

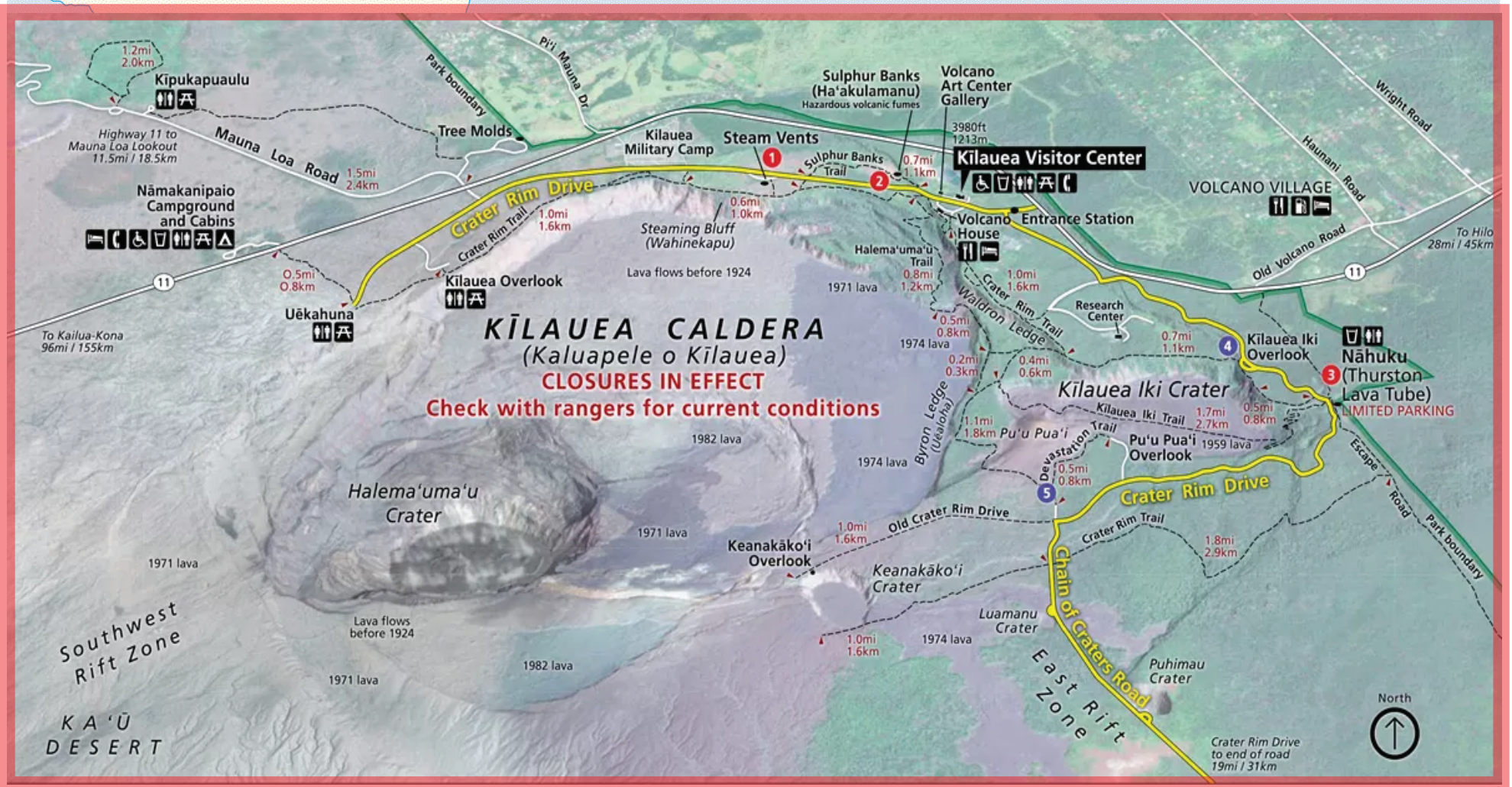
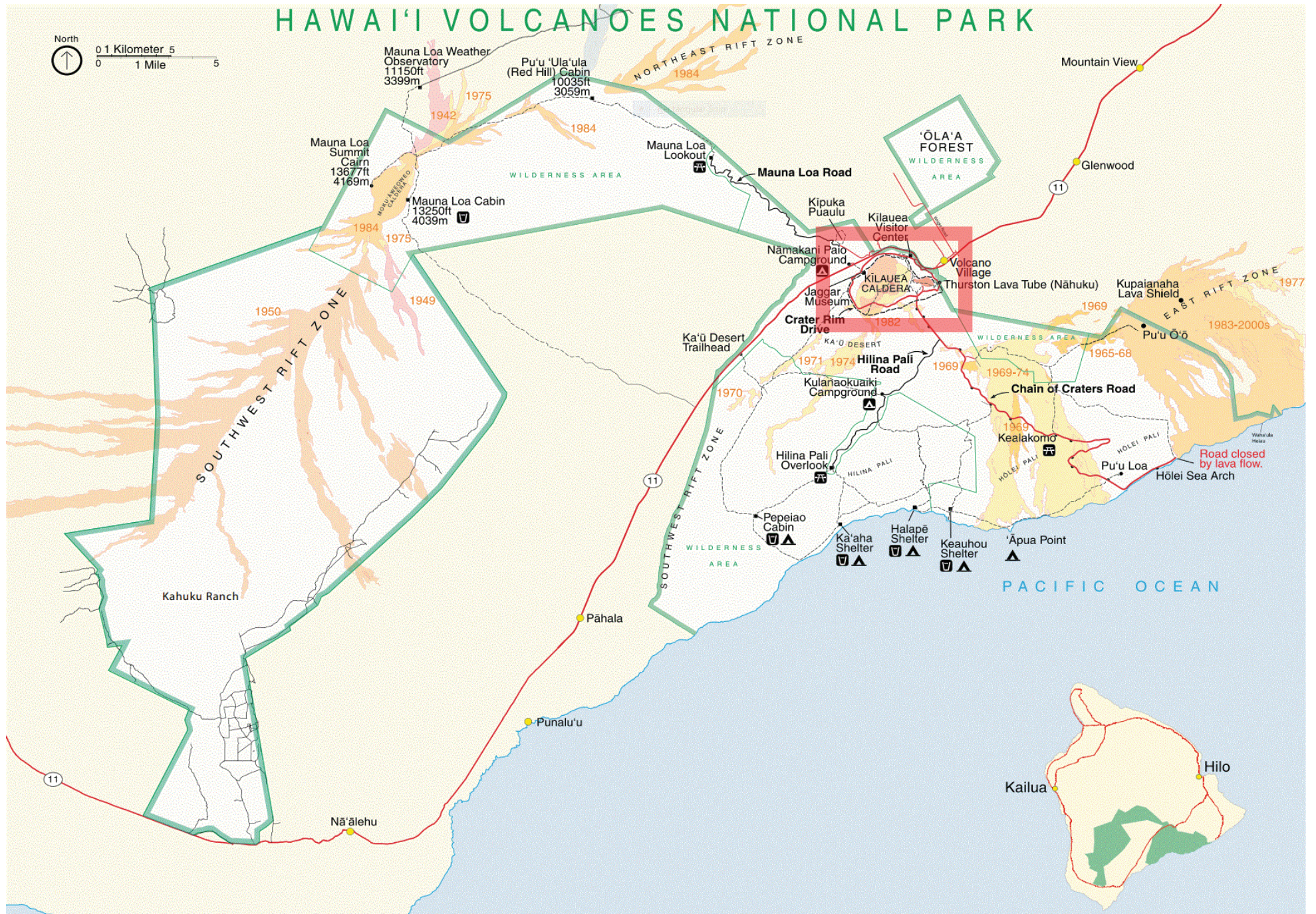
SCIENCE TEAM RESOURCE PACKET

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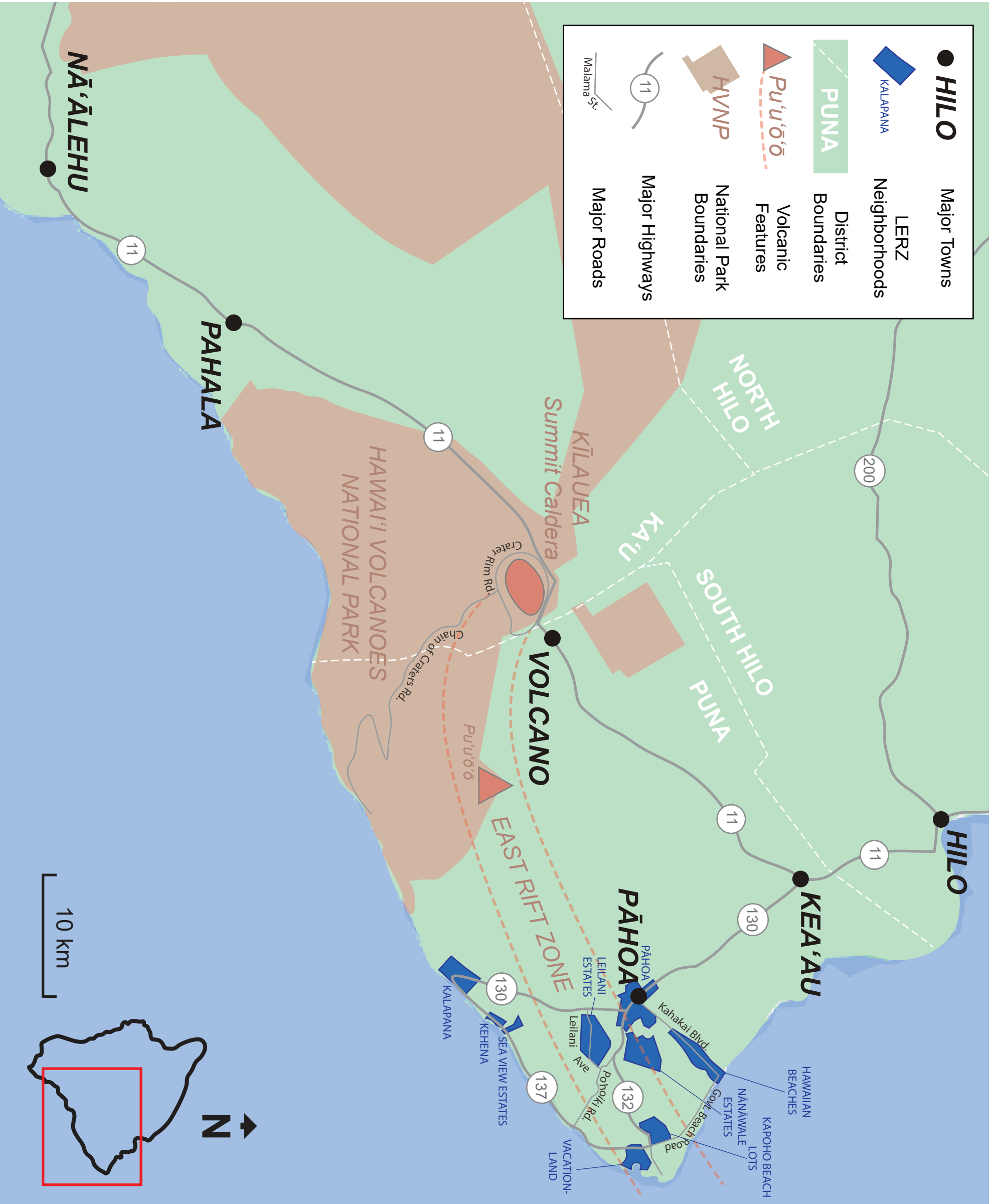
MAP OF HAWAI'I VOLCANOES NATIONAL PARK

Top: map of National Park boundaries, trails, important waypoints, major roadways, and towns. Orange- and yellow-painted areas represent significant historical lava flows. Red rectangle in top map marks bounds of bottom map. Bottom: detailed map of Kīlauea summit region, including National Park trails, buildings, and viewpoints; as well as significant natural features.












KĪLAUEA REGIONAL MAP

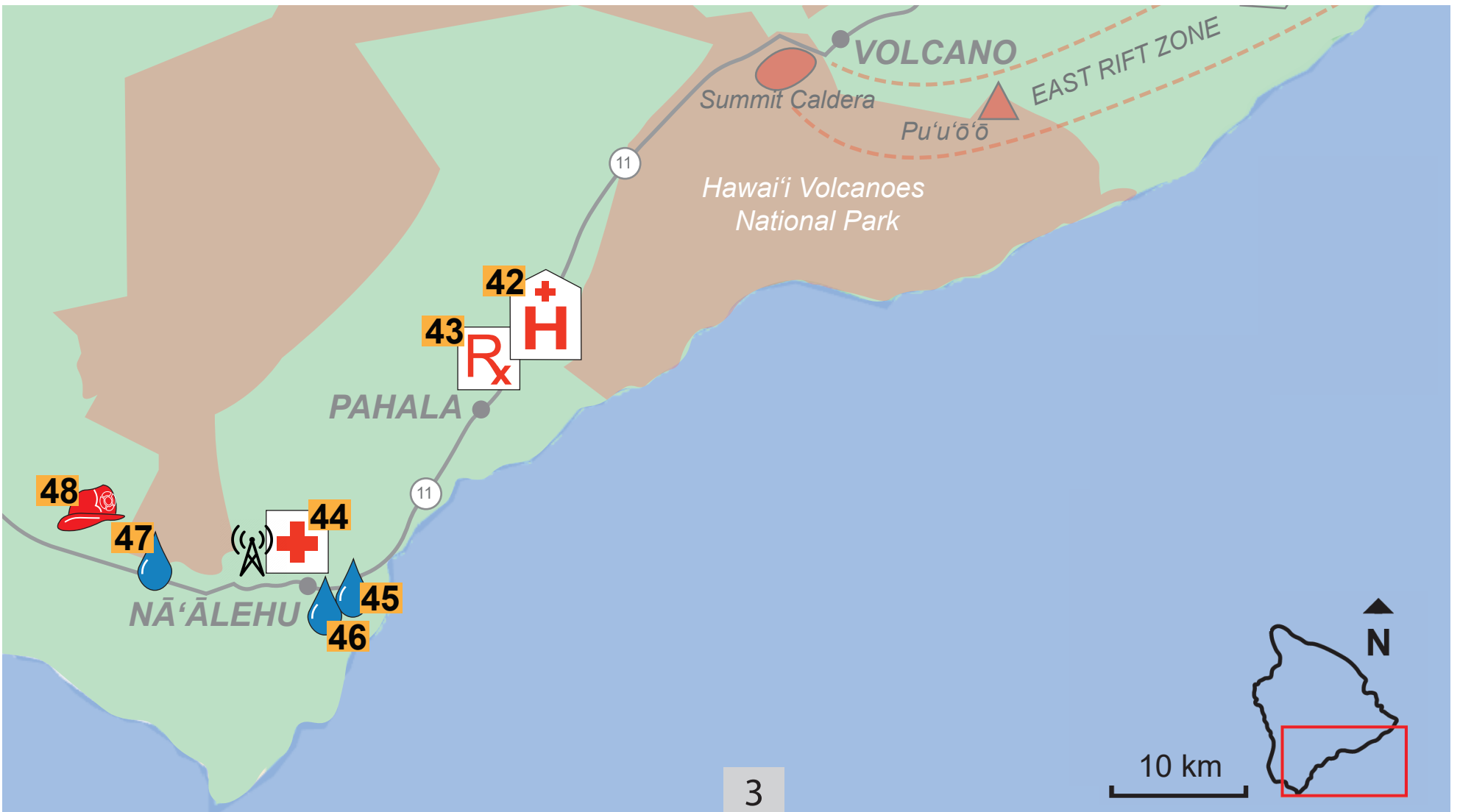
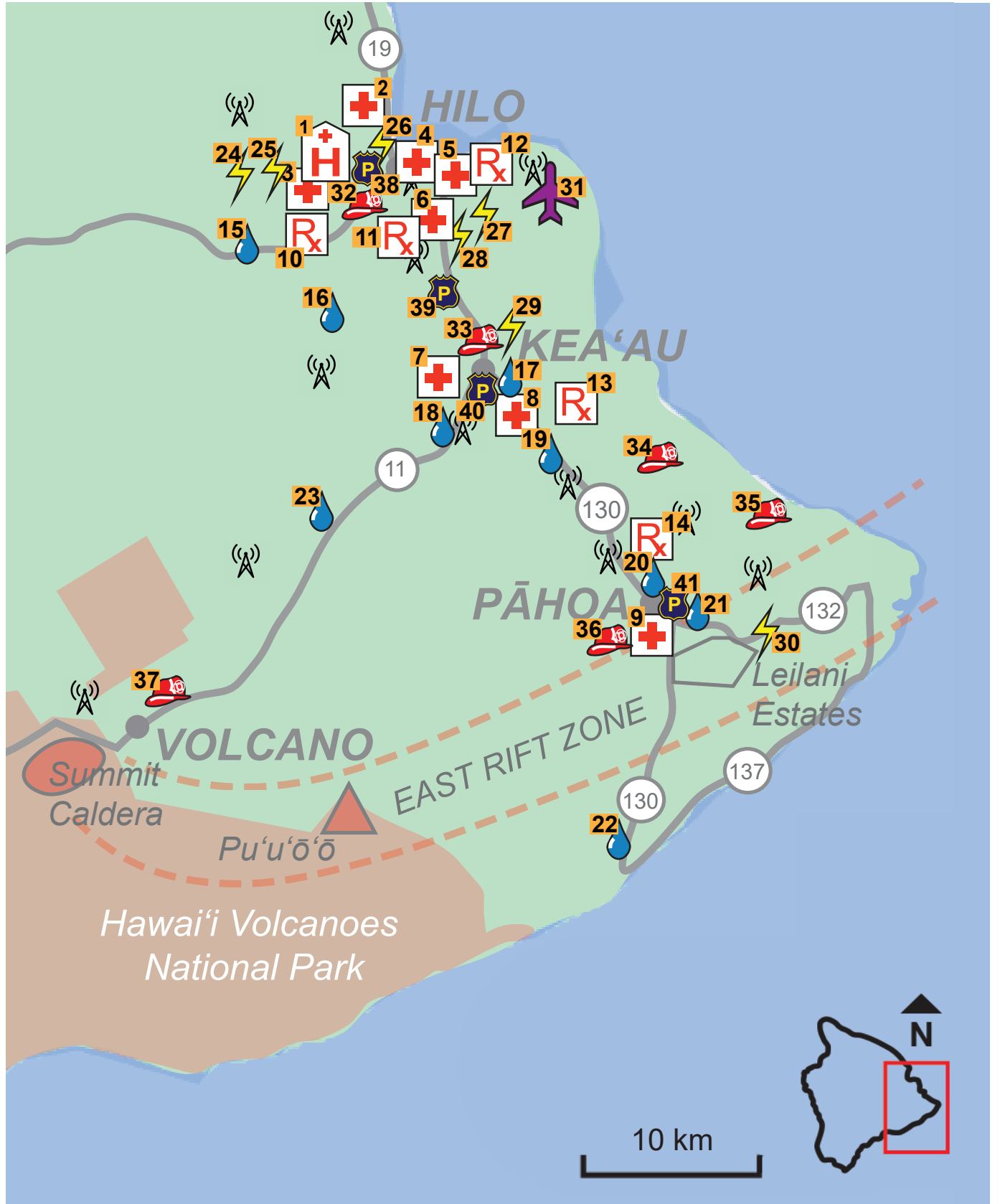
Map of significant features on and around Kīlauea Volcano. Use this map to complete tasks such as placing resources/workers, drawing boundaries, indicating travel routes, etc.



MAPS OF UTILITIES & SERVICES IN SOUTHERN HAWAII

Map of medical, energy, transportation, fire, police, and utility services in the southeast (top) and southwest (bottom) areas of Hawai'i. Base map features major highways and town centers as well as the boundaries of Hawai'i Volcanoes National Park.

-  **Hospitals**
 - 1 Hilo Medical Center *
 - 42 Ka'u Hospital & Rural Health Clinic *
-  **Primary Care Services**
 - 2 Bay Health Clinic - Hilo
 - 3 Kaiser Permanente - Hilo *
 - 4 Hilo Urgent Care *
 - 5 Linden Family Medicine Clinic, LLC
 - 6 Dr. S. A. Walsh, M.D.
 - 7 Kea'au Urgent Care *
 - 8 Bay Health Clinic - Kea'au
 - 9 Puna Community Medical Center *
 - 44 Bay Health Clinic - Ka'u
-  **Drugstores & Pharmacies**
 - 1 CVS - West Hilo
 - 11 CVS - South Hilo
 - 12 Shigi Drug Company
 - 13 Longs Drugs - Kea'au
 - 14 Longs Drugs - Pāhoā
 - 43 CVS - Ka'u
-  **County Water Spigots**
 - 15 at Kaumana
 - 16 at Waiākea Uka
 - 17 at Kea'au Transfer Station
 - 18 at Kurtistown Ball Park
 - 19 at Kīpuka Farms
 - 20 at Keonepoko
 - 21 at Nānāwale Estates
 - 22 at Kalapana
 - 23 at Mountain View Gymnasium
 - 45 at Wai'ōhinu Park
 - 46 at Wai'ōhinu Transfer Station
 - 47 at Hawaiian Ocean View Estates
-  **Power Plants**
 - 24 Wailuku *hydroelectric*
 - 25 Wai'au *hydroelectric*
 - 26 Pu'ueo *hydroelectric*
 - 27 W. H. Hill *petroleum*
 - 28 Kanoelehua *petroleum*
 - 29 Puna *petroleum*
 - 30 Puna Geothermal Venture *geothermal*
-  **Airports**
 - 31 Hilo International Airport
-  **Fire Stations**
 - 32 Hawai'i County Fire Department - Hilo
 - 33 Kea'au Fire Station
 - 34 Volunteer Station 18
 - 35 Volunteer Station 10
 - 36 Pāhoā Fire Station
 - 37 Volunteer Station 19
 - 48 Ocean View Fire Station
-  **Police Stations**
 - 38 Hawai'i County Police & Sheriff's Department
 - 39 Hale Nani Police Academy
 - 40 Kea'au Police Station
 - 41 Pāhoā Police Station
-  **Cell Phone Towers**



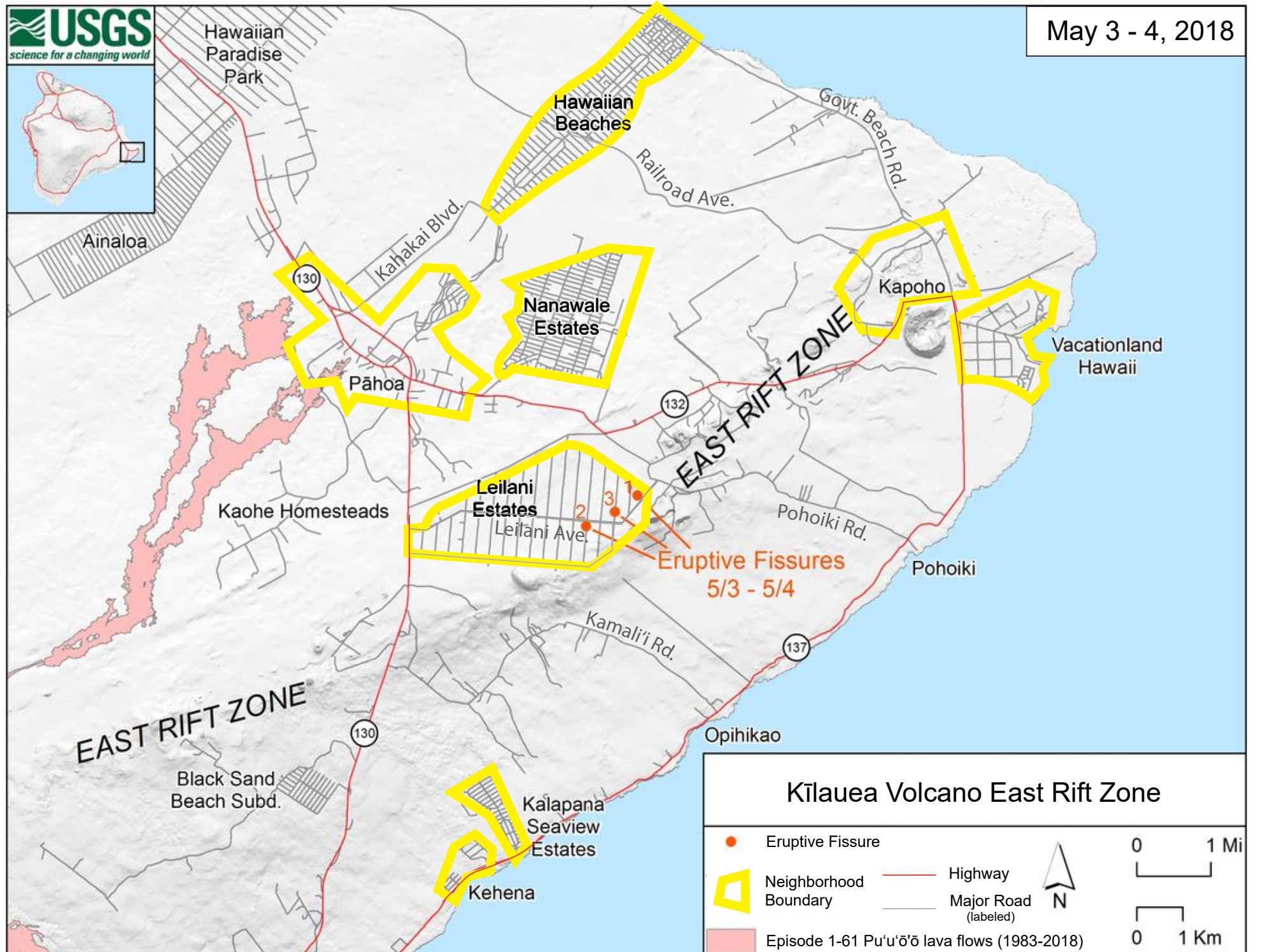
LEILANI ESTATES ROAD MAP

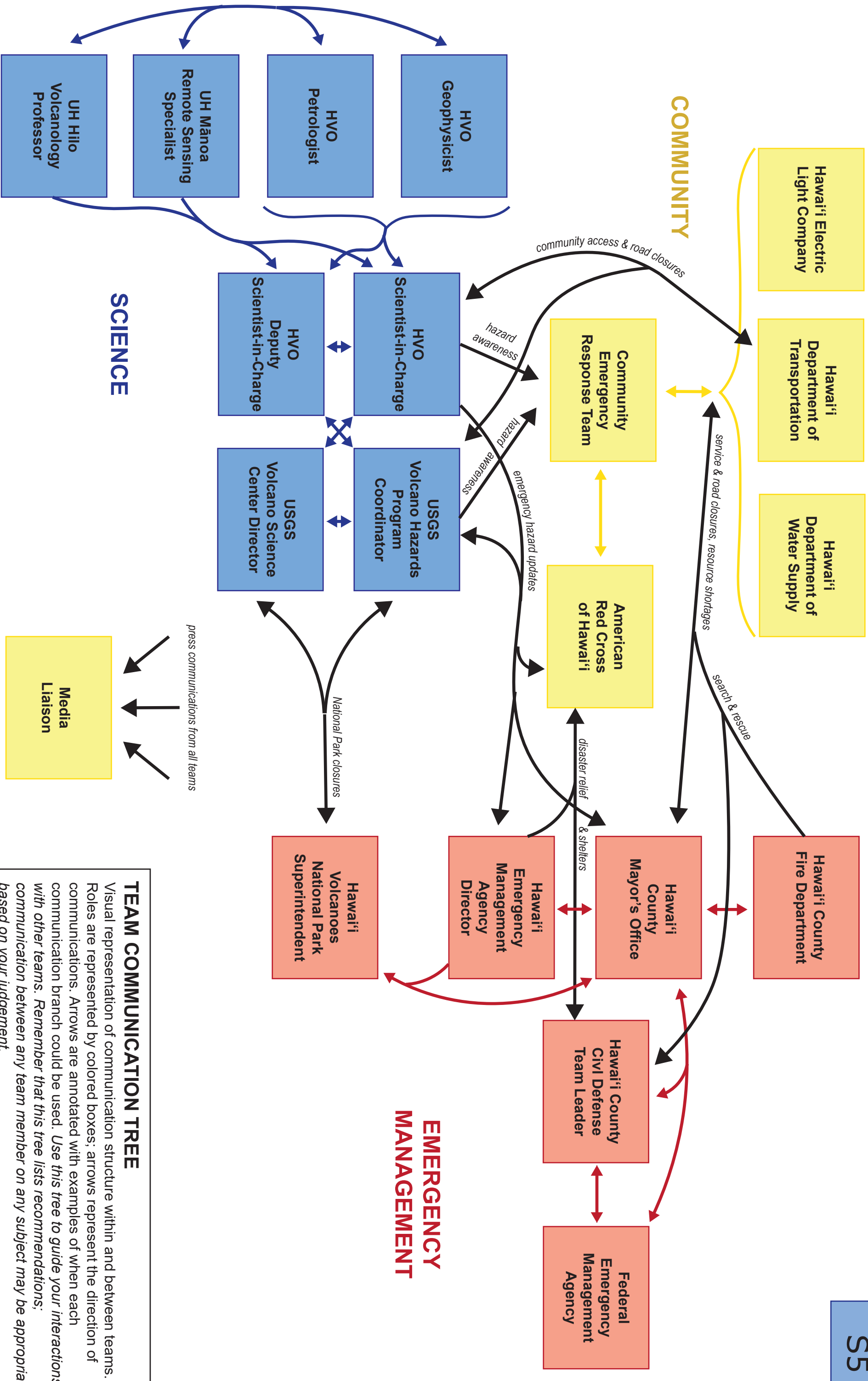
Satellite image overlaid with street names in and around Leilani Estates Subdivision.



KĪLAUEA LERZ NEIGHBORHOOD MAP

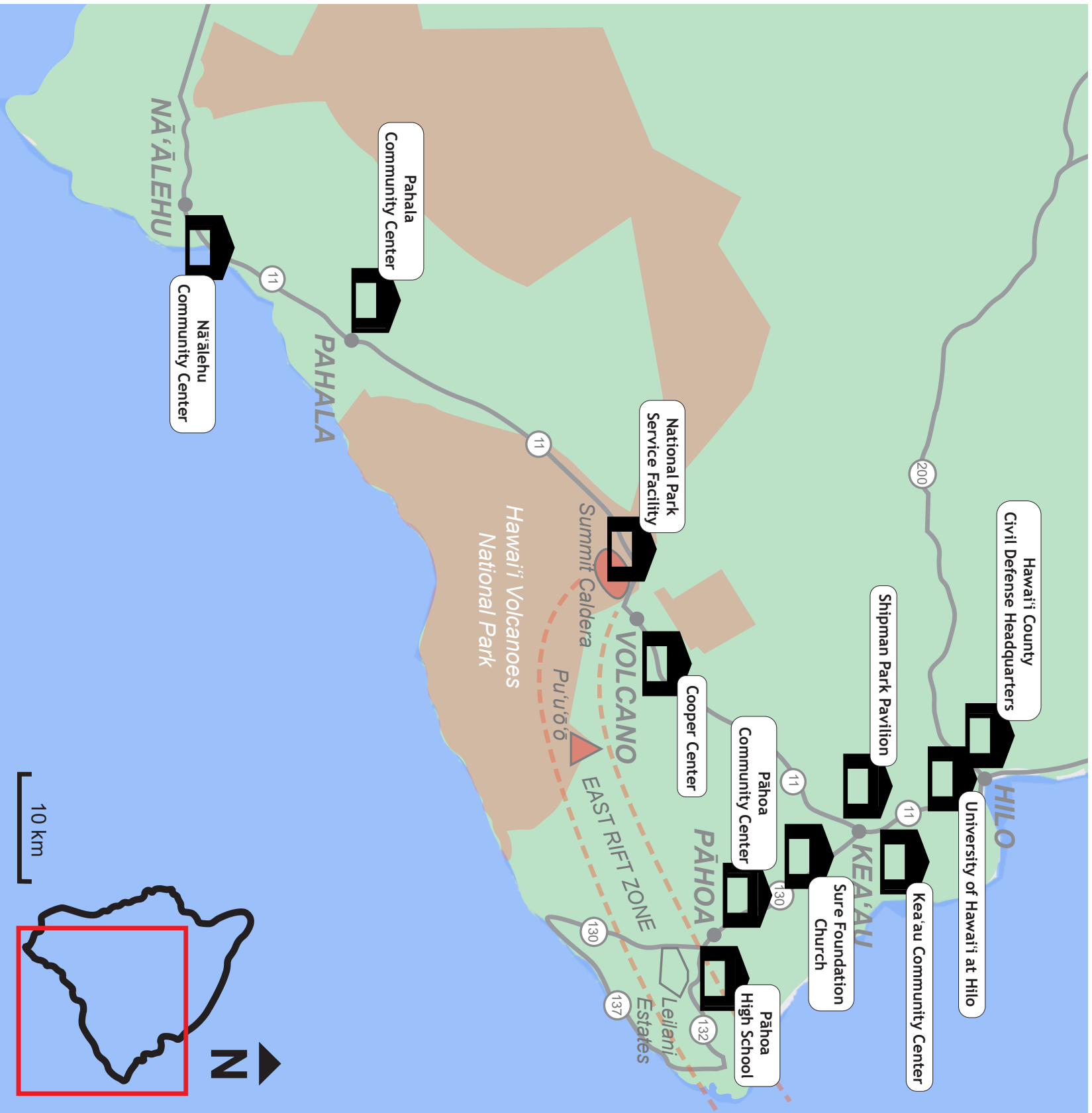
General boundaries and important roadways in neighborhoods of the Kīlauea Lower East Rift Zone (LERZ). Includes locations of the first three eruptive fissures from May 3 to May 4, 2018.





FACILITIES MAP & FACILITIES CARD

Map of useful facilities in the southern island of Hawaii. Each facility has a “card” (right) listing its available space and notable features. Use this map to select facilities for your team to use during certain tasks. Once a facility has been selected by one team, it must be crossed off (“in use”) and it may not be selected by any team for the rest of the activity.



| | |
|--|--|
| <p>Pāhoā Community Park</p> <ul style="list-style-type: none"> ❖ Largest indoor/outdoor community center in Puna ❖ Includes aquatic facilities, multiple-use fields, baseball parks, and basketball courts ❖ Has a 27,000 sq. ft. covered gym ❖ Has a 65,000 sq. ft. parking lot ❖ Is ADA accessible | <p>Pāhoā High School</p> <ul style="list-style-type: none"> ❖ Occupies 23 acres in the Lower Puna District ❖ Has open fields including a baseball, softball, football and track field as well as tennis courts ❖ Has an 8,000 sq. ft. gym with 1,000 seats ❖ Has a 55,000 sq. ft. parking lot ❖ Is ADA accessible |
| <p>Sure Foundation Church</p> <ul style="list-style-type: none"> ❖ Christian church typically used for worship, baptisms, and events ❖ Has a 27,000 sq. ft. area ❖ Has an additional 15,000 sq. ft. main sanctuary ❖ Has a 44,000 sq. ft. parking lot ❖ Is ADA accessible | <p>Kea'au Community Center</p> <ul style="list-style-type: none"> ❖ Indoor space with open floor plan ❖ Typically used for crafts, meetings, trainings, and community classes ❖ 8,000 sq. ft. building in Kea'au ❖ 7,700 sq. ft. parking lot ❖ Is not ADA accessible or air-conditioned |
| <p>Shipman Park Pavilion</p> <ul style="list-style-type: none"> ❖ A 2,200 sq. ft. outdoor pavilion ❖ The park contains a baseball field, basketball court, tennis court, and soccer field ❖ 480,000 sq. ft. total of open fields ❖ 14,000 sq. ft. parking lot ❖ Across the street of Kea'au Urgent Care | <p>Cooper Center</p> <ul style="list-style-type: none"> ❖ A 7,500 sq. ft. facility with many rooms for community events and gatherings ❖ Near entrance to Hawaii's Volcanoes National Park and next to the Volunteer Fire Station ❖ Hosts classes, projects, farmers markets, swap meets, food pantries, craft fairs, etc. ❖ 13,500 sq. ft. parking lot |
| <p>Pahala Community Center</p> <ul style="list-style-type: none"> ❖ 6,400 sq. ft. community center in Pahala ❖ 8,000 sq. ft. parking lot ❖ Directly next to an open field ❖ Contains Ka'u district gym food distribution center ❖ Hosts numerous community events | <p>Nā'ālehu Community Center and Park</p> <ul style="list-style-type: none"> ❖ 7,200 sq. ft. indoor facility in Nā'ālehu ❖ Typical hosts community events and gatherings ❖ 220,000 sq. ft. of fields including a baseball diamond, tennis courts, and basketball courts ❖ Across the street from the Sacred Hearts Church Food Distribution Center |
| <p>Hawaii County Civil Defense Headquarters</p> <ul style="list-style-type: none"> ❖ Main office for the HCCD Agency ❖ Directly attached to the Hilo Drivers Licensing Station and Hawaii County Firearms Reg. ❖ 25,000 sq. ft. main building with 22,000 sq. ft. alternate buildings ❖ 11,000 sq. ft. storage ❖ 22,000 sq. ft. parking lot plus many close lots | <p>National Park Service Facility</p> <ul style="list-style-type: none"> ❖ Used for storage of National Park maintenance equipment and supplies ❖ Extensive scaffolding and shelving units ❖ 83,000 sq. ft. usable space: 43,000 covered and open-air, 40,000 covered and indoor ❖ 30,000 sq. ft. parking space ❖ Is ADA accessible |
| <p>University of Hawaii at Hilo Spare Rooms</p> <ul style="list-style-type: none"> ❖ On-campus classroom and laboratory spaces ❖ Access to university administrative services ❖ Several 1,000 sq. ft. classrooms ❖ Three 3,000 sq. ft. lab spaces ❖ Easily accessible from Hilo International Airport and Highway 11 ❖ Is ADA accessible | |

Select items and workers from this catalog to accomplish tasks.

An item or worker can be selected an unlimited number of times within the given task requirements and budget.

“How long to get results” includes data collection and analysis. Only Field Items may be used in the field and placed on the Kīlauea Map.

SCIENCE TEAM CATALOG

Field Items

Laser Range-Finder



Description: measures the elevation and length of far away objects, such as the surface of a lava lake in a crater below

Data collected: distances to flow fronts, lava lake levels and depths

Ease of transport: difficult (heavy)

Cost / unit: \$5,000

How long to get results: 1 hr

Seismometer Network



Description: a seismometer network contains multiple nodes that record ground shaking by tracking the velocities, depths, and origins of seismic waves in a given area

Data collected: earthquake location and magnitude

Ease of transport: moderate

Cost / unit: \$500

How long it to get results: 2 hr

UAV Overflight – INSAR



Description: over time, repeated drone overflights of an area allows high-precision instruments to detect how the ground surface has inflated, deflated, shifted, or warped

Data collected: ground movement up, down

Ease of transport: easy

Cost / unit: \$10,000

How long to get results: 3 hr

UAV Overflight - Video Footage



Description: drone overflight of an area with a video camera provides an eyewitness viewpoint of eruption phenomena without endangering human life

Data collected: aerial video

Ease of transport: easy

Cost / unit: \$5,000

How long to get results: 0 min

Volcanic Gas Monitoring Kit



Description: A single kit samples volcanic gas emissions to quantify amounts of H₂O (steam), CO₂, and SO₂ released by a nearby vent

Data collected: local volcanic gas concentrations and emission rates

Ease of transport: moderate

Cost / unit: \$200

How long to get results: 5 min

Sampling Kit

(Rock Hammer, Water Bucket, and Thermocouple)



Description: scientists collect a liquid lava sample from a flow and submerge it in water to cool it into solid rock. They insert a thermocouple into the lava flow to measure its temperature.

Data collected: lava temperature, lava samples for geochemical analysis

Ease of transport: difficult (heavy)

Cost / unit: \$50

How long to get sample: 5 min

High-Speed Video Camera



Description: High-resolution cameras capture small explosions with better resolution than simple cameras or the human eye

Data collected: slow-motion eyewitness of eruption; eruption velocity and volume

Ease of transport: easy

Cost / unit: \$2,000

How long to get results: 0 min

Sampling Kit

(Shovel and Sieve Set)



Description: scientists collect buckets of material from blankets of ash ejected by a vent. They then sort these ash particles by size to determine the velocity and intensity of the eruption

Data collected: eruption intensity, ash particle size, ash particle distribution; tephra samples for geochemical analysis

Ease of transport: moderate

Cost / unit: \$200

How long to get results: 30 min

Select items and workers from this catalog to accomplish tasks.

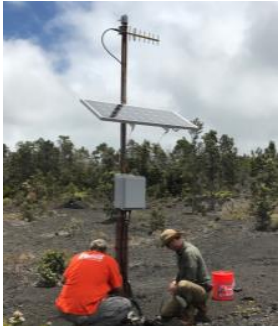
An item or worker can be selected an unlimited number of times within the given task requirements and budget.

"How long to get results" includes data collection and analysis. Only Field Items may be used in the field and placed on the Kīlauea Map.

SCIENCE TEAM CATALOG

Field Items

Tiltmeter



Description: uses a level to determine ground movement relative to horizontal, such as relative inflation and deflation

Data collected: deformation (inflation/deflation)

Ease of transport: difficult (heavy)

Cost / unit: \$750

How long to get results: 1 hr

Livestream Webcam



Description: solar-powered video camera livestreams eruption footage to get a real time view of activity

Data collected: ground-based video

Ease of transport: moderate

Cost / unit: \$1,000

How long to get results: 0 min

Laboratory Items

Binocular Microscope



Precision: low

Description: microscope used for visually assessing small fragments or slices of lava and tephra samples

Data collected: sample texture and mineral content

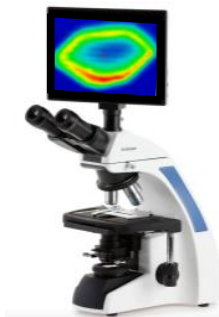
Analysis cost / sample: \$25

Instrument cost / unit: \$500

How long to get results: 10 mins

De-installation time: 30 min

Fourier Transform Infrared Microscope



Precision: moderate

Description: microscope measures how a sample absorbs of different wavelengths of electromagnetic radiation

Data collected: sample chemical composition, including gas content

Analysis cost / sample: \$25

Instrument cost / unit: \$1,500

How long to get results: 10 mins

De-installation time: 30 min

Backscatter Electron Imaging Analysis on Scanning Electron Microscope



Precision: moderate

Description: electrons are fired at the sample surface; some bounce back. "Bounce-back" creates an image where denser materials appear brighter, less dense materials appear darker.

Data collected: microscopic mineral identification and chemical composition

Analysis cost / sample: \$50

Instrument cost / unit: \$200,000

How long to get results: 30 min

De-installation time: 6 hr

Electron Microprobe Geochemical Analysis



Precision: very high

Description: an electron beam is fired at a sample, causing the sample to release electromagnetic waves. Software converts these waves into chemical information.

Data collected: sample chemical composition, including gas content

Analysis cost/sample: \$125

Instrument cost / unit: \$1 million

How long to get results: 1 day

De-installation time: 6 hr

Automatic Sieve Kit



Precision: moderate

Description: scientists collect buckets of material from blankets of ash ejected by a vent. They sort these ash particles by size to determine the velocity and intensity of the eruption.

Data collected: eruption intensity, ash particle distribution

Analysis cost / sample: \$25

Instrument cost / unit: \$2,000

How long to get results: 15 min

Hours for de-installation: 2 hr

Mass Spectrometer Geochemical Analysis



Precision: very high

Description: a sample is carefully processed with acid to isolate the element of interest. Atoms of that element are then accelerated through a magnetic field, allowing each isotope of that element to be counted separately.

Data collected: element isotope ratio, which acts as a fingerprint of the lava sample's source within the volcano

Analysis cost / sample : \$200

Instrument cost / unit: \$2 million

How long to get results: 2 weeks

De-installation time: 8 hr

RESIDENT TESTIMONIALS

During the 2018 eruption, Puna District residents provided the quotes and context below to media outlets.

"I lived my life here, I raised my kids here, I buried animals here, I married my wife here, and you know, naked as it is, it's still where I've lived for 25 years. And I said when I die, they'll spread my ashes here."

Sam Knox

Leilani Estates Resident, owner of property cross-cut by Fissure 8

"They say there is a mandatory evacuation but no-one's come to tell us we have to go yet. If you do leave, the question is when will they let you back in, and you have to worry about people looting. We'll stay until they make us leave."

Joyce Jennett

Owns a home 1.2 miles away from active vent

"I'm not going, because this is my home. This is everything I have. Everything I worked for all my life is right here. Why would I leave?"

Hannique Ruder

Leilani Estates Resident

"If Pele comes, Pele comes. We have to do what we got to do, but ... now we're kind of crossing our fingers to see what Pele might do next."

Curt Redman

Puna Resident

"You're in Lava Zone 1, so it's always in your head that it could happen. But for the last 30 years, it's been flowing down to Kalapana. Then in 2014, it almost cut Pahoa in half."

"I don't think anyone thought it would be a reality. They know it was coming, I just don't think anybody ever thought it would be in their lifetime."

Heath Dalton

Leilani Estates Resident

Claims that people who live in the area choose to take a risk. Many do because land is so cheap. A small lot can be purchased for just \$8,000 if you're willing to put in the effort to clear it and understand the risk that comes with living on the side of an active volcano. Because the community sits in a zone deemed by the U.S. Geological Survey to have a high risk of lava, few insurance companies will issue policies there. And those policies that are available cost thousands of dollars a year, a hefty cost many residents simply forgo. According to the Census Bureau, the median family income in Pahoa is about \$30,000 annually. "They knew what they were getting into."

Jeno Encencio

Puna Resident

After a divorce a few years ago, she got full ownership of her four-bedroom house, which was valued at about \$200,000 before the eruption. With her mortgage paid off, she lived simply, subsisting on disability payments after being diagnosed with a disease affecting the central nervous system. She drives a battered 2003 Toyota Echo that she recently bought for \$700. "Who's going to want to buy my home now?" Ms. Garnett asked, emphasizing that she could not afford to buy insurance for volcanic activity. "I'm facing the prospect of losing all I have."

Ms. Garnett

Leilani Estates Resident

"We had to evacuate. My mother was out of portable oxygen, so that's a first concern. She's 88 years old."

Stephen Clapper

Evacuee

"We've made a home away from home. We accept where we are now, but we are looking forward to getting home."

Dennis Gillespie

Leilani Estates Resident, Evacuee

"My house is surrounded by lava right now. I can't ever get back into my house until they build another road."

"I'm one of the fortunate few. My home is still standing. Although I can't go back to it for the foreseeable future, I still have a home. Those people there are losing their homes as we speak. Their homes are being burnt down left and right. It has changed my life dramatically like everybody else,

Victor Hoapili

Leilani Estates Resident

"It's been a real shocker. We're about to enjoy eating dinner, and the cops show up and tell us you have to go, and everything changes in an instant. You have five minutes to pack your bags with what you think you're going to need and you're off."

Timothy Trun

Leilani Estates Resident

"Just basically heartbreak. My wife and I have been married going on 26 years. It was pretty much our dream home that we've been looking for all this time. Just knowing that we're not going to have a house, my wife is still in tears."

Neil Valentine

Leilani Estates Resident

"I woke up at about 1 a.m. I heard a roar — and this is two miles away — a roar, like a jet engine. I go out and I look out the window and I see the sky glowing red. [There was] a cinder cone being created, lava spewing in the air 100 feet. I was standing about 50 yards from that and I could feel the warmth. It was probably 90 degrees Fahrenheit. Just the sound, the experience, the ground was shaking."







Scott Wiggers

Leilani Estates Resident

VOLCANIC ACTIVITY NOTICE (VAN) GUIDE

Criteria for issuing a Volcanic Activity Notice (VAN) and Volcano Observatory Notice for Aviation (VONA). Each announcement includes a Volcano Alert Level (normal, advisory, watch, or warning) and Aviation Color Code (red, orange, yellow, green). Acceptable combinations of Alert Level and Color Code are listed in the table at top right. Generally, a volcanic activity update is called a VAN; if it is particularly relevant to aviation hazards, it may be more appropriate to call the announcement a VONA. Each VAN/VONA includes the date and observations of eruptive activity. Quantitative information is included as often as possible.

Allowed Combinations for Volcano Updates

| | | Aviation Color Code | | | | | |
|----------------------|----------|---|---|---|---|----------------------------|--|
| | | Green | Yellow | Orange | Red | Inc. level of concern ↓ | |
| Volcano Alert Levels | Normal |  | | | | | |
| | Advisory | |  | | | | |
| | Watch | | |  |  | | |
| | Warning | | |  |  | | |
| | | ← Increasing level of concern → | | | | | |

Example Volcanic Activity Notice (VAN)

from Tuesday, April 24, 2018

KĪLAUEA VOLCANO

Current Volcano Alert Level: WATCH

Current Aviation Color Code: ORANGE

High lava lake levels in the informally named “Overlook Crater” within Halema’uma’u at the summit of Kīlauea Volcano have resulted in a series of overflows of lava onto the Halema’uma’u crater floor, beginning late on April 21 and continuing intermittently through this morning. These are the first significant overflows of the summit lava lake since May 2015 (a small overflow also occurred in October 2016). Accompanying this high stand of lava within the Overlook crater are nearly continuous areas of spattering along the margins of the lava lake. Sulfur dioxide gas emissions from the lake remain elevated.

Volcano Alert Levels Used by USGS Volcano Observatories

Alert Levels inform people on the ground about a volcano’s status and are issued in conjunction with the Aviation Color Code. Notifications are issued for both increasing and decreasing volcanic activity. They are accompanied by text about the nature of the unrest and/or eruption and its potential or current hazards.

| Term | Description |
|-----------------|--|
| NORMAL | Volcano is in typical background, noneruptive state or, after a change from a higher level, volcanic activity has ceased and volcano has returned to noneruptive background state. |
| ADVISORY | Volcano is exhibiting signs of elevated unrest above known background level or, after a change from a higher level, volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase. |
| WATCH | Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain, OR eruption is underway but poses limited hazards. |
| WARNING | Hazardous eruption is imminent, underway, or suspected. |

Aviation Color Code Used by USGS Volcano Observatories

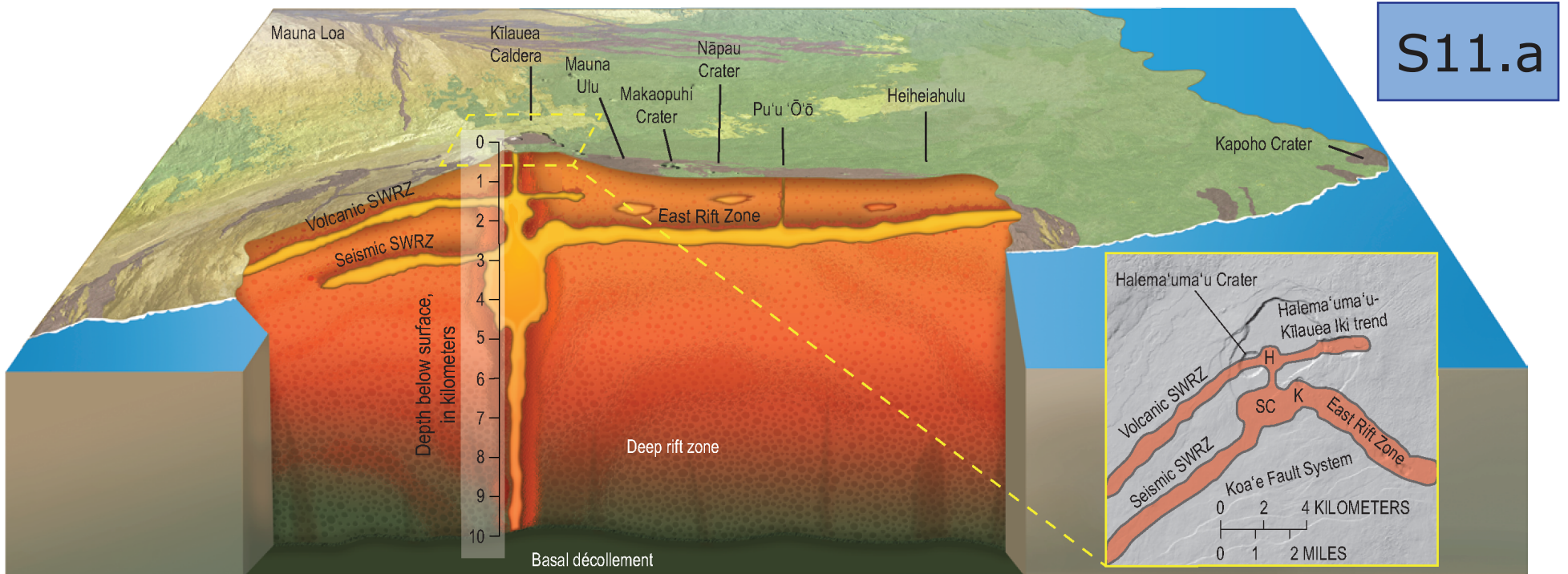
Color codes inform the aviation sector about a volcano’s status and are issued in conjunction with the Volcano Alert Level. Notifications are accompanied by text about the nature of the unrest or eruption, especially in regard to ash-plume information. Ash emissions are particularly hazardous to commercial air travel if they reach heights of 3,000 m (10,000 ft) or greater.

| Color | Description |
|---------------|--|
| GREEN | Volcano is in typical background, noneruptive state or, after a change from a higher level, volcanic activity has ceased and volcano has returned to noneruptive background state. |
| YELLOW | Volcano is exhibiting signs of elevated unrest above known background level or, after a change from a higher level, volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase. |
| ORANGE | Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain, OR eruption is underway with no or minor volcanic-ash emissions [ash-plume height specified, if possible]. |
| RED | Eruption is imminent with significant emission of volcanic ash into the atmosphere likely OR eruption is underway or suspected with significant emission of volcanic ash into the atmosphere [ash-plume height specified, if possible]. |

* Note: emission events may qualify as “significant” from their intensity and/or frequency. If many emission events occur within a short timeframe (high frequency), then they may be significant regardless of their low intensity. If a single emission event is very powerful (high intensity), then it may be significant regardless of its low frequency.

KĪLAUEA VOLCANIC PLUMBING SYSTEM

Schematic cross section of magma reservoirs and conduits within the Kīlauea volcanic edifice. First, molten material ascends into the system from the mantle. Then, this material is stored below the summit region in a magma chamber or series of magma chambers. This magma may intrude laterally into “arms” of the plumbing system, called “rift zones”, where it may stagnate or erupt.

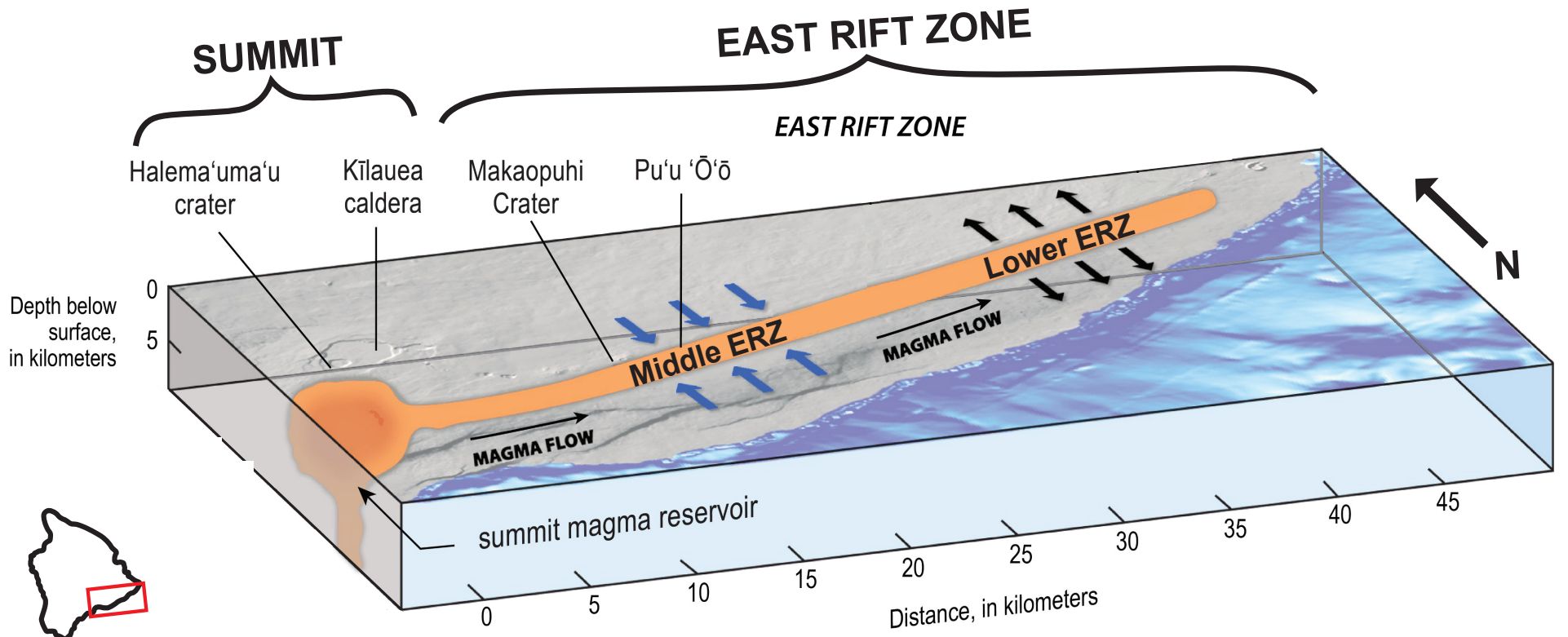


S11.a

KĪLAUEA EAST RIFT ZONE PLUMBING SYSTEM

Schematic cross section of the East Rift Zone (ERZ), the most active rift zone of Kīlauea Volcano. Arrows in the Middle and Lower ERZ indicate deformation in these regions during the onset of the 2018 eruption.

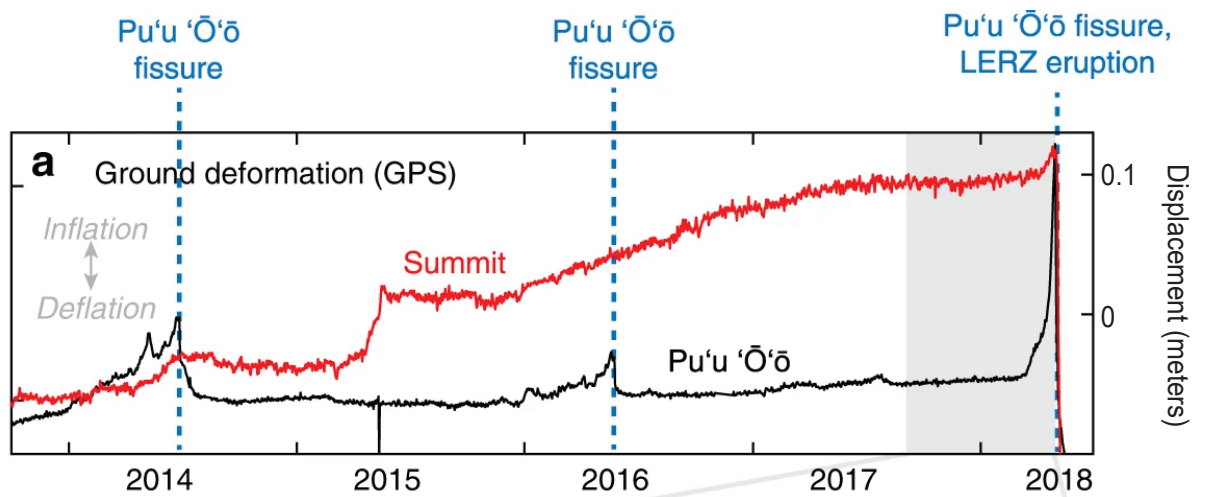
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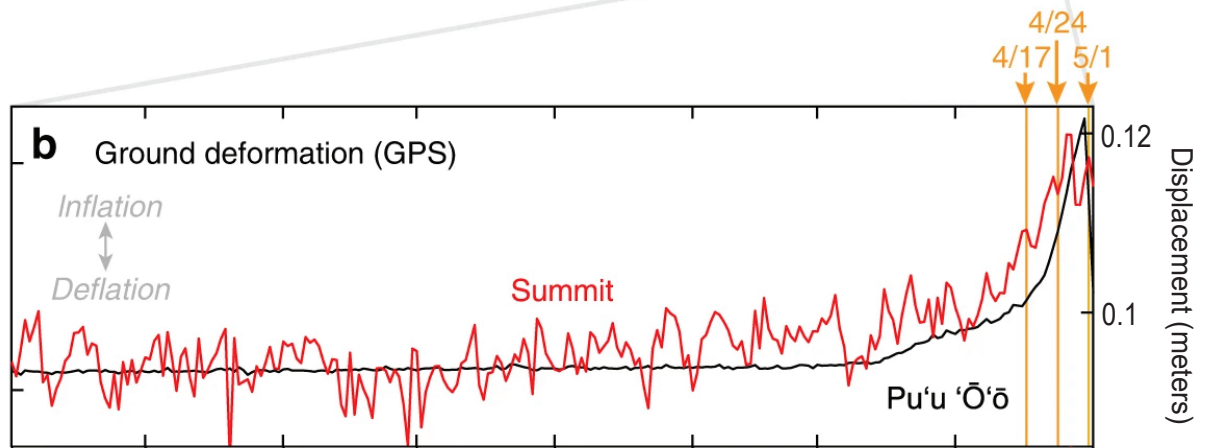
S11.c

DEFORMATION AND SEISMICITY PRECEDING 2018 ERUPTION

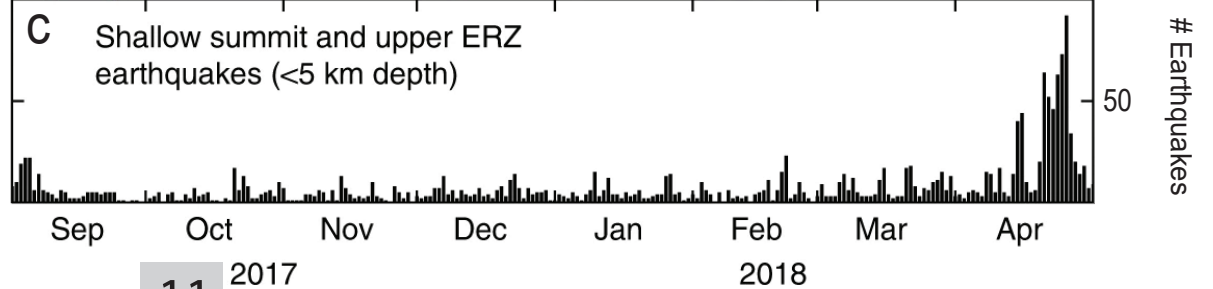
a) Ground deformation (in meters) measured by GPS from 2013 to 2018. Red line gives trend for the Kīlauea summit region; black line gives trend for the MERZ. Note the relationship between deformation and the timing of MERZ fissure openings.



b) Ground deformation (in meters) measured by GPS from late 2017 to early 2018. Red line gives trend for the Kīlauea summit region; black line gives trend for the MERZ. Note sudden changes the MERZ trend at the beginning of May 2018.



c) Frequency of shallow earthquakes in the Kīlauea summit and upper ERZ.



VOLCANIC GAS & ASH EXPOSURE FACT SHEET

Information on health hazards and symptoms of exposure to sulfur dioxide (SO₂; a major constituent of volcanic gas emissions) and volcanic ash (the smallest particle fraction of solid material ejected from a vent). Winds may disperse gas and ash far from the eruptive vent, so this hazard is relevant to communities within and outside the Kīlauea LERZ.

HAZARDS OF SO₂ AND VOLCANIC ASH EXPOSURE

What is Sulfur Dioxide?

Sulfur dioxide is a colorless gas with a strong odor that is released into the atmosphere during volcanic eruptions. It can cause negative health effects for people exposed.

What is Volcanic Ash?

Volcanic ash consists of fine particles of volcanic rock that are less than 2mm in diameter. It can affect wide areas around an eruption and can cause negative health effects for people exposed.

EFFECTS OF EXPOSURE

Eye Symptoms

- SO₂ exposure can lead to eye irritation, burning, and possible eye damage
- Volcanic ash exposure can lead to eyes becoming itchy, painful, or bloodshot, eye discharge, and corneal scratches

Other Symptoms

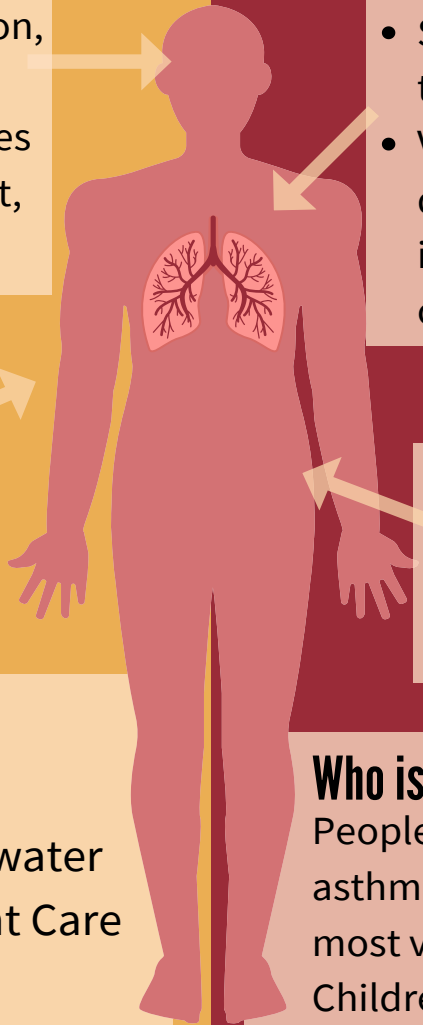
- SO₂ exposure can also lead to loss of smell, headaches, nausea, and dizziness

Respiratory Symptoms

- SO₂ exposure can lead to irritation of the nose, throat, and lungs
- Volcanic ash exposure can lead to chest discomfort, increased coughing, throat irritation, nasal irritation, and shortness of breath

Skin Symptoms

- SO₂ exposure can lead to skin irritation and burning
- Volcanic ash exposure can lead to skin irritation such as itching or scratching



First Aid for SO₂ Exposure

Remove person from exposure.

For **eye irritation**, flush eyes with water for at least 15 minutes, go to Urgent Care if symptoms continue.

For **skin irritation**, immerse skin in water, go to Urgent Care if symptoms continue.

For **respiratory symptoms**, go to Urgent Care. Severe symptoms may indicate pulmonary edema (fluid buildup in lungs) where hospitalization will be required.

Who is Vulnerable?

People with chronic lung diseases such as asthma, bronchitis, or emphysema are the most vulnerable to both SO₂ and volcanic ash. Children are the most vulnerable age group to volcanic ash.

Protect yourself from volcanic ash by limiting driving, wearing eye protection and ash masks, closing windows and doors, and keeping children indoors.

MAGMA GEOCHEMISTRY TABLE - May 3

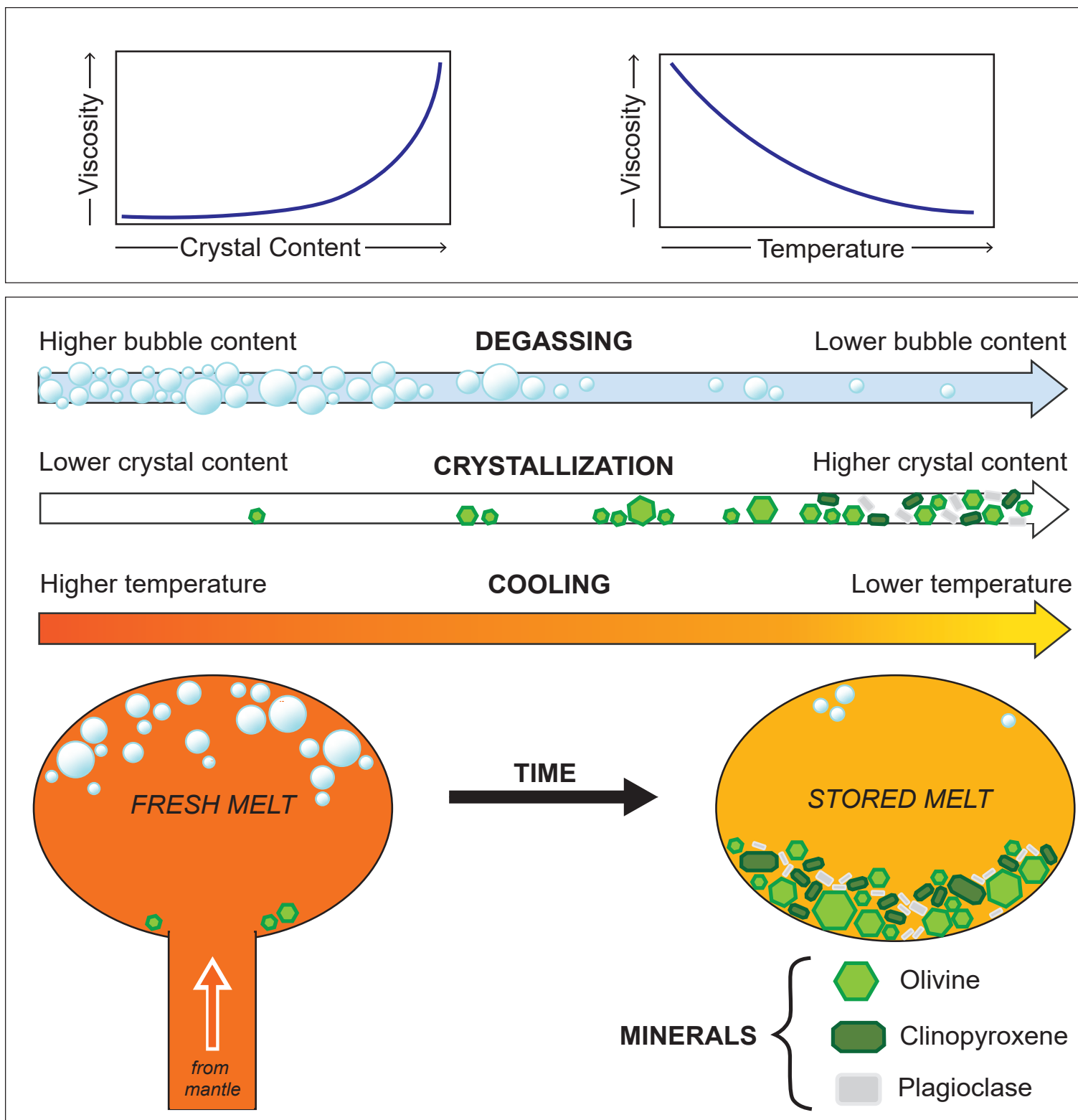
Table listing composition and physical properties of lava samples collected from LERZ fissures. For reference, information on “fresh” lava from deep within the volcanic edifice and “stored” within the shallow volcanic edifice is also provided. Relative percentage of aluminum oxide (Al_2O_3), magnesium oxide (MgO), and calcium oxide (CaO) are given because concentrations of Al, Mg, and Ca in a lava change as a magma cools and forms crystals (see below). These shifts in composition correspond with changes in physical properties of the lava, such as temperature, crystal and bubble content, and viscosity (resistance to flow). Bulk magma viscosity describes the flow of the magma as a whole, including liquid, solid (crystals), and gas (bubbles). Melt viscosity describes the flow of the liquid only.

| | 2018 FISSURE SAMPLE LAVA | REFERENCE LAVA | |
|------------------------------------|--------------------------|----------------|----------|
| | May 3 Fissure 1 | “Fresh” | “Stored” |
| Major Element Concentration | | | |
| Al_2O_3 (wt. %) | 12.32 | 13.51 | 2.25 |
| MgO (wt. %) | 4.35 | 10.98 | 2.79 |
| CaO (wt. %) | 8.45 | 10.01 | 6.74 |
| Physical Properties | | | |
| Temperature ($^{\circ}\text{C}$) | 1100 | 1145 | 1070 |
| Crystal content (by volume) | 35% | 2% | 40% |
| Bubble content (by volume) | 10% | 60% | 5% |
| Melt viscosity (Pa s) | 1820 | 140 | 13000 |
| Bulk magma viscosity (Pa s) | 6640 | 950 | 35000 |

S13.a

MAGMATIC PROCESSES AND THEIR EFFECT ON MAGMA PROPERTIES & CHEMISTRY

Schematic diagrams illustrating the effects of degassing, crystallization, and cooling on magma chemistry and physical properties. Degassing refers to the process of magma releasing gas into the surrounding environment, within the volcano or on its surface. Crystallization refers to the process of magmatic liquid (melt) turning into a solid (crystals) with the composition of various minerals (olivine, clinopyroxene, and plagioclase feldspar). Cooling refers to the loss of heat from the magma body. Note the changes in melt chemistry associated with crystallization of each mineral.



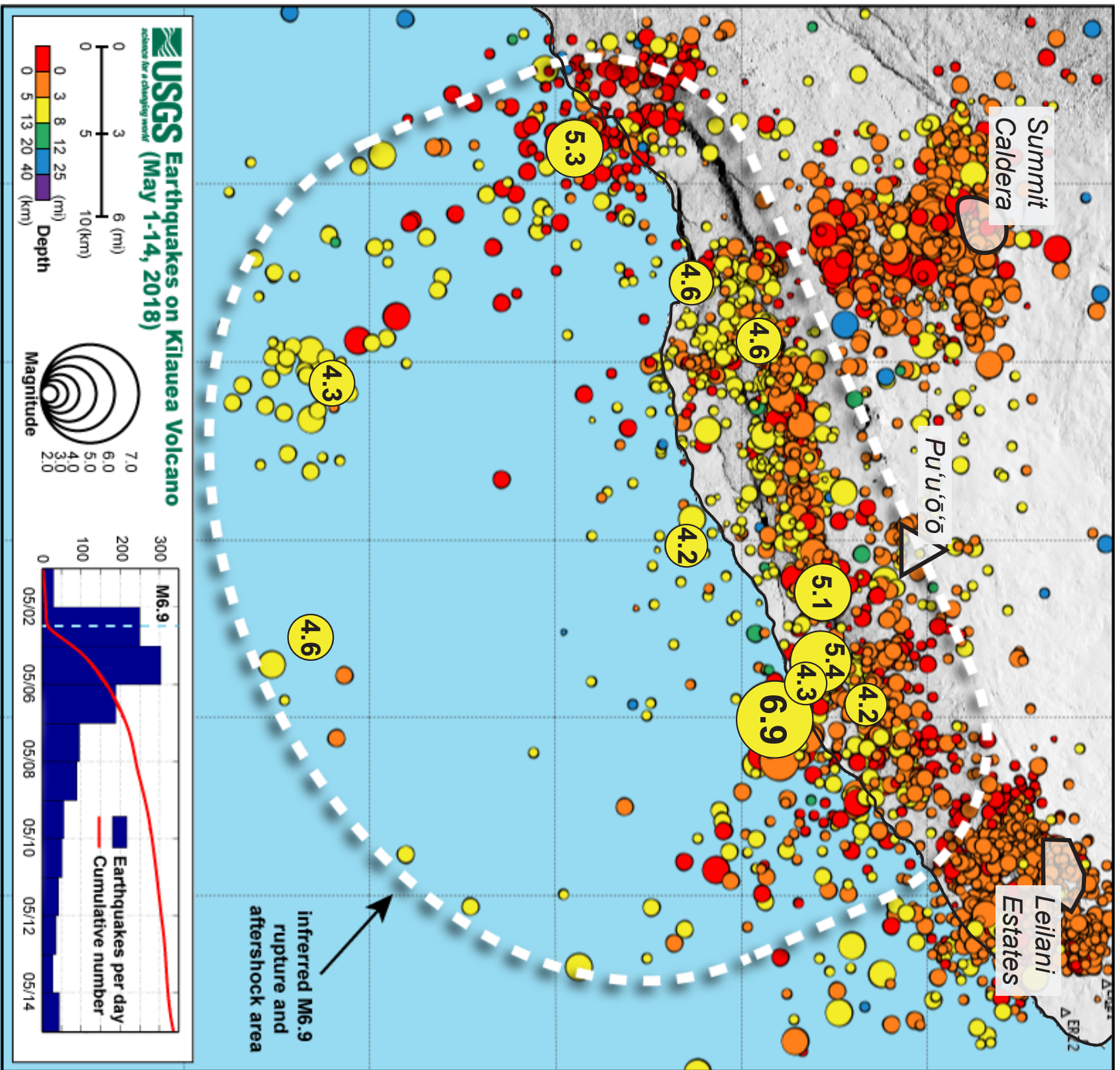
S13.b

| This mineral . . . | is rich in these elements . . . | so crystallization causes the melt to decrease in contents of . . . |
|--------------------|---------------------------------|---|
| Olivine | magnesium | MgO |
| Clinopyroxene | calcium, magnesium | CaO, MgO |
| Plagioclase | calcium, aluminum | CaO, Al_2O_3 |

S14.a

MAP OF M6.9 EARTHQUAKE AND LERZ SEISMICITY

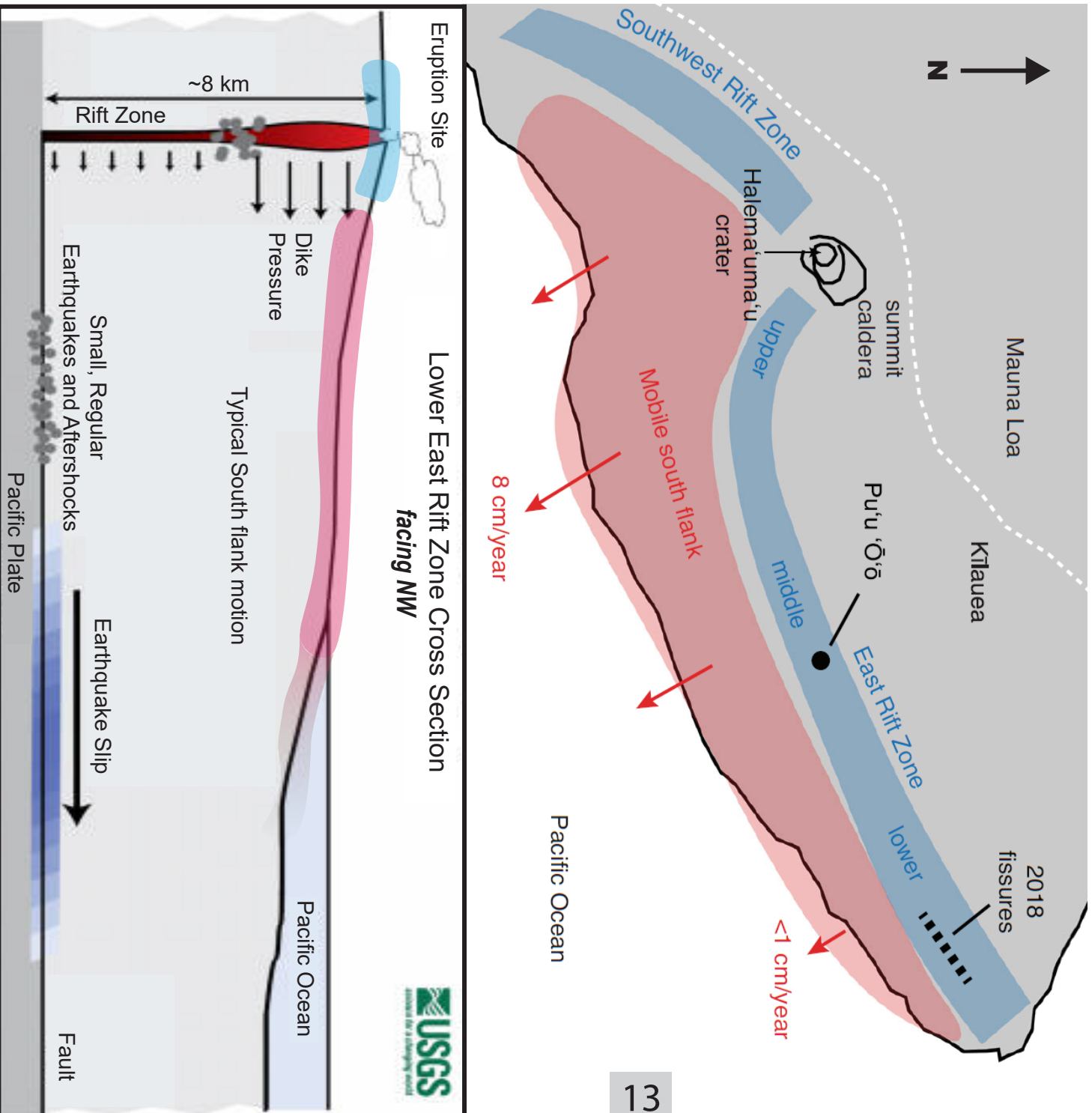
Magnitude (circle size), depth (circle color), and epicenter location of earthquakes in the Kilauea LERZ from May 1 - May 14, including the M6.9 earthquake and its aftershocks.



S14.b

DIAGRAM OF KILAUEA SOUTHERN FLANK MOTION

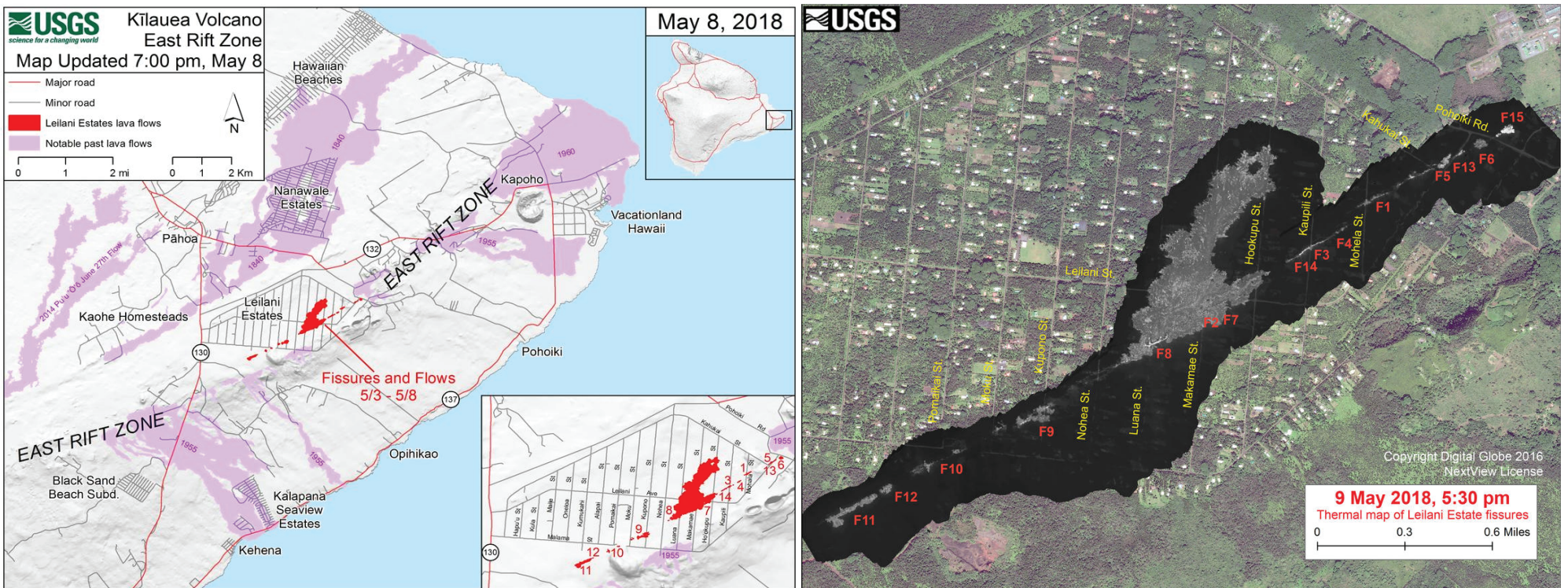
Schematic diagrams illustrating the motion of the southern flank of Kilauea. The M6.9 earthquake occurred along the base of the Kilauea volcanic edifice and the underlying Pacific Plate (bottom). The slip direction along this fault demonstrates how Kilauea's southern flank moved to the southeast, relieving pressure and allowing expansion in the rift zones (top).



LERZ ACTIVE FISSURE MAPS - May 8 to 9

General (left) and thermal (right) maps of active LERZ fissures and flows. On the thermal map, black indicates areas where no lava is present; areas with grayscale fill indicate active flows, with lighter grays indicating higher surface temperatures.

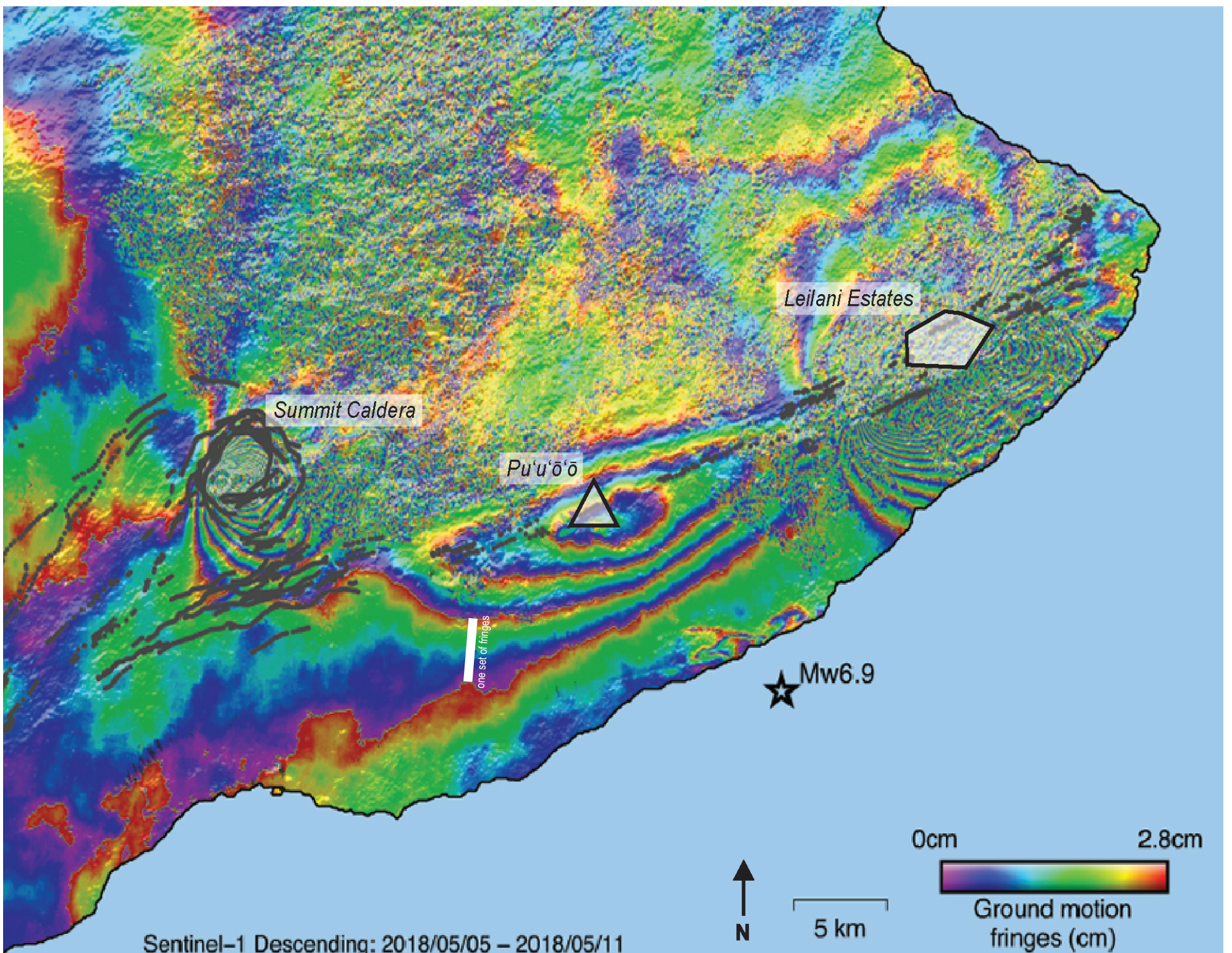
S15.a



LERZ DEFORMATION MAP - May 5 to 11

Interferometric Synthetic Aperture Radar (InSAR) data illustrating deformation of the Kīlauea volcanic edifice. Each sequence of rainbow colors ("fringes") represents 3 cm of motion, either up or down. One "fringe" is marked on the map below with a thick white line. A given set of concentric fringes (starting at purple and ending at red) indicates downward motion of the ground surface if the blue fringe forms a larger circle than the red fringe (i.e., if the blue circle is outside the red circle). Conversely, if the blue circle forms a smaller circle than the red fringe (i.e., if the blue circle is inside the red circle), then the fringe sequence indicates upward motion.

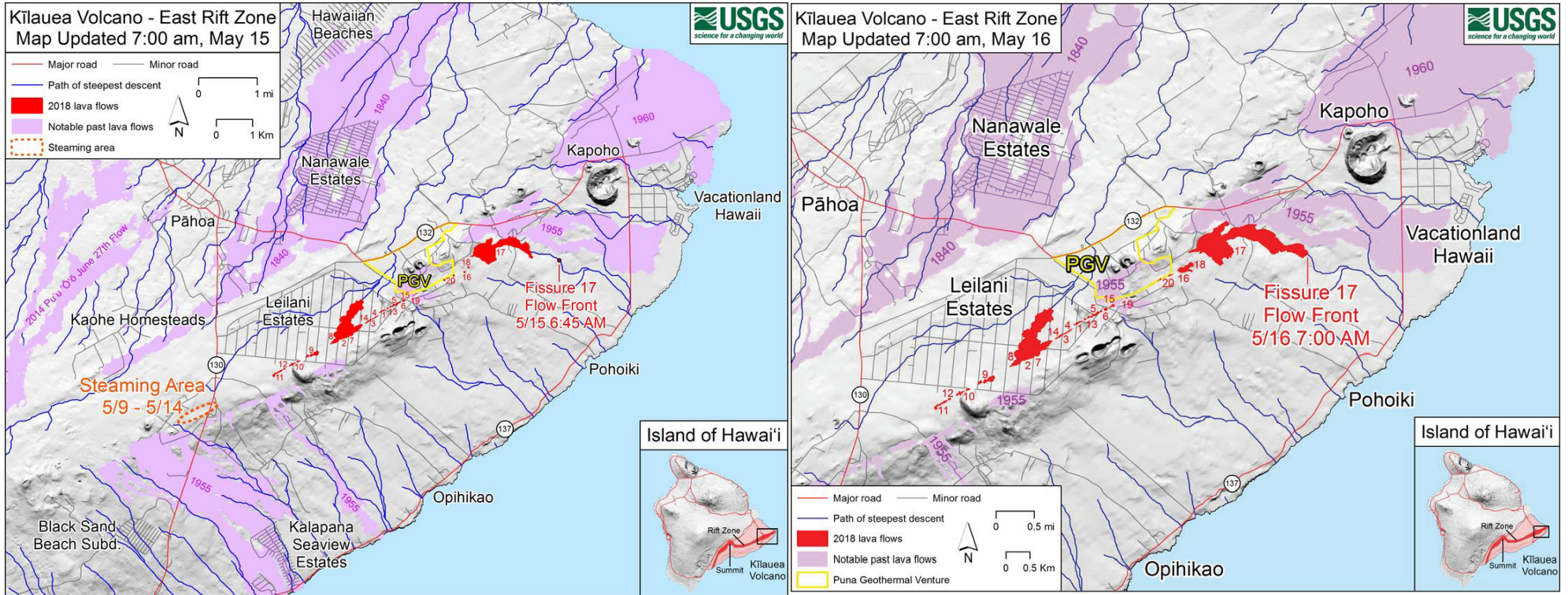
S15.b



LERZ ACTIVE FISSURE MAPS - May 15 to 16

Map of active fissures and flows (red regions) in the LERZ.

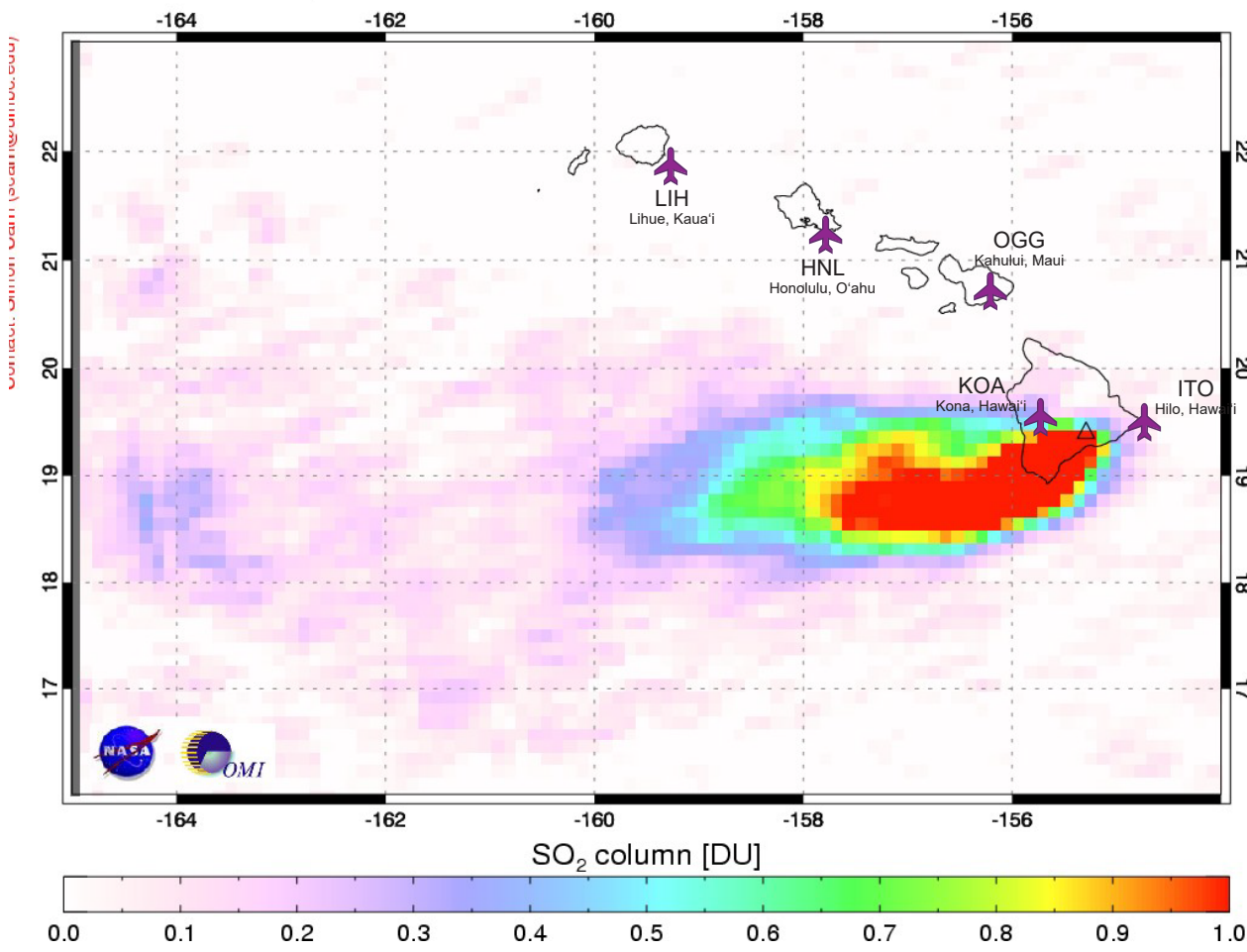
S16.a



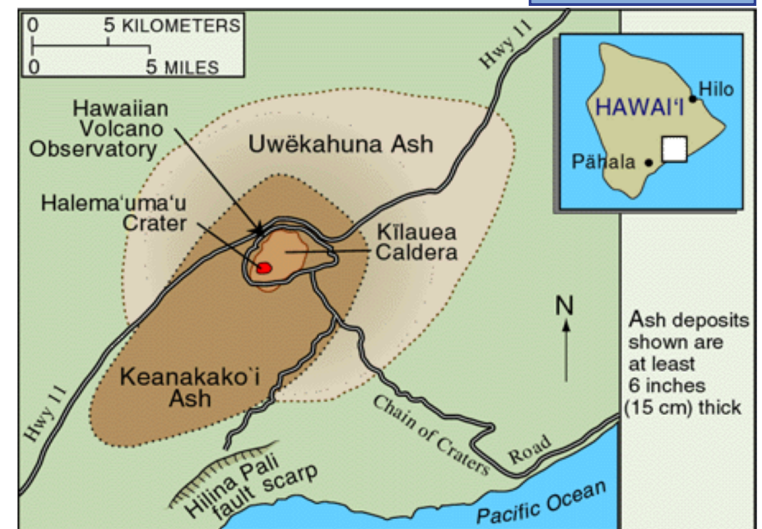
S16.b

SO₂ DISTRIBUTION MAP (left)

Output from NASA's satellite-based Ozone Monitoring Instrument, recording the concentration of sulfur dioxide (SO₂) released during a single explosive event in the Kīlauea summit region on March 19, 2008. This explosive event is an analog for explosive events in the summit region in 2018. SO₂ concentration is reported in Dobson Units (DU); one DU is equal to 0.0285 g of SO₂ in a volume of air with a base of one m² and a height of 0.01 mm. Also marked on the map are locations of important airports in the Hawaiian Islands.

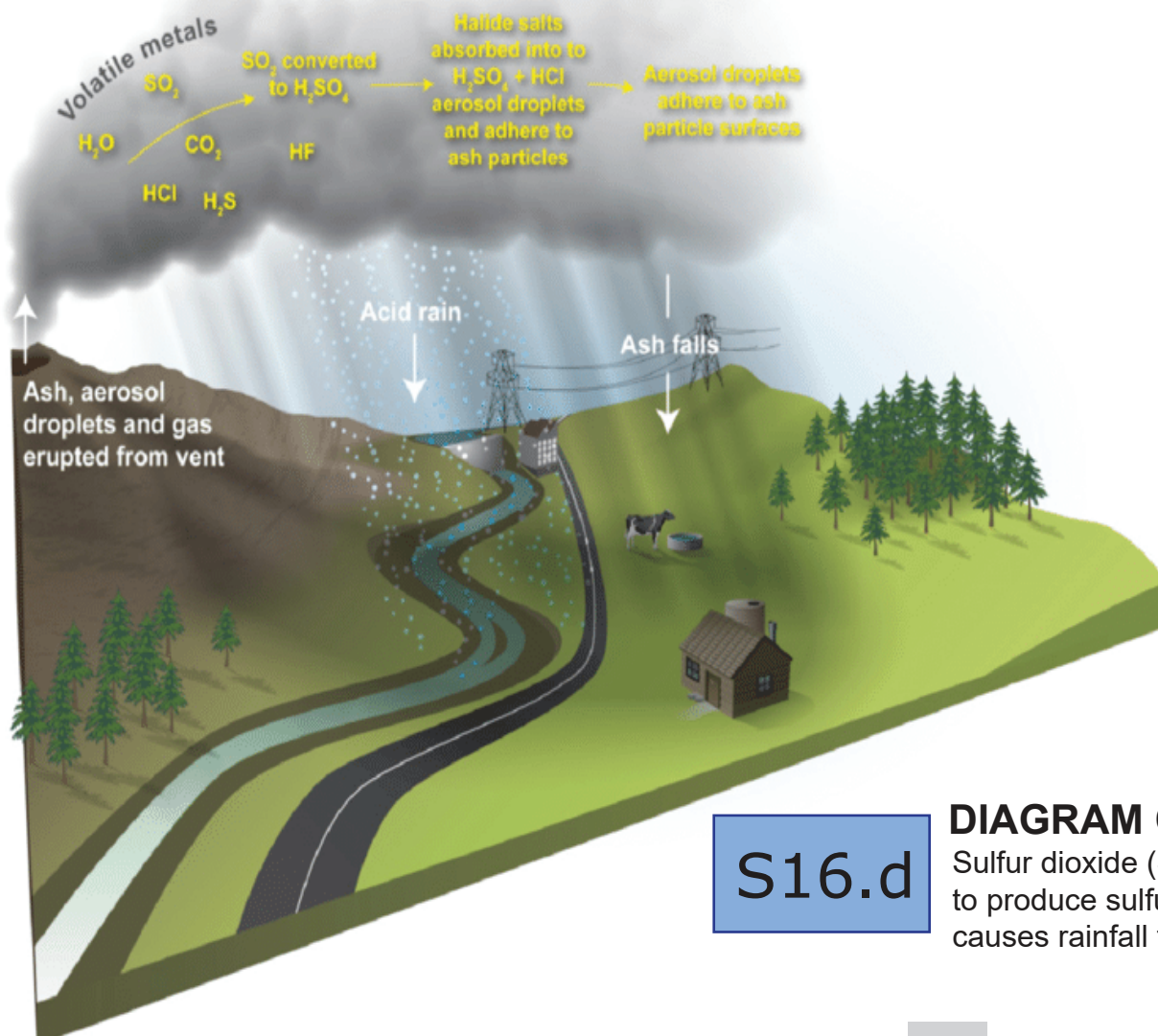


S16.c



ASH DISTRIBUTION MAP (above)

Approximate spatial distribution of ash blankets from historical explosive episodes of activity within Kilauea Caldera. Note: these ash blankets were produced by many explosive events over many centuries; the ash blanket from explosive events in 2018 may have a similar distribution, but would be much, much thinner than 15 cm.



S16.d

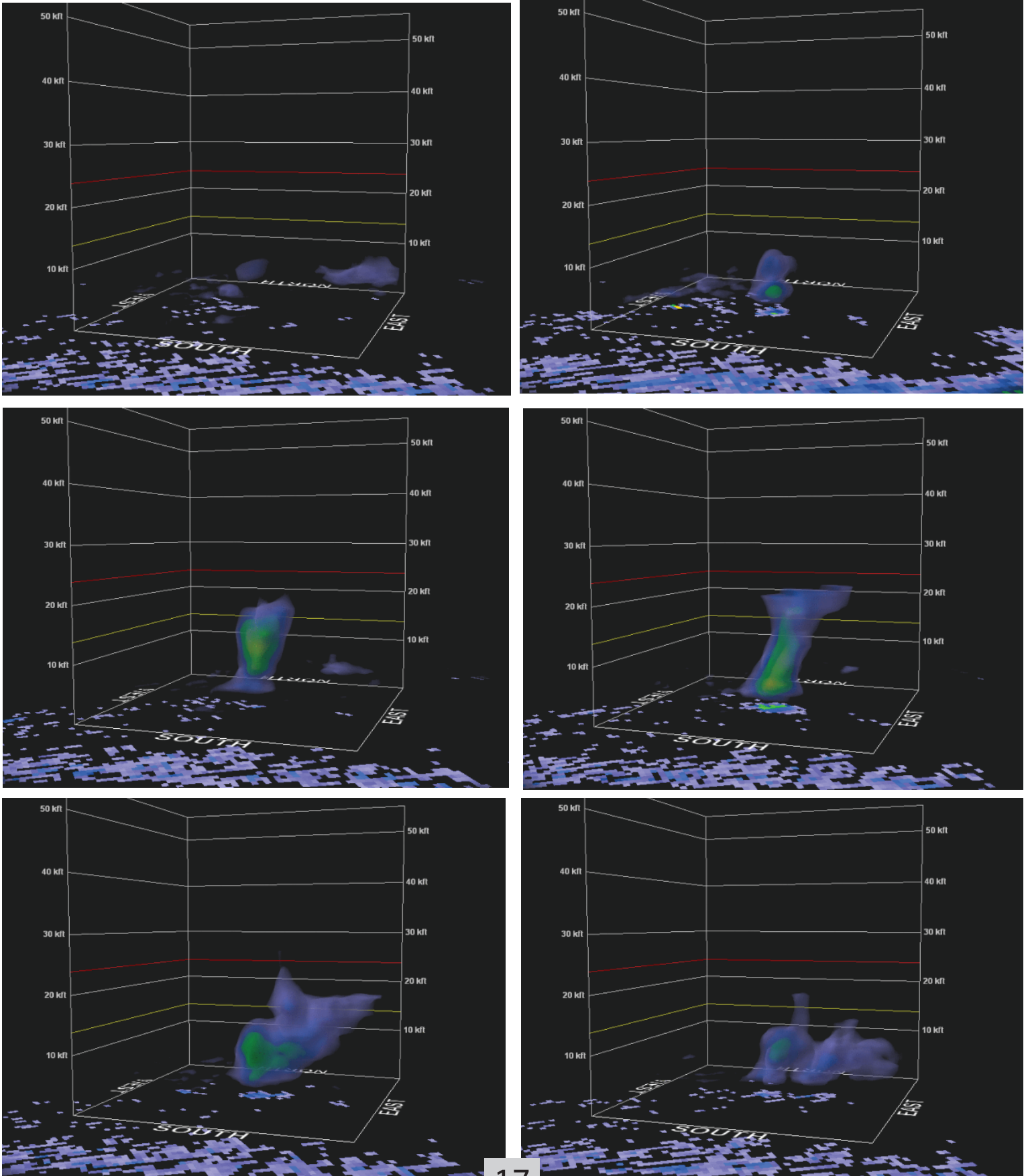
DIAGRAM OF ATMOSPHERIC EFFECTS OF SO₂

Sulfur dioxide (SO₂) reacts with water vapor (H₂O) in the atmosphere to produce sulfuric acid (H₂SO₄) and sulfur aerosols. Sulfuric acid causes rainfall to be more acidic.

MODEL RESULTS OF MAY 17 ERUPTIVE PLUME

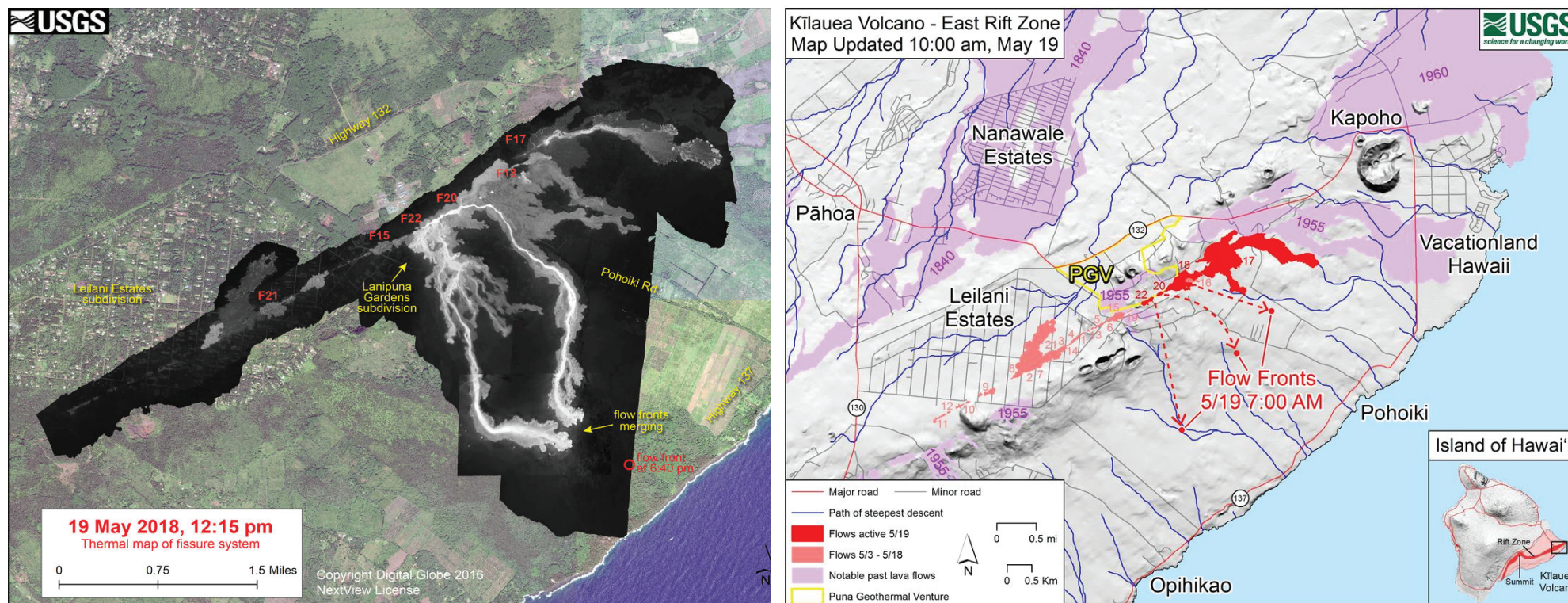
S17

The images below are screenshots of a three-dimensional model of SO₂ concentration in the eruptive plume from the May 17 explosion in the summit caldera. Blue indicates low SO₂ concentration; yellow indicates high SO₂ concentration. The Z (vertical) axis is height above sea level in thousands of feet ("kft"); this view of the eruptive plume is from the southeast.



LERZ ACTIVE FISSURE MAPS - May 19

Thermal (left) and general (right) map of active fissures and flows. On the thermal map, black indicates areas where no lava is present. Gray areas indicate the presence of lava on the surface, with lighter grays indicating higher temperatures.



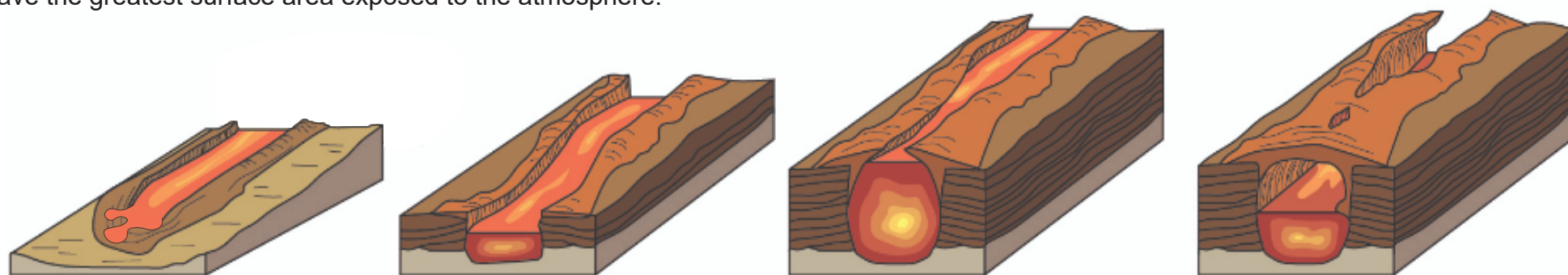
MAGMA GEOCHEMISTRY TABLE - May 3, 12, & 19

Table listing composition and physical properties of lava samples collected from LERZ fissures. For reference, information on “fresh” lava from deep within the volcanic edifice and “stored” within the shallow volcanic edifice is also provided. Relative percentage of aluminum oxide (Al₂O₃), magnesium oxide (MgO), and calcium oxide (CaO) are given because concentrations of Al, Mg, and Ca in a lava change as a magma cools and forms crystals (see below). These shifts in composition correspond with changes in physical properties of the lava, such as temperature, crystal and bubble content, and viscosity (resistance to flow). Bulk magma viscosity describes the flow of the magma as a whole, including liquid, solid (crystals), and gas (bubbles). Melt viscosity describes the flow of the liquid only.

| | 2018 FISSURE SAMPLE LAVA | | | REFERENCE LAVA | |
|--|---------------------------|-----------------------------|-----------------------------|----------------|----------|
| | May 3 <i>Fissure 1</i> | May 12 <i>Fissure 16</i> | May 19 <i>Fissure 20</i> | “Fresh” | “Stored” |
| Major Element Concentration | | | | | |
| Al ₂ O ₃ (wt. %) | 12.32 | 12.54 | 13.03 | 13.51 | 2.25 |
| MgO (wt. %) | 4.35 | 4.79 | 5.61 | 10.98 | 2.79 |
| CaO (wt. %) | 8.45 | 9.09 | 9.68 | 10.01 | 6.74 |
| Physical Properties | | | | | |
| Temperature (°C) | 1100 | 1110 | 1110 | 1145 | 1070 |
| Crystal content (by volume) | 35% | 23% | 8% | 2% | 40% |
| Bubble content (by volume) | 10% | 10% | 50% | 60% | 5% |
| Melt viscosity (Pa s) | 1820 | 1072 | ? | 140 | 13000 |
| Bulk magma viscosity (Pa s) | 6640 | 2890 | ? | 950 | 35000 |

DIAGRAM OF LAVA FLOW CROSS SECTIONS

Schematic diagram illustrating cross sections of an active pāhoehoe lava flow. A single flow may have any or all of these cross sections at different times during the eruption and at different distances from the main eruptive vent. These morphologies develop because lava cools quickly to form a solid crust. This crust allows lava flows to be “constructive,” building levees and roofs around and over the flow channel. This crust also insulates the lava, preventing heat loss and maintaining its fluidity. In general, the sections of the flow that cool fastest will have the greatest surface area exposed to the atmosphere.



1. A continuously fed, fluid lava flow moves downslope. “Breakouts” at the front and edges of the flow cause the flow front to advance.
2. As the flow continues, its outermost edges solidify and it becomes “channeled” into a few main streams. Overflows of lava from these streams create stacked layers of lava on either side of the channel.
3. As channel walls and levees build over time, the channel develops a taller, narrower cross section. The edges of the channel may cool and solidify inwards, forming the beginnings of a “roof.”
4. This roof may cover the channel entirely, enclosing the channel to form a lava tube. Although lava may not be visible from the surface, it may still be flowing great distances at high temperatures.

LERZ ACTIVE FISSURE MAPS - May 30 to June 1

General (left) and thermal (right) maps of active fissures and flows. On the thermal maps, black indicates areas where no lava is present; filled gray areas with no change in grayscale represent areas covered with previous flows from the 2018 eruption; and areas with variable grayscale fill represent active surface lava flows, with lighter grays indicating higher temperatures.

