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Enhanced Mid-Infrared Emission from Igneous Rocks under Stress

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Introduction Enhanced thermal infrared (TIR) emission from the Earth's surface retrieved by satellites prior to earthquakes, also known as "thermal anomalies", has been frequently reported[1] but there is no widely accepted physical explanation as to why land surface temperatures seen in TIR satellite images should fluctuate rapidly and apparently without correlation to surface/subsurface temperatures. We are looking at the process from a solid state physics viewpoint.

Experimental We conducted laboratory experiments with large (30x60x7.5 cm^3) blocks of granite and anorthosite subjecting a small volume in the center to axial stress. We measured the IR emission from a 5 cm diameter spot on the front face, 40-50 cm from where the rock is loaded, using a BOMEN FTIR Spectroradiometer, with a custom-built radiance temperature calibration[2] covering the 7-14 μm range.

Upon application of stress we observe a near-instant change in the TIR emission spectrum. There is enhanced emission at wavelengths consistent with vibrationally highly excited O–O bonds and of excited Si–O and Al–O bonds.

Discussion From prior work[3] we know that, during application of stress but long before failure, electric charge carriers are activated in igneous rocks. These charge carriers are defect electrons in the O 2p-dominated valence band of the otherwise insulating silicate minerals, known as positive holes or p-holes. The p-holes are electronic states associated with O^- in a matrix of O^{2-}. Normally they lie dormant as positive hole pairs (PHP), equivalent to peroxy links O_3X-OO-XO_3 with X=Si, Al.

Traveling in the valence band of otherwise insulating silicate minerals, p-holes are capable of spreading from where they are generated. They can cover macroscopic distances, of the order of meter in the laboratory, possibly kilometers in the crust.

Important for pre-earthquake research is the fact that PHPs can be activated by stress[3]. It costs energy to break PHPs and to activate the p-holes. When p-holes recombine, some of this energy will be regained.

Theory[4] predicts that p-holes accumulate at the rock-to-air interface. Therefore we can expect that p-holes will preferentially recombine at the rock-to-air interface. Recombination leads to vibrationally highly excited O–O bonds. These O–O bonds can de-excite either by emitting specific mid-IR photons in the 11–12 μm region (800–930 cm^{-1}) or by channeling excess energy into neighboring Si–O and Al–O bonds, which in turn will emit in the 8–10 μm region.

Our experiments confirm that stimulated mid-IR emission takes place from the rock surface within seconds of the application of stress 40-50 cm away from the emitting rock surface. This observation and the spectral signature of the emitted IR radiation provide strong evidence that the underlying effect is a kind of mid-IR luminescence arising from the recombination of p-holes at the rock surface.

Conclusion We propose an explanation for “thermal anomalies” from a solid state physics viewpoint, namely that the IR emission giving rise to the apparent land surface temperature fluctuations is due to the radiative decay of vibrationally highly excited O–O bonds, which form at the rock surface during recombination of positive holes, activated by the build-up of stress deep in the Earth’s crust.

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References

[1)] Ouzounov, D., Freund, F.T. Mid-infrared emission prior to strong earthquakes analyzed by remote sensing data, Adv. Space Res. 33, 268-273, 2004; Gorny, V.I., A.G. Salman, A.A. Tronin, and B.B. Shilin, Earth’s outgoing IR radiation as an indicator of seismic activity, Proc. Acad. Sci. USSR, 301, 67-69, 1988; Tronin A., M. Hayakawa,

O. A. Molchanov, Thermal IR satellite data application for earthquake research in Japan and China, J. Geodyn. 33, 519-534, 2002.

2) Wan, Z., Zhang, Y., Ma, X., King, M.D., Myers, J.S., Li, X. Vicarious calibration of the Moderate-Resolution Imaging Spectroradiometer Airborne Simulator thermal-infrared channels, Appl. Optics 30, 6294-6306, 1999.

3) Freund, F. Charge generation and propagation in rocks. J. Geodynamics 33: 545-572, 2002; Freund, F. T. On the electrical conductivity structure of the stable continental crust. J. Geodyn. 35: 353-388, 2003.

4) King, B. V. and F. Freund, Surface charges and subsurface space charge distribution in magnesium oxide containing dissolved traces of water. Phys. Rev. B. 29: 5814-5824, 1984.