A0027/78

NOV,1978

IRON-NICKEL 50-50 SUPERSTRUCTURE IN THE SANTA CATHARINA METEORITE

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Iron-nickel 50-50 superstructure in the Santa Catharina Meteorite.(*)

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(*) To be published in Nature.

Mössbauer effect and X-ray diffraction measurements have shown that thin lamellae of the Cape York and Toluca meteorites contain the ordered phase FeNi (50%-50%) with the structure L 10.[1)2)3)] The bulk of these meteorites consists mainly of b.c.c. iron-nickel α-phase alloy. We report here Mössbauer spectra, electron microprobe and X-ray measurements which show that contrary to this, the bulk of the Ni-rich (≈ 35%) Santa Catharina Ataxite consists of up to 50% FeNi superstructure.[4)]

Thin slices of the bulk of the Santa Catharina meteorite from specimens of the collection from the Museu Nacional in Rio de Janeiro were cut with a precision saw, carefully avoiding thermal stresses in the work piece. Absorbers for Mössbauer spectra measurements were prepared by polishing the slices to a thickness around 70 μm . The spectra were recorded with a 20 mC source ^{57}Co in Rh matrix with a velocity drive coupled to a multichannel analyzer of 1024 channels. A 370/145 IBM computer was used for folding and analysing the data with a lorenzian least square fitting.

Figure 1 compares a spectrum of the Santa Catharina sample with a spectrum obtained in the same conditions with a thin lamella of the Toluca meteorite, in which X-ray determinations showed the presence of the superstructure.[3)] Both spectra are a superposition of two spectra: (1) a central line from a paramagnetic phase and (2) an asymmetric six line spectrum, due to the L 10 superstructure, which gives rise to a quadrupole splitting caused by the non-cubic surroundings of the iron atoms in this alloy.[5)6)7)] The magnetic hyperfine field H_i and the electric quadrupole shift ε of the Santa Catharina sample are about the same as those observed with the lamella (lamella: $H_i = 289 \pm 2$ kG, $\varepsilon = 0{,}20 \pm 0.02 \frac{mm}{sec}$; Santa Catharina: $H_i = 291 \pm 3$ kG, $\varepsilon = 0{,}17 \pm 0.02 \frac{mm}{sec}$). The linewidths obtained with the Santa Catharina ($\Gamma \approx 0{,}52 \frac{mm}{sec}$) are larger than the linewidths obtained with the Toluca lamella ($\Gamma \approx 0{,}32 \frac{mm}{sec}$). This may be due to the larger thickness of the sample. Only minor changes, both in the paramagnetic central line and in the magnetically splitted Mössbauer spectrum, were observed on going from room temperature to liquid nitrogen (77 K) and liquid helium (4.2 K). This is a surprising result, which will be discussed in detail in a forthcomming publication.

As has been observed with the Cape York lamellae[2)], the Mössbauer spectra of samples from the Santa Catharina meteorite at 732 K show that the breakdown of the superstructure occurs in a time scale of about 10 hours.

From our results, f.inst. the area ratio of the 6-line spectrum to the single line, one concludes that about 50% of the Santa Catharina meteorite consists of the ordered FeNi alloy with L 10 structure. In the limits of sensibility of the Mössbauer effect no evidence was found for other iron containing minerals.

Electron microprobe (Microscan 5, Cambridge Scientific Instruments) analysis of the polished Santa Catharina samples shows clearly the presence of at least two phases[8)] as is illustrated in figure 2. Microanalysis at points of the two phases indicate, from an average of 50 determinations, that the darker phase has a homogeneous composition, 51%-50% (by weight) of Ni and 49%-48% of Fe and that the lighter phase has a more heterogenous composition containing around 30% of Ni. The two phases form domains of oriented intergrown which implies that slices cut from the meteorite will always contain both phases. The presence of O and S in maximum amounts of 1%-2% were found uniquely on the Ni rich phase. Larger proportions of O have been reported in this phase from earlier microprobe work.[9] The discrepancy may be due to the fact that earlier measurements were made on a severely oxidized sample. We have also studied the sample from Santa Catharina by X-ray techniques. Oscillating crystal photographs show that the sample over areas of at least 1 mm^2 is essentially a single crystal, and that it contains the superstructure L 10 of FeNi.

It is remarkable that around 50% of the Santa Catharina meteorite, which originally may have been a 25000 kg meteorite[10] consists of the ordered FeNi structure. This structure has only been obtained by strong neutrons- or electron irradiation of disordered alloys at temperatures near the ordering temperature ($T_c \approx 320°C$).[5)6)7)] Diffusion processes substantially below T_c are too slow to obtain thermodynamic equilibrium.[11] The presence of the ordered FeNi in Santa Catharina is probably due to the slow cooling rate of the meteorite, when it resided in its parent body.

Further experiments are in progress in order to clarify the nature of the iron rich paramagnetic phase as well as the magnetic properties of the ordered FeNi phase.

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Figure Captions:

Figure 1

Mössbauer absorption spectra of a) a thin slice ($\approx$ 70 m) of the Santa Catharina meteorite and b) thin lamellae of the Toluca meteorite. The spectra were recorded at room temperature ($\approx$ 22°C). Source, ^{57}Co in Rh.

Figure 2

Back-scatter electron image from electron microprobe analysis of a polished surface of the Santa Catharina sample. From point analysis determination it is found that the dark areas correspond to the Fe-Ni ordered phase whereas the ligh ones correspond to the Fe-rich paramagnetic phase. Distintly to be seen in the oriented nature of the intergrowths of the two phases.

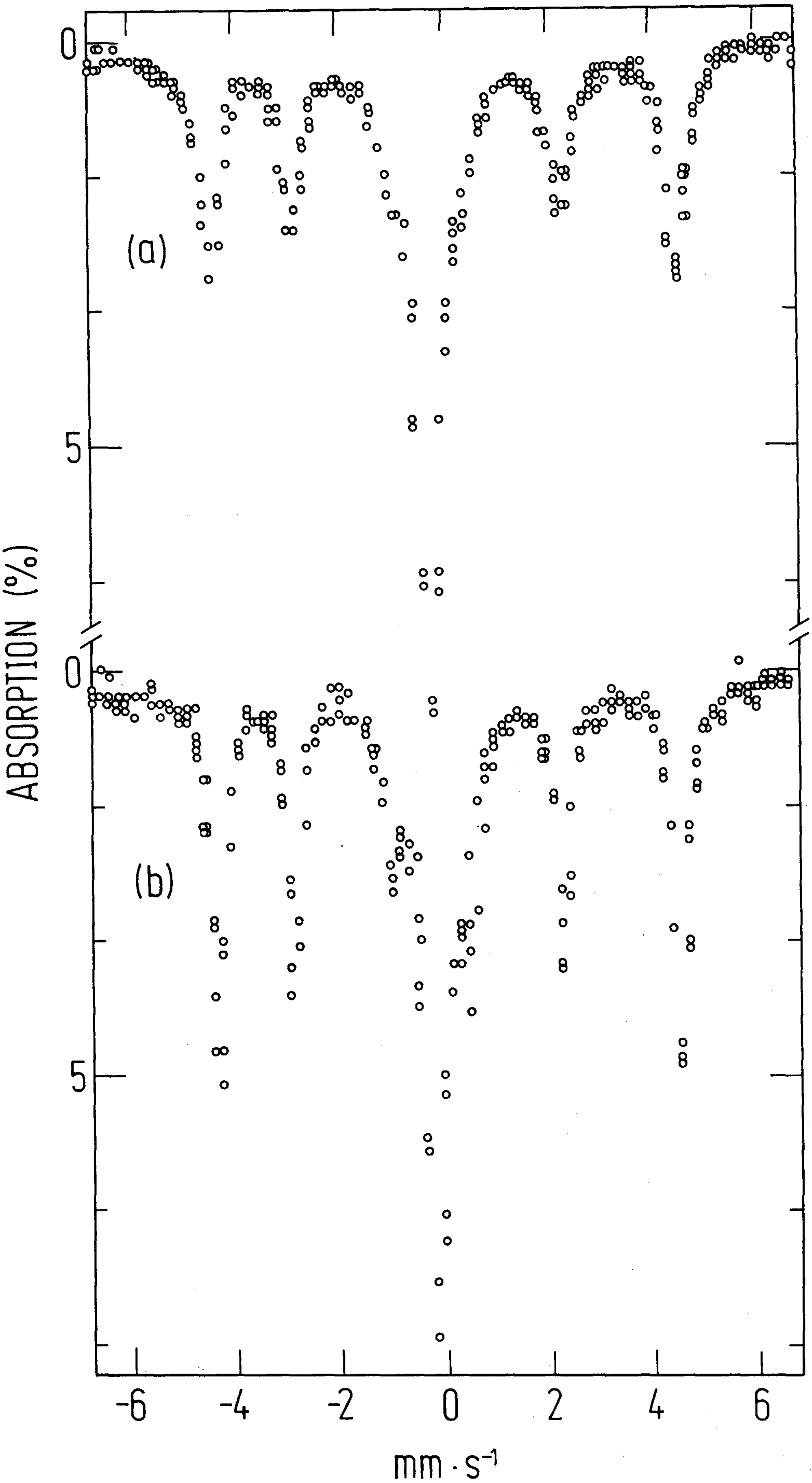

Figure 1.

fig 2