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Thermal and Kinematic Development of the Metamorphic Sole of the Oman Ophiolite

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Ophiolite emplacement is an enigma—the rates at which ophiolites are emplaced, the mechanisms by which they are emplaced, the stress and temperature histories of the rocks—all of these are incompletely understood. The Oman ophiolite is extremely well exposed ophiolite and has been studied extensively by field geologists. An integrated thermal and kinematic computer model of the temperature, stress, rock-type, and displacement fields during the early stages of the emplacement of the Oman ophiolite was developed to illustrate how laboratory measurements can be used to explain field relations and provide insight into the ophiolite emplacement process. The thermal evolution is calculated by a finite-difference algorithm for heat conduction, considering heats of metamorphic reactions, deformational heating, and advection. The stress and displacement fields are calculated by an analytical model using a velocity boundary condition, power-law constitutive relations, and a brittle frictional sliding relationship.

The model indicates that the lithosphere subducted beneath the Oman ophiolite was young (≈5 Ma old), rather than old (≈100 Ma old). In young, hot lithosphere, a wider portion of the decollement deforms by power-law creep, and deformation occurs at lower stresses and slower strain rates, minimizing the deformational heating compared to a colder slab. The accelerated rate at which dehydration occurs in younger, hotter lithosphere removes heat from the subducted plate at an earlier stage, causing the zone of brittle deformation to propagate downward more rapidly. The peridotite near the base of the ophiolite deforms at differential stresses of ≈30 MPa during intraoceanic subduction, and power-law creep of the peridotite is generally restricted to temperatures greater than 750°C. Power-law creep of the basaltic rocks is limited to temperatures greater than 450°C, and occurs at differential stresses of the order of 10-100 MPa. The principal features of the metamorphic sole evolve within a few million years. The metamorphic field gradient and the spatial distribution of rock types in the metamorphic sole might be used to infer the emplacement direction of any Tethyan-type ophiolite.