Exploration of Charge Carriers in Obsidian

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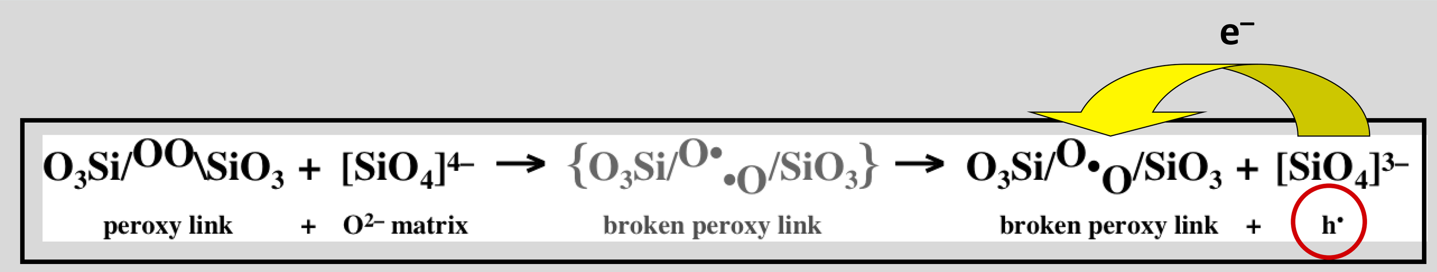
Abstract

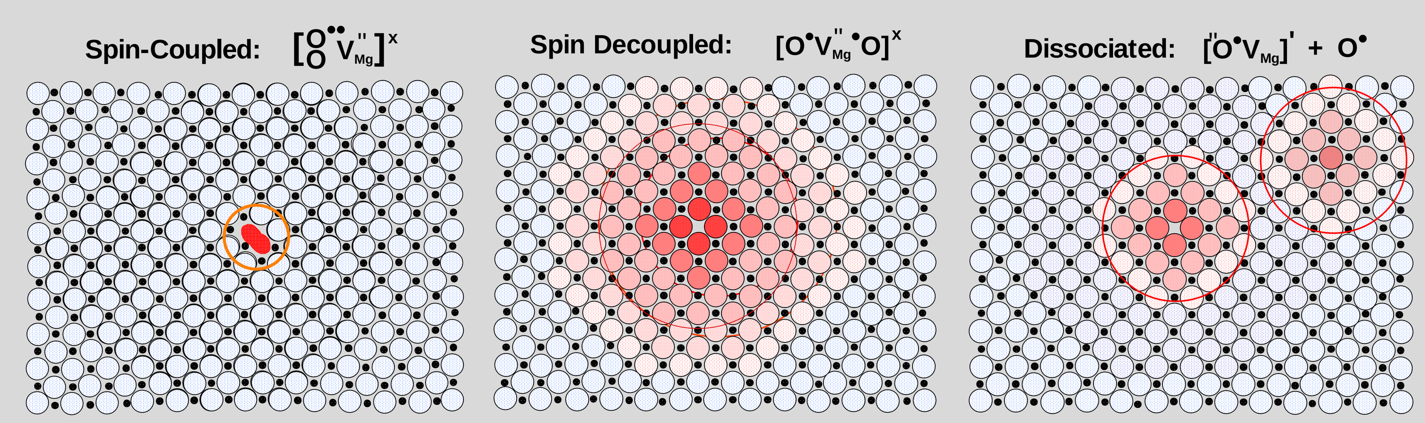
This research effort is part of an ongoing investigation into stress-activated positive hole charge carriers in common igneous and high-grade metamorphic rocks. The findings have already revealed potential early earthquake detection mechanisms and caused a re-think on the processes that could conceivably contribute to the formation of and evolution of life. Positive holes are defect electrons in the oxygen anion sub-lattice of silicate minerals that have demonstrated some intriguing capabilities: flowing out of a stressed rock volume; causing oxidation reactions at the rock-water interface and ionization at the rock-air interface; and traveling great distances. This research seeks to determine if obsidian (volcanic glass) is also capable of yielding stress- or temperature-activated charge carriers.

In this study, a measurable change in current and voltage when obsidian samples are put under mechanical stress would suggest that charge carriers are available. The motivation for this research, among other reasons, is that it will add breadth to positive hole phenomena; provide additional evidence for stress- or temperature-activated positive hole formation; and create possibilities for monitoring volcano activity.

The Theory: Positive Hole Charge Carriers

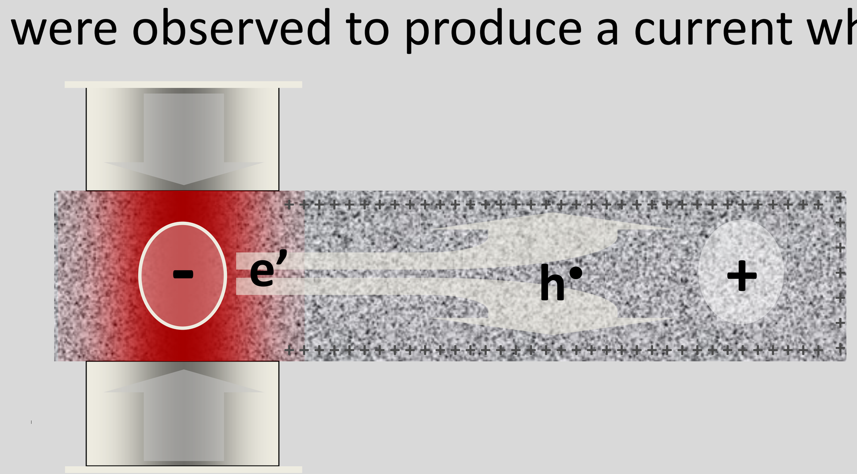


- Obsidian has a high Silica (SiO_2) content
- Silicon atoms are bonded with peroxy links
- When these links are broken, a positive hole (h˙) is created
- A positive hole can be defined as:
  - … a missing electron in the O^{2-} sublattice
  - … O^{-} in a matrix of O^{2-}
  - … an electronic state that can move through mineral grains and beyond
- When a sample is placed under stress or heated, the peroxy links break and positive holes form

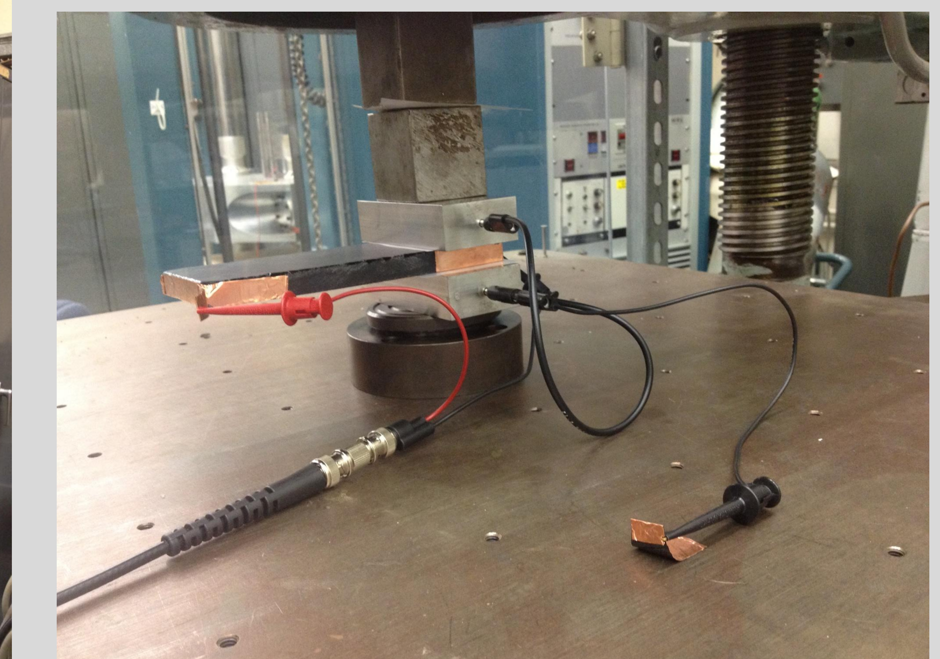


Stress Activation

- The diagram below shows the proposed movement of charge through rock samples placed under uniaxial compression
- Positive holes flow out of the stressed sub-volume
- This results in a potential gradient, and in effect turns the sample into a battery with measurable increases in voltage and current
- Prior to testing obsidian, only samples containing crystalline structures were observed to produce a current when under stress



Experimental Setup



- A hydraulic press was used to apply uniaxial compression to one side of the obsidian sample (see above)
- Electrodes (copper tape) were placed on both ends of the obsidian sample, which were connected to a picoammeter
- The pistons used to apply stress were grounded

Findings

- There was a non-discovery of a change in current when the samples of obsidian were placed under stress
- All samples tested fractured prior to a measurable change in current (see photo to right)

Interpretation of Results & Next Steps

Unlike the crystalline rock samples previously subjected to this experimental setup, obsidian is amorphous. This suggests that the location of the peroxy links are embedded within the glass structure of the sample. Therefore, breaking these links, and activating the positive holes, will first result in the sample fracturing. Given obsidian's limitations for activating the positive holes with stress, a series of measurements will be conducted using thermal activation.

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References:

Freund, F. T. (2003), On the electrical conductivity structure of the stable continental crust, *J. Geodynamics*, 35, 353-388

Freund, F. , Whang, E., Lee, J. *Highly Mobile Hole Charge Carriers in Minerals: Key to the Enigmatic Electrical Earthquake Phenomena? in Electromagnetic Phenomena Related to Earthquake Prediction Ed. by Hayakawa, M. and Fujinawa, Y. 1994. Terra Scientific Publishing Co. : Tokyo. p. 271 - 292.*