Suggested Lesson Outline for
Columns of the Giants Immersive Virtual Field Experience

Each "stop" of this Immersive Virtual Field Experience (IVFE) is designed to have students generate geologic inferences about the observable landscape seen at the Columns of the Giants in the Sierra Nevada Mountains, California. The experience facilitates careful observations, the underutilized skill of scientific sketching and open-ended scientific discourse between small groups of three students as well as whole-group class discussions led by an instructor. *This should not be a hands-off activity for the instructor.*

Learning Goals

1. Students will explore the six nonannotated "Stops" without guidance from questions to make sketches and notes of observations they think are geologically interesting or useful.
2. Students will partake in small group and large group scientific discourse.
3. Students will use their data to synthesize a geologic story that explains the formation of the Columns of the Giants.
4. Student will apply their new geology skills and knowledge to interpret the origins of landscapes across the world (and perhaps even out of this world).

Suggested Time:

- High School with little background knowledge: Five 50-minute Periods (Five Days)
- Introductory College Class: Three 60-minute classes?

Materials Needed:

- Computer/ tablet to access the Columns of the Giants trip at http://www.sciencefriday.com/photosphere
- Printed class set, one per student, of the following:
  - Field Notebook Basics
  - Geologic Evidence Guide
  - Simplified Igneous Rock ID Chart.
  - Student Field Book (Some Assembly Required) – Every student should have their own.
    - At least four front-to-back copies of the gridded paper are needed to create the pages of the notebook. Once assembled, the book needs two staples on the spine.
- OPTIONAL: "The Final Story" – A final summary of the geologic sequence of events found at the Columns of the Giants.
- OPTIONAL: "Guided Stop Questions" – A print version of the questions within the IVFE.

Files can be downloaded individually from the "Educator's Toolbox" at the very bottom of the activity website or as one file from the Rendezvous website for this presentation.

Day 1 – Exploration & Field Sketching

1. Students will use viewers/tablets/computers to individually explore the nonannotated IVFE (The first one on the website). They should consult the reference materials to search for features they may recognize. Don't fret if there is a lot of "collaboration" that takes the form of "Hey, check this out!". That's a good thing!
2. In their field book, students should sketch one or two areas that they think provide interesting clues. Students should use proper Field Book formatting for their sketches and notes as seen in "Field Notebook Basics" handout.
3. After students have finished initial sketches, take 5 minutes to have students use scientific discourse to share their answers to the following questions amongst their small groups of three:
   a. What about this site was interesting or unusual to you?
   b. What areas of the site might provide useful clues about how the landscape was formed?
   c. What questions do you have about this area?

4. Optional: Introduce Field Guide Basics as a 10 minute class discussion with example sketches.

Days 2, 3 & 4 – Using Field Guides & Discourse to Generate Geologic Inferences.

1. Students will tackle the annotated version (second photosphere on the website) in small groups of three. Ideally, each student will have their own screen to discuss the progression of questions while interacting with the photospheres and 3D models of the rocks.
2. Claims and evidence created by the student groups should be recorded in their field notebooks. Group members may disagree, but that's okay. The most common argument I witnessed was "it's andesite because… No, it's basalt because…"
3. There is purpose to the sequence of questions at each stop, but it is not necessary for the students to complete the questions sequentially. Just as in a real field experience, students are encouraged to return to places they've already been or to move to a new spot to help formulate their ideas.
4. The questioning at each stop promotes the 3D-learning of the Next Generation Science Standards. There are no obvious "right" answers to the questions. Instead they require the students to answer in the form of claims based on evidence and/or reasoning.
5. The teacher's job is to actively facilitate the "unsticking" of groups by asking probing questions, lending suggestions of how you'd solve the problem (where to look) or to offer your content expertise when needed. This should not be a hands-off activity for the instructor.
6. It took my pilot group of classes three days to get through the six field trip stops.

Day 5 – Bringing it all together to Create a Geologic Timeline & Applying Knowledge.

1. This should be a teacher-facilitated group discussion.
2. Teacher will draw a timeline on whiteboard or interactive screen. Ask students to provide suggestions for timeline beginning and ending dates. (Ideally this should be ~80 Ma to Present)
3. Have student groups consult their notebooks and offer various pieces of information they discovered while on the field experience. For example, the types of rocks that were seen, the ages of the rocks, the process of how the rocks were formed, evidence of glaciation, lichen and plant growth, etc.
4. Most of the ideas will be fairly randomly offered, so before the next step, have students offer grouping suggestions for ideas listed on the board. I used my interactive whiteboard to drag evidence into groups the students suggested.
5. Have students offer suggestions for where each of the grouped pieces of evidence should be placed on the timeline. The timeline will not be to scale since so many of the events occurred in the last 150,000yrs, while the granites formed over 80Ma years ago. There will likely be lively discussions. Be sure to have students offer their reasoning for their timeline placement claims.
6. Once a timeline that matches the evidence is agreed-upon, have students record the final timeline in their notebooks.
7. The last student task is to have students write a paragraph summarizing the geologic events and timeline that created the Columns of the Giants.
8. After the students have finished their summaries, scroll to the "Apply Your Geo-sleuthing Skills" section of the sciencefriday.com/photosphere website and project the photos.
9. Follow the prompts for discussion on the website and have students hypothesize how each of the landscapes pictured were formed.
10. Collect Field Notebooks to grade based on your own criteria.

Field Notebook Basics

Field notebooks are kept by scientists who work outdoors, in the "field." The notes and sketches that scientists record allow them to make detailed observations of spatial patterns and relationships. Below is a short list of suggestions for keeping a geology and geomorphology field notebook.

Each page should include the following identifying features:

- Name and partner's name (if applicable)
- Date
- Descriptive title
- Page number
- The name or location where you are working. This can be a place name, latitude/longitude, or other creative way to make sure others who read your field book know where to go.

Sketching Tips:

- Plan what you want to show and at what scale you want to show it before you start.
    - Put a scale on your drawing, and do your best to draw to scale.
    - If your drawing isn't to scale, say so in a note.
- Make sketches as large as possible.
- It's okay to use a ruler or other straight-edged object if lines are needed.
- Make a "Detailed Area" with a larger scale if you need to show a "zoomed-in" area.

Annotate your sketches.

- Notes are used to clarify sketches. For example, you may need to describe a rock type or geomorphic feature, or record measurements.
- Notes can be used to record questions about an area.
- Use your best printing so that the notes are neat and clear.
- Place notes in empty spaces so they don't detract from the sketch.
- Assume that you're writing for someone else. That means you should be clear and concise.

For more detailed field notebook guidelines and examples of geology field notebook pages, check out the Fundamentals of Field Notes by Dr. Christie D. Rowe of McGill University.

Field Book Created by Ryan J Hollister

www.mrhollister.com

Field Book

Note and Sketch

Observations and ideas in this book belong to:

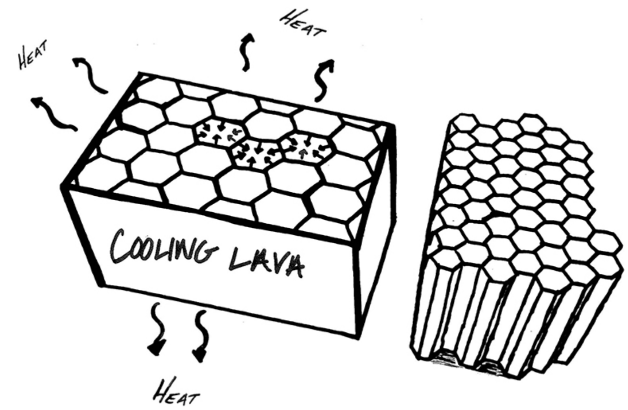
____

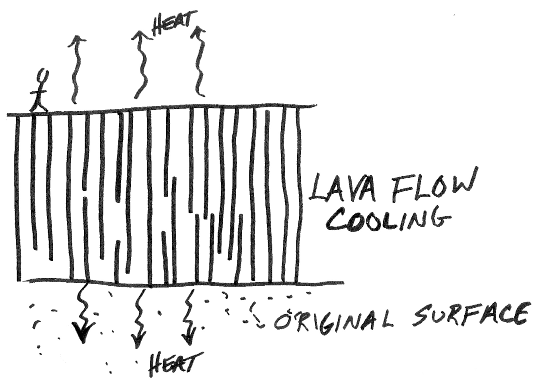
Geological Evidence Guide

Look for Evidence of Lava Flows

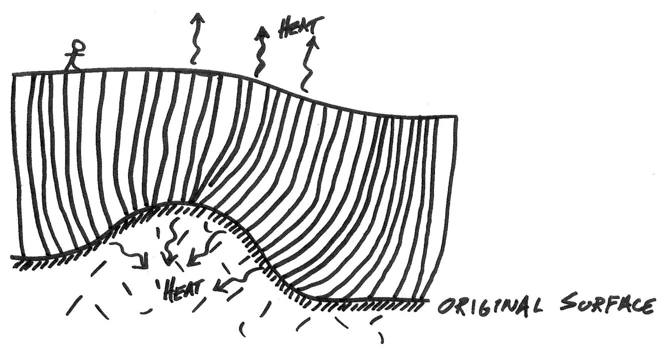
Lava flows leave behind many clues that help geologists understand how the lava flowed out of the volcano, as well as how quickly it cooled. Below are several clues left behind by the flow at the Columns of the Giants.

Columnar jointing happens when stagnant pools of lava cool slowly. As the lava cools and crystallizes into rock, the atoms in the lava become more organized and take up less space than when the lava was a hot liquid. As a result, the solidifying rock shrinks, causing cracks to form in the surface. The cracks radiate outward at 120-degree angles from one another, forming hexagonal shapes that lend the surface a honeycombed appearance.



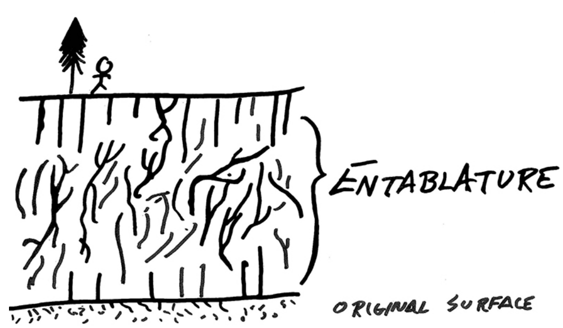


Over a cooling period of several decades, those cracks, called “joints,” also spread down through the solidifying rock, meeting other cracks spreading up from the bottom, and forming column-like shapes.



Columns form perpendicularly to the surface that the original pool of lava rested upon. These columns will lean or bend if the bottom of the lava pool lies on top of surfaces that are uneven, such as a hill or stream channel.

When lava cools particularly quickly, cracks form in a disorganized fashion, resulting in small columns that point in seemingly random directions. Disorganized jointing and columns are called **entabulatures**.



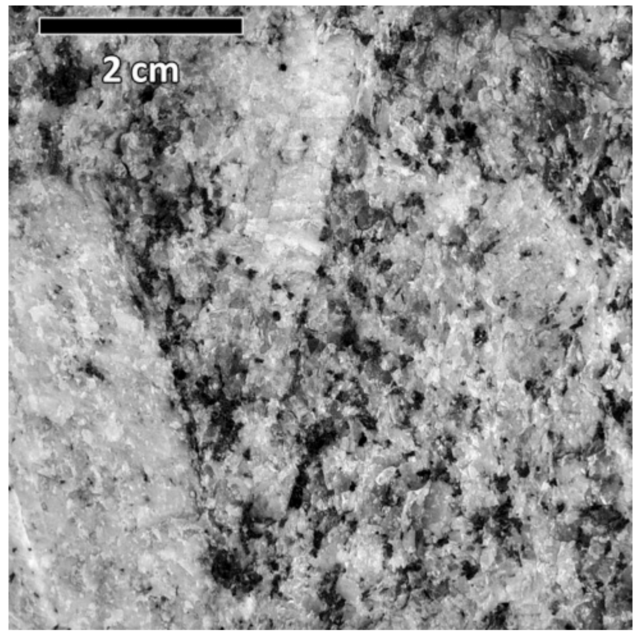
By Educator Collaborator Ryan Hollister

Examine and Identify Rocks

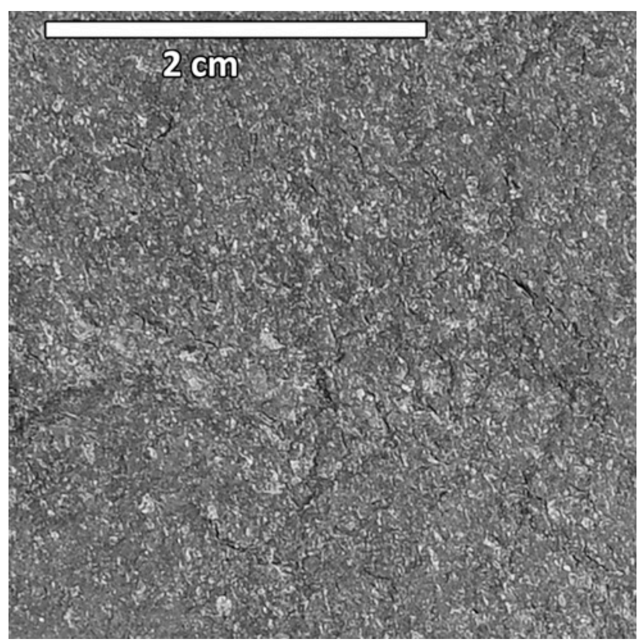
The Columns of the Giants, as well as the surrounding Sierra Nevada mountains, are part of a family of rocks called igneous rocks.

Igneous rocks form when magma (hot liquid rock) cools and solidifies, either underground or after erupting onto earth's surface as lava. By examining the crystal size and composition of igneous rocks, you can infer their origins.

Igneous rocks that contain large interlocking mineral crystals (what geologists call a coarse-grained texture) formed from magma that slowly cooled and solidified miles beneath earth's surface over a period of millions of years.



Fine-grained igneous rocks (as well as those with a glassy texture) likely formed in a volcanic eruption that occurred above ground and cooled very quickly in a matter of hours, days, months, or years.

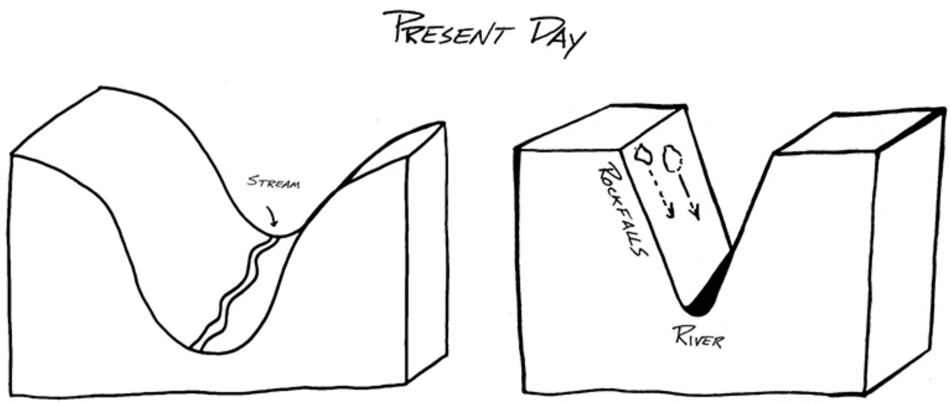


By Educator Collaborator Ryan Hollister

Look for Evidence of Glaciers

Scientists can gather evidence of glaciers that have retreated by studying freshly exposed rock.

Valleys carved by a river appear V-shaped (see the image to the right). Glaciers flowing down V-shaped river valleys will pluck and grind rocks, widening the valley into a **U shape**.,



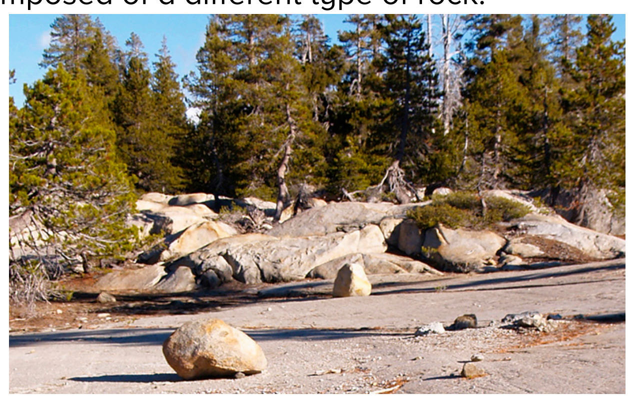
U-shaped valley (left) and V-shaped valley (right).)

Glacial Striations

When a glacier with rocks and dirt stuck in its base grates the ground over which it flows, it creates parallel scrape marks on rocks.

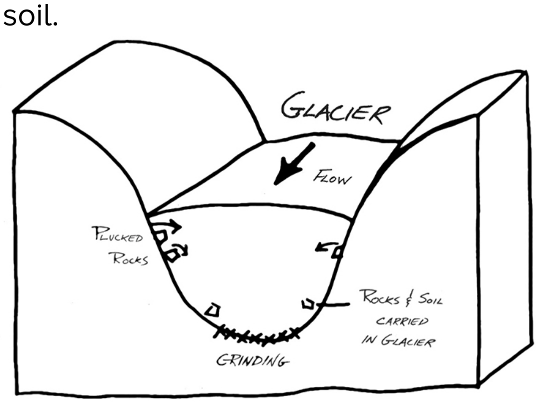
Glacial Erratics

These are rocks that were trapped inside and transported by a glacier. When glaciers melt, they leave the rocks behind, typically on ground composed of a different type of rock.



Absence of soil

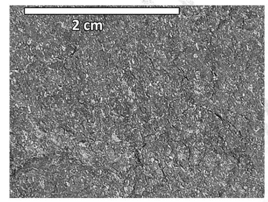
As glaciers scour an area, they strip the surface of all soil.



SCIENCE FRIDAY

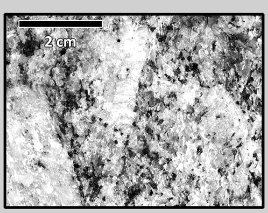
SIMPLIFIED
IGNEOUS ROCK
IDENTIFICATION

FINE-GRAINED ROCKS ARE FORMED AFTER A VOLCANIC ERUPTION



FINE-GRAINED
rock has no crystals visible to the naked eye

- rock has holes (vesicles)
  - dark-colored
    - looks glassy → **scoria**
    - not glassy → light grey → **andesite**
  - light-colored → **pumice**
- rock has no holes
  - looks glassy → black → **obsidian** → dark grey → **basalt**
  - not glassy
    - light grey → **andesite**
    - dark grey → **basalt**



COARSE-GRAINED
rock has crystals visible to the naked eye

- dark-colored fresh rock surface → **gabbro**
- light-colored fresh rock surface → **granite**

COARSE-GRAINED ROCKS ARE FORMED IN A SLOWLY COOLED MAGMA CHAMBER MILES BENEATH EARTH'S SURFACE

Use this gradient to determine a rock's color

light | light grey | dark grey | black

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Illustrated by Ariel Davis

Columns of the Giants Guided Questions

Stop 1

1. This is the namesake area for the Columns of the Giants. The entire hill in this scene is made of the same rock type.
    a. Why do you think this area was named Columns of the Giants?
    b. What clues in the rocks suggest how the rocks and this hill were formed?
    c. There are two distinct rock "layers" here. Why? Refer to the section in your *Geologic Evidence Guide* that discusses columns and entablatures.

2. "Talus" is the word geologists use to describe broken rocks that have fallen from a higher elevation.
    a. Do you notice any interesting shape patterns in the individual pieces of talus?
    b. Where do you think this talus came from? What evidence supports your idea?

3. This is a fairly freshly broken rock surface, which makes it easy to identify the rock type.
    a. Is the rock dark in color or light in color? (Consult the *Rock Identification Chart*.)
    b. Do you notice any large, visible crystals? Zoom in to the rock to get a better view.
    c. Based on your observations, what type of rock do you think this is?

4. The yellow-green, dark black, dark brown, and rusty-colored spots on top of the rocks are lichens. Lichens, which consist of algae and fungi living symbiotically, generally grow about 2–5mm per year. The rocks in this talus pile are about 50cm in diameter.
    a. Would freshly fallen talus have lichen on it?
    b. Can you think of a way to use this lichen to help you figure out how many years it has been since the rocks fell?

5. Make several observations about where the trees and plants are growing in this scene.
    a. Why are the trees and plants growing where they are? Why are there areas with no trees or plants growing?

6. To help you get a feeling for how big things in this scene are, this column is about 70cm tall and sits at the end of the Columns of the Giants Interpretive Trail.

Stop 2

1. You are now standing on top of the Columns of the Giants, directly above **Stop 1**. First, compare this location with the rest of the scene. The size of this rock is about 25cm across.
    a. What is different about the rocks in this spot versus those just a few feet away, to the south and west (behind you)?
    b. The rocks here have cracks (joints) that make a pattern. Focus on the shapes they make.
        i. How many sides does each rock have?
        ii. Using your *Geological Evidence Guide*, how do rocks with this kind of jointing pattern form?

2. Notice the flat, smooth surface of this area.
    a. If you zoom in to this area, you should see parallel sets of grooves that run east to west on the flat surfaces.
        i. What do you think could have made such grooves?
    b. In some places the oxidized ("rusty") flat areas of this rock surface are chipped, exposing fresh surfaces of the rock and making it easier to identify. Based on the dark color of the freshly exposed surface and the lack of large crystals, what kind of rock do you think this is? Use your *Rock Identification Chart* to help you.
    c. Is this rock generally similar or different to those observed at **Stop 1**? How?

3. Use the apple for scale. About how big do you think this rock is? Note: Author practices [Leave No Trace] and did not leave the apple behind.

4. The rocks at Tag 4 and Tag 5 are interesting. Take a good look at their shape and color. Compare them to the majority of the rocks lying around the area.
    a. What is similar or different about these rocks?
    b. Stop #4 and Stop #5 will provide more examples of these rocks to help guide your inquiry.
    c.
5. Here is more of the same rock type you observed at stop #4. What is similar or different about these rocks compared to nearby rocks?

6. The black chunks in this area appear to be the charcoal remnants of a possible lightning-sparked log that smoldered. There is no evidence of a human-influenced disturbance in this particular area.

Stop 3

1. The view looking east, up canyon, is the main purpose of this stop. The canyon is about one mile wide at the base.
    a. Does this canyon resemble a U-shape or V-shape?
    b. What does the shape of the canyon tell you about its formation?

2. What is the general rock type in this area? It should become easier to identify this rock, because you see it at nearly every site. Why do you think all of these rocks are the same type?

3. Zoom in to this pile of rocks. Do you notice any similarities to those seen at the previous stop (Stop #2)?
    a. What might be responsible for the flat and smooth surfaces seen at the top of this pile?

4. A lack of soil generally means the surface is geologically young (less than several hundred thousand years).
    a. Based on the soil and plant life, do you think this is a geologically young or geologically old area?

Stop 4

1. Look down on the columns and talus piles in Tag 1 (these also appeared at Stop #1).
    a. What does the orientation of the columns suggest about how the lava that formed these rocks cooled? (Consult your Geological Evidence Guide.) Did the cooling occur slowly and uniformly from the bottom and top, or was the cooling relatively quick? What evidence supports your idea?

2. Take a closer look at this rock, ignoring the black lichen spots. This rock is different from the rocks underneath it.
    a. Based on the rock's color and crystal structure, what kind of rock is this?
    b. How did this rock likely form? Use your Rock Identification Guide to help you.
    c. How could such a large rock (1.5m x 0.70m x 0.65m) end up on top of this cliff?
    d. Take a close look at the tree root under the rock. Which came first, the rock or the root? What evidence supports your conclusion?

3. Highway 108

4. The rock here is granite. It has been rounded and smoothed by a natural process.

5. This is the western extent of the rocks that make the Columns of the Giants.

6. Here's a backpack for scale. It's about 80cm tall.

Stop 5

1. This is the best view west (downstream) of the canyon in which the Columns of the Giants formation resides. Does the valley generally make a V shape or a U shape? What does the shape of the valley tell you about the geologic history of the area?

2. How did a rock this large (2m x 1m x 1m) come to rest atop a steep cliff?
    a. What kind of rock is this? Use its color and crystal shapes to help you determine the rock name. (Ignore the black lichen spots.)
    b. Is this big boulder the same type of rock as those on which it sits? How do you know?
    c. Does the rock appear to be sunken into the rocks beneath, or is it perched atop them?
    d. What other field trip stops display a similar type of rock to the boulder? (Look at all of the stops!)
    e. What could have easily moved a boulder of this size?
    f. Click on the 3D model icons located on the nearby granite boulder to see it in 3D.

3. How did a rock this large (.6m x .5m x .4m) get perched atop a steep cliff?
    a. Use the same observations that you used in Tag #2 to explore this rock. How did this rock get here, and where did it come from?

4. What type of rock makes up the majority of this flat area?

5. Zoom in to this area, or consult the nearby 3D model. There is a small exposed section of very flat, smooth, dark-colored rock. It has parallel scratch marks running across the face of the rock that point directly towards the west (down canyon).
    a. What could have produced these marks, as well as left behind huge boulders?

6. Backpack for scale (about 80cm).

Stop 6

1. The mineral crystals that make up rocks can tell amazing stories.
   a. What do you notice about the color of these rocks?
   b. Do you notice anything about the crystals in these rocks that might help a geologist learn about their story? Are the crystals large or small? Are they all the same size?
   c. What type of rock might this be, based on the color and crystal size?
   d. Do these rocks have any similarities with those seen at other stops?

2. Use the local topography to make a hypothesis about how glaciers moved across the landscape.
   a. What do you notice about the steepness of the highway at this spot?
   b. What would happen if you spilled a bottle of water on the road? Which direction would it flow?
   c. What would happen if you put a large, heavy block of ice on the road? Would it stay put? Would an even larger block of ice stay put, or would it flow down the road as well?
   d. What useful elevation clues do this spot provide about how glaciers may have moved across this landscape?

3. Freshly Broken Surface
   This part of the rock was recently broken (probably during highway maintenance). Freshly broken surfaces haven't had time to oxidize, so they show the "true" colors of the rock, not the oxidized orange.

4. The Columns of the Giants formation is located just behind this mountain where the valley curves to the left. If you had X-ray vision, you'd see it. Based on your view here, would the Columns of the Giants appear to be below or above this location?

5. The cracks in this rock are called joints. How do the patterns of cracks in these rocks compare to those seen at the Columns of the Giants? What is similar? What is different?

The Final Story:
Columns of the Giants Immersive Virtual Field Experience

Basaltic lava erupted onto the granitic floor of the Stanislaus River Canyon about 150,000 years ago from a nearby, but as-of-yet unidentified, crack (fissure) in the Earth's crust. The lava flowed down the canyon to the west and likely ran into a large pile of rocks left behind by glaciers (moraines) during previous ice-ages. The lava pooled on top of the original granite floor of the canyon to a thickness of several hundred feet. The flow cooled at a fairly uniform rate from the top and the bottom of the lava flow. As the lava cooled, it shrank and created the hexagonal fractures visible in the rock. Cracks following the hexagonal patterns grew from the top-down and bottom-up as the lava pool continued cooling towards the middle of the flow. This made the beautiful, large columns we see today.

Sometime after the first lava flow cooled, a second basaltic lava flow erupted from a nearby source and covered the colonnades. This second flow cooled under much-less ideal conditions which made the cracking much more random. The random nature of the cracking created the entablature observed.

There have been five periods of glaciation (Ice Ages) identified in nearby parts of the Sierra Nevada during the past 150,000 years. Each glaciation lasted several thousands of years. Based on the ample evidence provided glacial erratics, striations & polish on rock surfaces and u-shaped valleys, it can be concluded that large glaciers flowed down the Stanislaus River Canyon during each of those glaciations.

The striations on top of the Columns of the Giants are evidence that glaciers flowed over the Columns of the Giants and carried away an unknown volume of lava. Since the striations run from east to west, they show that the glaciers flowed downhill and carried large boulders of granite that were plucked from the higher elevations. The granite boulders that were stuck inside or rafted atop the glacier were dropped as the glacier melted away at the end of the ice ages. Several dozens of those boulders are the erratics sitting on top of the Columns of the Giants.

The last glaciation in the Stanislaus River Canyon ended about 10,000 years ago. When the glaciers melted they left behind scoured and steep slopes in the basaltic lava flow as well as a widened u-shaped valley in the rest of the canyon. Rock walls with lots of cracks (jointing) and steep slopes tend to succumb to gravity over time. The Columns of the Giants have spent the last 10,000 years breaking and falling off the steep north-facing wall which accounts for the large pile of talus at its base.

The stories of Earth's history revealed by just a few geologic observations at The Columns of the Giants are quite amazing. Lava was erupted into a canyon, it cooled and cracked into columns and then was bulldozed by glaciers. There are still many geologic questions to be answered in this area and perhaps this exercise will inspire you to be one of the people that solves those problems.