

INSTITUTE OF GEOLOGY AND MINERAL EXPLORATION(IGME)

Tools for sustainable exploration of gold resources in Greece

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SDIMI'07-Milos 17-20/06/07

Exploration, Primary Extraction and Mine Closure

Networked minerals intelligence

Improved exploration technology

Using the knowledge base to upgrade
the sector

Improved extraction methods

Progressive site closure

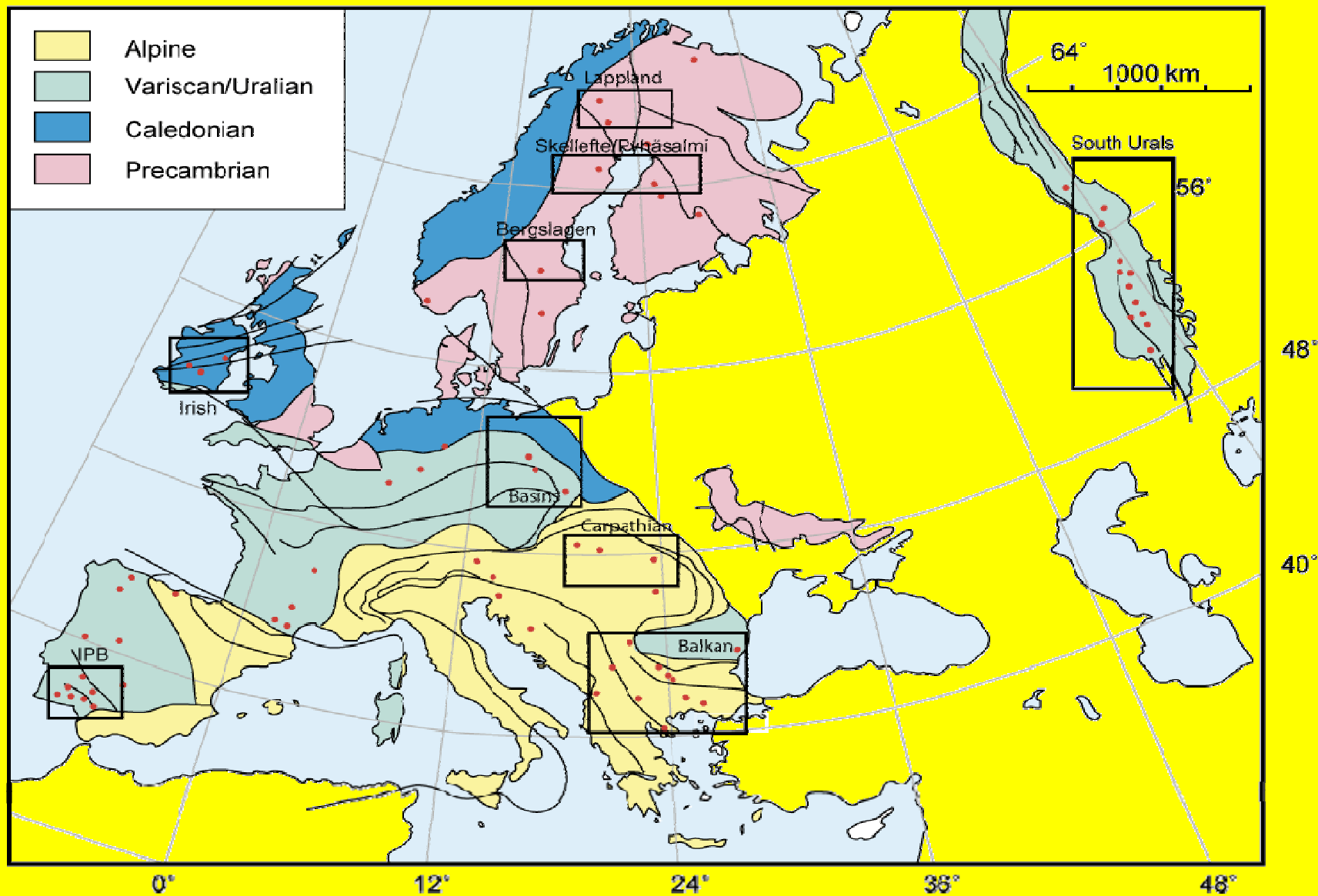
Social acceptance of mining

IMPROVED EXPLORATION TECHNOLOGY

- Develop metallogenic research and models at regional and deposit scales
- Develop the database of undiscovered mineral deposits
- Support exploration for particularly strategic minerals
- Search for **deeply concealed** metal deposits onshore (**>3 km**) to reduce environmental impact and provide clean, silent and unseen mines
- Devise new multi-parameter **optical, radar**, geophysical and geochemical sensors, embodying new **nano- and microtechnologies and ground-penetrating radar** to detect and map new mineral occurrences in inaccessible or buried locations.
- Devise new technologies to capture metallic minerals from Nature's own ongoing creation processes along active onshore and submarine volcanic zones

Note: EGS recommends to skip the >3 km limit as this may be subject to much discussion. For the time being, in most cases only the resources of the few first hundred metres of the lithosphere are being used!

EUROPEAN MINERAL BELTS



4D RESOURCE MODELLING

The priority research areas for *new exploration technologies* in EU are:

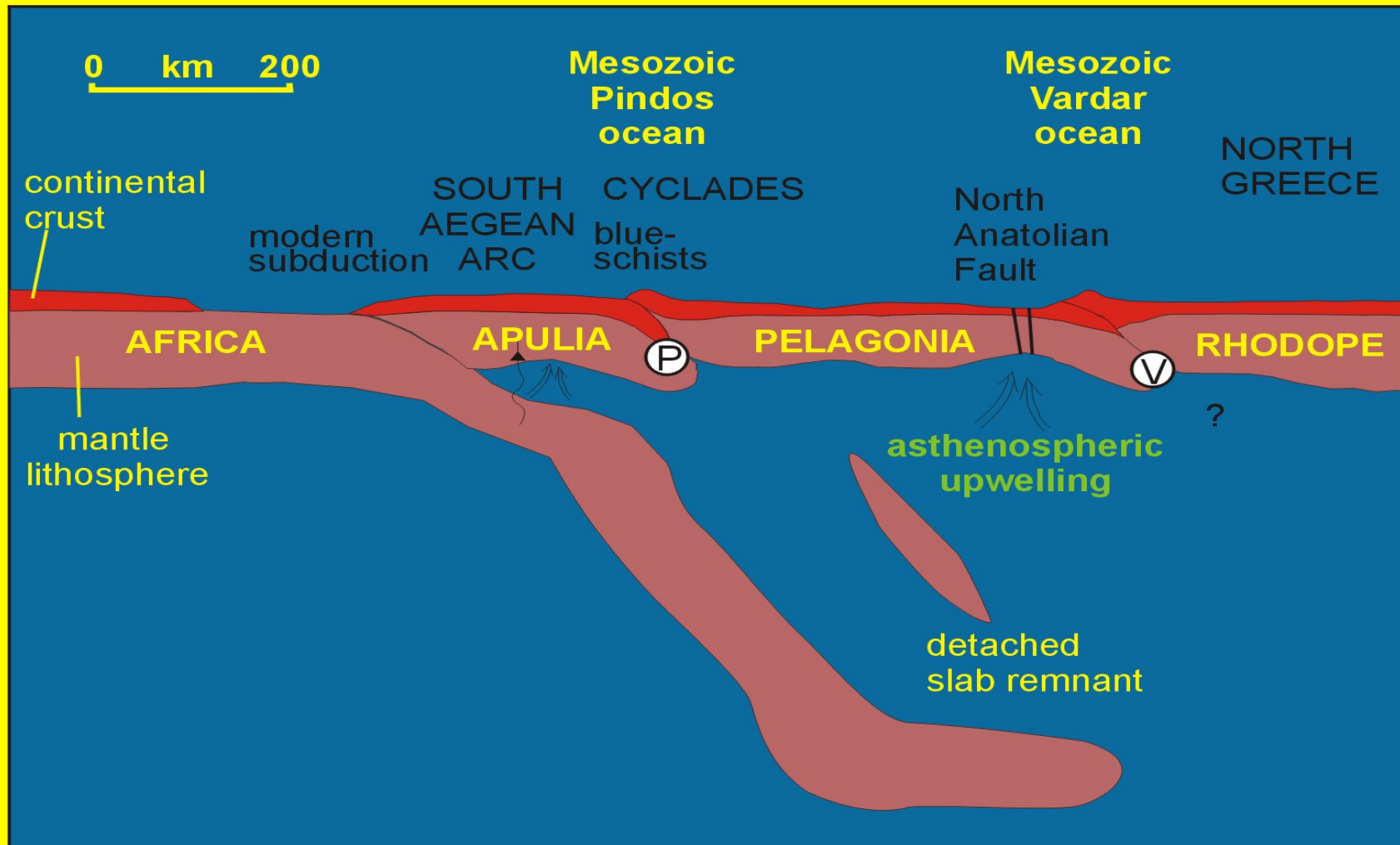
- Pan-EU predictive resource assessment
- 4-D mineral belt models
- Pan-EU GIS/CAD data management and visualisation systems for mineral endowment
- Development of new exploration tools
- *This will lead to robust 4D-geomodels visualised in EU-standardized GIS-systems which can be used for resource estimation as well as measure the likely environmental and societal impacts of mineral extraction throughout the entire life cycle from discovery to closure, as well as financial and legislative limitations, to avoid conflicts in land use.*

PRESENT PAPER

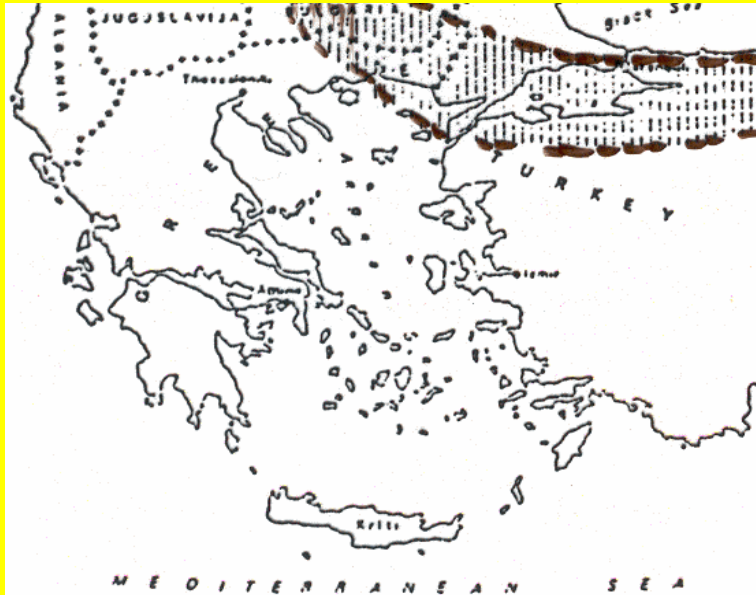
- Sustainable exploration tools
 - Geological setting
 - Metallogenetic control (regional scale)
 - Genetic model (local scale)
 - Ore prospective/feasibility
 - Ore potential/economic perceptiveness
 - Application of environment friendly, less-invasive and cost-effective techniques
- Sustainable development indicators
 - Case study approach

Schematic present distribution of micro-continental blocks and subducted slabs

(after Pe-Piper, 2004)

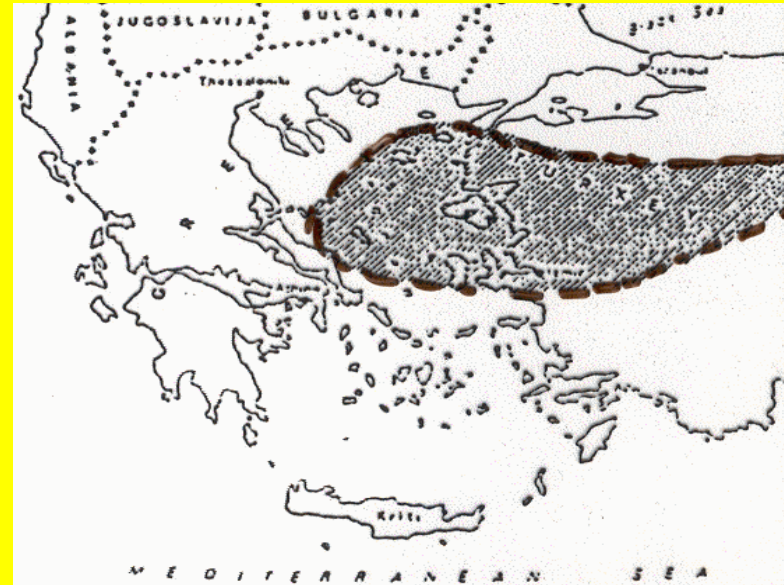
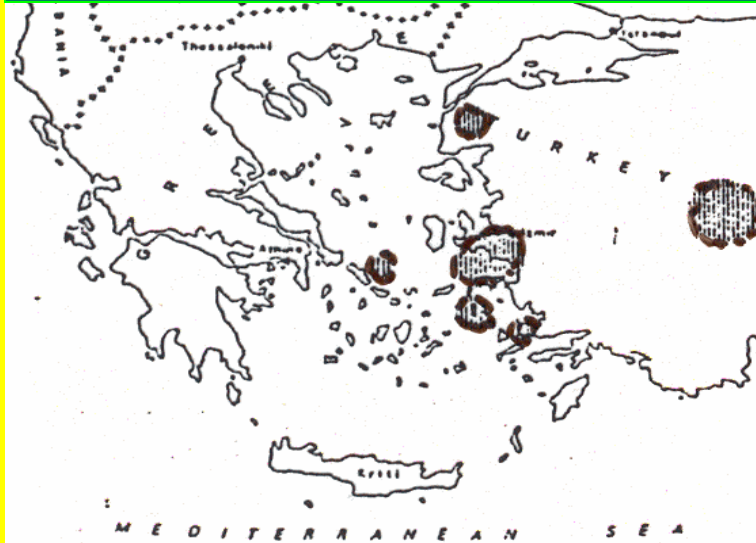


TERTIARY VOLCANISM *(modified after Fytikas et.al.1980)*



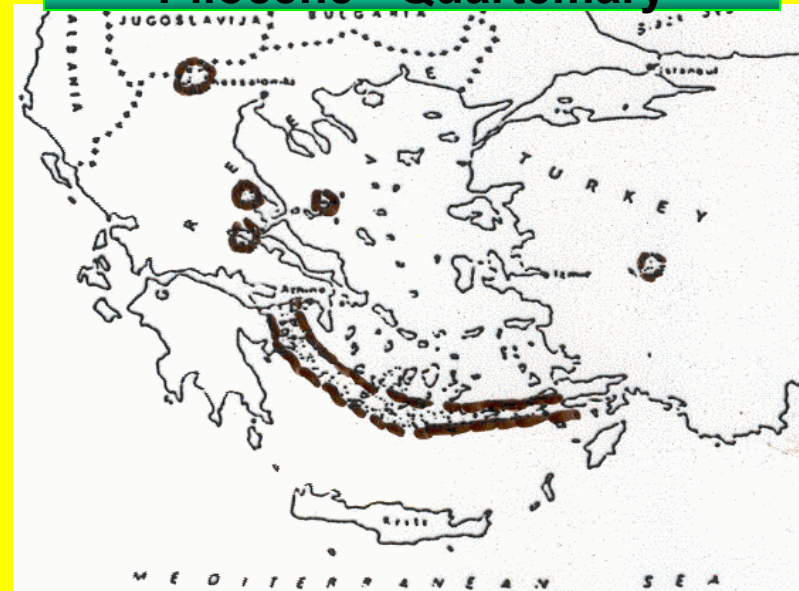
Oligocene

Upper Miocene



Lower-Middle Miocene

Pliocene - Quaternary



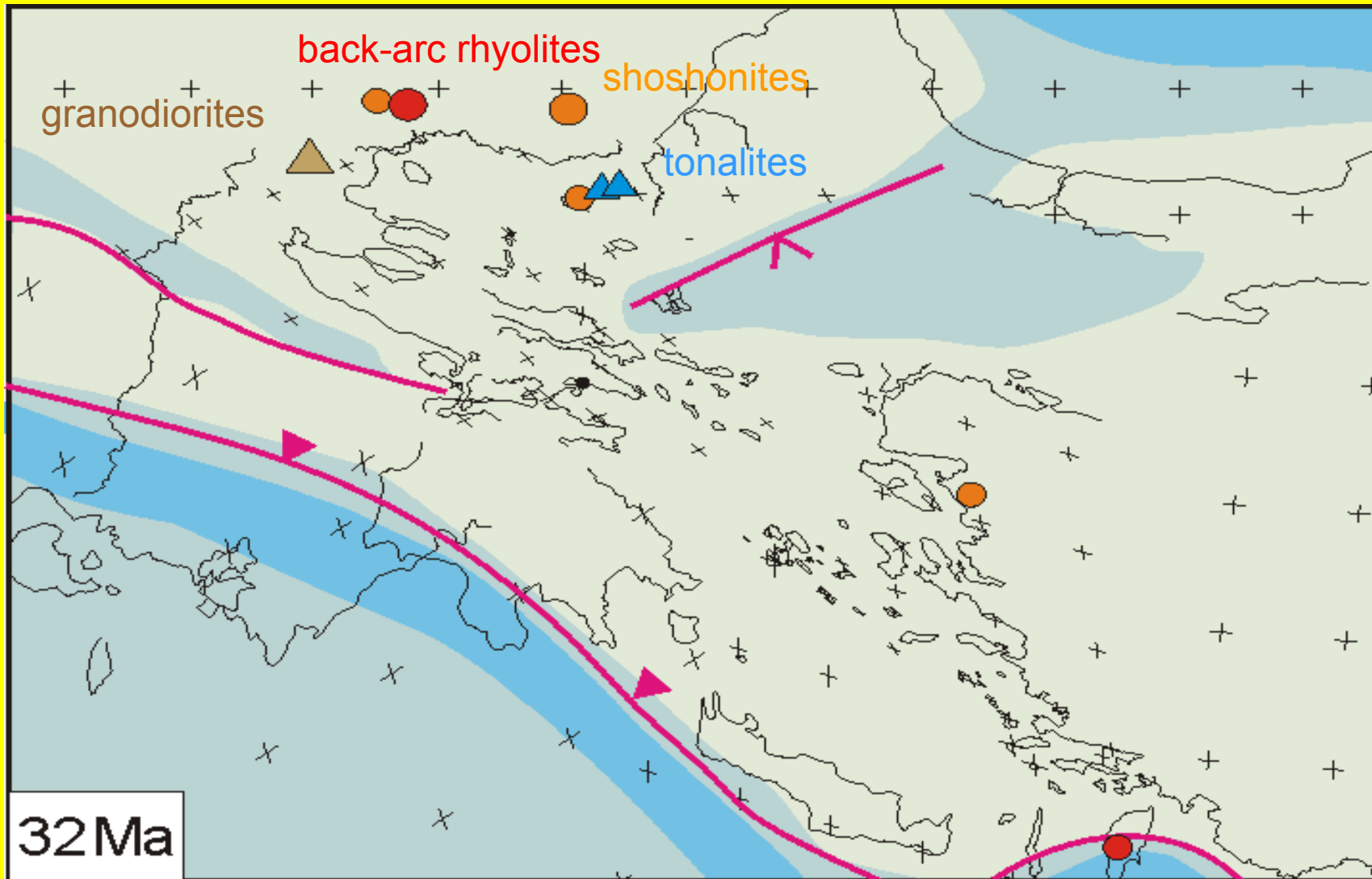
FROM 35-25 Ma (OLIGOCENE), WIDESPREAD PLUTONISM AND VOLCANISM IN NORTH GREECE AND BULGARIA

- Granodiorite plutons with minor gabbro and monzonite; porphyry copper mineralisation
- Voluminous high-K calc-alkaline volcanics

**SYNCHRONOUS WITH RAPID BASIN
FORMATION AND REGIONAL EXTENSION**

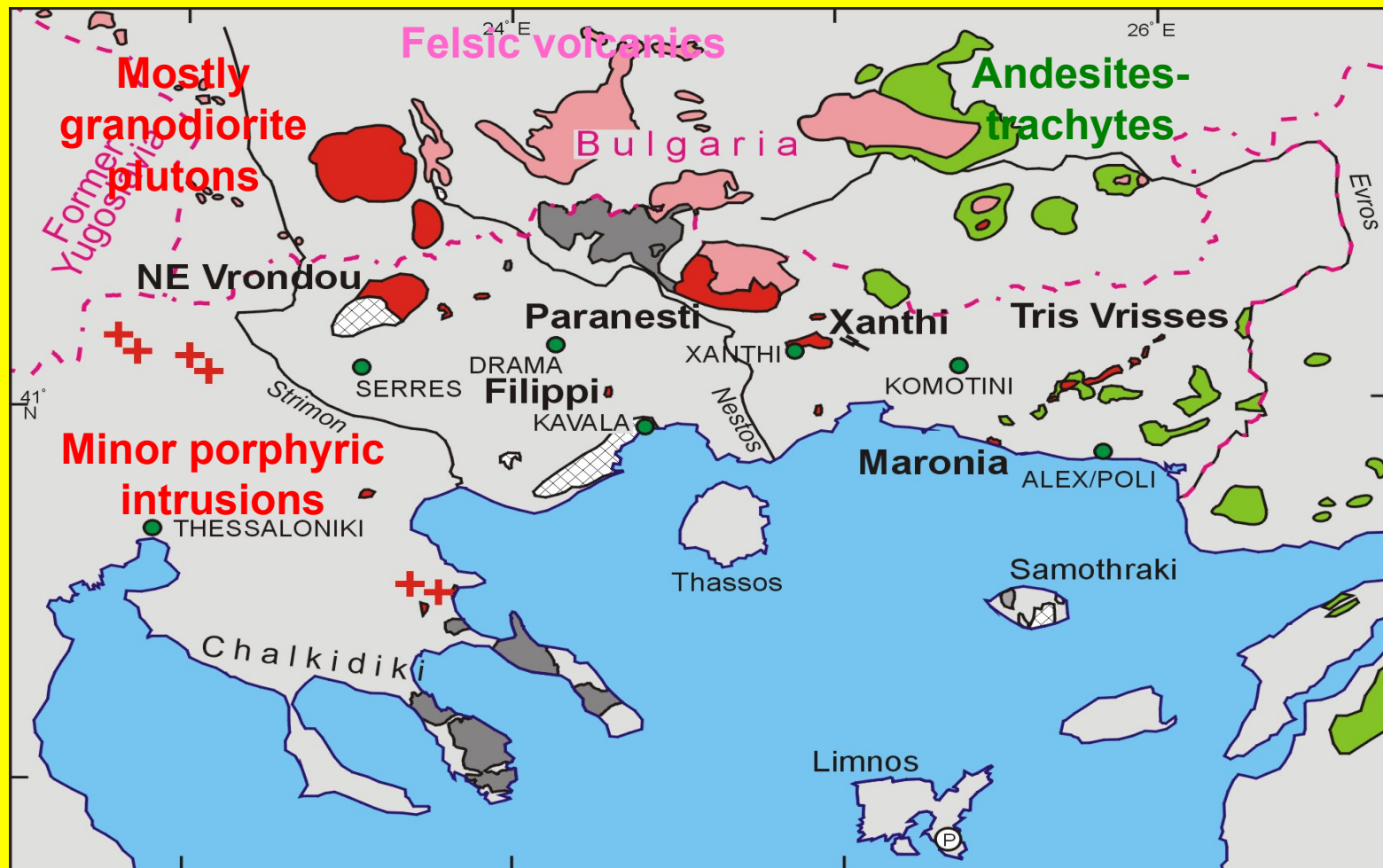
GEOLOGICAL SETTING

- Oligocene magmatic activity (*after Pe-Piper, 2004*)

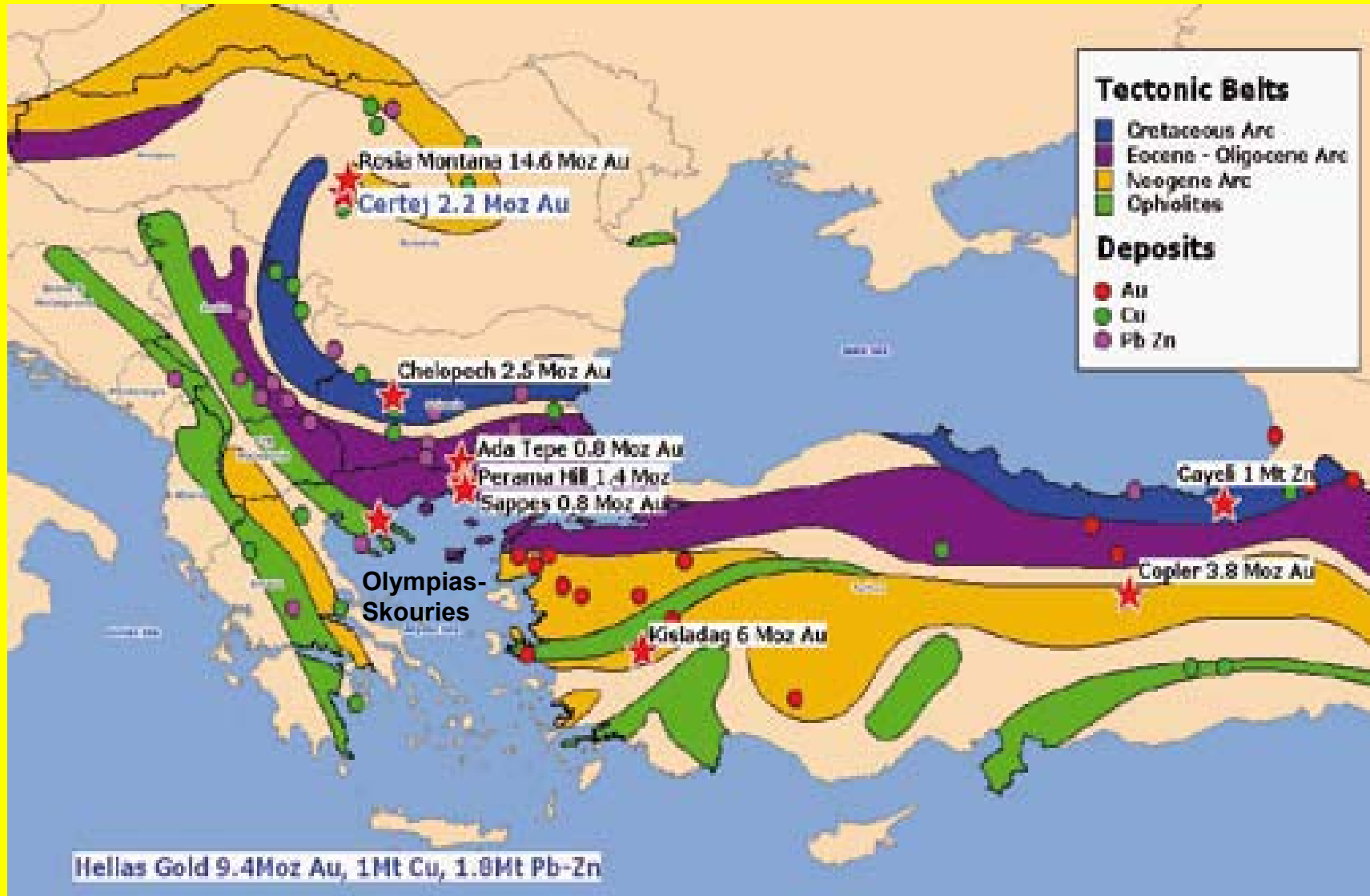


I-type plutons ranging from gabbro to leucogranite, but mostly granodiorite; volcanics geochemically similar to plutons, including andesites, trachytes and rhyolites.

(modified after Pe-Piper, 2004)

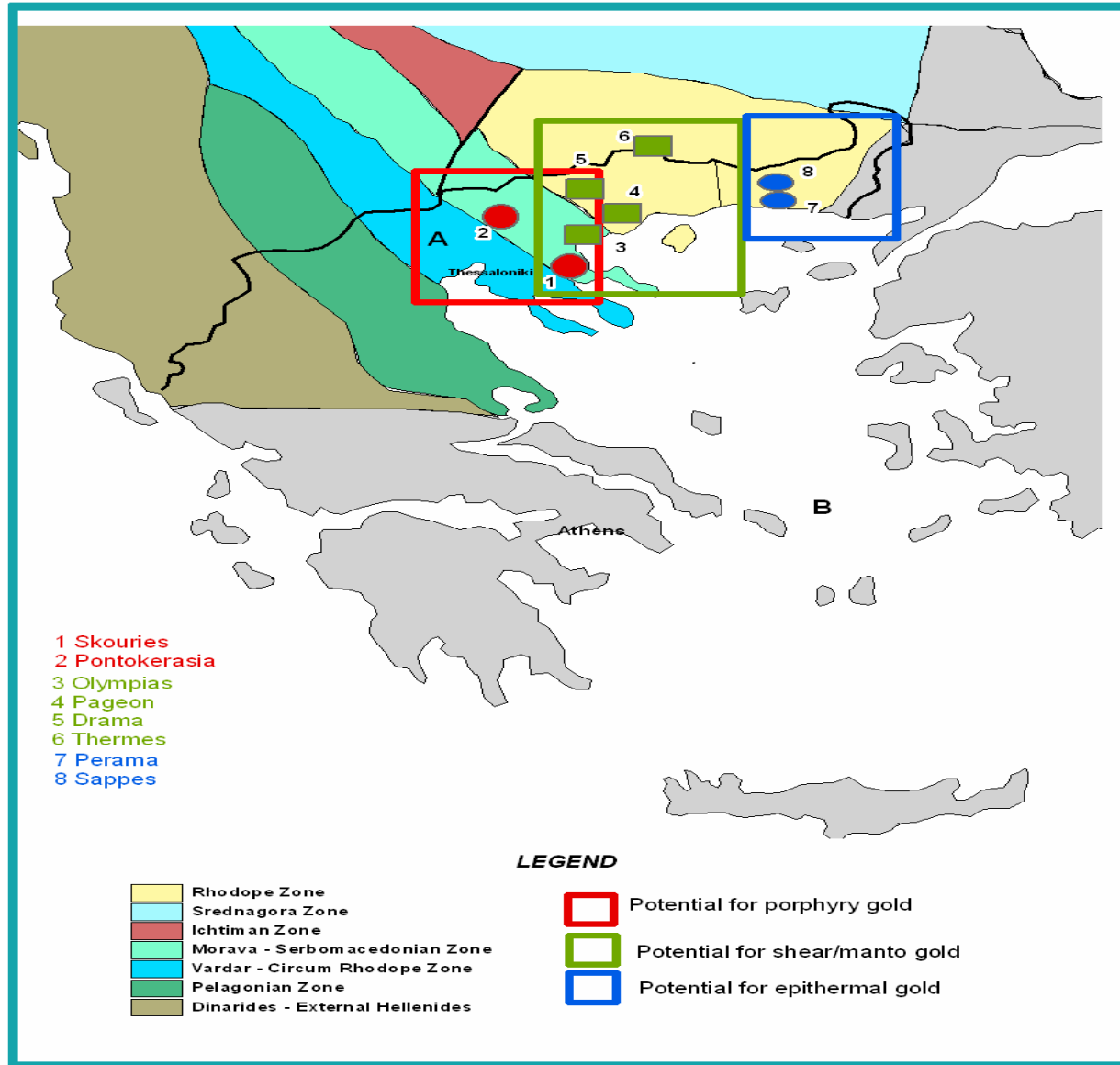


REGIONAL GOLD METALLOGENY

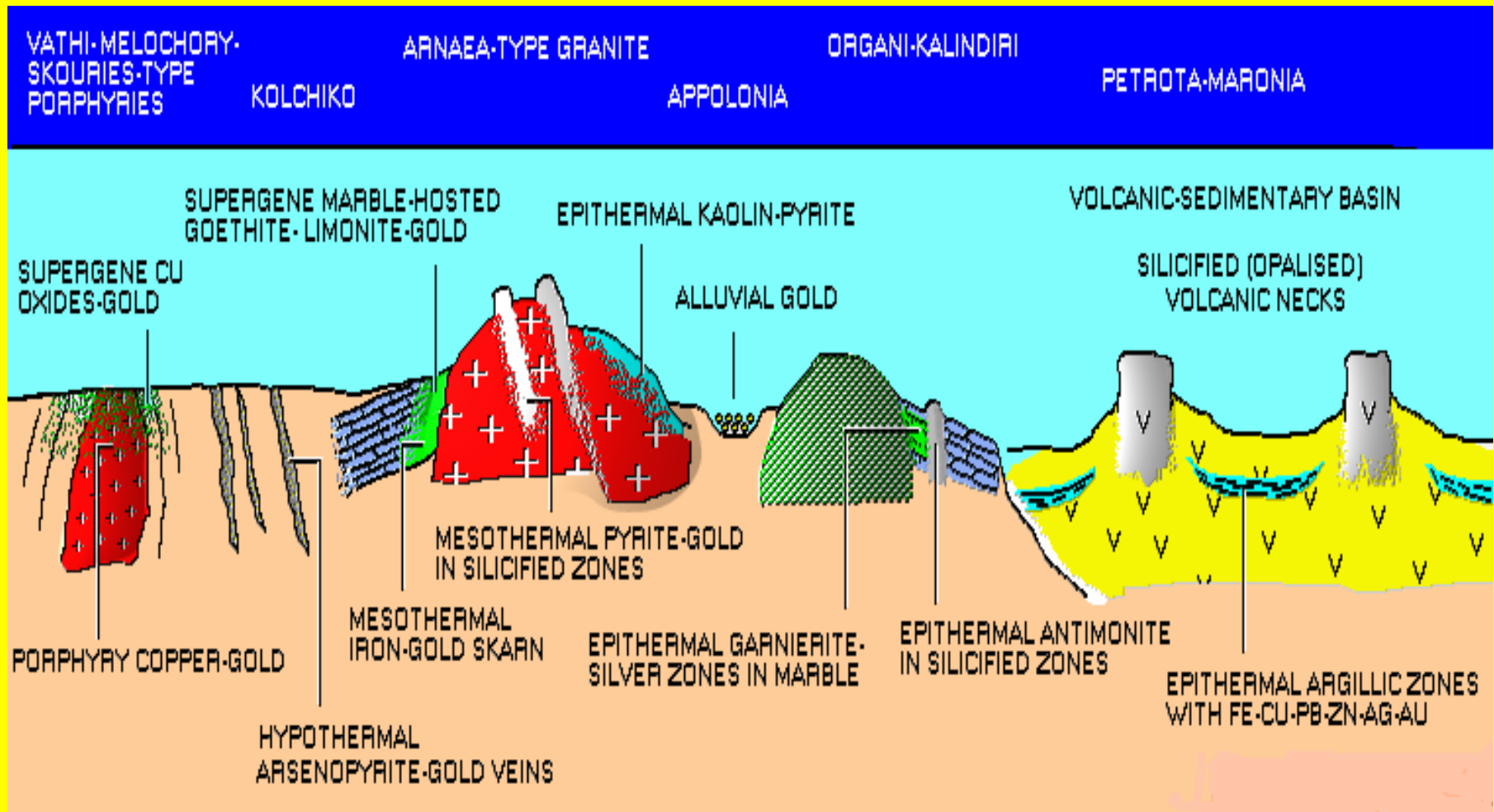


CarpathoBalkan Gold Deposits

MAJOR Au GENETIC TYPES IN GREECE



W-E VIEW OF GOLD METALLOGENESIS



EPITHERMAL GOLD

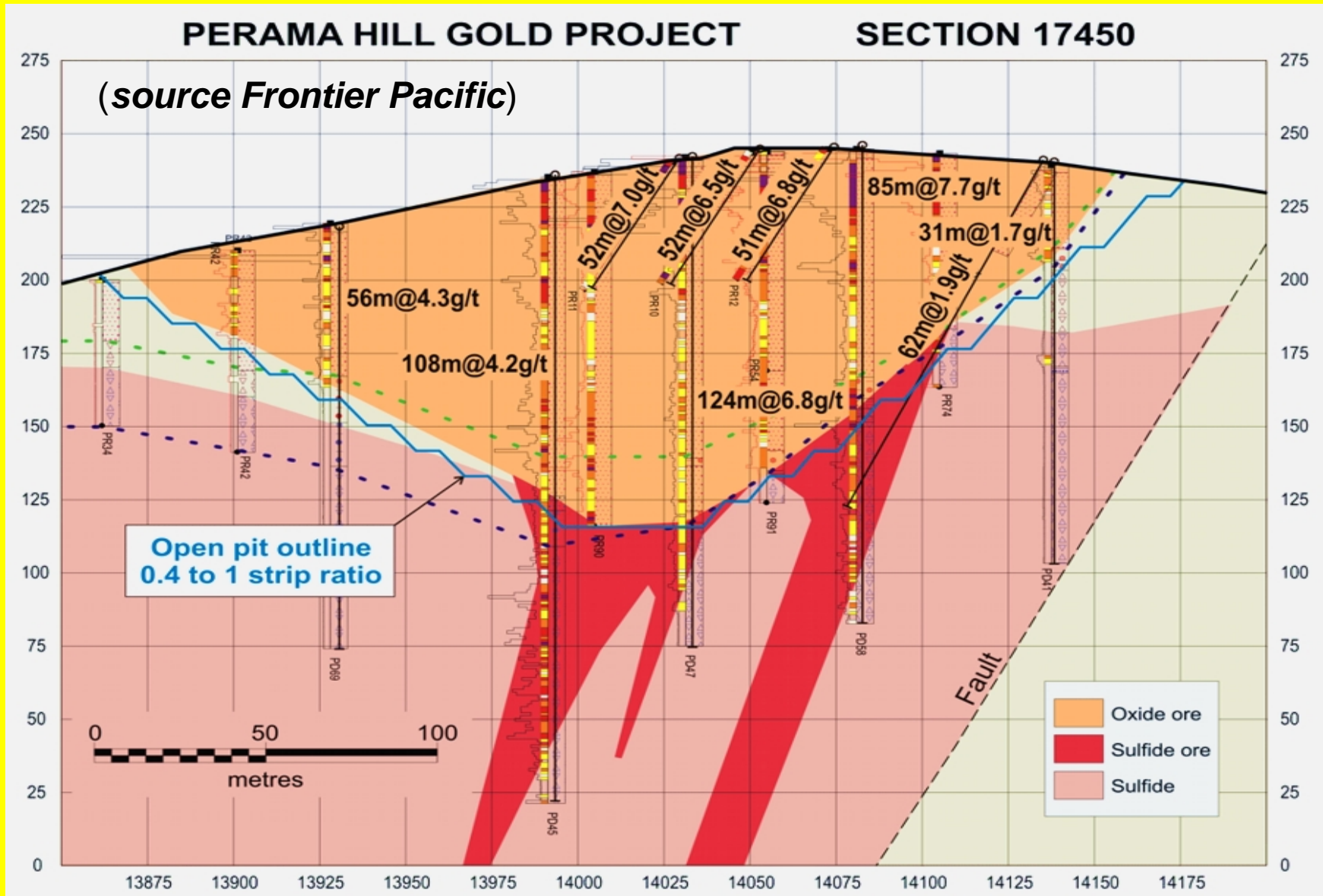
- Perama Hill (Surnak, Sedefche in Bulgaria)



PERAMA HILL

- stratabound, sediment-hosted oxidized epithermal deposit of Eocene to Oligocene age located in intermediate to felsic volcanics and, controlled by a north – northeast trending graben fault
- gold mineralisation has been fed into the system by structurally controlled feeders inside Andesitic volcanic breccias and disseminated into overlying porous units of epiclastic sandstones to form a “mushroom shaped” deposit
- high sulphidation(Cu sulphides,Ag-Au tellurides) overprinted by low sulphidation (qtz-barite veins)
- pervasive alteration(kaol-illite,silicification) followed by hydrothermal fracturing (qtz-barite) and supergene overprint(FeOH and secondary gold)
- resources of 11.7 m.t.at 3.62g/t Au and 8.22g/t Ag (1.7Moz Au)

PERAMA HILL



PERAMA HILL

- The surface expression of the deposit covers an area approximately 700 meters in length and up to 300 metres in width occupying the crest of a low ridge
- Gold mineralization is very uniform throughout the deposit, with Au grain size less than 2 microns. In the oxide part gold related with quartz, clay, iron-oxides and in the sulphide part with pyrite



(source *Frontier Pacific*)

12 hww



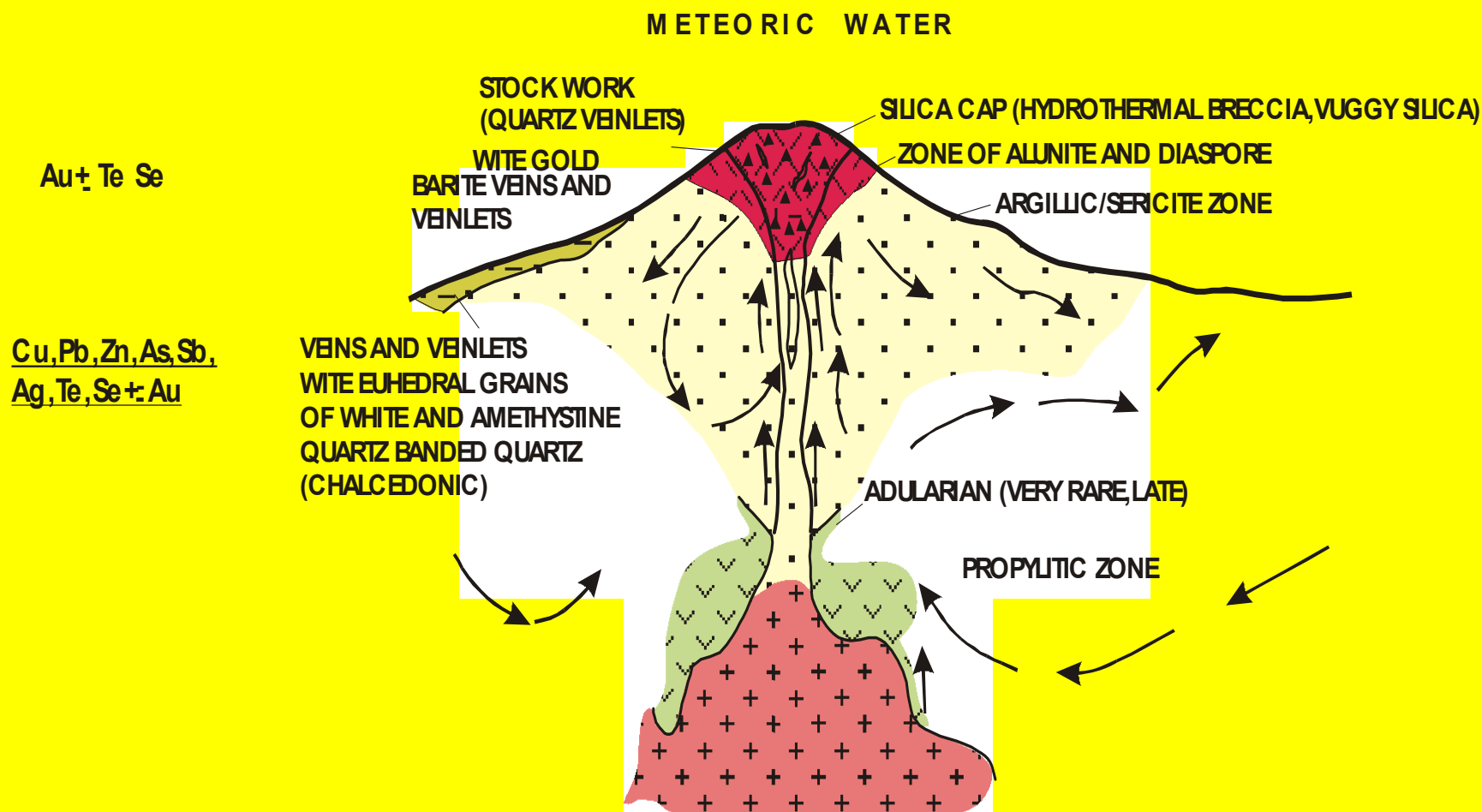
SAPPES EPITHERMAL GOLD

- Graben tectonics and tertiary rift-basin volcanics
- Fault-controlled domes of rhyodacitic porphyry bodies
- Silica caps marking fissure vent systems
- Strongly brecciated and silicified host volcanic rocks
- Vent zone surrounded by alteration halo of amorphous silica veins near surface to quartz-chalcedony, silica-alunite and kaolinite-baryte veining at depth
- Geochemistry changes from a Ag-dominated system to a Au-dominated system at >100 m depth
- Early-stage of high sulphidation Au-mineralisation

SAPPES EPITHERMAL GOLD

- Three deposits located
- Viper; 1.2 m.t. of 18.4 g/t Au, 9.4 g/t Ag, 0.34% Cu. Gold in Cu-sulphide minerals, tellurides and free within silica
- St. Demetrios and Scarp (discovered by IGME in 1987); 264000 t. of 3.5 g/t Au and 5.1 g/t Ag. Free gold grains within silica and iron oxides. Oxidised low-grade remnants of a silicified gold orebody

SAPPES GENETIC MODEL

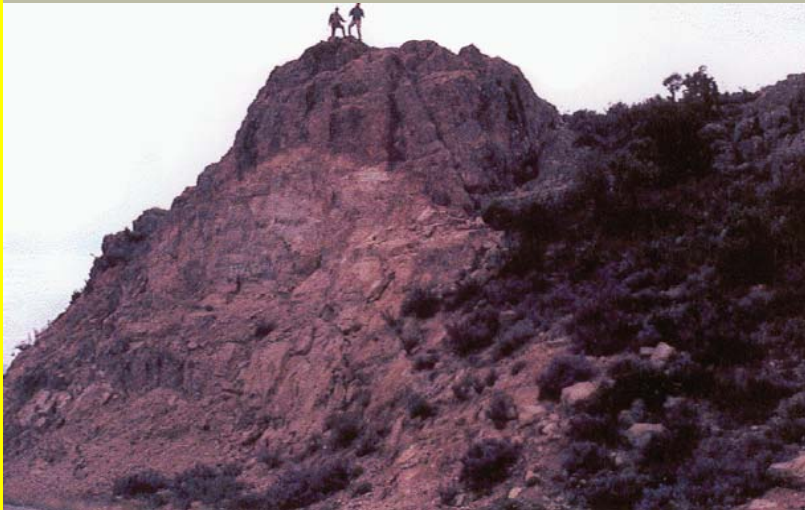


Schematic model of Saint Demetrios deposit (Sappes area)
C. Michael (1993)

EPITHERMAL GOLD SYSTEMS STRUCTURAL GUIDES



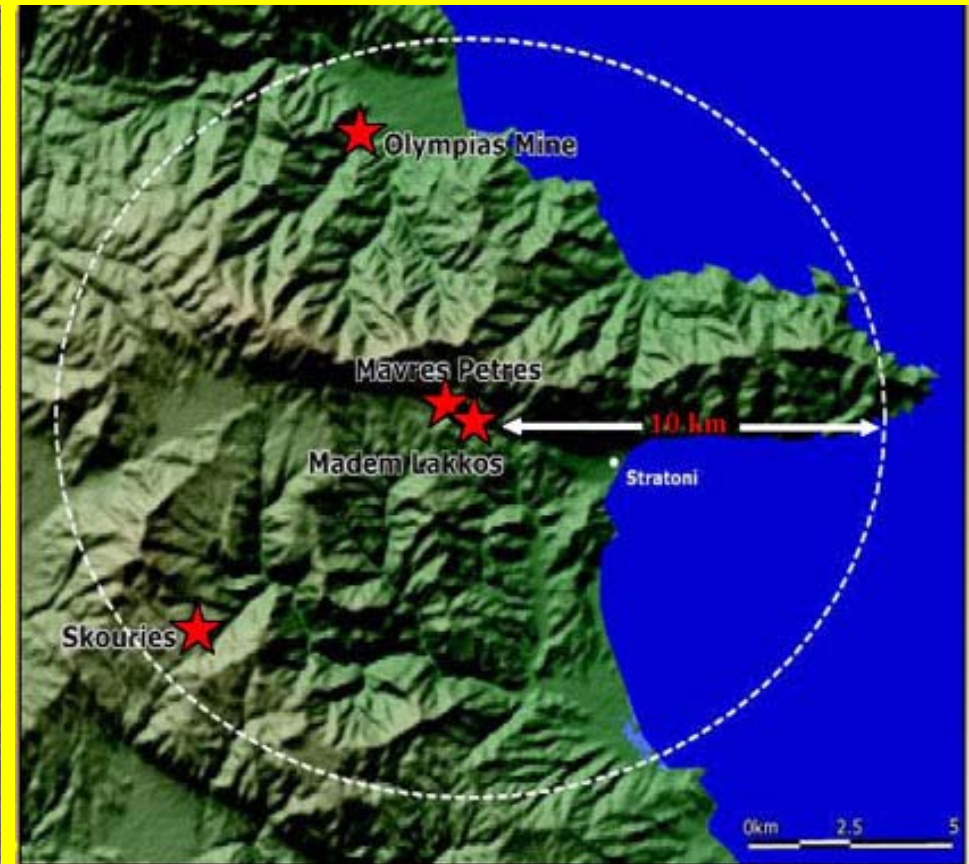
Silicified gold structures



Silica caps

HYPOTHERMAL(MESO-) MANTO-TYPE

- Olympias massive sulphide deposit



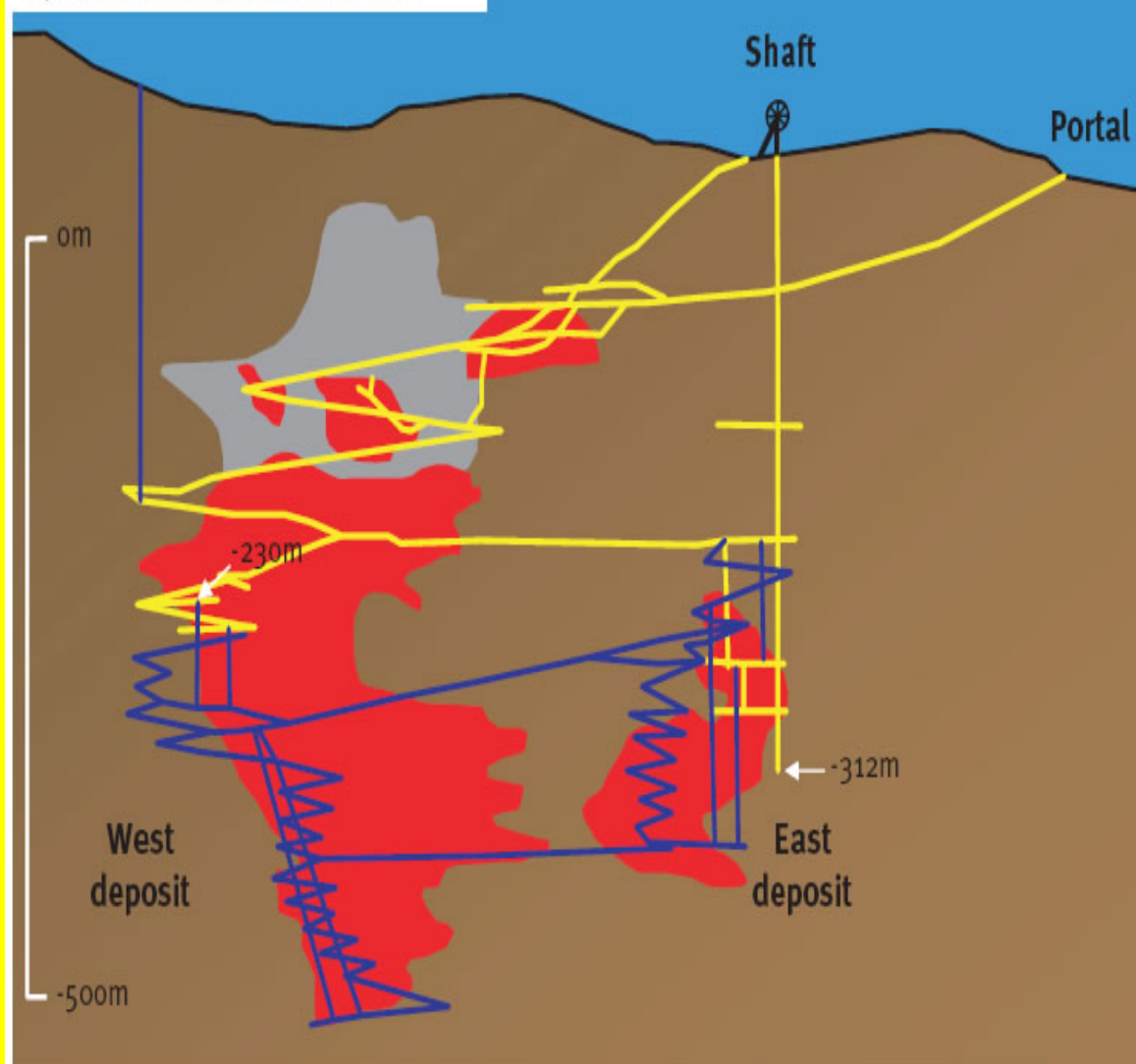
(source Hellas Gold)

OLYMPIAS DEPOSIT

- consists of pods of massive stratabound replacement polymetallic sulphide mineralisations hosted within a marble / gneiss contact. Two main deposits have been identified, the West and East deposits.
- sulphide mineralisations comprise pyrite, arsenopyrite, sphalerite, galena, tetrahedrite – tenantite, boulangerite and chalcopyrite. Gold values are associated almost exclusively with arsenopyrite and pyrite.
- the total resources and nearly reserves, were estimated to 14.528.000 tonnes, with 9,31 g/t gold, 128,6 g/t silver, 4,18 wt% lead and 5,58 wt% zinc. Corresponding total amounts of metal contents are 4,35 Moz gold, 60,06 Moz silver, 607.000 tonnes Pb and 810.000 tonnes zinc

OLYMPIAS DEPOSIT

Olympias mining infrastructure

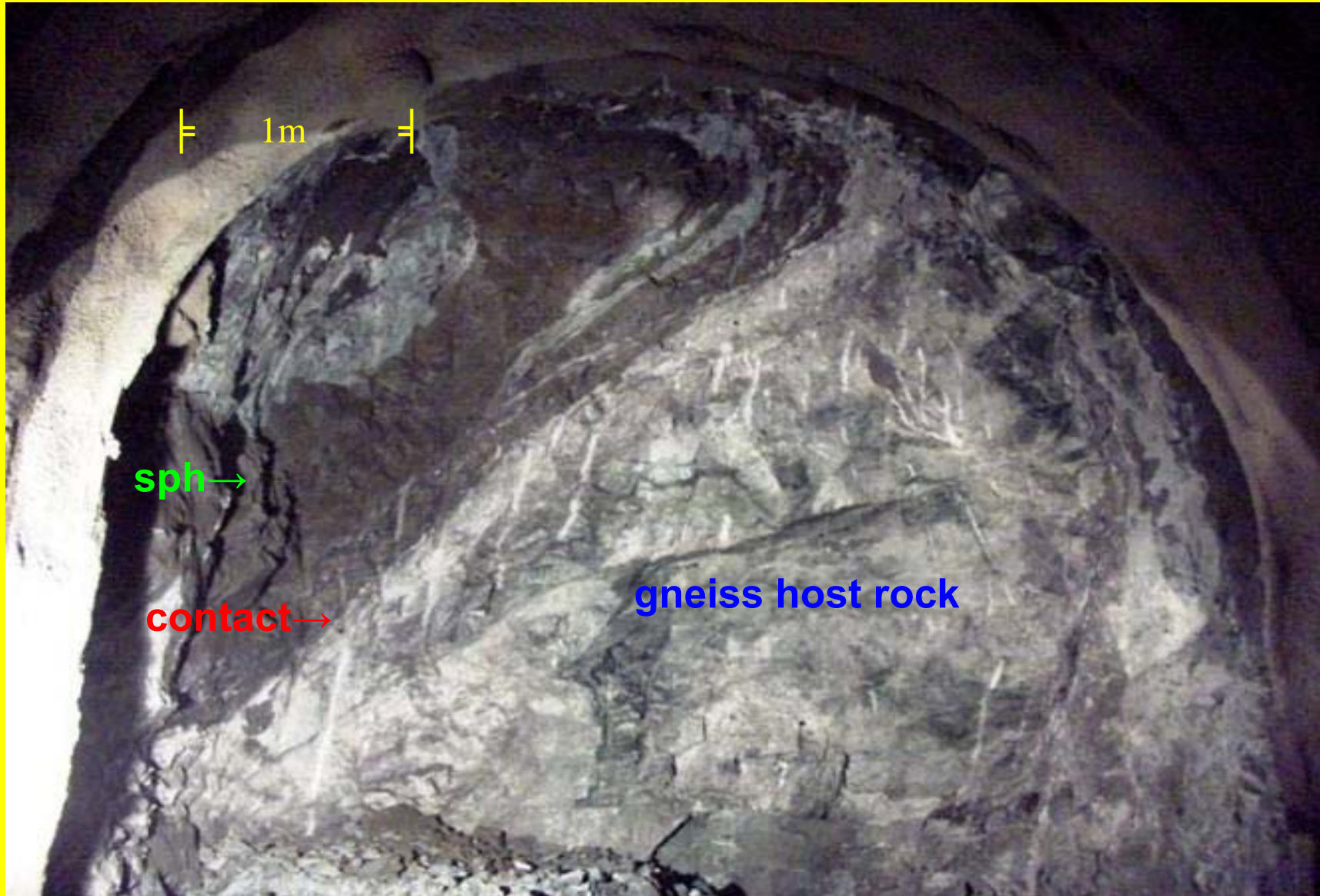


(source Hellas Gold)

- Existing development
- Proposed development
- Deposit
- Mined-out area

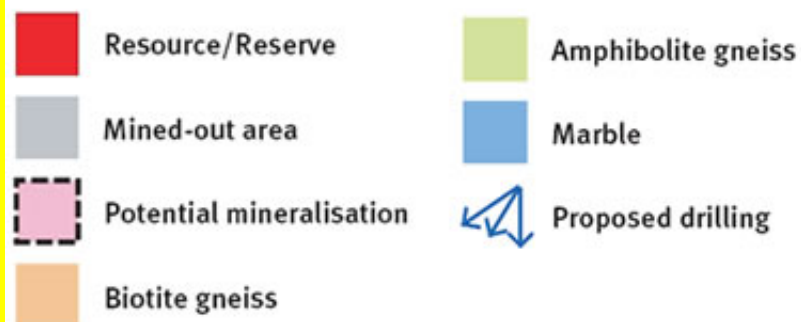
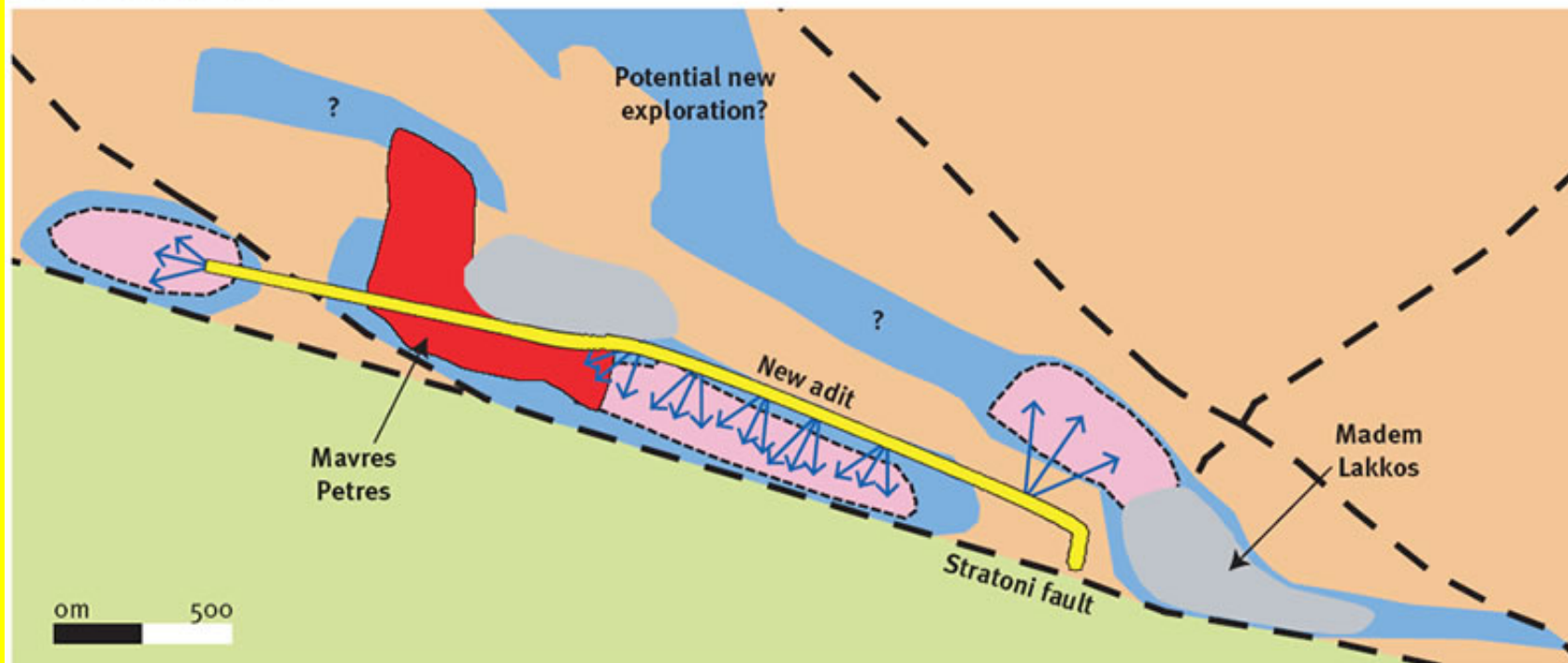
Transverse section through the Olympias deposit showing existing and proposed new infrastructure in relation to the deposits

MASSIVE ORE-HOST ROCK CONTACT



STRATONI DEPOSIT

Stratoni upside



Exploration potential will be drill-tested from the new adit

(source Hellas Gold)

MASSIVE SULPHIDE MANTO Au



MAGMATIC PORPHYRY TYPE

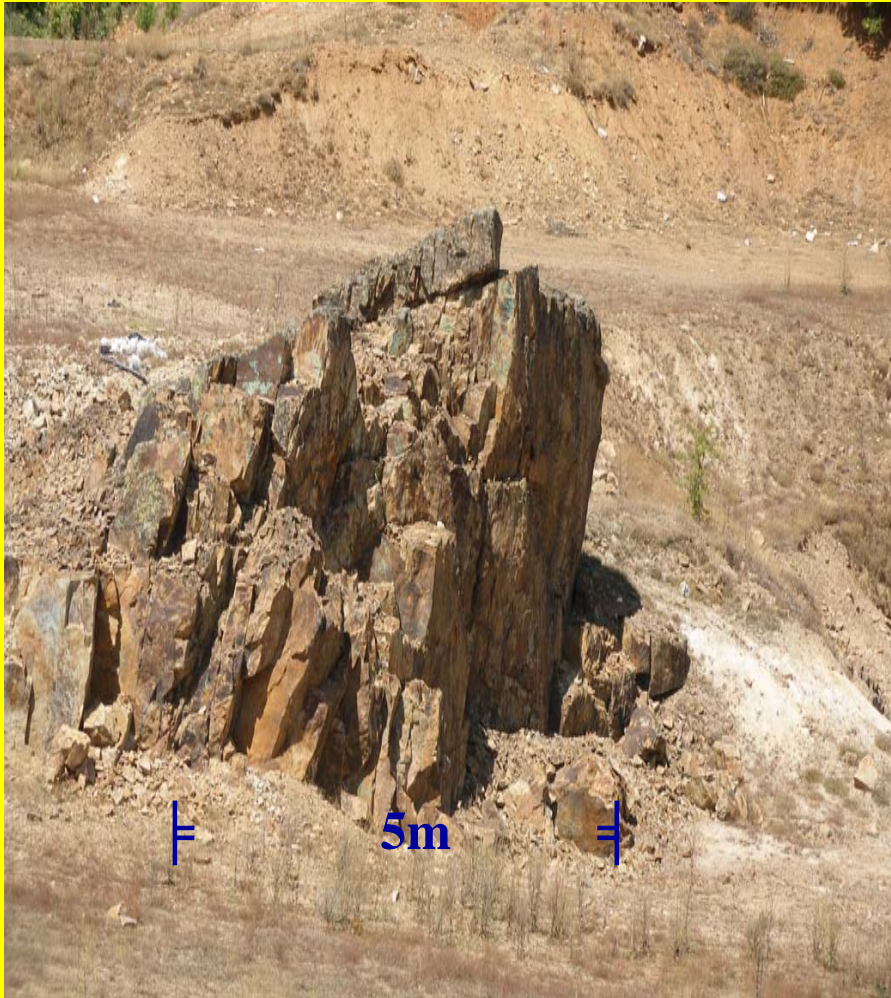


SKOURIES DEPOSIT

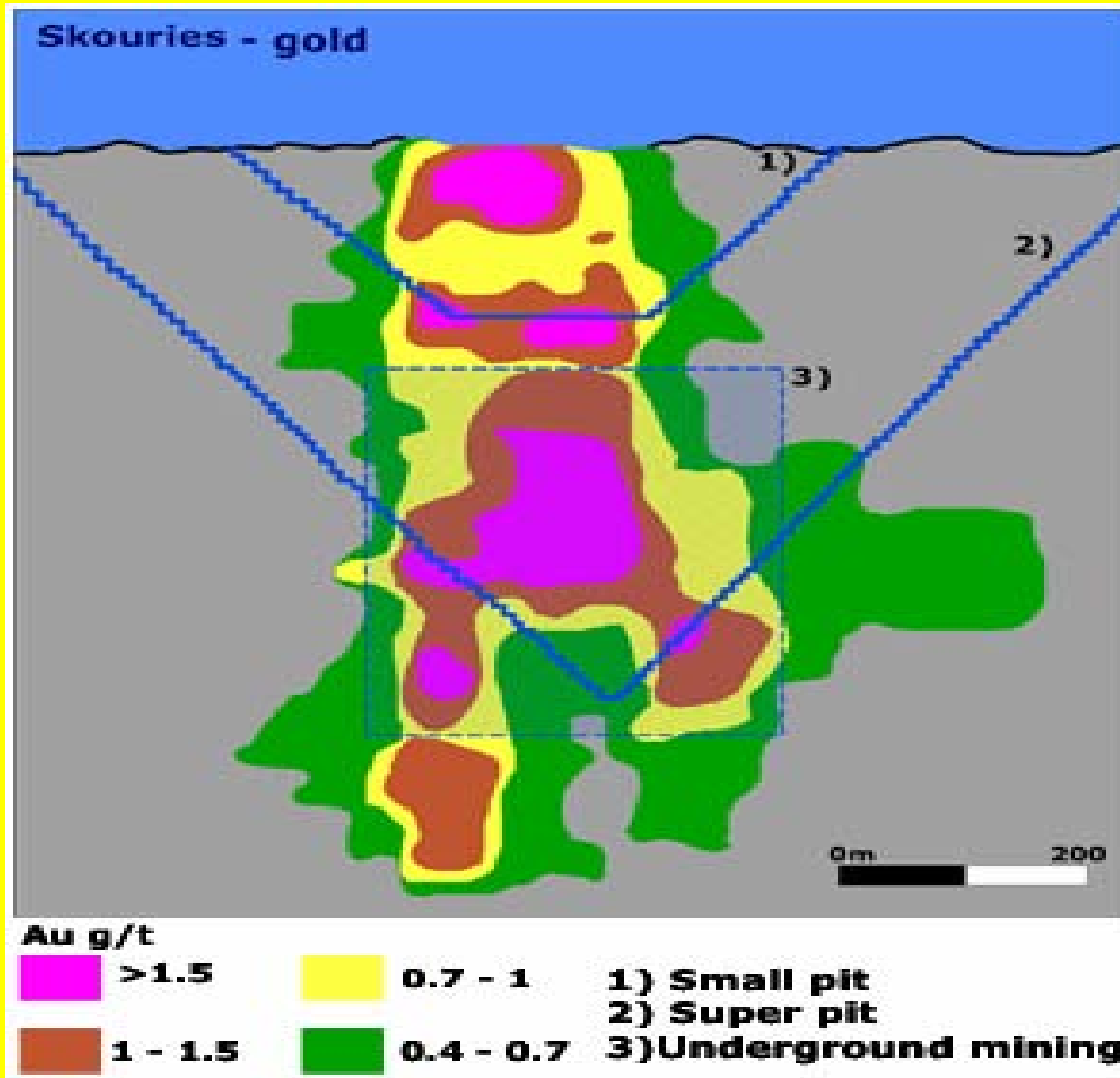
- a typical sub – alkaline gold-copper porphyry forming a near – vertical pipe intruded into amphibolite and biotite schist country rock
- characterized by concentric alteration zones comprising an inner potassic zone, with stock work quartz veinlets and an outer propylitic zone, affecting mostly the host schists.
- weak phyllic and argillic alteration is confined to vein haloes and faults
- mineralisations within the potassic zone primarily comprises chalcopyrite veinlets with subordinate bornite and disseminated chalcopyrite and bornite. Mineralisation within the propylitic zone contains disseminated pyrite, molybdenite and rare chalcocite. **Gold mineralisation occurs as native gold associated with gangue minerals. It also occurs as blebs within sulphides.** An oxide zone occurs from surface to 30 to 50 metre depths and includes malachite, cuprite, secondary chalcocite and minor azurite, covellite, digenite and native copper. There is no significant secondary enrichment blanket.
- **The total resources were estimated to 191.200.000 tonnes, with 0,82 g/t gold and 0,55 wt% copper, or in terms of total metal amounts, 5,03 Moz gold and 1.043.000 tonnes copper**

SKOURIES DEPOSIT

- Skouries outcrop

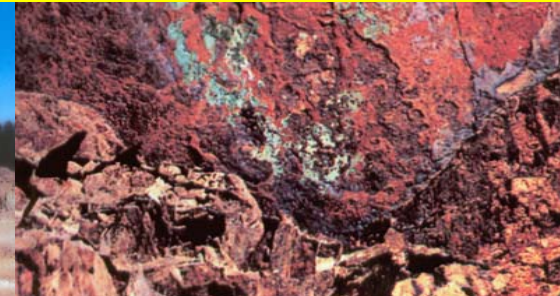
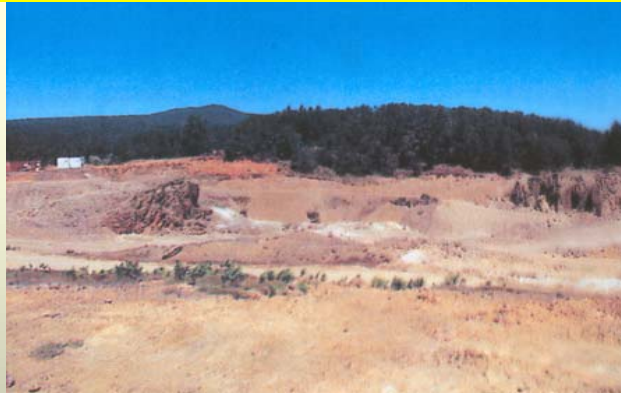


SKOURIES DEPOSIT



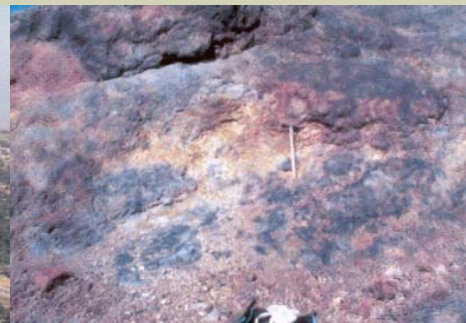
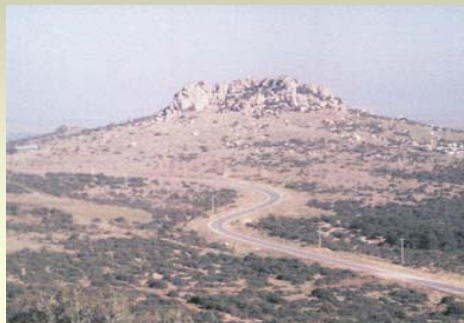
(source
Hellas Gold)

PORPHYRY GOLD MINERALISATION OUTCROPS



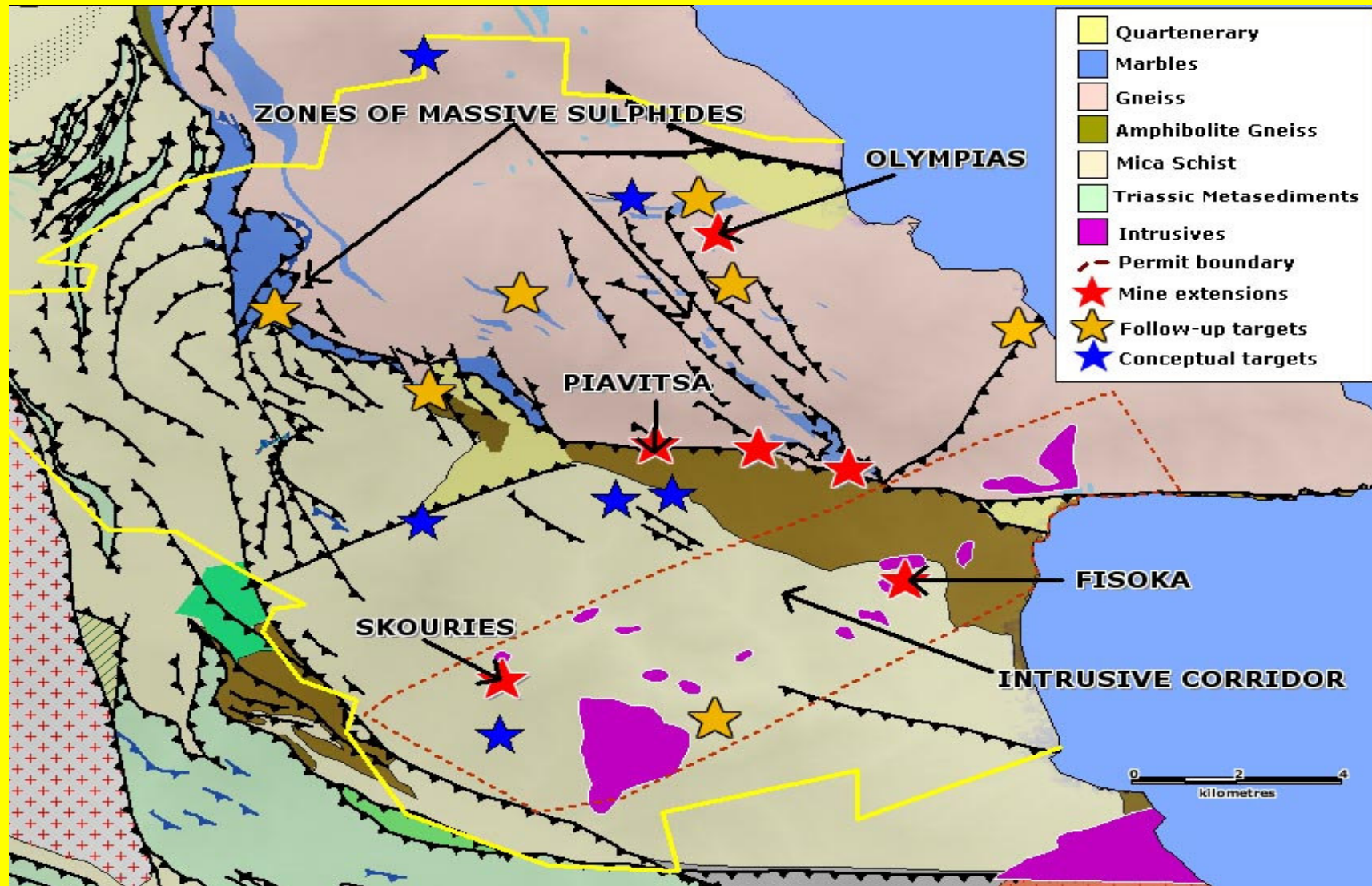
Porphyry Cu-Au mineralisation

Malachite oxide zone



Epithermal gold systems

PROSPECTING OF PORPHYRY AND MANTO GOLD

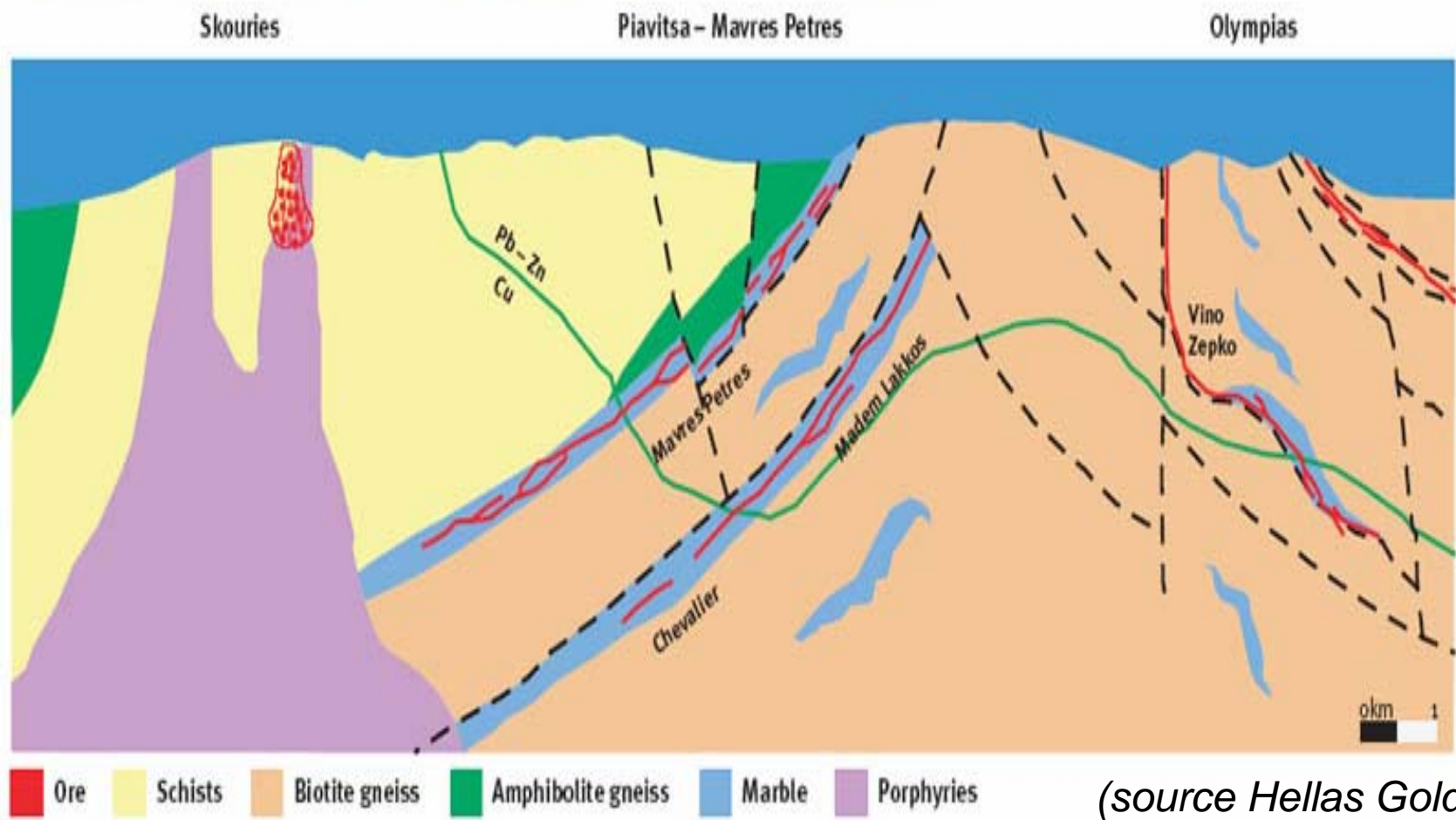


(source Hellas Gold)

OLYMPIAS-SKOURIES MODEL

Section of manto-type Au-mineralisations

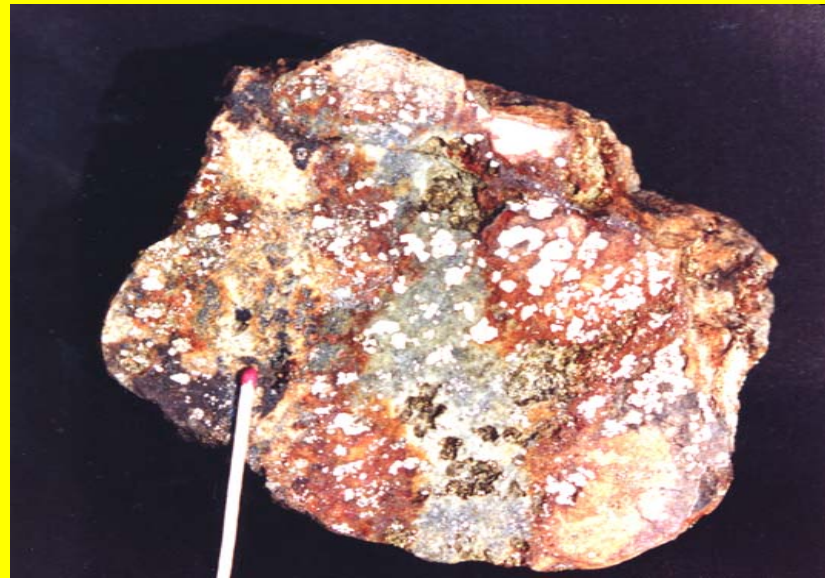
Geological model highlighting the location of polymetallic deposits and porphyries



OLYMPIAS EXPLORATION GUIDES

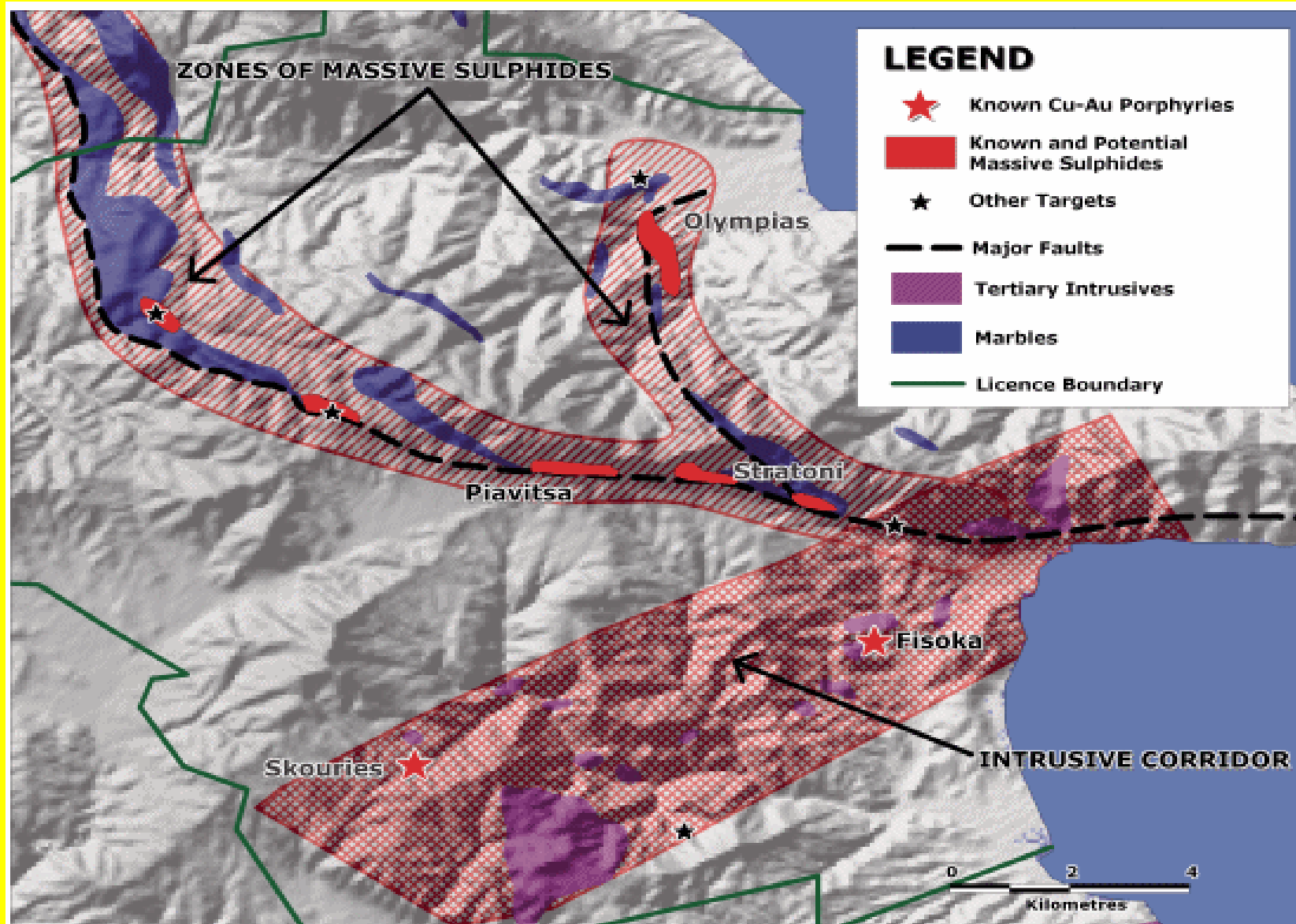


Olympias epithermal gold-pyrite silicification zones



Olympias manto/replacement massive gold-polymetallic sulphides(sph-ga-aspy-rdh)

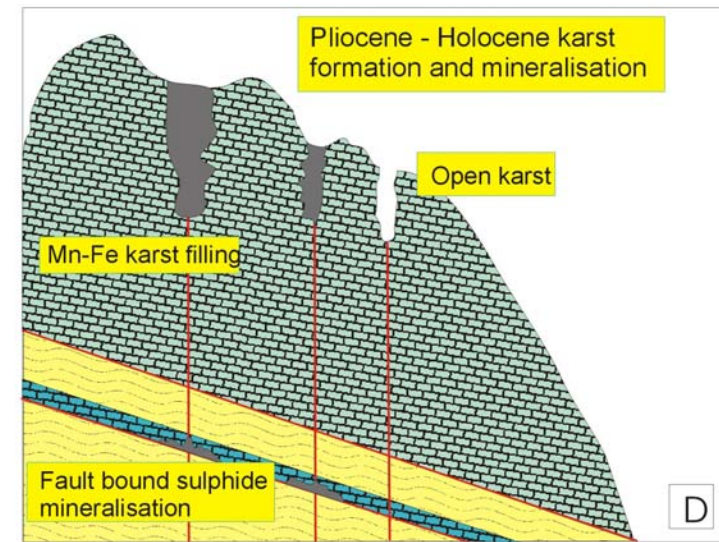
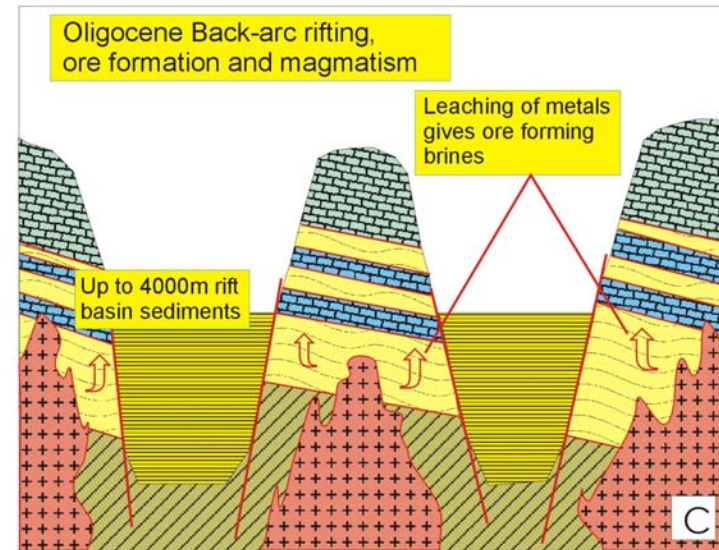
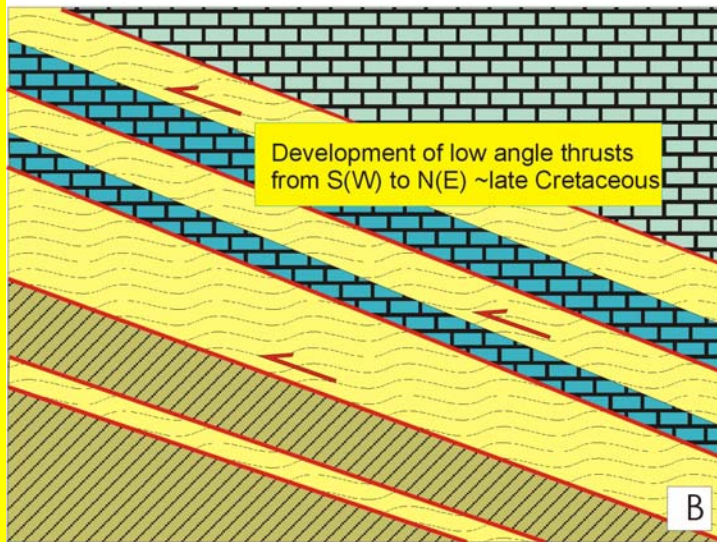
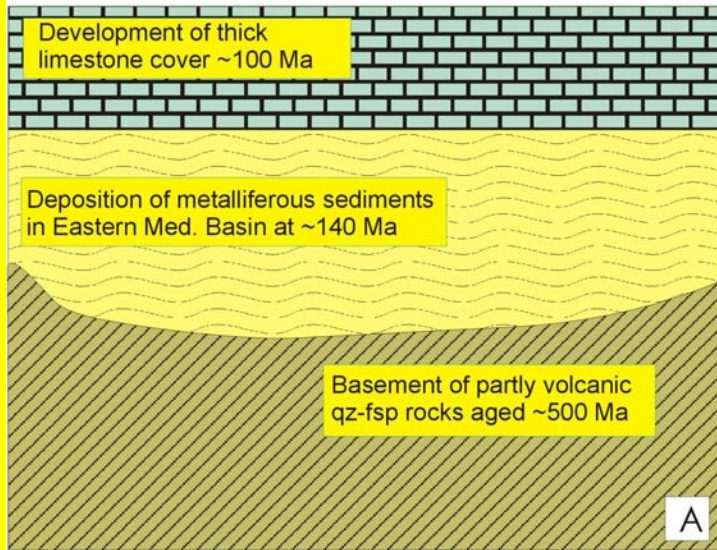
EXPLORATION STRATEGY



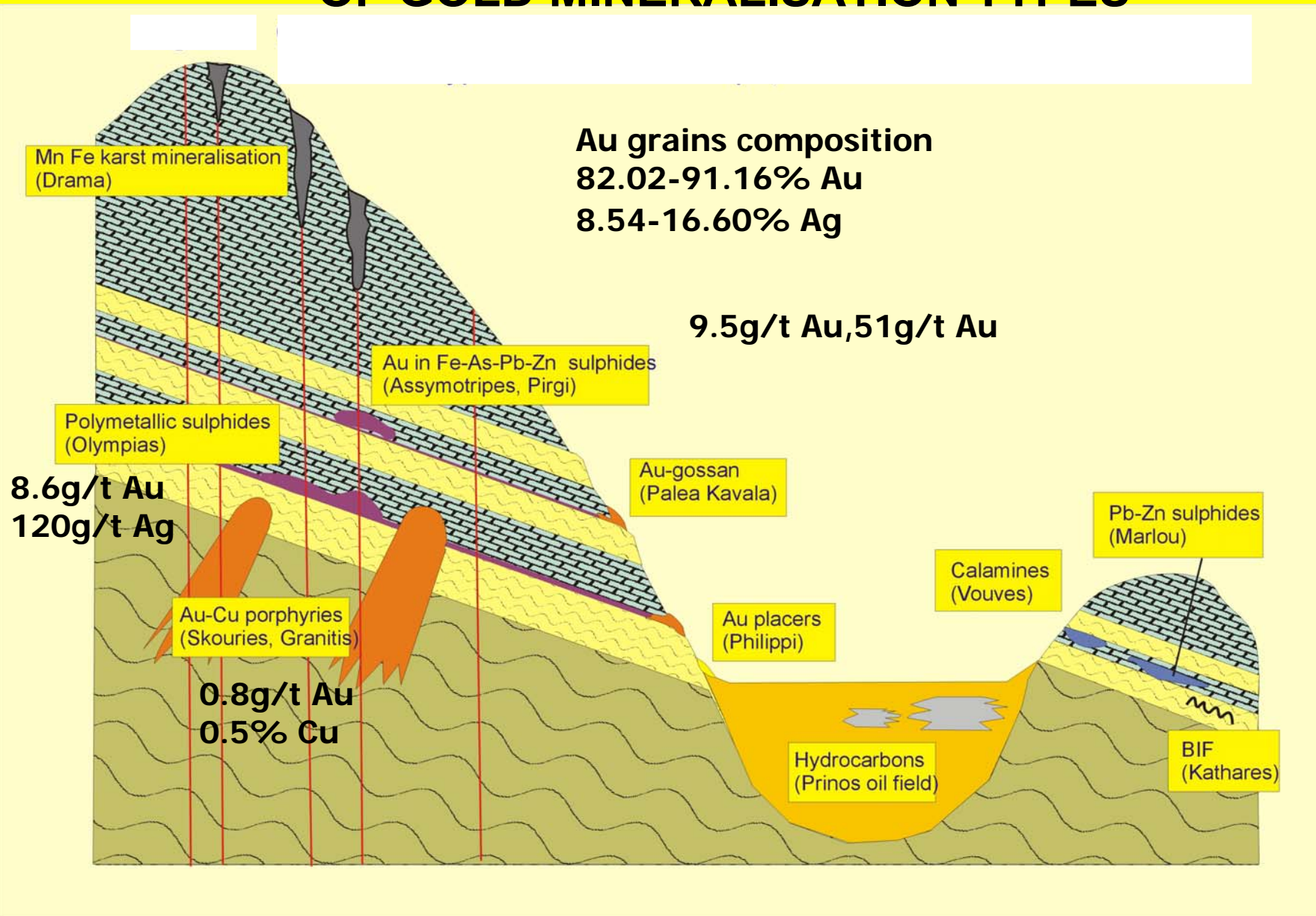
(source Hellas Gold)

MINERALISATION FORMING MODEL

Simplified integrated four phase model for mineralisation and karst forming in West Rhodope, N. Greece



RELATIVE POSITIONS AND GENETICAL LINKS OF GOLD MINERALISATION TYPES



CONCLUSIONS

The classification of gold mineralizations to specific genetic types is contributing to

- **(a)** knowledge-based more efficient exploration and prospect evaluation
- **(b)** safer assessment of ore potential and economic perspectives
- **(c)** rational management of resource production, and
- **(d)** applying sustainable development practices.

**THANK YOU FOR YOUR
ATTENTION**

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**Part of the work presented has been delivered
within the ongoing EU funded project BIOMINE**

ENVIRONMENTAL INDICATORS

- Determined and confident monitoring and analyzing protocols of all natural recipients
- Tools for source oriented control and mitigation of water and soil pollution, as well as measures for protection. Implementation of novel technologies for water cleaning and sustainable remediation of contaminated land, following the terms of WFD and Soil Thematic Strategy
- Communicating information and consultation for properly addressing risks related to heavy metals to employees and the public developing sound management practices
- Risk management for possible toxic pollutants related to gold mining by considering issues related to product stewardship, recycling, worker safety and public health regulations and knowledge-based R&D activities

SOCIOECONOMIC IMPACTS

- Main disputes with local communities
 - cyanide treatment of gold (use of biotechs / BioMine project)
 - subsidence problems at the surface above the mine
 - use of underground blasting right below urban areas
 - potential risks for toxic leaching of the cement stabilized tailings used for backfilling of mine drifts
- Main benefits for local communities
 - direct employment of about 2000 local workers; work will be provided for another 900 in the construction phase
 - in the case of the operating Stratoni mine a committee comprising ministry personnel and members of the local community was appointed to monitor environmental issues
 - financial and technical support to infrastructure and social projects. Plans for geo-mineral parks and mining museums