The formation of olivine coronas in mesosiderites.

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Olivine coronas are a common feature of most thermally metamorphosed mesosiderites. The coronas consist of the following (idealized) layers separating olivine from a polymineralic matrix: 1) an inner layer adjacent to olivine containing up to 91 vol.% orthopyroxene, 7% chromite and 6.4% merrillite; 2) an outer layer containing orthopyroxene and up to 30% anorthite and 19.6% merrillite, with merrillite concentrated just outside the chromite-rich zone; 3) an outermost layer adjacent to and similar to matrix except lacking tridymite and metal (1, 2). To provide constraints on the metamorphic processes involved in the formation of these coronas, they were modelled by assuming steady-state diffusion and local equilibrium in the system $MgO\text{-}AlO_{3/2}\text{-}CaO\text{-}SiO_2\text{-}PO_{5/2}$. The initial reactants (prior to layer growth) were taken to be forsterite (F) and a mesosiderite-like matrix containing enstatite (E), diopside (D), tridymite (T), anorthite (A) and merrillite (M) in the average proportions observed for mesosiderite matrix, except that the merrillite matrix abundance was free to vary. If local equilibrium is maintained, then layer growth will be governed by diffusion-controlled reactions, and the layer sequence that forms will depend on kinetic parameters (L-coefficients) that are proportional to the concentrations of the diffusing components in the intergranular medium and the velocity with which these components diffuse. Forsterite reacts with matrix tridymite to produce the initial sequence F|EDAM|EDTAM at low (< few kilobar) pressures. This sequence is unstable to steady-state diffusion for all values of L-coefficients, and additional layers, including a layer containing spinel (S), must form between F and EDAM. Except for highly volatile species, the intergranular diffusion coefficients appropriate for metamorphism and layer growth are probably not too different from one another, suggesting that a case with all L-coefficients equal to one another might be realistic. The results for this case are given in Table 1. The predicted layer sequence, F|ESM|EAM|EDAM|EDTAM, closely resembles observed mesosiderite olivine coronas. The relative widths of the corona layers in mesosiderites is poorly known, but the inner chromite-rich zone is typically ~40% of the thickness of remaining layers, in agreement with the model results, in which the spinel-bearing ESM layer is about half as thick as the combined EAM and EDAM layers (Table 1). It thus appears that the overall layer sequence, composition of layers, and layer widths in mesosiderite coronas can be adequately modelled if all diffusing components had similar values of transport parameters (L-coefficients). An even better match between model results and the observations is achieved if the diffusive flux of $PO_{5/2}$ was much larger than for other components, which is consistent with the possibility that phosphorus was transported, at least in part, as a P-rich gas during corona formation. In any case, it appears that an additional source of P besides that present in merrillite in the matrix is required to account for the most phosphate-rich coronas in mesosiderites. References: This work was supported by NASA grant NAG 9-37. (1) Nehru C. E., Zucker S. M., Harlow G. E. and Prinz M. (1980) *GCA* **40,** 1103–1118. (2) Delaney J. S., Nehru C. E., Prinz M. and Harlow G. E. (1981) *PLPSC* **12B,** 1315–1342.

TABLE 1. Characteristics of the steady-state reaction sequence produced when all L-coefficients are equal. The molar merrillite/tridymite ratio in the matrix has been raised to a minimum value of 0.136 (approximately a factor of 2 higher than typically observed), to prevent exhaustion of merrillite in the EDAM, EAM, and ESM zones.

Zone	Modal composition (vol.%)	Relative zone widths
Forsterite		
ESM layer (adjacent F)	enstatite (91.15%) + spinel (8.85%) + trace or no merrillite	0.450
ESM layer (adjacent EAM)	enstatite (85.70%) + spinel (0.69%) + merrillite (13.62%)	0.483
EAM layer	enstatite (61.87%) + anorthite (34.30%) + merrillite (3.83%)	0.665
EDAM layer	enstatite (54.71%) + diopside (14.58%) + anorthite (30.70%) + trace merrillite	1.0
Matrix		

Siderophile elements in the lunar highlands and lunar bombardment.

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Calculations of the meteoritic material in the lunar highlands crust based on siderophile elements require two estimates: the abundances of these elements in the uppermost sampled materials (from measurements on lunar samples), and how much of the lunar crust is represented by them. Most authors have grossly overestimated both parameters, in turn overestimating the amount of meteoritic material and hence amount of bombardment in the lunar highlands. For instance, (1) give a preferred estimate of 0.7 km equivalent of meteoritic material, based on a mixing depth of 35 km and a "generally agreed" 2% meteoritic component.

Most estimates have been derived from measurements of siderophiles in the regolith. However, for mature, flat areas, a correction for the post-Orientale/Imbrium micrometeorite component (from mare sites) must be made. Then the Apollo 16 Cayley ~3.8 Ga surface contained less than 1% Ir chondrite-equivalent (IrCE), most derived from a single and unusual (low Ir/Au) 3.85 Ga impact melt component. Thus any older meteoritic component in the soil is virtually absent. When corrections are made for Luna 20 soil and the lunar meteorites, again only a small residual old component remains (0–0.2% IrCE). Even without any correction, these samples contain less than 1% IrCE. So do the fresher soils (most representative of bedrock) from the Apennine Front and the Taurus-Littrow massifs.

A better estimate can be made from North Ray Crater soils (little micrometeorite component) which have no more than 0.75% IrCE, or better still the subregolith feldspathic breccias, which probably represent Nectaris ejecta, and average about 0.25% IrCE. Similar abundances are found in Apollo 14 feldspathic breccias (14063), and 0.25% IrCE is a reasonable estimate for the pre-Nectaris upper crust on the lunar frontside. Even if this represented 100 km of crust, this is equivalent to only 250 meters of meteoritic material. It probably represents considerably less of the crust, such as 15 km, and thus only 40 meters equivalent. Such low abundances are compatible with the visible cratering record, but not with an intense bombardment from 4.5 Ga of which the extant record is merely the tail.