

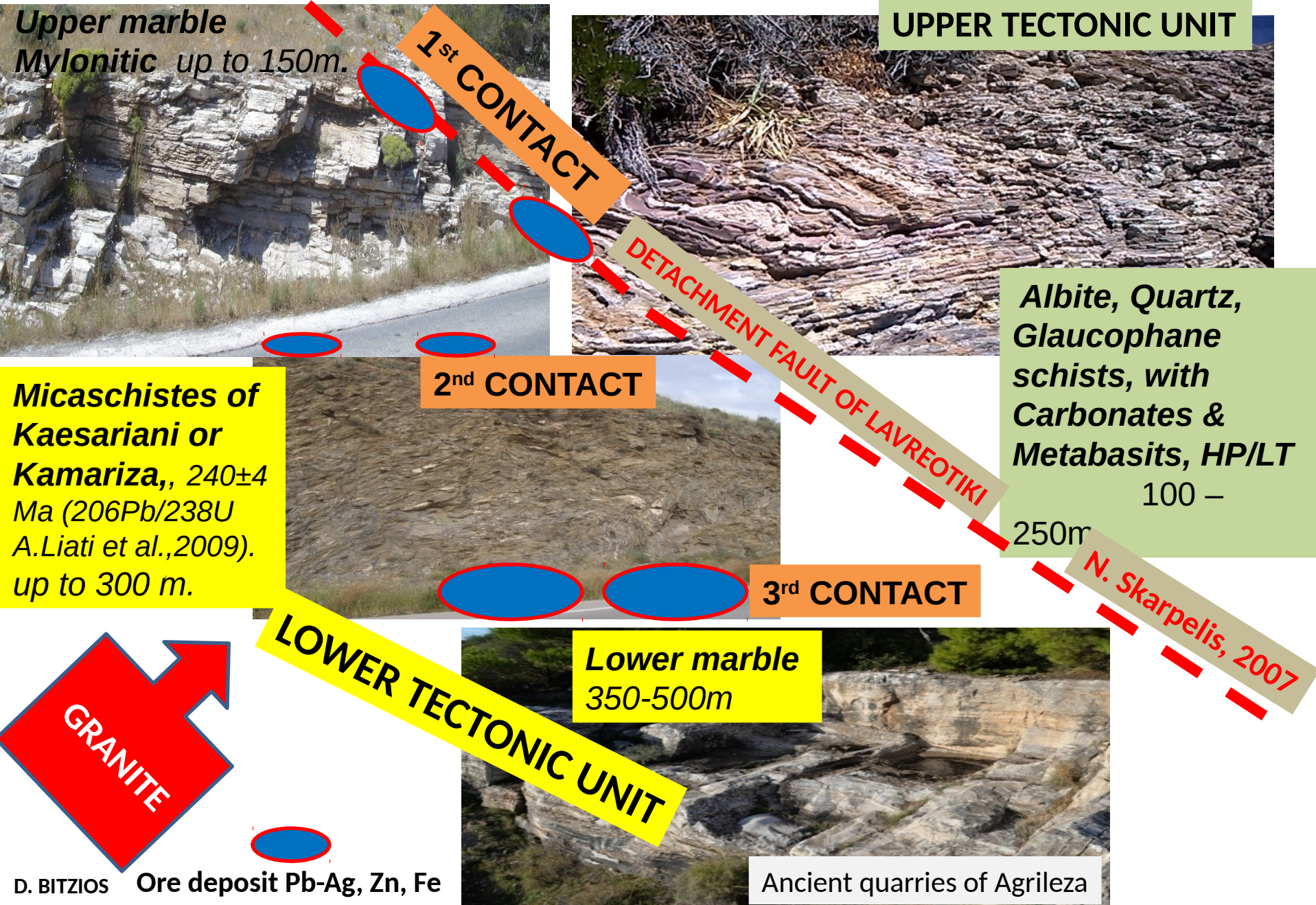


**“Η ΓΕΩΛΟΓΙΑ ΚΑΘΟΡΙΣΤΙΚΟΣ ΠΑΡΑΓΟΝΤΑΣ ΤΗΣ
ΑΝΑΠΤΥΞΗΣ ΤΟΥ ΑΡΧΑΙΟΥ ΜΕΤΑΛΛΕΥΤΙΚΟΥ ΛΑΥΡΙΟΥ”.
“THE CRITICAL ROLE OF GEOLOGY IN ANCIENT LAVRION
MINING DISTRICT”**

By Dr. Dimitris Bitzios



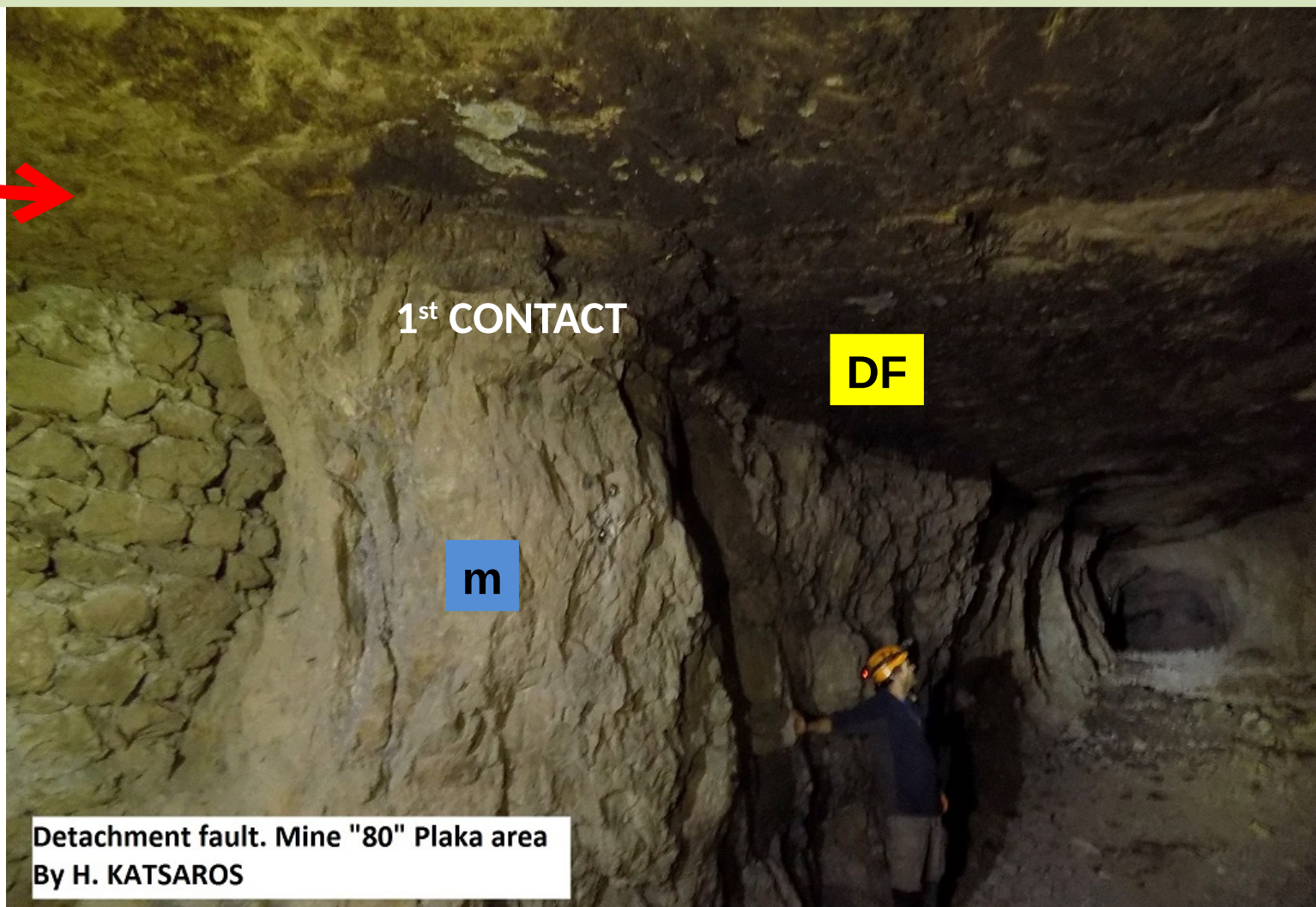
TWO MAIN TECTONIC UNITS OF METAMORPHIC ROCKS ARE IDENTIFIED, SEPARATED BY A DETACHMENT FAULT



Transfer of the metal-bearing fluids 7,6 Ma (A. Berger, et. al.2012), via the detachment fault.

Μεταλλοφόρα διαλύματα κυκλοφόρησαν πριν από 7,6 εκμ. χρόνια περίπου μέσω του ρήγματος αποκόλλησης.

Detachment Fault (DF). (Orange - brownish dolomitic breccias). (11,9 - 8,3 Ma, A. Liati, N. Skarpelis & G. Pe-Piper ,2009) The footwall rock is the upper marble (m).

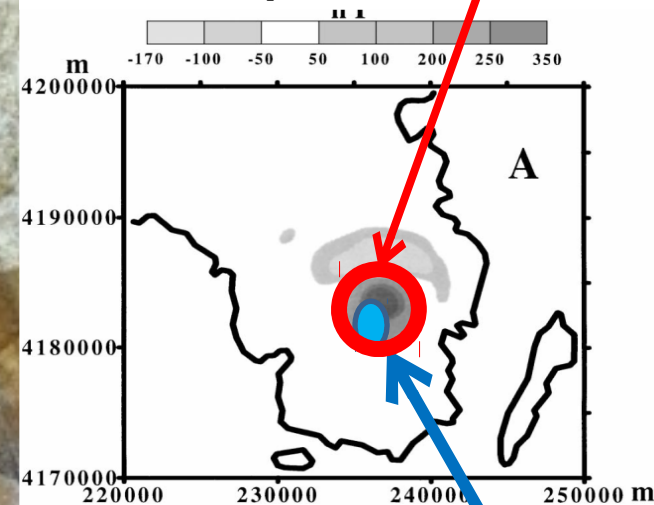


Detachment fault. Mine "80" Plaka area
By H. KATSAROS

GRANODIORITE in the Plaka area

7.1±0.6 - 7.9 ± 0.6 Ma (U-Th/H , A. Berger, et. al.2012).

The long-wave length aeromagnetic anomaly, reflects on a hidden body that is most probably a granitic intrusion.(Tsokas et al. 1998).



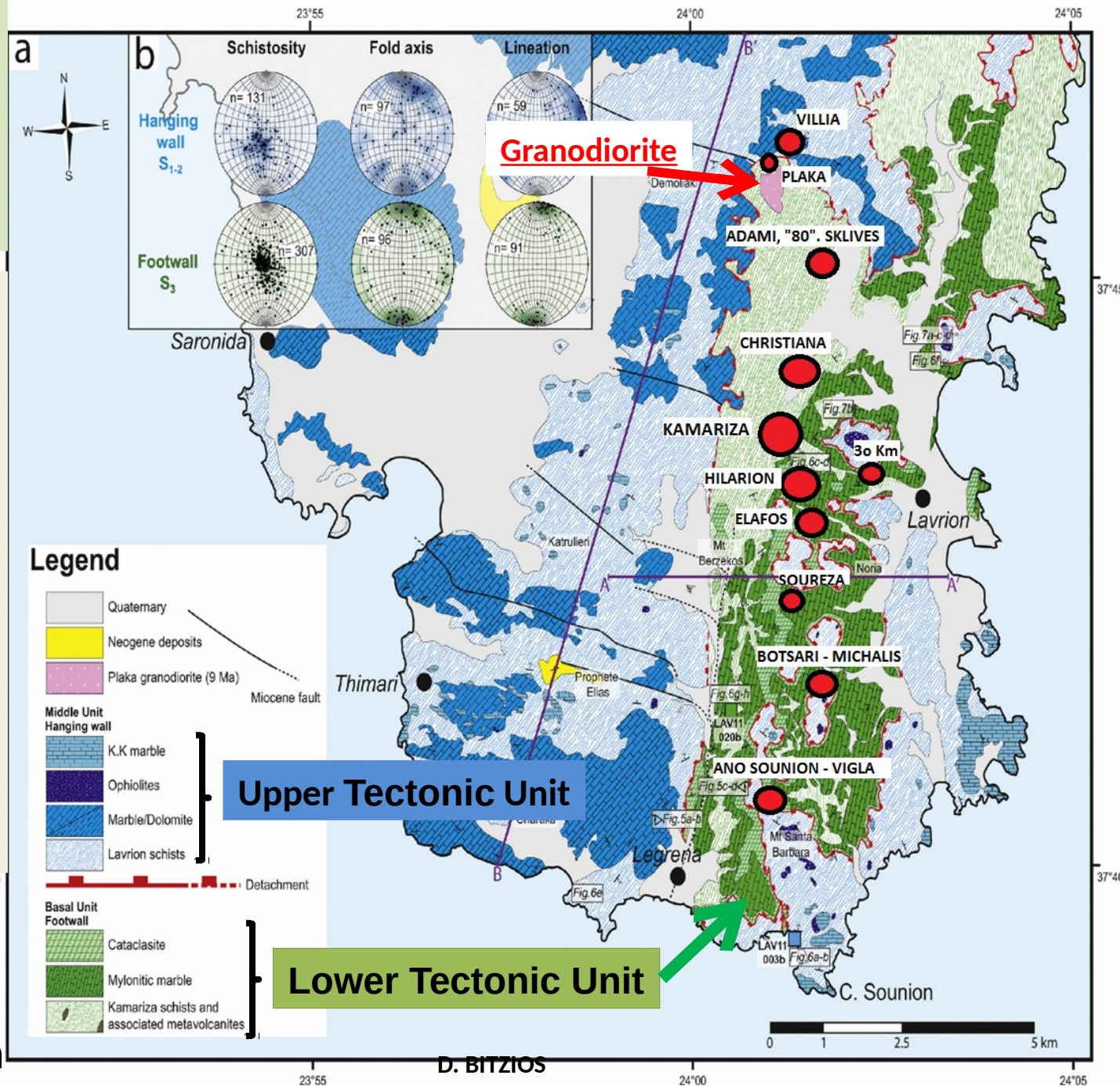
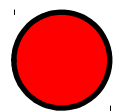
Kamariza ore body

Source of metals, heat transfer & associated hydrothermal solutions

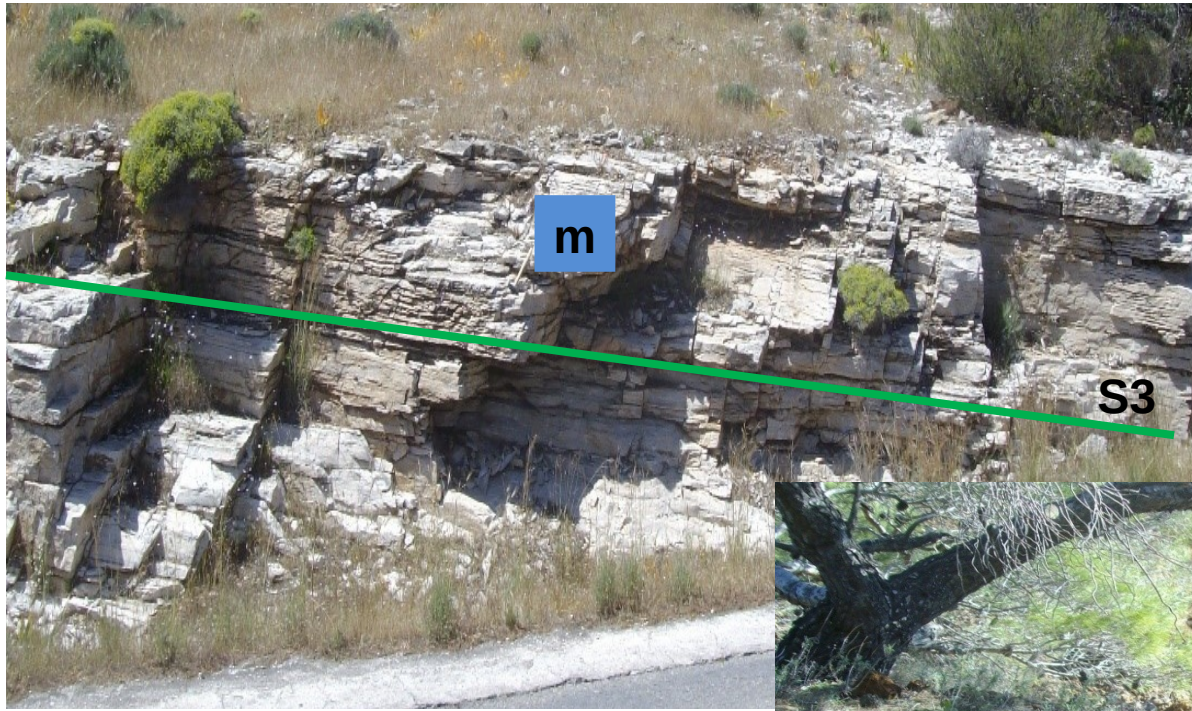
GEOLOGICAL MAP OF LAVRION PENINSULA

By Scheffer, C.,
 Vanderhaeghe, O.,
 Lanari, P.,
 Tarantola, A.,
 Ponthus, L.,
 Photiades, A.,
 France, L., 2015
 Modified after: G,
 Marinos & W.
 Petrascheck, (1956), A.
 Photiades & N. Carras,
 (2001), N. Skarpelis,
 (2007)

Main Ore Deposit :
Pb-Ag, Zn,
Fe ± Cu ± Mn

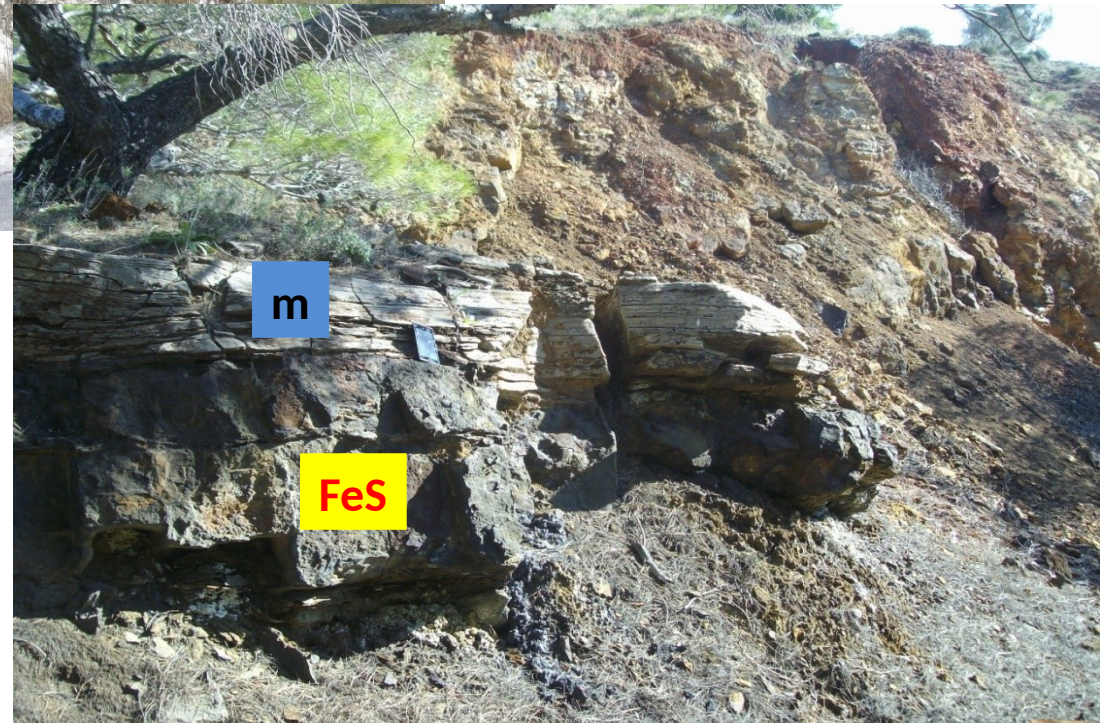


Μηχανισμός αντικατάστασης του μαρμάρου από μετάλλευμα. Replacement mechanism of marble by massive ore bodies.

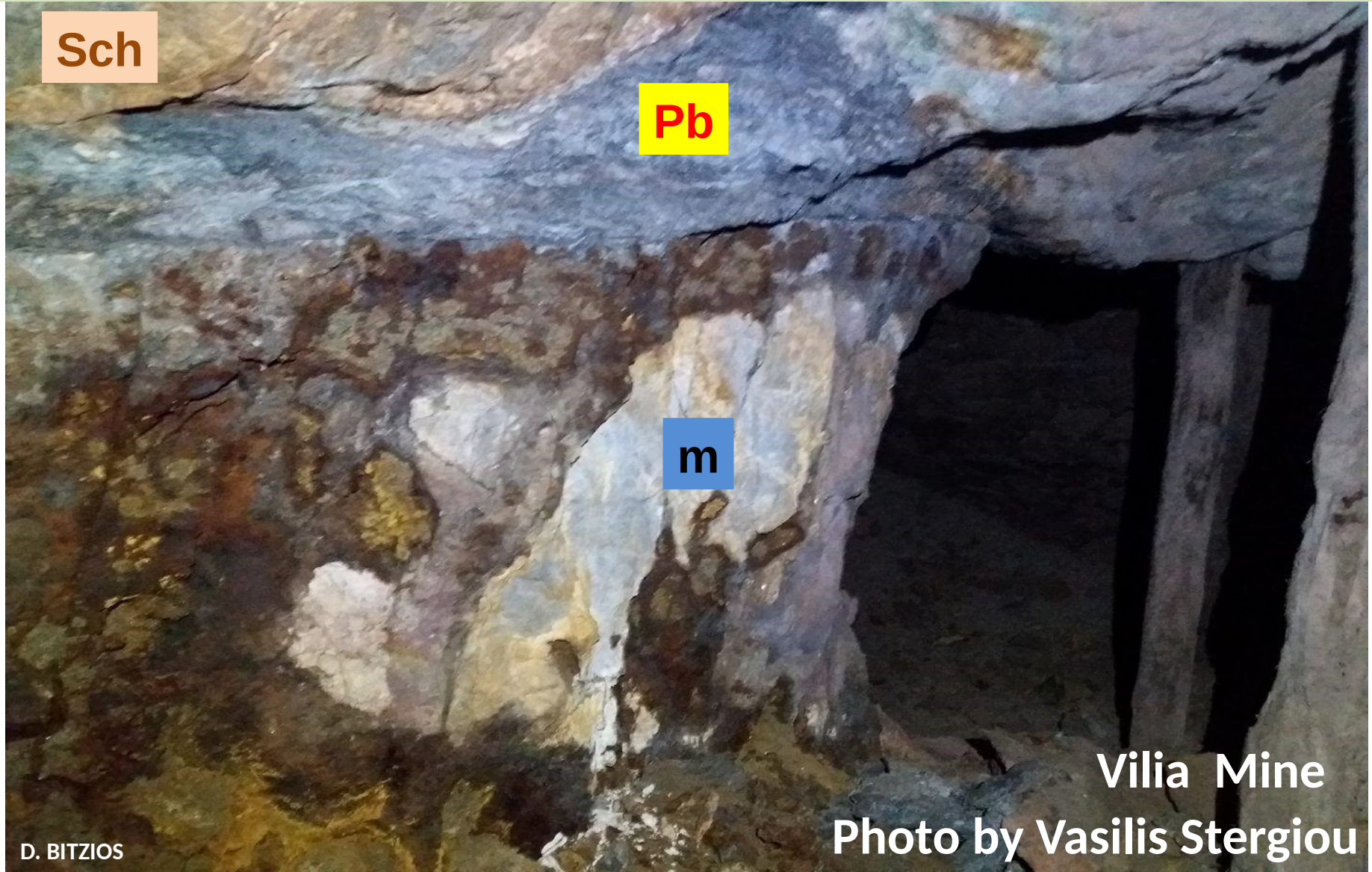


Upper Marble (m) with subhorizontal mylonitic foliation (S3).

Ore bodies of stratabound massive Pyrrhotite (FeS) with minor Pb-Zn sulfide mineralization, within the marble (m). They occur as planar layer oriented subparallel to the marble foliation.



Stratabound Pb-Ag sulfide ore body (**Pb**), indicating marble (**m**) replacement along his contact with the overlying schist (**Sch**).



Sch

Pb

m

Vilia Mine

Photo by Vasilis Stergiou

Υπεργενετικές διεργασίες- Οξειδώσεις Supergene process of primary ore minerals



Mineralogical Museum
of Lavrion

GALENA $PbS - Ag$

The ancient miners were only searching for galena and mainly cerussite because these minerals were argentiferous.



Collection H. Katsaros

Foto by B. Ottens

CERUSSITE $PbCO_3 - Ag$

Supergene process



Oxidation & leaching

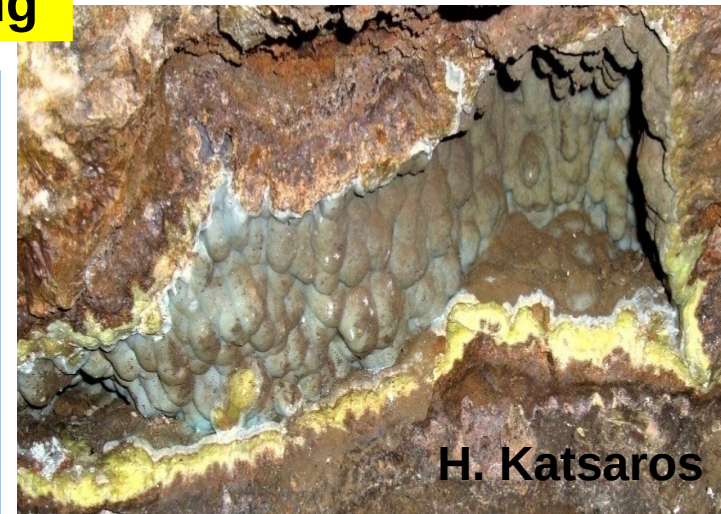


SPHALERITE ZnS

“The oxidized zone observable today may exceed 270 m in thickness...”

N. Skarpelis and
A. Argyraki, 2008

D. BITZIOS



H. Katsaros

SMITHSONITE $ZnCO_3$

ANCIENT LAVRION - HISTORICAL DATA

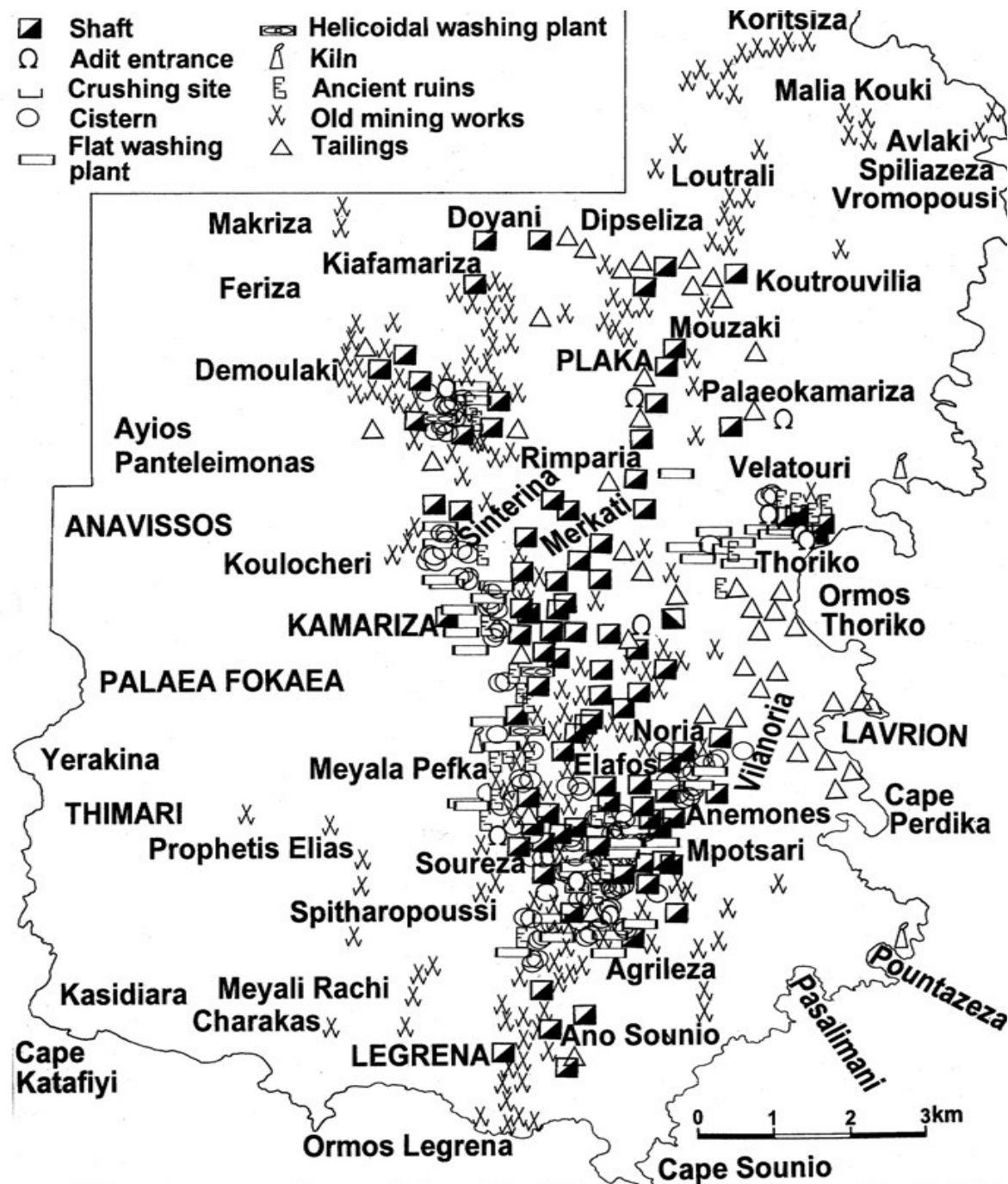
- The mining activities of the silver – bearing lead ore deposits at Lavrion, began in about 4.000- 3.000 BC at Thorikon.(1st metalliferous contact of marble – schist).
- In 483 BC is marked by the very important discovery of the large ore deposit at Maroneia (today Kamariza). It is lying on the 3rd contact of marble-schist, at a depth of 100m.
- From the proceeds of Lavrion Silver exploitation, the Athenian fleet was constructed to defeat the Persians at Salamina naval battle in 480 BC, preserving the freedom and Hellenic culture. The immortal monuments of the Acropolis during the Golden Age of Pericles were the highlights of the cultural contribution made by ancient Lavrion.
- During the 7th - 1st century BC 3,500 tons of silver (Ag) and 1,400,000 tons of lead (Pb) were produced from the ancient silver mines of Lavrion (K. Konogafos, 1980).
- In modern times (1865-1977) Lavrion became an important European mining and metallurgical centre for producing argentiferous lead, calcined calamine, iron ores and others (G. Dermatis,2004).



Athenian coin (tetradrachm)
of Lavrion silver 5th c. BC

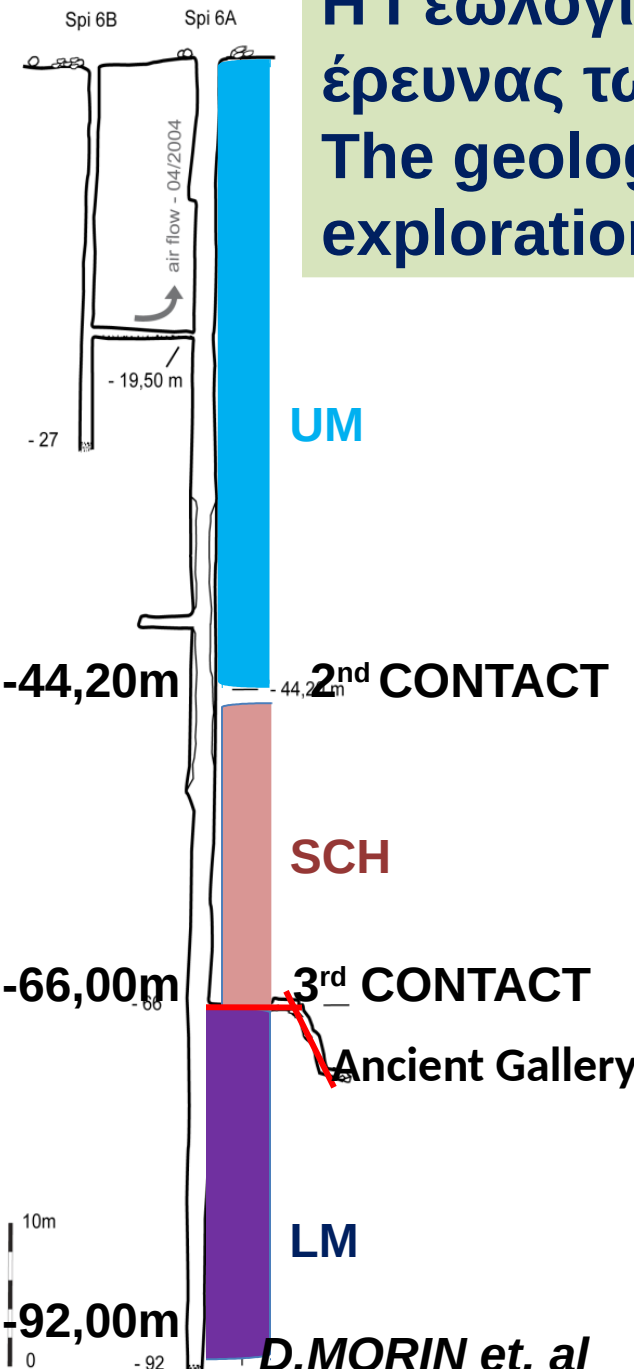
Χάρτης της
Λαυρεωτικής με
τις θέσεις της
αρχαίας
μεταλλευτικής
δραστηριότητας.

Map of Lavreotiki
with the positions
of the ancient
mining and
metallurgical
activity.



Η Γεωλογική δομή καθόρισε τις αρχαίες μεθόδους έρευνας των κοιτασμάτων.
 The geological structure controls the ancient exploration methods.

**ΦΡΕΑΤΑ ΟΡΥΤΤΕΙΝ
 THE LAVRION SHAFTS**



SPITHAROPOUSI
 1,30 X1,90m or 1,90X2,00 m.
 Depth 25- 50 m, with a maximum 120m.

D.MORIN et. al

D.MORIN, R.HERBACH & P.ROSENTHAL (2012).

D. BITZIOS

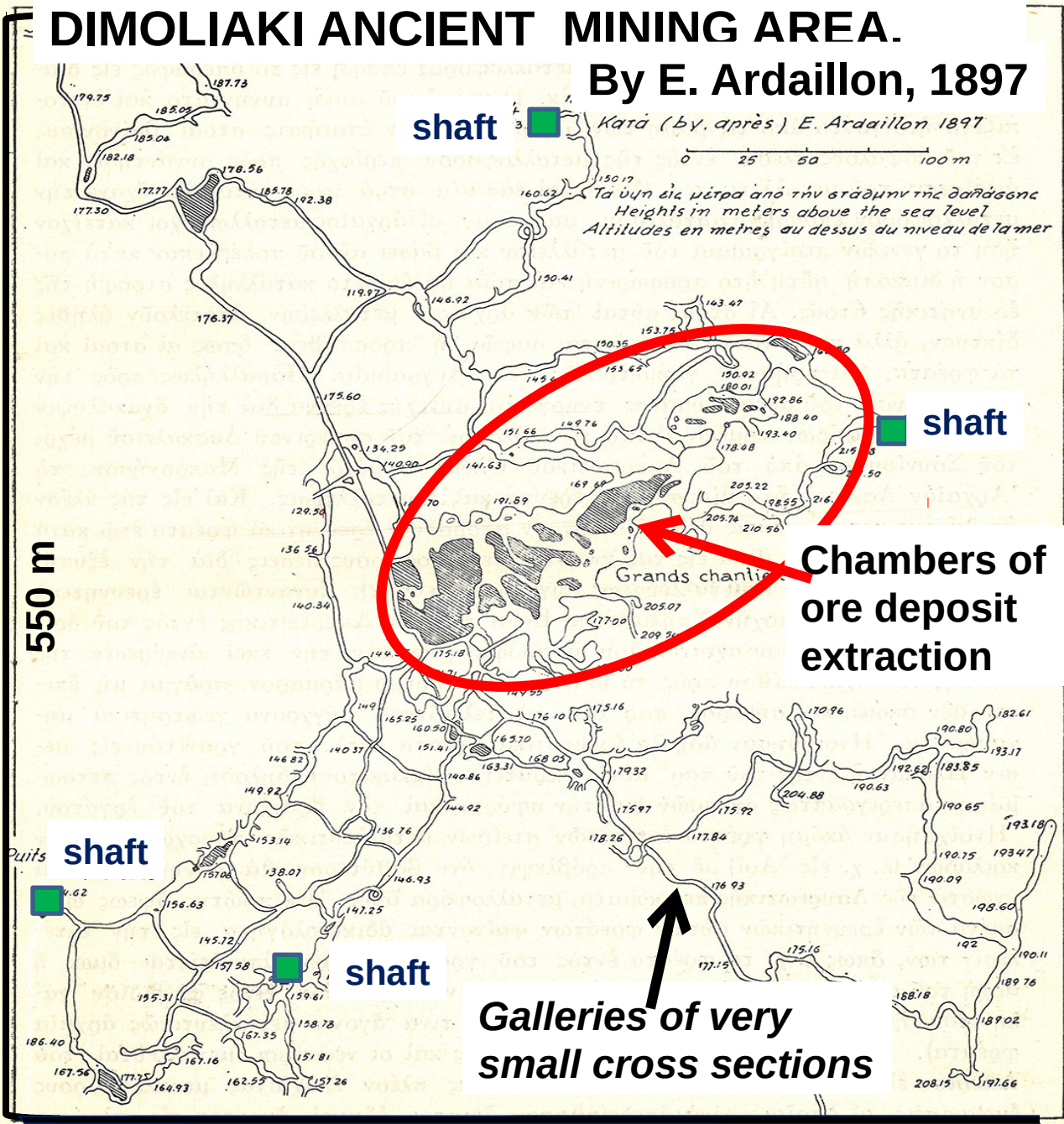
The structure of development of the ore bodies determines the ancient method of mining technique

“They started driving galleries of very small cross sections, usually 0.6 m² (0.7 m x 0.85m)”.

“When the galleries intersected the metalliferous area, they were enlarged in order to win the ore, forming considerable chambers or rooms” (J. Economopoulos, 1996)

DIMOLIAKI ANCIENT MINING AREA.

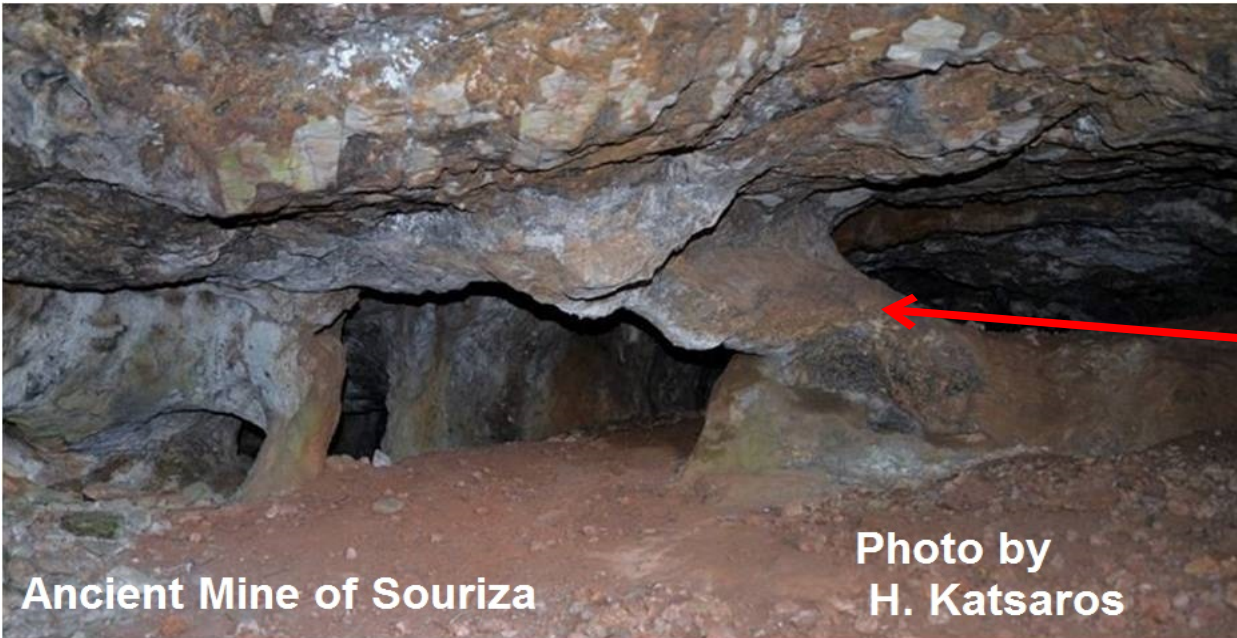
By E. Ardaillon, 1897





Ancient Mine "3rd Km".

The ore was extracted from its surface or deep deposits using galleries and shafts



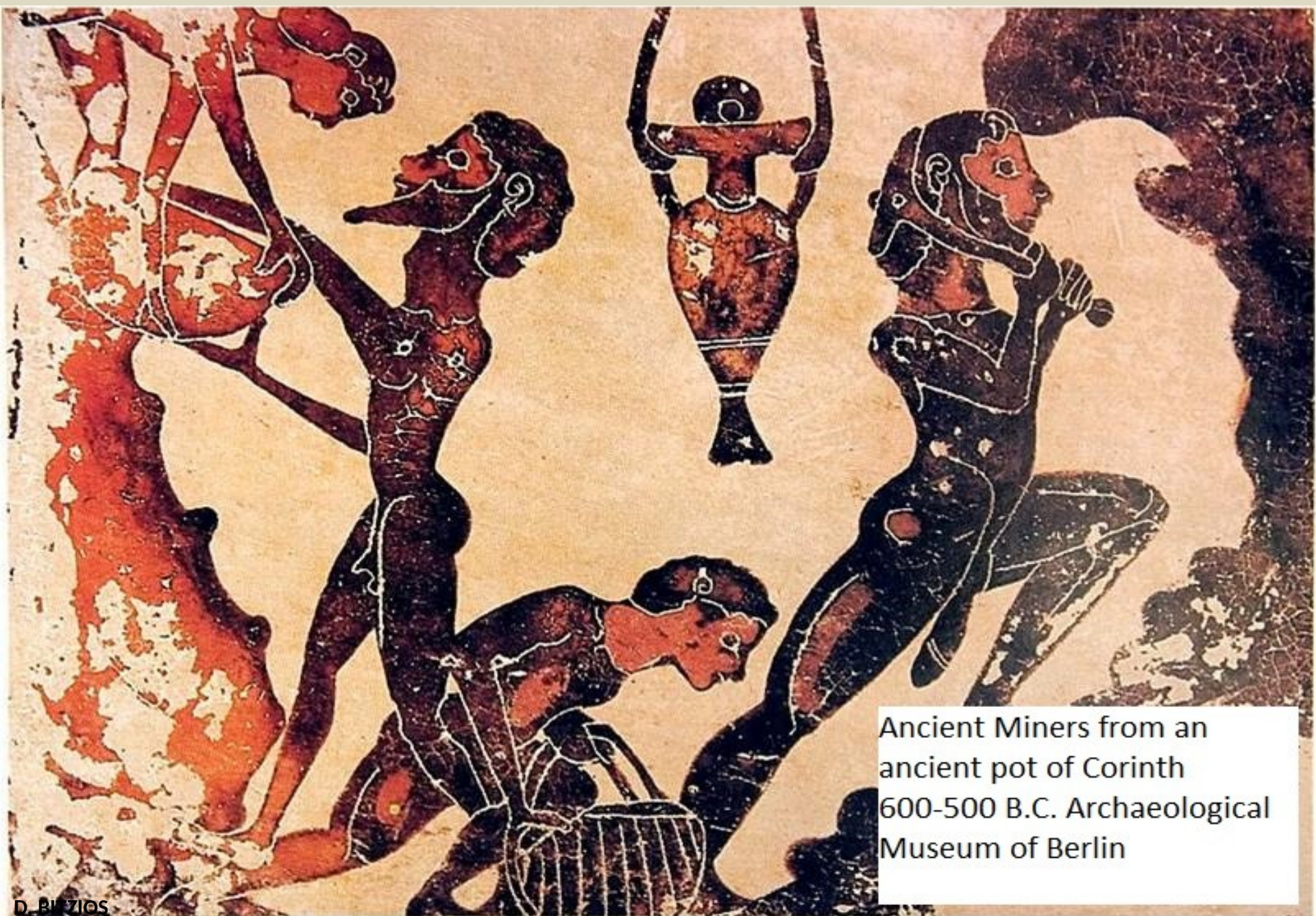
Ancient Mine of Souriza

Photo by
H. Katsaros

Considerable chamber of ore mining.

They applied the "room and pillar" mining method (widely used today) to support the roof.

Honor and glory to the miners heroes of the ancient Lavrion



Ancient Miners from an ancient pot of Corinth
600-500 B.C. Archaeological
Museum of Berlin

Οι φυσικές ιδιότητες των ορυκτών καθορίζουν τον τρόπο κατεργασίας. The physical properties (Specific Gravity) of minerals, determine how to process the ore.

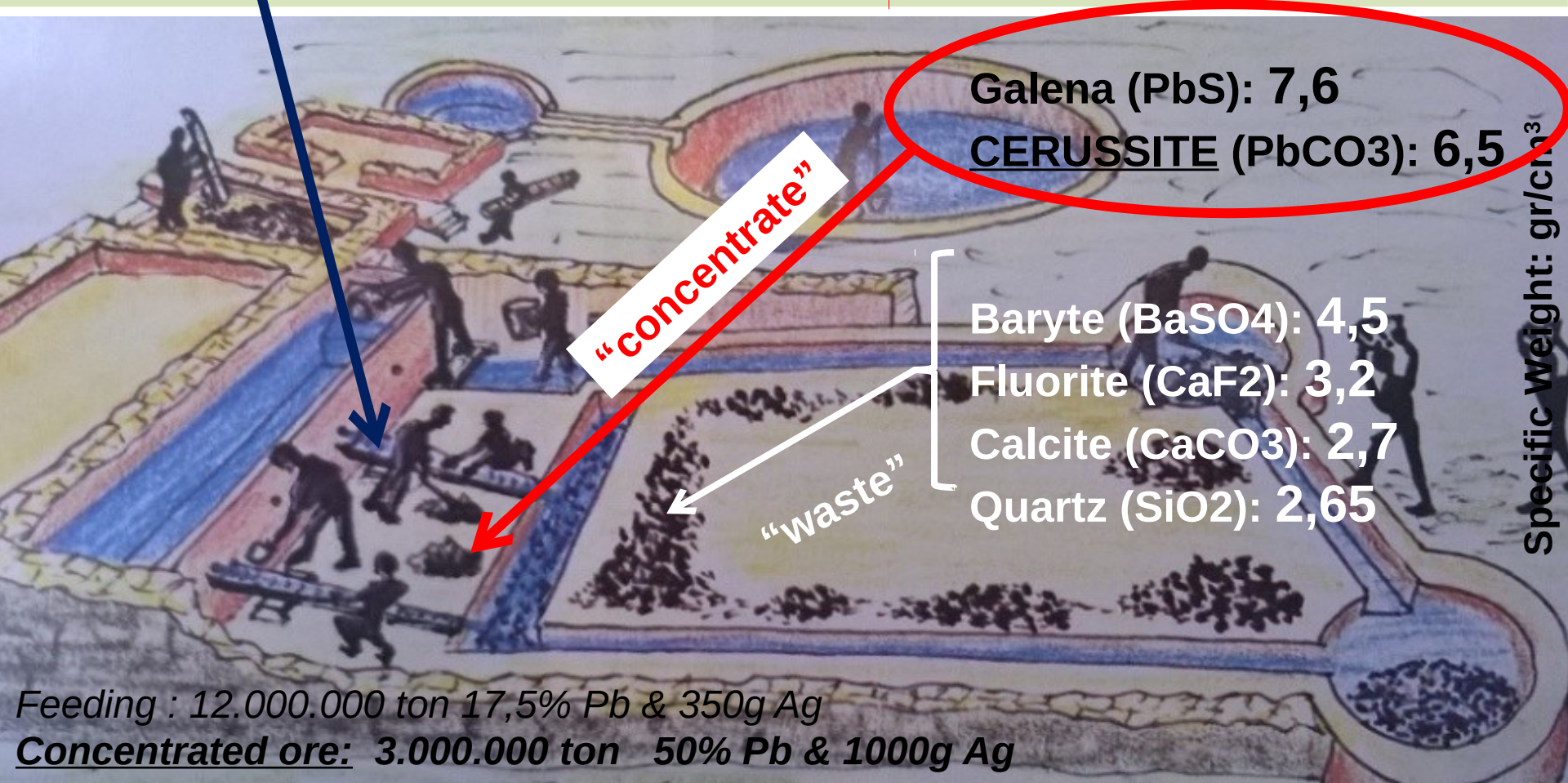
RECTANGULAR ORE WASHERIE OF SOURIZA LAVRION FOR THE CONCENTRATION OF THE ORE.

SOURIZA



Archaeological Excavation by E. KAKAVOGIANIS

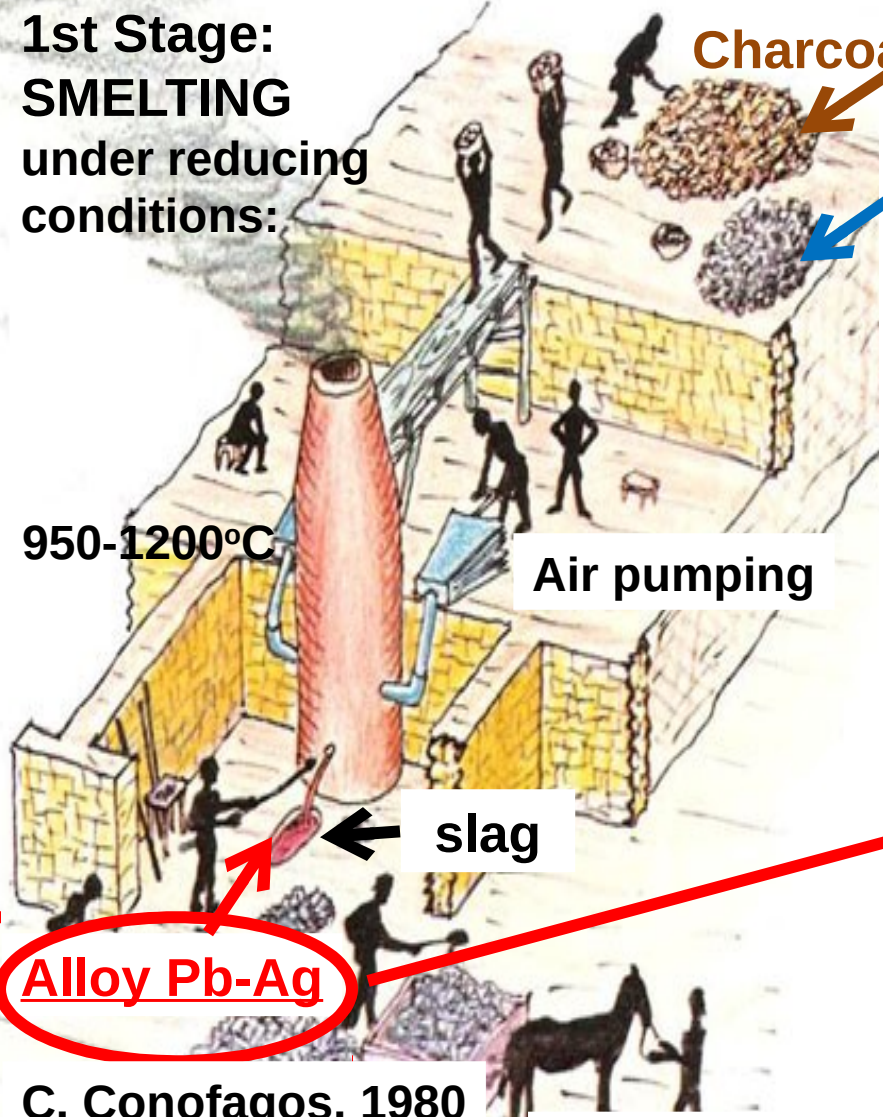
They were washing the fine-milled ore in a flow of water, into wooden troughs (sluices), contained cuplike depressions, in order to separate the useful minerals from the “sterile”. The processing was based on the difference of the minerals specific gravity .



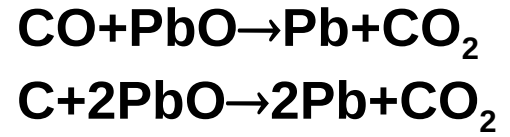
Feeding : 12.000.000 ton 17,5% Pb & 350g Ag
Concentrated ore: 3.000.000 ton 50% Pb & 1000g Ag
 Waste: 9.000.000 ton 6,6% Pb & 133g Ag

C. Conofagos, 1980

The extensive oxidation zone, giving rise to the prevalence of cerussite (PbCO₃) against the galena (PbS), was the reason why the process of reduction smelting of the ore applied.

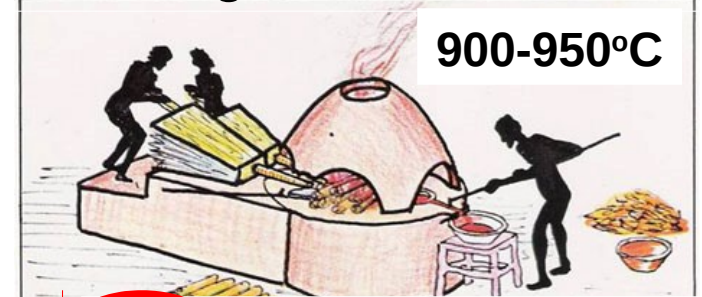


Concentrated ore minerals
Cerussite (90%) + Galena (10%)



As the cerussite (oxidized lead form) is the main mineral, the process of roasting, namely the oxidation of metal sulfide ores didn't need to be activated.

2nd Stage: CUPELLATION



Ag and PbO (litharge)

3rd Stage:
Resmelting

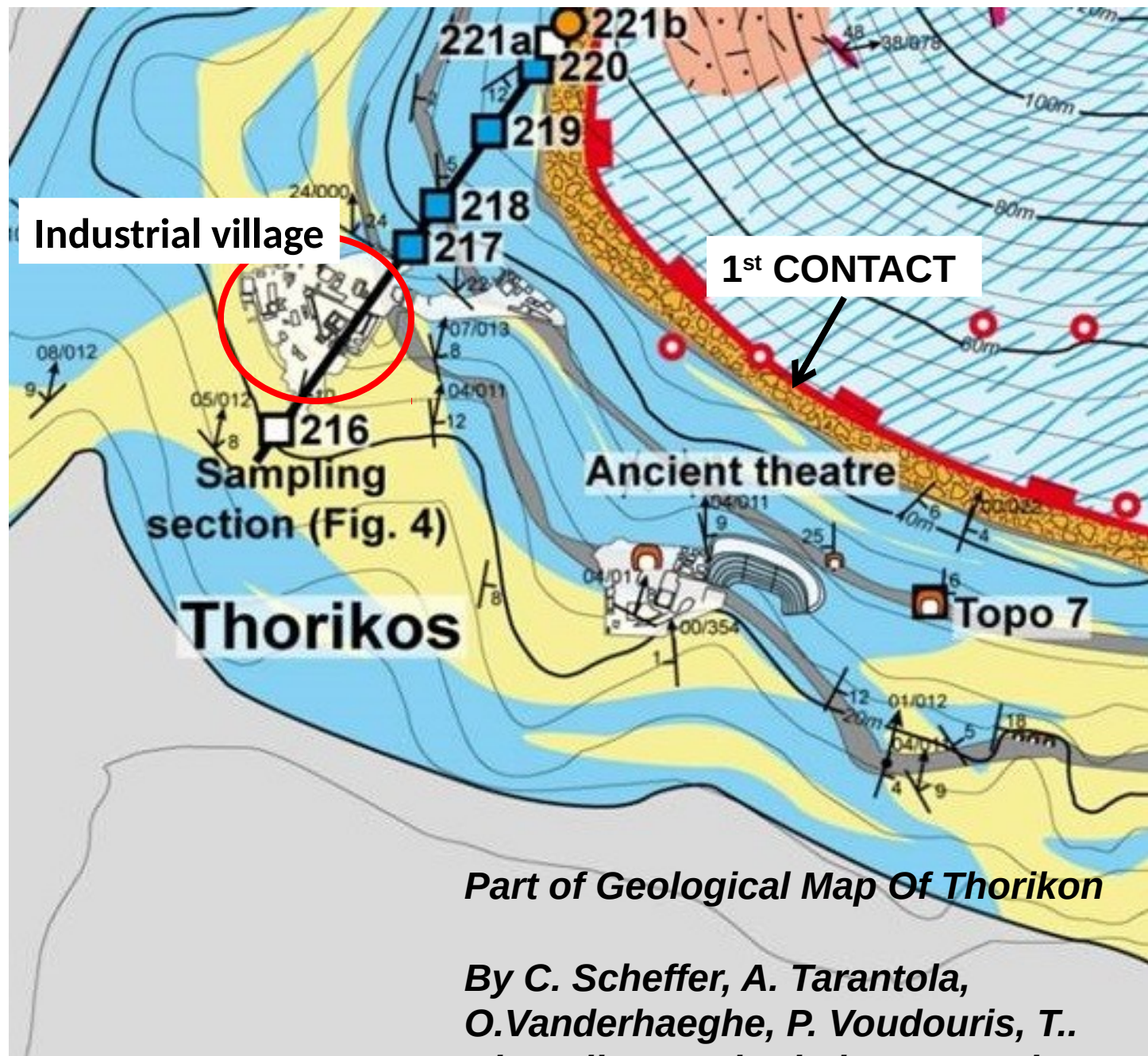
Pb

C. Conofagos, 1980

D, BITZIOS

3,500 tons Ag & 1,400,000 tons Pb.

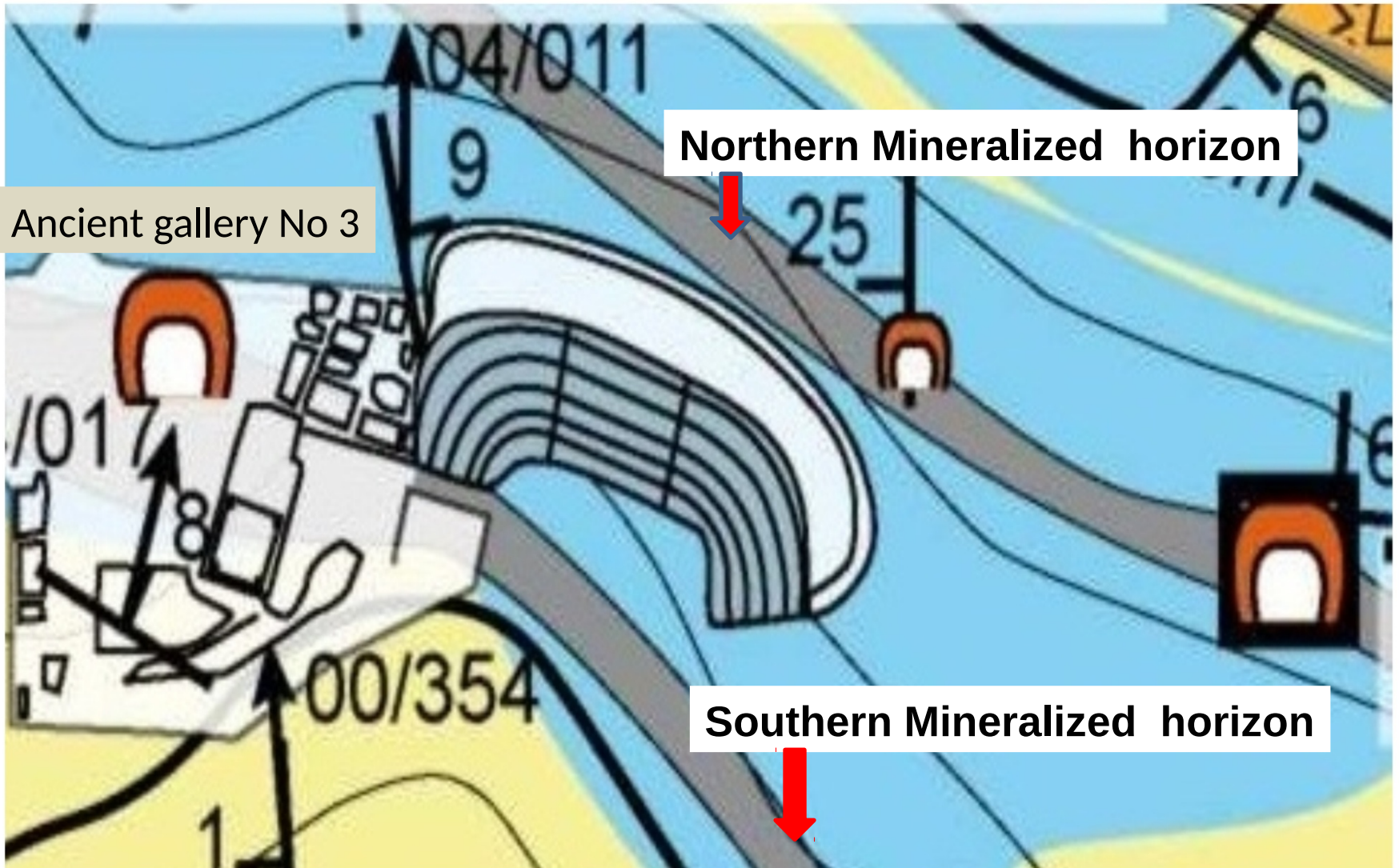
The geology of the ore deposits influenced the spatial planning of the ancient Thorikos (industrial village), as well as the unusual elliptical in shape of Thorikos ancient theatre.



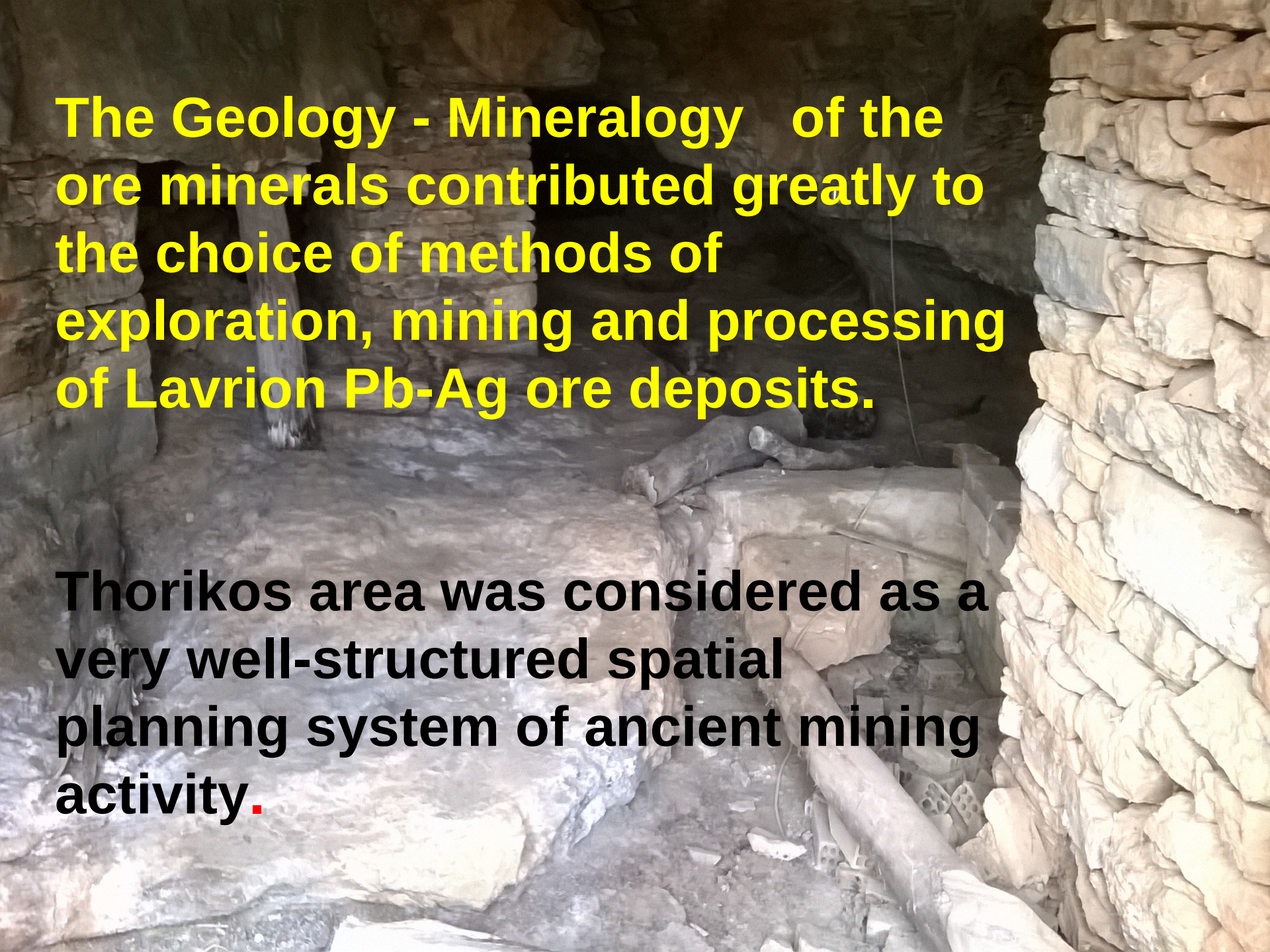
Part of Geological Map Of Thorikon

By C. Scheffer, A. Tarantola, O.Vanderhaeghe, P. Voudouris, T. Rigaudier, A. Photiades, D, Morin,

The unusual elliptical in shape of Theatre, allowed the mining activities during the Theatre operations .




***Part of Geological Map of Thorikon
By C. Scheffer et al. 2017***



The Geology - Mineralogy of the ore minerals contributed greatly to the choice of methods of exploration, mining and processing of Lavrion Pb-Ag ore deposits.

Thorikos area was considered as a very well-structured spatial planning system of ancient mining activity.



ΘΕΜΑΤΙΚΟ ΠΑΡΚΟ
ΓΕΩΛΟΓΙΚΗΣ, ΜΕΤΑΛΛΕΥΤΙΚΗΣ & ΠΟΛΙΤΙΣΤΙΚΗΣ
ΚΛΗΡΟΝΟΜΙΑΣ ΕΝΑ ΟΡΑΜΑ ΤΟΥ ΔΗΜΟΥ.
ΘΑ ΣΥΓΚΕΝΤΡΩΝΕΙ ΟΛΗ ΤΗΝ ΠΛΗΡΟΦΟΡΗΣΗ
ΚΑΙ ΔΥΝΑΤΟΤΗΤΑ ΕΓΚΥΡΗΣ ΠΕΡΙΓΗΓΗΣΗΣ
ΜΕ ΣΥΓΧΡΟΝΟ ΤΡΟΠΟ.
ΑΣ ΣΥΜΒΑΛΟΥΜΕ ΟΛΟΙ ΝΑ ΓΙΝΕΙ
ΠΡΑΓΜΑΤΙΚΟΤΗΤΑ ΚΑΙ ΠΑΓΚΟΣΜΙΑΣ ΕΜΒΕΛΕΙΑΣ

THANK YOU FOR YOUR KIND ATTENTION

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