Geophysical Research Abstracts, Vol. 9, 07042, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-07042

Geodynamic control of shear reversal, exhumation of metamorphic core complexes and ore mineralization in the Aegean arc

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The Cycladic islands of the Aegean Sea expose a high-pressure metamorphic belt as part of the Cycladic metamorphic zone stretching from Turkey through Cycladic islands to mainland Greece. Formation and subsequent exhumation of these mostly Eocene blueschist- and eclogite-facies successions is considered to directly result from the Hellenic subduction zone still operating in the Eastern Mediterranean Sea, and the Aegean Sea represents therefore a test site for such processes. Based on detailed structural work on Sifnos and further observations on other Cycladic islands, a new model has been developed for exhumation of eclogites/blueschist belt, associated fluid transfer processes and resulting widespread ore mineralizations and of the geodynamic control of these processes.

The overall result is that a shear reversal occurred in Aegean Sea extension from initial, Eocene to Middle Miocene NE-directed shear parallel to the operating subduction zone to S-directed Late Miocene to Recent shear towards the subduction zone. Consequently, three different modes of extension were involved in exhumation of the Cycladic blueschist belt: (1) initial extrusion-type exhumation within the subduction channel, (2) underplating by a H_2O-rich sedimentary wedge, which released much water, and (3) subsequent southward-directed extension triggered by retreat of the subduction zone.

On Sifnos, the oldest deformation (D_1) event is recorded in the massive eclogite with a foliation formed at peak P conditions. These eclogites are overprinted are overprinted by foliated, fine-grained eclogites at deformation stage D_{2a}grading into blueschist fabrics formed at lower P-T conditions, and similarly oriented D_{2c} greenschist facies fabrics. D_2 shows a top NE-ward shear based on shear sense indicators include S-C fabrics, σ-porphyroclastic garnet and asymmetric strain shadows around garnet grains. These fabrics are interpreted to result from operation of a ductile, top NE-directed low-angle normal fault. The new structural data suggest that the entire ductile deformation of stages D_1 to D_{2b} is related to decompression and exhumation of the Sifnos metamorphic complex along a subduction channel within high-pressure metamorphic conditions. Greenschist facies D_{2c} deformation represents similar kinematics with the only principal difference that the temperature equilibrated to normal crustal conditions and hydrous fluids flushed the lower section. It appears likely that advective percolation of hydrous fluids supported temperature increase and equilibration of metamorphic assemblages.

The subsequent brittle stage of exhumation of the high-pressure metamorphic succession of Sifnos Island formed during late Miocene (< 11 Ma) to Recent times. S- to SSW-directed high-and low-angle brittle normal faults formed mainly at the boundary between Greenschist-Gneiss unit and Lower Marble unit, and these were heavily affected by hydrothermal fluids including ore-forming systems. The initial brittle stage is NE-SW to N-S extension which is related to back arc formation within the Aegean Sea and associated thinning of the orogenic wedge due to retreat of the subduction zone. Extensional structures are subsequently overprinted by NW-SE extension due to stretching parallel to the Hellenic arc. Ascending and descending fluids mineralized extensional gashes, normal faults and affected country rocks. Mineralization including ore precipitation is strongly controlled by the temperature gradient between footwall and hangwall blocks, chemical environment and structural permeability.

The structure of ore mineralizations is controlled by large-scale brittle extension of the uprising Aegean metamorphic core complex. Compilation of structural data from other mineralizations of the western Aegean Sea indicate that hydrothermal fluids possibly originated from two distinct sources: (1) Fluids connected with the emplacement of andesitic-dacitic magmas, which derived from continuous subduction; and (2) metamorphic fluids originating in the underlying subduction plate and which resulted in pervasive retrogression during hydration of previously dehydrated high-pressure metamorphic rocks.