

Gems in Greece: Geology, mineralogy and crystallizing environment

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In the accretionary Hellenides Orogen, gems occur in various rock types of mainly four tectonometamorphic units, the Rhodope- and the Attico-Cycladic massifs, the Pelagonian zone, and the Phyllites-Quartzites of Crete Island (Fig. 1). In crystalline rocks, two groups of gems are distinguished, those formed during regional metamorphism and those associated with late alpine-type fissures (Voudouris *et al.*

2019 a,b). The first group includes Mn-bearing silicates (Mn-andalusite, spessartine, Mn-grossular, Mn-clinozoisite, Mn-zoisite and orange-colored Fe-Mn-kyanite; Fig. 2a-d) hosted in gneisses and marbles in both Thassos and Paros Islands (Rhodope- and Attico-Cycladic massifs respectively), as well as corundum in Xanthi-Drama areas/Rhodope massif and Naxos-Ikaria Islands (Attico-Cycladic massif).

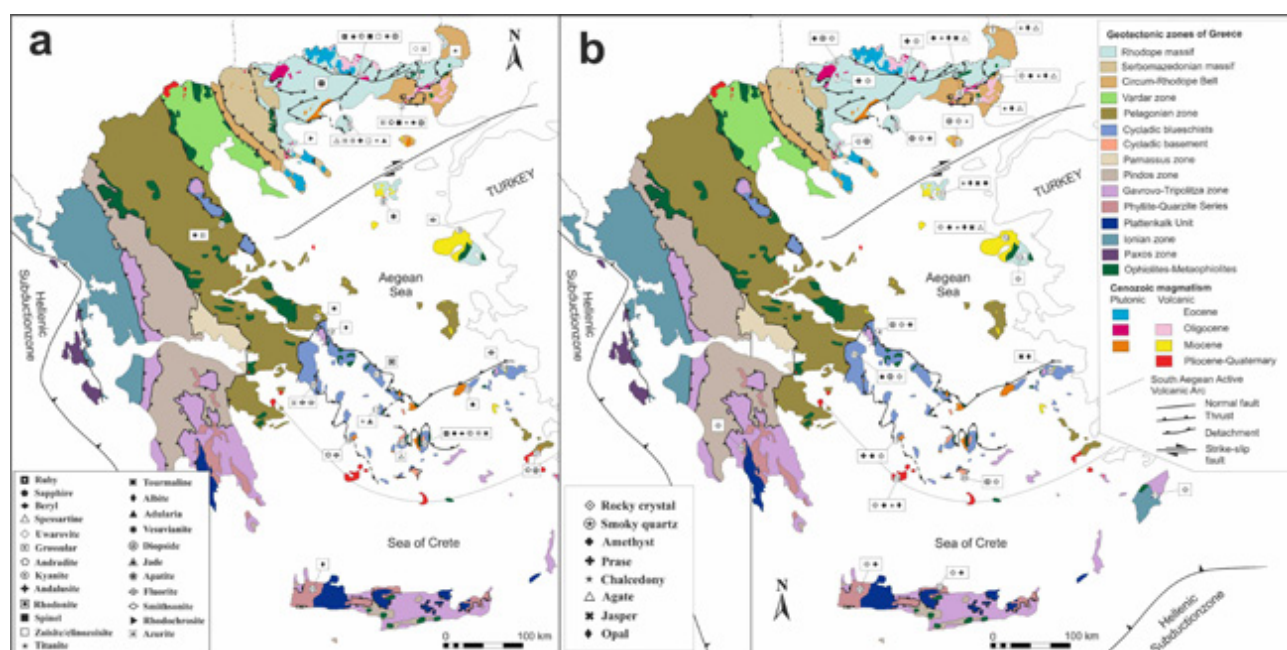


Figure 1. (a) Occurrences of various gemstones in metamorphic and igneous rocks of Greece: 1&2 Evros, 3. Maronia/Rhodopi, 4. Kimmeria/Xanthi, 5. Paranesti/Drama, 6. Trikorfo/Thassos, 7. Olympiada/Chalkidiki, 8. Limnos Island, 9. Lesvos Island, 10. Larissa, 11&12 Evia Island, 13. Andros Island, 14. Samos Island, 15. Ikaria Island, 16. Lavrion/Attika, 17. Syros Island, 18. Serifos Island, 19. Paros Island, 20. Kinidaros/Naxos Island, 21. Kos Island, 22. Crete Island; (b) Occurrences of gem silica varieties

in metamorphic and igneous rocks of Greece: 1-3. Evros 4. Sapes/Rhodopi, 5. Xanthi, 6&7. Drama, 8. Trikorfo/Thassos, 9. Straton-Olympiada/Chalkidiki, 10. Samothraki island, 11. Limnos Island, 12&12. Lesvos Island, 14. Evia Island, 15. Pentelikon Mt/Attika, 16. Samos Island, 17. Serifos Island, 18 Taygetos Mt. 19. Milos Island, 20. Ios Island, 21. Rhodes Island, 22&23. Crete Island. Modified after Voudouris *et al.* 2019a.

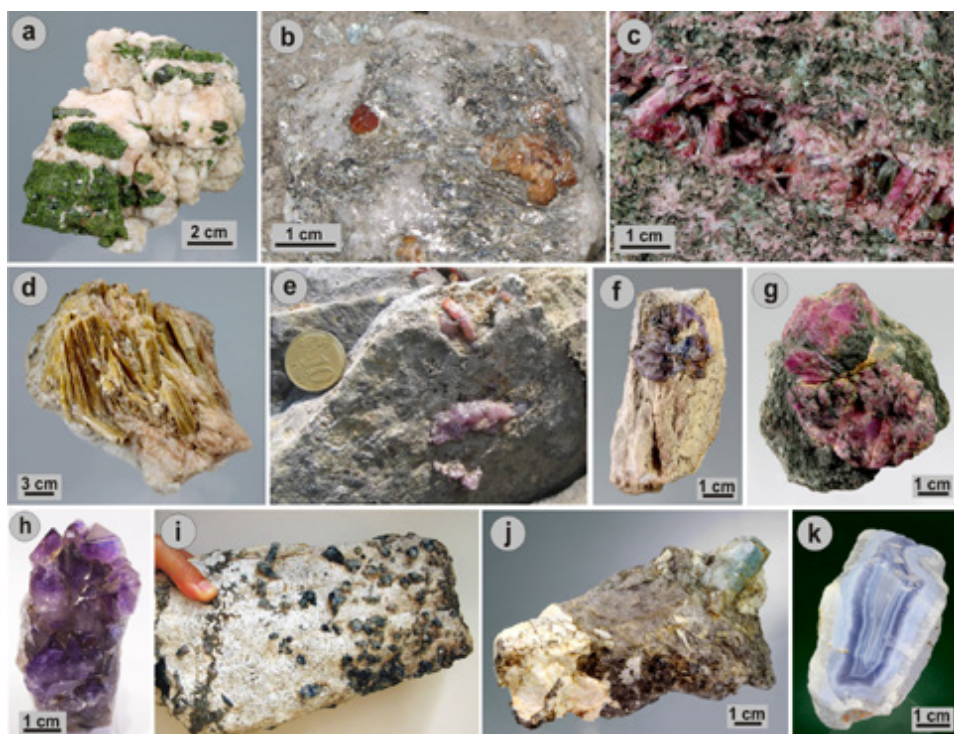


Figure 2. Photographs demonstrating various gem minerals from Greece. (a) Mn-rich andalusite from Trikorfo, Thassos Island; (b) spessartine crystals from Trikorfo; (c) Pink-red, Mn-bearing zoisite/clinozoisite from Trikorfo; (d) Orange kyanite at Trikorfo; (e,f) Pink to purple sapphires within Xanthi marbles; (g) Ruby within pargasite schist from Paranesti/Drama; (h) Amethyst from Dassoto, Drama; (i) Blue sapphires within desilicated pegmatite from Kinidaros, Naxos Island; (j) Aquamarine within pegmatite from Kinidaros, Naxos Island; (k) Blue agate from Aetochori, Evros. Photographs a,d,f,g,h,j,k are courtesy of Berthold Ottens.

In the Xanthi-Drama area, corundum mineralization (sapphires and rubies) occurs within marbles and eclogitic amphibolites within the Nestos suture zone (Fig. 2e-g). In the Attico-Cycladic massif, blue sapphires are found within marble-hosted metabauxites (Ikaria and Naxos Island).

Metamorphic/metasomatic processes within a subduction channel, resulted in the formation of the jadeitite bodies at Syros Island and of garnet and vesuvianite in rodingite bodies at the Rhodope massif and the Pelagonian zone. Alpine-type fissures in Greece contain gem quartz (green quartz-prasiolite-, amethyst, smoky and colourless quartz; Fig. 2h), albite and titanite. Host lithologies are ortho- and paragneisses and metabasites in the Rhodope- (Drama, Thassos Island) and the Attico-Cycladic (Pentelikon Mt, Evia, Ios Islands) massifs, and metaquartzites (Crete Island).

The Tertiary magmatic-hydrothermal environments in Greece (granitoids, pegmatites, skarns and carbonate-replacement deposits, and volcanic rocks) may also provide gem material of several species (beryl, corundum, garnet, vesuvianite, diopside, epidote, fluorite, rhodochrosite, silica varieties). The Naxos pegmatites are prospective for aquamarine and

blue, purple to pink coloured sapphires (Fig. 2i,j). Mirolitic cavities and quartz veins cross-cutting granitoids (Samo-thraki Island, Maronia and, Kimmeria) contain colourless and smoky quartz. The endo- and exoskarns of Kimmeria and Maronia (Rhodope massif), Serifos Island (Attico-Cycladic massif) and Kos Island, contain grossular-andradite garnets, vesuvianite, epidote, as well as prasiolite and amethyst crystals. Rhodochrosite and fluorite occur in the carbonate-replacement deposits of Olympias/Chalkidiki and Lavrion/Attika respectively. Gems associated with hydrothermally altered volcanic rocks include amethyst, chalcedony (Fig. 2k), opal, fossilized wood and fluorite in Sapes, Soufli areas (Rhodope massif), Lesvos, Limnos and Samos Islands (northeastern and central Aegean volcanic arc) and Milos Island (Attico-Cycladic massif-south Aegean volcanic arc). Finally, the supergene oxidation of the Lavrion/Attika carbonate-replacement deposit contains smithsonite in several colourations. Figure 3 represents a hypothetical schematic model, where gem occurrences in Greece are related to the various geological environments (regional metamorphic-metasomatic, alpine-type fissures, plutonic-subvolcanic intrusions and pegmatites, zones of contact metamorphism and peripheral volcanic rocks).

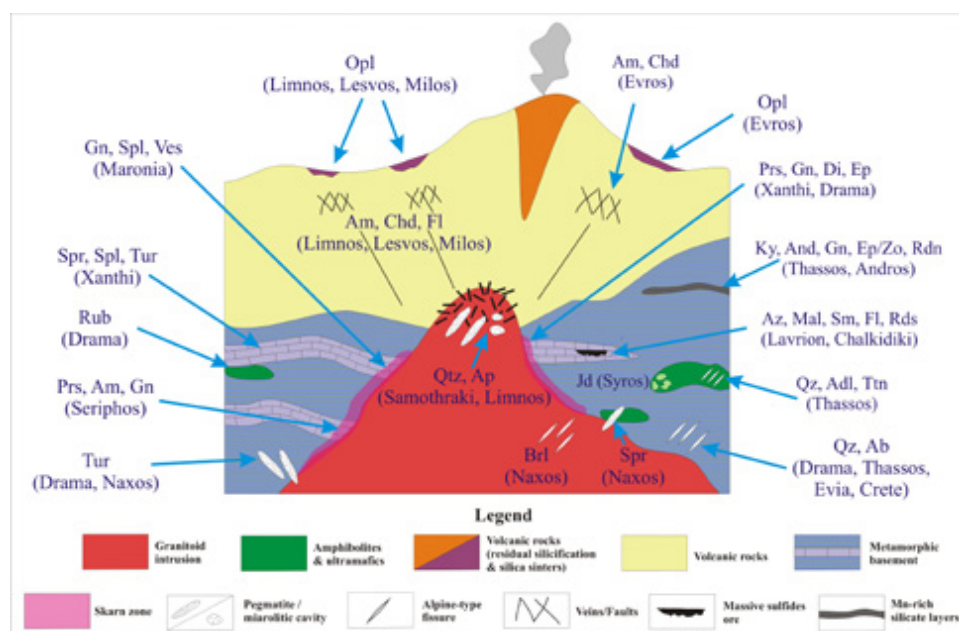


Figure 3. Hypothetical model presenting the various environments related to crystallization of gems in Greece. Abbreviations: Ab: Albite, Adl: Adularia; Am: Amethyst, And: Andalusite; Ap: Apatite; Az: Azurite; Brl: Beryl, Chd: Chalcedony, Di: Diopside, Epid: Epidote, Fl: Fluorite, Gn: Garnet, Jd: Jadeite; Ky: Kyanite; Prs: Prasiolite; Rdn: Rhodonite; Rds: Rhodochrosite; Sm: Smithsonian; Spr: Sapphire, Spl: Spinel; Ttn: Titanite; Tur: Tourmaline, Ves: Vesuvianite.

Greek corundum presents a variety of colour, with rough crystal sizes of up to 5 cm, transparent to translucent, having homogeneous colours (Fig. 4). Crystals of kyanite, green andalusite, garnet and red zoisite-clinozoisite from Trikorfo/Thassos, show vivid colours, and might be of gem quality. Finally, silica related gems can also be found (Fig. 4).



Figure 4. Various cut gems from Greece. Green Mn-andalusite from Thassos (2.2 cm length) in the left, dark green epidote from Kimmeria (1.3 cm) in the centre, ruby from Paranesti (4 cm) in the right of the photograph. The rest are silica related gems. Photo courtesy of Anastasios Tsinidis.

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