MATRIX PYROXENES IN HOWARDITES AND POLYMICT EUCRITES  Paul C. Buchanan and Arch M. Reid, Department of Geosciences, University of Houston, Houston TX 77204-5503

The study of lithic clasts in howardites and polymict eucrites (HPEs) has expanded the known range of rock types present in HED basaltic achondrites. A range of materials from magnesian diogenites through cumulate and intermediate eucrites to iron-rich eucrites has been documented. Variations in eucritic materials have been described using different classification systems. The term 'equilibrated' describes eucrites in which pyroxenes are unzoned and commonly exsolved; eucrites with zoned pyroxenes are 'unequilibrated' (1,2,3). This is an oversimplification as the various eucrites show a wide range in degrees of subsolidus annealing (e.g. 4). Eucrites can also be subdivided into two series based on compositions of coexisting pyroxene and plagioclase (5,6,7). In plots of average An (100Ca/Ca+Na+K) for plagioclase vs. average Mg# (100Mg/Mg+Fe) for coexisting pyroxene, 'type A eucrites' (e.g. Juvinas) have more calcic feldspar whereas 'type B eucrites' (e.g. Pasamonte) contain more Na-rich feldspar for the same Mg# of coexisting pyroxene. Type A eucrites are equilibrated, with unzoned pyroxenes and textures indicative of subsolidus annealing. Most, but not all, type B eucrites are unequilibrated with zoned pyroxenes and more pristine igneous textures that include a fine-grained mesostasis.

Large lithic clasts in HPEs are relatively rare; for most samples, the bulk of the meteorite comprises a fine-grained matrix of monomineralic fragments, predominantly pyroxene and plagioclase. We have attempted to develop criteria for relating the smaller and more abundant (hence, more representative) matrix pyroxene fragments to the different types of eucrites, using the database we have assembled for lithic clasts in HPEs and for monomict eucrites. Provenance of the major components in each HPE meteorite can then be assessed by the characteristics of matrix pyroxenes. Mineralogic and petrographic data for matrix pyroxenes from two howardites and twelve polymict eucrites (Bholghati, Petersburg, Nobleborough, Brient, ALHA77302, ALHA78132, ALHA78158, ALHA78165, ALHA79017, EETA79004, EETA79005, EETA87509, EETA87513, and EETA87531) were compared with similar data for monomict, non-Antarctic eucrites as well as lithic clasts from Bholghati, EETA87509, EETA87513, and EETA87531.

PETROGRAPHY. Petrographic analysis of matrix pyroxene grains for which we have compositional data indicates that unzoned, exsolved pyroxenes occur throughout the entire eucrite compositional spectrum (i.e. Mg# 25-70). Compositions in zoned pyroxenes also span the same range. Petrographic data indicate that components of equilibrated and unequilibrated materials are present throughout the entire range of eucritic compositions in HPE meteorites, as also inferred from the study of individual clasts (7).

PYROXENE COMPOSITIONS. Matrix pyroxene data for all fourteen meteorites define a broad spectrum of compositions in a bimodal distribution with maxima at pyroxene compositions equivalent to diogenites and common eucrites and a lower abundance of intermediate compositions (Mg# 50-70). Equilibrated pyroxenes can be distinguished from unequilibrated pyroxenes based on the compositional criteria we have established for lithic clasts and monomict meteorites. Pyroxene compositions from unequilibrated eucrites (e.g. Pasamonte) define a regular trend of increasing Mn with decreasing Mg# (Fig. 1). In exsolved pyroxenes from equilibrated eucrites (e.g. Juvinas), Mn partitions between low-Ca host and augite lamellae. The fine lamellae are not completely resolved by the electron microprobe beam, resulting in trends with steeper slopes (Fig. 1) than the Pasamonte trend. Unequilibrated pyroxenes have low Al contents, but are consistently richer in Al than equilibrated pyroxenes (Fig. 2). We have also noted, in comparing structural formulae of equilibrated and unequilibrated pyroxenes, that equilibrated pyroxenes do not contain sufficient Si and Al to fill the pyroxene tetrahedral sites. Application of these compositional criteria to matrix pyroxenes in HPE meteorites indicates that both equilibrated and unequilibrated eucritic components are present in all the meteorites we analyzed. Unequilibrated pyroxenes are present in approximately equal amounts throughout intermediate and iron-rich compositions (Mg# 25-70), in part reflecting the influence of zoning. The proportions of equilibrated pyroxenes appear to increase from relatively small proportions at Mg# 60-70 to higher proportions at iron-rich values, approximately the composition of pyroxenes from common eucrites.
DISCUSSION. All of the HPE meteorites studied contain pyroxenes with compositions intermediate between those of diogenites and common eucrites. Some HPEs comprise a dominantly bimodal distribution of diogenite and common eucrite components (e.g. EETA87513) with a minor proportion of intermediate compositions. Other HPEs are essentially unimodal with either diogenite (e.g. Bholghati) or eucrite (e.g. ALHA78158) compositions predominating, but also with intermediate compositions. Brient is an example of a polymict eucrite in which the dominant pyroxene component is intermediate in composition. Based on matrix pyroxene data, lithic clasts with intermediate compositions are most likely in ALHA79017, ALHA78132, Brient, Petersburg, Nobleborough, and Bholghati.

HPEs also vary in the proportions of equilibrated and unequilibrated eucritic materials. Some meteorites contain a large proportion of equilibrated pyroxenes (e.g. ALHA78158), while the meteorite Brient contains a large proportion of unequilibrated pyroxenes. Matrices of other HPEs contain approximately equal mixtures of equilibrated and unequilibrated pyroxenes (e.g. ALHA79017). Both equilibrated and unequilibrated pyroxenes display a continuous range from diogenitic compositions to compositions similar to, and more iron-rich than, Juvinas. The compositional range of non-cumulate, equilibrated eucrites apparently extends to much more magnesian compositions than the common eucrites.

From the deduced proportions of equilibrated and unequilibrated materials and from the compositional spectrum of pyroxenes in the matrices, it is apparent that all the HPE meteorites we have studied contain both type A and type B components. The intimate association of these two types of material and their similarities in composition and compositional range, all argue for a common source for the A and B components. Type A and type B eucrites must have formed in close proximity and cannot have been differentiated by any mechanism that requires substantial physical separation.