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Earth Science Lab Investigation: Earthquakes

Can Earthquake Be Predicted?

Introduction

At 1:11am local time on Saturday April 25th, 2015, a powerful earthquake awoke terrified residents of Kathmandu, the capital city of Nepal that is home to nearly 1.5 million inhabitants. The magnitude 7.9 quake, one the country's worst in 80 years, rocked both the mountainous countryside and urban centers where many homes are old, poorly built and packed close together. The quake killed more than 2,300 and injuring more than 5,000, leveled buildings and centuries-old temples, and left many trapped under mounds of rubble (Figure 1).

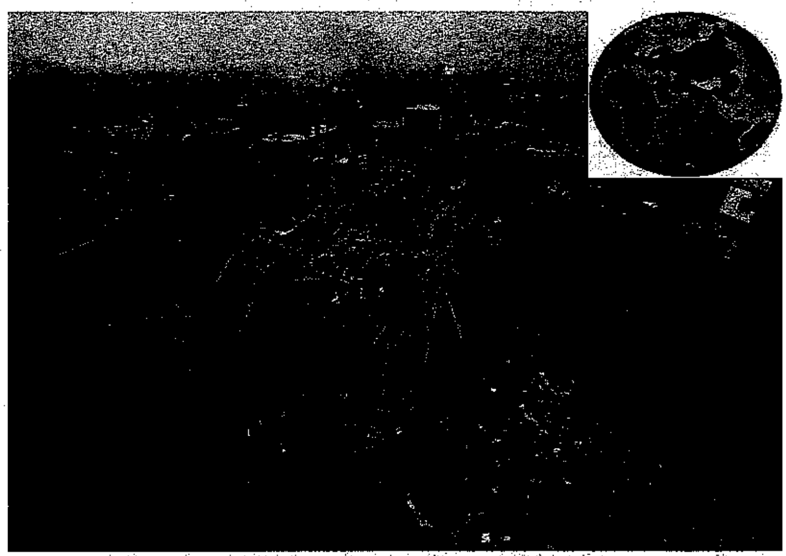

Figure 1. Rescue workers remove debris as they search for victims of earthquake in Bhaktapur near Kathmandu, Nepal. A major earthquake shook Nepal's capital and the densely populated Kathmandu Valley before noon Saturday, causing extensive damage with toppled walls and collapsed buildings, officials said. (AP Photo/Niranjan Shrestha)

The earthquake also triggered a major avalanche on the south slopes of Mt. Everest, located approximately 160 km east-northeast of the epicenter. The avalanche destroyed the base camp, where climbers were waiting for a break in the weather to ascend the mountain. According to reports, the avalanche killed at least 17 people and injured 61 others.

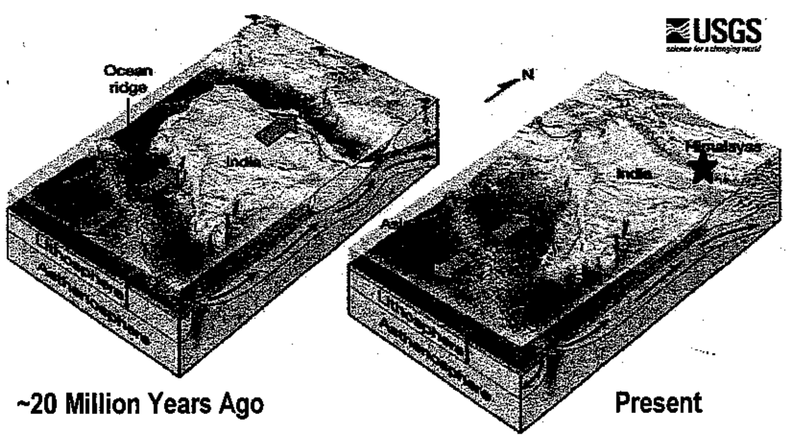

Figure 2. The Indian Plate (containing the subcontinent of India) has been moving steadily towards and colliding with the Eurasian Plate for the past 71 million years. At the location of this earthquake (illustrated with a star a right) the Indian Plate is converging with Eurasia at a rate of 45 mm/yr towards the north-northeast, driving the uplift of the Himalayas Mountains.

Earthquake activity in Nepal is caused by the ongoing collision between two *tectonic plates*; the Indian Plate and the Eurasian Plate (Figure 2). This is a collision that, over tens of millions of years, has produced the Himalaya Mountains and the Tibetan Plateau. As a result of this collision the rocks that make up these plates are slowly being deformed and storing potential energy. Eventually, the internal strength of the rock (if the rock has not previously fractured), or friction between the two sides of a pre-existing fracture is exceeded. When this occurs, the potential energy stored in the rock is released as an *earthquake* as the rocks fracture and return to an un-deformed state. This process, of generating earthquakes by slowly accumulating potential energy as rocks are deformed and then suddenly releasing it as kinetic energy, is known as the *Elastic Rebound Theory.* While this theory provides a general description of the process that generates quakes it does not directly provide answers to questions that would benefit those who live in Nepal or other seismically active regions; "When will the next earthquake occur?", or "How large will the next earthquake be?"

Modeling earthquakes in the classroom

Figure 3. The Earthquake Machine allows students to see how energy accumulated from their slow pull on the measuring tape can result in a sudden and unpredictable release of energy as the block slips forward.

Due to the scale of the geologic processes involved in the generation of earthquakes, it is impossible for us to explore the real phenomena in the classroom. However, we explore these processes using a physical model called the Earthquake Machine (Figure 3). The Earthquake Machine is useful as it allows one to visualize the energy inputs and outputs, and elastic behavior of a fault system along a plate boundary.

As illustrated in Figure 4, the entire model (wooden block with a sandpaper bottom, sandpaper base, and measuring tape) represents a tectonic plate. The block of wood (Figure 4) represents a locked edge of the plate, while the end of the measuring tape away from the block is analogous to the center of the plate, far from its margin, where the plate is in slow, yet constant motion. This motion is represented by a very slow, steady pull on the end of the measuring tape. The rubber band represents the elastic properties of the *lithosphere*, which deforms as one end of the system is locked and the other is in slow constant motion. Through this deformation, potential energy is stored up. Eventually, frictional forces between the block and sandpaper that held the block in place are overcome and potential energy is converted to kinetic energy as the block lurches forward. This sudden release of stored energy and propagation of seismic waves from the rubber band is analogous to an earthquake!

This model accurately simulates the energy that slowly accumulates in rock surrounding a locked fault that is released in a sudden slip event, a process known as the *Elastic Rebound Theory*. As such it is useful for helping us develop ideas about the processes that generate earthquakes. However, we must remember that as a model is ultimately an over-simplification of a complex earth system and has limitations. Be watchful for places where you think the model may be either like or unlike the real Earth.

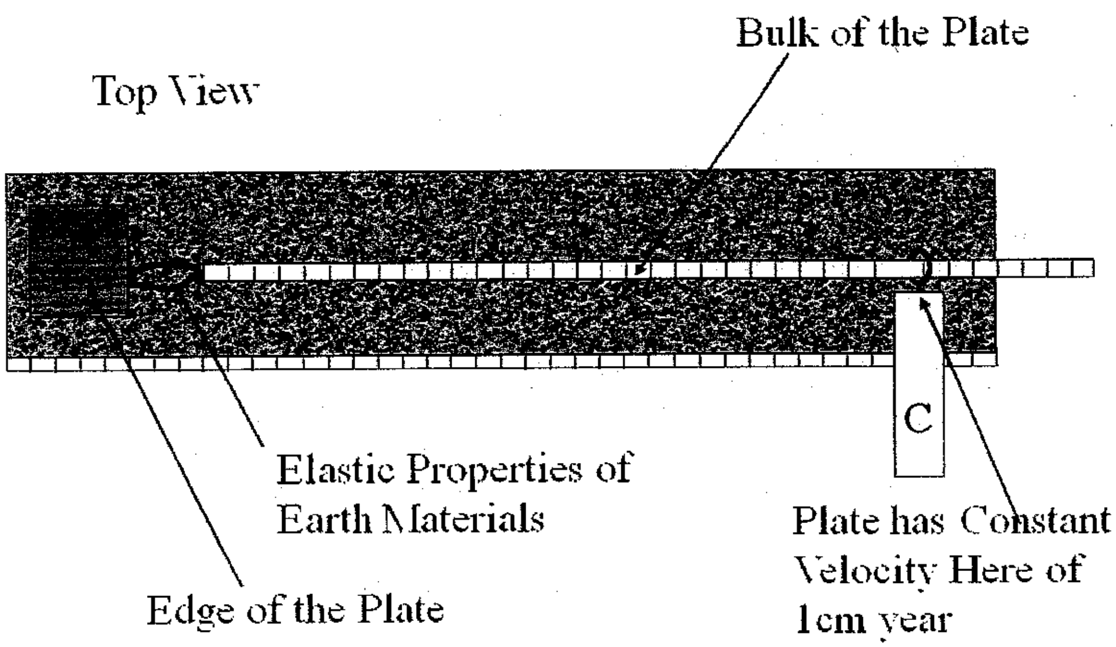

Figure 4. Mapping the earthquake machine model to the real Earth when viewed from above. At block B, the edge of the plate is locked. However, at block C, we will assume the plate has a constant velocity of 1cm/year.

The Task. Design and carry out an investigation(s) to identify variables that influence both the size and the frequency of earthquakes for the Earthquake Machine system. Be sure to describe the degree of influence of each variable. The guiding question of this investigation is: ***What combination of factors gives us the largest magnitude and the highest frequency of earthquakes?***

Materials. You may use any of the following materials during your investigation:

Consumables

- Duct Tape

Equipment

- Basic Earthquake Machine set-up
- Large Mass
- Small Mass

Equipment (cont.)

- Stiff rubber band
- Weak rubber band
- Salt
- Block with medium grit sand paper
- Block with fine grit sand paper
- Accelerometer (iPhone/iPod or other)

Investigation Proposal Required: ☐ Yes ☐ No

Safety Precautions. Follow all normal lab safety rules. Your teacher will explain relevant and important information about wearing safety goggles when working with stretched rubber bands.

Getting Started. Before you can design and carry out your investigation, you must determine what type of data you will need to collect, how you will collect it, and how will you analyze it. To help you make this determination, it will be useful to get to know the earthquake machine and its operation.

1) Obtain the necessary materials from your teacher.

2) Smooth the sanding belt out on the lab table so that there are no waves in it. It helps to roll it backwards on itself to help flatten it.
3) Use duct tape to secure each end to the table, grit side up.
4) Parallel to the sanding belt, tape down the uncut measuring tape in the same fashion as the sanding belt. (Be sure the metric side is up!)
5) Place Block B on one end of the sanding belt.
6) Hook the rubber band attached to the measuring tape to the screw eye.
7) Thread the other end of the split measuring tape through the screw eye of Block C and move it to the opposite end of the sanding belt. Block be will stand on its narrow edge with the screw eye over the center of the sanding belt. The screw eye in Block B serves as a marker to allow you to measure the amount of measuring tape pulled through it.
8) As illustrated in Figure 3 above, slowly pull the loose end of the measuring tape attached to Block B. *Remember - tectonic places move only mm/year so you need to pull with a slow consistent motion. For this activity we will make the assumption that the center of the plate (end of the measuring tape without the rubber band) is moving at a constant velocity of 1 cm/yr.*

As you explore the earthquake machine to determine ***what type of data you need to collect*** think about the following questions:

- The guiding question has two parts (e.g. largest magnitude and highest frequency). Will you be able to test for these simultaneously or will you need to test for one and then the other?
- What information will be important in order to be able to report event frequency?
- Magnitude is a description of the total amount of energy released during the earthquake. How will you know if the magnitude of an event is large or small? How could you quantify this?

To determine ***how you will collect your data***, think about the following questions:

- How many "earthquakes" are needed to provide enough data to draw conclusions about each investigation?

In order to determine ***how you will analyze your data*** think about the following questions:

- How will your group connect the data you recorded to the changes in the variables you made between investigations?
- What will be the best way to display/visualize your data?

Connections to Crosscutting Concepts and the Nature of Science and Scientific Inquiry. As you work through your investigation, be sure to think about:

- How models are used to study natural phenomena?
- How important is is to identify the underlying cause for observations of natural phenomena?
- What was the role of imagination and creativity in your investigation?
- How might this model be important in the generation of scientific knowledge?

Initial Argument. Once your group has finished collecting and analyzing your data, you will need to develop an initial argument. Your argument must include a claim. The claim is your answer to the guiding question. Your argument must also include evidence in support of your claim. The evidence is your analysis of the data and your interpretation of what the analysis means. Finally, you must include a justification of the evidence in your argument. You will therefore need to use a scientific concept or principle to explain why the evidence that you decided to use is relevant and important. You will create your initial argument on a whiteboard. Your whiteboard must include all the information shown in Figure 5.

Argumentation Session. The argumentation session allows all of the groups to share their arguments. One member of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. The goal of the argumentation session is not to convince others that your argument is the best one; rather the goal is to identify errors or instances of faulty reasoning in the initial arguments so these mistakes can be fixed. You will therefore need to evaluate the content of the claim, the quality of the evidence used to support the claim, and the strength of the justification of the evidence included each argument that you see. In order to critique an argument, you might need more information than what is included on the whiteboard. You might, therefore, need to ask the presenter one or more follow up questions such as:

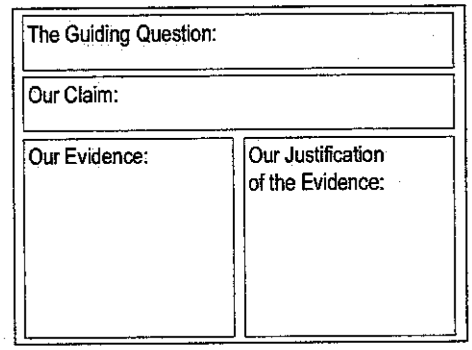

Figure 5. Argument Presentation on a Whiteboard

- [How did your group collect the data? Why did you use that method?]
- [What did your group do to make sure the data you collected are reliable? What did you do to decrease measurement error?]
- [What did your group do to analyze the data, and why did you decide to do it that way? What did you do to make sure that your calculations are correct?]
- [Is that the only way to interpret the results of your group's analysis? How do you know that your interpretation of the analysis is appropriate?]
- [Why did your group decide to present your evidence in that manner?]
- [What other claims did your group discuss before deciding on that one? Why did you abandon those alternative ideas?]
- [How confident are you that your group's claim is valid? What could you do to increase your confidence?]
- [Other question]

Once the argumentation session is complete, you will have a chance to meet with your group and revise your original argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most valid or acceptable answer to the research question!

Report. Once you have completed your research, you will need to prepare an ***investigation report*** that consists of three sections. Each section should provide an answer for the following questions:

1. What question were you trying to answer and why?
2. What did you do during your investigation and why did you conduct your investigation in this way?
3. What is your argument?

Your report should answer these questions in 2 pages or less. This report must be typed and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!