MÖSSBAUER SPECTROSCOPY OF TEKTITES AND OTHER NATURAL GLASSES

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Résumé.- L'effet Mössbauer du ^{57}Fe sur des tektites révèle :
1) l'absence du moindre vestige de structure cristalline qui pourrait être attendu d'un matériau produit par des impacts de météorites.
2) un rapport Fe^{3+}/Fe^{2+} excessivement faible, considérablement plus faible que la valeur obtenue par analyse chimique acqueuse. Au contraire, on a observé des verres d'impact terrestre, où le Fe^{3+} a pu être facilement détecté par spectroscopie Mössbauer, et qui présentent de remarquables inhomogénéités en fer. Ces résultats suggèrent que les tektites n'ont pas été formées à partir de matériaux terrestres fondus par impact de météorites et que le matériau précurseur des tektites fut un matériau fondu ayant eu un temps considérable pour atteindre un équilibre.

Abstract.- ^{57}Fe Mössbauer measurements on tektites from every major strewn field reveal :
1) the absence of any vestigial crystalline structure involving iron that might be expected in materials produced by meteoritic impact and
2) an exceedingly low Fe^{3+}/Fe^{2+} ratio, considerably lower than the values obtained by wet chemical analysis. In contrasts, terrestrial impact glasses contained Fe^{3+} at concentrations easily detectable by Mössbauer spectroscopy and exhibited remarkable inhomogeneities with respect to iron. These results suggest that tektites were not formed from molten terrestrial material produced by meteoritic impact and that the precursor material to tektites was a thoroughly molten material having considerably time to approach equilibrium.

1. Introduction. - Tecktites are naturally occuring glasses found in widely-separated localities, North America, Czechoslovakia, Australia, and Southeast Asia, and are characterized inter alia by their occurrence as large groups of specimens in each locality and among the specimens by the absence of vesicles, volatile substances and a low ferric/ferrous ratio /1/. It has been established for some time that the occurence of tektites is associated with meteoritic impact; the crucial question is whether tektites were derived from the meteorite itself or if they were formed by impact melting of terrestrial material. If the tektites are indeed fragments of the meteorite itself, then one must answer the question of whether they were produced by meteoritic impact on a planetary body other than the Earth, i.e. the Moon, or by some other natural, glass-making process, i.e. lunar volcanism.

It is known that the melting of crystalline rocks by meteorite impact leads to a highly non-equilibrium melt and the retention of significant vestigial crystallinity /2/. Furthermore, it is known that impact melting of terrestrial rocks leads to a decrease in the ferric/ferrous ratio; the decrease, however, is on the order of 2-to 5-fold and not within the range of 10 - 1000-fold. Since ^{57}Fe Mössbauer spectra are sensitive to local order and have been found to be superior to wet-chemical analysis for ferric/ferrous determinations, the above-mentioned, two aspects of the solid state chemistry of tektites that relate to their origin have been investigated by ^{57}Fe Mössbauer spectroscopy.

Transmission spectra were obtained on more than fifty, analyzed tektites; polished, 50 x 10^{-6}m thick sections were used to minimize oxidation that might occur during the preparation of powdered absorbers. A 1 mm^2 active area Co^{57}/Rh source was employed in conjunction with an electromechanical transducer and 1024 multichannel analyzer operated in time-mode. The spectra were fitted by a least-mean-squares technique employing Lorentzian-shaped lines.

2. Results and discussions.- A typical ^{57}Fe Mössbauer spectrum of a tektite is shown in figure 1; the spectrum at 80 K is unchanged from that at 298 K except for the SOD shift and a small change in the electric quadrupole splitting. At neither temperature are there features that might be attributed to a limited number of distinct iron sites due to vestigial crystallinity or a high degree of local order. In contrast, there is clear evidence for retained crystallinity and chemical inhomogeneities of the parent rock in the spectrum of a known terrestrial impact glass as shown in figure 2. The degree of local order and chemical homogeneity of tektites are consistent with that expected for well-equilibrated melts and are compatible with that expected for a glass derived from impact-melted terrestrial rocks.

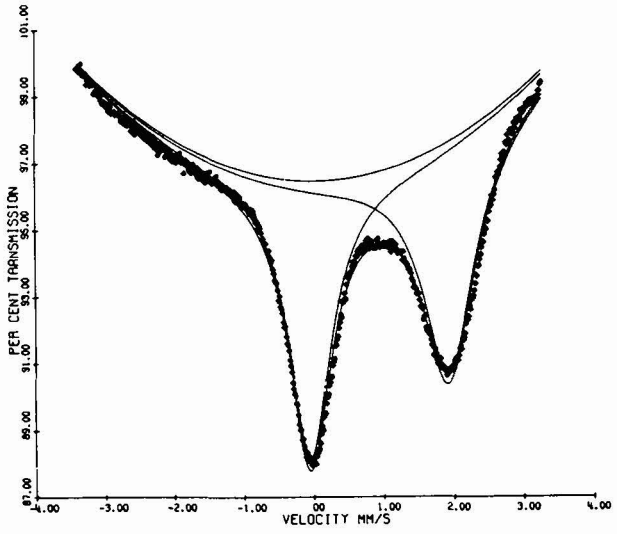

Fig.1 : ^{57}Fe Mössbauer spectrum of an Australasian tektite at 298 K. The solid line through the data points represent a two-line, Lorentzian fit. Note the overestimation of the spectral intensity by this fit between 0.5 mm s^{-1} and 1.0 mm S^{-1}.

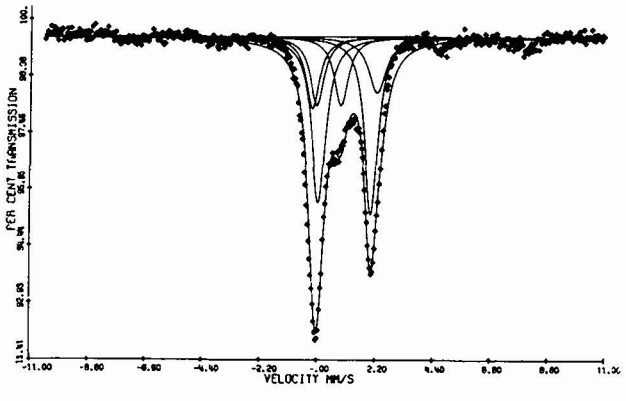

Fig.2 : Spectrum of an impact glass at 298 K from Lonar Lake India, exhibiting appreciable absorptions due to Fe^{3+} and a crystalline, Fe^{3+}-containing magnetic phase.

From the two line fits to the spectrum, the following average values were obtained for the hyperfine parameters : 1.950 mm s^{-1} for ΔE_Q, 1.08 mm s^{-1} for δ, 0.72 mm s^{-1} for Γ at low velocities and 0.91 mm s^{-1} for Γ of the high velocity line. Despite the fact that the two-line fits overstimate the intensity of the low velocity line between 0.5 mm s^{-1} and 1.0 mm s^{-1} (cf. Fig. 1), the area of the low velocity line is only 0.98 that of the high velocity line. Six-line fits to the spectra, which accurately describe the line profiles, give a low velocity line area of 0.96 relative to that of the high velocity line. By comparison with a spectrum of a basalt glass having a Fe^{3+}/Fe^{2+} ratio of 0.2, shown in figure 3, it is clear that tektites have Fe^{3+}/Fe^{2+} ratios much less than 0.05. Spectrum simulation indicates that Fe^{3+}/Fe^{2+} ratios as low as 0.001 are detectable via the asymmetry of the area of the two apparent lines. Thus tektites show a degree of iron reduction that cannot be obtained by impact melting of terrestrial rocks with their average Fe^{3+}/Fe^{2+} ratio of 0.5. Among well-documented terrestrial impact glasses only Aouelloul Crater glass and Darwin glass have Mössbauer line asymmetries similar to those of tektites. Other impact glasses exhibit either low velocity lines with areas larger than the high velocity lines, clear evidence of an unresolved Fe^{3+} component or obvious, partially resolved Fe^{3+} patterns as shown in figure 2. Tektites reported to have Fe^{3+}/Fe^{2+} ratios of 0.05 and 0.1 on the basis of wet chemical analysis have been reinvestigated in this study and found to contain no more Fe^{3+} than tektites reported to have Fe^{3+}/Fe^{2+} ratios of <0.001 on the basis of wet chemical analysis.

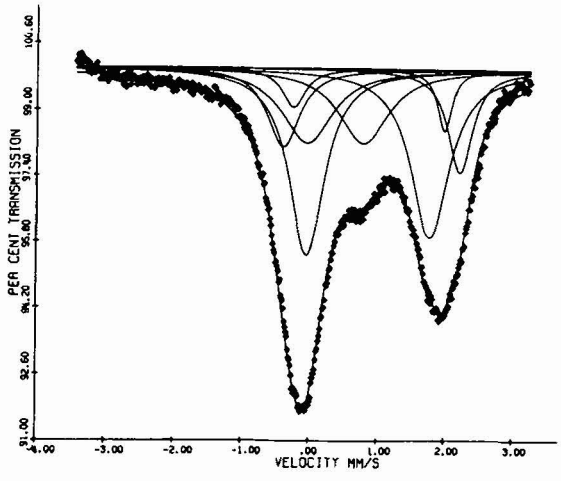

Fig. 3 : Spectrum of synthetic basalt-like glass at 298 K. The Fe^{3+} absorption is obvious and corresponds to a Fe^{3+}/Fe^{2+} of 0.2 as determined both by wet chemical and Mössbauer analysis.

3. Conclusion.- ^{57}Fe Mössbauer measurements reveal that tektites have Fe^{3+}/Fe^{2+} ratios that are too low for them to have been derived by impact melting of terrestrial rocks and that the degree of local order in the atomic configurations is too low for them to have been produced by meteoritic impact melting of crystalline rocks on either the Earth or the Moon.

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