Pyroxene Microstructures in the Equilibrated Eucrite Juvinas N. Hanowski and A. J. Brearley. Institute of Meteoritics, Dept. of Earth and Planetary Sciences University of New Mexico, Albuquerque, New Mexico 87131.

We have examined the compositional and microstructural characteristics of pyroxenes in equilibrated eucrite, Juvinas by SEM, TEM and electron microprobe analysis in order to elucidate the postcrystallization thermal history of this meteorite. These studies show large variations in exsolved augite lamellae in different grains of Juvinas pyroxenes, supporting brecciation and subsequent different thermal histories for these grains. Equilibration of the meteorite was halted relatively early by quenching. Subsequent slow cooling lead to the exsolution of several generations of opaque phases. The rare occurrence of shock related features indicates a rather small influence by impact processes.

Introduction
The equilibrated eucrites have experienced a complex evolutionary history involving magmatic crystallization, slow cooling, metamorphism and impact processing involving brecciation [1]. A record of many of these processes is evident in the pyroxenes of equilibrated eucrites such as Stannern and Juvinas, which exhibit exsolution textures and clouding which is widely regarded as being the result of a late metamorphic overprint. Although the post crystallization history of the equilibrated, noncumulate eucrites has been the focus of a number of studies, many aspects of the thermal history of these meteorites remain unclear. In order to improve our understanding of the evolutionary history of these meteorites, we have been carrying out compositional and microstructural studies of pyroxenes in the equilibrated eucrites, Stannern and Juvinas by SEM, TEM and electron microprobe. Here we report new observations on exsolution textures and clouding in Juvinas and compare them with data for Stannern which we have obtained previously [2].

Augite Exsolution Lamellae
Optical microscopy and BSE imaging show that Juvinas pigeonites have undergone extensive unmixing and developed augite exsolution lamellae. The dominant set of exsolution lamellae are on (001), typical for augite exsolutions in pigeonite. In Juvinas the thickness of the (001) lamellae is variable from ~0.1µm up to 3µm suggesting that grains with different thermal histories may be present. Electron microprobe analysis of coexisting augite and pigeonite host are shown in Fig. 1. The Fe/Mg ratios of the two phases in Juvinas are closely comparable with those in Stannern, but the Stannern augites extend to more Ca-rich compositions, indicating equilibration at a lower temperature than Juvinas. The compositions of the coexisting phases yield equilibration temperatures between 600°C and 650°C [3] for Juvinas pyroxenes. Wide lamellae generally appear to have larger mean lamellar wavelengths in different grains than thin lamellae. This trend has been observed in Stannern as well.
In contrast to rare occurences in Stannern a second generation of fine (100) augite lamellae is visible in TEM images of most pyroxene grains in Juvinas. The widths of these lamellae are smaller than 5nm and their wavelength is about 0.9µm. Some bright field images hint to the existence of a second generation of (100) lamellae, but widths smaller than 2nm. The wavelength of this second generation is about 0.25µm. The (100) lamellae generally appear to be more evenly spaced than the ones observed in Stannern. They appear to have nucleated heterogeneously on interfaces of the (001) lamellae and the pigeonite host. Some grains show a variable number of (100) lamellae crosscutting first generation lamellae whereas other grains show no crosscutting at all. Shock related features in the pigeonite host and exsolution lamellae of Juvinas, like dislocations and stacking faults, are rare compared with their abundance in Stannern. The occurrence of abundant stacking faults in Juvinas pyroxenes in other studies [4] has been associated with shocked clasts.

Opaque Exsolution Products
Previous studies have reported clouding in pyroxenes of Juvinas [5]. Our TEM studies show that the main opaque phase that exsolved is Ti-Mg-bearing chromite. The chromite appears as crystallographically oriented rods 0.4µm to 0.8µm in length and 0.2µm to 0.3µm in width

(aspect ratio: 0.5 - 0.375). A few exceptionally large chromite inclusions (> 10μm) have also been observed and seem to be less oriented and more irregular in shape. These grains may have nucleated and grown along fractures. The interfaces between the chromite and the pigeonite exhibit a high degree of coherency with no evidence of misfit dislocations. Electron diffraction patterns show that the crystallographic orientation relationship between the pigeonite and chromite is $[100]_{pig} || [112]_{chr}$ and $(010)_{pig} || (111)_{chr}$. Bright field images reveal that chromite nucleation has frequently occurred on interfaces of the (001) augite lamellae with the pigeonite host. In contrast to Stannern the chromite has typically exsolved within the pigeonite host. Two additional orientations of exsolved chromites have been observed in pyroxenes of Juvinas, but their exact orientation relationships have not yet been determined. Many exsolved chromites show fine and regular internal structures, which may be exsolution lamellae or antiphase boundaries indicating relatively slow cooling following exsolution of the chromites. Another opaque phase that exsolved after the augite lamellae formation is ilmenite. The ilmenite morphologiesand grain sizes are similar to the chromite and the orientation relationship between these phases suggests contemporary formation of ilmenite and chromite.

Discussion

Juvinas (overall) may have cooled initially at a slower rate than Stannern which allowed thick lamellae to grow with a larger wavelength. However the lamellae compositions suggest that the pyroxenes may have been quenched from higher temperatures than Stannern, because the pyroxene compositions in Juvinas indicate equilibration at a somewhat higher temperature. This quenching may have been the result of excavation due to impacts. The initial slower cooling rate may have prevailed when the (100) exsolution lamellae formed in Juvinas, but not in Stannern. Stannern appears to have cooled more rapidly at high temperatures. The occurrence of grains in Juvinas with unusually large exsolution lamellae with large lamellae spacing is consistent with the idea that this meteorite has been brecciated [1] and contains clasts of material with somewhat different thermal histories than the host. Although pyroxenes in Juvinas are highly fractured, indicative of shock processing, our microstructural observations show that Juvinas is less highly shocked than Stannern. This is strongly suggested by the absence of dislocations or stacking faults in Juvinas pyroxenes which are very common in Stannern pyroxenes.

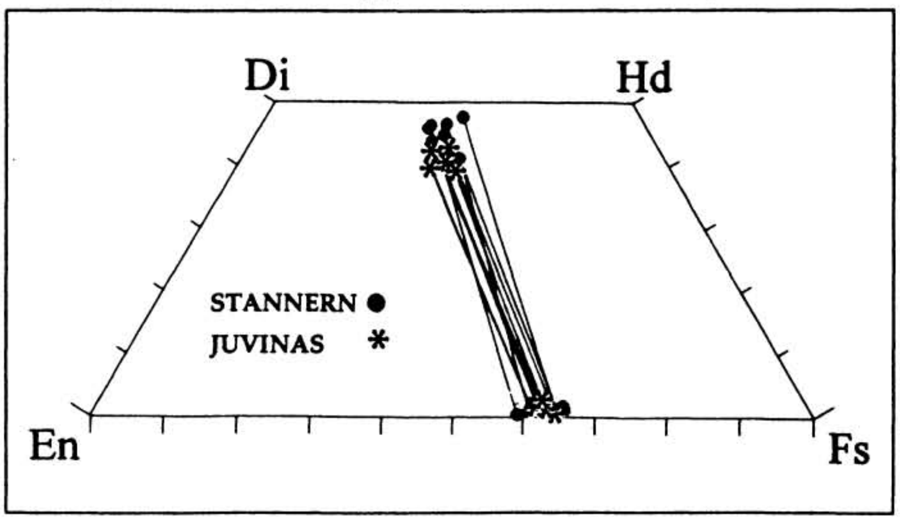

Fig. 1 Composition of coexisting host and lamellae in Juvinas and Stannern.

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References

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