Teachers of Earth and environmental sciences in grades 8–12 will welcome this activity book centered on six “data puzzles” that foster critical-thinking skills and support science and math standards. Earth Science Puzzles presents professionally gathered Earth science data on the topics of paleoclimate, weather forecasting, earthquakes, estuaries, watersheds, and hydrothermal vents. Students step into scientists’ shoes to use temporal, spatial, quantitative, and concept-based reasoning to draw inferences from the data.

For the teacher, each puzzle is supported by an extensive Pedagogical Content Knowledge Guide with background information, required student skills, common student misconceptions, an answer key to the questions in the student section, and a bank of resources for further exploration of the topics.

The time-efficient puzzles—each taking approximately one 50-minute period to complete—can be the beginning of exciting, data-rich classroom experiences.

“Those authentic samples of data taken by real scientists give students several benefits: a real sense of what scientists do, an understanding of concepts to help students comprehend how the world works, and the experience of synthesizing that conceptual understanding from numbers. It’s hard to go wrong with this approach to teaching science.”

— Luke Sandro, high school biology teacher, Springboro (Ohio) High School

“Each activity is an excellent stand-alone and can easily be inserted into any Earth science or geology sequence as complementary or supplemental material.”

— Len Sharp, high school Earth science teacher and past president of the National Earth Science Teachers Association

“The puzzles are well crafted and well thought out. I definitely plan to use several of them in my classes.”

— Robert W. Blake Jr., PhD, associate professor in the Elementary Education Department at Towson University

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EARTH SCIENCE PUZZLES
MAKING MEANING FROM DATA
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Preface

Why Teach With Data?

Data are the foundation of science. Every insight and every fact in every science textbook is grounded in data. Making meaning from data is a central activity in the life of a scientist.

*Science* has been defined as “the use of evidence to construct testable explanations and predictions of natural phenomena, as well as the knowledge generated through this process” (National Academy of Sciences 2008, p. 10)*. In science, “evidence” begins with data. If we teach our students only about “the knowledge generated,” and don’t teach them about the “use of evidence to construct …,” we have only done half our job as science educators.

Data form a strong link from the classroom to real-world phenomena. Data can provide students with evidence for processes that seem counterintuitive and can reveal relationships among phenomena that initially seem unrelated. Interpreting data draws on higher-order thinking skills that will serve students well regardless of their paths in later life.

The time is ripe to incorporate more data into science teaching practice. In recent years, science-rich institutions, such as universities and government agencies, have made their data treasure troves available to the public via the web. This has opened up the possibility that high school and undergraduate students can learn from the same data sets that scientists ponder.

We (the authors) think that learning from data is an inherently rewarding activity and a habit of mind that is key to the way scientists learn about the world. As such, it deserves a central place in science education. Our experiences in trying to foster the use of data in education have shown us that use of authentic Earth data can be empowering and exhilarating for both students and teachers.

But—there are substantive barriers to overcome in teaching and learning with data. It takes a lot of classroom time to extract insights from data, especially when we bear in mind that those same insights could be stated in just few minutes. Teachers may not have sufficient prep time to explore a data set on their own and may hesitate to launch their students on an exploration of a data set that they themselves do not know thoroughly. Most teachers did not learn Earth science through data and may wonder how to guide students’

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productive exploration through the labyrinth of a large geoscience data set. In the end, it can be difficult to assess whether students have done a good job analyzing and interpreting complex data.

Earth Science Data Puzzles have been developed with the specific goal of overcoming these problems. The major attributes of the puzzles are as follows:

- **Selected Authentic Data.** Each puzzle uses authentic data from the Earth’s lithosphere, hydrosphere, and/or atmosphere. The data are carefully selected in order to illuminate fundamental Earth processes that are typically taught in Earth science classes and are included in the National Science Education Standards: Because the authors have pre-selected insight-rich data snippets, the puzzles are time-efficient, taking approximately one class period to complete.

- **Aha! Insights.** Each puzzle was designed to achieve Aha! Insights—moments when the connection between data and process becomes clear in a rewarding burst of insight and illumination. Aha! moments are the true reward of doing science, the intrinsic thrill that keeps scientists going through thick and thin.

- **Critical Thinking.** Data Puzzles foster the ability to go beyond looking up values in a graph, to thinking deeply about “What does this data mean?” A variety of reasoning processes are called for in the puzzles, including spatial reasoning, temporal reasoning, quantitative reasoning, and reasoning that combines data and concepts (see pp. xv–xvii for a discussion of these four types of reasoning processes).

- **Knowledge Integration.** Data Puzzles require students to combine information from the provided data with their knowledge of Earth processes and to integrate multiple kinds of data, including graphs, tables, maps, images, and narratives. From these intertwining lines of evidence, students must craft coherent claims about the Earth system and support their claims with evidence from data and scientific reasoning.

- **Pedagogical Content Knowledge.** Each puzzle is accompanied by a Pedagogical Content Knowledge Guide. The term *pedagogical content knowledge* (PCK) refers to the knowledge of how to teach something, as opposed to knowledge of the content itself. Our PCK Guides include a step-by-step tour through the reasoning needed to solve each puzzle, a heads-up about common student misconceptions, and other information intended to make the teacher’s job easier and more effective.
For teachers who have little experience using data, Data Puzzles can serve as a bridge from a data-free teaching style to a mode of teaching in which students use authentic data to solve problems and answer questions. For those teachers who are already comfortable with data, Data Puzzles can be used to permeate the curriculum with data-using opportunities that can be slipped into homework problems, exam questions, or in-class activities.

Good luck to you and your students as you explore the Earth through data!

—Kim Kastens and Margie Turrin
Introduction

How Have Teachers Used Data Puzzles in the Past?

Data Puzzles are designed as in-class exercises for eighth- through twelfth-grade students. As the word puzzle implies, they are intended to be challenging, but our pilot testing shows that they are within the grasp of students in this age group with appropriate instruction and scaffolding. Test teachers have found it beneficial to team students in pairs or small groups. Such grouping brings the “self-explanation” effect into play as students explain their ideas to one another. Some of the puzzles have built-in stopping points, at which point the teacher can lead a class discussion and confirm that all students understand a necessary insight or result before moving on to the next section of the puzzle. Advanced Placement Science students may be able to complete the puzzles on their own as homework, although there is still value in having students discuss their reasoning in pairs or small groups.

Our test teachers elected to use Data Puzzles after the relevant topic had already been taught through conventional means, such as diagrams, photographs, and text. When used in this manner, a Data Puzzle serves as a knowledge integration activity—to deepen, broaden, and challenge newly learned concepts and to link concepts with science process skills.

Each of the six puzzles addresses a topic that is typically taught in Earth science at the high school level (paleoclimate, weather forecasting, earthquakes, estuaries, watersheds, and hydrothermal vents). Some of our test teachers also used one or more puzzles in other courses, including chemistry, biology, environmental science, oceanography, and general science. Each puzzle is freestanding, so puzzles can be done in the order that suits the local syllabus. The order of presentation in the book is from least to most quantitatively demanding (see table on p. xix) because the target audience is transitioning from the more qualitative approach to science that is typical of
elementary and early-middle school toward the math-based approach found in upper high school and college science courses.

The authors encourage teachers to let students attempt to complete the puzzles without too much teacher support. There is a careful balancing act between, on the one hand, allowing students to struggle just enough so that the Aha! insights come with a rewarding sense of accomplishment and, on the other hand, allowing students to struggle so much that they become frustrated. Teachers know their students best and should watch carefully to provide enough just-in-time help, but not too much, keeping in mind that the later steps in each puzzle build on the earlier steps. The puzzles intentionally do not specify how to solve the problem—for example, students are not told what mathematical formula to use. An important part of the challenge is for students to figure out which of their intellectual “tools” will help them move toward a solution.

Why No “Teachers Guide”?

Each of the student puzzles is accompanied by a rich support document for the teacher. Rather than calling this a “Teachers Guide,” we called it a “Pedagogical Content Knowledge Guide.” Scholars of teaching and learning have found that excellent teachers draw on three distinct bodies of knowledge: content knowledge (e.g., how hurricanes form); general pedagogic knowledge (e.g., assessment strategies); and a specialized body of knowledge about how to effectively teach the understandings and skills characteristic of a specific discipline. This last type of knowledge is called pedagogical content knowledge (PCK), and it can be the secret ingredient that makes the difference between an OK teacher and a great teacher.

Traditionally, teachers developed PCK through experience and informal sharing with other teachers. More recently, education research has added to the stock of PCK insights (Appendix A, “Bibliographic Notes,” points the reader to relevant education research literature.) PCK covers such issues as what learning goals are appropriate and achievable for a given audience, prior understandings that students need before they can tackle a specific new topic, alternative concepts that students may have, and what activities or representations are effective for explaining a specific phenomena.

Our PCK Guides are designed to support teachers in their use of specific Data Puzzles and to develop teachers’ PCK for teaching with data more broadly. We recommend that teachers read through the entire PCK Guide before using a puzzle with their students. Each guide includes the following:
Aha! Insights: Each PCK Guide begins with a statement of the insights that the puzzle was designed to bring forth from students. For the purposes of lesson planning, you can think of the Aha! Insights as learning goals or learning performances. When possible, we have quoted or paraphrased the wording from actual students to express Aha! Insights.

Prior Skills Needed and Prior Understandings Needed: Skills and concepts students will need before attempting the selected Data Puzzle.

Teacher Preparation: A heads-up of key vocabulary to review with the students, materials to collect, and other suggestions for teachers to consider before introducing the puzzle to their students.

Optional Pre-Puzzle Activities: Activities that teachers may wish to include in their instruction before the class works on the Data Puzzle.

Step-By-Step: How to Solve This Puzzle: A two-part section for the teacher that includes (a) answers to the questions in the student pages and sketches and graphics completed as the student would be expected to complete them, and (b) the application of critical-thinking skills needed by students to complete each step of the puzzle.

Common Student Misconceptions: Conceptions that have been compiled by examining the work of student testers, tapping into the insights of experienced Earth science teachers, and consulting the research literature on student alternative conceptions. This section can help teachers anticipate, diagnose, and overcome students’ difficulties.

Tough Questions (With Answers): Questions that students might ask about the puzzle, the data, or the underlying concepts. Each question includes a suggested response. Teachers can also use these questions to provide additional challenge to students who are finding the main puzzle too easy.

Extension Activities: A range of extra activities that can be done in class or as homework.

Sources and Resources: Links and references to supporting activities, data sources, and background readings.

Why No Scoring Rubrics?

Although we do provide—in the PCK guides—the answers to the questions in each puzzle, we intentionally do not provide scoring rubrics for grading student answers. For our target audience of eighth- through twelfth-grade Earth science students, we think that the most constructive way to use these challenging
Introduction

Making meaning from data is key to scientific ways of knowing—and yet this appears to be an underrepresented component of science education. The authors hope that these Data Puzzles will challenge students to think broadly and deeply about how the Earth works and about how scientists use data to figure out how the Earth works.
Using Data Puzzles to Foster Critical Thinking and Inquiry

Critical thinking is thinking that goes beyond recall of information and concepts to which students have been previously exposed. Developing students’ ability and willingness to use critical thinking is an important goal of science education at all levels. Data Puzzles are rich in opportunities to use critical-thinking skills because they call on students to reason from the provided data to make inferences about Earth processes.

In this book, we focus on four kinds of critical thinking: spatial reasoning, temporal reasoning, quantitative reasoning, and concept-based reasoning. Spatial reasoning and temporal reasoning are fundamental to Earth science but less common in other sciences. Earth science teachers, therefore, may need to provide extra support for those kinds of reasoning, which may be new to some students. Quantitative reasoning and concept-based reasoning are common across all of the sciences.

In the next section, we describe these four kinds of thinking, using examples from Data Puzzle #4, “Is the Hudson River too salty to drink?” An annotated synopsis of this puzzle on page xvii shows where each type of reasoning is called into play. Note that it is common to combine several types of reasoning to complete a single step of a puzzle.

Four Types of Critical Thinking Highlighted in the Data Puzzles

Spatial/Visual Reasoning (S)

When using spatial reasoning, students make inferences from observations about the location, orientation, shape, configuration, or trajectory of objects or phenomena. In Earth science, this often means extracting insights from maps or from data displayed on maps. A common spatial-thinking approach in Earth science is to look for gradients across space—that is, to look for evidence that some observable property varies systematically onshore/offshore, upstream/downstream, north/south, in rural/urban areas, or with distance from some event. For example, in “Is the Hudson River too salty to drink?” students observe a north/south gradient in the salt concentration of river water and interpret that in terms of the mixing of freshwater from the
north and salty ocean water from the south. Another common challenge in Earth science is to visually observe a shape or pattern that is similar to—but not identical to—a shape or pattern that has been seen previously. Recognizing fossils or minerals and identifying features in photographs are examples of the “visual” part of spatial/visual reasoning.

Temporal Reasoning (T)
When using temporal reasoning, students make inferences from observations about the timing, rates, and sequence of Earth events and processes. One common line of temporal reasoning is that the sequence of events constrains causality—in other words, if A happened before B, then A can have caused or influenced B, but B cannot have caused or influenced A. For example, in “Is the Hudson River too salty to drink?” students reason that the heavy rain on April 15 of the data set could have caused the gradual freshening of the river on April 16, 17, and 18.

Another type of temporal reasoning is recognizing cycles or parts of cycles in time series data, including day/night cycles, tidal cycles, seasonal cycles, or glacial/interglacial cycles. For example, in the Hudson River puzzle, the ~12 hr. time interval between salinity peaks is an important clue that salinity is being influenced by tidal processes. Rates of Earth processes tell us about how powerful the process is. For example, in the hydrothermal vents puzzle, the rate at which hot water spews out from the vent constrains how much heat energy is delivered to the ocean from the Earth’s interior.

Quantitative Reasoning (Q)
Quantitative reasoning makes use of numerical information. Quantitative reasoning would include making a calculation, deciding which mathematical operation is needed, changing numerical values into more useful units, comparing and contrasting numerical values, describing trends or patterns in numerical data, and making inferences about cause and effect from such trends and patterns. For example, in “Is the Hudson too salty to drink?” students use their number sense to grasp the huge difference in saltiness between some sampling localities (26,000 ppm salinity) and others (<100 ppm salinity), and recognize that this huge difference is a significant observation that needs to be explained. A Note on Units and Scientific Notation: Some teachers require scientific notation and others do not, so our PCK guides provide answers in both formats. In general, we have used SI units. In a few cases, we used everyday units when we thought this would help students tap into their experiential knowledge and physical intuition (e.g., we used °F in the weather forecasting puzzle and calories in the hydrothermal vent puzzle).
Concept-based Reasoning (C)

In concept-based reasoning, students must tap into their knowledge of Earth science concepts and apply this knowledge to complete a step of the Data Puzzle. The question cannot be answered by merely reading information off the provided graph, map, or table; students must integrate information from the provided data with prior learning to construct interpretations and explanations. For example, in “Is the Hudson River too salty to drink?” students must draw on their conceptual understanding of tides to interpret the twice daily increase and decrease of salinity on April 15 as a result of the ebb (fall) and flood (rise) of the tidal cycle.

How to Use the PCK Guides to Foster Critical Thinking

The Pedagogical Content Knowledge Guides that accompany each Data Puzzle spell out the types of critical thinking that students will need to complete each step of the puzzle. The table on page xviii is an excerpt from the two-part “Step-by-Step” section of the PCK Guide for Data Puzzle #4, “Is the Hudson River too salty to drink?” The left-hand side of the table repeats each step of the puzzle from the student pages and is followed by a fully correct answer for that step. The right-hand side of the table shows the critical-thinking processes that students need in order to construct
the correct answer. The thought processes are coded according to the type of thinking, with (S) for spatial/visual reasoning, (T) for temporal reasoning, (Q) for quantitative reasoning, and (C) for concept-based reasoning.

(Excerpt) **Step-by-Step: How to Answer Data Puzzle #4**

<table>
<thead>
<tr>
<th>Answer Key</th>
<th>Critical Thinking</th>
</tr>
</thead>
</table>
| 6c. Compare and contrast the salt front location for the two time intervals plotted. Be sure to use river miles and mention specific communities in your response. The salt front in August and September remained fairly consistent, moving only between RM 62 and RM 73 (approximately Newburgh to Poughkeepsie). In March and April the salt front is closer to the ocean. Also, in March and April the location is more variable than for August and September, ranging from RM 68 (north of Newburgh) all the way down to RM 0 at the southern tip of Manhattan. | (S)(T) Students interpret the position versus time graph in terms of
• *position* (in March and April the salt front is always closer to the ocean—i.e., farther south—than in August and September)
• *variability of position* (in August and September, the salt front location is more stable than in March and April) |

We suggest three ways to use the critical-thinking information in the right-hand column to strengthen your students’ thinking skills.

1. **Provide Scaffolding**
   Learning to reason from data is a big step for students, and many teachers find that they need to ease their students into the process gradually. By scanning down through the critical-thinking column of the PCK Guide, teachers can plan where they want to give their students additional clues and where they want to hang tough and insist that the students do the hard thinking themselves. For example, when a step calls for concept-based reasoning, a useful clue might be “take a look at the diagram on page 99 in your textbook.” Don’t fall into the trap of doing all the hard thinking for the students, leaving them to do just the mechanical steps such as completing a calculation or plotting points onto a graph.
2. Diagnose Difficulties

If you find that many of your students are struggling at a specific point in the puzzle, the comments in the critical-thinking column of the PCK Guide can help you diagnose the problem. If they are stuck on a (C) step, perhaps they haven’t fully understood a requisite concept. If they are stuck on a (Q) step, perhaps they know from math class how to carry out a mathematical operation but don’t know how to identify situations where that operation is appropriate. If they are stuck on an (S) or (T) step, perhaps they have not encountered these kinds of reasoning in their prior science courses, and you may need to model them by doing a think-aloud as you work through the puzzle with the whole class.

3. Target Specific Thinking Skills

Each puzzle has a different balance of types of critical thinking. If you are interested in fostering a specific thinking skill, the “Targeting Specific Critical-Thinking Skills” table below will help you choose the puzzles most suited to your learning goal. In the table, numbers indicate how many instances of each type of reasoning are called for in each puzzle. For example, if you wish to strengthen your students’ quantitative reasoning, then “Where did the water go?” or “How much heat is released by a seafloor hydrothermal vent?” would be good choices.

<table>
<thead>
<tr>
<th>Data Puzzle</th>
<th>Spatial (S)</th>
<th>Temporal (T)</th>
<th>Quantitative (Q)</th>
<th>Concept-Based (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 How do we know what the climate was like in the past?</td>
<td>10</td>
<td>11</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>#2 How do we decide “weather” or not to proceed with a trip?</td>
<td>11</td>
<td>14</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>#3 What does an earthquake feel like?</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>#4 Is the Hudson River too salty to drink?</td>
<td>11</td>
<td>11</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>#5 Where did the water go?</td>
<td>12</td>
<td>3</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>#6 How much heat is released by a seafloor hydrothermal vent?</td>
<td>5</td>
<td>2</td>
<td>26</td>
<td>9</td>
</tr>
</tbody>
</table>
Using Data Puzzles to Foster Critical Thinking and Inquiry

The Role of Data Puzzles in an Inquiry-Oriented Curriculum

Educators committed to fostering student inquiry may be concerned that Data Puzzles are too structured. After all, we have preselected the data snippets to be examined, declared (in the title of each puzzle) what question shall guide the activity, and choreographed the students’ path through the data by means of a step-by-step format.

We share with our inquiry-committed colleagues the ultimate goal that students should be able to tackle open-ended inquiries. Students should be capable of identifying a question, planning an inquiry to address that question, navigating their way through the relevant data, and interpreting subtle or complex data patterns in terms of causal processes. It is our belief that Data Puzzles serve a critical role in helping students develop a tool kit of reasoning skills and data analysis techniques that will enable them to take their science inquiries to a higher level of complexity.

Back in elementary and lower-middle school, students were able to accomplish meaningful inquiries with small, student-collected data sets, interpreted through commonsense lines of reasoning. In college, students may find that they are expected to analyze and interpret large data sets, which they did not see being collected, using multi-step lines of reasoning. In adult life, they may be called on to make data-informed decisions in fields as varied as business, epidemiology, education, and criminal justice.

The transition from an elementary or a middle school mode of learning from data to a college-level or adult mode is complicated and multifaceted. High school represents an opportunity to make this transition. Elementary and middle school students typically interpret one data set at a time, whereas college and adult data interpreters commonly consider interactions among multiple data parameters. One hundred data points would be a large data set at the elementary level, but college and adult data sets are measured in megabytes. Further, when children work with data they collected themselves, they have experiential knowledge of the environment and circumstances represented by the data. As older students or adults, working with professionally collected archival or real-time data, they don’t have that personal knowledge of the data’s context; instead, they have to build up an understanding of context from the accompanying narrative or metadata. Finally, the process of crafting defensible scientific claims from the evidence contained in data requires a suite of reasoning processes that go far beyond simple common sense, including spatial reasoning, temporal reasoning, and quantitative reasoning. We think the structured approach of Data Puzzles can help high school students prepare for the kinds of complex inquiries they may encounter later in life.
Perhaps an analogy will help. Inquiry activities in which students generate their own questions and design their own investigations to address those questions can be compared with a game of youth soccer or lacrosse. Players have to cope with a lot going on at once, react to the unexpected, and coordinate many factors toward the goal of winning the game.

Good coaches and physical education teachers spend time developing skills important for success—skills that will enable the players to be independent, to make their own decisions on the field. Data Puzzles are like the drills that help players isolate and practice the skills that will enable them to excel in the game—not simple drills, but challenging drills that the best coaches use, the drills in which players have to combine multiple skills—for example, dribble, pass, pass back, dribble, shoot.

A sports team that doesn’t have organized practices, that only plays games, won’t improve very quickly. A combination of structured practices that isolate and practice key skills and prepare players to make rapid independent choices on the field, together with games that integrate those skills, produces improvement in youth sports—and we hypothesize that the same is true in youth science.
The Data Puzzles Project was implemented in collaboration with Liberty Science Center (www.lsc.org). It was supported by National Science Foundation (NSF) Geoscience Education grant GEO-06-08057 and with funds from the Office of the Director at the Lamont-Doherty Earth Observatory of Columbia University.

The primary authors for each of the puzzles are named in the table of contents. Additional assistance with specific puzzles was provided by the following organizations and colleagues:

- “How do we know what the climate was like in the past?” Dr. Dorothy Peteet, Quaternary paleoecologist and paleoclimatologist, assisted in interpreting this data and developing the puzzle. The NSF Graduate Research Fellowship Program also supported the development of this puzzle.

- “What does an earthquake feel like?” Dr. John Armbruster, seismologist, provided data and advice in developing this puzzle. Holly Chayes and Katherine Cagen assisted with data processing.

- “Is the Hudson River too salty to drink?” This puzzle was created with help from the Beczak Environmental Center and the student and teacher participants of “A Day in the Life of the Hudson River” project.

- “Where did the water go?” Black Rock Forest Consortium constructed the stream station that generated the data used in this Data Puzzle. Americorps member Tanessa Hartwig assisted with data analysis and early development of the activity.

- “How much heat is released by a seafloor hydrothermal vent?” The late Karen von Damm, marine geochemist, provided data and advice regarding this puzzle. Research scientists with the RIDGE 2000 program—Dan Fornari, Julie Bryce, Marv Lilley, Rachel Haymon, Florencia Prado, and Vicky Ferrini—helped to interpret the data and provided information and insights about the field area. Development of this puzzle was also supported by NSF grant OCE 02-28117.
Acknowledgments

The Data Puzzles and Pedagogical Content Knowledge Guides were refined and tested by a group of science teachers and their students over a period of two years. Our teacher team consisted of the following people:

Ijaz Akhtar, Theater Arts Production Co. School, New York City
Tamara Browning, Tenafly Middle School, Tenafly, NJ
Missy Holzer, Chatham High School, Chatham, NJ
Deena Bollinger Kramarczyk, Orangetown South Middle School, Blauvelt, NY
Anne Marie Nowak, Booker T. Washington Middle School, New York City
Drew Patrick, Fox Lane High School, Bedford, NY
Rich Pearson, Bloomfield High School, Bloomfield, NJ
Bryan Roessel, George F. Baker High School, Tuxedo Park, NY
Rosemarie Sanders, Mount Vernon High School, Mount Vernon, NY
Kathy Siddi, Spring Valley High School, Spring Valley, NY
Jim Signorelli, Academies@Englewood High School, Englewood, NJ
Sandra Swenson, John Jay College of Criminal Justice, City University of New York
Laura Tedesco, Troy High School, Troy, NY
Dorene Thornton, James J. Ferris High School, Jersey City, NJ
Brent Turrin, Rutgers, The State University of New Jersey

Linda Pistolesi, web and graphics specialist at Lamont-Doherty Earth Observatory, oversaw the illustration program, including graphic design, GIS (geographic information system), permissions, website design, and curation of the image collection; she also reviewed the manuscript for both Earth science accuracy and layout design. Anthony Bisulca of Liberty Science Center oversaw the project evaluation and the testing of the Data Puzzles in an informal science education venue. Frank Gumper, board member of Lamont-Doherty Earth Observatory, provided leadership and support for the effort to develop Data Puzzles as a signature Lamont-Doherty contribution to K–12 education. The name “PCK Guide” comes from Professor Ann Rivet, the Earth science teacher educator at Columbia Teachers College.

Reviews of portions of the manuscript by Dr. John Armbruster, Dr. Dorothy Peteet, Dr. William Schuster, Dr. Tim Crone, Dr. Yochanan Kushnir, and NSTA’s six anonymous reviewers greatly strengthened the book.
About the Authors

Kim A. Kastens is a Lamont Research Professor at Lamont-Doherty Earth Observatory of Columbia University. She holds a bachelor’s degree in geology and geophysics from Yale University and a PhD in oceanography from Scripps Institution of Oceanography at the University of California, San Diego. Her early research interests were in marine geology, and she has published extensively on seafloor tectonic and sedimentary processes. Over the last 15 years, her professional interests have shifted toward building a citizenry that knows more, understands more, and cares more about the Earth and environment. To this end, she works with journalists and inservice and preservice teachers and in the areas of instructional technology, curriculum development, and research on learning. Her current research focus is spatial thinking in geosciences. Dr. Kastens blogs at “Earth & Mind: The Blog” (www.earthandmind.org).

Deena Bollinger Kramarczyk has been teaching New York State Regents Earth Science and eighth-grade general science for 12 years. She earned her BS in meteorology and her MAT in Teaching Secondary Earth Science at Cornell University. For several years, she served as the middle school subject area representative for the Science Teachers Association of New York State, Westchester Section. Ms. Kramarczyk has also served as a consultant, writer, and editor for several publishing companies and has developed educational applications for use on mobile devices. As an adjunct professor at various colleges, Ms. Kramarczyk has taught numerous undergraduate and graduate courses in teacher education and science and has presented workshops on strategies for teaching K–12 science at local and regional conferences.

David McGee is a postdoctoral researcher in paleoclimatology at the University of Minnesota and Lamont-Doherty Earth Observatory. His research focuses on reconstructing past climate changes recorded in the geochemistry of cave deposits and marine sediments. Prior to pursuing graduate studies in Earth science at Columbia University, he taught Earth science, physical science, and physics at the middle and high school levels in Pittsburgh and New Orleans. During this time, he earned a master’s degree in teaching with a focus on environmental education. While a graduate student at Tulane University and Columbia University, Mr. McGee led a variety of science enrichment
activities in local high schools. He also served as a National Science Foundation graduate K–12 teaching fellow in a New York City high school.

**Rosemarie Sanders** has been teaching New York State Regents Earth Science for more than 10 years. In addition to teaching, she has authored Earth science curriculum for the national nonprofit organization New Leaders for New Schools and has worked as a project adviser for WNET-13, the New York public television station. Ms. Sanders is the Earth science subject area representative for the Science Teachers Association of New York State, Westchester Section. She wrote *Earth Science Investigations Lab Workbook*, recently published by Topical Review Book Company.

**Margie Turrin** is an education coordinator at Columbia University’s Lamont-Doherty Earth Observatory. She coordinates and leads science education programs for a wide range of audiences: specialists in the field of informal community education, middle school and high school students, undergraduate students, K–12 teachers, and college faculty. She holds a BS degree from the University of California, Irvine, and an MS from San Jose State University. Through her science education projects, she seeks to engage students and the general public in understanding the Earth and environment. The topics of her projects include human interactions and impacts on the environment, Hudson River education, biodiversity, mapping and spatial skills, and the planet’s dynamic polar regions. At Lamont, she serves as the lead educator for the Hudson River education and outreach efforts as well as for several polar education projects.
Have you ever felt an earthquake? If you are like most people who live in the central or eastern United States, the answer is probably no. But once in a while, an earthquake is felt in this area. Such an earthquake shook the Northeast on August 10, 1884.

Directions: Follow steps 1 to 9 below. You will be working individually on steps 1 to 3, in a small group for steps 4 to 6, and as a class for steps 7 to 9. Use additional sheets of paper as needed and answer questions in complete sentences.

1. Read the newspaper accounts written about the 1884 earthquake provided by your teacher. (Other students will have different newspaper accounts.) How do these accounts differ from modern newspaper stories?

2. Back in the 1800s, there was no network of seismographs for recording earthquakes. Scientists who study historical earthquakes have developed a scale for quantifying the severity of a given earthquake at a given position, based on observations from eyewitness accounts. Read down through the Modified Mercalli (MM) Intensity Scale (pp. 46–47). MM intensity values are reported in roman numerals from I (barely felt) to XII (catastrophic). (See Figures 3.1a and 3.1b for images of two severe earthquakes.)

3. For the towns described in your newspaper accounts (see step 1), estimate the MM intensity of the August 10, 1884, earthquake. Be sure to pay attention to the intensity scale.

Figure 3.1a
Damage Characteristic of Earthquake Intensity
MM VIII

“Considerable damage to ordinary substantial buildings.”

Source: U.S. Geological Survey (USGS)
Photographic Library, San Francisco earthquake 1906. Photo 83, photographer G. K. Gilbert (Gilbert photo 2893).
attention to negative evidence (i.e., what is NOT stated in the article). Your answer may be a range rather than an exact value. Use Table 3.2 on page 48 to organize and document what evidence you used to decide on the MM intensity. A sample answer (from the Trenton[NJ] Evening Times) has been filled in for you.

4. **Now come together with two or three other students who have independently evaluated the same articles that you did.** Compare your answers and reasoning with those of the other students. Come to a consensus with your group about the MM intensity value for each town that you read about.

5. On your group’s copy of the map (Figure 3.2), plot the Modified Mercalli intensity value for each town that your group considered. Write the intensity value in roman numerals next to the name of the town.

6. Contribute your group’s MM intensity values to the Master Map, which will combine data from all the student groups. Plot your group’s data on the Master Map by coloring in the circles next to the city names on the map. See the suggested color scheme in Table 3.1.

7. As a class, examine the Master Map. Discuss where you think the August 10, 1884, earthquake was located. With this technique, you should be able to identify an approximate position but you will not be able to pinpoint the earthquake exactly. Mark on the Master Map where the class thinks the earthquake was located.

8. If you live in the northeastern United States, mark the location of your own town or city on the map. Read aloud the newspaper account from the city closest to where you live. What other questions do you wish the reporter had asked to give you a fuller sense of the earthquake?

9. As a class, discuss how earthquake science has changed since the development of the Modified Mercalli Intensity Scale.

---

**Figure 3.1b**

Damage Characteristic of Earthquake Intensity MM VII

“Cracked chimneys; broke weak chimneys.”


**Table 3.1**

Colors to Use With Map in Figure 3.2

<table>
<thead>
<tr>
<th>MM Intensity</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>I to II</td>
<td>Purple</td>
</tr>
<tr>
<td>III to IV</td>
<td>Blue</td>
</tr>
<tr>
<td>V</td>
<td>Green</td>
</tr>
<tr>
<td>VI</td>
<td>Yellow</td>
</tr>
<tr>
<td>VII</td>
<td>Orange</td>
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</tbody>
</table>
Figure 3.2
Map of Northeastern United States: Modified Mercalli Intensity Values for Earthquake, August 10, 1884 (to be completed by students)
Modified Mercalli (MM) Intensity Scale

MM I. Not felt, or rarely under especially favorable circumstances.

MM II. Felt indoors, especially on upper floors. Sometimes hanging objects may swing, especially when delicately suspended. Sometimes doors may swing very slowly. Sometimes dizziness or nausea is experienced.

MM III. Felt indoors by several people. Sometimes not recognized to be an earthquake at first. Duration estimated in some cases. Motion usually consists of rapid vibration, similar to the vibration of passing of light trucks. Hanging objects may swing slightly. Movement may be appreciable on upper levels of tall structures.


MM V. Felt indoors by practically everyone, outdoors by many or most. Awakened most. Frightened few—a few ran outdoors. Buildings trembled throughout. Broke some dishes, glassware. Cracked windows (in some cases, but not generally). Overturned small or unstable objects. Hanging objects and doors swing generally or considerably. Knocked pictures against walls, or swung them out of place. Opened or closed doors and shutters abruptly. Moved small objects and furniture (the latter to slight extent). Spilled liquids in small amounts from well-filled open containers.

MM VI. Felt by all, indoors and outdoors. Frightened many, excitement general, some alarm, many ran outdoors. Awakened all sleepers. Liquid set in strong motion. Small bells rang, for example, in church, chapel, or school. Damage slight in poorly built buildings. Fall of plaster in small amount. Plaster cracked somewhat, especially fine cracks in chimneys. Broke dishes
and glassware in considerable quantity; also some windows. Fall of knick-knacks, books, and pictures. Overturned furniture in many instances. Moved moderately heavy furniture.

**MM VII.** Frightened all. General alarm; all ran outdoors. Some found it difficult to stand. Waves occurred on ponds, lakes, and running water. Damage slight to moderate in well-built ordinary buildings. Cracked chimneys to considerable extent, walls to some extent. Fall of plaster in considerable to large amounts; also some stucco. Broke numerous windows. Broke weak chimneys at the roofline. Dislodged bricks and stones. Overturned heavy furniture, with damage to furniture.


**MM IX to X.** Panic general. Cracked ground up to widths of several inches; fissures up to a yard in width run parallel to canal and stream banks. Landslides considerable from river banks and steep coasts. Damage serious to dams, dikes, and embankments. Severe damage to well-built wooden structures and bridges: some collapse in large part; frame buildings completely shifted off foundations; dangerous cracks in excellent brick walls. Serious damage to reservoirs; underground pipes sometimes broken.

**MM XI to XII.** Damage total. Practically all works of construction damaged greatly or destroyed. Broad fissures, earth slumps, and landslides; fall of rocks of significant character; slumping of river banks, numerous and extensive. Fault slips in firm rock, with notable horizontal and vertical offset displacements.

<table>
<thead>
<tr>
<th>State</th>
<th>City</th>
</tr>
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<tbody>
<tr>
<td>NY</td>
<td>Marlborough</td>
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</table>

<table>
<thead>
<tr>
<th>Newspaper Article Number</th>
<th>Newspaper</th>
<th>Characteristics From MM Intensity Scale</th>
<th>Evidence From Newspaper Article</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>Trenton Evening Times</td>
<td>IV: “glassware and crockery clink and clash”</td>
<td>“glasses jingled and mirrors shook perceptibly”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mercalli Intensity</th>
<th>Mercalli Intensity Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV-V</td>
<td>IV-V</td>
</tr>
</tbody>
</table>

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Newspaper Accounts of the August 10, 1884, Earthquake

To the Teacher: The following newspaper accounts are for use by students in steps 1–8 of Data Puzzle #3. Give each student at least three different accounts. Consider printing them on card stock or laminating them for longer use. They have been numbered 1–35 to help you keep track of them; these numbers do not signify position or earthquake intensity. For more information on using these accounts with your class, see pages 69–72.

1

THE EARTHQUAKE

Undulating Waves Ripple Roughly Over the Ground’s Surface
The Country was Shaken… Cracking Walls and Toppling Chimneys

Accounts From Ohio to New England

Telegraphic reports afterwards brought the intelligence that the shock was … unnoticed in Richmond [Virginia], and was scarcely felt in Portland [Maine]. In Cleveland [Ohio] it caused a ripple of excitement, but Indiana and Illinois residents read with surprise the news of the disturbance in the neighboring States.

(from an article in The Easton [PA] Express, Monday Evening, Aug. 11, 1884)

2

THE EARTHQUAKE

Undulating Waves Ripple Roughly Over the Ground’s Surface
The Country was Shaken… Cracking Walls and Toppling Chimneys

Accounts From Ohio to New England

Harrisburg [PA], Aug. 10—Large numbers of people in this city were startled this afternoon at 2 o’clock by a violent shock of about five seconds’ duration. There was a very perceptible vibration of the earth and houses were shaken in a very lively manner. Some people were almost thrown from their chairs, and … were awakened from sound slumber to see beds and other furniture shaken and to hear … glassware rattle.

(from an article in The Easton [PA] Express, Monday Evening, Aug. 11, 1884)
3  THE EARTHQUAKE

Undulating Waves Ripple Roughly Over the Ground’s Surface
The Country was Shaken… Cracking Walls and Toppling Chimneys

Accounts From Ohio to New England

Columbia [PA], Aug. 10—[Special.] The citizens of Columbia were gently excited at 2:12 o’clock this afternoon by a most mysterious shock, which, it is believed, came from an earthquake or some other internal disarrangement of the earth. In some parts of the town it was felt more severely than others. On Locust street, more especially at the upper end, the houses shook, while the dishes in cupboards and the windows rattled. The occupants of the houses of Locust and Fifth streets ran out into the street, so violently did their houses sway from side to side. The only damage done was the breaking of several window panes.

(from an article in The Easton [PA] Express, Monday Evening, Aug. 11, 1884)

4  THE EARTHQUAKE

Undulating Waves Ripple Roughly Over the Ground’s Surface
The Country was Shaken… Cracking Walls and Toppling Chimneys

Accounts From Ohio to New England

Doylestown [PA], Aug. 10—About 2 o’clock this afternoon a rumbling noise as of distant thunder was distinctly heard here, followed by a general vibration of the earth, causing dishes to rattle, furniture to move from its position, doors to unlatch and open. No serious damage has been reported in the vicinity of the town. The earthquake was also felt at other places.

(from an article in The Easton [PA] Express, Monday Evening, Aug. 11, 1884)
5

THE EARTHQUAKE

Undulating Waves Ripple Roughly Over the Ground’s Surface
The Country was Shaken... Cracking Walls and Toppling Chimneys

Accounts From Ohio to New England

Long Branch [NJ], Aug. 10—The earthquake shock reached Long Branch just as people were sitting down to dinner. The first indication of the phenomenon was a rumbling noise, followed instantly by a trembling as it seemed of all creation. It was all over in half a dozen seconds, but the time was long enough to set all Long Branch in a panic. The cottages and hotels poured forth their inmates. Plazas and lawns were dotted with shaking men, weeping children and fainting women.

The seven hundred guests at the table at the West End made a rush for the doors and shrank back laughing foolishly when the danger was passed, but dainty food went almost untouched after that.... When the first sound was heard and the startled guests were wondering what it all meant the fool somewhere in the crowded room shrieked, “Fire! Fire!” Then there was a wild rush. Instantly women and children fell and strong men ruthlessly stepped over and in some cases on them and forced their way first to the doors....

At one of the hotels a lady who was taking a bath in her room rushed out into the hallway clothed only in a towel. Chairs and beds rocked like hammocks. Henry Haggerty, a guest at the United States Hotel, who was taking a nap, was awakened by the swaying of his bed. The appearance of sky and sea was unchanged during the disturbance, but a woman who was in bathing was thrown off her feet. No serious injury or damage resulted, and after the shock the people were laughing at their own fright.

(from an article in The Easton [PA] Express, Monday Evening, Aug. 11, 1884)
THE EARTHQUAKE

Undulating Waves Ripple Roughly Over the Ground’s Surface
The Country was Shaken... Cracking Walls and Toppling Chimneys

Accounts From Ohio to New England

Asbury Park [NJ], Aug. 10—The earthquake treated the saints of Ocean Groves and the sinners of Asbury Park alike. It scared pretty nearly everybody. There was a loud rumbling sound, quickly followed by a shock which set the cottages and hotels to rocking in the liveliest kind of a manner. People on the beach did not feel it. Houses were quickly emptied of their occupants, the dinner tables were deserted and people with napkins about their necks rushed into the streets with faces as white as chalk. Nobody seemed to know what was the matter for some time. Rumors that boilers in the Sheldon House had blown up caused a stampede in that direction over in the Grove, but there was nothing the matter there.... The streets were filled with excited people, who stood around all the afternoon waiting for another shock and afraid to return to their rooms.

Some of the scenes were ludicrous. Women with babies in their arms rushed into the streets, and some of the big hotels there was the liveliest kind of a panic. The earthquake shock had no effect whatever upon the water. Thousands of people loitered upon the boardwalk hunting for a tidal wave, but beyond some ships out at sea, some gulls hunting for fish and a grand surf they saw nothing.

(from an article in The Easton [PA] Express, Monday Evening, Aug. 11, 1884)
7  

**THE EARTHQUAKE**

Undulating Waves Ripple Roughly Over the Ground’s Surface  
The Country was Shaken… Cracking Walls and Toppling Chimneys  

*Accounts From Ohio to New England*

Stamford [CT], Aug. 10—A very perceptible shock of earthquake was felt at 2:09 P.M. today, shaking buildings and causing considerable excitement. A centre table was overturned in the resident of R.H. Gillespie and a handsome ornament smashed. Pictures fell from the walls and other damage was done. Fifteen years ago a similar shock was felt at night, and forty years ago a still greater one was experienced.  

(from an article in *The Easton [PA] Express*, Monday Evening, Aug. 11, 1884)

8  

**AN EARTHQUAKE SHOCK**

Houses Shake and Chimneys Fall in Philadelphia;  
The Atlantic Coast Disturbed from Washington, D.C., to Portland, Me.-  
No lives Reported lost.

Reading [PA], Aug. 10—At 2:12 this afternoon two distinct shocks of earthquake were felt throughout this city and country, shaking houses, moving furniture and dropping blinds. Considerable excitement prevailed among the people, many running into the street.  

(from an article in *The Philadelphia Record*, Monday Morning, Aug. 11, 1884)
9  AN EARTHQUAKE SHOCK

Houses Shake and Chimneys Fall in Philadelphia; The Atlantic Coast Disturbed from Washington, D.C., to Portland, Me. - No lives Reported lost.

Bordentown [NJ], Aug. 10—At precisely eight minutes after 2 o’clock this afternoon the people of this place were thrown into a state of great excitement by an earthquake shock, which lasted fully half a minute. The people were panic-stricken, and rushed pell-mell into the street. Farnsworth Avenue was immediately alive with women and children. The shock was most severely felt at the hilltop, where several children were prostrated. The chimney of Mr. Valentine Woods’ house, in Church street, was tumbled into the street. Pans and dishes were thrown off Mr. James Powell’s dresser in West Street. Those who were at the riverfront say that the Delaware sent up large waves over the Pennsylvania and Jersey shores.

(from an article in The Philadelphia Record, Monday Morning, Aug. 11, 1884)

10  AN EARTHQUAKE SHOCK

Houses Shake and Chimneys Fall in Philadelphia; The Atlantic Coast Disturbed from Washington, D.C., to Portland, Me. - No lives Reported lost.

Peekskill [NY], Aug. 10—At 2:07 P.M. Peekskill experienced two severe shocks of earthquake. The shock caused windows, shutters, and dishes to shake and rattle loudly, persons ran out of their houses wondering and fearful as to the cause of the terrible sensation.

(from an article in The Philadelphia Record, Monday Morning, Aug. 11, 1884)
11 AN EARTHQUAKE SHOCK

Houses Shake and Chimneys Fall in Philadelphia; The Atlantic Coast Disturbed from Washington, D.C., to Portland, Me.- No lives Reported lost.

Mount Vernon [NY], Aug. 10—At 10 minutes after 2 o’clock this afternoon, Mount Vernon, Yonkers, New Rochelle, Port Chester, White Plains and other places in Westchester county, had a lively shaking up by an earthquake. The chimneys of a house were shaken down and the brick walls badly shattered.

(from an article in The Philadelphia Record, Monday Morning, Aug. 11, 1884)

12 AN EARTHQUAKE SHOCK

Houses Shake and Chimneys Fall in Philadelphia; The Atlantic Coast Disturbed from Washington, D.C., to Portland, Me.- No lives Reported lost.

Washington, D.C., Aug. 10—Commander Sampson, Assistant Superintendent of the Naval Observatory, reports that he observed slight vibrations of the earth around 2 o’clock this afternoon, lasting about sixteen seconds. He was in the second story of his house, adjoining the observatory. The windows of the room rattled and the articles on a marble-top table moved. No phenomena were observed on the lower floors of the house. A few persons have reported this evening that they observed some unusual motion of the earth about 2 o’clock this afternoon, but very few such reports have been made.

(from an article in The Philadelphia Record, Monday Morning, Aug. 11, 1884)
AN EARTHQUAKE SHAKES US

Bethlehem [PA]—For the first time since the year 1828, so the oldest citizens say, a perceptible shock of an earthquake was felt in the Bethlehems at 2:06 o’clock yesterday afternoon. A rumbling noise, resembling that which is heard when approaching the skating rink, accompanied the shock, which lasted about twelve seconds. Houses were shaken in all sections of the town, and in many instances mantel ornaments were thrown to the floor, window curtains knocked down and doors unlatched. The damage done in Bethlehem was slight. The handsome residence of William Stubblebine, situated at the corner of Church and New streets, was damaged, the southeastern wall being cracked. The residence of Wm. King, on Leibert Street, West Bethlehem, was also damaged. The walls on the inside were cracked to such an extent to resemble a map of Hungary. We are informed that the doorbells of Drs. Wilson and Detwiller were rung by the shock.

The shock of the earthquake yesterday afternoon caused much alarm among our citizens. Women and children ran out of their homes crying and for a time much consternation prevailed. In some residences on Fountain Hill vases, brick-a-brac, &c., were knocked off the mantelpieces. In the First Reformed Church, Fourth Street, the bible was thrown from the pulpit. The shock was most severe in the elevated portions of the town, persons residing on Second Street and in the Third Ward scarcely feeling it.

(from an article in the Bethlehem [PA] Daily Times, Aug. 1884)
Earthquakes

14 SHAKEN BY AN EARTHQUAKE

A Very Terrible shock of an Earthquake startles York.

Yesterday afternoon, about ten or twelve minutes after two o’clock, York [PA] went through a novel experience, in the very sensible feeling of an earthquake shock. The shock lasted, perhaps, from eight to ten seconds, and was felt with more or less effect in the various parts of town.

Many who were taking their Sunday afternoon nap were awakened from their slumbers by the shaking of their beds; and not a few nervous people were badly frightened. Windows rattled, buildings trembled, pictures and looking-glasses trembled on the walls, and for a few moments the town seemed to have a general shaking up.

Few people seemed to have an idea of the cause of the singular sensation. Some thought an explosion had occurred somewhere; to others it appeared as if an unusually heavy team had passed the house shaking the foundations, while others again looked upon it as a token of evil and their forebodings of direful disaster soon to come, made them terrible with fright. In some sections of town it was more perceptible than others and the beds on which people were comfortably resting shook so perceptibly as to awaken the sleepers. In one instance an individual thought some one was under the bed moving it. Many people thought the end of all things was at hand, and there was doubtless more praying than the usual amount of Sunday praying for a little while at least.

(from an article in the York [PA] Dispatch, Aug. 1884)
Special Dispatch to The Philadelphia Press. New York [City], Aug. 10—The city and vicinity felt a smart earthquake shock at about five minutes past 2 o’clock this afternoon, or rather two or three distinct shocks, which startled the whole city and set everybody to talking about it.

At the Brevoort House, at Fifth Avenue and Eight Street, the shock was also perceptibly felt. The night clerk, who was still in bed, was awakened by the low rumbling noise, which jarred the furniture in the room sufficiently to break his slumbers. He rushed to the window and found half the windows in the block filled with excited people. Mr. Murant Haistead, of the Cincinnati Commercial-Gazette and the new evening paper was engaged in the writing in an upper room of the same hotel. Mr. Haistead says the vibration was perfectly perceptible but thinks it did not last longer than two or three seconds.

At the New York on Broadway, Mr. Samuel J. Randall, of Pennsylvania, and a few political friends were lunching. Suddenly there was a rattling of glass and a general shaking of dishes, which brought the ex-Speaker to his feet in a jiffy. A South American gentleman in the party recognized the sensation at once. “Why, that is an earthquake!” he exclaimed, and the room was vacant in less time than one can count one.

Two blocks above the Vienna Café was filled with Sunday afternoon strollers, who had stopped for a little refreshment. The shock caused quite a panic among them. The cut glass prisms of the chandelier tinkled like sleigh bells—cups and saucers danced about in the trays in the most festive fashion, while the rumbling in the cellar shook the house from top to bottom and three of the globes on the chandeliers fell to the floor and were shivered a thousand pieces.

(from an article in The Philadelphia Press, Aug. 11, 1884)
Along the Jersey Coast—

The Phenomenon Divides Itself Into Three Sections at Atlantic City.

Special Dispatch to The Philadelphia Press, Atlantic City [NJ], Aug. 10—There was a series of three mysterious shocks felt here this afternoon at exactly nine minutes after 2 o’clock, which had all the effects of an earthquake. Inquiries were made generally concerning the phenomenon, in the belief that it resulted from an explosion, and the rumor prevailed that the gasworks had blown up.

At the Jackson House alarm was occasioned among the guests, who were seated at their dinner table, when the dishes rattled and the table shook as though it was affected by palsy. At Kuebrie’s Hotel and at Joseph A. Harstow’s house, on Pennsylvania Avenue, water pitchers were overturned and spilled over the floor. James Beckwith and John Hill Martin, of the Ocean House, were alarmed in their beds while William G. Bartlett’s family, on North Carolina Avenue, near Atlantic, ran out of doors in great consternation.…

At the Lighthouse the shock startled Major Wolf, the keeper, whilst he was writing, overturning the inkbottle over his Sunday trousers. A hundred such incidents are talked about through the town tonight and everybody was waiting for a tidal wave, which, old watermen say, is always sure to follow an earthquake.

Conductor-Bartlette, of the Camden and Atlantic railroad, says he was thrown from his chair while sitting at home. An unoccupied car on one of the roller coasting roads on Tennessee Avenue is said to have been started by the force of the shock, and to have gone dashing over the circuit.

(from an article in The Philadelphia Press, Aug. 11, 1884)
**17 Rhode Island’s Shaken Ground.**

Special Dispatch to *The Philadelphia Press*. Providence [RI], Aug. 10—The earthquake shock was felt very perceptibly in this city and state and people were temporarily alarmed. It happened at about 7 minutes past 2 o’clock this afternoon and was felt in various parts of the city. Mr. John Kendrick, one of Providence’s foremost citizens, was reading in his brick mansion on Westminster Hill, when suddenly the walls and floor of the room shook like a steamship at sea breasting the billows, and the statuary so agitated that Mr. Kendrick was in momentary fear that they would tumble from their pedestals. The duration was perhaps fifteen seconds and then after a quarter of a minute came a second shock of less violence.

In the tall Narragansett and Dorrance Hotels the guests felt the tremor very strongly. Some people who were enjoying Sunday afternoon naps were awakened from their slumber by the shaking of their beds. At Pawtucket, a large town four miles North of here, houses were shaken like reeds and the timbers of wooden buildings creaked like those of a ship in a heavy sea.

(from an article in *The Philadelphia Press*, Aug. 11, 1884)

**18 West Chester’s Bells Rung**

*How Bottles Rattled and a Chimney Lost Its Terra Cotta Top*

Special Dispatch to *The Philadelphia Press*. West Chester [PA], Aug. 10—The earthquake was felt very perceptibly in this borough, and lasted for fully a half minute. The quaking were divided into three distinct shocks. In the drug stores of Joseph S. Evans, H.R. Kervey and others the bottles on the shelves rattled quite loudly. The front door bell at the residence of Dr. Edward Jackson was rung. The shock sent people into the streets to find out what had happened, some thinking that duPont’s powder mill, at Wilmington, had exploded. The tremulous motion of the earth produced the effect of seasickness with some persons.

Telephone bells were rung, as were other bells in various parts of the town. At the Pennsylvania Railroad station one of the employees stated that he actually noticed the walls of the freight house shaking.

(from an article in *The Philadelphia Press*, Aug. 11, 1884)
19 Milton’s Up Heaving Pavements

Special Dispatch to The Philadelphia Press. Milton [PA], Aug. 10—A loud, heavy noise, like the rumbling of a continuous peal of thunder, was heard, and then followed by a terrible trembling of the earth. The shock was very perceptibly felt by those lying in bed. The furniture in some houses trembled…. The pavements were seen to vibrate as if an upheaval was about to occur.

Those who have experienced the feelings attendant upon an earthquake say that this of today here is exactly like it. There has been neither rain nor thunder storm here today, and a clear sky has prevailed since early this morning.

(from an article in The Philadelphia Press, Aug. 11, 1884)

20 A Plum-Picker Shaken From a Tree

Special Dispatch to The Philadelphia Press. Allentown [PA], Aug. 10—It was about 2:05 o’clock this afternoon, when a distinct shock of earthquake was felt in this city. It continued about fifteen or twenty seconds. Windows rattled, doors shook and chandeliers swung. The first thought was that a dynamite mill had exploded, but the shock lasted too long to hold to that theory. People ran out of their houses in fright, and many who were asleep were awakened by the quaking buildings. A lady on Seventh Street was thrown from a sofa. A man named Shafter, while picking plums, fell off the tree and broke his leg, whether from fright or from the shaking, is not known. The children in Sunday schools were badly frightened.

(from an article in The Philadelphia Press, Aug. 11, 1884)

21 Pike County Caught in the Wave

Special Dispatch to The Philadelphia Press. Matamoras [PA], Aug. 10—Two distinct shocks of earthquake were felt in this county this afternoon. Houses were shaken, dishes rattled and buckets of water slopped over. The two shocks were a few seconds apart and lasted about one minute. It was at first thought to be the explosion of a locomotive on the Erie Railway, but this was proven untrue.

(from an article in The Philadelphia Press, Aug. 11, 1884)
22 Milton’s Up Heaving Pavements

Special Dispatch to The Philadelphia Press. Honesdale [PA], Aug. 10—A severe shock of earthquake was felt here this afternoon. Dishes rattled on the tables and doors were opened by the shock.

(from an article in The Philadelphia Press, Aug. 11, 1884)

23 Saratogians Become Seasick

Special Dispatch to The Philadelphia Press. Saratoga [NY], Aug. 10—A slight tremor at 2:07 P.M., standard time, was felt at Saratoga. Some people at dinner were affected much as though by seasickness. Curiosity was excited to know the cause, and it was only after a dispatch came from New York and other points announcing an earthquake shock that its meaning was comprehended.

(from an article in The Philadelphia Press, Aug. 11, 1884)

24 Ground Vibrates in Wilkes Barre

Wilkes Barre [PA]—There was a perceptible tremor of terra firma about 2:15, and consisted of a series of vibrations, ranging from 2 to 5. The direction was from east to west or from northeast to southwest. It was not felt by everybody, and did not knock down any brick buildings, yet attracted the attention of hundreds of our citizens....

It was thought by the inquirers that a powder mill must have exploded in the vicinity of Wilkes-Barre ... a mine blast, or possibly a crash in the mineral spring colliery. Marcus Smith was lying on a sofa reading and was almost thrown off. He thought both gas-o-meters had gone up.

W. W. Brown saw the walls of his residence vibrate. Dick Brundage saw the pictures on the wall begin to rattle. Mrs. Douglass Smith was sitting quietly in a rocking chair, the vibration being strong enough to set her chair rocking. Mrs. M. B. Houpt felt the window shutters and doors rattle....

Editor J. C. Coon felt a north by northeast tremor and pinched himself to see if he wasn’t getting paralyzed. Harry Wilbur was napping on a lounge when he jumped up thinking all the mules in the stable were having a kicking picnic. Mrs. Bookseller Butler noticed her sewing machine trying to get up motion.

(from an article in the Wilkes-Barre [PA] Recorder, Aug., 11, 1884)
**Badly Shaken Up**

**New York Shaken**

New York [City], Aug. 11—A few minutes past 2:00 PM yesterday afternoon the city was visited by a genuine shock of earthquake which lasted for a full 15 seconds.

In several uptown bar-rooms glassware was shaken from shelves and broken. The police central building in Mulberry street was shaken from foundation to roof. The shock was very perceptible on the Brooklyn Bridge. All accounts agree that the shock was preceded by a low rumbling noise.

While a congregation of 250 were celebrating the consecration of the Holy Scroll in the B’Nai Drebnine synagogue on the second floor at the old building at Hester and Ludlow St., the building trembled, and several of the window panes broke and fell into the street. The worshippers rushed to the doors in alarm. Stalwart ushers turned them back. They sprang to the windows, and some tried to jump to the ground, a distance of twenty feet, but were held back.

The Italians occupying the row of tenements known as “the Barracks” opposite the Mott street end of the Central office, swarmed into the open air, evidently remembering their earthquake experiences in their own country.

(from an article in the Trenton [NJ] Evening Times, Aug. 11, 1884)

**A Curious Phenomenon**

Bridgeport [CT], Aug. 11—About 2:05 yesterday afternoon people in the city and vicinity were startled by a rumbling sound accompanied by a violent shaking of buildings. At first it was thought a violent explosion at the cartridge factory had occurred.

In some places dishes were thrown from the shelves and broken. At Stratford bricks were shaken from the chimneys, and in one house a man who was lying on a lounge was thrown to the floor.

In the Housatonic River a curious phenomenon occurred. Just as the rumbling began a wave started from either shore, and meeting in the center of the river rolled over and over, presenting a magnificent spectacle.

(from an article in the Trenton [NJ] Evening Times, Aug. 11, 1884)
27  **Badly Shaken Up**

**Water Thrown up into the Air**

*New Haven [CT], Aug. 11—Two severe shocks of an earthquake were felt in this city at about 2:15 o’clock yesterday afternoon. The first was about five seconds in duration and the latter thirty seconds later was much more severe. Pictures on the walls rattled, mirrors vibrated, and the citizens were much frightened. No serious damage was done however. In Branford the water in a small brook on the Rose farm was thrown up into the air quite a distance.*

(from an article in the *Trenton [NJ] Evening Times*, Aug. 11, 1884)

28  **Badly Shaken Up**

**Two Distinct Shocks**

*Albany [NY], Aug. 11—At 2:09 o’clock yesterday afternoon a shock of earthquake was experienced in this city, which lasted seven seconds. There were two distinct shocks which shook the houses throughout the city. Dishes were thrown together on tables, oranges and other fruit thrown to the floor, doors thrown open and blinds closed by the force of the shock. The course of the shock was from east to west apparently.*

(from an article in the *Trenton [NJ] Evening Times*, Aug. 11, 1884)
29  

**Badly Shaken Up**

**Beasts Strangely Affected**

**Marlborough [NY], Aug. 11**—A few minutes after 2 o’clock yesterday afternoon people along the Hudson river were startled by a dull, rumbling sound, followed by a trembling motion. In the vicinity of Marlborough houses were shaken so much that glasses jingled and mirrors shook perceptibly. Ladies and children were badly frightened, and dogs and beasts of burden were strangely affected.

(from an article in the *Trenton [NJ] Evening Times*, Aug. 11, 1884)

---

30  

**Badly Shaken Up**

**Somebody Told Them**

**Buffalo [NY], Aug. 11**—A shock that was almost imperceptible was felt at 2:30 yesterday afternoon at Black Rock and East Buffalo. It attracted little attention, and no damage was done. So far as can be learned there was no shock in the city. If there was it was too slight to excite any general apprehension.

(from an article in the *Trenton [NJ] Evening Times*, Aug. 11, 1884)
31  Explosion or Earthquake

Cape May Point [NJ], Aug. 10—There is no doubt that the tremor of an explosion or earthquake was felt both here and at Cape May by numbers of persons. They describe quite a shaking of furniture and rattling of window sashes about two o’clock.  
(from an article in the Public Ledger, Monday, Aug. 11, 1884, Philadelphia, PA)

32  Slight Earthquake Felt

Burlington [VT], Aug. 11—Two slight but very distinct earthquake shocks were felt here yesterday afternoon, the first at 2:30 and the second at 5:30.  
(from an article in the New York Evening Post, Monday, Aug. 11, 1884)

33  All Shaken Up

Springfield [MA], Aug. 11—The shock was preceded by a deep rumbling sound … in several parts of the city doors were thrown open, bells were rung and pictures swung from the walls. One person reports that he was aroused from a nap by the knocking of a pitcher against the marble sink in his room, and describes the motion like that of swinging in a hammock.  
(from an article in the Boston Globe, Monday, Aug. 11, 1884)
All Shaken Up

Boston [MA], Aug. 11 [Part 1]—Boston has had an earthquake. Not much of one, not enough to shake down any buildings nor throw anybody out of bed…. It was accompanied by swaying chandeliers, rocking tables and furniture, and a rumbling heavy sound like that of a well laden cart going over frozen ground. This lasted about ten seconds and then ceased.

D. J. Saunders was reclining in a room of his house at the South End at the time, reading a paper and inhaling tobacco fumes through the stem of a black “T. D.” pipe, when he felt his couch quivering and saw that his pipe was vibrating in an unusual manner.

An old woman was sleeping in the Collins block at Beach street and the jar woke her up. Mr. Nason, night manager of the Western Union Telegraph, was lying down and felt his bed shake for several seconds.

At the Fitchburg depot the restaurant cook and his wife were awakened from a sound sleep. Pictures upon the wall swung to and fro.

(from an article in the Boston Globe, Aug. 11, 1884)

All Shaken Up

Boston [MA], Aug. 11 [Part 2]—Boston has had an earthquake.

A gentleman in the upper story of the new savings bank on School Street felt the whole building sway and rock like a vessel at sea and thought the chimneys would all fall down.

On Charles St. several persons were aroused from sleep. On Ashburton place and at the offices as well as in many other parts of the city picture frames, books, crockery and other movables were endowed with sudden powers of locomotion. A young man employed at Ricker’s pharmacy says “The earthquake made the bottles on the shelves move.” None of the bottles was thrown from the shelves.

(from an article in the Boston Globe, Aug. 11, 1884)
What does an earthquake feel like?

In this Data Puzzle, students examine real newspaper accounts of the August 10, 1884, earthquake in the northeastern United States and gain firsthand experience applying the Modified Mercalli Intensity Scale to the event. Students gain insight into the history of science and how science can reveal patterns of nature by quantifying natural processes.

This puzzle works well in an Earth science or geology class and can also be tied into social studies or the history of science.

Prior Skills Needed
- Be able to analyze a newspaper article
- Be able to discern evidence from the surrounding context
- Have had experience in interpreting maps
- Be able to use Roman numerals I through X

Aha! Insights
- So that’s what earthquakes feel like. Yes, the Earth really does move! (for students who have never felt an earthquake)
- We have earthquakes and active tectonic processes in this region of the United States. I thought they only happened in California and other countries. (for students in the northeastern United States)
- Not all earthquakes occur at tectonic plate boundaries.
- The human senses can be tools of science.

Teacher Preparation
1. Work through the steps in the Data Puzzle yourself (pp. 43–48). Use “Step-by-Step: How to Solve Data Puzzle #3” (pp. 73–76) to anticipate which steps may be
difficult for students and plan what kinds of clues will help them past the sticky points without giving away the answers. Step-by-Step also shows the critical-thinking skills that students will need to solve each step.

2. Write down your learning goals. The goals you select will vary based on the academic needs and skills of your students and the specific focus of your school or your district. You may wish to consult Appendix B, which consists of tables that show the alignment of the Data Puzzles in this book with the National Science Education Standards and the Principles and Standards for School Mathematics. Also refer to your state standards.

3. Select key vocabulary related to this puzzle to review with students before they complete the puzzle—for example, earthquake, tectonic plate boundary, intensity, epicenter, qualitative data, and quantitative data.

4. Plan how your students will collaborate on analyzing the data. We recommend that students begin their analysis individually (steps 1–3), then compare and combine their findings in small groups (steps 4–6), and then come together as a full class (steps 7, 8, and 9). There are 35 newspaper accounts. To get a sense of the variability of the earthquake experience, each student should analyze at least three newspaper accounts and then compare his or her analysis with the analyses of at least two other students in a small group. Do not omit any of the newspaper accounts; the full suite of data points is needed for the pattern to emerge when the data are plotted on the map.

5. Plan how your students will combine their individual findings into one Master Map. Options include the following:

   • Photocopy the blank map (Figure 3.2 on p. 45) onto overhead transparencies (one per group) and have students record their answers onto the map with transparency markers. Superimpose all of the maps, and project them all at the same time.

   • Project the blank map onto a whiteboard or large sheet of white paper and have students record onto the projected map.

   • Pass a page-size blank map from group to group; each group adds its own data (a method most suitable for smaller classes).

6. Gather and prepare materials:
   - colored pencils or markers
   - For each student: a photocopy of Data Puzzle #3, pp. 43–48
   - For each group: blank map (Figure 3.2), extra copies of the blank data recording table (Table 3.2)
   - For each student: at least three newspaper accounts (pp. 49–67). Within a small group, all students should have the same accounts. Consider printing these on card stock or laminating for longer use. The accounts have been numbered 1–35 to help you keep track of them; these numbers do not signify position or earthquake intensity.
   - (optional) World map showing plate boundaries for discussion about the fact that not all earthquakes occur at plate boundaries (See “Resources,” U.S. Geological Survey. World Map of Plate Boundaries.)

7. Plan any pre-puzzle activities (see below) and extension activities (p. 90). Check the Data Puzzles website (www.ldeo.columbia.edu/edu/data_puzzles) for background materials, color versions of the graphics, and other supporting materials. Double-check any digital resources to be sure they can be accessed from your classroom.

Optional Pre-Puzzle Activities

- As a cross-curriculum activity with the social studies department, have students research the historical time period in which the earthquake took place. Consider research topics such as the following: How were houses and other buildings built in the 1880s? What was the position of women in 1880s society? How were immigrants viewed? What technological innovations were new at the time of the earthquake? How were newspapers reported and edited at that time? Insights from this research will enable students to provide nuanced answers to the question in step 1 of the Data Puzzle (“How do these [historical] accounts differ from modern newspaper stories?”). Some relevant websites are provided on page 92 under “Resources About Historical Context.”

- Have students find news accounts of a recent earthquake to compare to the 1884 articles.
Teaching Notes

This Data Puzzle focuses on qualitative data collected through the five senses of human beings (the people who experienced the earthquake and the reporters who wrote the newspaper articles) rather than quantitative data collected by instruments. The puzzle offers a nontextbook-like view of a powerful Earth process. Discussing the differences between qualitative and quantitative types of data deepens students’ understanding of the nature of science.

• Use of historic data lends itself to interdisciplinary work with history and social studies teachers. The need for students to closely read the newspaper articles and Mercalli intensity descriptions (pp. 46–47) is a good opportunity for interdisciplinary work with English teachers.

• Although this puzzle works for students in any geographic area, it will have the most impact among students who have never personally experienced an earthquake.

• This is a good activity for fostering discourse and collaboration skills. We recommend that steps 1, 2, and 3 be done individually, steps 4, 5, and 6 be done in small groups, and steps 7, 8, and 9 be done as a full class discussion. An important part of the impact of doing the puzzle is the discussion of the newspaper accounts and the coding selected by the students.

• If you are short on time, consider assigning steps 1, 2, and 3 as homework. Use your valuable in-class time for the questions that need small-group and full-class discussion.
Step-by-Step: How to Solve Data Puzzle #3

**Teaching Note:** To solve the puzzle, students must use critical-thinking skills. Each use of critical thinking is described in the right-hand column and is coded as follows: (S) Spatial, (T) Temporal, (Q) Quantitative, and (C) Concept-based. See pages xv–xvii for a discussion of these four types of critical-thinking skills. Decision making is also part of the skill set that students use to solve this Data Puzzle. Decision-making skills are noted where appropriate.

<table>
<thead>
<tr>
<th>Answer Key</th>
<th>Critical Thinking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Read the newspaper accounts of the 1884 earthquake provided by your teacher. (Other student groups have different newspaper accounts.) How do these accounts differ from modern newspaper stories?</td>
<td>(C) Students will need some familiarity with how modern newspapers cover natural disasters, such as earthquakes, storms, and tsunamis. If students don't have this background, the teacher may want to provide, or have students bring in, newspaper clippings about a recent natural disaster to allow a side-by-side comparison. Consider starting with a discussion putting 1884 in context historically. What was happening in history during this time period?</td>
</tr>
<tr>
<td>Answers could include the following:</td>
<td></td>
</tr>
<tr>
<td>• No photographs</td>
<td></td>
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<tr>
<td>• Old-fashioned, more literary vocabulary and vivid descriptions</td>
<td></td>
</tr>
<tr>
<td>• Specific people mentioned by name or occupation (plum picker, the hotel guest, the politician)</td>
<td></td>
</tr>
<tr>
<td>• Descriptions lack what we refer to today as political correctness</td>
<td></td>
</tr>
<tr>
<td>• Portrayal of gender differences</td>
<td></td>
</tr>
<tr>
<td>• Information transmitted by telegraph</td>
<td></td>
</tr>
<tr>
<td>• Moral judgments</td>
<td></td>
</tr>
<tr>
<td>• Newspapers weren’t for the masses but for the literate elite</td>
<td></td>
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<tr>
<td>• No mention of monetary damages</td>
<td></td>
</tr>
<tr>
<td>• Few interviews with experts; most interviews with “regular people”</td>
<td></td>
</tr>
<tr>
<td>• Attempts to provide scientific explanations without knowledge of plate tectonics</td>
<td></td>
</tr>
<tr>
<td>• No mention of magnitude of the earthquake</td>
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</tbody>
</table>

**Teaching Note:** After students develop their ideas about how the historical accounts differ from modern newspaper stories of similar events, it works well to have them state their ideas and read aloud their evidence. The descriptive detail and old-fashioned phrasing come alive when read aloud. Because student groups have different readings, it can be helpful to accumulate answers to this question on the board.

(T) In Earth science class, temporal thinking usually involves thinking about changes over geological timescales. History and archeology also use temporal thinking, although over shorter timescales. Here, students are using temporal thinking to think about changes over a historical timescale of a bit more than a century (1884–2010, the year this book was written). A learning goal could be for students to recognize that changes in culture (e.g., the role of women), technology (e.g., telegraph versus internet), and scientific understanding (e.g., plate tectonics) have occurred in parallel over the same time span.
Earthquakes

Student Pages

(continued)

<table>
<thead>
<tr>
<th>Answer Key</th>
<th>Critical Thinking</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2.</strong> Back in the 1800s, there was no network of seismographs for recording earthquakes. Scientists who study historical earthquakes have developed a scale for quantifying the severity of a given earthquake at a given position, based on observations from eyewitness accounts. Read down through the Modified Mercalli (MM) Intensity Scale on pages 46–47. MM intensity values are reported in roman numerals from I (barely felt) to XII (catastrophic).</td>
<td></td>
</tr>
<tr>
<td><strong>Q</strong> An important insight here is that observations made by human senses of sight, hearing, and touch are being turned into numbers, into data. Many data types of importance in Earth science began as observations made with human senses (e.g., air and water temperature, density and hardness of rocks, wind direction and velocity).</td>
<td></td>
</tr>
<tr>
<td><strong>3.</strong> For the towns described in your newspaper accounts (see step 1), estimate the MM intensity of the August 10, 1884, earthquake. Be sure to pay attention to negative evidence (i.e., what is NOT stated). Your answer may be a range rather than an exact value. Use Table 3.2 on page 48 to organize and document what evidence you used to decide on the MM intensity. A sample answer (from the Trenton [NJ] Evening Times) has been filled in for you.</td>
<td></td>
</tr>
<tr>
<td><strong>Q</strong> An optional math connection: Modified Mercalli intensity values are an example of an “ordinal scale,” a kind of scale that shows relative ranking rather than absolute quantity. MM II is stronger than MM I, but there is no implication that it is twice as strong.</td>
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</tbody>
</table>

See Table 3.3 (Data Recording Table With Answers), pp. 77–85. Keep in mind that a Modified Mercalli intensity value is an approximation. When assessing students’ performance, focus on how well students support their claims with evidence as well as on their numerical answers.

**Teaching Note:** If students are troubled by the concept of translating into a number the feelings they have experienced with their human senses, you might liken this process to walking outside and trying to determine the temperature just from the feeling of the weather.

**4.** Now come together with two or three other students who have independently evaluated the same articles that you did. Compare your answers and reasoning with those of the other students. Come to a consensus with your group about the MM intensity value for each town that you read about.

**Circulate among the groups. Encourage students to talk about what evidence they used and how they might weigh potentially conflicting evidence.**

**Q** This step requires students to re-examine the conversion of felt-experience into quantitative data and think critically about the evidence behind each claim. (They are re-examining the choices they made in step 3.)

(Decision Making) Students practice reaching consensus about the interpretation of complex and potentially contradictory Earth data.
Earthquakes

Answer Key

5. On your group’s copy of the map, plot the Modified Mercalli intensity values for each town that your group considered. Write the intensity value in roman numerals next to the name of the town.

   See Figure 3.3 (map with answers, p. 86).

Critical Thinking

(S) These data contain two different kinds of information: information about how strong the shaking was and information about where the specified amount of shaking was felt. In this step, students turn their attention from the “how strong” information to the “where” information. Without “where” information, the “how strong” information would not be nearly as valuable for science.

6. Contribute your group’s MM intensity values to the Master Map, which will combine data from all the student groups. Plot your group’s data on the master map by coloring in the circles next to the city names on the map.

   See Figure 3.3 (map with answers). For methods to combine maps, see “Teacher Preparation,” pages 69–71.

(S) In this step, students experience the process of organizing data spatially. A large amount of diffuse data, gathered from diverse sources by various investigators, can be organized onto a map to convey that information efficiently. In Earth sciences, new patterns and insights often emerge when data are organized spatially.

7. As a class, examine the Master Map. Discuss where you think the August 10, 1884, earthquake was located. With this technique, you should be able to identify an approximate position but you will not be able to pinpoint the earthquake exactly. Mark on the Master Map where the class thinks the earthquake was located.

   The earthquake was in the general region of New York City; the map in Figure 3.3 shows that the strongest shaking was experienced in northeastern New Jersey, southwestern Connecticut, and southeastern New York State. The shaking was less intense at locations farther away.

(S) In this step, students must scan across a spatial array of information, visually integrate across a lot of details, and extract the overall spatial pattern. The overall spatial pattern is that (a) the strongest shaking (highest MM values) is centered around New York City and (b) the intensity of shaking diminishes radially outward from that center. The use of color facilitates seeing the overall pattern.

   Teaching Note: Students should be trying to interpret the overall map pattern exhibited by the entire data set considered as a whole. They should not be simply looking for the single most extreme newspaper account or the individual town with the highest MM intensity. Any single eyewitness account could be influenced by the characteristics of the local geology or the writing style of the newspaper reporter.
(continued)

<table>
<thead>
<tr>
<th>Answer Key</th>
<th>Critical Thinking</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. If you live in the northeastern United States, mark the location of your own town or city on the map. Read aloud the newspaper account from the city closest to where you live. What other questions do you wish the reporter had asked to give you a fuller sense of the earthquake? <strong>Students should locate and mark their town or city if they live within the region of the map. Teaching Note:</strong> Questions that might have been asked by reporters will vary among students. These questions provide a window into which aspects of the earthquake your students wish to know more about.</td>
<td></td>
</tr>
<tr>
<td>(S) In this step, students position themselves spatially relative to the data they have been working with and relative to an Earth phenomenon.</td>
<td></td>
</tr>
<tr>
<td>9. As a class, discuss how science has changed since the development of the Modified Mercalli Intensity Scale.</td>
<td></td>
</tr>
<tr>
<td>(T) In this discussion, students will deepen their understanding of the history of observational science. Humanity’s ability to observe nature methodically and accurately has increased over historical time. Quantifying a natural phenomenon, turning felt experience into numbers, is a big breakthrough in the study of a natural phenomenon. As in the case of earthquakes, the first numerical data about a given Earth phenomenon are usually fairly imprecise and then gradually scientists figure out how to measure more and more precisely. Along with the ability to observe methodically and accurately has come the ability to interpret the causes and predict the consequences of Earth processes.</td>
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</tbody>
</table>

- Prior to the development of numerical intensity scales, humans could feel and hear earthquakes and could see the destruction caused by earthquakes, but they had no methodical way to compare one earthquake to another or to combine insights from multiple earthquakes.

- Development of the intensity scale allowed scientists to compare one earthquake to another, to map the locations of individual earthquakes, and to compile maps to show zones of both abundant and rare earthquake occurrences. Intensity scales were developed and refined in the 1800s.

- Later, in the 1900s, scientists developed seismographs, instruments that measure ground motions directly. Seismograph data allow scientists to pinpoint the location of earthquakes precisely, even in regions without human habitations. Seismograph data also allow scientists to quantify how much energy is released in an earthquake.
### Table 3.3
Data Recording Table With Answers (Newspaper Articles Appear on pp. 49–67.)

<table>
<thead>
<tr>
<th>Newspaper Article Number</th>
<th>State</th>
<th>City</th>
<th>Newspaper</th>
<th>Evidence From Newspaper Article</th>
<th>Characteristics From MM Intensity Scale</th>
<th>Mercalli Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>CT</td>
<td>Bridgeport</td>
<td>Trenton Evening Times</td>
<td>“violent shaking of buildings” “dishes were thrown from the shelves and broken” “bricks were shaken from chimneys” “a wave started from either shore, and meeting in the center of the river rolled over and over”</td>
<td>V: “Buildings trembled throughout” VI: “Broke dishes, glassware, in considerable quantity” VII: “Cracked chimneys” VII: “waves on ponds, lakes, and running water”</td>
<td>VI–VII</td>
</tr>
<tr>
<td>27</td>
<td>CT</td>
<td>New Haven</td>
<td>Trenton Evening Times</td>
<td>“pictures on the walls rattled, mirrors vibrated” “the citizens were much frightened” “no serious damage was done” “the water in a small brook … was throw up into the air quite a distance.”</td>
<td>V: “knocked pictures against walls” V: “Frightened few—a few ran out outdoors” VI: “Liquid set in strong motion”</td>
<td>V–VI</td>
</tr>
<tr>
<td>7</td>
<td>CT</td>
<td>Stamford</td>
<td>The Easton Express</td>
<td>“a centre table was over turned … and a handsome ornament smashed” “pictures fell from the walls and other damage was done”</td>
<td>VI: “overturned furniture” VI: “fall of knick-knacks, books, pictures”</td>
<td>VI</td>
</tr>
<tr>
<td>12</td>
<td>D.C.</td>
<td>Washington</td>
<td>The Philadelphia Record</td>
<td>“…observed slight vibrations … in the second story of his house” “the windows of the room rattled and the articles on a marble-top table moved” “no phenomena were observed on the lower floors of the house”</td>
<td>III: “motion usually rapid vibration; vibration like that due to passing of light trucks” IV: “Rattling of … windows” V: “Moved small objects” III: “Movement may be appreciable on upper levels of tall structures” NOT V: “Buildings trembled throughout”</td>
<td>III–IV</td>
</tr>
<tr>
<td>Newspaper Article Number</td>
<td>State</td>
<td>City</td>
<td>Newspaper</td>
<td>Evidence From Newspaper Article</td>
<td>Characteristics From MM Intensity Scale</td>
<td>Mercalli Intensity</td>
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<tr>
<td>34</td>
<td>MA</td>
<td>Boston</td>
<td>The Boston Globe (Part 1)</td>
<td>“not much of one, not enough to shake down any buildings or throw anybody out of bed” “swaying chandeliers” “rocking tables and furniture…. couch quierving and … pipe was vibrating … bed shake for several seconds” “the jar woke her up … cook and wife were awakened…. ” “Pictures upon the wall swung to and fro”</td>
<td>V: “hanging objects…swing considerably” V: “moved small objects and furniture, the latter to slight extent” V: “awakened most” V: “knocked pictures against walls”</td>
<td>V</td>
</tr>
<tr>
<td>35</td>
<td>MA</td>
<td>Boston</td>
<td>The Boston Globe (Part 2)</td>
<td>“felt the whole building sway and rock like a vessel at sea” “several persons were aroused from sleep” “picture frames, books, crockery and other movables were endowed with sudden powers of locomotion … bottles on the shelves move”</td>
<td>V: “Buildings trembled throughout” IV: “Awakened some” V: “knocked pictures against walls” V: “moved small objects”</td>
<td>V</td>
</tr>
<tr>
<td>33</td>
<td>MA</td>
<td>Springfield</td>
<td>The Boston Globe</td>
<td>“doors were thrown open” “bells were rung” “pictures swung from the walls” “One person reports that he was aroused from a nap”</td>
<td>V: “Opened or closed doors and shutters, abruptly” VI: “small bells rang” V: “knocked pictures against walls” IV: “awakened some”</td>
<td>V–VI</td>
</tr>
<tr>
<td>1</td>
<td>ME</td>
<td>Portland</td>
<td>The Easton Express</td>
<td>“scarcely felt”</td>
<td>I: “not felt or except rarely, under especially favorable circumstances”</td>
<td>I</td>
</tr>
<tr>
<td>6</td>
<td>NJ</td>
<td>Asbury Park</td>
<td>The Easton Express</td>
<td>“It scared pretty nearly everybody” “set the cottages and hotels to rocking in the liveliest kind of a manner” “houses were quickly emptied of their occupants” “the earthquake shock had no effect whatever upon the water”</td>
<td>VII: “frightened all—general alarm, all ran outdoors” V: “buildings trembled throughout” NOT VII: “waves on ponds, lakes, and running water”</td>
<td>VI</td>
</tr>
<tr>
<td>Newspaper Article Number</td>
<td>State</td>
<td>City</td>
<td>Newspaper</td>
<td>Evidence From Newspaper Article</td>
<td>Characteristics From MM Intensity Scale</td>
<td>Mercalli Intensity</td>
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<tr>
<td>16</td>
<td>NJ</td>
<td>Atlantic City</td>
<td>The Philadelphia Press</td>
<td>“the dishes rattled” “the table shook as thought it was affected by palsy” “water pitchers were overturned and spilled over the floor” “family … ran out of doors in great consternation” “overturning the ink bottle”</td>
<td>IV: “glassware and crockery clink and crash” V: “moved small objects, furniture” V: “Spilled liquids in small amounts from well-filled open containers” V: “Frightened few—a few ran outdoors” V: “Overtorn small … objects”</td>
<td>V</td>
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<tr>
<td>9</td>
<td>NJ</td>
<td>Bordentown</td>
<td>The Philadelphia Record</td>
<td>“the people were panic-stricken and rushed pell-mell into the street” “the chimney … was tumbled into the street” “several children were prostrated” “pans and dishes were thrown … off dresser” “the Delaware sent up large waves over the Pennsylvania and Jersey shores”</td>
<td>VII: “frightened all—general alarm, all ran outdoors” VII: “broke weak chimneys at the roofline” VII: “Some found it difficult to stand.” VI: “Fall of knick-knacks, books, pictures” VII: “waves on ponds, lakes, and running water”</td>
<td>VII</td>
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<tr>
<td>31</td>
<td>NJ</td>
<td>Cape May Point</td>
<td>Public Ledger</td>
<td>“quite a shaking of furniture and rattling of window sashes”</td>
<td>IV: “rattling of dishes, windows, doors” V: “moved small objects, furniture”</td>
<td>IV–V</td>
</tr>
<tr>
<td>5</td>
<td>NJ</td>
<td>Long Branch</td>
<td>The Easton Express</td>
<td>“all Long Branch in a panic” “The cottages and hotels poured forth their inmates” “was awakened by the swaying of his bed” “Chairs and beds rocked like hammocks” “a woman who was in bathing was thrown off her feet” “the appearance of sky and sea was unchanged during the disturbance”</td>
<td>VII: “frightened all—general alarm, all ran outdoors” VI: “awakened all sleepers” VI: “moved furniture of moderately heavy kind” VII: “Some found it difficult to stand.” NOT VII: “waves on ponds, lakes, and running water”</td>
<td>VI–VII</td>
</tr>
<tr>
<td>Newspaper Article Number</td>
<td>State</td>
<td>City</td>
<td>Newspaper</td>
<td>Evidence From Newspaper Article</td>
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<tr>
<td>10</td>
<td>NY</td>
<td>Peekskill</td>
<td>The Philadelphia Record</td>
<td>“the shock caused windows, shutters, and dishes to shake and rattle loudly”</td>
<td>IV: “Rattling of dishes, windows, doors” V: “Frightened few—a few ran out outdoors”</td>
<td>IV–V</td>
</tr>
<tr>
<td>28</td>
<td>NY</td>
<td>Albany</td>
<td>Trenton Evening Times</td>
<td>“dishes were thrown together on tables” “oranges and other fruit thrown to the floor” “doors thrown open and blinds closed by the force of the shock”</td>
<td>V: “Broke dishes, glassware, to some extent” V: “Overturned small or unstable objects” V: “Opened or closed doors and shutters, abruptly”</td>
<td>V</td>
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<tr>
<td>30</td>
<td>NY</td>
<td>Buffalo</td>
<td>Trenton Evening Times</td>
<td>“a shock that was almost imperceptible [felt in outlying areas]” “no shock in the city”</td>
<td>I: “not felt or except rarely, under especially favorable circumstances”</td>
<td>I</td>
</tr>
<tr>
<td>29</td>
<td>NY</td>
<td>Marlborough</td>
<td>Trenton Evening Times</td>
<td>“houses were shaken” “glasses jingled and mirrors shook perceptibly”</td>
<td>V: “Buildings trembled throughout” IV: “glassware and crockery clink and clash” V: “Hanging objects … swing generally or considerably”</td>
<td>IV–V</td>
</tr>
<tr>
<td>11</td>
<td>NY</td>
<td>Mount Vernon</td>
<td>The Philadelphia Record</td>
<td>“the chimneys of a house were shaken down and the brick walls badly shattered”</td>
<td>VII: “Broke weak chimneys at the roofline” VII: “Cracked walls…to some extent”</td>
<td>VII</td>
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</table>
## Earthquakes

### Mercalli Intensity

<table>
<thead>
<tr>
<th>Characteristics From MM Intensity Scale</th>
<th>Mercalli Intensity</th>
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<tbody>
<tr>
<td>V: &quot;Awakened most&quot;</td>
<td>V-VI</td>
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<tr>
<td>IV: &quot;Pins and needles shake&quot;</td>
<td>V-VI</td>
</tr>
<tr>
<td>III: &quot;Frightened many, generally of considerably&quot;</td>
<td>V-VI</td>
</tr>
<tr>
<td>II: &quot;Buildings tremble throughout&quot;</td>
<td>V-VI</td>
</tr>
<tr>
<td>I: &quot;Awakened, moved small objects&quot;</td>
<td>V-VI</td>
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### Evidence From Newspaper Article

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<thead>
<tr>
<th>Newspaper Article</th>
<th>City</th>
<th>State</th>
<th>Evidence From Newspaper Article</th>
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<tbody>
<tr>
<td>The Philadelphia Press</td>
<td>New York</td>
<td>NY</td>
<td>&quot;the night clerk ... was awakened by the low rumbling noise, which jarred the furniture in the room sufficiently to break his slumber... there was a rattling of glass and general shaking of dishes... the shock caused quite a panic among them...&quot;</td>
</tr>
<tr>
<td>Trenton Evening Times</td>
<td>New York</td>
<td>NY</td>
<td>&quot;glassware was shaken from shelves and broken&quot;</td>
</tr>
<tr>
<td>The Press</td>
<td>Saratoga</td>
<td>NY</td>
<td>&quot;some people at dinner were affected much as though by seasickness&quot;</td>
</tr>
<tr>
<td>The Easton Express</td>
<td>Allentown</td>
<td>PA</td>
<td>&quot;windows rattled, doors shook, and chandeliers swung&quot;</td>
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<td>The Easton Express</td>
<td>Allentown</td>
<td>PA</td>
<td>&quot;windows rattled, doors shook, and chandeliers swung&quot;</td>
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### Newspaper Article Number

- 15 NY New York
- 25 NY New York
- 20 PA Allentown
<table>
<thead>
<tr>
<th>Article Number</th>
<th>State</th>
<th>City</th>
<th>Newspaper</th>
<th>Evidence From Newspaper Article</th>
<th>Characteristics From MM Intensity Scale</th>
<th>Mercalli Intensity</th>
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<tbody>
<tr>
<td>13</td>
<td>PA</td>
<td>Bethlehem</td>
<td>Bethlehem Daily Times</td>
<td>“Houses were shaken in all sections of the town”&lt;br&gt;“mantel ornaments were thrown to the floor, window curtains knocked down and doors unlatched”&lt;br&gt;“residence … was damaged, the … wall being cracked”&lt;br&gt;“the walls on the inside were cracked to such an extent to resemble a map of Hungary”&lt;br&gt;“the doorbells … were rung by the shock”&lt;br&gt;“women and children ran out of their homes crying”</td>
<td>V: “buildings trembled throughout”&lt;br&gt;VI: “fall of knick-knacks, books, pictures”&lt;br&gt;V: “opened or closed doors and shutters”&lt;br&gt;VI: “cracked plaster somewhat, especially fine cracks in chimneys”&lt;br&gt;VI: “small bells rang”&lt;br&gt;VI: “Frightened many, excitement general, some alarm, many ran outdoors”</td>
<td>V–VI</td>
</tr>
<tr>
<td>3</td>
<td>PA</td>
<td>Columbia</td>
<td>The Easton Express</td>
<td>“the houses shook”&lt;br&gt;“the dishes in cupboards and the windows rattled”&lt;br&gt;“the occupants … ran out into the street”&lt;br&gt;“the breaking of several window panes”</td>
<td>V: “buildings trembled”&lt;br&gt;IV: “rattling of dishes, windows and doors”&lt;br&gt;V: “a few ran outdoors”&lt;br&gt;V: “cracked windows”</td>
<td>IV–V</td>
</tr>
<tr>
<td>4</td>
<td>PA</td>
<td>Doylestown</td>
<td>The Easton Express</td>
<td>“general vibration of the earth”&lt;br&gt;“causing dishes to rattle”&lt;br&gt;“furniture to move from its position”&lt;br&gt;“doors to unlatch and open”</td>
<td>IV: “vibration like that due to passing of heavily loaded trucks”&lt;br&gt;IV: “rattling of dishes, windows, doors”&lt;br&gt;V: “moved small objects, furniture”&lt;br&gt;V: “opened or closed doors and shutters”</td>
<td>IV–V</td>
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### Earthquakes Data Puzzle

#### Student Pages

<table>
<thead>
<tr>
<th>Newspaper Article Number</th>
<th>State</th>
<th>City</th>
<th>Newspaper</th>
<th>Evidence From Newspaper Article</th>
<th>Characteristics From MM Intensity Scale</th>
<th>Mercalli Intensity</th>
</tr>
</thead>
</table>
| 2                        | PA    | Harrisburg    | *The Easton Express*      | “very perceptible vibration of the earth”
“houses were shaken in a very lively manner”
“awakened from sound slumber”
“bed and other furniture shaken”
“glassware rattle”                                                                 | V: “buildings trembled throughout”
V: “awakened most”
V: “moved small objects, furniture, the latter to slight extent”
IV: “Rattling of dishes; glassware and crockery clink and clash”                                             | IV–V                           |
| 22                       | PA    | Honesdale     | *The Press*               | “dishes rattled on the tables”
“doors were opened by the shock”                                                                                                           | IV: “rattling of dishes, windows, doors”
V: “Opened or closed doors....”                                                                                                         | IV–V                           |
| 21                       | PA    | Matamoras     | *The Philadelphia Press*  | “houses were shaken”
“dishes rattled”
“buckets of water slopped over”                                                                                                            | V: “Buildings trembled throughout”
IV: “Rattling of dishes”
V: “Spilled liquids in small amounts from well-filled open containers”                                                                     | IV–V                           |
| 19                       | PA    | Milton        | *The Philadelphia Press*  | “terrible trembling of the earth...
... pavements were seen to vibrate”
“the shock was very perceptively felt by those lying in bed”
“the furniture in some houses trembled”                                                                                                     | II-IV: “Vibration”
IV: “felt indoors by many”
V: “moved small objects, furniture”                                                                                                          | IV–V                           |
| 8                        | PA    | Reading       | *The Philadelphia Record* | “shaking houses”
“moving furniture”
“excitement prevailed among the people, many running into the street”                                                                     | V: “buildings trembled throughout”
V: “moved ... furniture ... to slight extent.”
VI: “Frightened many, excitement general, some alarm, many ran outdoors”                                                                       | V–VI                           |
<table>
<thead>
<tr>
<th>Newspaper Article Number</th>
<th>State</th>
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<th>Evidence From Newspaper Article</th>
<th>Characteristics From MM Intensity Scale</th>
<th>Mercalli Intensity</th>
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</thead>
<tbody>
<tr>
<td>18</td>
<td>PA</td>
<td>West Chester</td>
<td><em>The Philadelphia Press</em></td>
<td>“the bottles on the shelves rattled quite loudly”</td>
<td>IV: “Rattling of dishes; glassware ... clink and clash”</td>
<td>V (?)</td>
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<td>“front door bell ... was rung”</td>
<td>VI: “small bells rang”</td>
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<td>“produced the effect of seasickness”</td>
<td>II: “Sometimes ... nausea experienced”</td>
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<td>“telephone bells were rung, as were other bells in various parts of the town”</td>
<td>V: “Buildings trembled throughout”</td>
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<td>“he actually noticed the walls of the freight house shaking”</td>
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<tr>
<td>24</td>
<td>PA</td>
<td>Wilkes-Barre</td>
<td><em>Wilkes-Barre Recorder</em></td>
<td>“series of vibrations ... walls of residence vibrate....vibration strong enough to set [rocking] chair rocking”</td>
<td>III-IV: “Vibrations....”</td>
<td>IV–V</td>
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<tr>
<td></td>
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<td>“it was not felt by everybody ... yet attracted the attention of hundreds”</td>
<td>IV: “Felt indoors by many, outdoors by few”</td>
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<td>“pictures on the wall begin to rattle ... the window shutters and doors rattle”</td>
<td>IV: “rattling of dishes, windows, doors”</td>
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<td></td>
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<td>“sewing machine trying to get up motion”</td>
<td>V: “Moved small objects, furniture, the latter to slight extent”</td>
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<tr>
<td>14</td>
<td>PA</td>
<td>York</td>
<td><em>The York Dispatch</em></td>
<td>“awakened from their slumbers by the shaking of their beds”</td>
<td>IV: “Awakened some, especially light sleepers”</td>
<td>IV–V</td>
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<td></td>
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<td>“not a few nervous people were badly frightened”</td>
<td>IV: “Frightened those apprehensive from previous experience.”</td>
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<td>“windows rattled, buildings trembled, pictures and looking-glasses trembled on the walls”</td>
<td>IV: “rattling of dishes, windows, doors”</td>
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<td></td>
<td>“beds ... shook ... perceptibly”</td>
<td>V: “Buildings trembled throughout”</td>
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<td>V: “Moved ... furniture ... to slight extent.”</td>
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<td>State</td>
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<tr>
<td>17</td>
<td>RI</td>
<td>Providence</td>
<td><em>The Philadelphia Press</em></td>
<td>“the walls and floor of the room shook like a steamship at sea” “the statuary was so agitated … fear that they would tumble from their pedestals” “some people … were awakened from their slumber by the shaking of their beds” “houses were shaken like reeds”</td>
<td>V: “Buildings trembled throughout” V: “Moved small objects, furniture, the latter to slight extent” V: “Awakened most”</td>
<td>V</td>
</tr>
<tr>
<td>1</td>
<td>VA</td>
<td>Richmond</td>
<td><em>The Easton Express</em></td>
<td>“unnoticed”</td>
<td>I: “not felt”</td>
<td>I</td>
</tr>
<tr>
<td>32</td>
<td>VT</td>
<td>Burlington</td>
<td><em>New York Evening Post</em></td>
<td>“two slight but very distinct earthquake shocks were felt”</td>
<td>I: “not felt, or rarely” II: “felt indoors”</td>
<td>I–II</td>
</tr>
</tbody>
</table>
Figure 3.3
Answers for Figure 3.2

Likely location of earthquake

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Common Student Misconceptions

- Only scientists can contribute to research.
  Nonscientists can also contribute, as seen in these newspaper articles.

- Earthquakes only occur at plate boundaries.
  As evidenced in this puzzle, earthquakes are NOT restricted to plate boundaries.

- Earthquake magnitude and intensity are the same thing.
  Magnitude measures the energy released at the source of the earthquake and
  is determined from measurements on seismographs. Intensity measures the
  strength of shaking produced by the earthquake at a certain location. Thus
  intensity varies from place to place, while magnitude is a constant for a given
  earthquake. Traditionally, intensity is determined from observations of the
  shaking’s effects on people, human structures, and the natural environment.

- The larger the structure the more damage it will have in an earthquake.
  Buildings of all sizes were affected by the 1884 event. In modern cities, larger
  buildings are usually built with earthquake-resistant construction techniques,
  and so smaller buildings or older buildings may have more damage than
  large buildings.

Tough Questions (With Answers)

These are questions that your students may ask you, or that you could ask
them. Many additional questions with answers are on the U.S. Geological
Survey Earthquake FAQs page (see “Resources”).

Q. Who was Mercalli and when did he do his work?
A. Giuseppe Mercalli was an Italian volcanologist, who lived from 1850 to
   1915. His work built on an earlier 10-step intensity scale called the Rossi-
   Forel scale. Between 1884 and 1906 Mercalli modified his intensity scale
   several times to include additional kinds of observations. After Mercalli’s
   death, the scale was revised several more times by other seismologists until
   it reached its current form, called the “Modified” Mercalli Intensity Scale.

Q. Are these real newspaper articles?
A. The accounts about the earthquake are taken from real newspaper articles.
   Some portions have been omitted to make the reading passages shorter and
   to provide observations that are internally consistent.
**Earthquakes**

**Q:** Most articles say the earthquake was on August 10, but one article, published on August 11, refers to events of “this afternoon.” Which date is correct?

**A:** The earthquake was on August 10. Note that many of the articles have a “dateline” at the beginning of the article, stating the date and place of the origin of the article. In the following example, the dateline is in boldface type: “Columbia [PA], Aug. 10 [Special]—The citizens of Columbia were gently excited at 2:12 o’clock this afternoon by a most mysterious shock....” This article was published on August 11, but the newspaper editor kept the original dateline of August 10 on the article. Back in those days, news traveled much more slowly than it does today, and newspapers often published accounts of events that had happened a day or even several days earlier. In the 21st century, with the electronic transmission of news, we are accustomed to having access to news within hours or even minutes of an event.

**Q. Why do several newspaper articles have the same headline?**

**A.** Some of the original newspaper articles reported eyewitness accounts from several towns or cities. In such cases, we split up the newspaper articles so that each reading covered only one locality, but we kept the original newspaper headline and subheads for all the readings.

**Q. Why did some locations close together seem to experience effects of the earthquake differently?**

**A.** There are two possible reasons:

1. *Actual heterogeneities in the Earth.* The nature of the bedrock and soil influence the intensity felt in a particular locality. For example, buildings on soft squishy ground sway more than building on solid rock, even if both buildings are the same distance from the epicenter.

2. *Imperfections in the data.* The job of a newspaper reporter is to report what is newsworthy, and thus he or she might tend to write about the most extreme situation rather than the most typical situation. For example, the destruction of one chimney might make it into the paper even if many other chimneys remained intact and the fallen chimney was unstable to begin with. Seismologists studying historical earthquakes try to account for this aspect of the data by reading multiple accounts if possible and by paying careful attention to what was not said as well as what was said.

**Q. Why do we care about the MM Intensity Scale now that we can measure ground motion with seismographs and calculate magnitude with computers?**

**A.** The MM Intensity Scale is still used to create “shake maps” that show how
intense the ground shaking was around a specific earthquake and to predict how much shaking could occur in different locations around a possible future earthquake. This is useful because intensity varies with position. Shake maps for recent earthquakes can be viewed at the U.S. Geological Survey ShakeMap website (see “Resources”).

Q. Why would there be an earthquake in New York?
A. Earthquakes can occur anywhere as strain builds up inside the rocks of the Earth’s crust. There are zones where earthquakes are more frequent; we call these plate boundaries. There are also zones where earthquakes are less frequent; we call these plate interiors. Every place, however, is a candidate for an earthquake sooner or later.

Q. What was the magnitude of the earthquake in the puzzle? And how was this magnitude determined, since there were no seismographs at the time?
A. The U.S. Geological Survey has estimated the magnitude of the August 10, 1884 event as 5.5. The first step in estimating the magnitude of a historic but pre-instrumental earthquake is to assemble eyewitness accounts, assign MM intensity values, and map the intensity values (just as students did in this puzzle). Then, the spatial distribution of MM intensities is compared to the spatial distribution observed for more recent earthquakes, for which both magnitudes and intensities are known.

Q. Isn’t the Mercalli scale fairly subjective?
A. Yes, Mercalli intensity values derived from damage reports and eye-witness accounts have an element of judgment in them. But they are still valid observations of an Earth phenomenon. It is common in the history of science that the first methodical observations of a phenomenon are qualitative (subjective). If qualitative data seem to be revealing interesting patterns or trends, then scientists may try to develop instrumentation (e.g., seismographs) to gather quantitative data.

Q. How long do earthquakes “last”?
A. Some of the newspaper accounts of the 1884 earthquake contain eyewitness impressions of how long the shaking lasted, in the range of 5 to 20 seconds. How long earthquake shaking can be felt by a human observer depends on how long it took for the earthquake to actually break the crustal rock and on how the earthquake waves traveled through the Earth. The duration of felt-shaking varies from place to place, even from the same earthquake. More detail can be found at the U.S. Geological Survey Earthquake FAQs site (see “Resources”).
Extension Activities

- Write an imaginary newspaper article for your local newspaper, describing the effects from the 1884 earthquake.
- Make a plan for how your family could prepare for an intensity VII earthquake.
- Discuss other situations or examples of scientists turning processes or phenomena that people experience with their senses into numbers. Student responses could include feeling—temperature (thermometer); hearing—sound (decibels); taste—salinity (ppt); sight—color (frequency); hearing—pitch (frequency); sight, kinesthetics—size and

Figure 3.4
Isoseismal Map of 1884 Earthquake

1884 08 10 19:07 UTC Magnitude 5.5 Intensity VII

distance (units of length, area, volume); feeling of muscles as you pick something up—weight (density).

- Figure 3.4 is a map from a professional paper showing the intensity of the 1884 earthquake. Compare this map with the responses of your students.

- Explore the U.S. Geological Survey’s Did You Feel It? website, where students can report an earthquake (see “Resources”).

- Research the similarities and differences between earthquake magnitude and intensity.

- Research seismographs: When were they invented? When was the global network of seismographs established? Where are there seismographs? Where is there a seismograph near our school?

- Research other historical earthquakes—for example, the 1811–1812 New Madrid quakes (in Arkansas and Missouri), the 1906 San Francisco quake, or the 1886 Charleston earthquake. Compare and contrast these events and their human impact with the 1884 northeastern event.

- Research recent earthquake activity. Find a recent earthquake that seems to have been approximately as destructive as the 1884 event. What was its magnitude?

- Research your local building codes to see if there is any mention of earthquake standards.

- Discuss emergency preparedness, and compare what it was like in 1884 versus what it is like in the present day.

**Sources for Data Puzzle #3**

Historical newspaper accounts courtesy of seismologist John Armbruster, Lamont-Doherty Earth Observatory.

Modified Mercalli (MM) Intensity Scale

http://earthquakescanada.nrcan.gc.ca/gen_info/scales/mercalli_e.php


http://earthquake.usgs.gov/regionalsevents/1884_08_10_iso.php

**Resources**

**General Information**

“Turning Nature into Numbers”: Reflections by the author of Data Puzzle #3 (Kim Kastens) on the process by which Earth scientists quantify aspects of nature so
as to capture and record information in a form that is more permanent and more
standardized than the output of the human senses.

http://serc.carleton.edu/earthandmind/posts/realitytonumber.html

Resources About Historical Context

History of Journalism in the United States
www.writesite.org/html/tracing.html
Timeline of Science, Technology, and Invention, 1867–1899
http://inventors.about.com/od/timelines/a/Nineteenth_3.htm
U.S. Family Life, 1880–1920
www.americancenturies.mass.edu/turns/theme.jsp?x=3&y=1
U.S. Immigrants, 1880–1920
www.americancenturies.mass.edu/turns/theme.jsp?x=3&y=3

Resources About Earthquakes

How to Get a Seismograph for Your School.
Incorporated Research Institutions for Seismology, Interactive Map of Recent
Seismic Activity.
www.iris.edu/seismon
http://earthquake.usgs.gov/learn/faq?showAll=yes
U.S. Geological Survey. Earthquake Preparedness Program. (A site to guide students in
preparing for an earthquake.)
http://quake.wr.usgs.gov/prepare
http://libraryphoto.cr.usgs.gov/earth.htm
http://earthquake.usgs.gov/eqcenter/recenteqsww
http://earthquake.usgs.gov/earthquakes/shakemap
http://pubs.usgs.gov/gip/dynamic/slabs.html
Use the Accelerometer in Your Laptop as a Seismograph.
www.indiana.edu/~pepp/manuals/Scream3.pdf
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