The three cumulate eucrites, Moama [1], Serra de Mage [2] and Moore County [3], because of their coarse pyroxene exsolution microstructures appear to have had similar high temperature cooling rates. Moore County, however, is unique among these eucrites because it appears to have been quenched from high temperature. This paper presents an optical and electron-microprobe study of a previously undescribed thin section of the Moore County eucrite (USNM #1664) which: 1) contains the first reported occurrence of primary augite in a cumulate eucrite; 2) sheds light on the mechanism of pigeonite inversion; and 3) shows that chemical equilibrium was maintained by the three pyroxene phases during the inversion.

Crystallization The thin section studied is 1.5 cm x 0.7 cm and consists of 55% plagioclase, 36% pigeonite (partly inverted), 7.2% tridymite, 1.4% augite, 0.4% chromite and ilmenite and widespread but minor troilite. The texture is equigranular with subhedral plagioclase (1.0 - 1.75 mm) and pigeonite (0.75 - 1.5 mm). A 1-mm thick fine-grained zone of pyroxene and plagioclase traverses the entire section. The grain size in this zone is 0.2 - 0.5 mm and the texture is more granoblastic than in the coarser grained areas. The optical continuity of some coarse primary pigeonite grains with the smaller clinopyroxenes indicates that the zone is a primary crystallization feature and not a product of shearing and subsequent recrystallization. The zone may represent a nucleation burst during crystallization, an origin suggested for fine-grained zones in terrestrial layered intrusions [4]. Tridymite is most abundant in the coarse-grained plagioclase areas and fills in large interstitial spaces. Plagioclase in contact with tridymite in these spaces is commonly lath shaped or has well-formed crystal faces. Primary augite has grain sizes 0.5 - 0.2 mm and forms as both isolated grains and epitaxial overgrowths on pigeonite. Chromite and ilmenite occur together as 0.2 - 0.3 mm-sized grains usually surrounded by tridymite. Chromite also forms as smaller grains included in pigeonite. The textural evidence indicates that chromite, plagioclase, and pigeonite were early crystallization products although plagioclase is commonly included in pigeonite but pigeonite is never included in plagioclase. Augite crystallized later both as epitaxial rims on pigeonite and as an interstitial phase. Tridymite and chromite filled the remaining interstitial space.

Subsolidus Changes Coarse (001) augite lamellae from Moore County, Moama and Serra de Mage pigeonites are comparable in thickness (25-50 μm) for all three meteorites and indicate a slow-cooling environment similar to that in terrestrial layered intrusions [1,2,3]. The main difference is that in Moore County the reaction pig + opx + aug has been arrested; only 20-30% of the pigeonite has reacted. In Moore County, the reaction has proceeded by two different mechanisms. The first is characterized by a two-dimensional orientation relationship between reactant and product and the second is characterized by no orientation relationship between reactant and product. The thin section studied has several examples that show that orthopyroxene formed initially by the oriented reaction in one pigeonite grain has continued across grain boundaries to transform adjacent pigeonite grains by the nonoriented mechanism (a concept initially suggested by Bonnichsen, 1969, p. 227). Had this process not been interrupted, the final product would have been orthopyroxene and augite in both oriented and nonoriented relationships such as are found in the Moama and Serra de Mage eucrites.
THERMAL HISTORY  Microprobe analysis (Fig. 1) of the three Moore County pyroxene phases (augite, pigeonite and orthopyroxene) show compositions which cluster tightly around Wo41.5En36Fs22.5, Wo65En46.5Fs47.5, and Wo13.5En49Fs47.5, respectively, regardless of origin. This suggests that during the reaction, the three pyroxene phases maintained equilibrium over at least several millimeters. Heating experiments on Moore County pyroxenes indicate that the reaction Opx + Aug + Pig takes place at 1000° - 1025°C [5] or less. The temperature of equilibration of the augite-orthopyroxene pair based on Ross and Huebner's geothermometer [6] is between 900° and 950°C. These limits indicate a cooling interval between the initiation of the reaction and the final equilibration of no more than 50° to 125°C during which local equilibrium was maintained and the reaction progressed 20-30% toward completion. After this interval, the rock was presumably excavated and quenched. It most likely remained in the regolith of the eucrite parent body [7] until planetary breakup or ejection from the body by impact. The only microstructural evidence for any shock events is the presence of abundant (100) twins and rare (001) twins in augite suggesting a maximum shock pressure of ~50 kbars [8].


Figure 1 COMPOSITIONS OF PYROXENES IN MOORE COUNTY METEORITE, USNM #1664
Compositions between the three phases represent analyses of multiple phases.