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SEISMIC SLEUTHS

AMERICAN GEOPHYSICAL UNION

S E I S M I C S L E U T H S

EARTHQUAKES

A Teacher's Package for Grades 7-12

Produced by

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AGU/FEMA EARTHQUAKE CURRICULUM

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Teachers who participated in the two 1994 Seismic Sleuths Leadership Institutes also conducted field testing and review of the lessons during the institutes. The suggestions and additions by the initial field test and institute teacher participants have contributed to a stronger curriculum package.

A special note of thanks to Katharyn E. K. Ross, whose comprehensive Fourth Edition of *Earthquake Education Materials for Grades K - 12* contributed greatly to the unit resource lists in this package, and to Sean Cox, teacher, Salem High School, New Hampshire, who provided the appendix to Unit Six.

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AGU

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Dear Colleague,

The American Geophysical Union (AGU) and the Federal Emergency Management Agency (FEMA) are pleased to present *Seismic Sleuths—A Teacher's Package for Grades 7–12*. Apprehension about what will happen during and after an earthquake can be alleviated with education and preparation. The goal of *Seismic Sleuths* is to provide the tools to prepare students for earthquakes and other natural disasters that may interrupt their lives and to help them get their lives back to normal after the event.

This package was developed as a joint effort of classroom teachers, research scientists, pedagogical specialists, AGU, and FEMA. The team approach was taken to ensure that the materials developed would be appropriate for classrooms, have correct and current content information, and reflect national science education reform efforts. In the introductory pages you will find matrices designed to help you match *Seismic Sleuths* materials with the National Science Teaching Standards content section. You will also find a matrix that indicates which lesson in *Seismic Sleuths* includes instruction material relative to discipline content.

Seismic Sleuths take a broad approach in preparing students for earthquakes. Hands-on/minds-on inquiry driven activities are balanced by library research and visits with disaster planning officials. Emphasis has been placed on cooperative learning and the constructivist approach to teaching. Students not only study the causes of earthquakes, they also study building construction and forces that damage buildings, then construct model buildings to test their knowledge. Students explore how their community is preparing for emergencies and are empowered with tools to bring about change in community disaster preparedness. Some of the activities may also be shared with others in your building, such as the social studies, language arts, mathematics, and industrial arts teachers.

A common thread connects the six units of *Seismic Sleuths*, but individual activities can be adapted to enhance your lessons already in place. The general introduction and overview of units sections will give you an idea of the content and layout of *Seismic Sleuths*. Each unit in turn has an introduction that gives you specific information about the unit's contents. Lessons and activities are written to give you complete procedures, material lists, and master pages for the students. Lessons are flexible and designed to be adapted to your teaching style and your students' learning ability.

When you choose a lesson or topic to include in your schedule, study it carefully to determine the activity's nuances. You will recognize some of the lessons as adaptations from other sources that have been rewritten for the *Seismic Sleuths* project. Many of the lessons are especially designed for *Seismic Sleuths*, and you will need to carefully follow directions to make them work in your classroom. While detailed instructions for students may be necessary in some cases, many of the activities can be adapted as a jumping off place for student exploration of the topic. In all cases, use the lessons as a departure for further study.

With desktop publishing technology these materials can easily be modified and new editions produced. While field testing and rewriting of lessons has been extensive, there will always be room for improvement. It is our wish to provide you with the most usable materials possible with current information. If you have comments or suggestions for future editions please forward them to my office.

My sincere thanks and congratulations to all the individuals involved in the project. A special thanks goes to FEMA for the forethought to fund the production of these vital teaching materials.

M. Frank Watt Ireton, Ph.D.
AGU/FEMA Earthquake Project Director

The American Geophysical Union encompasses the Earth and space sciences:
Geodesy, Seismology, Atmospheric Sciences, Geomagnetism and Paleomagnetism,
Ocean Sciences, Hydrology, Volcanology, Geochemistry, and Petrology,
Tectonophysics, Planetology, Solar-Planetary Relationships

Earthquakes are mystifying events. They are as unpredictable as they are powerful, and not even seismologists fully understand the forces within the Earth that set them in motion. As an educator, you can capitalize on that mysterious appeal to engage your students' interest.

Ultimately, however, the purpose of these lessons is to demystify earthquakes, and to counter the fatalism that frequently accompanies ignorance about natural phenomena. Interactive lessons invite students to discover what is known about quakes—the considerable body of knowledge that deals with their causes, the patterns of their occurrence, and what human beings can do to minimize their catastrophic effects on themselves and their communities.

The units in this package follow a pattern of zooming in and out, beginning with concerns closest to home, moving to general principles and global perspectives, then homing in again to engage students in evaluating their personal preparedness and that of their families, schools, neighborhoods, and communities. Look for the magnifying glass symbols opposite the text, which indicate essential vocabulary and helpful hints (Teaching Clues and Cues).

Units 1 and 6 deal most specifically with the personal and local, but every unit contains a mixture of general information and specific, local applications. A healthy respect for the power of earthquakes requires both kinds of understanding. Units 4 and 5 feature interactive lessons in architecture and engineering, topics seldom dealt with in grade 7-12 curriculum materials.

You may not find time to teach every lesson in this package. For teachers who must pick and choose, most of the lessons are designed to stand on their own. Take time to familiarize yourself with the outline, however. Read the unit introductions; take advantage of the background readings provided and of the unit resource lists. The Teacher Preparation section in each lesson outlines things you need to do before class begins, in addition to assembling the items on the materials list. Plan ahead now for the cooperation you will need in Unit 1, the materials you will need in Unit 4, and the field trips you will make in Unit 5. You'll see a burst of learning to reward your efforts and a wealth of ideas to enrich your science and social studies teaching.

Theory takes a back seat to hands-on experience in most of these lessons. As its name implies, this Seismic Sleuths package focuses on discovery. Ideally, the process of discovery will ripple through the town or city outside your classroom. Beginning in Unit 1, students will be interacting with a wide range of public officials. Please initiate and encourage these relationships. They will benefit the students, the school, and the community.

Through interacting with adults in positions of responsibility, students will develop a realistic sense of how their community functions day to day and how it would function in the aftermath of an earthquake or other natural disaster. Most will find it enormously reassuring to learn that emergency plans are in effect. Moreover, they will be empowered by the knowledge that their individual and collective actions can make a difference. Cultivating relationships within their community will also expose students to a variety of careers they might never have considered and provide a motivation to stay in school. In the long range, these activities will prepare today's students to be tomorrow's concerned and informed participants in democracy.

The school will benefit from these relationships by widening the pool of local adults who take an active interest in education, share their expertise and experience, and serve as role models for students. The community at large will benefit greatly, whether or not it is in an area known to be seismically active. Most of the kinds of emergency planning that students will learn about, and model in Unit 6, would be appropriate not only in the event of an earth- quake but also in case of flood, hurricane, or other large-scale disaster. In just the last few years, almost every section of the country has experienced destructive natural events.

Unit 1. This three-part introductory unit sets the stage for what follows. Every teacher should take time to include some of the materials contained in this unit. The introductory lesson assesses students' knowledge of earthquakes. In lesson two students describe their own experiences and tell how they would prepare for an earthquake. Lesson three requires students to make contact with emergency personnel in their community to ascertain emergency preparedness plans. Lessons in this unit are referred to in future units.

Unit 2. This five-part unit moves students beyond their personal survival into the causes of earthquakes. This unit sketches the big picture, building on students' knowledge from earth science or other science classes. The unit begins with students modeling stress buildup in the crust, followed by lessons on how earthquakes and other evidence tell scientists about the structure of the Earth. In the third lesson, students contrast historic time with the vastness of geologic time and simulate techniques of paleoseismology. The unit concludes with lessons on some potential side effects of earthquakes, such as tsunami, liquefaction, and landslides. Students study how the geology of an area influences the destructive effects and how high population density at unsafe sites can increase the amount of damage during an earthquake.

Unit 3. In this four-part unit, students learn about the different wave motions during an earthquake and how these motions are studied. A historical piece on the development of seismology adds background to students' knowledge. Students study and simulate the measurement of earthquakes using the Richter and Mercalli scales to find out how seismologists arrive at earthquake measurements. This unit concludes with activities that plot the distribution of earthquakes worldwide, then focuses in on local earthquakes, first in Japan, then in the United States. It offers a variety of lessons in science, mathematics, and social studies.

Unit 4. This five-part unit is designed to allow students to construct an understanding of how buildings respond to earthquakes. Lessons on building design and how earthquake forces act on various designs provide students with information on how to build earthquake resistant structures. Students then apply this knowledge by constructing testing devices and testing their designs. This unit is critical for developing students' understanding of why buildings collapse and what can be done to make buildings safer.

Unit 5. This five-part unit focuses students' attention on what to do before, during, and after an earthquake. By studying historical earthquakes as reported in the press, students learn how people have responded to earthquakes in the past. Students then learn what their response should be during an earthquake by planning and practicing earthquake drills. Students conduct safety assessments of their home, classroom, and community and see how secondary disasters associated with earthquakes can also be alleviated.

Unit 6. This concluding four-part unit offers a variety of summing-up and assessment activities. Writing activities, a fast paced quiz game, and a high pressure simulation allow students a chance to show off what they have learned in this curriculum. An extensive resource list provides detailed instructions for conducting a community-wide disaster simulation that becomes realistic and dramatic with the involvement of community disaster officials.

SEISMIC SLEUTHS MATRICES FOR THE NATIONAL SCIENCE EDUCATION STANDARDS

A *Seismic Sleuths* development team has put together the matrices on the following pages to use in correlating the *Seismic Sleuths* materials with the National Science Education Standards. The National Science Education Standards, under development by the National Research Council since 1993, will be released in late 1995. The Standards have been developed through consensus building among K-12 teachers, teacher education faculty, scientists, and other education specialists. Through this process a document that represents the broad thinking of the science education community is being developed as to what students should know, how they should be taught, and how they should be assessed. The Standards are meant to be descriptive rather than prescriptive and designed to be a tool to strengthen science education.

Using the *Seismic Sleuths* Standards matrices

The development team, working with the November 1994 draft of the National Science Education Standards, examined *Seismic Sleuths* section by section identifying correlations to the Science Content areas listed in the Standards. Two criteria were used: the section made a strong and direct connection to that content area, or the section made an indirect connection. A strong, direct connection is shown in bold faced type.

The following matrices are provided. Below is a summary of *Seismic Sleuths* and the content areas listed in the Standards. This page shows at a glance the correlations between *Seismic Sleuths* and the Standards. The next six pages describe more detailed correlations between *Seismic Sleuths* and the Standards using wording from the Standards. In some cases the development team felt that where a particular concept was not listed in the wording of the Standards a possible connection could be shown in parentheses.

When using the matrices it should be kept in mind the descriptive nature of the Standards. The connections shown in these matrices are suggested connections based on the development team's experience working with *Seismic Sleuths.* Many other correlations can be made and will become evident as the curriculum materials are used. Additionally, connections can also be made between *Seismic Sleuths* and *Benchmarks for Science Literacy,* (AAAS, 1993), *Content Core,* (NSTA, 1992), and *Earth Science Content Guidelines Grades K-12,* (AGI, 1991). The user is referred to these documents for further connections.

SEISMIC SLEUTHS SECTIONS	SCIENCE AS INQUIRY	PHYSICAL SCIENCE	EARTH AND SPACE SCIENCE	SCIENCE AND TECHNOLOGY	SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES	HISTORY AND NATURE OF SCIENCE	UNIFYING CONCEPTS AND PROCESSES
1.1	■	□	□	□	■	□	□
1.2		□		□	■		□
1.3				□	■		
2.1	■	■	□		□		□
2.2	□	□	■	□	□	□	□
2.3	□	□	■		□	□	□
2.4	□	■	■		■	□	□
2.5	□		□	□	■		□
3.1	■	■	□	■	□		□
3.2	■	□	■	■	■	■	■
3.3	■	■	■	■	■	■	□
3.4	■	■	□				■
4.1	□	■		■	■		■
4.2	■	■		■	■	□	□
4.3	■	■		■	■	■	■
4.4	■	■		■	□	□	■
4.5	■	■		■	■	□	■
5.1	■			■	■	■	□
5.2		□		■	■		
5.3		□		■	■		
5.4		□		■	■		
5.5		□		■	■		
6.1		□		■	■		■
6.2		□		■	■		
6.3						■	□
6.4	■	□	□	■	■		■

■ **Direct connection** □ **Indirect connection**

UNIT 1: What's It All About? Pre-assessment of student's knowledge of earthquakes and hazards preparedness.

SEISMIC SLEUTHS SECTIONS	SCIENCE AS INQUIRY	PHYSICAL SCIENCE	EARTH AND SPACE SCIENCE	SCIENCE AND TECHNOLOGY	SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES	HISTORY AND NATURE OF SCIENCE	UNIFYING CONCEPTS AND PROCESSES
1.1 What Do You Know About Earthquakes? Students explore their conceptions of earthquakes by writing about a hypothetical earthquake as seen through the eyes of a reporter, a scientist, and a member of the general public.	***Abilities related to scientific inquiry*** Understanding about scientific inquiry	Motions and forces	Structure of the Earth system Energy in the Earth system	Abilities of technological design	***Personal and community health*** ***Natural and human-induced hazards*** Risks and benefits Science and technology in local, national, and global challenges	Science as a human endeavor Nature of scientific knowledge	Evidence, models, and explanation Change, constancy, and measurement
1.2 It Could Happen Here Students consider their needs in an emergency and their preparation for an emergency.		Motions and forces		Understanding about science and technology	***Personal and community health*** ***Natural and human-induced hazards*** ***Risks and benefits***		Order and organization
1.3 Investigating Community Preparedness Students investigate their community's preparedness.				Abilities of technological design	***Personal and community health*** ***Natural and human-induced hazards*** ***Risks and benefits***		

UNIT 2: What Happens When The Earth Quakes? An exploration of earthquake processes, including causes and measurement.

SEISMIC SLEUTHS SECTIONS	SCIENCE AS INQUIRY	PHYSICAL SCIENCE	EARTH AND SPACE SCIENCE	SCIENCE AND TECHNOLOGY	SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES	HISTORY AND NATURE OF SCIENCE	UNIFYING CONCEPTS AND PROCESSES
2.1 Stick-Slip Movement Students model movement along a fault.	***Abilities related to scientific inquiry*** ***Understanding about scientific inquiry***	***Motions and forces (friction and energy)***	Energy in the Earth system (Dynamic crust)		Natural hazards		Evidence, ***models***, and explanation
2.2 Shifting Plates and Wandering Poles A three-part exploration about how scientists determine if the Earth's crust is in motion.	Abilities related to scientific inquiry Understanding about scientific inquiry	***Properties*** & changes in matter ***(magnetism)*** ***Motions*** and Forces	***Structure of the Earth system*** ***Energy in the Earth system*** ***Origin and evolution of the Earth system***	Understanding about science and technology	Natural hazards	Nature of scientific knowledge	Evidence, ***models***, and explanation
2.3 Earthquake in Geologic Time Students explore long time intervals and use models to study earthquakes in the past..	Abilities related to scientific inquiry Understanding about scientific inquiry	Motions and forces	***Earth's history*** ***Origin and evolution of the Earth system***		Natural hazards	**Historical perspectives**	Evidence, ***models, and explanation,*** maps
2.4 Earthquake Hazards Students use models, research, and mathematics to study earthquake hazards.	Abilities related to scientific inquiry Understanding about scientific inquiry	***Forces and motion (gravity, waves, and energy)*** ***Interactions of energy and matter***	***Energy in the Earth system***		***Natural hazards***	Historical perspectives	Evidence, ***models, and explanation*** Change, constancy, and measurement
2.5 Quake-Smart Siting Students interpret soil and earthquake related maps.	Abilities related to scientific inquiry Understanding about scientific inquiry		Structure of the Earth system	***Abilities of technological design***	**Natural hazards**		Evidence, ***models, and explanation,*** maps

UNIT 3: How Do People Learn About Earthquakes? Students explore the science and history of seismology.

SEISMIC SLEUTHS SECTIONS	SCIENCE AS INQUIRY	PHYSICAL SCIENCE	EARTH AND SPACE SCIENCE	SCIENCE AND TECHNOLOGY	SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES	HISTORY AND NATURE OF SCIENCE	UNIFYING CONCEPTS AND PROCESSES
3.1 The Waves of Quakes Students explore waves and discover how waves transfer energy. During this exploration, students connect this understanding to primary and secondary waves.	***Abilities related to scientific inquiry*** ***Understanding about scientific inquiry***	Motions and forces ***Interactions of energy and matter***	Structure of the Earth system		Natural and human-induced hazards		Change, constancy, and measurement
3.2 Pioneering Ideas Students explore the early work of three scientists.	***Understanding about scientific inquiry***	Forces and motions Interactions of energy and matter	***Energy in the Earth system*** ***Origin and evolution of the Earth system***	***Understanding about science and technology***		***Science as a human endeavor*** ***Nature of scientific knowledge*** ***Historical perspectives***	***Evidence, models, and explanation***
3.3 Sizing Up Earthquakes: The Mercalli Scale, Calling Station KWAT In this simulation of a radio talk show after an earthquake, students learn how seismologists establish earthquake intensity based upon damage people observe and report.	***Abilities related to scientific inquiry*** ***Understanding about scientific inquiry***	***Motions and forces*** Interactions of energy and matter	***Energy in the Earth system***	***Abilities of technological design***	***Natural and human-induced hazards***	***Science as a human endeavor*** ***Nature of scientific knowledge***	Change, constancy, and measurement
3.4 Distribution of Earthquakes Three activities on plotting the locations of earthquakes on map and making a 3-D model.	Abilities related to scientific inquiry Understanding about scientific inquiry		Structure of the Earth system Energy in the Earth system		***Natural hazards*** ***Risks*** and benefits	Historical perspectives	Evidence, ***models, and explanation***

UNIT 4: Can Buildings Be Made Safer? Students construct an understanding of how ground shaking during an earthquake can damage buildings and how buildings can be made better able to withstand this shaking.

SEISMIC SLEUTHS SECTIONS	SCIENCE AS INQUIRY	PHYSICAL SCIENCE	EARTH AND SPACE SCIENCE	SCIENCE AND TECHNOLOGY	SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES	HISTORY AND NATURE OF SCIENCE	UNIFYING CONCEPTS AND PROCESSES
4.1 Building Fun Students investigate the physical properties of building materials and design while considering how these might affect the way a structure withstands forces.	Abilities related to scientific inquiry	***Properties & changes in matter (physical)*** Motions and Forces		***Abilities of technological design***	***Natural and human-induced hazards***		***Evidence, models, and exploration***
4.2 Structural Reinforcement: The Better Building Students learn how additional structural elements strengthen a structure to carry forces resulting from earthquake shaking.	***Understanding about scientific inquiry***	***Forces and motions***		***Abilities of technological design*** ***Understanding about science and technology***	***Natural and human-induced hazards***	Nature of scientific knowledge	Evidence, models, and explanation
4.3 The BOSS Model: Building Oscillation Seismic Simulation Students investigate how energy enters a structure and discover the phenomenon of resonance. They measure the natural frequencies of the different height rod assemblies of the BOSS Models and correlate these motions to those of buildings and earthquakes.	***Abilities related to scientific inquiry*** ***Understanding about scientific inquiry***	***Forces and motions*** ***Interactions of energy and matter***		***Understanding about science and technology***	***Natural and human-induced hazards***	***Nature of scientific knowledge***	***Evidence, models, and explanation***
4.4 Earthquake in a Box In cooperative groups, students construct an inexpensive shake table for testing structures they have built.	***Understanding about scientific inquiry***	***Forces and motions*** ***Interactions of energy and matter***		***Abilities of technological design*** ***Understanding about science and technology***	Natural and human-induced hazards	Nature of science	***Evidence, models, and explanations***
4.5 The Building Challenge Students design and construct a structure then test it for the ability to withstand forces that could be encountered in an earthquake. This can be used s a performance assessment of the entire unit.	Abilities related to scientific inquiry ***Understanding about scientific inquiry***	***Properties & changes in matter (physical)*** ***Forces and motions*** ***Interactions of energy and matter***		***Abilities of technological design*** ***Understanding about science and technology***	***Natural and human-induced hazards***	Science as a human endeavor	***Evidence, models, and explanations***

UNIT 5: What Should People Do Before, During, and After An Earthquake?

SEISMIC SLEUTHS SECTIONS	SCIENCE AS INQUIRY	PHYSICAL SCIENCE	EARTH AND SPACE SCIENCE	SCIENCE AND TECHNOLOGY	SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES	HISTORY AND NATURE OF SCIENCE	UNIFYING CONCEPTS AND PROCESSES
5.1 Predicting Earthquakes Students explore the tantalizing possibilities of earthquake prediction.	Abilities related to scientific inquiry ***Understanding about scientific inquiry***			***Understanding about science and technology***	Personal and community health ***Natural hazards***	***Nature of science*** Historical perspectives	***Evidence, models, and exploration***
5.2 Starting Here, Starting Now Students learn how to react in the event of an earthquake.		Motions and Forces		***Understanding about science and technology***	***Natural hazards***		
5.3 Find and Fix the Hazards Students study home construction and retrofitting techniques.		Motions and Forces		***Understanding about science and technology***	***Natural hazards***		
5.4 Rapid Visual Screening in the Community Students evaluate the potential earthquake damage to various structures in their community.		Motions and Forces		***Understanding about science and technology***	***Personal and community health*** ***Natural hazards***		
5.5 Are the Lifelines Open? Students assess their community's vulnerability to earthquake damage.		Motions and Forces		***Understanding about science and technology***	***Personal and community health*** ***Natural hazards***		

UNIT 6: Now You Know It, Can You Show It? A variety of summing-up and assessment activities that showcase students' knowledge.

SEISMIC SLEUTHS SECTIONS	SCIENCE AS INQUIRY	PHYSICAL SCIENCE	EARTH AND SPACE SCIENCE	SCIENCE AND TECHNOLOGY	SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES	HISTORY AND NATURE OF SCIENCE	UNIFYING CONCEPTS AND PROCESSES
6.1 Preparing for the Worst Students assume the roles of emergency planning officials in a hypothetical community.		Forces and motions		***Abilities of technological design*** ***Understanding about science and technology***	***Personal and community health*** ***Natural and human-induced hazards***		Order and organization ***Evidence, models, and explanation***
6.2 Earthquakes Simulation: Putting Plans into Action An emergency simulation exercise.		Motions and forces		***Understanding about science and technology***	***Personal and community health*** ***Natural and human-induced hazards*** Science and technology in local, national, and global challenges		
6.3 What's Your E.Q., I.Q.? A quiz show format for assessment.						***Nature of scientific knowledge***	Evidence, models, and explanation
6.4 Hey, Look at Me Now! An assessment activity that repeats the writing exercise in 1.1.	Abilities related to scientific inquiry ***Understanding about scientific inquiry***	Motions and forces	Structure of the Earth system Energy in the Earth system Origin and evolution of the Earth system	***Understanding about science and technology***	***Personal and community health*** ***Natural and human-induced hazards*** ***Science and technology in a local, national, and global challenges***		***Evidence, models, and explanation***

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