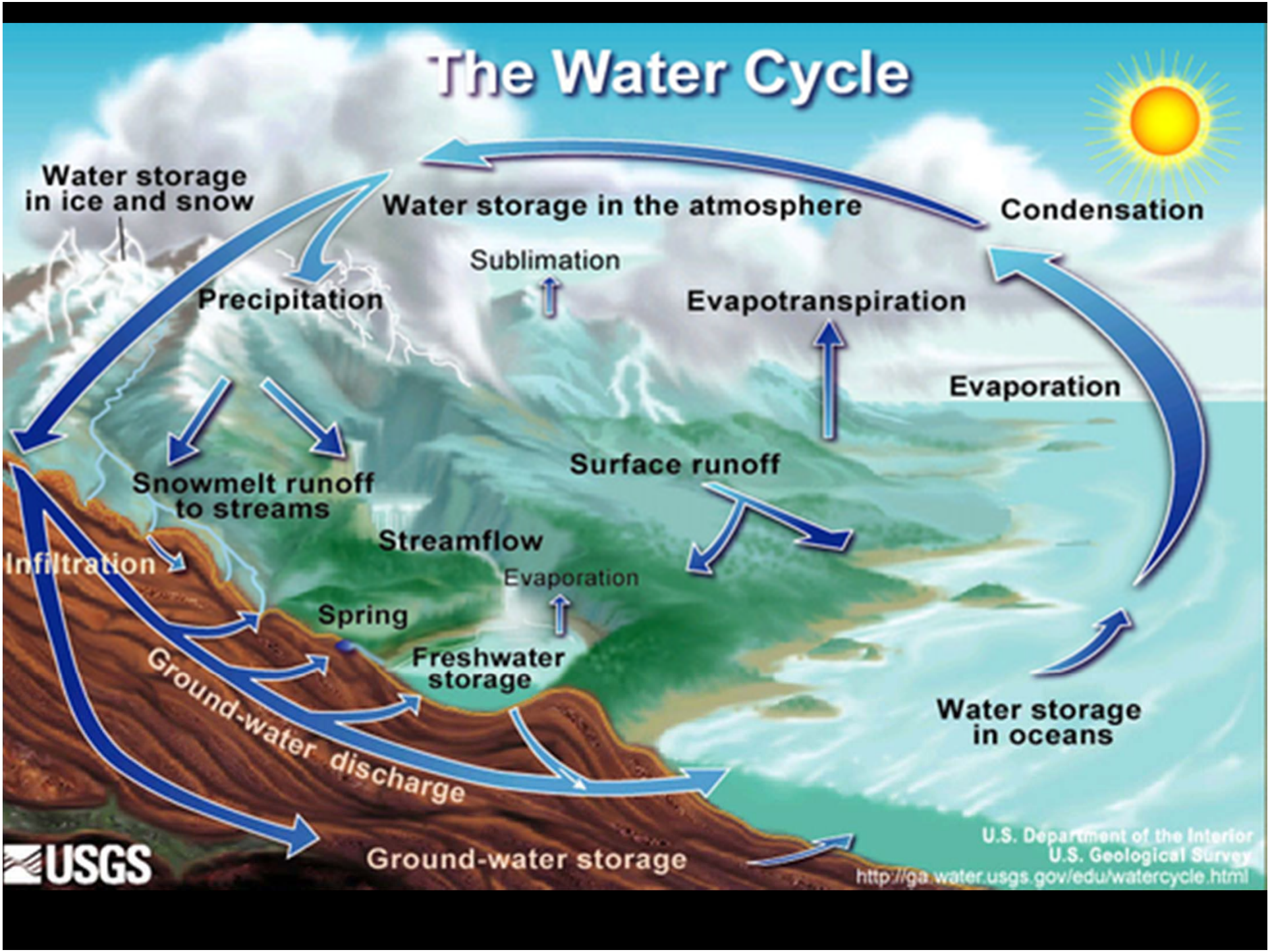
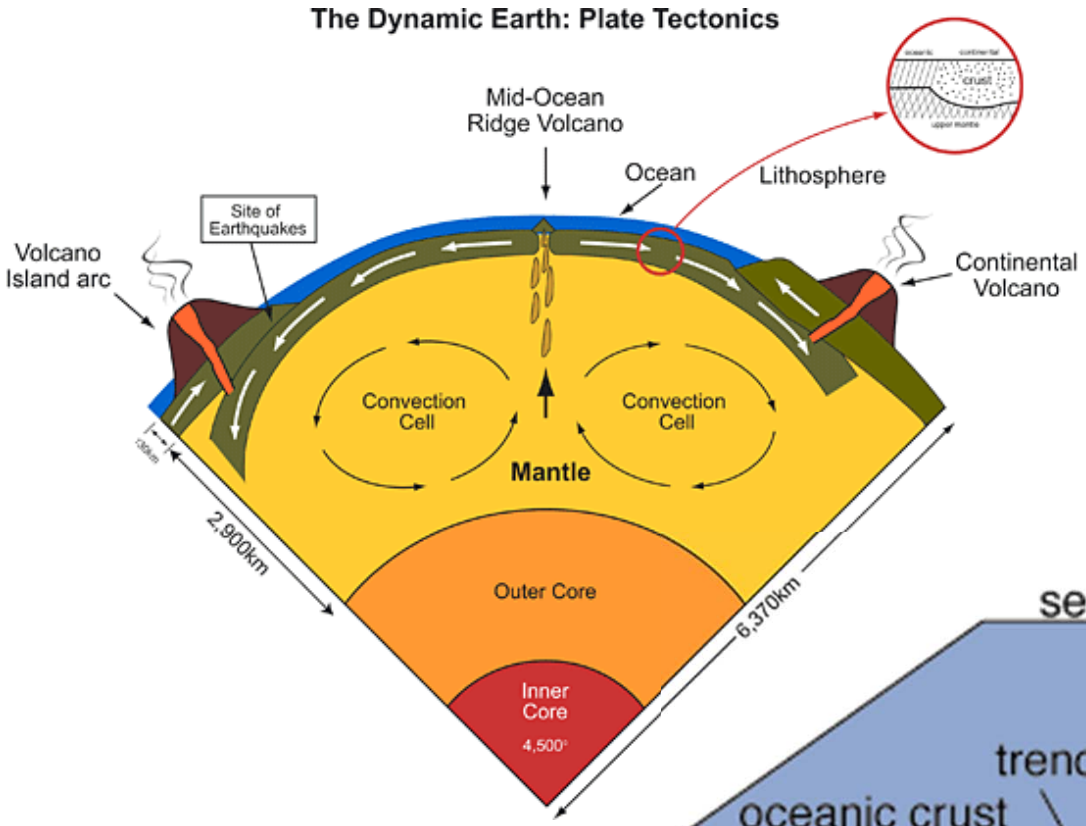
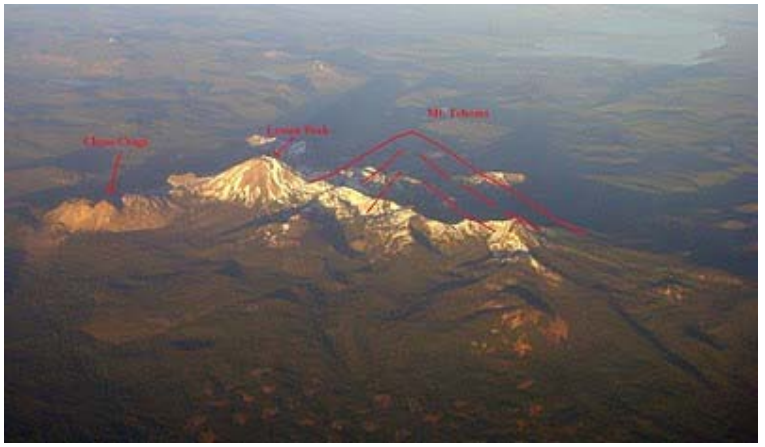
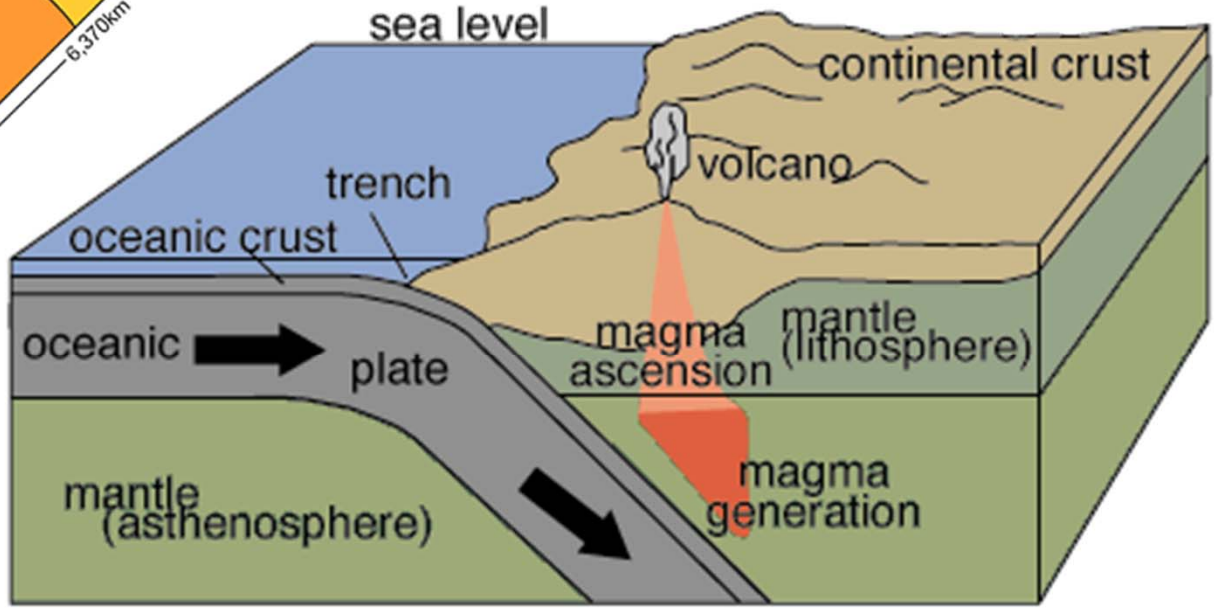
Lassen Volcanic National Park – Hydrothermal Habitats for Microbial Life

David Des Marais
Ames Research Center
NASA


The Water Cycle
Water storage in ice and snow
Water storage in the atmosphere
Condensation
Sublimation
Precipitation
Evapotranspiration
Evaporation
Surface runoff
Snowmelt runoff to streams
Streamflow
Infiltration
Evaporation
Spring
Freshwater storage
Ground-water discharge
Water storage in oceans
Ground-water storage
USGS
U.S. Department of the Interior
U.S. Geological Survey
http://ga.water.usgs.gov/edu/watercycle.html

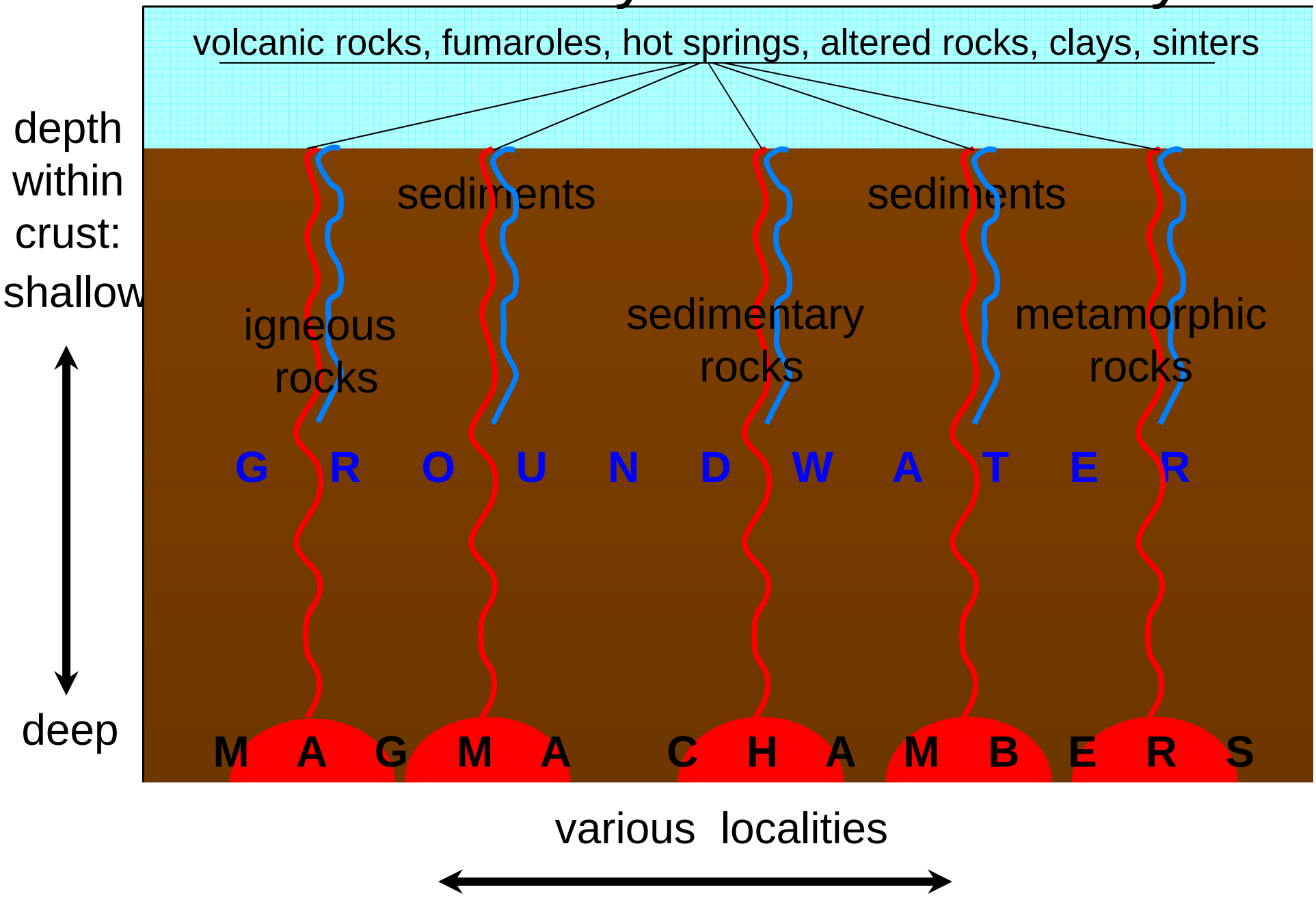


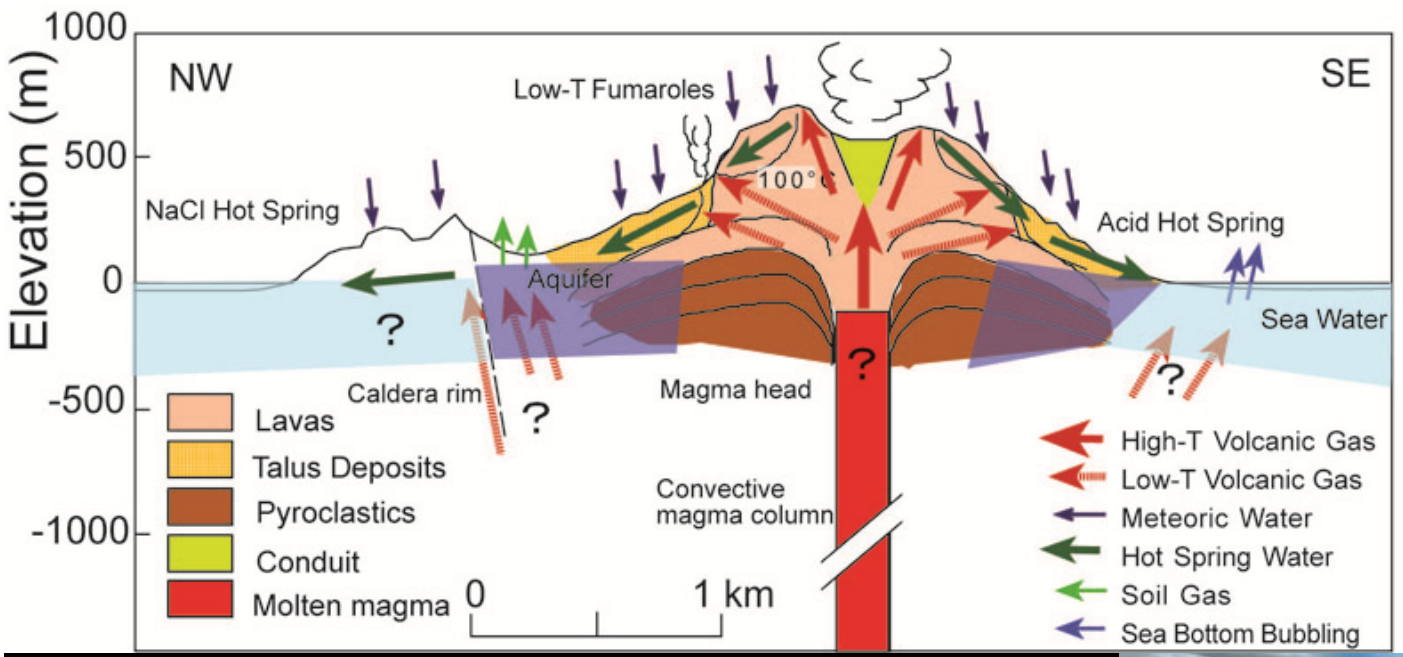


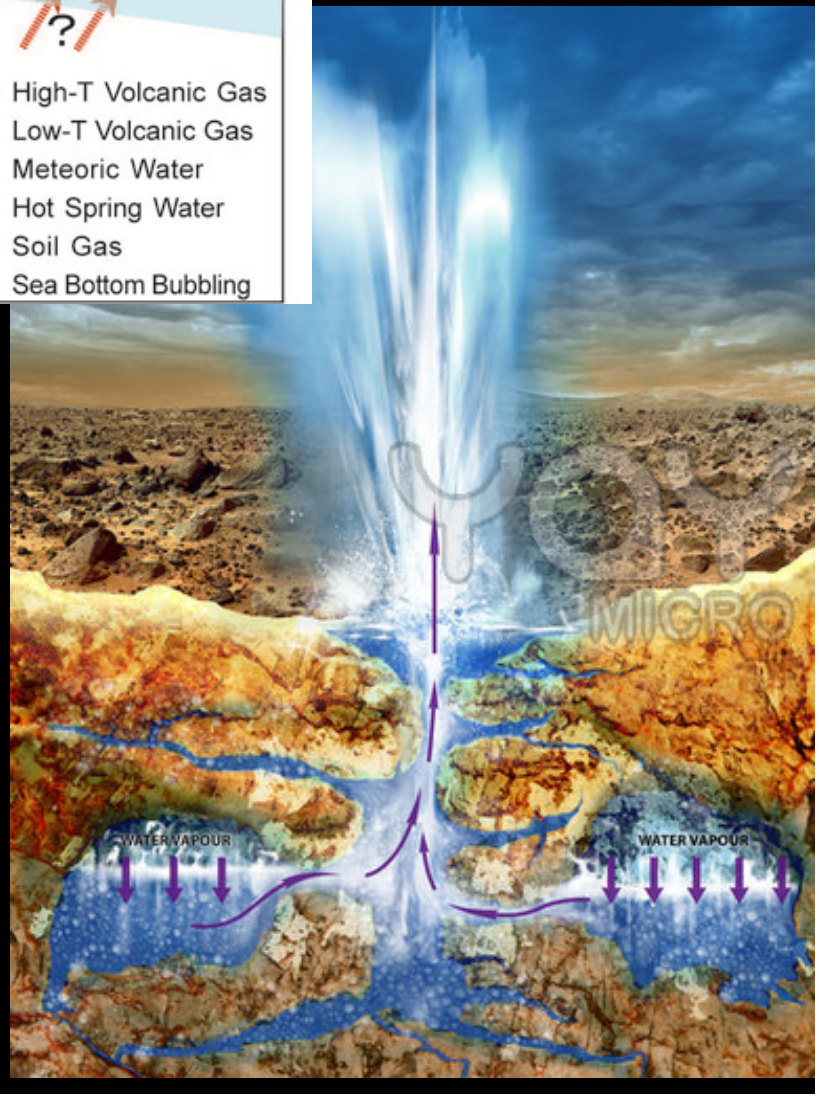


Magma is generated at subduction zones where dense oceanic plates are pushed under lighter continental plates.

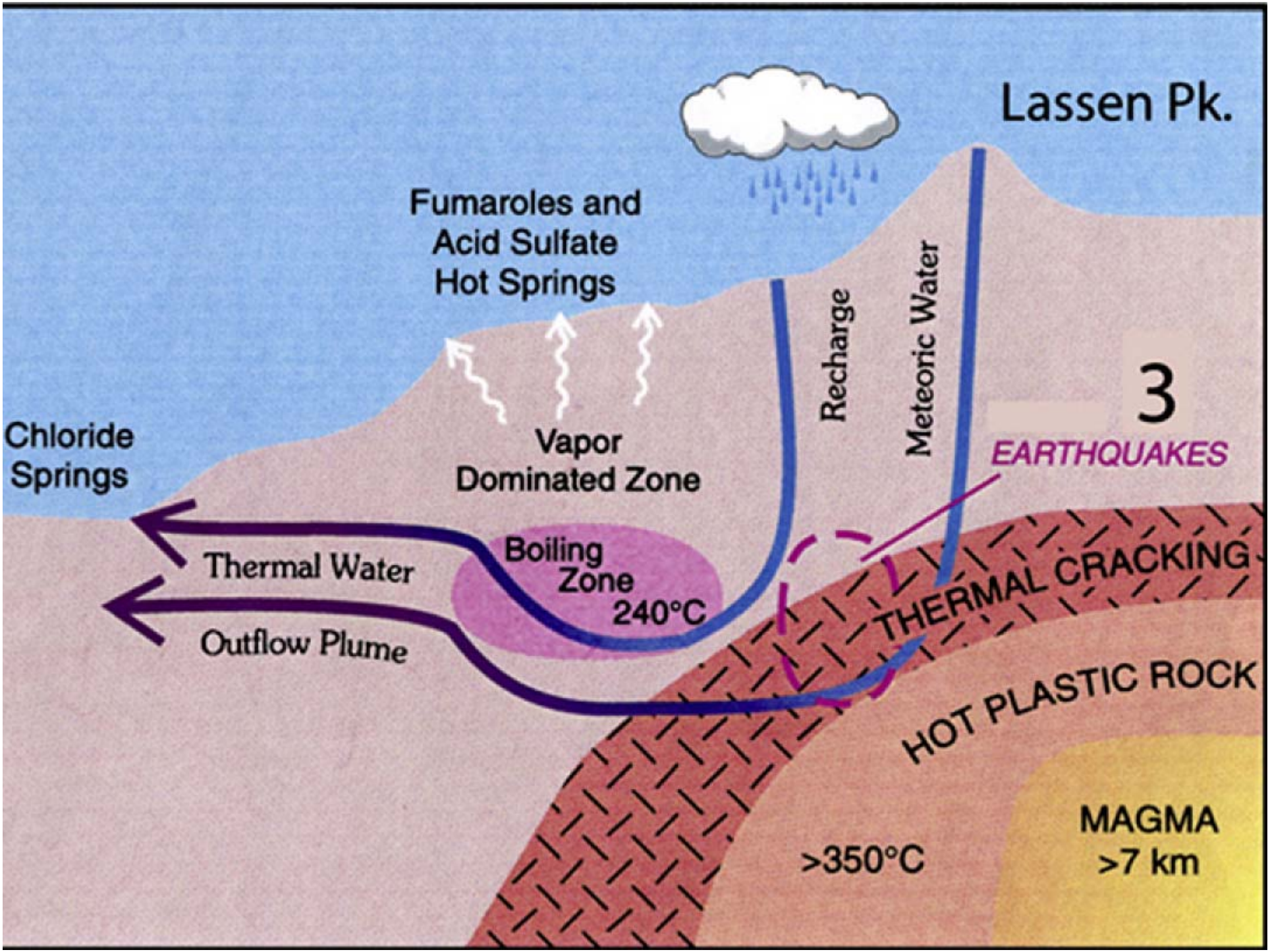
Volcanic and Hydrothermal Activity

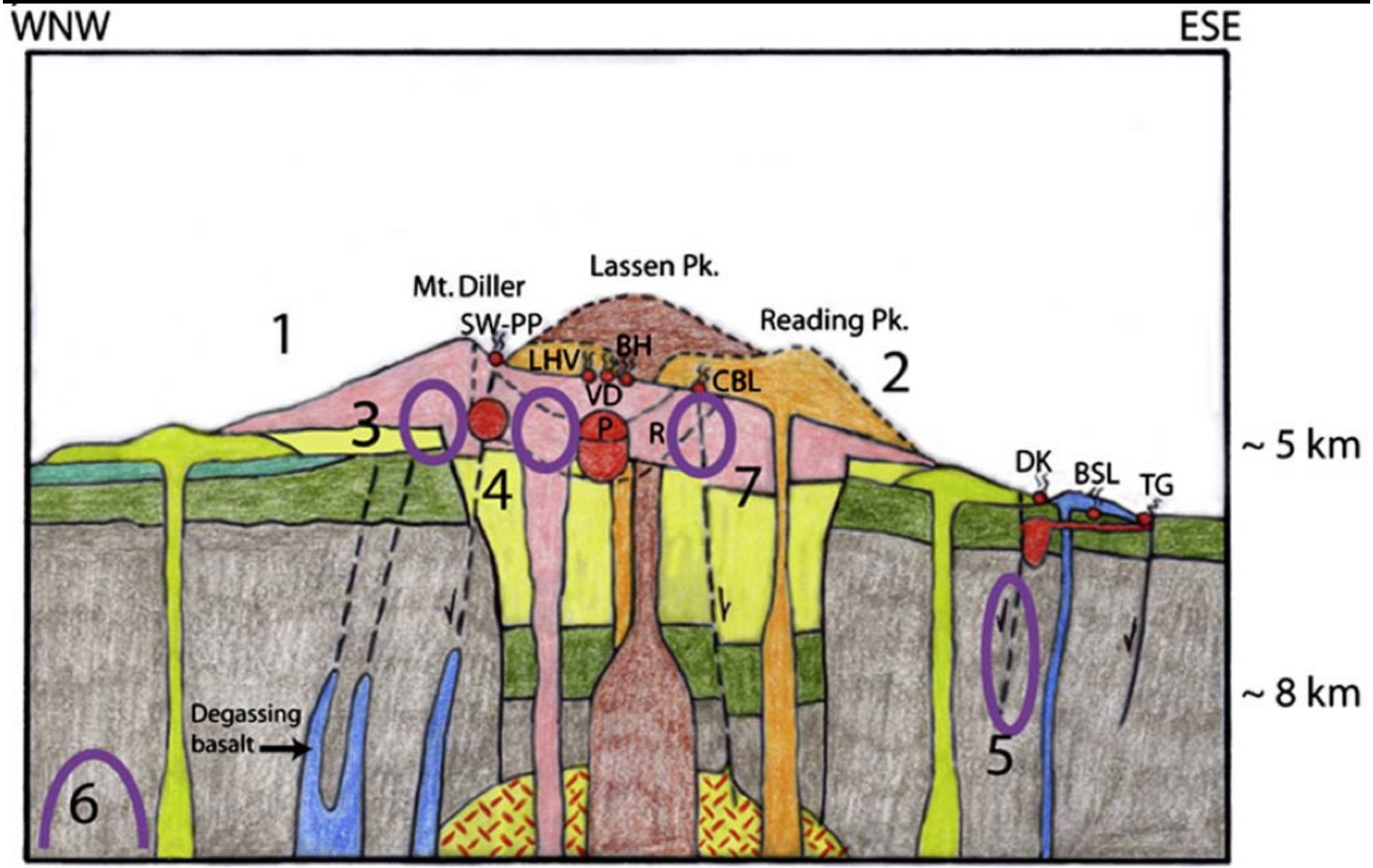



Elevation (m)
1000
500
0
-500
-1000
NW
SE
Low-T Fumaroles
100°C
NaCl Hot Spring
Acid Hot Spring
Aquifer
Sea Water
Caldera rim
Magma head
Convective
magma column
Lavas
Talus Deposits
Pyroclastics
Conduit
Molten magma
0
1 km
High-T Volcanic Gas
Low-T Volcanic Gas
Meteoric Water
Hot Spring Water
Soil Gas
Sea Bottom Bubbling

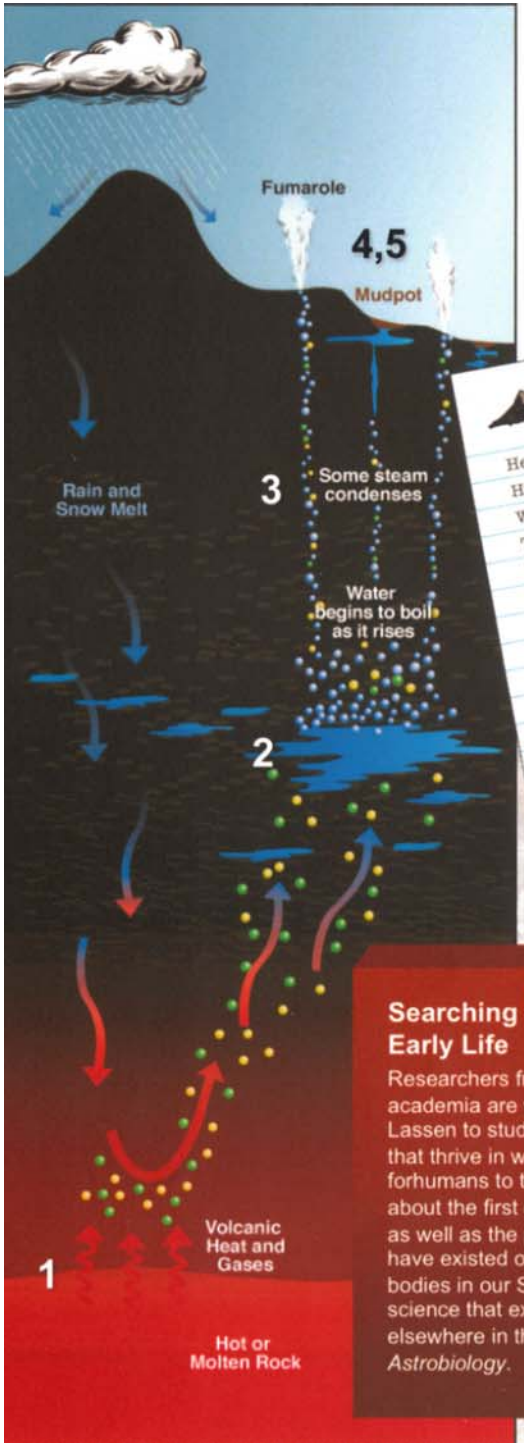

WATER VAPOUR
WATER VAPOUR


Chaos
Crags
Lassen
Peak
Mt. Tehama remnants


Lassen Pk.
Fumaroles and
Acid Sulfate
Hot Springs
Recharge
Meteoric Water
3
EARTHQUAKES
Chloride
Springs
Vapor
Dominated Zone
Thermal Water
Boiling
Zone
240°C
Outflow Plume
THERMAL CRACKING
HOT PLASTIC ROCK
>350°C
MAGMA
>7 km


WNW
ESE
Lassen Pk.
Mt. Diller
SW-PP
Reading Pk.
1
2
LHV
BH
VD
CBL
P
R
3
4
7
DK
BSL
TG
~ 5 km
~ 8 km
Degassing
basalt
5
6

Sulphur Works



Searching for Clues of Early Life

Researchers from NASA and academia are working together in Lassen to study microorganisms that thrive in water too hot forhumans to touch. They can tell us about the first organisms on Earth, as well as the potential for life to have existed on Mars or other bodies in our Solar System. The science that explores for life elsewhere in the Universe is called *Astrobiology*.

Mudpots

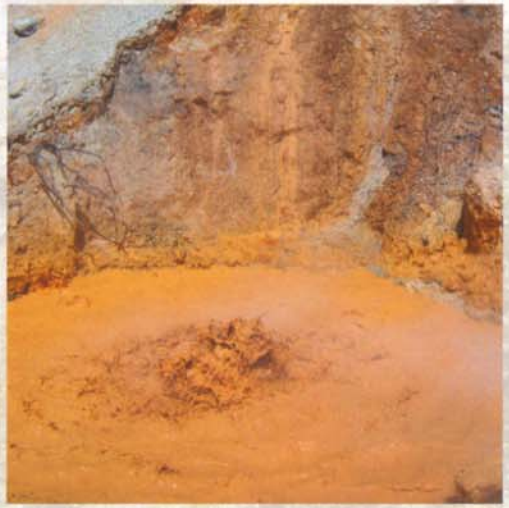
Recipe for

Heat (from deep within Earth's interior)
Hydrogen sulfide gas
Water
Thick layer of volcanic rock (rhyolite)
Heat-loving microorganisms (thermophiles)
Minerals

1. Let volcanic heat and gases rise through Earth's crust. 2. Boil water deep underground and add to gases. 3. Process mixture by forcing upward through cracks in the volcanic rock. 4. Simmer in large pot on the Earth's surface, adding water from rain and snow to make a sloppy consistency. 5. Add microorganisms and simmer while they consume gases and help turn mixture into an acidic marinade. Cook until acid breaks down volcanic rock into clay. Garnish with minerals for added color.

Making Mud

This vat of bubbling mud contains the perfect mix of ingredients to create mudpots: heat, gases, water, volcanic rock, minerals, acid, and thermophiles – heat-loving microorganisms too small to be seen with the naked eye. These thermophiles consume some of the gases and help convert them into sulfuric acid. The acid breaks down rock to form clay, which mixes with water to create mudpots.



Notice how the mudpots change through the seasons. In the late summer when there is very little precipitation, the mudpot on the left is very dry and is dominated by steam. In the spring when the snow begins to melt, the water mixes with the clay to form a bubbling cauldron of mud, as is shown in the mudpot on the right.

Exhibit made possible by support from NASA Astrobiology Institute and Lockheed Martin Exploration and Science

Volcanic Gases

Major

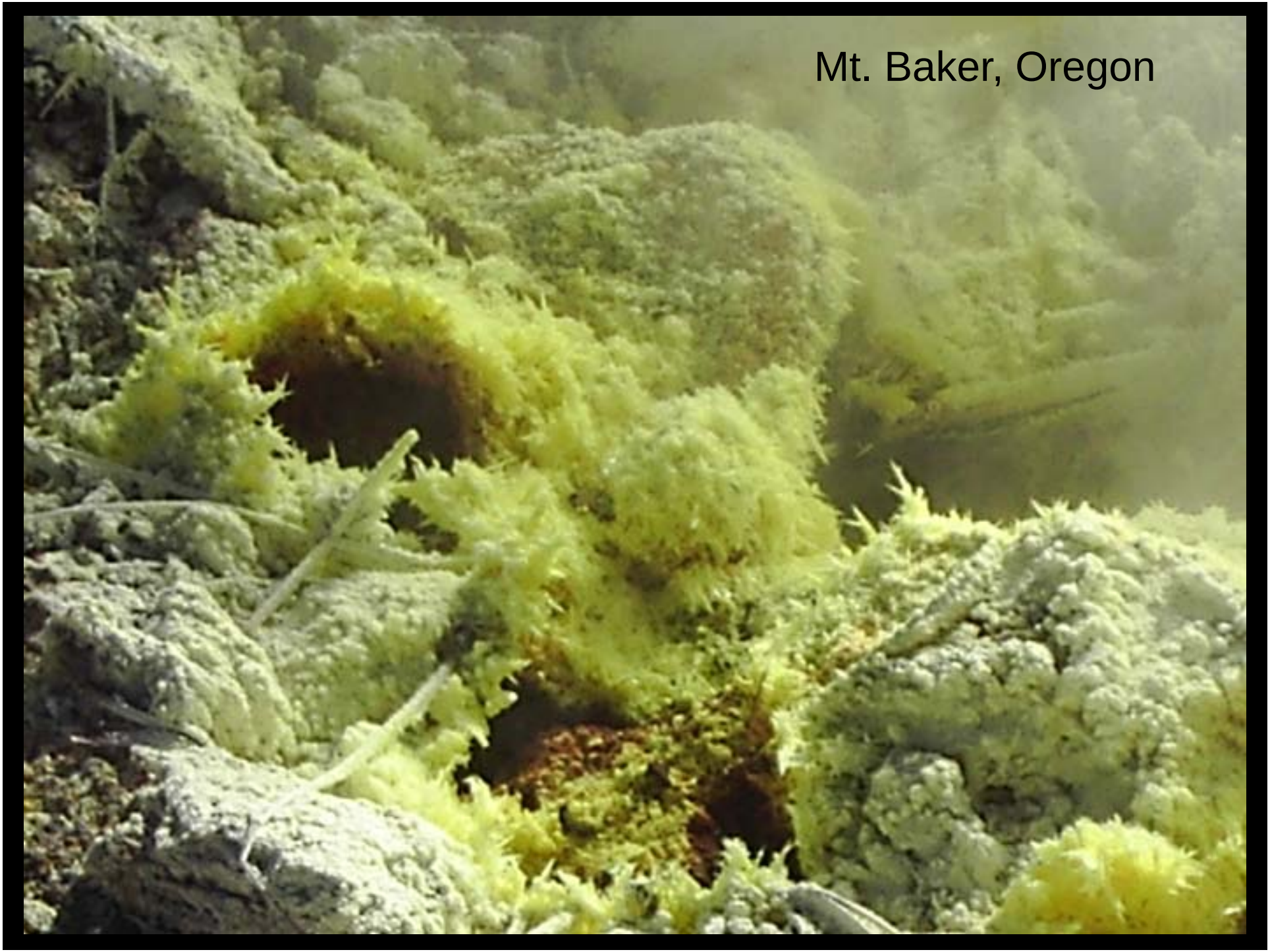
Water vapor
Carbon dioxide
Sulfur dioxide or
Hydrogen sulfide
Hydrogen

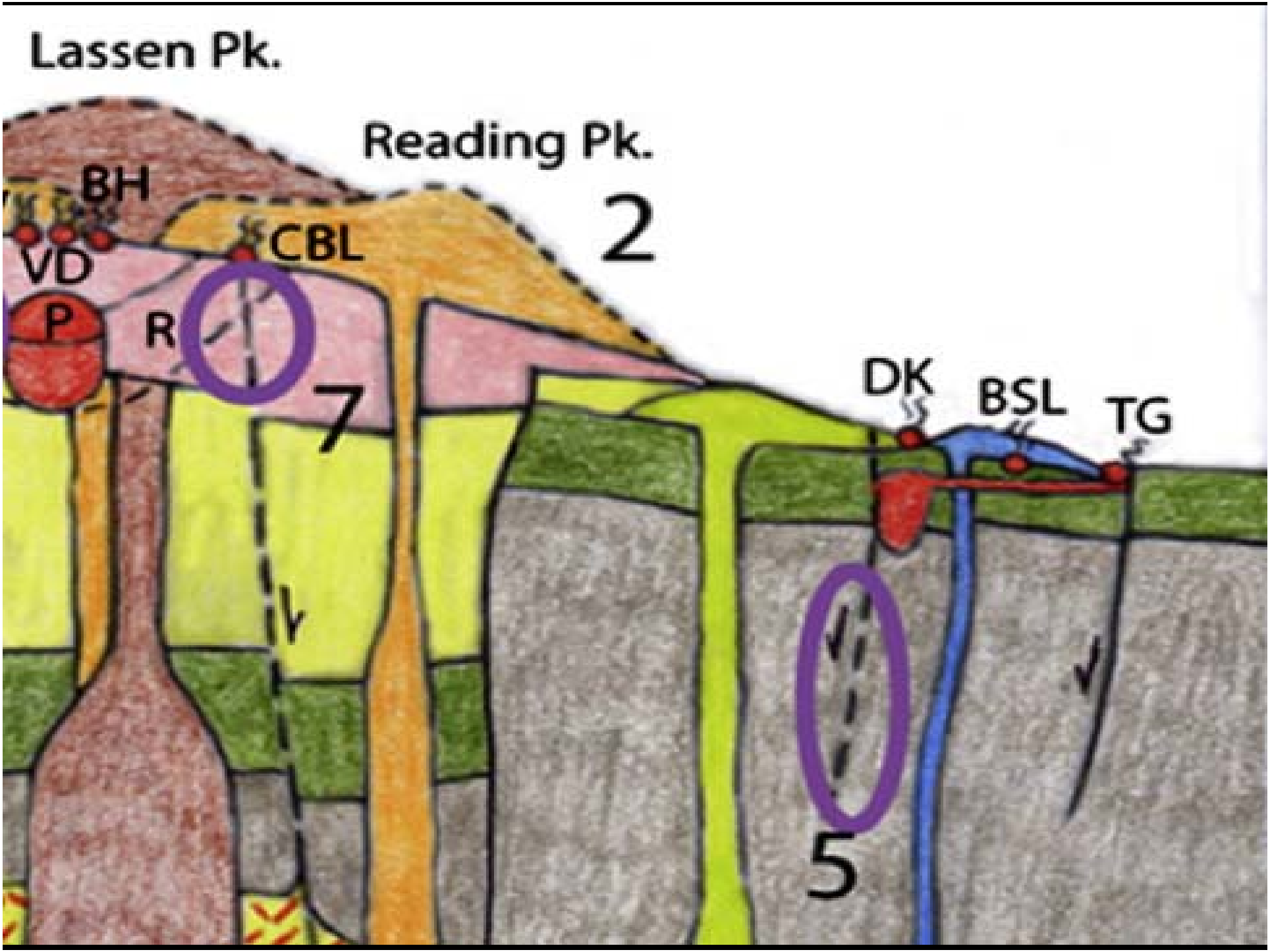
Minor

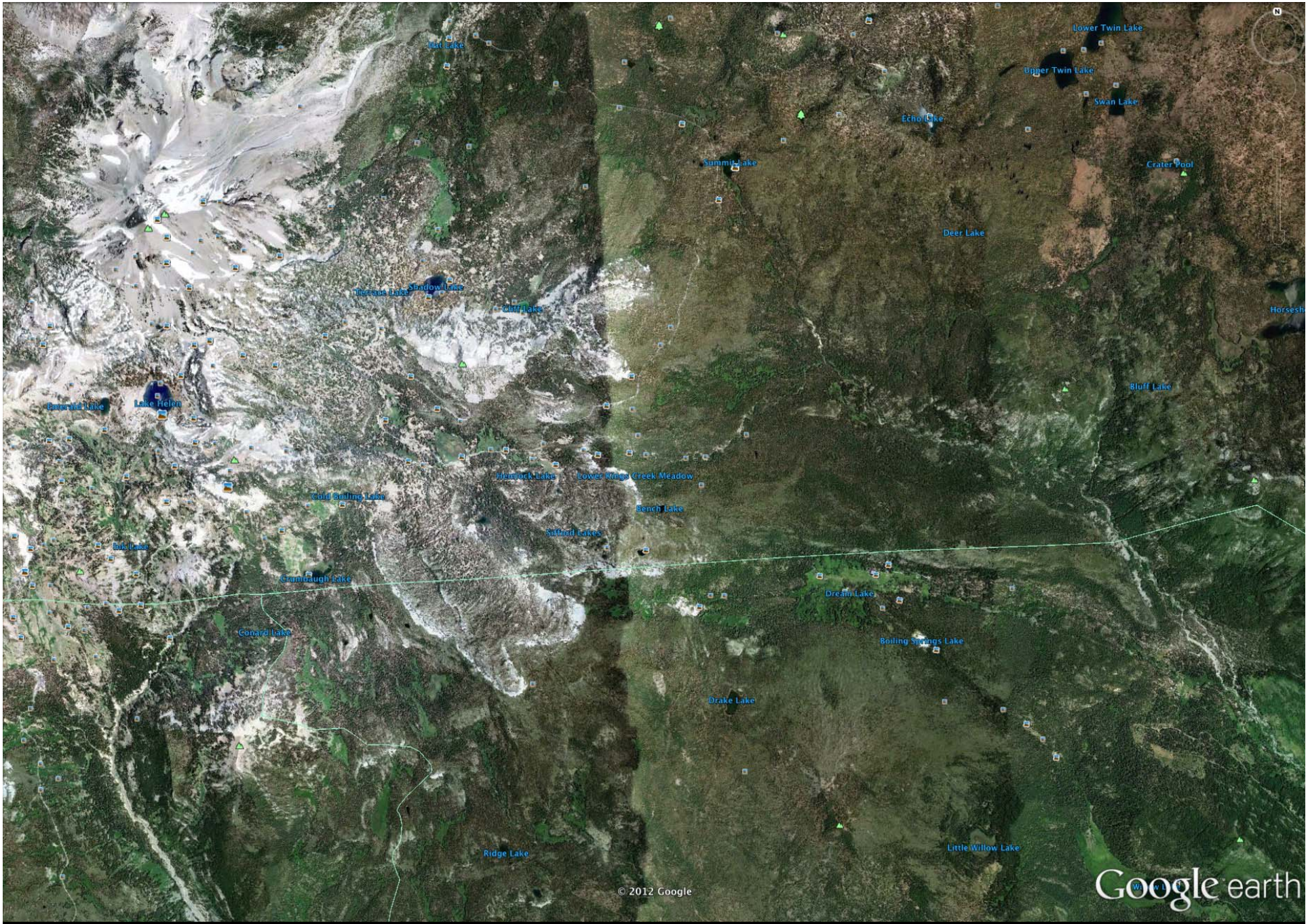
Nitrogen
Methane
Argon
Hydrogen chloride
Helium
Neon
Other halide gases

These chemicals affect the reactions that occur between rocks and water, especially at elevated temperatures

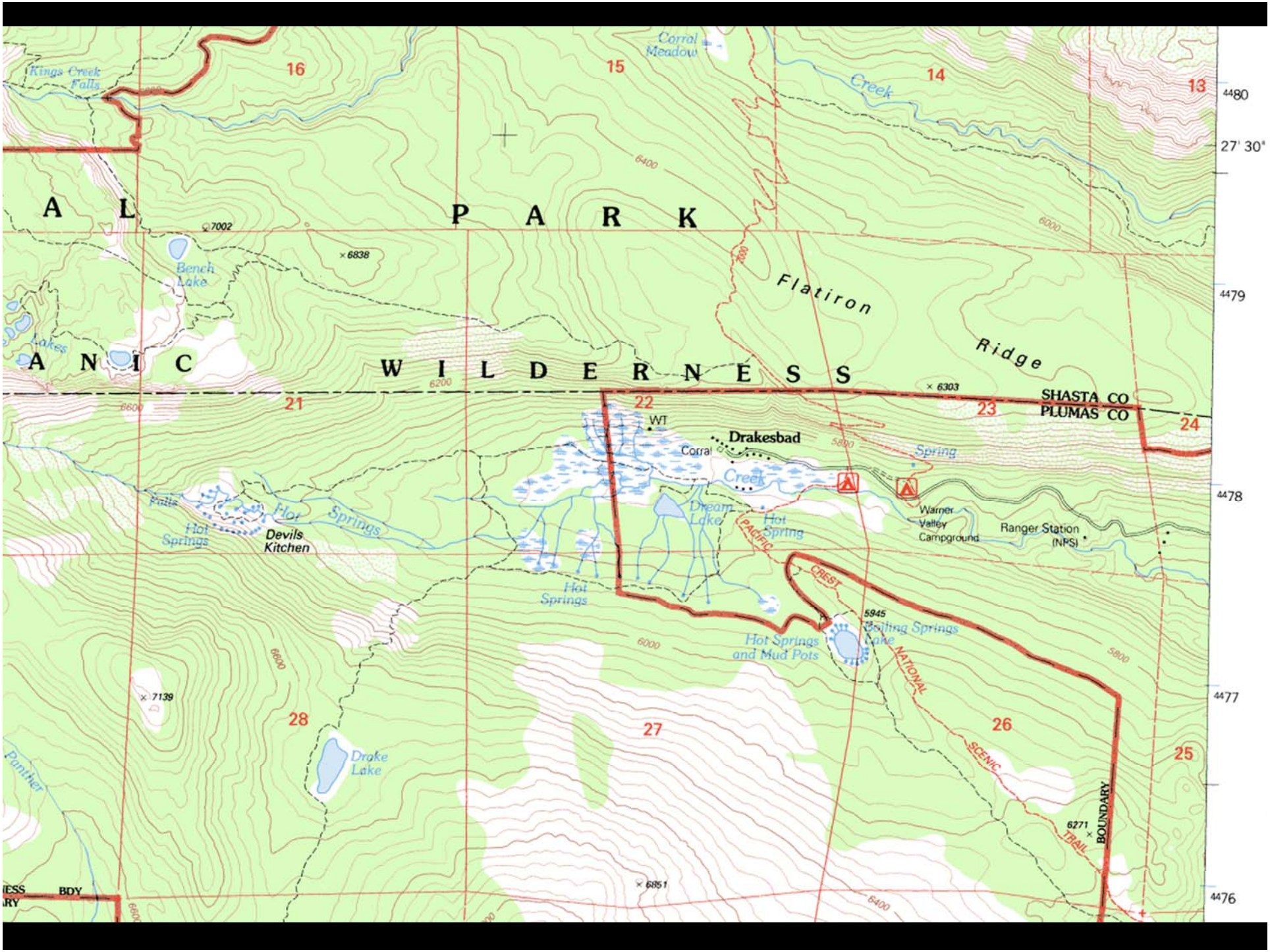
Mt. Baker, Oregon


Mt. Baker, Oregon


Lassen Pk.
Reading Pk.
BH
VD
CBL
P
R
2
7
DK
BSL
TG
5



altitude 10.42 miles


Kings Creek Falls
16
15
Corral Meadow
Creek
14
13
4480
27° 30'
A L P A R K
7002
6838
Bench Lake
6400
6000
Flatiron Ridge
Lakes
A N I C W I L D E R N E S S
6200
6600
21
22
6303
SHASTA CO
PLUMAS CO
23
24
WT
Drakesbad
Corral
5800
Spring
Creek
4479
Falls
Hot Springs
Devils Kitchen
Hot Springs
Dream Lake
Hot Spring
Warner Valley Campground
Ranger Station (NPS)
4478
PACIFIC CREST
Hot Springs
5945
Boiling Springs Lake
Hot Springs and Mud Pots
6000
5800
NATIONAL SCENIC TRAIL
7139
28
27
26
25
Drake Lake
Panther
6271
BOUNDARY
4477
BDY
6851
6400
4476

altitude 16240 feet

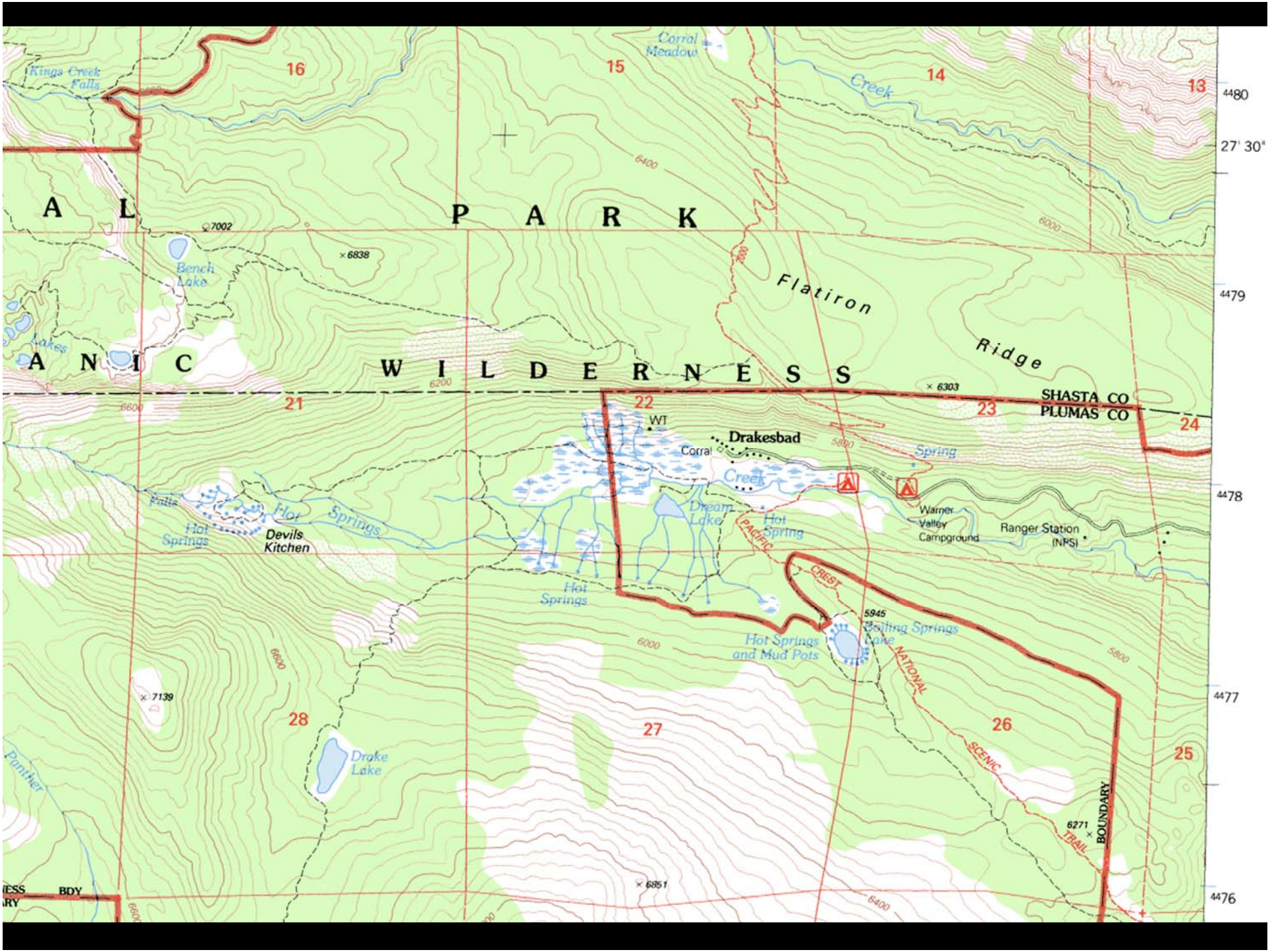
altitude 11679 feet, Drakesbad

altitude 8156 feet, meadow

altitude 16240 feet

altitude 11679 feet, Devils Kitchen

altitude 7598 feet, Devils Kitchen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BOUNDARY
4477
BDY
6851
6400
4476

Lassen Water Analyses

Solute	*Alkaline Springs*	*Neutral Springs*	*Acidic Springs*
pH			
Calcium			
Iron			
Potassium			
Magnesium			
Manganese			
Sodium			
Fluoride			
Chloride			
Silica			
Sulfate			

How do the water solutions indicate:

Rainfall

Rocks in watershed

Low temperature weathering of rocks

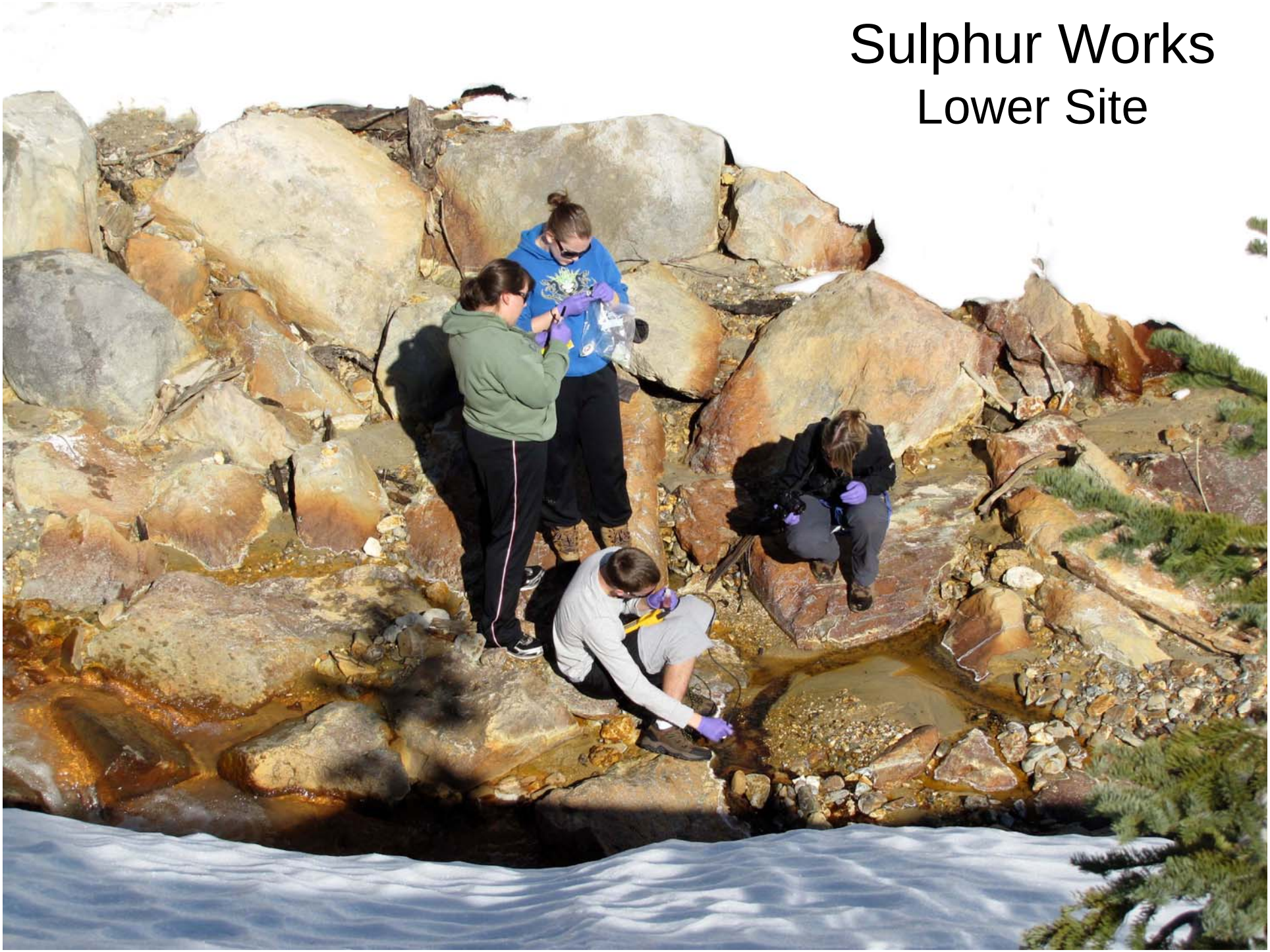
Volcanic gas emissions

High temperature alteration of rocks

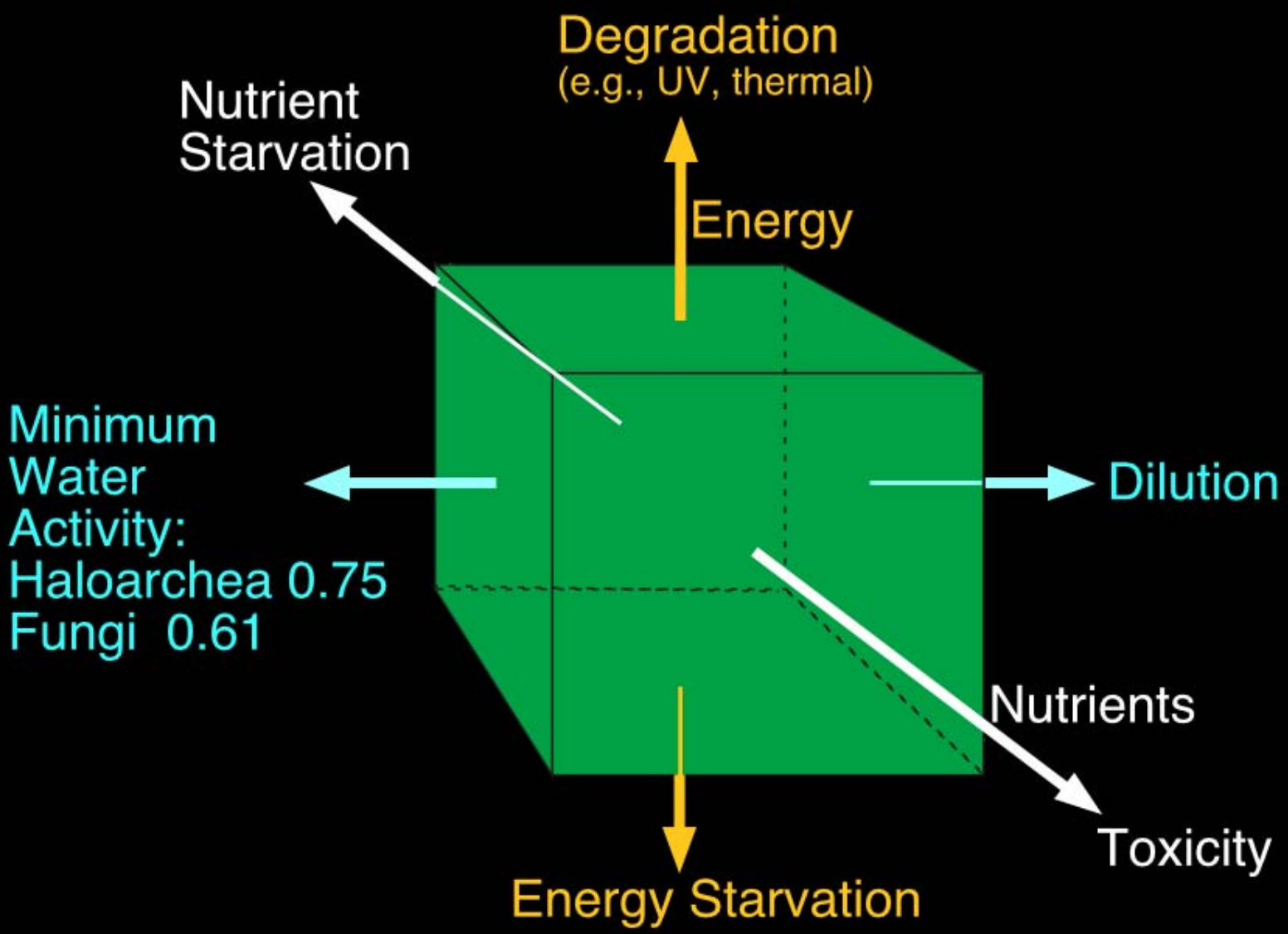
Minerals deposited from waters

? ? ?

Sulphur Works
Lower Site



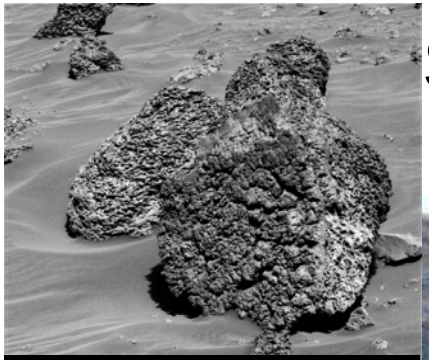
Range of Conditions that Sustain Life



3.5 Billion Years Ago: The Archean Earth

Spirit Rover on Husband Hill, Gusev crater, Mars

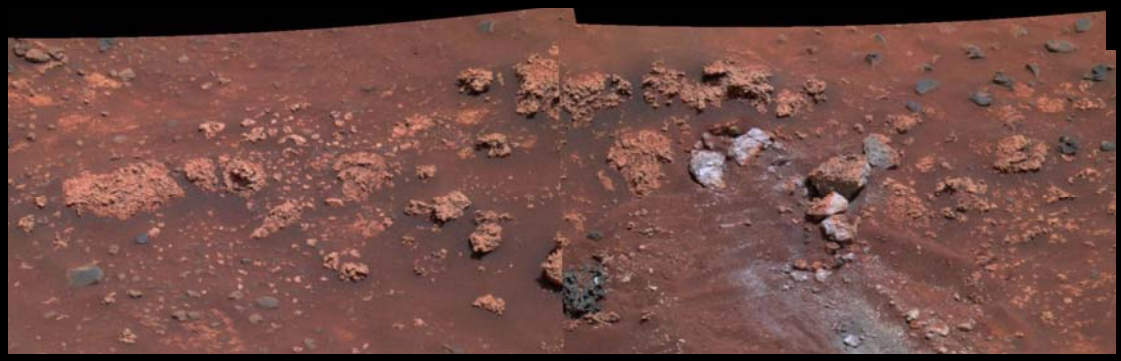
Spirit's discoveries at Home Plate: volcanic & hydrothermal deposits



Vesicular basalt

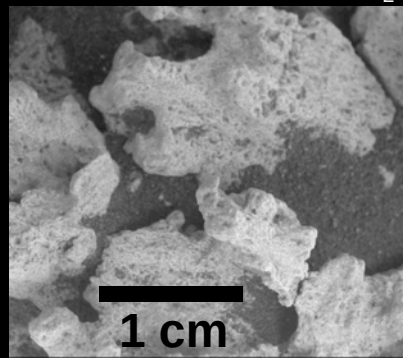
Tyrone: ferric sulfate

Kenosha Comets:
90 % SiO_2



Elizabeth Warren & friends: 70+ % SiO_2

Elizabeth Mahon: 70+ SiO_2



1. Understand how alkaline, acidic, and neutral pH springs form
2. Understand how temperature and pH dictates which microbes grow where
3. Understand how this relates to your enrichment cultures

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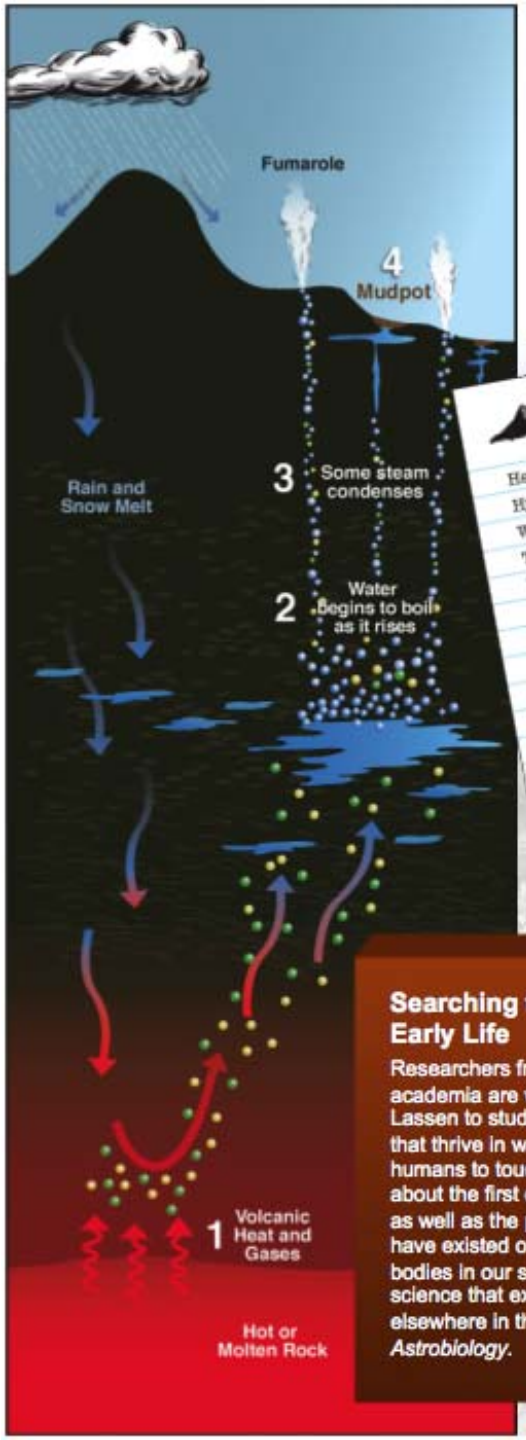
LIFE IN THE UNIVERSE

Types of hydrothermal features

1. Alkaline chloride
   a) Hot springs
2. Acid sulfate
   a) Fumaroles, mud pots, hot springs
3. Neutral pH (freshwater)

Sulphur Works



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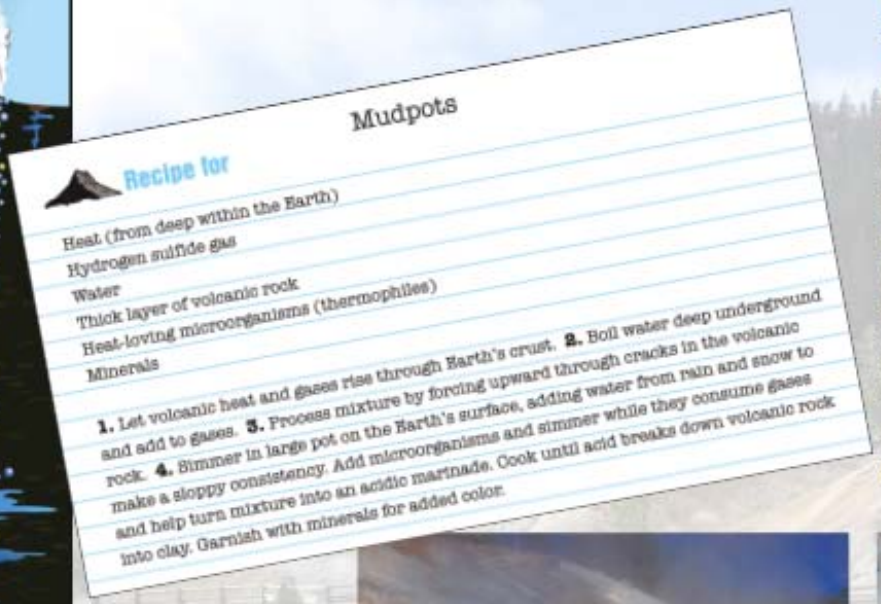

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Mudpots change with the seasons. In the late summer when there is very little precipitation, mudpots are dry and dominated by steam, as seen in the image on the left. The image on the right shows the same mudpot in the spring, when the snow melts and water mixes with clay to form a bubbling cauldron of mud.

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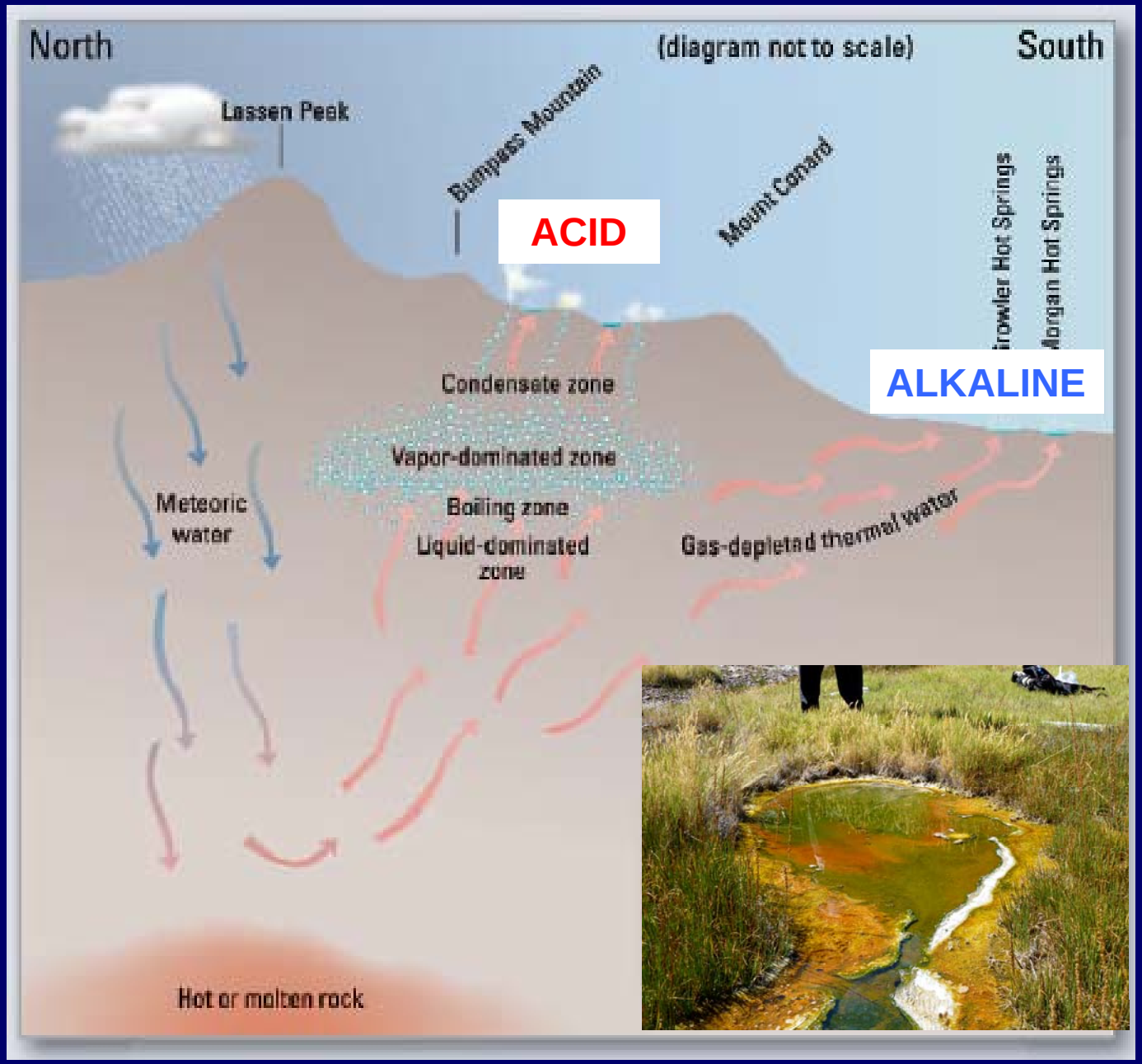
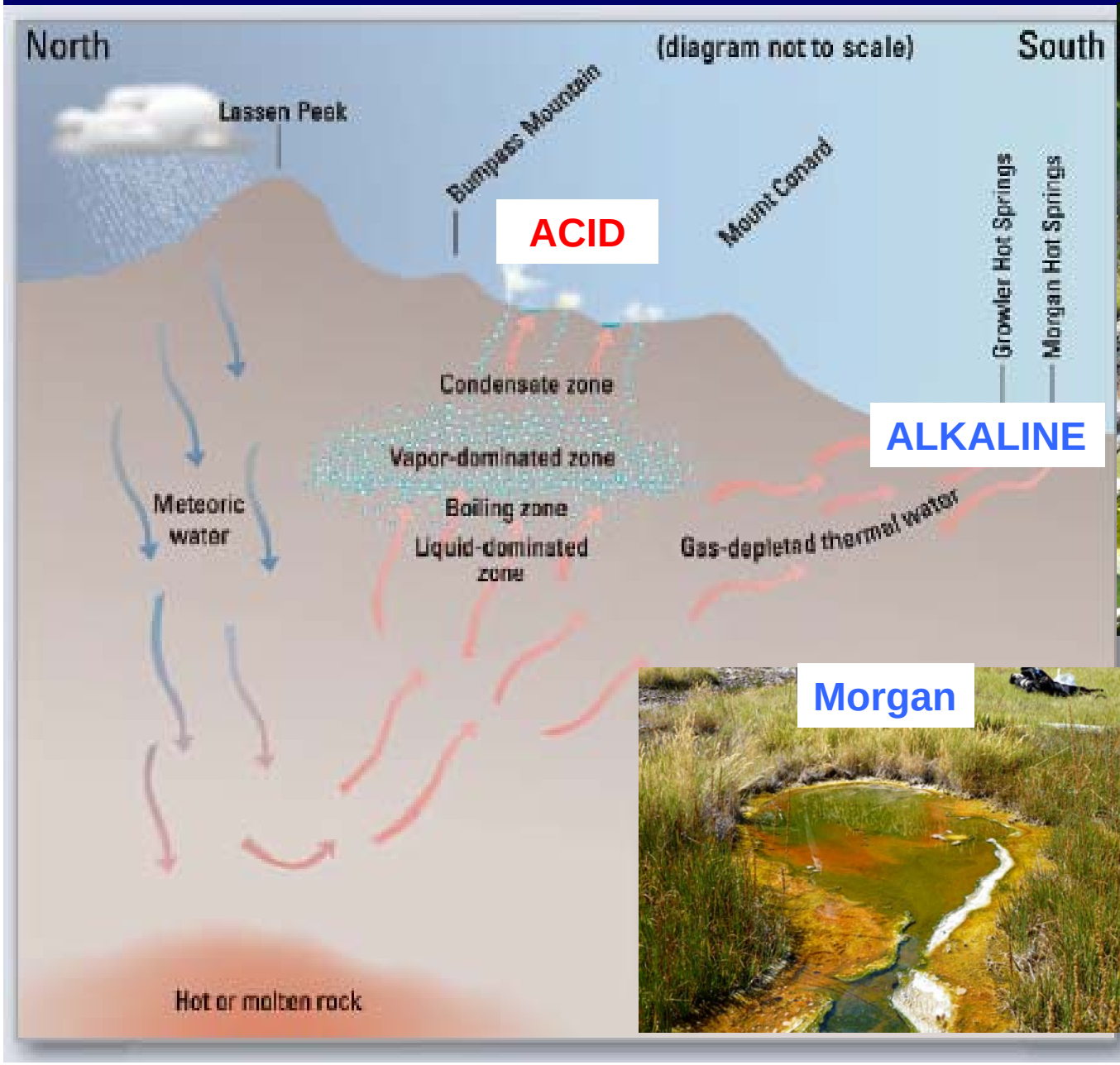
Lassen Volcanic Natl. Park



$H_2S \rightarrow SO_4^{2-}$

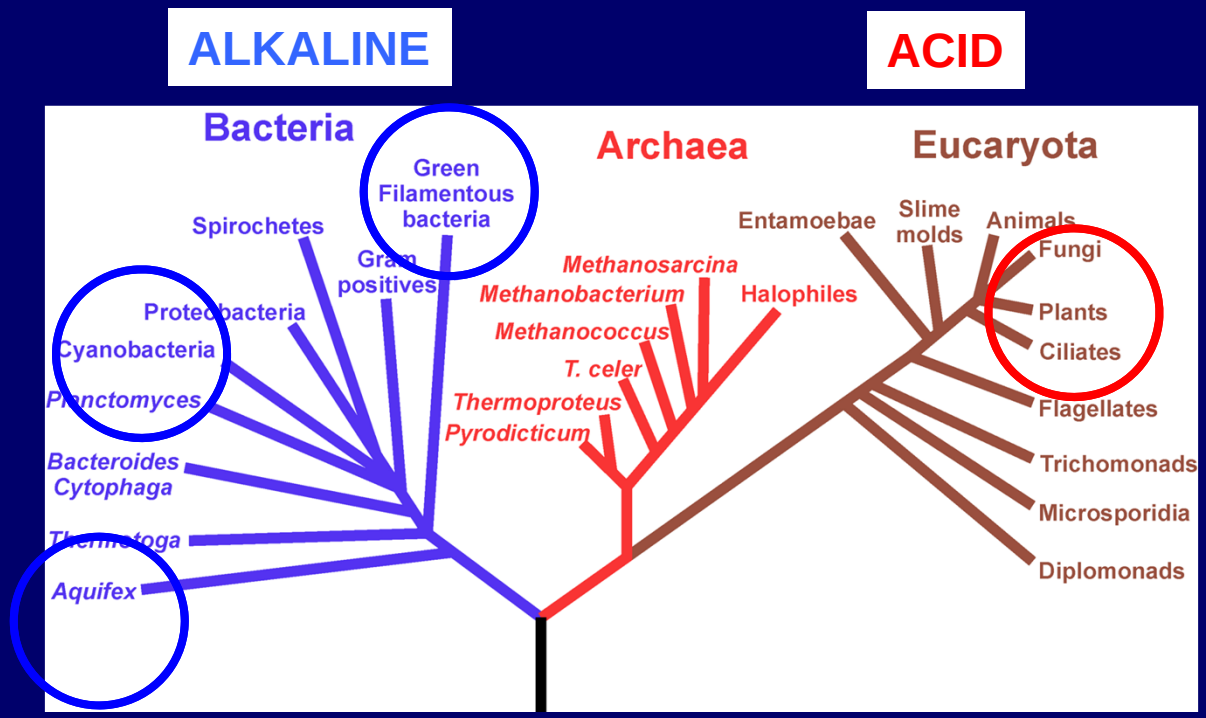
$SO_4^{2-} + H_2O \rightarrow$

H_2SO_4
Sulfuric acid!


North
(diagram not to scale)
South
Lassen Peak
Bumpass Mountain
Mount Conard
Growler Hot Springs
Morgan Hot Springs
ACID
ALKALINE
Condensate zone
Vapor-dominated zone
Meteoric water
Boiling zone
Liquid-dominated zone
Gas-depleted thermal water
Hot or molten rock


Growler

Morgan



16S rRNA tree of life

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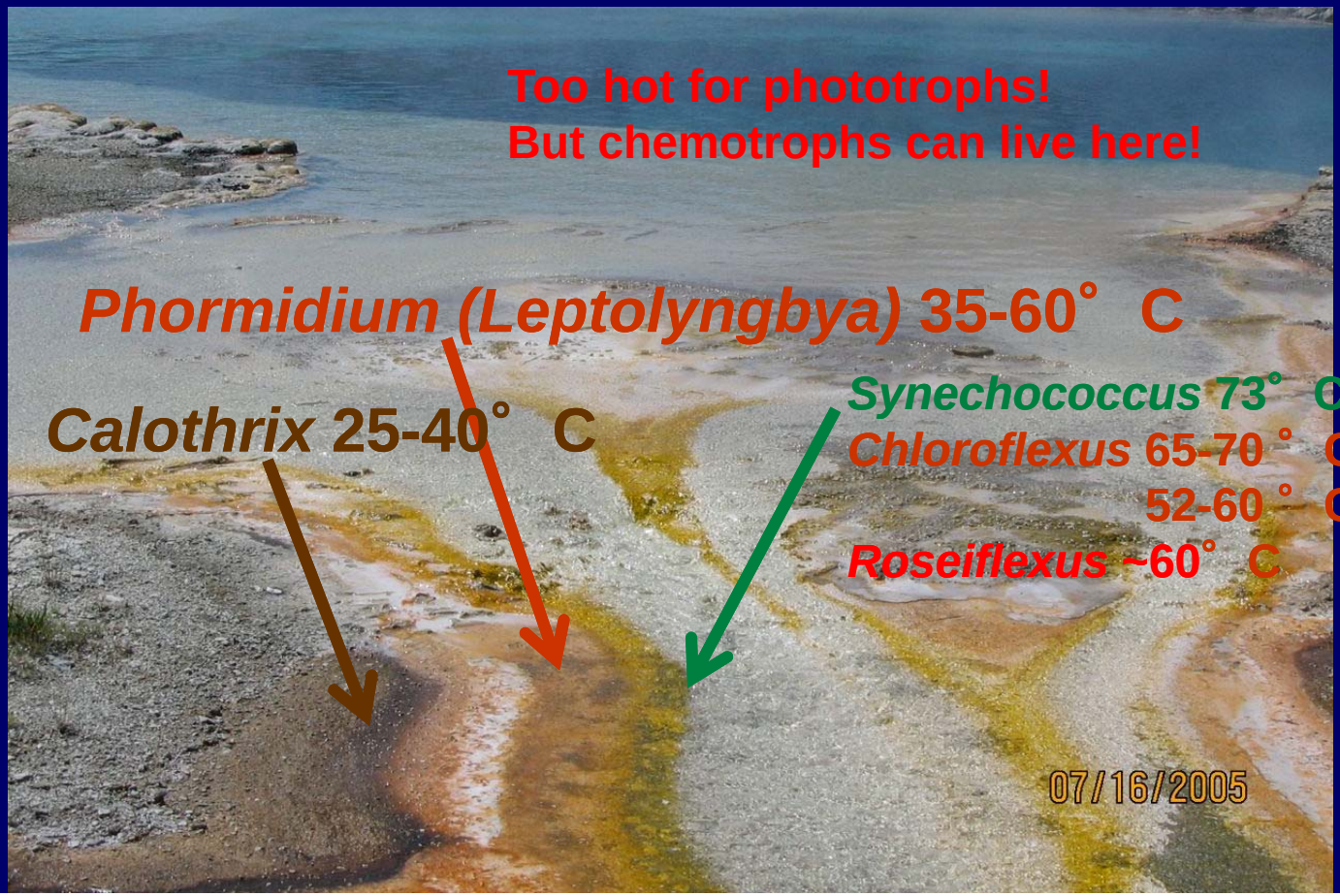
Temperature and pH dictates who grows where

Temperature zonation



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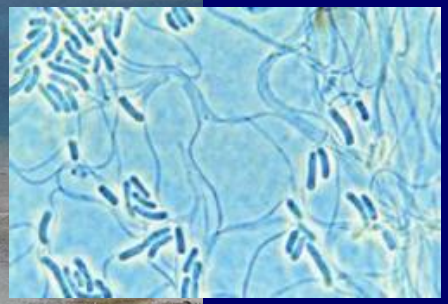
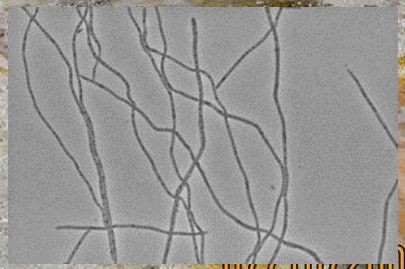
Phototrophic Mats: alkaline chloride

Phormidium



Calothrix

Synechococcus
Chloroflexus
Roseiflexus



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Temperature and pH dictates who grows where

Eukaryotes

Cyanidiales (red algae)
pH 0.2 – 4.0
40 – 56˚ C

End