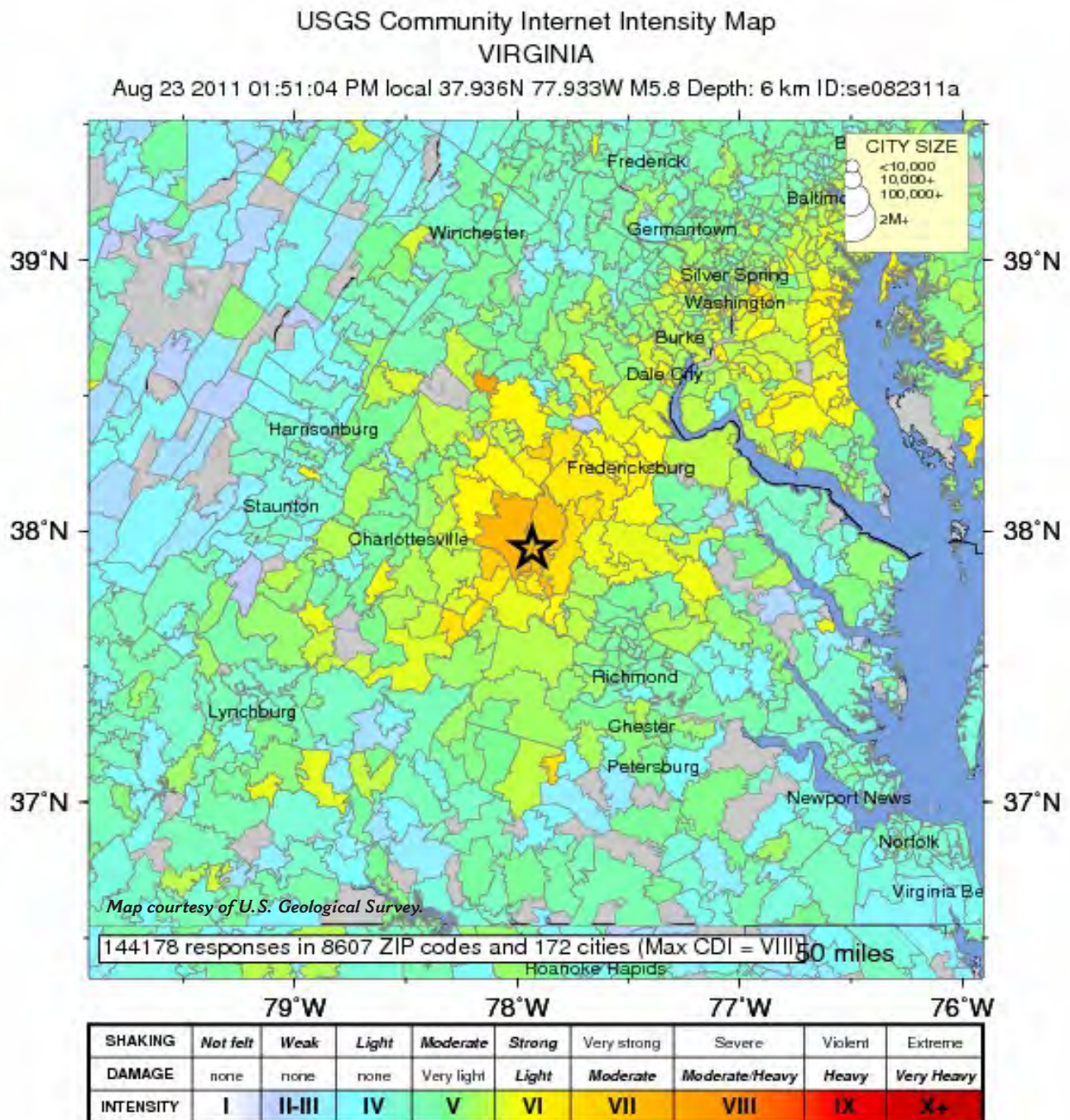


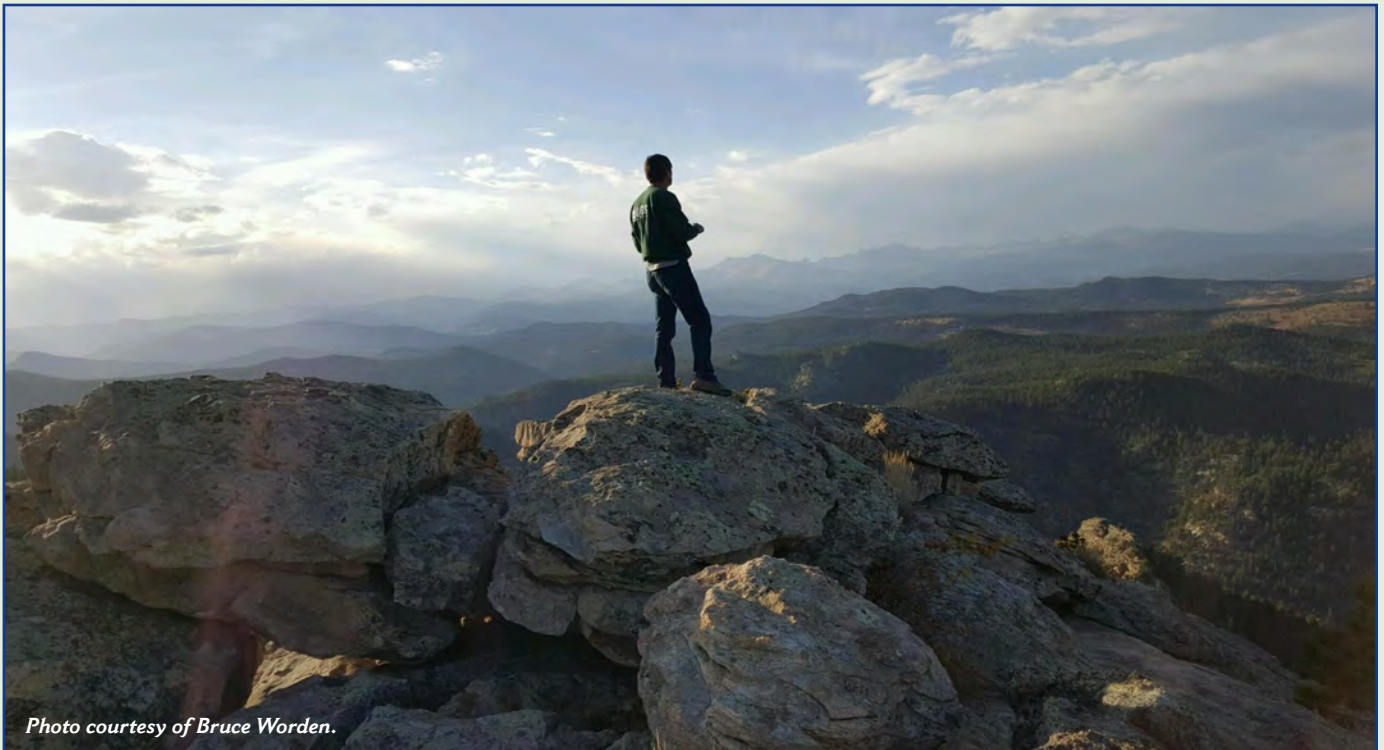
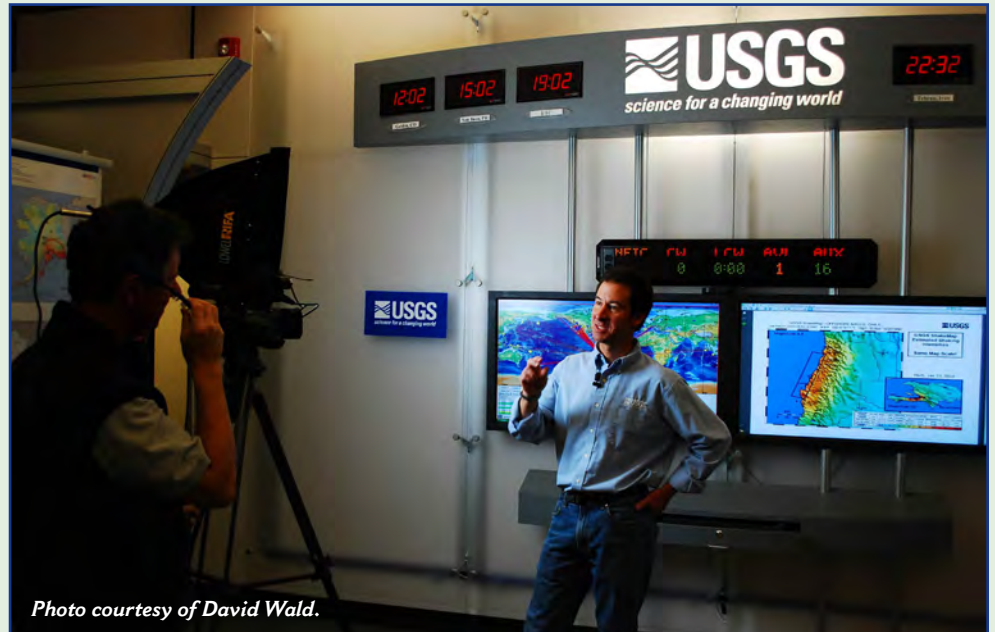
All Over The Map

Investigating the "Did You Feel It?" Citizen Science System



Meet the Scientists

► **Dr. David Wald**, Earthquake Seismologist: My favorite science experience is coming up with new (or even obvious) ways for solving tough problems while doing something unrelated: running, hiking, daydreaming. When an idea or solution pops into my head, it's **invigorating**.



▲ **Dr. Bruce Worden**, Earthquake Seismologist: I enjoy bringing data together with theory. Sometimes the data tell you that your idea could be right, and other times you discover that you are wrong. Either way, you've learned something new about the world.

Glossary words are **bold** and are defined on page 34.

What Kind of Scientist Did This Research?

earthquake seismologist: This type of scientist studies earthquakes and the waves (or vibrations) created by earthquakes.

Thinking About Science

Scientists gather, analyze, and evaluate data to solve problems or gain additional information about a topic.

Scientists work in many different areas of the world and study a wide variety of topics. Did you know that you can help scientists with their work? Individuals who help scientists collect data are called citizen scientists. Citizen scientists are valuable because citizen scientists enable scientists to gather more data and cover more areas than the scientists would be able to do by themselves.

Citizen scientists often use the Internet to submit data, and citizen science takes a variety of forms. Examples of some citizen science projects include gathering data about soil, asteroids, weather, plants, **migratory** dragonflies, and earthquakes. Citizen scientists usually have some degree of training in gathering data. Sometimes, however, citizens help with gathering scientific data but have not received training. When this happens, the work they do is referred to as citizen-based science.

The scientists in this study were particularly interested in earthquakes and the data provided by citizen-based science related to earthquakes. To learn about some citizen science and citizen-based science projects, read the Citizen Science Resources on page 89 of this journal or visit <https://www.citizenscience.gov>.



Thinking About the Environment



An earthquake happens when two blocks of earth move past each other suddenly (**figure 1**). The movement of the two blocks of earth causes a release of energy which in turn creates vibrations and movement in the surrounding area. The place at which the two blocks of earth move past each other is called the fault or fault line. Earthquakes typically start deep within Earth. The point on Earth's surface above where the earthquake starts is called the epicenter (**figure 2**).



Figure 1. An earthquake occurs when two blocks of earth move past each other suddenly. Illustration by Stephanie Pfeiffer.

The U.S. Geological Survey is the Federal Government agency that monitors and studies earthquakes. Earthquakes are recorded by instruments called seismographs (**figure 3**).

The first seismographs were used in 1890. Since that time, a seismographic network has been built across the United States called the Advanced National **Seismic** System (**figure 4**).

Number Crunch



For how many decades have seismographs been used?

Figure 2. The **epicenter** is the point on Earth's surface above where the earthquake starts. Illustration by Stephanie Pfeiffer.

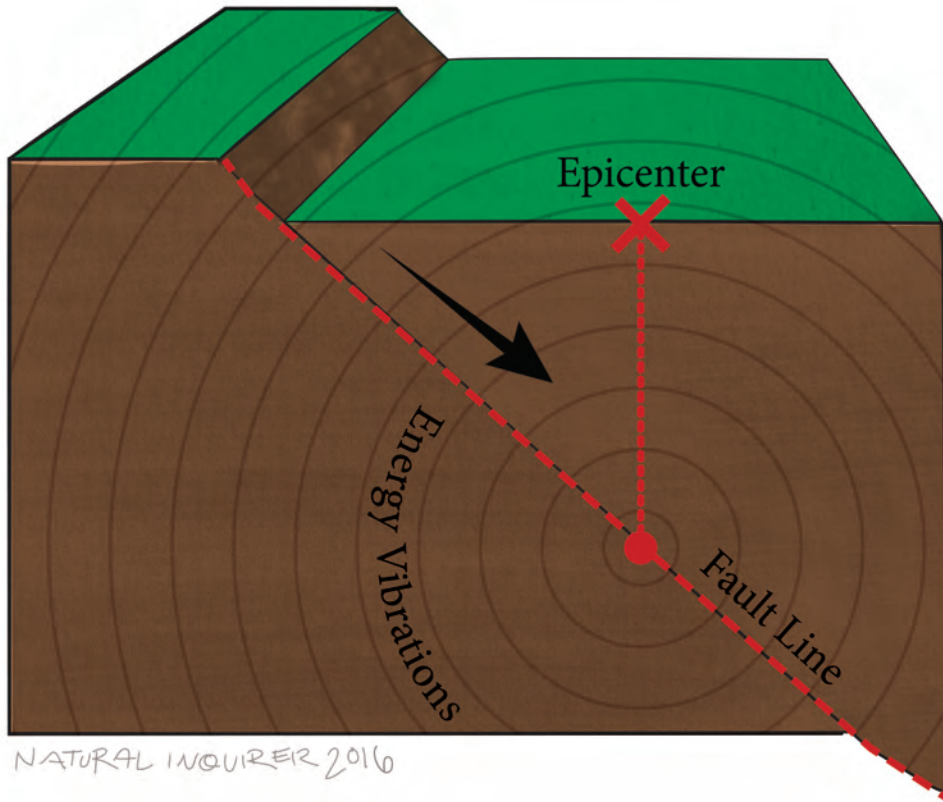
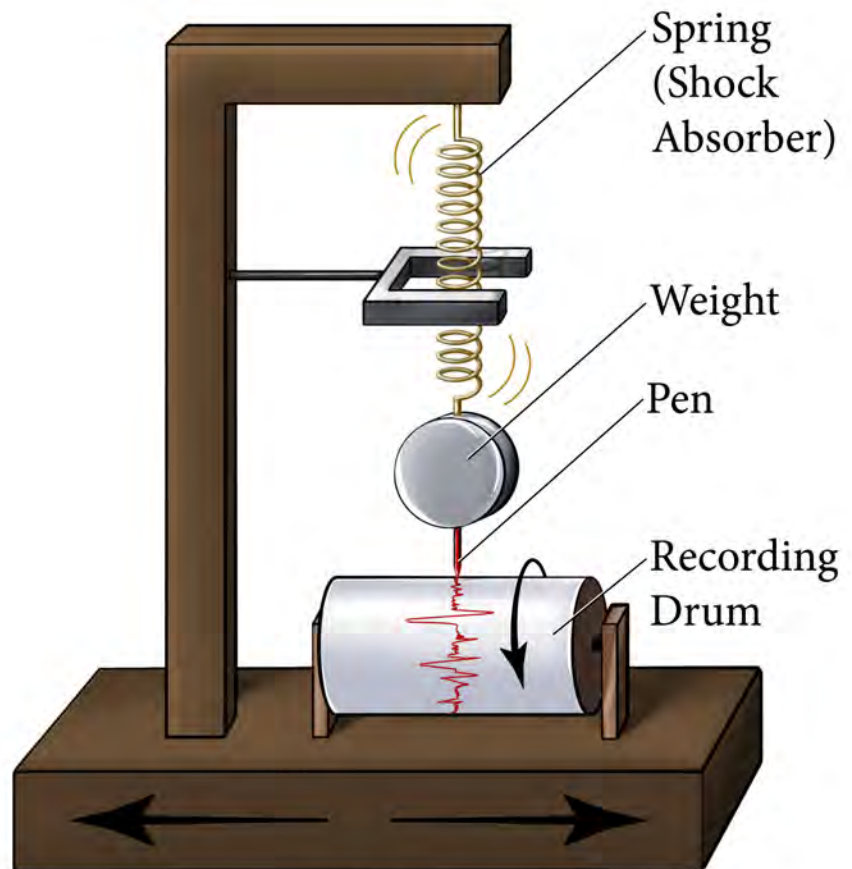


Figure 3. Seismographs are instruments used to detect and record earthquakes. The seismograph has a base that sits firmly on the ground with a heavy weight that hangs free.

When an earthquake occurs, the base of the seismograph moves, but the weight does not move. The spring in the seismograph absorbs the movement instead. The seismograph records the difference in position between the shaking part of the seismograph and the motionless part of the seismograph. Illustration by Stephanie Pfeiffer.



Additionally, a larger, global network called the Global Seismographic Network has locations across the planet (**figure 5**). These two networks of seismographs collect data about the occurrence of earthquakes.

Information from the seismographs help scientists assign a **magnitude** to an earthquake. Magnitude measures the energy released at the source of an earthquake. Another earthquake measurement is called intensity. Intensity is a measurement of the strength of shaking at a certain location; and

an earthquake produces many intensities of shaking at different locations. The Modified Mercalli Intensity Scale is used to measure intensity (**figures 6a and 6b**). The following table gives intensities that are typically observed at locations near the epicenter of earthquakes of different magnitudes.

When an earthquake occurs, scientists want to gather as much data as possible. These data enable scientists and decisionmakers to more successfully respond to and prepare for earthquakes.

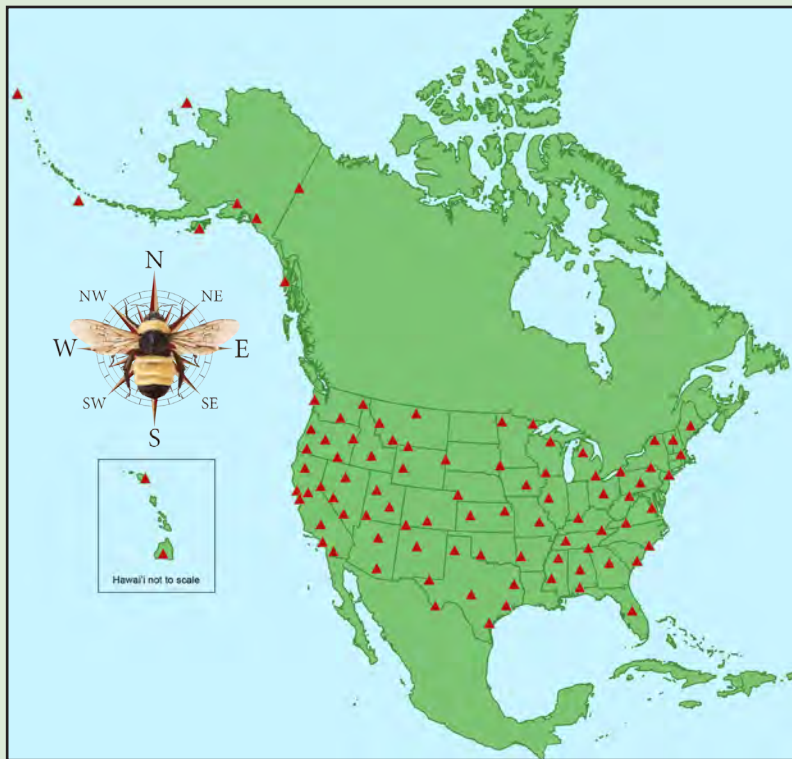
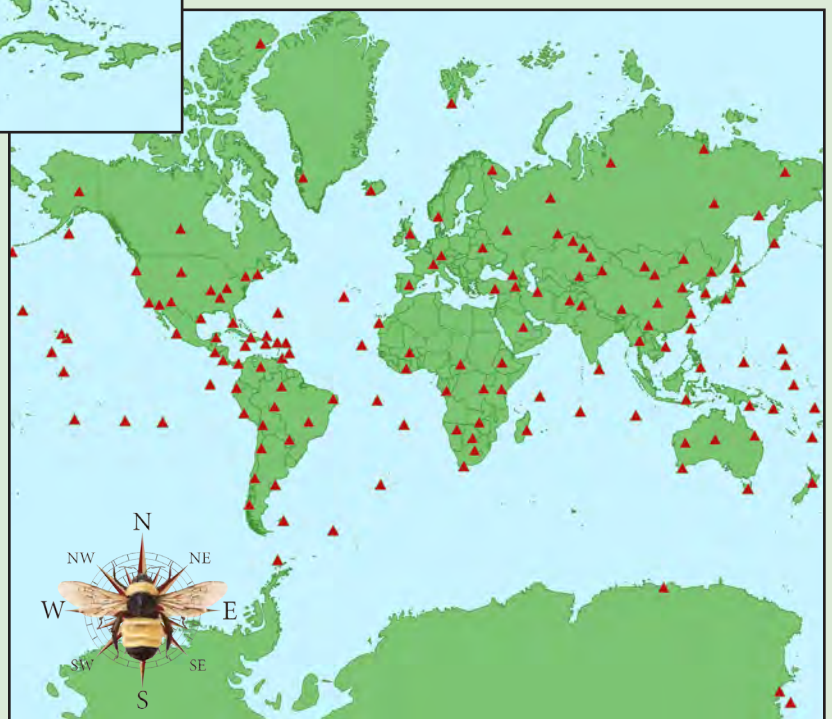


Figure 4. The Advanced National Seismic System has seismic stations across the Nation. Is a station located near where you live? Map by Carey Burda and Stephanie Pfeiffer.

Figure 5. The Global Seismographic Network has locations across the globe. Map by Carey Burda and Stephanie Pfeiffer.



Magnitude	Typical Maximum Modified Mercalli Intensity
1.0 - 3.0	I
3.0 - 3.9	II – III
4.0 - 4.9	IV – V
5.0 - 5.9	VI – VII
6.0 - 6.9	VII – IX
7.0 and higher	VIII or higher

Figure 6a. A comparison of magnitude and intensity measurements for earthquakes.

Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

Figure 6b. This figure shows a more complete version of the Mercalli Modified Intensity Scale. Abridged from *The Severity of an Earthquake*, a U.S. Geological Survey General Interest Publication. 1989: 288–913.

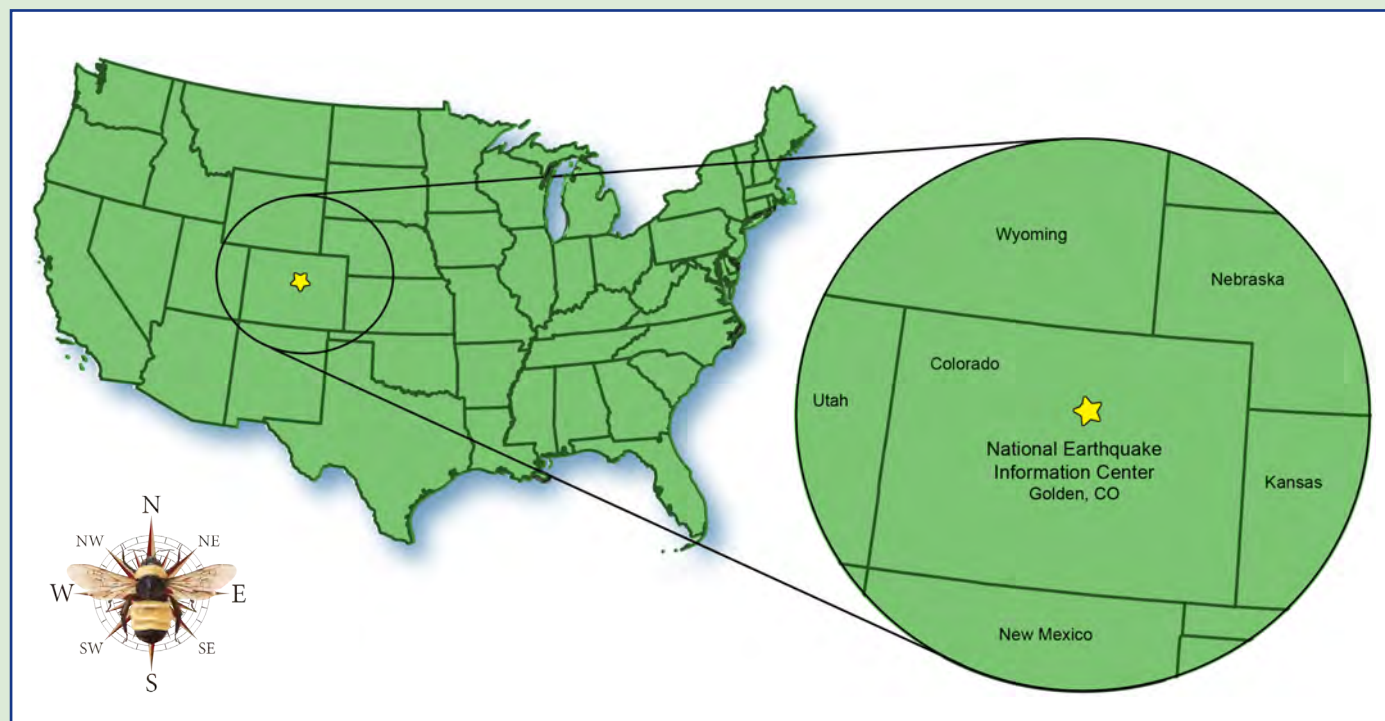
What Is the National Earthquake Information Center (NEIC)?

The National Earthquake Information Center (NEIC) is part of the U.S. Geological Survey and is located in Golden, Colorado. The NEIC has three main missions: (1) to locate and determine the size of an earthquake as quickly as possible, (2) to collect and provide data about earthquakes to scientists and the public, (3) to maintain an active research program to improve understanding and response to earthquakes. The NEIC reports on earthquakes registering a magnitude of about 2.5 or greater in the United States and about 4.5 or greater in other locations around the world. Currently, the NEIC reports on approximately 30,000 earthquakes per year. Based on this number, how many earthquakes occur each day on average?

To learn more about NEIC, visit <http://earthquake.usgs.gov/contactus/golden/neic.php>.



NEIC meeting room. Photo courtesy of David Wald.



The NEIC is located in Golden, Colorado. Map by Carey Burda and Stephanie Pfeiffer.

Introduction

The Advanced National Seismic System is a nationwide network of seismographs. These seismographs gather and record data about a wide variety of earthquakes across the Nation. However, some earthquakes in remote areas are not recorded due to the lack of seismographs in the area. Some scientists wanted to get a more complete description of earthquakes, including their effects and the extent of damage. The scientists thought that information provided by citizens experiencing earthquakes would be useful. To capture this information, the “Did You Feel It?” (DYFI) system was created in 1997.

The DYFI system allows Internet users to report earthquake data when they feel

an earthquake. The data submitted are put into computer programs that create “Did You Feel It?” Maps. The data collected are used to create color-coded maps based on the ZIP Codes. The map colors correspond to the earthquake intensity reported by the DYFI users (**figure 7**). More than 4 million entries have been submitted from 1999 to 2017.

The scientists wanted to know how the DYFI system changed from 1999 to 2013. The scientists wanted to know the advantages and disadvantages of gathering earthquake intensity data through a citizen-based science network. Additionally, the scientists wanted to measure the accuracy and timeliness of the DYFI system data.

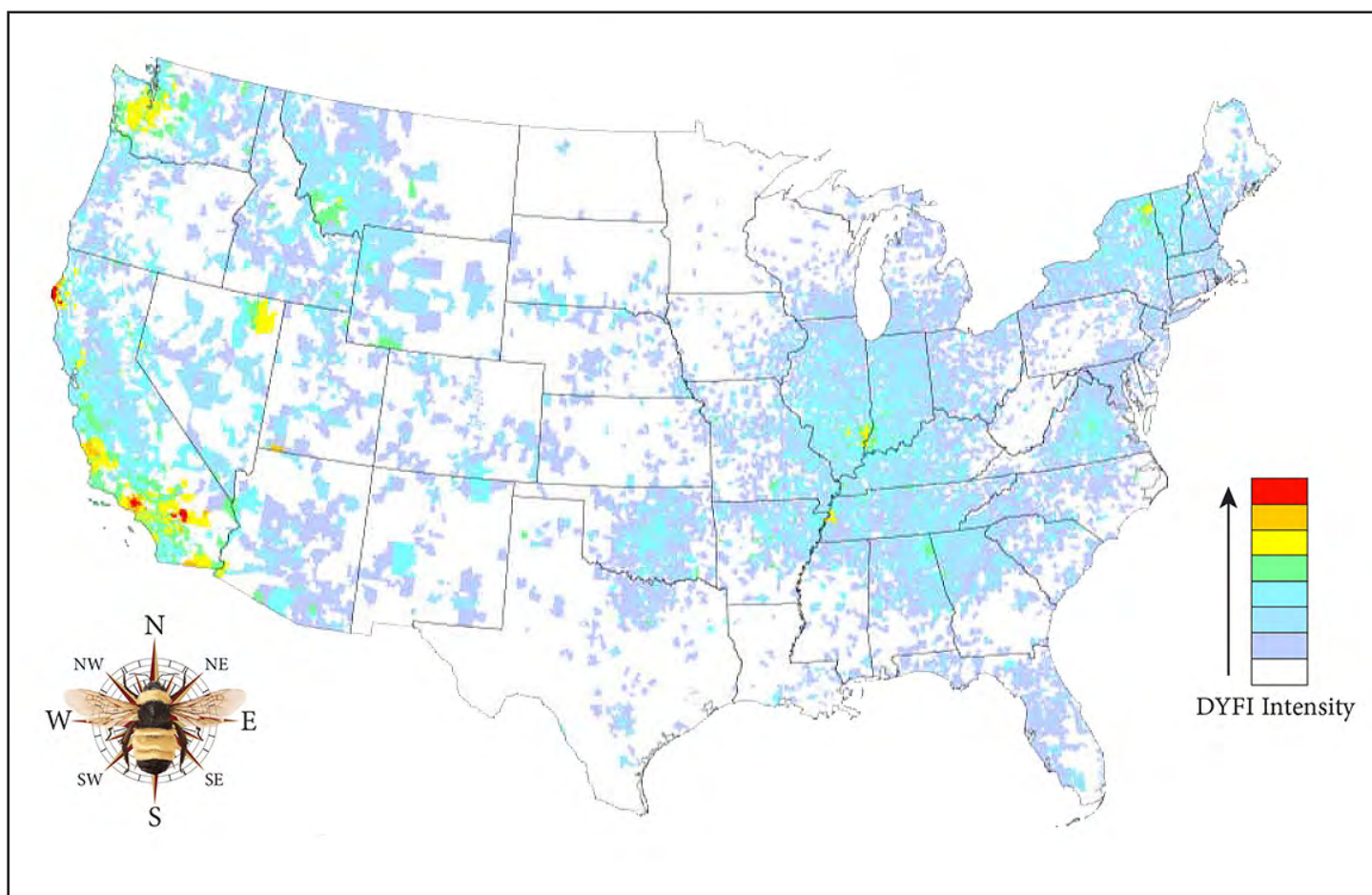


Figure 7. The DYFI map shows data entries from 1999 to 2013. Map courtesy of the U.S. Geological Survey.

Reflection Section



- ✿ In your own words and in the form of a question, explain what the scientists were interested in studying.
- ✿ Based on what you have read so far, provide one example of how the DYFI system allows citizens to participate in science research.

Number Crunch

- ✿ Write out 1.6 million in numeric form.

Methods

The scientists examined more than 10 years of data from the DYFI system. The scientists compared these data to other earthquake maps and data gathered by the U.S. Geological Survey. National Seismic Hazard Maps are produced every 6 years and display potential earthquake ground motions based on differing levels of **probability**. These maps help people understand the probability that earthquake ground motion will occur in certain areas. Earthquake ground motion is how much the Earth shakes in response to the earthquake's seismic waves.

The ground motion probabilities are indicated by different colors on the map. For example, colors on the 2008 map show the levels of horizontal shaking. Horizontal shaking is the ground movement that goes in a horizontal motion. The map shows the chance that in a 50-year period this horizontal shaking will occur (**figure 8**).

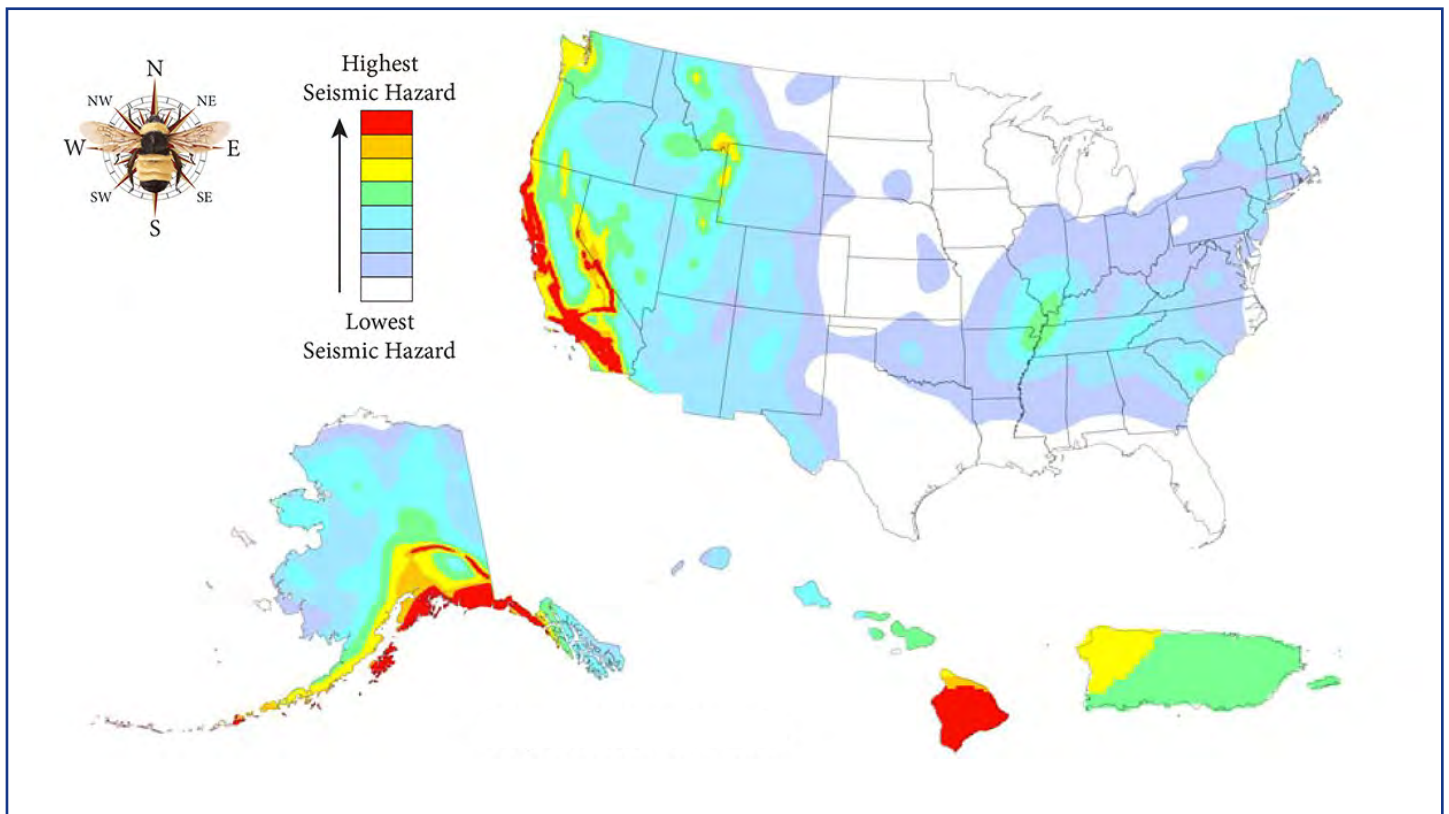


Figure 8. Where do you see the highest levels of probability? Map courtesy of the U.S. Geological Survey.

The scientists compared the 2008 National Seismic Hazard Map to a national map based on 10 years of DYFI data (**figure 9**). Intensity levels are color coded to approximately match each other. The DYFI national map is based on 1.6 million individual entries from more than 25,000 ZIP Codes. The scientists also compared the DYFI data with ShakeMaps (**figure 10**). ShakeMaps are maps that represent the ground shaking produced by an earthquake as recorded on the seismic

instruments. An earthquake produces a wide variety of ground shaking depending upon the ground's distance from the earthquake's epicenter, the rock and soil conditions, and differences in the seismic waves moving through Earth's crust.

The scientists also compared the data from 10 years of DYFI entries to measure the accuracy and timeliness of the data. The scientists used computers and computer software to analyze the data.

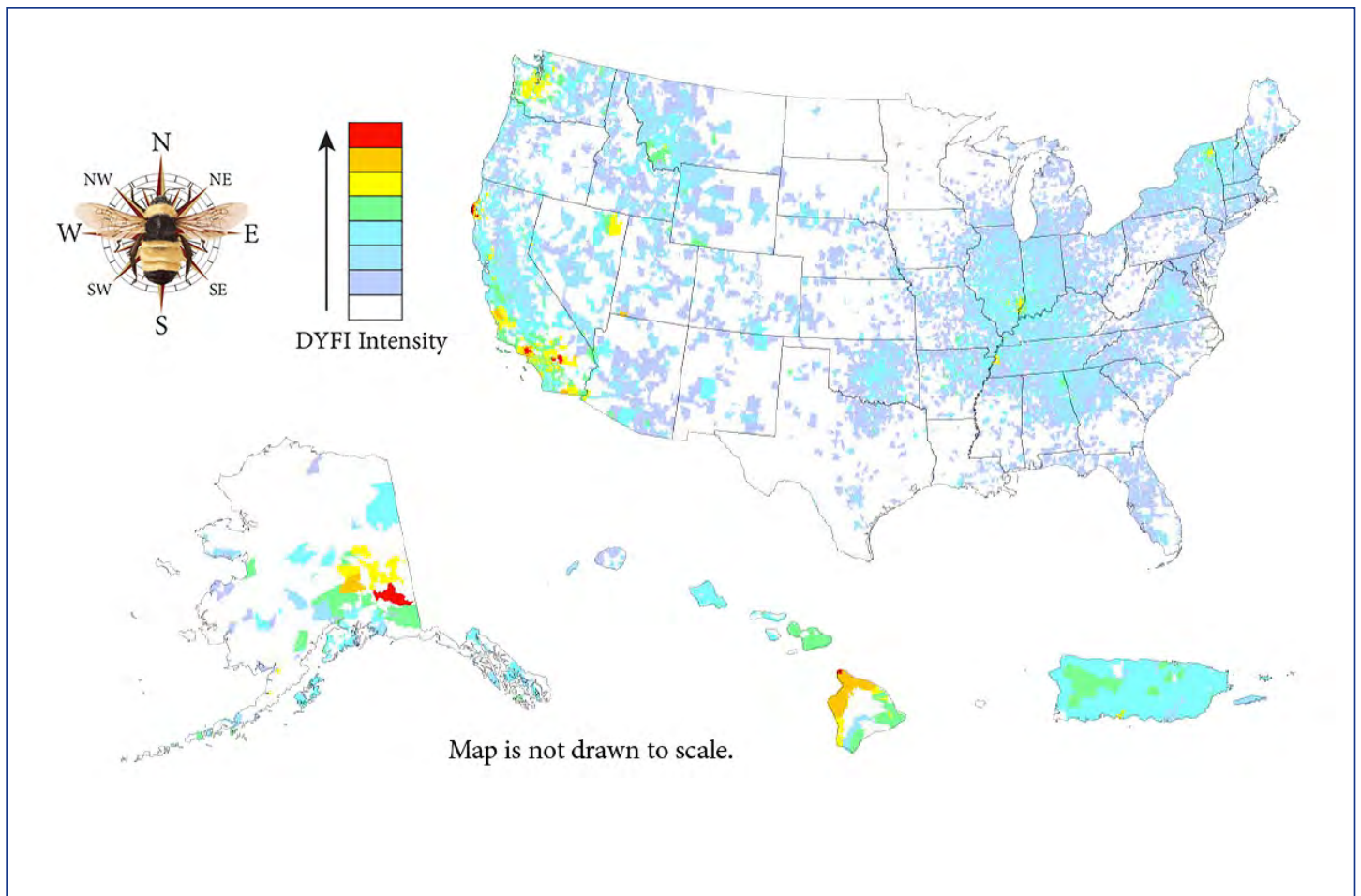


Figure 9. Compare this map to the map in Figure 8. What is one similarity between the maps? What is one difference between the maps? Map courtesy of the U.S. Geological Survey.

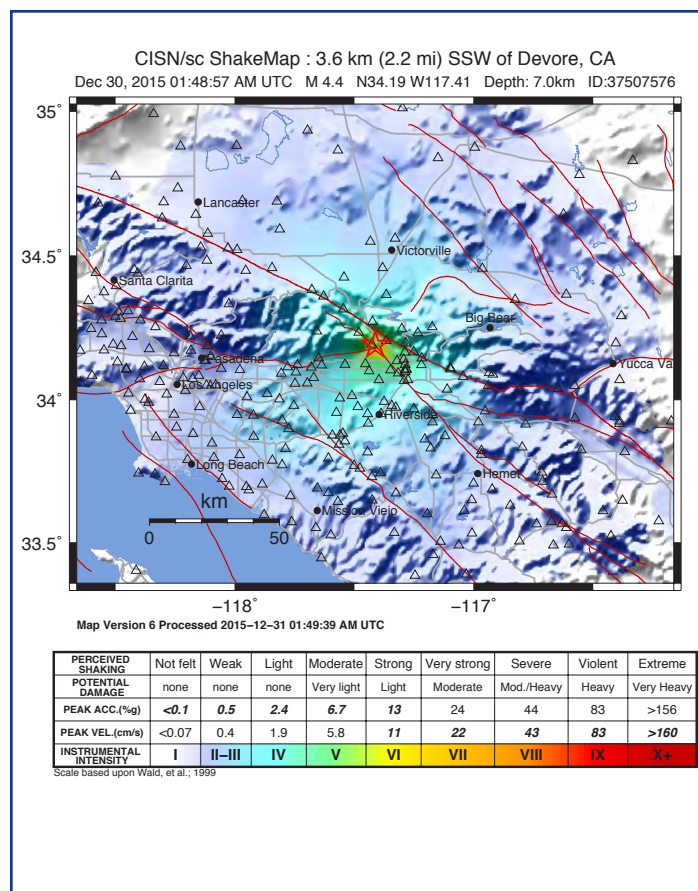
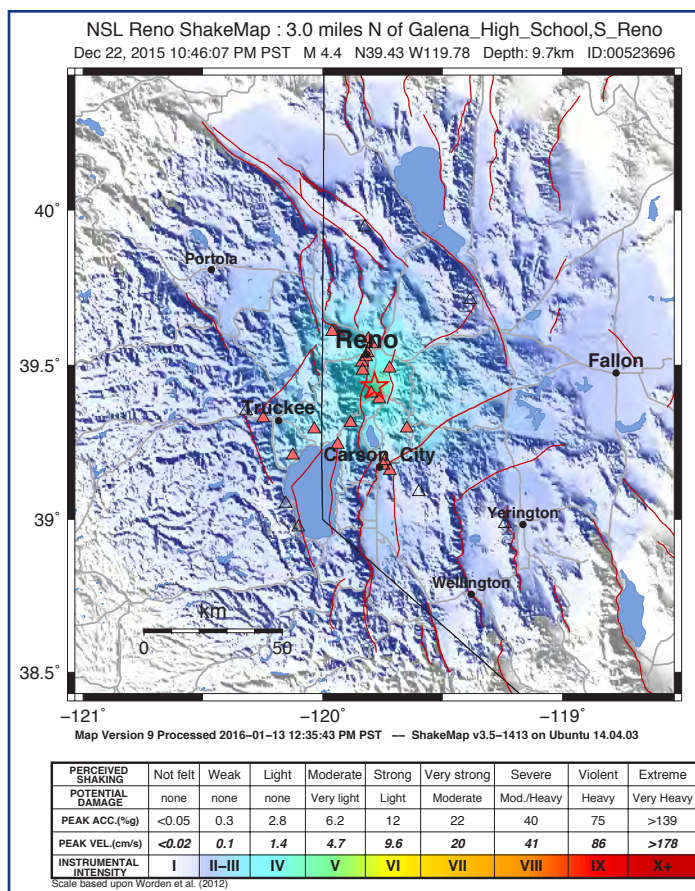


Figure 10. ShakeMaps show the ground shaking produced by an earthquake as recorded by the seismic instruments. Maps courtesy of U.S. Geological Survey.

Reflection Section

- Name one reason you think the scientists were interested in learning about the timeliness and accuracy of the data from the DYFI system. Why do you think this reason is important?
- What do you think are one or two advantages of comparing different maps for earthquake data?

Findings

Before the DYFI system, collecting shaking intensity information from citizens in an area impacted by an earthquake required a great deal of effort and time. The data weren't available until long after the earthquake occurred, and the amount of data was relatively small and sparse. Because of the immense effort required to collect shaking data, intensity maps using the Modified Mercalli Intensity Scale were rarely made for earthquakes with a magnitude of less than 5.5.

DYFI has changed all that! Since DYFI makes collecting the data fast and easy, the scientists found that they can collect information for earthquakes with any magnitude, as long as it was felt. Previously, in areas where there were no seismic instruments close by, some small-magnitude earthquakes were not recorded at all. The scientists found that, based on the data provided through DYFI, even earthquake events with less than a magnitude 2.0 are routinely reported. They also found that the DYFI data are timely. The

scientists calculated that, after an earthquake, approximately 62,000 responses are processed in an hour, or around 1,000 responses per minute!

DYFI maps are created not only for earthquakes, but also for other events that cause shaking and vibrations. These other events include mining events and other explosions, **supersonic** aircraft flights, and **bolides**.

Additionally, the DYFI data accuracy is high. The scientists found that the large amount of data that is collected through DYFI provides more accurate information overall. The large amount of data could be compared and averaged, and any responses that seemed out of the ordinary could be discarded.

The quality and quantity of DYFI data, however, ultimately depends on how many people experience an earthquake and how many have access to the Internet. Areas with large populations and easy access to the Internet provide better quality and greater quantities of data. The scientists also found that DYFI data

from citizen scientist reports usually agree with the ShakeMap data recorded by seismic instruments.

Reflection Section



- ✿ The scientists found that the data were of better quality in areas with large populations and easy access to the Internet. Why do you think an area with a large population may have a better quality of data?
- ✿ Now that you have read about what the scientists found in their study of the DYFI system, name one advantage of citizen-based science.

What Is a Bolide?

A bolide is an **astronomical** word for exceptionally bright meteors that can be seen over a wide area. Some people also refer to bolides as fireballs. For more information on bolides, visit the National Aeronautics and Space Administration Near Earth Object Program website at <http://neo.jpl.nasa.gov/fireballs/>.

Photo courtesy of <http://www.iStockphoto.com>



Out of This World Science!

People have become accustomed to using the DYFI system for events that cause shaking. People are so used to reporting to the DYFI system that a descending space shuttle flying over Los Angeles caused enough entries to create its own DYFI page. The DYFI users provided so much data that an accurate map of the re-entry **trajectory** of the spacecraft could be created!



Photo courtesy of Bill Ingalls, National Aeronautics and Space Administration.



Citizen Science Connections

The Did You Feel It? (DYFI) system was created to gather information about earthquakes from the people who experience the earthquakes. Using the Internet, scientists can get information quickly about what citizens experience and the effects of earthquakes. Scientists who study earthquakes combine the citizen-based science data from DYFI with state-of-the-art data collection technology.

Did You Feel It? lets citizen scientists:

- Search and view data on earthquakes around the world;
- Report earthquake events in their location;
- Learn about the science of earthquakes.



Did You Feel It? is a project of the U.S. Geological Survey. The DYFI system has collected nearly 3 million data points from citizen scientists since 1997. For more information about the DYFI system, visit <https://earthquake.usgs.gov/data/dyfi>.

Discussion

With the DYFI system, U.S. Geological Survey scientists said that they can now monitor and collect data on all felt and reported earthquakes. The DYFI system also provides other benefits. The scientists found that the DYFI system helps educate the public. The system provides a human perspective on an earthquake and creates data that scientists can use to help understand earthquakes better.

The DYFI system also provides emotional support to people experiencing an earthquake. The system gives citizens the opportunity to share and confirm their experiences with each other. The DYFI system provides high-quality and timely data about earthquakes. This information allows scientists to better understand and respond to earthquake events.

Additionally, the scientists found limitations to the DYFI system. They found that the highest rates of response came from areas with large populations, easy Internet access, and a lack of significant damage and power outages. Therefore, the DYFI system may lack entries from areas harder hit by earthquakes.

These missing data would be important for better understanding an earthquake. However, the main purpose of the DYFI system is to provide scientists with more data to evaluate earthquakes after they have occurred. The DYFI system has provided scientists and the public with more data about earthquakes. Moreover, these data are provided in a timely manner.



Reflection Section

- ❦ U.S. Geological Survey scientists said that they can now monitor and collect data on all felt and reported earthquakes. Why do you think this may be useful to scientists and the public?
- ❦ Scientific research often exposes advantages and disadvantages of programs or topics being studied. One of the main disadvantages of the DYFI system is that the system is not able to get a lot of entries from areas harder hit by earthquakes. The scientists in the research paper discuss both the advantages and disadvantages of the DYFI system. Why do you think it is important to examine a system's advantages and disadvantages?

Glossary

accustomed (ə kəs təmd): Being in the habit or custom.

astronomical (as trə nă mi kəl): Of or relating to astronomy, which is the scientific study of stars, planets, and other objects in outer space.

bolide (bō līd): A large meteor or fireball; especially, one that explodes.

invigorate (in vi gə rāt): To cause (something) to become more active and lively.

magnitude (mag nə tūd): A number that shows the power of an earthquake.

migratory (mī grə tōr ē): Having a characteristic of moving from one place to another on a periodic basis.

probability (pră bə bi lə tē): A measure of how often a particular event will happen if something (such as tossing a coin) is done repeatedly.

seismic (sīz mīk): (1) Of, subject to, or caused by an earthquake; (2) Of or relating to an earth vibration caused by something else (as an explosion or the impact of a meteorite).

supersonic (sü pər să nīk): Faster than the speed of sound.

trajectory (trə jek t(ə-)rē): The curved path along which something (such as a rocket) moves through the air or through space.

Accented syllables are in **bold**. Marks and definitions are from <http://www.merriam-webster.com>. Definitions are limited to the word's meaning in the article.

Adapted from Wald, D.J.; Quitoriano, V.; Worden, B.; Hopper, M.; Dewey, J.W. 2011. USGS "Did You Feel It?" Internet-based macroseismic intensity maps. *Annals of Geophysics*. 54(6): 688-707.

FACTivity

Time Needed

One class period

Materials

(for each student or group of students)

- Two earthquake data tables
- Graphing paper
- Pencils
- Highlighters

The questions you will answer in this FACTivity are: How do the number of earthquakes from the 1990s compare to the number of earthquakes in the 2000s? How do the magnitudes of the earthquakes compare between the two time periods?

Methods

Look at the two earthquake data tables on page 35. Highlight the row in each table for

total earthquakes. Create two bar charts and compare total earthquakes for the 1990–1999 time period with the 2000–2009 time period. Here are a few questions to think about:

- Which year had the most earthquakes during 1990–1999?
- Which year had the most earthquakes during 2000–2009?
- Look closely at the two data tables. Circle magnitudes with the highest occurrence of earthquakes. Is the magnitude you highlighted the same in each time period?
- Do you think that the two time periods are similar or not? Why do you think this? Use evidence from the tables to help support your thinking.



Number of Earthquakes in the United States for 1990–1999
Located by the U.S. Geological Survey National Earthquake Information Center

Magnitude	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
8.0 to 9.9	0	0	0	0	0	0	0	0	0	0
7.0 to 7.9	0	NA	2	0	1	0	2	0	0	NA
6.0 to 6.9	2	4	15	9	4	6	4	6	3	6
5.0 to 5.9	64	49	72	62	64	45	100	63	62	50
4.0 to 4.9	284	242	404	270	333	350	612	362	411	352
3.0 to 3.9	626	713	1717	1119	1543	1058	1060	1072	1053	1398
2.0 to 2.9	414	559	998	1009	1196	822	654	759	742	814
1.0 to 1.9	1	3	5	7	2	0	0	2	0	0
0.1 to 0.9	0	0	0	0	0	0	0	0	0	0
No Magnitude	877	599	368	457	444	444	375	575	508	381
Total Earthquakes	2268	2171	3581	2933	3587	2725	2807	2839	2779	3003
NA = Not Applicable										

Number of Earthquakes in the United States for 2000–2009
Located by the U.S. Geological Survey National Earthquake Information Center

Magnitude	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
8.0 to 9.9	0	0	0	0	0	0	0	0	0	0
7.0 to 7.9	0	1	1	2	0	1	0	1	0	0
6.0 to 6.9	6	5	4	7	2	4	7	9	9	4
5.0 to 5.9	63	41	63	54	25	47	51	72	85	58
4.0 to 4.9	281	290	536	541	284	345	346	366	432	288
3.0 to 3.9	917	842	1535	1303	1362	1475	1213	1137	1486	1492
2.0 to 2.9	660	646	1228	704	1336	1738	1145	1173	1573	2379
1.0 to 1.9	0	2	2	2	1	2	7	11	13	26
0.1 to 0.9	0	0	0	0	0	0	1	0	0	1
No Magnitude	415	434	507	333	540	73	13	22	20	14
Total Earthquakes	2342	2261	3876	2946	3550	3685	2783	2791	3618	4262

Technology FACTivity



Time Needed

One class period

Materials

(for each student or group of students)

- Computers with Internet access
- Two maps chosen from <http://earthquake.usgs.gov/earthquakes/byregion/> (Recommended: one map from the East Coast of the United States and one from the West Coast of the United States)
- 2014 National Earthquake Hazard Map http://earthquake.usgs.gov/hazards/hazmaps/conterminous/2014/images/HazardMap2014_lg.jpg

The questions you will answer in this FACTivity are: How does the seismic data compare between different States? What is the seismic activity like in your State? What does the 2014 National Earthquake Hazard Map tell you about the seismic hazard in your State?

Methods

On a computer, go to <http://earthquake.usgs.gov/earthquakes/region.php>. Select one State from the East Coast and one from the West Coast. Compare the map data between the two States. Answer these questions:

1. What are the main differences between the maps from each State?
2. What is one similarity between the maps?
3. Based on the State maps you are looking at, which State would you say has the most seismic activity? Why?
4. Now, take a moment to look at your own State map. Also, go to http://earthquake.usgs.gov/hazards/products/conterminous/2014/HazardMap2014_lg.jpg and look at the 2014 National Earthquake Hazard Map. Specifically, look at your State. List three things you notice on the maps about your State. What surprises you about the seismic activity in your State?

Web Resources

Did You Feel It?

<https://earthquake.usgs.gov/data/dyfi>

U.S. Geological Survey Earthquake Hazards Program

<https://earthquake.usgs.gov/>

U.S. Geological Survey Earthquakes for Kids

<https://earthquake.usgs.gov/learn/kids/>

Rock n' on Shakey Ground by U.S. Geological Survey

<https://earthquake.usgs.gov/learn/kids/RockShakeyGround.pdf>

Advanced National Seismic System

<https://earthquake.usgs.gov/monitoring/anss/>

National Aeronautics and Space Administration Sonic Booms

<https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-016-DFRC.html>

