

Gold deposits in Greece are spatially associated with back-arc/arc related volcanic, subvolcanic and plutonic rocks, which were controlled by extensional kinematic conditions when metamorphic core complexes in the Rhodope-Serbomacedonian and Attico-Cycladic Massifs were uplifted to near surface levels over the south-westward retreating Hellenic subduction zone. Porphyry Cu-Mo-Au, high-intermediate sulfidation epithermal Au-Ag deposits and other intrusion-related proximal to distal systems (skarn, carbonate replacement, metamorphic rock-hosted quartz veins) are characterized by enrichment of trace metallic minerals like bismuth sulfosalts and Bi-sulfotellurides, precious- and base metal tellurides and Se-bearing phases, which can be considered as pathfinder minerals for gold as they are intimately associated with gold-bearing ores. Mineralogical studies of various styles of gold deposits in Greece can be applied as an exploration tool and selected examples are presented here.

3. Other Intrusion-related systems

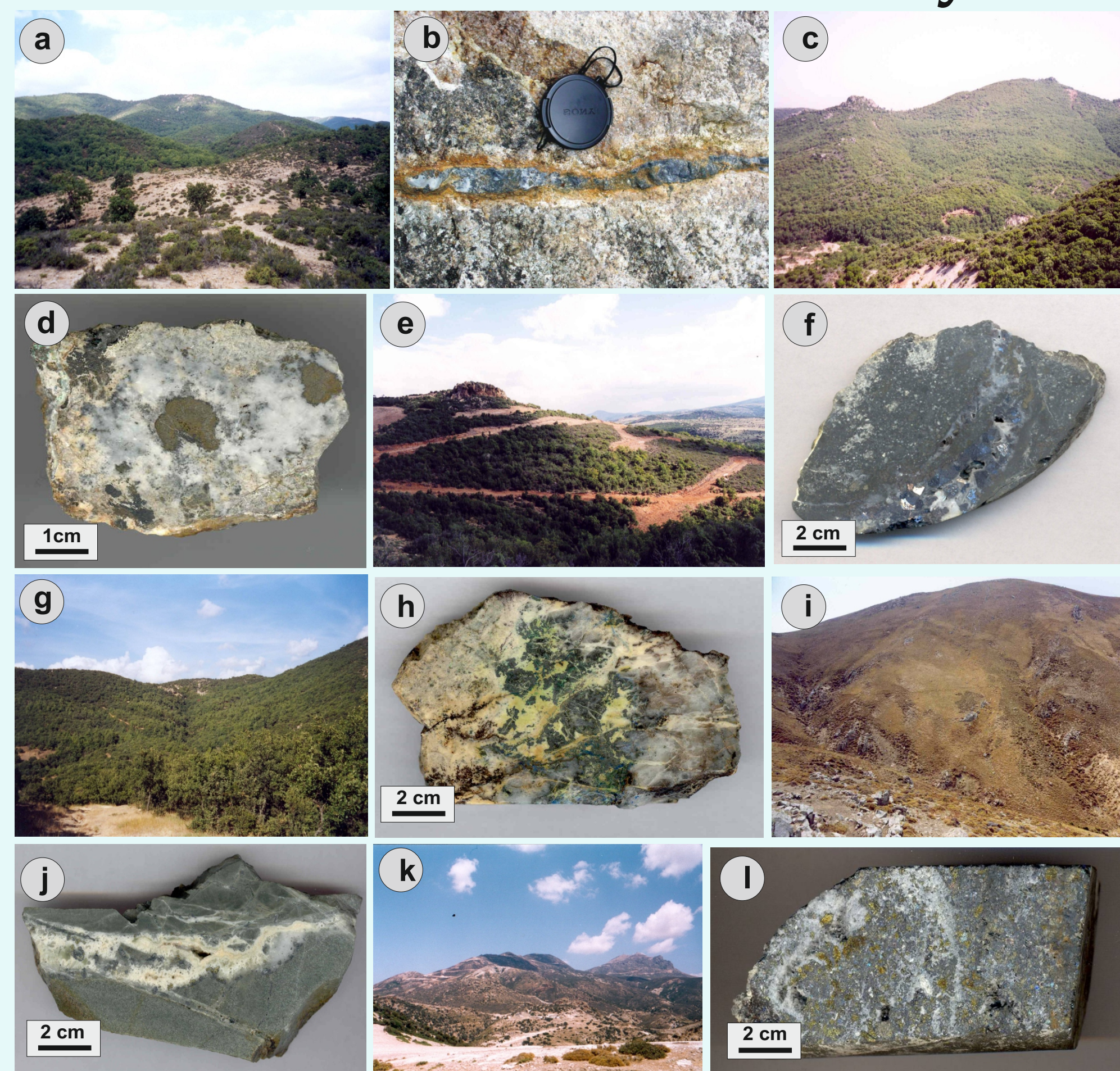


Figure 2. Photographs showing various telluride and Bi sulfosalts/chalcogenide mineralization in porphyry-epithermal systems of Greece: (a) Porphyry-Cu-Mo mineralization in the Pagoni Rachi area; (b) Late-stage carbonate-quartz veins with Bi-sulfosalts and silver tellurides crosscutting sericitized dacitic andesite, Pagoni Rachi area; (c) Porphyry-Cu-Mo and epithermal Au-Ag mineralization in the Kassiteres/Sapes area; (d) Chalcopyrite-telluride mineralization hosted in intermediate sulfidation epithermal carbonate vein at Kassiteres/Sapes area; (e) High-intermediate sulfidation epithermal mineralization at Perama Hill deposit; (f) Early stage enargite-bismuthinite within massive silica, and late-stage galena-tennantite-telluride mineralization related to barite-quartz veins at Perama Hill deposit; (g) High-intermediate sulfidation epithermal mineralization at Pefka deposit; (h) Chalcopyrite-telluride mineralization hosted in intermediate sulfidation epithermal carbonate vein in the Pefka area; (i) Porphyry-epithermal mineralization on Limnos island (Aegean Sea): Fakos prospect; (j) Galena-telluride mineralization hosted in intermediate sulfidation epithermal carbonate-quartz vein at the Fakos prospect, Limnos island. (k) Panoramic view of the shallow submarine epithermal Au-Ag mineralization at the Profitis Ilias deposit, Milos island; (l) Semi-massive base metal-telluride mineralization at Profitis Ilias deposit, Milos island.

Table 1: Characteristics of magmatic-hydrothermal Au-Ag deposits in Greece.

Deposit name	Deposit style	Critical and precious metal mineralogy	References
Konos Hill	Porphyry-epithermal	Re-Mol, Rhn	[18,4,12]
Koryfes Hill	Porphyry-epithermal	Ttd	[18]
Pagoni Rachi	Porphyry-epithermal	Bn, Re-Mol, Au, Rhn, Ttd, Hes, Ptz, Stz, Alt, AgAu, Aik, Hmr, Ber, Lnd, GusLill ss, SeBi sulf, Wic	[11,4,5]
Myli	Porphyry-epithermal	Re-Mol, Au	[4]
Maronia	Porphyry-epithermal	Re-Mol, Bsm	[2]
Melitena	Porphyry-epithermal	Re-Mol	[4]
Skouries	Porphyry	Syl, Hs, Clv, Tbm, Mer, Au, Bn	[13,14]
Fakos, Sardes	Porphyry-epithermal	Mol, Au	[15,16]
Stypsi	Porphyry-epithermal	Hes, Ptz, Alt, Ag-sulf	[15]
St. Demetrios	HS-IS epithermal	Re-Mol, Bsm	[17, 18]
Viper	HS-IS epithermal	Clv, Syl, Hs, Stz, Alt, Au, Glf	[18,19]
St Barbara	HS epithermal	Bn, Hs, Ptz, Syl, Alt, Te, Au	[18,19]
St Philippos	HS-IS epithermal	Bsm, Eng, Hs, Alt, Tbm	[5]
Perama Hill	HS-IS epithermal	Gn, Bsm, Hey, GusLill ss, Hs, Ptz, Syl, Kre, Clv, Col, Te, Mln	[21]
Mavrokoryfi	HS-IS epithermal	Gld, Au	[20]
Pefka	HS-IS epithermal	Ttd, Hs, Stz, Alt, Te, Au, Col, Syl, Glf	[19,22]
Milos	IS Epithermal	Hs, Ptz, Au, Alt	[23]
Kavala	Intrusion-related	Bsm, Ttd, Bisulfosalts, Cos, Au	[24,25,28]
Kimmeria	Intrusion-related	Bsm, Aik, Pek, Mat	[26,27]
Pangeon Mt	Intrusion-related	Ttd, Bsm, Au	[29,30]
Thasos	Intrusion-related	Bsm, Grf, Ttd, Hs, Au	[31,32]
Thermes	Intrusion-related	Grf, Hs, Alt, Au	[33]
Angistron Mt	Intrusion-related	Bsm, Bi, Cos, JosA, Lill hom	[34]
Aberdeen	Intrusion-related	Bsm, Emp, Aik, Wic, Ttd, Hs, Au	[35]
Madem Lakkos, Mavres Petres	Intrusion-related	Bsm, Gbm, Cos, Aik Au	[36,37]
Lavrio	Intrusion-related	Au, Bsm, Aik, Lill, Grf	[38]
Syros	Intrusion-related	Mol, Au	[39]
Stanos	Intrusion-related	Bsm, Pek, Gla, Kru, Gus-Lill ss, Cos, Emp, Bi, Au, JosA	[40-42]
Laodikino	Intrusion-related	Au, Pls	[3]
Koronouda	Intrusion-related	Bsm, Aik, Bi, Au, Hs, Ptz, Syl, Pls, Tbm, Jos-B	[43,44]
Kallianoi	Intrusion-related	Hs, Syl, Cvl, Stz, Ptz, Emr, Te, Col, Au	[45]
Tinos	Intrusion-related	Hs, Syl, Alt, Te, Stz, Crv, Mln, Rck, Vul, Wei, Kos, Kre, Ptz, Clv	[46,47]

For references and mineral abbreviations see text.

4. Conclusions

- A common feature of the metallic mineralization in Greece is the close relationship between gold (either in form of native element and/or as gold-silver tellurides) and other trace minerals that incorporate Bi, Te and Se in their structure. These minerals can be considered as pathfinders for gold and they may guide exploration to discover distinct types of gold-bearing ores.

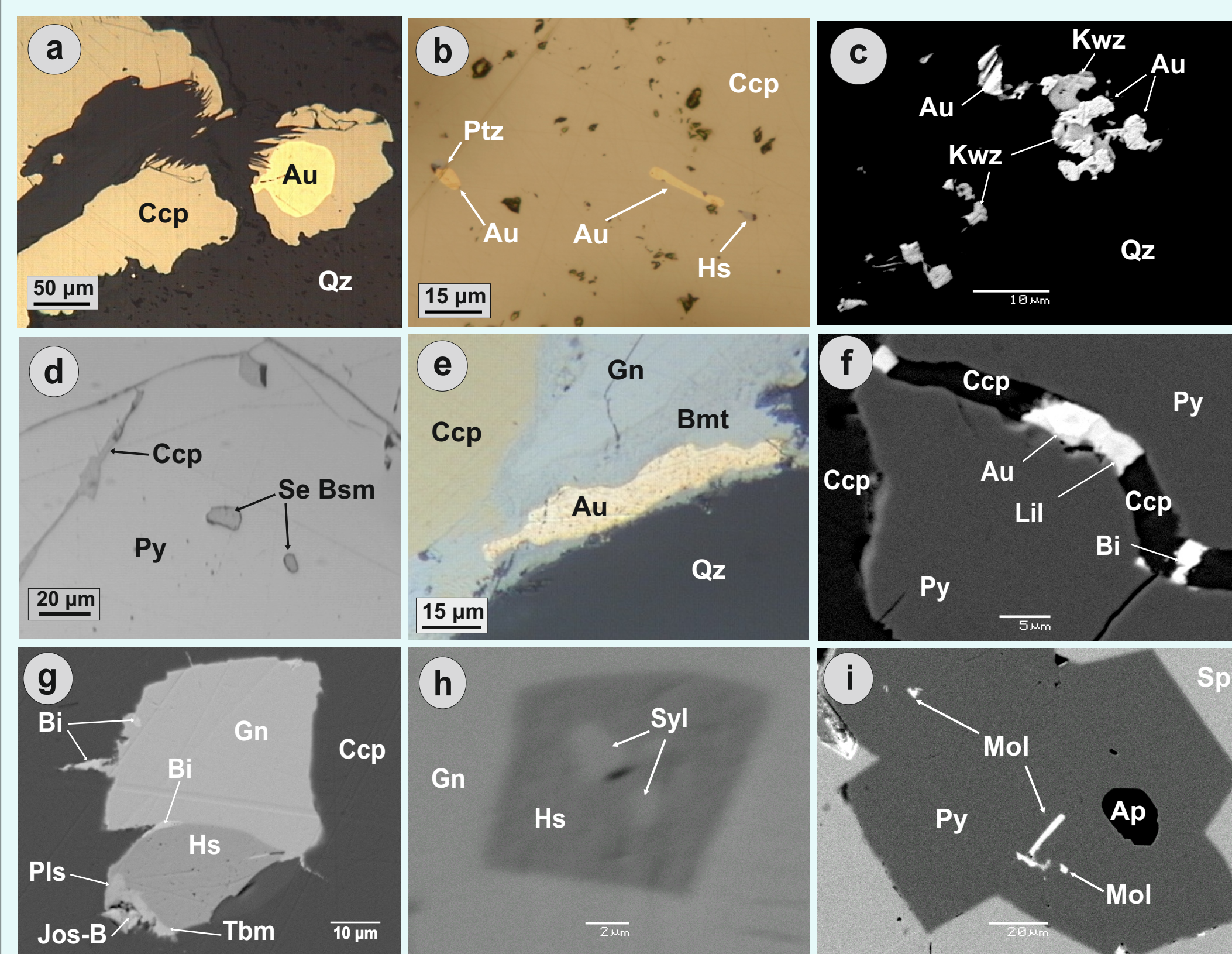


Figure 4. Reflected light and BSE microphotographs of ore parageneses of various Au-Ag telluride and Bi sulfosalts/chalcogenide bearing gold ore systems in Greece: (a) Native gold (Au) included in chalcopyrite (Ccp), Skouries porphyry Cu-Au deposit. Quartz (Qz) is gangue; (b) Native gold (Au), hessite (Hs) and petzite (Ptz) included in chalcopyrite. Viper high-sulfidation epithermal gold deposits, Sapes; (c) Native gold and kawazulite (Kwz) intergrowth; high-sulfidation epithermal Perama Hill deposit; (d) Se-bearing bismuthinite (Se-Bsm) included in pyrite (py). Kimmeria granodiorite-hosted quartz vein mineralization; (e) Native gold included in bismuthinite (Bmt) and associated with chalcopyrite and galena. Kamariza, Lavrio carbonate-replacement deposit; (f) Lillianite homologue (Lil), native gold (Au), native bismuth (Bi) and chalcopyrite (Ccp) filling fissure in pyrite (Py), Stanos intrusion-related deposit; (g) Bleb of galena (Gn) within chalcopyrite (Ccp) associated with hessite (Hs), native bismuth (Bi), pilsenite (Pls), joseite-B (Jos-B) and tellurobismuthite (Tbm), Koronouda intrusion-related deposit; (h) Sylvanite (Syl) and hessite (Hs) included in galena (Gn). Kallianou intrusion-related deposit; (i) Molybdenite (Mol) and apatite (Ap) included in pyrite. Sphalerite (Sp) is also present. Syros island carbonate-replacement deposit.

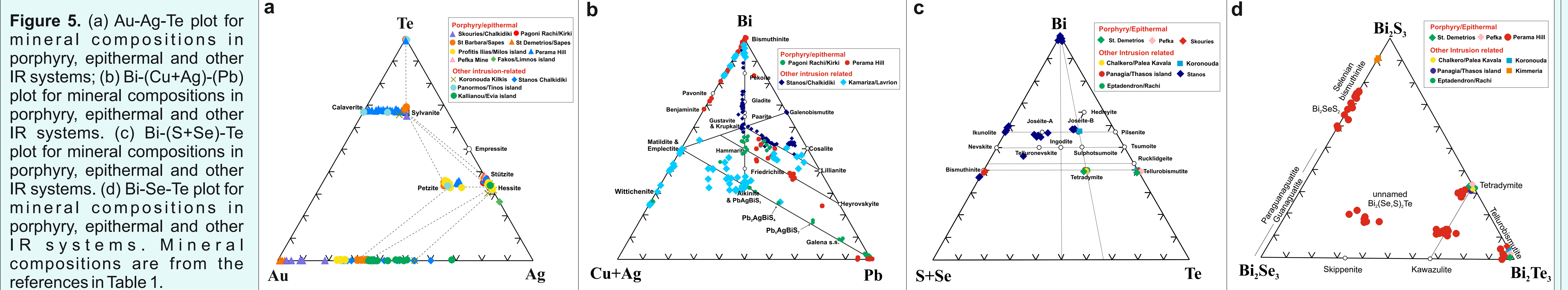


Figure 5. (a) Au-Ag-Te plot for mineral compositions in porphyry, epithermal and other IR systems; (b) Bi-(Cu+Ag)-(Pb) plot for mineral compositions in porphyry, epithermal and other IR systems. (c) Bi-(S+Se)-Te plot for mineral compositions in porphyry, epithermal and other IR systems. (d) Bi-Se-Te plot for mineral compositions in porphyry, epithermal and other IR systems. Mineral compositions are from the references in Table 1.

1. Introduction and Regional Geology

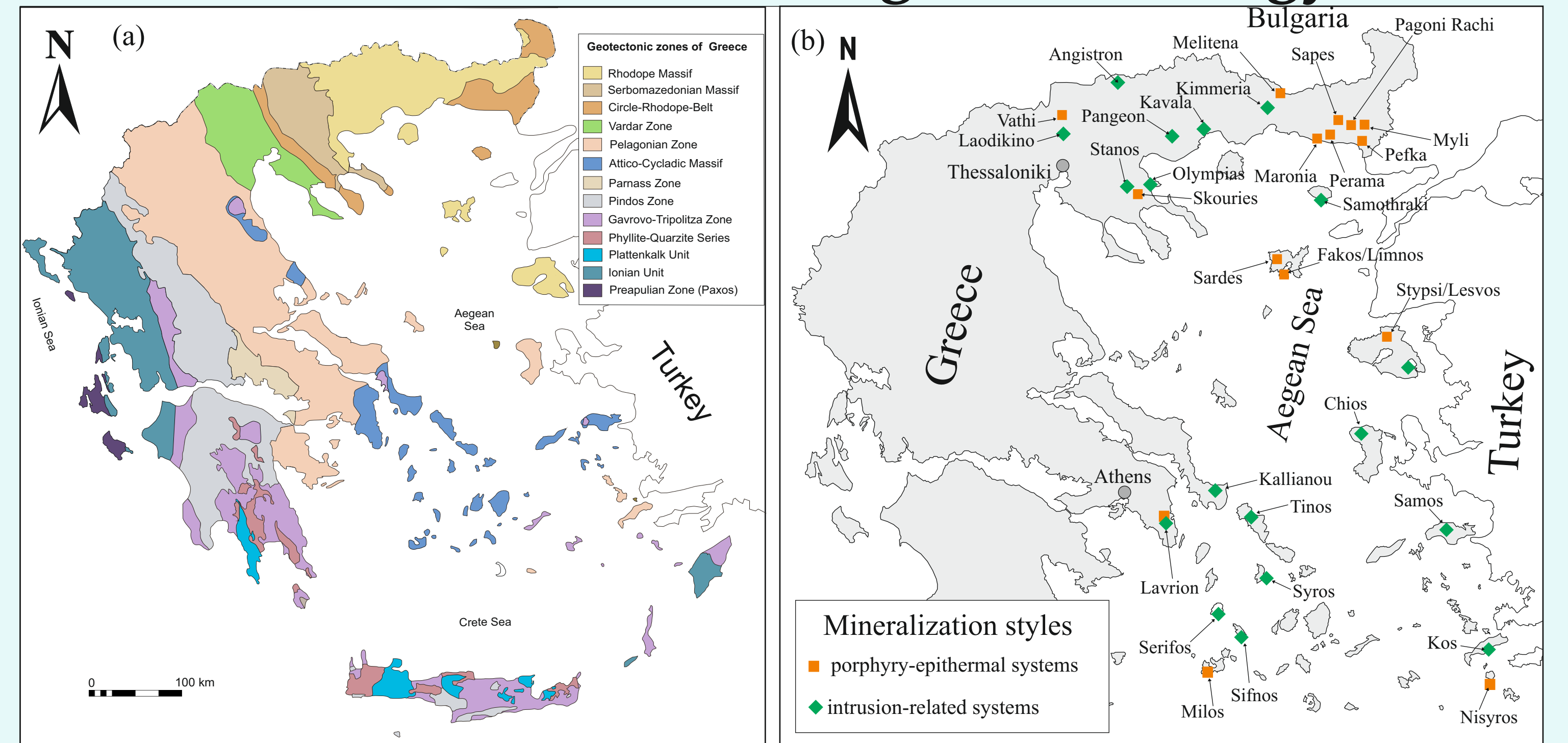


Figure 1. (a) Simplified geologic map of the Hellenides (modified after Ottens and Voudouris, 2018) and (b) location of the gold-bearing mineralization (modified from Voudouris et al. 2007, 2013a).

2. Porphyry- and epithermal-style deposits

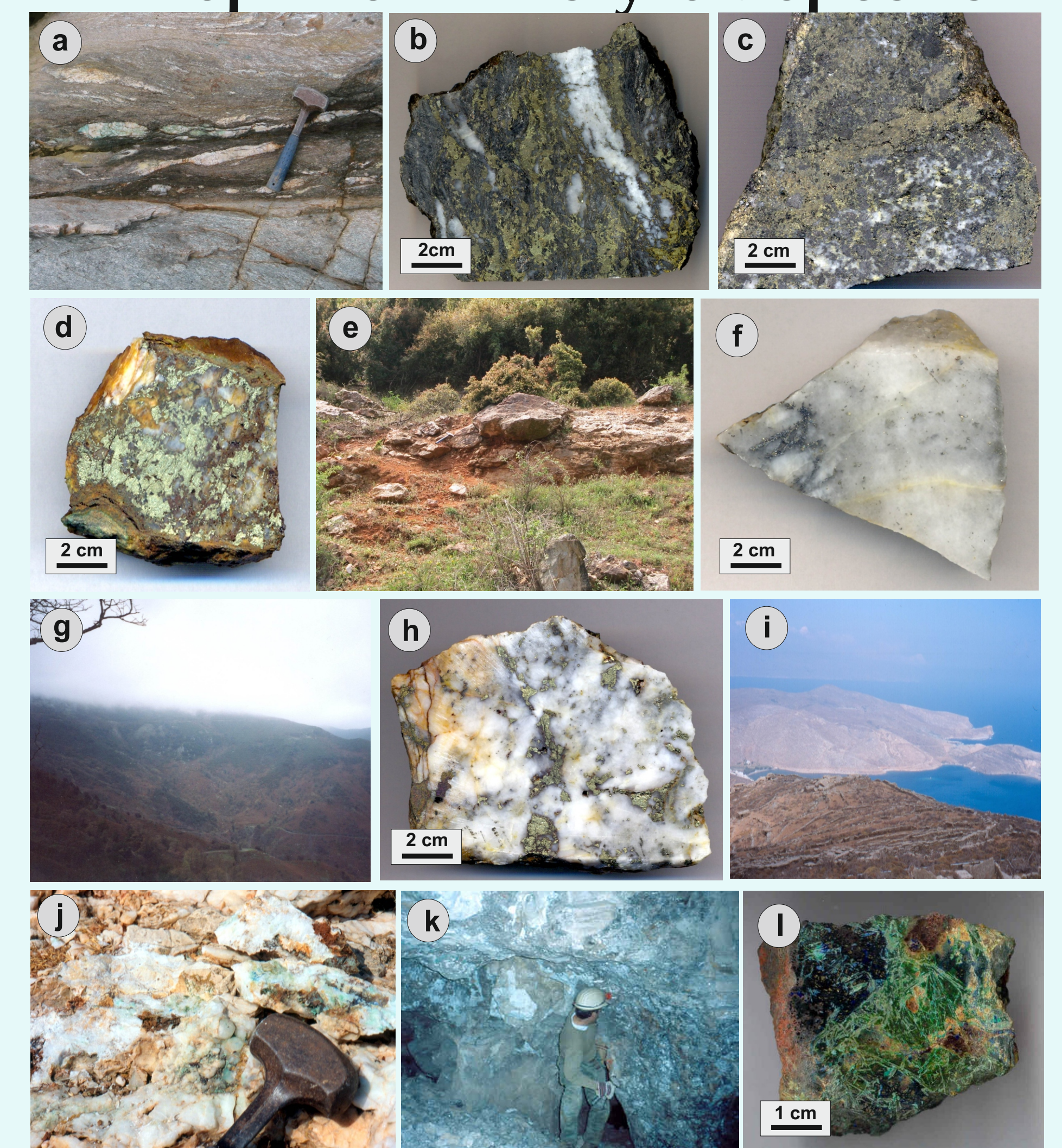


Figure 3. Photographs of various telluride and Bi-sulfosalts mineralization in reduced "granitoid-related" mineralization. Shear zone-hosted and intrusion-related mineralization in the Servomacedonian Massif: (a) Stanos mineralization; (b) Chalcopyrite+tellurides hosted in sheared mica-gneiss, Stanos area; (c) Arsenopyrite+chalcopyrite+tellurides hosted in sheared amphibolite, Laodikino/Kilkis area; (d) Chalcopyrite+tellurides in sheared quartz vein, Koronouda/Kilkis area; (e) Shear zone-hosted and intrusion-related mineralization in the Rhodope Massif; (f) Palea Kavala vein mineralization; (g) Bismuthinite+tetradymite hosted in quartz vein from shear zone-related mineralization at Palea Kavala area; (h) Panoramic view of Kallianou deposit, Evia island; (i) Chalcopyrite-telluride mineralization hosted in quartz veins from Kallianou/Evia island; (j) Panoramic view of Panormos deposit, Tinos island; (k) Quartz veins crosscutting marbles at Panormos mineralization; (l) Carbonate replacement mineralization in the Lavrio deposit; (m) Oxidized chalcopyrite-bismuthinite-gold mineralization in the Lavrio area.