

Stress-Activated Positive Hole Charge Carriers

Key to Understanding Pre-Earthquake Phenomena

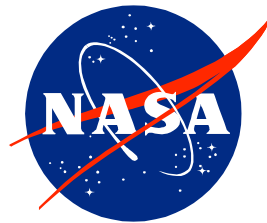
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NASA Ames Research Center



San José State
UNIVERSITY

Physics Department

Pre-seismic

Co-seismic

Post-seismic

Magnetic Field Anomalies
ULF/ELF Emissions
ULF Pulse Activity
Geo-Electric Signals
“Earthquake Lights”
Radon Emanation
Fog/Haze/Clouds
Air Ionization/Air Conductivity
Atmospheric Gravity Waves
Ionospheric Perturbations
Ground Water Chemistry
Microseismicity

Instant Warning
<30 sec

First responders

Organized help

Clean-up

Recovery

Months Weeks Days Hours Seconds Hours Days Weeks Months

Time before earthquake

0

Time after earthquake

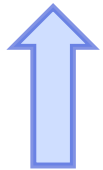
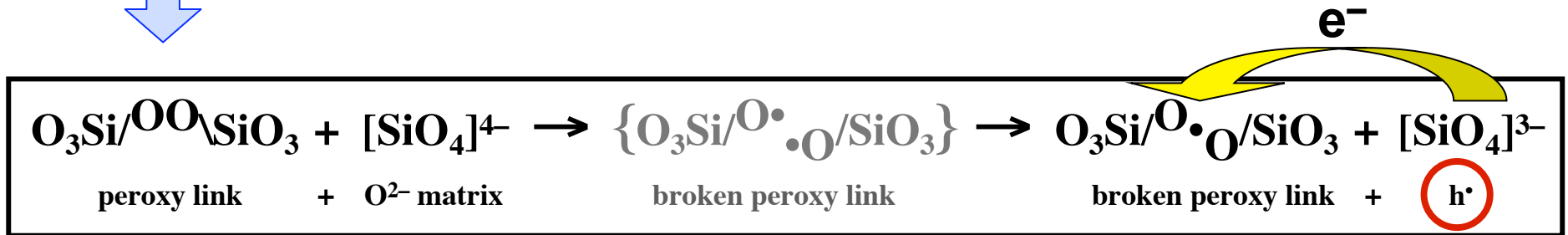
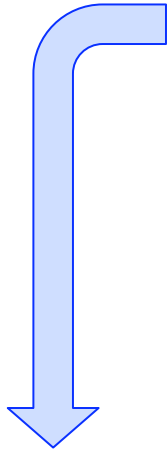
Hidden in plain sight

Rocks themselves offer a solution...

- Dormant electronic charge carriers exist in rocks
- They become activated when stresses wax
- They go “back to sleep” when stresses wane
- Ready to wake up again next time.

Positive Holes have been overlooked by the scientific community

Peroxy defects are the parents of positive hole charge carriers



Dormant



Transient



**Trapped
electron**



**Positive
hole**

A positive hole is...

- ...a missing electron in the O^{2-} sublattice
- ...a **defect electron** in the valence band
- ...positively charged
- ...an electronic state that can move through mineral grains and beyond
- ...can travel fast and far – meters in the lab, presumably tens of kilometers in the field

Positive holes have been characterized by their effects on...

- **Electrical conductivity** ✓
- **Thermal expansion** ✓
- **Dielectric susceptibility** ✓
- **Magnetic susceptibility** ✓
- **Infrared and Raman spectroscopy** ✓
- **X-ray photoelectron emission** ✓
- **Electron spin resonance spectroscopy** ✓
- **Muon spin relaxation spectroscopy** ✓
- **and more...**

Why positive holes?

- **Observation:**

many pre-EQ phenomena point to electrical processes inside the Earth's crust and at the ground-air interface

- **Examples:**

Transient regional magnetic field variations

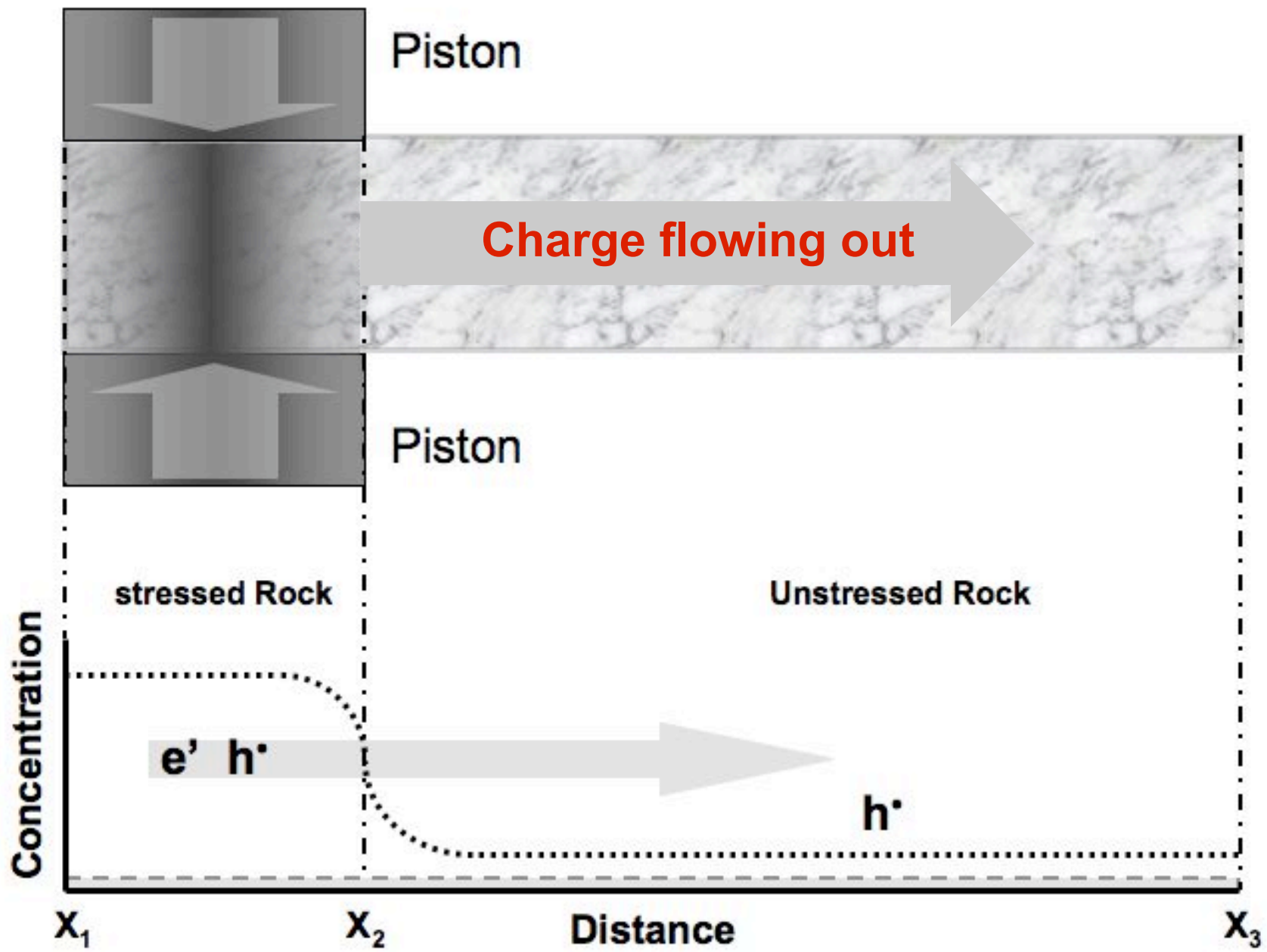
EM emissions ranging from ULF to VIS

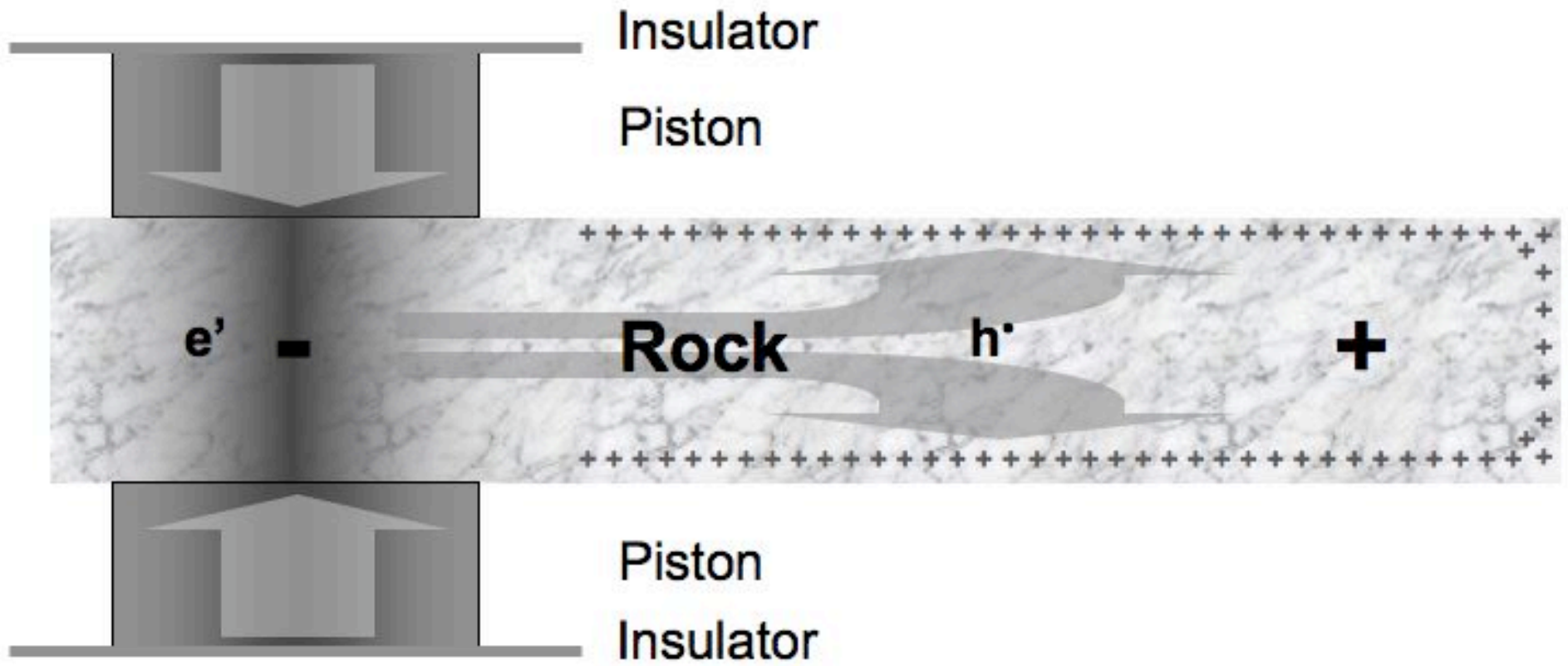
Air ionization

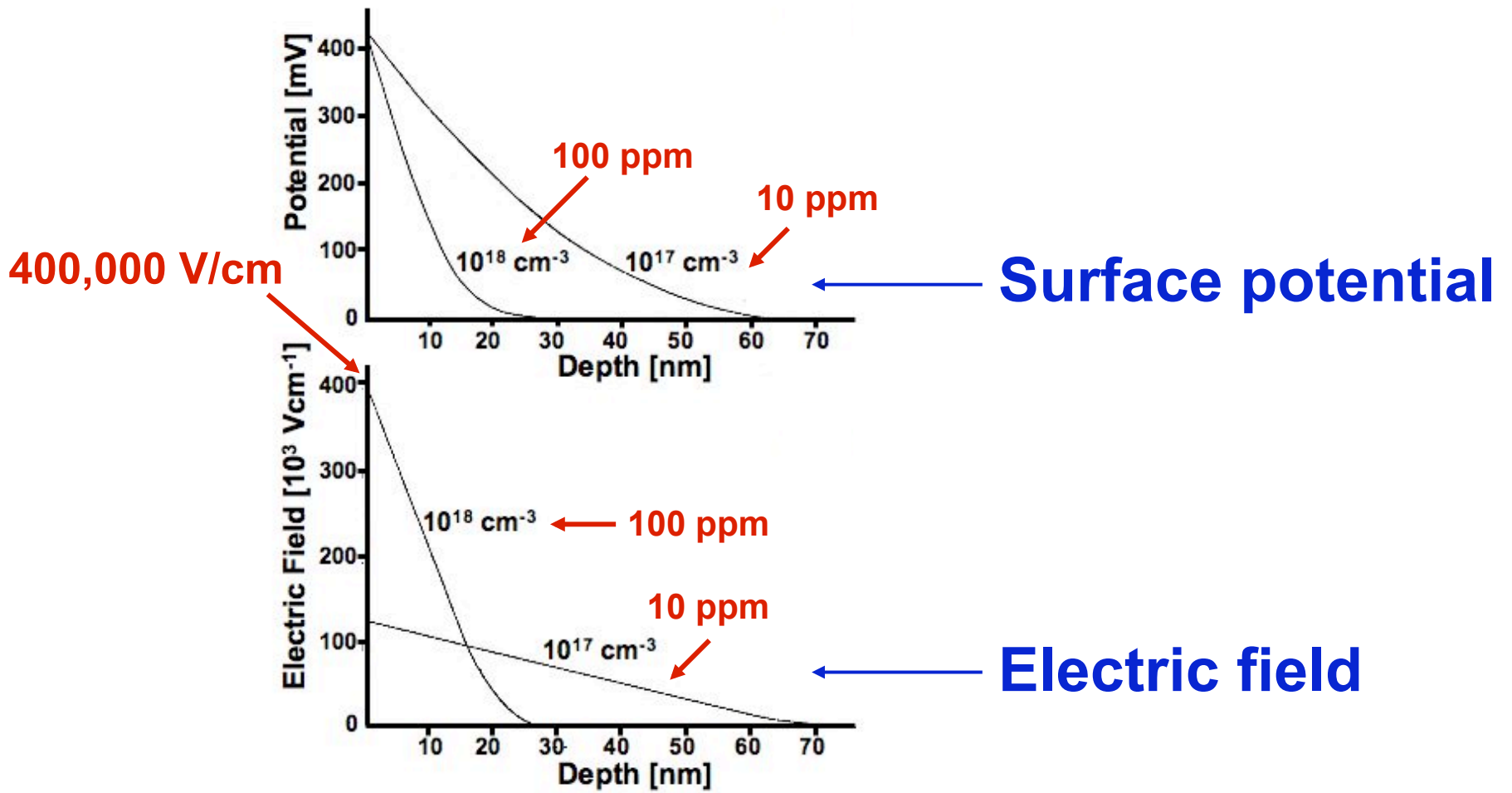
Ionospheric perturbations

- **Question:**

Can positive holes help us understand these and other alleged pre-EQ phenomena?





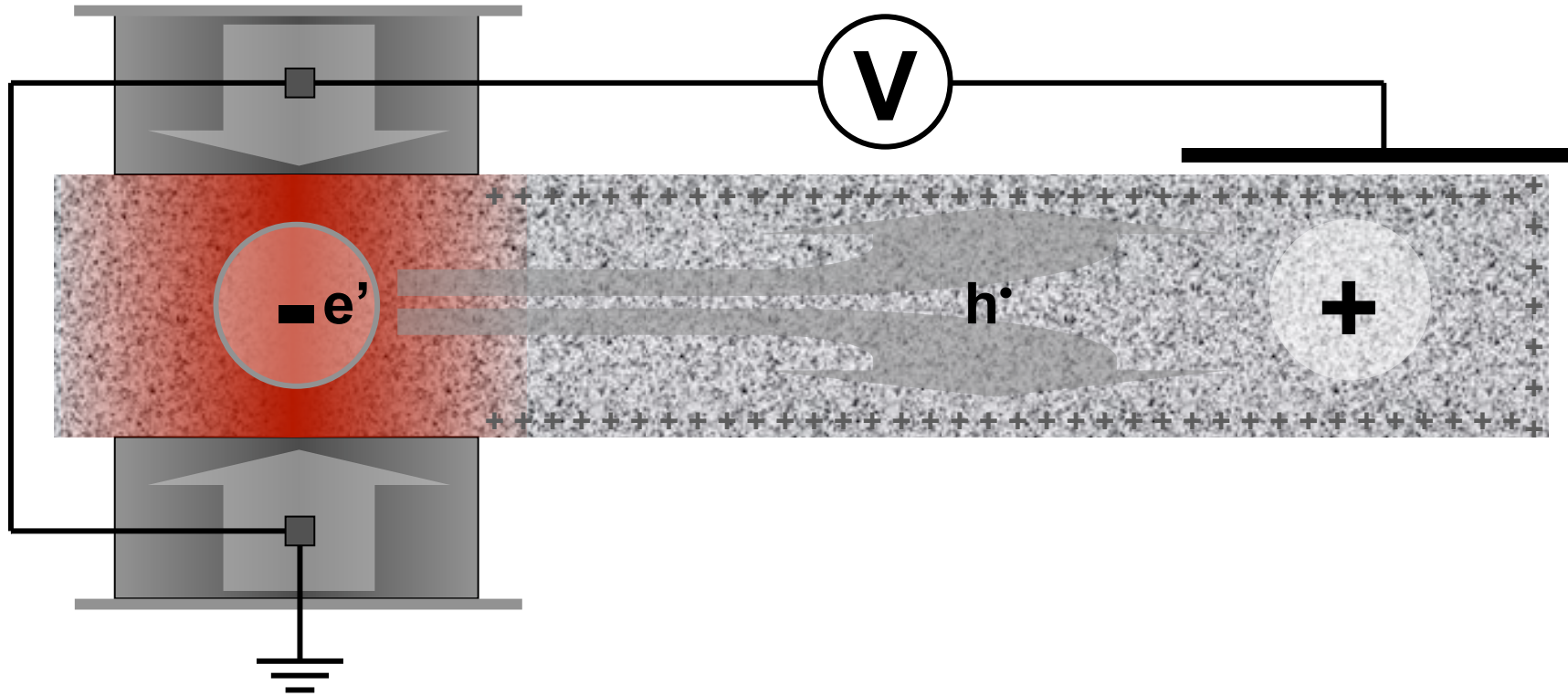


Calculated for a dielectric constant $\epsilon = 10$

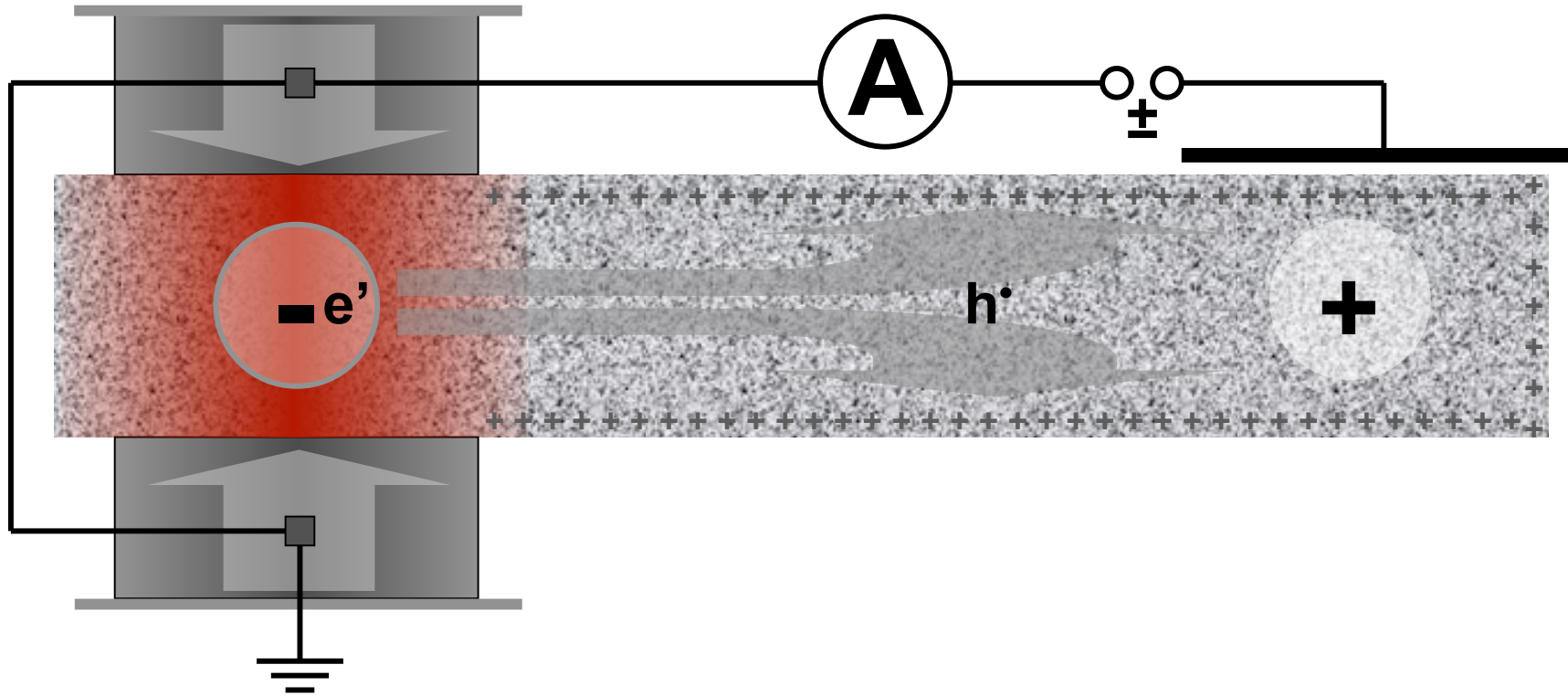
What can happen at the surface?

- **Surface potential** Step I
- **Surface electric field**
 - **Field-ionization of air molecules** Step II
 - **Corona discharge** Step III
- **Recombination of positive holes**
 - **Vibrationally excited surface states**
 - **Infrared emission / temperature increase**
 - **Electronically excited O atom emission**

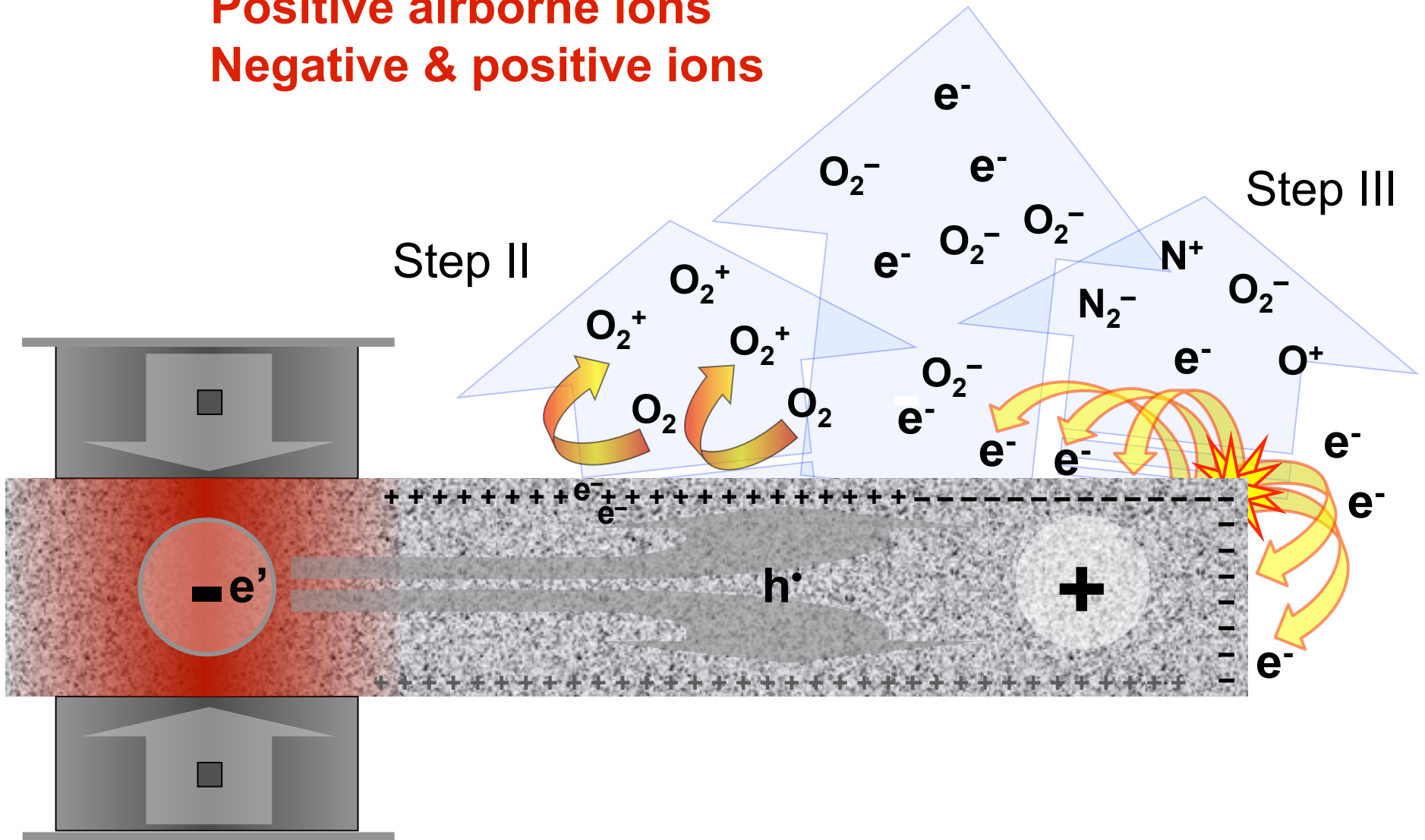
We can measure the surface potential



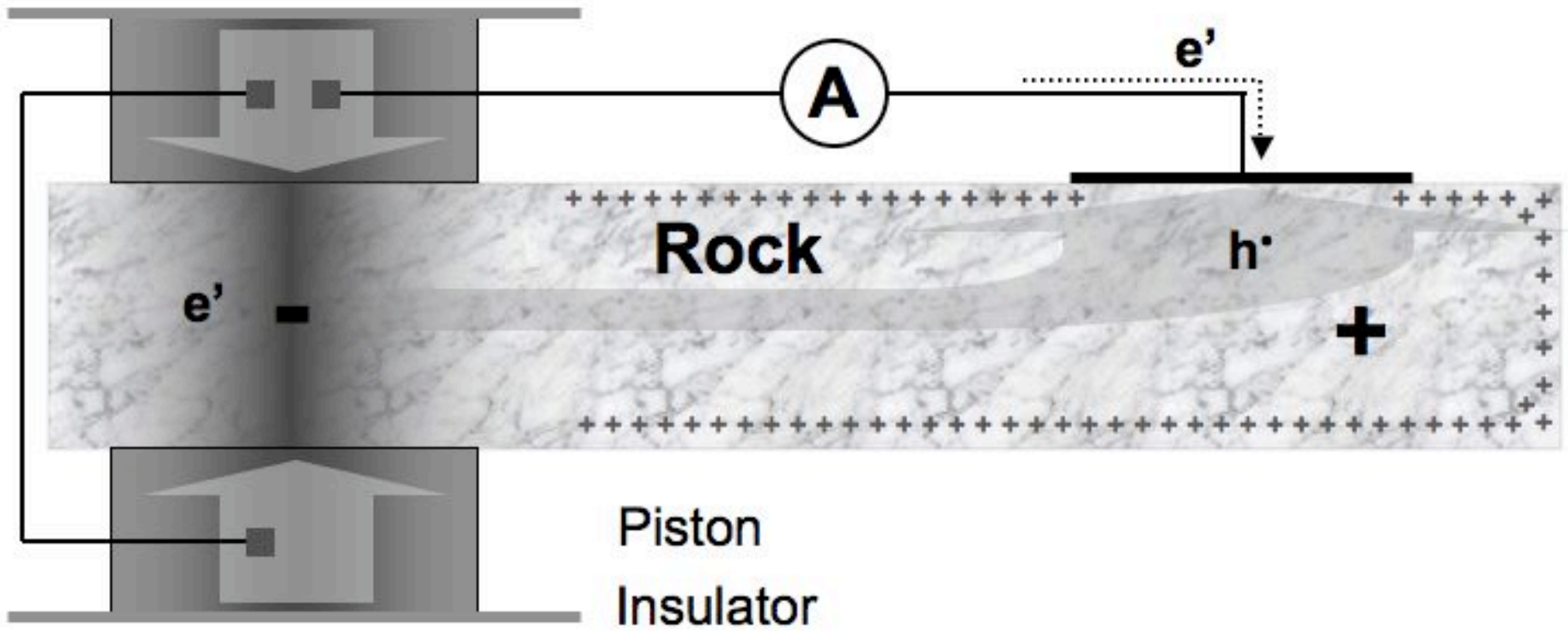
\pm ion currents through air gap



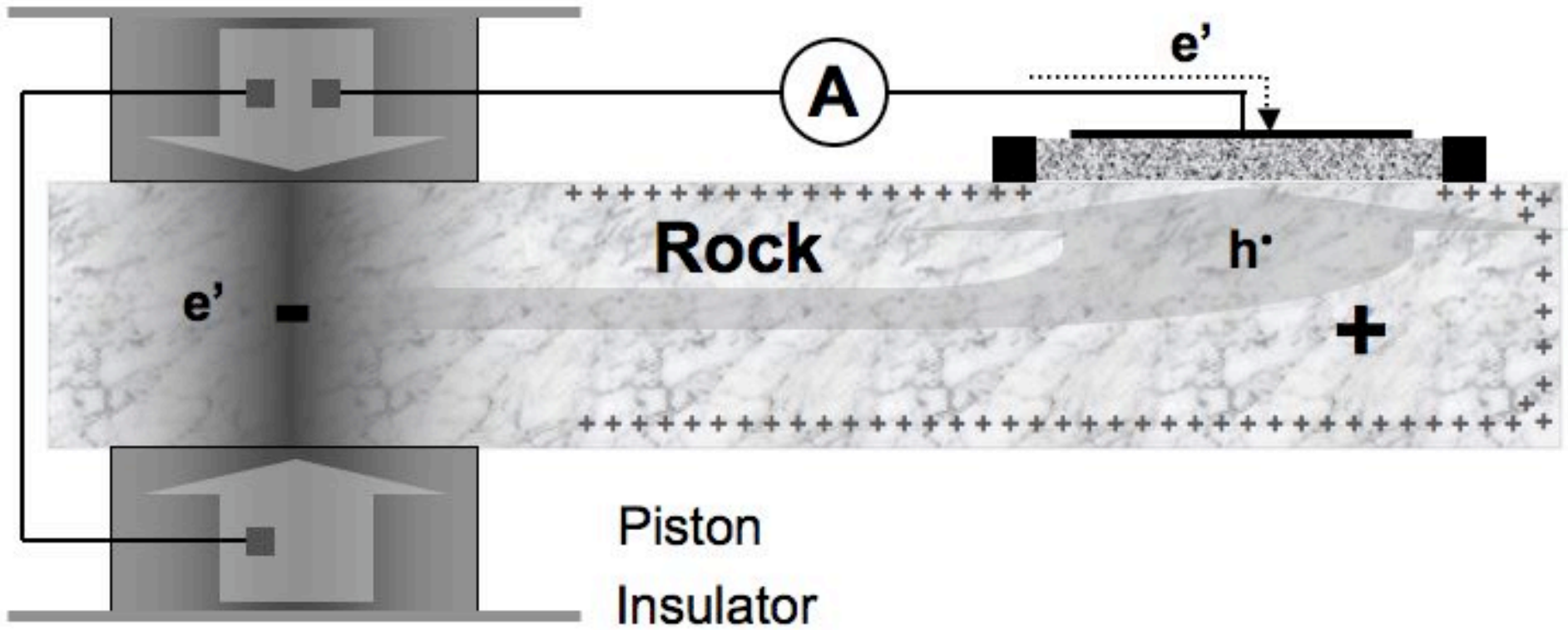
Ionization processes at surface:
Positive airborne ions
Negative & positive ions



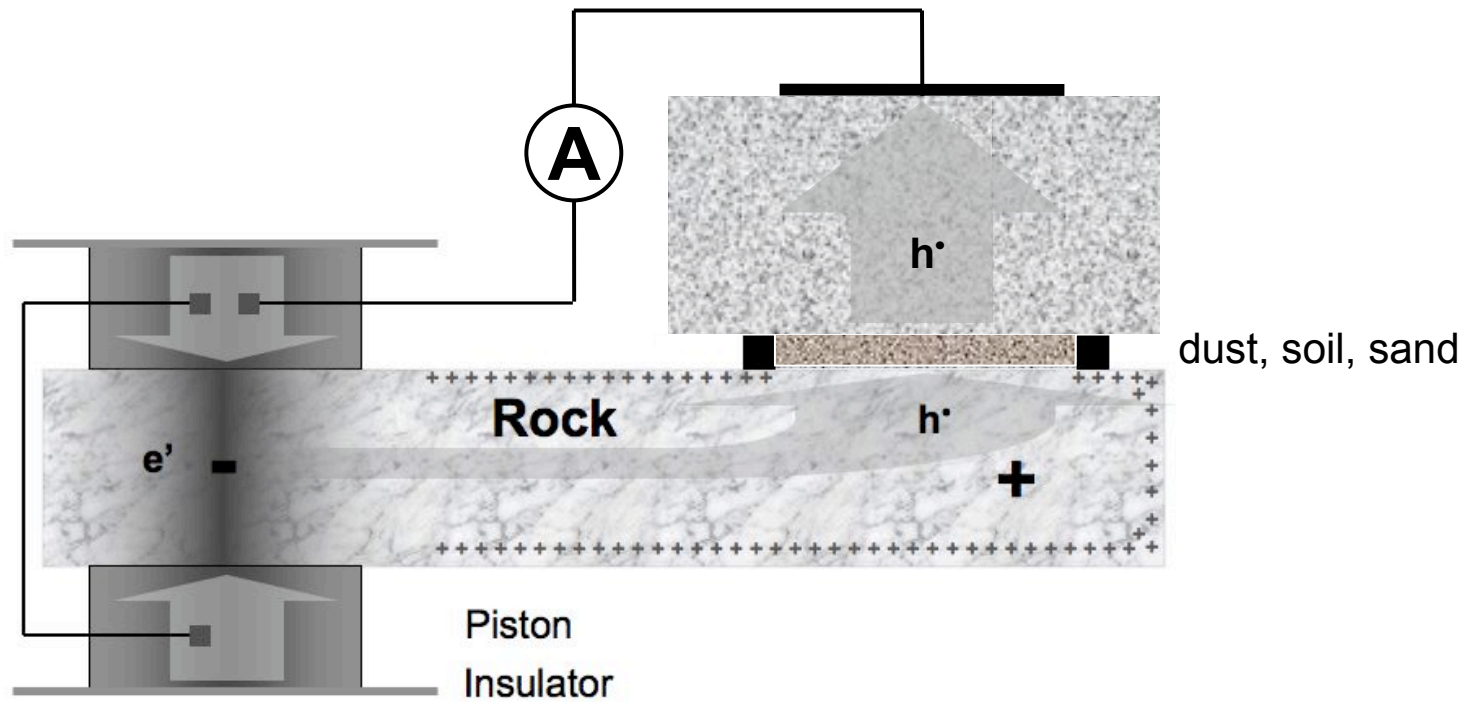
We can build a “rock battery”



The rock battery works even when the currents need to run through dust/sand/soil



Positive hole currents flow through dust, soil, sand and back into solid rock



Concept of Rock Battery

- ...if stresses activate charge carrier at different concentration levels in different parts of the crust, we'll have electric potentials and electric currents.

However,

- ...battery currents can only flow, if and when the battery circuit is closed.

How can the Battery Circuit close?

- It's easy in the lab: just run a Cu wire from the stressed to the unstressed rocks.

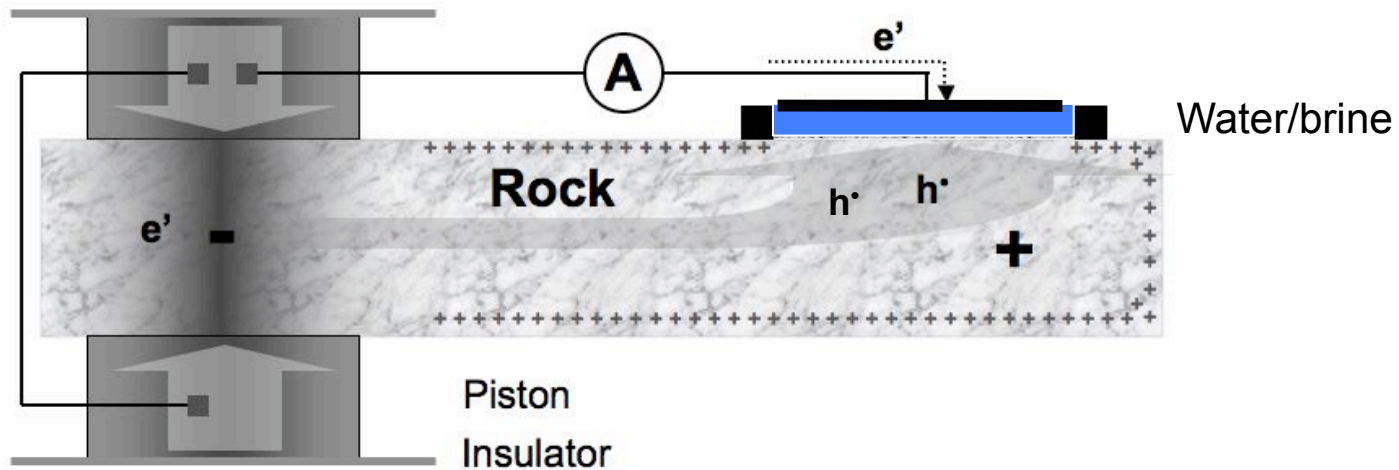
However,

- Nature does not run Cu wires.

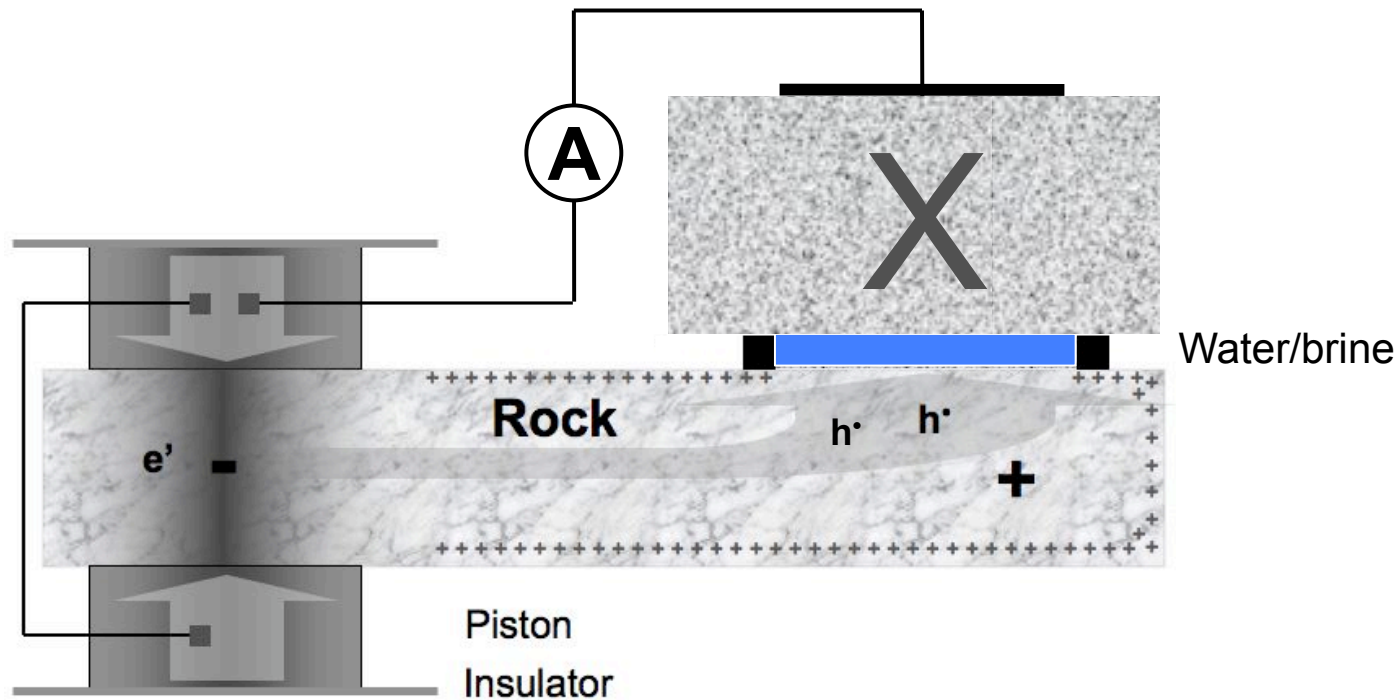
However,

- Nature provides other means to close the battery circuit.

What happens when positive holes flow into water?
The current continues to flow



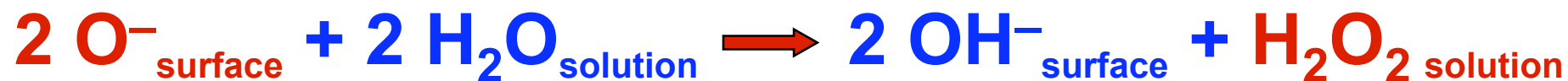
While positive holes flow into water, they cannot re-enter the rock indicating that something happens at the rock-water interface

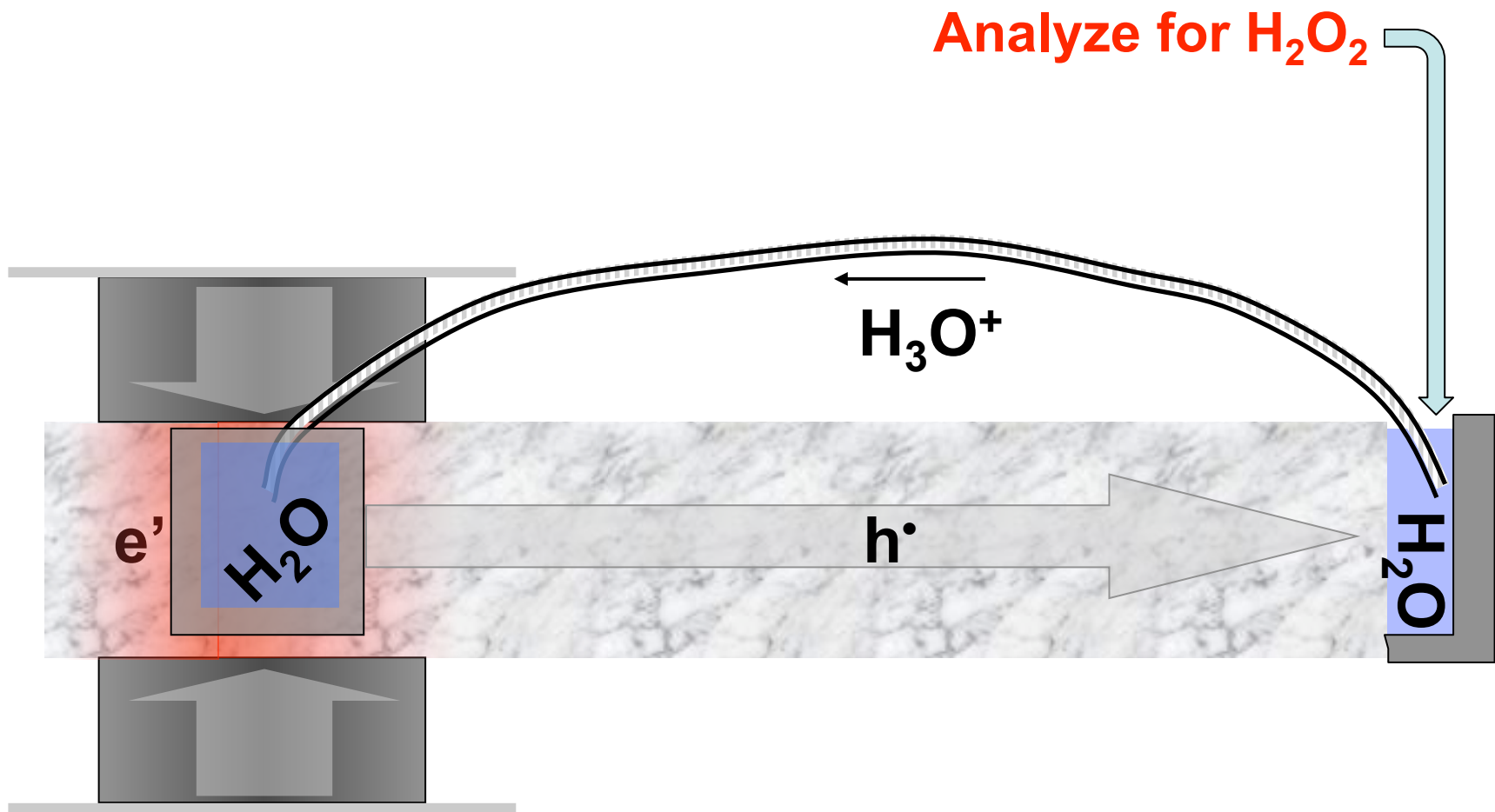


An h^\bullet is equivalent to an O^-

O^- is an oxygen radical, highly oxidizing.

Stoichiometrically oxidizes H_2O to H_2O_2 :





We built the world's first battery without any metal parts or wires

Positive hole charge carriers...

- allow us to look at alleged EQ precursors in a **new way**
- provide a **physical basis** for many types of reported pre-EQ signals
- provide a **causal link** between them

It is wonderful...

to be part of a meeting,

first of its kind in decades,

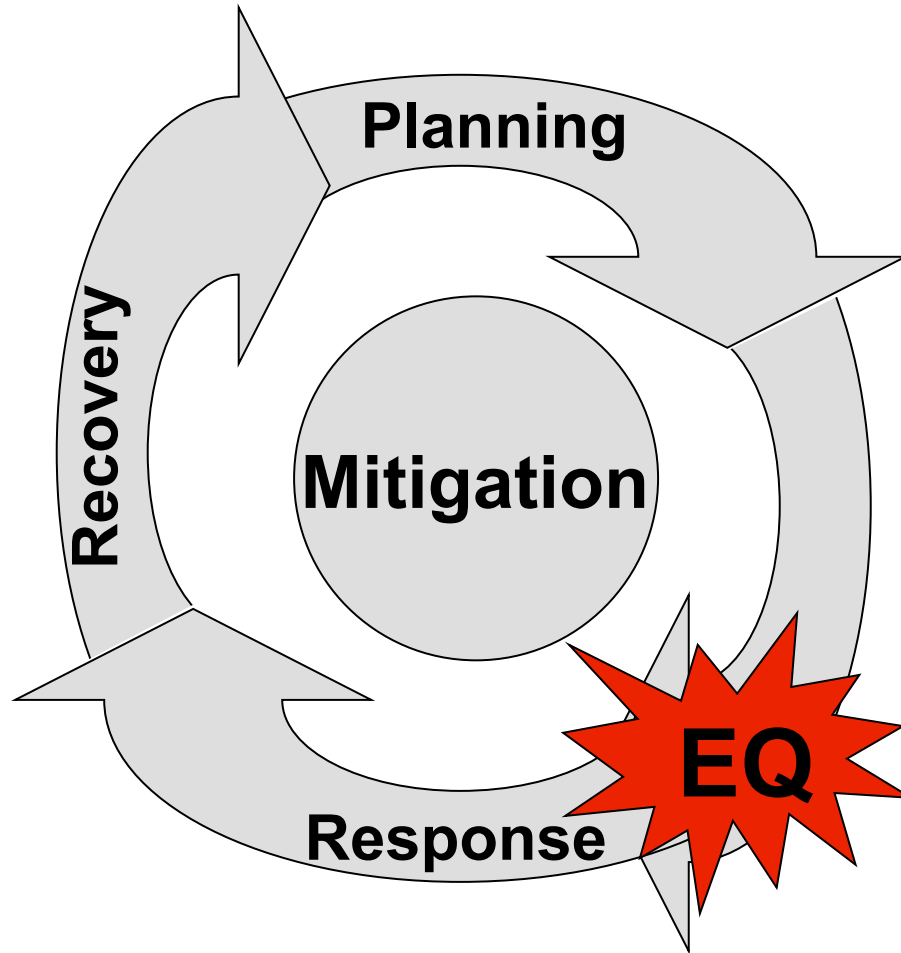
that brings together an interdisciplinary

community with interest and knowledge

about earthquakes

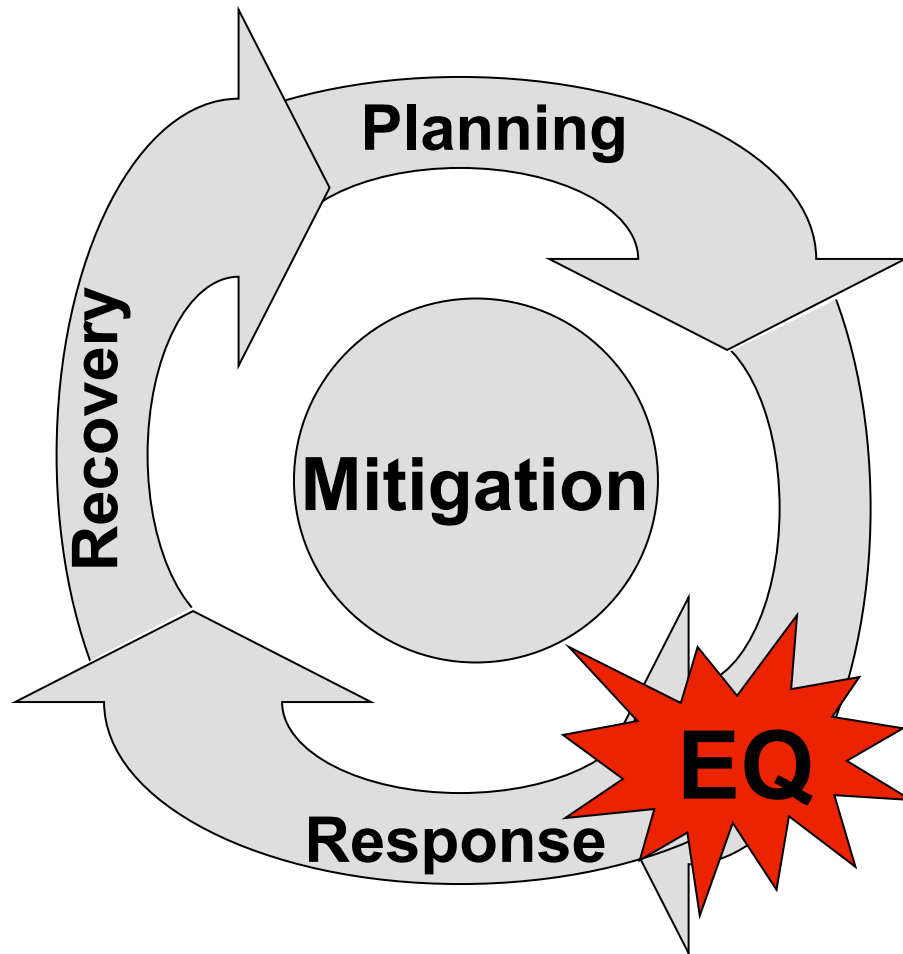
and earthquake precursors.

Current Disaster Management Cycle



Sit and wait

Future Disaster Management Cycle



... or monitor
for pre-EQ
signals

