PETROLOGIC CONSTRAINTS ON THE SURFACE PROCESSES ON ASTEROID 4 VESTA AND ON EXCAVATION DEPTHS OF DIOGENITE FRAGMENTS; T. L. Grove, Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139

The eucrite-howardite-diogenite meteorite groups are thought to be related by magmatic processes [1,2]. Asteroid 4 Vesta has been proposed as the parent body for the these basaltic achondrite meteorites [3]. The similarity of the planetesimal's surface composition to eucrite and diogenite meteorites and the large size of the asteroid (r = 250 km) make it an attractive source, but its position in the asteroid belt far from the known resonances from which meteorites originate make a relation between Vesta and eucrite-howardite-diogenite group problematic. It has been proposed that diogenites are low-Ca pyroxene-rich cumulates that crystallized from a magnesian parent (identified in howardite breccias [4]), and this crystallization process led to evolved eucrite derivative magmas. This eucrite-diogenite genetic relationship places constraints on the physical conditions under which crystallization occurred. Elevated pressure melting experiments on magnesian eucrite parent compositions [5,6] show that the minimum pressure at which pyroxene crystallization could lead to the observed compositions of main series eucrites is 500 bars, equivalent to a depth of 135 km in a 4 Vesta-sized eucrite parent body. Therefore, the observation of diogenite on the surface of 4 Vesta [7] requires a post-crystallization process that excavates diogenite cumulate from depth. The discovery of diogenite asteroidal fragments [8] is consistent with an impact event on 4 Vesta that penetrated the deep interior of this planetesimal.

Models for eucrite formation Based on experiments carried out at 1-atm, Stolper [9] concluded that eucrite basalts could be generated by small extents of partial melting of a chondritic olivine-rich composition at shallow depths in the eucrite parent body. Consolmagno and Drake [10] reached a similar conclusion from an analysis of rare-earth element systematics. These shallow level partial melting models do not provide a mechanism for generating diogenite cumulates; rather, they would generate lherzolite residues. Although higher extent partial melts could undergo fractional crystallization of low-Ca pyroxene under near-surface conditions, the relation of the olivine-low-Ca-pyroxene reaction boundary to the partial melt composition is such that pyroxene crystallization would lead to derivative melt compositions that do not resemble any sampled eucrite lavas. Bartels and Grove [5,6] carried out experiments at elevated pressures and showed that magnesian eucrite parent magmas could generate diogenite cumulates and main series eucrite lavas by fractional crystallization at pressures achieved in the interior of a Vesta-sized parent body (> 500 bars).

Advantages of a major impact A major impact on the surface of 4 Vesta therefore reconciles several issues concerning the origin of eucrites and diogenites. Binzel and Xu [8] have observed numerous small asteroids of eucrite and diogenite material between 4 Vesta and the 3:1 resonance. These fragments have orbital elements similar to those of Vesta, and they propose that these fragments are excavated from Vesta and suggest that it is now dynamically possible for the eucrite-howardite-diogenite meteorite group to be linked to Vesta. A large impact on Vesta also allows the observation of diogenite [6] on the surface to be reconciled with petrologic constraints. The observed presence of diogenite-rich areas on the surface of Vesta requires an event that disturbed the interior. Petrologic constraints indicate that diogenite is excavated material from a depth of at least 135 km, placing some constraints on dynamic modeling of the impactor. Higher resolution imaging studies of Vesta might focus on determining whether the asteroid has experienced a few large impacts that have excavated deeply or whether the planetesimal is chaotically reassembled like Miranda, the Uranian moon.

References [1] B. Mason, 1962, *Meteorites*, Wiley, New York. [2] B. Mason, 1963, Am. Mus. Novit. 2155, 1-13. [3] T. B. McCord et al., 1970, Science 168, 1445. [4] Dymek et al , 1976, Geochim Cosmochim Acta 40, 1115-1130. [5] K. S. Bartels and T. L. Grove, 1991, Proc. Lunar Planet. Sci. 21, 351-365. [6] T. L. Grove and K. S. Bartels, 1992, Proc. Lunar Planet. Sci. 22, 437-445. [7] M. J. Gaffey, 1983, Lunar Planet. Sci. XIV, 231-232. [8] R. P. Binzel and S. Xu, Science (submitted). [9] E. M. Stolper, 1977, Geochim Cosmochim Acta, 41, 587-611. [10] G. C. Consolmagno and M. J. Drake, 1977, Geochim Cosmochim Acta, 41, 1271-1282.