TEACHING PLATE TECTONICS THEORY FROM A HISTORICAL PERSPECTIVE WITH REAL WORLD CONNECTIONS

by

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Abstract

Students generally learn science from textbooks that promote rote memorization of "final form"science. Learning science this way, however, tends to "turn off" students who then soon become bored. This thesis argues that students can gain an understanding of science that goes far beyond the memorization of facts, principles, and laws. How this can be accomplished is partly suggested by the findings of the history and philosophy of science. These disciplines present science as a dynamic enterprise that depends on imaginative thinking and cooperation between scientists. Moreover, research clearly suggests that there is a parallel between the historical development of scientific concepts and theories and how students learn science. This parallel provides clues as to how students can be shown to make real world connections to the science learned in the classroom.

Lessons were designed to follow the historical development of the Theory of Plate Tectonics and these lessons are described in the case study. Students modelled the scientific community by doing team research. The feedback from the students is given, showing an enthusiastic response to the unit and indicating an increased understanding of the scientific enterprise. This case study illustrates the importance for science teachers to understand the history and philosophy of science so that they can present a more dynamic view of science for their students, with real world connections.

TABLE OF CONTENTS

Chapter 1

Introduction

Students frequently lose interest in science because of the memorization of information that is often required on tests and exams. In my first class this year, when two students were given the textbook and they saw the Periodic Table on the inside back cover, they asked me "Do we have to memorize this?". Most students view the textbook as a list of facts that often makes no sense to them. Their way of coping with this incomprehension is to memorize the main points in order to reproduce them on tests. Do students gain a better understanding of scientific knowledge and the scientific process by having a teacher apply a dynamic historical pedagogy which goes beyond the memorization of "final form" science?

The word science has many different meanings to people, depending on their educational and personal view of the world. It is impossible to define science in a few words, and "even philosophers [of science] disagree on the details of a general definition of science" (Williams and Stinner, 1993, page 1). Matthews states that "Science is a peculiar way of thinking about, and investigating, the world; the procedures of science need to be learnt as much as its findings" (1994, page 28). Students, however, often see science as a difficult subject at school because it contains too many concepts.

Most teachers tend to rely on textbooks for teaching science (Denny,1983; Yore,1991; Yager, 1992; Stinner,1996) in an effort to cover the necessary material outlined in the curriculum, or in order to prepare students for the next level of schooling (Yager, 1992). Moreover, science textbooks generally promote the idea of "final form" science (Duschl, 1990), which often leads to rote memorization on the part of the students (Denny,1983; Linn, 1992; Stinner,1996). I have noticed in my own teaching experience that students often approach science with the idea that they will memorize the information given in the text because they feel it is too difficult to understand. According to a Newsweek article "Rx for Learning-There's no secret about how to teach science" (Begley et al, 1990):

> Educators take children who demand "Why?" and "How?", who poke and drop and squeeze like the most exuberant experimenters - and turn them off to science completely and irreversibly. As Nobel Prize-winning-physicist Leon Lederman of the University of Chicago puts it, schools take "naturally curious, natural scientists and manage to beat the curiosity right out of them." Along with the curiosity goes the interest. By third grade, half of all students don't like science; by eighth, 80 percent dislike it. (page 55)

The problem is that "most schools still teach science by lecture, textbook and memorization" ...even though "the best way for students to learn science is to have them do science"(page 55). Stinner (1992) discusses this problem in his article "Science Textbooks and Science Teaching: From Logic to Evidence". He states that science teaching "has been a textbook-centered affair in the English-speaking world since Whewell's textbooks appeared in the 1820's" and that "teachers seem to emphasize the finished product of 'scientific fact'". The students then become "trapped by the efficiency of memorizing the 'scientific fact'", and he further argues that students "see little connection between their ideas about the world and what they learn in science textbooks" (page 2). I will call these connections "real world connections".

Warren (1994, page 44) mentions a similar problem in medical education, namely the "need for memorization of too many facts, which has been a pitfall of many a curriculum", and the "passive obtaining of knowledge by the students from the popular staff person's handout of Xeroxes is to be deplored". Further, the article quotes Eisenberg as saying: "The fact is that medical education, far from being 'too scientific' suffers too much from memorizing evanescent 'facts' and too little on science as a way of framing questions and gathering evidence."(page 43) Warren suggests using a small group model for teaching medical students that will encourage the teamwork necessary in practice, and the use of "the rich resources of the library" (page 44). This teamwork model for the science community is used by Finkel (1992) in her classroom plans, and will be incorporated into my classroom practice and described later.

More than thirty years ago, Schwab commented that "our publics [must] become cognizant of science as a product of fluid inquiry, understand that it is a mode of investigation which rests on conceptual innovation, proceeds through uncertainty and failure, and eventuates in knowledge which is contingent, dubitable, and hard to come by" (1960, page 5). He complained that science was being taught as a rhetoric of conclusions rather than as a fluid scientific inquiry. Science textbooks tend not to show this "fluid inquiry" nature of science, so it becomes the responsibility of the teacher to ensure that the students see the developments or evidential reasoning in science that led to the information given in the textbook. It is especially important for students to see the development of the big theories in science like Newton's theory of universal gravitation or the theory of evolution, including and discussing many of the dead ends that are often encountered in the research (Watson and Crick's first model for DNA, for example).

Research suggests that teachers should present science in a historical context so students can develop an understanding of the concepts rather than seeing only the final product to memorize (Kauffman, 1989; Martin, Kass and Brouwer, 1990; Brackenridge, 1989; Stinner, 1993; Luhl, 1990; Benchmarks, 1993). Williams and Stinner (1993) state "there is a vigorous attempt on an international level to explore ways to introduce the history and the philosophy of science into science teaching" (page 48). A good example of a connection to the classroom would be having the students follow the historical development of the Theory of Plate Tectonics right up to the present day and in doing so gain an appreciation and understanding of how science works. Cavalli-Sforza, Weiner, and Lesgold (1994) argue that:

> discussion about historical and contemporary scientific controversies is a route towards students' understanding of scientific knowledge as interconnected, tentative, subject to revision, and established by the work of many fallible people engaged in practices that students themselves can attain to [sic] and embedded in a community. (page 595)

The classroom practice that will be described in Chapter 3 will be designed with this quote as a guide. I will describe an attempt to incorporate the historical development of one of the big scientific theories into classroom practice. A detailed account of the classroom events and responses from the students will be given, including samples of their work. The literature suggests using one of the big theories of science. I chose the Theory of Plate

Tectonics which is outlined in the Grade 9 Science Curriculum Guidelines in Manitoba. Essentially, the Theory of Plate Tectonics states that the Earth's crust is broken into many pieces called plates which are in constant motion, causing earthquakes, volcanic eruptions, and mountain building. The unit on Plate Tectonics is the second one that I teach, after starting with the Chemistry unit.

The textbook Science Dimensions 9 by Heath (1993) presents the Theory of Plate Tectonics partially from a historical perspective. Therefore, I decided to use the textbook as a reference along with other sources to guide the students through the development of the theory.

Duschl also advises that "an understanding of the growth of scientific knowledge is best obtained through an understanding of the development of scientific theories" (1990, page 7). The students need to see the accumulation of evidence in support of a given theory, and follow it from its beginnings rather than start with the finished product as most curricula do. He recommends that "Each school year, a minimum of one instructional unit - four to six weeks of instruction - should focus on the context of discovery. The best theme or context for such an instructional unit is one of the theories scientists embrace as a central component of their discipline."(page 11) He also challenges science teachers "to design science instruction that reinforces rather than ignores what we intuitively know will happen to scientific knowledge - that it will change." (page 5) Elizabeth Finkel answers this challenge with her article "Philosophy of Science in the High School Classroom: An Example" (1992), and she lists four implications that will be described in more detail later, namely:

1) it is possible to combine science content with the nature of science,
2) students are capable of asking questions about the nature of science,
3) the teacher's role does not have to be that of disseminator of information, and
4) students should be allowed to participate in knowledge construction. (page 307)

Nadeau and Desautels (1984) specifically advise teachers to set up their classrooms in such a way that they will reflect how science works today. They make the following four suggestions :

1) The students in the class constitute a microcosm with characteristics resembling those of the scientific community.

2) The students are divided into teams of two or three, representing research groups.

3) Decisions as to the validity of the models are made by the entire group.

4) The teacher acts as group leader and promotes discussion of the epistemological aspects of the exercise. (page 34-35)

I will try to follow these suggestions and use them as a guide in setting up the Plate Tectonics unit, while keeping a historical perspective. The students will become "research scientists" working in groups to examine the accumulating evidence that is available in support of the theory. One of the goals of this unit will be to impress students with the idea that scientific research is an ongoing process, and that the textbook reports are limited by the information available at the time of publication. Another important goal of the unit will be to make science more “real”, with connections to the real world, and to have the students model the science community by working in teams.

The following three ideas were important strands that followed through the lessons in the case study:

1) History - The lessons were arranged in a chronological fashion as much as possible, starting with early maps of the world and the geological age of the earth leading up to present day information.

2) Teams - The students were put into research teams for the unit and given research questions to investigate and report on to the rest of the class. They did some individual assignments also, working with other team members.

3) Real World Connections - The students in Manitoba experience very little earthquake or volcanic activity, so efforts will be made to make the unit more "real" for them. Examples include a trip to the University of Manitoba to see the seismic vault, and the use of recent newspaper clippings and up-to-date Internet data.

The limitations of the study are set by the school where I teach which is located in suburban Winnipeg near the University of Manitoba. I teach 3 classes of Senior 1 (Grade 9) students in a large junior high school of about 600 students. The students are mainly from middle class families with a keen interest in doing well at school and going on to post-secondary education.

The classroom activity of plotting the recent earthquake data requires Internet access. The information can be found by the teacher on one computer with a modem and then copied for the students, as was done in this case study. If a computer lab is equipped with modems and Internet access, then the students can look for their own lists of earthqake data to plot. The U of M field trip to the Wallace building to see the seismometer was worthwhile and may be difficult for other teachers to arrange if they are not in the city.

The significance of the study for the students will be partially revealed in the answers and responses to the survey questions given out at the end of the unit and documented in the Chapter on Evaluation. The significance to me as a teacher of science has been the profound shift that occurred in how I now approach my classes. This profound shift will be further discussed in the last chapter. The significance to teachers, on the other hand, will be in the reading of this thesis and perhaps considering an application similar to mine in the classroom.

Chapter 2
Literature Review

There have been many books and articles written about the history and philosophy of science, but little has been written about ways to include the history and philosophy of science in classroom practice. The following references are examples of the literature available on the subject. The most representative writings that covered both the philosophical and practical aspects of science education used in this thesis are those of Kuhn, Nadeau and Desautels, Stinner, Duschl, and Finkel.

Thomas S. Kuhn, in his influential book The Structure of Scientific Revolutions (1962), proposes a radically new understanding of how scientific ideas evolve. The article by Robert Nadeau and Jacques Desautels (1984), made available by the Science Council of Canada, discusses Kuhn's impact on our understanding of the nature of science and gives several examples of appropriate classroom activities that relate to the ideas of Kuhn. More recently, Duschl contributed significantly to science education in his Restructuring Science Education (1990) about *The Importance of Theories and Their Development*. He argues that the historical development of scientific theories should be taught, rather than just the finished scientific laws or models resulting from years of scientific research. Duschl discusses the learning of four scientific theories concerning Matter (Chemistry), Motion (Physics), History of Life on Earth (Life Science) and Moving Plates (Earth Science). His discussion on the development of the Moving Plates Theory is relevant to what I later planned for the students in my classroom practice.

Locally, Dennis A. Hodgins wrote a Master's thesis, under the supervision of Art Stinner at the University of Manitoba (1992), in which he argued that the evidence given in Science textbooks is generally insufficient for the students to follow the historical development of scientific theories. My work should be seen as being a continuation of his research, using practical applications. Finkel describes her incorporation of the challenge from Duschl into the classroom during a summer school session in science. The last few articles cited in this literature review will have examples or suggestions for actual classroom activities.

Thomas Kuhn presents a picture of science, consisting of three stages, namely “preparadigm”, “normal” science and “revolutionary” science. “Preparadigm” science refers the intuitive ideas that precede the development of a large theory, such as the idea put forth by Francis Bacon in 1620 that it looked as if South America and Africa fit together like puzzle pieces and may have been connected at one time. “Normal” science includes all of the information gathered at any given point in time by scientists, and believed to be correct, such as the Theory of Plate Tectonics as it is known today. Moreover, the information would promote a certain way of looking at science that can be further identified as a particular paradigm. Millar (1989) states that if “Kuhn is correct, scientific creativity comes, not from encouraging learners (especially in the early stages) to think divergently, but from steeping them in the current paradigms. Learning science then is learning ‘normal science’” (page 591). When fundamental problems and anomalies that do not fit into “normal science” persist and accumulate, then a “revolution”, or a paradigm-shift, occurs and a new theory may eventually appear. According to Stinner and Williams in Notes for a Science Curriculum Reform : "Science educators are now promoting Kuhn's picture of science - pre-paradigm, normal science, revolutionary science - a valid, personal, imaginative and dynamic science." (1995, page 8) Chapter 3 will describe an attempt to incorporate the pedagogical applications of "normal"science and "revolutionary"science into the classroom. The students will first be exposed to "pre-paradigm"science with the continental drift ideas of Alfred Wegener being rejected for the fixed earth model of the early 1900's. The "normal"science phase then will comprise the entire Theory of Plate Tectonics as it is understood today. The "revolutionary"science phase of Plate Tectonics Theory is the paradigm shift that occurred following World War II when overwhelming evidence was obtained from new technologies to support the continental drift idea that was first proposed by Alfred Wegener in the early 1900's.

Kuhn identifies two aspects of scientific history which he calls internal and external. He calls internal history the content of the discipline, and describes external history as the study of the activities of scientists as a social group in the context of a larger culture. Kuhn seems to recommend that educators should include the history of science in their lessons, but in fact does not give any ideas on how this is to be done. Kuhn argues that science textbooks "systematically disguise" the history of science (page 136). Arguing further along Kuhn's lines, one could say the students may miss the sense of how scientific theories are the product of a historical setting, and may not gain an appreciation for the struggle involved in the establishing of these theories. If students are to understand the workings of science, they need to be exposed to the revolutionary changes in scientific history, as well as the "normal" science that follows such a revolution.

It is noteworthy that on one hand, Kuhn praises textbook-centered teaching because it has been successful in producing scientists steeped in the "normal" paradigm, but on the other hand he condemns it as "not well designed to produce the man who will easily discover a fresh approach." (page 166)

The widely used discussion paper "Epistemology and The Teaching of Science" by Nadeau & Desautels begins with a reference to Kuhn and his picture of the scientific enterprise. The authors describe a development towards a revitalization of science teaching by having students develop their own scientific models to explain phenomena in order to become more aware of the nature of scientific activity. Nadeau and Desautels state their hypothesis this way:

> By giving insufficient thought and attention to the nature of scientific knowledge and the conditions under which it has been developed, science teaching reinforces beliefs and myths that are inherent in scientistic ideology. (page 8)

Nadeau and Desautels attempt to answer two questions in the discussion paper:

> The first question we will deal with is that of the nature of the beliefs inherent in this ideology. We must also ask how we can interest high school students in the epistemological aspects of science and encourage them to examine their own thinking. (page 8)

Nadeau and Desautels then go on to describe a map making activity that I will use to introduce this unit to my students. The questions that they recommend using with the map activity will be found later in Chapter 3.

In his book Restructuring Science Education (1990), Duschl discusses many interesting ideas for the classroom science teacher. What is significant for this thesis is his emphasis on the development of theories in science, as indicated in the subtitle of the book *The Importance of Theories and Their Development*. He stresses the importance of what the history and philosophy of science have to say, and the need for classroom teachers to avoid teaching what he calls "final form" science (often also referred to as "products of science"). The word "restructuring" is used in reference to scientific theories and scientific learning. He draws parallels between the development of science knowledge over time and how science concepts are learned. Research strongly suggests that students' conceptual development is similar to the historical development of scientific theories. Duschl agrees with Kuhn that it is especially difficult to impart a sense of history to science students, because they already "know the right answers" (Kuhn, page 62).

Duschl then goes on to discuss two components of science called the "context of justification" and the "context of discovery", ideas he has borrowed from the earlier writings of the philosopher of science Hans Reichenbach (Salmon et al, 1992, page 143). The "context of justification" involves the gathering of evidence and establishing the validity of that evidence. The "context of discovery" involves the historical context, the origin and evolution of ideas, much along the lines discussed by Kuhn. Both contexts can be identified in the Theory of Plate Tectonics in the events following World War II, that resulted in a significant shift from the ideas of continental drift to the presently accepted Theory of Plate Tectonics.

Continental drift was based on the notion that the continents were moving (drifting) as separate land masses (boats) floating in the ocean. The new technology developed during World War II produced astonishing new evidence for plate tectonics after the war. Newer rocks in the middle of the Atlantic were getting progressively older towards the continents, for example, indicating that the sea floor was somehow involved, not excluded, from the process of moving continents. It was found that the Earth's crust is broken up into many pieces called plates. Most of the plates include a continent which gives the plate its name, such as the North American Plate, but the largest plate is the Pacific Plate which is almost entirely under water. Alfred Wegener only saw evidence of the continents moving, and missed the Pacific Plate because the technology was unavailable to him at the time. The term continental drift, therefore, no longer adequately describes the process we now call plate tectonics.

Two types of technology developed during World War II to track submarines (magnetometers and sonar) were used after the war to investigate the sea floor. Scientists who were expecting to find a fairly level and thick layer of sediment on the sea floor were surprised to find mountain ranges circling the globe instead. The magnetometers found magnetic stripes on the sea floor that could not be explained using the fixed earth model that was generally accepted at the time. This new information indicated to scientists that the sea floor was definitely involved in the crustal movement taking place on Earth, and is an example of the "context of discovery". The "context of justification" then would involve taking a closer look at the evidence and understanding how the evidence supports the present Theory of Plate

Tectonics.

Duschl goes on to describe the commonly held notion that science has two faces called products (concept instruction) and processes (investigative procedures). He argues, however, that what is missing from most science lessons is "the chain of reasoning that has brought us to this point of understanding" (page 10). He says:

> As the processes of science used in gathering and evaluating scientific evidence become more sophisticated, the need to establish a curriculum that examines the chain of reasoning that has brought us to this point gains in importance. Each school year, a minimum of one instructional unit - four to six weeks of instruction - should focus on the context of discovery. The best theme or context for such an instructional unit is one of the theories scientists embrace as a central component of their discipline. (page 11)

Duschl challenges science teachers "to design science instruction that reinforces rather than ignores what we intuitively know will happen to scientific knowledge - that it will change" (page 5). Elizabeth Finkel uses this quote as the basis for her classroom practice and I would like to meet this challenge in my classroom. The unit on Plate Tectonics Theory ends with the students reading recently published information, taken mainly from Earth magazine. One example is found in the May 1993 Earth magazine which contains an article called CAT Scanning the Earth By Jim Dawson which describes evidence of huge areas of hot and cold rock being found as deep as 450 miles underground. This changes slightly the model of the earth's structure that most books contain, and supports the notion of convection currents in the mantle causing the movement of the plates.

Dennis Hodgins, while a graduate student working with Art Stinner at the University of Manitoba, recently looked at the notion of evidence in science textbooks in his thesis "The Notion of Evidence in Science Textbooks" (1992). He argues that textbooks usually present the products of science (Duschl's "final form science") and give the students insufficient evidence that led to the products. He recommends that science textbooks report how and why science changes over time. I will interpret his recommendation to mean that good science teaching includes the history of science, or the historical development of scientific ideas. Hodgins further argues that students should be given the opportunity to evaluate the evidence that supports any given theory so that they may understand "the scientific enterprise" better (page 106). His specific recommendations for teachers include becoming familiar with the history and philosophy of science in order to better present the curriculum to the students. He also recommends that resource materials such as Scientific American and documentaries such as The Double Helix be used in classroom instruction (page 107). Following Hodgins' suggestions, I used Earth magazines and the Imax film The Blue Planet in the lessons in the classroom. In addition, the students used many other sources of evidence such as the CD-ROM Plate Tectonics. The role of the textbook changed from the only source to one of many. The text contained a good historical account of the development of the Theory of Plate Tectonics, but we delved even further into its history using other sources.

Nussbaum compares the historical development of scientific ideas to science students' concept development in his article "Classroom Conceptual Change: Philosophical Perspectives" (1989). He tries to "show the importance of this analogy on a higher level - that of understanding the process of conceptual change in general among students" (page 530) . Nussbaum discusses the alternative philosophical frameworks for studying the history of science, and summarizes them on the following chart. This chart is very helpful and clearly shows the relationship between the main philosophies of science and suggests that the history of science plays a central role in clarifying these relationships.

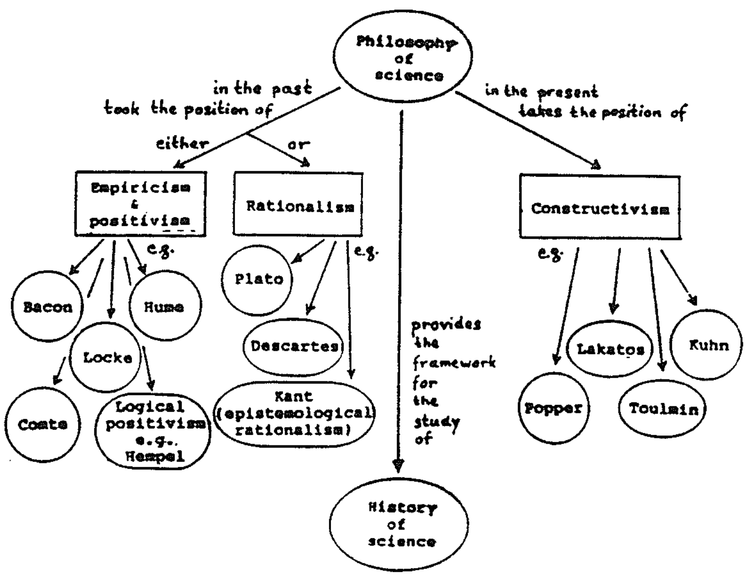

Figure 1. Alternative philosophical frameworks for studying the history of science.

(page 531)

Nussbaum states that, "constructivism is today's generally accepted philosophical stream" for understanding conceptual change among students. Simply put, constructivism compares the conceptual changes among students, to what happens to scientists during their conceptual change. Nussbaum explains that "the Constructivist approach in teaching require(s) that both the teacher and the curricular activities help the students to actively construct their own meaning of the material under study" (page 537). He then continues:

> My educational experience suggests that if a problem regarding a natural phenomenon is raised in a stimulating manner, and if it is then followed by a discussion of students' beliefs and by open debate, then even young children or those considered educationally disadvantaged would demonstrate genuine intellectual enthusiasm and good reasoning. Under peer pressure, the student's attempts to adapt the formulation of their beliefs could lay the basis for conceptual change. (page 537)

Derek Hodson explains the shift away from teaching science as a "body of established knowledge toward science as a human activity, with increasing emphasis on experience of the processes and procedures of science" , in his widely cited article "Toward a Philosophically More Valid Science Curriculum"(1989, page 19). Hodson states that actual classroom practice tends to be more teacher directed than the activity-based curriculum would describe. He argues that "discovery"- based learning without any prior conceptual framework is largely ineffective. Following Kuhn, he describes science as "pre-paradigm", "normal", and "revolutionary", and he looks at ways to pedagogically apply Kuhn's ideas to science programs. The role of the scientific theory in the classroom is then discussed, along with the functioning of the scientific community.

Michael Matthews presents a similar argument in his book Science Teaching - The Role of History and Philosophy of Science (1994). He states that an increased role of the history and philosophy of science in science teaching should lead to a better understanding of the cultural, social and philosophical dimensions of science and science subject matter being taught and learned better. He recommends that the organization of the curriculum be guided by the history of science. He looks at the history of science teaching and the failure of reforms during the 1960's, 1970's and 1980's to have the expected effects. One reason that Matthews gives for the failure of the reforms is that "Science was taught as a rhetoric of conclusions, to use Schwab's term, and the fluid nature of scientific inquiry and conclusions was seldom apparent." (page 19) Matthews then recommends inclusion of the history and philosophy of science in the classroom, and gives a detailed account of the study of the motion of the pendulum as an example. He claims that the pendulum case provides "a wonderful opportunity to learn about science at the same time that one is learning the subject matter of science" (page 135). He concludes by stating:

> Finally, it is clear that "contextual" science, as suggested here, is not a cop-out from serious, or hard science, but the reverse. To understand what happened in the history of science takes effort. Further, it is appealing to students. A frequent refrain from intelligent students who do not go on with study in the sciences is that "science is too boring, we only work out problems." The history of human efforts to understand pendulum motion is far from boring: it is peopled by great minds, their debates are engaging, and the history provides a story line on which to hang the complex theoretical development of science. As well as improved understanding of science, students taught in a contextual way can better understand the nature of science, and have something to remember long after the equation for the period of a pendulum is forgotten. (page 135)

My students studied the Theory of Plate Tectonics in a "contextual" way. Some of the students found it difficult to follow the development in a historical fashion because they had already studied continental drift in Grade

7 and thought that they knew the "right answers", as Kuhn correctly pointed out (1962, page 76).

Matthews goes on to identify three domains for people's ideas and ways of thinking:

1) their immediate sensory experience of the world,

2) their participation in everyday life with its conversations, newspapers, television etc., and

3) their formal instruction which takes part mostly in school. (page 28)

I will incorporate newspaper articles and television programs into the classroom lessons (what I call real world connections) in order to alleviate the "constant problem for science education ...to keep these domains in some sort of harmony (page 28).

Elizabeth Finkel's article "Philosophy of Science in the High School Classroom: an Example" (1992) is especially relevant and important for this thesis. The article begins with Duschl's challenge to science teachers: "to design science instruction that reinforces rather than ignores what we intuitively know will happen to scientific knowledge - that it will change" (Duschl, 1990, page 5). She set up a curriculum for a group of students during a summer school session titled "The Blind Men and the Elephant: Changing Perspectives in Scientific Thought". She designed four sections within the curriculum, one of them dealing with Plate Tectonics. Finkel discusses the importance of problem-posing in science and the need for students to be involved with the probing and persuasion of peers. The readings that were assigned to the students included "The Validation of Continental Drift" by Stephen Jay Gould, and "Causes of Earthquakes" by

Duschl. Finkel designed the specific activities in order to emphasize "the process of discovery or creation of scientific knowledge" (page 306). She lists four implications from her experience that are relevant to my study:

> 1) it is possible to combine important science content with discussions of the nature of science in such a way that students make meaningful connections between the accepted scientific models of today and their development,
>
> 2) students in high school are capable of asking sophisticated questions about the nature of science and are willing and able to struggle with those questions verbally and in writing,
>
> 3) the role of the teacher does not need to be that of disseminator of information, rather it is important to give students opportunities to construct models and evaluate theories themselves, with teachers available as coaches and guides, and
>
> 4) in addition to giving students the opportunity to participate in knowledge construction, it is important to provide them with an outlet for reflecting on their ideas; class discussions are helpful, journals also serve a vital role, providing a private place for students to try out some new ideas. (page 307)

The unit that I will design on Plate Tectonics for my students will be an attempt to incorporate the four implications made above. The students will research the answers to scientific questions in groups, and use the group research to write reports on their findings for the class. They will discuss the report within their groups before presenting to the class, and then answer questions from the class after the oral presentations.

Gil-Perez and Carrascosa-Alis advocate an adoption of the constructivist approach to science by "linking science learning to the way of doing science" (page 301) in "Bringing Pupils' Learning Closer to a Scientific Construction of Knowledge: A Permanent Feature in Innovations in Science Teaching" (1994). They state that the "learning by discovery" paradigm (page 301) and the "reception learning paradigm" or ("teaching by verbal transmission") (page 303) have both been failures. Gil-Perez and Carrascosa-Alis propose a model of science learning using research activities. The model includes "organizing the students in small groups to carry out the activities and making possible the exchange of information between groups" (page 311). I will use this model in my classroom, and divide the classes into small groups for the unit on Plate Tectonics. Gil-Perez and Carrascosa-Alis clarify their model by stating that "the metaphor that guides our teaching strategies conceives pupils as novice researchers and teachers as experts who can orientate the pupils' work" (page 310)... and the "metaphor of students as 'novice researchers'... and the teacher and texts as 'scientific community'" (page 309).

The students in my classes will be given several research questions that require sources in addition to the text "Science Dimensions" for complete answers. Gil-Perez and Carrascosa-Alis argue that "researchers can dedicate more than 50% of their time reading and a lot of time also to verbal presentations and debates" (page 309). My students will use class time for their research reading and also verbal presentations. Each group will be required to do a written report that is handed in to the teacher before the presentation day. The teacher will make photocopies of each report to hand out to all the members of the class to keep in their notes. The photocopied written report makes it possible for the students to focus on the oral discussion after the report because note-taking will be unnecessary.

Gil-Perez and Carrascosa also believe that there is a "certain parallel between the historical evolution of a science in its first steps and the formation of children's intuitive conceptions" (page 305). The questions for the students to research will be arranged in a chronological sequence in an attempt to take them through the historical development of Plate Tectonics. I hope that the students in my classes will learn how the scientific theory developed and avoid the situation where "science learning is usually centered on declarative knowledge (knowing "what") and forget the procedural type (knowing "how")" (page 306).

Stinner has written extensively about classroom applications of the history and philosophy of science. However, he is especially concerned about textbook-centered teaching leading students to become "trapped by the efficiency of memorizing the 'scientific fact' and the efficacy of applying the 'formulas' in solving exercise problems" (1992, page 2). Stinner and Williams (1994) recommend that the "text-teacher relationship change and that teachers plan and execute activities aimed at conceptual development and modification" (page 8). They also believe that in textbooks the "emphasis should be on the 'Big Ideas of Science'...[and how they] came about, what evidence is there for them, and what are their implications for us now and in the future?" (page 9)

In order to move away from rote memorization of scientific facts, Stinner advises that teachers give the students "a historical sense of how scientific theories are the product of a historical setting and ... the struggle involved in the establishing of new theories" (1989, page 595). He stresses the importance of the historically based science story in the article "Conceptual Change, History, and Science Stories" (1993)written with Harvey Williams. Stinner goes on to present a plan for contextual teaching using the LCP (Large Context Problem) as a vehicle for science teachers to include the historical context of science in the classroom. He has designed several LCPs for use in high school physics courses, including "Physics and the Bionic Man" and "Physics on the Moon". In these LCPs, Stinner gives the students an opportunity to use their physics knowledge in a unique application which the students tend to find more interesting and motivating than textbook exercises or problems. For my work, one attempt to integrate the LCP idea into the classroom would be the map activity in which the students plot the Internet earthquake data for November of 1994. Stinner has commented that the entire Plate Tectonics unit could be construed as one huge LCP (private communication).

Marcia Linn has presented suggestions for alternate methods of teaching science in the article "Science Education Reform ; Building on the Research Base"(1992). She recognizes that most students tend to memorize scientific information rather than try to understand it (pages 823, 828, and 835). Linn states that "instruction is more effective when students are helped to construct ideas by themselves" (page 823). She identifies two views of science, one she calls "static" and the other "dynamic". The "static" view of science is promoted by traditional science courses that "convince students that science is a collection of facts to be memorized rather than a set of principles that are warranted by evidence....and that everything in the science book will always be true." (page 824) In contrast, a "dynamic" view of science includes the ideas that "science proceeds by fits and starts, that scientists seek to explain diverse phenomena with broad principles, that conclusions are based on evidence, and that the way to learn science is to make an effort to understand complicated ideas."(page 825) Linn suggests that students should construct parallels between their own struggles to integrate diverse observations and ideas with the activities of research scientists, which should help them to move towards a more "dynamic" view of science, and a better understanding of the role of evidence in scientific advances. She argues that students become empowered to participate when they understand the spirit of scientific investigation. The students feel that the science that they learn in school is not connected to the world outside the classroom, or the real world, and teachers need to be sure to make those connections possible.

The last research article that is relevant to my thesis is called "Authentic Science: A Diversity of Meanings" written by Martin, Kass, and Brouwer (1990). It is relevant because many other ways of looking at science, besides "final form" science, are given, including historical science. The authors discuss the "scientisic" attitudes of teachers and students (page 543) put forth in the article by Nadeau and Desautels and Kuhn's central idea of paradigm development (page 544). Nine aspects of what would comprise "authentic" science are listed, including:

1. **Methodologic fidelity** - The process movement of the past decade has tried to identify a scientific method by which to design instruction, but it is almost impossible to agree on one authentic method of science, without missing the "rich diversity of approaches that have been used. (page 542),

2.Epistemological considerations - The three philosophies of science to be considered are:A) Presuppositionalists i.e. Polanyi and Kuhn discuss the dominant role that personal belief and commitment play in science,
B) Falsificationists i.e. Popper believes that science progresses by hypothetical- deductive reasoning and not by inductive reasoning, and only by falsification of theories can we progress, and
C) Hedonists i.e. Feyerabend advocates encouragement of the proliferation of ideas or a " follow your own inclinations". (page 543-545),

3.Personal science - The scientist's own view of science is not as objective as we think it is, and Polanyi's thesis that " a great deal of what constitutes science, its methods, judgements, passions can only be acquired through personal involvement of the student with that science". (page 545),

4.Private science - This is the science research done before results are published, including the blind alleys and false starts in research that we usually do not hear about. (page 546),

5.Public science - The science that is interpreted for the public through the media, i.e. Suzuki's books and documentaries, and science magazines such as Earth, New Scientist, and Scientific American. (page 546),

6.Popper's Third World of objective knowledge - This refers to the ideas, arguments, theories, etc. that are found in scientific journals and books, or "text", and the idea that oral societies cannot have science. (page 546),

7.Historical science - Science is part of our cultural heritage and historical insights can help reveal the tentative nature of science. (page 548),

8.Societal science (science, technology, and society) - Science is part of a societal matrix and is affected by the values of society.(page 549), and

9.Technological science - Science and technology have a profound effect on humanity, and most science is interwoven with technology (eg. the Hubble Telescope science data). (page 549)

Martin, et. al. state that "science teachers are being challenged to present science as it 'really is' rather than promote a mythic, textbook science."(page 541) They also write that Report 36 of the Science Council of Canada suggests that "a more authentic portrayal of science would include the history of science, science, and technology and reflection on the nature of scientific knowledge." (page 542) The student's ideas and perceptions of the world are crucial in science education, and the article recommends that we avoid the "'intellectual dependence' that characterizes the relationship between many students and teachers" (page 551).

Chapter 3
Case Study

A) Introduction and Setup of Research Teams - Classroom Map

At the beginning of the Plate Tectonics unit the students were told that we would be trying something that was different from the previous unit. We had just finished the Chemistry unit of the curriculum. They were told that we would be modelling the scientific community in the classroom by forming research groups and collecting evidence for the scientific theory of Plate Tectonics. The students were divided into groups of three or four according to their marks in the Chemistry unit. Each group contained a student with high, medium, and low marks in an effort to make the groupings heterogeneous, so that one particular group did not contain all strong or weak students. They were told that we would be modelling the scientific community with our groups being research teams. The teacher would be in a position of research leader, and each group would also have an assigned leader. The students were also told that they would be looking for the answers to questions that would be given out in chronological or historical sequence.

A handout that outlined the topics to be investigated (Appendix a), and an article from the Winnipeg Free Press (Sat., Nov. 19, 1994) that described an international scientific research team in action was given to each student. The article reported the creation of atoms of Element No. 110 by an international team of scientists from Germany, Russia, Slovakia, and Finland. This article connected to our previous unit (chemistry) and was a timely example of the idea that scientific research is ongoing. The students could see that the Periodic Table in their textbooks Science Dimensions 9 was not in its "final form", since it only contained elements up to No. 103. An even better example to give the students would be the fact that scientists are finding that the inert gases may actually enter into chemical reactions, and not be completely unreactive as expected. The textbook references for each topic were listed on the handout, but these were to be used only as basic references with at least two other sources being found in the library. The students would research their topics during several classes in the library and would write a report to share with the class. Copies of each report would be made for each student in the class so it was necessary to hand them in before presentation day. Each student was required to take a turn at doing the oral presentation for the team. Every member of each team would receive the same mark for the written and oral reports.

Following the discussion of the handout, the newly formed research teams were given their first assignment : to make a map of the classroom (taken from the Science Council of Canada document, Nadeau and Desautels, April 1984). They were given no other instructions except that it should be done in one 40 minute class and would NOT be marked. There were two purposes for giving this assignment to the students. The first was to get the teams to work together for the first time and become familiar with each other. The second was to make them aware of the limitations of making their maps accurately portray the reality of the classroom, and thus the limitations of scientific models.

The students began their maps with enthusiasm, and I noticed that some of the weaker students were actually more involved than usual and were directing the others in the team on how the map should be done. This enthusiastic response from the students was predicted by Nussbaum (1989) in his article called "Classroom Conceptual Change: Philosophical Perspectives" when he writes "those [students] considered educationally disadvantaged would demonstrate genuine intellectual enthusiasm and good reasoning" if given a problem in a stimulating manner (page 537). One of the weaker students asked if two maps would be okay because her team wanted to do them from different perspectives. I saw her later explaining what a bird's eye view was to the rest of her group. Another weaker student asked to go to the art room to get a large piece of paper because her team did not think they could do an adequate map on loose leaf paper. She also thought that one class was not enough time and asked for more. These two responses from students who had not previously shown much interest in science class were encouraging to me, since they were now becoming more interested and involved in their own learning.

The students presented their maps (Appendix b,c and d) to the rest of the class and considered the questions from the article by Nadeau and Desautels:

1) What criteria were used to select the elements represented on the map?
2) Is there a similarity between these elements and those shown on the map?
3) Does the map reflect the complexity of the reality that it is intended to represent? (It may then be suggested that a further map be drawn for a part of the area, leading to the question of how many maps would be needed to exhaust the reality.)
4) Does the map reflect the dynamics (changing aspects) of the reality it is intended to represent? (1984, page 20)

A discussion followed about whether it was even possible to represent the dynamics of the room on a map. Most of the maps showed the desks and counters that were in the room, and some had the safety equipment marked. Sinks, gas outlets, and doors were shown on some of the maps, but not all. It became apparent that the maps had similarities (the desks) and differences (chairs only on some). My name was on some of the maps, and I guess to some of the students I was part of the room. Each group had determined different priorities for what should go onto the map, just like scientists deciding what should be shown on a model. We then discussed the limitations of scientific models, like the model of the atom which we had just studied, and the model of the structure of the Earth which they were about to look at.

B) Continental Drift - Research and Presentations

I composed six questions that would cover the main points of this part of the curriculum. In the previous year, I had worked through all of the "Check It Out" questions, end of Chapter questions, Inquiries, and made notes on all of Chapters 5 and 6 of Science Dimensions 9 for the Teacher's Resource Package material for D.C. Heath Publishers. This is like a teacher's manual to accompany the recently published Science Dimensions 9 textbook. I felt liberated by the publication of this text since in the years before I had taught without a text and felt great responsibility to provide the students with the basic information described by the curriculum guide in photocopied handouts and notes. Teaching without a textbook made the students totally dependent on the teacher to "give" them the content that was required by the curriculum. The textbook was not expected to be the ultimate source of information, but removed the idea of the curriculum being in the teacher's head and needing to get into the students' heads. Now the students had the basic information described by the curriculum in the textbook and I was excited about providing supplemental material for them to use in their research. The library was well stocked with books , CD-ROM disks, and a laser disk Planet Earth - The Force Within. The laser disk contains a 20 minute video, several 1-2 minute video clips, and 100's of slides or stills on the subject that are all bar coded by topic and could be used as part of a presentation to the class.

The six questions related to continental drift were written on separate pieces of paper and put into a small box. Each research team picked one of the papers out at random and copied down the question to be researched.

Since the classes each had 8 groups, two of the questions were picked twice. This developed into a problem which will be discussed later. The questions were:

1.**Maps** - Find as many maps of the world as you can from the 1400's, 1500's, 1600's, 1700's, and 1800's. Compare these maps to today's map of the world and discuss Bacon's observations of the new maps.

2.**History** - Discuss the significance of the information from the following three people on the idea of continental drift : Lyell, Hutton, Wegener. Explain uniformitarianism.

3.**Time line** - Make a time line for the Earth with paper or yarn, with a scale to represent millions of years. Mark on the line Pangaea, Jurassic Period, age of plants, dinosaurs, humans and any other dates that you think are significant. How do we know the age of the Earth?

4.**Climate** - Find evidence of tropical climates that can be found in colder areas of the world today, and find evidence of glaciers where the climate is now tropical, that support the idea that the continents must have moved.

5.**Fossils** - Find fossil evidence that supports continental drift eg) Lystrosaurus.

6.**Pangaea** - Describe the formation and breakup of Pangaea.

Note: The handout (Appendix a) listed the pages in the science textbook Science Dimensions 9 where the students would find some information relevant to the six questions. The students were reminded that some information could be found on pages 174-185 of the text, but other references would be required to answer their questions completely. For example, the Question #1 on maps has only one map in the textbook on page 175, so the students would have to look elsewhere to find more old maps of the world. The date for the map in the text is not given, so the students would also have to compare it to others to guess when it was made.

The students were told that they should collect enough information on their questions to fill a one page typed report. They were also told that it was required to have three different references at the end of their report (with the librarian providing the format for the referencing). It was recommended that each report include diagrams or maps as examples of their research findings, with the source of the diagram being cited. The students were scheduled into the library for the next five classes to do their research where they used books as well as the CD-ROM disks Encarta, Grolier's Encyclopedia, and Plate Tectonics, and the laser disk called Planet Earth - The Force Within.

The group that was working on question **2. History** was told that there was actual film footage on the laser disk showing Alfred Wegener walking on the ice over Greenland and showing the horses pulling his supplies. They watched it with great interest and used it in their presentation to the class. This little bit of film seemed to make the person called Wegener more "real" to them since their eyes appeared to light up when they watched it.

The written reports (Appendix e) and oral presentations were all well done, with the students asking each other questions at the end of each one. Several of the written reports used the word ***prove***:

- "For Wegener, his research on fossils conclusively ***proved*** that a supercontinent existed..."
- "All of these animals and plants are ***proof*** that a supercontinent called Pangaea existed..."
- "The only way you can ***prove*** the theory of continental drift by maps is..."
- "The fossils could ***prove*** that the continents were linked..."

This use of the word prove led to a discussion about whether it was possible to prove a scientific theory or merely support it. Indeed, this is a major argument in the philosophy of science, that theories are tentative, and evidence only is confirmation or support, NOT PROOF for the theory. I told the students that they would lose a mark on their report if it contained the word "prove" or "proof", and explained that the word "support" was a better word to use. They developed eagle eyes and were quick to point out the word if it appeared in any of the later reports.

We discussed the evidence Wegener put forth in support of continental drift, and the fact that Wegener's ideas were not widely accepted because of the lack of a plausible mechanism to explain how such huge land masses could possibly move. I hoped that exposing these students to the ideas of the early 1900's would steep them in the "normal" science, or paradigm, of that time - the generally accepted fixed earth model - and they would better understand the "revolutionary" science of the 1950's with the wide acceptance of the notion of Plate Tectonics.

The two groups in each class that presented the report for the second time, however, (only 6 questions and 8 groups) were at a disadvantage because the students were not as attentive or interested the second time around. I decided that it would be preferable to have 8 different questions so there would not be any repetition. The two additional questions could be:

7. **Rocks** - Find and explain rock or geological evidence that supports continental drift.

8. **Wegener** - Describe Wegener's idea of continental drift and why it was not generally accepted.

I also noticed that some of the students got so absorbed in one particular question, that they lost the connection to the overall topic of continental drift, so I decided that in future use it would be a good idea to have the students put **1. Continental Drift - Maps**, and so on for titles, and add at the end of each question: "How does your topic support, or help to explain continental drift?"

One student asked if she could have a map of the world to hand out and have the students cut up to form the landmass called Pangaea. I was thrilled to hear this idea come from a student, especially since it was an activity that I had assigned to the students in previous years. This particular student was not usually motivated or involved in classroom activities but when she approached me about it in the hallway between other classes, it indicated to me that she was becoming more involved in her own learning. She was given credit for the next activity in her class and in the other two classes it remained a teacher generated idea. Interestingly, this student involvement was predicted by Nussbaum (1989).

C) World map - Jigsaw Puzzle to Pangaea

The students were given a map of the World (Appendix f) and a map of Pangaea (Appendix g) from the Black Line Masters at the end of the Teacher's Resource Package that accompanies Heath's Science Dimensions 9 . They were asked to mark on the map of the World all of the evidence from fossils, ancient climates, and rock types found in their text and in the reports from the teams, using a legend of their own making. After plotting all of the evidence on the map of the world, they were to colour each of the continents on the two maps (Pangaea and the world) the same colour and write the names on them. This was easily done for all the continents except India which is part of Eurasia now but used to be a separate piece of land. Once all of this was done, the students were to cut up the map of the world and fasten it to a coloured piece of paper which was provided, making sure to transfer the legend also. They could work in their teams but each student was to hand in two completed maps for marking (10 marks) . The maps were very well done, compared to the ones that had been done in previous years. The textbook (Science Dimensions 9) suggests doing this map activity twice: once just as a jig-saw puzzle (Inquiry 5A- page 176), and the second time using a map that shows the continental shelves (Inquiry 5B- page 179). I have found that these Inquiries lead to some strange positionings for the continents based solely on their shapes. In this activity, using the fossil evidence given on page 177 of the text and the rock evidence on page 182 of the text, along with additional evidence from the student reports (Appendix h), the maps were really well done. South America and Africa were easy to position, but North America and Eurasia posed a problem. The rock evidence on page 182 of the text was helpful in lining up the east coast of North America with Britain and Scandinavia. The students did ask questions about Greenland and learned about different projections of maps causing some distortions in size and shape. Greenland on our map was bigger than it should be but could be included between the two larger land masses. There were two difficult aspects to the reconstruction of Pangaea : India must be cut away from Eurasia, and Antarctica was the wrong shape (not round, but a long narrow strip) because of the map projection. I told them it was okay to use only part of Antarctica instead of the long strip on the map in order to fit the other land masses onto it. I asked them to keep the part that had fossil evidence marked on it. Most of the teams figured this out and helped each other with the finished product.

A few parents and students had expressed concern about this unit being evaluated using team marks for everyone so part of the reason for this individual assignment was to satisfy their need for individual evaluation for some of the assignments.

D) Earthquakes - Research and Presentations

Six questions related to earthquakes were again written on pieces of paper and the teams picked topics that they were interested in. This activity was different than the previous selection which was random. I asked the students to listen to the questions first and then decide for themselves which one they might like to do. I made suggestions to some of the groups beforehand which question they might find appropriate for them. One group had a member who was Japanese and I recommended they do the **Tsunami** topic since it is a Japanese word and Japan experiences many tsunamis (huge sea waves caused by earthquakes on the sea floor). I suggested to the more powerful groups (as demonstrated in the first report) that they do the more difficult topics without saying they were more difficult but suggested how they might find them more interesting. I also tried to have the weaker groups do the easier questions, again without making them aware of the reason. The harder questions were contained in the following topics: **Waves**, **Seismometer**, and **Focus and Epicenter**. The easier questions dealt with: **Plate Movement**, **Tsunami**, and **Scales**.

The first reports had generated a lot of photocopying and paper use (8 reports/class with 3 classes = 24 reports with 30 copies of each = 720 copies). As a result, the students were asked to shorten their written reports to half a page, and were given overhead plastic for their diagrams. They were also encouraged to involve more than one team member in their oral presentations, with one person managing the overhead while another talked. It was also suggested that posters or models might be used to explain their topic to the class. The questions given out to the students were as follows:

1. **Waves** - Name and describe the three kinds of waves generated by an earthquake.

2. **Seismometer** - Describe what a seismometer is and how it works.

3. **Focus and Epicenter** - Define the focus and epicenter of an earthquake and explain how they are located.

4. **Scales** - Name and describe <u>two</u> different scales that can be used to measure the strength of an earthquake.

5. **Tsunami** - What is a tsunami and where do they happen most often?

6. **Plate Movement** - Describe the three kinds of ground movement that can cause earthquakes. Give examples of each.

<u>**Note**</u>: It became clear to me that the wording of the questions was critical in order to obtain appropriate responses from the students. The question listed on **Plate Movement** was too vague and required clarification. I was hoping that the students would identify **divergent, convergent** and **transform** boundaries, but the wording of the question lead to confusion with **folding** and **faulting**, which is also caused by earthquakes. This question should be worded:

2. **Plate Movement** - Name and describe the three kinds of movement that occurs at plate boundaries and give a location at which each occurs.

When the students found diagrams or illustrations that they wanted to use, I was kept busy running to the photocopy machine, making overheads for them. Some students chose to draw or trace their own overheads and the librarian gave them overhead pens to borrow. The most well-used book was the geology text by Tarbuck and Lutgens and the pages started falling out of our copy of the fifth edition. The librarian made several photocopies of the most used pages, and put them on the trolley that was holding all of the books we were using. The new copy of the sixth edition was kept on a separate shelf for teacher use only or in case the other book went missing, which it did a couple of times. One enterprising student got a copy of the book from the public library, and one had a copy at home from a parent. The books in our school library were put on reserve on the trolley so we were sure to have them when the classes came in to do research.

The CD-ROM discs were very popular and I had to limit each group to 15 minutes at a time so everyone had a chance to use them. The Plate Tectonics disk is a great resource that I first saw at an in-service at the Wallace Building with other science teachers. It arrived at the school during this research session and all of the students were keen to use it. The fossil evidence section of the disk shows different dinosaurs leaving tracks across South America, Africa, and India. It shows the Mesosaurus splashing water across the same continents, and a Glossopteris fern popping out of the ground in Antarctica. The students liked to replay the scene in which a car is flipped over in an earthquake! The disk has review questions and is interactive. It has a high-school version and a college version on the same disk, and it is necessary to use the college version for one of the final questions in the next section on **Magnetometers** but the high school version covers all the other questions.

The oral reports (Appendix i) this time were more interesting for everyone because the students explained more in their own words rather than reading from the handout as they tended to do the first time. Most of the teams had more than one overhead to help in explaining their topic and several used props such as the slinky to demonstrate earthquake waves, and blocks to demonstrate the movement at divergent, convergent and transform boundaries. The written reports took less paper but there was the unexpected bonus of a more concise format in the condensed form with only the essential information being given out.

E) Mapping of Earthquakes of November 1994 (from Internet)

This assignment was done by each student in the team and handed in for evaluation. A map of the world (Appendix j) with latitude and longitude lines was handed out to each student (from the Black Line Masters at the end of the TRP). This map is intended to go with Inquiry 6A on page 215 of Science Dimensions 9. In the textbook Inquiry there is a list of earthquake data for the students to plot, but I thought the Internet data would be more "real" and accomplish the same goal: to make the students aware of the pattern formed by earthquake epicenters outlining the plate boundaries. Each team was given a copy of a sixteen page printout (Appendix k) from the Internet that listed all of the earthquake activity worldwide from November 5, to 26, 1994. The list gave latitude and longitude locations for each earthquake as well as depth, magnitude, region and also supplied comments. The students were asked to plot as many earthquakes as possible in two 40 minute classes, and answer two questions on the back of their maps before handing them in. The questions were:

1. Do you notice any locations that have lots of earthquakes? List the locations by name if you can.

2. Do you notice a pattern to the earthquake locations? Try to explain in general terms where most of the earthquakes occur.

It was hoped that the students would recognize that most of the earthquake activity takes place on the Pacific rim and the northern coast of the Mediterranean, outlining the edges of the plates in the process. Some of them came to ask me how to mark another spot on the map when it was already full of spots in a certain location. The students did notice that their maps (Appendix l) became full of earthquake activity in Alaska, California, and Japan. The students seemed more interested in this activity than the comparable one in the text that had been used in previous years. They started with enthusiasm and appeared to be working hard to finish as many pages of data as possible in the two class periods.

When the maps were handed back, the students were shown another printout from Internet (Appendix m) that showed one week of earthquake activity on a world map and looked similar to their maps. They were also shown a map of California's earthquake activity from Internet (Appendix n). It is interesting to note that since this activity was done, our school has set up a new computer lab with Internet access on all the machines where previously we had limited access. The students were able to get their own lists of earthquakes (Appendix o) with longitude and latitude to plot on the map. Out of curiosity, I asked them to do the textbook list on page 215 also, and then asked them to compare the two activities. Surprisingly, some of the students preferred the text list because it was much easier for them to read. The Internet lists tended to have unnecessary information on depth, magnitude, time, etc. which some of the students found confusing compared to the simple list of latitude, longitude, location, and year given in the text. However, most of the students still appreciated the process of finding their own data on the Internet and plotting it. The maps did tend to outline the Pacific Plate no matter when the data was obtained or from which Web site. Some of the students were able to find maps of world-wide earthquakes already completed on the Internet. We discovered that a colour printer is necessary to see the data displayed effectively with colour coding for earthquakes of different magnitudes, depths, and timing being used on the Internet. The students were able to save a great deal of Earthquake information on computer disks, this year, and wrote positive responses to the process.

F) Kobe Earthquake - January 1995

On January 17, 1995, an earthquake measuring 7.2 on the Richter Scale occurred in Japan. The epicenter was about 30 kilometers from the city of Kobe, and because of the magnitude, over 5000 people lost their lives in the destruction caused by the earthquake. This unfortunate event was timely for the students who had just finished learning about earthquakes and became the topic for several classes as more information became available through the media. It was a little uncanny that on January 17, 1994, the previous year, a similar occurance had taken place with the Northridge, California area experiencing a major earthquake at the same point in our studies of earthquakes.

The first article in the Free Press (January 17, 1995), "Huge quake rocks Japan" (Appendix p) was read and discussed in class. It contained references to the Richter Scale and the epicenter. The students noticed that the article incorrectly stated that the "epicentre was located about 20 kilometres beneath the island of Awajishima which is about 30 kilometres off the coast of Kobe." The paper should have used the word focus instead of epicentre, since the focus of an earthquake is a location under the ground where the rock actually breaks, and the epicentre is the surface location directly above the focus. Each day there were more articles in the newspaper about the Kobe earthquake (Appendix q)that I made overheads of and discussed in class. The students and I followed the unfolding story with great interest. The students appeared to be more interested in the news reports than information in their textbook. They also were gaining an understanding of the impact of this earthquake on the people living in the area.

I brought in a videotape of the Susan Powter Show in which she interviews people who experienced the 1994 earthquake in Northridge, near Los Angeles (aired on January 17, 1995). One of the students had asked me why people decide to live in California when they know that there is so much earthquake activity. Susan Powter asked her guests that question so the student had the opportunity to hear their answers. Also, during the commercial break there was a news bulletin of the Kobe earthquake including a scene filmed inside an office during the earthquake with the filing cabinets and desks moving violently. The students heard the guests describe nights spent in their vehicles after the main earthquake hit because the aftershocks may have caused their houses to collapse. They also heard about the looting that can happen and patrols that need to be established, and the difficulties with communication, water and food supplies following an earthquake. The reports seemed to make the earthquake phenomenon more real to the students.

This past year, Nova produced a TV program called _The Day the Earth Shook_ that documents the two earthquakes that happened exactly one year apart in California (Northridge) and Japan (Kobe). This video is available for purchase (~$20) and is well worth showing to the students. The video shows the same clip shown in the news broadcast during the Susan Powter Show of an office with moving furniture during the earthquake. There is a person sleeping in that office who can be seen in the corner of the screen. The video also shows an interview with the driver of the bus that was pictured on the front page of the Winnipeg Free Press (Jan.17,1995 - Appendix q)) as it hung over the edge of a collapsed section of freeway after the Kobe earthquake.

The driver tells the viewers that all of the passengers of the bus managed to get off safely as it hung over the edge of the freeway. The students were intrigued with a model house that shakes like in an earthquake so people in Japan can practise diving under tables or doorways for protection.

G) Field Trip to the Wallace Building at U of M - Seismometer

All of the students were taken to see the seismic vault in the basement of the Wallace Building (Appendix r). We walked down to the bottom of the stairs and past a crawl space with a bare ground floor. The students then were ushered into the vault area that contained a huge concrete block with several small electronic boxes on the top. We were told that the concrete was anchored in bedrock to register any seismic vibrations that occur. The students were invited to try to make the seismic needle move by jumping up and down on the floor and then having a look on the paper upstairs in the main entrance. We then visited the seismograph drum that records any seismic activity in the main entrance, and saw that none of the jumping had registered. The students were shown actual seismic readings and given samples to take home with them (Appendix s). A university geology student was present to answer their questions, including "Did the Kobe earthquake register here?". In fact it did register on the machine and the reading was on display for the students to see. The students also looked at the fossils in the display cases on the main floor and saw evidence of tropical ferns and creatures that lived in this area 200-400 million years ago when North America was closer to the Equator.

H) Volcanoes, Mountain Building, Technology - Research and Presentations

These last three topics were done at the same time because we were near the end of the six week period that was set aside for this unit. Instead of assigning the questions at random, the teams were assigned particular questions according to their past performance on the earlier two research questions. The more challenging questions were given to the teams that had demonstrated a keen interest in the subject and strong academic ability. The shortened format of half a page was requested for the handout, and the teams were asked to have all members at the front of the room for the oral presentation. One team member could speak while another organized the overhead machine with examples on transparencies, and all team members could answer questions at the end. The questions were:

1. **Volcanoes** - Describe three different kinds of volcanoes, by their shape, and give an example of each one.

2. **Mountains** - Describe the formation of mountains by folding and faulting and explain the role of plate tectonics.

3. **Sonar** - Explain how sonar works, what it was originally developed for, and what evidence was found by using it to support the theory of plate tectonics.

4. **Magnetometers** - Explain how magnetometers work, what they were originally developed for, and what evidence they provided to support the theory of plate tectonics.

5. **Deep Sea Drilling** - Explain what deep sea drilling was originally designed for, and what evidence it provided to support the plate tectonics theory.

6. **Radioactive Dating** - Explain how radioactive dating works, and what evidence it provided to support the theory of plate tectonics.

7. **Hot Spots** - Explain what hot spots are and how **Hawaii** provided evidence for plate tectonics.

8. **Hot Spots** - Explain what hot spots are and how **Iceland and Yellowstone** provide evidence for the theory of plate tectonics.

The teams all did high quality presentations (Appendix t) on their questions. The most difficult question was #4 on magnetometers, which had information only on the college version of the CD-ROM Plate Tectonics and books written for university level geology students such as the text by Tarbuck and Lutgens. One team did such an amazing presentation (Appendix u) using the CD-ROM and laser disk on the big screen TV that they used the entire 40 minute class. They prompted many questions such as :
"What happens to the Earth when the magnetic field reverses?"
"How many millions of years does the magnetic field stay the same?"
"Why are the magnetic stripes different sizes?"
"How long ago did the last reversal take place?"
The students answered all of these questions with ease, having come across the answers in their research. I had not been asked these questions before, and would have difficulty in answering them. These students had reached a level of expertise that surpassed mine, and they had stimulated an interest in a topic that I had not witnessed before.

The students tended to lose the significance of their topic in the Plate Tectonics Theory, even though it was part of their question. I would put the title **Plate Tectonics** - followed by their individual topic if doing this unit again.

At this point in the lessons I felt that it was necessary for me to step in and clarify the development of the Theory of Plate Tectonics for the students who had become immersed in their individual questions and seemed to be losing the connections to the other student's research. We reviewed the evidence that Wegener had collected and the reasons for his ideas not being accepted at the time. I showed the video The Blue Planet which brings us up to the present day with film of the Earth taken from the space shuttle, which was of course not available in Wegener's lifetime. The students see how the continents look from outer space and also see computer generated earthquake waves move across California.

I handed out copies of the cross-section of the Earth that is shown in the text and had the students label the crust, mantle, asthenospere, etc. We discussed the main points of Plate Tectonics and the impact of modern technology on the development of the Theory. There are still unanswered questions, among them:

What causes the convection currents that move the plates?,

What is the composition of the core of the Earth?, and

Can we predict when and where an earthquake will happen?

Some of these questions will be answered in the future as technology develops to investigate further. The students will see the results of research done since the publication of the text in the magazine articles done in the next assignment.

I) Recent Magazine Articles - Team Summaries and Presentations

The students were shown several *Earth*, *National Geographic*, and *Scientific American* articles that described some form of recent evidence to support the theory of plate tectonics. Each team was asked to read the article together and make a short summary of what the article said to present to the rest of the class. The magazines and articles used included:

-*Scientific American,* July 1978, The Kiwi by William A. Calder III.

-*National Geographic,* Vol.182, No.6, December 1992 - Volcanoes, Crucibles of Creation by Noel Grove.

-*Earth,* May 1993, CAT Scanning the Earth by Jim Dawson.

-*Earth,* January 1994, Did the Himalaya Warm the World? by Tom Waters, and Earth's Near-Death Experience by Joseph Alper.

-*Earth,* July 1994, Journeys in Iceland by Ruth Flanagan, Island Invaders by Patrick Huyghe, and Nova Scotia's Cape Chignecto Coast by Scott Cunningham.

-*Earth,* September 1994, Exploring Loihi: The Next Hawaiian Island by Noreen Parks, and Against the Grain by Scott Fields.

-*Earth,* November 1994, Dynamic Earth by Tom Yulsman.

-*Earth,* December 1994, Continental Crunch by Alexandra Witze, Lizzie the Lizard by William A. Shear and W.D.Ian Rolfe, and Earth's Violent Birth by Joe Alper.

The Cat Scanning the Earth article by Jim Dawson has an amazing picture of hot red blobs of rock under the oceans of the world and cold blue blobs under the continents, supporting the convection current idea. The students seemed to enjoy reading these articles and summarizing them.

Chapter 4
Evaluation and Feedback

There was a total of 195 marks for this unit. It might be better to make the total raw score 200 marks by assigning 5 marks to the classroom map done at the beginning of the unit, or by giving the earthquake map 10 marks instead of 5. The breakdown of the marks that were collected follows:

Continental Drift questions .... 10 marks written report
.... 10 marks oral report
Pangaea Map .... 10 marks
Earthquake questions .... 10 marks written report
.... 10 marks oral report
Earthquake map .... 5 marks
Test (Appendix v)..............................50 marks
Plate Tectonics questions .... 10 marks written report
.... 10 marks oral report
Magazine articles .... 10 marks
Plate Tectonics notes .... 10 marks
Final Test (Appendix w).................... 50 marks

The students received an evaluation out of ten marks for each oral and written presentation, for a total of sixty marks. Each member of the group received the same mark. It was originally planned to have five questions to research but there was only time for three. While the students were presenting their reports to the class, it became necessary to deduct a mark from anyone who was talking, and I decided to add a mark to students who asked good questions. This meant that all of the students in one group may not get exactly the same mark, depending on their response to the other reports. The map assignment that required the students to plot the evidence for continental drift on the world map and then cut it up to recreate Pangaea was collected and marked out of ten marks. The world map of earthquake activity during November 1994 (Internet) was also collected and marked out of five marks. The first activity of making a classroom map was collected and displayed, but was not evaluated.

The fifty mark test at the end of this unit ended with a survey of eight questions that were designed to give me some feedback from the students. The survey and the results follow:

SURVEY

Please answer the following questions as accurately as possible, and try to express complete answers where possible. (This is NOT for marks!)

1. In your opinion, was the last unit on plate tectonics more interesting than our chemistry unit?

YES-61 NO-14

2. In your opinion, was the team work that we did a valuable experience?

YES-51 NO-25

3. Do you feel that you have a better idea of how science works after modelling the science community in the classroom?

YES-52 NO-21

4. Do you feel that you have a better understanding of how science theories develop after studying the theory of plate tectonics?

YES-66 NO-7

5. Try to write a definition of <u>science</u>.

The student answers which follow have key words **highlighted** by me:

- **"**a search for new ideas, and **evidence"**
- "trying to figure out stuff we don't understand"
- "People trying to figure out how things work, and how they are made, and such."
- "Science explains how life came on earth and everything about earth and human life."
- "a way to **prove** or to find out what hapens to enything hapens to a item" [sic]
- "Science helps us identify the living actions surrounding us, **a process in todays world changing and ongoing**."
- "Science is the study of all things applying to the nature of our Earth and Space."
- "Science is studying our environment and everything in it so we can make it better for the future."
- "The study of how the universe operates and all things within the universe (and beyond)."
- "An art which is made up of facts and theories about our earth and the life and happenings upon it which is **always changing**."
- "any opinion that is stated in an scientific manor?!?"
- "A subject where everything is different and has different meaning"
- "the study of our world and the things inside"
- "a definition of a theory or explanation using a scientific theory. It's a theory that **always changes**."

- "the study of the knowledge about the world around us (who and where we are)"
- "Science is the study of all living and non-living things."
- "Science is everything, living , non living."
- "Science is the study of everything in our environment and how all these things interact."
- "Science - study of things affecting us around the earth. Shows how thing interact."
- "Science is the study of our surroundings on earth."
- "Science is the study of the earth, ourselves, and everything that we know of."
- "It is something that is a mystery but people are trying to figure it out. I think that what we don't know, we are not supposed to know."
- "Science is the study of how the universe and earth works."
- "The understanding of the world around us and how everything works."
- "is something that has no answers and many questions. It has no limits."
- "Science is what gives us a history about our earth, and it's surroundings."
- "How things work, what makes them work and how they came to be."
- "Science is a group of categories that contain knowledge and are based on theories, not facts and figures."
- "Science is something you learn to understand the concepts of what a scientist does."
- "Science is anything that we study to learn more about our world."
- "Science is a group of theories on how the Earth works."
- "Science is the study of the earth and the study of all the things that it is

made up of. It is also about working together to form beliefs, and how **not just one guy made science history**."

- "Science is the quest to find out"
- "A way of figuring out how things are made, and what causes them. A study of the earth as a whole."
- "Science is the study of things and learning things. Nothing is for sure. There are theories and hypothesis but **usually nothing is proven**, although there is some fact."
- "The study about our earth and how it works."
- "The learning of things that is hard to understand and really I find everything hard to understand."
- "Science is trying to discover and learn ways of creating, doing, and understanding almost everything."
- "A group of theories and ideas that get **proved** right or wrong **as time goes on** and develop."
- "The study of the things around us."
- "Science is to define and identify the unknown, and then explore and analyse it."
- "the study of biological, astronomical, ecological, and geological work and **changing ideas**."
- "is a whole bunch of stuff that explains the earth and universe."
- "The hypothesizing of the world and everything in it by researching, planning, and discovering how the earth really works and why."

6. Do you think that your definition of science has changed since last year? If so, how?

YES-43 NO-34

7. Try to define scientific theory.

The student answers which follow have key words **highlighted** by me:

- "I've learned that anyone can model science research teams to come up with answers to simple questions, It's **not something only in books, because it keeps on expanding."**
- "I've learned more things about science, so I know more than before."
- "because **we learned more than just the facts"**
- "In my opinion, I've always known that science is constantly changing. This unit was interesting, but hard. It was a good example of how **information is not always in one tidy book, but has to be searched for in many other articles and books**."
- "I think that **science is more than just facts**, it's also theories and thoughts. I also learned about how **science is going on and changing in our world**."
- "because every opinion should count!"
- "Cause every year the world changes so much, and it's hard to keep up"
- "Yes it's **never proven, it's constantly changing"**
- "because **new ideas and research have taken place**."
- "last year I thought it was just a superstitious subject, but now I know that there is **evidence to support it."**
- "because last year **I thought all the answers were in our textbook and that they were positive answers**."
- "Yes because this year I have done better and with the research teams it

helps you to understand and learn better."

- "**Science is always changing** and being added to and last year I didn't know that **scientists worked in groups**."
- "I now know that in the science community, they **(scientists) work together in research teams as opposed to one person**."
- "I used to think that **science was always fact, but now I know that it changes** all the time."
- "**Last year I thought science was set. I thought it was all fact**. After this unit I learnt [sic] different."
- "because I looked at Science in a different way, I thought it was boring but you've proved me wrong. I quite like it!"
- **"we worked like scientists, in groups, so we got a better idea of it."**

8. Do you think that your definition of scientific theory has changed since last year? If so, how?

YES-29 NO-47

Chapter 5

Discussion and Implications for Further Investigation

The unit on Plate Tectonics was designed with three main strands or goals in mind that were identified in Chapter 1 as History, Teams, and Real World Connections. The first goal of history, was to take the students away from the idea of "final form" science as conventionally presented in science textbooks that students tend to memorize. I wanted to show the students a more dynamic, ongoing science by emphasizing the historical development of the theory of plate tectonics. This development continues beyond the publication of the text in 1993 with new evidence being published in each issue of Earth magazine and other sources. The expectation of this goal was that the students would understand the Theory of Plate Tectonics rather than memorizing the information contained in it. The second goal of teams, was to have students come to a better understanding of how science works by modelling the science community with their team work on research assignments and presentations. A third goal was to give the students real world connections so what they were learning in the classroom would become more meaningful to them.

History - The numbers of students that answered "YES" to questions 1- 4 indicate to me that most of the students benefitted in a positive way from the design of this unit, and felt that they now had a better idea of how science works and how scientific theories develop. The question 4. "Do you feel that you have a better understanding of how science theories develop after studying the theory of plate tectonics?" received a positive response of 66 students answering YES, and only 7 answering NO. The text Science Dimensions 9 starts Chapter 5 with a historical account of the earliest maps of the world and Alfred Wegener's work on continental drift. It then describes the evidence collected after WWII that led to the development of the Theory of Plate Tectonics. Chapter 6 describes how plate tectonics helps to explain earthquakes, volcanoes and mountain ranges. I have changed the order of the information so that the earthquake and volcanoe data gives information about where the plate boundaries are when plotted on a world map, and leads into a discussion of plate tectonics. The answers to question 6 "How has your definition of science changed since last year?" were encouraging to me since some of the students mentioned the idea that science knowledge is constantly changing as more research is done, and the text may not have all the facts or "final form" science:

- "...last year I thought all the answers were in our textbook and that they were positive answers"
- "...It's not just something in books, because it keeps on expanding"
- "...science is more than just facts, it's also theories and thoughts"
- "...information is not always in one tidy book, but has to be searched for in many other articles and books"
- "...we learned more than just the facts"
- "...I also learned about how science is going on and changing in our world"
- "...new ideas and research have taken place"
- "Science is always changing and being added to..."

These responses made me realize that it would have been a good idea to have the students keep a daily or weekly journal during this six week unit to better document their definitions of the terms "science" and "scientific theory" and any changes that may have occurred. Elizabeth Finkel describes the use of journals with her students and how this makes them more aware of any mental shifts in their own perceptions. I would consider having students keep a journal in the future to monitor growth in their own understanding of science and scientific theories. By only asking my students these questions at the end of the unit, they did not have the opportunity to articulate their thoughts prior to doing the unit and may have missed some changes in their own thinking.

The historical development of the Theory of Plate Tectonics includes a significant name change from that of continental drift. Some of the students had difficulty understanding the differences between the names. The problem of using the terms interchangeably is exacerbated by books and other sources that use the terms synonymously. We discussed the differences in class, but a more formal approach for clarifying the problem would be better. One way to accomplish this would be to have students do an assignment to find three similarities and differences between the two ideas. The similarities would include all of Wegener's evidence: geological, biological, and climatological. The differences would be the evidence from modern technology could only apply to plate tectonics, the Pacific Plate is not mentioned in continental drift (since it has no continent on it), and the whole sea floor is not included in continental drift. Once this comparison is made, the students may not be as confused about the terms and should be able to use them more appropriately.

Teams - The majority of the students found the team work a valuable experience, since 51 answered YES to question 2, and 25 said NO. The team work could be further investigated in terms of how to best choose students for the team, and how to deal with problems of variable interest and ability levels within the teams. I feel fortunate that only 2 of the 24 teams required restructuring during this unit. Allowing the students to choose their own teams could be one solution. Some of the students who had acheived good marks in the first term and were put in charge of a team did not have the leadership skills needed. Other students with lower marks actually showed good leadership skills within those groups. Students at this age are preoccupied with relationships and it is a good idea to let them work with a friend if possible. How the groups are arranged is important, and should be given careful thought by the teacher, and explained carefully to the students at the beginning.

The modelling of the science community appears to have been successful, based on the answer to question 3: "Do you feel that you have a better idea of how science works after modelling the science community in the classroom?". Again, the majority of the students, 52, said YES, and 21 said NO. Some of the comments on the final test's survey mentioned the teams and the modelling idea:

- "Science is...about working together to form beliefs, and how not just one guy made science history."
- "...last year I didn't know that scientists worked in groups"
- "I now know that in the science community, they (scientists) work together in research teams as opposed to one person."
- "we worked like scientists, in groups, so we got a better idea of it."

- "...this year I have done better and with the research teams it helps you to understand and learn better"

At the end of the school year I asked the students to write down three things that they enjoyed doing in science during the year, and should be done again next year. They also write three things that they didn't like and should be discontinued or changed. Many of the students mentioned that they liked the way the Plate Tectonics unit was taught and especially the group work. A smaller number of students said that they didn't like the group work. Some of the stronger students felt that most of the team's work was done by them and it was unfair for the other team members to get the same marks. A few parents expressed a concern about group marks as well, but the individual assignments and test scores seemed to settle their concerns. A couple of students told me that they felt the presentations from the other groups may not have given them enough information on a given topic to prepare for a test. They were told that the basic information on all the topics was contained in Science Dimensions 9 and the actual pages listed on the first handout (Appendix a). The students were as relieved to hear that as I was to say it, because it meant that they were not "intellectually dependent" (Martin,et al, 1990, page 551) on me to give them information out of my head. In fact, a few of the stronger students had gone beyond my knowledge on the more complex topics (radioactive decay) and I was unable to answer their questions. It can be unsettling for a teacher to recognize and admit that the students know more about a topic than she does. It is unavoidable, with the wealth of information available through the media, that a teacher's information will become dated. We have to be able to recognize that our students may learn more about a certain interest area than we know, and give them credit for their knowledge. Teachers can ensure that the "basics" of the curriculum are "covered" and at the same time, encourage those students who are interested to go beyond the curriculum.

I found that the students got excited about their research and really seemed to enjoy looking for the answers to questions. The class members got very involved in the team presentations, and asked more questions of their classmates than had ever been asked of me. The students who were presenting seemed to have pride in their knowledge, and felt good at the front of the class. They were becoming more actively involved in their own learning, instead of passive receivers of knowledge from the teacher or the textbook. The following questions are samples of those asked by students in the class after a presentation from one of the presenting research teams:

"What is an isotope?"

"How accurate is radioactive dating?"

"What is half life?"

"How do you date rocks that are millions of years old?"

"How do hot spots get there?"

"When did people find out that the world was round?"

"What happens to the earth when the magnetic field reverses?"

"How many millions of years does the magnetic field stay the same?"

"Why are the magnetic stripes different sizes?"

"How long ago did the last reversal take place?"

"Why do people live in California when they know about earthquakes?"

The last question is asked by Susan Powter of her guests who experienced the Northridge earthquake of January 17, 1993. They say that every place to live has its negative factors to consider, and give the extreme cold of the American north as an example. This question is a real world connection since it shows that the students are thinking of how their knowledge of earthquake zones on plate boundaries might effect where they choose to live as adults.

Real World Connections - The students appreciated seeing the seismic vault at the University of Manitoba, and it made earthquakes more real to them when they learned that the Kobe earthquake registered clearly here in Winnipeg. The news reports of the Kobe earthquake made it seem more real as a week went by and survivors were being rescued. The Free Press article written by Paul Pihichyn "Cyber buddy in Japan logs off - Net drives home disaster reality" (Appendix q) tells of his real world connection to the Kobe earthquake. He had made friends with Jon in Kobe on the Internet and was anxiously trying to communicate with him after the earthquake. Later he was informed that Jon had been killed in the disaster. My students were touched by this story and others.

It seemed to me that living where we do makes it difficult to understand the reality of earthquakes or volcanoes without hearing first-hand accounts. The guests on the Susan Powter Show described the experiences they had which helped me and the students to understand earthquakes more fully. My knowledge told me that an earthquake shook the ground and buildings may collapse causing people to be buried or killed. I did not understand that aftershocks were earthquakes in themselves, and the loss of services such as water and power that are common after an earthquake. One family that survived the Northridge earthquake spent several nights sleeping in their vehicle in the driveway because the aftershocks had weakened the walls of their house and it was in danger of collapsing. In addition, the vehicle acted like a cradle with the tires and shocks absorbing most of the movement from the aftershocks while they slept. The mother of that family reported that her husband had to do patrol shifts with the other neighbours to guard against looters. All of these comments made the earthquake phenomenon more "real" for my students.

The challenge that I now face, is to try to incorporate the history of science into the other units of the curriculum. For Chemistry there is the historical development of the atomic model which is given in the text. The students could research recent developments in the structure of the atom that are not in the text and discuss the topic in class. Kauffman(1989) recommends strongly that the history of chemistry be part of the curriculum or the "education of a chemist...remains somehow unsatisfactory and incomplete"(page 90). He argues that without a historical perspective, the student is "apt to regard the chemistry in his text and laboratory manual as a finished product unchangingly etched in stone. With some history, he learns that chemistry is a dynamic rather than a static structure, with today's theories merely being the leading edge of a trail from the past that stretches indefinitely into the future." (page 82) I will approach the teaching of chemistry from a different viewpoint now that this thesis is completed. The historical slant will be given to the students wherever appropriate, and new research made available in the media brought to class.

The Reproduction/Genetics unit ties in very well with a historical slant.

There is often media attention on reproductive technology such as *in vitro* fertilization and implantation. Great topics for debate can be found in the media as there are no laws that contend with technological progress. There is the recent issue in England of the thousands of frozen embryos that have been allowed to thaw and die, and the Canadian Clinic that is proposing to allow adoption of frozen embryos that are not needed by their original donors. The students need to be made aware of the ongoing human genome project in which scientists around the world are working to identify all of the genes contained in human DNA or chromosomes. I now show my students the movie documentary The Race for the Double Helix as part of the program, to make them aware of the struggle involved in scientific research.

This past year I have recognized that a number students come to science in Grade 9 with an abundance of knowledge and may not even need me to "teach" them the content of the curriculum. The textbook is useful in identifying these students, since it contains the curriculum content on every topic. The students can look at the two chapters dedicated to each unit and have a good idea what information is going to be covered. Susan Winebrenner has suggested allowing these students to write the test before the unit begins. I have tried this with the Genetics/Reproduction unit and had ten students out of eighty score over 90% and decide to do independent research on related topics while the class studied the unit with the teacher. The results of their research was amazing to me. They chose their own topics and produced written and oral reports. Several students interviewed doctors and geneticists and delivered impressive reports to the class. We all learned from their presentations, me included. It would appear that in an information age, teachers need to change their focus from one of disseminators of information, to one of managers of information or research directors. We need to help our students to find information, and use it to increase their own understanding. It can be unsettling for a teacher to let go of the control of knowledge, and allow, even encourage, students to go beyond their own understanding of a subject. One example of a student going beyond my knowledge was a boy who did a research paper on Cystic Fibrosis (CF) this past year. He has CF and part of his research involved interviewing his doctor to find out more about the genetics involved. The student gave a detailed report to the class and gave us all a first hand account of the daily treatments that are necessary to cope with the disorder. His account gave us a real world connection to genetic disorders, and the study of genetics.

The major shift that has taken place in my teaching since doing this thesis, is a philosophical one. The content of the curriculum has become a little less important, and the students perception of science in general more important. I now feel that it is imperative to emphasize the ongoing nature of science so that the students appreciate the excitement of scientific research. Hopefully this type of teaching will encourage students to pursue careers in scientific fields.

The role of the teacher in the classroom should be to insure that the students gain a historical picture of a dynamic science that is exciting and ongoing. It is important to use the textbook as only one source of information, and encourage students to use other sources as well. Team research and independent research is an integral part of the science process and should be part of science education. More research could be done into possible ways of setting up the teams in a classroom, and how to have them work together the most effectively. The incorporation of the history of each science is not an easy thing to do, and teachers need to encourage each other in this direction. A collection of media articles on relevant science topics would be a place to start. Further study could be done into the use of computers and the Internet in science education. Collaboration of students between schools and even cities would enhance the team spirit of research, and also be a real world connection for students. Curriculum committees need to include the historical development of the big theories of science that are part of the curriculum. Finally, it is necessary that textbooks are available that follow the historical development of a theory, and that teachers supplement these texts with up-to-date information.

The textbook design needs to be investigated. Aside from the obvious inclusion of the history of science, activities need to be provided that encourage the students to look at other sources of information. The text should discourage rote memorization of facts and encourage the development of a deeper understanding of science. Stimulating questions that interest the students need to be included. The task of designing such a textbook would be a complex one, and require further research and input from interested teachers of science. Unfortunately, there is a new curriculum in the planning stages for all of Canada with the prospect of a common test across provinces being proposed. Teachers will be even more inclined to teach content in order to have their students do well on the tests. The design of a standardized test, or science assessment in general, needs to be further investigated. With the new curriculum and common testing in mind, I hope that there will be an effort made to test students' understanding of science and not just their rote memorization of scientific facts. Once the new curriculum is available, the textbook publishers must design textbooks that stimulate the students natural curiousity, and the teachers need to do the same.

Further research should investigate the way assessment is done in schools. The memorization of facts for written tests does not encourage the kind of learning that should be taking place in schools. Finally, a more effective system of evaluation should be designed to accompany the new curriculum.

Teachers of science who attempt to meet the challenge of the new curriculum would find it helpful to have a comprehensive (good) understanding of the history and philosophy of science in order to meet the needs of their students in the next century. Without a sense of where we have come from, it will be difficult to know where we are going.

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a

Grade 9 Science Unit Two

Topics

1. Continental Drift (pages 174-185)
2. Earthquakes (pages 214-226)
3. Volcanoes (pages227-239)
4. Mountains (pages 240-250)
5. Technology (pages 185-194)
6. Plate tectonics (pages 195-207, 251)

Team Reports

1.Oral presentation- 5-10 minutes- 10 marks
2. Written handout - 250-500 words with title, date, names of team members - 10 marks
3. Tests at 3 weeks and 6 weeks for 50 marks each.

Winnipeg Free Press (Sat. Nov. 19/94)

Element 10 years in making

Discovery supplies clue to creation of the world

Associated Press

BERLIN — IT took 10 years to make and flickered into existence for less than a thousandth of a second. As-yet nameless, element 110 supplies another clue to the world's creation.

An international team at the Heavy Ion Research Centre at Darmstadt in southern Germany said it created the first atom of the element by bombarding lead atoms with nickel atoms in the centre's accelerator.

Scientists once thought uranium — No. 92 — was the last of the elements. But in the last half century, researchers equipped with nuclear theories and technology have detected 18 more, each heavier than the last.

What they now want to know is, whether there's a limit and if so, where?

"It concerns how the world was made," team leader Peter Armbruster said yesterday.

What does the discovery mean to the average person? For now, a new addition to the periodic table in textbooks around the world. Element 110 has an atomic weight of 269 — the heaviest ever produced.

Most matter is found in mixtures, but elements cannot be separated into other substances by ordinary chemical or physical means.

The team said it first detected the element on Nov. 9. It went public with the find late Thursday after producing four more atoms.

Each time the element disappeared in less than a thousandth of a second. But scientists knew it was there because they detected a helium nucleus it emitted as it decayed.

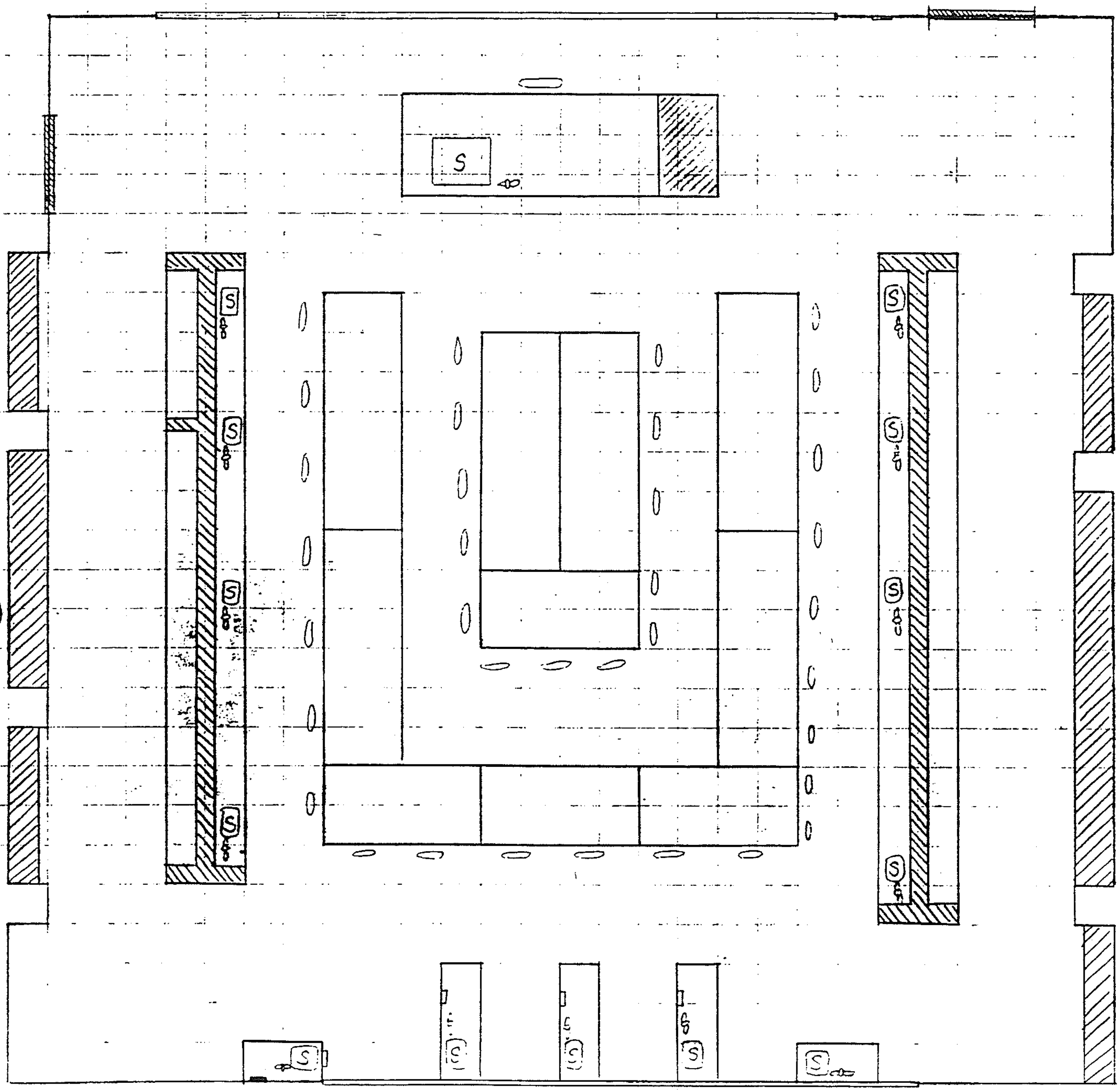
Figuring out how many elements can exist has been an eternal goal of science.

Twelve scientists share credit with Armbruster: six others at the Darmstadt centre, three from the Duma centre in Russia, two from the University of Bratislava in Slovakia and one from the University of Jyvaskyla in Finland.

↑ Research Team of scientists

b

Lab A ~ Map



Legend:

= Door

= Bulletin/White Board

= Chairs

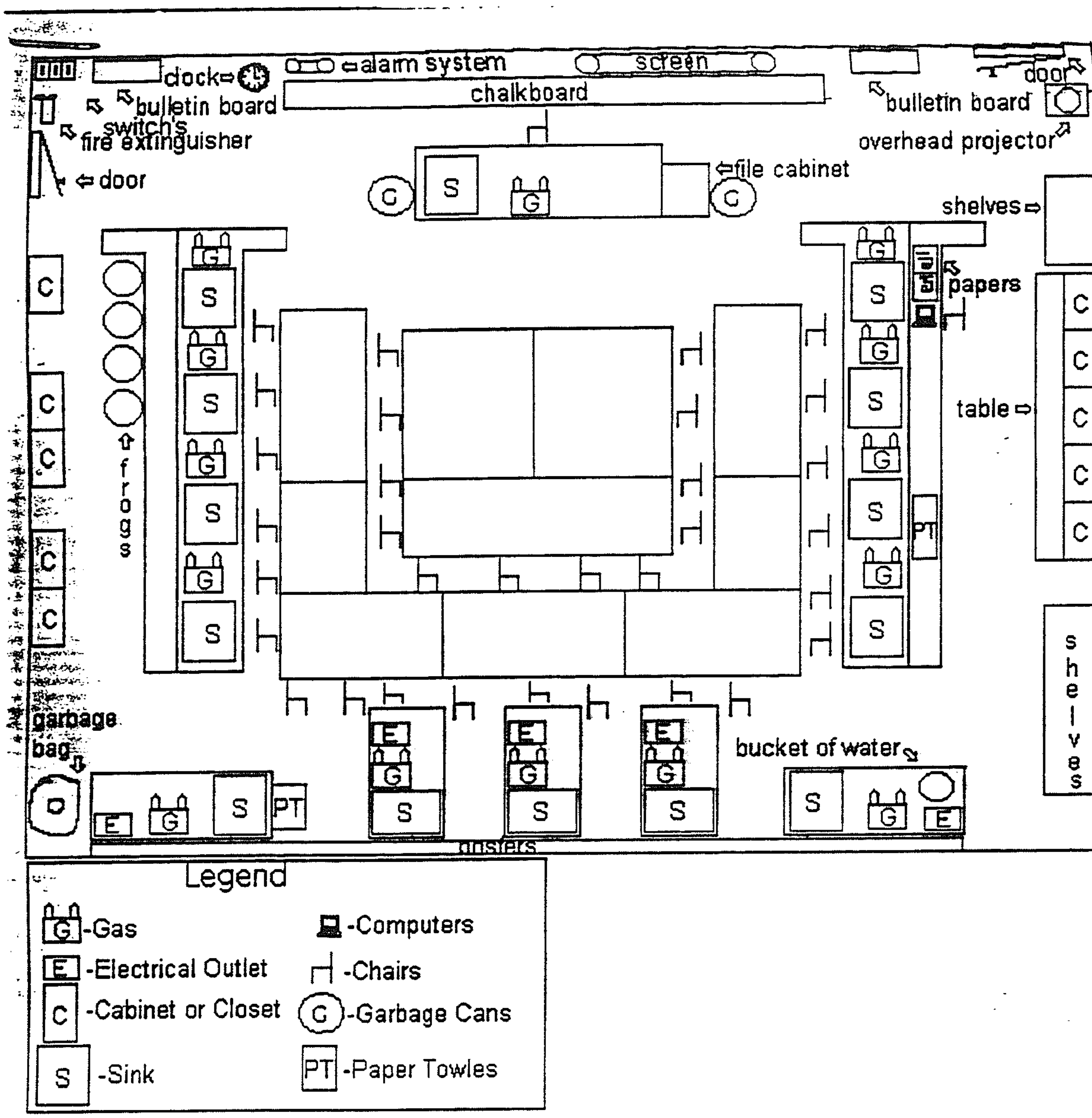
= Sink

= Gas (switches)

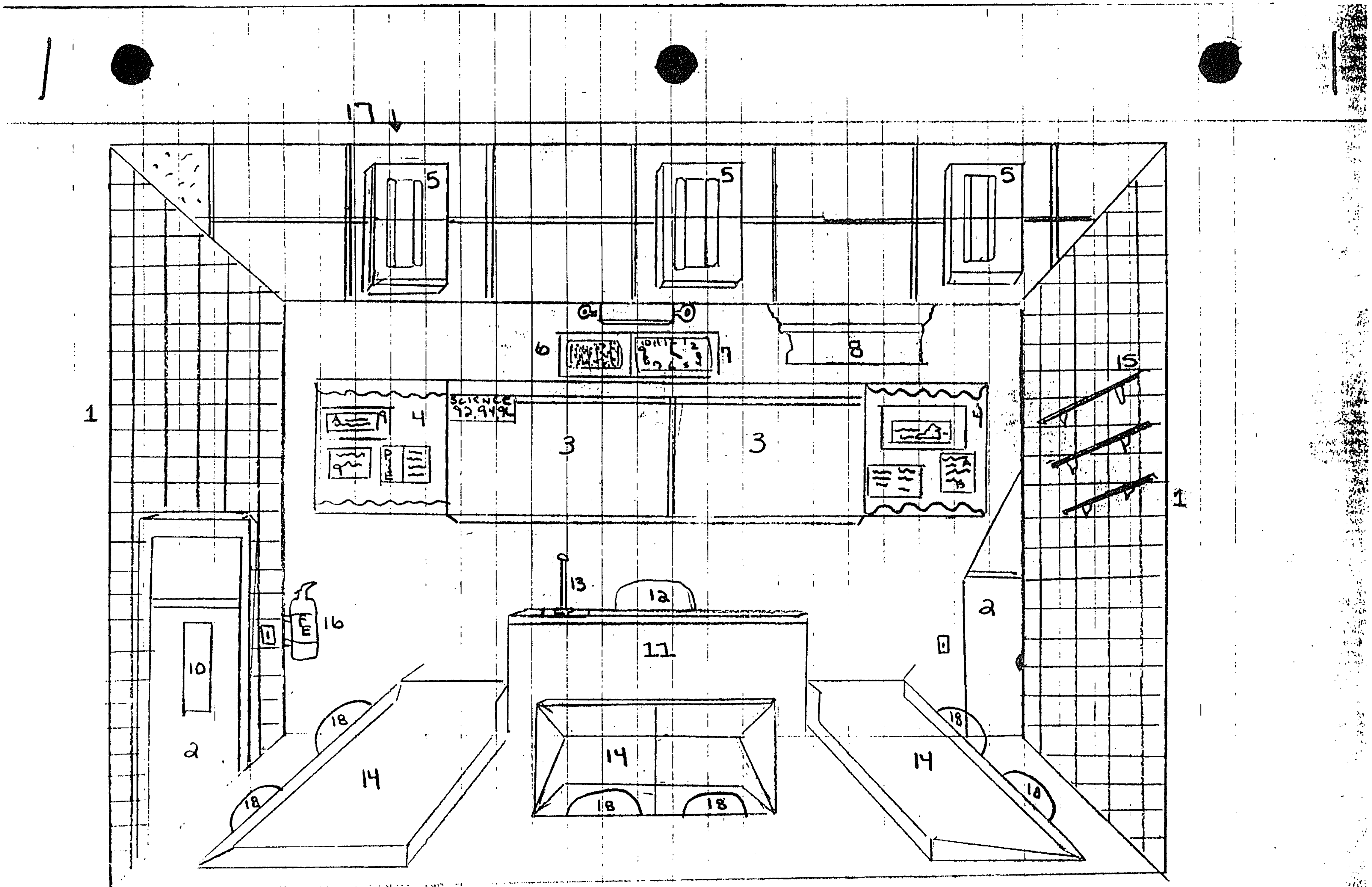
= Shelves/Cabinets

= Desks

c



clock
alarm system
screen
chalkboard
bulletin board
switch's
fire extinguisher
door
bulletin board
door
overhead projector
file cabinet
shelves
papers
table
frogs
shelves
garbage bag
bucket of water
posters
Legend
-Gas
-Computers
-Electrical Outlet
-Chairs
-Cabinet or Closet
-Garbage Cans
-Sink
-Paper Towles



9-6 Class Room

d

Classroom Legend

1) Walls
2) Doors
3) White board
4) Bulletin Board
5) Lights
6) Intercom speaker
7) Clock
8) projector
9) notices.
10) door window
11) Teacher's desk
12) Teacher's chair
13) Tap
14) Desks
15) Shelves
16) Fire Estinguisher
17) ceiling
18) chairs

e

The theory of continental drift was first pondered by Ben Franklin. In his time Ben's idea would have seemed insane. Today this theory would be incredibly believeable.

Scientists have studied the theory of continental drift for many years and many scientists believe that there once was a super continent. This super continent was named **Pangaea** meaning: **All-Lands.** According to the theory the land broke up and drifted over many millions of years to their present state.

When you look at a map of the earth the continents look like pieces of a **jigsaw puzzle.** They all seem to fit together neatly. The most apparent is **the eastern coast of South America, it is almost the exact reciprocal of the western coast of Africa.**

In fact early paleontologists thought that there was a land bridge connecting South America & Africa. This was because they found similar fossils on the coasts of South America & Africa. This supports the theory because it would be logical to believe that the two continents were once connected, less likely by a land bridge. This was further supported by the scientists & geologists who found as predicted the **date of rocks from Brazil** showed the same geologic province that were present **in Africa.** Similar situation in Europe + North America.

Fig 1

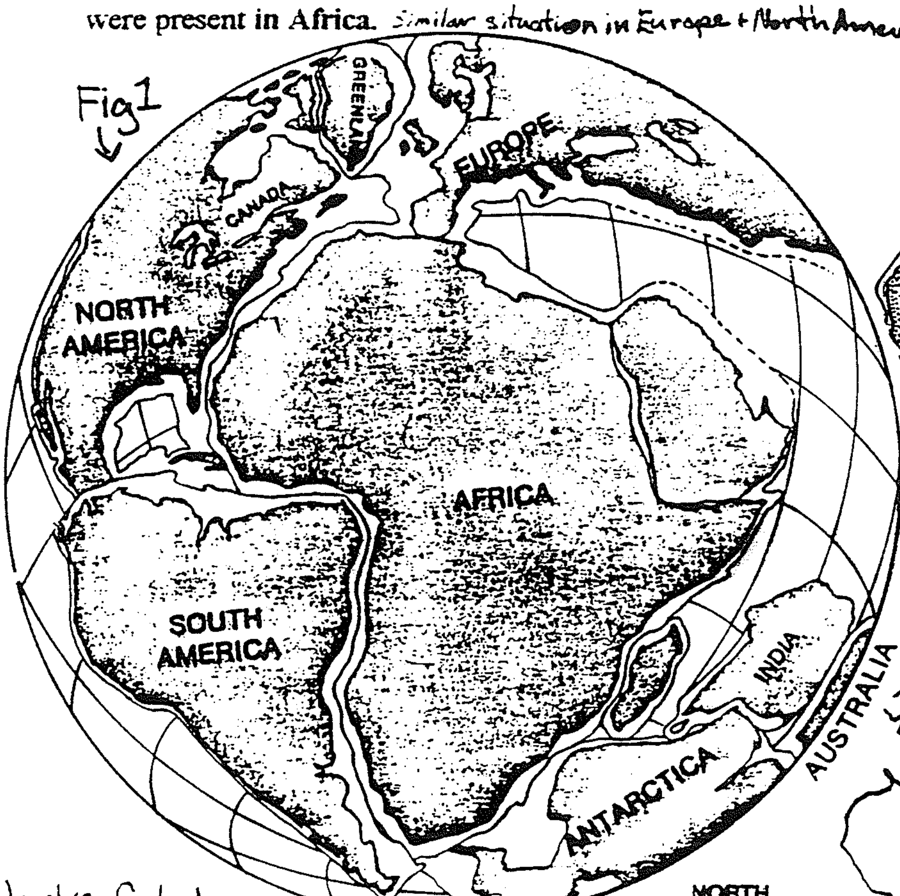
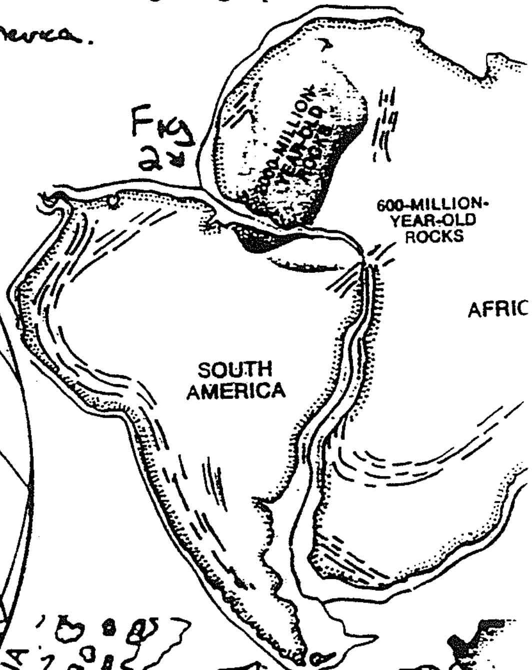
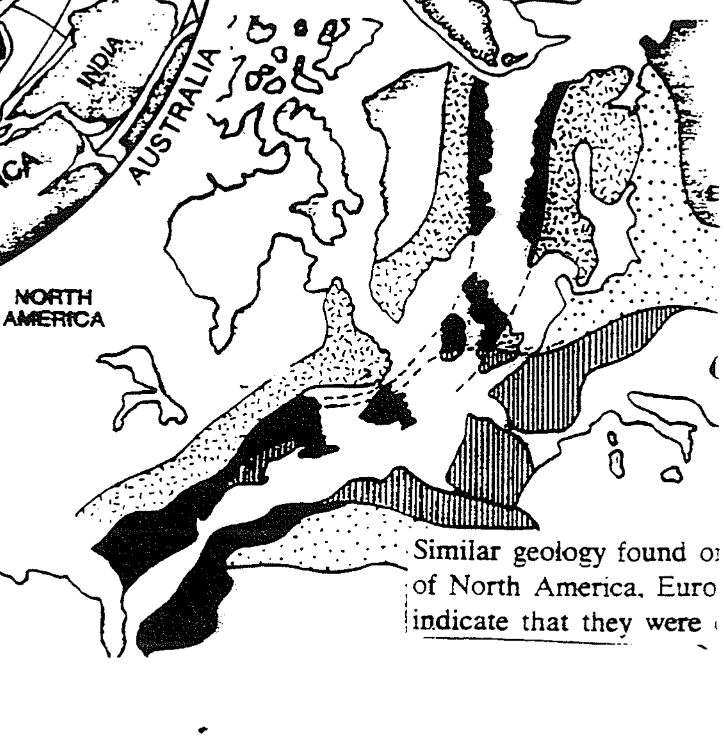


Fig 2





Similar geology found o
of North America, Euro
indicate that they were

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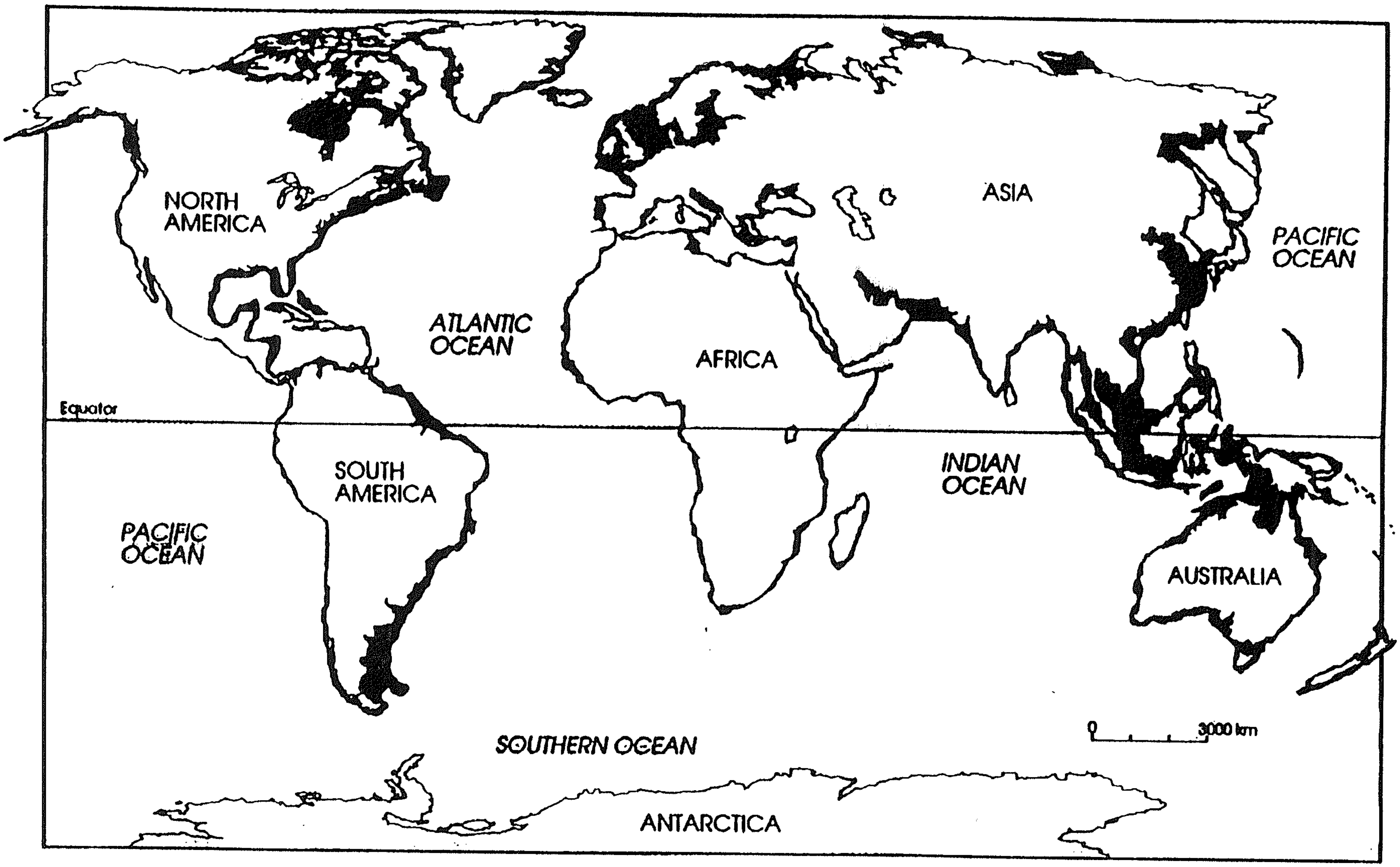
■ Use the following map when you do *Science Inquiry 5B*, on page 179 of your textbook.



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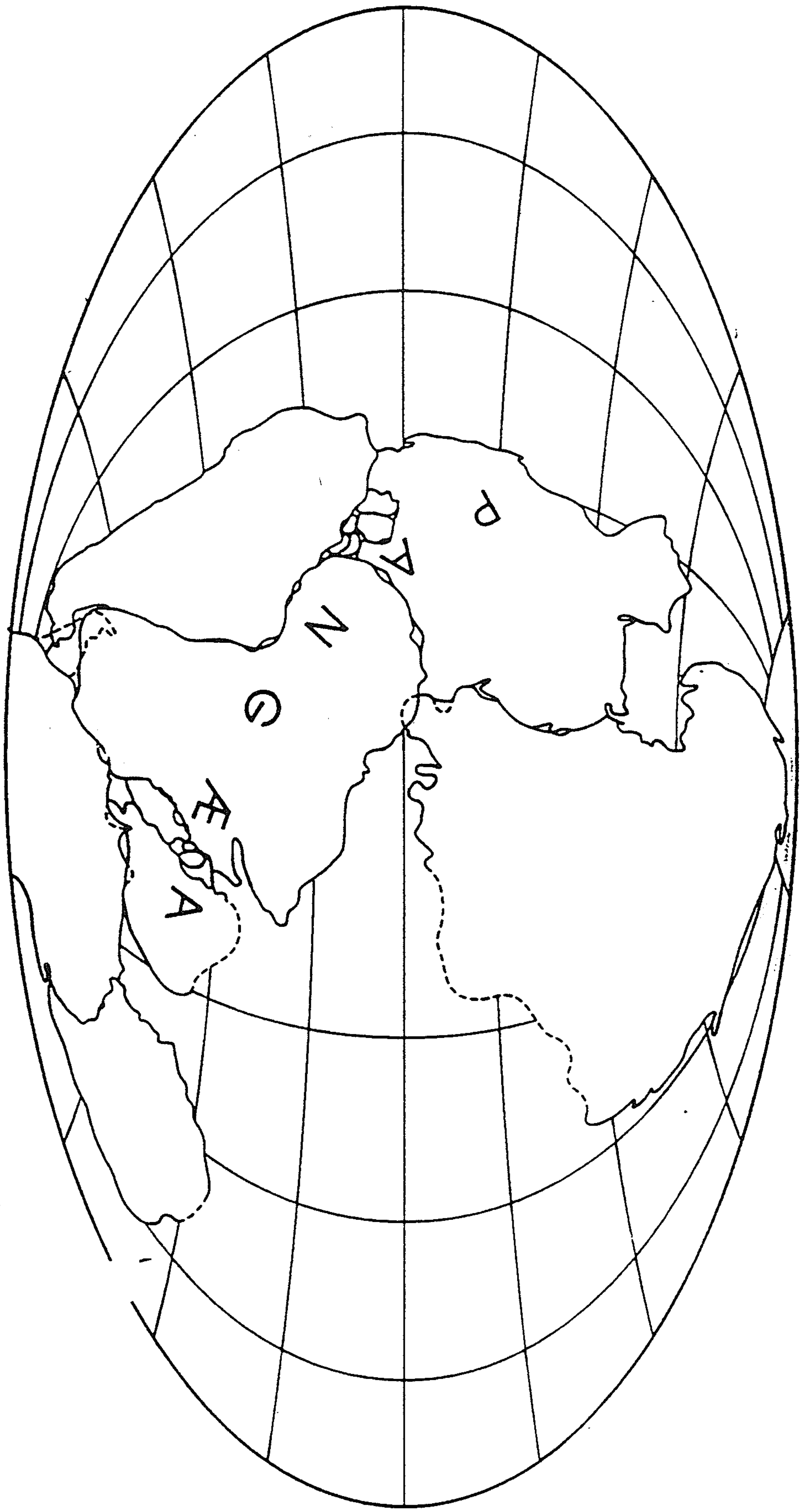

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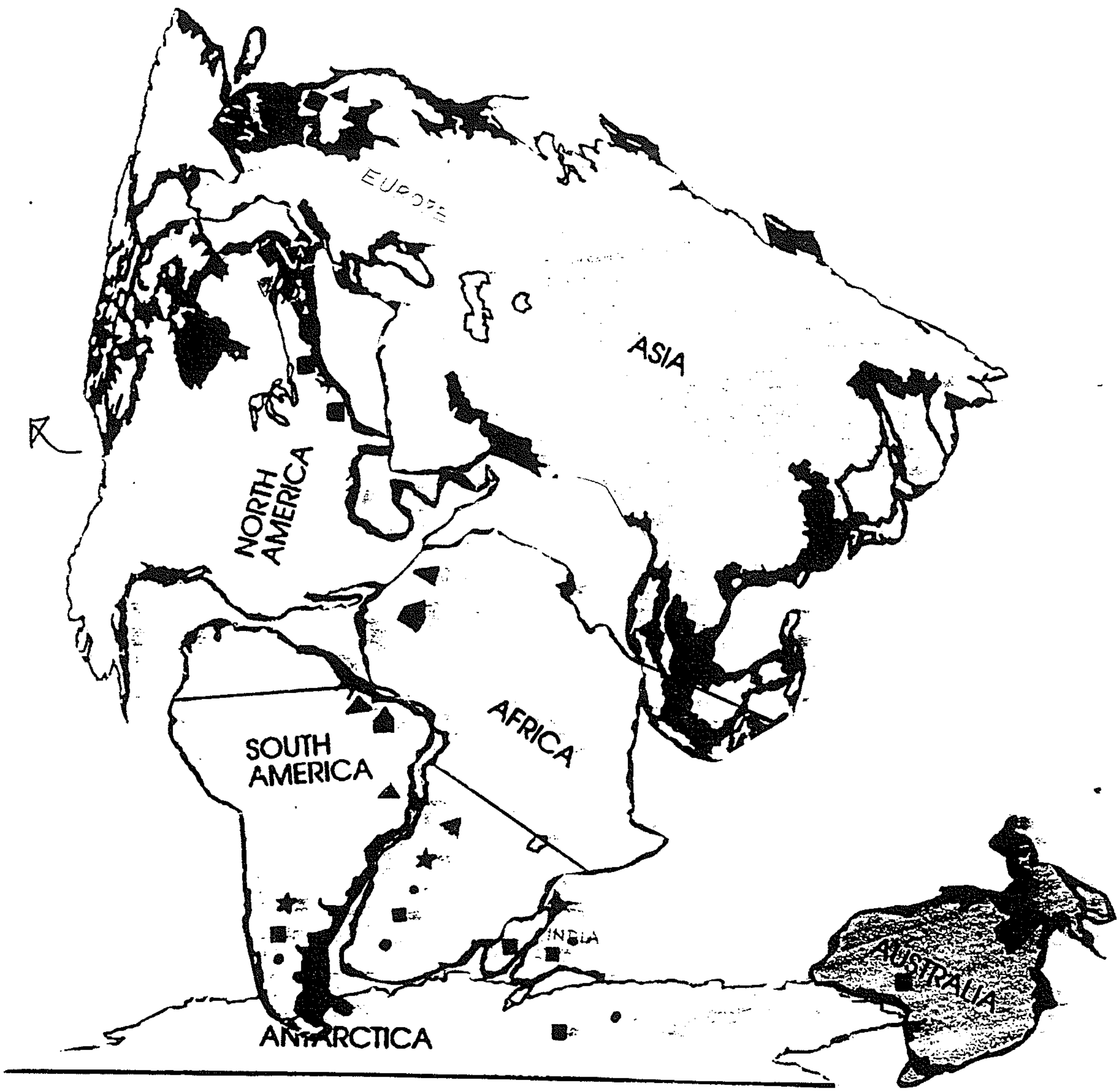
Name :

Class : 9-4

Date : Dec. 15/94

PANGAEA

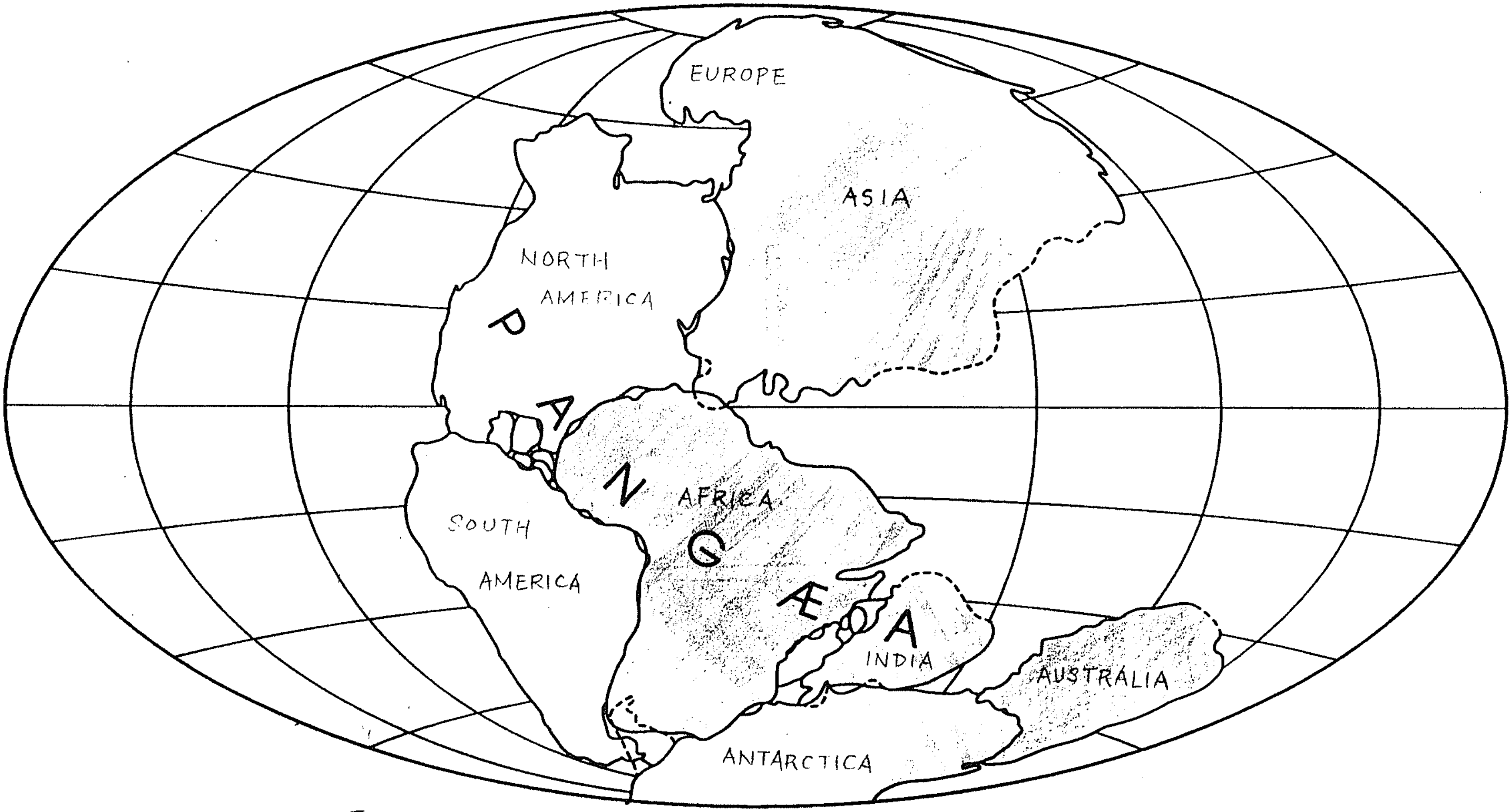


This land mass is called Pangaea. It existed 250 million years ago. It includes all of the continents today.

8/10

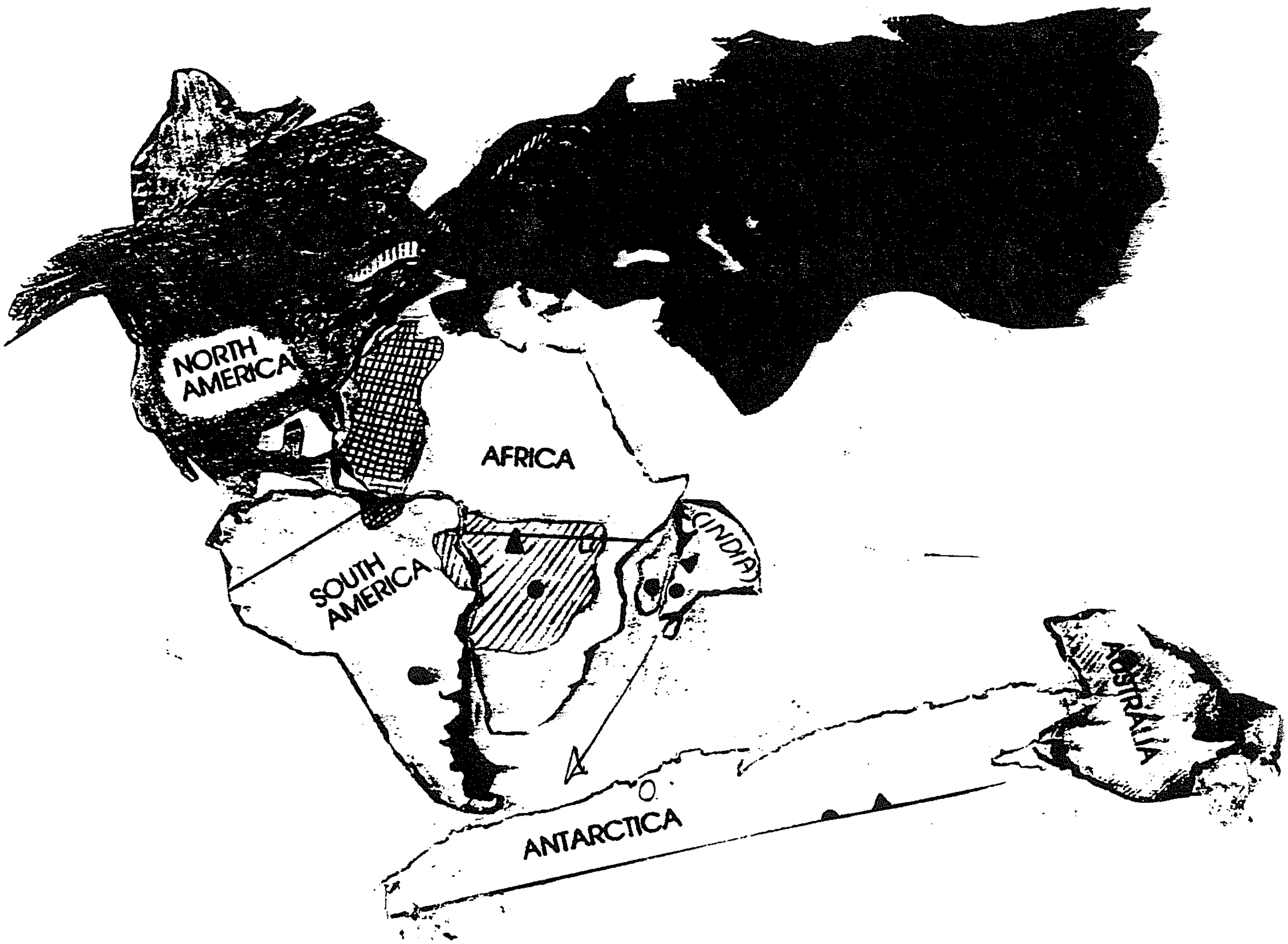
EGEND :

- ★ Cynognathus
- • Lystrosaurus
- ■ Glossopteris
- • Mesosaurus
- ■ geology (similar)
- ▲ 2000 million year old rocks
- ▲ Rock formation #1
- ▲ Rock formation #2


EUROPE
ASIA
NORTH AMERICA
PANGÆA
AFRICA
SOUTH AMERICA
INDIA
AUSTRALIA
ANTARCTICA

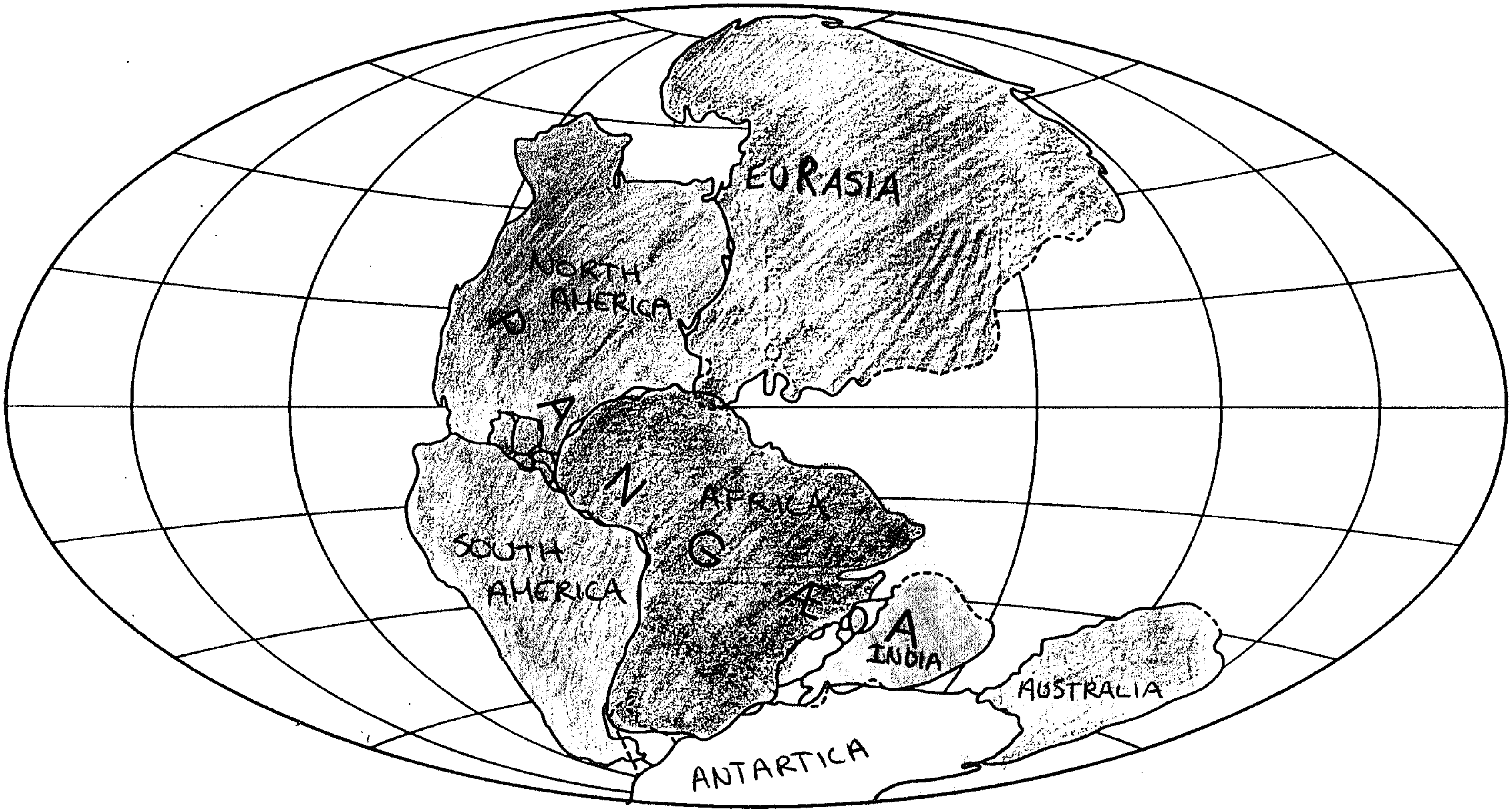
Pangaea

• Pangaea existed 250,000,000 years ago.



9/10 ✓

egend;
Lystrosaurus
Glossopteris
Rocks same composition
ountain ranges similar



The world 250 million years ago

PANGAEA

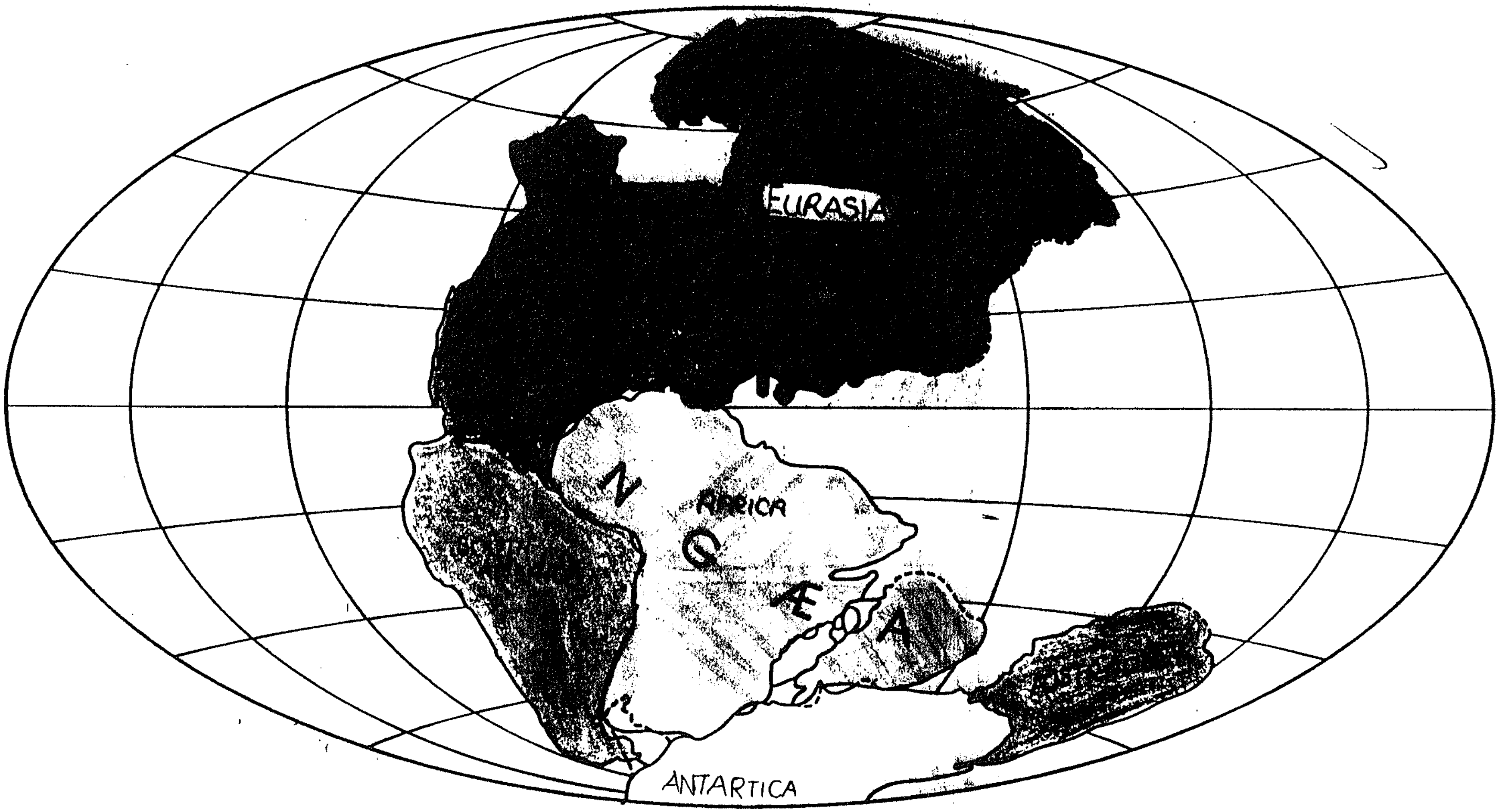
h

GEND

ıesosaurus
lossopteris
ystrosaurus
ynognathus
similiar rock and
mountain formations

8/10

A LOOK AT THE WORLD
250 MILLION YEARS AGO.


EURASIA
AFRICA
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ANTARTICA

Jan. 13, 1995

Earthquakes - Focus & Epicenter

9-6

The focus of an earthquake is an underground point where the release of accumulated pressure begins. The released energy moves outward from the focus and along the fault plane.

The epicenter of an earthquake is on the surface of the earth directly above the focus. This is where the damage is the greatest.

Scientists usually use information from three or more seismographs in three different locations to calculate the distance between the epicenter and seismographs by recording the difference between the arrival times of P-waves and S-waves. Since one measurement cannot tell scientists which direction the epicenter is located, they draw circles around the seismographs using the seismographs as the center. The calculated distance between the epicenter and seismograph is used as the radius of the circle. The location of the epicenter is where the different circles intersect.

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EARTHQUAKES
"TSUNAMI'S"

A Tsunami is a term used to describe large waves generated by undersea earthquakes. When an earthquake starts, the ocean floor tilt causing Tsunami's.

Tsunami's can sometimes reach speeds of up to 725Km/h to 800Km/h. Tsunami's can also reach heights of up to 30 meters high. Tsunami's have been known to destroy entire coastal settlements.

The wave, or Tsunami, originates out at sea being only a foot or so high. As it gets closer to the shore it loses speed. As it slows down, the height of the wave increases causing huge waves known as Tsunami's.

Tsunami's most often occur around the "Ring of Fire" which is located around most of the Pacific ocean.

Approximately 40 Tsunami's have occurred in the past 160 years on the Hawaiian Islands. This is most likely because it is along the coast of the Pacific ocean.

"WORKS CITED"

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Figure 6-10 By finding the epicentre, scientists can determine where an earthquake is likely to have had the greatest effect on people.

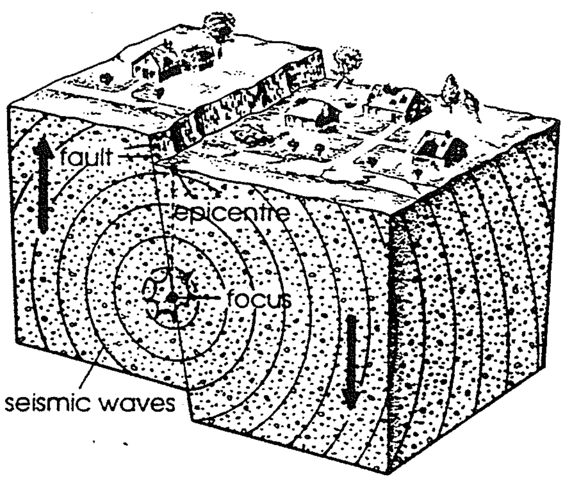
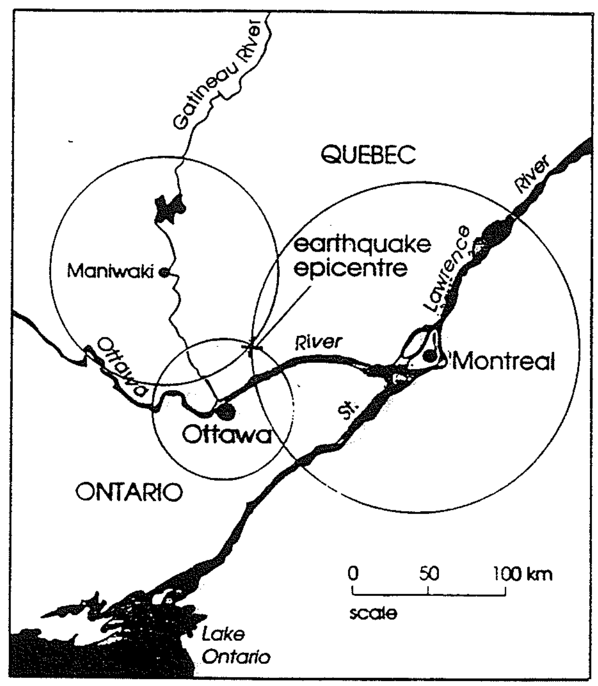


Figure 6-11 The epicentre of this earthquake in southwestern Quebec was located using data from three seismograph stations.



Free Press Mon. Dec 14/92

Rescuers search through rubble after quake kills 1,232 Indonesians

Coastal villages wiped out

From FP news services

JAKARTA — RESCUERS dug in wrecked houses and buildings yesterday searching for survivors of a powerful earthquake that killed at least 1,232 people in Indonesia, the government said.

Hundreds of people were injured when the quake rocked the East Nusa Tenggara province of Flores island Saturday afternoon, officials said.

Whole villages in coastal areas were wiped out by huge ocean waves caused by the quake, said Hendrik Nai, a spokesman for the rescue operation. The waves, called tsunami, were as high as 25 metres and swept as far as 300 metres inland, he said.

Nai said the tremor wrecked about 80 per cent of the buildings in Maumere, a town of 40,000 on the eastern part of the island. About 1,120 of the known deaths were in Maumere, the provinicial governor's office reported.

Poor communications hampered the gathering of information from remote parts of the island, a poor copras-growing area about 1,600 kilometres east of Jakarta.

The earthquake measured 6.8 on the Richter scale, said Indonesian officials.

The U.S. Geological Survey in Menlo Park, Calif., measured it at 7.5. A quake of that magnitude is capable of causing widespread, heavy damage.

Gov. Hendrik Fernandez visited Maumere yesterday and was shocked by the devastation, spokesman J. Gadidjou said.

"All our development efforts for the last 25 years have disappeared in just one day," Gadidjou quoted the governor as saying.

Gadidjou said ships were carrying volunteers, food and medicine from nearby towns to the damaged areas.

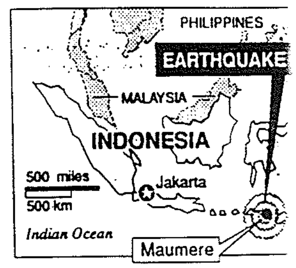
Rescue work was hindered by aftershocks that occurred about every five minutes until around midnight Saturday night, Nai said.

Most people spent the night in fields and other open areas w tents in a tropical rainstorm, f further collapses of buildings cials said.

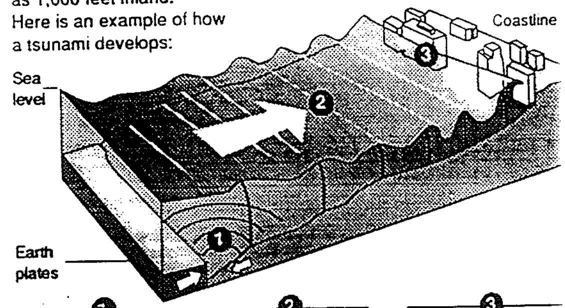
The quake destroyed gover buildings, schools, m churches and shops in Maume Larantuka.

Tsunamis: The killer sea waves

Whole villages in coastal areas in southeast Indonesia were wiped out by huge ocean waves triggered by a powerful earthquake that measured 6.8 on the Richter scale. The waves, called tsunamis, were as high as 80 feet and swept as far as 1,000 feet inland.



Here is an example of how a tsunami develops:



1
- Tsunamis are generated by massive underwater earthquakes and are common around the Pacific.
- The destructive waves can travel at more than 435 mph.

2
- The waves move inland from deep ocean to shallow water, growing larger.
- Individual waves may occur at intervals of 15 minutes, or 125 miles apart.

3
- Approaching a coast, the waves sk down, bunch up an rise. They may rise high as a ten-story building.
- When the waves break, they can ca great destruction.

Source: *The Random House Encyclopedia, Our Violent Earth*

The Globe and Mail, Monday, November 21, 1994

TIDAL WAVE / *A deadly 'mountain' of water swept Newfoundlanders to an icy Atlantic death*

Sand, pebbles may solve riddle of 1929 quake

BY KEVIN COX
Atlantic Bureau
Point au Gaul, Nfld.

ABOUT 7:30 p.m. on the moonlit evening of Nov. 18, 1929, seven-year-old Norah Hillier heard a loud roar, looked out of the window of her Newfoundland outport home a few metres from the sea and thought she saw thousands of sheep riding a mountain of water.

What the terrified child witnessed was the foam on the deadliest and most destructive tidal wave in Canadian history.

The wave, caused by an underwater earthquake 350 kilometres away, killed 29 people, including several young children and elderly people who drowned in wooden homes that were swept into the frigid Atlantic Ocean off southeastern Newfoundland. The only other death attributed to an earthquake in Canada occurred in Vancouver in 1946.

"We saw all this white coming and I cried 'Oh, all the sheep!' It seemed the water was mountains high," Mrs. Hillier recalled in a recent interview. "In a matter of seconds we were up to our waists in water. . . . My oldest sister pushed shut the door and we all held onto the doors, waiting for someone to rescue us. We were so frightened. We didn't know what it was."

The seven-metre-high tidal wave, known as a tsunami, was produced by a massive earthquake measuring 7.2 on the Richter scale, about 18 kilometres below the floor of the north Atlantic. It was bigger than the 1989 earthquake in the Oakland Bay-San Francisco area that registered 6.9 on the Richter scale, killed more than 50 people and caused $10-billion in property damage.

The 1929 quake was felt as far away as Bermuda and Portugal and swept a man to his death off Cape Breton. But its chief impact was in the narrow bays of the Burin Peninsula, where the wave first hit land.

Until the late 1980s there was little documentation of the disaster. Re-

"The wreckage was five feet high in places . . . it was only good for matchwood," Mr. Hillier said.

Word of the disaster did not reach St. John's for several days because telegraph lines were down and there were no roads into the area.

Doctors eventually treated more than 50 injured or sick people. The hundreds of survivors were helped by a $250,000 fund donated by other Newfoundlanders.

Sixty-five years later, Mr. Ruffman is still piecing together the story of the earthquake from elderly survivors and from a layer of pink pebbles and fine sand that he and Ms. Tuttle have discovered that the tidal wave left in peat bogs.

The Geological Survey of Canada says such an incident occurs once every 1,000 years. But Mr. Ruffman said no one can explain why the earthquake occurred where it did.

It "just is not understood at all," he said. "There is no obvious faulting. These may be faults that go back millions of years. If you'd looked at the geology even with our modern understanding you wouldn't have predicted an earthquake in that location."

THE WINNIPEG SUN Wednesday, December 16, 1992

Bodies left everywhere after giant waves strike

BABI ISLAND, Indonesia (CP) — Bodies hang from trees, lie scattered on the ground or float off the coast of this once-tranquil island, where 700 fishermen and their families died as giant tidal waves spawned by an earthquake roared ashore.

Tadje Djafar, a village chief on Babi Island, said he lost his wife and three children, including a baby.

"I did not know what to do, because giant waves were coming from the sea. I saved myself by climbing one of the big coconut trees," he said.

"I just don't know how I survived," said a fisherman called Narsisus. "I found myself plucked up and thrown on the beach. It was like the whole village was uprooted."

He lost his father, mother and sisters when the quake struck off the coast of the east Indonesian island of Flores on Saturday, sending huge walls of water crashing on to the main island and swamping Babi.

The governor of East Nusa Tenggara province, Hendrik Fernandez, said the death toll had reached 2,484 by late last night.

The death toll included the 700 dead on Babi island, where only 300 survived.

The once-azure waters around Babi, northeast of the town of Maumere on Flores island, are discolored by blood and the mud thrown up the earthquake.

Inland, not one building has withstood the fury of the earthquake or the waves.

Indonesian troops began mass burials to prevent the spread of disease. The province's military commander, Maj.-Gen. Suwardi, said the troops would also help to clean the debris and put up new homes for the homeless.

Fifty soldiers began digging mass graves on Babi. "There are many, many more bodies to bury," said one.

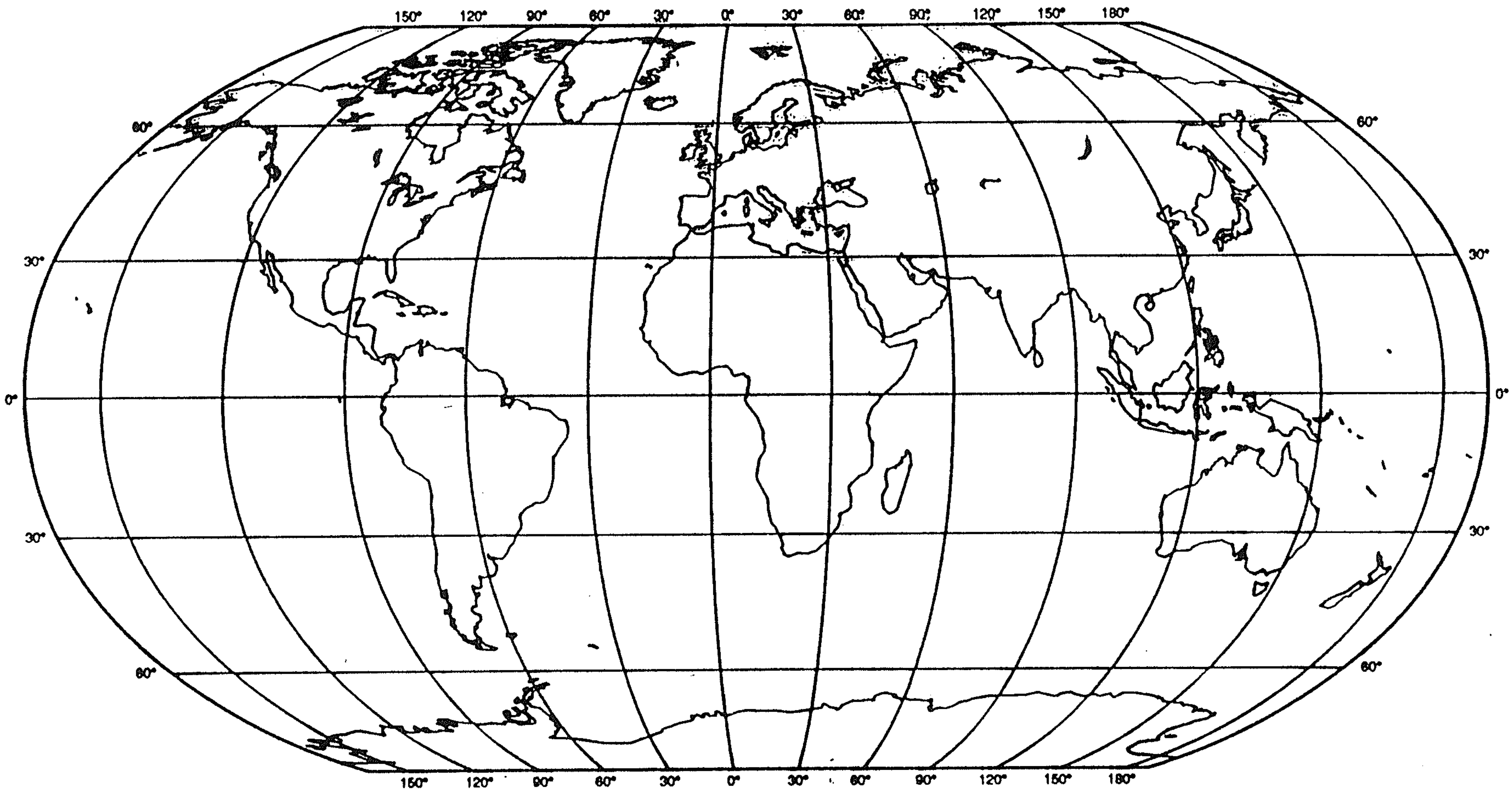
Rescuers spoke in hushed whispers of a dead baby found in a tree. Other bodies hung from branches. The dome of a mosque lay on the ground.

Damages were estimated at the equivalent of $98 million Cdn.

The Canadian Embassy in Jakarta has provided $25,000 to UNICEF for relief supplies to be used for essential supplies like tents, blankets, food and clothing.

So far, no Canadians have been reported among the casualties, the External Affairs Department said.

■ Use the following map of the world when you do *Science Inquiry 6A*, on page 215 of your textbook.



k

From vnielson Fri Dec 2 13:59:16 1994
Received: by access.mbnet.mb.ca id AA20581
(5.67b/IDA-1.4.4 for vnielson@minet.gov.mb.ca); Fri, 2 Dec 1994 13:59:14 -0600
Date: Fri, 2 Dec 1994 13:59:14 -0600
From: Val Nielson <vnielson@MINET.gov.MB.CA>
Message-Id: <199412021959.AA20581@access.mbnet.mb.ca>
Subject: qed94333NOV05.NOV26
Apparently-To: vnielson@minet.gov.mb.ca
Status: O
X-Status:

UTC TIME LAT LONG DEP GS MAGS SD STA REGION AND COMMENTS
HRMNSEC MB Msz USED

NOV 05
021601.0 57.209S 157.780E 10G 6.1 6.2 1.1 29 MACQUARIE ISLANDS REGION.
Mw 6.6

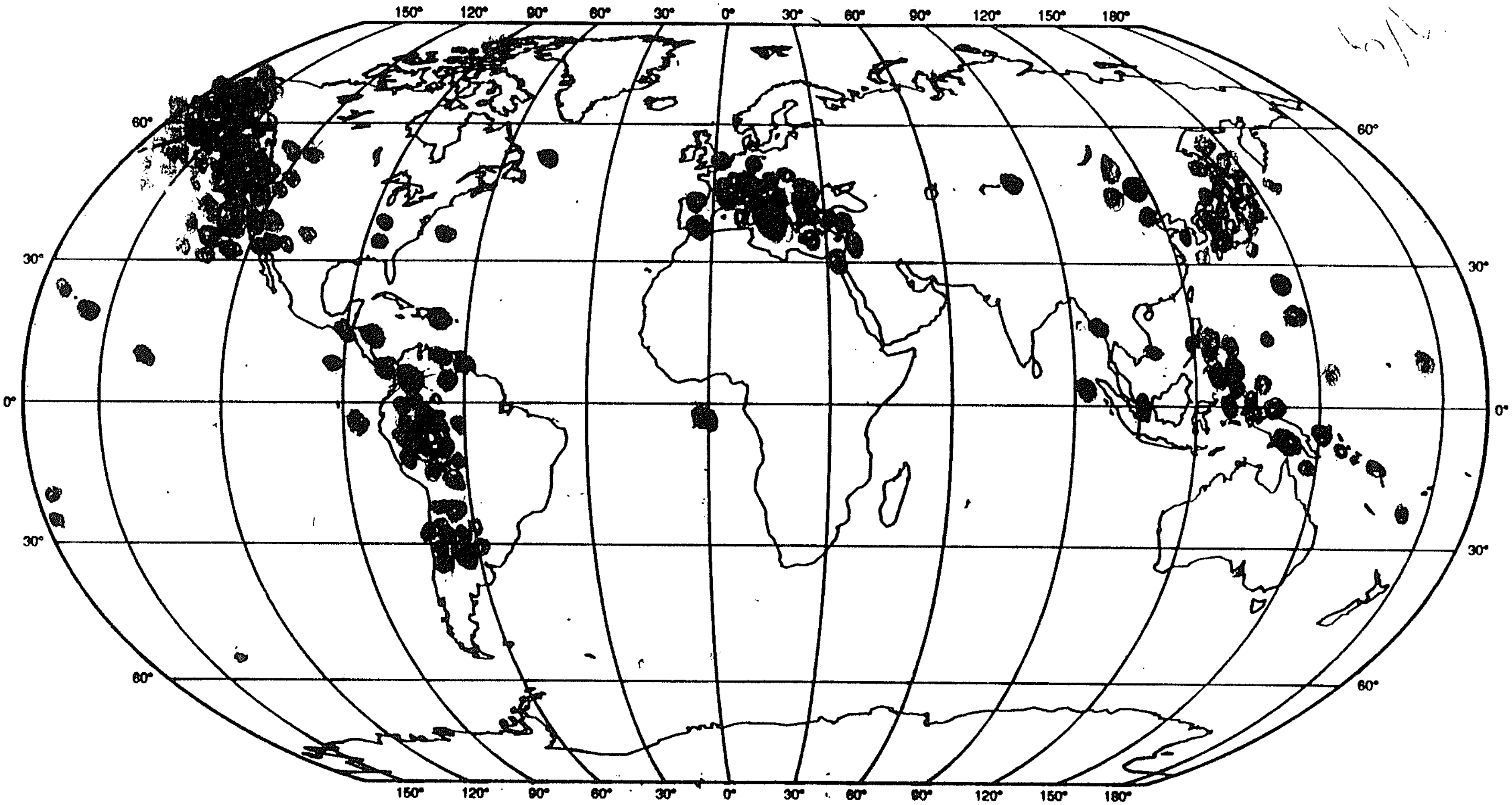
Dep 20.0; Principal axes: (T) Val=8.99, Plg=5, Azm=1; (N) Val=0.37, Plg=81, Azm=239; (P) Val=-9.36, Plg=7, Azm=91; Best double couple: Mo=9.2*10**18 Nm; NP1: Strike=136, Dip=81, Slip=-2; NP2: Strike=226, Dip=88, Slip=-171. Centroid, Moment Tensor (HRV): Centroid location: Origin time 02:16:10.9; Lat 57.31 S; Lon 157.21 E; Dep 26.4; Half-duration 3.6 sec; Principal axes: (T) Val=3.97, Plg=13, Azm=356; (N) Val=-0.13, Plg=67, Azm=233; (P) Val=-3.84, Plg=19, Azm=91; Best double couple: Mo=3.9*10**18 Nm; NP1: Strike=133, Dip=67, Slip=-4; NP2: Strike=224, Dip=86, Slip=-157.

041244.5? 42.86 N 128.68 W 10G 0.4 41 OFF COAST OF OREGON
042216.1 31.665N 116.215W 5G 0.6 36 BAJA CALIFORNIA, MEXICO. ML 3.2
(GS).
045730.4* 7.493S 75.761W 134D 4.6 0.8 30 NORTHERN PERU
085043.6% 45.016N 6.995E 5G 0.4 5 FRANCE. ML 2.0 (GEN).
095041.3* 43.834N 128.454W 10G 0.4 28 OFF COAST OF OREGON
095329.4* 43.142N 147.755E 33N 4.6 1.5 17 KURIL ISLANDS
105215.7 10.823N 141.286E 33N 5.3 5.2 1.0 93 WESTERN CAROLINE ISLANDS
120528.7 9.307S 71.391W 594D 5.6 0.9 187 PERU-BRAZIL BORDER REGION.
Mw
5.6 (HRV). Centroid, Moment Tensor (HRV): Centroid location: Origin time

Principal axes: (T) Val=3.42, Plg=4, Azm=276; (N) Val=-0.69, Plg=15, Azm=185; (P) Val=-2.73, Plg=75, Azm=19; Best double couple: Mo=3.1*10**17 Nm; NP1: Strike=21, Dip=43, Slip=-69; NP2: Strike=172,

■ Use the following map of the world when you do *Science Inquiry 6A*, on page 215 of your textbook.

Earthquakes

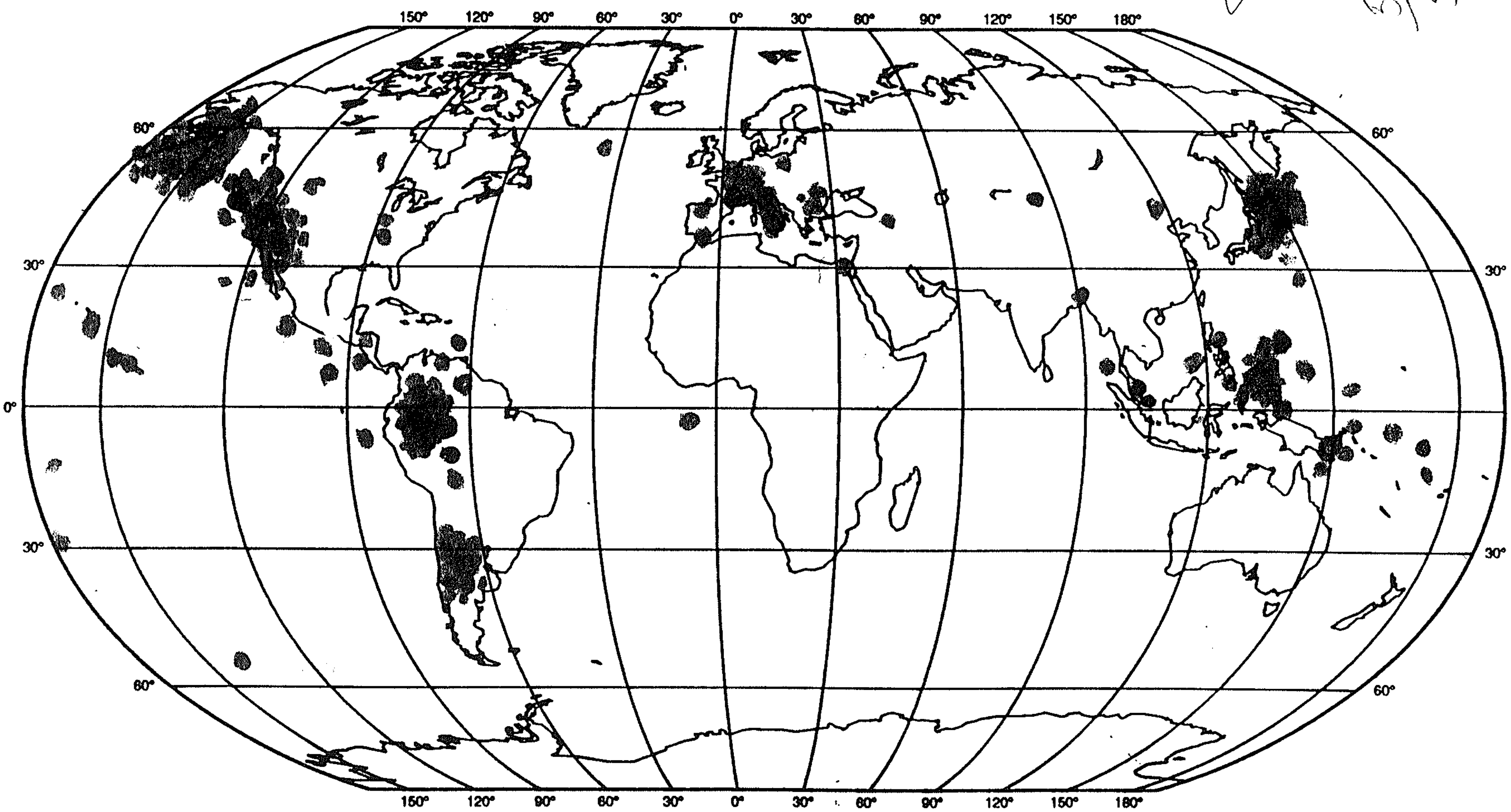


• every dot represents an Earthquake

■ Use the following map of the world when you do *Science Inquiry 6A*, on page 215 of your textbook.

Earthquakes

6/6

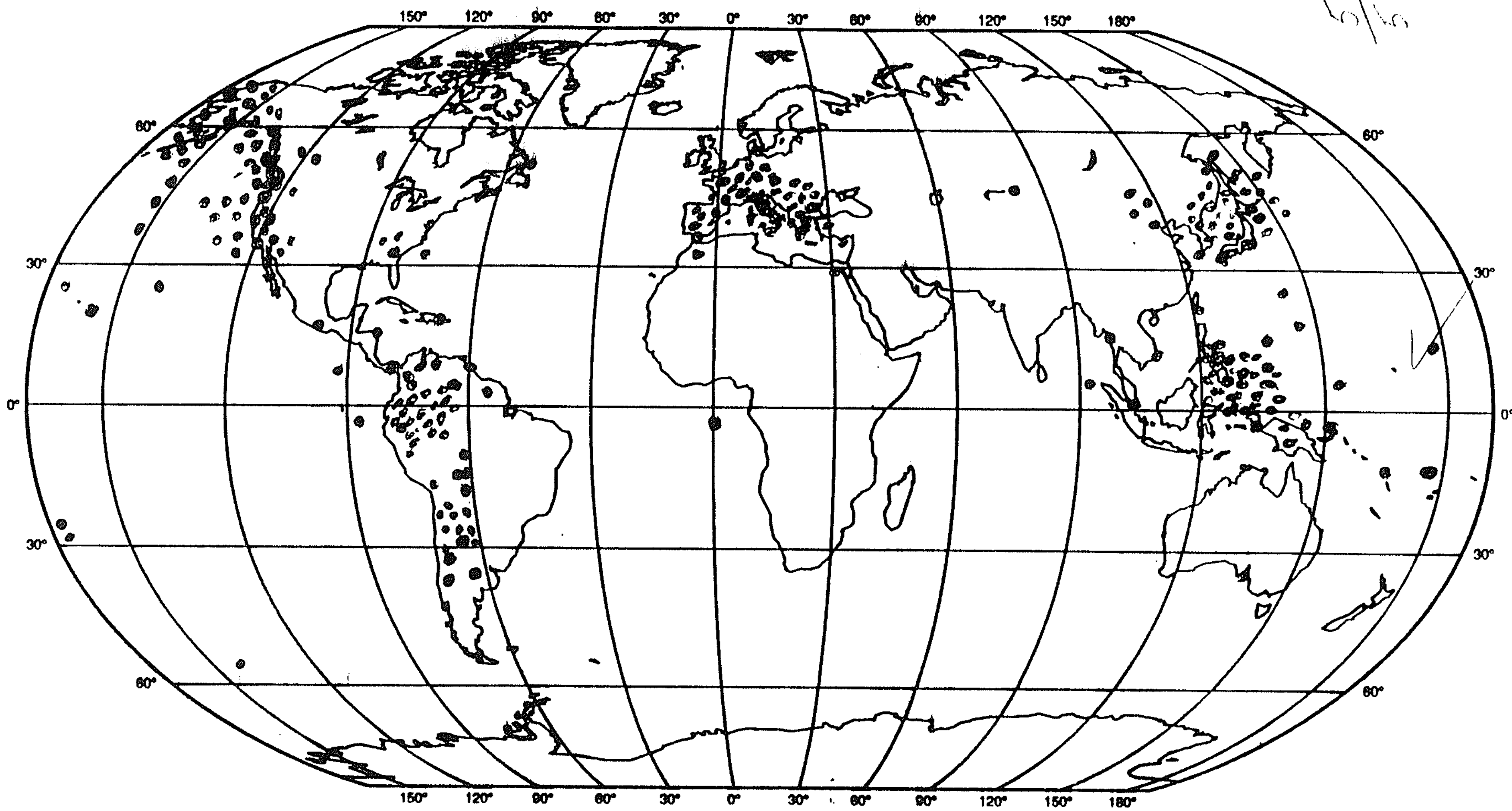


● = one Earthquake

■ Use the following map of the world when you do *Science Inquiry 6A*, on page 215 of your textbook.

Earth Quakes

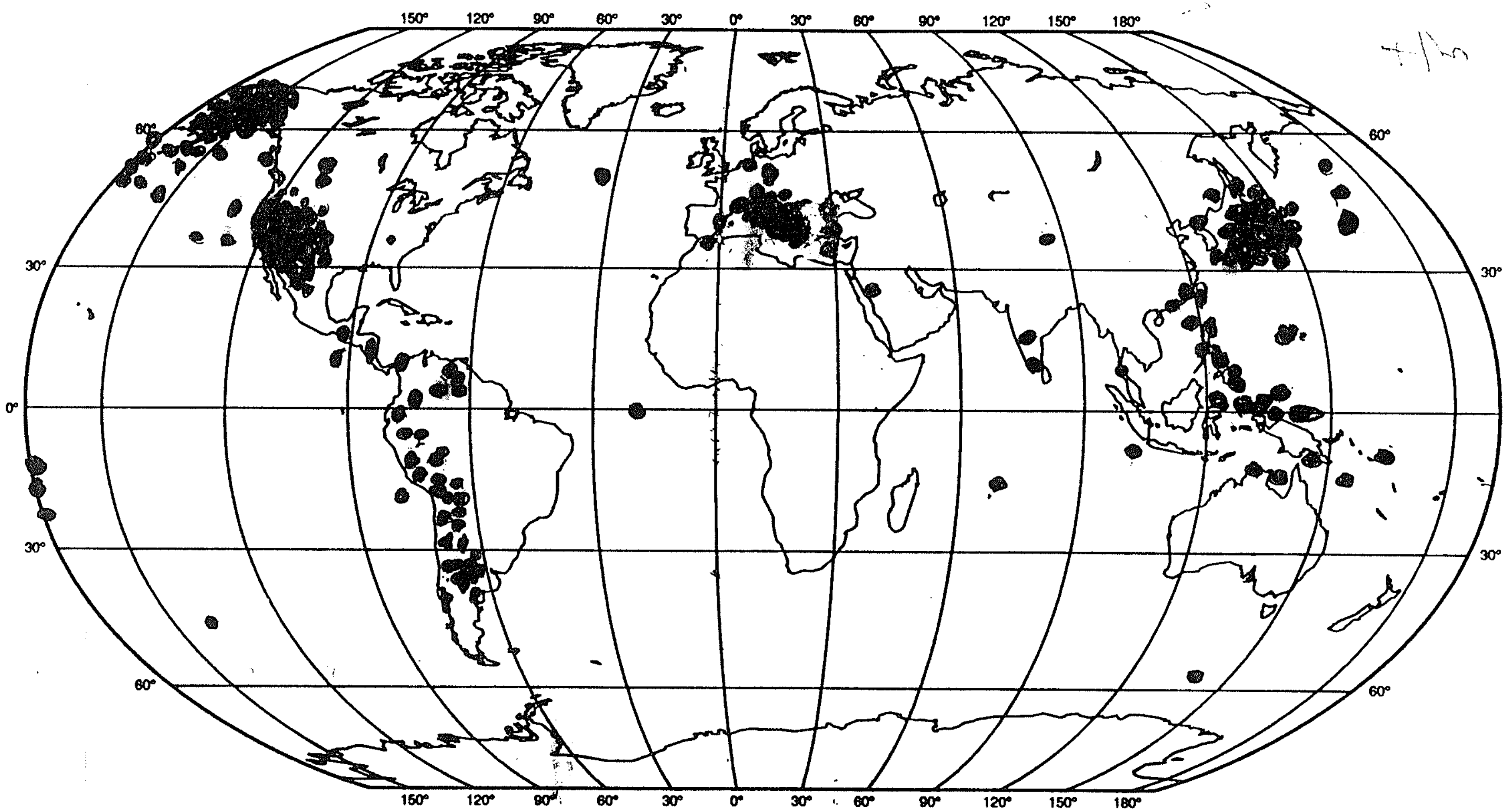
6/6



• every dot represents one earthquake

■ Use the following map of the world when you do *Science Inquiry 6A*, on page 215 of your textbook.

Earthquakes
Each dote represents an earthquake



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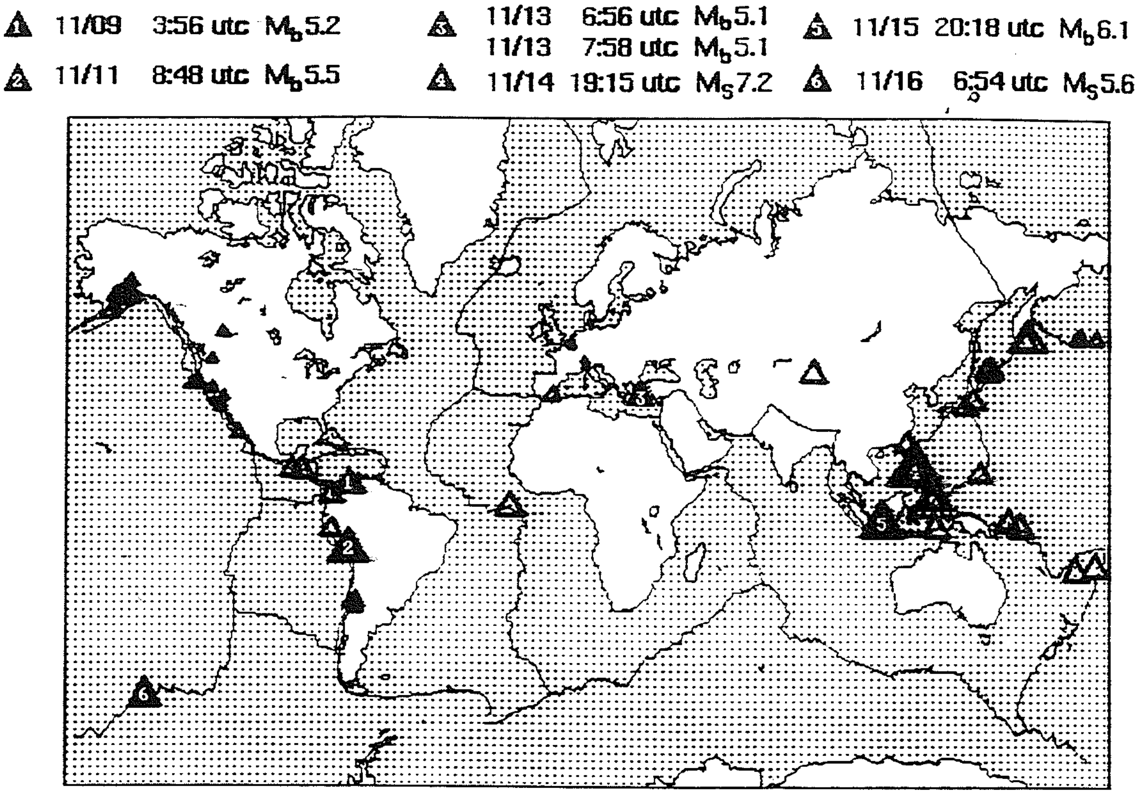
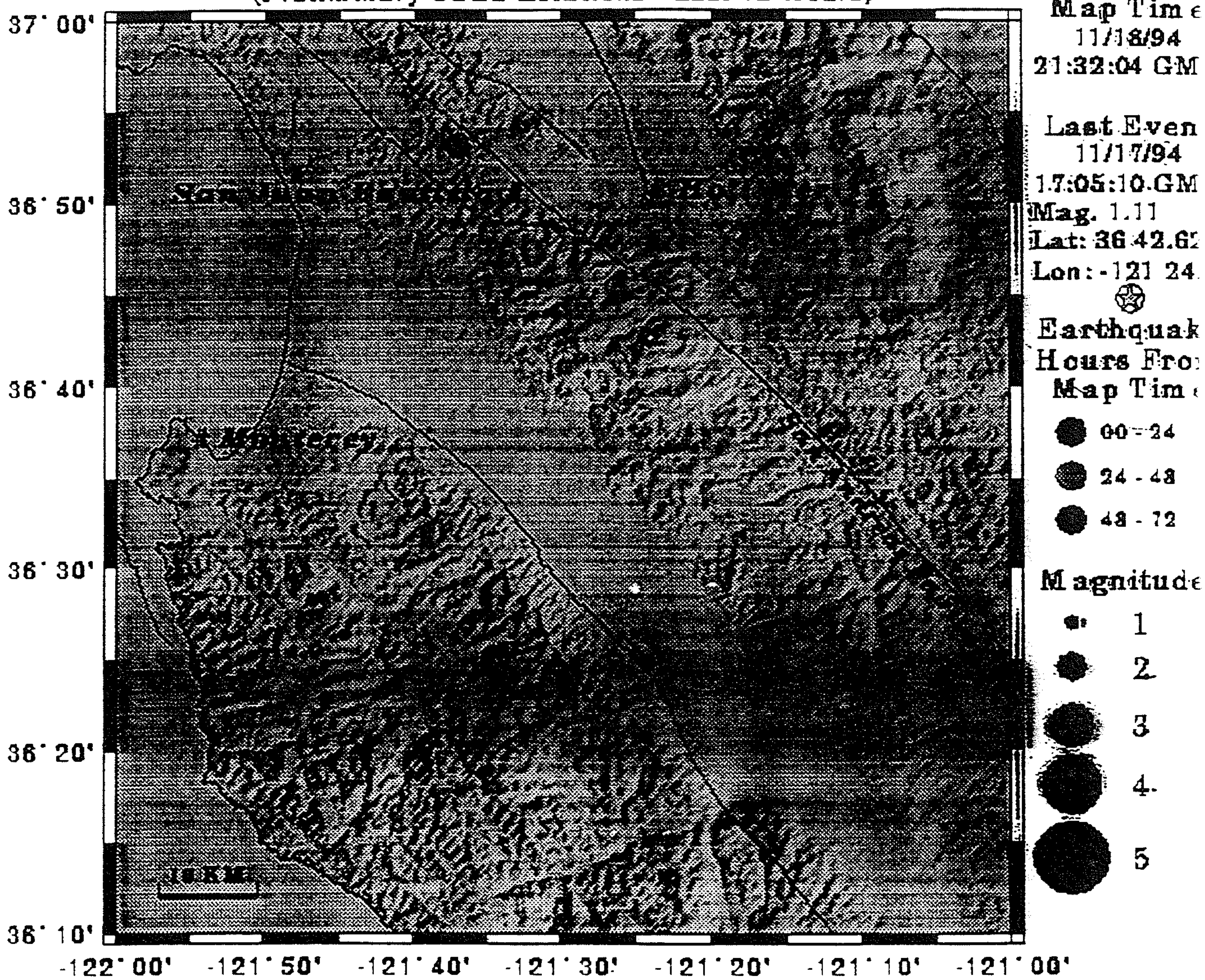


Figure 5

US Geological Service provides maps like this one from Nov. 9-16, 1994, of worldwide earthquake activity. Notice the outlining of the Pacific Plate along the west coasts of North and South America and the east coast of Asia, in only eight days of earthquake activity.

RECENT MONTEREY AREA EARTHQUAKES

(Preliminary USGS Locations - Last 72 Hours)



Recent Global Events

The following near-real-time Earthquake Bulletin is provided by the National Earthquake Information Service (NEIS) of the U. S. Geological Survey as part of a cooperative project of the Council of the National Seismic System. For a description of the earthquake parameters listed below, the availability of additional information, and our publication criteria, please finger qk_info@gldfs.cr.usgs.gov. Updated as of Mon Nov 27 11:12:50 MST 1995.

DATE-(UTC)-TIME		LAT	LON	DEP	MAG	Q	COMMENTS
yy/mm/dd	hh:mm:ss	deg.	deg.	km			
95/11/22	04:15:11	28.54N	34.75E	10.0	7.2Ms	B	EGYPT
95/11/22	07:55:31	29.06N	34.80E	10.0	4.6Mb	C	EGYPT
95/11/22	12:47:02	28.41N	34.67E	10.0	4.8Mb	B	EGYPT
95/11/22	13:27:54	3.03N	96.01E	33.0	5.8Ms	B	NORTHERN SUMATERA, INDONESIA
95/11/23	00:40:22	44.50N	129.13W	10.0	4.0Mb	B	OFF COAST OF OREGON
95/11/23	04:41:44	41.50N	142.51E	33.0	5.0Mb	A	HOKKAIDO, JAPAN REGION
95/11/23	14:13:13	40.29N	143.33E	33.0	5.0Ms	A	OFF E COAST OF HONSHU, JAPAN
95/11/23	18:07:17	29.19N	34.53E	10.0	5.2Ms	A	EGYPT
95/11/24	06:18:54	42.88S	172.07E	10.0	6.4Ms	B	SOUTH ISLAND, NEW ZEALAND
95/11/24	08:11:11	31.82N	116.69W	11.7	2.9Md		BAJA CALIFORNIA, MEXICO
95/11/24	08:26:38	40.64N	127.11W	10.0	4.4Ml	A	OFF COAST OF N CALIFORNIA
95/11/24	16:43:43	28.78N	35.11E	10.0	4.8Mb	A	WESTERN ARABIAN PENINSULA
95/11/24	17:24:12	44.39N	149.13E	33.0	6.4Ms	A	KURIL ISLANDS
95/11/24	21:49:31	51.31N	179.12W	33.0	5.6Mb	A	ANDREANOF ISL, ALEUTIAN IS.
95/11/25	04:05:01	26.76S	26.92E	5.0	5.1Mb	C	REPUBLIC OF SOUTH AFRICA
95/11/25	13:24:01	44.39N	149.17E	33.0	5.0Mb	B	KURIL ISLANDS
95/11/26	03:04:04	12.87S	166.27E	33.0	5.8Mb	C	SANTA CRUZ ISLANDS
95/11/26	13:54:36	28.08S	67.13W	196.1	4.9Mb	B	LA RIOJA PROVINCE, ARGENTINA
95/11/27	03:08:59	51.82N	173.69W	33.0	4.7Mb	B	ANDREANOF ISL, ALEUTIAN IS.
95/11/27	05:24:26	22.84S	70.08W	33.0	5.3Mb	A	NEAR COAST OF NORTHERN CHILE
95/11/27	15:52:58	44.52N	149.27E	33.0	6.0Ms	A	KURIL ISLANDS

Select one of the locations above for a map of that area. Or see the locations of the 5 largest magnitudes on a map of the world.

This message brought to you by the finger server: quake@gldfs.cr.usgs.gov, with the assistance of NMH, and the Department of Civil and Environmental Engineering at Carleton University, Ottawa.

P

Tuesday, January 17, 1995

Huge quake rocks Japan

Hundreds die, thousands hurt

Reuters-AP-CP

OSAKA, JAPAN — A powerful earthquake rumbled through central Japan this morning, killing at least 439 people, injuring thousands and causing apartment buildings and a major expressway to collapse.

Police said about 400 people were still trapped in the rubble of collapsed buildings four hours after the tremor, which struck as many residents were starting their commute to work in the industrial heartland of Japan.

The quake caused damage in the major Japanese cities of Osaka, the country's second largest, the ancient imperial capital of Kyoto and Japan's main western port of Kobe.

Japan's NHK television put the death toll at 513. Government officials said more than 13,000 people were injured.

No Canadians were reported hurt in the hours immediately following the quake, said Stephane Jobin, press officer at the Canadian Embassy in Tokyo.

Wilf Wakely, trade commissioner for the B.C. government in Kobe, sent a fax to Victoria saying he was safe.

Firefighters tackled gas leaks in the three main cities and off-duty doctors and nurses were called in.

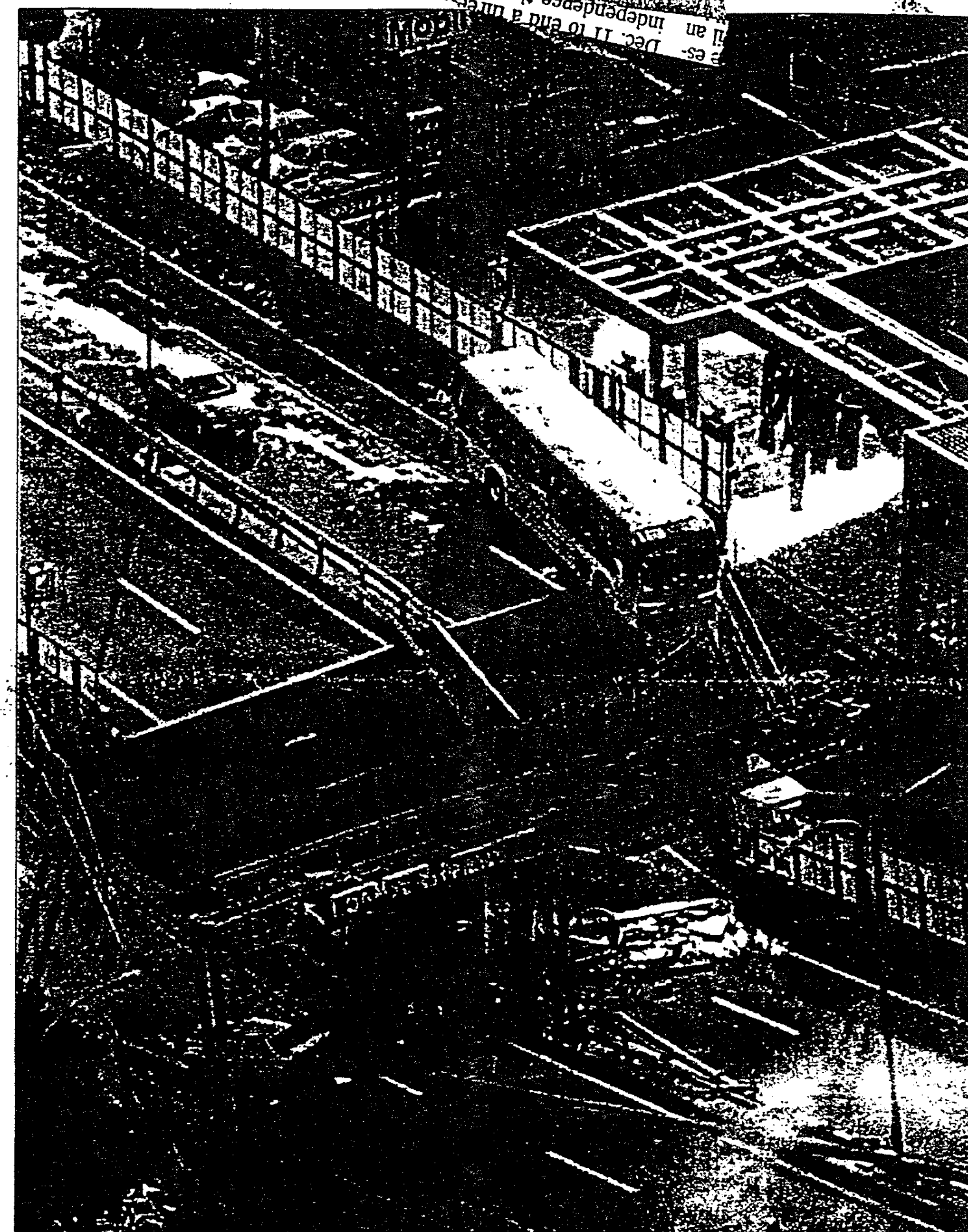
Television showed dozens of dazed residents in pajamas wandering streets in Kobe, small fires burning in all three cities and yawning gaps in the elevated Hanshin Expressway which connects Osaka to Kobe.

About 50 cars plunged off the expressway which was buckled in at least three locations near Kobe. Police said at least two motorists died and 20 were injured as their cars were flung from the expressway or drove into the gaps in the highway.

Ten trains were derailed by the tremor, which measured 7.2 on the open-ended Richter scale, the biggest earthquake to strike central Japan for 47 years.

The Japan Meteorological Agency said the earthquake rumbled across the centre of Honshu Island from the Japan Sea to t Pacific Ocean at 5:46 a.m. (2: p.m. CST). Its epicentre was cated about 20 kilometres benea the island of Awajishima which about 30 kilometres off the coast Kobe.

Experts have been warning of possible major earthquake for t past few weeks.



AP PHC

A bus hangs from Hanshin Expressway in western Japan after earthquake struck.

9

under the rubble

Rescuers race against clock as quake traps hundreds

AP-CP

KOBE, JAPAN — Rescuers dug desperately through the rubble today for survivors after a powerful quake tore through parts of western Japan, killing more than 2,000 people, toppling buildings and touching off raging fires.

Hundreds of people were still trapped in crumbled buildings.

▪ Brandon dad relieved / A4

▪ Thousands homeless / A5

Police said 2,014 people were known dead by midday today, 1,058 were missing and 11,977 injured.

Motorists perished as their cars skidded off collapsing highways. Tracks and bridges for Japan's fa- · bullet trains were damaged b ..y enough to be out of action for months. Hundreds of thousands of survivors struggled to live without electricity, gas or water.

Many of the fires touched off by the quake ran out of fuel and burned themselves out.

Hardly a block in Kobe, an industrial port city of 1.4 million people, had a house or building intact. Many streets were reduced to piles of rubble by the strongest quake to strike an urban area of Japan since 1948.

Osaka, Japan's second-largest city which is across the bay from Kobe, was also heavily damaged by the 7.2-magnitude quake that struck before dawn yesterday. The wreckage extended 80 kilometres northwest of Kobe to the sacred temples and statues of the ancient city Kyoto.

The quake was centred 20 kilometres under Awaji Island in the Inland Sea, the Central Meteorological Agency said. More than 600 aftershocks hit the Kobe area through this morning.

No Canadians were reported in-...l, said Jennifer Sloan, a For-...n Affairs spokeswoman in Otta-...a. There are more than 1,100 Canadians in the area.

About 100,000 people spent last night in emergency shelters.

I don't want to go inside a building," one middle-aged man said, shivering

A truck lies on its side after plunging from the collapsed Hanshin Expressway near Kobe.

9

Winnipeg Free Press
Jan. 1995

Major quakes in Japan this century

Date	Location	Magnitude	# Killed
Jan. 17, 1995	**Kobe**	**7.2**	**over 1,800**
Dec. 28, 1994	Hachinohe	7.5	2
Oct. 4, 1994	Hokkaido and Kuril Is.	8.1	8
July 12, 1993	Okushiri, Hokkaido	7.8	200
Jan. 15, 1993	Kushiro, Hokkaido	7.8	1
May 25, 1983	Sea of Japan	7.7	104
May 16, 1968	Tokachi	7.9	52
June 16, 1964	Niigata	7.5	26
March 4, 1952	Hokkaido	8.2	33
June 28, 1948	Fukui	7.1	5,131
Dec. 21, 1946	Shikoku	8.0	2,000
Sept. 1, 1923	Tokyo	8.3	100,000

Note: A tsunami caused by a quake off the northeastern coast killed 2,990 on March 2, 1933.

AP/Terry Kole

Experts say powerful aftershocks will strike in coming weeks

Associated Press

TOKYO — EVEN as Japan struggled to cope with an earthquake that shattered the western port city of Kobe, quake watchers warned that more powerful jolts could be on the way.

"The movement of active faults like this one would trigger other movements," said Kazuo Oike, a Kyoto University seismologist.

In the weeks before Tuesday's earthquake, Japan had an unusual amount of seismic activity.

Katsuyuki Abe of Tokyo University's Seismology Institute said there was a good chance that aftershocks with a magnitude of greater than six would strike in the coming weeks.

While the areas around Tokyo and the northern island of Hokkaido have suffered a series of quakes in the past few years, the western region around the commercial hubs of Osaka and Kobe has been nearly quake-free for some 40 years.

That may be about to change.

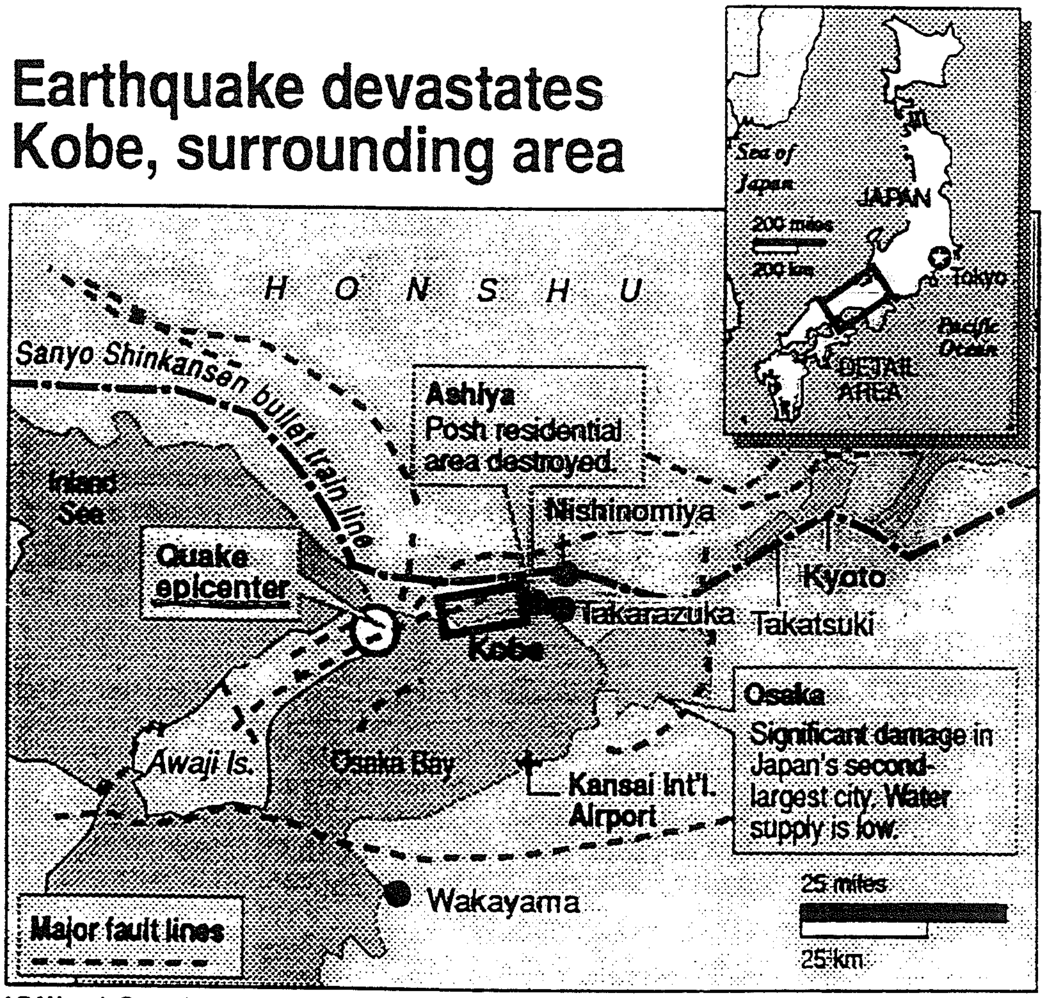
Oike of Kyoto University said this quake marks the start of a seismically active phase that could last two or three decades. In the short term, Oike said big aftershocks are likely to shake the region around Kobe for the next several months.

9

Winnipeg Free Press Jan. 1995

Earthquake in Japan

Earthquake devastates Kobe, surrounding area



AP/Wm. J. Castello, Karl Tate

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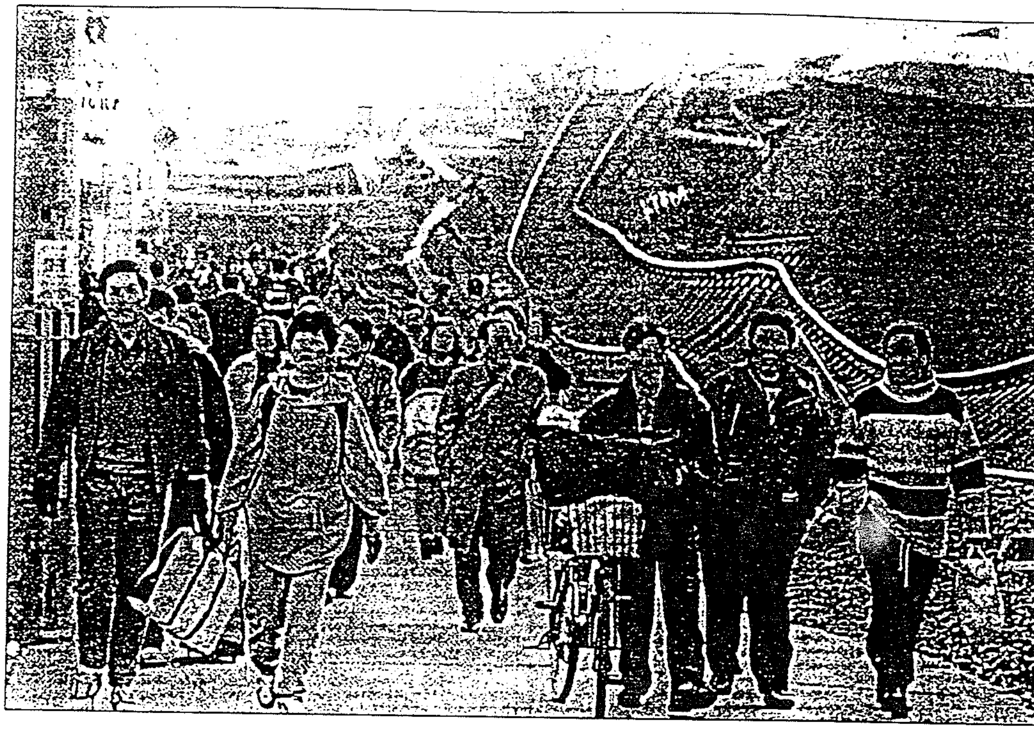
WINNIPEG FREE PRESS JAN. /95



AP PHOTO

People carrying relief goods pass a twisted railway track on their way to Kobe.

Cyber buddy in Japan logs off

Net drives home disaster reality

User Friendly

Paul Pihichyn

THIS IS a story about the human side of computing. About meeting people in far-away places, about using technology to communicate, about making friends. And about death.

Readers are well aware of my passion for the Internet. I see it as the great level playing field, where humanity can communicate, exchange ideas, and even indulge in a little recreation and entertainment.

The Net offers so much.

The Internet's World Wide Web is a rich treasure. It affords an opportunity for the 40 million people around the world who use the Net to admire each other's accomplishments, criticize their shortcomings, sell their Spam – a particularly hot commodity these days – and generally

their real names, but it isn't required, nor even expected.

This has given rise to a great deal of speculation about the legitimacy of chat sites on the Web. If you caught Saturday Night Live last weekend, you saw the skit about people pretending to be someone they are not. Even gender swapping is very much in vogue on some Web sites. The SNL skit captured it very well.

But let me tell you about Jon.

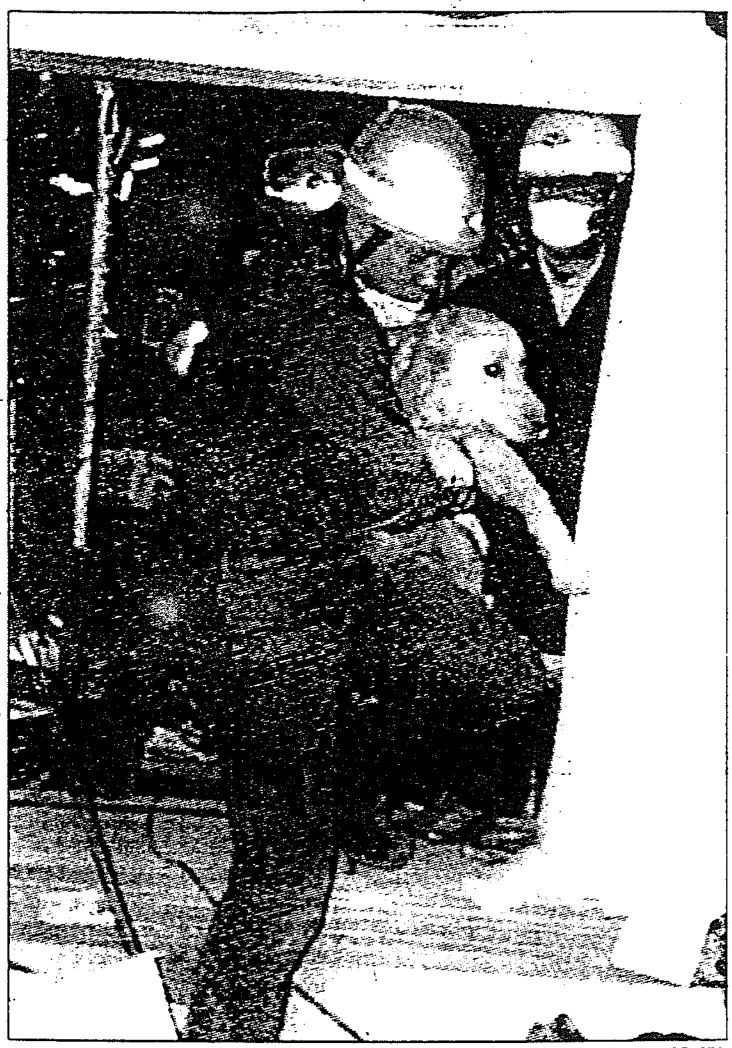
Jon and I met on the Web in early December. I learned that

a conversation about the baseball strike, and how the Japanese press had been speculating on which major league stars would show up over there if the labor dispute continued. Jon was a great fan of baseball.

Late the next afternoon, I read the first wire reports about the earthquake in Japan – the one that had just about wiped Kobe off the face of the Earth. That evening, I logged on the Net and left Jon a message. I said I'd heard about the quake and hoped he was OK. I didn't expect a response right away.

DAYS WENT by. Each night, I logged in, looking for a message from Jon. No response. That was understandable. Communications were down. The city was in

Winnipeg Free Press. Jan. 1995



AP PHOTO

Saved at last

A rescuer carries a dog out of the ruins of a destroyed house in Kobe, Japan, yesterday. The six-month-old golden retriever was rescued 18 days after an earthquake rocked the western Japanese port city. Today, a mild earthquake, with a magnitude of 4.5, hit northeastern Japan. There were no reports of damage or injuries.

Department of Geological Sciences Outreach
Coordinator: Jeff Young

School: Acadia Junior High
Level: Grade 9 / Senior I
Date: January 26, 1995
Time: 1:00 to 2:30 p.m.

Additional Notes

In addition to the handout yesterday I have received a call from the teacher who would like tours of the seismic vault and the seismograph. This means that the schedule, as previously planned, must be changed. To accommodate this request, the students will be broken up into three groups. These groups will visit the (a) seismic vault; (b) seismograph; and (c) Room 317 to look at ophiolitic rocks. Leaders will have about 10 to 15 minutes to go over the topic. To do this three people will be stationed at each location and the other three leaders will tour the groups from one location to another. The people that are touring the students between locations may have to field questions or entertain the students while waiting at the next location.

Location 1: Seismic Vault

The seismic vault is located in the basement of the building. There are three long period (west side of room nearest the door) and three short period seismometers (east side), plus an amplifier. In the seismic vault, I suggest that we cover the topic of earthquakes from the moment they are started (i.e. movement on the fault) to the point where they are recorded by our seismometers. This means going over the setup of the vault.

The seismometers are setup on a concrete platform that forms the top of a 20 m long pillar that extends about 1 m into the bedrock. For both the short period and long period siesmometers there is a central seismometer that measures vertical motion flanked by two seismometers that measure horizontal motion. These seismometers are hooked up to an amplifier that increases the seismic signal. The vertical motion, long period seismometer is hooked up to the seismograph in the foyer of the Wallace Building. We use th vertical motion seismometer, because most seismic waves that will reach us will have a distinct vertical component, but a lesser horizontal component. On the seismograms in the foyer we relatively receive strong signals from the P-wave and lesser signals from the S-waves, because for P-waves. the rock vibrates parallei to the direction of wave propagation, which is relatively vertical when received here. For S-waves the rock vibrates perpendicular to wave propagation, which would mean that they are moving relatively horizontal when these waves reach here.

The magnitude of an earthquake is the amount of energy released at the focus. Magnitude is determined by measuring the amplitude of the peaks on a seismogram that have been generated from a calibrated siesmometer. The seismometers in the vault are not calibrated and therefore only determine the distance to the earthquake.

Location 2: Seismograph

The seismograph is located in the main foyer of the Wallace Building and hooked up to the seismometers in the seismic vault. The seismograph consists of a rotating drum that records the movements of a pen that sweeps across the drum. Each rotation of the drum is 60 minutes or 1 hour and the ticks on the sides of the recording paper a 1 minute intervals. Therefore, by quickly estimating the difference in time between the P-wave and S-wave arrival we can estimate the distance to the earthquake. The P-waves travel faster (4 to 7 km/sec) than S-waves (2 to 5 km/sec)Relate the distance to the magnitude. In other words, the larger the amplitude that we record is not necessarily related to the size of the earthquake, but also must account for the distance and geology.

You may have to introduce the concepts of body waves (P and S waves) and surface waves (Rayleigh and Love waves). The scale that is most commonly used for the public is the Ritcher Scale. Geologists generally use the magnitude of the body or surface waves, which are similar in magnitude to the Ritcher Scale. All of these scales, will give a similar of magnitude. The scales are logarithmic, which means that there is a 10-fold increase in the amplitude of the earth's vibrations, but not in the energy released from the focus. An increase of 1 in magnitude indicates an 31 times increase in the energy released. No earthquakes will have a magnitude greater than 9 because this will exceed the strength of the rock (ie. the rock mass will not be able to withstand the forces.

The recent earthquake in Japan is posted on the side. Please note that the earthquake occurred along a strike slip fault, but have both vertical and horizontal motion. Furthermore the displacement on the fault was about 1 meter over an area of 50 km^2. The earthquake occurred at a depthof 20 km. Most damage was caused becaused of the two components of displacement, the reclamation of the sea in the bay and the engineering of the older homes, although even the newer earthquake-resistent homes were unable to withstand the shock.

Location 3: Ophiolites

There is suite of rocks from several ophiolites located in Room 317 (Al's microscope lab), plus some thin sections that can be shown on the TV monitor. These students probably have a minimal knowledge (or none) of rocks and minerals. They will know about convergent and divergent margins. Therefore I suggest that you: (1) introduce how geologists can get evidence of the oceanic crust; (2) how an ophiolite would form (ie. obduction); (3) the general structure of the oceanic crust. You may want to bring in some chemistry (ie. Fe and Mg rich minerals, pyroxene and olivine in the peridotites) to relate to the composition of the mantle. You may also want to show a thin section showing the different types of minerals.

Tours

The format for the tours are:

Harvey - locations 1, 2 and 3

Angela - locations 2, 3 and 1

Joanne - locations 3, 1 and 2

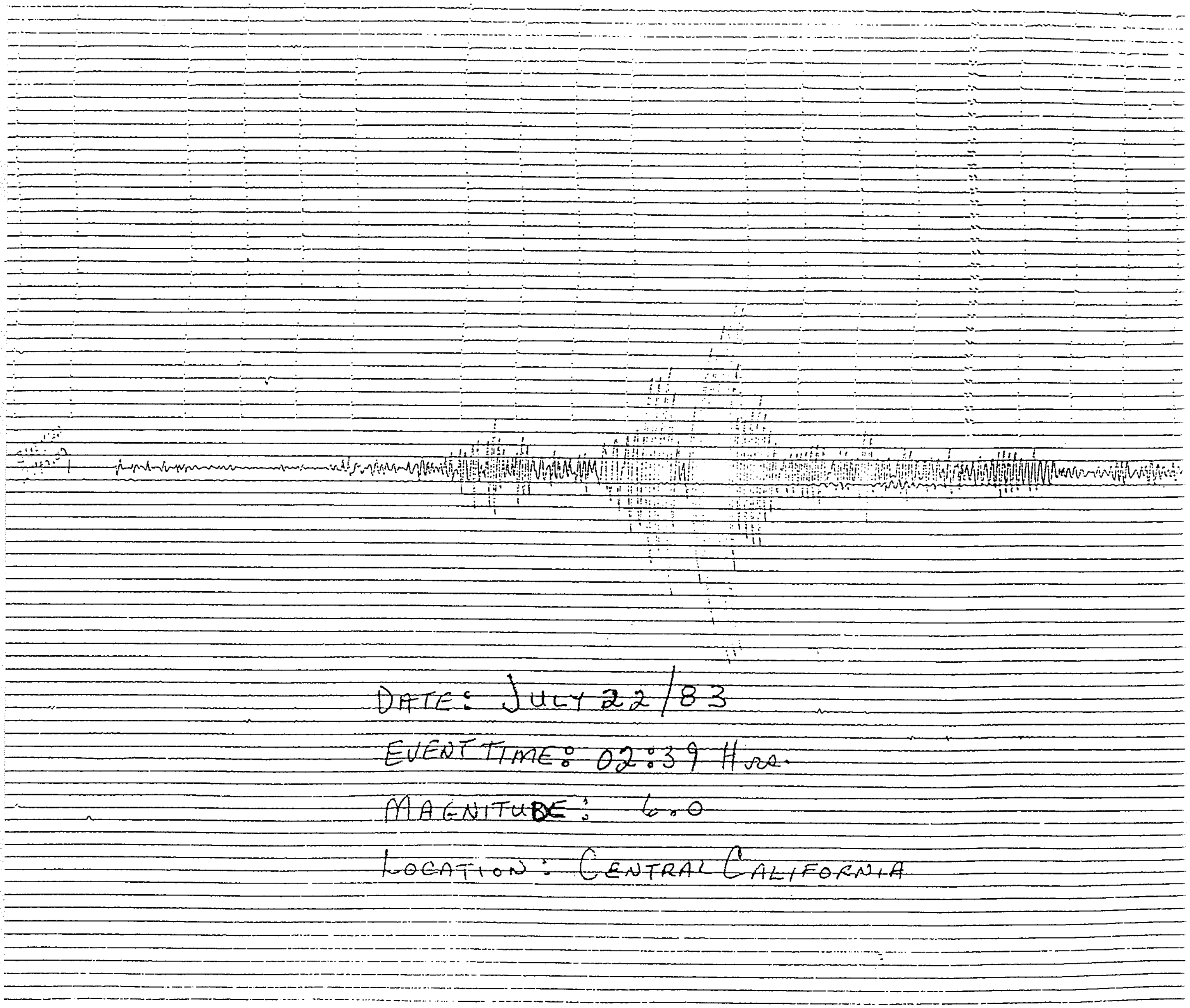
The following people will be at the following locations

Megan - Seismograph

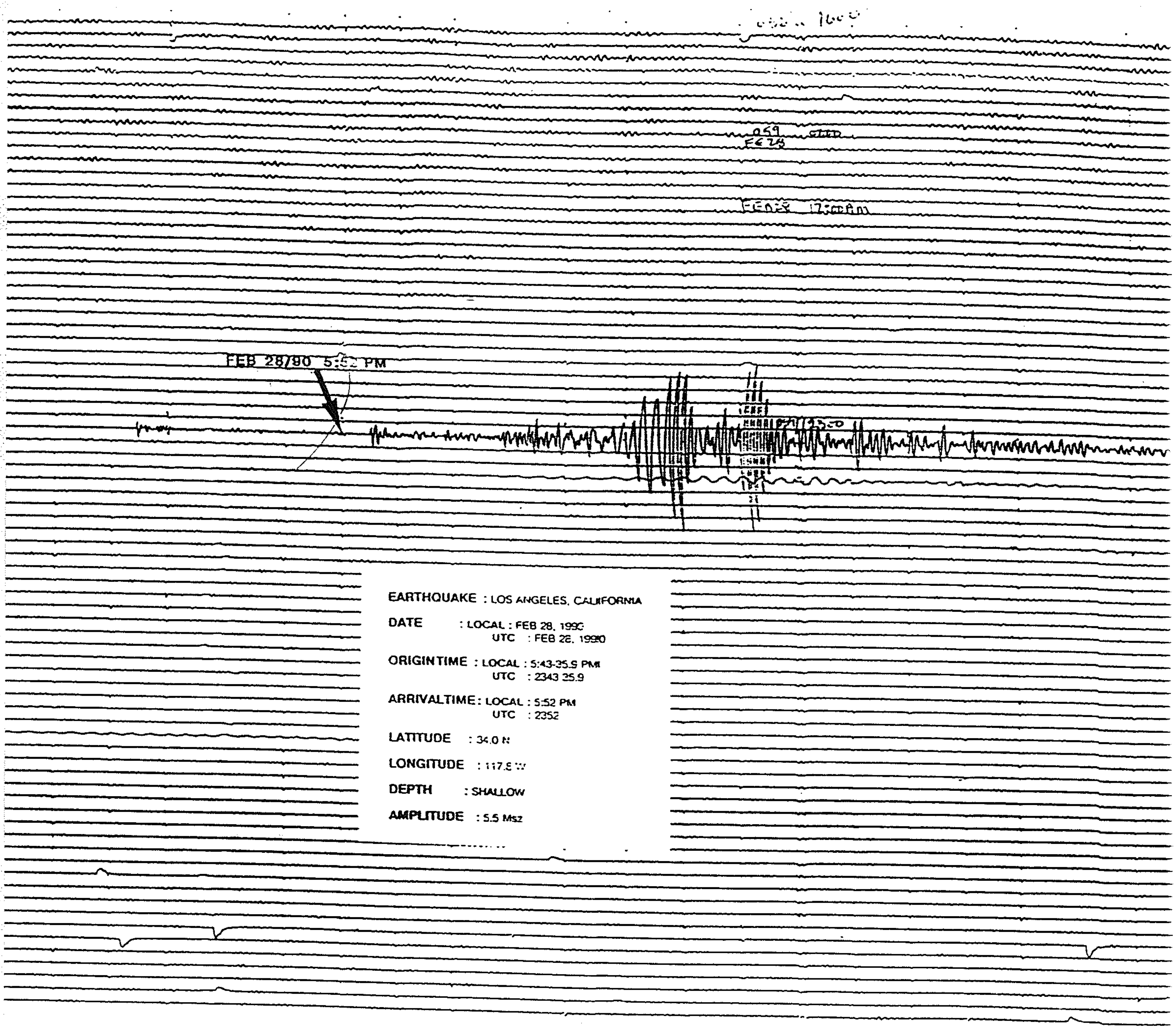
Scott - Ophiolite

Jeff - Seismic Vault

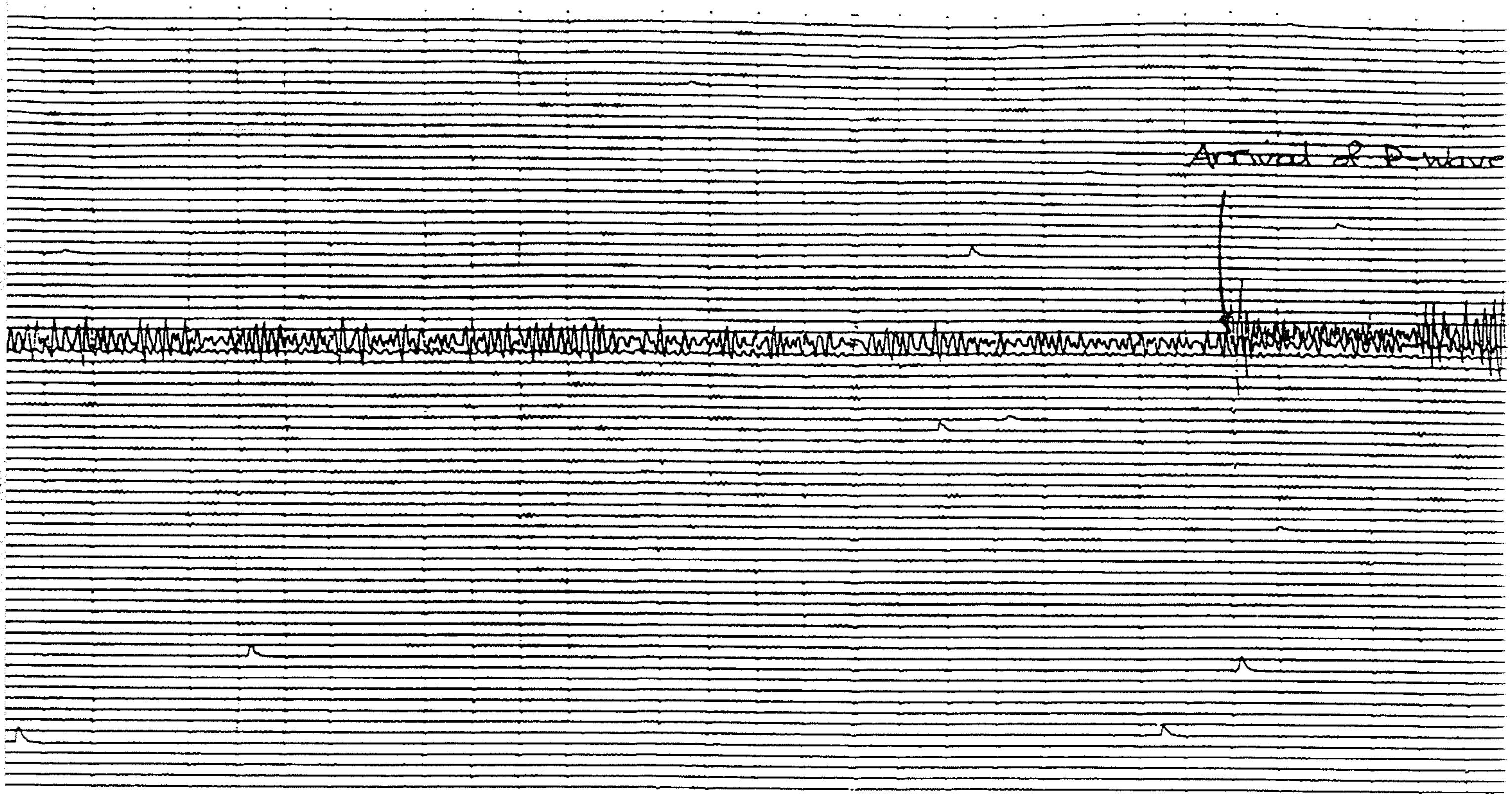
S



Actual seismic reading
from U of M
Wallace Building.



Actual seismic reading
from U of M
Wallace Building



Earthquake on Mendocino Fracture Z
California
Magnitude = 6.0
Latitude: 40.5°N
Longitude: 125.6°W

Actual seismic reading
from U of M
Wallace Building

Kinds of Volcanoes

A volcano, most people think that a volcano is a coneshaped kind of mountain. Actually, there are three types of volcanoes, the Ash-and-Cinder cones (volcanoes), Composite volcanoes, and Shield volcanoes. These three types of volcanoes each have a different shape and size.

1. Ash-and-Cinder cones (volcanoes) - These Ash-and-Cinder cones are shaped with a flat top and slightly wide bases. These volcanoes are formed by small rock materials, or ash, and big rock cinders. All these materials are exploded out the volcano extremely violent and usually making a very thick cloud of smoke. There are small and big particles that come out of the volcano while it is erupting. The smaller particles are usually blown away by the wind far away from the cone. The larger peices just fall on the base and makes a smaller cone on the base.

eg) Paracutin (Mexico)

2. Composite Volcanoes - These Composite volcanoes are shaped with a smaller flat top and is a higher coneshaped volcano. This kind of volcano is formed by layers of ash and lava that slowly flows out of the volcanoes opening. The lava that comes out of the volcano is really thick and really sticky so if its like this, the lava just sometimes get stuck before coming out. Now this can cause pressure and then forces the volcano to erupt in a dangerous way. The solid peice that was stuck would have popped out.

eg) Mt. St. Helen's (U.S.A.)

3 Shield Volcanoes - The Sheild volcanoes are shaped curved [...]m one side to the other side. These side slopes are very [...]tle looking like a sheild on its curved side up, thats why [...]ey were named the Sheild volcanoes. The lava flows out of the v[...]lcano easily because it has such a wide base. These volcanoes have really wide bases but still can grow to a very high height. These kinds of volcanoes hardly erupt violently like the other kinds of volcanoes because of the wideness.

eg) Hawaiian Islands

"Works Cited"

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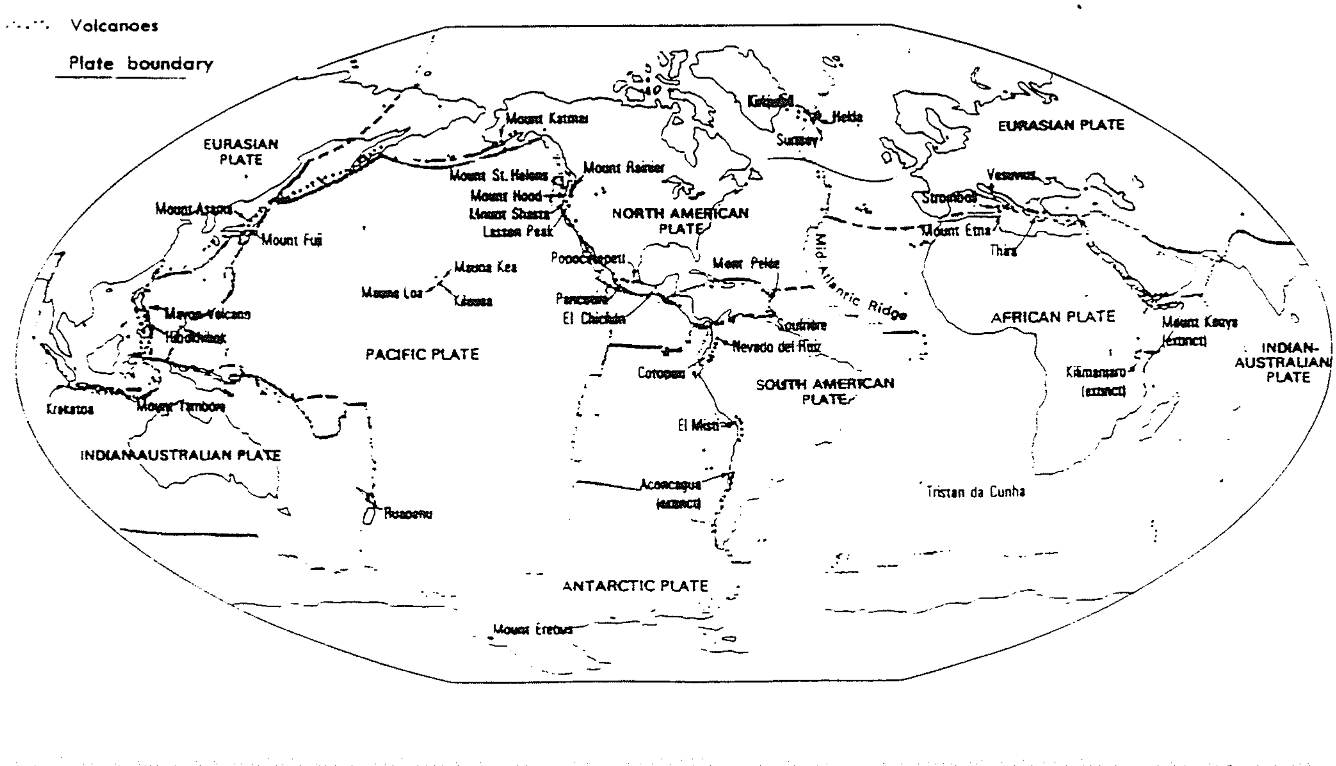
Czerneda, Et Al. Science Dimensions 9. Canada: D.C. Health Canada Ltd, 1993.
"Volcano" World Book Encyclopedia. 1993 ed.



Volcanic ash, rock drown 'pride of the South Pacific'

Associated Press

PORT MORESBY, Papua New Guinea — Police used tear gas yesterday to deter looters in Rabaul and turned back residents trying to get back to what's left of their homes after volcanic eruptions.

The government said it has not decided whether to rebuild or abandon the port city, destroyed for the third time in 60 years.

Rabaul, on the Bismarck Sea about 800 kilometres northeast of Port Moresby, is Papua New Guinea's sixth largest city. Considered the "pride of the South Pacific," it now lies under millions of tonnes of ash and rock from two volcanoes overlooking the harbor.

The Tavurvur and Vulcan volcanoes began erupting Monday and their fiery glow is still visible at night. Experts said the volcanic activity was decreasing yesterday but said there could still be flare-ups.

An estimated 52,000 people fled their homes and are staying in makeshift camps away from the worst damage. Most are Tolai, an indigenous people.

Police turned back crowds trying to return to their homes, a government statement quoted Rabaul police commander John Toguata as saying.

The statement said police used tear gas to halt looting but only fired it in the air.

Two people have been killed in the disaster. A boy was run over by a car in the confusion of Monday's mass evacuation. A man was struck by lightning from a thunderstorm touched off by the eruptions.

The city has been destroyed twice before this century — in the Second World War by Allied bombing of Japanese naval and air bases there and in 1937 by an eruption that killed 507 people.

Pinatubo's volcanic muck kills at least 13

Associated Press

SAN FERNANDO, Philippines — Steaming avalanches of volcanic debris cascaded down the slopes of Mount Pinatubo early yesterday, swamping a dozen villages and killing at least 13 people, officials said.

Seven people were missing after the volcanic muck swept through 14 villages 32 kilometres southeast of Pinatubo, Defence Secretary Renato de Villa said.

Nine people died in Bacolor and four bodies were recovered in nearby Porac, said Lucia Gutierrez, a social welfare officer in Pampanga province. The towns are about 64 kilometres north of Manila.

At least 1,000 houses were buried in the avalanche, regional disaster officials said. Volcanic debris is like quicksand when wet but hardens like cement as it dries.

Officials said as many as 29,733 people were affected but only about 20 per cent had been evacuated to government shelters.

Four members of one family died after they were burned by the steaming avalanche, said Diony Ventura, the regional police chief.

Police ordered an evacuation of the area just after midnight following rain earlier Thursday on the upper slopes of the volcano.

"It came suddenly," said Lucas Nuque, a mini-bus driver from Bacolor who was among hundreds of people seeking shelter in San Fernando, a few kilometres north of Bacolor.

"I bolted from the window and managed to save my life by clinging to a bamboo tree," he said. Rescuers found him still clutching the bamboo.

U

Plate Tectonics - Magnetometers

January 21, 1995

Magnetometers are instruments used for measuring magnetic intensity, especially that of the earth's magnetic field.

Magnetometers were first developed during World War II for tracking submarines in the ocean. Now they are being dragged behind research ships. They measure and record the magnetic patterns on the ocean floor.

By doing this, scientists discovered that there are regular patterns in the rock of the ocean floor. There are 'stripes' of rock on the ocean floor; they are stripes of normal magnetism and reversed magnetism.

These stripes are on both sides of the underwater ridges. The stripes on one side of the ridge match the ones on the other side of the ridge. The alternate magnetism shows that the Earth's magnetic field has been reversed many times, (when molten lava pours out of a fault in the ocean, its iron minerals line up according to the Earth's magnetic field).

Magnetometers show us the stripes of magnetized rock and we assume that the Earth's magnetic field is sometimes reversed.

Using radioactive dating we can tell if the opposite stripes are of the same age. This information shows us that the stripes far from the ridges are older than the stripes beside the ridge. This tells us that the two plates that join at that ridge are pushing away from each other and they are leaving magnetized stripes of hardened lava behind them.

The stripes that are the farthest from the ridge were the first to be formed and the stripes right beside the ridge are fairly recent.

Works Cited

Czerneda, Julie E., et al. Science Dimensions 9. Canada: DC. Heath Canada, 1993

'Plate Tectonics' CD ROM. Plate Tectonics.

V

PLATE TECTONICS TEST

PARENT SIGNATURE:____________________

STUDENT NAME: ANSWER SHEET

TRUE OR FALSE (5 MARKS)

DATE:________________ CLASS:______

___ 1. Earthquakes are more common on the east coast of North America than on the west coast.
___ 2. Seismographs at one location permit accurate determination of the epicenter of an earthquake.
___ 3. Large buildings with steel frames are usually less damaged than those of brick or stone in an earthquake.
___ 4. A suspended mass that tends to stay at rest is an essential part of a seismograph.
___ 5. P waves travel faster than S waves.

MULTIPLE CHOICE (1 MARK EACH) CIRCLE THE CORRECT ANSWER.

1. The seismic wave that reaches a seismometer first is the (S wave, body wave, P wave).
2. The term focus refers to the location of a(n) (observatory, rock-break, lens).
3. The mountain chains found on the sea floor are called (rift zones, mid-ocean ridges, transform faults).
4. Most of the damage done in an earthquake is caused by the (P, S, surface) waves.

COMPLETION (9 MARKS)

1. A) NAME the three types of plate boundaries.
   B) EXPLAIN the direction of movement at each one.
   C) Give an EXAMPLE of each one (name a location).

NAME **EXPLANATION** **EXAMPLE**

1.____

2.____

3.____

LONG ANSWER QUESTION: NAME three different types of evidence that support the continental drift idea and EXPLAIN each one. (6 MARKS)

A.____

B.____

C.____

/24

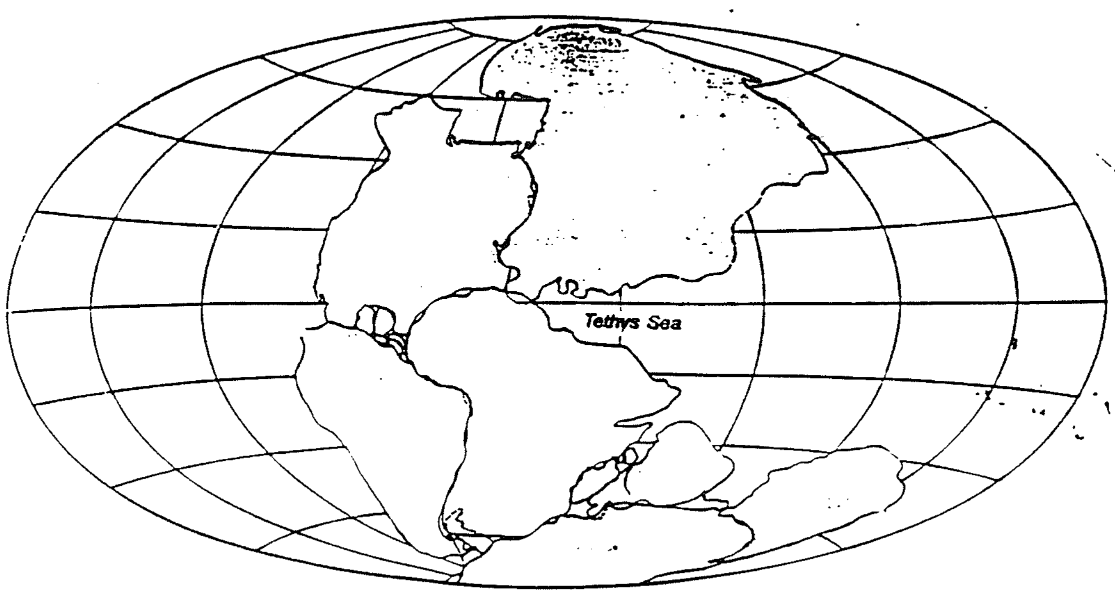
V

FILL IN THE BLANKS (20 MARKS)

In 1620, the scientist called ____________________ noticed that South America and Africa might fit together.The theory of continental drift was first proposed by ______________________ in about ________. He named the supercontinent that contained all of the present day continents ______________. It existed about _______ million years ago. It broke into two pieces called __________________ in the north and ______________________ in the south. The fossil plant that gives evidence of the southern piece is called ____________________, and a fossil animal from the same area is called ___________________.

Earthquakes under the ocean may cause a seismic sea wave called a _________________ which comes from the ________________ language. Epicenters are located directly above the ____________ of an earthquake. To locate the epicenter, at least _____________ seismographs in different locations are required. Three kinds of earthquake waves are _________, _________, and _________. The scale that measures earthquakes is called the _____________ scale. On January 17, 1995 there was a major earthquake that killed over 5000 people in the city of _________ in the country of _________, that measured ______ on the scale. On the same day in 1994 there was an earthquake in California that only killed about 50 people.

NAME SIX OF THE CONTINENTS ON THE FOLLOWING MAP: (6 MARKS)



36

W

Plate Tectonics Unit Test

Name: ____________
Class: ____

① Name the three kinds of earthquake waves: ____ ____ ____. The one that travels the fastest is the ____ wave, and the one that does the most damage is the ____ wave.

② A huge wave caused by an earthquake is called a ________, a word from the ________ language.

③ The three kinds of mountains are called ______ ______ and ________. Most mountains are ________ mountains.

④ The machine that measures earthquakes is called a ________. Most earthquakes are measured according to the ________ scale. The surface location of an earthquake is called the ________ and the actual rock break that starts the earthquake under the ground is called the ________.

25

⑤ The man who first noticed that South America and Africa might fit together in 1620 was ________

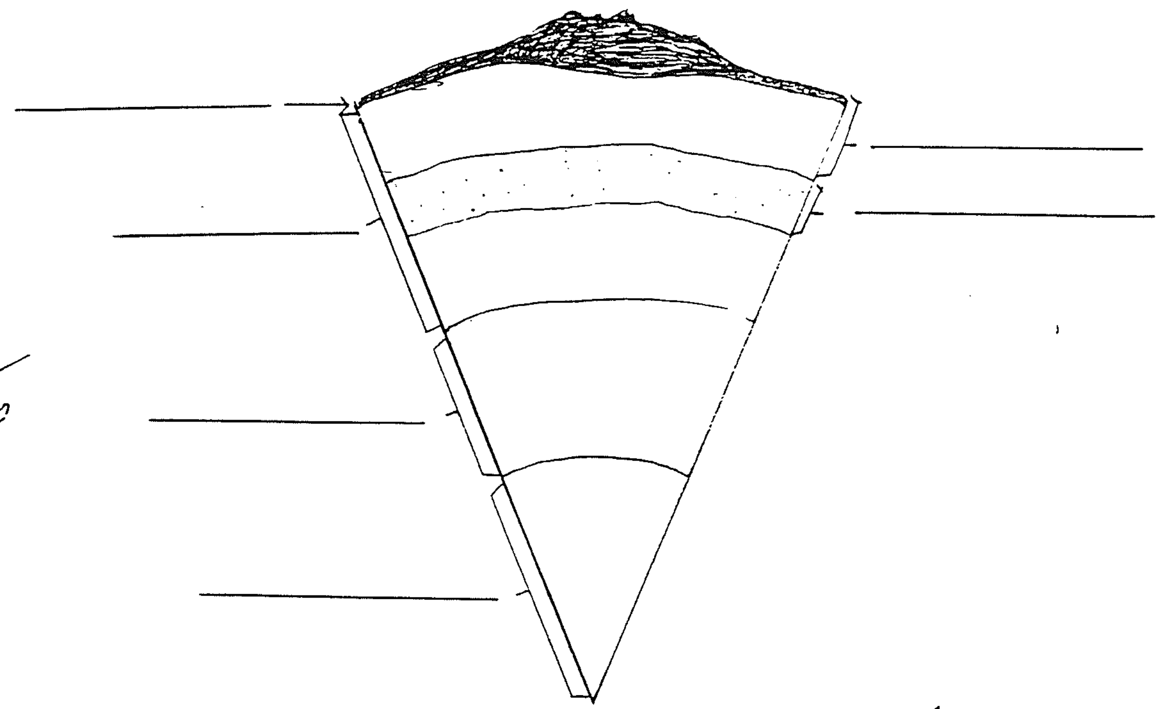
⑥ The man who published the theory of continental drift in 1912-1914 was ________. His three main types of evidence to support his ideas were ________, ________ and ________
His ideas were not widely accepted because he could not logically explain ________
________.

⑦ The recent earthquake in Japan killed thousands of people in the city of ______ and measured ______.

⑧ Explain what a subduction zone is and give one example: ________________ eg) ________

W

(9) Label this model of the Earth: (6 marks)



/6

(10) Name three different kinds of volcanoes, and give one example of each kind: (6 marks)

	NAME	EXAMPLE
(1)		
(2)		
(3)		

/6

(11) Name three different kinds of plate boundaries, explain the movement for each, and give examples: (9 marks)

	NAME	MOVEMENT	EXAMPLE
(1)			
(2)			
(3)			

/9

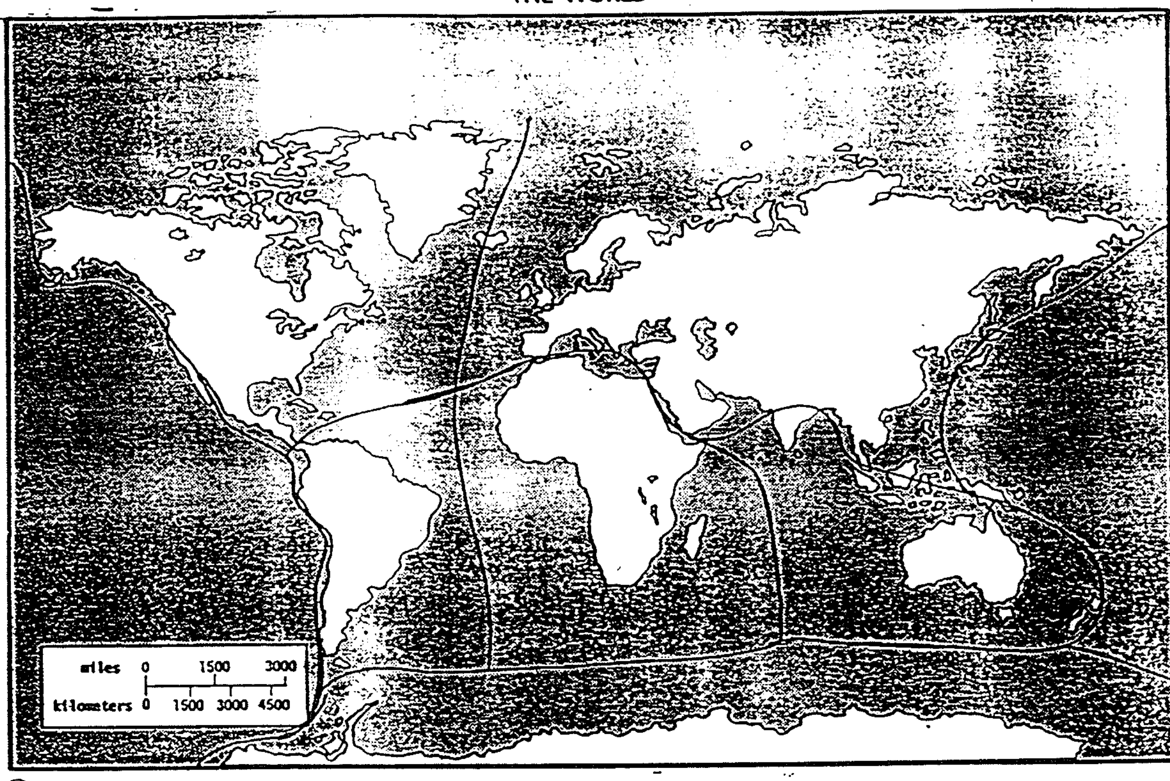
/21

W

(12) Name six (6) plates on the following map:
(1/2 mark each = 3 marks)

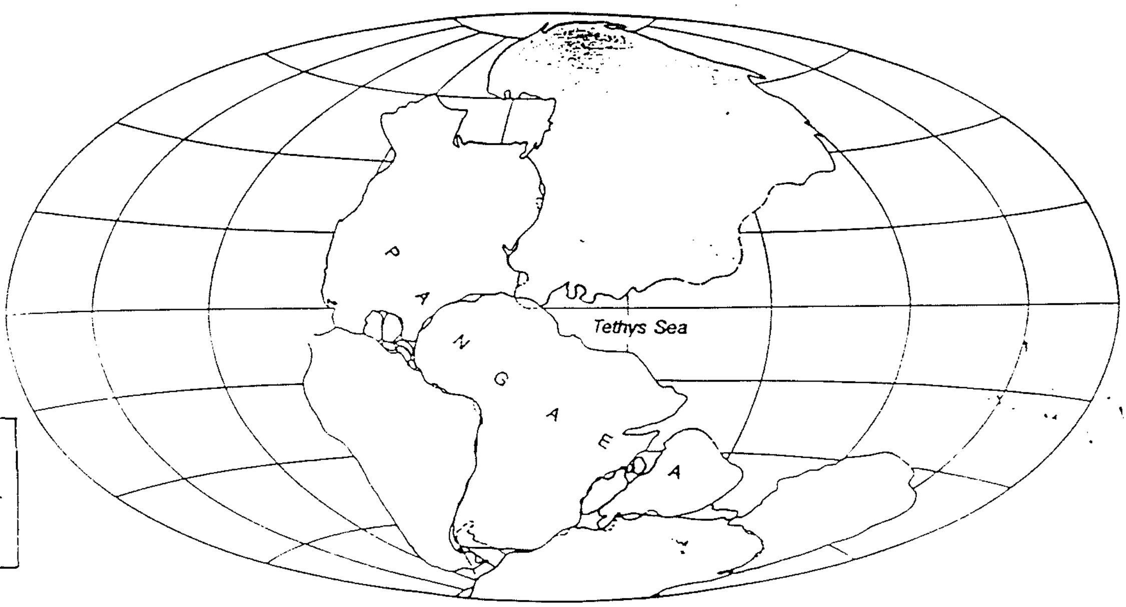
4

THE WORLD



3

(13) Name six (6) of the continents on the map of Pangaea:
(1/2 mark each = 3 marks)



3

6

TOTAL MARK

PAGE 1		PAGE 2		PAGE 3		
25	+	21	+	6	=	50

ACTUAL SURVEY: W

Please answer the following questions as accurately as possible, and try to express complete answers where possible. (This is NOT for marks!)

① In your opinion, was the last unit on plate tectonic more interesting than our chemistry unit?

yes		no	

② In your opinion, was the team work that we did a valuable experience?

yes		no	

③ Do you feel that you have a better idea of how science works after modelling the science communi in the classroom?

yes		no	

④ Do you feel that you have a better understanding of how science theories develop after studying the plate tectonics theory?

yes		no	

⑤ Try to write a definition of science.

⑥ Do you think that your definition of science has changed since last year? ______ If so, how?

⑦ Try to define scientific theory.

⑧ Do you think that your definition of scientific theory h changed since last year? ______ If so, how?