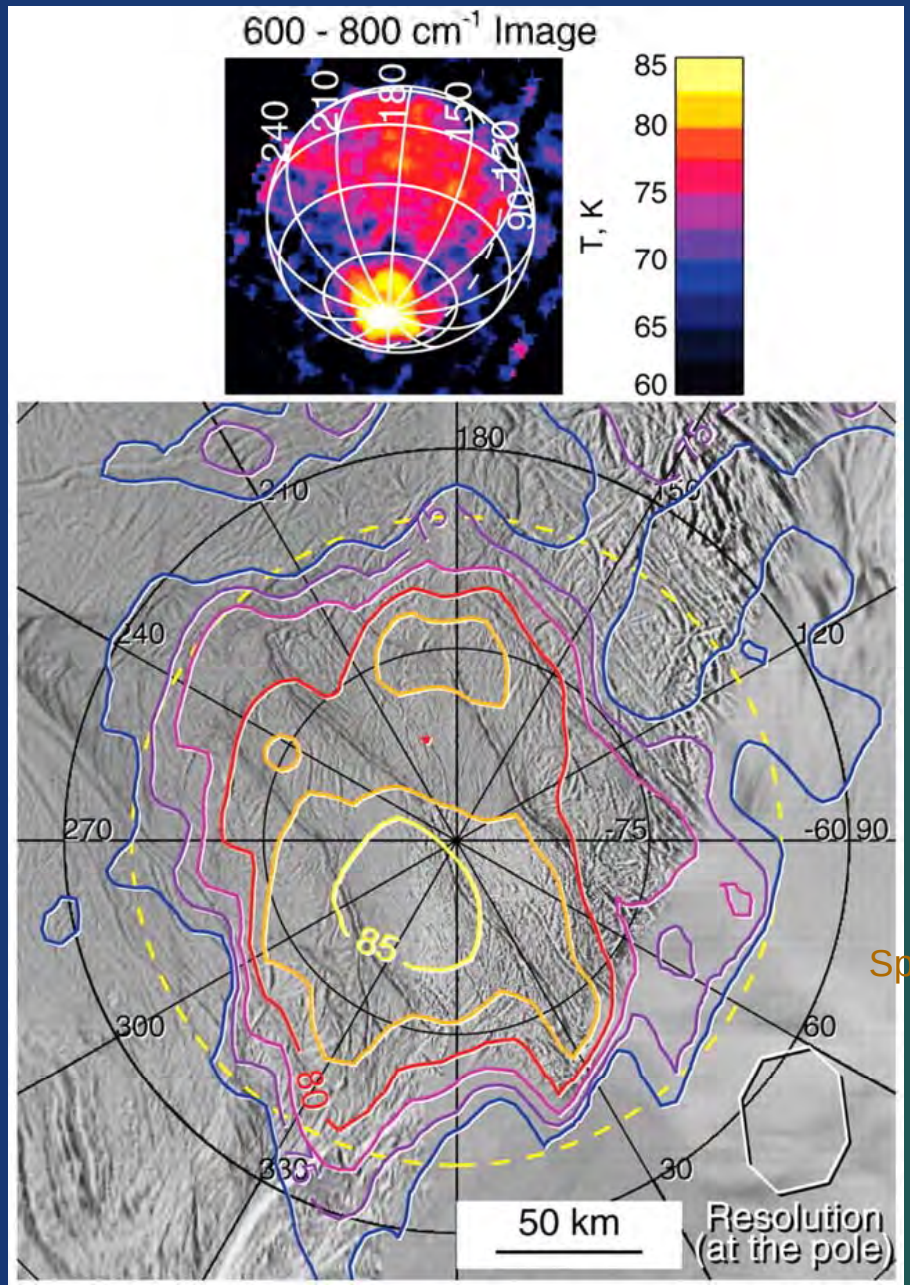
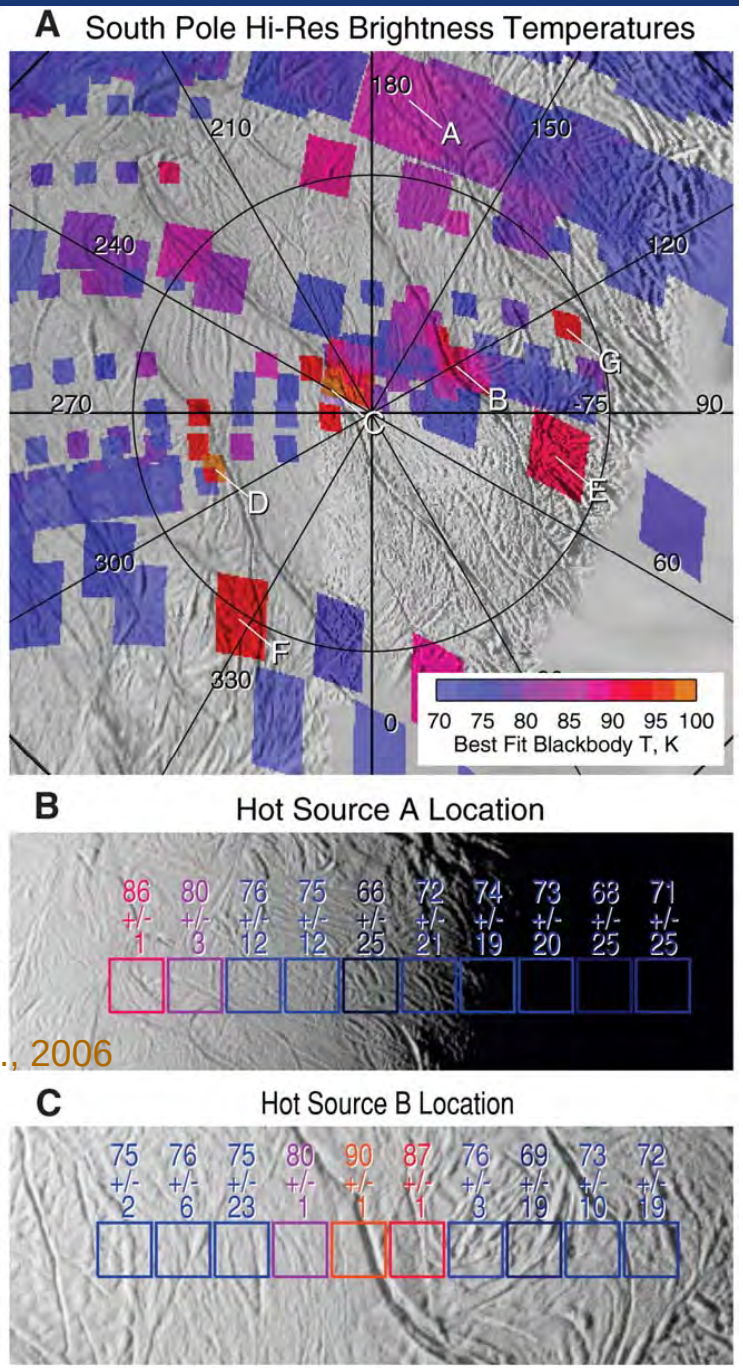
Enceladus

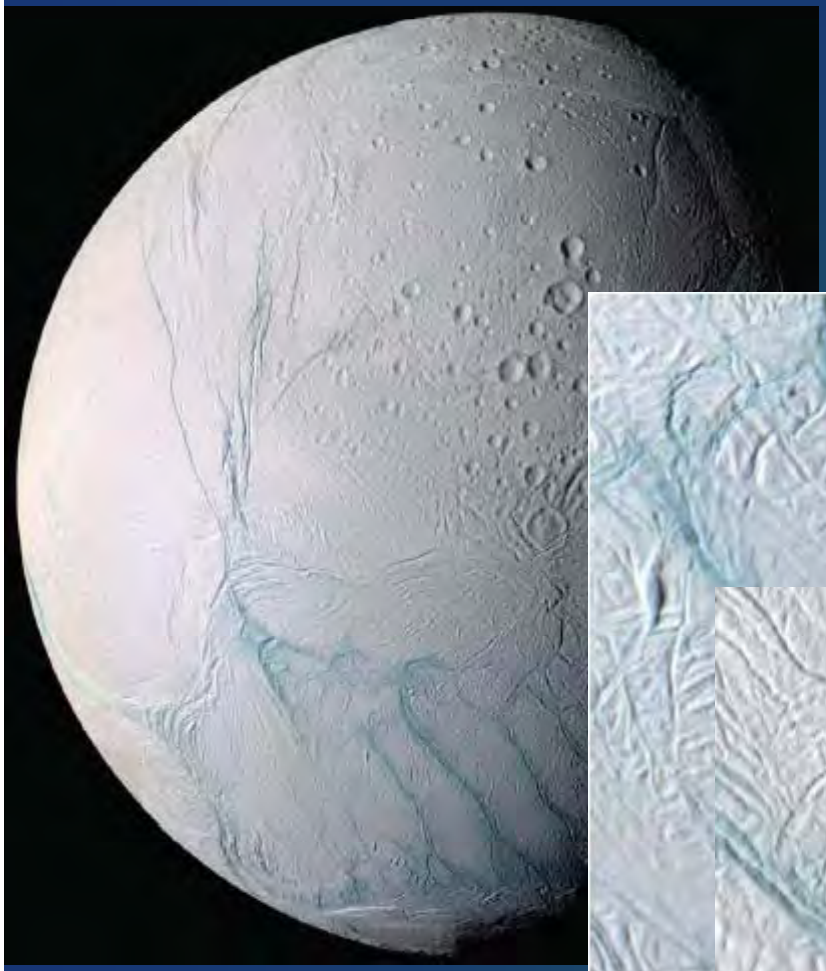
- *Hot-spot at the south pole*



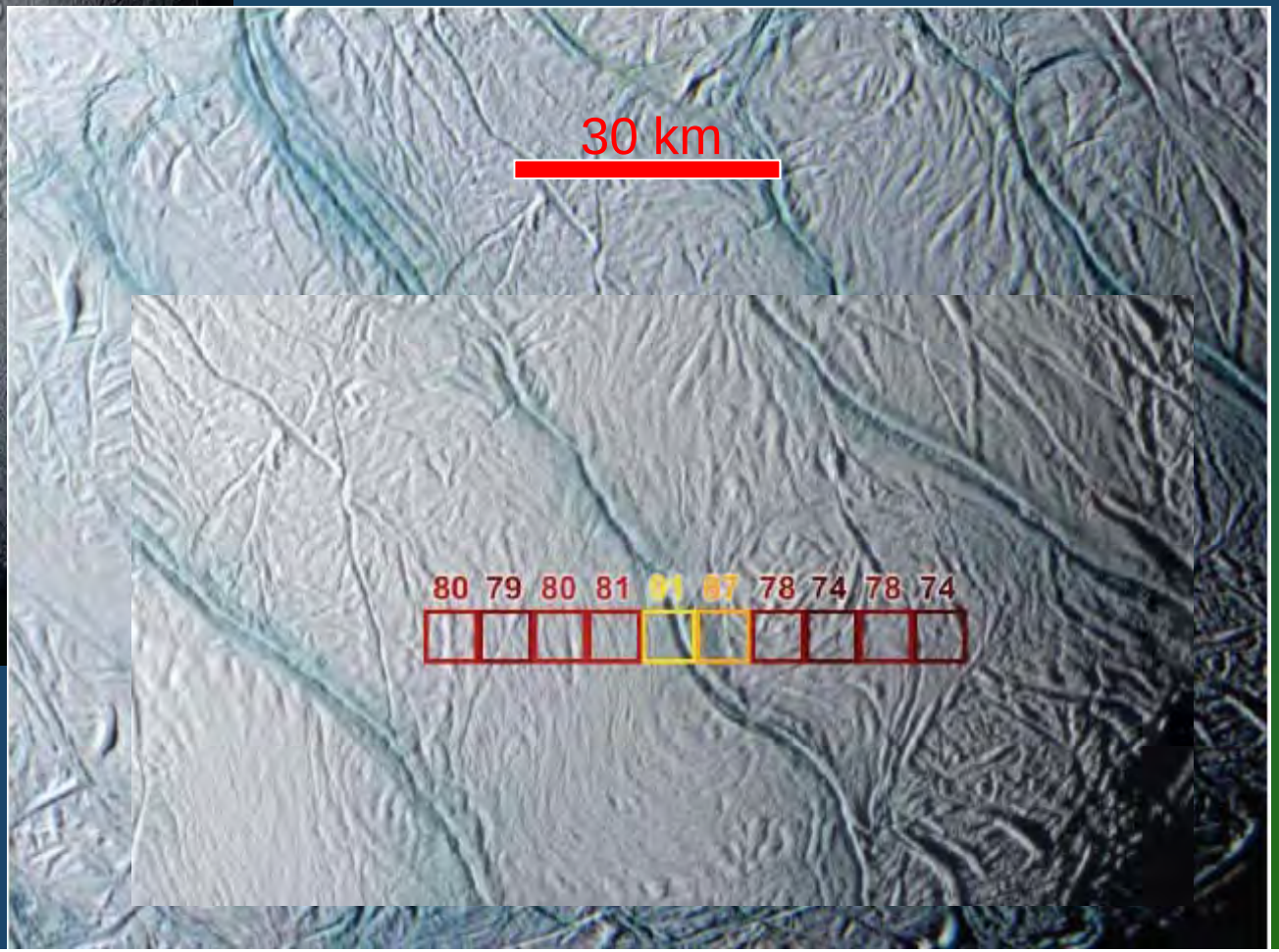


Spencer et al., 2006

“Tiger Stripe” Region



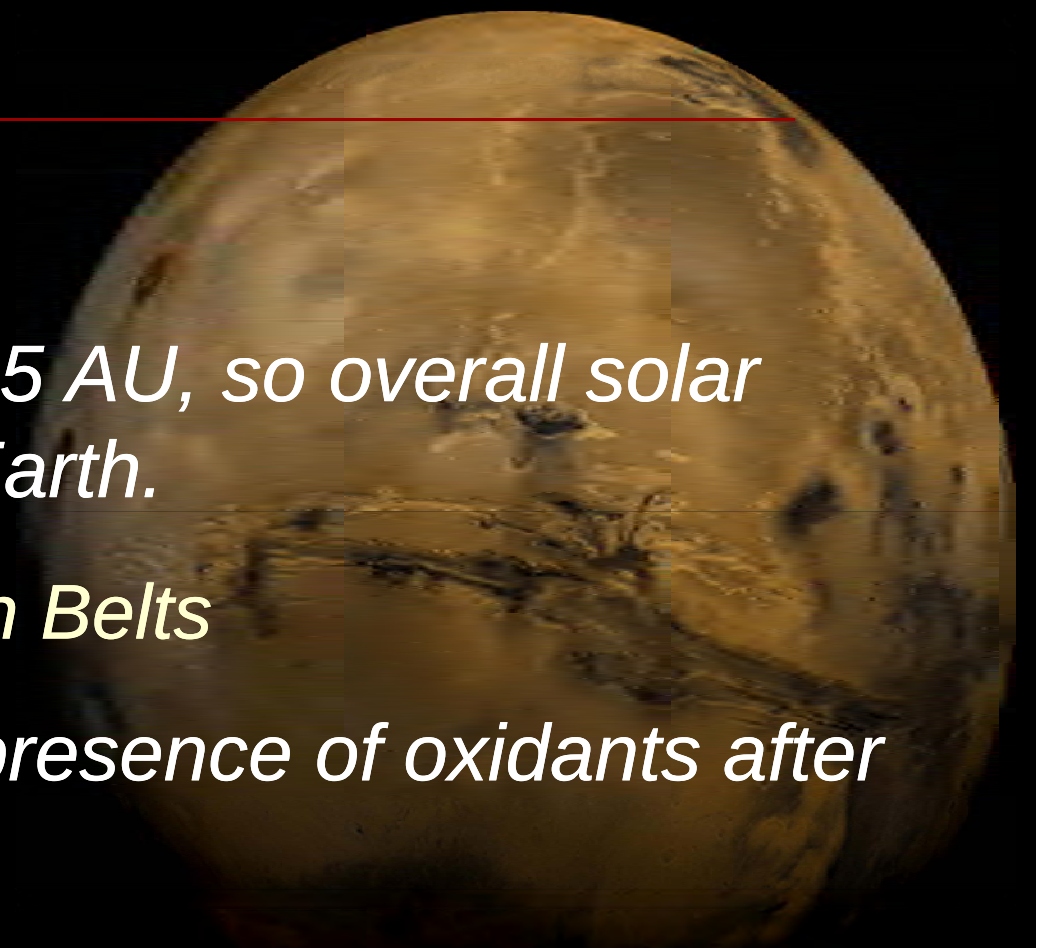
- *Correlates with water geyser venting to space*
- *No impact craters (young)*



Porco et al. 2006


Extremophiles and
Mars

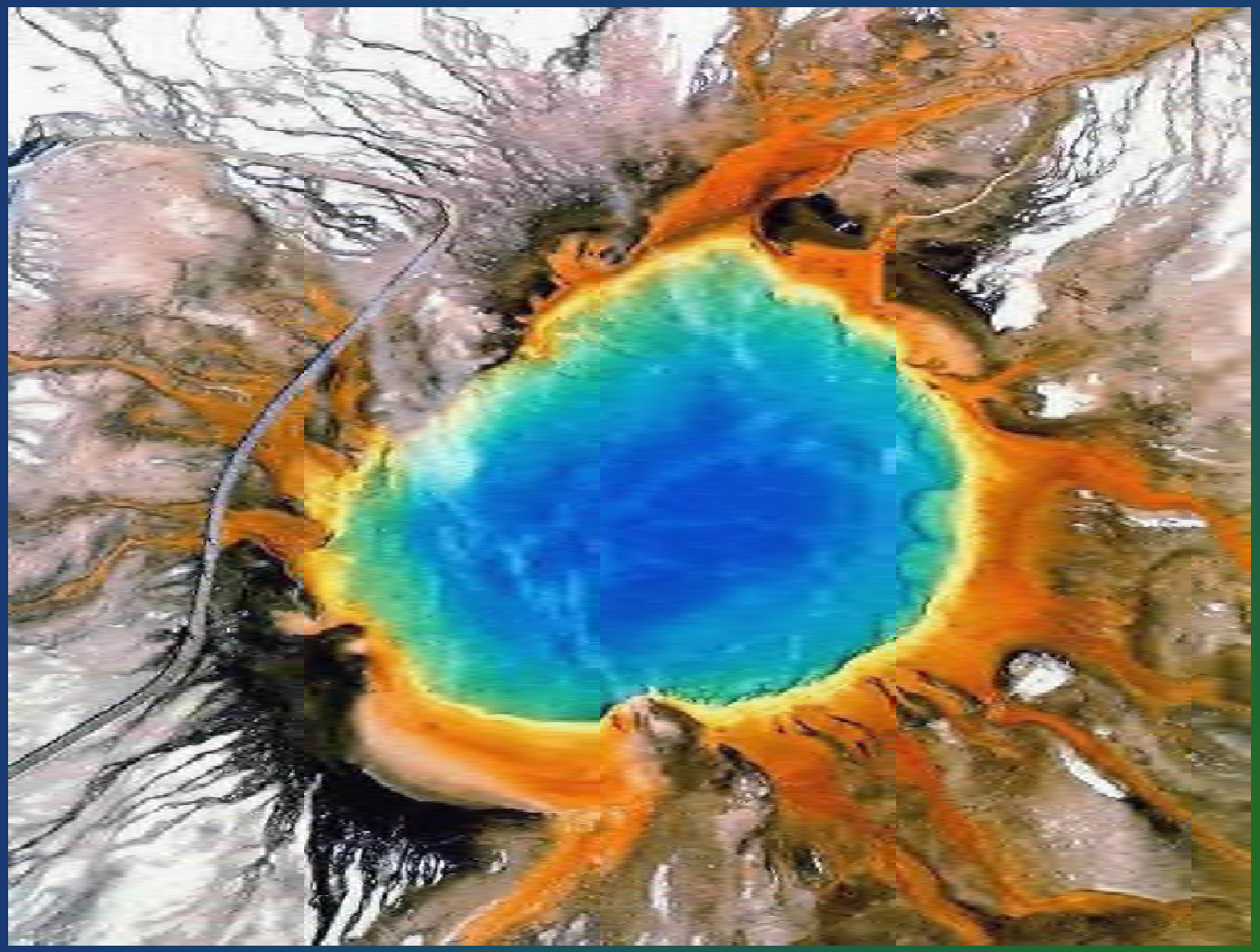
Mars as an extreme environment



- *Temperature: nippy.*
- *Radiation: Mars is 1.5 AU, so overall solar radiation is 43% of Earth.*
  - *But, no Van Allen Belts*
- *Oxidants: Realized presence of oxidants after Viking.*
- *Liquid water? Past, periodic, hydrothermal activity?*

Mars has many large volcanoes that were active throughout its history

What do you get when you combine heat and water in the crust?



Volcanic outgassing leads to sulfuric acid:

$$4SO_2 + 4H_2O = 3H_2SO_4 + H_2S$$

or

$$H_2S + 2O_2 = H_2SO_4$$

+

rocks

Sulfates on Mars

- *~8 wt% in soils globally*
- *Identified from orbit and* in situ *by the Mars Exploration Rovers*
- *Many probably formed in hydrothermal systems early in Mars' history.*

Martian sulfate salts in disturbed soil

Midway Geyser, Yellowstone

Sulfates and Biology

- *Early terrestrial biota relied upon chemical energy from disequilibria and not photosynthesis.*

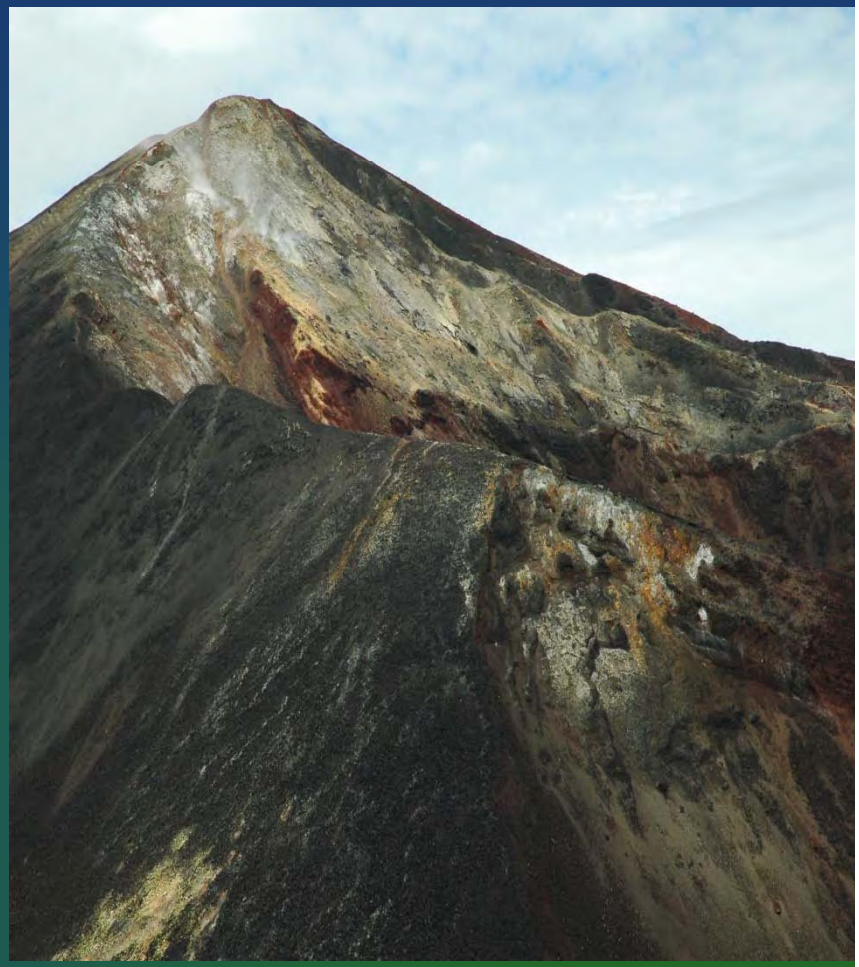
- *Redox of sulfur compounds can be energetically advantageous.*
  - *Sulfur metabolizers have been implicated in the origin of life on Earth.*

- *Sulfates can preserve organics and biosignatures.*

A good analog for acid-sulfate weathering: Cerro Negro (Black Mountain), Nicaragua

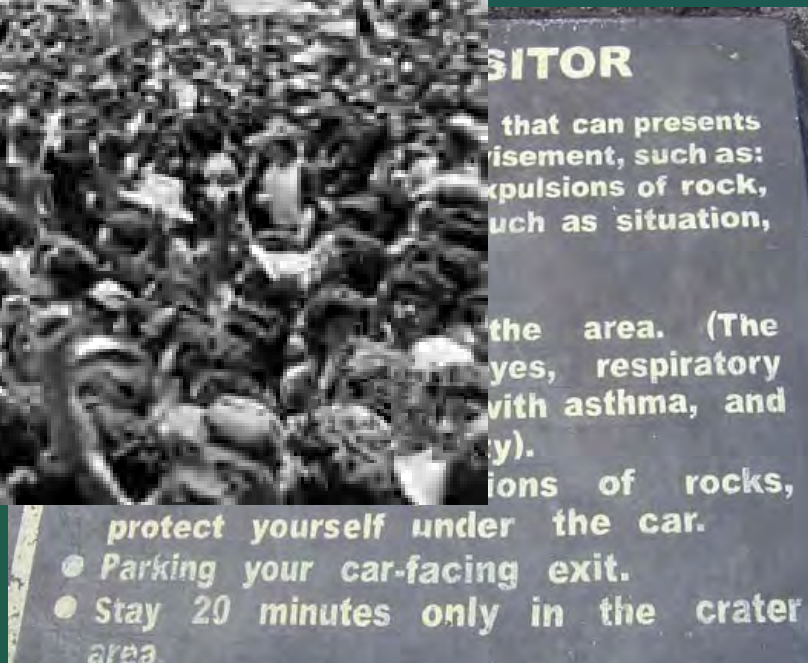
Cerro Negro, Nicaragua

- *One of the youngest volcanoes in the world.*
  - *Erupts about every 6 years.*
- *Fumaroles are belching out sulfur-rich steam.*
- *The chemistry of the altered rocks are like that of places on Mars.*



Is Nicaragua safe?

Sure, just follow these simple rules:



November 2008 Field Campaign

Why Nicaragua's Capital Is in Flames

By TIM ROGERS / MANAGUA Friday, Nov. 14, 2008

Riot police patrol a street in Managua. Clashes between supporters of Nicaragua's ruling Sandinist National Liberation Front, FSLN, and of the opposite Liberal Constitutionalist Party, exploded after the FSLN claimed victory Monday in Sunday's nationwide municipal elections.
Esteban Felix / AP

The last time rival political forces fought one another street by street for control of the Nicaraguan capital was three decades ago, in July 1979, at the culmination of the Sandinista insurrection that overthrew the Somoza dictatorship. This week, the streets of Managua were once again aflame amid the boom of mortar rounds, as the Sandinistas and their rivals battled for control — but it was the erstwhile revolutionary movement that now stands accused of being a dictatorship.

The prize, this time, is not control of the Nicaraguan state, but simply the mayorships in 146 municipalities, which were up for election on November 9. But allegations of massive vote fraud and conflicting claims of victory have set off several days of violence between

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- Is This Detroit's Last Winter?
- A Pirate Ransom Deal: Who Gets the Money?
- The Auto Hearings, Part Deux
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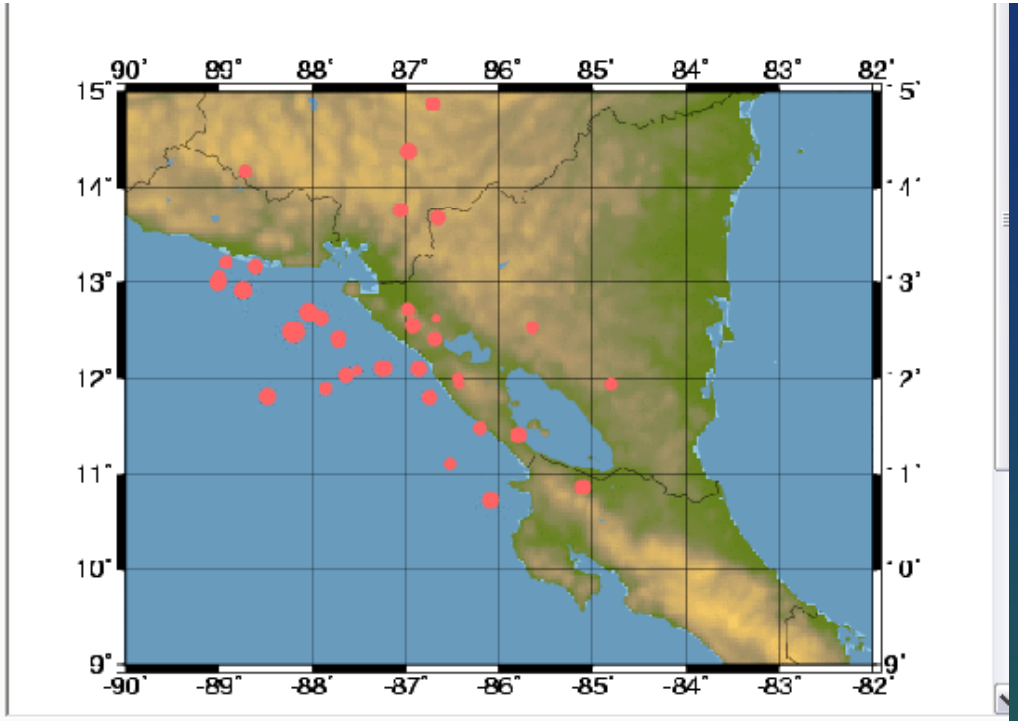
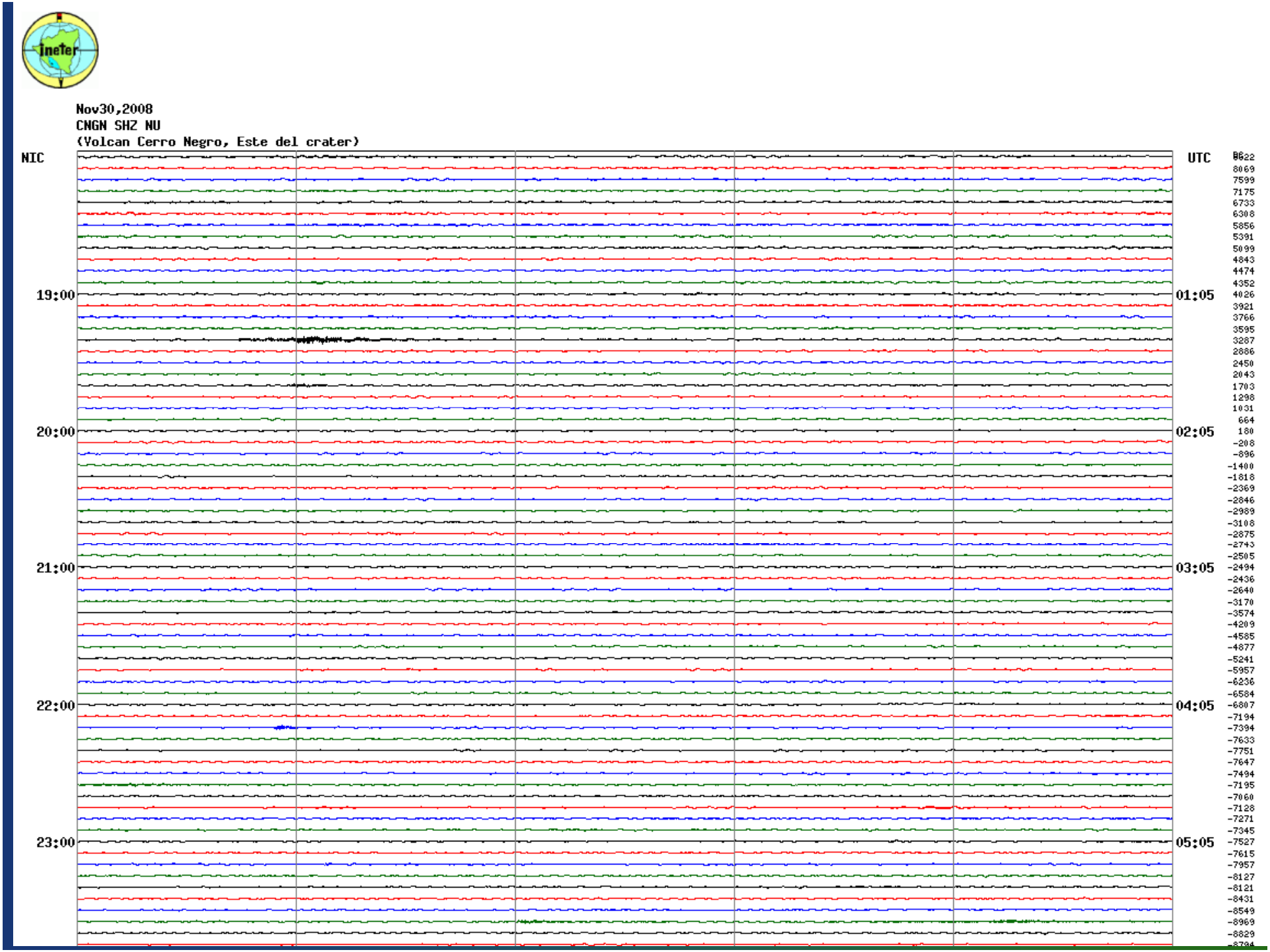
4. The Auto Bailout May Wind Up on Obama's Plate

But there is more than political unrest these days: earthquakes, eruptions, mudslides, etc.



Selecciona un evento de la lista de abajo haciendo click en él para ver su ubicación en un mapa interactivo.

Fecha	Hora Local (UTC -6)	Latitud	Longitud	Prof. (Km)	Magnitud (Richter)	Región
08/12/04	10:30:38	12.01N	86.44W	57.5	2.5ML	Oeste-Suroeste de Managua
08/12/04	08:38:17	11.81N	88.48W	28.0	3.7ML	Oceano Pacífico de Nicaragua
08/12/04	06:38:16	14.17N	88.72W	23.1	2.9ML	Honduras
08/12/04	01:46:36	12.10N	86.86W	93.7	3.5ML	Frente a Puerto Sandino
08/12/03	23:00:52	11.80N	86.74W	65.5	3.3ML	Frente a Masachapa
08/12/03	22:42:23	12.42N	87.72W	67.9	3.7ML	Frente al Cosigüina
08/12/03	20:39:58	14.87N	86.71W	101.2	3.1ML	Honduras
08/12/03	11:49:15	11.94N	86.43W	30.1	2.3ML	Oeste-Suroeste de Managua
08/12/03	05:19:49	12.63N	86.68W	1.0	2.0ML	Nicaragua
08/12/03	04:28:46	12.42N	86.69W	194.2	3.1ML	Cerca del Volcan Cerro Negro
08/12/02	21:12:02	12.92N	88.74W	67.7	3.9ML	Frente a El Salvador


Nov30,2008
CNGN SHZ NU
(Volcan Cerro Negro, Este del crater)
NIC
UTC
19:00
01:05
20:00
02:05
21:00
03:05
22:00
04:05
23:00
05:05

12:00
13:00
14:00
15:00
16:00
17:00

19:05
20:05
21:05
22:05
23:05

Dec. 4 , San Cristobal Volcano; 40 km north

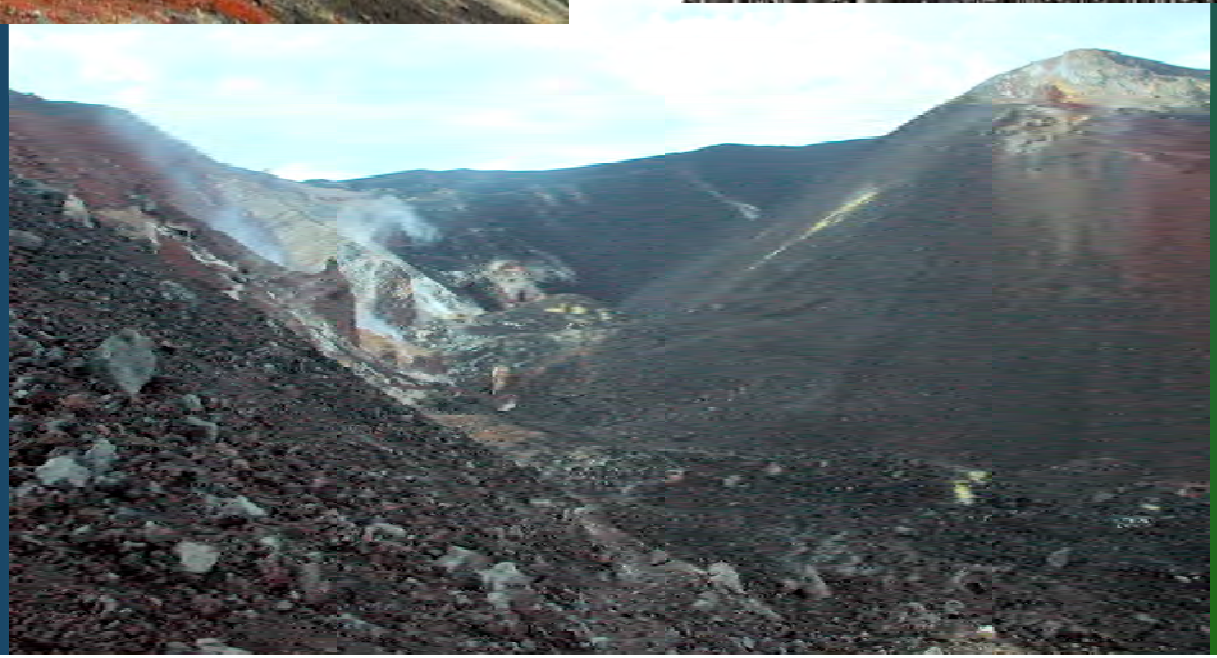
00 01 02 03 04 05

TIME (MINUTES)

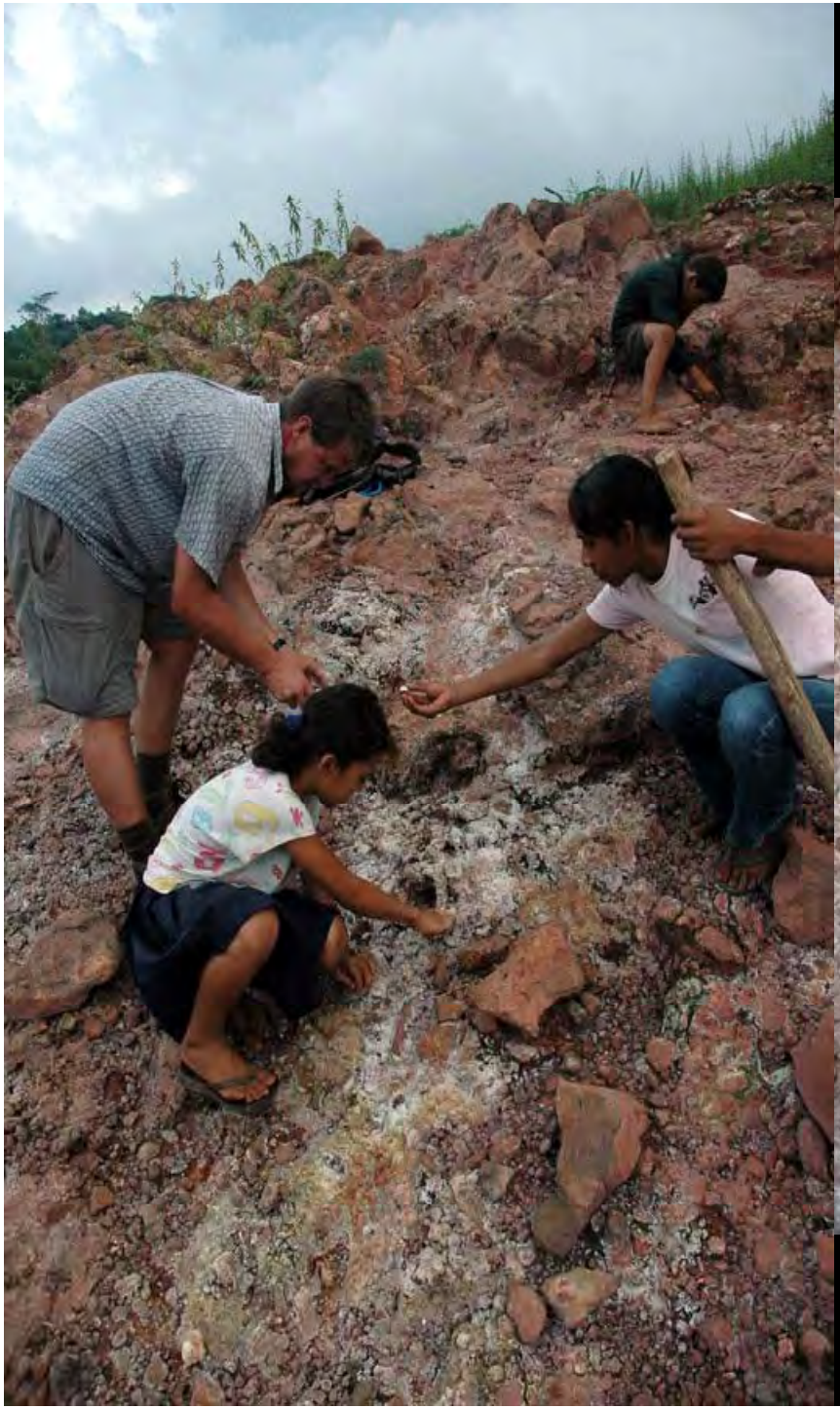
Each Vertical Division = 50.00 microvolts

Traces clipped at plus/minus 20 vertical divisions

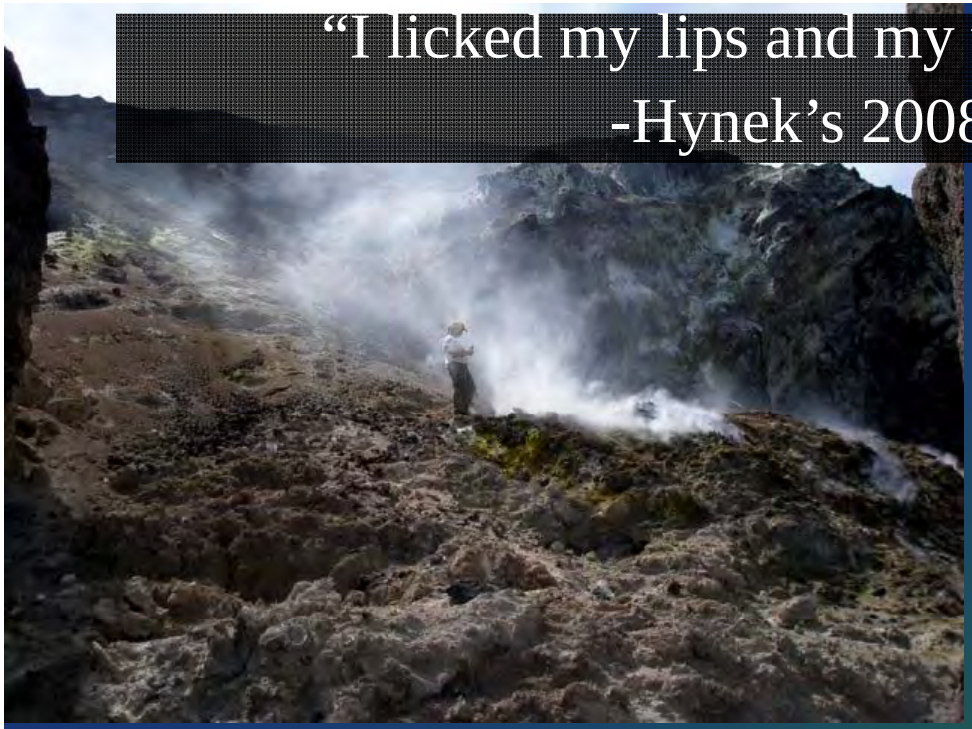
Cerro Negro

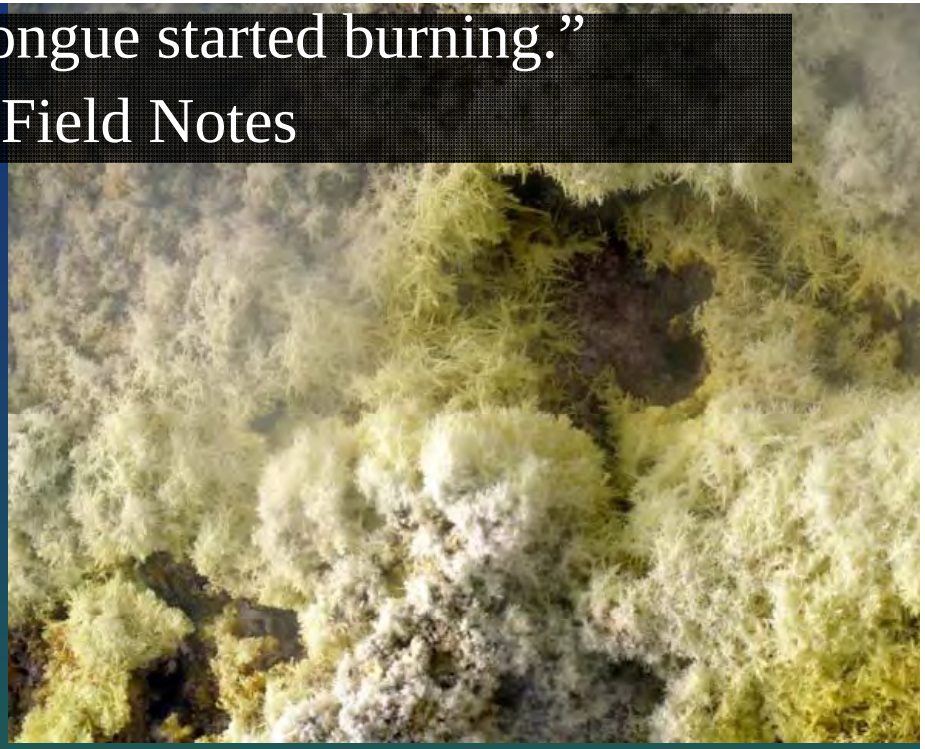


Inside the crater

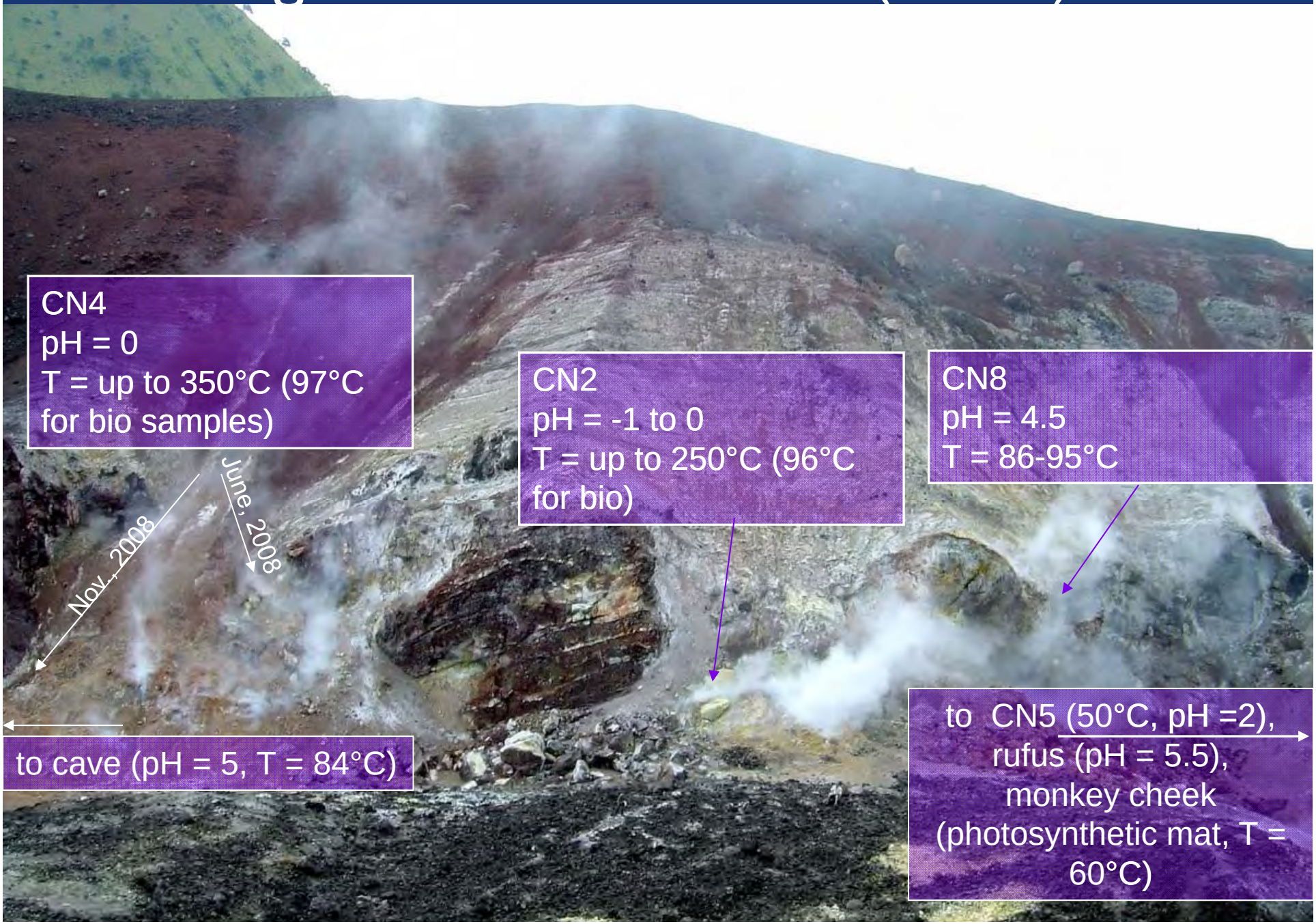


“I licked my lips and my tongue started burning.”
-Hynek’s 2008 Field Notes

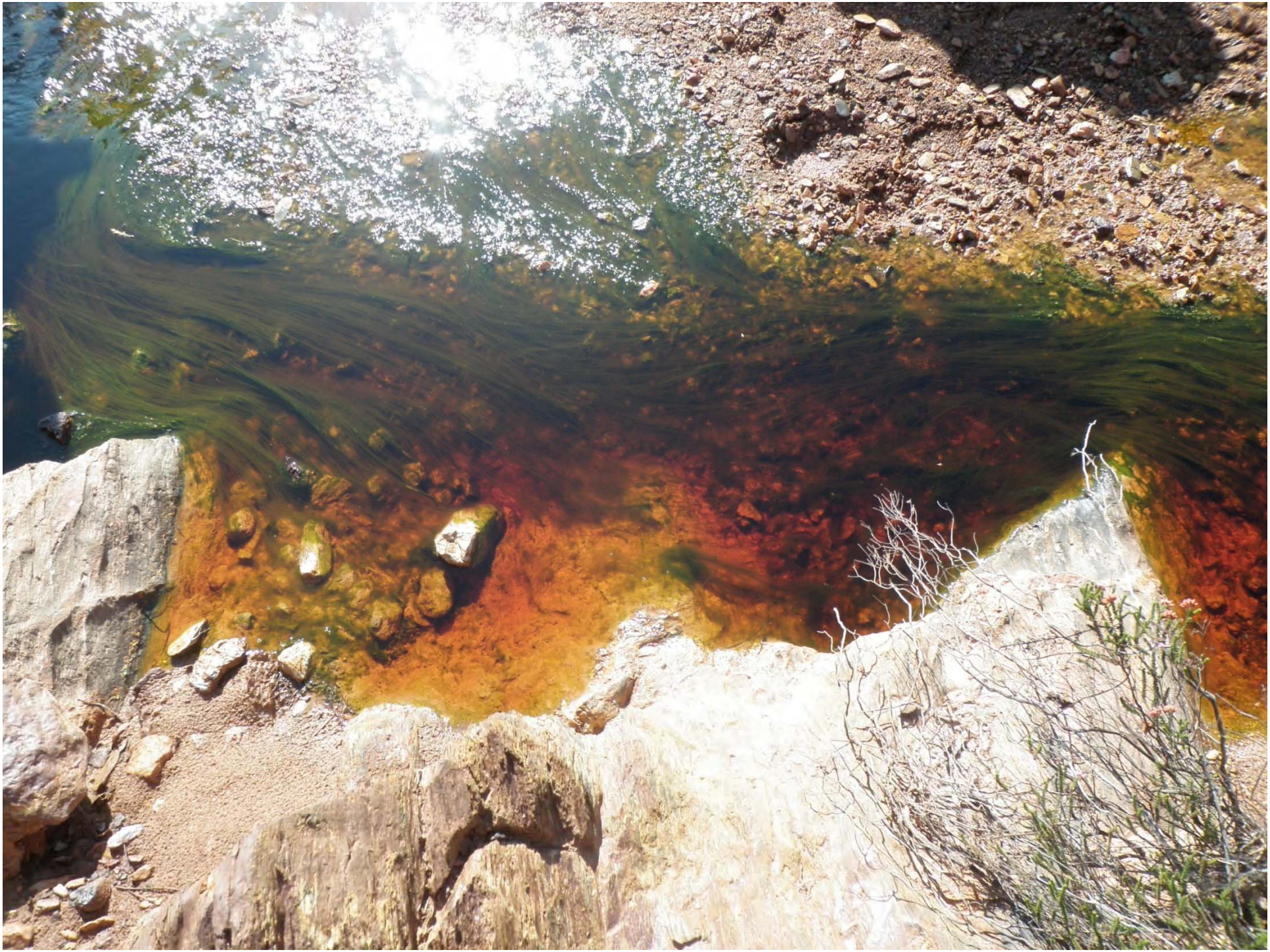




Looking at 1992 crater wall (south)



On to Rio Tinto, Spain: Another Mars analog




Hawaii, Dec, 2011

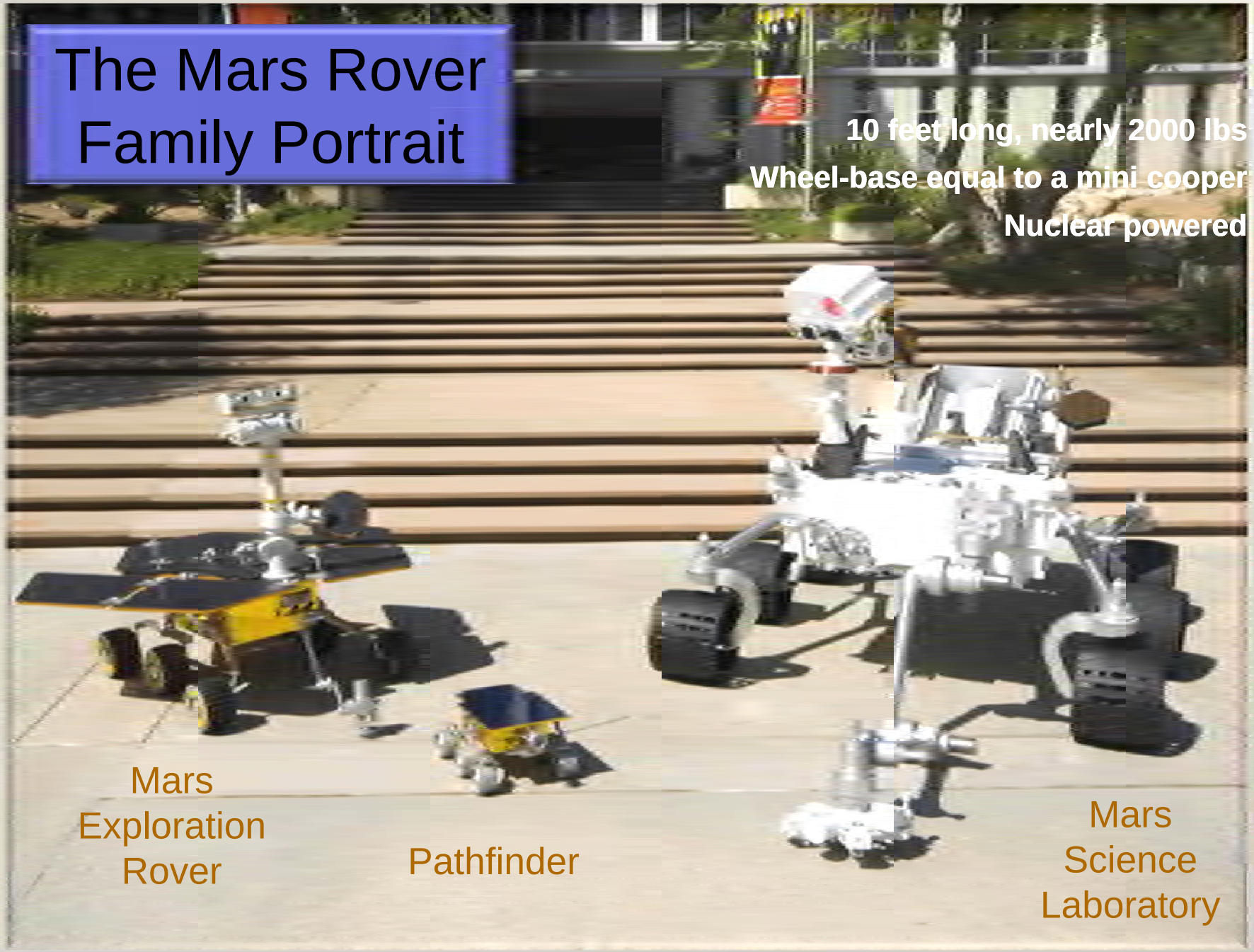

CAUTION
X-RAY PRODUCED WHEN
ENERGIZED
inXitu

2011 Mars Science Laboratory

Launch: after Nov. 24, 2011 on an Atlas V rocket
Land: Aug., 2012

3 Earth years of planned operations while traveling at least 20 km (12 miles).

The Mars Rover Family Portrait



2011 MSL Key Goals

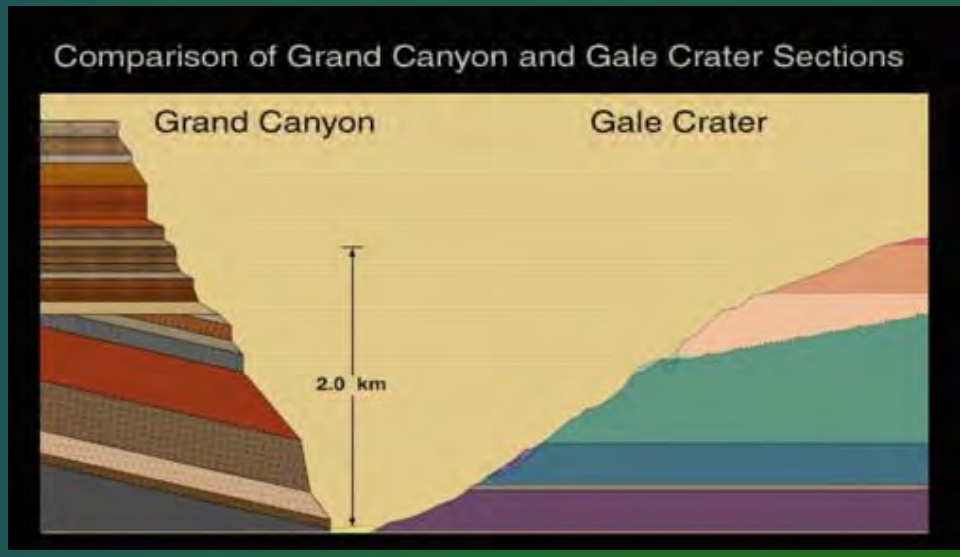
- *Characterize a site that:*
  - *was a habitable environment.*
    - *What does this mean?*
  - *is likely to have preserved biosignatures.*
  - *can be related to the "Big Picture".*

- 40 distinct rock layers are exposed, spanning 2 billion years of geologic history!
- The rocks tell the story of times of volcanic eruptions and mountain building, shallow seas and coral reefs, tidal marshes, enormous deserts, beaches, and ancient lakes.
- Walking from the Colorado River up to the rim, one can study what the local environment was like for nearly half of the history of the Earth!

We plan to apply the same principles at Gale Crater to assess the geologic history of the sediments.

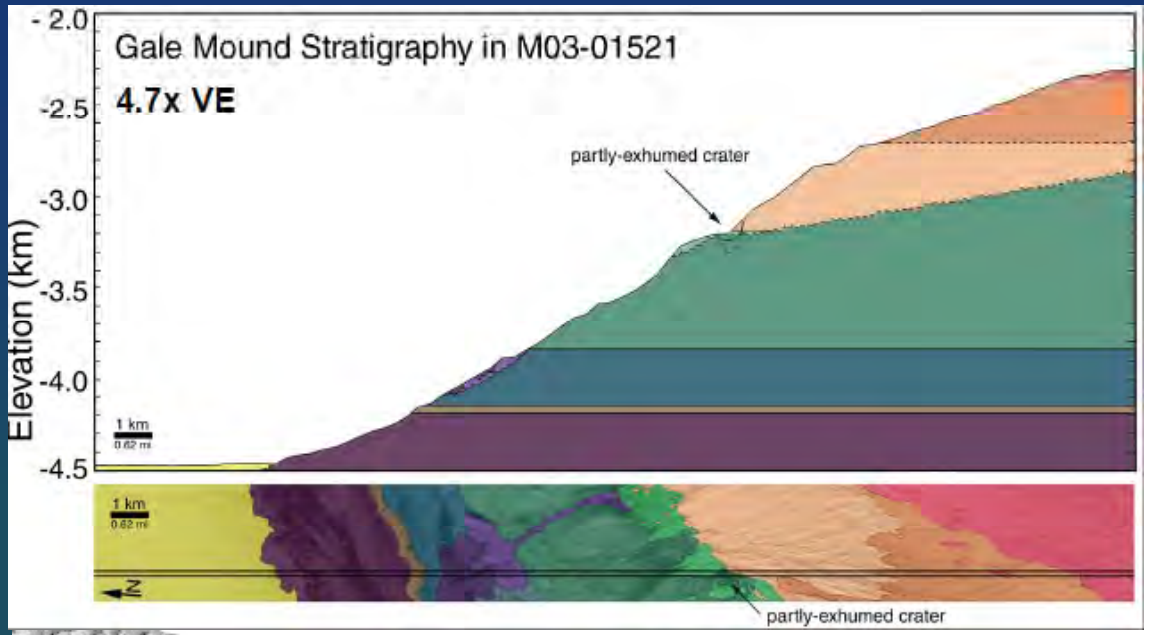
- A traverse up the central mound will reveal the depositional environments, the amount, duration, and chemistry of the water and address habitability through time

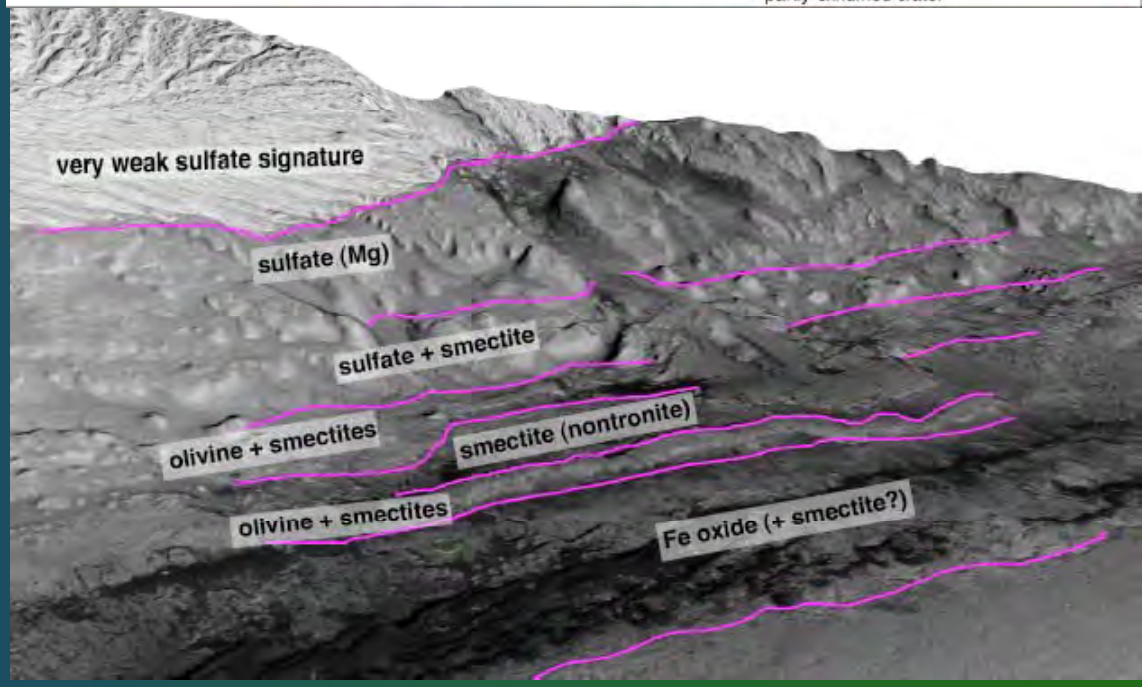
The Grand Canyon



Gale Crater

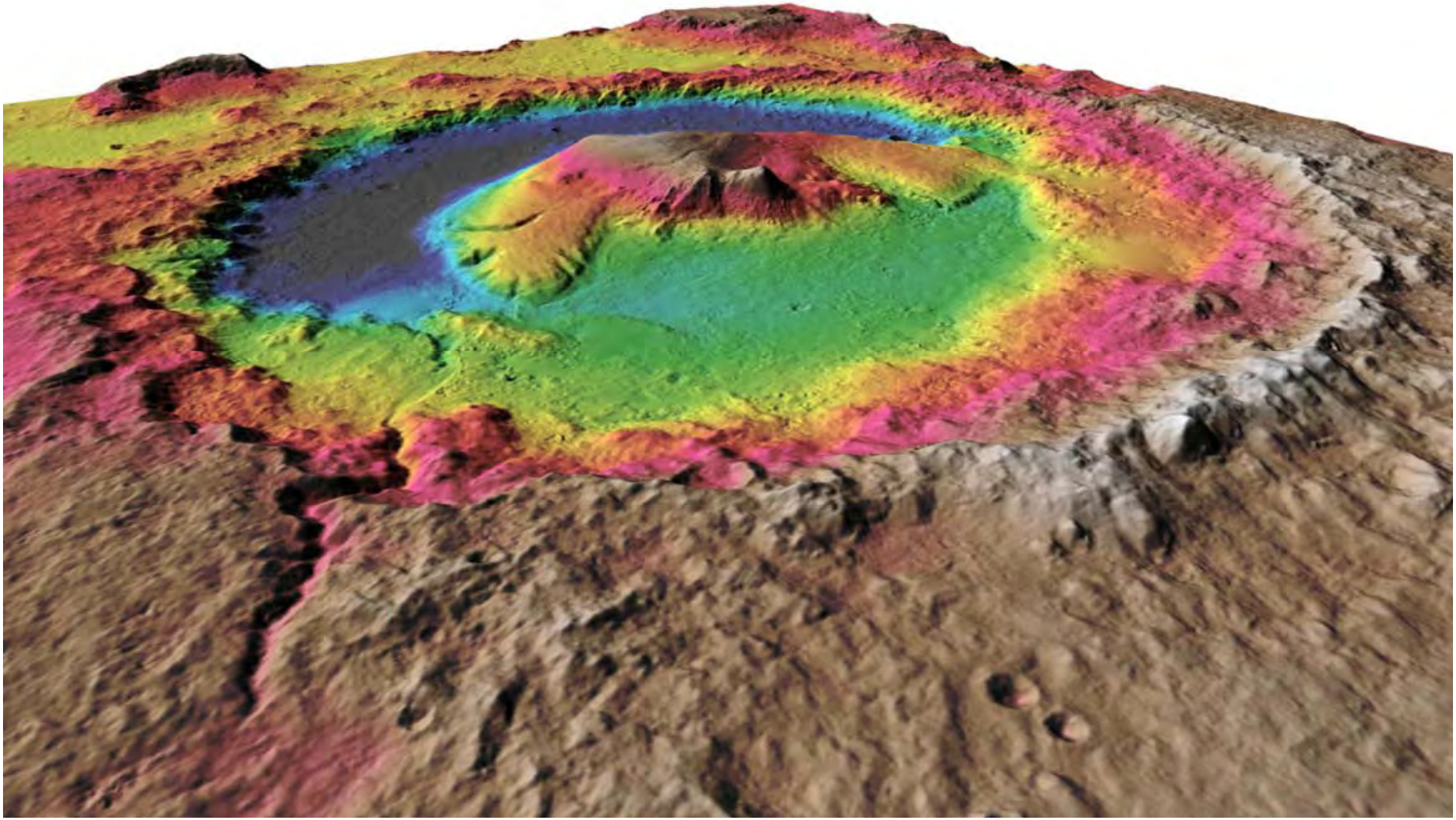
- High diversity of geologic materials with different compositions and depositional conditions
- Stratigraphy records multiple early Mars environments in sequential order
- The findings at Gale Crater will provide insights into global Martian processes: climate and atmosphere, geologic processes and the role of water.





Gale Crater provides:

1) A long history of deposition by numerous processes.
2) A significant history of water in the crater.
3) A variable chemistry and mineralogy.



Summing Up Habitability

- *Volcanoes like Cerro Negro (and similar enviros on Mars) present many challenges for biology*
  - *low pH, high temp, high sulfur, limited water, high salinity, limited nutrients, and short timescale.*
  - *Certainly organisms can survive, but it's tough.*

- *Still, Mars had all the necessary materials for terrestrial life to survive: water, biogenic elements, & energy sources.*

Conclusions

- *Life has evolved in extreme environments, many of which have only recently been uncovered.*
- *The ancient Earth was a different place. Extreme for us, but in some ways more benign.*
- *The study of extreme environments on Earth informs the search for habitats for life on Mars and beyond.*