Lab Manual

Physical Geology

LabPaq: GK-1

16 Small-Scale Experiments for Independent Study

Published by
Hands-On– Labs, Inc.

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The Best Way to Learn Science

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Laboratory Manual of Experiments
For the Independent Study of Physical Geology
To accompany Geology LabPaq GK-1 – 022811

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The experiments in this manual have been and may be conducted in a regular formal laboratory or classroom setting with the user providing their own equipment and supplies. The manual was especially written, however, for the benefit of independent study students who do not have convenient access to such facilities. It allows them to perform geology experiments at home or elsewhere by using LabPaq GK-1, a collection of science equipment and supplies packaged by Hands-On Labs, Inc. to accompany this manual.

Use of this manual and authorization to perform any of its experiments are expressly conditioned upon the user reading, understanding, and agreeing to abide by all the safety precautions contained herein.

Except where otherwise noted, all charts and graphics were provided by Hands-On Labs. Although the author and publisher have exhaustively researched all sources to ensure the accuracy and completeness of the information contained in this book, we assume no responsibility for errors, inaccuracies, omissions or any other inconsistency herein. Any slight of people, organizations, materials or products is unintentional.

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Introduction

Important Information to Help Students Study Science

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WELCOME TO THE WORLD OF SCIENCE!

Don't be afraid to take science courses. When you complete them, you will be very proud of yourself and will wonder why you were ever afraid of the “S” word – Science! After their first science course most students say they thoroughly enjoyed it, learned a lot of useful information relevant to their personal lives and careers, and only regret not having studied science sooner.

Science is not some mystery subject comprehended only by eggheads. Science is simply a way of learning about our natural world and how it works by testing ideas and making observations. Learning about the characteristics of the natural world, how those characteristics change, and how those characteristics interact with each other make it easier to understand ourselves and our physical environment and to make the multitude of personal and global decisions that affect our lives and our planet. Plus, science credits on an academic transcript are impressive, and your science knowledge may create some unique job opportunities.

All sciences revolve around the study of natural phenomena and require hands-on physical laboratory experiences to permit and encourage personal observations, discovery, creativity, and genuine learning. As increasing numbers of students embrace online and independent study courses, laboratory experiences must remain an integral part of science education. This lab manual’s author and publisher are science educators who welcome electronic technology as an effective tool to expand and enhance instruction. However, technology can neither duplicate nor replace learning experiences afforded to students through traditional hands-on laboratory and field activities. This does not mean that some experiments cannot or should not be replaced or reinforced by computer simulations; but any course of science study must also provide sufficient hands-on laboratory and field experiences to:

- Engage students in open-ended, investigative processes by using scientific problem solving.
- Provide application of concepts students have seen in their study materials which reinforce and clarify scientific principles and concepts.
- Involve multiple senses in three-dimensional rather than two-dimensional learning experiences that are important for greater retention of concepts and for accommodation of different leaning styles.

- Stimulate students to understand the nature of science including its unpredictability and complexity.
- Provide opportunities to engage in collaborative work and to model scientific attitudes and behavior.
- Develop mastery of techniques and skills needed for potential science, engineering, and technology careers.
- Ensure advanced placement science courses transfer to college credit.

The knowledge gained from science courses with strong laboratory components enables students to understand in practical and concrete ways their own physical makeup, the functioning of the natural world around them, and contemporary scientific and environmental issues. It is only by maintaining hands-on laboratory experiences in our curricula that the brightest and most promising students will be stimulated to learn scientific concepts and avoid being turned-off by lecture- and textbook-only approaches. Physical experimentation may offer some students their only opportunity to experience a science laboratory environment. All students – as potential voters, parents, teachers, leaders, and informed citizens – will benefit from a well-rounded education that includes science laboratory experiences, when it is time for them to make sound decisions affecting the future of their country and the world.

19th century scientist, Ira Remson (1846-1927) on the subject of Experimentation:

"While reading a text book of chemistry, I came upon the statement, "nitric acid acts upon copper." I was getting tired of reading such absurd stuff and I determined to see what this meant. Copper was more or less familiar to me, for copper cents were then in use. I had seen a bottle marked "nitric acid" on a table in the doctor's office where I was then 'doing time'! I did not know its peculiarities, but I was getting on and likely to learn. The spirit of adventure was upon me. Having nitric acid and copper, I had only to learn what the words "act upon" meant. Then the statement "nitric acid acts upon copper" would be something more than mere words. All was still. In the interest of knowledge I was even willing to sacrifice one of the few copper cents then in my possession. I put one of them on the table, opened the bottle marked "nitric acid", and poured some of the liquid on the copper, and prepared to make an observation. But what was this wonderful thing which I beheld? The cent was already changed, and it was no small change either. A greenish blue liquid foamed and fumed over the cent and over the table. The air in the neighborhood of the performance became colored dark red. A great cloud arose: This was disagreeable and suffocating--how should I stop this? I tried to get rid of the objectionable mess by picking it up and throwing it out the window, which I had meanwhile opened. I learned another fact--nitric acid not only acts upon copper but it acts upon fingers. The pain led to another unpremeditated experiment. I drew my fingers across my trousers and another fact was discovered. Nitric acid acts upon trousers. Taking everything into consideration, that was the most impressive experiment, and, relatively, probably the most costly experiment I have ever performed. I tell of it even now with interest. It was a revelation to me. It resulted in a desire on my part to learn more about that remarkable kind of action. Plainly the only way to learn about it was to see its results, to experiment, to work in a laboratory."

This lab manual can be used by all students, regardless of the laboratory facilities available to them. The experiments are based on the principles of micro- and small-scale science which have been successfully used in campus laboratories for decades. LabPaq's micro- and small-scale experiments can also be performed at home, in a dorm room, or at a small learning center that lacks a formal laboratory.

What are Micro- and Small-scale Experiments?

You may be among the growing number of students to take a full-credit, laboratory science course through independent study, due to the development and perfection of micro-scale and small-scale experimentation techniques over the past half century. While experimentation on any scale is foundational to fully understanding science concepts, science courses in the past have required experimentation to be performed in the campus laboratory due to the potential hazards inherent in traditional experimentation.

Potential hazards, increasing chemical, specimen, and science equipment costs, and environmental concerns made high schools, colleges, and universities reexamine the traditional laboratory methods used to teach science. Scientists began to scale down the quantities of materials and the size of equipment used in experiments and found reaction results remained unchanged.

Over time, more and more traditional science experiments were redesigned to be performed on micro and small scales. Educational institutions eventually recognized that the scientific reaction, not the size of the reaction, facilitates learning. Successive comparative assessments have proven that students' learning is not impaired by studying small-sized reactions. Many assessments even suggest that science learning is enhanced by small-scale experimentation.

The primary pioneer and most prominent contributor to micro- and small-scale experimentation was Dr. Hubert Alyea, a chemistry professor at Princeton University, who began utilizing micro-scale experiments in the 1950s. Dr. Alyea reformatted numerous chemistry experiments and also designed many of the techniques and equipment used in micro- and small-scale science today. In the mid-1990s, Dr. Peter Jeschofnig of Colorado Mountain College pioneered the development of LabPaq's academically aligned, small-scale experiments that can be performed at home. Hands-On Labs, Inc. has subsequently proven that students can actually perform LabPaq's rigorous science experiments at home and still achieve an equivalent, if not higher, level of learning than their campus-based peers.

The Organization of this Lab Manual

Before proceeding with your experiments, please thoroughly read and understand each section of this lab manual, so you understand what is expected of you.

Introduction and How to Study Science: These sections include important information about general scientific subject matter and specific information about effectively studying science and conducting science experiments. Read these sections carefully and take them to heart!

How to Perform an Experiment and Laboratory Equipment and Techniques: Adhering to the procedures described in these sections will greatly facilitate experimental activities. The laboratory techniques and equipment described primarily apply to full-scale experiments and formal laboratories; however, knowledge of these items is important to a basic understanding of science and is relevant to home-based experimentation.

How to Write Lab Notes and Lab Reports: Like all serious scientists, you must record formal notes detailing your activities, observations, and findings for each experiment. These notes will reinforce your learning experiences and science knowledge and provide the basis from which you will prepare Lab Reports for your instructor. This section explains how these documents should be organized and prepared.

Safety Concerns: The Basic Safety Guidelines and Safety Reinforcement Agreement are the most important sections of this lab manual and should be reviewed before each experiment. The safety sections are relevant to both laboratory and non-laboratory experimentation. The guidelines describe potential hazards as well as basic safety equipment and safety procedures designed to avoid such hazards.

Required Equipment and Supplies: If you are performing these experiments in a non-laboratory setting, you must obtain the LabPaq specifically designed to accompany this lab manual. The LabPaq includes all the basic equipment and supplies needed to complete the experiments, except for minor items usually found in the average home or obtained at local stores. At the beginning of each experiment you will find a materials section listing which items are found in the LabPaq and which items you will need to provide. Review this list carefully before you begin an experiment to ensure you have all required items.

Experiments: The experiments included in this lab manual were specifically selected to accompany related course materials for a traditional academic term. These experiments emphasize a hands-on, experimental approach for gaining a sound understanding of scientific principles. The lab manual's rigorous Lab Report requirements help reinforce and communicate your understanding of each experiment's related science principles and strengthen your communication skills. This traditional, scientific method approach to learning science reflects the teaching philosophy of the authors, Hands-On Labs, Inc., and science educators around the globe.

HOW TO STUDY SCIENCE

It is unfortunate that many people develop a fear of science somewhere early in life. Yes, the natural sciences are not the easiest subjects to learn; but neither are they the hardest. Like in any other academic endeavor, if you responsibly apply yourself, conscientiously study your course materials, and thoughtfully complete your assignments, you will learn the material. Following are some hints for effectively studying science and any other subject, both on or off campus.

Plan to Study: You must schedule a specific time and establish a specific place in which to seriously devote yourself to your studies. Think of studying like you would think of a job. Jobs have specific times and places in which to get the work done, and studying should be no different. Just as television, friends, and other distractions are not permitted on a job, they should not be permitted to interfere with your studies. If you want to do something well, you must be serious about it, and you cannot learn when you are distracted. Only after you have finished your studies should you allow time for distractions.

Get in the Right Frame of Mind: Think positively about yourself and what you are doing. Put yourself in a positive frame of mind to enjoy what you are about to learn, and then get to work. Organize any materials and equipment you will need in advance so you don't have to interrupt your work later. Read your syllabus and any other instructions and know exactly what your assignment is and what is expected of you. Mentally review what you have already learned. Write down any questions you have, and then review previous materials to answer those questions. Move on, if you haven't found the answer after a reasonable amount of time and effort. The question will germinate inside your mind, and the answer will probably present itself as you continue your studies. If not, discuss the question later with your instructor.

Be Active with the Material: Learning is reinforced by relevant activity. When studying, feel free to talk to yourself, scribble notes, draw pictures, pace out a problem, or tap out a formula. The more physically active things you do with your study materials, the better you will learn. Have highlighters, pencils, and note pads handy. Highlight important data, read it out loud, and make notes. If there is a concept you are having problems with, stand up and pace while you think it through. Try to see the action taking place in your mind. Throughout your day, try to recall things you have recently learned, incorporate them into your conversations, and teach them to friends. These activities will help to imprint the related information in your brain and move you from simple knowledge to true understanding of the subject matter.

Do the Work and Think about What You Are Doing: Sure, there are times when you might get away with taking a shortcut in your studies, but in doing so you will probably shortchange yourself. The things we really learn are the things we discover ourselves, which is why we don't learn as much from simple lectures, passive videos, or someone simply telling us the answers to our questions. Discovery learning – figuring things out for ourselves – is the most effective and long-lasting form of learning. When you have an assignment, don't just go through the motions. Enjoy your work, think about what you are doing, be curious, ask yourself questions, examine your results, and consider the implications of your findings. These critical thinking techniques will improve and enrich your learning process. When you complete your assignments independently and thoroughly, you will be genuinely knowledgeable and can be very proud of yourself.

How to Study Independently

There is no denying that learning through any method of independent study is very different from learning through classes held in traditional classrooms. It takes a great deal of personal motivation and discipline to succeed in a course of independent study where there are no instructors or fellow students to give you structure and feedback. These problems are not insurmountable, and meeting the challenges of independent study can provide tremendous personal satisfaction. The key to successful independent study is having a personal study plan and the personal discipline to stick to that plan.

Properly Use Your Learning Tools: The basic tools for web courses and other distance learning methods are often similar, consisting of computer software, videos, textbooks, and study guides. Check with your course instructor to make sure you acquire all the materials you will need. You can obtain these items from campus bookstores, libraries, or the Internet. Related course lectures and videos may even be broadcast on your local public and educational television channels. If you choose to do your laboratory experimentation independently, you will need the special equipment and supplies described in this lab manual and contained in its companion LabPaq.

For each study session, first work through the appropriate sections of your course materials, because these serve as a substitute for classroom lectures and demonstrations. Take notes as you would in a regular classroom. Actively work with any computer and text materials, carefully review your study guide, and complete all related assignments. If you do not feel confident about the material covered, repeat the previous steps until you do. It is wise to always review your previous work before proceeding to a new section to reinforce what you've previously learned and prepare you to better absorb new information. Actual experimenting is among the last things done in a laboratory session.

Plan to Study: A normal science course with a laboratory component may require you to spend as many as 15 hours a week studying and completing your assignments. To really learn new material requires at least three hours of study time each week for each hour of course credit taken. This applies as equally to independent study as it does to regular classroom courses. On a school campus science students are usually in class for three hours and in the laboratory for two to three hours each week. Then, they still need at least nine hours to read their text and complete their assignments. Knowing approximately how much time is required will help you formulate a study plan at the beginning of the course.

Schedule Your Time Wisely: The more often you interact with study materials and call them to mind, the more likely you are to reinforce and retain the information. It is much better to study in several short blocks of time rather than in one long, mind-numbing session. Accordingly, you should schedule several study periods throughout the week or during each day. Please do not try to do all of your study work on the weekends! You will burn yourself out, you won't learn as much, and you will probably end up feeling miserable about yourself and science too. Wise scheduling can prevent such unpleasantness and frustration.

Choose the Right Place for Your Home Laboratory: The best place to perform at-home experiments will be determined by the nature of the individual experiments. However, this place is usually an uncluttered room where a door can be closed to keep out children and pets; a window or door can be opened for fresh air ventilation and fume exhaust; there is a source of running water for fire suppression and cleanup; and there is a counter or tabletop work surface. A kitchen usually meets all these requirements. Sometimes the bathroom works too, but it can be cramped and subject to interruptions.

Review each experiment before starting any work to help you select the most appropriate work area. Because some of the equipment and supplies in your LabPaq may pose dangers to small children and animals, always keep safety in mind when selecting a work area, and always choose an area where you cannot be disturbed by children or pets.

Use a Lab Partner: While the experiments in the LabPaq can be performed independently, it is often fun and useful to have a lab partner to discuss ideas with, help take measurements, and reinforce your learning process. Whether your partner is a parent, spouse, sibling, or friend, you will have to explain what you are doing, and in the process of teaching another, you will better teach yourself. Always review your experiments several days ahead of time so you have time to line up a partner if needed.

Perform Internet Research: Students in today's electronic information age are often unaware of how fortunate they are to have so much information available at the click of a mouse. Consider that researchers of the past had to physically go to libraries, search through card catalogs for possible sources of information, and wait weeks to receive books and journals that may not contain the information they needed. Then they had to begin their search all over again! Now you can find information in a matter of minutes.

Since most courses today include online components, it is assumed that you have reasonable computer skills. If you make ample use of those skills and include online research as part of your study routine, you can greatly enhance your depth of learning as well as improve your grades. Keep a web browser open as you review your course materials and laboratory assignments. When you encounter words and concepts that you have difficulty fully understanding, perform a quick web search and review as many sites as needed until the definition or concept is clear in your mind.

Web searches are especially valuable in science. For example, if you have difficulty with a concept, you can usually perform an image search that will help visually clarify the object of interest. Perform a text search to find descriptions and information from leading scientists at famous institutions all over the world. For unfamiliar terms, enter the word “define” plus the unfamiliar term into your search engine and a myriad of differently phrased definitions will be available to help you.

This lab manual lists numerous respected websites that you may find useful, and you will undoubtedly find many more on your own. Rely only on trusted government and educational institutions as sources for valid research data. Be especially skeptical of and double-check information garnered from personal blogs and wiki sites like wikipedia.org, where anyone, regardless of their expertise or integrity, can post and edit information. As students all over the world are finding, the worldwide web is a treasure trove of information, but not all of it is valid!

Finally, while website links in this lab manual were valid at the time of printing, many good websites become unavailable or change URLs. If this happens, simply go to one of the other sites listed or perform a web search for more current sites.

HOW TO PERFORM AN EXPERIMENT

Although each experiment is different, the process of preparing, performing, and recording an experiment is essentially the same.

Read the Entire Experiment before You Start: Knowing what you are going to do before you do it will help you organize your work and be more effective and efficient.

Review Basic Safety: Before beginning work on any experiment, reread the lab manual’s safety sections, try to foresee any potential hazards, and take appropriate steps to prevent safety problems.

Organize Your Work Space, Equipment, and Materials: It is hard to organize your thoughts in a disorganized environment. Assemble all required equipment and supplies before you begin working.

Outline Your Lab Notes: Outline the information needed for your Lab Notes and set up any required data tables before the experiment, to make it easier to enter observations and results as they occur. LabPaq CDs normally include a Report Assistant containing .rtf files of each experiment's questions and data tables. These files can be copied and pasted into your Lab Notes to facilitate your compilation of data and text information.

Perform the Experiment According to Instructions: Follow all directions precisely in sequential order. This is not the time to be creative. Do not attempt to improvise your own procedures!

Think About What You Are Doing: Stop and give yourself time to reflect on what has happened in your experiment. What changes occurred? Why? What do they mean? How do they relate to the real world of science? This step can be the most fun and often creates "light bulb" experiences of understanding.

Clean Up: Always clean your laboratory space and laboratory equipment immediately after use. Wipe down all work surfaces that may have been exposed to chemicals or dissection specimens. Blot any unused chemicals with a paper towel or flush them down the sink with generous amounts of water. Wrap dissection specimens in newspaper and plastic and place them in a sealed garbage can. Discard used pipets and other waste in your normal trash. Return cleaned equipment and supplies to their LabPaq box and store the box out of reach of children and pets.

Complete Your Work: Complete your Lab Notes, answer the required questions, and prepare your Lab Report. If you have properly followed all the above steps, the conclusion will be easy.

Why Experimental Measurements Are Important:

> *When you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind.*
>
> *Lord Kelvin*

We measure things to know something about them, to describe objects, and to understand phenomena. Experimental measurement is the cornerstone of the scientific method; thus, no theory or model of nature is tenable unless the results it predicts are measurable and in accordance with the experiment.

Your primary tasks in a science laboratory course are to create experimentally measured values, compare your results to accepted theoretical or measured values, and gain a full understanding of scientific concepts. This is true for experiments done both inside and outside of a formal laboratory. Each experiment is predicated upon a theory of scientific principle and represents a test of that theory through experimentation, observation, measurements, and analysis.

Laboratory Equipment and Techniques

While many of these techniques and equipment are most applicable to specific science disciplines in formal laboratory facilities, knowledge of these items is often required for the study of other science disciplines and when working in a home laboratory.

Dispensing Chemicals: To avoid contamination when pouring liquid chemicals from a reagent (ree-ey-juhnt) bottle with a glass stopper, hold the stopper in your fingers while carefully pouring the liquid into the desired container. When pouring from a screw-cap bottle, set the cap down on its top so that it does not become contaminated or contaminate anything. Be certain to put the correct cap on the bottle after use. **Never pour excess chemicals back into a reagent bottle,** because this may contaminate the reagents. If any liquid spills or drips from the bottle, clean it up immediately.

To obtain samples of a powdered or crystalline solid from a container, it is best to pour the approximate amount of solid into a clean, dry beaker or onto a small piece of clean, creased paper for easy transport. Pour powders and crystals by tilting the container, gently shaking and rotating the solids up to the container lip, and allowing the solids to slowly fall out. If you pour too much solid, **do not put any solid back in the container**. Also, never put wooden splints, spatulas, or paper into a container of solids to avoid contamination.

Dropping Chemicals: In micro-scale science, you use only small drops of chemicals, and it is extremely important that the drops are uniform in size and carefully observed. To ensure uniformity of drop size, use scissors to cut off the tip of the pipet perpendicular to the pipet body; cutting at an angle will distort drop sizes. Turn the pipet upside down so the dispensing chamber behind the dropper is full of liquid. Then hold the dropper in front of your eyes so you can carefully observe and count the number of drops dispensed as you slowly squeeze the pipet.

Note the angled dropper.

You can see the incorrect (left) and correct (right) way to dispense drops. The pipet should be held in a vertical position at eye level to ensure drops are uniform in size and the correct drops are dispensed.

Note the vertical dropper.

Heating Chemicals: Heat solid and liquid chemicals with great care to prevent explosions and accidents.

Liquids in Beakers: To heat liquids in beakers or flasks, ensure that these containers are well supported above the heat source. Generally, the beaker or flask is placed on wire gauze supported by an iron support attached to a stand. The heat source is placed under the beaker or flask.

Liquids in Test Tubes: When heating liquids in test tubes, always use a test tube holder. Evenly heat the test tube contents by carefully moving the test tube back and forth in the flame. Heat the test tube near the top of the liquid first; heating the test tube from the bottom may cause the liquid to boil and eject from the tube.

Heating Sources for Small-scale Techniques: For micro- and small-scale science experimentation, the most commonly used heat sources are alcohol burners, candles, and burner fuel. Alcohol burners can be a problem because their flame is almost invisible, and they cannot be refilled while hot. Candles, while effective for heating small quantities of materials, tend to leave a sooty, carbon residue on the heated container that obstructs observations. Sterno and similar alcohol based fuels are very volatile and cannot be safely shipped; however, the Glycol-based fuel used in LabPaqs is safe to ship. Chafing dish (i.e., burner fuel) is actually the best of these alternatives because it has a visible flame, is easily extinguished, and does not leave excessive flame residue. Regardless of the type of burner used, **never leave an ignited heat source unattended.**

Mass Measurement Equipment: Note that weighing scales are often called balances since weights are calculated using balance beams. Triple and quadruple beam balances are the most common measuring equipment found in laboratories. However, with today's precision technology, digital top-loading balances are becoming increasingly popular.

Triple and Quadruple Beam Scale: These balances typically include a hanging pan and vary in their degree of accuracy. After the scale has been set at zero, the object to be weighed is placed in the hanging pan, and balancing weights are added or subtracted by moving a pointer across a horizontal bar scale. When exact scale is achieved, the pointer indicates the object's mass.

Digital Top Loading Balance: This scale is initially zeroed by pressing the zero button. If you are using weighing paper or a small beaker, first **tare** the paper or beaker by placing it on the scale and pressing the tare button. This will produce a zero reading, and the weight of the paper or beaker will be excluded from the weighing process.

Hanging Spring Scales: Measurements are taken by suspending the item from a scale, often within a container. Spring scales are not easily tared, so the container weight should be separately calculated and subtracted from the combined weight of the item and the container.

The Non-digital Analytical Balance: This instrument is very delicate, and the instructions for its use are quite detailed. Because of its extreme sensitivity, weighing on the analytical scale must be carried out in a closed chamber that is free from drafts. This instrument is seldom used by first-year science students.

Volume Measurement Equipment: To obtain accurate measurements from any glass volume measurement container, such as a beaker or graduated cylinder, you must identify and correctly read a curved surface known as the meniscus. The meniscus of water and water-based solutions concaves downward and is read at the very bottom of its curve. A mercury meniscus is convex and is read at the very top of its curve. There is no meniscus issue associated with plastic containers.

Filtration Equipment: Gravity filtration is used to remove solid precipitates or suspended solids from a mixture. It works like a small funnel or spaghetti strainer, except that it is lined with fine, conical filter paper to trap the solids. After pouring a mixture into the filter from a beaker, use a special spatula, called a rubber policeman, to scrape any remaining solids from the beaker wall into the conical filter paper. Then, use a wash bottle to rinse residue from both the beaker and rubber policeman into the filter cone to ensure that all the mixture's particles pass through the filter.

Suction filtration uses a vacuum to suck a mixture through a filter. It is much faster than but not always as efficient as gravity filtration. The required vacuum is usually created by the aspirator of a laboratory water faucet.

Bunsen Burner: This old, tried-and-true heat source relies on the combustion of natural or bottled gas. To achieve the best flame, you must properly adjust the burner's gas inlet valve and air vent. Open the valves only halfway before lighting the burner. The safest way to light the burner is to bring a lighted match to the flame opening from the side, not the top. When the burner is lit, close the air vent and adjust the gas inlet valve until the flame is approximately 10 cm high. The flame should be luminous and yellow. Next, open the air vent until the flame becomes two concentric cones. The outer cone will be faintly colored and the inner cone will be blue. The hottest part of the flame is at the tip of the blue cone.

Graduated Cylinder: Graduated cylinders are available in a wide range of sizes. To read a volume in a graduated cylinder, hold the cylinder at eye level so the contents level and you can directly view the meniscus. Looking at a meniscus from below or above will create parallax and cause a false reading. Always read any scale to the maximum degree possible, including an estimate of the last digit.

Buret: Burets are long, graduated tubes usually used in titration. They have a stopcock or valve on the bottom that allows you to dispense liquids in individual drops and accurately measure the quantity dispensed. Use caution when opening the stopcock to ensure that only one drop is dispensed at a time.

Pipet: Pipets are small tube-type containers with openings at one end if made of plastic or at both ends if made of glass. They come in a range of volumes and are generally used to transfer specific amounts of liquids from one container to another.

Berel Pipet: These soft and flexible pipets are made of polyethylene plastic and are extensively used in LabPaqs. They have long, narrow tips and are used to deliver chemicals and to collect products. Berel pipets come in different sizes, and their tips can have different diameters and lengths. You can modify them to serve diverse purposes such as chemical scoops, gas generators, or reaction vessels.

Volumetric Flask: Volumetric flasks are pear-shaped flasks with long necks used for the preparation of solutions whose concentrations need to be very accurate. Flasks come in a variety of sizes ranging from a few milliliters to several liters, and their volume levels are precisely marked. When the liquid level inside a volumetric flask is such that the meniscus lines up with the calibration mark on the neck, the volume of the liquid is exactly as stated. Unlike volumetric flasks, the markings on beakers, Erlenmeyer flasks, and most other laboratory containers are very good approximates but are not intended to be exact and precise volume measurements.

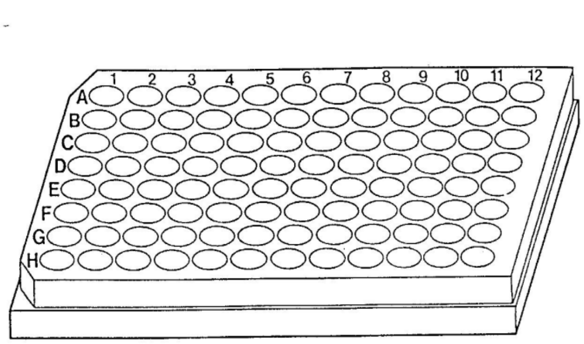
Wash Bottles: These plastic squeeze bottles produce a small stream of water that can be easily dispensed as needed (e.g., washing out residue from a container). The bottles usually contain distilled or deionized water and are typically used to top off the last few milliliters of a vessel and avoid overfilling. In micro- and small-scale experimentation, plastic pipets are used for similar functions.

Tissue Culture Well Plates: These microplates are plastic trays containing numerous shallow wells arranged in lettered rows and numbered columns. Similar to test tubes and beakers, you can use the wells to observe reactions, to temporarily store chemicals during experiments, and to hold pipets. The most commonly used plates are 24-well and 96-well.

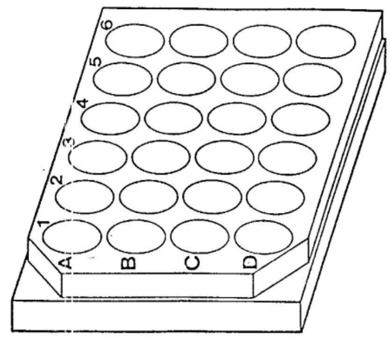
Distilled Water and Deionized Water: Tap water frequently contains ions that may interfere with the substances you are studying. To avoid such interference, use distilled or deionized water any time water is needed for dilution of concentration or the preparation of experimental solutions. Wash used glassware with soap, rinse with tap water, and rinse again with distilled water.

MICRO & SMALL SCALE EQUIPMENT

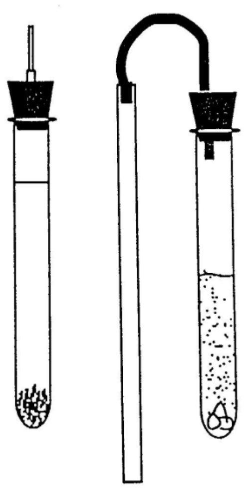
The primary types of equipment used in micro and small scale experimentation



96-Well Plate



24-Well Plate



Gas Generation Test Tubes with Typical Assemblies

Long Stem Pipet

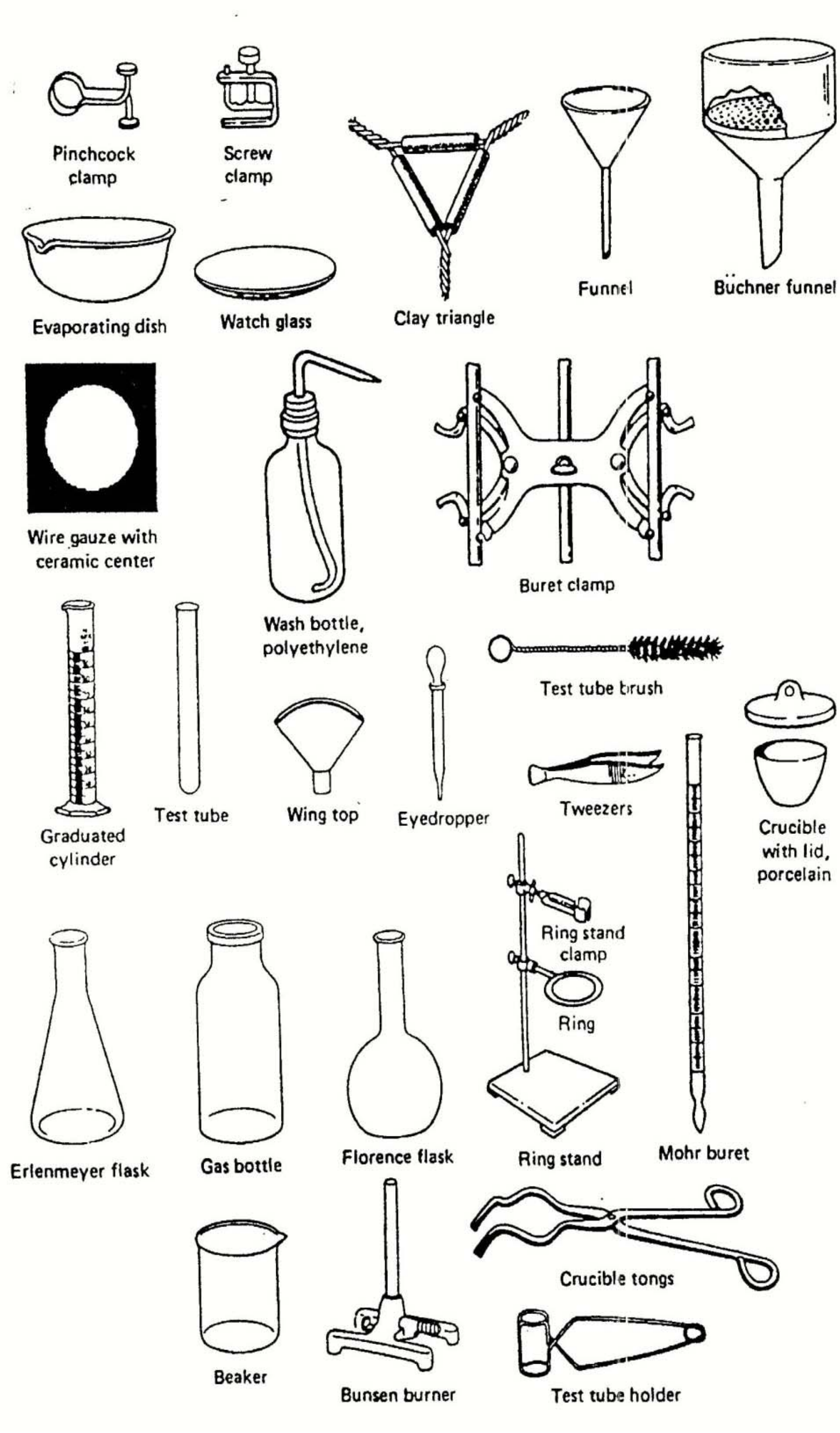
Graduated Pipet

Jumbo Pipet

Micro Pipet

FULL SCALE LAB EQUIPMENT

For familiarization with the types of full scale equipment used in formal labora



Use, Disposal, and Cleaning Instructions for Common Materials

These procedures are not repeated for each experiment, because it is assumed students will always refer to them before beginning any experiment. Properly cleaning the laboratory after experimentation is a safety measure!

Instrument Use

- Small quantities of chemicals are usually packaged in thin stem pipets. The drop size dispensed from small dropper bottles is different from that of the pipets. Most experiments require pipet-sized drops. It may be necessary to squeeze a few drops of chemical from a dropper bottle into a well plate, and then use a clean, empty pipet to suck up and drop the chemical.

- Once dispensed, do not return chemicals to their dropper bottles as this could cause contamination. To avoid over-dispensing, squeeze out only a few drops of chemicals into a well plate at a time. Squeeze out more as needed.

- To use burner fuel, unscrew the cap, light the wick, and place the can under a burner stand. Extinguish the fuel by gently placing the cap over the flame to deprive it of oxygen. Leave the cap sitting loosely on top of the wick when you are not using the fuel in order to avoid unnecessary evaporation and ensure an ample supply of fuel for all experiments. Allow the fuel to cool completely before tightly screwing on the cap for storage. If you screw the cap on while the fuel is still hot, you may create a vacuum that will make it very difficult to reopen the fuel can in the future.

- To reseal a pipet, heat the tip of a metal knife and press the pipet tip onto the hot metal while twirling the bulb. Never simply hold a flame to the tip of the stem!

- To minimize contamination, avoid touching the surfaces of clean items that might later come in contact with test chemicals.

Storage and Disposal

- Items in LabPaq auxiliary bags are generally used multiple times or for several different experiments. Always clean and return unused auxiliary items to the bag after completing an experiment.

- Blot up used and leftover chemicals with paper towels and place in a garbage bin or flush down a drain using copious amounts of water. The quantities of chemicals used in LabPaqs are very small and should not negatively impact the environment or adversely affect private septic systems or public sewer systems.

- Discard non-chemical experimental items with household garbage but first wrap them in newspaper. Place these items in a securely covered trash container that cannot be accessed by children and animals.

- LabPaqs containing dissection specimens will usually contain specific information regarding their handling. After completion of any dissecting work, wrap dissection specimens in news or waste paper, seal in a plastic bag, and place in a closed trash bin for normal garbage disposal.

Cleaning Instructions

- To clean a thin-stemmed plastic pipet, squeeze the bulb to draw up and then expel tap water from the bulb several times. Repeat this process with distilled water. Dry the pipet by repeatedly squeezing the bulb while tapping the tip on a clean paper towel. Then use gravity to help dry the pipet by forcefully swinging the pipet into a downward arch while squeezing the bulb. Lay the pipet on a clean paper towel or place it in a test tube stand and allow it to air dry.

- Use a mild liquid dishwashing detergent mixed with warm water to loosen solids or oils that adhere to experimental glassware, plastics, and equipment and to clean laboratory equipment and the laboratory area after an experiment. Use tap water to rinse washed items well and remove all traces of detergent.

- Use a soft cloth or a test tube brush to loosen and clean residue from the surfaces of experimental glassware, plastics, and equipment.

- Use a final rinse of distilled water to clean tap water mineral residue from newly washed items, especially beakers, cylinders, test tubes, and pipets.

- Dry test tubes by placing them upside down in the test tube rack. Air dry other items by placing them on paper towels, aluminum foil, or a clean dishtowel.

Important Notice Regarding Chemical Disposal: Due to the minute quantities and diluted and/or neutralized chemicals used in LabPaqs, the disposal methods previously described are well within acceptable levels of disposal guidelines defined for the vast majority of local solid and wastewater regulations.

Since regulations occasionally vary in some communities, you are advised to check with your local area waste authorities to confirm these disposal techniques are in compliance with local regulations and/or if you should seek assistance with disposal.

HOW TO WRITE LAB NOTES AND LAB REPORTS

Generally two basic records are compiled during and from scientific experimentation. The first record is your **Lab Notes** which you will record as you perform your experiments. Entries in your lab notebook will be the basis for your second record, the **Lab Report**. The Lab Report formally summarizes the activities and findings of your experiment and is normally submitted to your instructor for grading.

Lab Notes

Scientists keep track of their experimental procedures and results as they work by recording Lab Notes in a journal-type notebook. In laboratories these notebooks are often read by colleagues, such as directors and other scientists working on a project. In some cases scientific notebooks have become evidence in court cases. Consequently, Lab Notes must be intelligible to others and include sufficient information so that the work performed can be replicated and there can be no doubt about the honesty and reliability of the data and the researcher.

Notebooks appropriate for data recording are bound and have numbered pages that cannot be removed. Entries include all of your observations, actions, calculations, and conclusions related to each experiment. Never write data on pieces of scratch paper to transfer later, but always enter the data directly into the notebook. When you record erroneous data, neatly draw a light, diagonal line through the error, and write a brief explanation as to why you voided the data. Also record information you learn from an error. Mistakes can often be more useful than successes, and knowledge gained from them is valuable to future experimentation.

As in campus-based science laboratories, independent study students are expected to keep a complete scientific notebook of their work which may or may not be periodically reviewed by the instructor. Paperbound 5x7 notebooks of graph paper work well as lab notebooks. Since it is not practical to send notebooks back and forth between instructors and students for each experiment, independent study students usually prepare formal Lab Reports and submit them along with their regular assignments to the instructor via email or fax.

Lab Notes of experimental observations can be kept in many ways. Regardless of the procedure followed, the key question for deciding what kind of notes to keep is: Do I have a clear enough record that if I pick up my lab notebook or read my Lab Report in a few months, I can still explain to myself or others exactly what I did?

Lab Notes generally include these components:

Title: Match the title to the title stated in the lab manual.

Purpose: Write a brief statement about what the experiment is designed to determine or demonstrate.

Procedure: Briefly summarize what you did to perform this experiment and what equipment you used. Do not simply copy the procedure statement from the lab manual.

Data Tables: Always prepare tables before experimenting, so they will be ready to receive data as it is accumulated. Tables are an excellent way to organize your observational data, and where applicable, the Procedure section advises a table format for data recording.

Observations: Record what you observed, smelled, heard, or otherwise measured? Generally, observations are most easily recorded in table form.

Questions: Thoughtfully answer the questions asked throughout and at the end of experiments. The questions are designed to help you think critically about the experiment you just performed.

Conclusions: What did you learn from the experiment? Base your conclusions on your observations during the experiment. Write your conclusions in your best, formal English, using complete sentences, full paragraphs, and correct spelling.

Some general rules for keeping a lab notebook are:

- Leave the first two to four pages blank so you can add a Table of Contents later. Entries in the Table of Contents should include the experiment number, name, and page number.

- Neatly write your records without being fussy.

- Do not provide a complete Lab Report in your lab notebook. Instead, record what you did, how you did it, and what your results were. Your records need to be substantial enough that any knowledgeable person familiar with the subject of your experiment can read the entries, understand exactly what you did, and repeat your experiment if necessary.

- Organize all numerical readings and measurements in appropriate data tables. Refer to the sample Lab Report in this lab manual.

- Always identify the units (e.g., centimeters, kilograms, or seconds) for each set of data you record.

- Always identify the equipment you are using so you can refer to it later if you need to recheck your work.

- Capture the important steps and observations of your experiments using digital photos in which you are pictured. Photos within your Lab Report document both what you observed and that you actually performed the experiment.

- Record more rather than less data. Even details that may seem to have little bearing on your experiment (e.g., time and temperature variances when the data were taken) may turn out to have great bearing on your future results analysis.

- Make a note if you suspect that a particular data set may not be reliable.

- Never erase data. If you think an entry in your notes is in error, draw a single line through it and note the correction, but don't erase or scratch it out completely. You may later find that the information is significant after all.

Errors: Although experimental results may be in considerable error, there is never a wrong result in an experiment. Whatever happens in nature, including the laboratory, cannot be wrong. If you made your observations and measurements carefully, your results will be correct. Errors may have nothing to do with your investigation, or they may be mixed up with so many other unexpected events that your report is not useful. Even errors and mistakes have merit and often lead to our greatest learning experiences. Errors provide important results to consider; thus, you must think carefully about the interpretation of all your results, including your errors.

Experiment Completion: The cardinal rule in a laboratory is to fully carry out all phases of your experiments instead of "dry-labbing" or taking shortcuts. The Greek scientist, Archytas, summed this up very well in 380 B.C.:

> *In subjects of which one has no knowledge one must obtain knowledge either by learning from someone else or by discovering it for oneself. That which is learned, therefore, comes from another and by outside help; that which is discovered comes by one's own efforts and independently. To discover without seeking is difficult and rare, but if one seeks it is frequent and easy. If, however, one does not know how to seek, discovery is impossible.*

Lab Reports

This lab manual covers the overall format that formal Lab Reports generally follow. Remember, the Lab Report should be self-contained, so anyone, including someone without a science background or lab manual, can read it, understand what was done, and understand what was learned. Data and calculation tables have been provided for many of the experiments in this lab manual, and you are encouraged to use them. Computer spreadsheet programs such as Microsoft® Excel® and websites like nces.ed.gov/nceskids/Graphing/Classic/line.asp can also greatly facilitate the preparation of data tables and graphs. Visit www.ncsu.edu/labwriter/ for additional information on preparing Lab Reports.

Lab Reports are expected to be word processed and to look organized and professional. They should be free of grammar, syntax, and spelling errors and be a respectable presentation of your work. Avoid writing in the first person as much as possible.

Lab Reports should generally contain and clearly distinguish the sections discussed in detail below. The presentation and organization skills you'll develop by producing science Lab Reports is beneficial to all potential career fields.

<u>Lab Report Format:</u>

Title Page

This is the first page of the Lab Report and consists of:

a. Experiment number and/or title
b. Your name
c. Names of lab partner(s)
d. Date and time experiment was performed
e. Location if work was performed in the field
f. Course number

Section 1: Abstract, Experiment, and Observation

Abstract: Even though the abstract appears at the beginning of the Lab Report, you will write it last. An abstract is a very concise description of the experiment's objectives, results, and conclusions and should be no longer than a paragraph.

Experiment and Observation: In chronological order, carefully and concisely describe what was done, what was observed, and what, if any, problems were encountered. Describe what field and laboratory techniques and equipment you used to collect and analyze the data on which the conclusions are based. Insert photos and graphic illustrations in this section; graphics should be in .jpg or .gif format to minimize electronic file size.

Show all your work for any calculations performed. Title every graph and clearly label the axes. Data point connections should be "best-fit curves," which are smooth, straight or curved lines that best represent the data, instead of dot-to-dot data point connections.

Include all data tables, photos, graphs, lists, sketches, etc. in an organized fashion. Include relevant symbols and units with data. Generally one or two sentences explaining how data was obtained is appropriate for each data table.

Note any anomalies observed or difficulties encountered in collecting data as these may affect the final results. Include information about any errors you observed and what you learned from them. Be deliberate in recording your experimental procedures in detail. Your comments may also include any preliminary ideas you have for explaining the data or trends you see emerging.

Section 2: Analysis – Calculations, Graphs, and Error Analysis

Generally, the questions at the end of each experiment will act as a guide when preparing your results and conclusions. The analysis is written in paragraph form and no more than one or two pages long. As you write, consider the following:

a. What is the connection between the experimental measurements taken and the final results and conclusions? How do your results relate to the real world?

b. What were the results of observations and calculations?

c. What trends were noticed?

d. What is the theory or model behind the experiment?

e. Do the experimental results substantiate or refute the theory? Why? Be sure to refer specifically to the results you obtained.

f. Were the results consistent with your original predictions of outcomes or were you forced to revise your thinking?

g. Did errors (e.g., environmental changes or unplanned friction) occur? If so, how did these errors affect the experiment?

h. Did any errors occur due to the equipment used (e.g., skewed estimates due to a lack of sufficient measurement gradients on a beaker)?

i. What recommendations might improve the procedures and results?

Error Analysis: In a single paragraph, comment on the accuracy and precision of the apparatuses used, include a discussion of the experimental errors, and include an estimate of the errors in your final result. Remember, errors are not mistakes. Errors arise because the apparatus and/or the environment inevitably fail to match the ideal circumstances assumed when deriving a theory or equation. The two principal sources of error are:

> *Physical phenomena*: Elements in the environment may be similar to the phenomena being measured and may affect the measured quantity. Examples include stray magnetic or electric fields or unaccounted for friction.
>
> *Limitations of the observer, analysis, and/or instruments:* Examples include parallax error when reading a meter tape, the coarse scale of a graph, and the sensitivity of the instruments.

Human errors and mistakes that are not acceptable scientific errors include: calculator misuse (e.g., pushing the wrong button, misreading the display); misuse of equipment; faulty equipment; incorrectly assembled circuits or apparatuses.

Section 3: Discussion, Results, and Conclusions

Discussion: Carefully organize your discussion to include consideration of the experiment's results, interpretation of the results, and uncertainty in the results. This section is written in paragraph form and is generally no more than one to two pages in length. Occasionally it will be more appropriate to organize various aspects of the discussion differently. While not all of the following questions will apply to every experiment, consider them when writing your Lab Report.

Results:

a. What is the connection among your observations, measurements, and final results?

b. What were the independent or dependent variables in the experiment?

c. What were the results of your calculations?

d. What trends were noticeable?

e. How did the independent variables affect the dependent variables? For example, did an increase in a given independent variable result in an increase or decrease in the associated dependent variable?

Interpretation of Results:

a. What is the theory or model behind the experiment you performed?

b. Do your experimental results substantiate or agree with the theory? Why or why not? Be sure to refer specifically to your experimental results.

c. Were these results consistent with your original beliefs or were you forced to reevaluate your prior conceptions?

Uncertainty in results:

a. How much did your results deviate from expected values?

b. Are the deviations due to error or uncertainty in the experimental method? Can you think of ways to decrease the amount of uncertainty?

c. Are the deviations due to idealizations inherent in the theory? What factors has the theory neglected to consider?

d. In either case, consider whether your results display systematic or random deviations.

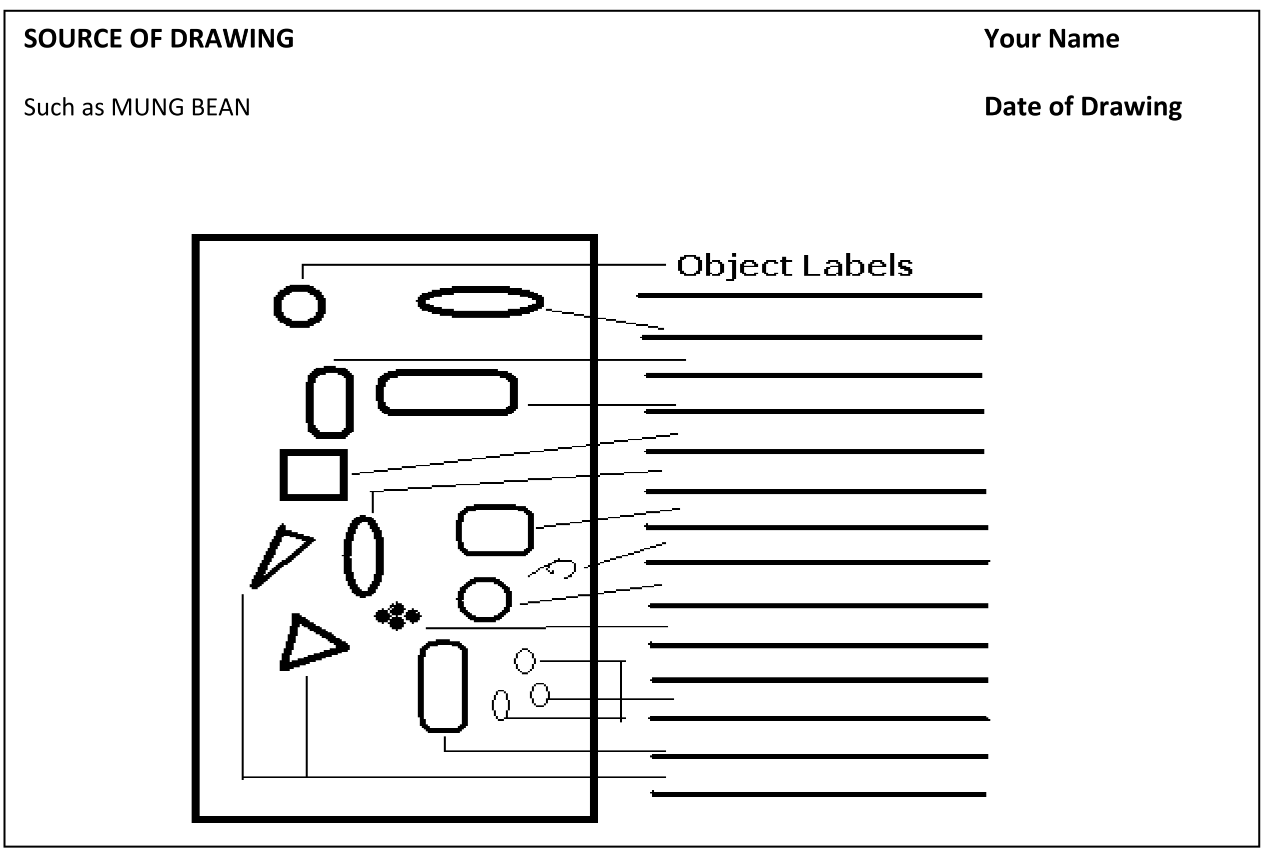
Lab Notes and Lab Reports undoubtedly sound complex and overwhelming at first, but don't worry. They will make more sense to you when you begin performing the experiments and writing reports. After writing your first few Lab Reports, the reports will become second nature to you. Refer to the sample Lab Report in this manual.

Laboratory Drawings

Laboratory work often requires you to illustrate findings in representational drawings. Clear, well organized drawings are an excellent way to convey observations and are often more easily understood than long textual descriptions. The adage "a picture is worth a thousand words" really is true when referring to Lab Notes.

Give yourself ample drawing space and leave a white margin around the actual illustration so it is clearly visible. Also leave a broad margin along one side of your drawing to insert object labels. Use a ruler to draw straight lines for the labels and connecting lines to the corresponding objects. The image below provides an example of how laboratory drawings should look when they are included in a formal Lab Report.

Students often believe they can't draw; however, with a little practice, anyone can illustrate laboratory observations. A trick many artists use is to form a mental grid over the scene and draw within the grid. For example, quickly make a free hand drawing of the diagram below. Now, mentally divide the diagram into quarters and try drawing the diagram again. In all likelihood, the second, grid-based drawing yielded a better result.



Visual Presentation of Data

Like pictures, good graphs and tables can quickly and clearly communicate information visually; hence, graphs and tables are often used to represent or depict collected data. Graphs and tables should be constructed to stand alone – all the information required to understand a graph or table should be included.

Tables

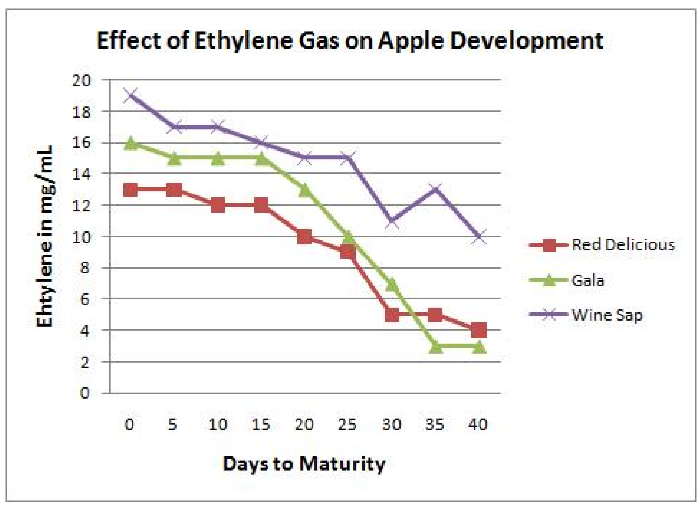
A table presents data clearly and logically. Independent data is listed in the left column and all dependent data is listed to the right. While there will be only one independent variable, there can be more than one dependent variable.

The decision to present data in a table rather than a graph is often arbitrary; however, a table may be more appropriate when the data set is too small to warrant a graph or is large, complex, and not easily illustrated. Often, data tables display raw data, and a graph provides visualization of the data.

Concentration of Plant Fertilizer versus Plant Height	
X-Axis	Y-Axis
Fertilizer % solution	Plant Height in cm
0	25
10	34
20	44
30	76
40	79
50	65
60	40

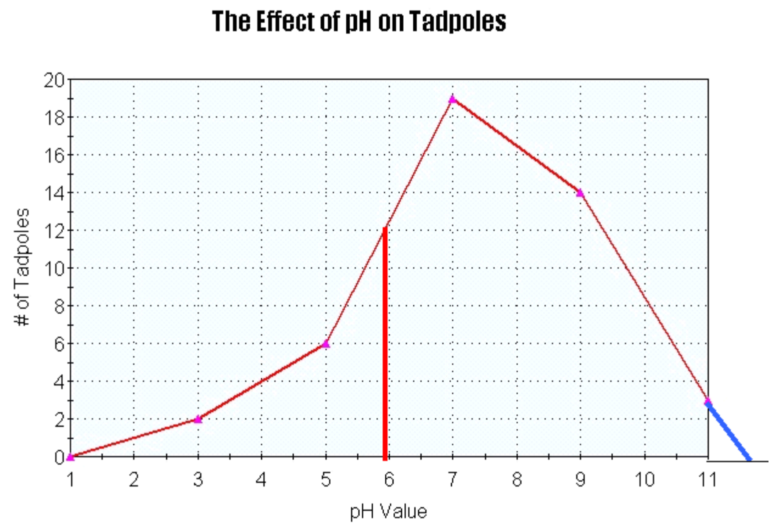
Graphs

A graph is composed of two basic elements: the graph itself and the graph **legend**. The legend provides the descriptive information needed to fully understand the graph. In the graph at right, the legend shows that the red line represents Red Delicious apples, the brown line represents Gala apples, and the green line represents Wine Sap apples. Without the legend it would be difficult to interpret this graph.

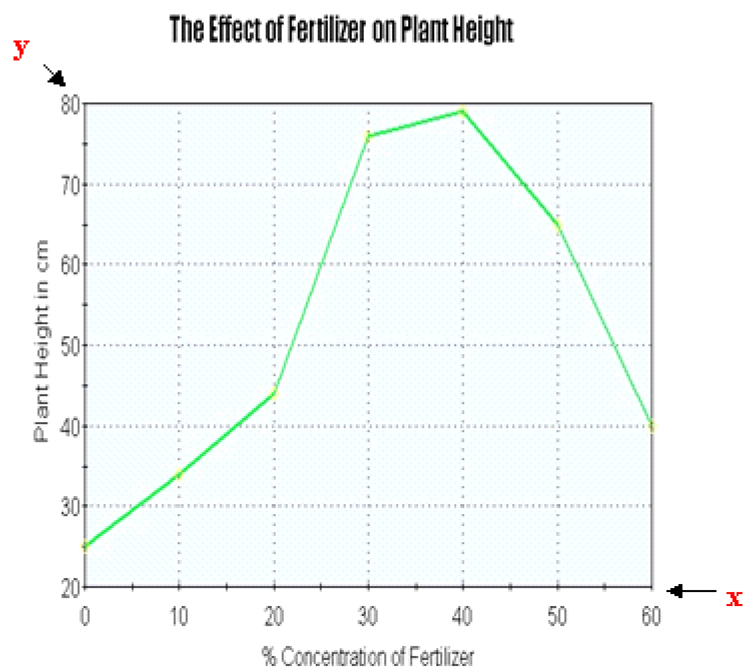


One of the most important uses of a graph is to predict data that is not measured. In **interpolation,** a graph is used to construct new data points within the range of a discrete set of known data points. As an example, if the data points on the following pH graph are recorded at pHs 1, 3, 5, 7, 9 and 11, but the researcher wants to know what happens at pH 6, the information can be found by interpolating the data between pH 5 and 7. Following the red line up to interpolate the value, there would be 12 tadpoles living at a pH 6.

Similarly, a graph line can be extended to **extrapolate** data that is outside of the measured data. For example, if the researcher wanted to know what would happen at a pH greater than 11, the information can be extrapolated by extending the line. In the graph at right, the blue line represents an extrapolation that allows scientists to predict what might happen.



Graph Setup: Consider a simple plot of the Plant Fertilizer versus the Plant Height data from the first table. This is a plot of points on a set of X and Y coordinates. The X-axis or **abscissa** runs horizontally; the Y-axis or **ordinate** runs vertically. By convention, the X-axis is used for the **independent variable** – a manipulated variable in an experiment whose presence determines the change in the dependent variable. The Y-axis is used for the **dependent variable** – the variable affected by another variable or by a certain event. In this example, the amount of fertilizer is the independent variable and goes on the X-axis. The plant height, since it may change depending on changes in fertilizer amount, goes on the Y-axis.



One way to determine which data goes on the X-axis versus the Y-axis is to think about what affects what. Does fertilizer affect plant height or does plant height affect fertilizer. Only one of these options should make sense. Plant height will not change the fertilizer, but the fertilizer will affect the plant height. The variable that causes the change is independent, and the variable that changes is dependent.

If the data deals with more than one dependent variable, it would be represented with three lines and a key or legend would identify which line represents which data set. In all graphs, each axis is labeled, and the units of measurement are specified. When a graph is presented in a Lab Report, the variables, the scale, and the range of the measurements should be clear.

Refer to the table below when setting up a line graph.

How to Construct a Line Graph

Step	Explanation
1 Identify the variables.	• Independent variable: Controlled by the experimenter. - Goes on the X-axis – the abscissa. - Located on the left side of a data chart. • Dependent variable: Changes with the independent variable. - Goes on the Y-axis – the ordinate. - Located on the right side of a data table
2 Determine the range.	• Subtract the lowest data value from the highest. - Calculate each variable separately.
3 Determine the scale.	• Choose a scale that best fits each variable's range (e.g., increments of one, two, five, etc.). - Choose a scale that spreads the graph over most of the available space.
4 Number and label each axis.	• The axes tell what the graph's data lines represent. - Always include units of measure (e.g., days, time, meters, etc.).
5 Plot the data points.	• Plot each data value on the graph with a dot. - Add the numerical data next to the dot, if there is room and you avoid cluttering the graph.
6 Draw the graph.	• Draw a straight or curved line that best fits the data points. - Most graphs are shown as smooth lines, not dot-by-dot connections.
7 Title the graph.	• The title should clearly tell what the graph is depicting. • Provide a legend to identify different lines, if the graph has more than one set of data.

Computer Graphing Using MS Excel

These instructions apply to the 2003 version of Excel. If you have a newer version, perform an Internet search for current instructions.

This set of general instructions will be used to plot the following data:

Time, t (seconds)	Distance, x (cm)
0	0
.1	9.8
.2	30.2
.3	59.9
.4	99.2
.5	148.9

When graphing x-y data, you must first determine which variable will be the X-variable and which will be the Y-variable. If you are unsure, review the previous Visual Presentation of Data section.

Create a File

1. Open a blank Excel spreadsheet.

2. Save the file under an appropriate name, such as *Exercise 1-Time vs Distance*.

Create Data Table

1. Enter the X-data points in the first column (A).

2. Enter the Y-data points in the second column (B).

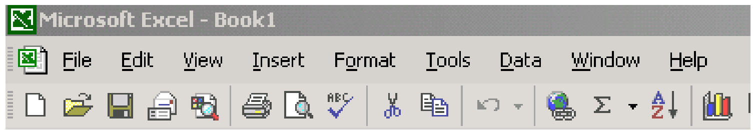
Note: It is often useful to enter zero as the first data value, but not always. Nonetheless, it is a good habit to start.

3. Highlight all the data values by placing the curser in the first cell to be highlighted (A1) and either:

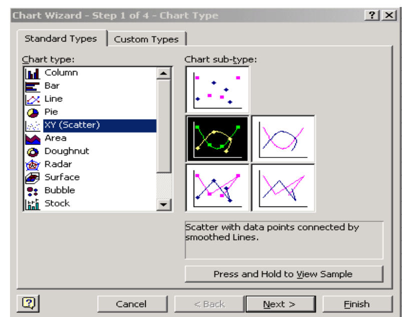
    - Clicking and holding the left mouse button while pulling the mouse and curser down and to the right so the cells are highlighted and then releasing the button.
    - Holding the <Shift> key on the keyboard and using the direction arrows to move the cursor over the desired area until all cells are highlighted.

Create Graph

4. Click the **Chart Wizard** icon on the toolbar or select **Chart** from the **Insert** menu. 



Step 1: Chart Type

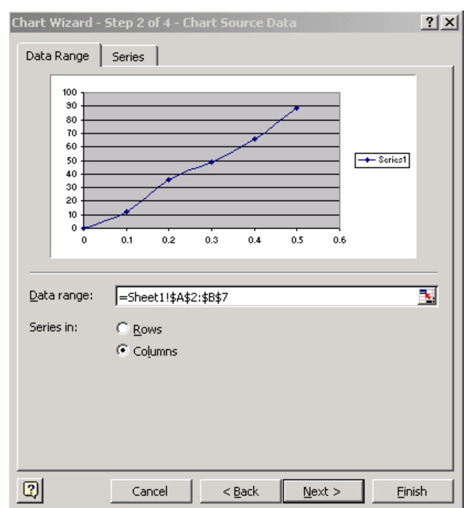


5. Select **XY (Scatter)** from the **Standard Types** tab.

6. Select your preferred **Chart sub-type**. Although you can choose graphs with data points, graphs with smooth lines are preferable.

7. Click **Next >**.

Step 2: Chart Source Data



Carefully review this information to ensure the graph has the correct values for the vertical and the horizontal axes.

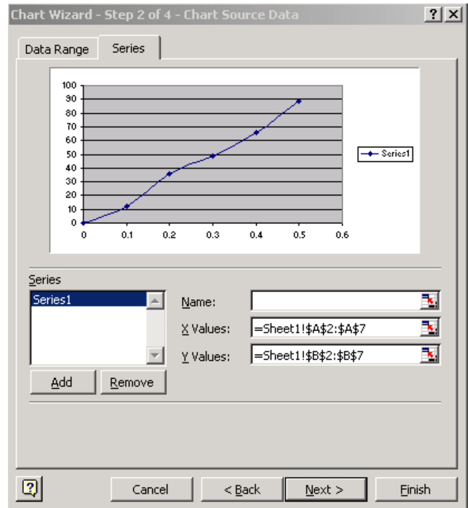
8. Select the **Columns** option button on the **Data Range** tab.

The range should read **=Sheet1!$A$2:$B$7**

This means the data:

- Comes from Sheet 1 of the workbook.
- Comes from cells A2 through B7.
- Has been organized by data columns instead of data rows.

9. Under the **Series** tab, the values for the X- and Y-axes are as follows:



X Values: =Sheet1!$A$2:$A$7
Y Values: =Sheet1!$B$2:$B$7

This means:

- The data comes from Sheet 1 of the workbook.
- The X-value data comes from cells A2 through A7.
- The Y-value data comes from cells B2 through B7.

Note: If the data is reversed, replace the incorrect column letters and numbers with the correct ones.

10. To maintain the appropriate reference, rename the series of data points from the default, *Series1*, by entering another name in the **Name** field. *Data* is commonly used.

11. Click **Next >.**

Step 3: Chart Options

12. Chart Options allows you to assign titles and labels to your graph as well as determine the appearance of gridlines and legends. Make your selections.

13. Click **Next >**.

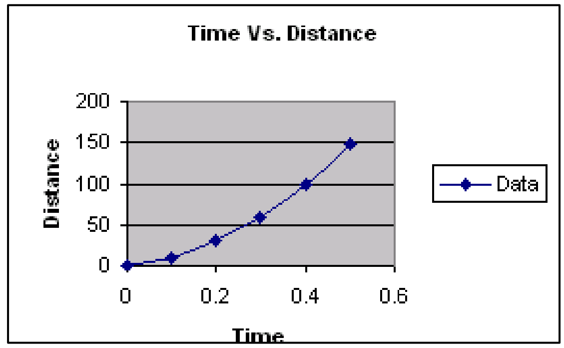
Step 4: Chart Location

14. Choose the location where your graph will be created.

- **As new sheet:** Opens a new page on which the graph will appear.
- **As object in:** Places the graph in the current spreadsheet.

If you're unsure, select **As object in** so the data and graph will appear on the same page.

15. Click **Finish** to complete the graph.



SAFETY CONCERNS

You, as a responsible science student and researcher, are solely responsible for safely storing and using your LabPaq materials and for conducting your experiments in a safe and responsible manner.

Items in your LabPaq can be especially dangerous to children and pets, so the LabPaq should always be kept safely stored out of their reach. The LabPaq may contain acids or other chemicals that can cause burns if mishandled plus serious illness and or death if consumed.

Many LabPaq items are made of glass and/or have sharp edges that pose potential risks for cuts and scratches. While LabPaq thermometers do not contain mercury, they might still break and cause injury. LabPaqs contain small items and materials that could cause choking, injury, or death if misused.

Experimentation may require you to climb, push, pull, spin, and whirl. While these activities are not necessarily dangerous, they can pose hazards, and you should always undertake these activities cautiously and with consideration for your surroundings. If you need to climb to take measurements, make sure any stool, chair, or ladder you use is sturdy and take ample precautions to prevent falls. It is wise to have a partner help keep you stable when you must climb. Be especially aware of experimental equipment that you must put in motion, and act cautiously to ensure that items cannot go astray and cause injury to people or property.

If you or anyone accidentally consumes or otherwise comes into contact with a substance that could be toxic or cannot be easily washed away, immediately call:

The National Poison Control Center: 1-800-222-1222

Your eyesight is precious and should be protected against chemical spills or splashes as well as flying objects and debris. Always wear safety goggles when working with chemicals of any kind and when working with non-chemical objects that could possibly fly into your eyes.

Since chemicals, dirt, and germs are often involved in laboratory experiments, you should never eat or smoke in your laboratory area. Protect your body by keeping your hair tied back from your face and by wearing old clothing that fully covers your arms and legs.

You also need to protect your home furnishings from damage during your experimentation. Cover your work surface with plastic or paper towels when appropriate to prevent ruining furniture and to aid in cleanup.

The best safety tools you have are your own mind and intellectual ability to think and plan. After previewing each experiment, carefully think about what safety precautions you need to take to experiment safely, and then take them!

Since it is impossible to control students' use of this lab manual and related LabPaqs or students' work environments, the author(s) of this lab manual, the instructors and institutions that adopt it, and Hands-On Labs, Inc. – the publisher of the lab manual and the producer of LabPaqs – authorize the use of these educational products only on the express condition that the purchasers and users accept full and complete responsibility for all and any liability related to their use of same. Additional terms authorizing the use of a LabPaq are contained in its Purchase Agreement available at www.LabPaq.com.

Basic Safety Guidelines

This section contains vital information that you must thoroughly read and completely understand before beginning to perform experiments.

Science experimentation is fun but involves potential hazards which you must acknowledge to avoid. To safely conduct science experiments, you must learn and follow basic safety procedures. While there may be fewer safety hazards for physics and geology experimentation than chemistry and biology, safety risks exist in all science experimentation and should be taken very seriously. Thus, the following safety procedures review is relevant to all students regardless of their field of study

While this lab manual tries to include all relevant safety issues, not every potential danger can be foreseen, as each experiment involves different safety considerations. You must always act responsibly, learn to recognize potential dangers, and always take appropriate precautions. Regardless of whether you will be working in a campus or home laboratory setting, it is extremely important that you know how to anticipate and avoid possible hazards and to be safety conscious at all times.

Basic Safety Procedures

Science experimentation often involves using toxic chemicals, flammable substances, breakable items, and other potentially dangerous materials and equipment. All of these things can cause injury and even death if not properly handled. These basic safety procedures apply when working in a campus or home laboratory.

- Because eyesight is precious and eyes are vulnerable to chemical spills and splashes, shattered rocks and glass, and floating and flying objects:
  - Always wear eye protecting safety goggles when experimenting.

- Because toxic chemicals and foreign matter may enter the body through digestion:
  - Never drink or eat in laboratory areas.
  - Always wash your hands before leaving the laboratory.
  - Always clean the laboratory area after experimentation.

- Because toxic substances may enter the body through the skin and lungs:
  - Ensure the laboratory always has adequate ventilation.
  - Never directly inhale chemicals.
  - Wear long-sleeved shirts, pants, and enclosed shoes when in the laboratory.
  - Wear gloves and aprons when appropriate.

- Because hair, clothing, and jewelry can create hazards, cause spills, and catch fire while experimenting:
  - Always tie or pin back long hair.
  - Always wear snug fitting and preferably old clothing.
  - Never wear dangling jewelry or objects.

- Because a laboratory area contains various fire hazards:
  - Smoking is always forbidden in laboratory areas.

- Because chemical experimentation involves numerous potential hazards:
  - Know how to locate and use basic safety equipment.
  - Never leave a burning flame or reaction unattended.
  - Specifically follow all safety instructions.
  - Never perform any unauthorized experiments.
  - Always properly store equipment and supplies.

- Because science equipment and supplies often include breakable glass and sharp items posing potential risks for cuts and scratches; and small items and dangerous chemicals potentially causing death or injury if consumed:
  - Carefully handle all science equipment and supplies.
  - Keep science equipment and supplies stored out of the reach of pets and small children.
  - Ensure pets and small children will not enter the lab area while experimenting.

- Because science experimentation may require students to climb, push, pull, spin, and whirl:
    - Undertake these activities cautiously and with consideration for the people, property, and objects that could be impacted.
    - Ensure stools, chairs, or ladders used to climb are sturdy and take ample precautions to prevent falls.

- Because your best safety tools are your own mind and intellectual ability:
    - Always preview each experiment, carefully think about what safety precautions need to be taken to experiment safely, and then take them.

<u>Basic Safety Equipment:</u>

You can find the following pieces of basic safety equipment in all campus laboratories. Informal and home laboratories may not have all of these items, but you can usually make simple substitutions. You should know the exact location and proper use of these items.

Eyewash Station: All laboratories should have safety equipment to wash chemicals from the eyes. A formal eyewash station looks like a water fountain with two faucets directed up at spaces to match the space between the eyes. In case of an accident, the victim's head is placed between the faucets while the eyelids are held open, so the faucets can flush water into the eye sockets and wash away the chemicals. In an informal laboratory, you can substitute a hand-held shower wand for an eyewash station. After the eyes are thoroughly washed, consult a physician promptly.

Fire Blanket: A fire blanket is a tightly woven fabric used to smother and extinguish a fire. It can cover a fire area or be wrapped around a victim who has caught on fire.

Fire Extinguisher: There are several types of fire extinguishers, but at least one should be available in all laboratories. You should familiarize yourself with and know how to use the particular fire extinguisher in your laboratory. At a minimum, home laboratories should have a bucket of water and a large container of sand or dirt to smother fires.

First-Aid Kit: This kit of basic first-aid supplies is used for the emergency treatment of injuries and should be standard in both formal and informal laboratories. It should always be well stocked and easily accessible.

Fume Hood: A fume hood is a hooded area containing an exhaust fan that expels noxious fumes from the laboratory. Experiments that might produce dangerous or unpleasant vapors are conducted under this hood. In an informal laboratory such experiments should be conducted only with ample ventilation and near open windows or doors. If a kitchen is used for a home laboratory, the exhaust fan above the stove substitutes nicely for a fume hood.

Safety Shower: This shower is used in formal laboratories to put out fires or douse people who have caught on fire or suffered a large chemical spill. A hand-held shower wand is the best substitute for a safety shower in a home laboratory.

Safety Goggles: There is no substitute for this important piece of safety equipment! Spills and splashes do occur, and eyes can very easily be damaged if they come in contact with laboratory chemicals, shattered glass, swinging objects, or flying rock chips. While normal eyeglasses provide some protection, objects can still enter the eyes from the side. Safety goggles cup around all sides of the eyes to provide the most protection and can be worn over normal eyeglasses when necessary.

Spill Containment Kit: This kit consists of absorbent material that can be ringed around a spilled chemical to keep the spill contained until it can be neutralized. The kit may simply be a container full of sand or other absorbent material such as cat litter.

Potential Laboratory Hazards:

Recognizing and respecting potential hazards is the first step toward preventing accidents. Please appreciate the grave dangers the following laboratory hazards represent. Work to avoid these dangers and consider how to respond properly in the event of an accident.

Acid Splatter: When water is added to concentrated acid, the solution becomes very hot and may splatter acid. Splattering is less likely to occur if you add acid slowly to the water. Remember this ***AAA*** rule: **A**lways **A**dd **A**cid to water, **never** add water to acid.

Chemical Ingestion: Virtually all chemicals found in a laboratory are potentially toxic. To avoid ingesting dangerous chemicals, never taste, eat, or drink anything while in the laboratory. All laboratories, and especially those in home kitchens, should always be thoroughly cleaned after experimentation to avoid this hazard. In the event of any chemical ingestion, immediately consult a physician.

Chemical Spills: Flesh burns may result if acids, bases, or other caustic chemicals are spilled and come in contact with skin. Flush the exposed skin with a gentle flow of water for several minutes at a sink or safety shower. Neutralize acid spills with sodium bicarbonate – simple baking soda. If eye contact is involved, use the eyewash station or its substitute. Use the spill containment kit until the spill is neutralized. To better protect the body from chemical spills, wear long-sleeved shirts, full-length pants, and enclosed shoes when in the laboratory.

Fires: The open flame of a Bunsen burner or any heating source, combined with inattention, may result in a loose sleeve, loose hair, or some unnoticed item catching fire. Except for water, most solvents, including toluene, alcohols, acetones, ethers, and acetates, are highly flammable and should never be used near an open flame. As a general rule, **never leave an open flame or reaction unattended.** In case of fire, use a fire extinguisher, fire blanket, and/or safety shower.

Fume Inhalation: To avoid inhaling dangerous fumes, partially fill your lungs with air and, while standing slightly back from the fumes, use your hand to waft the odors gently toward your nose. Lightly sniff the fumes in a controlled fashion. **Never inhale fumes directly!** Treat inhalation problems with fresh air, and consult a physician if the problem appears serious.

Glass Tubing Hazards: Never force a piece of glass tubing into a stopper hole. The glass may snap, and the jagged edges can cause serious cuts. Before inserting glass tubing into a rubber or cork stopper hole, be sure the hole is the proper size. Lubricate the end of the glass tubing with glycerol or soap, and then, while grasping the tubing with a heavy glove or towel, gently but firmly twist it into the hole. Treat any cuts with appropriate first aid.

Heated Test Tube Splatter: Splattering and eruptions can occur when solutions are heated in a test tube. You should never point a heated test tube towards anyone. To minimize this danger, direct the flame toward the top rather than the bottom of the test tube. Gently agitate the tube over the flame to heat the contents evenly.

Horseplay: A laboratory full of potentially dangerous chemicals and equipment is a place for serious work, not for horseplay! Fooling around in the laboratory is an invitation for an accident.

Shattered Glassware: Graduated cylinders, volumetric flasks, and certain other pieces of glassware are **not** designed to be heated. If heated, glassware is likely to shatter and cause injuries. Always ensure you are using heatproof glass before applying it to a heat source. Take special caution when working with any type of laboratory glassware

CAUTION for Women:
If you are pregnant or could be pregnant, you should seek advice from your personal physician before doing any type of science experimentation.

Material Safety Data Sheets

An important skill in the safe use of chemicals is the ability to read a Material Safety Data Sheet (MSDS). An MSDS is designed to provide chemical, physical, health, and safety information on chemical reagents and supplies. It provides information about how to handle, store, transport, use and dispose of chemicals in a safe manner.

An MSDS also provides workers and emergency personnel with the proper procedures for handling and working with chemical substances. While there is no standard format for an MSDS, any MSDS provides basic information about physical data, toxicity, health effects, first-aid procedures, chemical reactivity, safe storage, safe disposal, required protective equipment, and spill cleanup procedures. An MSDS is required to be readily available at any business where any type of chemical is used. Even daycare centers and grocery stores need MSDSs for their cleaning supplies.

It is important to know how to read and understand an MSDS. An MSDS is generally organized into the following sections:

Section 1: Product Identification
Chemical name and trade names

Section 2: Hazardous Ingredients
Components and percentages

Section 3: Physical Data
Boiling point, density, solubility in water, appearance, color, etc.

Section 4: Fire and Explosion Data
Flash point, extinguisher media, special fire fighting procedures, and unusual fire and explosion hazards

Section 5: Health Hazard Data
Exposure limits, effects of overexposure, emergency and first-aid procedures

Section 6: Reactivity Data
Stability, conditions to avoid, incompatible materials, etc.

Section 7: Spill or Leak Procedures
Steps to take to control and clean up spills and leaks and waste disposal methods

Section 8: Control Measures
Respiratory protection, ventilation, protection for eyes or skin, or other needed protective equipment

Section 9: Special Precautions
How to handle and store, steps to take in a spill, disposal methods, and other precautions

The MSDS is a tool available to employers and workers for making decisions about chemicals. The least hazardous chemical should be selected for use whenever possible, and procedures for storing, using, and disposing of chemicals should be written and communicated to workers.

View MSDS information at www.hazard.com/msds/index.php. You can also find a link to MSDS information at www.LabPaq.com. If there is ever a problem or question about the proper handling of any chemical, seek information from one of these sources.

Safety Quiz

Refer to the illustration on the following page when answering the questions.

1. List three (3) unsafe activities in the illustration and explain why each is unsafe.

2. List three (3) correct procedures depicted in the illustration.

3. What should Tarik do after the accident?

4. What should Lindsey have done to avoid an accident?

5. Compare Ming and David's laboratory techniques. Who is following the rules?

6. What are three (3) things shown in the laboratory that should not be there?

7. Compare Joe and Tyler's laboratory techniques. Who is working the correct way?

8. What will happen to Ray and Chris when the instructor catches them?

9. List three (3) items in the illustration that are there for the safety of the students.

10. What is Consuela doing wrong?


LINDSEY
JOHN
WHINE
PETE
SAFETY BLANKET
DAVID
CHRIS
CONSUELA
MING
MIRROR
JOE
RAY
CHIPS
AYANNA
OUCH!
TARIK
SODA
TYLER
JENNIFER
EYE WASH

Science Lab Safety Reinforcement Agreement

Any type of science experimentation involves potential hazards, and unforeseen risks may exist. The need to prevent injuries and accidents cannot be overemphasized!

Use of this lab manual and any LabPaqs are expressly conditioned upon your agreement to follow all safety precautions and accept full responsibility for your actions.

Study the safety section of this lab manual until you can honestly state the following:

- ❑ Before beginning an experiment I will first read all directions and then assemble and organize all required equipment and supplies.
- ❑ I will select a work area that is inaccessible to children and pets while experiments are in progress. I will not leave experiments unattended, and I will not leave my work area while a chemical equipment is set up unless the room is locked.
- ❑ To avoid the potential for accidents, I will clear my home laboratory workspace of all non-laboratory items before setting up equipment and supplies for my experiments.
- ❑ I will never attempt an experiment until I fully understand it. If in doubt about any part of an experiment, I will first speak with my instructor before proceeding.
- ❑ I will wear safety goggles when working with chemicals or items that can get in my eyes
- ❑ I know that except for water, most solvents, such as toluene, alcohols, acetone, ethers, and ethyl acetate are highly flammable and should never be used near an open flame.
- ❑ I know that the heat created when water is added to concentrated acids is sufficient to cause spattering. When preparing dilute acid solutions, I will always add the acid to the water – rather than the water to the acid – while slowly stirring the mixture.
- ❑ I know it is wise to wear rubber gloves and goggles when handling acids and other dangerous chemicals; I should neutralize acid spills with sodium bicarbonate; and I should wash acid spilled on skin or clothes immediately with plenty of cold water.
- ❑ I know that many chemicals produce toxic fumes, and cautious procedures should be used when smelling any chemical. When I wish to smell a chemical, I will never hold it directly under my nose, but will use my hand to waft vapors toward my nose.
- ❑ I will always handle glassware with respect and promptly replace any defective glassware. Even a small crack can cause glass to break, especially when heated. To avoid cuts and injuries, I will immediately dispose of any broken glassware.

- ❑ I will avoid burns by testing glass and metal objects for heat before handling. I know that the preferred first aid for burns is to immediately hold the burned area under cold water for several minutes.

- ❑ I know that serious accidents can occur when wrong chemicals are used in an experiment. I will always read labels before removing chemicals from their containers.

- ❑ I will avoid the possibility of contamination and accidents by never returning an unused chemical to its original container. To avoid waste I will try to pour only the approximate amount of chemicals required.

- ❑ I know to immediately flush any chemical spill on the skin with cold water and consult a doctor if required.

- ❑ To protect myself from potential hazards, I will wear long pants, a long-sleeved shirt, and enclosed shoes when performing experiments. I will tie up any loose hair, clothing, or other materials as well.

- ❑ I will never eat, drink, or smoke while performing experiments.

- ❑ After completing all experiments I will clean my work area, wash my hands, and store the laboratory equipment in a safe place inaccessible to children and pets.

- ❑ I will always conscientiously work in a reasonable and prudent manner to optimize my safety and the safety of others whenever and wherever I am involved with any type of science equipment or experimentation.

It is impossible to control students' use of this lab manual and related LabPaqs or students' work environments. The author(s) of this lab manual, the instructors and institutions that adopt it, and Hands-On Labs, Inc. – the publisher of the lab manual and producer of LabPaqs – authorize the use of these educational products **only** on the express condition that the purchasers and users accept full and complete responsibility for all and any liability related to their use of same. Please review this document several times until you are certain you understand it and will fully abide by its terms. Then sign and date the agreement were indicated.

I am a responsible adult who has read, understands, and agrees to fully abide by all safety precautions prescribed in this lab manual for laboratory work and for the use of a LabPaq. Accordingly, I recognize the inherent hazards associated with science experimentation; I will always experiment in a safe and prudent manner; and I unconditionally accept full and complete responsibility for any and all liability related to my purchase and/or use of a science LabPaq or any other science products or materials provided by Hands-On Labs, Inc. (HOL).

______________________________________ ____________

Student's Name (print) and Signature Date

EXPERIMENTS

Crystal Growing and the Rock Cycle

Trina Johnson Riegel, M.S. Version 09.1.01

Review the safety materials and wear goggles when working with chemicals. Read the entire exercise before you begin. Take time to organize the materials you will need and set aside a safe work space in which to complete the exercise.

Experiment Summary:

Students will have the opportunity to use evaporation to grow synthetic crystals from a supersaturated solution of both alum and magnesium sulfate. They will study the relationship between cooling rate and crystal size by making sugar glass and measuring interfacial angles of minerals. Students will study the dissolution point of certain crystals.

Objectives

- To grow synthetic crystals from a supersaturated solution by evaporation,
- To measure the interfacial angles of minerals,
- To make sugar “glass,”
- To understand the role of evaporation in mineral growth, and
- To determine the dissolution point of certain crystals.

Materials

Materials From:	Qty	Item Description:
Student Provides	1	Pan, small
	1	Spoon or blunt knife
	1	Cup saucer
	1	Stovetop burner
	1	Refrigerator
From LabPaq	1	Beaker, 100 mL, plastic
	3	Petri dish, 90 mm
	1	Protractor
	1	Rock – Igneous rock #19
	1	Rock – Metamorphic #47
	1	Rock – Sedimentary #36
	1	Rock – Set of 18 Minerals
	1	Ruler, Metric
	1	Scale-Digital-500g
	1	Magnifier, Geologic Hand
	1	Tweezers, plastic
	1	Thermometer-in-cardboard-tube
Alum, Aluminum Sulfate-Bag	1	Alum, Aluminum Sulfate - 25 g in Bag 4"x 7"
Epsom Salts in grams-Bag	1	Epsom Salts 65 grams in Bag 4"x 7"
Sugar in grams-Bag	1	Sugar 50g- Assembly

Discussion and Review

The textbook definition of a mineral is *"a homogeneous, naturally occurring, solid substance with a definable chemical composition and an internal structure characterized by an orderly arrangement of atoms in a crystalline structure"* ((from *Earth; Portrait of a Planet*; Stephen Marshak (Norton, 2005)).

A crystal grown in a lab is not a true mineral since it did not form by geologic processes. However, crystals grown in a lab are virtually identical to true minerals in many other aspects: they are solid, inorganic, homogeneous, and have a definite chemical composition and an ordered structure.

By growing crystals in a laboratory setting you will be able to investigate the different properties that define a mineral. In addition, growing synthetic minerals can offer insight into the factors that affect the crystal growing process in a true geologic setting. By "watching" your crystals grow, you'll be able to better understand how crystal faces develop in rocks and what influences them, plus you won't have to wait through geologic time to view the results!

Since you will know the composition of the material that went into your crystals and guided the crystal growth from beginning to end, you'll be able to identify your crystals easily. However, you may have picked up a "pretty rock" at one point or another in your life and wondered how to go about identifying it. Since <u>all rocks are composed of a mixture of one or more minerals,</u> the first step in identifying that pretty rock is identifying the minerals of which it is composed. Minerals are identified on the basis of several different physical characteristics which can be determined through tests, and you will perform some of these tests with the crystals you grow. This will help to increase your confidence about identifying minerals. Eventually you'll be able to identify each mineral in your LabPaq by using those same tests, and this knowledge will then help you identify rocks.

<u>The Law of Interfacial Angles</u>, first described by Nicolaus Steno in 1669, is one characteristic or test used to distinguish between minerals. This law states that <u>the angles between the faces of a crystal are constant for that particular mineral</u>, no matter how large or small the faces are. Thus, if you know the interfacial angles for a particular mineral, you can identify it by this rule.

<u>Crystal form</u> is another physical characteristic used to identify minerals. Some of your larger crystals should show a distinctive geometric shape. Look at crystals displayed by several different minerals in your LabPaq and you'll notice their different shapes. A crystal's shape is indicative of how the individual molecules are arranged in the crystal and is an excellent means of identification in minerals that exhibit good crystal form. Unfortunately, as you will see in growing your own crystals, good crystal form is rare due to competition for space during the growth process. Your crystals' edges and corners may be inter-grown with other crystals, and the bottoms will be flat due to the crystals growing upward from the flat surface of a petri dish. However, most of your crystals will tend to have the same general shape: perhaps a cube, an octahedron, or a rectangular form. This is the mineral's crystal form. Crystal form can be distorted into needles, flattened, or elongated into prisms. Competition for space can cause a mineral's crystals to not have any discernable geometric shape at all; this is shown well in igneous rocks which are composed of several different minerals. To

verify how competition for space distorts their shape, examine your LabPaq's igneous rock sample #19 with your hand lens and try to discern the geometric shapes of the crystals it contains.

The Rate of Crystal Growth forms a basis for identifying igneous rocks since all igneous rocks are formed from the cooling of magma. Igneous rocks are said to be *phaneritic* if the individual minerals are large enough to see and *aphanitic* if the individual minerals are too small to see with the naked eye. This size of the mineral crystals directly relates to how rapidly the rock cooled. In some cases, the lava cools so rapidly that its molecules do not have sufficient time to organize into crystals and instead form into a volcanic or natural glass like obsidian. Volcanic glass is essentially a super-cooled liquid blob with no crystals. This lab simulates creating natural glass with molten sugar.

Chemical Sedimentary Rocks can form from the evaporation of seawater which concentrates the chemicals in solution to the point where the chemicals will eventually precipitate out of the water and form minerals. The two most common minerals to form in this way are gypsum and halite. Gypsum and halite are names for both minerals and rocks; if the mineral deposit is large in scale, it is designated a rock unit as opposed to a smaller mineral occurrence. Mineral sample #9 and sedimentary rock sample #36 are examples of a material in both its mineral and rock forms. An example of a halite sedimentary rock unit is the salt flats around the Great Salt Lake in Utah. An example of a halite mineral occurrence would be if several halite crystals were found in the crevice of an igneous rock along the ocean shoreline. In lab we will grow Epsom salt and alum crystals by the evaporation method. The crystals you grow will be sufficiently small in scale and so would be considered mineral occurrences if they were formed by natural processes.

Metamorphic Rocks are formed by heat, pressure, and/or the introduction of fluids like water and magma that alters the preexisting rock. Metamorphic rocks sometimes crystallize new minerals as part of the metamorphism process; garnet crystals are a good example of this. A metamorphic rock must stay at least partially solid at all times and never transform into a liquid during metamorphism; otherwise it becomes an igneous rock. However, chemicals in solution can be dissolved out of the host rock, transported to another place, and crystallize into new minerals during metamorphism. This lab will show how metamorphic rocks crystals can dissolve and reform naturally.

In all crystal formation cases, the crucial component is a liquid solution. This lab will determine the temperatures at which our newly formed crystals will dissolve into solution. Dissolved minerals will precipitate out of a saturated solution at temperatures below their melting point. As you can see, many aspects of crystal growing can have applications to the different types of rock. Hopefully by completing this lab you will gain a better appreciation of the rock cycle.

PROCEDURE:

Part I: First, you will investigate the process of mineral crystallization by allowing Epsom salt and alum crystals to form by precipitation from evaporating water.

1. Create Epsom salt crystals as follows:

    a. Turn on and open the digital scale's lid. With an empty beaker on its weighing surface, press the scale's tare or zero button so it reads "0" grams. Add Epson salt to the beaker until the scale reads exactly 30 grams. Pour the Epson salt into a small pan.

    b. Measure 50 mL of warm tap water into a beaker and add the water to the pan of Epsom salt. Stir well. If the Epsom salt does not fully dissolve, place the pan on a stovetop burner and turn the heat on low. Constantly stir the contents as the pan slowly heats until you reach the point, but not beyond, where the Epsom salt is completely dissolved. Do NOT boil.

    c. Remove the pan from the heat and pour its saturated solution into a petri dish. A saturated solution is one that contains as much dissolved solute as it can under existing conditions and no additional quantity of that solute can be dissolved in it.

    d. Wash the pan and beaker with dish soap, rinse, and dry well for their next use.

    e. Prepare a label by writing on the top half of a 4x4" sheet of paper: Science Experiment – Not Dangerous – Please Do Not Disturb. Fold the paper in half so that a petri dish can sit on one half and the writing will face out and be immediately noticeable.

    f. Set the petri dish, uncovered, with its label in a safe place where it will not be disturbed, jiggled, bumped, or otherwise moved and where natural evaporation can take its course, preferably in a sunny, dry area. Within a few days you should see crystals beginning to form in the petri dish. Depending upon the humidity in your area, your dish should be fully evaporated and your crystals fully formed within 6 to 9 days. Don't worry if for several days there is nothing in the Petri dish. Once crystallization begins, it will proceed quite rapidly.

    g. Once the water has completely evaporated, allow the crystals to dry out for 24 hours and then examine them closely with your hand lens. There may still be some residual water underneath the crystals. Record your observations and draw a sketch of the specimen's crystal form. The photo below is of Epsom salt crystals grown by the author. As you can see from the picture, they are not museum-worthy specimens. Due to competition for space in the Petri dish and the supersaturated conditions, the crystals are very crowded together.

h. Do **NOT** discard this petri dish or its contents; they are used again in this lab.

2. Create alum crystals by following the above instructions, A through H, except this time you will measure and dissolve only 10 grams of alum in 50 mL of water. The photo below is of alum crystals. Again, competition for space and rapid growth in a supersaturated solution leads to crowding of crystals.

Part II: Measure the interfacial angles of different mineral crystals.

1. Select the best four minerals from the LabPaq's 18 numbered minerals that show good crystal form plus one of the best Epsom salt and alum crystals grown in Part One.

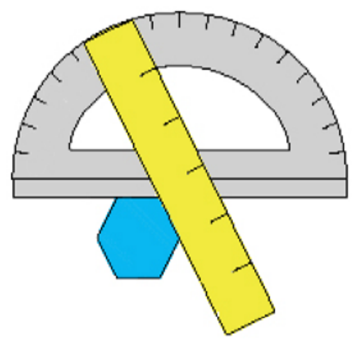
2. Prepare a data table similar to Table 1 below, and record the numbers of the LabPaq minerals selected for measuring.

Data Table 1

	Interfacial angle measurements				
Mineral No.	Angle 1	Angle 2	Angle 3	Angle 4	Average
#					
#					
#					
#					
Epsom Salt					
Alum					

3. Measure interfacial angles of the four selected mineral crystals. It will not be easy to find good crystal interfacial angles as you must try to differentiate between the external form the mineral takes when it grows and the form it may show when it breaks. Your samples will probably contain many parts of broken crystals, but they should also show a few crystals that are reasonably well-formed. A further complication is that the crystals of most minerals have more than one set of interfacial angles. Try to recognize and measure the interfacial angles of similar faces for similar crystals at the same adjacent crystal faces. To do this:

   a. Hold the straight edge of a ruler against the line of one crystal face and the protractor against the adjacent crystal face as shown in the following illustration. The straight-edge ruler should intersect the protractor at an angle as shown. Tweezers and a hand lens will be helpful in this process. Record the angle in your table.



   b. Try to find at least two, but preferably four, interfacial angles in each mineral to measure. Record each measurement in your data table.

   c. For your home-grown crystals, disregard the angles between the bottoms of the crystals where they adhered to the petri dish. Since your crystals were prohibited from growing into the petri dish, they will not show interfacial angles or crystal form in all directions. Measure the angles as best you can, using your hand lens and tweezers to assist you if needed. You may have trouble due to the small size of the crystals. Record any measuring problems you encounter in your lab notes.

   d. Compute and record the average interfacial angles of the crystals for each mineral and your home grown crystals. You need to compute the average for the measurements taken because the method of measuring is too imprecise to discover the actual constant angles. To compute an average, add together the measured angles of each mineral and divide this total by the total number of measurements taken. For example, assume the angle measurements for mineral #8 were 102, 104, 100, 101, 103, and 102 which totals 612. Divide 612 by 6 and you arrive at an average angle of 102.

Part III: Now you will observe how a crystal growth is affected by its cooling rate.

1. Forming crystals through rapid cooling:

   a. Look closely at the sugar crystals in your packet. Use your hand lens to observe them carefully and make a sketch of the sugar crystals' shape.

   b. Place a clean, dry petri dish on a saucer.

   c. Measure 50 grams of table or raw sugar and place it in a small dry saucepan. Heat and stir over very low heat until, but not beyond, the point where all of the sugar is completely melted into a liquid solution. Do not add any water. Also, do not overheat the sugar or you'll soon have caramel candy! Continuously stir the sugar over very low heat just until it is completely melted into a liquid. BE CAREFUL! MOLTEN SUGAR CAN CAUSE NASTY BURNS!

   d. Once the sugar has completely melted, immediately pour it into a petri dish resting on the saucer which will guard against spills and potential burns while transporting the melted sugar. Also, take care because the Petri dish may melt! Place the saucer with petri dish of sugar solution into your refrigerator and leave it undisturbed until it cools completely. This should take only a few minutes. What you are doing is trying to replicate lava solidifying while it cools in the air after being shot out of a hot volcano.

2. Once the sugar has cooled, take the petri dish out of the refrigerator and inspect it. Hopefully you have just made sugar glass, where the cooling rate was so fast that no sugar crystals were able to form.

3. Use your magnifying hand lens to examine the sugar glass and observe if there are any crystals in the sugar glass.

4. Save the petri dish of sugar glass in your LabPaq to observe in a future experiment.

Part IV: In this step, you will re-dissolve the alum and Epsom salt crystals you grew in Part One and find their melting temperatures which by inference should be the same as their maximum crystallization temperatures.

1. Re-dissolve the Epsom salt crystals by doing the following:

   a. Remove from the dish of Epsom salt any large crystals you might like to save or try to grow into larger crystals (optional instructions follow).

   b. Place 50 to 100 mL of tap water into a pan. Measure the water's temperature with a thermometer and record it in your notes. [Note: The quantity of water used is not important here, but use the smaller amount if you want to have a well saturated solution for further crystal growing. See Optional Fun below.]

c. With a spoon or blunt knife, scrape all of the crystals from the petri dish into the water. Stir and observe. Do the crystals dissolve?

d. If the crystals do not dissolve in Step 1C, heat the pan's contents slowly while stirring. When the crystals are completely dissolved, promptly remove the pan from the heat source and measure the liquid's temperature with a thermometer.

e. After you have finished this and any chosen optional experiments (see below), discard your crystal solution by washing it down the sink with water.

2. Re-dissolve the alum by following Steps 1A through 1E above using alum crystals.

Optional Fun Experiments with Crystals:

1. You can pour the saturated solution liquids from Part Four back into their petri dishes or other containers and let them evaporate again! If you wish, you can crystallize and dissolve your crystals over and over again this way.

2. Sprinkle a few grains of table salt in your hand, examine them with your hand lens, and note their perfectly cubical shape. You can grow larger salt crystals in a petri dish or other container similar to the way you grew crystals in Part One. To make a saturated solution of salt water, continue to add and stir in small amounts of salt into any quantity of warmed water until an additional amount will no longer completely dissolve. That's when you know your solution is fully saturated.

3. To grow a larger crystal, first allow the saturated solution to cool to room temperature and then pour it into a narrow glass or container. Tie a piece of thread around a single crystal you've already grown. Suspend the crystal in the middle of the solution. Tie the opposite end of the string to a spoon or knife placed across the top of the glass. This seed crystal should be suspended in the middle of the solution and not be touching the glass. Observe the crystal daily for the next week and you should see it grow much larger! You may need to periodically adjust the string's length to ensure the crystal is always submerged in the saturated solution.

   Note: Your LabPaq contains sufficient alum and Epsom salt to perform Part One's instructions twice in case you have a problem on your first try. Thus, you should have ample materials left over to make extra solutions and grow very nice large crystals. It's fun to see how large a crystal you can grow!

4. You can also use your new knowledge about crystal growing to make rock candy. Prepare a saturated solution of sugar water and suspend a line of string or a thin wooden skewer into the water as you would to grow a seed crystal. Within a few days crystals will begin growing along the string or skewer and you'll eventually produce a nice sweet snack of rock sugar crystal candy. To prepare a saturated sugar solution, continue to add and stir in small amounts of sugar into any quantity of hot water until an additional amount will no longer completely dissolve. That's when you know your solution is fully saturated.

Results and Conclusions: Include in your formal report all tables, graphs, calculations, lists, sketches, charts, etc. that you produced in this lab.

Questions: (Please give thoughtful and complete responses to the questions following this lab and all future labs as required.)

A. Describe in detail the crystal form of Epsom salt, alum, and sugar.

B. Regarding your sugar glass, how can you relate what you did to the way in which obsidian forms? Is your sugar glass phaneritic, aphanitic, porphyritic, or glassy? Explain your answer.

C. Do evaporate minerals tend to show good crystal form? Why or why not? Did the Epsom salt or alum show better crystal form?

D. Review your table of interfacial angle measurements. Does the Law of Interfacial Angles hold true for your mineral samples and the crystals you grew?

E. At what temperatures did the Epsom salt and alum dissolve? In a metamorphic process where there was an introduction of water into a surface-temperature rock, would these two minerals probably be among the first or last to dissolve? What if the rock was buried deep in the earth and heat was also part of the metamorphic process.

Mineralogy & Identification

Trina Johnson Riegel, M.S. Version 09.1.01

Review the safety materials and wear goggles when working with chemicals. Read the entire exercise before you begin. Take time to organize the materials you will need and set aside a safe work space in which to complete the exercise.

Experiment Summary:

Students will have the opportunity to learn and apply the classification criteria for identifying minerals. They will learn common uses of some minerals.

Objectives

- To learn the classification criteria for identifying minerals,
- To apply the classification criteria for identifying minerals, and
- To identify common uses of various minerals.

Materials

Materials From:	Qty	Item Description:
Student Provides	1	Paper towels
	1	Hammer
From LabPaq	1	Goggles-Safety
	1	Rock - Set of 50 rocks
Mineral Identification Kit	1	Hydrochloric Acid, 3% - 10 mL in Dropper Bottle
	1	Magnet bar
	1	Magnifier, Geologic Hand
	1	Nail, zinc-coated
	1	Penny
	1	Plate, Streak plate set

Discussion and Review

In the crystal growing lab you learned about the Law of Interfacial Angles first proposed by Nicolaus Steno (1638 -1686). Using that law is one way to identify minerals, but not the only way.

As you probably discovered, finding and measuring the interfacial angles is not always easy! Competition for space during the crystal growth process can result in blob-like forms where neither the crystal forms nor the interfacial angles are very apparent. This is why other diagnostic tests are used.

Color, luster, streak, hardness, cleavage, and specific gravity are other diagnostic characteristics for identifying minerals. Some minerals may share some of their characteristics with other minerals. For example, there may be several whitish minerals with a nonmetallic luster and a white streak in the kit, but each mineral will have its own unique <u>combination of the diagnostic characteristics</u>. You should always perform and cross-check several different tests to make sure you have identified your mineral specimen correctly. Ideally, you should run through all the identifying tests every time you identify a new mineral sample in order to increase your accuracy. Some of the more popular tests for identifying minerals are shown below.

Mineral Identification Tests:

1. Color: This is the external color of a mineral, but it is not always reliable because a mineral may come in different colors and certain colors such as light tan or translucent white can indicate a wide variety of minerals. Thus this test, while important, is of limited usefulness. However, color is the first thing you notice about a mineral, and it should be recorded.

2. Luster: This refers to the brightness that shines from a mineral's surface in reflected light; minerals do not produce light, they only reflect it. The luster test separates the metal ores from the nonmetallic minerals. Often metallic minerals are shiny, but a better way to think about it is whether the sample appears to look like it is mostly metal in composition.

3. Streak: This refers to the color of a mineral in its powdered form. It is a more reliable diagnostic test than external color since it gets rid of the weathering rind that can often form on the outside of minerals and distort color after exposure to the elements. Streak is also a good test for identifying metallic minerals.

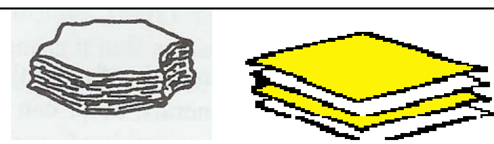
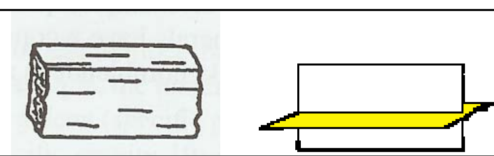
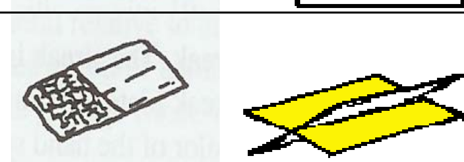
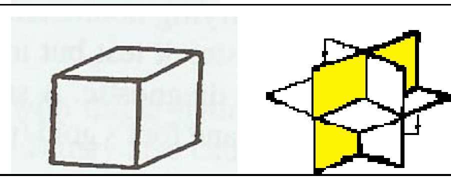
4. Specific Gravity: This is a comparison of the displacement of water by the sample to the weight of an equal displacement of water. Toss the sample in your hand. Minerals with a high specific gravity will feel heavy for their size. To get a good feel for this, heft several different mineral samples of approximately the same size and list them in your estimated order of weight. Then weigh the samples on the digital scale to determine if your estimates were correct. Try this with additional samples until you have a good feel for differentiating among the weights of the minerals.

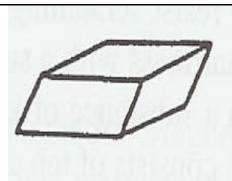
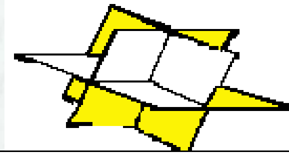
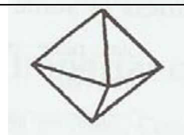
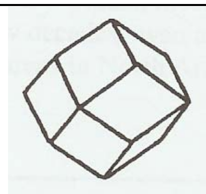
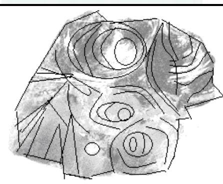
5. **Hardness:** This is the test of a mineral's resistance to scratching. As you may know, diamond is the hardest mineral. Minerals can be used against each other to determine the relative hardness of each (i.e., what scratches what). Similarly, a material of known hardness can be used on the mineral to determine which is harder. Start by trying to scratch a mineral with your fingernail. A fingernail has a hardness of 2.5. Then progress by testing with the items in your mineral identification kit.

Item	Hardness
A penny	3
A nail	5
A piece of glass	5.5

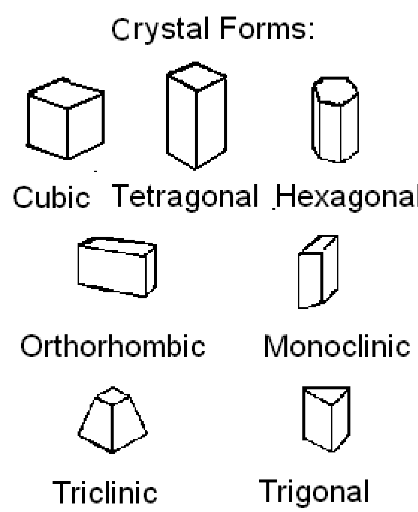
6. **Cleavage and Fracture:** These are patterns in the way specific minerals break under stress that are related to the positioning of the atoms in those minerals. Cleavage refers to a mineral's property that allows it to break smoothly along specific internal planes. If stress causes part of a crystal to break off and the broken piece retains a crystal shape, the mineral has cleavage. Fracture occurs when a mineral breaks in a random pattern. In fracture, the resulting pieces exhibit no smooth planar surfaces like those shown in cleavage where a break of a crystal face forms a new crystal face. Not all minerals exhibit cleavage, but all minerals can exhibit fracture, including those that exhibit cleavage. As shown below in Data Table 1, there are several different types of cleavage. However, we'll concentrate on only three types of cleavage: 1.) basal, 2.) cubic, 3.) non-cubic and rhombohedral; we'll also concentrate on fracture. These will later be described in more detail.

Data Table 1

Cleavage Overview		
Cleavage	**Sketches**	**Example(s)**
Basal cleavage: In only one direction - resembles layers of sheets		biotite, muscovite
Two directions, intersecting at right angles		feldspars
Two directions – NOT intersecting at right angles		hornblende
Cubic: Three directions Intersecting at right angles		halite, galena

Rhombohedral: Three directions - NOT intersecting <u>at a right angle</u>	 	calcite
Octahedral: Four directions		fluorite
Dodecahedrons: Six directions with 12 faces		sphalerite
Fracture: Irregular masses – no flat surfaces - only fractures or swirls		Quartz (non-crystalline)

Crystal Form: If a mineral can grow without being crowded by other minerals, its crystals will take on a characteristic shape or form like those that follow. Some minerals have more than one crystal form, and some crystal forms are found with more than one mineral. Thus, crystal form alone is rarely conclusive for mineral identification, but there are several beautiful, fragile minerals that can be identified on this single basis. However, unless a mineral exhibits exceptionally good crystal form and you know all the various forms a mineral's crystals can take, you must still perform additional tests.



7. **Interfacial Angles:** As previously discussed, each mineral, if it displays good crystal form, has a constant angle between its crystal faces. However, there are different sets of interfacial angles as shown by the hexagonal form pictured at left. Note that the angle between any two sides of the hexagon and the angle between its ends and any side are not the same. The key here is to look for adjacent and corresponding angles. One set of corresponding angles is found on the six sides of the hexagon. Another set is the angles formed by the hexagon's top and bottom with its six sides.

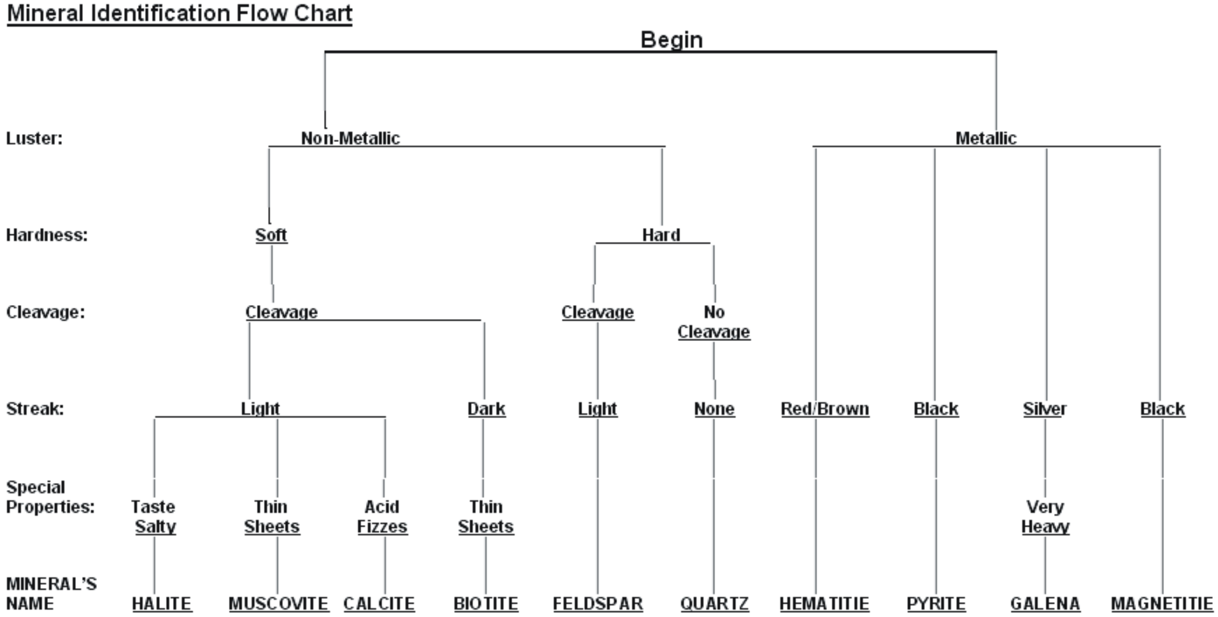
8. **Striations:** These are fine, thin, grooved lines present on the cleavage surfaces of some minerals. Striations are often caused by "crystal twinning" which can occur when crystals contact each other. A boundary line, or striation, is created at the point of contact; and more striations are created as the minerals continue to grow. Generally striations are parallel as in the photo at left, but some are triangular or even crossed. The best examples of striations might be found on quartz, pyrite, and feldspars, but there are many others.

9. **Magnetism:** Magnetism is a property by which minerals are attracted to a magnet. The only common magnetic minerals are magnetite and, in rare cases, hematite which is weakly magnetic.

10. **Reaction to acid:** All carbonate minerals will react with dilute hydrochloric acid (HCl; 1–3% solution) and effervesce or "fizz" to some extent. Calcite ($CaCO_3$) is a good example of a carbonate mineral which will "fizz" actively when a drop of dilute HCl is placed on any surface. If HCl is not available, undiluted table vinegar, which is 4 - 5% acetic acid may also be used for this test.

    Utilizing a flow chart like the one that follows is another good way to identify minerals.

Mineral Identification Flow Chart



11. The following is a partial list of common metallic and non-metallic minerals with their primary properties. Study and familiarize yourself with these minerals and their properties as you will encounter them often.

Data Table 2

Metallic Minerals and Their Properties	
Bornite:	iridescent blue or purple, dark gray streak, metallic, softer than a 5
Chalcopyrite:	brass yellow, dark gray streak, metallic, softer than a 5
Copper:	Copper color, copper streak, malleable, metallic, softer than a 5
Galena:	silvery gray, excellent 90 degree cleavage, dark gray streak, softer than a 5
Graphite:	dark gray color, dark gray streak, 1 or 2 in hardness, “pencil lead”
Hematite:	silvery gray, black or red/brown color, red/brown streak, metallic, less than a 5 in hardness
Limonite:	brown, yellow brown streak, metallic, looks like rusted iron, softer than a 5
Magnetite:	dark gray/black color, dark gray streak, metallic, can scratch glass, attracts a magnet
Pyrite:	brass yellow, greenish-black or dark gray streak, metallic, can scratch glass
Sphalerite:	brown, yellow brown, or red color, white streak, metallic, excellent cleavage, softer than a 5

Nonmetallic Minerals With Their Properties	
Amphibole group:	opaque dark green to black, 2 cleavages at 60 and 120 degrees, hardness of 5.5 to 6
Apatite:	colorless or pale green, blue, or white, hexagonal prisms, no cleavage, hardness of 5
Azurite:	deep blue color, light blue streak, hardness of 3-4
Barite:	colorless or white, can form roses, very heavy for its size
Biotite Mica:	black, basal cleavage, hardness of 3
Calcite:	colorless but can also be any color, usually translucent, rhombohedral cleavage, effervesces with acid, hardness of 3
Chert/Chalcedony:	opaque, any color, microcrystalline, no cleavage, scratches glass

Chlorite:	green short opaque prisms, basal cleavage, hardness between 2 and 3
Chrysocolla:	turquoise, very light blue streak, hardness between 2 and 4
Corundum:	white or gray, often in hexagonal prisms, no cleavage, scratches glass
Dolomite:	colorless but can also be any color, usually opaque, rhombohedral cleavage, effervesces with acid only after being powdered first, hardness = 3
Epidote:	opaque green, poor cleavage, hardness of 7
Fluorite:	purple, blue, green, yellow, colorless, cubic crystal form with octahedral cleavage, hardness of 4
Garnet:	transparent to translucent red, green, or black, no cleavage, hardness of 7
Gypsum:	colorless, white, or gray, can scratch with fingernail, hardness of 2
Halite:	colorless, white, cubic cleavage, tastes salty, hardness of 2.5
Kaolinite:	opaque white or brown, hardness of 1-2, no cleavage, attracts water and will stick to your tongue
Malachite:	green, pale green streak, effervesces in acid, hardness between 3 and 4
Muscovite Mica:	colorless, silver, light brown, basal cleavage, hardness of 2
Olivine:	green, no cleavage, transparent or translucent
Plagioclase feldspar:	white or gray, near but not exactly right angle cleavage, has striations on faces, scratches glass

Nonmetallic Minerals With Their Properties	
Potassium feldspar:	salmon, white, gray, green, near right angle cleavage, ex-solution lamellae but no striations, scratches glass
Pyroxene group:	opaque green to black, cleavage at 90 degrees, hardness of 5-6
Quartz:	almost any color but blue; usually clear or milky white, no cleavage, crystal form is hexagonal pyramid, scratches glass

Serpentine:	opaque green, can be silky like asbestos, white streak, hardness of 2
Staurolite:	brown opaque prisms that can form crosses, hardness of 7
Sulfur:	yellow, smells of sulfur or rotten eggs, no cleavage, hardness of 1-2
Talc:	opaque white, gray, green, or brown, greasy or soapy feel, no cleavage, hardness of 1
Tourmaline:	black, pink, yellow, or dark green, long narrow striated prisms, hardness of 7

Exercise 1

PROCEDURE:

Part I: Armed with firsthand knowledge from Lab One about how minerals grow and develop, how crystals form, and how interfacial angles will develop on every mineral showing good crystal form, you can now incorporate the additional mineral diagnostic tests described in this lab to identify the mineral samples in your LabPaq.

Identification is fairly logical and straightforward if you follow the steps and use the process of elimination. First, set up a worksheet similar to Table 3 to record results of the mineral diagnostic tests identified above and more specifically detailed in the Flow Chart below for each mineral in your LabPaq.

Perform, in the order given, the various mineral diagnostic tests which are more fully described below for each mineral in your kit and record your findings. After testing, you should be able to narrow down the possibilities for each mineral's identity and make an educated guess as to the mineral's name.

Data Table 3

Mineral Identification Data Table												
	Test	Test	Test	Test 4:	Test	Test	Tests 7...					
	1:	2:	3:	Specific	5:	6:	7 through 11:					Mineral's
Sample #	Color	Luster	Streak	Gravity	Hardness	Cleavage	Diagnostics					Name
#1												
#2												
#3												
etc.												
#18												

Diagnostic Tests for Mineral Identification

1. **Color:** Note the color of the mineral. Disregard any weathering effects, which may leave a white powdery residue on the surface or stain the mineral a rusty red. Concentrate on the "true" color. To do this you may have to break the mineral to obtain a fresh surface. Some possibilities for colors are: transparent or nearly so, milky white, peach, and shades of tan, red/brown, black, dark green, or silvery gray.

2. **Luster:** Determining a specimen's luster is actually an educated guess about the mineral's composition. Based on outward appearance, you are guessing whether the sample is mostly "metal" or not. Metallic minerals will feel heavy for their size and are often shiny, but some can have dull or earthy appearance. Typically, metallic minerals are darker in color. Some examples of metallic minerals are: galena, magnetite, hematite, and sphalerite. Nonmetallic minerals make up the majority of mineral varieties and can be glossy, satiny, earthy, dull, glass-like, shiny, pearly, or waxy, but they don't look like they're made of metal. Some examples of nonmetallic minerals are quartz, feldspar, fluorite, talc, gypsum, diamond, corundum, and pyroxene.

3. **Streak:** Recall that this is the color of a mineral in its powdered form. To powder the mineral, run the sample across the porcelain streak plate from your kit. If the mineral is very hard, it will actually scratch the porcelain plate, appear to leave a white streak, and you should be able to feel or see the scratch after you brush away the powdered porcelain. The streak left by minerals softer than the plate is not actually a real scratch on the plate. Rather, it is powdered mineral that has been scratched off by the plate leaving a powdered line of crumbled mineral behind on the plate. Use your hand lens to note the color of the powder. Some examples are: graphite = dark gray streak; hematite = red brown streak; magnetite = black streak; azurite = blue streak; malachite = green streak; gold = gold streak; and fluorite = a true white streak. Topaz, quartz, feldspar, corundum, and diamond are all too hard to powder and will scratch the porcelain streak plate.

4. **Specific gravity:** Heft a mineral sample in one hand, while hefting another similar-sized sample in the other hand. How do they compare? The one that feels heavier has the higher specific gravity. Do the samples feel heavy or light compared to what you would expect for the size? Record this information as low, medium, or high specific gravity.

5. **Hardness:** Hardness is a test of a mineral's resistance to scratching. Some minerals are very soft and can be scratched with your fingernail. Others are hard enough to scratch glass; hard minerals tend to make good gemstones since they can withstand a lot of wear in a ring or piece of jewelry. The standard hardness scale, called the Mohs Scale, is shown in Table 4 below:

Data Table 4

Mohs Scale of Mineral Hardness			
Hardness	Mineral	Hardness	Mineral
1	Talc	6	Feldspar
2	Gypsum	7	Quartz
3	Calcite	8	Topaz
4	Fluorite	9	Corundum
5	Apatite	10	Diamond

To determine a sample's hardness, first try scratching it against the glass plate in your kit. Observe carefully whether it makes a mark on the glass, or whether the mineral is actually scratched by the glass. It may take several passes to determine this. If the mineral:

- <u>Scratches glass:</u> It's at least a 6 in hardness and could be quartz, topaz, corundum, diamond or feldspar. However, feldspar is just hard enough to scratch glass and so will be a little difficult to identify.

- Doesn't scratch glass but is harder than your fingernail: If it is softer than glass and/or a nail, but can't be scratched by a fingernail, it's a 3 to 5 in hardness and could be calcite, fluorite, or apatite. Apatite will just be able to mutually scratch with the nail. Calcite will just be able to mutually scratch with the penny.

- Can be scratched by a Fingernail: it's either a 1 or 2, and could be talc, gypsum, or a form of mica.

6. **Cleavage and Fracture:** While testing for hardness, you may have broken your mineral. If not, it is time to break it now. Wrap a mineral specimen in a paper towel; take it, your goggles, and a hammer outside to a concrete drive, sidewalk, or similar hard surface. Put the goggles on, set the paper-wrapped mineral on the concrete and carefully give it a solid, medium-hard, whack with the hammer. Remember, your objective is just to break, not to pulverize, the sample! Also keep in mind that you will need to refer back to these samples in the future; thus, if you can distinguish cleavage/fracture without breaking the specimen that is preferable. If your mineral winds up in small pieces, gather them up and place them in a small zip bag labeled with the specimen number for future reference. Observe how the mineral broke. Is there fracture or cleavage? If there is cleavage, what is its pattern? Look especially closely at edges and corners. Do you see:

   - 90 degree "stair step" angles? If so, that indicates **cubic cleavage**. Some examples are galena, pyroxene, and halite.

   - Off 90 degrees, "slanted stair-step" angles? If so, that may be **rhombohedral cleavage**, or if the angles formed are about 60 and 120 degrees, the mineral may be **amphibole**. The most common mineral to show rhombohedral cleavage is calcite.

   - Peeling off in sheets like pages in a book? If so, that is **basal cleavage**. You don't need to hit the mineral with a hammer to see this: you'll be able to peel off layers of the mineral easily with your fingers. All micas have this type of cleavage: muscovite (clear, yellow, or silver), biotite (black), chlorite (green), lepidolite (lavender), and phlogopite (brown).

   - Breaking randomly or in curving lines? This is **fracture**. If it breaks in curving lines as glass often does, it is **conchoidal fracture**. The best mineral example of conchoidal fracture is quartz.

7. **Crystal form:** Examine each mineral carefully and see if you can observe its crystal form. This may not always be possible. Some mineral crystal forms are: quartz (hexagonal pyramid); halite, galena, and fluorite (cube); corundum and apatite (hexagonal); diamond (octahedral); and garnet (dodecahedron).

8. **Interfacial angles:** You may have noticed other angles and faces while examining your specimens for cleavage. When looking at a mineral sample showing crystal form, you should see the interfacial angles between corresponding crystal faces that form when there is no competition for space during the growth process.

9. **Striations:** Examine each mineral closely with a hand lens to observe if there are any striations. Being able to identify striations will be useful when trying to identify igneous rocks in the next laboratory exercise.

10. **Magnetism:** Pass a magnet close to each mineral sample; if it is attracted to the mineral, the specimen demonstrates magnetism. **Note:** Only metallic minerals will demonstrate magnetism.

11. **Acid test:** Carefully place one or two drops of dilute hydrochloric acid on the sample. Observe to see if there is a "fizz" reaction; then wipe the drop of acid off the specimen with a piece of paper towel. **Note:** Remember to wear old clothes and goggles to protect your eyes when working with chemicals. HCl spills can burn in your clothing that may not appear until after it is washed.

<u>Part II</u>: Understanding how minerals are used in our everyday lives helps us better understand them and geology. Now that you have learned to recognize your 18 minerals, perform web searches to identify at least two common uses for each, and record your findings in a data table similar to Table 5 that follows.

Results and Conclusions: Include in your formal lab report all tables, graphs, calculations, sketches, lists, charts, etc. that you produced to identify the names of the 18 mineral samples in the LabPaq.

Data Table 5: Common Mineral Uses		
Mineral # and /Name	Common Use: 1	Common Use: 2
# 1		
# 2		
# 3		
# 4		
# 5		
# 6		
# 7		
# 8		
# 9		
#10		
#11		
#12		
#13		
#14		
#15		
#16		
#17		
#18		

Igneous Rock Identification

Trina Johnson Riegel, M.S. Version 09.1.01

Review the safety materials and wear goggles when working with chemicals. Read the entire exercise before you begin. Take time to organize the materials you will need and set aside a safe work space in which to complete the exercise.

Experiment Summary:

Students will have the opportunity to learn how igneous rocks are formed. They will learn the classification criteria for identifying igneous rocks and then apply this knowledge to identify samples of igneous rocks.

Objectives

- To learn the classification criteria for identifying igneous rocks, and
- To apply the classification criteria for identifying igneous rocks.

Materials

Materials From:	Qty	Item Description:
From LabPaq	1 1	Rock - Set of 50 rocks Goggles-Safety
Mineral Identification Kit	1 1 1 1 1 1	Hydrochloric Acid, 3% - 10 mL in Dropper Bottle Magnet bar Magnifier, Geologic Hand Nail, zinc-coated Penny Plate, Streak plate set

Discussion and Review

Igneous rocks are formed by the solidification of molten material that originates far below the earth's surface. This molten material is called magma when it is inside of the earth and lava when it is flows onto the earth's surface or sea floor. When magma is blasted out of the earth in a violent eruption, the resultant materials of varying sizes and shapes are referred to as pyroclastic debris. Examples of pyroclastic materials include volcanic ash and pumice. Rocks formed from cooling magma while inside the earth are intrusive igneous rocks; those formed above the earth's surface are extrusive igneous rocks. Intrusive igneous rocks that formed very deep inside the earth are also categorized as plutonic after Pluto, the Roman god of the underworld. There are two basic criteria for classifying igneous rocks; they are: texture and chemical composition.

Texture: Texture refers to the size of the individual crystals or minerals within a rock and is directly related to the rate at which the magma cooled. When magma moves to the surface very quickly, such as in a volcanic eruption, the individual minerals do not have time to grow before the magma solidifies and its minerals are too small to be seen with the naked eye. This is called aphanitic texture: Examples of rocks showing aphanitic texture are basalt, andesite, and rhyolite.

Take texture a step further and consider how lava very quickly solidifies as it is flying through the air. This creates a glassy texture as the resultant rock is essentially super-cooled glass in which the elements have not had time to organize into minerals before solidification (recall the sugar glass you made in Lab 1). Obsidian is the best example of a glassy texture, although pumice is glassy as well. Pumice doesn't look like glass because it is full of holes that were once bubbles in the lava. The term glassy texture means the rock lacks crystals, not that it looks like glass. Recall that the sugar glass made in Exercise 1 was glassy in texture, but it was not actually composed of glass.

Conversely, there are textures that indicate the rock had ample time to cool and allow the minerals to grow larger. Texture where the individual minerals are large enough to be distinguished with the naked eye are said to be phaneritic in texture. Some examples of rocks with phaneritic texture are granite, diorite, and gabbro.

Pegmatites have a very coarse-grained texture. They are igneous rocks that contain large, well-formed mineral crystals of 2 cm or greater. The crystals in pegmatites range from pebble and fist-sized to over 10 meters long! Granite rocks that contain large crystals, usually of quartz, feldspar, and mica, are the most common pegmatites; however, if a granite rock contains only tiny crystals, it is not considered a pegmatite. Similar to the way you previously grew crystals from a saturated solution, pegmatites form from the residual fluids of the most water-rich portions of magma that contain high concentrations of dissolved minerals. This explains why pegmatites are often rich in rare earth elements such as lithium, boron, fluorine, and uranium; in gemstones such as aquamarine, tourmaline and topaz; and in minerals such as tin and tungsten.

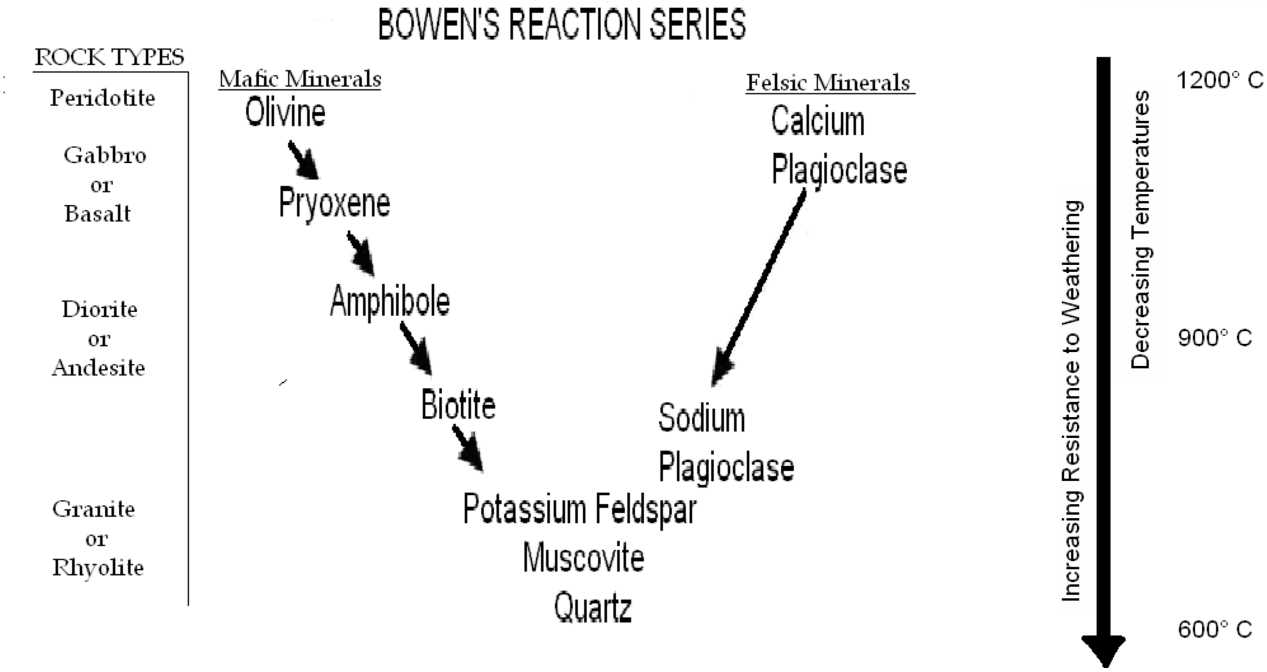
When there is a combination of the two cooling rates, a porphyritic texture results. It usually consists of a few larger minerals that crystallized at a higher temperature in a background of finer-grained minerals that cooled more quickly cooled rock. The condition that led to this type of rock can be thought of as a two-stage cooling process. First, the magma may have started to cool slowly underground. Then, it was brought suddenly to the surface, perhaps volcanically. This process leads to what you observe: the large crystals are left over from the rock's residence underground, and the fine background is the result of the rest of the magma cooling in a hurry. To name this type of rock you would first use its aphanitic background and then add "porphyry" to the end.

Chemical Composition: The second consideration in identifying igneous rocks is their chemical composition which is observed via their mineral composition.

Felsic is the name for a group of rocks and minerals that predominantly contain the minerals feldspar (fel-) and silica (-sic) or quartz. These minerals tend to be light in color. The major minerals found in felsic rocks are quartz, potassium feldspar, and mica.

A second group of rocks and minerals named for its chemical content is called Mafic. Mafic rocks and minerals predominantly contain magnesium (ma-) and iron (-fic). These minerals tend to be darker in overall color. Mafic rocks are commonly composed of the minerals olivine, pyroxene, amphibole, and plagioclase feldspar.

Bowen's Reaction Series provides a good general guide for identifying igneous rocks. In 1922, N. L. Bowen conducted experiments on the melting points of different minerals. He found that minerals with similar melting points tend to be found together in the same igneous rock (recall that minerals' melting points are equal to their crystallization points when the temperature is decreasing instead of increasing). The idealized progression Bowen determined is still accepted as the general model for the evolution of magmas during the cooling process. Igneous rocks that crystallized at higher temperatures contain olivine, pyroxene, and calcium-rich feldspar. Igneous rocks that crystallized at relatively cooler temperatures contain muscovite, potassium-rich feldspar, and quartz.



Volcanoes: As discussed earlier, when magma is rapidly brought to the surface, the resulting igneous rock may be aphanitic or even glassy in texture. Another important issue to consider is that at very high temperatures, magma is fluid. Extremely hot magma thus flows well and allows volatiles and gases to escape more easily than does viscous magma. The variability in fluidity among magmas is a consequence of both their composition and temperature. Silica-rich magmas form silicate chains that give the magma greater viscosity than magmas low in silica content. This explains why a high-temperature magma eruption is less violent and, like the high temperature volcanoes of Hawaii, is characterized more by lava flows than explosions. The rocks produced by these lava flows are normally basalt or vesicular basalt which contains lots of holes that were former gas bubbles. On rare occasions, ultramafic rocks like komatiite can also be formed. Komatiite is so rare that there is no sample of it in your rock collection, but it is believed to have been more common billions of years ago when the earth was hotter.

Hot magma eruptions solidify into the basaltic rocks that are found in shield cones, in lava flows, and at sites of submarine eruptions near mid-oceanic ridges. Shield volcanoes are composed almost entirely of fluid lava flows. Flow after flow pours out in all directions from a central summit vent, or group of vents, building a broad, gently sloping domical shape with a profile much like that of an ancient warrior's shield. The Hawaiian Islands are composed of chains of this type of volcanoes. They include two of the world's most active volcanoes, Kilauea and Mauna Loa on the island of Hawaii.

Magmas rich in felsic elements have lower crystallization temperatures and remain liquid at these lower temperatures; this causes their chains of silicates to congeal and become very viscous. Thick, viscous magma does not flow well; it tends to clog the volcanic pipe and prevent gases and volatiles from escaping. Tremendous internal pressure then builds up inside the volcano as rising trapped gases expand before the pent-up pressure is violently released in a dangerous and often deadly eruption. The 1980 eruption of Mount St. Helens is an excellent example of a pressure eruption which usually produces ash, dust, obsidian, small rock particles called cinders, pumice, plus rhyolite, andesite lava, and welded tuff which is a rock composed of consolidated pyroclastic material which is material that is a product of an eruption. Composite cones, cinder cones, and volcanic domes are volcanic shapes prone to explosive eruptions.

Data Table 1

IGNEOUS ROCK IDENTIFICATION GUIDE		
Phaneritic Texture (large grains)	Mineral Composition	Aphanitic Texture (small grains)
Granite	Quartz is more than 10% of the rock. Potassium feldspar is noticeably greater than plagioclase. Contains few other minerals. Light in color, may look pink.	Rhyolite
Diorite	Always has less than 10% quartz, but usually has none. Its content of potassium feldspar and plagioclase are approximately equal. Has other noticeable dark minerals. The intermediate color tends toward a salt and pepper appearance and may look gray.	Andesite
Gabbro	Contains no quartz. Usually the only feldspar it contains is plagioclase, but can have some potassium feldspar. Is a very dark gray, may look black.	Basalt
Ultramafic: Peridotite	Contains all dark mafic minerals, but no quartz, no potassium feldspar, and little plagioclase feldspar. Dark green to black.	Komatiite
	Volcanic glass, solid, black.	Obsidian
	Volcanic glass, frothy, light.	Pumice
	Glassy texture, pyroclastic composition, typically light in color, only volcanic.	Tuff

PROCEDURE:

1. Prepare a worksheet similar to Table 2 that follows to record your observations during the igneous rock identification process.

Data Table 2

Igneous Rocky Identification Worksheet						
Rock No.	Color: Light, dark Intermediate	Grain size/ Texture: Coarse, fine, porphyritic	Main Feldspar: K-feldspar* Plagioclase	Other Minerals : Quartz, biotite, muscovite, etc.	Classification: Volcanic, plutonic	Rock Name
#19						
#20						
Etc.						
#29						

* K is the chemical symbol for potassium

2. Remove mineral specimens #1 through #8 from your geology LabPaq to assist you in identifying your igneous rocks. These eight minerals are the most common igneous rock-forming minerals and include:

   Amphiboles such as hornblende
   Biotite
   Muscovite
   Olivine
   Plagioclase feldspar
   Potassium feldspar
   Pyroxene
   Quartz

3. Separate the minerals into two groups:

   - Felsic: Includes quartz, potassium feldspar, muscovite, and biotite.
   - Mafic: Includes amphibole, olivine, pyroxene, and plagioclase feldspar.

4. With your hand lens observe and carefully study the physical properties of the minerals. Then consider same as you examine each igneous rock sample to determine its mineral content and identification. You may wish to refer back to the mineral identification lab to ensure you have properly identified each mineral.

5. Closely examine and test each of the igneous rock samples numbered 19 through 29 in your geology LabPaq and record your observations. Your hand lens and the tools in the mineral identification kit will be helpful in this process.

6. Finally, use what you've learned about the texture and chemical composition of igneous rocks, plus the previous identification charts and data to identify each of your eleven igneous rock samples.

Results and Conclusions: Think about what you've learned thus far about geology, the earth, and how minerals and igneous rocks are formed. Apply that knowledge to thoughtfully respond with full explanations to the following questions. Include in your formal report all tables, graphs, calculations, sketches, lists, charts, etc. that you produced in this lab.

Questions:

A. If you had a sample of granite, what would its texture be? What about obsidian? Andesite? Why?

B. Which of the following rocks cooled slowly at depth: granite or basalt? How do you know?

C. Which of the following rocks cooled at the highest temperature: granite, diorite, or gabbro? How do you know?

D. Which of the following rocks cooled at the lowest temperature: rhyolite, andesite, or basalt? How do you know?

E. Why are igneous rocks classified on the basis of texture and composition instead of size and shape of the rock?

F. Which of the following rocks cooled quickly from a volcano: obsidian or diorite?

G. If you found quartz in an igneous rock, what other minerals would you expect to find?

H. If you found olivine in an igneous rock, what other minerals would you expect to find?

I. Would you expect to find olivine and quartz in the same rock? Explain your answer.

J. Rocks #24 through #29 are volcanically derived, as you've undoubtedly discovered in identifying them. Which of those rocks would you expect to find as a product of:

   1. A shield cone volcano?
   2. A composite cone volcano?
   3. A lava flood?
   4. A cinder cone volcano?
   5. A volcanic dome?
   6. A submarine eruption?

K. For the volcanic rocks #23 through #29, are the lighter colored ones associated with more violent eruption styles?

L. If specimen #29 were to become a rock, which rock number would it be closest to?

M. What are the names of the igneous rocks #19 through 29 samples you identified?

Sedimentary Rock Identification

Trina Johnson Riegel, M.S. Version 09.1.01

Review the safety materials and wear goggles when working with chemicals. Read the entire exercise before you begin. Take time to organize the materials you will need and set aside a safe work space in which to complete the exercise.

Experiment Summary:

Students will have the opportunity to learn how sedimentary rocks are formed. They will learn and apply classification criteria for identifying sedimentary rocks.

Objectives

- To learn the classification criteria for identifying sedimentary rocks, and
- To apply the classification criteria for identifying sedimentary rocks.

Materials

Materials From:	Qty	Item Description:
From LabPaq	1	Rock - Set of 50 rocks
	1	Goggles
Mineral Identification Kit	1	Hydrochloric Acid, 3% - 10 mL in Dropper Bottle
	1	Magnet bar
	1	Magnifier, Geologic Hand
	1	Nail, zinc-coated
	1	Penny
	1	Plate, Streak plate set

Discussion and Review

Sedimentary rocks account for the majority of rocks found on the surface of the earth. Because they are formed at or near the earth's surface, sedimentary rocks are indispensable for gaining insight into what the world's environment was like at the time they were formed.

Sedimentary rocks often contain fossils that provide evidence of past life. In addition, many of the earth's useful resources come from sedimentary rocks, including gypsum from which Plaster of Paris is made; trona which is a glassy white mineral and natural source of bicarbonate; plus bauxite which is a clay-like mineral that is the principal ore of aluminum. Fossil fuels such as coal, oil, and gas are found in sedimentary rocks. Groundwater, the source for most of the world's drinking water and irrigation needs, is also found in sedimentary rocks.

Like igneous rocks, sedimentary rocks are classified on the basis of their texture and composition, but the criteria, composition, and terminology are completely different. Both texture and composition offer insights into the rock's past environment. Preexisting rock is broken down into different sized particles ranging from gravel-size all the way down to microscopic ions which can be carried in solution. The sedimentary rocks that are formed from fragments of preexisting rocks are classified as having a detrital or clastic texture and origin. Detrital is typically used synonymously with the term clastic, but some geologists differentiate between the two. However, the differences are very hard to distinguish so this manual also uses the terms synonymously.

Particle size is a very important characteristic of detrital sedimentary rocks because it relates to the energy of the water, wind, or glacial ice that carried the particle. There is a progressive nature to the sorting of rocks and rock particles. The principles of sorting is most commonly associated with moving water that first deposits only the largest, heaviest rocks as it swiftly moves down an inclined stream. As the streambed levels and the speed of the water slows, the water progressively deposits increasingly smaller rocks and particles as it progressively slows down. Sand, silt, and clay particles are small enough to be carried along by a stream, and their respective successional deposits indicate a gradual slowing of the stream.

Thus, fast moving streams tend to leave deposits that form conglomerates; these are sedimentary rocks composed of large particles. Moderately moving streams may deposit sand that later becomes sandstone; slow streams may leave deltas and offshore sediments of clay that later form mudstone and shale. Additional clues about a rock's history are given by the degree to which the grains have become rounded; this indicates the length of time they were transported. The more time the particles of a sedimentary rock spent being exposed to physical weathering by water, the more rounded will be their edges. The larger the particle, the more quickly the rounding is achieved in transport. Therefore rounding as a function of length of time in transport is not so simple. Silt-sized particles tend to remain platy and clay-sized particles do not become round.

Sorting is a process by which the energy of a transporting medium like running water or wind separates rock particles by size. In geology, sorting refers to the proportion of material of the same size within a sedimentary rock. Sedimentary rocks containing primarily particles of the same size are said to be well sorted while those with many different sized particles are said to be poorly sorted. Water helps to sort rocks; thus, the longer time rock particles are transported by water, the more the particles will tend to be the same size and form a sedimentary rock of a uniform texture.

Surface texture of rock grains: The surface of rock grains may be pitted, smooth, or display various surface textures. Water smoothes and polishes the grains, but wind action tends to pit the surface of each grain and give the grains a "frosted" look. Use the hand lens to really get a good look at the individual grains in a sandstone specimen to better see the degree of rounding, sorting, and the surface features such as pitting or smoothing. The composition of a sedimentary rock's particles also affects its texture. Unlike rocks containing quartz particles that are highly resistant to weathering and will be reflected in a rock's surface's texture, minerals like olivine and pyroxene break down quickly due to chemical weathering that breaks down these more unstable minerals. In general, the higher the temperature of crystallization, the more susceptible the mineral is to chemical weathering. Refer to the Bowen's Reaction Series in Lab Three on igneous rocks and note the line indicating the identified minerals' resistance to weathering.

Detrital or clastic sediments still need to undergo lithification; this is the process of transforming sediments into rock. Lithification is accomplished through two processes.

- Compaction where individual particles of sediments become packed very closely together from the pressure of being buried under overlaying sediments.

- Cementation, when ion-rich solution flows around the sediments and deposits material in the space around the grains. The cement acts like glue to hold the rock together. Three of the most common types of cement are:

    1. **Calcite:** A weak cement that is subject to breaking down over time with exposure to rain, especially acid rain.

    2. **Silica (dissolved quartz):** A strong and enduring cement.

    3. **Iron oxide:** This cement can give rocks a red color.

Chemical sedimentary rocks are formed differently than detrital rocks. Inorganic chemical rocks are formed by the direct deposition of chemicals, either in a supersaturated ocean, or by the evaporation of water in a lake or shallow sea. The term inorganic means that the rocks are not composed of animal or plant origin. In the crystal growing lab, you saw how the process of evaporation concentrates the minerals in the remaining water to the point that they become supersaturated and begin to precipitate from solution. Chemical rocks such as gypsum and rock salt are very close chemically to the minerals gypsum and halite; however, they differ by the mass of the rock layer they compose.

Biological sedimentary rocks are formed by the compaction and cementation of organic materials. Limestone is a biological sedimentary rock primarily formed from the calcium of deposited sea shells and cemented together by chemical secretion from marine organism. Another biological rock is coal which is formed by the compaction of organic matter that once grew in swamps.

The relationship of sedimentary rocks to their formative environments can be determined by their texture and composition. Environments are classified as either terrestrial, land based including the water bodies on that land, or marine, ocean based. On land, rivers deposit sediment according to their energy level. High-energy streams flowing down mountains with a steep gradient will deposit large particles that become rounded due to abrasion. The rock that is commonly formed is conglomerate.

A calm river flowing over flat ground deposits finer grained material like sand and clay that form sandstone, siltstone, or a mixture, depending on the length of time the particles spent in transport. The finest grained sediments are deposited in lakes and produce shale or mudstone. If the lake has abundant vegetation, it can become a swamp and may form coal. Lakes in arid areas often dry out, leaving evaporate rocks such as gypsum or halite. Deserts contain frosted and pitted particles of sand transported and deposited by wind into sand dunes that can be compacted into sandstone rocks. Alluvial fans are bird-claw-shaped deposits of material like feldspar grains that build at the bottom of a steep slope. This can happen all at once or over long periods of time; the resultant poorly-sorted, angular rock formed is called arkose.

In a marine setting, the beach is a high energy environment that produces abundant, well-rounded, and polished quartz that can form into quartz sandstone. Continental shelves may leave deposits of mud in the oceans. Some continental shelves have steep slopes where material that has been sorted by size accumulates, not unlike a delta on land or an alluvial fan in a desert. This forms a rock called greywacke or turbidite. Lagoons have deposits of fine grained limestone that may contain fossils. The back and forth actions of currents in a shallow sea can form spherical shapes called ooides that become lithified into an oolitic limestone or an oolite. Reefs and carbonate platforms are also composed of limestone, coral, and sometimes dolomite.

The names of sedimentary rocks are often modified by various descriptive adjectives to describe secondary constituents, these include:

- **Fossiliferous** = contains fossils; Ex: Fossiliferous limestone
- **Siliceous** = contains silica or silica cement; Ex: siliceous shale
- **Calcareous** = contains calcite or calcite cement; Ex: calcareous shale
- **Ferruginous** = rich in iron; Ex: Ferruginous shale
- **Argillaceous** = contains clay; Ex: argillaceous limestone
- **Arenaceous** = contains sand; Ex: arenaceous limestone

Exercise 1

PROCEDURE:

1. Prepare a worksheet similar to Table 1 to record your observations and conclusions as you identify the sedimentary rocks in your LabPaq.

Data Table 1

Sedimentary Rock Identification Worksheet					
Sample #	Grain size, if visible	Mineral/ grain type	Fizzes w/ HCl	Description	Rock name
#30					
#31					
Etc.					
#42					

2. Carefully review mineral specimens #7 through #10 plus #15 which you should have identified, but not in this order, as: calcite, gypsum, halite, potassium feldspar, and quartz. Sedimentary rocks are primarily composed of these minerals.

   Note: You will use your identification kit more in this lab than you did in the igneous lab, as many of the minerals are similar in color and will need further testing. Have your bottle of acid handy to test for effervescence, or "fizzing." Calcite and calcareous limestone, which is composed of calcite, will fizz readily. Dolomite will fizz only after scratching it first with a nail.

3. To help you identify each sedimentary rock sample, use the following Sedimentary Rock Identification Table 2 and the flowchart outlined in Step 4 below. Record all observations that support your final identification of each sedimentary rock's name.

Data Table 2

Sedimentary Rocks Identification Table:				
Texture/origin	Grain Size	Composition	Other Features	Rock Name
Clastic	>2 mm (gravel)	Rock fragments, quartz, feldspar	Rounded	Conglomerate
Clastic	>2 mm (gravel)	Rock fragments, quartz, feldspar	Angular	Breccia
Clastic	1/16 - 2 mm (sand)	Mainly quartz, some feldspar	Rounded	Sandstone
Clastic	1/16 - 2 mm (sand)	Quartz, abundant feldspar, reddish	Angular	Arkose

Clastic	1/16 - 2 mm (sand)	Quartz, feldspar, contains mud	Angular, poorly sorted	Greywacke
Clastic	<1/16 mm No visible particles	Clay minerals	No layers, breaks into chunks	Mudstone
Clastic	<1/16 mm No visible particles	Clay minerals	Layered	Shale
Chemical	No visible particles	Calcite	Fizzes w/ HCl	Limestone
Chemical	No visible particles	Dolomite	Fizzes w/ HCl only in fresh scratch	Dolomite
Chemical	No visible particles	Silica (quartz)	Hard, scratches glass	Chert
Chemical	No visible particles	Gypsum	Very soft	Rock Gypsum
Chemical	No visible particles	Halite	Salty taste, soft	Rock Salt
Biological		Organic material, plant fragments	Black, light-weight	Bituminous coal
Biological		Shell & skeletal fragments	Made up of shells and shell debris	Coquina
Biological		Calcite with fossils	Fossils or fossil fragments	Fossiliferous limestone
Biological		Calcite with oolites	Spherical grains	Oolitic limestone

4. Sedimentary Rock Identification Flow Chart:

   a. **Visible particles:** Does the sample have visible particles? If so, this places the rock into the detrital category.

      i. <u>Gravel sized</u> visible particles, generally >2mm in diameter:
         - Rounded particles = conglomerate
         - Angular particles = breccia

      ii. <u>Sand size</u> particles:
         - Well-rounded and sorted, mostly quartz = sandstone
         - Reddish, more angular, abundant potassium feldspar = arkose
         - Angular, poorly sorted, contains mud = greywacke

   b. **No visible particles:** with the exception of fossils.

      i. <u>Dark</u> color

         - Layered, breaks easily into fine layers = shale
         - No layers, breaks into chunks = mudstone
         - Black, lightweight = sedimentary coal

ii. Light color

- Reaction with acid
    1) White to gray, may have fossils = limestone
    2) White to gray, soft, very fine grained = chalk
    3) Composed entirely of shells = coquina
    4) Fizzes only on a fresh scratch = dolomite
    5) White to gray, perfectly spherical grains = oolitic limestone

- No reaction with acid
    1) Hard enough to scratch glass = chert
    2) Salty taste, soft = rock salt
    3) Very soft, scratches with fingernail = rock gypsum

Results and Conclusions: Include in your formal report all tables, graphs, calculations, lists, charts, etc. that you produced in this lab.

Questions:

A. Why are mafic minerals such as olivine and pyroxene so rare in sedimentary rocks? HINT: Refer to Lab Three's Bowen's Reaction Series diagram and think about the temperature at which the minerals crystallized versus their current temperature.

B. How might you differentiate between limestone and basalt?

C. What do oolites indicate about a rock's former environment?

D. How are rock salt and gypsum formed?

E. How can you distinguish between tuff (welded volcanic material) and quartz sandstone?

F. What does quartz sandstone indicate about a former environment?

G. How does coal form?

H. How does the energy of transport correlate with particle size in detrital rocks?

I. What type of cement holds your sandstone sample(s) together?

J. What type of cement, calcite or quartz, would make the best building stone and why?

K. What are the names of the sedimentary rocks #30 through #42 you identified?

Metamorphic Rock Identification

Trina Johnson Riegel, M.S. Version 09.1.01

Review the safety materials and wear goggles when working with chemicals. Read the entire exercise before you begin. Take time to organize the materials you will need and set aside a safe work space in which to complete the exercise.

Experiment Summary:

Students will have the opportunity to learn how metamorphic rocks are formed. They will learn and apply classification criteria for identifying metamorphic rocks.

Objectives

- To learn the classification criteria for identifying metamorphic rocks, and
- To apply the classification criteria for identifying metamorphic rocks.

Materials

Materials From:	Qty	Item Description:
From LabPaq	1 1	Goggles-Safety Rock - Set of 50 rocks
Mineral Identification Kit	1 1 1 1 1 1	Hydrochloric Acid, 3% - 10 mL in Dropper Bottle Magnet bar Magnifier, Geologic Hand Nail, zinc-coated Penny Plate, Streak plate set

Discussion and Review

Metamorphic rocks are formed by the alteration of preexisting rocks called parent rocks. Both physical and chemical changes may occur that lead to changes in the new metamorphic rock's texture and composition. Metamorphism must be accomplished with the rock staying in a solid or semi-solid plastic-like state; if it completely melts, it becomes an igneous rock.

Metamorphism generally takes place over long periods of time and at great depths; thus, the process has not been directly observed. However, the resulting metamorphic rock can provide important clues about the temperatures and pressures needed to form the minerals and texture it exhibits. Metamorphic rocks make up a significant portion of many mountain cores and are closely associated with tectonic plate boundaries where the plates that make up the earth's crust meet each other. The study of plate tectonics is addressed in later labs in this manual.

Convergent plate boundaries where tectonic plates crash, albeit very slowly, into each other are the sites of several different metamorphic regimes:

- Low temperature and high pressure as the descending plate is pushed beneath the overriding plate,
- Both high temperature and pressure at depth, and
- High temperature and low pressure as ascending magma bodies come into contact with the surrounding rock.

The resulting metamorphic rocks are slate, phyllite, schist, and gneiss. Divergent boundaries can also produce metamorphic rock when existing rocks are exposed to hot seawater with dissolved minerals that affect the chemistry of the rock. One metamorphic rock produced may be hornfels. Transform boundaries may produce a metamorphic rock called fault breccia by the pressure of two plates sliding past each other.

Metamorphism is accomplished by three agents, often working in conjunction: heat, pressure, and chemically active fluids. Heat action is similar to what a potter does to convert soft clay into hard ceramic by placing it in a kiln. The clay minerals change into other minerals that are stable at higher temperatures and a solid state is maintained throughout. Metamorphic rocks include marble, formed from limestone or dolomite; and quartzite, formed from sandstone.

Contact metamorphism occurs when hot magma comes into contact with and heats, thus altering the surrounding rock. This causes the rock to "cook," but not completely melt, and it sometimes creates new minerals as the elements in the semi-solid rock recombine. Important ores such as copper, iron, lead, tin, tungsten, and zinc result from contact metamorphism. The most common type of metamorphism is regional metamorphism which occurs over large areas deep within the earth's crust and is usually caused by a combination of tremendous pressure, temperature, and deformation. Regional metamorphism is often associated with the mountain building that occurs at the boundaries of convergent tectonic plates that crash into each other.

Pressure typically changes a rock's texture and squeezes the strata into unusual shapes such as shown in the photo of migmatite to the right. The act of squeezing a rock causes some of the minerals to dissolve and then re-crystallize in areas of lower stress. This results in a foliated texture which can flake off in sheets like slate does.

The texture varies with the amount of pressure applied. Low intensity pressure produces slaty cleavage, where the platy minerals like biotite and muscovite align parallel to each other. The term slaty refers to a rock's tendency to split along parallel planes as in the photo of slate to the left. The resulting rock is called slate if it has a dull earthy appearance or phyllite if it has a slight satiny sheen.

Higher pressure develops schistosity which is like slaty cleavage in that it splits in parallel lines, but like the photo to the right it is more coarse-grained, often to the point where the mica minerals are noticeable. The resulting rock is called schist. Gneissic layering is produced by the highest pressures and is composed of alternating layers of different composition. Typically these are bands of light colored quartz and feldspar and dark colored pyroxene and amphibole. The resulting rock is called gneiss.

Chemically rich fluids aid in the metamorphic process by helping dissolve the former minerals, transporting ions to the new sites, and helping to crystallize new minerals. Some examples of minerals formed mainly through metamorphic processes are garnet, kyanite, andalusite, and sillimanite.

Exercise 1

Data Table 1

Metamorphic Rock Identification Chart				
Texture	Minerals	Definitive Test Results	Parent Rocks	Rock Name
Foliated	Alternating light (felsic) and dark (mafic layers)		Granite shale/felsic igneous rocks; sandstones	Gneiss
Foliated	Individual mineral grains visible; major mineral(s) included as name modifier		Shale/ Mudstone; Mafic igneous rocks	Schist Ex: Mica Schist
Foliated	Too fine grained to see; shiny due to increased size of micaceous material		Shale/ mudstone	Phyllite
Foliated	Too fine grained to see, dull, good parallel fracture		Shale/ mudstone	Slate
Foliated	Alternating light and dark layers; highly folded and contorted		Granite	Migmatite
Weakly Foliated to Non-foliated	All amphibole and plagioclase		Basalt/andesite/ gabbro	Amphibolite
Non-foliated	Fine-grained equi-dimensional grains; Micas, garnets, quartz, etc.		Mudstone Mafic igneous rocks	Hornfels
Non-foliated	All calcite or dolomite	Fizzes w/ HCl	Limestone/dolom ite	Marble
Non-foliated	All quartz		Sandstone	Quartzite
Non-foliated	Carbon		Bituminous coal	Anthracite coal

Exercise 1

PROCEDURE:

1. Closely examine minerals #4, #5, #7, #8, and #16. These are biotite, garnet, muscovite, potassium feldspar, and quartz (but not necessarily in numeric order given as you should be able to recognize these minerals by now!). They can be found in metamorphic rocks.

2. From your igneous rocks, take out #19 and #25. One of them is granite and one is basalt.

3. From the sedimentary rocks, select #32, #34, #37, #38, #39, and #42, which are (but not necessarily, in numeric order given as you should be able to recognize these rocks by now!) quartz sandstone, sedimentary coal, shale, and 4 types of limestone. These are all common parent rocks of metamorphic rocks.

4. Set up a data table similar to Table 2 below to record your observations and test results.

   Data Table 2

Metamorphic Rocks Identification Table:					
Sample #	Foliation	Grain size	Color	Other	Rock Name
#43					
#44					
Etc.					
#50					

5. Use the preceding Table 1 and the following flowchart to help you identify each of the metamorphic rock samples. Record all of your test results and the name of each metamorphic rock identified.

   a. **Foliated:** Is the rock foliated? For example, does it display slaty cleavage, schistosity, or gneissic banding? The parent rocks for these are typically shale or granite. If yes, then:

      i. Does it bear a strong resemblance to shale? = slate (parent shale)?

      ii. Are the grains are almost visible: rock has a satiny surface sheen = phyllite (parent shale)?

      iii. Is it coarse grained: mica common = schist (parent shale)?

      iv. Is it very coarse grained: minerals are segregated into layers = gneiss (parent granite) **Note:** The *sedimentary* parental lineage of gneiss is first sedimentary shale that turns into slate, then phyllite, then schist, and finally into gneiss. Since they look so different it's hard to believe all these rocks were derived from the same shale parent.

b. **Not foliated:** The grains remain randomly oriented but the rock looks “cooked.”

   i. Light color, scratches glass = quartzite (parent quartz sandstone)

   ii. Light color, reacts with acid = marble (parent limestone or dolomite)

   iii. Dark color, dull appearance, massive not layered = hornfels (parent basalt) **Note:** Hornfels is a contact metamorphic rock whose *sedimentary* parent may be shale

   iv. Dark color, lightweight, shiny surface = anthracite (the parent is actually sedimentary coal)

c. **Tink test:** This is a simple field method for distinguishing between shale (a sedimentary rock composed of clay, the mineral) and slate (a metamorphic rock composed of interlocking grains of minerals with basal cleavage). Since shale is composed of piles of loose debris, it makes a sound like "thunk" when dropped, while slate is harder and more tightly inter-grown and makes a sound like "tink" when dropped. Try it with suspected samples and you’ll hear the difference.

Results and Conclusions: Include in your formal report all tables, graphs, calculations, sketches, lists, charts, etc. that you produced in this lab.

Questions:

A. Is contact metamorphism likely to produce foliated rocks? Explain why or why not.

B. What are the major differences between metamorphism near plate boundaries and other types of metamorphism?

C. Why would clay minerals change to mica with increased metamorphism?

D. How can you distinguish between:

   1) marble and limestone
   2) sandstone and quartzite
   3) sedimentary and metamorphic coal
   4) slate and shale
   5) granite and gneiss
   6) basalt and hornfels

E. What are the names of the metamorphic rocks # 43 through 50 you identified?

Weathering

Trina Johnson Riegel, M.S.

Version 09.1.02

Review the safety materials and wear goggles when working with chemicals. Read the entire exercise before you begin. Take time to organize the materials you will need and set aside a safe work space in which to complete the exercise.

Experiment Summary

Students will have the opportunity to learn about different types of weathering and how weathering differs from erosion. They will investigate weathering processes and observe the effect of chemicals on different rock types.

Objectives

The student will have the opportunity to:

- Investigate weathering processes.
- Observe the chemical weathering rates of different rock types.

Time Allocation: Allow 48 hours for this experiment.

Note: This experiment should be started at least 36 hours in advance of the report due-date!

Materials

Materials	Label or Box/Bag	Qty	Item Description
Student provides		1 1 1 5	Distilled water, 200 mL Masking tape or similar for labels Plastic wrap sheet Paper towels or a clean cloth or towel
LabPaq provides		8 1 1	Cup, Plastic, 9 oz Tall Rock - Weathering set of 8 Scale-Digital-500g
	Mineral Identification Kit	1	Magnifier, Geologic Hand
	Miscellaneous Bag-GK-1	1	Vinegar - 60 mL in Dropper Bottle

Discussion and Review

Weathering of rocks is a transformation process that includes breaking down, disintegrating, and decomposing the physical and chemical characteristics of surface rocks. Weathering is primarily caused by water, atmospheric agents, living things, and gravity. Weathering is an important factor in the formation of soils. The two basic weathering processes are:

- **Physical (mechanical) weathering** – This is a process that breaks rocks into smaller pieces. It only alters the rocks' physical characteristics without affecting their chemical composition.

- **Chemical weathering** – This is a process that breaks down and alters rocks through chemical reactions such as oxidation, hydration, carbonization, and the loss of chemical elements in solution.

Although the terms are often used interchangeably, do not confuse **weathering** with **erosion**. While closely related through the action of similar forces as weathering, erosion is a process primarily involved with transporting from one place to another the physically and chemically changed particles created by weathering. Weathering tends to occur through natural forces. Similar natural forces such as rain, rivers, glaciers, and wave action also create erosion. But erosion, especially today, is often caused by human activities such as digging, excavating, and blasting. Humans can accelerate weathering and erosion by digging and later burning coal, which releases sulfur into the atmosphere and creates acid rain.

Physical weathering is also called **mechanical weathering.** Rocks can be physically weathered by swift water that tumbles and breaks rocks apart; by the expansive forces of large temperature changes, especially where freezing and thawing causes the rocks to expand and contract; by plant roots that intrude into and break rocks apart; and also by gravity that causes weakened rocks to fall against other rocks and thus break into smaller pieces.

While scientists could mechanically break down rock samples in a lab by simply smashing them with a rock hammer; the rocks' composition would remain the same, but they would be in much smaller pieces. This might be a fun and stress-reducing exercise, but its conclusions are foregone: the scientist would have a lot of smaller rocks, but the rocks' chemical properties would remain the same as before. That is why this lab instead experiments with chemical weathering.

*The photo on the left shows **physical weathering**. The cracks were made in a stone from repeated freezing and melting of water within its fissures. **Biological weathering** may also contribute significantly to the breakdown of stone. The colored lichen formations in the photo on the right feed off of the rock's chemistry and slowly add to its physical and chemical breakdown. Photo courtesy of Wikimedia Commons.*

Chemical weathering takes considerable time in a natural environment, and is accomplished via acid solutions, hydrolysis, and oxidation.

- **Acidic Solutions** are primarily water-based solutions that can actually dissolve certain rocks. This can come from acid rain that develops when carbon dioxide dissolves in rain forming a slightly acidic carbonic acid. Limestone and marble contain calcite that is soluble in acidic water. Caves and caverns form in this process. See Figure 1.

- **Hydrolysis** refers to the transformational chemical reaction that occurs between water and the minerals – typically silicates – contained in certain rocks. For example, when feldspar reacts with water, hydrolysis removes its ions into solution and transforms the feldspar into quartz and kaolin clay. This can also include the process where minerals in the rock absorb water and expand, creating stress that causes the disintegration of rocks.

- **Oxidation** involves the chemical process whereby oxygen ions in the air combine with exposed minerals, primarily iron-bearing silicate minerals, and causes the "rusting" that commonly gives rocks a reddish color. See Figure 2.

Figure 1- Dave Bunnell showing stalagmites, stalactites, and draperies by a pool in Lechuguilla Cave, New Mexico, USA. Courtesy of Wikipedia.

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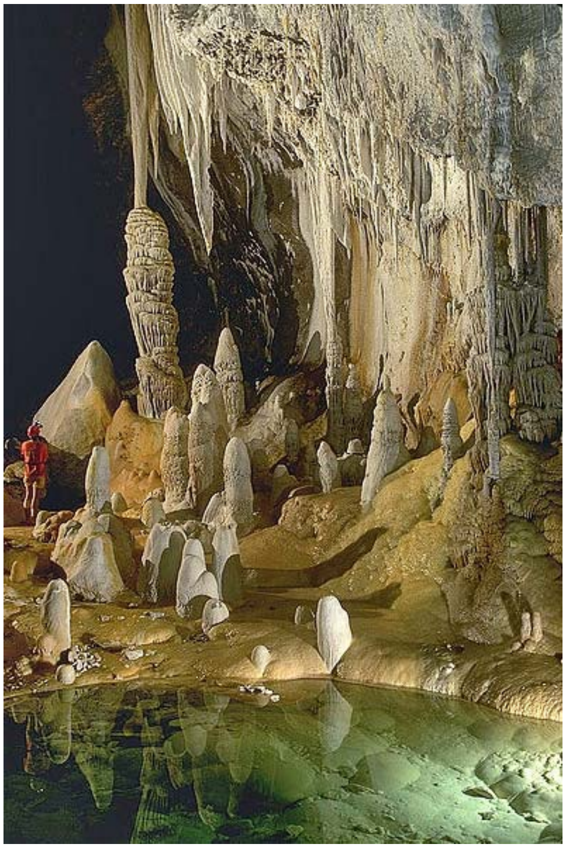


Figure 2 - An example of oxidation - Red Rocks in Colorado

While chemical and physical weathering both wear down a rock at the same time, they do not necessarily affect the stone at the same intensity. Scientists do not have the luxury of observing the rainwater's chemical weathering properties over a few million years, but can observe this process' effects first-hand by using a stronger acid to speed up the weathering reaction. In this lab, the stronger acid will be used to observe the weathering reaction in a short period of time.

Figure 3 – Salt weathering of sandstone near Qobustan, Azerbaijan. Petroglyphs attributed to prehistoric humans are visible on the left side of the image. Courtesy of Wikipedia.

Exercise 1: Weathering

PROCEDURE:

For this experiment, the student will compare the mass of various rocks before and after the simulated weathering experiment.

CAUTION: This lab uses a 5% acetic acid solution – also known as basic household vinegar. While seemingly weak, vinegar's acid content has sufficient caustic properties to dissolve rocks! Thus, it is wise to wear safety goggles and appropriate clothing when performing this experiment and to wash hands when finished.

Part I: Setting up the experiment

1. Record observations and mass for this procedure into Data Tables 1 and 2 located in the lab report.

Data Table 1 – Change in Mass

	Granite		Quartz Sandstone		Calcareous Shale		Limestone	
Cup number	#1	#2	#3	#4	#5	#6	#7	#8
Solution in cups	Distilled Water	Vinegar	Distilled Water	Vinegar	Distilled Water	Vinegar	Distilled Water	Vinegar
Initial mass - grams								
Final mass - grams								
Change in mass - grams								

Data Table 2 – Observations & change in appearance

	Granite	Granite	Quartz Sandstone	Quartz Sandstone	Calcareous Shale	Calcareous Shale	Limestone	Limestone
Cup number	#1	#2	#3	#4	#5	#6	#7	#8
Solution in cups	Distilled Water	Vinegar	Distilled Water	Vinegar	Distilled Water	Vinegar	Distilled Water	Vinegar
Initial appearance								
Visible Chemical activity								
Final appearance								

2. Use distilled water to rinse away all surface dirt from the rocks and use a towel or cloth to dry each pair of the rock samples. Use the Geologic Hand Magnifier (magnifying glass) to observe each rock's surface. Record the observations into lab report Data Table 2 as "Initial Appearance".

3. Use the digital scale to measure the mass of each rock separately. Record the mass in grams under "Initial mass" into lab report Data Table 1.

4. Prepare 8 different cups by labeling each cup with a number for each of the items listed. Immerse each stone into their corresponding cups with the appropriate liquid shown in the list.

Table 1 – Cup labeling for stone to be immersed in liquid

Cup Label	Stone	Immerse stone with:
Cup 1	Granite stone	distilled water
Cup 2	Granite stone	vinegar
Cup 3	Quartz sandstone	distilled water
Cup 4	Quartz sandstone	vinegar
Cup 5	Calcareous Shale	distilled water
Cup 6	Calcareous Shale	vinegar
Cup 7	Limestone	distilled water
Cup 8	Limestone	vinegar

5. Record into lab report Data Table 2 any reactions that appear for each rock and its liquid. Reactions should appear within a few minutes, if not instantly. An example would be the production of gas as evidenced by bubbling. This represents a chemical reaction.

6. Cover each clear plastic cup with plastic wrap. It might be necessary to tape the wrap onto the cup if the wrap does not stay in place.

7. Place the cups in an area at room temperature where they will not be disturbed for the next 24 hours.

Part II: Recording Results

1. Find a work surface impervious to water. Alternatively place a plastic sheet or a towel onto the work surface, or place two layers of paper towels to absorb the water.

2. Pour all of the water and vinegar out of each cup into a sink while keeping the rock inside.

3. Empty each rock onto the towel and keep the cup next to the rocks or just place the rocks in order from #1 to #8.

4. Allow the rocks to dry thoroughly before taking the final mass measurement. While waiting for the rocks to dry examine them carefully with the Geologic Hand Magnifier and record any changes observed into Data Table 2 located in lab report.

5. Weigh each rock and record the mass into Data Table 1 as the “final mass” values.

6. Calculate any change in mass by subtracting the final mass from the initial mass. Record the change in mass into Data Table 1 as “Change in mass”.

QUESTIONS:

A. Did any of your rocks gain or lose mass in this experiment? If so, what do you think caused this change?

B. Did this experiment simulate chemical weathering in any rock samples? Explain.

C. Rank the rocks 1, 2, 3 etc., in order of their resistance to weathering. For example, the most resistant rock – showing little to no change in mass – would be ranked as number 1. The second most resistant as number 2, etc.

D. Describe several ways that climate might impact physical and chemical weathering?

E. Using the information gathered in this experiment, which of the four types of stones used would be a better choice to use for construction of buildings? What might be some reasons for not using this type of rock in construction?

Optional Exercise: Visit a cemetery and look at gravestones made of different material that are approximately the same age. If visiting a cemetery is not a choice, look for stone statues, gargoyles on buildings, or older building faces to see if there is evidence of weathering. Which rock material appears to hold up the best? What is the composition of the stones? Can you observe any deterioration and/or weathering patterns in their surfaces?

Porosity and Permeability

Trina Johnson Riegel Version 09.1.03

Review the safety materials and wear goggles when working with chemicals. Read the entire exercise before beginning. Take time to organize the materials needed and set aside a safe work space in which to complete the exercise.

Experiment Summary:

Students will have the opportunity to learn how porosity varies in different kinds of rocks and how porosity is quantified. They will determine the porosity, specific yield, and specific retention of six different rock samples. Students will learn the advantages and disadvantages of different levels of porosity in rocks and how humans impact aquifers.

Objectives

- To observe and determine the porosity, specific yield, and specific retention of several different types of materials

- To consider the impact of human activities on aquifers.

Materials

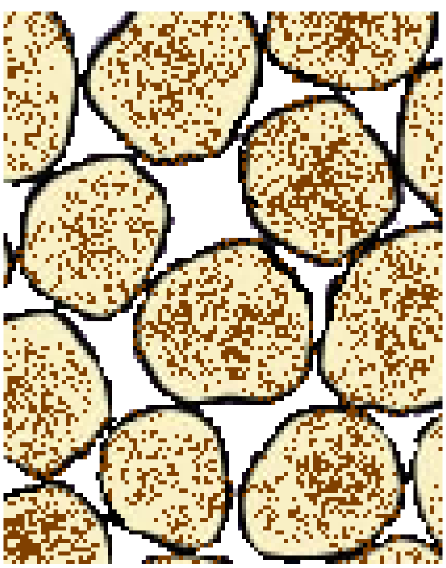
Materials From:	Label or Box/Bag:	Qty	Item Description:
Student Provides		1 1	Water Soil sample from any location, 100 cc Paper towels
From LabPaq		1 6 6 1	Beaker, 100 mL, plastic Cup, Plastic, 9 oz Tall Cup, Styrofoam, 12 oz Cylinder, 25 mL
Clay,powdered in cc-Bag	Clay,powdered in cc-Bag	1	Clay,powdered 235cc-in a bag
Gravel, Pea in cc-Bag	Gravel, Pea in cc-Bag	1	Gravel, Pea - 235 cc in a bag
Gravel, Squeege in cc-Bag	Gravel, Squeege in cc-Bag	1	Gravel, Squeege - 235 cc in a bag
Miscellaneous Bag	Miscellaneous Bag-GK-1	1 1 6	Cheesecloth, 24" x 4" Pipet, Long Thin Stem Rubber Bands
Potting Soil-Bag	Potting Soil-Bag	1	Potting Soil, 1 cup in Bag 4"x 7"
Sand in cc-Bag	Sand in cc-Bag	1	Sand 235cc - in a bag

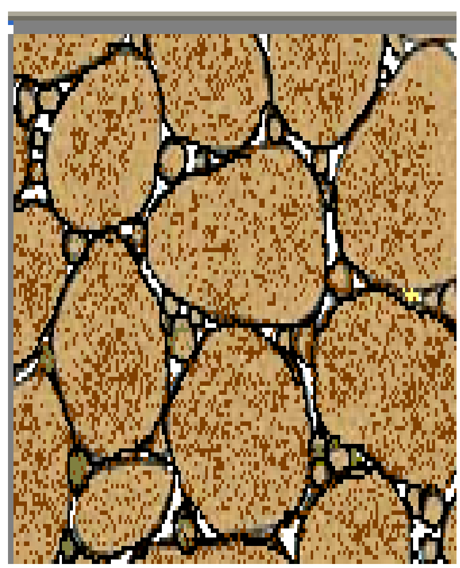
Discussion and Review

When fresh water is not readily available through rivers, streams or lakes, mankind (and some animals) has learned how to tap into a fresh water source known as aquifers. Aquifers are huge storehouses of water beneath the ground and they are one of the most valuable resources to a landowner or community. An aquifer is a layer of water-bearing rock that easily transmits that water to the surface through springs or man-made wells. Below some depth (which varies), water is saturated in material, like a sponge, but in this case, the "sponge" is porous and permeable rock material. In this lab, porosity and permeability of various materials for a better understanding of this valuable resource as well as the type of rock units that tend to display these characteristics. Understanding these characteristics of rocks allows drilling efforts to be successful whether the target is groundwater, oil or gas reserves or even when the rock unit will act as a containment facility. Southern California Gas is one of many utilities that use porous rock units as a storage for gas reserves for the city. For more information on such facilities, search Aliso Canyon Gas Storage facility and look for a cross section.

Aquifers are composed of rock units that have both good porosity and permeability. Rock units that do not are called aquitards. Aquitards serve a useful purpose because they act as a dam, a cap or a container for the groundwater and serve other functions of containment at landfills or gas and oil reserves. For more information on aquitards and their uses, key in the words "aquitard" into your internet search engine, images.

Porosity is defined as the percentage of the volume of open space compared to the total volume of the rock or, stated differently: it is the percentage of a rock's total volume that is pore space. A rock with good porosity has a large amount of pore space and can hold a large amount of fluid. Porosity first depends upon sorting. Sorting refers to how many of the rock particles are the same size. The illustrations show that when the particles are similarly sized, they are not able to compact as tightly as are different sized particles where the smaller grains fill in the gaps left by larger ones.





It is easy to observe the numerous open spaces in a well sorted rock unit versus the lack of open spaces in the poorly sorted rock unit. The size of the particles is also an important factor to the porosity of the rocks. The larger particles create larger open spaces between each particle than smaller particles. The larger the similar-sized grains, the greater the porosity, so a block of similarly sized gravels would have more porosity than a field of similarly sized sand.

Other considerations in porosity are:

- Packing: how closely the grains are packed together
- Cementation: the type of cement holding the particles together
- Shape: angular particles fit more closely together so there is less open space and rounded particles leave more open space

There are many factors composing porosity, but it is only the first step in calculating whether a rock or soil unit is capable of acting as an aquifer or a containment unit.

Of even greater importance is the **permeability**, defined as the capacity of a material to transmit water ~ the ability of water to move from one place to another. It does no good if a rock material can hold a lot of water if there is no way to pull it out of the rock. Rocks such as clay and shale, for instance, have very good porosity and hold a lot of water, but the minerals are arranged in such a way that the water is essentially trapped in the rock and does not move very easily or quickly. A rock's ability to transmit water can be quantified by measuring the following:

- Specific yield: The percentage of water in a material that will drain out by gravity

- Specific retention: The percentage of water left behind in a material.

In the procedures that follow, porosity of 6 materials will be hypothesized and the specific yield and retention values for these six sample materials will be determined. Five sample materials are provided in the LabPaq plus one sample will be provided by the student. The resulting data will be graphed for additional quantitative analysis of the characteristics of porosity and permeability.

Groundwater replenishment, or **recharge**, is accomplished through **precipitation** (rain, snow, sleet or hail). When precipitation occurs, water soaks into the ground and migrates downward until it reaches the **zone of saturation** where all of the open spaces within the rock material are filled. Wells drilled into an aquifer by a private landowner or a municipality may pump out more water than the precipitation that recharges the aquifer. If this occurs, the zone of saturation will drop over time and may cause the wells to run dry, or simply pump air instead of water. Because this is such an important resource to a landowner or a community, being aware and monitoring aquifers are vital.

Human activity can also prevent water from migrating into the aquifer by paving roads, installing storm drains or building structures closely together. Paved roads and storm drains prevent the water from soaking into the ground and the water is eventually diverted to a stream or reservoir. This decreases the recharge of aquifers and increases the risk of flooding since water which otherwise would have soaked into the ground now flows from the storm drains into the stream.

Exercise 1

PROCEDURE:

1. Set up a data table similar to Table 1 to record your test results.

Data Table 1: Six Samples of Porous and/or Permeable Materials

	A	B	C	D	E	F
Test Material	Material Volume (cc)	Saturation Volume (mL)	B/A * 100 = %Porosity	Drained Water (mL)	D/B * 100 = % Specific Yield	100 – E = % Specific Retention
			% Porosity		*% Specific Yield*	*% Specific Retention*
Sand						
Gravel						
Squeege*						
Clay						
LabPaq Soil						
Student's Soil						

*Squeege is a construction material composed of assorted sands and gravels

2. Cut the cheesecloth into 6 pieces of about 6”x6” each and set aside.

3. Extract a soil sample from somewhere in your neighborhood of sufficient quantity to fill your 100-mL beaker.

4. Based upon your current knowledge, record a hypothesis about which of your six materials you think will have the highest porosity (% of open space) versus the material with the highest specific retention or the amount of water left behind in the material.

5. Column **A Material Volume:** Beginning with the sand from the Labpaq, fill the beaker to 100mL, tapping gently on the material to ensure a level surface. **Note:** 100cc of solid material is equivalent to 100mL of liquid which is why the beaker is used for this measurement. Pour the sand into the clear plastic cup and repeat this step with the 5 other materials, wiping out the beaker with a paper towel after each measurement.

6. Column **B Saturation Volume:** Saturation is the maximum absorption level of the greatest possible amount of a liquid, solid, or gas by any solution or material. When a material is saturated, it will be very wet, but water will not be floating above the surface of the material. The water level should exactly match the level surface of the material. Beginning with the sand, saturate the material with water by performing the following steps. Be sure to keep an accurate measurement of the amount of water used in this part of the experiment.

a. Measure exactly 25 mL of tap water into the graduated cylinder. This is not as easy as it sounds, but the process is simplified by using a thin stemmed pipet to adjust the water level in the cylinder until it reads exactly 25 mL when held at eye level. Remove excess water from the cylinder by squeezing the pipet bulb while the tip is in the water. This will suck water from the cylinder into the pipet bulb. To add water, simply suck up tap water into the pipet, and carefully add drops to the cylinder until you reach the 25 mL mark as shown in the photo.

b. To saturate your samples, slowly add a sufficient quantity of water from the graduated cylinder into the sample cup until the sample is fully saturated. The clay will need extensive stirring to ensure the water reaches the bottom of the cup.

c. If the sample is not completely saturated after the first 25 mL addition of water, write 25+ in the saturation volume column of your data table, refill the graduated cylinder with exactly 25 mL of water, and repeat Step B. Continue to work with 25 mL increments of water until the material's saturation point is finally reached. Make sure you record each 25 mL addition of water. If the material reaches saturation and there is leftover water in the graduated cylinder, subtract this amount from the total amount of water used. Record the total amount of water in column B.

Note: If the sample seems oversaturated such as excess water puddling above the sample, tip the cup gently and siphon the excess water into the thin-stemmed pipet. Once the cup is level, it may be necessary to add a few drops of water back into the cup to achieve an equal level of water and material. The amount of water removed from the cup must be recorded and subtracted from the amount of water recorded in column B. Squeeze the pipet with the remaining water into the graduated cylinder and read the measurement from eye level.

7. Column C: % Porosity. For each sample, divide the total quantity in mL of water required to saturate each sample (column B) by the total volume of the sample measured in mL (column A) and multiply by 100. This is the percentage of "porosity" to be recorded in column C.

8. **Column D Drained Water:** For each saturated sample, place a piece of cheesecloth over the top of each sample cup and secure it tightly with a rubber band or tape. Make certain that all of the cheesecloth edges are tucked in under the rubber band so that no materials fall out when the sample cup is inverted.

   a. Carefully invert each plastic sample cup over and into the slightly larger Styrofoam cup as shown and let the cup drain for an hour. To avoid creating a vacuum and preventing the water from draining, it is important to tip the cup a bit as shown in the photo. You may need to brace the cups against something heavier to prevent them from tipping over.

   b. After the samples have drained for an hour, remove the plastic cups from the foam cups and set aside.

   c. Next, working with one sample at a time, pour any water from the foam cup into the graduated cylinder. Observe and record in mL exactly how much water was drained from the sample and record this quantity in Column D.

9. **Column E % Specific Yield:** Divide the quantity of drained water (column D) by the amount of water it took to originally saturate the sample (column B) and multiply by 100. The result is the percentage specific yield and should be recorded in column E.

10. **Column F % Specific Retention**: Subtract the percentage specific yield from 100 to arrive at and record this value as a percentage of specific retention. This represents the amount of water that is still held in the sample due to water adhering to its particles.

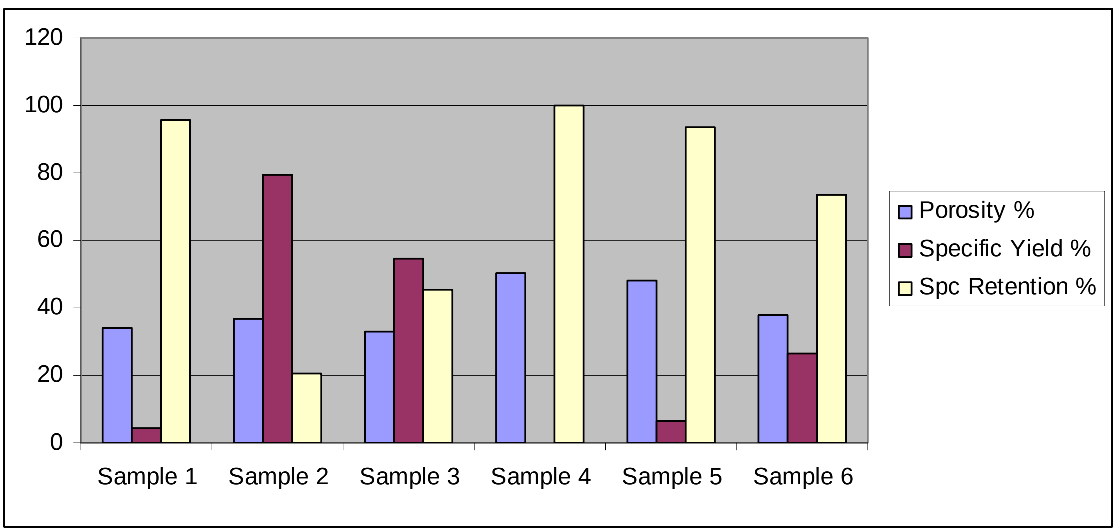
11. Finally, convert your data into a column bar graph. An illustrative sample data table and chart are shown below, but your actual data will be different.

Note: Your LabPaq contains sufficient materials to perform this experiment twice, in case a mistake is made the first time. If there are no problems the first time, the experiment may be performed twice to increase and verify the accuracy of your data.

Data Table 2: Example of a complete data table for Porosity and Permeability Lab (this data will be different from your results)

	A	B	C	D	E	F
Illustrative Sample Data	Volume Material (cc)	Saturation Volume (mL)	B/A * 100 = %Porosity	Drained Water (mL)	D/B * 100 = % Specific Yield	100 – E = % Specific Retention
			Porosity %		*Specific Yield %*	*Specific Retention %*
Sample 1	100	34	34	1.5	4.41	95.59
Sample 2	100	36.5	36.5	29	79.45	20.55
Sample 3	100	33	33	18	54.55	45.45
Sample 4	100	50.5	50.5	0	0.00	100.00
Sample 5	100	48	48	3	6.25	93.75
Sample 6	100	38	38	10	26.32	73.68

Graph 1 Illustrative Sample Data



IMPORTANT - Special Cleanup Directions: The sand, gravel, clay, squeege, and soil will be used again in future labs. Thus, you should allow the cups of materials to thoroughly dry over a few days and then re-bag and return them to your LabPaq. The clay may solidify into a solid block and need to be pulverized back into fine particles. Place the solid clay into several old plastic grocery bags and rap the material firmly with a hammer. Further crushing and pulverizing may be done using a blender, food processor, or coffee grinder.

Results and Conclusions: Include in your formal report, all tables, graphs, calculations, sketches, lists, charts, etc. that you produced in this lab.

Questions:

A. Compare the testing results with your original hypothesis regarding porosity and specific retention. Discuss how the new data changes or confirms your original hypothesis.

B. Study your data graph and analyze the relationships between porosity, specific yield, and specific retention for each material. For each material tested, describe those relationships.

C. Describe the ideal rock layers under the Earth that would support an aquifer. Support your response with details and examples.

D. Describe the types of materials that would make a poor choice for drilling a well for a landowner. Support your response with adequate details and examples.

E. Describe the ideal rock layers for a landfill. Describe how each rock layer would contain the landfill and make it safer for the community.

F. Oil forms in the Earth's crust and migrates to high porosity rock layers in much the same way as waters for aquifers. When drilling and pumping oil, geologists must consider accidental oil spills in their analysis. Describe how the cleanup of such an oil spill would depend on the material it leaked into?

G. Now consider how urbanization significantly increases flooding danger by increasing the runoff into streams, while decreasing the amount of water infiltrated into groundwater aquifers. Performing the following calculations will help illustrate this point.

   1. Over the course of one summer storm, approximately 1 cm of precipitation soaks into the ground. An average house has a roof area measuring 12 x 18 m and the precipitation that falls on the roof is diverted down the gutters and into a storm drain. Calculate the amount of water that is diverted from the ground into drains in m^3. **Note:** Remember that 1 cm = 0.01 m. You must calculate the area (length x width) and then multiply by the depth of rainfall in meters. This will give the rain volume in m^3. Now convert this amount into gallons knowing that 1 m^3 = 264 gallons.

   2. What if an entire subdivision of homes had 18x12-m roofs as above? Calculate the volume of water that goes down the drain instead of infiltrating into the ground in both m^3 and gallons if it rains to a depth of 1 cm on 20 homes in a new subdivision.

   3. Now calculate the volume of a 1-cm rainfall over downtown Denver which has an approximate area of 401 km^2. The conversion of km^2 to m^2 is 1km^2= 1,000,000m^2. Calculate the amount of water in m^3 and gallons.

4. In this case, runoff is defined as the amount of water that does not soak into the ground. Runoff promotes erosion when not controlled and intricate storm drains are required when building in an urban or suburban area to prevent erosion and damage to property and buildings. In an urban area, runoff accounts for about 90% of the precipitation that falls to the ground versus 20% in a rural area or an area of undeveloped land. How many gallons of water are going into the storm drains of Denver instead of infiltrating into the ground?

5. What are some ways we could reduce this problem, assuming that simply abolishing the city and all its dwellings isn't realistic?

Ice and Glaciers

Trina Johnson Riegel, M.S. Version 09.1.01

Review the safety materials and wear goggles when working with chemicals. Read the entire exercise before you begin. Take time to organize the materials you will need and set aside a safe work space in which to complete the exercise.

Experiment Summary:

Students will have the opportunity to learn about the concept of albedo and how it relates to the freezing and melting of ice. They will also learn about the formation and movement of glaciers. Students will observe the effects of pressure on melting ice.

Objectives

- To observe and understand the concept of albedo,
- To gain understanding about how water freezes to ice and ice melts,
- To gain understanding about glacial formation and movement, and
- To observe and understand the effects of pressure on melting ice.

Materials

Materials From:	Qty	Item Description:
Student Provides	1 1 1 1 1 1 1 1	Small saucepan Stovetop Ice cube tray(s) Tap water Crushed ice Stir stick or spoon Kitchen timer (optional) Sunlight or strong lamp
From LabPaq	2 1	Petri dish, 60 mm Thermometer-in-cardboard-tube
Miscellaneous Bag	1	Food Coloring Mix (Red, Blue, Green) 2 mL in Pipet

Discussion and Review

Albedo is a general term that refers to the reflectivity of sunlight. Things with low albedo tend to absorb heat well, such as forests. High albedo materials, such as snow and ice, reflect sunlight and thus absorb very little heat. Albedo depends on color; try wearing a black T-shirt on a hot summer day, followed by a white T-shirt on the next equally hot day. Chances are that you'll feel much warmer the day you wear the black T-shirt, because black absorbs light and reflects very little. Since white reflects most of the light and absorbs little, light colored items feel cooler than darker colored ones. On a cool but sunny day, try sitting on a dark colored rock and on concrete. The dark colored rock will absorb much more heat and feel warmer.

Albedo affects glaciers since an expanse of white glacial ice will reflect a substantial amount of sunlight, thus decreasing temperatures perhaps globally, depending on the size of the glacier. Glaciers are thus somewhat self-perpetuating. Their ice sheets reflect sufficient sunlight so their temperatures stay cold enough to keep the ice from melting.

The reverse is true of forests; since they have a dark green overall color, they will absorb sunlight and heat. This warming effect on forests is offset and forests seem cooler because of the cooling effects of evapotranspiration from the trees (which is similar to how your sweat cools you down) and the shade they provide.

The process of melting and freezing ice is more complicated than it seems. As you know, ice melts at 0 degrees Celsius, which is the same as saying that water freezes at 0 degrees Celsius. We previously looked at the melting/crystallization point of minerals; since ice is theoretically a mineral, the same concepts apply. However, a certain amount of heat is needed simply to melt ice and produce its phase change from solid to liquid. This is called the heat of fusion. Ice melts naturally because it absorbs heat from its surroundings, and in turn, it cools the substances around it while melting. Conversely, when water freezes to ice, it releases a certain amount of heat. This released heat is the reason why the air temperature slowly rises during a prolonged snowfall.

How do glaciers fit in here? Glaciers are huge masses of accumulated snow, and ice plus rock and other debris. The thickness of a glacier varies from tens of meters to several kilometers. The weight of the ice on the top of a glacier affects the freezing/melting point of ice at the base of the glacier.

Adding pressure raises the melting point of most substances, including rocks. For example, rocks far beneath the earth's surface remain solid because of enormous pressure, but if that pressure is released as in a volcano, the rock melts into lava. The same is not true for ice where pressure causes melting, and the release of that pressure actually causes the ice to refreeze.

Most substances contract when they freeze, but water behaves just the opposite and instead expands and creates pressure when it freezes. Additional pressure lowers ice's melting point. Therefore, ice at the bottom of a glacier can melt when there is enormous pressure from above. Once the pressure is released, the ice freezes again. This process where ice melts under pressure and refreezes when pressure is released is called regelation.

You can demonstrate regelation by making a snowball. The pressure created by your hands in packing a snowball causes some melting of the snow, and the release of the pressure refreezes the snow and makes it stick together. Ice skating is another example of the regelation process; here the pressure of your skates melts a little bit of ice and allows you to glide on your skate blades, and the release of pressure after your skates have passed refreezes the ice. In a glacier, increased weight and pressure creates basal melting that provides a low friction base for the glacier to slide over. When the weight and pressure are reduced, the glacier base refreezes. This combined with gravity is what causes a valley glacier to slowly advance downhill.

Exercise 1

PROCEDURE:

Part I:

1. Half a day or more before starting the experiment, make 5 regular ice cubes and 5 dark colored ice cubes per the following directions.

    a. To prepare the dark-colored ice cubes mix about 250 mL of water with 10 or more drops of dark food coloring from the pipet in your LabPaq. Simply snip the end squarely off the pipet tip and slowly squeeze out 10 drops. If your trays have separate compartments for each cube, both the regular and colored water cubes can be made in a single tray. However, if your ice cube trays contain dividers where the liquids can merge, you will need to use two separate ice cube trays.

    b. Fill half of the compartments of an ice cube tray with regular water and the other half with colored water. It is important that you to fill the compartments to the same depth so all the cubes will be similar sized. Freeze the cubes until solidly frozen and you are ready to begin.

2. Form and record your hypothesis as to which ice cube you expect to melt first and include the reasons for your expectation.

3. Prepare a table similar to Table 1 to record your number of trials, the time for melting each cube, and average time for melting each type of cube.

Data Table 1

Data for Ice Melting Experiment						
Plain water ice cubes	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Avg
Start time						
End time						
Total minutes to melt						
Dark colored ice cubes	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Avg
Start time						
End time						
Total minutes to melt						

4. The melting part of the experiment is best done on a sunny day to maximize reflection and speed up the reaction. However, if sunlight is not available you may substitute strong light from a desk lamp.

5. When the ice cubes are well frozen, remove 1 plain water ice cube and 1 colored ice cube from the tray and return the remaining cubes to the freezer. Place the selected cubes into two separate small petri dishes. Record the start time in the data table.

6. Set both petri dishes with the ice cubes in the sunlight or under a strong lamp. Do NOT stir. It is extremely important that you keep a very close eye on your melting ice cubes and the time. If you have one, a kitchen timer is very helpful in doing this.

7. Record the time at which each ice cube is completely melted. Compute and record the total length of time it took each cube to melt.

8. When the first set of cubes has melted, dry the petri dishes, remove a new set of plain and colored ice cubes for the next trial, return remaining cubes to the freezer, and record the start time and begin timing again.

9. After completing five trials, compute an average time for your plain water and colored water ice cubes to melt.

Part II:

1. Prepare a table similar Table 2 to record the temperature vs. time data.

Data Table 2

Temperature versus Time data	
Time (minutes)	Temperature (°C)
0 (start)	
1	
2	
3 etc	

2. Fill a small saucepan with about 2 cups (500 mL) of regular crushed ice. You can purchase crushed ice or crush your own ice cubes in a blender; the consistency should be reasonably fine, but not slush.

3. Place your thermometer in the center of the ice. Observe and record the starting temperature.

4. Set the pan on the stovetop over very low heat – use the lowest temperature setting on your burner – and take a temperature measurement once a minute until the ice is melted. As you take temperature readings, stir the ice to ensure complete melting and an accurate temperature of the water/ice mixture. When you take the temperature, do NOT let the thermometer touch the bottom of the pan, or your reading will be inaccurate.

5. Continue taking temperature readings every minute for 10 minutes after the ice has melted completely. Do NOT leave the thermometer in the pan between readings.

6. Finally, prepare an x-y graph from your data table. Use time as the X-axis and temperature as the Y-axis. (See the Excel® tutorial for details)

Results and Conclusions: Include in your formal report all tables, graphs, calculations, lists, charts, etc. that you produced in this lab.

Questions:

A. Which ice cube melted faster on average, the clear or the dark colored one? Why do you think this was? What can you say about each ice cube's albedo? How do the results relate to your initial hypothesis?

B. Which type of glacier would likely melt back first: a clean ice glacier or a rocky ice glacier filled with debris? Would the answer to this question also show up in observations of piles of snow melting after a snowstorm? Explain your answers.

C. Does the growth of glaciers depend on temperature alone, or other factors? How do glaciers get started in the first place if albedo is low? How do they ever melt if they have such a high albedo?

D. Using what you have learned about pressure and melting points, is sledding better done when the air temperature is 25 degrees F or 0 degrees F?

E. What happened to the temperature during the ice melt process in Part B? Did it rise as melting was taking place?

F. If the temperature did not rise while melting was occurring, what happened to all of the heat you supplied from the stove burner?

G. Predict what the time vs. temperature chart would look like if you continued heating the water to the boiling point, then let it boil away, while measuring temperature the same as you did for the ice melting. You can actually try this if you like, just be careful once the water starts boiling away and avoid placing your thermometer bulb on the bottom of the pan.

H. If glaciers worldwide were to melt, would temperatures around the glacier rise, fall, or remain the same as the glacier was melting?

Mass Wasting

Trina Johnson Riegel, M.S. Version 09.1.01

Review the safety materials and wear goggles when working with chemicals. Read the entire exercise before you begin. Take time to organize the materials you will need and set aside a safe work space in which to complete the exercise.

Experiment Summary:

Students will have the opportunity to learn how mass wasting occurs and what factors affect it. They will experiment with different soil types, quantities of water, and varying angles of repose to study the effects on mass wasting.

Objectives

- To experiment with factors such as soil type, water quantities, and angle of repose in order to assess their contribution to mass wasting.

Materials

Materials From:	Qty	Item Description:
Student Provides	1 1 1	Plastic wrap or similar Cookie sheet or similar Soil sample – from Lab 7 or new
From LabPaq	1 5 1 1 1	Beaker, 100 mL, plastic Cup, Plastic, 9 oz Tall Cylinder, 25 mL Funnel Protractor
Clay,powdered in cc-Bag	1	Clay,powdered 235cc-in a bag
Gravel, Pea in cc-Bag	1	Gravel, Pea - 235 cc in a bag
Gravel, Squeege in cc-Bag	1	Gravel, Squeege - 235 cc in a bag
Potting Soil-Bag	1	Potting Soil, 1 cup in Bag 4"x 7"
Sand in cc-Bag	1	Sand 235cc - in a bag

Discussion and Review

Mass wasting is defined as the downslope movement of material due to gravity. “Landslide” is a popular term that is used in everyday language; however, in a geological sense the term landslide is strictly defined, as we’ll see below.

Geologists and civil engineers recognize four factors that define mass wasting:

- Material type involved, such as clay, soil, gravel, or ice;
- Velocity of movement from 300 kilometers/hour to less than a centimeter/year;
- State of the moving mass: if it is chaotic, coherent, or a slurry; and
- Location of the movement: if it takes place on land or underwater.

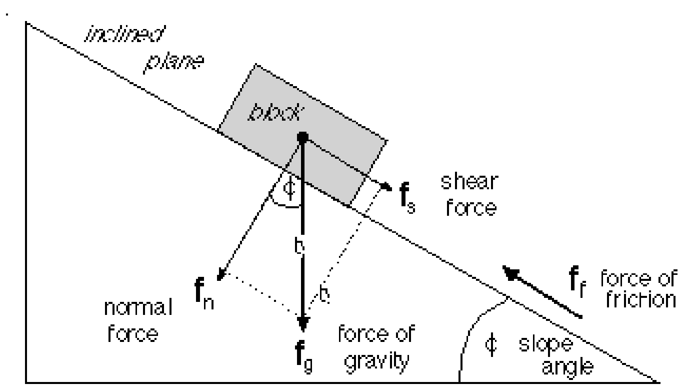
The types of mass wasting depend on an interaction of the above four factors. Creep moves very slowly and involves water saturated sediment. Rock glaciers, composed of rocks and ice, creep in centimeters per year. Mudflows, composed solely of mud, and debris flows that may or may not incorporate some rocks, move more quickly, possibly several kilometers per hour. Lahars are mudflows produced by a volcanic eruption that can create much death and devastation. Landslides are the sudden movement of debris down a non-vertical slope.

When material slides away, it can be either translational where it moves downward parallel to the angle of the slope, or rotational where it rotates around the center of the slope’s angle and commonly leaves a curved head scarp cliff at the top.

Avalanches are a turbulent mixture of air and debris; if the debris is snow it is a snow avalanche. A rockfall is the quickest type of mass wasting; here pieces of bedrock come loose and fall directly down from a vertical slope.

A slump is a mass movement of consolidated rock and/or materials that slides downward and outward along a concave slip plane. Submarine slumps occur in underwater environments. Evidence of past slumps is found all along the margins of the Hawaiian Islands. If the rocks or material break apart into smaller particles they can create a slurry of submarine debris flow.

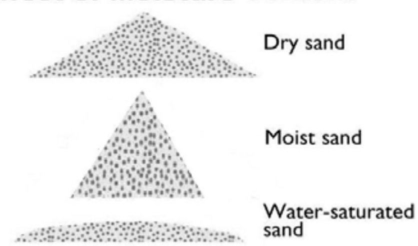
Since material is moving downslope in response to gravity, the slope of the hill plays a crucial part in determining the speed and type of mass wasting event. Vertical slopes such as cliffs obviously cause the movement to be very swift. Near-horizontal slopes can move material perhaps only a few centimeters every year.



The force acting to hold the material back is the force of friction (f_f); it incorporates the chemical bonds in minerals, surface tension, and cementation of the material. The gravitational forces seeking to pull the material down are separated into the normal force (f_n) perpendicular to the slope and the downslope shear force (f_s) parallel to the slope. As the slope becomes steeper, the downslope shear force increases at the expense of the normal force, eventually causing the material to overcome the resistant force of friction and move. The maximum slope angle that a material can maintain and remain stationary is called the **angle of repose** and typically varies between 15 and 45 degrees.

The angle of repose is the highest angle that a material can withstand and still be stable. The angle depends on the material. Perfectly rounded particles will have a lower angle of repose than angular particles because the irregular edges and corners of angular particles will help hold the material together. An example is best seen in the different types of volcanoes. Basalt is very runny like water and so forms a low angle shield cone. Cinders are irregularly shaped and can pile up higher, so cinder cones have very steep slopes, sometimes above 40 degrees. Materials with a low angle of repose form flatter piles than do material with a high angle.

Angle of Repose-
Effect of Moisture Content



Adding water will affect the angle of repose. Dry particles are bound together by the strength of their chemical bonds and any cementation to produce the resistant force. A little water will provide additional stability by adding surface tension to the resistant force. The same material might hold a steeper angle of repose if damp as opposed to dry.

However, flooding the material with water will destroy the cohesion and add lubrication, thus reducing the resistant force and making movement easier. That is why the Malibu coast in California is apt to cause problems during the annual rainy season; the extra water both destroys cohesion and adds weight, making the hillsides susceptible to sliding. In lab, you'll take a look at some of these factors and determine how they influence movement and ultimately mass wasting.

Exercise 1

PROCEDURE:

1. Prepare a table similar to Table 1 below.

Data Table 1

Angle of Repose Data																	
Material	Original Angle				Damp Angle				With 50 mL				With 100 mL				Total mL
Test #	#1	#2	# 3	Ave	# 1	# 2	# 3	Ave	# 1	# 2	# 3	Ave	# 1	# 2	# 3	Ave	to NO slope
Sand																	
Gravel																	
Clay																	
LabPaq Soil																	
Student Soil																	

2. First, determine the angle of repose for each of your five samples.

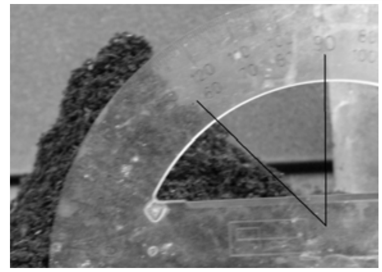
   a. You are about to make a muddy mess; have ample paper towels handy! Think about where would be best to perform this experiment to avoid damaging anything as well as major clean up. You need an indoor or outdoor area that will allow you to experiment with one pile of sample materials at a time as you progressively add water to it. Then you will need to save the material between tests and for the future, so you need a way to trap the materials and their run off. A cookie sheet or large, semi-flat cardboard box lined with plastic wrap or something similar is perfect for this chore.

   b. Make sure your samples are completely dry before you begin and measure out 200 cc of sand.

   c. Cut the tip off of your plastic funnel a little above where it intersects the funnel itself. The cut should be just big enough to allow the pea gravel sized materials to pass through it.

   d. While holding the funnel in a steady upright position about 15 cm (6 inches) above the work surface, pour the sand sample slowly through the funnel, letting it pile up into a natural cone shape. Don't move the funnel while pouring. This can be done with 100 cc of sample, but the angles are much easier to measure with 200 cc samples.

e. Measure the angle of repose by holding the protractor with the straight edge parallel to a flat horizontal plane and with the middle of the straight edge lined up with the bottom edge of the slope as shown in the photo at right. Read and record the angle where the slope intersects the protractor.



f. To improve your precision and accuracy, repeat this step at least three times for each sample in order to obtain a meaningful average slope. Keep careful records of your work and measurements for an eventual table.

g. Repeat this process with the other samples: clay, gravel, sand, and soil.

3. Gather up each sediment sample, place it into a separate cup, add 50mL of water, mix to incorporate and repeat Step 2.c – 2.e above. Record data as Damp Angle of repose.

4. Continue adding water to the samples in 50 mL intervals plus measuring and recording the angles of repose for the 5 sample materials until each no longer holds any kind of slope and flows out like a puddle.

Results and Conclusions: Include in your formal report all tables, graphs, calculations, lists, charts, etc. that you produced in this lab.

Questions:

A. Rank each material in order of increasing angle of repose when dry. Is there any relation between particle size and angle of repose? Explain.

B. Carefully study the response of each sediment sample to water. Rank the samples according to amount of water needed to completely destroy cohesion. Is there any relationship between particle size or type and increased water? Describe.

C. Did any material exhibit an unusual response to a partial saturation with water (dampening) such as early failure or an extremely high angle of repose? Explain.

D. If you were to build a house on one of these sediments, which one would you choose and why?

E. If two homes sat on slopes of identical angle and composition, how might climate affect which home is likely to be a victim of mass wasting?

F. If you were in the market for a new home and looked at several homes on hilltops featuring great views, what information would you need to gather before purchasing?

Seawater and Freshwater

Trina Johnson Riegel, M.S. Version 09.1.01

Review the safety materials and wear goggles when working with chemicals. Read the entire exercise before you begin. Take time to organize the materials you will need and set aside a safe work space in which to complete the exercise.

Experiment Summary:

Students will have the opportunity to learn about the properties of salt and fresh water and the interaction between both types in the environment. They will investigate salt and freshwater water mixing at deltas and estuaries and study how salt water encroachment endangers coastline wells. They will use ice, wood, and pumice rock to measure the densities of freshwater and saltwater and compare differences in buoyancy.

Objectives

- To measure the density of saltwater vs. freshwater,
- To test the concept of buoyancy,
- To calculate the amount of metals and salts in water,
- To investigate water mixing at deltas and estuaries, and
- To investigate salt water encroachment in coastline wells.

Materials

Materials From:	Qty	Item Description:
Student Provides	1	Ice cubes
	1	Tap water
	1	Calculator
From LabPaq	1	Beaker, 100 mL, plastic
	1	Rock - Set of 50 rocks
	1	Scale-Digital-500g
	1	Map pins, black-50-GK
	1	Map pins, white-50-GK
	1	Wood blocks, 1-inch cubes
Salt in grams-Bag	1	Salt 30g- Assembly

Discussion and Review

Density and specific gravity are numerically the same. Specific gravity is the weight of a substance in air divided by the weight of an equal volume of water. In this lab, you will find the density of minerals by first weighing the mineral sample in air, then measuring the amount of water it displaced. Since one cubic centimeter of water weighs one gram, the volume of water displaced by each mineral is the same as the weight of water displaced.

The buoyant force of water upon an object is the same as the volume or weight of water displaced. Perhaps you have noticed that some objects float on water because they are less dense than the water. Even things denser than water appear to weigh less in water than in air; you notice this when you go fishing and a fish seems to weigh more once you pull it from the water.

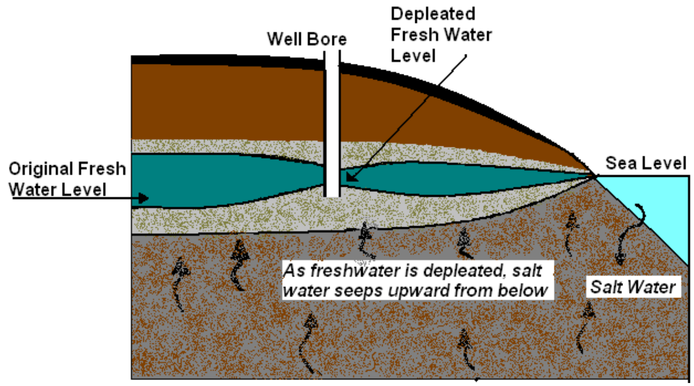
This buoyant force is due to the upward force that water or any liquid exerts upon something placed in it. Buoyant force is exactly equal to the weight of water displaced by an object as Archimedes discovered over 2,000 years ago.

What about the density of the water itself? Is there any difference in density between seawater and freshwater? Yes, there is. In the lab, you will make a saltwater solution, but true seawater is composed of a number of different dissolved solids, not just salt. The following Table 1 shows the average amount of material in grams dissolved in one kilogram of freshwater or seawater.

Data Table 1

Dissolved Solids in Fresh and Sea Water			
Fresh Water:		Sea Water:	
Mineral	Average Content	Mineral	Average Content
Sodium	0.006	Sodium	10.8
Chlorine	0.0078	Chlorine	19.4
Magnesium	0.0041	Magnesium	1.29
Sulfur	0.0037	Sulfur	0.9
Calcium	0.015	Calcium	0.42
Potassium	0.0023	Potassium	0.38
Gold	0.000000002	Gold	0.0000000049
Silver	0.0000003	Silver	0.0000000027
Phosphorous	0.00002	Phosphorous	0.000071
Iron	0.00004	Iron	0.00000006
Aluminum	0.00005	Aluminum	0.0000008
Lead	0.000001	Lead	0.000000002
Silicon	0.0065	Silicon	0.0028
Arsenic	0.000003	arsenic	0.0000017

The interplay between fresh water and seawater takes place at deltas and estuaries. In deltas, rivers deliver fresh water to the sea. The strength of the current pushes the fresh water seaward mixing the two waters. However, this is opposed by the difference in densities between the two waters. Fresh water is of lower density and tends to float on seawater which is of higher density. This creates stratification, or layering of the water.



The strength of the river current, the thickness of the plume of river water entering the sea, and the density ratio between the two waters is what determines what ultimately happens at the delta-ocean interface. This also affects where and how sediment gets deposited and what types of life can be found in the delta area.

In estuaries, the two important processes are molecular diffusion where the "salt" molecules move from areas of high concentration to areas of low concentration, and turbulent mixing which moves the waters to closer proximity with each other by way of eddies in the current. The effectiveness of these two processes are what makes an estuary either well-mixed, stratified, or somewhere in between. Estuaries that have a large river input will become stratified.

When tidal energy increases in an estuary, it can create internal waves and much more turbulent flows. Mixing along this interface can produce a brackish layer between the fresh and salt water. Well mixed estuaries can develop a horizontal flow where the tide delivers salt water and the river delivers fresh water in opposite directions and the mixing is so effective that there is no salinity gradient in the vertical direction.

Coastal areas that depend on groundwater for their drinking water can sometimes have a problem with saltwater intrusion. This occurs after a community has been using well water for quite some time. The withdrawal of freshwater causes a pressure difference between the salt and the fresh water, and salt water will fill in and close the gap as shown in the illustration. Thus, people's drinking water will become increasingly saline over time. Los Angeles suffers from this problem and has installed freshwater injection wells that pump freshwater back into the aquifer. This restores the pressure, lets the less dense freshwater remain "floating" on top of the more dense seawater, and keeps the drinking water fresh.

Exercise 1

PROCEDURE:

Determine the density of an ice cube, a piece of wood, and a pumice sample, first in fresh water, then in salty water, and finally in saturated salt water. Observe and record you results in a table similar to Table 2

Data Table 2

Density Determination			
Fresh Water	**Ice cube**	**Wood block**	**Pumice**
Mass in air (g)			
Scale: Volume – submerged			
Scale: Volume – floating			
Beaker – water level – initial			
Beaker – water level – submerged			
Beaker – water level – floating			
Percent submerged – floating			
Density: mass/volume (submerged)			
Salty Water (10g NaCl/50 ml)			
Scale: Volume – submerged			
Scale: Volume – floating			
Beaker – water level – initial			
Beaker – water level – submerged			
Beaker – water level – floating			
Percent submerged – floating			
Density: mass/volume (submerged)			
Very Salty Water (18g NaCl/50 ml)			
Scale: Volume – submerged			
Scale: Volume – floating			
Beaker – water level – initial			
	Ice cube	**Wood block**	**Pumice**
Beaker – water level – submerged			
Beaker – water level – floating			
Percent submerged – floating			
Density: mass/volume (submerged)			

Part I: Density determination in fresh water.

1. ICE CUBE:

   a. Prepare ice water by adding several ice cubes to a glass containing about 200 mL of water and stirring well until the water is very, very cold.

   b. Half-fill the 100-mL beaker to the 50-mL line with the ice water prepared above. Record this initial water level.

c. Working as quickly as possible, weigh an ice cube with the digital scale. Record its mass in the data table.

d. Place the beaker of water on the digital scale and tare the reading to zero.

e. Gently push the ice cube into the water with a map pin. The cube should be completely submerged and not touching the sides of the beaker

f. Observe and record the mass now shown on the scale. This represents the weight of the water displaced by the ice cube. The water's mass in grams is equivalent to its volume in mL and also in cc or cm^3; thus, the mass of the water displaced by the ice cube represents its volume of the specimen. Record the cm^3 mass of the submerged ice cube as its volume in the data table.

g. While the ice cube is still fully submerged try to read the volume of the water increase in the beaker. You may have to interpolate your reading since it is unlikely that the new volume will be aligned exactly with one of the beaker's volume markings. Record the net volume by subtracting the original water volume from the final volume.

h. Let the ice cube return to its natural floating state. Record the mass of the submerged portion as shown by the digital scale reading and by the volume increase of the beaker's water level with the floating ice cube.

i. Finally, estimate and record in grams the percentage of the floating ice cube that is submerged in water. You can verify your visual estimate by using what you know about the volume of water displaced, that volume equals the weight of the water displaced, and that weight equals the weight of that portion of the ice cube that is submerged. For example, if the scale reading with the ice cube fully submerged is 5 g (5 cc), and the scale reading for the floating ice cube is 4.5 g (4.5 cc), then (4.5/5)x100 = 90% submerged. You should be able to get a similar relationship from reading volume from the beaker's levels, but since these readings involve more guessing, the results will not be as accurate.

j. Compute the density of ice cube = mass (in air)/total volume (fully submerged).

k. Observe and record the mL level of the water while the ice cube is freely floating in the beaker. Allow the ice cube to fully melt and then again observe and record mL level of the water

2. WOODEN BLOCK:

a. Repeat the procedures used above, but substitute the wooden block for the ice cube.

b. For the wooden block there is an additional easy method to determine the volume. Simply measure to one decimal accuracy the cube's length, width and height in cm, and then obtain the volume by multiplying length, width and height. For example: 1.8 cm x 2.2 cm x 1.7 cm = 6.7 cm3. Compare the volume obtained this way to the other two methods and see how close they are to each other.

Note: Wood will absorb some water in this process. If you need to repeat this part of the experiment you need to wait a few hours for the wood to dry completely. Otherwise repeated trials will give different results. After completing the experiment, dry and save the wooden block for a future experiment.

3. PUMICE: Repeat the procedures used above, but substitute the pumice for the ice cube.

Note: The density of pumice may vary greatly. Like wood, pumice will absorb some water in the process of floating and being submerged. If you need to repeat this part of the experiment, you need to wait a few hours for the pumice to dry completely. Otherwise repeated trials will give different results.

Part II: Density determination in saline water.

1. Dissolve 10 g of salt into 50 mL of ice water and stir until dissolved.

2. Repeat all the steps from Part B, except this time you will use salt water rather than fresh water.

Part III: Density determination in saturated salt water.

1. Dissolve an additional 8g of salt into the saltwater used in Part II. This will make a very salty solution. Stir until dissolved. If a little salt remains at the bottom of the beaker it means that the solution is saturated. A little salt in the bottom of the beaker will not affect your results.

   Note: If the salt water from Part II has become too warm, it will melt the ice cube too quickly for good results; thus, you may need to start Part Three with fresh ice water. If so, dissolve 18 g of salt into 50 mL of ice water.

2. Repeat all the steps from Part I, except this time use saturated salt water rather than fresh water.

3. Record your findings as precisely as possible, as the density differences between the three types of water may be quite small.

Part IV: Compare the densities of fresh and salt waters.

1. Calculate the density for each of the two salt water fluids by using the following equation for objects that float:

$$\text{density}_{\text{object}}/\text{density}_{\text{fluid}} = \text{volume}_{\text{submerged part while floating}}/\text{volume}_{\text{object}}.$$

For example: Density of wood = .6
Volume of wood submerged 4.4 cc
Volume of wood = 6.7 cc
.6/x = 4.4/6.7
.6/x= .66
.66/.6 = 1.1 = density of fluid

2. Review Table 1 of dissolved solids in fresh water and sea water. Make a list of the elements whose concentrations are higher in seawater than in freshwater, and a second list of the elements whose concentrations are higher in fresh water than in sea water.

Results and Conclusions: Include in your formal report all tables, graphs, calculations, sketches, lists, charts, etc. that you produced in this lab.

Questions:

A. In the buoyancy experiment, which object floated the highest and displaced the least amount of water? Which floated the lowest and displaced the most amount of water? Could these results relate to how high the mountains stand above the plains? How about the oceans, could a buoyant-type force make the oceans stand lower? Explain your reasoning.

B. Why are icebergs a serious potential hazard to ships?

C. Why is it easier for a person to float in the Great Salt Lake or the Dead Sea rather than in a freshwater lake? Would a ship float higher on the Great Lake or the ocean?

D. If exactly the same objects are placed in fresh, salty, and very salty water, which type of water will show the most displacement? Do your findings make sense if very salty water is denser than seawater?

E. If an object floating on a lake is 25% submerged, what is the density of the object? Hint: Use the formula in Part Four, Step 1, but solve for the object.

F. Based on your observations and understanding of buoyant force, what would be the effect on sea level if all the existing icebergs in the world were to melt?

G. What was your determination for the density of each type of salt water? How close are your values to the average density of seawater which is approximately 1.036 g/cc centimeter?

H. Why are the concentrations of metals higher in freshwater than seawater?

I. Why is seawater referred to as "salty?" What's the difference between fresh and seawater?

J. Given what you know about density differences, what happens to the salinity concentration from the sea landwards at a delta? Do the waters mix, or tend to stay separate?

K. What is happening to the salinity concentration in an estuary where the salinity actually increases from the sea towards the river as it does at Spencer Gulf in Australia? HINT: Think about the amount of salt vs. the amount of water and also about the arid climate of Australia.

L. Why is saltwater encroachment an issue with coastline water wells? Do density differences keep them separate?

Plate Tectonics I

Trina Johnson Riegel, M.S. Version 09.1.01

Review the safety materials and wear goggles when working with chemicals. Read the entire exercise before you begin. Take time to organize the materials you will need and set aside a safe work space in which to complete the exercise.

Experiment Summary:

Students will have the opportunity to study the theory of plate tectonics and how the theory is supported in the earth's topographical features. They will use a map to identify types of boundaries and determine the direction of plate movement.

Objectives

- To understand and identify how the theory of plate tectonics is expressed in the earth’s topographic features.

Materials

Materials From:	Qty	Item Description:
Student Provides	1	Colored pencils and/or chalk
From LabPaq	1	Map-World-relief-map

Discussion and Review

Plate tectonics is probably the most revolutionary concept of geology and has become the central framework to view all of earth's processes. It is a relatively new theory that gained acceptance in the 1960s because it explains and ties together so many processes on and within the earth. Ample supporting evidence for this theory is found in:

- The fit of the continents, particularly South America and Africa: If you consider the continental margins, the shallow offshore regions underlain by continental crust, as part of the true continents then the fit is even closer.

- Similarity in rock types across continents: For example, you can find similar evidence of glaciers, including glacial sediments and landforms in both South America and Africa. There is also parallel evidence of past mountain-building in North America, the British Isles, and Scandinavia. However, landforms and mountains are not found on the sea floor between these continents

- Fossil evidence: The best evidence again comes from the Southern Hemisphere, where the fossil Lystrosaurus is found on southern continents. This animal did not swim well enough to cross oceans, so the continents must have been joined at one time. Even better fossil evidence is the Glossopteris plant, found on southern continents. This plant required a similar climate on all continents, and that climate is not found there today.

- Age of the Seafloor: Advances in technology made age dating of the seafloor possible, and a marked trend was found that corresponds to the mid-ocean ridges, the sites of volcanism. The age of the seafloor gets progressively younger toward the ridges. Older seafloor occurs around trenches where earthquakes and volcanism seem to indicate that the crust is sinking, or subducting, back into the interior of the earth

- Paleomagnetic studies: These studies show that the earth's magnetic field has varied throughout geologic history. Rocks with iron will crystallize with the iron crystals pointing to magnetic north. Studies of old oceanic rocks show how the earth's magnetic polarity has switched over time. Further, there are symmetrical records of past reversals in polarity on both sides of the mid-ocean ridges.

The conceptual framework of plate tectonics is that the earth's crust is broken into plates that move in relation to one another. These plates are slowly drifting across the surface of the globe, driven by convection currents within the mantle deep below. Their shifting accounts for the major geologic activity that occurs at plate borders; this activity includes the creation of oceans, continents, mountains, volcanoes, and earthquakes.

The rigid oceanic and continental crusts and the uppermost part of the mantle, jointly called the lithosphere, are broken into seven large plates and 11 or more smaller ones. Continental plates are thicker than oceanic plates because of differences in the thickness of their crust. These plates slide around on the asthenosphere, the soft but solid, putty-like mobile rock that makes up the lower part of the upper mantle. The plates are 100 to 350 kilometers thick and move at a rate of 1 to 12 centimeters per year creating continental drift. The plates may separate, slide past one another, or collide and in this process form the following:

- Rift zones, where plates are separating and moving away from each other on continents.

- Mid-ocean ridges, where plates are separating and moving away from each other in oceans.

- Transformation of fault boundaries, where plates are sliding past each other, such as in the San Andreas Fault.

- Trench, earthquake, volcano, and mountain ranges, where an oceanic plate is colliding with a continental plate. As the oceanic plate sinks, or subducts, it forms a trench. Earthquakes occur in conjunction with this movement. As a plate sinks far enough to partially melt, volcanoes form. The pressure of the two plates colliding form mountain ranges.

- Trench, earthquake, volcano, and island arcs, where two oceanic plates converge: Here, the difference is that the denser oceanic plate does the subducting, and the mountains and volcanoes that form tend to produce island arcs, such as the Aleutians and the Philippine Islands.

- High mountain ranges, earthquakes, and suture zone, where two continental plates collide: No subduction occurs here because continental plates are not dense enough to subduct. The two plates collide and there is “no way to go but up,” as tall mountains form. Earthquakes accompany this pressure, and the suture zone marks the joining line of the two continents. The best modern-day example is the Himalayan Mountains.

Today we have a good understanding of how the plates move and how such movements relate to earthquake activity. Most movement occurs along narrow zones between plates; this is where the results of plate-tectonic forces are most evident.

There are four types of plate boundaries:

- Divergent boundaries – occur along spreading centers where plates are moving away from each other and new crust is created by magma pushing up from the mantle as in the Mid-Atlantic Ridge.

- Convergent boundaries – can take several forms. They may involve two continental plates, two oceanic plates or an oceanic plate and a continental plate.

- If one plate sinks below another plate, this is called subduction. There are several good examples of subduction, where an oceanic plate dips under a continental plate. The oceanic Nazca plate dips under the S. American continental plate. Volcanism, earthquake activity and ocean trenches are often associated with these subduction zones.

- When two oceanic plates meet, one subducts below the other, and typically forms an ocean trench like the formation of the Marianas Trench where the Pacific plate converges with the Philippine plate.

- When two continental plates meet head-on the crust tends to buckle and is pushed upward or sideways. The collision of India into Asia 50 million years ago caused the Eurasian Plate to crumple up and override the Indian Plate. Over millions of years this collision pushed the Himalayas and the Tibetan Plateau up to their present heights.

- Transform boundaries – where crust is neither produced nor destroyed as the plates slide horizontally past each other. Most transform faults are found on the ocean floor. They commonly offset the active spreading ridges, producing zigzagged plate margins. However, a few occur on land such as the San Andreas Fault zone in California.

- Plate boundary zones – are broad belts in which boundaries are not well defined and the effects of plate interaction are unclear. In some regions, the boundaries are not well defined because the plate-movement deformation occurring there extends over a broad belt called a plate-boundary zone. One of these zones marks the Mediterranean-Alpine region between the Eurasian and African Plates within which several smaller fragments of plates, microplates, have been recognized. Plate-boundary zones involve at least two large plates and one or more microplates caught up between them. They tend to have complicated geological structures and earthquake patterns.

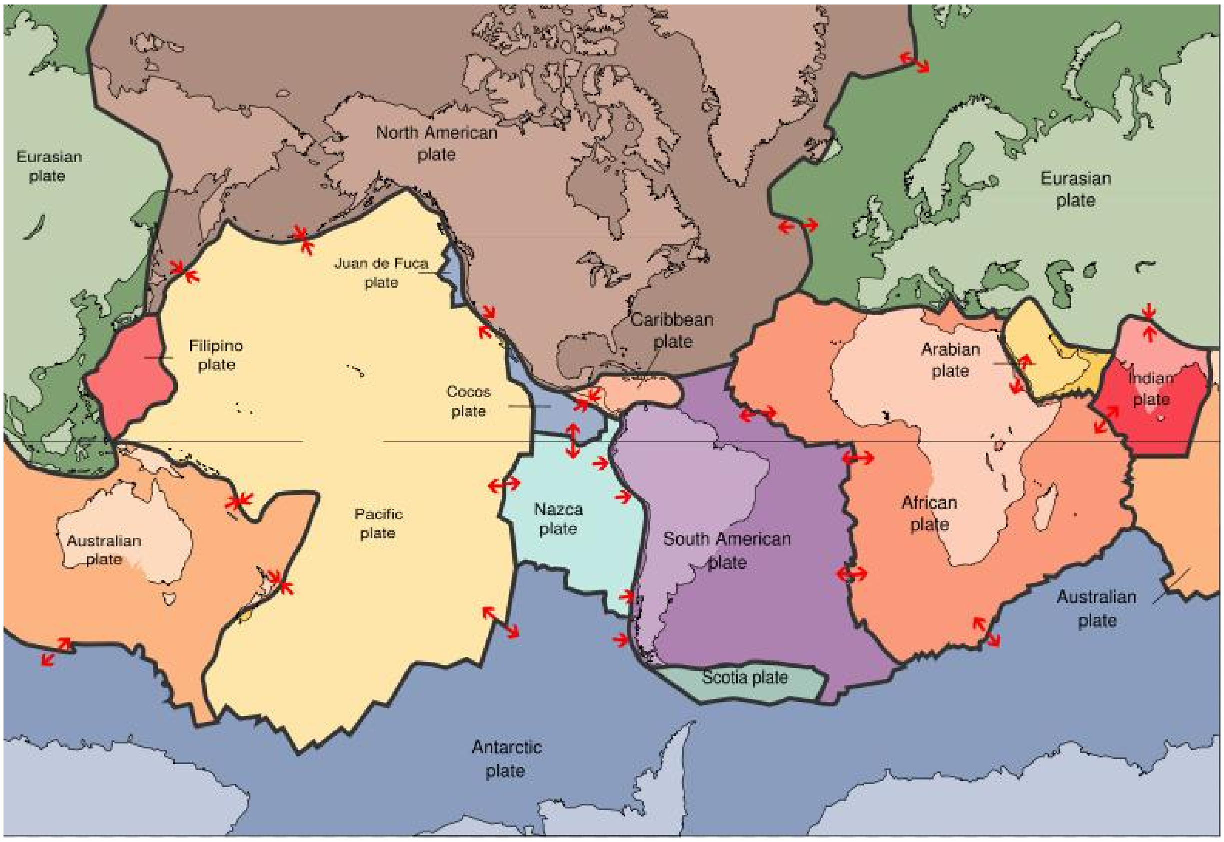
Introduction to the Digital Map: The LabPaq's map of the world shows the continents and ocean floor in relief. The map was generated by computer, using satellites and elevation data. The mid-ocean ridges show up as elevated topography running the length of each ocean. Trenches are the deepest parts of the oceans and are depicted by a darker blue. This digital map explains how:

- The mid-Atlantic ridge is a spreading and separating the Americas from the African and Eurasian plate. The Americas are heading west; Eurasia is moving east, and Africa is moving north.

- The large Pacific plate is moving in a northwesterly direction.

- The Australian-Indian plate is moving north.
- The Nazca, Cocos, and Juan de Fuca plates are moving east.
- Everything seems to be moving away from the Antarctic plate, a unique situation.

Major Tectonic Plates of the World



Useful web sites:
(USGS) http://geology.er.usgs.gov/eastern/plates.html

(NASA) http://denali.gsfc.nasa.gov/research/lowman/lowman.html

(Geology.com) http://geology.com/plate-tectonics.shtml

(U. of Oregon) http://zebu.uoregon.edu/1996/ph123/l13a.html

(Berkeley) http://www.ucmp.berkeley.edu/geology/tectonics.html

(USGS- The Dynamic earth) http://pubs.usgs.gov/gip/dynamic/

(IRIS-Incorporated Research Institutions for Seismology) – http://www.iris.edu/seismon/
This map is continuously updated to show each day's earthquakes around the world.

IRIS – General earthquake info - http://www.iris.edu/quakes/quakes.htm

IRIS maps – http://www.iris.edu/quakes/maps.htm This site maps and reflects earthquake activity for the past 24 hours, the past week, the past month, or the past year. www.geolbinghamton.edu/faculty/jones/SeismicEruptionSetup.exe This is one of the best software packages showing the relationships between plate boundaries plus earthquake and volcanic activities. It was written by Alan L. Jones of SUNY Binghamton and displays maps of many portions of the world plus shows earthquakes and volcanic eruptions in speeded-up time. You can generate your own maps interactively. Three-dimensional and cross-sectional views can also be displayed. Hypocenter files for the world from 1960 through the present of magnitude 5.0 and above and for the USA of magnitude 4.0 and above and California of magnitude 3.0 and above for the same period are provided via the U.S. Geological Survey. There is also a dataset for Cook Inlet, Alaska, provided by the Global Volcanism Program of the Smithsonian Institution. The name of each volcano is displayed while it is erupting. To update your earthquake data, click on Options/Update from Internet. This software will also be useful for the next chapter on earthquakes and volcanism.

PROCEDURE:

1. Use the previous map, your textbook, and internet research as guides to help you find and identify the world's major plates and plate boundaries on your digital world map. With different colored pencils or chalk, trace the boundaries to easily differentiate them at a glance.

2. Consider, make and highlight labels on your map for the following:

    - Types of plate boundaries,
    - The names of the plates, and
    - Arrows indicating the direction of plate movement.

3. Observe, consider, and contrast the areas encompassed by each and all plates and record the highlights of your observations. For example, how can you tell at a glance where divergent boundaries are? Convergent?

Results and Conclusions: Include in your formal report all tables, graphs, calculations, lists, charts, etc. that you produced in this lab.

A. What type of plate boundary is under the Red Sea?

B. How are oceanic ridges identified?

C. What types of plate boundaries are associated with oceanic trenches?

D. The major mountains of the world are associated with what plate boundaries?

E. Where are the locations of at least three major transform boundaries?

F. What are some similarities and differences between the Caribbean and Scotia plates?

G. Is it possible to have a tectonic plate completely surrounded by convergent boundaries? Why or why not? Does one exist?

H. How is the Juan de Fuca plate related to the volcanism of northern California, Oregon, and Washington?

I. What will happen to Africa in the future? What will it look like?

J. Imagine that you are looking at pictures sent back of a newly discovered planet. You are specifically looking for evidence of plate tectonics. What topographic features would you look for and why?

Density and the Earth's Interior

Trina Johnson Riegel, M.S. Version 09.1.01

Review the safety materials and wear goggles when working with chemicals. Read the entire exercise before you begin. Take time to organize the materials you will need and set aside a safe work space in which to complete the exercise.

Experiment Summary:

Students will have the opportunity to learn how to measure the specific gravity of several minerals. They will compare their measurements to the average density of the earth and draw conclusions about the earth's core composition.

Objectives

- To measure the specific gravity of several minerals,
- To compare those measurements to the average density of the earth, and
- To draw conclusions about the earth's composition.

Materials

Materials From:	Qty	Item Description:
From LabPaq	1 1 1 1 1	Beaker, 100 mL, plastic Cylinder, 25 mL Rock - Set of 50 rocks Scale-Digital-500g Thread for PK-2/S 1M per kit

Discussion and Review

Density is the ratio of an object's mass to its volume: D=M/V. The average density of the earth as a whole is about 5.5 grams per cubic centimeter. This number was calculated by using Newton's law of universal gravitational attraction and by knowledge about the earth's dimensions and spherical shape. The calculation is not very difficult. First, you need both the mass and the volume of the earth. Find the volume first by using the approximation of the earth as a sphere. The equation is:

$$V=4(pi)r^3/3$$

Thus to compute the earth's volume, all you need to know is the earth's radius, r, which is 6371 kilometers or 6.371×10^6 meters. Recall that pi, π, is equal to 3.14 and the volume of a sphere is (4/3) * (πr^3). Now you can substitute the volume equation into the density equation like this:

$$D=M/V=M/(4\pi r^3/3)=3M/(4\pi r^3)$$

You next need to find the mass M. Since there is no scale large enough to weigh the planet, you must measure it indirectly. Do this by using the gravitational constant which is:

$$G=6.673 \times 10^{(-11)}\ m^3/kg\ s^2.$$

The earth's gravity, g, can be found by the period of a pendulum which represents the relationship between the time it takes a pendulum to complete one swing and the pendulum's length. That determination gives us g at 9.8 m/s^2. We already know the radius r. Thus, the equation for the mass is:

$$M=g\ r^2/G$$

Returning to the first equation armed with the knowledge of M and V, we can now obtain our own answer for the average density of the earth! The mass of earth = 5.9742×10^{24} kilograms, and the average density of earth = 5.515 g/cm^3 or 5,515 kg/m^3. If you've performed your calculations correctly, your average density of the earth should be very close to the published value of 5,515 kg/m^3

Measurements of the continental crust, with its primarily diorite and granite composition, average about 2.7 grams per cubic centimeter. The basalt composition of the oceanic crust is denser, measuring 3.0 grams per cubic centimeter. Both types of crust are less dense than the earth as a whole, so the material of the mantle and core must be substantially denser in order to compensate for the overall value.

No one has ever directly observed rocks of the lower mantle and core to see their composition, but some possibilities include: peridotite, iron, magnesium, or nickel. Since it is impossible to observe the rocks of the mantle and core firsthand, indirect methods must be used to determine their composition. Measuring and comparing the density of known minerals to obtain a rough idea about the density of an unknown mineral is an indirect method often used.

Density is the ratio of mass to unit volume. Geology uses specific gravity to measure density; this represents the amount of water displaced by a mineral compared to the density of water. Density and specific gravity are numerically the same; however, they are not exactly the same since density is stated in its units of measurement such as cc^3, cm^3, or m^3, but there are no units of measurement stated with specific gravity. In other words, the density of a sample may be 5.5 grams/cm^3 (per cubic centimeter), but its specific gravity is stated as simply 5.5. The reason they are numerically equal but density has units and specific gravity does not is that the units are “divided out” in computing specific gravity. Freshwater’s density is one gram/cm^3. This makes dividing very simple. When you measure the amount of freshwater displaced, you are in effect making this division and stating the specific gravity without units.

Each mineral has its own specific gravity. So, if the mass is increased by measuring a bigger sample, the volume is also increased and the ratio remains the same. Likewise, if the sample is smaller, then the unit volume will decrease, leaving the overall ratio the same. Determining the density of minerals allows us to form hypotheses about the earth’s interior makeup. If we can calculate the average density of the earth as a whole, and we know the average density of rocks at the surface, then we can make an educated guess about some possibilities for the composition of the interior of the earth. That is exactly what you will do in this lab.

Exercise 1

PROCEDURE:

1. From your LabPaq kit, take out all of the mineral samples. Make sure they are identified correctly; refer to your mineral lab or your instructor if you are unsure.

2. Prepare a table similar to Table 1 for recording data.

Data Table 1

Specific Gravity Data								
Mineral	Gram Weight	Start mL	End mL	mL Water Displaced	Density	Specific Gravity	Published Sp Gravity	% Diff
Biotitie								
Calcite								
Corundum								
Etc.								

3. Weigh each sample on the digital scale and record the weight in grams.

   Determine the volume of each mineral in your LabPaq: Since density = m/V, we must first determine each mineral's volume. There are several different possible methods to determine the volume of a rock or mineral, but we will use Archimedes Principle:

   a. Fill your 100-mL beaker with exactly 50 mL of water.

   b. Place the beaker of water on the scale and tare the balance to read zero.

   c. Tie a piece of thread around the mineral specimen.

   d. Gently lower the specimen completely into the water without allowing it to touch the bottom or sides of the beaker.

   e. Observe and record the mass indicated by the scale. This mass represents the mass of the water displaced by the specimen. Recall that the water's mass in grams is equivalent to its volume in mL or cc. Therefore the mass of the water displaced by the specimen represents the volume of the rock.

   Note: Another method of measuring a rock's volume is through water displacement: Water is added to a certain mark of a graduated cylinder, the rock is placed into cylinder, and the increase in the water mark represents the volume of the rock. Since rocks and minerals are usually too large to fit into a graduated cylinder, this method is generally not applicable for their density determination.

A third method is to immerse the rock into a beaker filled to the very top with water, while the beaker sits in a container. The rock is placed into the beaker and the overflow of water is transferred from the container into a graduated cylinder for measurement since the volume of water overflowed into the container theoretically represents the volume of the rock. However, it is almost impossible to ensure all the overflow water goes into the cylinder or to get a genuinely flat water surface at the top of the beaker due to surface tension, etc.; thus, major inaccuracies result. This method is too inaccurate for our purpose.

4. Determine the density by dividing the weight of the mineral in grams, by the volume displaced in mL. The result will be grams per milliliter or grams per cm^3.

5. Next determine the specific gravity by dividing the density of the rock by the density of water which is 1 g/cm3. Remember, the only difference between density and specific gravity is the absence of units for specific gravity.

6. Research the published specific gravity of the minerals you just measured. Compute and record how close your calculated specific gravity came to the stated specific gravity by dividing your number by the published number and then multiplying by 100. Compute and record the percentage of any difference by subtracting your percentage of agreement from 100%.

Results and Conclusions: Include in your formal lab report all tables, graphs, calculations, lists, charts, etc. that you produced in this lab.

Questions:

A. Given that the average density of the continental crust is 2.7 grams per cubic centimeter and the oceanic crust is 3.0 grams per cubic centimeter, which minerals from your measurements are likely to be found: On the continents? In the oceans?

B. Why is it difficult to obtain an exact measurement of the continental and oceanic crust? Why do we have to rely on an average when we are able to obtain precise measurements for the density of minerals?

C. From what you've learned in this lab, calculate the average density of the earth, showing all of your work.

D. Given that the density of the mantle and core must be higher than 5 grams per cubic centimeter, which minerals could you eliminate as not likely to be components of the mantle and core? Which ones are likely candidates?

Now, consider this scenario: what if the mantle was still composed of minerals of lower density, but the core made up for it by containing minerals of very high density? In other words, what you considered in question “D” was if the mantle and core were all the same material. Now, consider if they are two separate compositions. Could some of the minerals that you eliminated in question “D” now show up in the mantle only, but not the core?

Research the specific gravity of pure nickel and iron. Given the specific gravity of iron and nickel, could they be components of the core and mantle, or perhaps the core only? What other minerals and/or elements are possible? What about lead and gold?

Stress and Deformation

Trina Johnson Riegel, M.S. Version 09.1.01

Review the safety materials and wear goggles when working with chemicals. Read the entire exercise before you begin. Take time to organize the materials you will need and set aside a safe work space in which to complete the exercise.

Experiment Summary:

Students will have the opportunity to learn about different kinds of stress deformation and elasticity. They will test eight different materials for responses to different forces. They will plot stress/strain modulus for various materials and then repeat the experiment to investigate how temperature affects stress responses.

Objectives

- To observe and plot stress/strain modulus for different types of materials,
- To observe the stress deformation that occurs with different materials, and
- To observe the effects of temperature on stress responses.

Materials

Materials From:	Qty	Item Description:
Student Provides	1	Colored pencils
	1	Scissors
From LabPaq	1	Aluminum Foil sheet - 3"x11"
	1	Foam block - 3 Pieces - 2"x1"x1"
	1	Play-doh, 1-oz.
	2	Rock - Mica Muscovite
	1	Rock - Set of 50 rocks
	2	Sponges, 2-in. square
	3	Tootsie Rolls®
	2	Wood blocks, 1-inch cubes

Discussion and Review

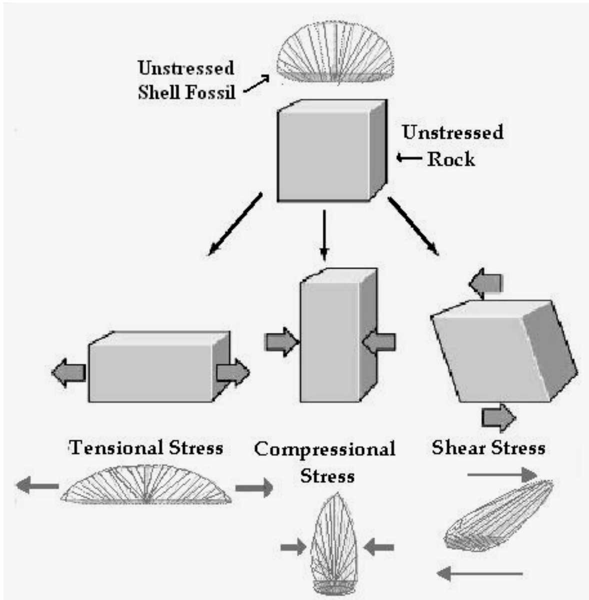
Stress in science is defined as an applied force that strains or deforms an object. Stress can be applied to any material, but for geology it typically refers to a rock unit. Stress can be tensional, compressional, or shear:

- Tensional stress is the force applied in trying to pull an object apart.
- Compressional stress is the force of squeezing an object.
- Shear stress is a parallel force moving in opposite directions against an object.

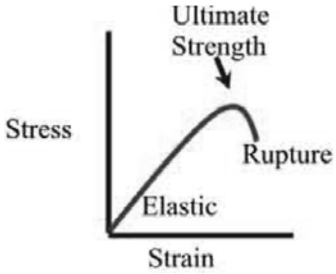
Every material, including rocks, can withstand a certain amount of force and still return to its original shape. Some rocks can withstand more stress than others. Elastic limit is the amount of deformation a rock or any material can withstand without being permanently deformed. The illustration that follows reflects the effects of the three types of stress. It shows how stress can distort the original shape of a shell fossil and of a rock.

The elastic limit can be determined experimentally. For example, consider a rubber band: you can stretch it and it will move back to its original position once the stress is removed. However, if you stretch it too far, it will surpass its elastic limit and break permanently. Rocks, surprisingly, also behave elastically. Rocks deform as seismic waves pass through them, but once the wave passes, they return to their original shape, provided that the seismic wave was not large enough to surpass the rocks' elastic limit. The amount of a rock's elastic response can be measured, but this requires very sensitive instruments as the elasticity of rocks is extremely small. Thus, this lab will concentrate on qualitative rather than quantitative differences in evaluating materials' responsiveness to stress.

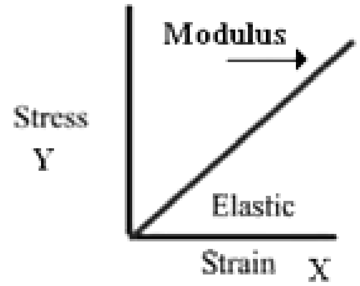
Strain is the response to stress as evidenced by deformation or change in the shape of a material and possibly by a change in its volume as well. If the change is temporary, it is called an elastic response. If the strain exceeds the elastic limit of the material, then the change is permanent. The material may exhibit a ductile response, similar to bending, or a brittle response, similar to breaking or tearing.



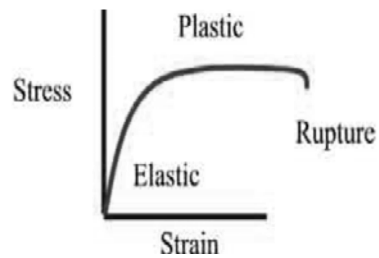
The strain depends on the material undergoing stress, and it is also affected by time and temperature. For example, greater proximity to heat tends to favor a ductile response, while the relatively cooler temperatures at the earth's surface favor a brittle response. Dough, for example, is somewhat brittle and will not roll well when you first take it out of the refrigerator. However, let it warm up a little and it becomes very ductile and rolls out easily.



Stress applied over a long period of time can create a ductile response, while a short sharp stress can lead to breaking. The following graph illustrates the relationship of different rocks to stress vs. strain. Stress is reflected along the Y axis and is normally measured in Force units, such as lbs/in^2 (pounds per square inch) or similar. Strain is reflected along the X axis and is the percent of elongation, shortening, or changes in volume that the rock underwent.

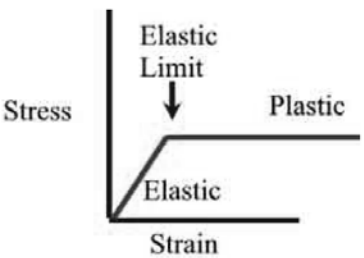


The slope of the line is known as the modulus and reflects the direction of stress/strain. The first graph at right is an example of elastic behavior and shows a linear plot of stress vs. strain. When stress is applied, strain is instantaneous. And instantaneous recovery results upon removal of stress. Some rocks at shallow depths and for short periods of time approach ideal elastic behavior during small magnitudes of deformation. Seismic waves are an example of elastic behavior.



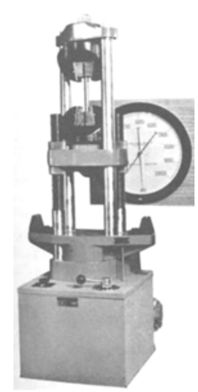
The graph to the right represents a generalized stress-strain curve for rocks. It shows how rocks in general have a very small range of elasticity. Beyond that range, the rocks will rupture or break

This third graph of stress vs. strain at left is an example of brittle rocks which exhibit some elastic behavior before they rupture.



Finally, the graph at left depicts an example of ductile rock behavior. Here, the rock exhibits elastic and then very plastic behavior before it ruptures.

When stress-strain experiments are conducted in research laboratories, sophisticated machines are used. The stress-strain machine at right can exert thousands of pounds of tensional or compressional force on rock samples, while measuring deformation.



Exercise 1

PROCEDURE:

Part I: For each of the eight materials tested, you will develop your own stress graphs by plotting force against resultant change to determine the stress/strain modulus for each material. Since you have no sophisticated instruments to measure force, you will use qualitative measurements to estimate the force you apply to objects.

1. Prepare a data table similar to Tale 1 to record your test results

Data Table: 1

Material Change in Response to Stress								
Force/Material	Styrofoam	Muscovite	Wet Sponge	Alum Foil	Wood Block	Play Doh	Granite	Tootsie Roll®
Hypothesis								
Small Force								
Moderate Force								
Strong Force								
Notes:								

** Moisten and wring out the sponges for testing

2. Cut the aluminum foil strip in half to yield two pieces about 2x7" long.

3. Record a hypothesis about how you think each material will respond to the different types of stress.

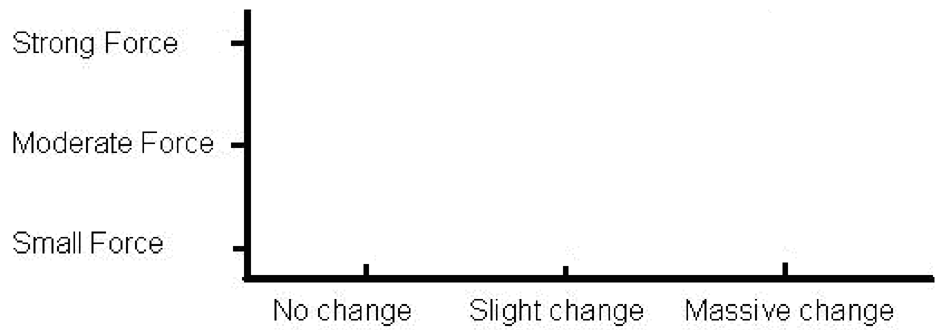
4. Working with one material at a time, perform the following tests. First apply a small, then a moderate, and finally a strong force. Closely observe each material as each level of stress is applied. Do you see the material deform in any way or exhibit any stress markings? Does it spring back to its original form when the stress is relieved? Does the change become permanent? If so, does that happen after applying a slight, moderate, or strong force? Record your findings and note all your observations in the data table.

   a. Tensional Stress: Firmly grasp the item with both hands, hold it parallel to the floor, then slowly but steadily pull your hands horizontally apart. First apply a small, then a moderate, and finally a strong force. Record your observations for each level of tensional stress applied.

   b. Compressional Stress: Compression is similar to packing a snowball. Firmly grasp the item with both hands and then slowly but steadily push your hands together as though squeezing the material. First apply a small, then a moderate, and finally a strong force. Record your observations for each level of compressional stress applied.

c. Shear Stress: Firmly grasp the item with both hands and hold it parallel to the floor. Horizontally move one hand towards you and the other hand away from you as though trying to tear the object apart in opposite directions. First apply a small, then a moderate, and finally a strong force. Record your observations for each level of shear stress applied.

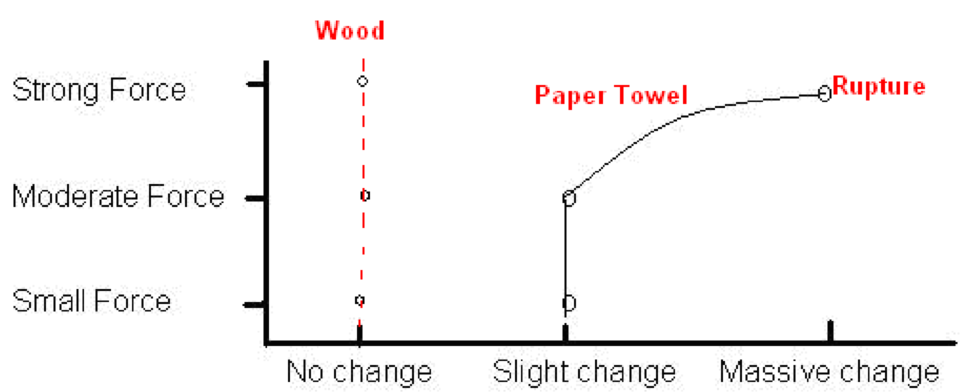
5. Prepare <u>three</u> separate graphs similar to the one below. Label the graphs a) Tensional Stress, b) Compressional Stress, and c) Shear Stress. Use different colored pencils or unique lines for each material, then plot and draw modulus lines for each material's elastic limits per type of stress.



For example, assume your test of a wooden block and paper towel reflected the following results for tensional stress:

Material Change in Response to Stress		
Force/Material	**Wooden Block**	**Paper Towel**
Small	None	Slight
Moderate	None	Slight ripping
Strong	None	Rupture

After plotting and connecting the data points on a tensional stress graph, it would resemble the following graph.



Note: Obviously, if we could apply a varying mechanical force, we would get very different results. For example, the above wood block would show no change for a small force, a slight change for a moderate force, a massive change in response to a strong force, and it would finally rupture. This would result in a diagonal line.

A lot of stress with hardly any strain results is a high modulus and indicates a strong material. You may not be able to find the material's elastic limit. However, a material that deforms permanently with hardly any stress applied has a low modulus and will surpass its elastic limit easily.

Each material will have a modulus, which may be a straight line reflecting no change in shape no matter how much stress you apply; a curved line representing no permanent change until elastic limit is reached, then a bending of the material; or a sloped line that abruptly ends for materials that temporarily deform to their elastic limit and then break or tear. Bending, either elastically or permanently, is a sloped line that may have a curve.

Part II: Test the effects of speed of stress and temperature on stress reactions

1. Use your hands and fingers to well knead and then reform the compressed Tootsie Roll® to its original shape. Let it rest for 5 minutes to dissipate any heat absorbed from your hands and to return to room temperature. Apply very slow but steady tensional pressure. Record your observations of the response.

2. Again, use your hands and fingers to well knead and reform the Tootsie Roll® to its original shape and let it return to room temperature. This time apply very rapid tensional pressure by quickly and forcefully snapping your hands apart. Record your observations of the response.

3. Well knead and reform the Tootsie Roll® to its original shape and then warm it by briskly rolling it between your hands for 30 seconds. Repeat the slow and rapid stress tests in Part II, Steps 1 and 2 and record your observations of the warm Tootsie Roll's® responses.

4. Again well knead and reform the Tootsie Roll® to its original shape and place it in a freezer for five minutes. Repeat the slow and rapid stress tests in Part II, Steps 1 and 2 and record your observations of the cold Tootsie Roll's® responses.

Results and Conclusions: Include in your formal report all tables, graphs, calculations, sketches, lists, charts, etc. that you produced in this lab.

Questions:

A. Were your hypotheses about the materials' reactions to stress correct? What, if any, surprises did you encounter?

B. How did the stress/strain modulus differ for various materials in the tensional vs. compressional stress tests?

C. Which is the strongest material you observed? Which is the weakest? Which materials surpassed their elastic limit? How could you tell?

D. Speculate on how the materials would respond if you steadily applied the stress over a longer amount of time?

E. Which materials showed brittle deformation and which showed ductile deformation?

F. Which materials from your observations would be the best to build with? Would you select a material with a high or a low modulus?

G. If you were living in an earthquake prone region, would you want a material that deformed in a brittle or a ductile fashion?

H. Did the room temperature Tootsie Roll® respond differently to stress applied very slowly? What about to stress applied very rapidly?

I. Did the stress response of the Tootsie Roll® change under conditions of increased temperature? What about under conditions of decreased temperature? If so, how?

J. How do the Tootsie Roll® responses to stress as well as the responses of other materials relate to geologic deformation?

Earthquakes and Volcanoes

Trina Johnson Riegel, M.S. Version 09.2.01

Review the safety materials and wear goggles when working with chemicals. Read the entire exercise before you begin. Take time to organize the materials you will need and set aside a safe work space in which to complete the exercise.

Experiment Summary

Students will have the opportunity to study how plate boundaries are associated with earthquakes and volcanoes. They will learn about the different kinds of waves associated with earthquakes and how they disrupt Earth's surface. Students will test the relationship of earthquake wave damage to different types of sediment by simulating earthquakes on different soils. They will also analyze seismic data and use triangulation to find the epicenter of an earthquake.

Objectives

The student will have the opportunity to:

- Gain further understanding of the theory of plate tectonics.
- Test if earthquake and volcano locations coincide with plate boundaries.
- Test the relationship with earthquake wave damage to sediment types.

Time Allocation: Allow 3 hours for this experiment.

IMPORTANT: Part I of this lab must be started at least two weeks in advance of the lab report due-date!

Materials

Materials	Label or Box/Bag	Qty	Item Description
Student provides		1 1 1 4 1	Tape Scissors Large piece of cardboard or similar Coins of different sizes Soil sample from your area, 200 cc
LabPaq provides		1 1 1 1 1 1 1	Compass, drawing Cup, Plastic, 9 oz Tall Map-World-relief-map Ruler, Metric Scale-Digital-500g Map pins, black 50 GK Map pins, white 50 GK
	Clay, powdered in cc-Bag	1	Clay, powdered 235cc-in a bag
	Gravel, Pea in cc-Bag	1	Gravel, Pea - 235 cc in a bag
	Sand in cc-Bag	1	Sand 235cc - in a bag

Discussion and Review

Plate boundaries were first identified from the locations of earthquake and volcano activity. As a plate subducts, it eventually reaches a depth where partial melting occurs. Magma is then sent toward the surface and may create a volcanic eruption. Thus, the locations of volcanoes tend to be in the proximity of subduction zones. The "Ring of Fire" around the Pacific Ocean is one notable example. However, the Hawaiian Islands are an exception; they are not near any plate boundary but instead erupt due to a stationary plume of magma.

Figure 1 – Movement of magma in asthenosphere. Courtesy of Wikimedia Commons.

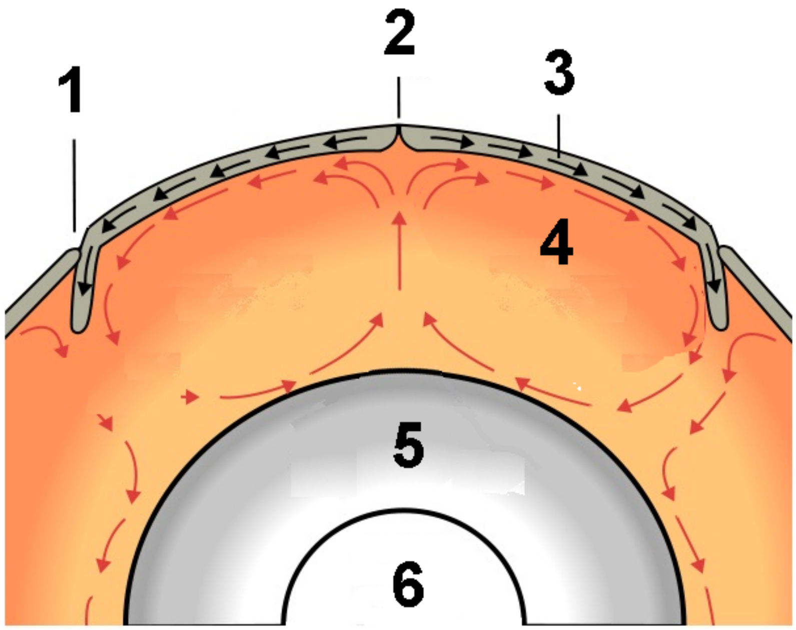


Table 1 – Items for asthenosphere

Item	Description
1	Trench
2	Ridge
3	Lithosphere
4	Asthenosphere
5	Outer core
6	Inner core

Earthquakes also occur near subduction plate boundaries where rigid plates subduct beneath more buoyant plates and create movement within the earth. The path of descending plates can be traced by the focal depth of resultant earthquakes in the **Benioff Zone**, a seismically active zone prone to producing earthquakes beneath the subducting plate's boundary.

Transform boundaries are sites of frequent earthquake activity, as anyone living along the San Andreas Fault in California can affirm. Volcanoes do not often occur in association with transform boundaries.

Earthquakes also occur at divergent boundaries, but these are usually of lesser magnitude than the earthquakes caused by transform boundaries. However, volcanoes do often occur at divergent boundaries since the plates separate and magma rises to fill the gap. This type of volcanic eruption is commonly found on the seafloor.

Figure 2 – Types of Plate Boundaries. Courtesy of USGS.

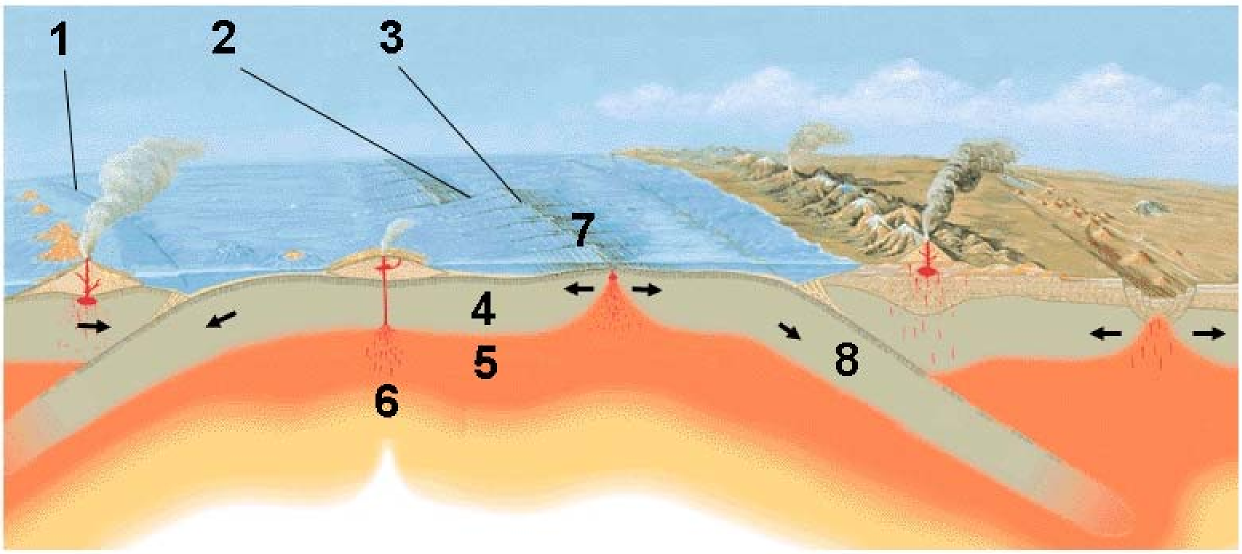


Table 2 – Items for plate boundaries

Item	Description
1	Convergent plate boundary
2	Transform plate boundary
3	Divergent plate boundary
4	Lithosphere

Item	Description
5	Asthenosphere
6	Hot spot
7	Oceanic spreading ridge
8	Subducting plate

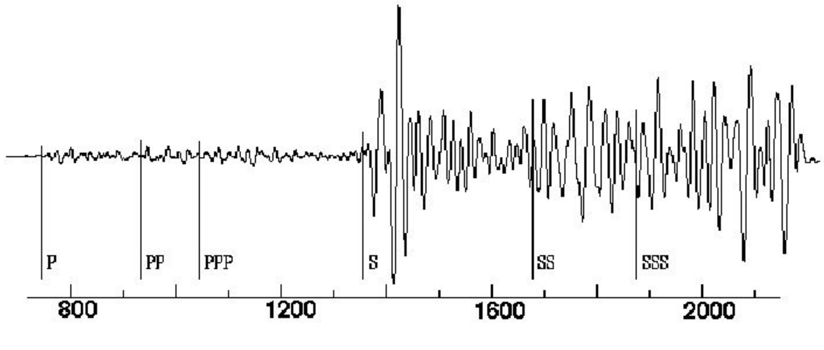
The sudden slippage of huge rock masses sets up shock waves that travel through the earth. The point within the earth where the actual movement takes place is called the focus, and the point on the surface directly above the focus is called the epicenter.

Figure 1 is a seismogram of the San Francisco earthquake of 1906 recorded at a seismic station in Goettingen, Germany, some 9100 km away. As one can see on the labeled seismogram, P-waves (the direct, compressional wave) travel fastest and marks the first arrival of waves from the earthquake. S marks the arrival of the slower S or shear wave. P-waves generally do not cause as much shaking as some of the larger, later-arriving shear waves. The lines PP, PPP, SS and SSS indicate the arrivals of waves which have once or twice bounced off the surface of the earth in traveling to the seismograph.

From S-waves we can easily calculate the distance – but not direction – from the epicenter to the recording seismic station. Thus at least three earthquake recording stations are required to find the location of the earthquake epicenter.

Exercise 1: Earthquakes and Volcanoes

Figure 3 – Seismogram for the 1906 San Francisco earthquake as recorded in Goettingen, Germany



Earthquakes cause damage to structures because of the energy they release. This energy travels through the earth and along the surface in the form of waves. Surface waves do the most structural damage. The type of surface materials partially impacts the severity of the damage. Unconsolidated sediment is the worst material; each particle vibrates at its own frequency and intensifies the shaking.

It is ironic that most of the damage caused by the 1987 Loma Prieta earthquake was in the Marina District where expensive homes were built on unconsolidated fill, including rubble left from the 1906 San Francisco earthquake!

Like any mechanical system, the earth possesses a natural vibration that can be excited by external or internal forces. Consequently, after large earthquakes, the earth will oscillate (or ring) like a bell for a relatively long period of time. These self-excited long period vibrations are called free oscillations of the earth. Free oscillations have relatively long periods of vibrations, from hours to days.

The reason free oscillations are of interest to us is because the depth of stress penetrations is proportional to the periods of oscillations. Generally, long period oscillations (> 50 min) cause stresses to penetrate the whole earth. In other words, long period waves are able to penetrate the deep interior of the earth. Waves with a period of a few minutes will pass the upper mantle only. Even shorter period waves are only able to penetrate the top 200 km or less.

To fully understand all aspects of the destructive power of earthquakes, we should also look at the relationship of the natural frequencies of buildings or other man-made structures to earthquake-caused frequency of the ground motion. Buildings have their own natural frequency, where frequency is the inverse of period, the time it takes for a building to make one complete vibration. A short building with a high natural frequency has a short natural period. Conversely, a very tall building with a low frequency has a long period. For example, it takes the Empire State Building a comparatively long time to sway back and forth during a strong gust of wind.

When the frequency of the ground motion is close to the building's natural frequency, we say that the building and the ground motion are in **resonance** with one another. Resonance tends to increase or amplify the building's response. Because of this, buildings suffer the greatest damage from ground motion at a frequency close or equal to their own natural frequency.

The Mexico City earthquake of 1985 provides an excellent illustration of this. A majority of the many buildings which collapsed during this earthquake were around 20 stories tall, i.e., they had a natural period of around 2.0 seconds. These 20 story buildings were in resonance with the frequency of the earthquake. Other buildings, of different heights and with different vibration characteristics, were often found undamaged even though they were located right next to the damaged 20 story buildings.

There are excellent earthquake simulations available online. They allow you to select various simulated conditions including: ground conditions, stable solid ground, proximity to a fault zone, loose gravel, coastal ground, building construction types and prevention features, and the magnitude of earthquake. After performing the earthquake simulation, it shows how much damage will be done to a multistory building based upon the conditions selected.

- The Learning Channel provides an excellent simulation site: http://tlc.discovery.com/convergence/quakes/interactives/makeaquake.html.

- IRIS provides maps of current world-wide earthquake activities. This site maps and reflects earthquake activity for the past 24 hours, the past week, the past month, or the past year.
  http://www.iris.edu/quakes/maps.htm

- The USGS National earthquake Information Center.
  http://earthquake.usgs.gov/regional/neic

- Global Volcanism Programs by the Smithsonian and USGS. Click on the World Map for visual display.
  http://www.volcano.si.edu/reports/usgs and http://volcanoes.usgs.gov/

- Alan L. Jones of SUNY Binghamton and displays maps of many areas of the world showing earthquakes and volcanic eruptions in speeded-up time.
  http://pods.binghamton.edu/~ajones/SeismicEruptionSetup.exe

  If available, this is a great software package showing the relationships between plate boundaries plus earthquake and volcanic activities. You can generate your own maps interactively. Three-dimensional and cross-sectional views can also be displayed. Hypocenter files from 1960 through the present are provided by the U.S.G.S. for the world of magnitude 5.0 and above; for the USA of magnitude 4.0 and above; and for California of magnitude 3.0 and above. There is also a dataset for Cook Inlet, Alaska, provided by the Global Volcanism Program of the Smithsonian Institution. The name of each volcano is displayed while it is erupting and you can update its earthquake data.

Part 1:

Test the theory that plate boundaries are the most likely sites of earthquakes and volcanoes by tracking worldwide activity for a period of two weeks.

1. Mount your world map with tape onto a large piece of cardboard or a similar flat surface such as plywood, corkboard, or perhaps a wall.

   NOTE: If you choose to mount the map on a wall, be aware that you could damage the wall as you will be inserting pins into the map to record earthquake and volcano activity.

2. Perform an Internet search to find and bookmark the above websites and additional ones that provide good worldwide earthquake and volcano updates. Where possible, sign up to be alerted to tectonic activity on a daily basis. Remember, you need to track activity worldwide – not just in the U.S. Also note that websites often produce maps without plate boundaries marked, so you may need to verify the exact activity locations for accurate placement of your earthquake and volcano activity pins.

3. Designate one color of map pins for earthquakes and the other for volcanoes.

4. Every day for two weeks, track worldwide volcanic eruptions and earthquakes over a magnitude of 4.0. Note each day's events by placing appropriate colored pins into the exact event locations on the world map.

5. The activity needs to be tracked for at least two weeks, but if you can track longer, you will have more information for greater accuracy in your conclusions.

Part 2:

Test the relationships between earthquake wave damage and sediment types.

1. Prepare a data table similar to Table 1 below to record your observations.

Data Table 1 – Earthquake Damage Data

	Coin Size		Sand		Gravel		Clay		Soil	
Coin #	Wt.	Dia.	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
#1										
#2										
#3										
#4										
Est. Damage										

2. Use scissors to cut down a plastic cup's rim so that a 200 cc sample of compacted sediment will completely fit inside the cup and very little rim rises above the sample.

3. You will simulate earthquake damage created by different dry sediment materials:

   a. Fill a plastic cup with a 200 cc sand sample and moderately compact it with your fingers. Recall that 100 mL is the equivalent of 100 cc.

   b. Measure and record the weight and diameter for each of the four coins of different sizes. Vertically place the coins halfway into the top of the sediment so that all the coins are firmly standing on their edges and protruding halfway out of the material. Leave as much space as possible between the coins when you randomly place them inside the cup.

Figure 4 – Random coin placement

   c. Hold the cup in one hand, then for about 5 seconds rapidly shake the cup from left to right as you might expect a violent earthquake would.

   d. Record the "surface damage" whether and to what degree each coin fell over, or was dislodged in your simulated earthquake. This can be simply done with appropriately angled straight lines such as: /, \, I, or __.

   e. Empty the sample back into its storage bag so that it and the cup can be reused.

   f. Repeat the above procedure for the gravel, clay, and a soil sample from your area. Try to use the same magnitude of violence in shaking each sample. **Note:** If your clay sample has dried into a solid block, you must first pulverize it back into fine particles with a hammer, rolling pin, blender, or similar tool.

   g. After all dry samples are tested, rank the materials by severity of your estimated total damages from 1 to 4, with 1 being the least damage and 4 being the most.

4. Working with only one sample at a time, mix 200 cc of the sample with some water, just enough to saturate but not flood it.

   a. Again fill the altered cup with the sample, but this time pack the sediment down as much as possible.

   b. Vertically push your coins halfway into the sediment, and again produce a violent earthquake by rapidly shaking the cup from side to side, using approximately the same magnitude as before for shaking each sample.

   c. Record the damage caused by wet, "consolidated" sediment.

   d. You may discard the sample as this is the last time is will be used.

   e. Repeat the above steps for the sand, gravel, clay, and your local soil sample.

   f. After all wet samples are tested, rank the materials by severity of your estimated total damages from A to D, with A being the least damage and D being the worst.

Part III: Find the magnitude and epicenter of an earthquake from five seismograms of the same earthquake as recorded at five different locations.

Note: The seismograms, map, and graph later referenced are shown at the very end of this lab. Data points on the first seismogram recorded at Pinyon Flats have been marked for you as an example of what is expected in the instructions that follow. This data is already inserted into Table 2.

1. Set up a table similar to Table 2 below for entering your data.

Data Table 2 - Simulated earthquake data

Earthquake Magnitude Data				
Location	T_S - T_P seconds	Amplitude mm	Distance	Magnitude
Pinyon Flats, CA	59	10	472 km	5.7
Pasadena, CA				
Salt Lake City				
Tucson, AZ				
Yuma, AZ				
			Average =	

2. For each of the remaining four seismograms, determine the time difference in seconds between the arrival time of the P-waves and the S-waves (T_S - T_P). Do this by following the sub-steps below:

a. Draw a vertical pencil line from the start of the P-wave to the “seconds” scale.

b. Draw another vertical pencil line from the start of the S-waves to the “seconds” scale.

c. Interpolate the time difference and enter it in the data table.

3. On the same seismogram, draw a horizontal pencil line from the <u>amplitude</u> scale to its left to the highest S-wave amplitude. Enter the mm value in the data table.

4. For each seismogram convert the T_S - T_P values to <u>distances</u> by using the following equation and insert same into your data table. **Note:** The Pinyon Flat (T_S - T_P) value of 59 sec gives a distance of 59 x 8 = 472 km.

$$\text{Distance in km} = (T_S - T_P) \times 8$$

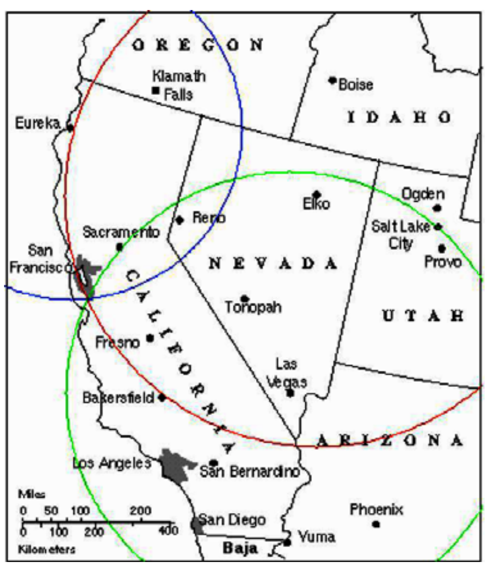
5. Use the Magnitude Interpretation Graph (Figure 8) to determine the actual <u>magnitude</u> of the earthquake as follows:

a. Working with one seismograph at a time, mark each location’s T_S - T_P value and its amplitude onto the Magnitude Interpretation Graph.

b. Draw a straight line between the points and read each site’s magnitude from the middle column. The example shown reflects T_S - T_P at 24 seconds, an amplitude of 23 mm, and a magnitude of 4.9 on the Richter Scale.

c. Compute the average magnitude of the five seismic station locations. This average represents the actual magnitude of the earthquake.

Figure 5 – Map showing earthquake intensity readings with a triangulated epicenter



6. To triangulate the epicenter of the earthquake, first ensure the pencil in your drawing compass is set at the same length as its pivot point when the two arms are flush next to each other. Then:

   a. On the map of the Western US (Figure 9), insert the compass point at the zero mark on the map scale and extend the pencil to the other end of the scale to set a radius.

   b. Without changing the set radius of the drawing compass, place its needle point at the first seismic station location and draw a circle around that point.

   c. Repeat Steps 6.a and 6.b for all stations. The point where all of the five circles intersect is the location of the epicenter. Figure 2 shows an epicenter triangulation for an earthquake located just south of San Francisco.

Results and Conclusions: Include in your formal report all tables, graphs, calculations, lists, charts, etc. that you produced in this lab.

QUESTIONS:

A. What percentage of earthquakes and volcanoes occurred on or near plate boundaries?

B. What were the locations of the volcanoes that didn't erupt near a plate boundary? Can they be tied to hot spot activity?

C. Choose one earthquake that occurred away from a plate boundary and conduct some research into it. What are some possible reasons it occurred? Is it near an old fault? Was it a result of human activity? Could it be due to a sort of "rebounding" of the land?

D. What percentage of earthquakes and volcanoes occurred over the "Ring of Fire?" Is this nickname well deserved, based on your research?

E. Based on your research alone, how would you draw the plate boundaries if you had to start from scratch? Would they be the same or different than they appear now?

F. Regarding your coin and sediment experiment: if you lived in an earthquake-prone area, which material would you prefer to build a house on, and why?

G. Did you find a correlation between "damage" and consolidated (wet) vs. unconsolidated (dry) sediment?

H. Did any particular coin(s) tend to withstand damage better than the others? If so, what might be some reasons why?

I. How resistant to earthquake damage is the soil in your local area?

J. What was the magnitude and location of the earthquake plotted in Part III?

Figure 6 – Seismogram for Pinyon Flats, CA

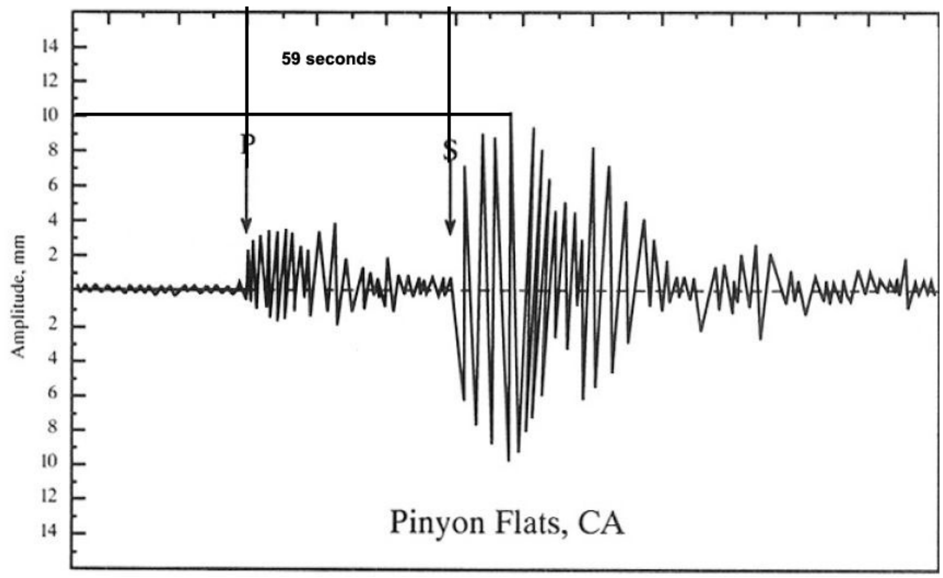


Figure 7 – Seismogram for Pasadena, CA

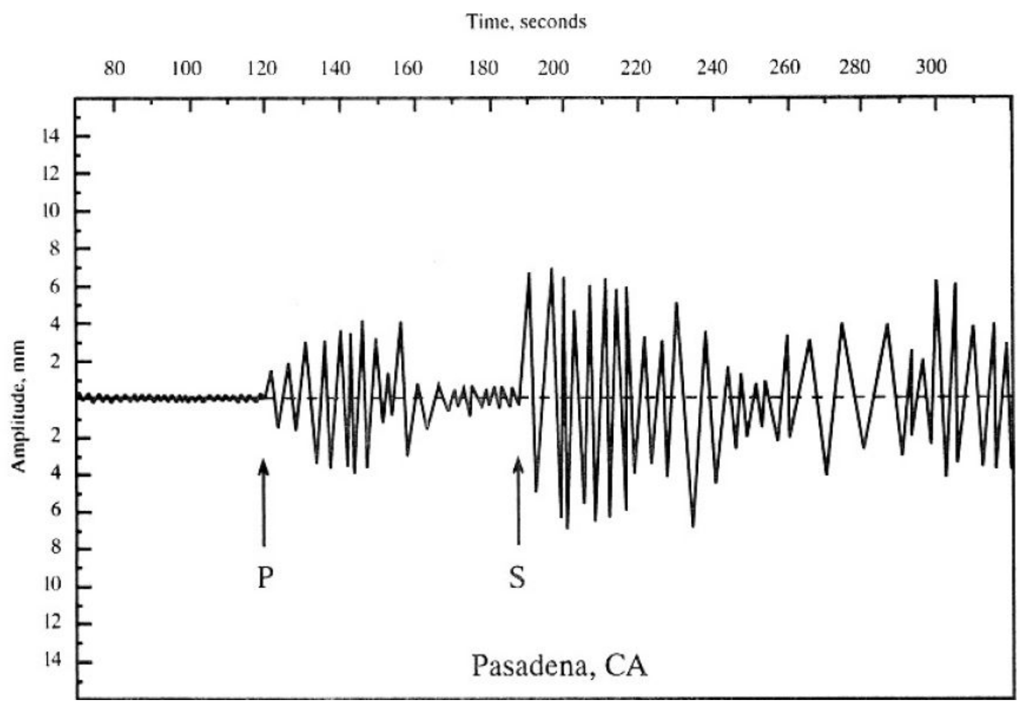


Figure 8 – Seismogram for Salt Lake City, UT

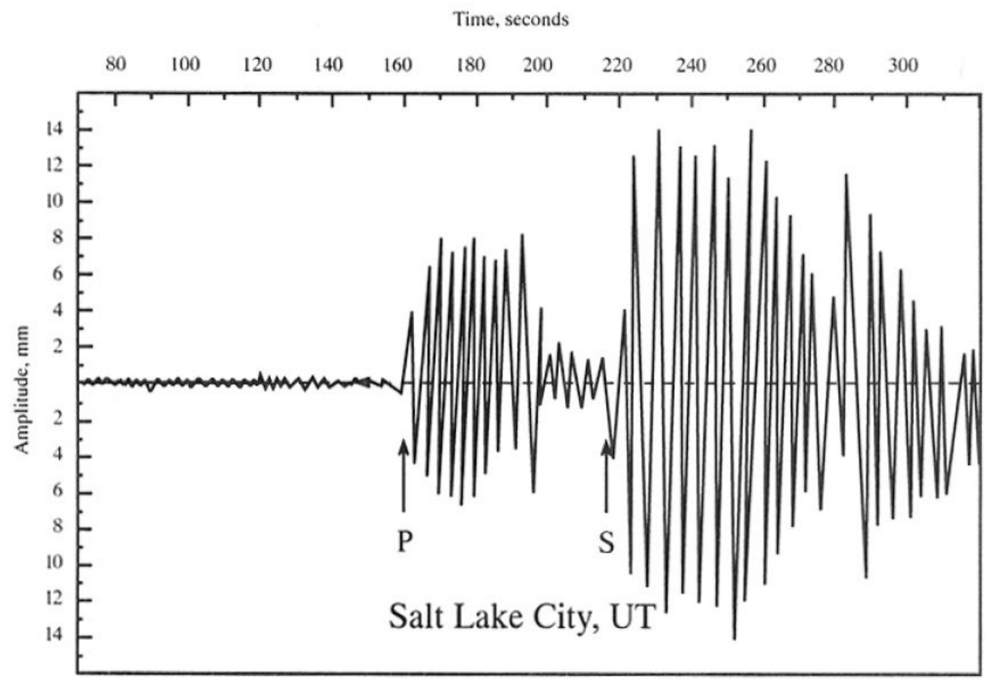


Figure 9 – Seismogram for Tucson, AZ

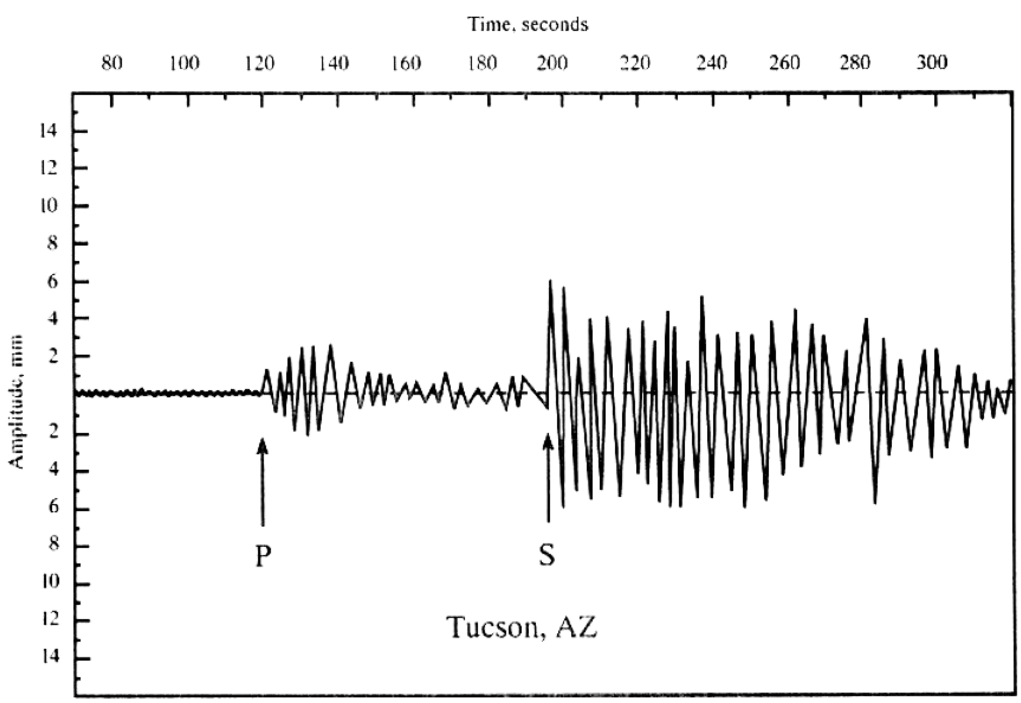


Figure 10 – Seismogram for Yuma, AZ

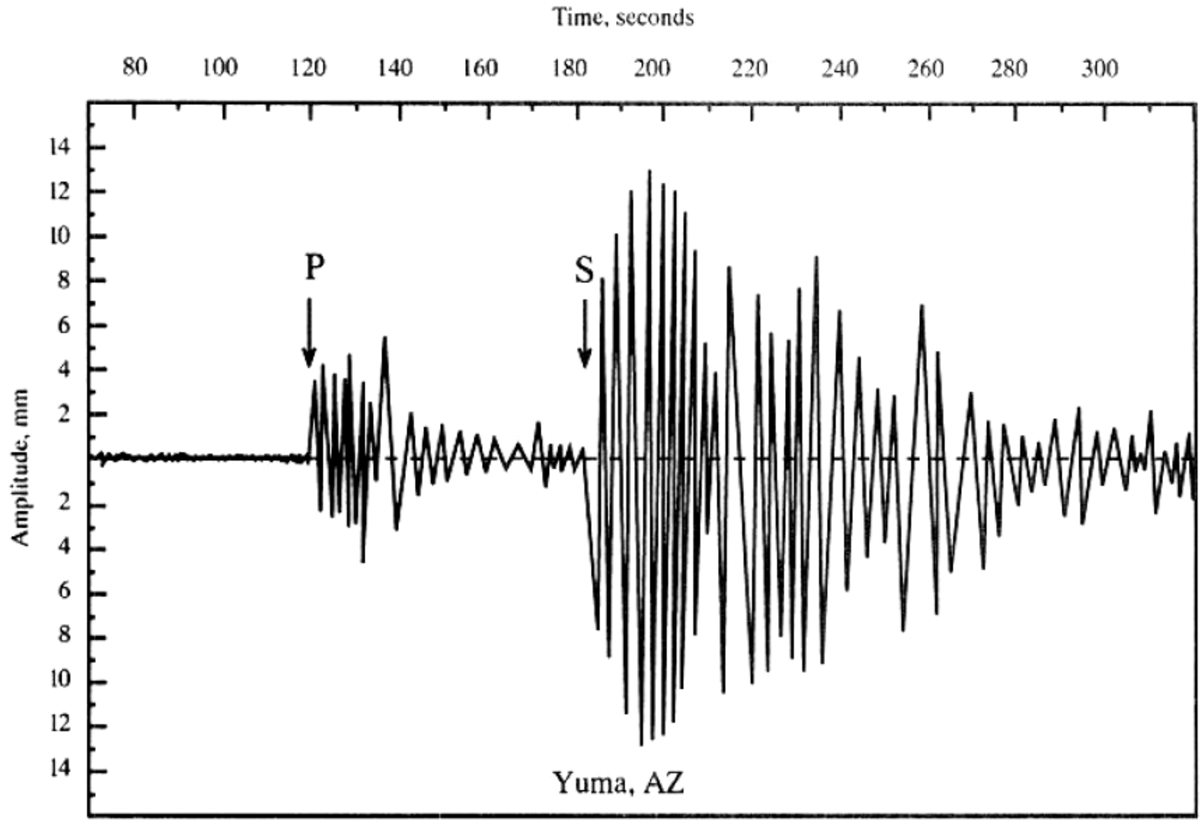
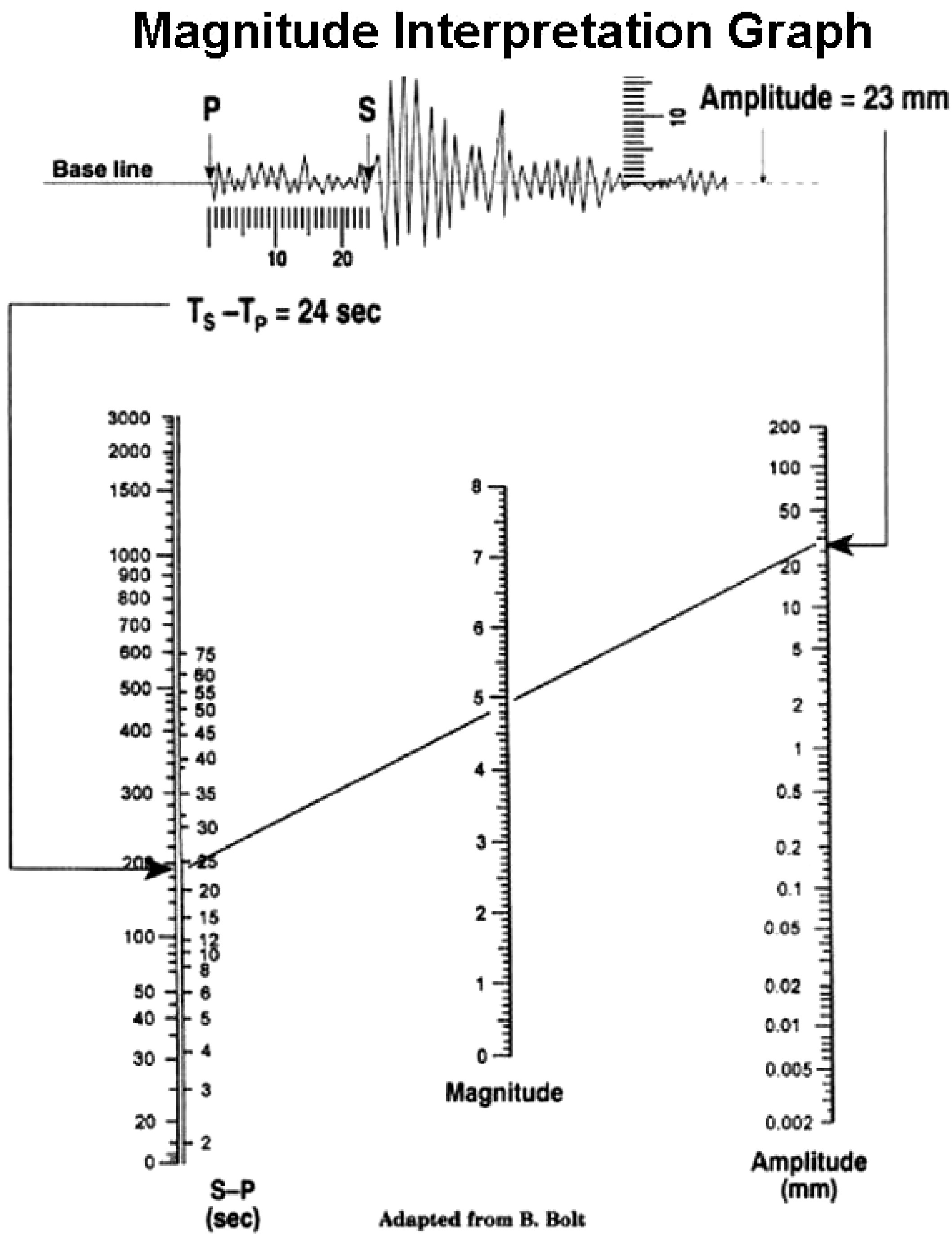


Figure 11 – Magnitude interpretation graph



The previous seismograms and Magnitude Interpretation Graph were prepared by the American Geophysical Union and the FEMA division of the Department of Homeland Security (published 1995) and are from their public domain website: http://Training.fema.gov/emiweb

Figure 12 – Map of the Western US

Plate Tectonics II

Trina Johnson Riegel, M.S. Version 09.1.01

Review the safety materials and wear goggles when working with chemicals. Read the entire exercise before you begin. Take time to organize the materials you will need and set aside a safe work space in which to complete the exercise.

Experiment Summary:

Students will have the opportunity to observe surface deformations from tectonic plate movements simulated in the experiment. Students will study topographical maps to learn how to recognize features found at plate boundaries.

Objectives

- To observe surface deformations created by tectonic plate movements,
- To reinforce an understanding of plate tectonics, and
- To recognize the topographic expression of plate boundaries.

Materials

Materials From:	Qty	Item Description:
Student Provides	1 1	Tap water Scissors
From LabPaq	1 1 1	Beaker, 100 mL, plastic Map-World-relief-map Transparency Paper
Cornmeal in grams-Bag	1	Cornmeal 100g - in a Bag

Discussion and Review

The theory of seafloor spreading grew out of the ocean floor studies conducted by Harry Hess after WWII. Better mapping techniques and subsequent magnetic reversal pattern studies lent additional evidence for what became known as the theory of plate tectonics. Recall that plate tectonics holds that the earth is broken up into a series of rigid plates that slide around on a lower surface called the asthenosphere. Major geologic events such as earthquakes, volcanoes, and mountains occur at the margins or boundaries of the plates.

The spreading of seafloors is a result of divergent plate boundaries. The ocean floor splits apart at mid-ocean ridges and newly formed crust wells up out of underwater volcanoes. This new crust is hot and thus occupies more volume, causing the oceanic ridges to stand out like mountain ranges in relief.

Zones where plates collide are called convergent plate boundaries. What happens in collision zones is dependent on what meets up with what.

- Where an oceanic crust meets a continental crust, the denser oceanic crust will subduct or slide beneath the less dense continental crust, causing some bending and breaking of the continental crust.

- In ocean to ocean collision zones, the denser plate subducts and the lighter plate above it forms a curved island arc.

- In continental to continental collision zones, neither plate subducts. Instead the plates push against each other forming mountains that continue to be pushed ever higher by the movement of the plates.

Transform plate boundaries are so named because they “transform” or connect a divergent and a convergent boundary. The plates slide past each other horizontall, causing earthquakes but not much volcanism.

Exercise 1

PROCEDURE:

Part I: Test and observe how surface deformations are created by tectonic plate movements:

1. Simulate tensional stress at divergent plate boundaries:

    a. Use scissors to cut the sheet of heavy plastic exactly in half, yielding two 4.25 x 5.5-inch half sheets.

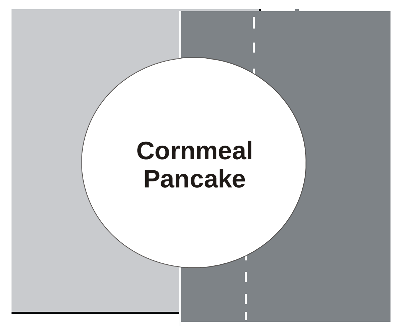
    b. Add 50 ml of water to 100 cm^3 of cornmeal; thoroughly mix the water and cornmeal together and form into a ball.

    c. Overlap the 2 sheets of thick plastic by 1 to 2 inches and center the cornmeal ball over the overlap edges of the plastic sheets.

    d. With the palm of your hand flatten and smooth the cornmeal ball to the thickness of a fat pancake. Smooth the edges. The simulation should now look like the illustration at right.

    e. Very gently apply tensional force by gripping the outside edges of the two plastic sheets and very slowly pulling them apart. Carefully observe and sketch the resulting deformations.

    Overlapped Plastic Sheets

    f. Repeat Steps 1.c through 1.e two more times; each time observe and sketch the deformations.

2. Simulate shear stress and the strike-slip motion that occurs at transform plate boundaries:

    a. Reform the moist cornmeal into a ball and pat in into a pancake in the center of two overlapped plastic sheets as directed in Steps 1.C and 1.D above.

    b. Grasp one plastic sheet at the top and the other sheet at the bottom. Then apply shear stress by very slowly and simultaneously pulling one sheet up and one sheet down. Carefully observe and sketch the resulting deformations. **Note:** If any material is pushed up above the surface level of the other layer, this is similar to strike-slip mountain building.

    c. Repeat Steps 2.a and 2.b two more times; each time observe and sketch the deformations.

3. Simulate compressional stress at convergent boundaries:

    a. Reform the moist cornmeal into a ball and pat in into a pancake in the center of two overlapped plastic sheets as directed above in Steps 1.C and 1.D.

b. Place one hand, palm down, on the underlying plastic sheet directly adjacent to the cornmeal pancake. Grasp the outside edge of the overlying plastic sheet and apply compressional stress by slowly pushing the overlying plastic sheet toward your hand. Carefully observe and sketch the resulting deformations.

c. Repeat Steps 3.a and 3.b two more times; each time observe and sketch the deformations.

Note: The material pushed up against your hand represents compressional mountain building. If the results of this compression exercise are not as good as you would like, try this modification: Place your hands, palms down, on each side of the pancake and slowly push them together, while observing the deformations.

4. Consider the following questions before moving on to Part Two. Include in your formal report all tables, graphs, calculations, sketches, lists, charts, etc. that you produced in this lab.

Questions:

A. How do the above surface deformation experiments verify or re-enforce what you have learned about tectonics? Fully explain your response.

B. What kind of fracture patterns did you observe in the simulations of: tension, shear, and compression stress?

C. Give geographic examples for each type of force simulated. Include locations in the world where your examples might occur.

Part II: Carefully study the color digital relief map of the world and the larger-scale maps that follow to gain a fuller understanding about what is occurring in specific tectonic plate zones and to fully respond to the following questions for your lab report.

Questions:

Divergent Boundaries: East African Rift Valley

A. Plate boundaries do not always follow coastal boundaries. How can you tell where plate boundaries have extended into continents as in East Africa?

B. What is the relationship between east Africa, the Indian Ocean, and the Red Sea?

C. What clues tell that a divergent boundary exists in east Africa?

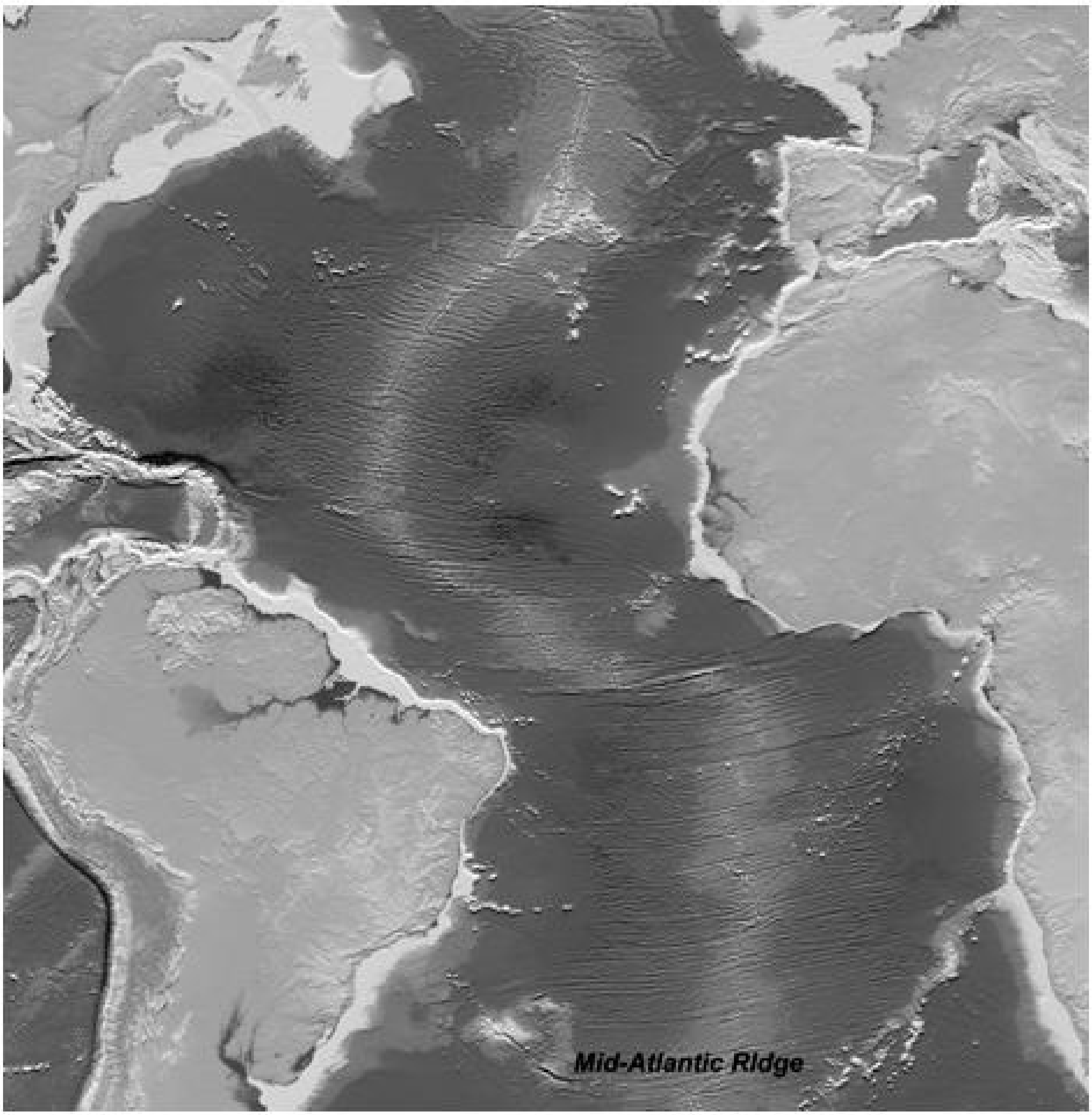
D. How is the Red Sea related to the Atlantic Ocean?

Divergent Boundaries: Mid-Atlantic Ridge

A. Does the Mid-Atlantic ridge act as a mirror for the South American and African shoreline? Why?

B. Why would the color of the ocean depicted on the map change as distance increases from the mid-ocean ridge?

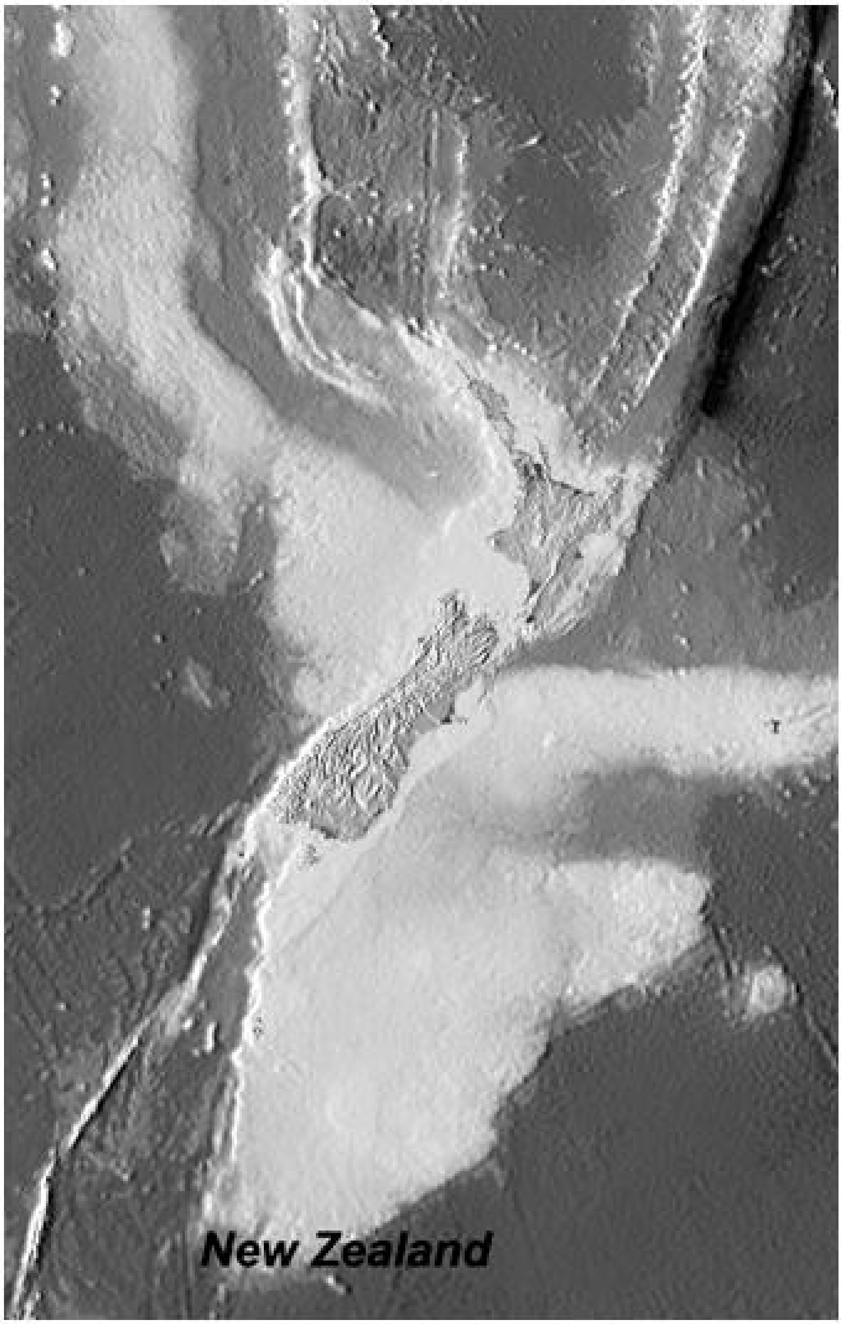
C. How did the long lines perpendicular to the mid-ocean ridge form?



Transform Boundaries: New Zealand

A. Study the boundary that runs through New Zealand. What two boundaries does it lie adjacent to?

B. Could New Zealand expect earthquakes, volcanoes, or both?



Transform Boundaries: Caribbean Sea

A. What types of plate boundaries are expressed in the Caribbean Sea? What features do you base your answer upon?

B. Do the islands lie parallel to the plate boundaries? How can you tell?

NOTE: Turn page sideways for proper viewing.

Convergent Boundaries: South America

A. What is the relationship between the Pacific Ocean and the western coast of South America? Draw a cross-section of how this boundary would look.

B. Would you expect a pattern to the earthquakes that occur on the western side of South America, given the motion of the oceanic plate as it subducts, or sinks, beneath the continent? Describe the pattern in location and depth of the earthquakes.

C. In a paragraph compare and contrast the tectonics of the Andes and the Himalayas.

D. Considering their location, would the Rocky Mountains have likely been formed by a plate boundary process? You may need to conduct additional research to expand upon your answer.

E. Would the Appalachian Mountains have likely been formed by a plate boundary process, given their location? You may need to conduct additional research to expand upon your answer.

Convergent Boundaries: Alpine-Himalaya Belt

A. What is the reason behind the low areas right in front of the Alps, Iraq, and the Himalayas? Could it be related to the type of plate boundary occurring there, and if so, how?

B. Could an argument be made that the mountain chain is continuous from the Alps to the Himalayas? On what basis?

C. How could the Mediterranean have formed? Did the plate boundary types change over time? Could a reversal of plate tectonics have occurred, as in the plate margin switching from convergent to divergent?

***Note:** The copyrights on all the tectonic maps in this lab plus the geology LabPaq's' digital world map are held by Chalk Butte, Inc., Boulder, Wyoming, and have been licensed to Hands-On Labs, Inc. Map credits are as follows:*

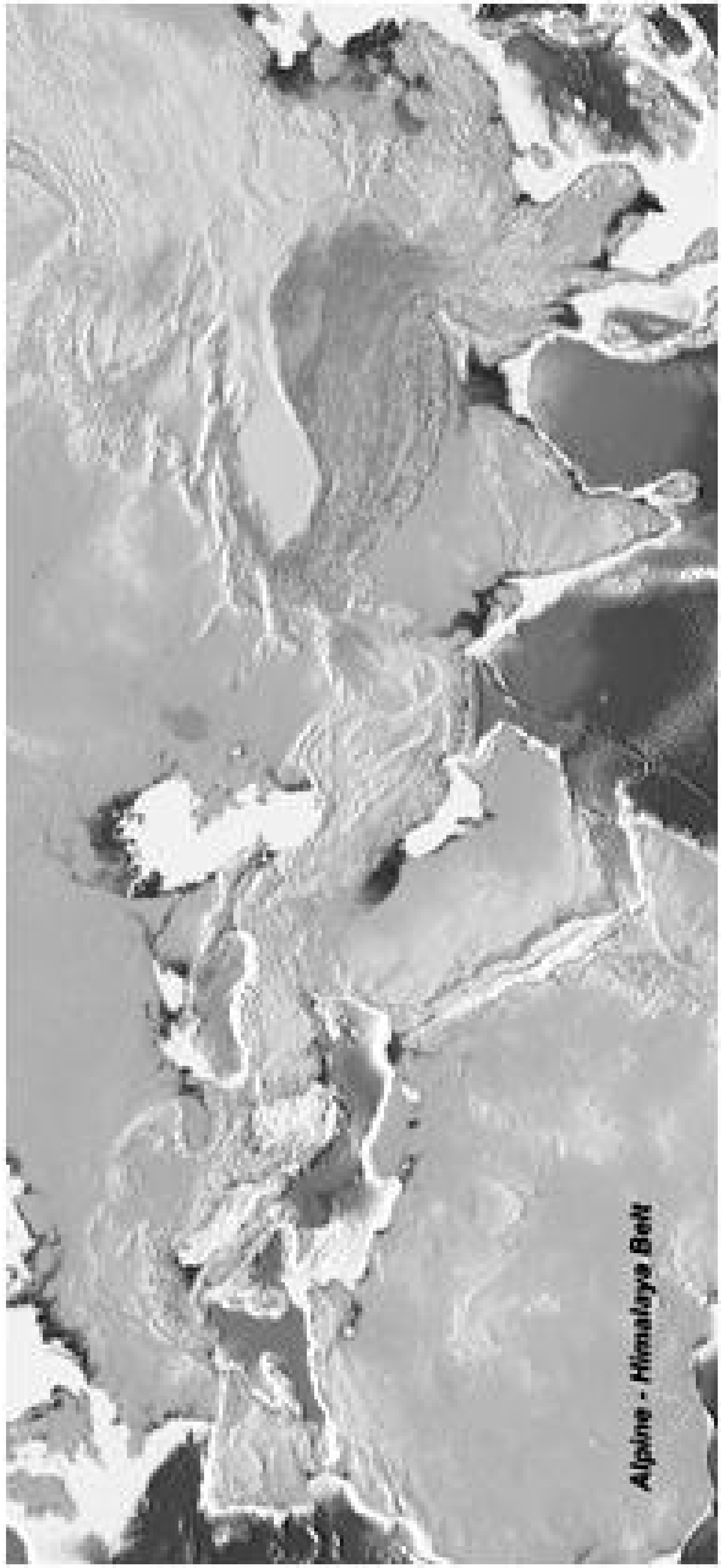
Data Source:

Smith, W. H. F. and D. T. Sandwell

Global Seafloor Topography from Satellite Altimetry and Ship Depth Soundings

Scripps Institute of Oceanography
La Jolla, California

Map Computed by:
Chalk Butte Inc., Boulder, Wyoming



Field Trip Project

Trina Johnson Riegel, M.S. Version 09-1.01

Read the entire experiment and organize time, materials, and work space before beginning. Remember to review the safety sections and wear goggles when appropriate.

Experiment Summary:

Students will have the opportunity to conduct a study of geological features found near their home environment. They will research the history of their area by studying past geological events that occurred in the area. Students will use both topographical maps and field research to write a report regarding the geology of their area.

Objectives

- To research, explore, and observe the geology in the student's local area,
- To apply knowledge gained in Physical Geology course through field work, and
- To prepare a field report documenting a field trip's activities and findings.

Materials

Materials From:	Label or Box/Bag:	Qty	Item Description:
Student Provides		1 1 1	Digital camera Hammer or rock hammer if available Maps and directions to each site
From LabPaq		1	Rock - Set of 50 rocks
Mineral Identification Kit	Mineral Identification Kit	1 1 1 1 1 1	Hydrochloric Acid, 3% - 10 mL in Dropper Bottle Magnet bar Magnifier, Geologic Hand Nail, zinc-coated Penny Plate, Streak plate set

Discussion and Review

Now that you have gained a firm foundation in geology from your studies, it is time to apply your knowledge by taking and reporting on a self-directed field trip. Hopefully, you have already considered possible field trip locations and selected an appropriate site. If not, you should immediately contact local geology clubs, talk with friends and neighbors, and explore potential field trip sites with your instructor to help you select an interesting and convenient site. This will not be a "virtual" field trip. You will actually have to get outdoors and examine the rocks you find!

Even if you live in the middle of an urban area, there are still ample geology field trip opportunities such as natural stone buildings that can be researched, waterways that can be observed and charted, rock outcrops within parks and along trails that can be studied, etc. You may slant your field trip toward economic geology, mineralogy, hydrology, or any major aspect of physical geology covered in your course. With a little creativity and forethought, you will certainly find an interesting geology field trip site and focus plus have the chance to enjoy an outing in nature and demonstrate your knowledge of geology.

This field trip project can be taken any time after you have completed the first ten labs, provided you have also previewed Labs 11 through 15. The trip should take anywhere from several hours to all day. Try to plan the trip for a day when the weather will be nice for it's no fun sloshing through snow or rain looking for rocks! This assignment provides an excellent excuse to plan a fun outing with friends and/or family who you can then dazzle with your newfound knowledge of geology.

Your field trip should begin on the information superhighway where you will conduct initial research. First gather historical geologic information on the state or region of the world where you live and then specific information on the locality of the site you will visit, plus the site itself, if available. Pre-trip research will increase your enjoyment of the trip as well as help you identify relevant geologic features and rocks as you encounter them. Next, follow up by researching additional relevant websites plus appropriate journal articles and/or books that reference your site area. In the U.S., there are excellent Roadside Geology© books available at most bookstores for almost all of the states; these are a great source for selecting sites as well as beginning your research. You should record pertinent data from the websites, journal articles, books, etc. from which you gather information to include in the references section of your report. A good field trip report will include at least three references that do not include your course textbook.

The field trip report should include a road log with specific directions to the site presented in such a way that another person can easily find it. Make note of highway mile markers and identifying landmarks during your trip to include in your directions. Mapquest.com and similar mapping sites can be useful for accurately conveying the exact directions to your filed trip sites.

Try to find, use, and include geologic and topographic maps in your research, your field trip, and your report. They will be very helpful in identifying and describing your sites as well as in helping others to find and identify it too, especially if some hiking is involved. Geologic maps typically reflect an area's different rock types with different colors, and they show unique geologic structures through the use of different symbols; refer to the map's key to help you identify these things. Topographic maps depict the elevation and general layout of the land. The contour lines on topographic maps show differences in elevation such as hills and valleys; the closer spaced the lines, the steeper the slope. Topographic maps by the United States Geology Survey are available online at http://store.usgs.gov and are often found in sporting goods stores and where fishing and hunting licenses are sold.

Most importantly, you should bring a field notebook to record the geology observed during your trip. Your field notebook may be the same as your lab notebook since both are organized in a similar fashion. Start by recording your route to the site, the date, who accompanies you, and the weather conditions. Record all your observations beginning with a general overview of the area, including references to maps, and then narrowing down specific outcrops, landforms, or rocks. Record your observations as they occur; don't rely on memory to fill in the gaps later for you may forget a lot of things! If you later find you incorrectly identified a rock or landform in your field notebook, use the same procedure used in your lab notebook and simply cross it out with a single line.

Make certain to reference your notes to pictures of the area and to any samples you collect. Numbering rock samples is the easiest way to keep them organized. With a permanent marker write a number on the sample; then refer to that sample number when recording your notes. Draw simple sketches of the interesting rocks and/or landform that you take pictures of and annotate them with a note to "see photo # ___. Relating what you observe with the pictures you took is a great way to organize for writing your report. Your report can be based on more than a single outing, you may go on as many geology field trips as you wish and then select the best one(s) for your project.

The field trip must include at least three stops, and your report will need to well document the trip with a minimum of eight digital pictures from the different site stops you visit. Make certain that you are in some of the photos taken to verify that you actually took the trip! Take overview pictures of the site stops plus specific pictures of unique geologic features and areas from which you pick up rock specimens for examination. Try to identify interesting rocks you find while you are still in the field. If any rocks stump you, you can always take them home to research and examine further.
Your report should approximate the length of a 5 to 10 page report, be word processed, utilize appropriate grammar and organization, and professionally present the results of your activities and observations. Since the report will include photos and graphics, it should be saved in a *.pdf, .jpg. or .html* format to avoid distortion when sending it to your instructor or sharing it with peers and friends. You might want to create and/or upload your report to your own website or blog. It's easy to create a personal blog at online sites such as http://www.blogger.com.
There is no specific required format for your field trip report. Instead, this is your opportunity to be creative and design a format that will best demonstrate what you did, what you saw, and what you learned in the field. Before leaving on your field trip, research online geologic

field trip reports to see the many ways they can be presented and to give you ideas about how to best present your own. Having a general idea about how you want to write and present your report will help you decide what kind of pictures to take and what information to accumulate during the trip itself. It might be fun as well as instructional to review some of the exciting international field trips the author of this manual has taken, see her blog at http://www.geologyteacher.blogspot.com/.

One good way to approach your report is to pretend you are writing it for someone you know who is completely unfamiliar with geology. Then try to fully explain and define all the geologic concepts and terms you use in such a way that that person will fully understand everything you say. This approach will help you to write a report that is clear and comprehensible to your instructor and allow others to replicate your field trip.

Although you will select the format, your field trip report should include descriptions of the geology at each stop and any geological points of interest between your stops. The report should address the objectives of the trip in sufficient detail to leave a demanding instructor satisfied and to demonstrate your working knowledge of geologic processes and ability to properly use geology terms. It should conclude a references section citing all the resources consulted to design, implement, and report upon the field trip. Your instructor may have other special field trip requirements or instructions. Make certain you check with him or her to find out what, if any, those requirements might be.

APPENDIX

Final Cleanup Instructions

Congratulations on completing your science course's lab assignments! We hope you had a great science learning experience and that what you've learned in this course will serve you well in the future. Studying science at a distance and performing laboratory experiments independently are certainly not easy tasks, so you should be very proud of your accomplishments.

Since LabPaqs often contain potentially dangerous items, it is important that you perform a final cleanup to properly dispose of any leftover chemicals, specimens, and unused materials. Please take a few minutes to protect others from possible harm and yourself from future liability by complying with these final cleanup instructions.

While you may wish to sell your used LabPaq, this is not advisable and would be unfair to a potential purchaser. It is unlikely that a new student trying to utilize a used LabPaq would have adequate quantities or sufficiently fresh chemicals and supplies to properly perform all the experiments and to have an effective learning experience. Further, it is doubtful that adequate safety information would be passed on to a new student in the same way it was presented to you. This is a significant concern and one of the reasons why a new user would not be covered by LabPaq's insurance. Instead, you would be responsible for any problems experienced by a new user.

Chemical Disposal

- Due to the minute quantities, low concentrations, and diluted and/or neutralized chemicals used in LabPaqs, it is generally sufficient to blot up any remaining chemicals with paper towels and dispose of them in a trash bin or flush remaining chemicals down a drain with copious amounts of water. Empty dispensing pipets and bottles can be placed in a normal trash bin.

  These disposal methods are well within acceptable levels of the waste disposal guidelines defined for the vast majority of state and community solid and wastewater regulations. However, since regulations can vary in some communities, if you have any doubts or concerns, you should check with your area authorities to confirm compliance with local regulations and/or if assistance with disposal is desired.

Specimen and Supply Disposal

- To prepare any used dissection specimens for normal garbage disposal, wrap them in news or waste paper and seal them in a plastic bag before placing them in a securely covered trash container that will prevent children and animals from accessing the contents.

- Non chemical supplies can also be discarded with household garbage, but should first be wrapped in news or waste paper. Place such items in a securely covered trash container that will prevent children and animals from accessing the contents.

Lab Equipment

- Many students choose to keep the durable science equipment included with their LabPaq as most of these items may have future utility or be used for future science exploration. However, take care to store any dangerous items, especially dissection knives and breakable glass, out of the reach of children.

- Please do not return items to LabPaq as we are unable to resell items or issue any refunds.

Best wishes for a happy and successful future!

The LabPaq Team