ANGRITE-LIKE CLASTS FROM THE EREVAN HOWARDITE; M. A. Nazarov, Vernadsky Institute of Geochemistry and Analytical Chemistry, Moscow 117975, Russia; F. Brandstätter and G. Kurat, Naturhistorisches Museum, Postfach 417, A-1014, Vienna, Austria

Angrites are very rare and remarkable achondritic rocks which have never been found in an association with HED meteorites. Here we report on the identification of two angrite-like clasts in the Erevan howardite. These clasts are composed mainly of Ca-rich pyroxene and plagioclase but have different bulk compositions, which, however, are similar to those of angrites. In contrast to angrites the clasts are rich in alkalis and do not contain a fassaite pyroxene. The angrite-like rocks cannot be related to HED magmatic rocks, and consequently must represent xenoliths produced from a source enriched in CAI-like material. The question arises whether this source is a different parent body or the solar nebula. The latter seems to be the more likely source that also provided carbonaceous chondrite clasts which are abundant in the Erevan howardite.

Results. The Erevan howardite is a gas-rich polymict breccia [1] containing abundant clasts of carbonaceous chondrites [2,3] and fine-grained, partly glassy rocks [4]. Two angrite-like clasts (#s 413 and 453) were found in one polished section far apart from each other. Representative electron microprobe analyses of mineral phases and bulk compositions of the clasts obtained by a broad beam method are given in the Table.

Clast 413 has an angular shape and measures about 120x150 µm. It shows a somewhat recrystallized eutectic-like texture (Fig.1). Main phases are Ca-rich pyroxene (Wo 44.6; En 42.3) and plagioclase (An 90.5). Orthopyroxene (Wo 3; En 64) forms rare laths in the eutectic intergrowths. Accessories are minute chromite and troilite grains. All phases do not reveal significant compositional variations. The modal composition of the rock is CPX 55, OPX 5, PL 40 (vol.%). A computer modelling [5] of equilibrium and fractional crystallization sequences of the rock shows that the melt is close to co-saturation of augite (Wo50; En 45) and plagioclase (An 90) followed by olivine (Fo 70).

Clast 453 has a size of 100 µm and consists mainly of Ca-rich pyroxene (Wo 41; En 32) and plagioclase (An 85) forming a partly recrystallized eutectic-like texture (Fig. 2) very similar to that of clast 413. Rare lath-like orthopyroxene (Wo 3; En 53) is also present in the eutectic intergrowths. Rare rounded grains of pigeonite (Wo 8; En 53) with some exsolution lamellae were found in the outer part of the clast. Accessories are troilite, ilmenite, and silica. All phases have limited compositional ranges. Modal composition of the rock is CPX 46, OPX+PIG 9, PL 42, opaques 3(vol.%). The computer modelling [5] of equilibrium and fractional crystallization of the rock indicates that the melt is co-saturated with augite (Wo 50; En 38) and plagioclase (An 89) followed by olivine (Fo 50).

Discussion. Only three angrites (Angra dos Reis, LEW86010, and LEW87051) are known [6]. A related clast was also found in the N. Haig polymict ureilite [7]. All angrites are of significantly different bulk composition (Table, Fig.3) but all of them contain fassaite, olivine, and magnetite, are extremly depleted in volatile and siderophile elements, and have oxygen isotope abundances and initial Sr ratios similar to those of basaltic achondrites. The Erevan clasts have bulk compositions which are within the compositional ranges of angrites (Table, Fig.3), except for alkali contents. However, Ca-rich pyroxenes in the clasts are poorer in Al and Ti than fassaites in the angrites. Also no olivine and magnetite were identified in the clasts, although according to the model calculations the angrites and the Erevan rocks have a similar crystallization sequence and olivine should crystallize from the Erevan angrite melts. A possible reason for the absence of olivine is that the Erevan clasts were recrystallized and equilibrated at a low temperature. In spite of the differences the Erevan clasts are much closer in phase and chemical compositions to angrites than to HED rocks (Fig.3, compositions of eucritic and howarditic melt clasts are shown) and other known basaltic achondrites, and, therefore, they should be classified as angrite-like rocks.

Although the angrite-like clasts are associated with HED rocks, it can be suggested that the clasts are of foreign origin, similar to the carbonaceous clasts. However, the Fe/Mn ratio of the angrite clasts as well as the LEW 87051 angrite is close to that of HED rocks which suggests that the angrite rocks could somehow be related to the HED parent body. Other angrites have a chondritic Fe/Mn ratio and very low Na and K contents indicating an origin in another, very different environment. The computer simulation of changing melt compositions during equilibrium (solid lines) and fractional (dashed lines) crystallizations (Fig.3) demonstrates that rocks 413 and 453 could be related. In principle, rock 413 could be a cumulate formed from a 453 melt whose liquidus Ca-rich pyroxene is close in composition to the pyroxene of the 413 rock. However, the eutectic-like textures and cotectic compositions of the rocks suggest that they are rather quenched melts which were formed by different degree of partial melting of a similar source. The computer simulation also shows (Fig.3) that the source cannot be of a mafic (chondritic or howarditic) composition. Such a source could be suitable for eucrites but it cannot produce Ca-rich melts neither by equilibrium nor by fractional crystallization. It is also impossible (Fig.3) that eucrites can be derived by partial melting or fractional crystallization from the angrite rocks. Thus, the occurence of the angrite-like clasts in the HED association suggests that the HED parent body mantle was possibly inhomogeneous and contained local regions of Ca-rich (perhaps CAI-like) material which could be a source for the angrite rocks. Another possibility is a derivation of the angrite-like clasts from CAI-like matter altered in the solar nebula, a source which is also suitable for the abundant carbonaceous chondrite clasts in Erevan and other howardites.

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Table. Representative analyses of mineral phases in clasts 413 and 453, and bulk compositions of the clasts and angrites [6].

	Clast 413				Clast 453				ADOR	LEW 86010	LEW 87051	N.Haig Clast
	Aug	Opx	Plg	Bulk	Aug	Opx	Plg	Bulk	Bulk	Bulk	Melt	Bulk
SiO_2	51.3	52.9	43.8	48.8	51.5	50.9	46.6	47.6	43.5	38.0	42.1	45.9
TiO_2	0.4	0.29	0.03	0.38	0.32	0.19	0.03	1.16	2.9	1.59	0.79	0.84
Al_2O_3	4.1	0.76	35.8	11.3	0.82	0.27	33.6	11.6	9.8	14.2	20.3	11.6
Cr_2O_3	0.32	0.19	0.03	0.33	0.25	0.12	0.02	0.17	0.28	0.13	0.14	0.63
FeO	7.9	21.0	0.43	8.2	16.3	32.8	0.65	14.7	9.3	20.2	14.2	8.8
MnO	0.32	0.60	<0.02	0.19	0.51	0.94	0.04	0.45	0.08	0.22	0.34	0.12
MgO	14.3	22.9	0.34	11.5	10.9	13.8	0.02	7.1	11.2	7.1	4.6	10.9
CaO	21.0	1.6	18.7	18.9	19.2	1.41	17.7	16.7	23.7	18.5	17.6	20.5
Na_2O	0.2	<0.02	1.0	0.55	0.09	<0.02	1.69	0.5	0.04	0.03	<0.02	0.05
K_2O	<0.02	<0.02	0.04	<0.02	<0.02	<0.02	0.09	0.04	<0.02	0.03	<0.02	<0.02

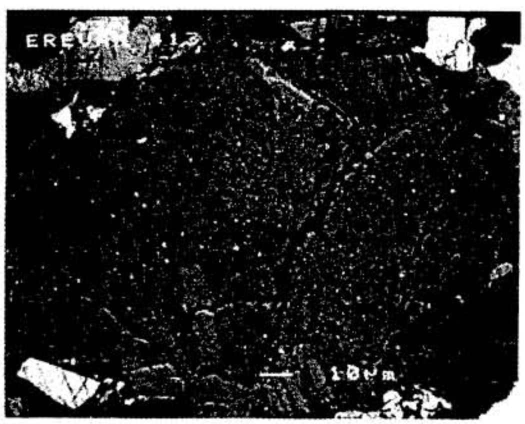

Fig.1: Clast 413 with eutectic-like texture from the Erevan howardite

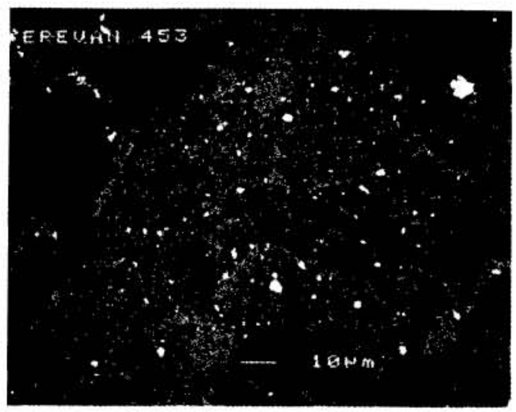

Fig.2: Clast 453 with eutectic-like texture similar to clast 413

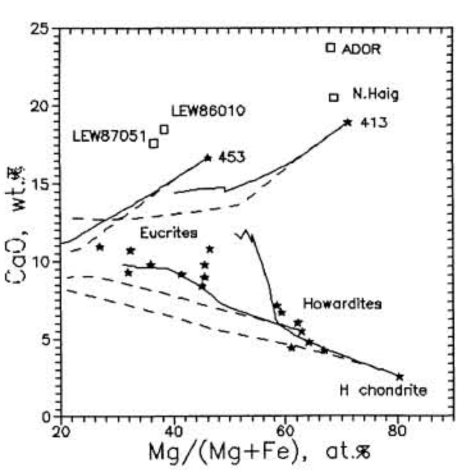

Fig.3: Comparison of compositions of clasts 413 and 453 with angrites and HED rocks. Computer simulation of changing melt compositions during equilibrium and fractional crystallization is indicated by solid and dashed lines, respectively.