

Geological and mining history of Serifos Island, Greece: current state and perspectives for protection of mineralogical and petrological geotopes

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Geology

The Serifos island, located in the south Aegean Sea, represents a multiple mineralized district including intrusion-hosted, skarn, carbonate-replacement and vein-type ores. Serifos belong to the metamorphic core complex of the Attic-Cycladic Crystalline Belt, which represents a polymetamorphic terrane within the Alpidic orogen of the Hellenides. The Serifos mineralization is related with the emplacement of I-type plutonic rocks, controlled by extensional kinematic conditions, when the metamorphic core complexes reached near-surface levels. The Serifos granodiorite is considered to be synchronous with Miocene extensional detachment faulting, and intruded schists and marbles causing an extensive contact metamorphic aureole.

Serifos' mines history

The mines exist on the island since the 3.000 BC. Mines continued to work during the Roman times while it was the Venetians later on that systematically organized the mining operations in the island. However, due to the frequent attacks of pirates, the mining activity stopped for a long time. A new company appeared in 1880, the French interests "Serifos-Spiliazeza and in 1884 the company commissioned by contract the operation of the iron ore mines to the German mineralogist Emile Grohmann. When Grohmann undertook the operation of the mines, the headquarters of the company were transferred in Mega Livadi where a two-story neoclassical building, with architectural elements of the "Ziller" style were created, ruins of which still stand at the end of the beach today. Mega Livadi was the main iron ore export harbor of Serifos, equipped with all the necessary sorting and shipment facilities (Fig. 1).



Figure 1. (a) Mega Livadi (b) the Headquarters of the iron ore mines

The economy of the island boomed but the working conditions in the mines were awful for the miners. The safety measures were inadequate and many of the workers died in work accidents. A strike broke out on August 7th 1916, when the miners refused to load a cargo ship. The workers stopped working and demanded better working conditions and an eight-hour work per day rule. A fatal fight between the strikers and the police forces in August 21th, 1916, ended with the death of four workers and decades of them were injured. However, the union achieved the 8-hour work-day in the mines that was officially established by the Greek State in 1925. The iron ore mines were finally cease operations in 1965 when the Gromman's heirs found richer mines in South Africa and abandoned the mines of Serifos, as a result of the depletion of stocks, the high costs of relatively small-scale exploitation, but mainly as a result of the collapse in iron ore prices worldwide. The Ministry of Culture declared as historical monuments the Headquarters of the mines, the loading bridge in Megalo Livadi, the loading bridge in Koutalas, the workers' residencies as well as any kind of equipment that remains to provoke memories both of the flourishing of the island in another era, and of the tragic events of 1916.

Mineralogical and petrological Geotope

Serifos, is not only famous because of the mining activity during the past, it shows also unique mineralogical and petrological features: Its very rare and worldwide known skarn minerals (e.g. garnets, quartz and its green variety called prase, ilvaite; Fig. 2), attracted scientists and mineral collectors from all over the world. The SW part of Serifos island including the Agia Marina - Koutalas, Mega Livadi - Koundouro and Avessalos subaereas, displays all the criteria necessary to be characterized as a mineralogical and petrological Geotope. The Avessalos area is the best site in the world in respect to the mineral green quartz (prase). The crystal forms, intergrowths and sizes (up to 40cm) of green

quartz specimens from this locality are spectacular. The area is characterized by a granatitic ((Fig. 2a) and hedenbergitic skarn and by the development of huge geodes filled by prograde and retrograde skarn minerals. In the Neroutsika location in Avessalos area two forms of prase are observed the first variety refers to very deep green colored crystals accompanied by iron roses. The second variety refers to double-coloured crystals of prase-amethyst. The transition between these two crystals is abrupt within the same crystal, where prase occurs at the base and amethyst at the top of the crystal. The amethysts are transparent and of gemstone quality. In the southern part of Avessalos area large geodes, containing unique quartz crystals, not only in respect to their quality but also for their crystal forms, reflecting very special growth conditions, occur. Rare combinations of prase-amethyst scepter crystals contain phase alternations, including transitions from prase towards amethyst and finally to prase even within a single composite crystal. Scepters include both normal and reverse forms. Calcite-prase intergrowths, abundant within the southern Avessalos geodes, were found for the first time in Serifos island: Calcite crystals, either as rhomboeder, or in platy forms alternate with the prase suggesting contemporaneous deposition probably during boiling processes. The Agia Marina area is characterized by splendid occurrences of andraditic garnets in association with quartz crystals (Fig. 2b). The garnets (up to 5cm in size) accompany quartz and hematite in quartz veins crosscutting hornfelsic gneiss or hedenbergitic skarn. The Koundouros area is characterized by hedenbergitic skarn including the best ilvaite crystals worldwide. Geodes within the skarn are filled by idiomorphic crystals of ilvaite, hematite (iron roses), quartz and calcite. The ilvaite crystals replace hedenbergite, forming radial aggregates reaching sizes up to 50cm (Fig. 2c).



Figure 2. (a) Garnet associated with hedenbergite (Neroutsika); (b) Quartz (Agia Marina); (c) Ilvaite crystals replacing hedenbergite (Koundouros).

Geotourism - Geotouristic development

Geotourism, the tourism through earth features and monuments, is an alternative way of tourism that includes wondering in nature, experiencing the monuments of geology, landscape, environment, history and culture of an area. All these can be found in abundance at the Serifos Island. The geotouristic development of mineralogical and petrological geotopes at Serifos, ensures the preservation of the geological heritage of Serifos Island and also offers the opportunity for sustainable development. Special geo-trails have been developed in order to discover the natural, geological and cultural treasure of the island. Geo-trails have been mapped using modern Geographical Information Systems, as below:

- **Mega Livadi – Koundouros.** Koundouros' area is characterized by hedenbergitic skarn including the best ilvaite crystals worldwide. Mega Livadi area could be described as an outdoor mining museum, with underground mining galleries, iron rails, semi-destroyed bridges, wagons and a loading bridge compose a unique scenery. At the nearby bay of Almiros you can see, near the sea, the mineral water springs.
- **Agia Marina- Koutalas.** Agia Marina area is characterized by splendid occurrences of andraditic garnets in association with quartz crystals. Koutalas' area is characterized by the operations of mining activity such as rail systems, ore transport, wagons and the workers' residencies.
- **Avessalos.** Avessalos' area is the best site in the world in respect to the mineral green quartz (prase). The crystal forms, intergrowths and sizes (up to 40cm) of green quartz specimens from this locality are spectacular.
- **Chalara** with iconic mining infrastructure.
- **Miners pathway.** The hiking trail leading from “Giftika” area to Ano Chora, was the road that the miners used to take, in order to reach the western areas of the island and get to work. It was built in 1858, it is still well-preserved and it constitutes one of the most beautiful paths of the island.

The Serifos geotopes belong to the Greek mineralogical and geological heritage and can be considered as mineralogical treasures, unique throughout world. They deserve to become part of the European Natural Geoparks, following a policy which enhances the natural mineral wealth, so as to protect and promote it.

References

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