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Activities to Explore Acid Rain and Building Stones

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Explore some of the concepts and processes related to acid rain and building stones with the activities in this report. Many of the activities were developed for "Science Discovery Day" workshops designed to excite students about science and to encourage them to experience and explore science. Each activity poses a question, lists materials needed, and outlines the steps for the activity so that you can observe and explore the topic and discover what happens. A brief explanation of the phenomenon is given with the activity in "what happened?". Questions and suggestions in "stretch your mind" are intended to expand and extend the activity for an integrated learning experience or for advanced students. The section "In Your Community" suggests some field trip activities that can also extend your exploration of earth science, applied to the problem of acid precipitation. Sources for some materials are suggested, and a list of additional resources and references is provided.

A. Introduction

Acid rain is formed when air pollutants, primarily oxides of sulfur and nitrogen, mix with rain, snow, fog, or dew to form strong acids (like sulfuric and nitric acid). Principal manmade sources of these pollutants are industrial and power-generating plants and transportation vehicles. Acid rain can hurt fish, forests, and lakes because some species and ecosystems are sensitive to changes in acidity. Air pollution and acid rain may also harm monuments and buildings by causing them to deteriorate more quickly than they would if they were not exposed to pollution.

All stone weathers (deteriorates) as part of the normal geologic cycle; however some stones may deteriorate faster if they are exposed to urban air pollution. How rapidly a stone deteriorates depends on the composition of the stone, the environment, and the conditions to which the stone is exposed. Acid rain and air pollution affect marble and limestone buildings in particular because these stones are more likely than other stone types to react with acid.

Acid rain and urban air pollution deteriorate limestone and marble through two processes: dissolution and alteration. Portions of buildings or monuments that are exposed to rain show dissolution effects that include: roughening of the stone surface, loss of sharp edges or carved details, and preferential weathering around inclusions. Stone that is sheltered from rain is at risk from alteration deterioration. Blackened surficial crusts are primarily composed of gypsum (hydrated calcium sulfate) plus dirt, and form from the reaction between calcite in the stone, and sulfur dioxide and moisture in the air. The gypsum alteration crusts accumulate in areas that are protected from washing by rain because gypsum is soluble in water. The crusts are black because dust and pollutants are trapped by the gypsum crystals that form on the stone surface. The blackened alteration crusts look ugly on buildings and the stone under the crusts often crumbles when the crust is removed.

The publication "Acid Rain and our Nation's Capital: A Guide to Effects on Buildings and Monuments"[a] discusses acid rain and its effect on marble and limestone. It also outlines a tour in Washington, D.C. to examine deterioration of some of our buildings and monuments. The deterioration effects that are described can be seen on marble and limestone buildings in many cities. Many aspects of acid rain and stone deterioration can also be explored in a classroom or at home.

This report suggests activities to explore some of the concepts and processes related to acid rain and building stones. Activities 1 through 6 explore acidity, what makes acid rain, and the geographic distribution of acid rain. Activities 7 through 11 explore some of the effects of acid rain on stone. Activity 12 illustrates how you can look at the texture of a rock and tell something about how it was formed. Any of the activities can be done as a stand-alone investigation. The activities are designed to use materials that are fairly readily available. Each of the basic exploratory activities, except for activity 10, can be completed in about 20 - 30 minutes. If you choose to make the activities more quantitative, or if you wish to expand the activities using some of the suggested ideas, they will take longer to complete. Some of the activities present opportunities for students to discover that measuring, labeling, or careful observation will aid their interpretation; the activities can easily be repeated to see if a different technique works better.

[a] See Resources, listed in section E.

B. Activities

1. WHAT IS AN ACID?

Materials needed:

various household solutions (try to include things like: lemon juice, vinegar, carbonated beverage, coffee, tea, detergent, baking soda mixed with water, etc.)
pH meter[1], litmus paper[2], red cabbage, or indicator solution[3]
small cups
stiff white paper (like index cards)
eyedroppers or thin straws (like those used with cocktails)

[1,2,3] For sources, see section C.

Procedure:

<u>If you use a pH meter:</u>

1. Place a small amount of the solution to be tested in a cup.
2. Put the tip of the pH meter into the solution and wait a moment or two for it to adjust.
3. Note the reading on the pH meter.
4. Test other solutions and compare the results for each of the solutions.

<u>If you use litmus paper:</u>

1. Place a small amount of the solution to be tested in a cup.
2. Put the end of the litmus strip into the solution and wait a moment or two for it to adjust.
3. Note any color change on the strip.
4. Test other solutions with a fresh piece of litmus and compare the results for each of the solutions.

<u>If you use red cabbage:</u>

1. Firmly rub pieces of red cabbage on an index card, so that you have several purple spots on the card.
2. With the eyedropper or straw, put a drop of one of the household solutions on one of the purple spots.
3. Note any change in the spot color where you put the solution.
4. Test other solutions on more red cabbage spots and compare the results for each of the solutions. Compare the colors of your test spots with each other and with an untested (control) spot of the red cabbage rubbing.

<u>If you use indicator solution:</u>

1. Place a small amount of the indicator solution in a cup. Keep some indicator solution in a separate cup to compare with the tests.
2. Add a few drops of the solution to be tested.

Activity 1 con't.

3. Note any color change in the solution. If you add more test solution does the color change more?
4. Test other solutions and compare the results for each of the solutions. Compare the color of your tested solution with the color of the original, unchanged (control) indicator solution.

What happened?

Solutions that are acid will have a low reading on the pH meter. Numbers less than 7 indicate an acid; numbers greater than 7 indicate a base. The lower the number, the more acidic the solution (the stronger acid it is). Some products (like shampoo) carry a label that says they are "pH balanced", meaning that the shampoo has a neutral pH, or a pH near 7.

Solutions that are acid will turn litmus paper red and they will also turn the red cabbage spot or the indicator solution red. Solutions that are basic will turn litmus and indicator solution blue. The stronger the acid or base, the more red or blue the color (respectively).

You may know acids as substances with a sour taste (lemon juice, vinegar, tomato juice). An acid is a substance that releases protons (or H^+, hydrogen ions) when it is in solution. When you measure the acidity of a substance you are measuring the amount of free protons in the solution. The stronger an acid is, the more free protons it releases in solution.

The pH scale which is used to measure acidity, indicates the inverse of the protons, thus the more protons there are in the solution (the more acidic the solution) the lower the number on the pH scale. The pH scale is also logarithmic which means that each unit of pH is ten times stronger than the next pH unit; so lemon juice with a pH of 2 is ten times more acidic than vinegar which has a pH of 3.

Stretch your mind:

• Can you identify some characteristics that are similar for the acids that you tested? Can you identify some characteristics that are similar for the bases that you tested? [Think about what the acids or bases are used for; this tells you more about how acids and bases are used in our everyday lives than it tells about acids or bases.]

• Can you think of other solutions to try to test? Before you test, try to predict whether the solution will be an acid or a base. Why do you expect it to be an acid (or base)? [Remember, not all solutions will be acidic or basic, or a solution may be so weakly acidic or basic that you cannot measure its acidity with the technique you are using.]

• When you tested the solutions, did you have any puzzling results? (For example: something you thought would be an acid, did not seem to turn the litmus or solution a red color...) Did

Activity 1 con't.

you try the test again? Could your testing method have affected the results? [Think about whether your hands may have mixed the solutions. Is it possible that spills in your work area might have touched a test strip before you put your solution on it? Have you made sure not to mix droppers into more than one solution?...] If you are using red cabbage or indicator solution, do you think the initial color of your test solution may have made it harder to determine the result of your test?

• You can begin to look at relative strengths of acids by comparing all of the acids you tested. [See activity #2] When you compare strengths of acids, you are constructing a pH scale. Bases fit into the scale because the stronger base is, the less acid it is.

• Many people have heard of a "volcano in a bottle" or have made a homemade volcano by mixing vinegar and baking soda. What happens when these two substances are mixed? [Think about how you classified the vinegar and the baking soda solution.] When you are cleaning up, try pouring some of the baking soda solution and vinegar together. Do you see a chemical reaction? Do you think you will get a similar reaction by mixing other solutions that you tested? How would you choose the solutions to mix together to look for a reaction? [It might be best to try some of this over a sink, as you discard your test solutions.]

2. HOW STRONG IS THE ACID?

You can see the strength of an acid in two different ways: (a) by measuring its acidity [this activity], or (b) by examining its effect (amount of reaction) [see activity 3].

Materials needed:

various household solutions (try to include things like: lemon juice, vinegar, carbonated beverage, coffee, tea, detergent, baking soda mixed with water, etc.)
pH meter[1], litmus paper[2], red cabbage, or indicator solution[3]
small cups
stiff white paper (like index cards)
eyedroppers or thin straws (like those used with cocktails)

[1,2,3] For sources, see section C.

Procedure:

<u>If you are using a pH meter or litmus paper -</u>

1. Choose an assortment of household solutions and put a small amount of each into cups that you have labeled.
2. Test each solution and record the response:
   - With pH meter - put the pH meter tip into the solution and wait a moment or two for it to adjust; record the pH value once the reading has settled. Rinse or wipe off the tip of the meter and then measure the next solution.
   - With litmus paper - use a separate piece of litmus paper for each solution that you test; dip a part of the paper into the solution for a moment or two and then set the litmus paper aside with the cup that you tested (you may want to label the litmus paper).
3. When you have measured all of the solutions you can order the solutions by the pH value that you measured. Determine which solution is the strongest acid and which is the weakest by comparing their pH values. Compare the numbers you read with the pH meter or the color strength (or number) from the litmus paper chart.

<u>If you are using red cabbage -</u>

1. Firmly rub pieces of red cabbage on an index card, so that you have several purple spots on the card.
2. With the eyedropper or straw, put a drop of one of the household solutions on one of the purple spots.
3. Note any change in the spot color where you put the solution.
4. Test other solutions on more red cabbage spots and compare the results for each of the solutions. You can compare the strengths of the acids by comparing the colors of your test spots with each other and with an untested (control) spot of the red cabbage rubbing. The stronger acids will turn the spots more red in color, the weakest acids will turn the spots more blue. Neutral solutions will leave the

spot the same color as the original spot, like the control spot.

If you are using indicator solution -

1. In order to compare these, you must be sure to use the same amount of indicator solution and the same amount of household solution for each test cup.
2. Put a small amount of the indicator solution into a cup. Also, make a control (for comparison) by putting the same amount of indicator solution into a cup that you set aside.
3. Add a small amount (like a few drops) of a household solution to the indicator solution in one cup. Observe the color of the solution, compare it with the control that you set aside. Label the cup so you will know which household solution you added. Test other household solutions by adding the same small amount of the solution to the indicator solution in another cup.
4. You can compare the strengths of the acids in your household solution by comparing the colors of the solutions in each cup. The stronger acids will have a more red color, the weakest acids will have a more blue color. Neutral solutions will have a color like the control solution.

What happened?

Solutions that are acid will have a low reading on the pH meter. Numbers less than 7 indicate an acid; numbers greater than 7 indicate a base. The lower the number, the more acidic the solution (the stronger acid it is).

Solutions that are acid will turn litmus paper red and they will also turn the cabbage spots and indicator solution red. Solutions that are basic will turn litmus, cabbage spots, and indicator solution blue. The stronger the acid or base, the more red or blue the color (respectively).

Stretch your mind:

• Did you test any solutions that turned your litmus, indicator, or spot some color other than red, blue? Did any solutions leave the color the same? What do you think that means? [Could the initial color of your test solution influence the test?] Red cabbage and litmus are best for testing pH's within a certain range; do you think a color that is not blue or red might tell you something about the strength of the acid or base?

• What do you think would happen to your strength scale results if you diluted some of the solutions with water? Dilute one or more of the acids or bases by adding different measured amounts of water. [Try mixing proportions like: 1 part acid, 2 parts water; 1 part acid, 4 parts water; 1 part acid, 1/2 part water, etc.] Test the solutions for their acidity. Do you get a range of strengths of acid with the different dilutions? How do the dilutions of one acid compare with the full strength acidity of another acid?

3. CAN YOU SEE HOW STRONG AN ACID IS?

Materials needed:

various household acids (lemon juice - fresh, bottled; vinegar, carbonated beverage, muriatic acid[4], coffee, tea, etc.)
chalk, baking soda, or antacid tablets
small cups or dishes
eyedropper (optional)
magnifying glass or hand lens[5] (optional)

[4,5] For sources, see section C.

Procedure:

1. In order to make a good comparison in this test, you should try to use the same amount of solid and acid for each test.
2. Put a small piece (or amount) of chalk, baking soda, or antacid tablet into a cup or a dish.
3. Drop a few drops of one of the household acids on the solid and watch for a reaction. Record what household acid you used and record some information about what you saw happen.
4. Use the same procedure for another household acid and compare the amount of reaction that you see with each acid.
5. To see more reaction, you might try crushing or breaking your solid into small pieces and then add the drops of acid.

What happened?

The solid material that you used is a base and the liquid is an acid. When an acid meets a base, a chemical reaction occurs. You can see the reaction with these solids because carbon dioxide gas (CO_2) is a product of the reaction. Carbon dioxide is created by the reaction, and you see the bubbles and "fizzing" as the gas forms. The stronger the acid, the stronger the reaction with the base. You will see more fizzing if you use the same amount of a strong acid compared to a weak acid, and you will see the reaction happen more quickly with a stronger acid. With a weak acid, you may not be able to see the reaction very well at all; you can try making the reaction again and watching it with a magnifying glass or a hand lens.

If you break up or powder the solid material, then you have made more surface area for the acid to react with, making it easier for the reaction to occur. Also, materials like chalk (especially if it is "dustless") or antacid tablets may have been processed to make them smoother and harder on the outside so they won't crumble. The hard smooth outer surface makes it more difficult for the acids to react with material, just as it is harder to dissolve those pieces.

If you keep adding acid to the solid material, the bubbling may continue for a little while, but then it may slow down and stop. Once all of the acid has reacted with the base, the reaction stops and the acid has been neutralized.

Activity 3 con't.

Stretch your mind:

• Do you think that if you left a piece of chalk, baking soda, or antacid tablet in one of the acids that the solid material would completely disappear (react)? Try it. What could you do to help the reaction to occur? [Does it just need more time? Think about stirring the acid, or adding fresh acid to the solution; would either of these ideas help? Why? (see activity #4)]

• To compare the strengths of the acids you had to use the same amount of solid material with each acid you tested. Does the method you use to measure the same amounts of solid make a difference? You could measure volume (teaspoon, milliliters) or weight (ounces, grams) of your material. [Some materials take up a lot of space (volume) but don't weigh very much, like feathers; other materials weigh a lot for the size they are. This is the idea of density: the property of a material that describes its mass per volume.]

• Do different types (or brands) of antacid tablets react less strongly with the same acid? Why do you think this happens or doesn't happen? [Think about ingredients and fillers in the tablets. Not all ingredients are reactive!]

4. WHAT IS NEUTRALIZATION?

Materials needed:

- small cups
- indicator solution[3]
- choose one or more household acids (lemon juice - fresh, bottled; vinegar, carbonated beverage, muriatic acid[4], coffee, tea, etc.)
- choose one or more household bases: chalk, baking soda, or antacid tablets (you may want to make a base solution by mixing some of the powder with water)
- eyedropper
- pH meter[1] (optional)

[1,3,4] For sources, see section C.

Procedure:

1. Pour a small amount (perhaps 1-2 tablespoons) of indicator solution into a cup and set it aside to use as a control to compare with the solutions that you will change.
2. Pour a small amount (perhaps 1-2 tablespoons) of one of the acids into two other cups and then add some indicator solution to each cup. Observe the color of the liquid in the cup. Compare the color of the solution with your control cup to make sure that it looks red compared to the control. (If it doesn't, add some more acid to it.)
3. Gradually add small amounts of a base (or drops of base solution) to one of the cups with the acid and watch what happens to the color. Compare the color in the cup with your control cup and with your acid cup.
4. Record how much acid you used and then how much base you needed to add to make the solution change to a color like your control cup.
5. Repeat the experiment with another household acid and compare how much base you needed to add this time.

<u>To measure the neutralization:</u>

1. Pour a small amount (perhaps 1-2 tablespoons) of one of the acids into a cup.
2. Measure the pH of the starting acid solution.
3. Gradually add base to the solution until the pH meter reads 7 (neutral on the pH scale) and record how much base you needed to add to get to neutral.
4. Repeat the procedure with the same starting acid and use another base. Or, repeat the procedure but use the same amount of a different acid for your start, record its pH, and then compare how much base you needed to add to get to neutral pH 7 with that acid.

What happened?

The color of the indicator solution changes from red to purple to blue as you change the solution from acid --> neutral --> base. You started with an acid solution (the indicator solution looked red) and as you added the base to it, a chemical reaction occurred and the solution changed color. The acid and base react with each other to form water and a salt. If you stopped adding base to the acid when the solution was the same color as your control you made a solution that was neutral; the amount of acid and base in the solution balanced each other. If you kept on adding base to the solution until it turned blue you then made a solution with more base than acid in it.

If you compare how much acid and base you used and also compare the amounts for several acids you will begin to see that some acids are stronger than others. The stronger acids need more base added to them to make them neutralize. You can also try the experiment the other way, by starting with a basic (blue) solution and gradually adding drops of acid.

If you measured how much acid or base you needed to neutralize the solution using a pH meter, you saw that different acids started with different pH's and they required different amounts of base to neutralize them. Remember the lower the pH number, the stronger the acid. You may have also observed that a unit of pH is 10 times stronger than the next unit of pH, by comparing the amounts of base you added to different pH levels of acid.

Stretch your mind:

- Another way to neutralize an acid (or base) solution is to add water. The more water you add, the more dilute (and the less acid) it becomes. This may be a little hard to see with the indicator solution, but if you start with an acid solution and gradually add water to it, watch what happens to the color. To test that the lighter color of solution is a weaker acid you would need to measure its pH before and after you added the water to it. This is an important factor for acid rain. Some small rain storms in polluted areas will have lower pH's (higher acidity) than larger rain storms in the same polluted area, because the more rain that is added to the same amount of pollutant, the weaker the acid rain becomes.

- Determine how many drops (from the eye dropper) it takes to equal the volumes of solution you are using. Before you start, measure an amount of water that equals the amount of indicator solution you will put in a cup, for example: 1 tablespoon, 10 milliliters, or some convenient amount. Then count how many drops (from the eye dropper) it takes to fill the same volume (one tablespoon or 10 milliliters, whatever you are using to measure). Use this information as you measure and dilute the solutions.

- If you want to quantify the acid strengths, carefully measure and record how much solution you use and then find out how many drops of base (or acid) you used to neutralize the solution. Do the same thing with several acids and bases. Can you use this information to set up a chart that shows the strengths of the acids? If you repeat the experiment with the same acids and bases, do you need the same number of drops each time? [You could do the experiment three times each and compare your results with others results.] Can you show that there is a statistical variation? What would cause the variation? [Think about drop size, your eye's estimate of the

Activity 4 con't.

color of the solution.]

• If you start with a blue solution and add acid to it does it take the same amount of drops to get the solution to neutral (purple) as it does if you start with a red solution and add drops of base to make it neutral? What could explain any variation that you find? [This is sometimes called "bracketing" a point if you try to approach it in an experiment from two directions. There may also be some statistical variation here, you may get a range of answers for how many drops it takes to make a neutral solution (instead of always coming up with one specific answer!). Scientists often expect that the answer might vary slightly because of experimental conditions can vary in the real (as opposed to theoretical) world.]

• Can you predict what will happen if you mix two acids and use the mixture to neutralize the solution? Will it take fewer drops, the same, or more, than it did with each acid alone?

5. WHAT MAKES RAIN ACID?

Materials needed:

- paper cups
- straws
- pH meter[1]
- tap water

[1] For sources, see section C. *Many thanks to W.G. Wilber for this activity idea.*

Procedure:

1. Put some water in a cup and measure its pH:
   To measure the pH: Put the tip of the pH meter into the water to measure the pH of the water. A pH of 7 is neutral; values less than 7 are acidic, values greater than 7 are basic.
2. Gently blow through a straw into the water for about 2 minutes.
3. Measure the pH of the water again.

What happened?

When you blew through the straw, you were blowing carbon dioxide and other gases into the water. Carbon dioxide is a natural gas that we breathe out. The carbon dioxide mixes with water to form carbonic acid. Carbon dioxide that is present normally in air makes "clean" (unpolluted) rain slightly acidic (pH 5.6).

Air pollutants like sulfur dioxide and nitrogen oxides make stronger acids when they mix with moisture in air, making acid rain. In the United States, average rain pH ranges from 4.2 to 5.9. Manmade sources of sulfur dioxide and nitrogen oxides include power plants and transportation vehicles.

Stretch your mind:

- What if you keep blowing into the water for more than 2 minutes? What if two people blow into the cup at the same time? If you use less water in the cup, do you get the same effect on pH after blowing for 2 minutes?

- If several people try the experiment, you can compare the measured results and see if you can explain any variations or similarity. Does everyone get the same change in pH when they blow into the water? Why or why not? [Think about how hard you blow (can that be measured?), think about the meter you use to measure the pH - is it sensitive enough to show variations?]

Activity 5 con't.

• Water may be able to hold only a certain amount of carbon dioxide. Try it with cold water and with warm water, temperature can affect how much carbon dioxide can be dissolved in water; this is important for various creatures that live in streams, lakes, and oceans.

• Carbon dioxide gas is what gives carbonated beverages their bubbles. If you test the acidity of a carbonated beverage is it an acid? How does it compare with other carbonated beverages and with the water that you blew into? [The bubbles in the soda show that the carbon dioxide is not dissolved, that may affect the acidity of the solution!]

• What happens if you try the blowing experiment with carbonated water instead of plain water?

6. WHERE IS THE RAIN ACID IN THE UNITED STATES?

Materials needed:

Outline map of the United States (showing state boundaries)
measured rainfall pH values for various locations[6] (either already plotted on the map or a list of values and their locations)
pencils

[6] For sources, see section C. *Many thanks to S.L. Russell-Robinson for this activity idea.*

Procedure:

1. If you start with a blank map of the United States, record the rain fall pH values from the list on the map.
2. Look at the values on the map. What states have experienced the most acid rainfall? What states have experienced the least acidic rainfall?
3. You can draw contour lines for various pH levels on the map to see areas covered by specific pH ranges.

   To draw contours: Choose a level, such as pH = 4.4 and find a point where that value was recorded. With a pencil, start at that point and draw a line to another place with the same pH value, placing your line between dots for other pH measurements where it would belong. For instance, if you start at pH 4.4 as you move towards another point of 4.4, draw the line between points with pH = 4.5 and pH = 4.3. As you draw each portion of the line you need to look around the point in all directions to identify the correct place to draw the line through those points. The contour lines for each level that you make (4.4, 4.6., 4.8, etc) should never cross each other. Each line should be a smooth curve. For this type of data you may not be able to close all of the contour lines into complete loops. There also may be some areas where a contour line is repeated but it does not connect to lines of the same value elsewhere in the map.
4. Is there a particular region or area of the United States that has more acidic rainfall? Why do you think one region might have more acidic rain than another region?

What happened?

Remember, the lower the pH the more acidic the rain. States east of the Mississippi River tend to have more acidic rain than states west of the Mississippi. In particular, Ohio, Pennsylvania, Maryland, New York, and New Jersey have more acidic rain. Western states, such as California and Nevada have less acid rain. Rain in the east tends to be acidic because there are more concentrated sources of pollution in those areas where population and industry are concentrated. Monthly averages of rain pH may vary because of the amount of rainfall in the measurement period.

Contours of pH of rain will tend to show a "bulls-eye" type figure for acid rain that is centered around Pennsylvania, Ohio, New Jersey, and New York. Contour lines in the southeast and west tend to be broad and don't have a noticeable trend or shape.

Activity 6 con't.

Stretch your mind:

- Look at some pH maps for several years. How has the pH changed for the time span? Can you find an area in which rain has become more acid? Can you find an area in which rain has become less acid? Has there been any change where you live? Why do you think these changes have happened? Can you see a trend in the rain acidity, is the geographic area affected by acid rain getting larger or smaller? [What if you compare different intervals of time?]

- See if you can get some local information about rain acidity. How does your local rain pH compare with the national rain measurements? Is your local rain different from the yearly or monthly average for your area? [Think about single measurements vs averages, local effects vs broader areas.]

- Make a plot (bar or line graphs) of site vs pH for each month of data. Compare all the months. Do you see a season or a month that is more acid than the others? Is one less acid? Why might this happen? [Think about rainfall amounts during those periods, or pollution sources that might be more prevalent at one time than at another.]

- Calculate an average pH for each site for the year using the monthly averages. How do the year averages compare with the monthly data? Which do you think is a good representative of the rainfall pH? What value would you use to describe the rainfall acidity for your state? [Think about how that information might be used: Do you need it for a general environmental description? Are you concerned about trends to the future? Are you concerned about single points that might have a 1 time effect? Would you use different values if you wanted to support a special point of view?]

- How much difference is there between the lowest and highest pH? Is this significant? [Remember, each unit of pH is ten times as strong as the next unit.]

7. WHAT IS DISSOLUTION?

Materials:

clear glass jars or beakers (or clear plastic cups)
sugar and (or) salt; lumps of sugar
water
spoons

Procedure:

1. Put some water into a jar.
2. Add some sugar or salt and watch what happens. You can also taste the solution.
3. Try adding more sugar or salt, observe and taste again. You can try stirring the solution to see if you can dissolve more sugar or salt.
4. Try using the lump of sugar instead of loose grains. Watch what happens. Try tasting it. Compare your observations with the solution that you made with loose grains of sugar.

What happened?

When you add the sugar or salt to the water the solid disappears. The solid reacts with the water and is dissolved by the water. You can tell that you have changed the water because now the water will taste salty or sweet from the addition of salt or sugar. If you add more solid it may take longer for the solid to dissolve; stirring the solution helps it to dissolve because you move the water and solid around and expose more of the grains of solid to a larger portion of water. If you keep adding sugar or salt you will eventually add so much that the water won't dissolve any more (even when stirred); the solution is "saturated" or full of the sugar or salt.

If you use a lump of sugar and compare it with the same amount of loose grains, it will take longer for the lump to dissolve compared with the loose grains. The loose grains have more surface area (more places for the water to touch and react with the surfaces of the sugar) than the lump of sugar. In order for the lump of sugar to dissolve, each layer must dissolve before the next part is exposed to the water and can begin reacting; with loose sugar all the surfaces meet the water at once.

Another experiment that you might try is to compare how quickly or easily sugar or salt will dissolve in water at different temperatures. Try room temperature water, cold water, and very hot water. The warmer something is the faster its molecules move around, so in hot water there will be more collisions between water molecules and the sugar or salt.

Stretch your mind:

• Measure the loose sugar so that you have the same amount as the sugar cube: try weighing the cube and get the same weight of loose sugar (what can you do if a sugar cube is too light for your scale?), or try comparing the same volume of sugars.

Activity 7 con't.

• Use the same amount of water for equal amounts of loose and cube sugar. Time them to see which will dissolve faster. Will you stir them? [Think about how or if you can treat them the same if you stir them.]

• Try the experiment again, but compare different temperatures of water. If you use a very hot temperature (or a very cold temperature) will you reach a point where it makes no difference in the time it takes the loose sugar to dissolve compared with the cube sugar? Is there a linear relation between temperature and the time it takes to dissolve the sugar (loose or cube)?

• Measure the same amount of water into two cups and put the same amount of loose sugar in one and cube sugar in the other. Don't stir them. After 1-2 minutes, put a finger in each of the solutions and then taste a drop of the water. Which tastes sweeter? Did you sample the cube sugar solution near the cube or away from it? Does it make a difference where you sample, in how sweet the water seems? [Think about the transport of material away from the sugar cube as it is being dissolved; if you stirred the solution what are you changing?] Could you see an effect of one area being sweeter than another for the case of the loose sugar? What might you have to change in your loose sugar experiment to get zones of sweetness in the cup? [Think about volume of sugar, compared to volume of water, temperature of the water, other ideas?]

8. HOW DOES DISSOLUTION AFFECT ROCKS?

Materials:

bars of soap
knives (plastic knives will work)
plastic squirt bottles[7] filled with water
sink or large pan or bucket (aluminum roasting pans work well)

[7] For sources, see section C.

Procedure:

1. Carve a groove into the edge of a bar of soap. Feel how sharp the edge of the groove is and how pronounced the cut feels.
2. Hold the bar of soap over the pan or sink and spray the carved area with water from the squirt bottle (or faucet) for several minutes.
3. Feel the edge of the carved groove now.
4. Try the same thing, but compare several kinds of soap. This would be like different types of rocks.

What happened?

Water tends to smooth and wear down sharp edges; it may also loosen inclusions. That is a normal part of the weathering of rocks to form soil, but acid rain may speed up the weathering of stone buildings or monuments that are located in polluted cities.

You experience this same effect when you open a new bar of soap and gradually see the name on it disappear as you use the soap. Tombstones are a typical place where you can see the effect of rain on carving. Tombstones provide a way to examine stones of different rock types and of different ages for the effect of rain on carving.

Stretch your mind:

• For one of your types of soap use a "lava soap". What happens when water runs over the surface of this type of soap for a long time? Does it get as smooth as the other soap? [Think about how lava soap is different from regular soap; it contains grit (sometimes volcanic ash!) to help clean better. The soap part of the bar may dissolve around those grit grains, like what happens when some stones like sandstone or limestone are exposed to rain.

• Does the temperature of the water you use affect how quickly the sharp edges and letters disappear on a bar of soap? Time it. How do you make sure that the bars start out the same or almost the same? You could try this several times or have several people try it; then you can determine the average time it takes to smooth the edges. Can you think of a way to compare

Activity 8 con't.

the smoothness of several bars of soap after they have had water on them? [These are some problems that we face trying to compare tombstone weathering rates!]

- Let one bar of soap sit in water, let water drip on another bar, and let the water flow over a third bar of soap. Which method will have the biggest effect on the bar of soap? Try a slow flow rate compared to a faster slow rate. What has a greater effect on the loss of detail of a bar of soap: water temperature, the flow rate of the water, or the way the water moves around the bar of soap?

9. DOES THIS MATERIAL REACT WITH ACID?

Materials needed:

pieces of various building materials: brick, cement (or mortar), limestone, marble[8], granite, road gravel, sea shells, etc.
household acid such as lemon juice or vinegar
magnifying glass or hand lens[5] (optional)
eyedropper (optional)

[5,8] For sources, see section C.

Procedure:

1. Choose a material and drop a few drops of acid on it.
2. Watch for a reaction; you may want to try examining it closely with the hand lens to see a reaction.
3. Try other materials with the acid.

What happened?

The materials you tested are used in buildings and structures. Rocks that contain the mineral calcite (calcium carbonate or $CaCO_3$) bubble and give off carbon dioxide gas when weak acid reacts with, and dissolves the calcite. Materials that do not contain calcite (like granite, brick, and many diabase gravels) will not react with the weak acid.

The limestone and marble are rocks that were originally formed from sea shell deposits (you may even see small shell bits in the limestone). Even though the limestone and marble were changed when they formed the rocks, their composition stayed the same as the original shell material; the limestone, marble, and sea shells all react with acid because most shells contain calcite.

Some concrete may not react very strongly with acid, but other pieces of concrete (or mortar) may react well. Concrete aggregate contains rounded pebbles and stones so it may not react as readily because the pebble and stone in the aggregate are mostly silicic (contains quartz, SiO_2) in composition. Mortar used with bricks reacts with acid while brick does not. From a preservation and maintenance perspective it is preferable that mortar reacts more readily than brick because it is easier to repoint (replace mortar around bricks) than it is to replace bricks in a wall.

Stretch your mind:

- Why choose a building stone that reacts with acid at all? [Think about the properties of different stones such as appearance and hardness. What other reasons can you think of that might cause a builder or architect to choose a particular type of stone?]

Activity 9 con't.

• Try testing sandstone for reaction with acid. What do you think will happen? [Think about what sandstone is made of and how it is formed.] Try to get sandstones from several places to test because the composition of sandstone can vary quite a bit. If a sandstone reacts with acid, can you observe any details of what part of it reacts? Why might some sandstones react and others not react? Can you observe any physical differences in sandstones that react compared to ones that don't react with acid?

• Concrete and mortar are kind of like a manmade rock. They are mixtures of several ingredients (cement, aggregate, etc). Does one component of the mixture react more strongly with acid than another component? Would it be a good idea to minimize the amount of the component that reacts with acid when making the concrete or mortar mix? [Think about what varying the proportions might do to the finished product; what is the intended use of the concrete or mortar; is it okay if the material is slightly sensitive to the acidity in rain?]

10. HOW DO ALTERATION CRUSTS GROW?

Materials needed:

- salt
- water
- small cups
- small aluminum tins (with flat bottoms)
- hot plate (or use an electric frying pan set at a very low temperature)
- stirrers (toothpicks, popsicle sticks, etc)
- magnifying glass or hand lens[5]

[5] For sources, see section C.

NOTE: This activity takes awhile to complete because at two points it must sit for several hours or overnight to give the crystals time to grow.

Procedure:

1. Examine the salt crystals by looking at them with the magnifying glass. Note their shape and approximate size.
2. In a small cup, mix salt into warm water and stir the solution. Dissolve as much salt in the water as you can; keep adding salt and keep stirring until the water looks almost cloudy.
3. Pour some of the salt water solution into two small aluminum pans. Reserve the rest of the salt solution for later.
4. Set the pans on a hot plate, which is set to a warm (but not hot) temperature. Let the water evaporate so that you get an even coating of salt on the bottom of the pan. Note where the salt first begins to crystallize, and what the crystals look like.
5. When all of the water has evaporated, remove the pans from the hot plate. Set the pans aside and let them cool completely (overnight, or several hours).
6. Pour some of the reserved salt solution onto the base of salt crystals that formed in one of the aluminum pans. Observe what happens. Let it sit at room temperature for several hours or overnight.
7. Examine the crystals in both aluminum pans. Look at the shape of the crystals, and the crystals at the center and the edge. Compare the crystals that you added the reserved solution to, with the crystals that you set aside once they formed. How do the crystals that you grew compare (in shape and size) with the salt crystals you started with?

What happened?

The salt crystals that grew when the salt solution sat on the hot plate are small because they grew fairly quickly. They also probably do not have good crystal (cubic) form like the salt grains you started with, because they grew rapidly. The crystals formed a base, like the stone of a building surface. When you added the salt solution to the base, some of the crystals dissolved, but as the solution sat on the base and slowly evaporated at room temperature, the new crystals that formed are larger and have a more cubic shape because they had time to grow

Activity 10 con't.

and a source of salt (from the base and the solution) to add to the growing crystals.

Alteration crusts form on marble and limestone buildings when the calcite (calcium carbonate, $CaCO_3$) in the marble or limestone reacts with moisture and sulfur dioxide in polluted air, to form the mineral gypsum (a hydrated calcium sulfate - $CaSO_4 \cdot 2H_2O$). Gypsum crystals grow when moisture sits on the surface of marble or limestone. The longer the stone surface stays damp without being washed by water, the more time the gypsum crystals have to grow and they will be large. Also, the more sulfur dioxide there is in the air near the stone surface, the more gypsum can form on the stone surface.

Stretch your mind:

- Try the same experiment, but use three pans of base and add ordinary water to one of the pans at step 6. Compare what happens in the pan when you add the salt solution and in the pan when you add the water. Compare the crystal size and shapes in the pans after they have been allowed to completely evaporate. [Like salt, gypsum is soluble in water, so if you put plain water on your salt base instead of the reserved salt solution, you would dissolve the salt but you may not grow more crystals. Gypsum crusts can form on any surface of a marble or limestone building, but they only accumulate (build up) on surfaces that are protected from rain or washing.]

- Try the same experiment with epsom salt instead of ordinary table salt. Compare the shape of the epsom and salt crystals; do you find there is a difference in how the crystals grow in the experiment? Does it take longer for one of the salt solutions to grow crystals?

- Many stone surfaces on buildings experience repeated cycles of wetting and drying. Try several cycles of evaporation and adding a salt solution to the pan. Do you get bigger crystals of salt with more cycles of drying and wetting?

- Try controlling the amount of salt solution that you add and changing the way in which it is added to the base. Add all of the salt solution at once to the base crystals and examine the crystals that grow. In an another pan, add salt solution in small increments that are separated by intervals in which you allow the salts to dry out (make sure that in the end you have added the same amount of salt solution to both pans). How do the crystals in the two pans compare?

- What happens if there is a "wind" on your sample while it is drying? [On buildings, we see differences in the shape of the gypsum crystals that form in areas that are exposed to wind compared to areas that are likely to dry more slowly.] Try devising an experiment to let a sample dry in a wind and one in still air. [Do you think you might see more of an effect if you use epsom salt crystals (which are rectangular) rather than salt crystals (which are cubic)?]

11. WHY DO PARTS OF SOME BUILDING SURFACES LOOK BLACK?

Materials needed:

- black construction paper
- wax paper, overhead transparency sheet, or plastic wrap
- chalkboard eraser with chalk dust on it
- magnifying glass or hand lens[5]

[5] For sources, see section C.

Procedure:

1. Pat the dusty eraser on the black construction paper.
2. Pat the dusty eraser on the wax paper or overhead transparency.
3. Observe the two surfaces.
4. Try to rub or shake the dust particles off both papers.
5. Use the magnifying glass to observe the particles and the paper surfaces.

What happened?

The construction paper is made of many small fibers, the transparency sheet is very smooth. The fine particles of chalk dust are trapped by the rough, fibrous surface of the construction paper. Shaking the construction paper may remove some of the chalk dust, but not all of it will come off. The dust particles stick to the plastic sheet at first, but they can be rubbed off of the smooth surface.

Dirt that is brought to building surfaces by wind sticks more easily to rough surfaces of stone. If it rains, the dirt may be washed off, but if the stone surface is protected from rain or if the surface is very rough the dirt will stay on the stone surface. When gypsum alteration crusts form on marble and limestone buildings surfaces, the crystals of gypsum make a rougher surface than the original surface of the stone. The rough surface of new crystals acts as a trap for dirt particles and the alteration crusts become black even though gypsum is a white mineral.

Stretch your mind:

• You probably had to rub the chalk dust off the overhead transparency (rather than just shaking it). Since the transparency has a smooth surface, what force do you think held the fine dust particles to the surface? Would that force also work if you hold the sheet up against a wall (vertically) when you patted the chalk dust on it?

• Could you make a part of the black construction paper look white just using the eraser and chalk dust? Watch the paper color as you add chalk dust, when you think the paper looks white (or lighter) does it make a difference how closely you look at the paper?

Activity 11 con't.

• Could you devise a "dirtiness" scale using the paper and chalk dust? One of the concerns for people maintaining buildings, is to define "clean"; they must decide when a building should be cleaned, and how much work (chemicals, scrubbing) should be done to make the building "clean". Would you want a very old building to be so clean that the stone looked like new? (Would it still seem like an old or historic building then?)

12. CAN YOU CLASSIFY A ROCK BY ITS GRAINS?

Materials needed:

- jigsaw puzzle
- Rice Krispy treats, Planters Peanut Candy Bar, or Perler bead item[9]
- several samples of sandstone, granite, marble[8], and other rocks in which you can see the grains fairly easily
- magnifying glass or hand lens[5]

[5,8,9] For sources, see section C.

Procedure:

1. Look at the jigsaw puzzle and its pieces. How do the pieces fit together? Look at the edges of the pieces. What kinds of shapes are the pieces?
2. Look at the Rice Krispy treats, Peanut candy bar, or Perler bead piece. Look at the pieces that make up the item. What kinds of shapes are pieces? Look at the edges of the pieces. How are they held together?
3. Compare the jigsaw puzzle and its pieces with the Perler beads (or treats) and its pieces.
4. Look at the various rock samples and examine the grains that make up the sample. Does the sample belong with the jigsaw puzzle group or with the Perler bead/treat group?

What happened?

The jigsaw puzzle is held together the way an igneous or metamorphic rock is held together. The pieces (grains) are irregularly shaped and they "lock" together to form the puzzle or rock. The Perler beads, Rice Krispy treats, or candy bar have rounded grains that are fused or held together by a cement (or matrix) the way the grains in a sedimentary rock are held together.

An igneous rock is formed by grains crystallizing from a melt (from magma). As the melt begins to cool, crystals start growing at various points. As the melt continues to cool, the grains grow together until they meet and the neighboring crystals grow up against each other to form a locking network of crystals, much like the pieces of a jigsaw puzzle. Granite is an example of an igneous rock that is used in buildings.

A metamorphic rock also has a crystalline structure. A metamorphic rock forms when a rock is heated and (or) squeezed by geologic processes. The grains in the rock may change form and recrystallize as they are exposed to the changing conditions. As the grains react, they form a network of crystals and grains that is different from the grains in the original rock because the boundaries and edges of the grains have changed. These grains also form an interlocked network much like pieces of a jigsaw puzzle. Marble and gneiss are examples of metamorphic rocks that are used in buildings.

A sedimentary rock is formed when sediments (portions of rocks that are broken up and carried by water or wind) are deposited in layers. As the layers accumulate, the grains in the layers are compressed by the weight of the layers above them. Water that trickles through the layers of sediment reacts with the grain edges and the whole is cemented together. In a sedimentary rock the grains are held together by a matrix or cement. The grains often look rounded because the rocks are formed from pieces that were carried some distance before the rock formed. Sandstone and limestone are examples of sedimentary rocks that are used in buildings.

Stretch your mind:

- The grains of a rock can tell you something about how the rock formed. Many of the grains in sedimentary rock appear rounded, could you have a sedimentary rock with angular grains? How would such a rock form? [Think about the transport of sediments to form a sedimentary rock; how far or how long would angular grains have traveled?]

- Compare a coarse grained sedimentary rock with a fine grained sedimentary rock (like a sandstone with a siltstone). What can you tell about the type of place that these rocks formed? Where the grains transported by wind or by water? If they were transported by water was the water moving rapidly (like in a river) or was it a calm place (like in a lake). Walk along a creek and see if you can see clusters of coarse and fine grained sediments. Observe where they are in the creek and how the water seems to move around those areas. Can you suggest how the grains have been sorted? Where or how else could sediments be sorted by size?

- Some igneous rocks have very large crystals and some have small crystals. The grains in igneous rocks have not been transported like those in sedimentary rocks. What do you think the grain size in an igneous rock tells about the conditions under which the rock formed? [Remember igneous rocks form from a melt; think about how the crystals would grow as the melt cools.]

- Have you ever seen a rock that has rounded and angular grains in it? See if you can find one. Try to explain how the rock formed with a mixture of grains like that. [Think about what type of rock it might be and how the main rock types (sedimentary, igneous, and metamorphic) form.]

C. Sources for Materials

[1] Pocket pH meters are available for about $40 each from scientific supply companies (such as Cole-Parmer); they operate using small batteries and are fairly easily used by elementary students. Some require calibrating solutions (also supplied by the companies); others that may be a little more expensive do not require calibrating solutions.

[2] Litmus papers or strips are fairly inexpensive and can be purchased from scientific supply companies or possibly from some educational toy or nature stores. Most litmus papers just show whether a solution is an acid or a base, but there are some available that can indicate a specific pH range.

[3] Indicator solution can be made by chopping up a red cabbage, pouring hot water over it and letting it sit for about 45 minutes. Drain the solution from the cabbage, discard the cabbage and you will have a purple-red solution. If an acid is added to the solution, the solution will turn red, if a base is added to the solution, it will turn blue. The solution will keep for several weeks. (It does smell slightly like cabbage.)

[4] Muriatic acid is a fairly strong acid that is sometimes used to clean bricks. It may be available at a hardware store.

[5] Pocket hand lenses are useful for examining small details. Most magnifying glasses have only a 3x magnification that is okay, but a 10x is better for examining grains and features in rocks. Hand lenses (or loupes) are available from scientific supply companies, and may also be available from stores whose emphasis is on educational or nature items.

[6] Samples of measured rainfall pH values for various locations in the United States are shown at the end of this section. Monthly data of rainfall pH is available from: National Water Information Clearinghouse 1-800-426-9000 at the U.S. Geological Survey, or contact the NADP/NTN Coordination Office, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO 80523. Local rainfall pH information for where you live may be obtained from your local weather service, or from local agencies that monitor pollution like county or state environmental protection agencies, or local health departments.

[7] Plastic wash bottles are available from scientific supply companies, but equally satisfactory bottles may be available at a drug store. Another possibility is to use old dish detergent bottles. (Pouring water from a cup over the soap in activity 7 also works but is more tedious than squirting it.)

[8] Marble chips may be available from garden supply stores (used for decorative landscaping). Marble and other stone samples may also be available from a place that supplies stone for landscape, fireplace, or decorative work.

Sources, con't.

[9] Perler beads are small plastic cylinders with holes in the middle that are used in children's craft kits. (The beads are placed on a form that has spikes to hold the beads in place; when the design is assembled the beads are fused together with an iron to form a network of beads in one piece.) The kits are available in toy stores.

[10] Small disposable aluminum tins (used for weighing) may be available from a scientific supply company (like PGC Scientific). You can also use small aluminum pie tins.

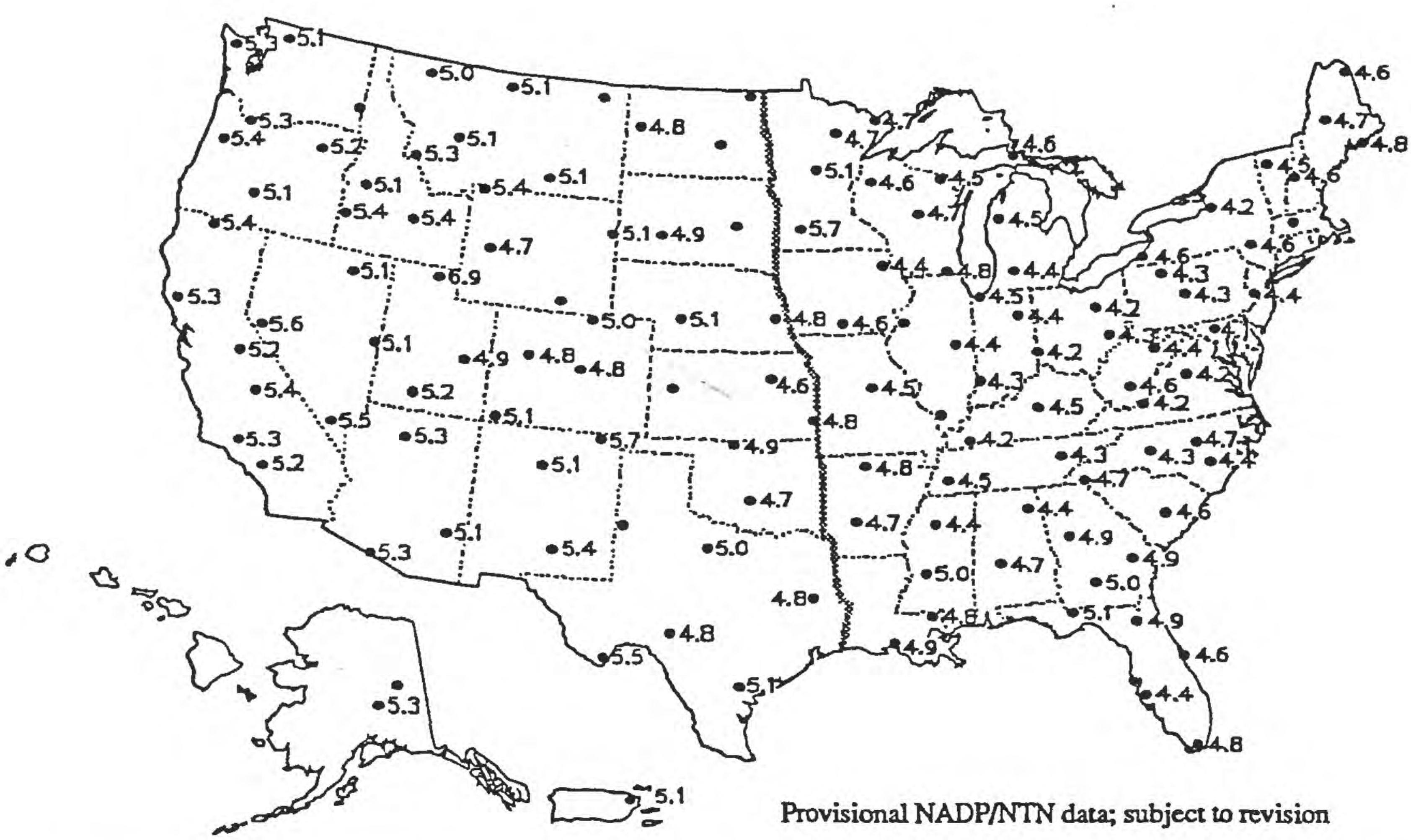
[11] Science kits for testing acid rain may be available in educational toy stores or possibly in a store that emphasizes nature study. You might also try an educational science supply company.

Monthly Acid Precipitation Measurements

The United States Geological Survey (USGS) in cooperation with Federal, State and private organizations, collects and analyzes water samples from more than 100 sites across the nation, including Alaska and Hawaii. This network of sites is part of the National Acid Deposition Program / National Trends Network (NADP/NTN). A list of the sites comprising the total network and information about the sites is available from the NADP/NTN Coordination Office, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO 80523, Monthly pH of precipitation data from the network are available on the internet through the USGS home page at: http://www.usgs.gov

The next four pages are samples of monthly data that were released in 1994. The four months shown could be used to evaluate seasonal differences as they are for the periods: January 24 - February 20, April 25 - May 22, July 25 - August 21, and September 26 - October 23. The maps could be used for exercises contouring the data, or the data could be taken from the maps and graphed in various ways (compare the variation in several states within one period, compare the variation in one location over the four periods of measurement). Discussion of the graphs could focus on variations, are they significant, are there any particular seasonal or geographic trends? These might also be used in comparison with more recent (or older) data; or for comparisons with locally measured rainfall pH's.

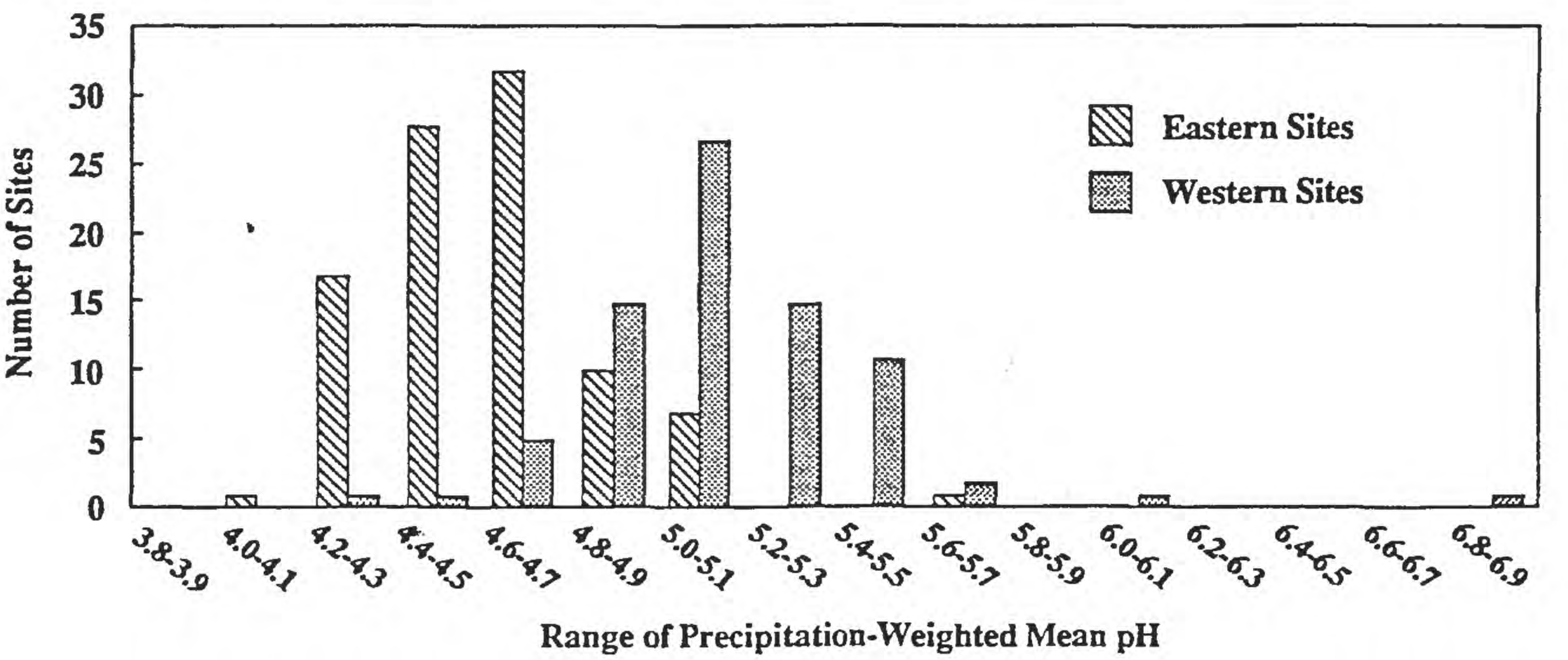
pH of Precipitation for January 24-February 20, 1994



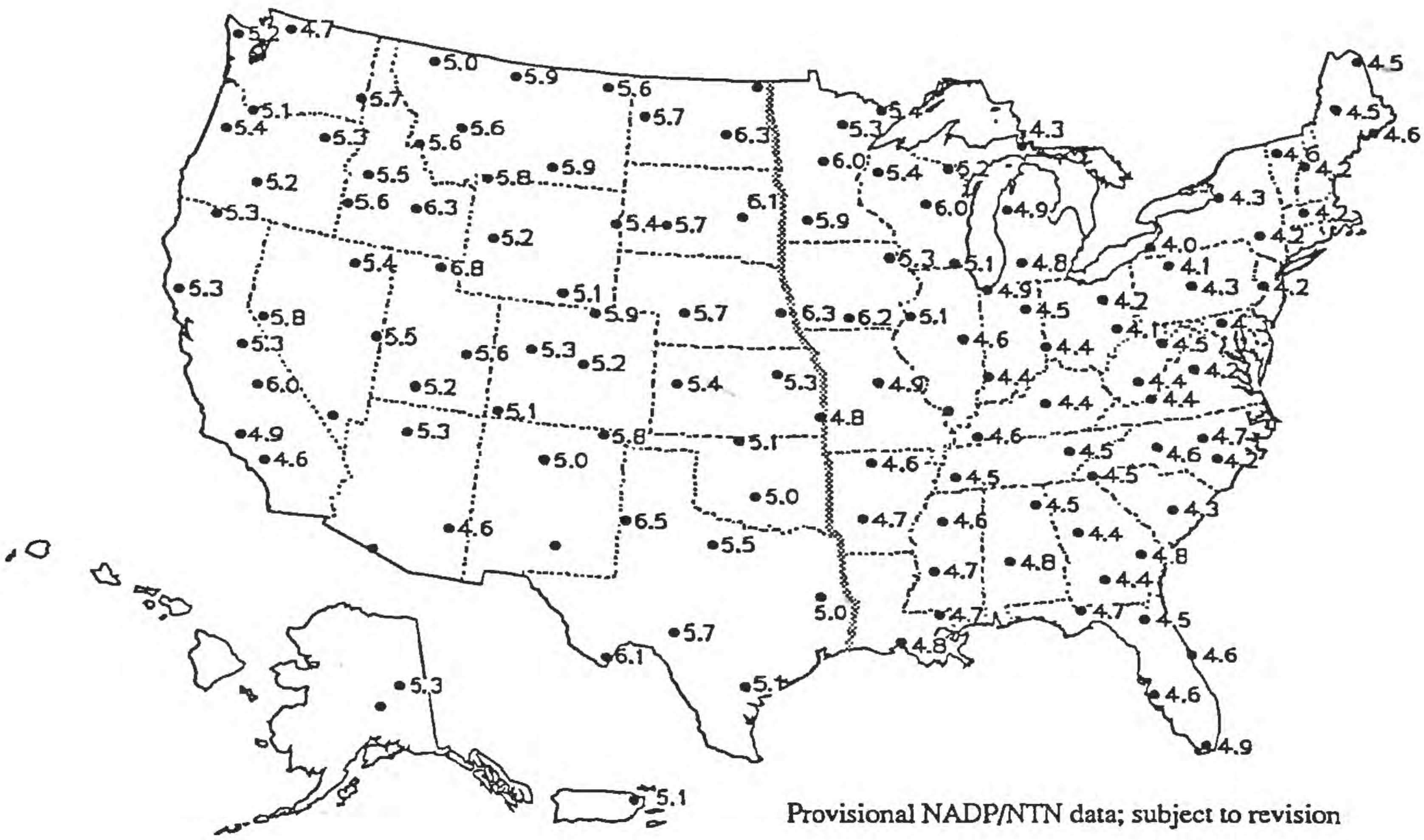
Current pH data shown on the map (• 4.9) are precipitation-weighted means calculated from preliminary laboratory results provided by the NADP/NTN Central Analytical Laboratory at the Illinois State Water Survey and are subject to change. The 129 points (•) shown on this map represent a subset of all sites chosen to provide relatively even geographic spacing. Absence of a pH value at a site indicates either that there was no precipitation or that data for the site did not meet preliminary screening criteria for this provisional report.

A list of the approximately 200 sites comprising the total Network and additional data for the sites are available from the NADP/NTN Coordination Office, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO 80523.

Distribution of precipitation-weighted mean pH for all NADP/NTN sites having one or more weekly samples for January 24-February 20, 1994. The East/West dividing line is at the western borders of Minnesota, Iowa, Missouri, Arkansas, and Louisiana.



pH of Precipitation for April 25-May 22, 1994



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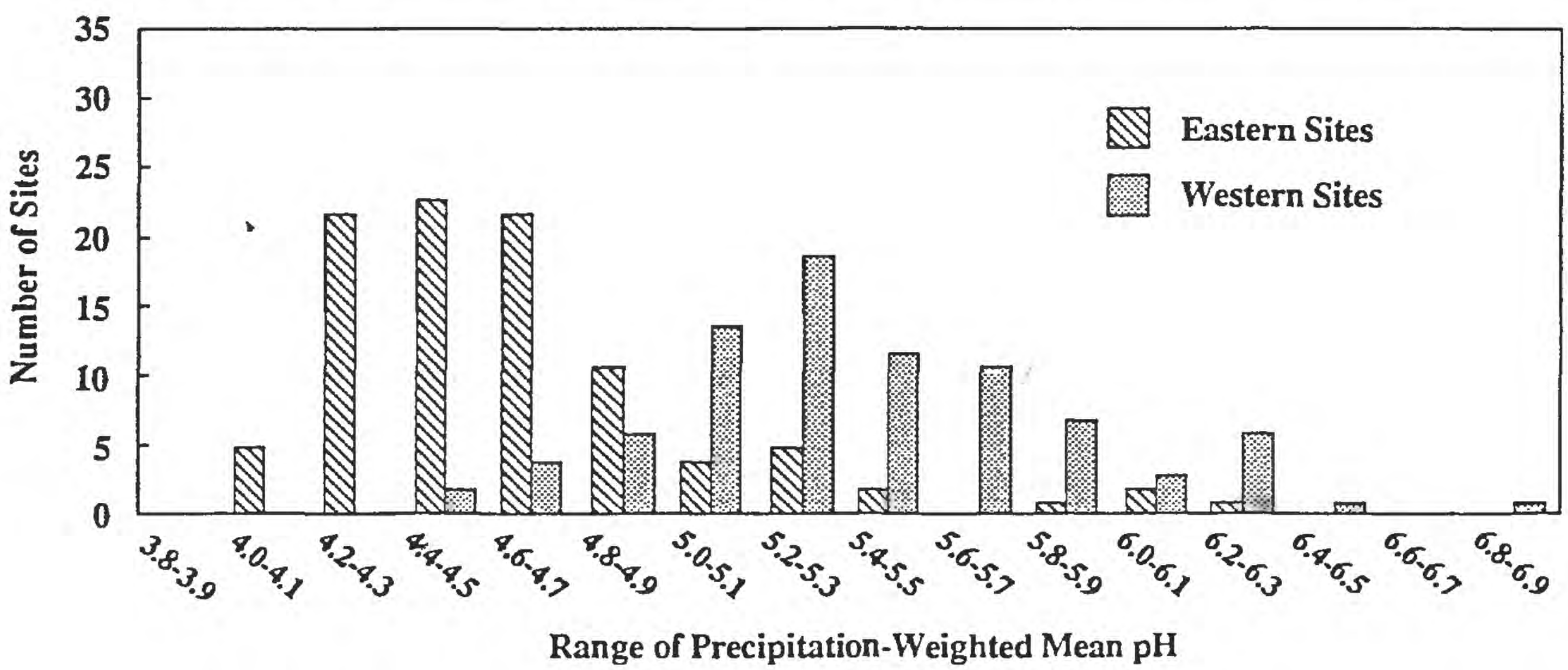
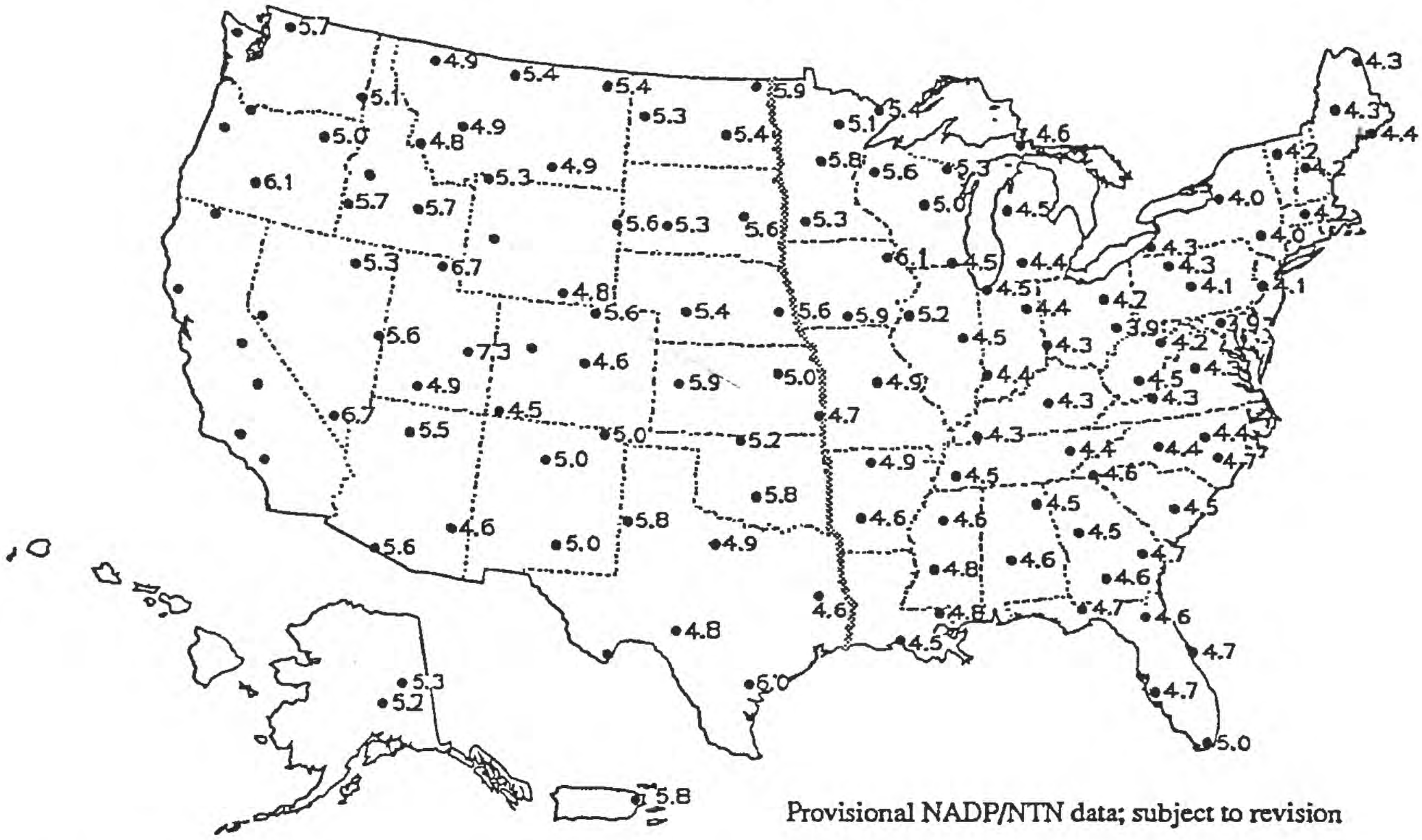
Distribution of precipitation-weighted mean pH for all NADP/NTN sites having one or more weekly samples for April 25-May 22, 1994. The East/West dividing line is at the western borders of Minnesota, Iowa, Missouri, Arkansas, and Louisiana.



pH of Precipitation for July 25-August 21, 1994



Current pH data shown on the map (• 4.9) are precipitation-weighted means calculated from preliminary laboratory results provided by the NADP/NTN Central Analytical Laboratory at the Illinois State Water Survey and are subject to change. The 128 points (•) shown on this map represent a subset of all sites chosen to provide relatively even geographic spacing. Absence of a pH value at a site indicates either that there was no precipitation or that data for the site did not meet preliminary screening criteria for this provisional report.

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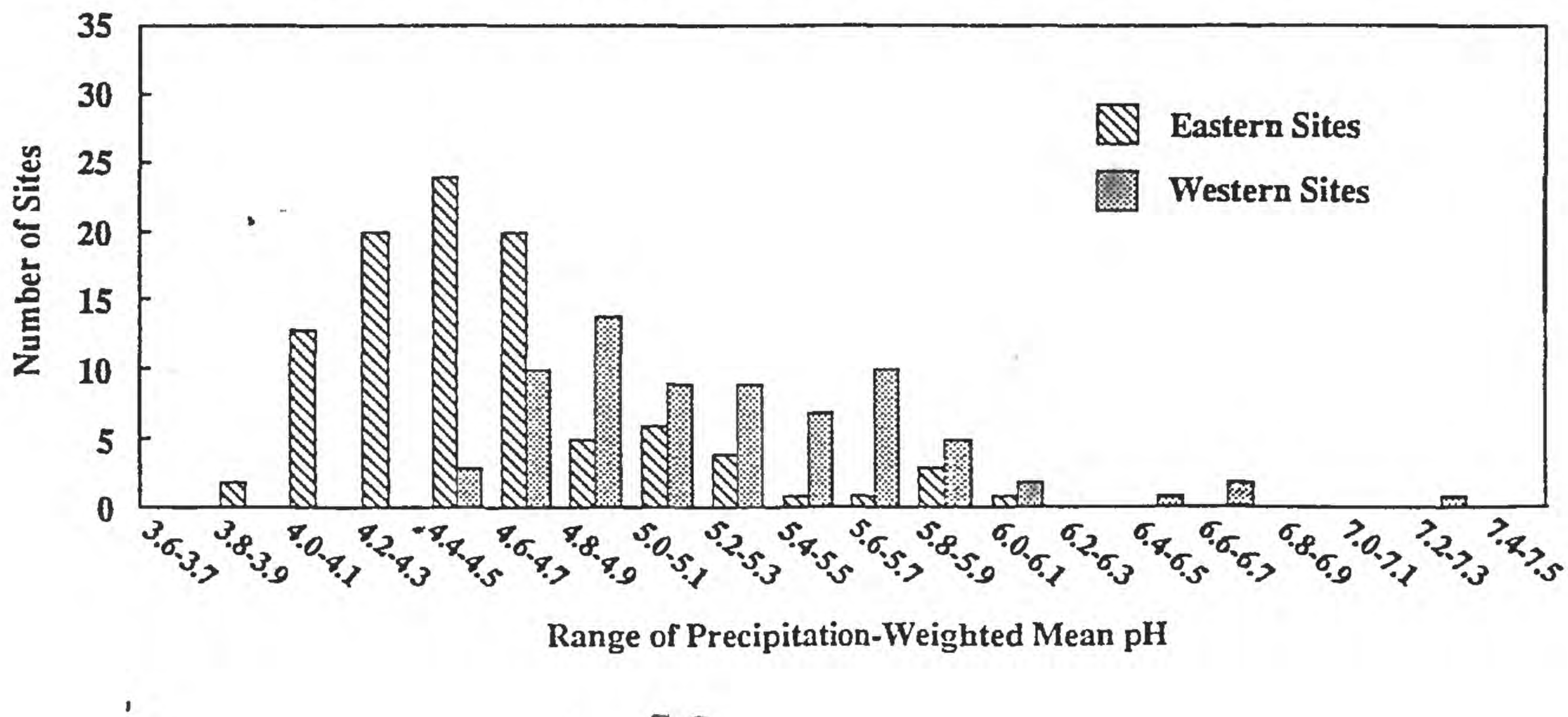
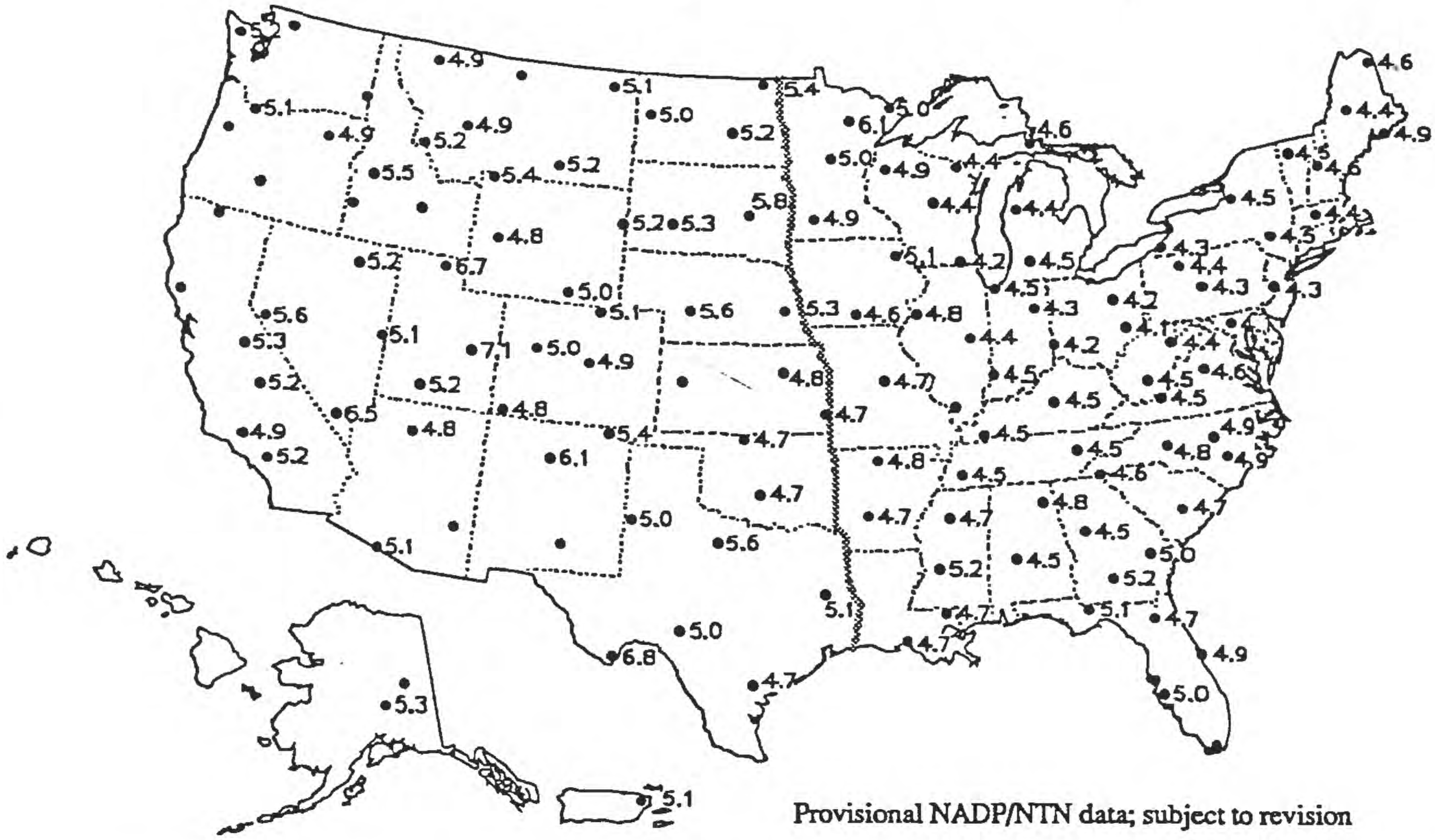
Distribution of precipitation-weighted mean pH for all NADP/NTN sites having one or more weekly samples for July 25-August 21, 1994. The East/West dividing line is at the western borders of Minnesota, Iowa, Missouri, Arkansas, and Louisiana.



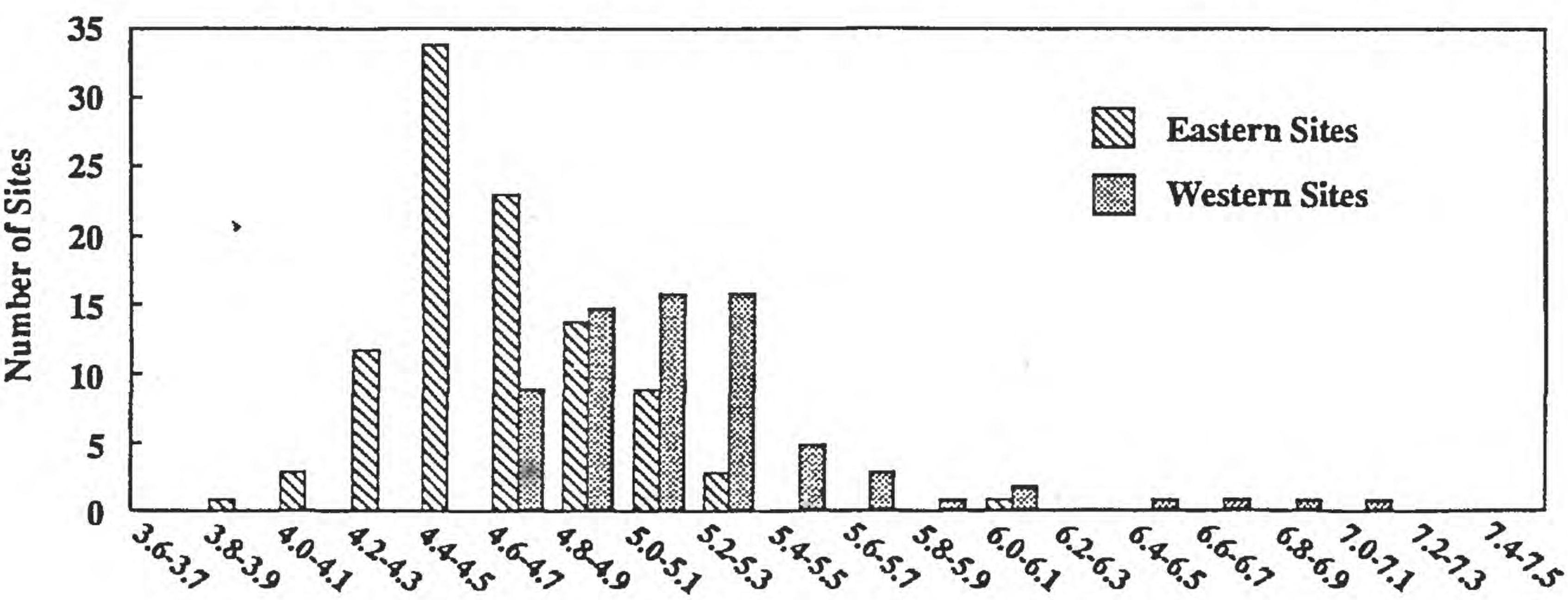
pH of Precipitation for September 26-October 23, 1994



Current pH data shown on the map (• 4.9) are precipitation-weighted means calculated from preliminary laboratory results provided by the NADP/NTN Central Analytical Laboratory at the Illinois State Water Survey and are subject to change. The 128 points (•) shown on this map represent a subset of all sites chosen to provide relatively even geographic spacing. Absence of a pH value at a site indicates either that there was no precipitation or that data for the site did not meet preliminary screening criteria for this provisional report.

A list of the approximately 200 sites comprising the total Network and additional data for the sites are available from the NADP/NTN Coordination Office, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO 80523.

Distribution of precipitation-weighted mean pH for all NADP/NTN sites having one or more weekly samples for September 26-October 23, 1994. The East/West dividing line is at the western borders of Minnesota, Iowa, Missouri, Arkansas, and Louisiana.



D. In Your Community

There are many ways to use the resources of your local community to explore acid rain and its effect on buildings. Keep in mind that not all stone deterioration comes from acid rain. People, plants, and birds can affect building durability as much (and sometimes more) than rain, wind, and temperature cycles that are part of the normal weathering cycle. There may be many explanations for the variations and deterioration that you find. Part of the adventure of looking, is thinking of reasons and trying to determine causes or factors for what you see.

Test or monitor the rain acidity in your community

Devise a method to measure rain acidity; you might be able to use litmus paper[2], a pH meter[1], or a pH testing kit[11]. You may need to be sure that your measuring method is sensitive enough to see the variations (or range of acidity) that is typical for your community.

• Try to measure the rain pH over an extended period of time to look at the variations. Also, keep track of how much rain fell during each 'rain event' that you measure. [If you have an approximately constant level of pollution, but different volumes of rain falling, small rains will be more acidic than large rains because they are less dilute. How will you define one "rain event'?]

• Can you establish a local network of sites to measure the rain pH in your community? What kind of places would you try to choose to see if there is any variation based on location? [Think about wind and storm direction, local sources of air pollution, proximity to automobile or truck exhaust.]

• Do you measure the rain after the storm has ended? Do you measure it at the beginning? Do you measure it after a certain amount of rain has been collected each time? There are many things you can vary, and many things you should think about keeping constant in order to compare your measurements or to test your ideas. [Is the beginning of a rain storm more acidic than the end?] Do you measure the pH right at a specific site, or do you collect a sample and measure it later, at home or school? [Do you think where or when you measure acidity might make a difference? Think about activity #5!]

• Find out if rainfall pH is recorded in your community by the local weather service, news media, or environmental agency. How do their measurements compare with yours? Do they measure in one location only or in several?

• Contact the National Acid Deposition Program / National Trends Network (NADP/NTN)[6] to find out about the nationwide network that monitors, analyzes, and releases data about rain pH collected from approximately 200 sites nationwide.

Rain and streams

Test or monitor (over a period of time) the acidity of the local streams (and or ponds or lakes) in your community.

• How does the stream acidity compare with the acidity or the rainfall? Think about the timing of your measurements if you are comparing rain and streams. Could the stream be carrying water from a source with very different pollution levels, very different rocks in the stream bed, or could you be seeing the effect of a rain storm that added to the stream flow, but did not reach you as rain?

[1,2,6,11] For sources, see section C

• What type of rocks (or soil) is typical for your area, do you think it might influence the stream acidity? [think about activity #4.] Other factors could strongly influence measurements in streams: is there substantial runoff to the streams from areas treated with fertilizer or other chemicals? Is there any connection between the local sewer or storm drain system and the streams that you are measuring?

• Are you measuring stream acidity where the water is fairly still or where it is flowing swiftly? If you are measuring in a lake or pond, are you measuring (or making comparisons) where the lake is fed or drained?

Graveyards

Graveyards are a good spot to start looking at various stones and their durability. The stones have dates, and the legibility of the inscriptions gives some idea of the stone's durability. Some things to think about as you explore this resource:

• How many different varieties of stones can you find in the cemetery?

• Are the stones of one type mostly from a certain time period? [try a graph to show age of the stones and type of rock used]

• Are the oldest stones the same type of rock as the local rocks in your area? [local stones were frequently used in some of our oldest buildings; local stones may be less expensive because of lower transportation costs.]

• Do you see any stones with old dates that are in much better condition than other stones from that time? [Sometimes grave markers are placed long after a person has died!]

• Can you think of a way to measure the inscriptions in the stones so that you can quantify their weathering? How will you account for variations in the original carving depths? If you measure a lot of stones will you get more consistent results? (think statistics!)

• If there is more than one cemetery in your community; how do the stone types, durabilities, and ages compare? Do you think the variations in durability might come from the location of the cemetery in the community? (think about pollution sources, rain, wind, and storm directions, and don't forget to consider what maintenance the cemetery may have had!)

Buildings

Buildings and monuments in your town may be made of stone. Look especially at older buildings, and check out your city or town hall, post office, and churches. Notice the trim, windowsills and doorsteps, especially on older buildings where stone may have been used as a trim on a brick building. Monuments and statues are great places to see stone weathering; often bronze statues have a stone base.

• Can you find signs of dissolution on the exposed parts of stone buildings and monuments? Look for: roughened surfaces, rounded edges, loss of detail in carved features, inclusions that stand above or below the surface of the stone, etc. Compare these areas with similar areas that are sheltered or protected from rain or regular washing.

• Can you find signs of alteration on the sheltered parts of stone buildings and monuments? Look for: blackened surficial encrustations, stone that has crumbled in an area that is not regularly exposed to rain or washing.

• Look for signs of cleaning on older buildings. If it has been cleaned, do you think the cleaning helped, or could it be a cause for more harm to the building? [think about whether the surface is rougher now than before: it might attract more dirt now! Do you think the cleaning might have caused the stone to lose some of its original detail or sharp edges?]

• Plants, birds, and people can also add to the deterioration of stone in buildings and monuments. Can you find any signs of this? [Look for algae or moss in the cracks, and between grains, ivy or other plants attached to the stone surface, bird droppings, graffiti, poor repairs, etc.]

• Watch the way rain flows over statues, or some parts of buildings during a storm. How do you think this influences the deterioration that you see (or might eventually see) in the stone? Are some parts of the stone more likely to be worn from the rain than others? Do you think the wearing down of the stone is probably due to acid rain or can you think of some other factor? [Stone weathers by chemical, physical, and biologic processes. Can you find signs of these processes, or the agents that might cause them?]

• Stone used in buildings, like other things, is subject to people's taste and fashion. In the early part of this century stone was widely used, but its used declined when other materials (like concrete) became more available. Recently stone is being used again in some construction. Look for stone used in new buildings as well as old. How do the types used compare? Why would they choose the types of stones that were used? [Sometimes a stone is considered special: marble is often used for monuments or special buildings; sometimes stone (or other material) used in a modern building is selected to be harmonious with the older buildings nearby...]

• Stone use in a city might correlate with geographic and economic factors; how do the ages of the buildings and types of stone relate to the growth and history of the city?

Local rocks

Find out about the local rocks in your community. What type of stone is under your feet?

• Contact the state geological survey to get information about the local geology. Visit local, state, or national parks in your area for information.

• Find out if there are any quarries nearby. What is the stone used for? Do you see it used in your community (as road gravel, building material, etc.) or is it shipped for use elsewhere? If material is transported for use elsewhere, is it processed in some way first?

• Sometimes communities have traces of old quarries that were used when the area was first settled. Stone may have been used for building foundations, fences, or for processes like making coke or lime to aid local manufacturing or industry.

• Do you see the local rocks reflected in stone use in your community? Besides buildings and cemeteries, look at the curbs in your town, are there any old stone fences?

E. Resources for Background Materials and More Information

Acid Rain and our Nations Capital: A Guide to Effects on Buildings and Monuments

A 1995 U.S. Geological Survey publication in the INF- series (free). Contact the U.S.G.S. Earth Science Information Center 507 National Center, Reston, VA 22092; (703) 648-6045 or 1-800-USA-MAPS.

Information about acid rain:

Internet access to US Geological Survey Home Page -- http://www.usgs.gov [information about monthly pH of precipitation for United States is available on the internet]

National Water Information Clearinghouse -- 1-800-426-9000 or write to: National Water Information Clearinghouse, 423 National Center, Reston VA 22092

USGS Earthfax -- (703) 648-4888 section 3 has water resource information, including information about the USGS Water Home Page on Internet, and a fact sheet on acid rain

NADP/NTN Coordination Office, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO 80523

National Acid Precipitation Assessment Program, 1110 Vermont Ave., N.W., Suite 810, Washington, DC 20005

Publications on acid rain:

The Acid Rain Story; Environment Canada, Information Directorate, 10 Wellington St, Ottawa, Ontario, K1A OH3 Canada

Acid Rain; U.S. Geological Survey Water Factor Sheet, U.S.G.S. Open File Report 87-399, 1987.

Acid Rain: A Student's First Sourcebook; U.S. Environmental Protection Agency, Office of Environmental Processes and Effects Research, Washington, DC 20460 EPA/600/9-90/027; July 1990 [copies available from: Office of Research and Development, Distribution Unit, U.S. Environmental Protection Agency, Cincinnati, OH 45268]

Check with the following organizations for information:

National Wildlife Federation, National Audubon Society, Electric Power Research Institute