SHOCK-INDUCED COLOR CHANGES IN NONTRONITE: A POSSIBLE MARTIAN SURFACE PROCESS, Ray J. Weldon, Mark B. Boslough, Thomas J. Ahrens, Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California 91125.

The iron-rich smectite, nontronite, is one of the favored candidate materials comprising the Martian fines (1). This material appears to cover much of Mars and may be quite old. Recovery impact experiments were performed to determine the effect of meteoritic bombardment in this surface material. The nontronite used was collected near Riverside, California by the Viking x-ray fluorescence team and is one of the natural samples that most closely matches the Viking x-ray fluorescence spectra.

Nontronite samples impacted to 180 kbar and 300 kbar using the techniques described in (2) were successfully recovered and analysed by x-ray diffraction, IR and optical spectroscopy. Mössbauer spectroscopy is currently being applied to shocked samples and should help confirm the observations from the other techniques.

The most striking change in the nontronite was color. The original nontronite was olive-yellow, corresponding to 2.5Y 6/6 in the Munsell color chart (3). The material shocked to 180 kbar turned yellow-brown, 1.0Y 5/6, and the nontronite brought to 300 kbar was strong brown, 7.5YR 4/6. The increase in shock pressure caused a shift in hue, towards red, and value, towards black.

The color change appears to be due to a shift in the $Fe^{+3}$-$O^{-2}$ charge transfer absorption band from the near UV into the visible (see Figure). This effectively cuts out part of the blue end of the spectrum, leaving the color redder (hue) and darker (value). The most likely reason for this shift in the absorption band is some change in the nature of the $Fe^{+3}$ site that lowers the covalency of the $Fe^{+3}$-$O^{-2}$ bond to the point that the charge transfer absorption takes place at a lower energy, i.e. a longer wavelength, as observed.

There are other possibilities for the color change, such as the oxidation of some $Fe^{+2}$ or the formation of some completely new phase as a pigmenting agent, but these appear unlikely. Our sample appears to have little $Fe^{+2}$ (as is the case for most yellow nontronites). $Fe^{+2}$ rich nontronites are green and exhibit a prominent $Fe^{+2}$ absorption band in the visible, which does not occur in our sample. IR and x-ray diffraction show that the sample is still nontronite even after a 300 kbar impact, with the loss of water as the only major structural change (2).

If one assumes that the change in the nontronite is due to post-shock heating and compares it to the thermal decomposition of nontronite (4), the results can be readily explained. As one heats up nontronite inhomogeneous reactions occur, slowly changing the nontronite to oxides (and iron metal under reducing conditions). The actual formation of the new phase occurs within the nontronite structure and there is no discrete point at which one can say a phase change occurs. This can explain why the shocked nontronite is still nontronite but is a different color.

It is possible that the continuation of this process, i.e. multiple events or shocking the material to higher pressure, could produce maghemite and explain the magnetic properties of the Martian fines (5). However, the changes in the magnetic properties of nontronite as it inhomogeneously reacts to oxides is yet unmeasured. Perhaps, the ferromagnetism property in the Martian fines also develops in an inhomogeneous manner so that the presence of maghemite as a discrete phase may not be necessary to explain the magnetic properties of the Martian fines.

If nontronite has existed on Mars long enough to have been subjected to sufficient meteoritic impaction, the color, and possibly the magnetic properties of the Martian fines, can be explained. If a weathering process such as proposed by Gooding (6) or Huguenin (7) were operating on Mars, one would expect to see its effect on the rocks (which one does not) and there should be a difference in degree of weathering on different sized grains. Generally in an impact-metamorphic process, as proposed here, we would expect the cumulative mineralogic reactions affecting optical and magnetic properties (8,5) to depend on total surface residence time and to a lesser degree on particle or clast size in contrast to a chemical weathering process whose rate depends primarily on surface area.

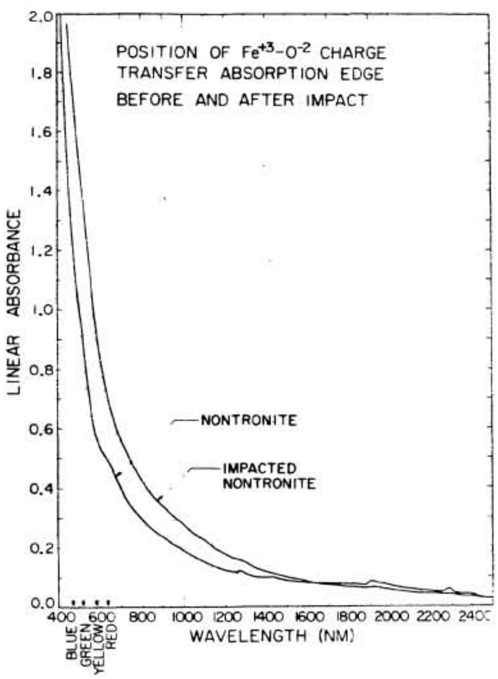


Figure: The edge of the $Fe^{+3}$-$O^{-2}$ charge transfer absorption band is shifted from the near ultra-violet (in unimpacted nontronite) into the visible (in nontronite shocked to 300 kbar) cutting out most of the blue and of the visible spectrum, leaving the impacted nontronite redder.

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