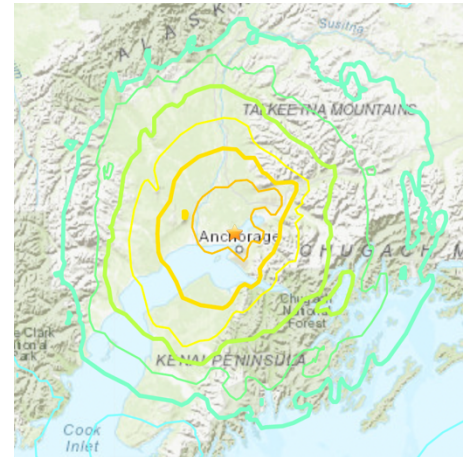


Earthquake Intensity

Describing the severity of an earthquake

When describing the severity of an earthquake at any given location, several measures are needed. The amount of energy released in the earthquake is reported as the *magnitude*, measured quantitatively using the Moment Magnitude scale. The energy released in an earthquake is a static number, regardless of how close you are to the epicenter. In contrast, the impact of the earthquake, in terms of shaking and damage caused, depends greatly on how close you are to the epicenter. The shaking caused by an earthquake at any given location is termed the *intensity*, which is measured qualitatively, using the Modified Mercalli Intensity (MMI) scale. In this introductory lesson, learners compare ShakeMaps between earthquakes in the same location but different magnitudes, and earthquakes of the same magnitude but different depths, to acquaint learners to the fundamental controls on intensity of shaking felt during an event: magnitude and distance from the earthquake source.



Essential Questions:

- How do seismic waves interact with matter?
- What controls earthquake shaking in different places?

Essential Understanding:

- The fundamental controls on earthquake shaking at a given location are the magnitude of the event, and the distance from the epicenter and depth to the hypocenter

Goals

Learners will:

- Distinguish earthquake magnitude and intensity
- Understand how earthquake intensity varies with changes in magnitude or distance to the hypocenter

NGSS Science Standards

- **MS-ESS2-2** Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales
- **MS-ESS3-2** Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects
- **HS-ESS3-1** Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity

Materials

- **Animation** Take 2: Magnitude vs Intensity
https://www.iris.edu/hq/inclass/animation/take_2_magnitude_vs_intensity
- **United States Geological Survey Event Pages**
 - 1964 M9.2 Prince William Sound earthquake
<https://earthquake.usgs.gov/earthquakes/eventpage/iscgem869809/executive>
 - 2018 M7.1 Point MacKenzie (Anchorage) earthquake
<https://earthquake.usgs.gov/earthquakes/eventpage/ak20419010/executive>
 - 2019 M7.1 Ridgecrest earthquake
<https://earthquake.usgs.gov/earthquakes/eventpage/ci38457511/executive>

Key Vocabulary

epicenter, hypocenter, intensity, magnitude

Refer to this glossary for definitions:

https://www.iris.edu/hq/inclass/fact-sheet/vocabulary_for_earthquakerelated_topics

Teacher Background & Instructions

Background

The severity of an earthquake can be described using two different scales: *magnitude* and *intensity*. Magnitude is a quantitative measure of the amount of energy released in the earthquake, and is measured using the **Moment Magnitude** scale. In contrast, intensity is a measure of the impact of the earthquake, in terms of shaking and destruction caused. One way to measure the effect of an earthquake uses the **Modified Mercalli intensity (MMI)** scale. This qualitative scale provides anecdotal descriptions of how strong the shaking is, such as “objects swing” to “dishes rattle” or “heavy furniture overturns.” Higher intensity such as IX or X reflect actual damage to buildings and structures. Data for the MMI scale is often reported in the form of a ShakeMap, depicting the geographic distributions of reports of shaking and damage.

Read more about Moment Magnitude and the MMI Scale in this USGS article: <https://www.usgs.gov/faqs/moment-magnitude-richter-scale-what-are-different-magnitude-scales-and-why-are-there-so-many>

Seismic waves propagate in all directions away from the hypocenter, and the energy of the waves tends to decrease with distance from the earthquake source. Therefore, the intensity of earthquakes tends to decrease with distance from the epicenter, and deeper earthquakes tend to cause less destruction than shallower earthquakes of the same magnitude.

Earthquake intensity is primarily controlled by magnitude and distance from the epicenter and depth to the hypocenter for a given event. However, there are other local factors such as soil or rock type, topography, and water saturation that affect earthquake shaking intensity. These local factors are featured more in the activity *Engaging With Earthquake Hazard and Risk* https://serc.carleton.edu/ANGLE/educational_materials/activities/245160.html

Learn more about the earthquakes featured in this activity on the USGS Event Pages (in Materials). Note that ShakeMaps can be accessed and downloaded from USGS Event pages for other earthquakes.

Suggested Prior Knowledge

Prior experience with earthquake magnitude and how it is measured would be helpful preparation. This can be accomplished by completing the activity *Pasta Quake*: https://serc.carleton.edu/ANGLE/educational_materials/activities/205500.html

Instructional Sequence

Step 1: Show the animation *Take 2: Magnitude vs Intensity* to introduce the difference between these two measures of earthquake severity.

Step 2: Group students in pairs or small groups and distribute ShakeMaps.

Step 3: Compare the ShakeMaps of the 1964 M9.2 Prince William Sound earthquake with the 2018 Point MacKenzie (Anchorage) earthquake. Point out that these earthquake epicenters are in a similar location (<100 miles apart). Note differences between the ShakeMaps – the 1964 event was felt over a much greater region of the state (note the differences in scale between the maps), as well as having areas of higher shaking intensity.

Step 4: Ask learners to formulate an explanation as to why the Alaskan ShakeMaps differ. [The difference in shaking between these earthquakes is mainly due to the extreme difference in magnitude. The 1964 M9.2 was the second largest earthquake ever recorded, whereas the 2018 was a M7.1].

Step 5: Compare the ShakeMaps of the 2018 Point MacKenzie (Anchorage) earthquake with the 2019 Ridgecrest earthquake. These earthquakes had the same magnitude of M7.1. Note differences, such as the center of the Ridgecrest earthquake is red (maximum MMI is IX), indicating much higher shaking than the Point MacKenzie ShakeMap (maximum MMI is VIII).

Step 6: Ask learners to formulate an explanation as to why the M7.1 ShakeMaps differ. Guide them to develop hypotheses. Provide access to the USGS event pages for students to confirm hypotheses, and/or project the event pages. [The differences in shaking between these two earthquakes is mainly due to the shallowness of the Ridgecrest earthquake (8.0 km) compared to 46.7 km for the Point MacKenzie earthquake.

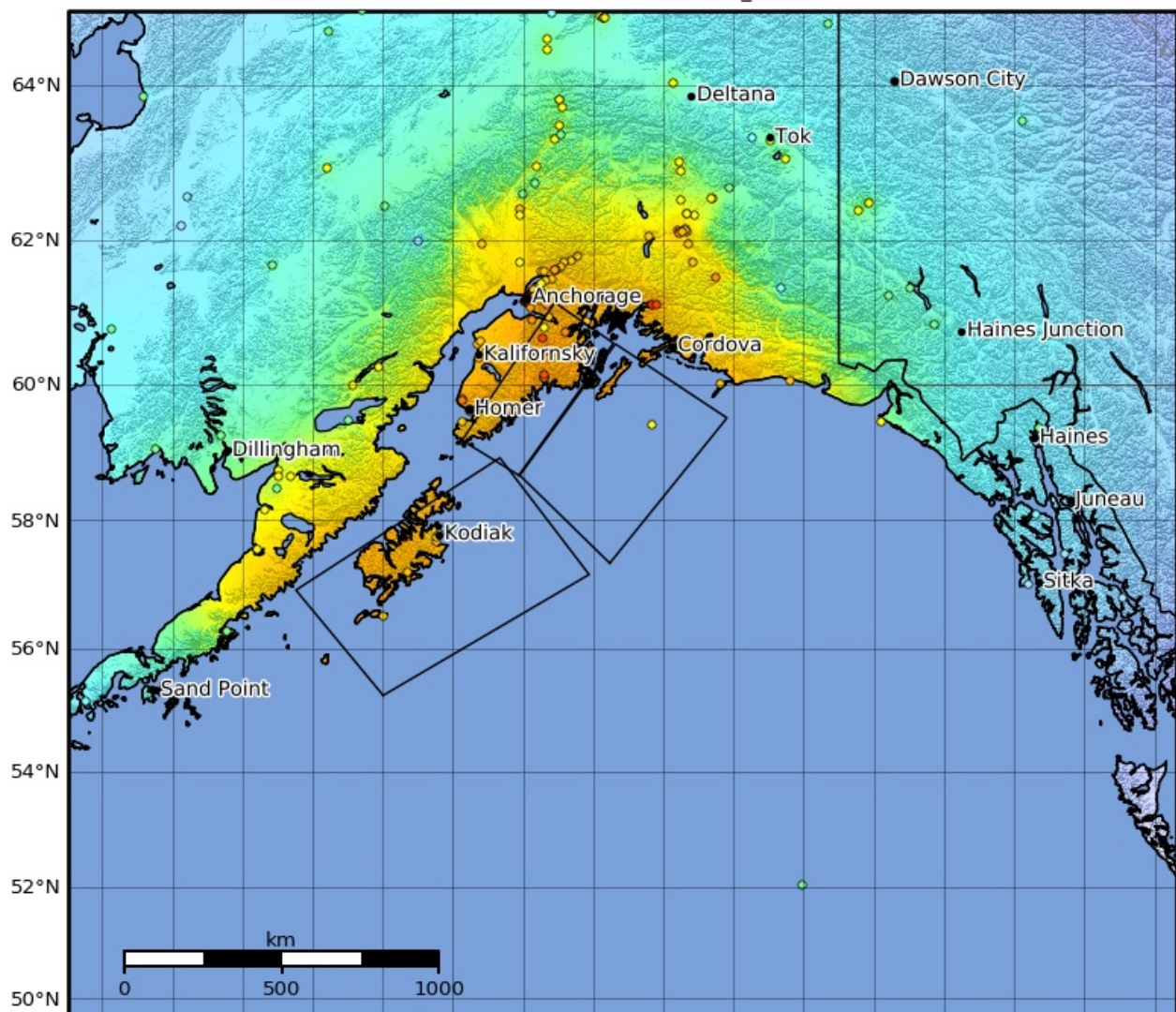
Step 7: Have learners make a claim about earthquake intensity, based on the evidence observed in the ShakeMaps and other data gathered about the earthquakes.

Suggested Follow-up Activities

Learn more about local site effects and impacts of earthquake shaking in *Engaging With Earthquake Hazard and Risk* https://serc.carleton.edu/ANGLE/educational_materials/activities/245160.html

Learn more about how shaking is measured in *Reading an Earthquake Seismogram* https://serc.carleton.edu/ANGLE/educational_materials/activities/245164.html

Macroseismic Intensity Map USGS
 ShakeMap: 1964 Prince William Sound Earthquake, Alaska
 Mar 28, 1964 03:36:16 UTC M9.2 N60.91 W147.34 Depth: 25.0km
 ID:official19640328033616_30



162°W 160°W 158°W 156°W 154°W 152°W 150°W 148°W 146°W 144°W 142°W 140°W 138°W 136°W 134°W 132°W

SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0464	0.297	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.0215	0.135	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Worden et al. (2012)

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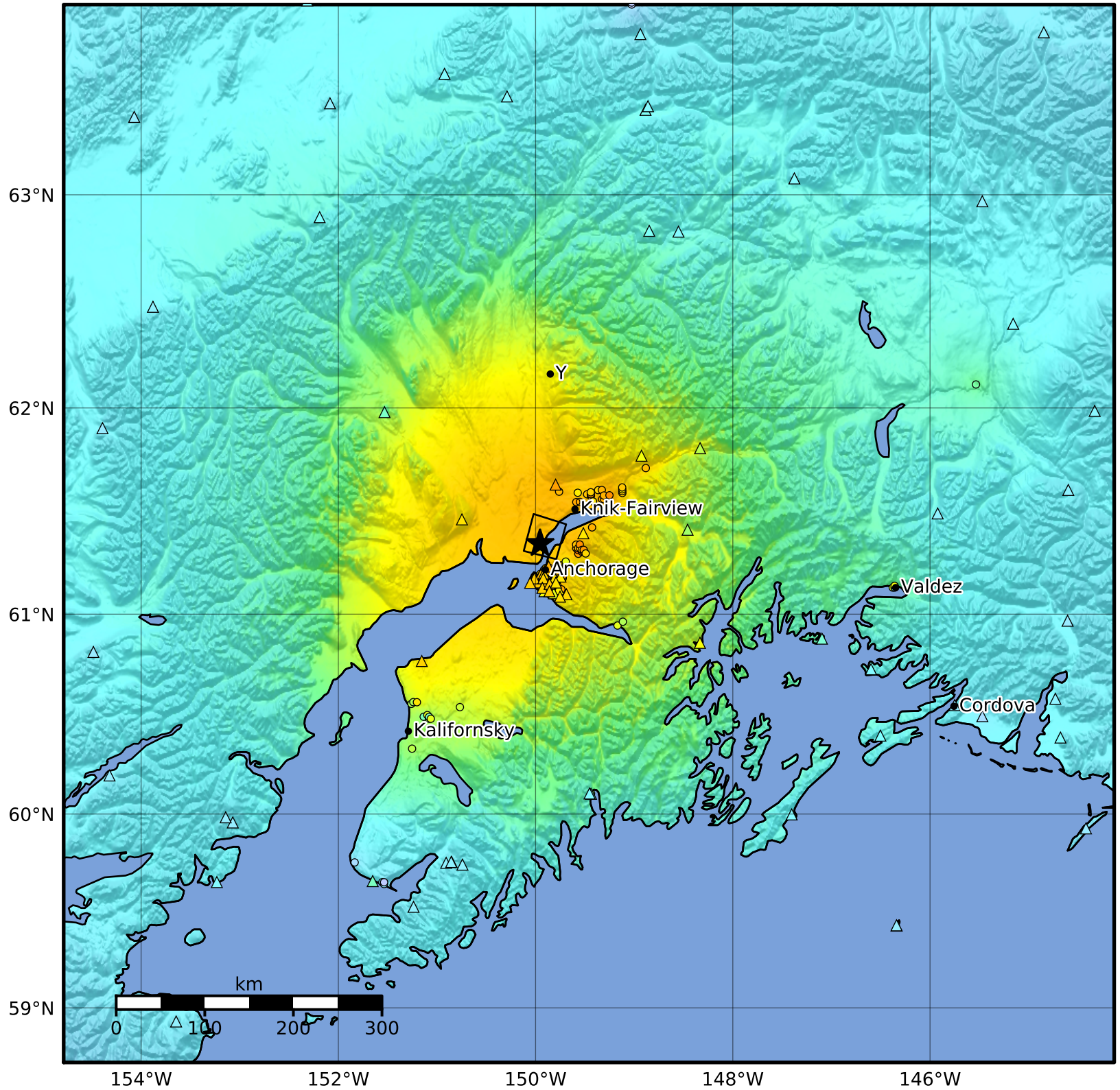
△ Seismic Instrument ○ Reported Intensity

★ Epicenter □ Rupture

Accessed at:

https://earthquake.usgs.gov/earthquakes/eventpage/iscgem869809/shakemap/intensity?source=atlas&code=official19640328033616_30

Macroseismic Intensity Map
 USGS ShakeMap: 14km NNW of Anchorage, Alaska
 Nov 30, 2018 17:29:29 UTC M7.1 N61.35 W149.96 Depth: 46.7km ID:ak20419010



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.05	0.3	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.02	0.13	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Worden et al. (2012)

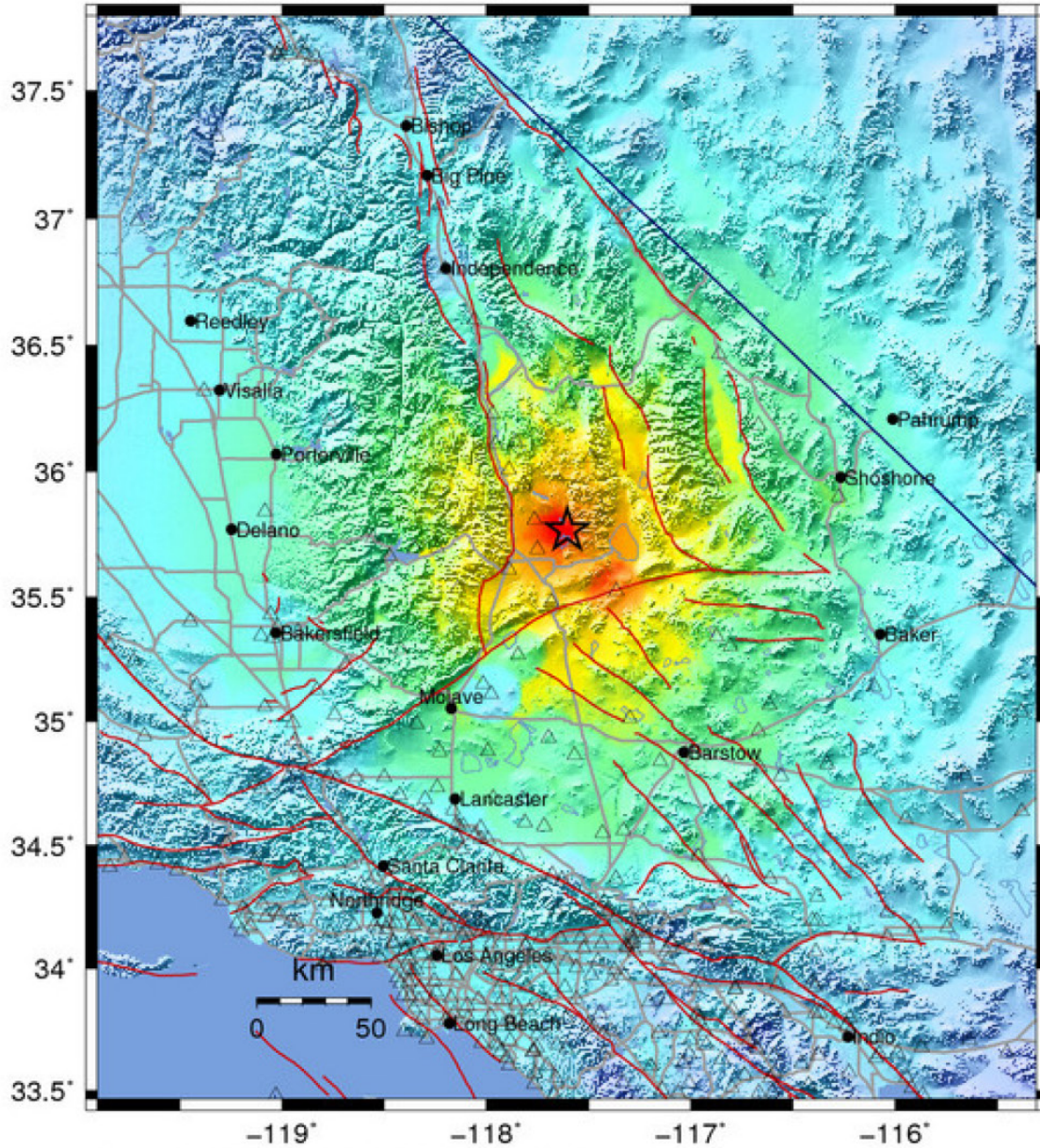
Version 1: Processed 2019-06-17T22:09:20Z

△ Seismic Instrument ○ Reported Intensity

★ Epicenter □ Rupture

CISN/sc ShakeMap : 17.4 km (10.8 mi) NNE of Ridgecrest, CA

Jul 6, 2019 03:19:52 AM UTC M 7.1 N35.77 W117.60 Depth: 8.0km ID:38457511



Map Version 7 Processed 2019-07-07 04:20:50 AM UTC

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.1	0.5	2.4	6.7	13	24	44	83	>156
PEAK VEL.(cm/s)	<0.07	0.4	1.9	5.8	11	22	43	83	>160
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Wald, et al.; 1999

Accessed at:

<https://www.usgs.gov/media/images/shakemap-m71-july-5-2019-earthquake-near-ridgecrest>