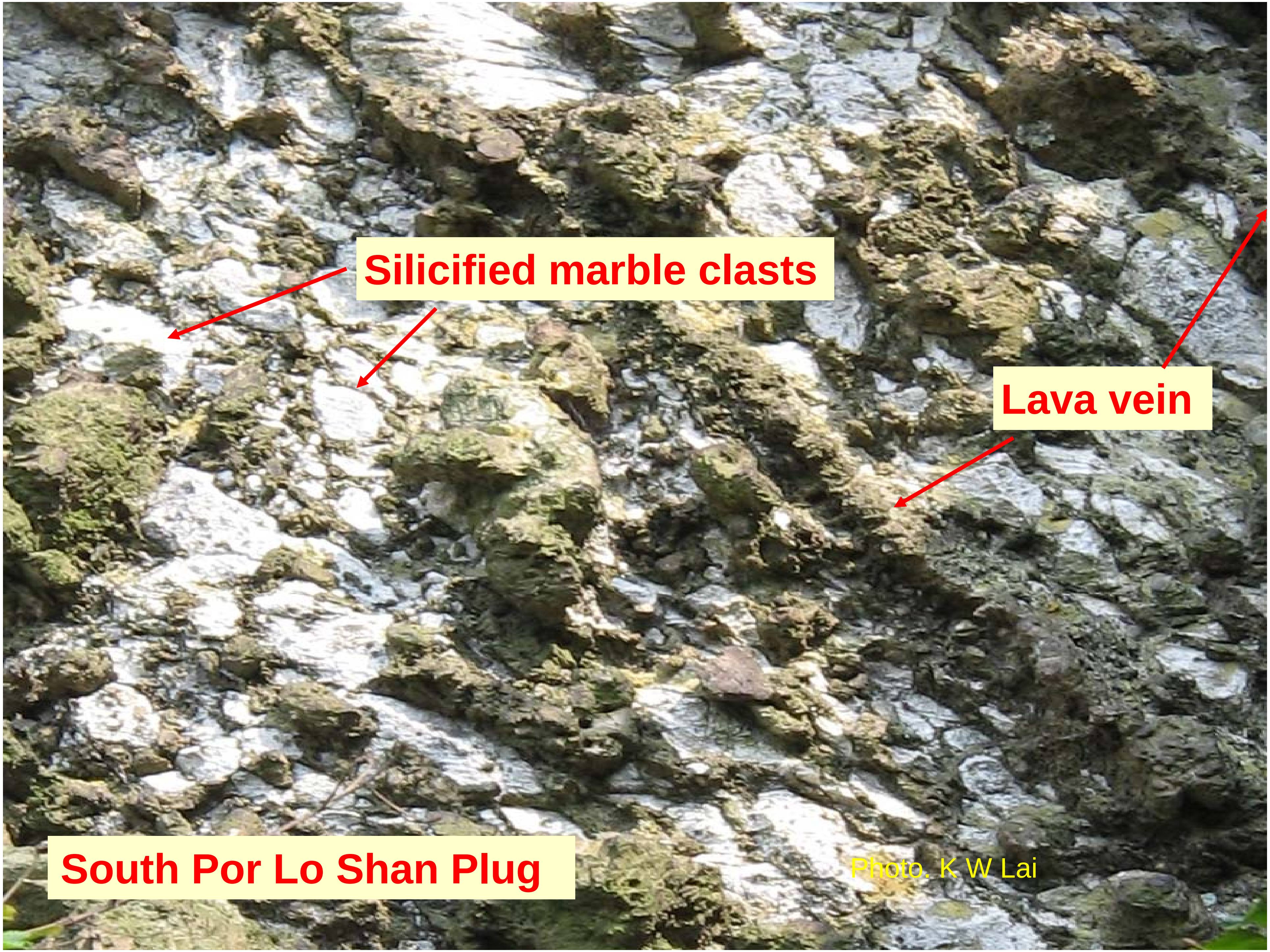
Evidence 2
Rock Composition

- Congealed magma, along with explosive breccia (vein breccia) and crosscut thin lava veins

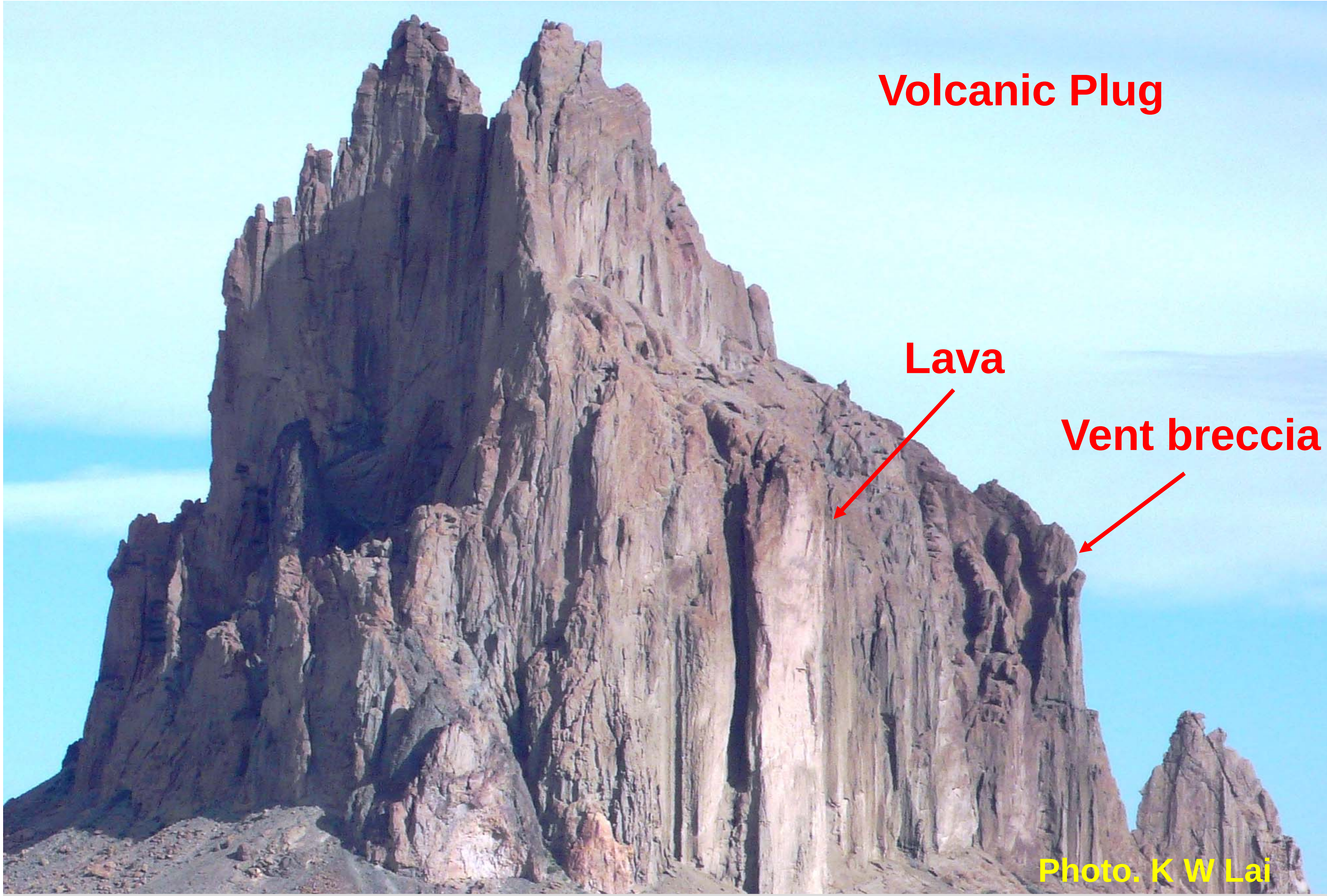
- Cyclic eruption: from violent explosion to quiescent (gentle) eruption


Vent Breccia
Lava vein (dyke)
Lava vein
Photo. K W Lai


Lava vein
Vent breccia
South Por Lo Shan Plug
Photo. K W Lai


Silicified marble clasts
Lava vein
South Por Lo Shan Plug
Photo. K W Lai


Tianchi, Changbai Shan, Jilin
(吉林長白山天池)
Lava
Vent
Breccia
Photo. K W Lai



Ship Rock, New Mexico, America

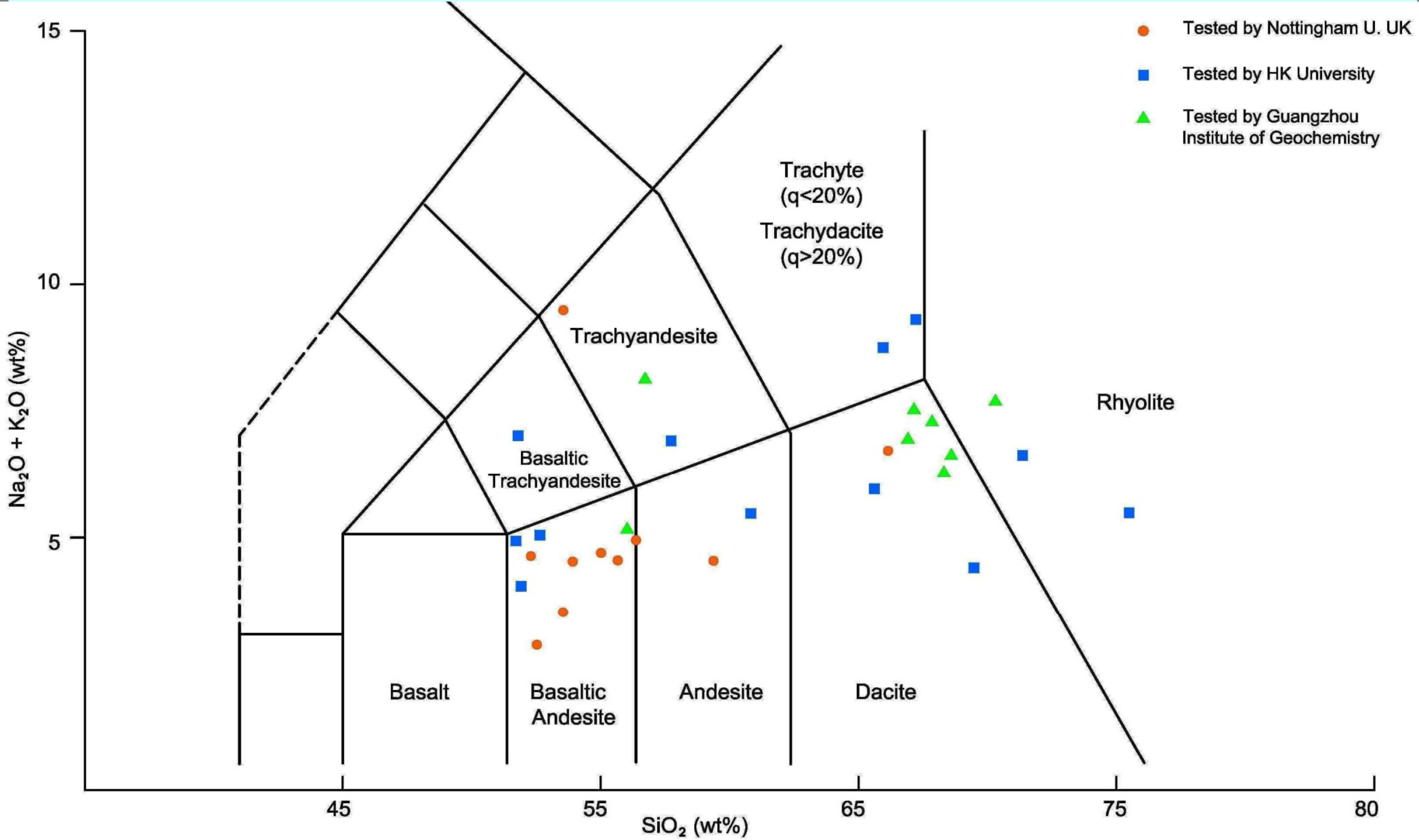
Ship Rock

Volcanic Dyke, Yik Yuen Tsuen

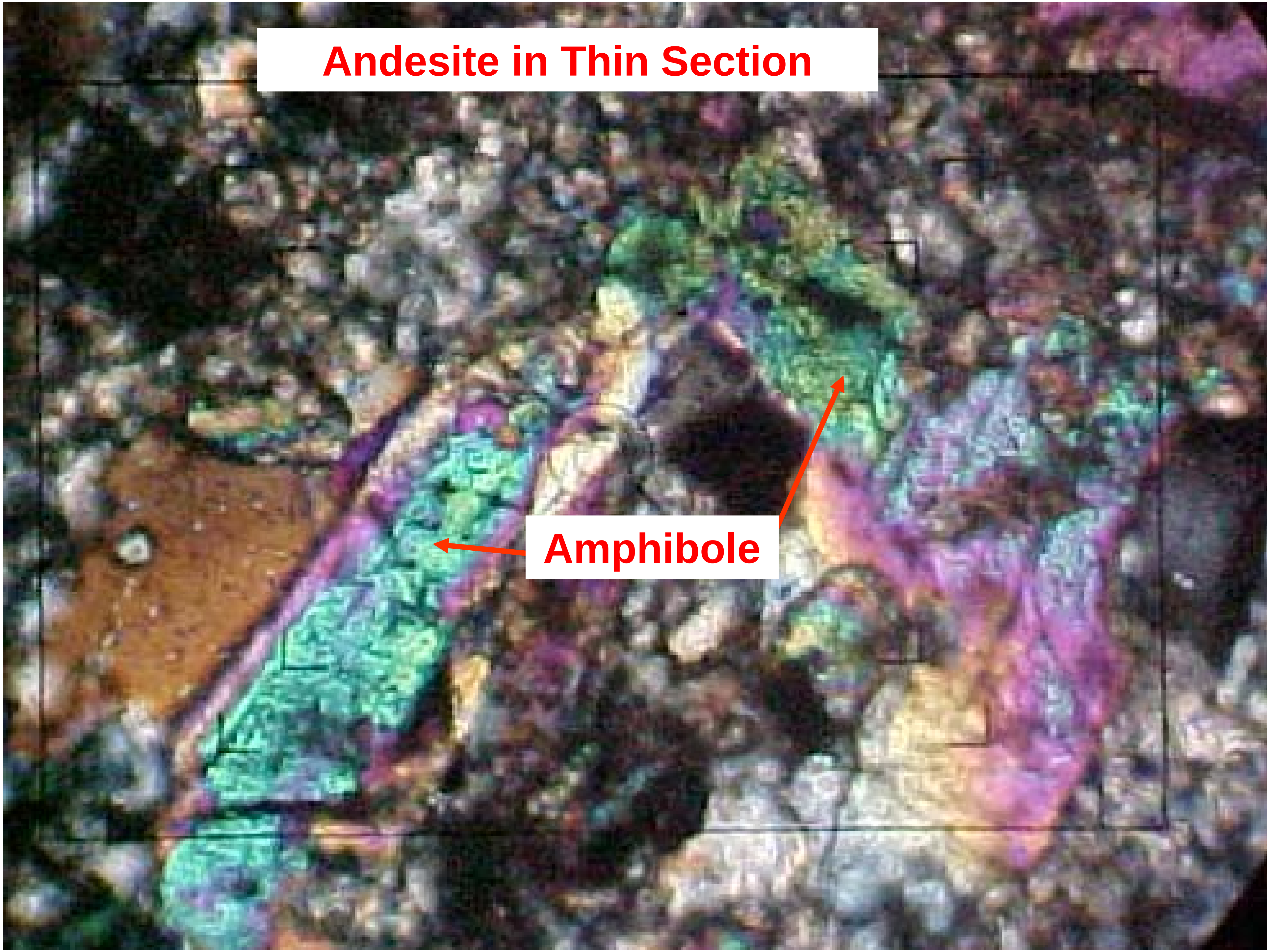
Volcanic dykes also composed of explosive breccia and andesite lava

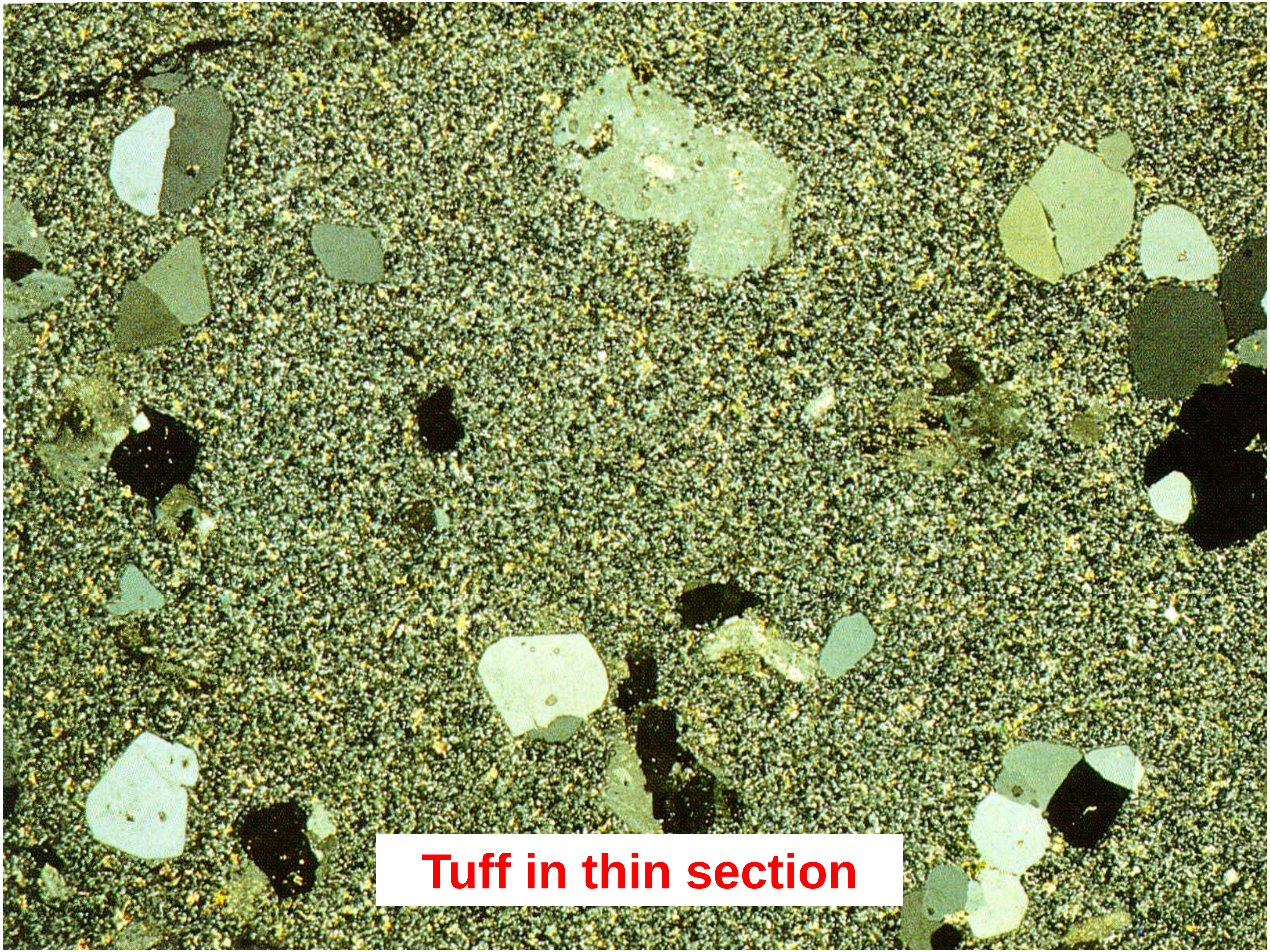
Explosive breccia of a dyke, Iceland

Evidence 3
Chemical and Mineral Composition



$Na_2O + K_2O$ Versus SiO_2 Plot for Volcanic Rocks, Tuen Mun Area


Andesite in Thin Section
Amphibole



Tuff in thin section

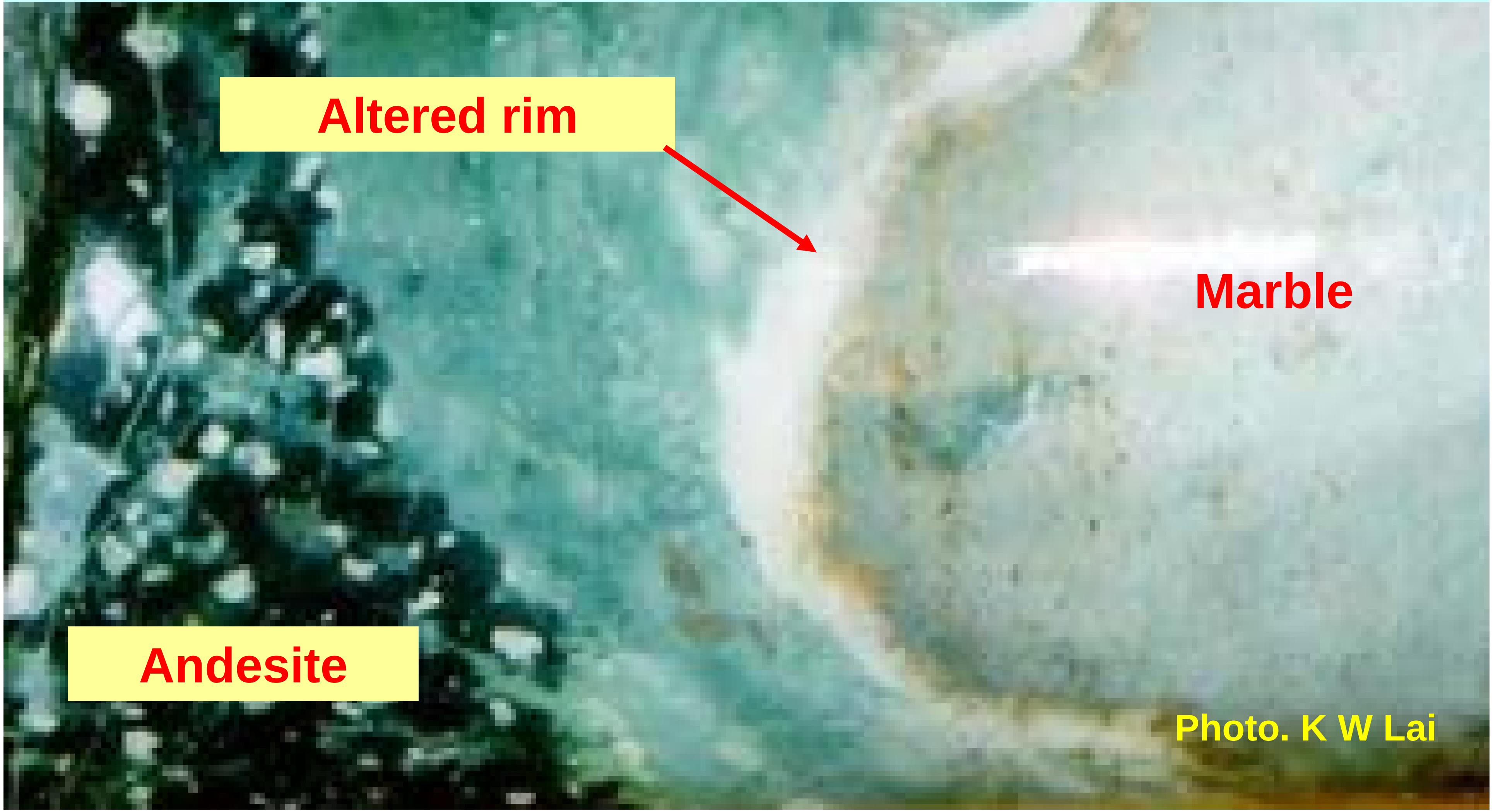
Evidence 4
Alteration of Rocks

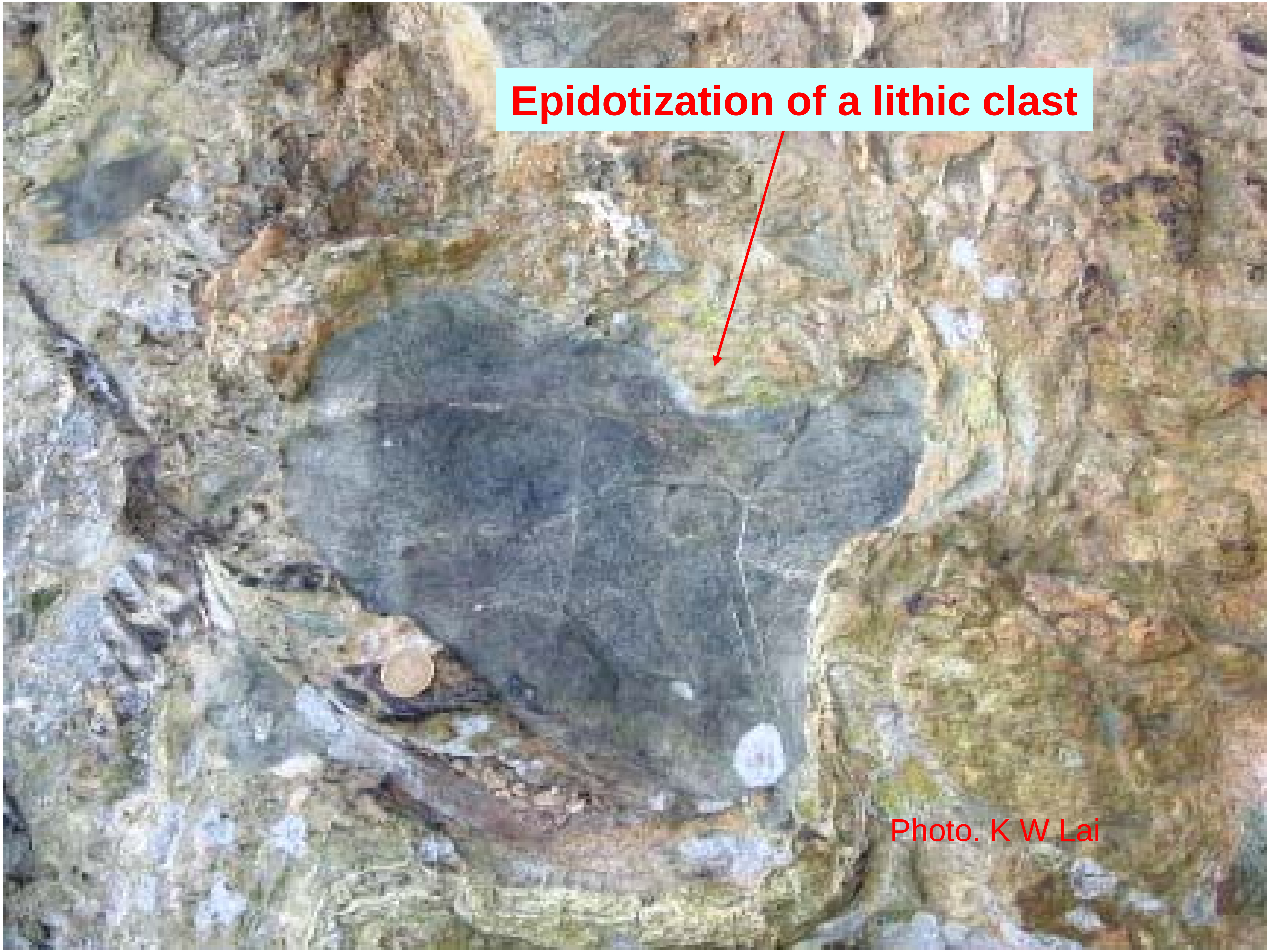
- The temperature of magma in the volcanic vent is from 800º C to 1200º C

- Lithic clast cemented by magma may take place to alter and form the reaction margin

Alteration occurs between andesite and marble

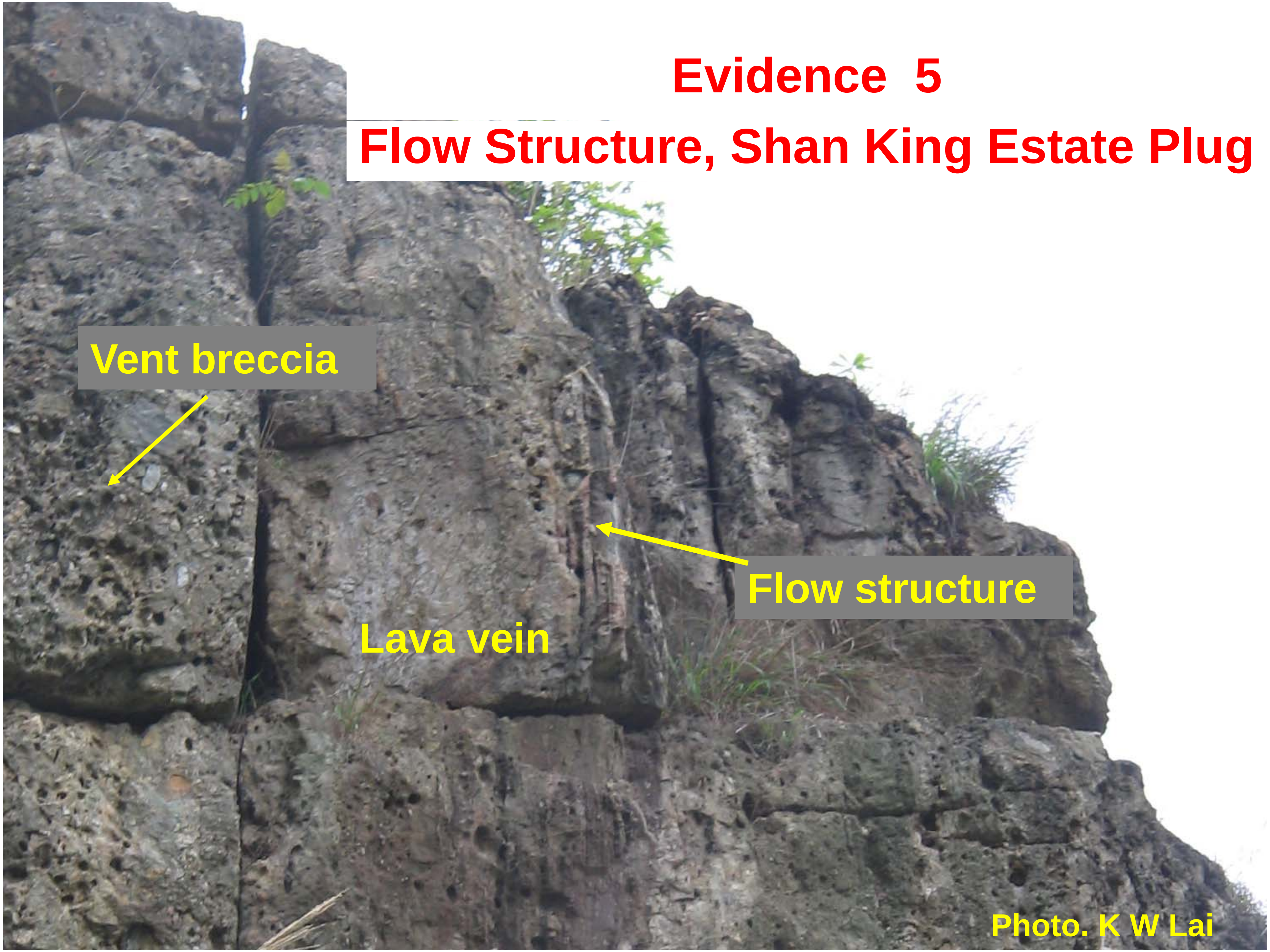
Tsing Shan Monastery




Epidotization of a lithic clast
Photo. K W Lai

Evidence 5

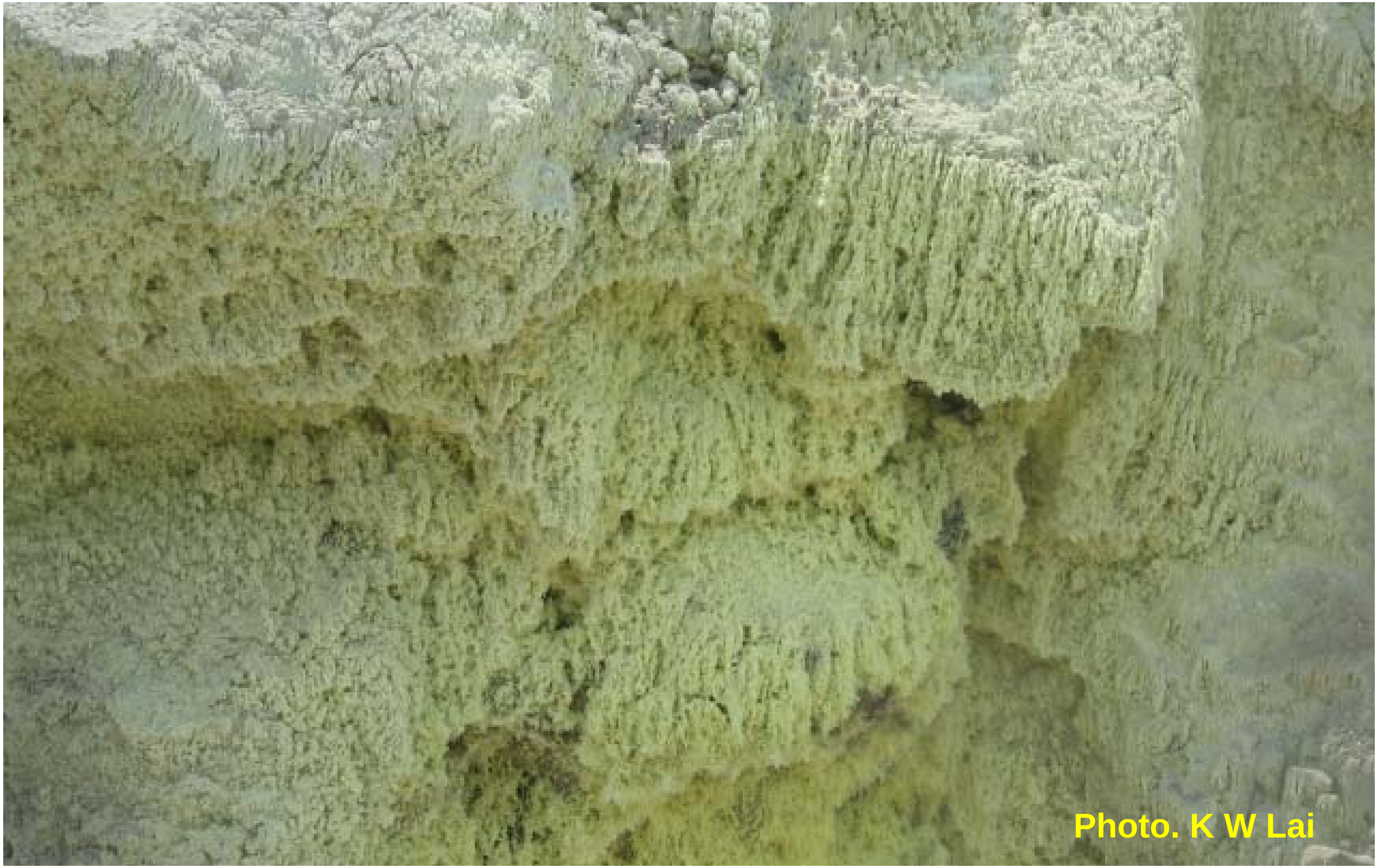
Flow Structure, Shan King Estate Plug



Flow structure, South Por Lo Shan

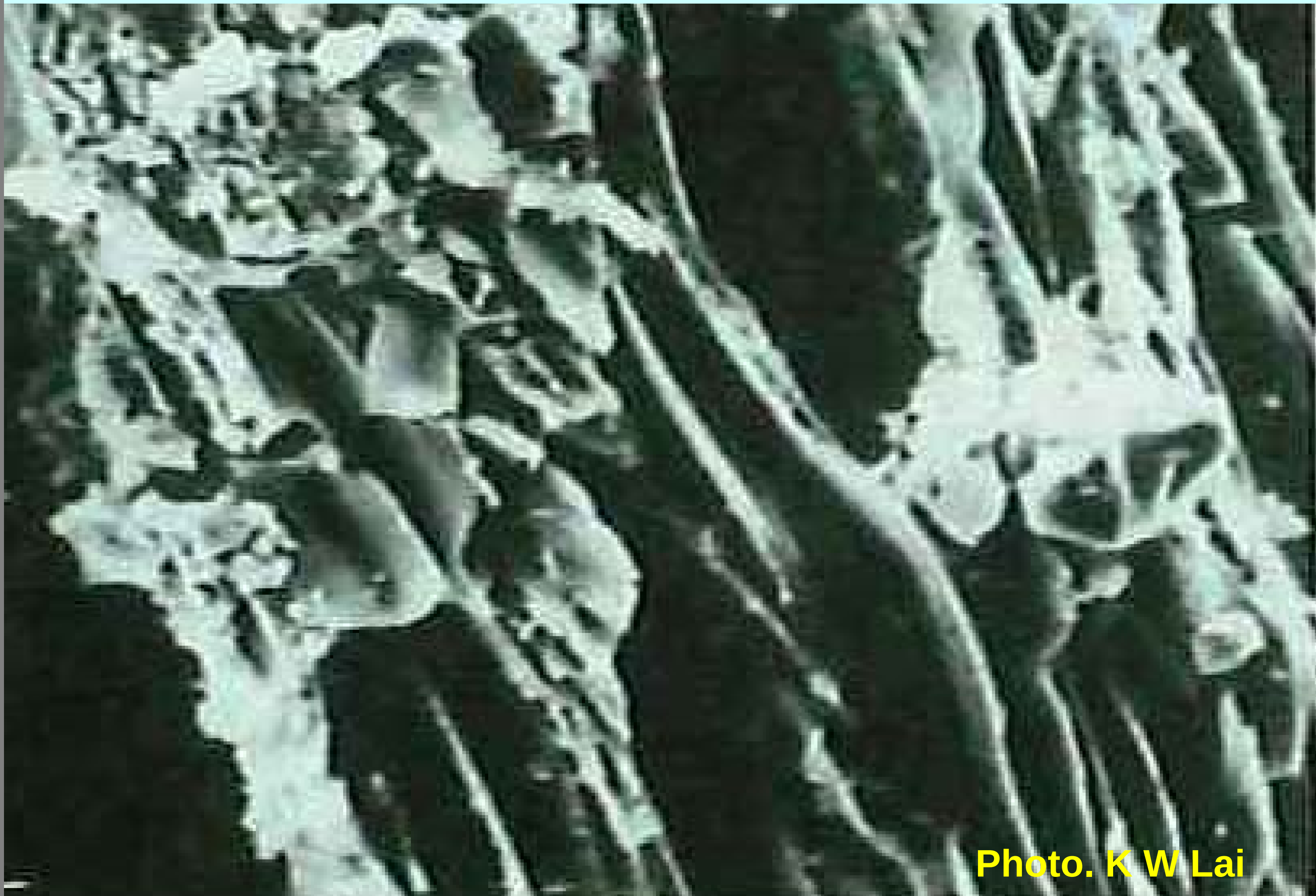
Explosive breccia in a crater, Iceland

Evidence 6. Degassing Structure,



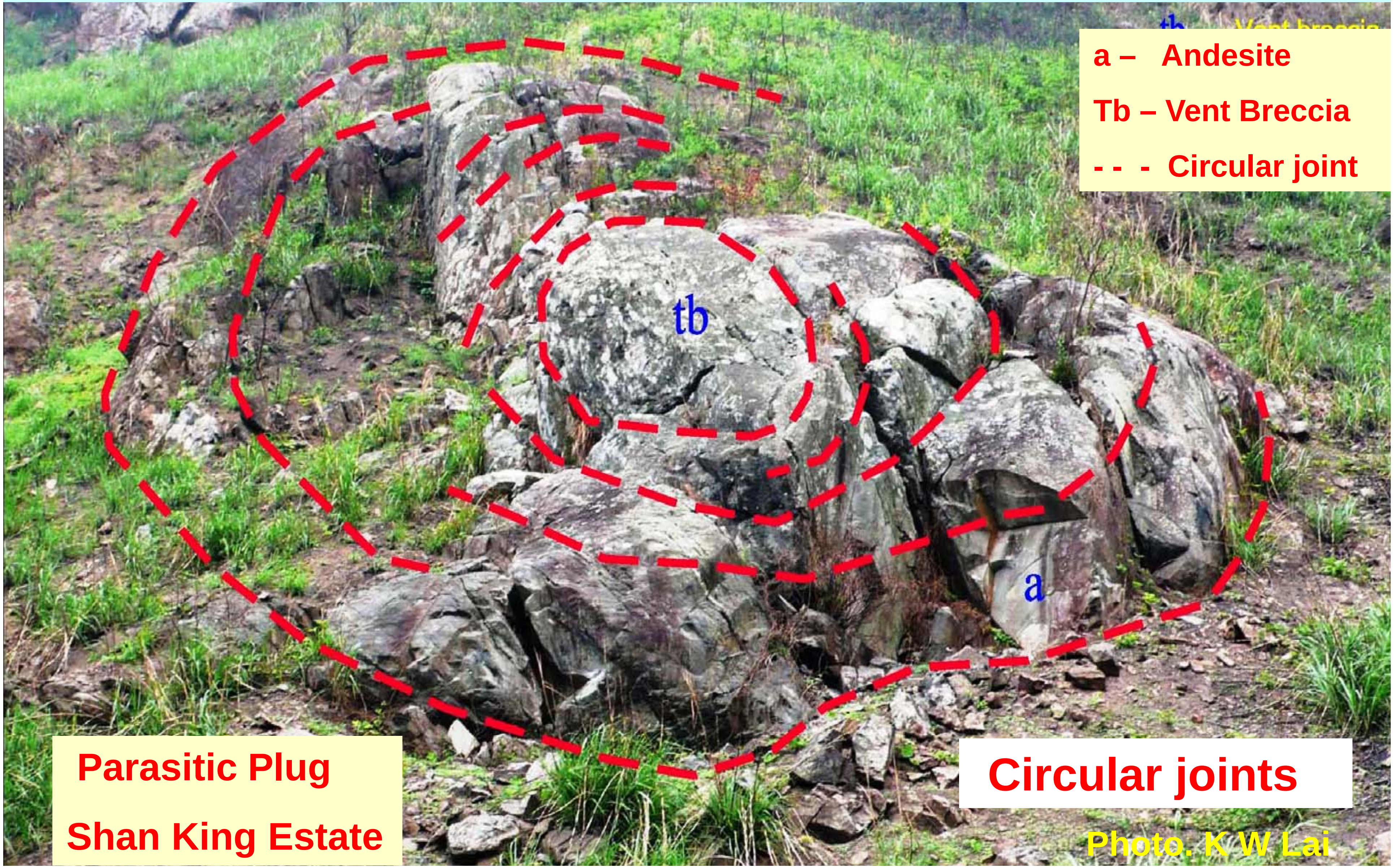
Degassing structure of Andesite,
Yang Ming Shan, Taiwan

Degassing structure of andesite under electronic microscope



Volcanoes of Taiwan (Song S W. 2006)

Evidence 7
Joint Type

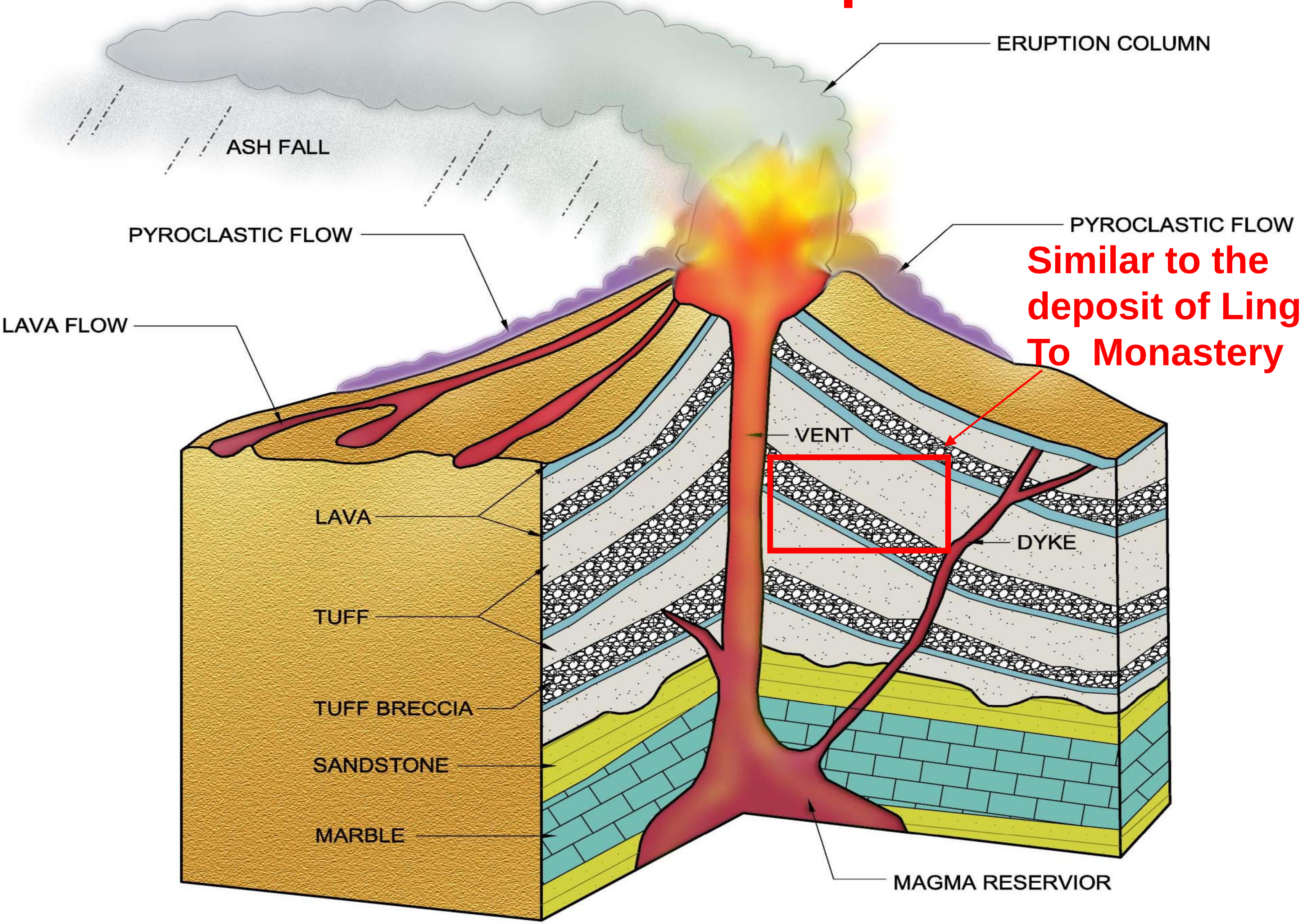


Irregular Columnar Joints

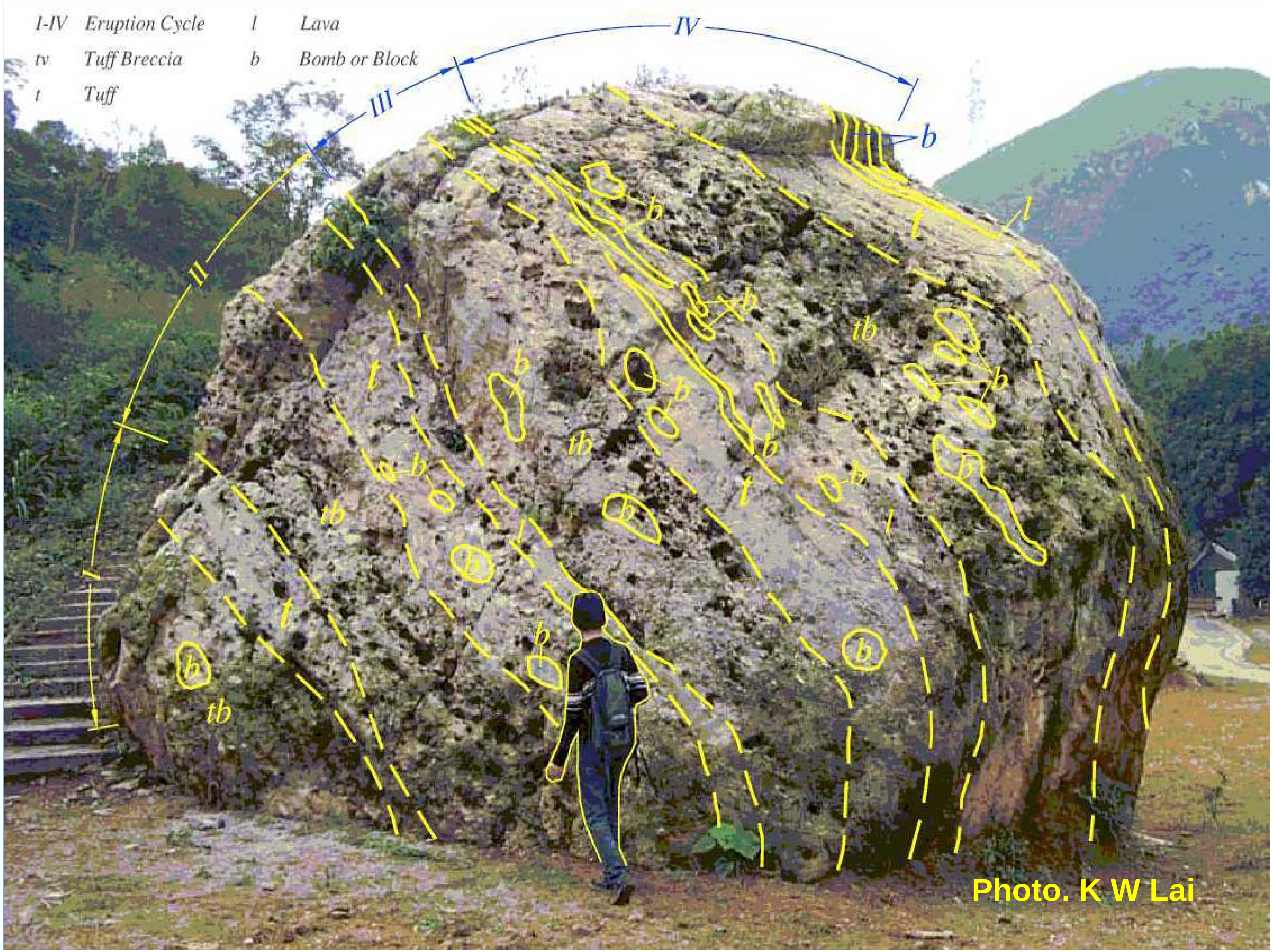
Shan King Estate

Ship Rock, New Mexico, America

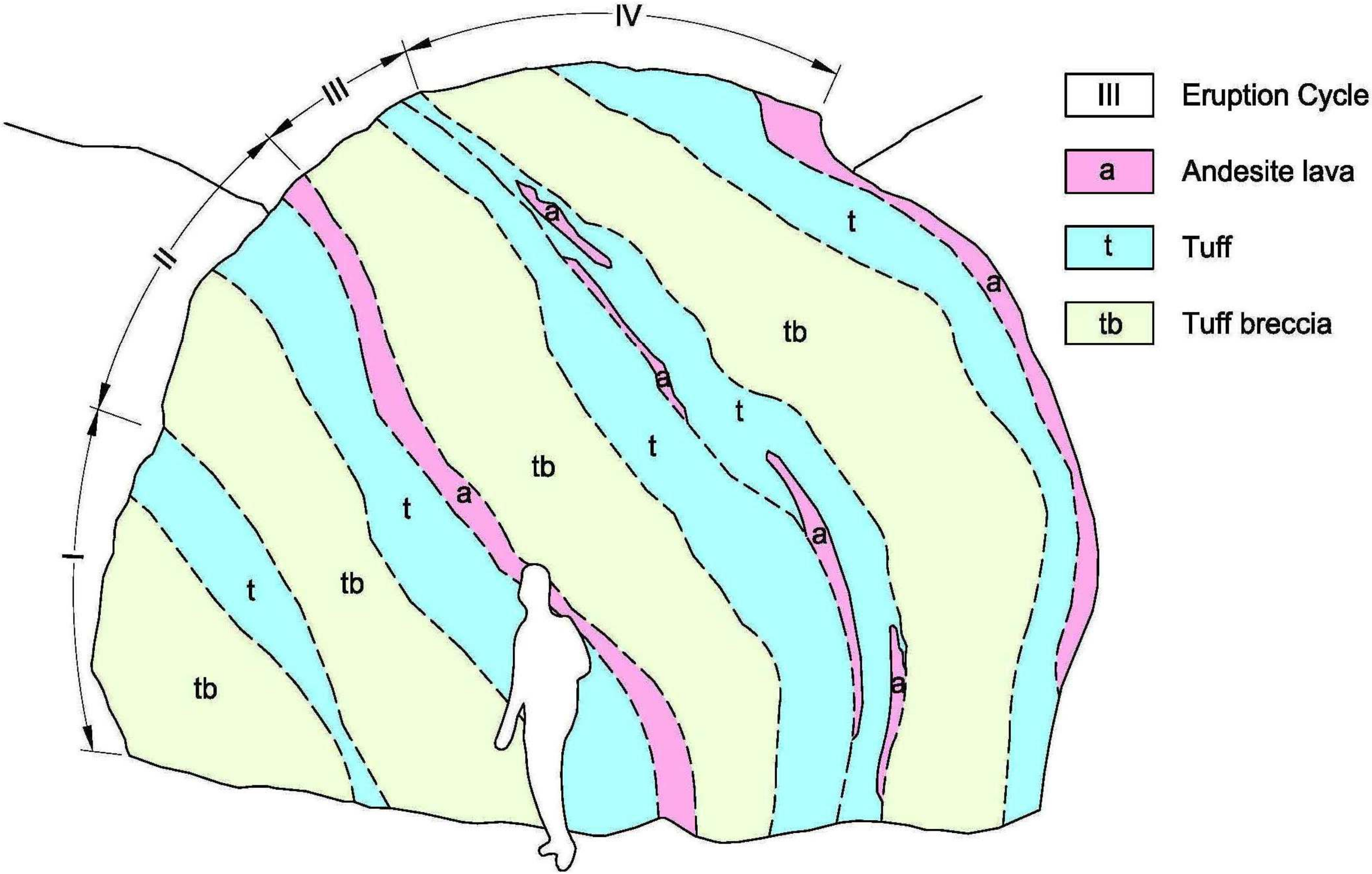
Stratovolcanic Deposits



Ling To Monastery


I-IV Eruption Cycle
tv Tuff Breccia
t Tuff
l Lava
b Bomb or Block
Photo. K W Lai

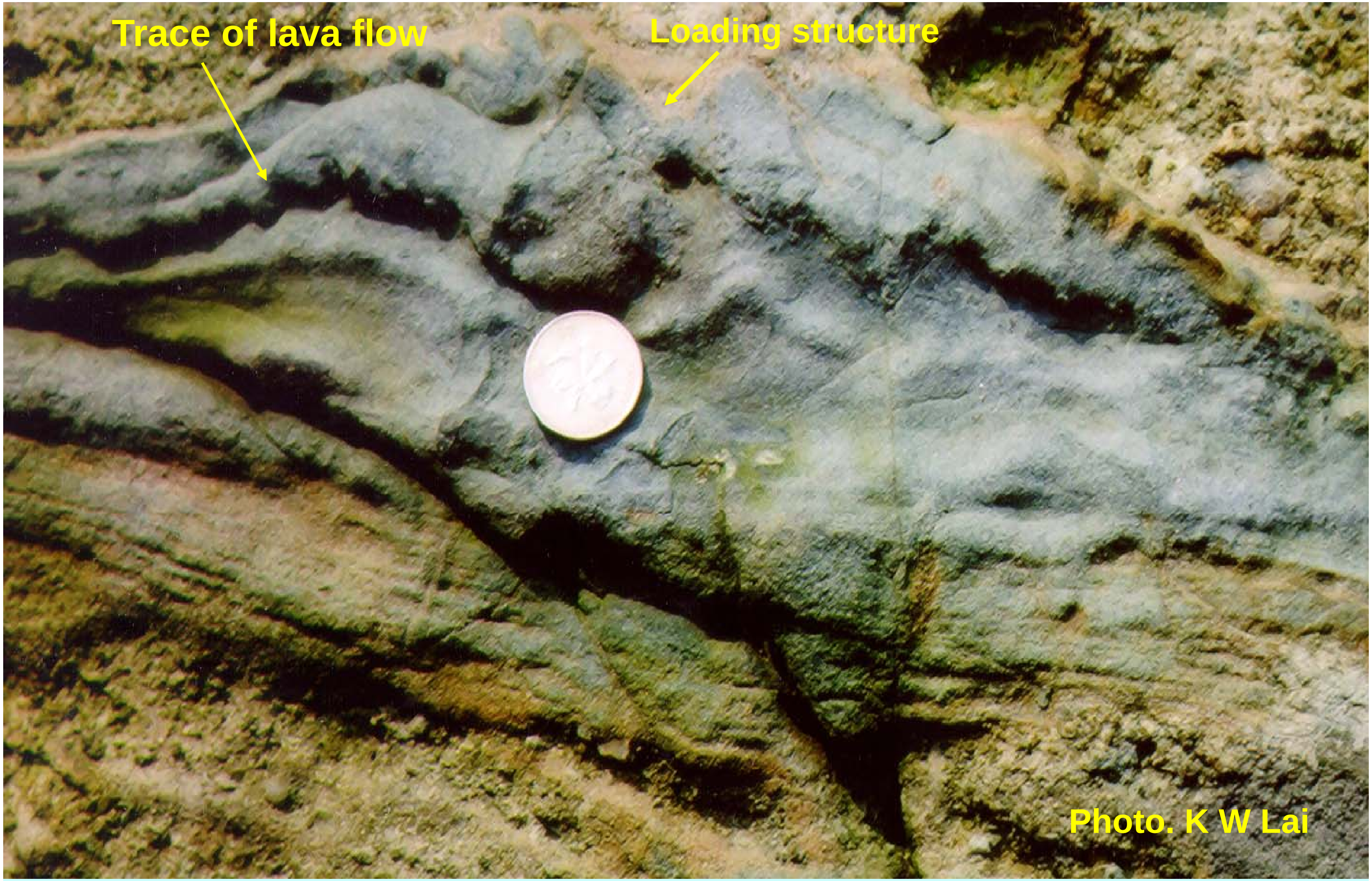
Cyclic Deposits of the Stratovolcano, Ling To Monastery



Ling To Monastery

Shuttle shape lithic clast with reaction margin of air fall deposits

Photo. K W Lai



Spatter Lava of the Air Fall Deposits
Ling To Monastery


Lava Flow Structure
Photo. K W Lai

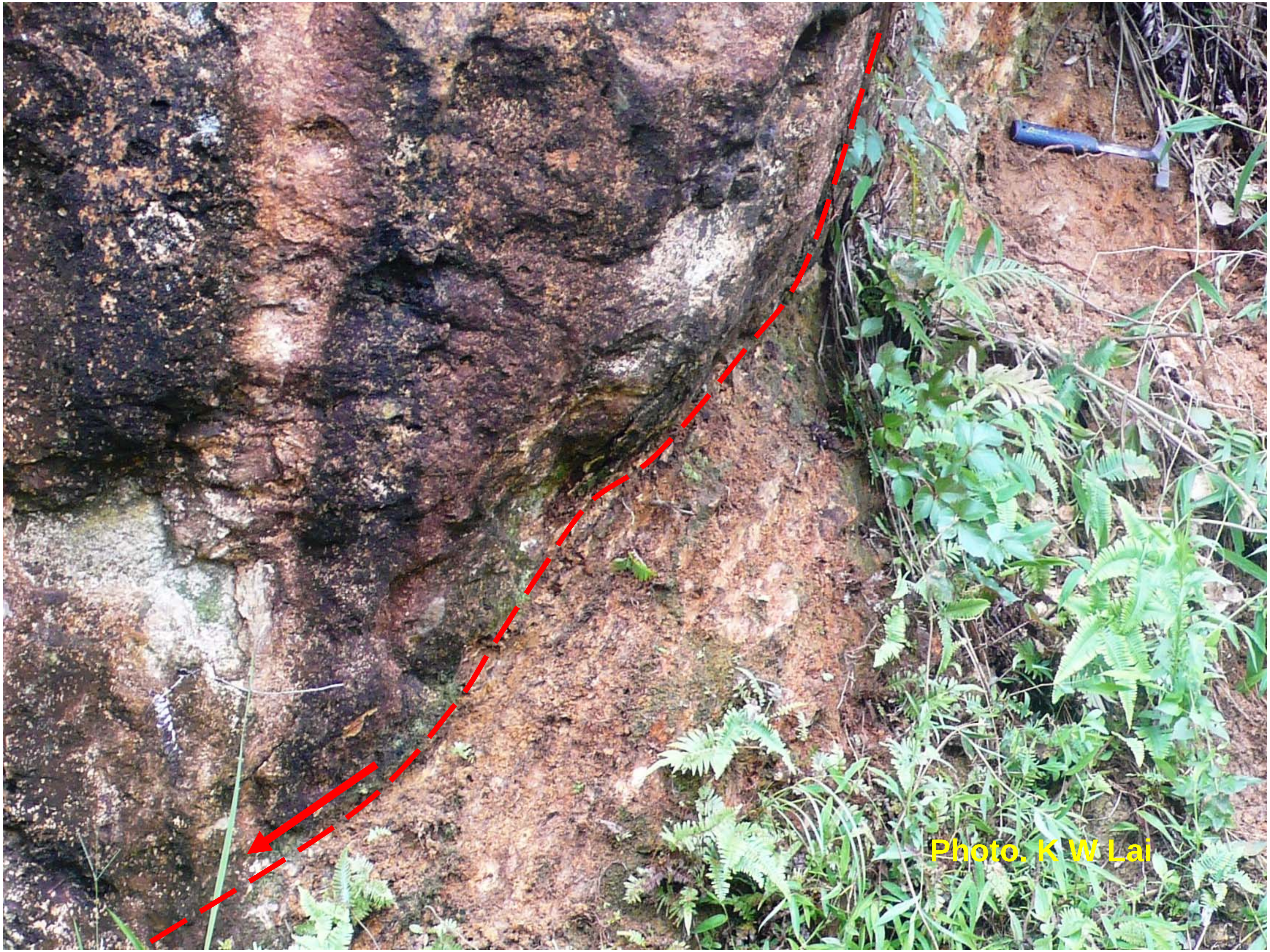
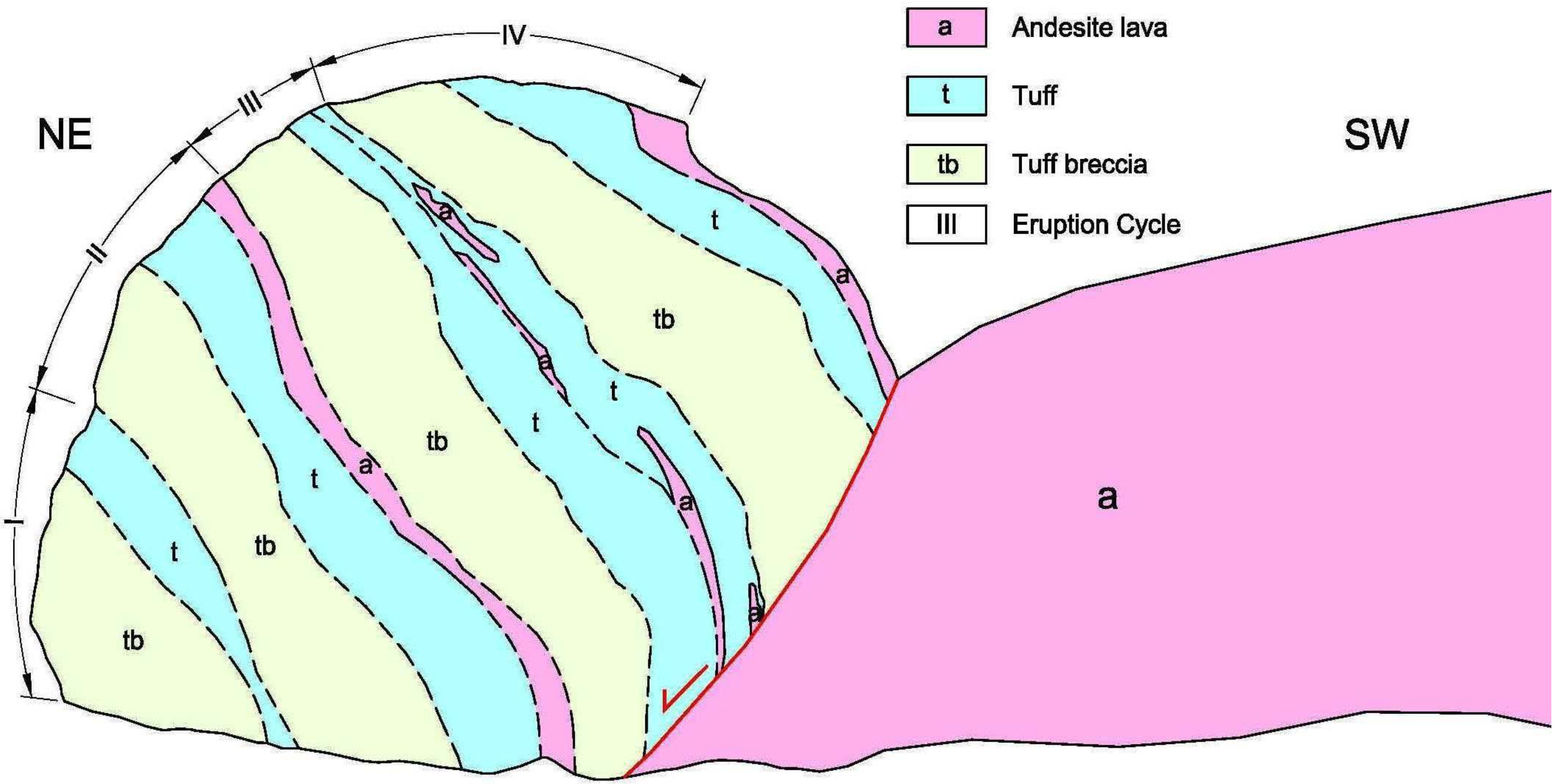


Photo. K W Lai

Fault Contact between the Stratovolcanic Rock and Andesite, Ling To Monastery



Air Fall Deposit Surrounding a Crater Lake
ZhenJiang Huguangyan Geopark

Pyroclastic Fall Deposits forming bedding Huguangyan Geopark, Zhenjiang (湛江湖江岩國家地質公園)

The strata of tuff and tuff breccia deposits in close proximity of a crater lake, Zhenjiang

Air Fall Deposit, Zhenjiang Geopark

Volcanic block fall into the layered tuff, Zhenjiang


Tuff
Tuff Breccia
Air Fall Deposit of Pinatubo
Stratovolcano, Philippine
Photo. K W Lai


Air Fall Deposit of Maal Volcano, Philippine
Photo. K W Lai

Rock Strength Properties

and their

Geotechnical Engineering Significance

Rock Strength Properties

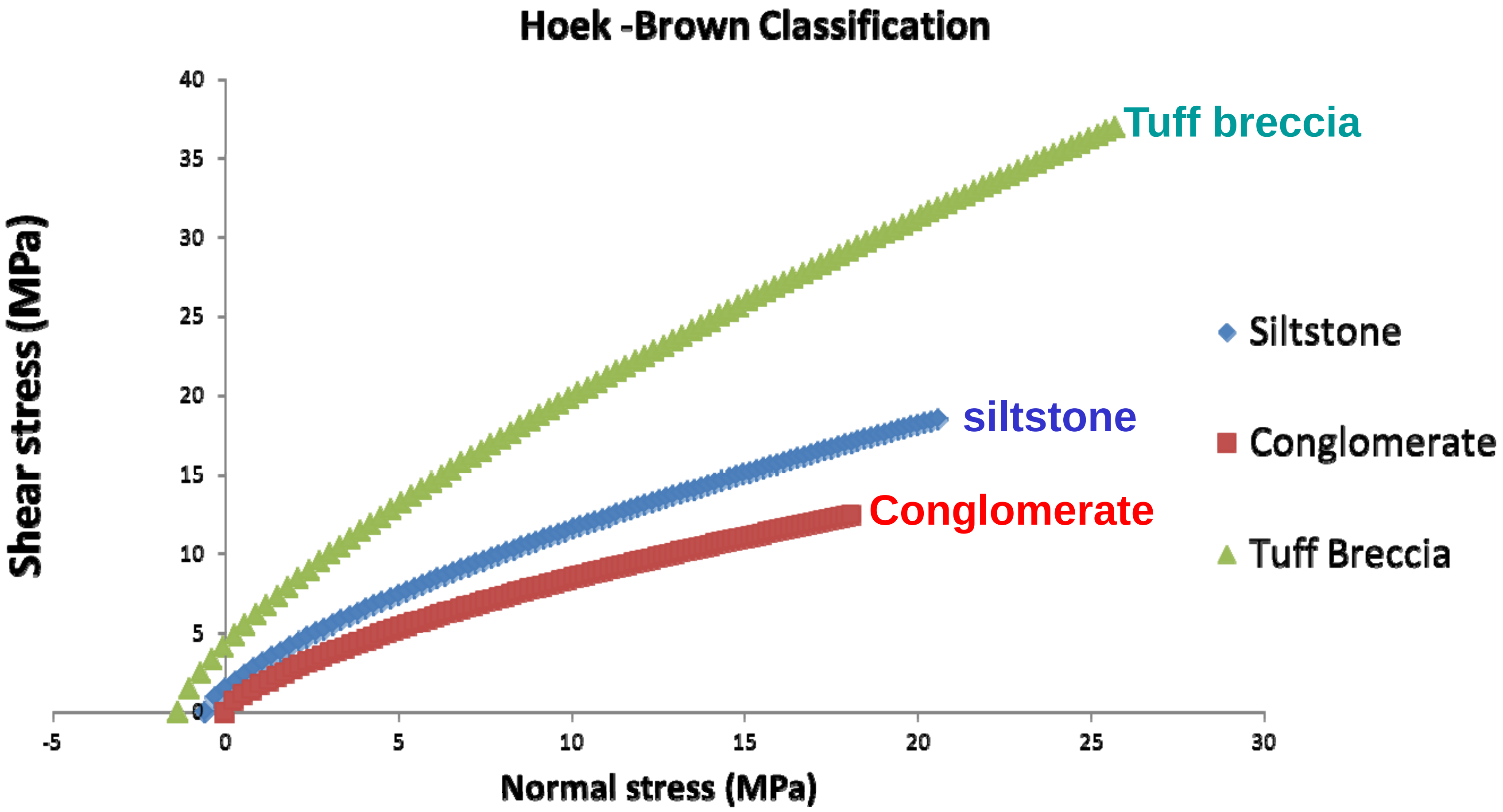
Volcanic rocks are stronger than sedimentary rocks based on uniaxial compression test results

Uniaxial Compressive Strength (MPa)			
Marble Clasts-bearing Tuff Breccia	Calcareous Conglomerate	Clayey Conglomerate	Marble
150 – 296 (1) **195 – 329 (2)**	**9.3 – 31.2 (3)**	**4.0 – 27.4 (4)**	**65 - 138 (1)**
Sources:	(1) GCO (Irfan, 1990) (3) Fugro Lab (2009)	(2) Chan & Kwong (2009) (4) FIGG Lab	

Point Load strength
(MPa)

	Tuff Breccia	Tuff	Metasiltstone/ Metasandstone
GCO(1990) Chan & Kwong (2009)	7.2 - 13 9 - 13	8.8- 11 -	Over 5.5 2 - 6

Hoek-Brown Classification



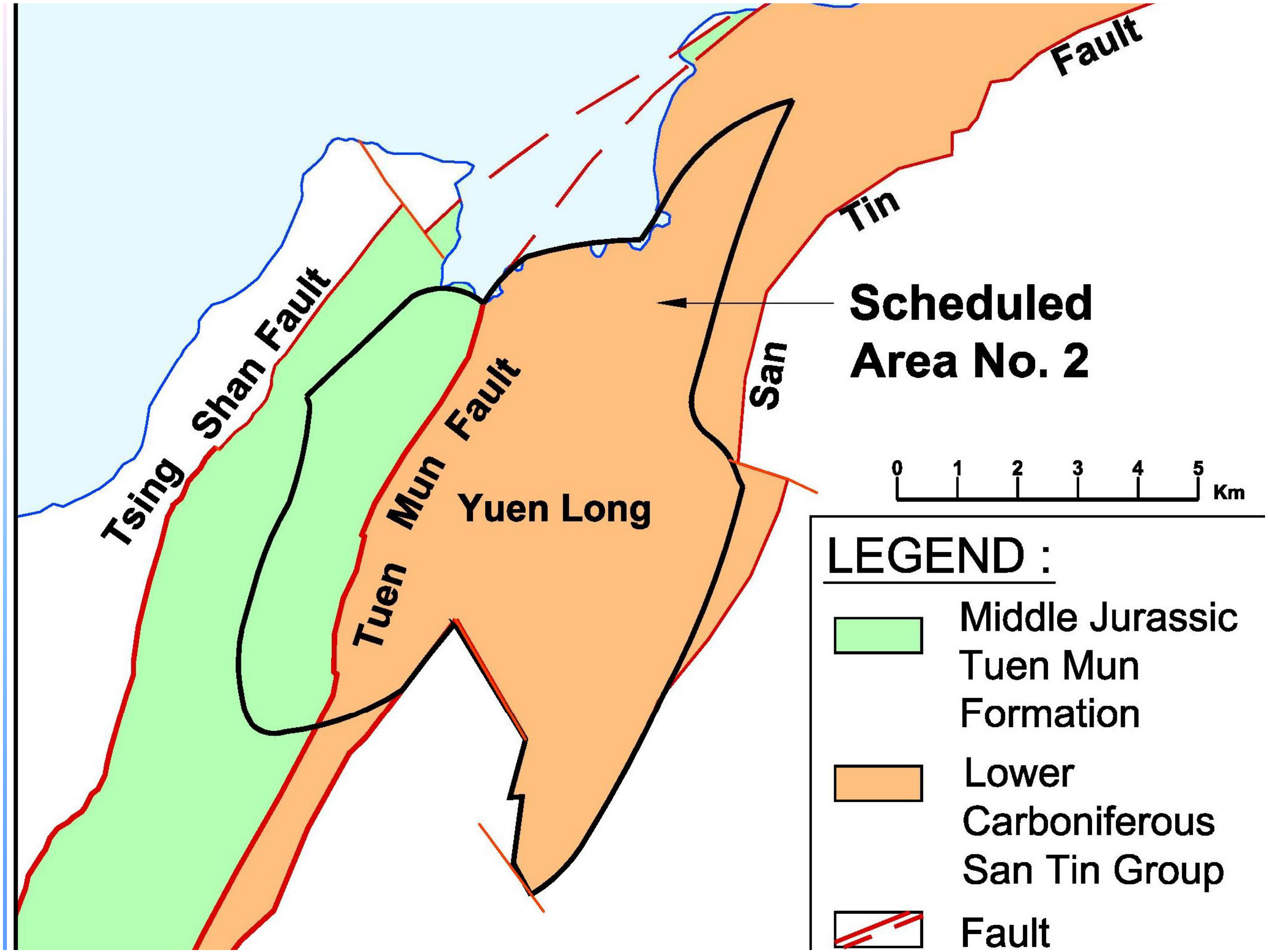
Engineering Concern of Different Rockmasses

Rockmass		Tuff Breccia	Conglomerate	Siltstone
Hock-Brown Classification Mohr-Columb Fit		C=6.5MPa Ø=56.1deg	C=2MPa Ø=31.4deg	C=3.2MPa Ø=38.2deg
Foundation (Bearing Capacity)		High	Low	Moderate
Tunnel	Support Pressure	Low	High	Moderate
	TBM Cutter Abrasion (Worn Out)	Moderate	High	Low
Site Formation (Control Blasting-Final Face Quality)		High	Low	Moderate

Accurate geological interpretation provides the correct geological model which affects the engineering design

- Foundation of a marble clasts–bearing tuff breccia site

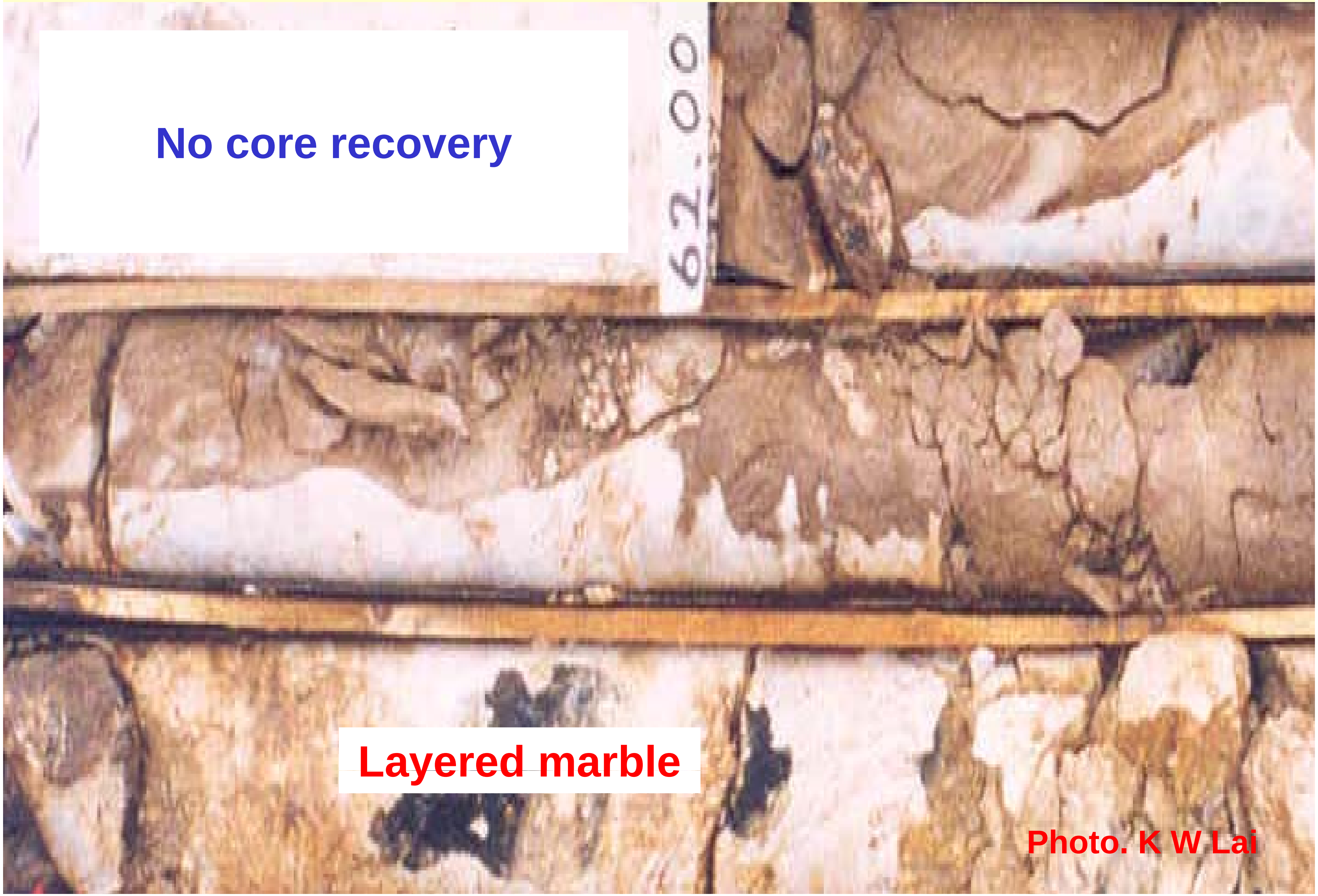
- Foundation of **a l**ayered marble site



Tsing Shan Fault
Tuen Mun Fault
San Tin Fault
Yuen Long
Scheduled Area No. 2
0 1 2 3 4 5 Km
LEGEND :
Middle Jurassic Tuen Mun Formation
Lower Carboniferous San Tin Group
Fault

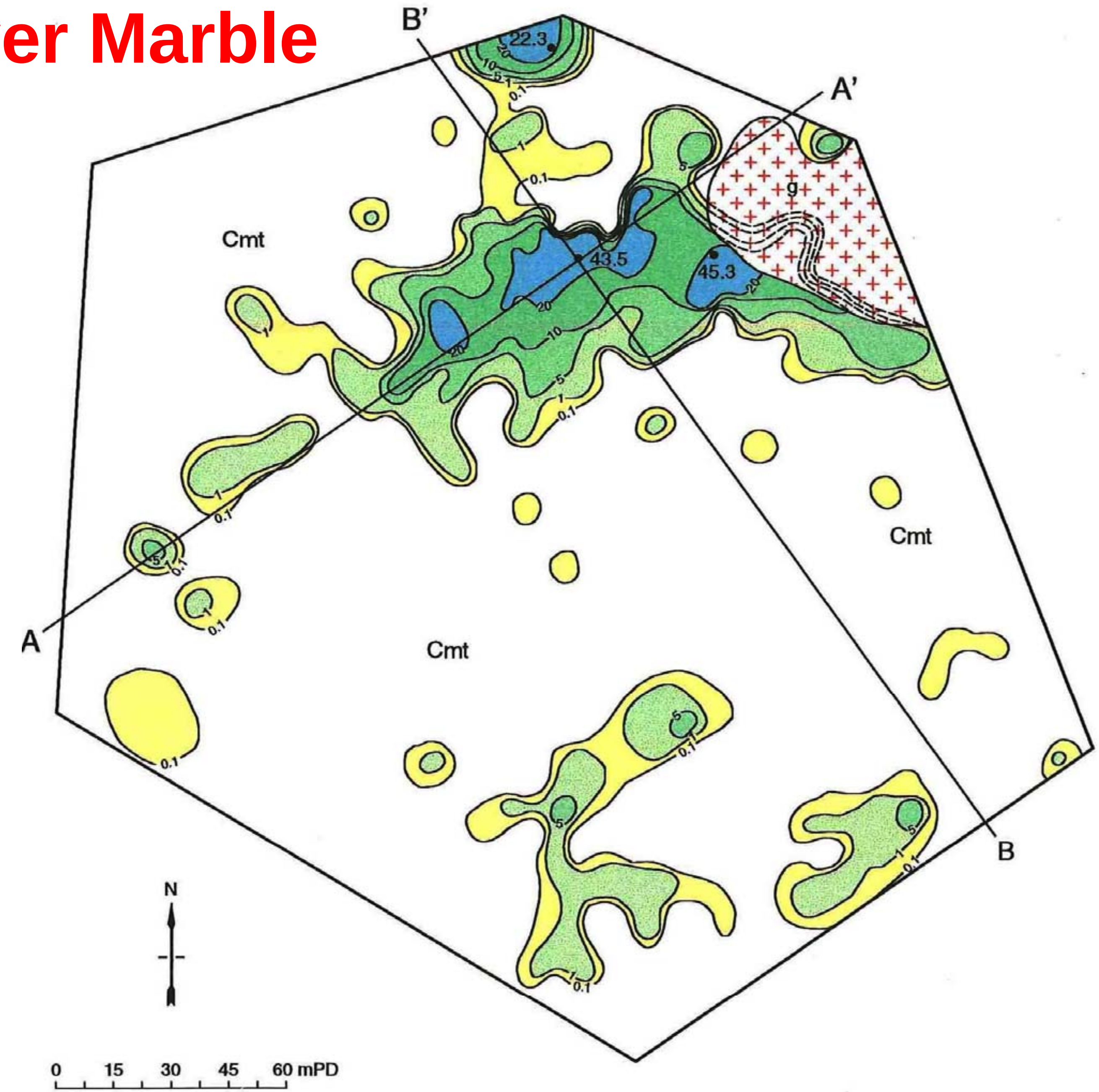
Layered marble (Sedimentary)

Layered marble can give rise to large cavities



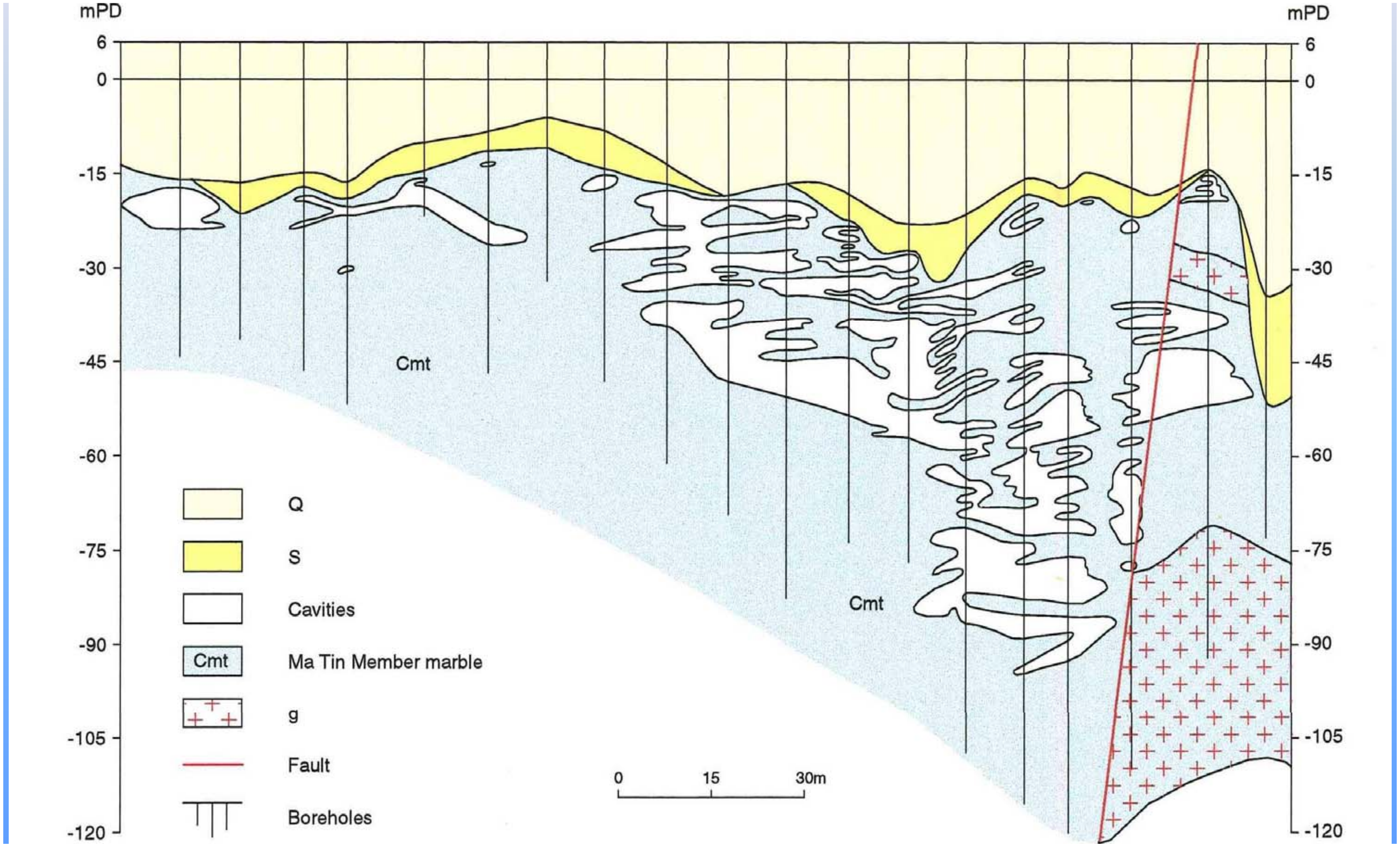
A Site of Layer Marble

Contour showing the cumulative length of cavities in borehole. (m)

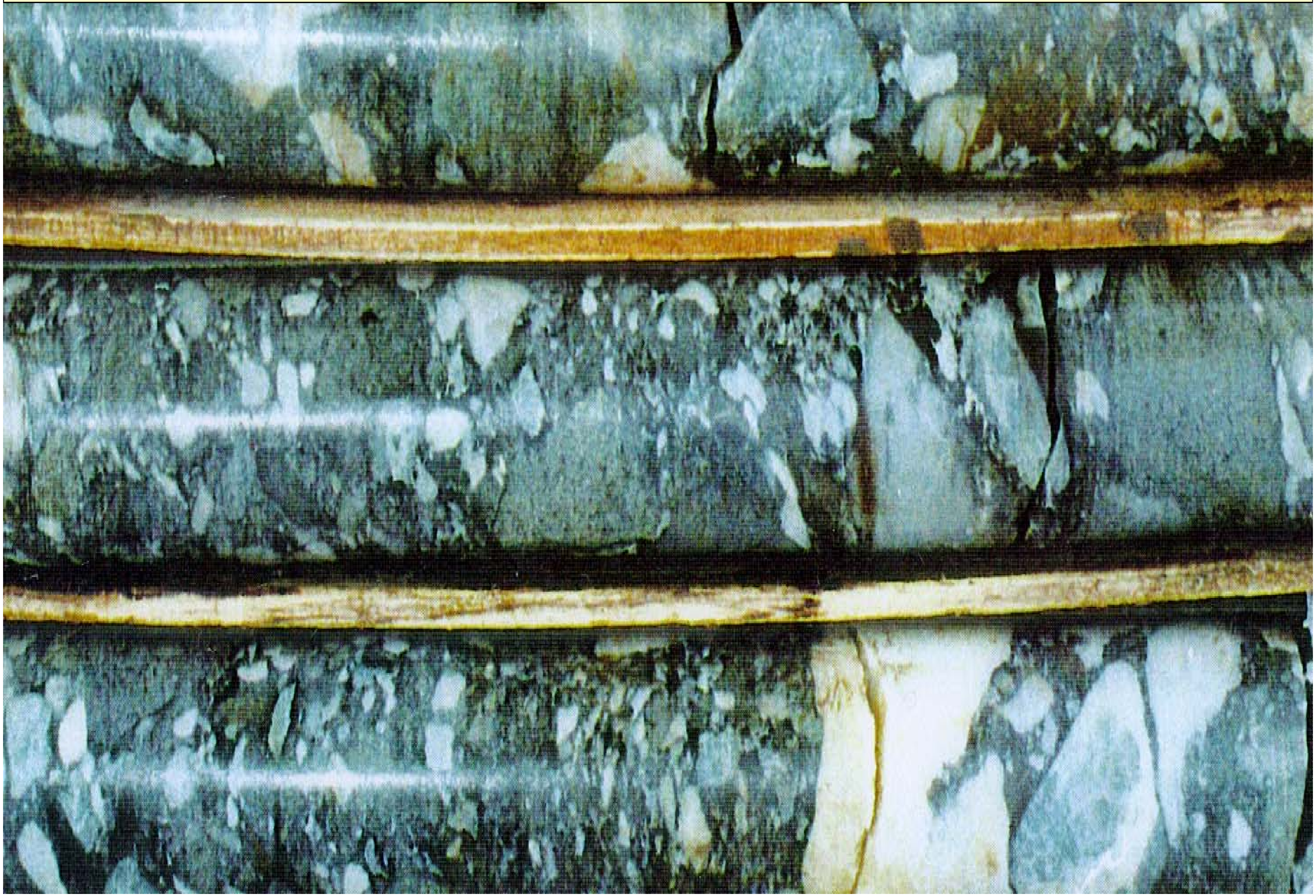


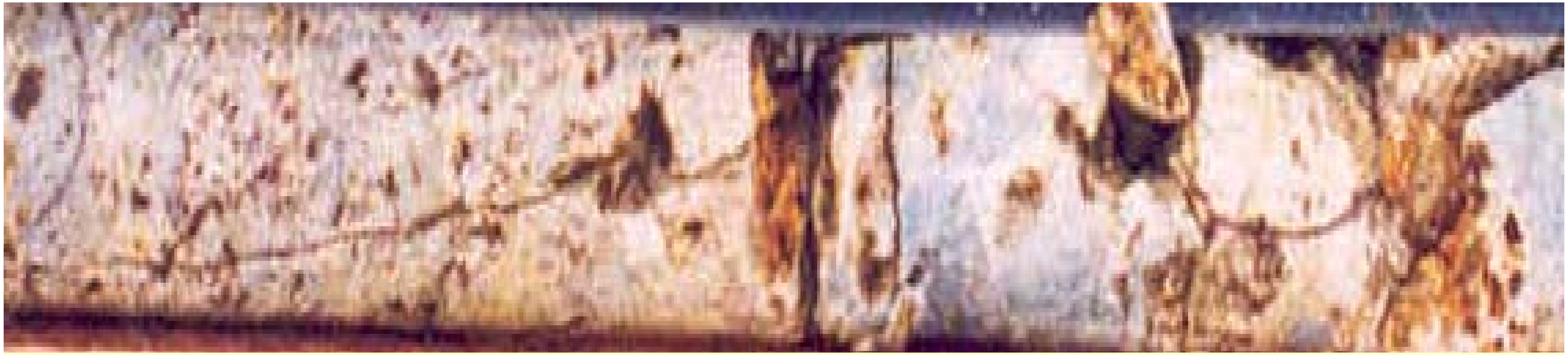
A Site of layer marble containing Large Cavities

A - A Section

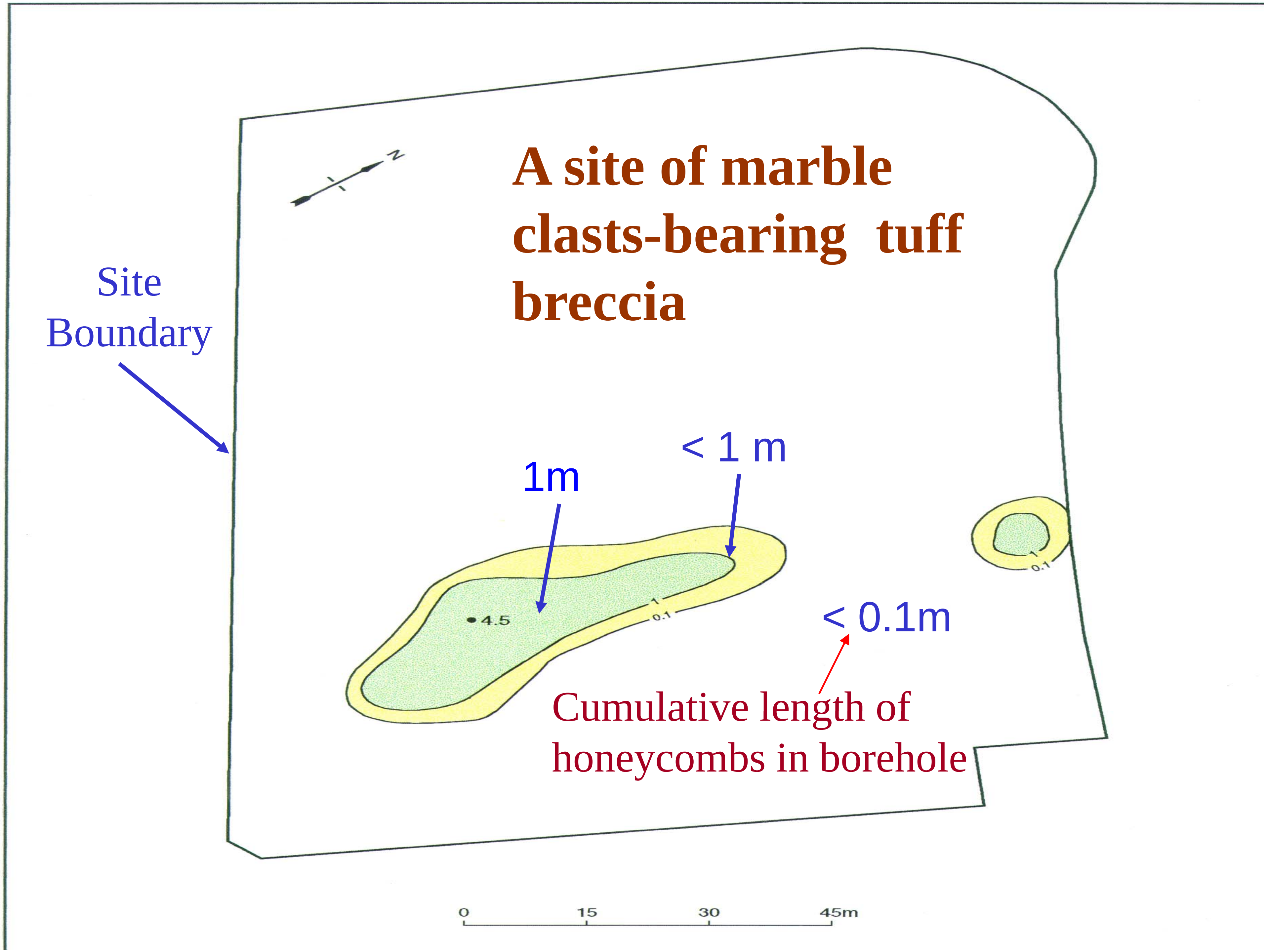


Marble clasts-bearing Tuff breccia (Volcanics)



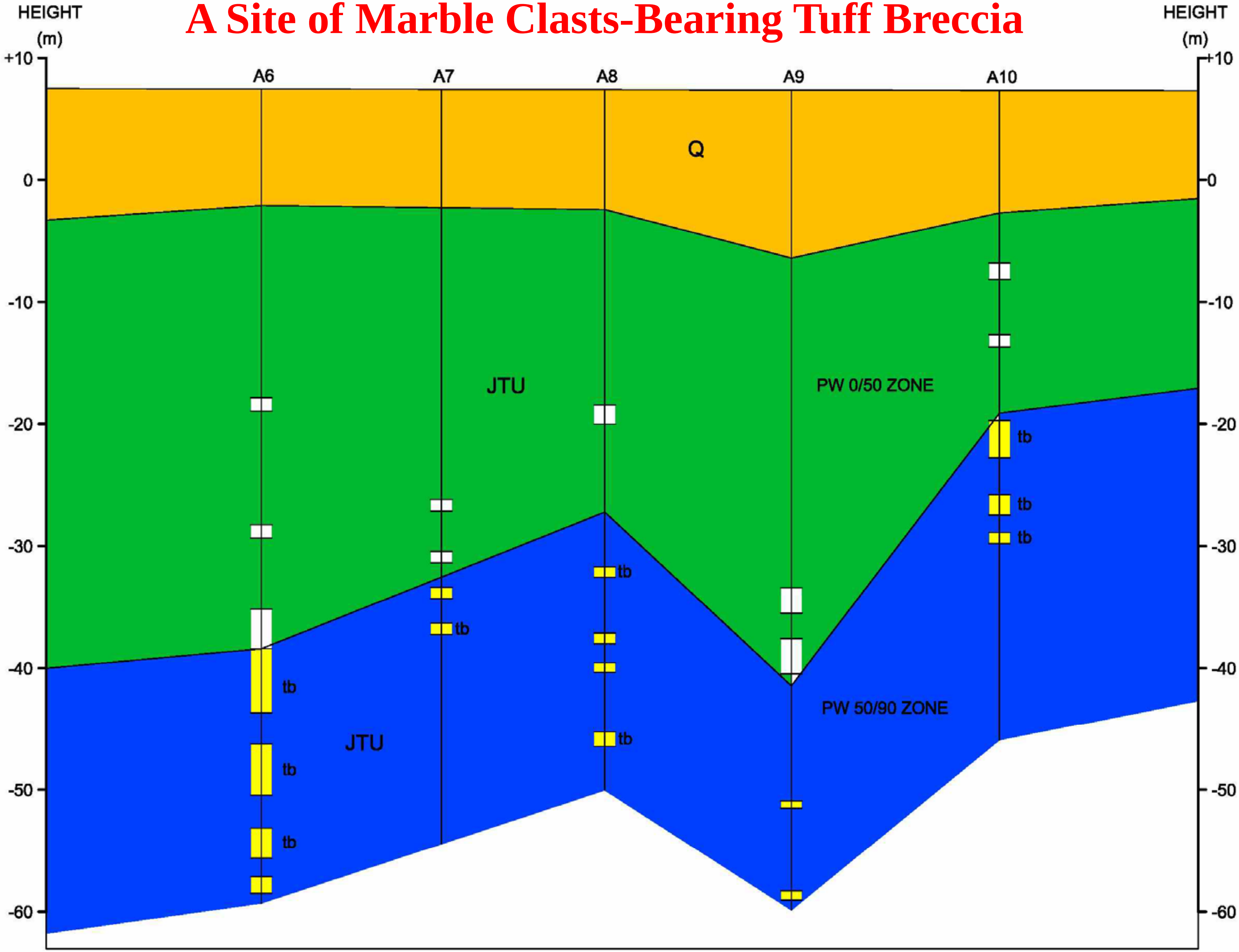


Honeycomb weathering occurs in the marble clasts- bearing tuff breccia



A site of marble clasts-bearing tuff breccia
Site Boundary
1m
< 1 m
< 0.1m
Cumulative length of honeycombs in borehole
4.5
1
0.1
0
15
30
45m
N

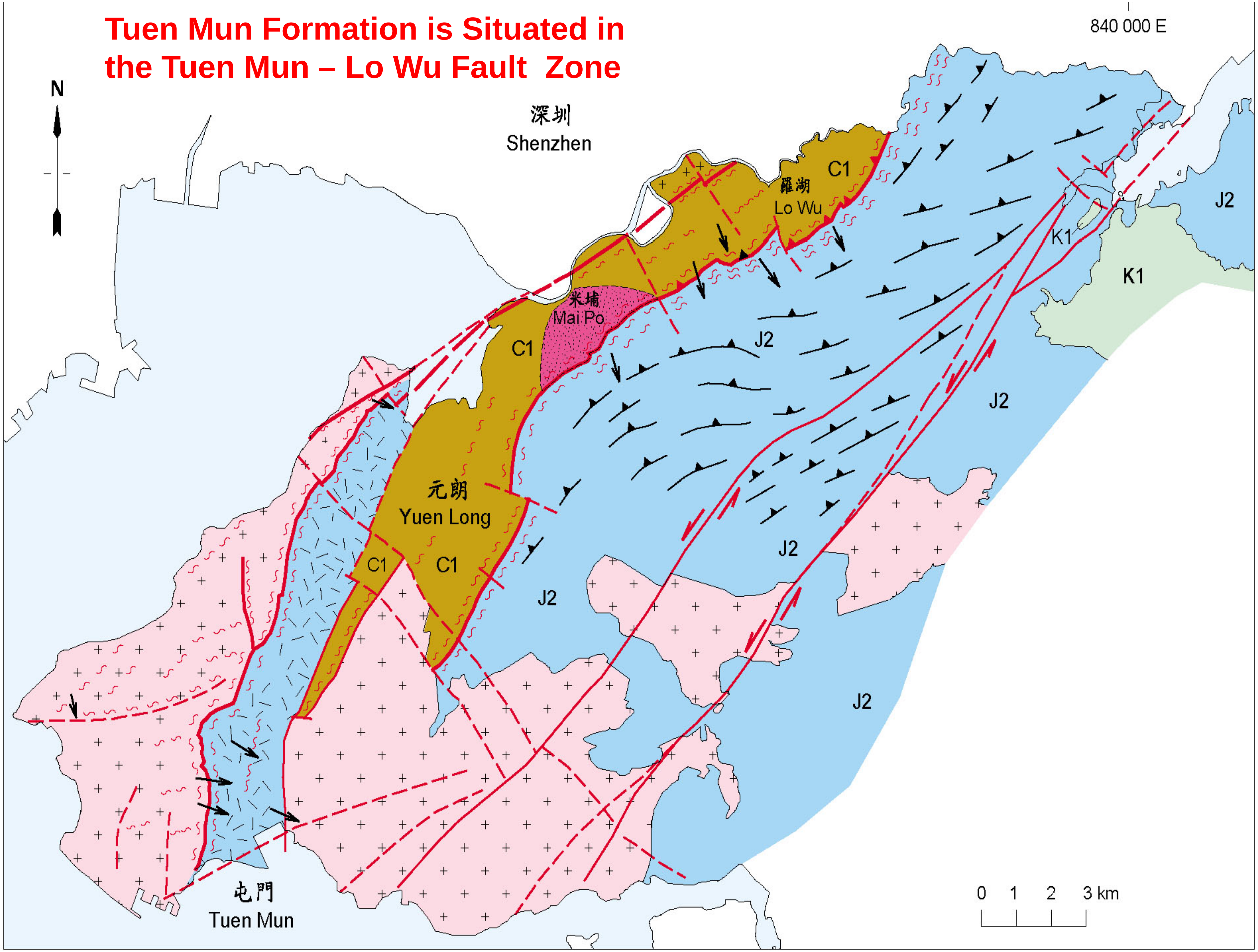
A Site of Marble Clasts-Bearing Tuff Breccia



Mylonitization of Marble Clast-bearing Volcanic Rocks

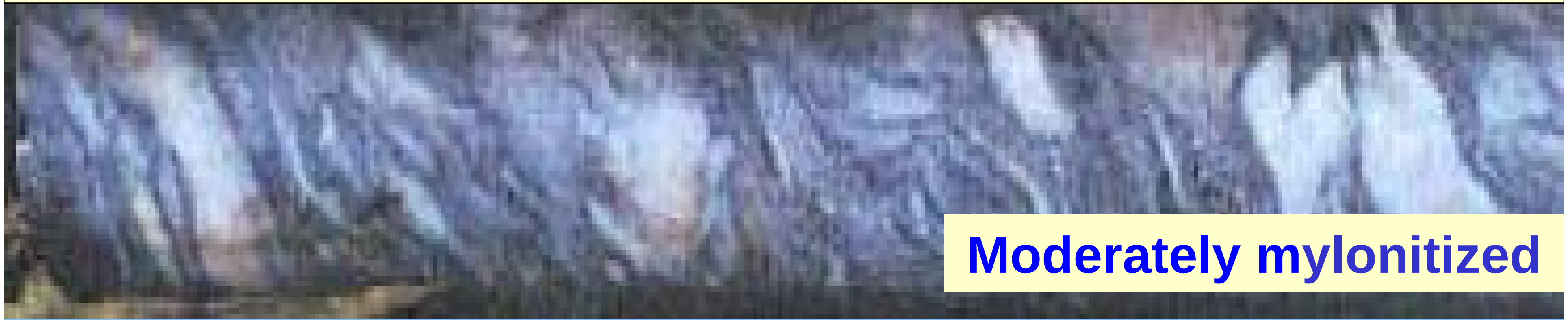
- Rocks were subject to ductile deformation and form mylonite when adjacent to or within a fault zone
- Mineal crystals decreased their grain size changing to subgrains and recrystallized
- The flattened and elongated mylonite of marble clast-bearing volcanic rocks are often misidentified as metasiltstone with thin layers of marble in borehole logs

Tuen Mun Formation is Situated in the Tuen Mun – Lo Wu Fault Zone



Mylonitized Marble Clasts - Bearing Tuff Breccia

Ductile Deformation of Marble Clast-Bearing Tuff Breccia



Conclusions

- The key reason to finalize the rock type of the Tuen Mun Formation is to allow detailed and accurate geological mapping
- Special attention should be paid to distinguishing the mode of occurrence on site
- For fine-grained volcanic rock, it is necessary to conduct chemical analysis to determine all the key chemical constituents to confirm the rock type


Many thanks