PALEOCLIMATE

Teacher's Manual

Table of contents

Subjects:

Earth Sciences

Duration:

Two class periods (~60 min.)

Class size:

10 - 30 students

Summary

Overview:

Students are introduced to methods that palynologists use to interpret past vegetation and associated climatic conditions. By introducing students to basic concepts such as biostratigraphy, proxy data, and analog analysis, they will be able to reconstruct the vegetation and climate histories of the southern Kuril Islands over the last ~8,000 radiocarbon years. Students will explore: 1) the relationship between modern climate and modern vegetation; 2) the relationship between modern and ancient vegetation using pollen data; and 3) the application of these relationships to infer past climatic change. Through the exercises the students will: 1) learn how to apply the basic principles of palynology; and 2) improve their appreciation of the dynamic nature of the environment (i.e., that modern ecosystems and climate patterns are not static but can change dramatically over time). Reconstructing paleoenvironments is a key tool that aids archeologists in better understanding possible human-environmental interactions, such as how changes in past environments might have influenced human activities.

Objectives:

- To teach students how palynologists infer past plant communities and how paleovegetation reconstructions act as proxy measurements of past climate.
- To engage students in the analysis and interpretation of biostratigraphic data.
- To allow students to explore the relationship of vegetation types to broader climatic conditions.
- To engage students in the examination of how past conditions may help us understand possible responses of the environment to future climate changes.

Material Included in the Box:

- Slide show illustrating the basic principles of palynological analyses.
- Handouts with modern vegetation and climate data and paleo-data from the Kuril Islands to be used in discussion and exercises.
- The scientists' interpretation of the data provided in the exercises.

Vocabulary

Analog analysis:

A method for analyzing and interpreting paleoenvironments that can be based on either statistics or qualitative observations. The basic principle is that of uniformitarianism — the present is the key to the past. In our exercises we rely on defining qualitative modern pollen-vegetation-climate relationships to aid in interpreting past changes.

Biostratigraphy:

The spatial relationship between biological indicators found in sedimentary deposits. These relationships have a time component: in unmixed deposits the lowermost sediments are the oldest and uppermost units the youngest.

Conifers/Coniferous:

Plants with needle-like leaves.

Deciduous:

Plants that shed there leaves in winter, often having broad leaves. Note that larch, a conifer, is deciduous.

Deposit:

Sediment put down on the earth's surface in the past either by natural or human action. An archaeological deposit was created by people in the past. It can include soil, artifacts, features, or other traces of human activity that signals anthropogenic (human) involvement in the deposition process. Deposits usually form layers or "strata" that stack up horizontally like a layer cake with the oldest at the bottom and the youngest at the top. As a result the oldest archaeological deposits (or geological deposits, such as volcanic ash layers) are found below younger ones, allowing us to develop histories of events by studying the stratigraphy. Even so, material within deposits can be out of place (for a number of reasons, like the action of burrowing animals) resulting in the possibility of misinterpretation of the stratigraphy of a site or excavation. (see Stratigraphy Module)

Gradient:

Change in one variable with respect to another variable. In palynology this change is always in respect to geography or spatial distribution, for example a temperature or a vegetation gradient reflects changes in climate or vegetation over a specific region.

Paleo:

Prefix indicating "past."

Palynology:

The study of pollen and spores. The applications are widespread from providing pollen counts during allergy season to interpreting paleoenvironments. A palynologist is a specialist in the field of palynology.

Pollen:

Microscopic grains produced by higher plant forms (angiosperms and gymnosperms; flower and seed producing plants), containing male genetic material required for sexual reproduction. A dusting of pollen is often seen on surfaces as a yellowish powder during the flowering season. Note: pollen is both the singular and plural form. It is incorrect to refer to "pollens."

Pollen assemblage:

The combination of pollen and spores that characterize a specific pollen zone in a diagram or a specific vegetation type in modern studies.

Pollen diagram:

The basic tool for interpreting palynological records. It consists of an x-y plot of pollen and spore values vs. depth or time. Values, plotted along the x-axis, are usually percentages but can also represent pollen accumulation rates. The shallowest depths and youngest ages appear at the top of the y-axis.

Pollen spectrum/spectra:

Percentages of all pollen and spores from a single (spectrum) or multiple (spectra) sediment samples. Pollen assemblages consist of 2 or more spectra.

Proxy data:

A type of data that is used as a substitute measure for another parameter. For example, current temperatures can be measured using a thermometer. However, it is impossible to directly measure paleotemperatures because paleothermometers do not exist. Therefore, we use another data type or "proxy" (e.g., pollen) which has a known relationship to temperature (e.g., different vegetation types have different temperature requirements) to infer past changes.

Radiocarbon date:

A numerical date which approximates time of death of an organism (plant or animal) based on the amount of radioactive carbon (prone to decay) that remains in it. Radiocarbon dates are often used by earth scientists and archaeologists to understand the time lines of events, geological or cultural, respectively.

Spore:

A microscopic grain produced by lower plant forms (cryptograms) and containing genetic material for asexual reproduction. Unlike the higher plants, cryptograms have no true flowers or seeds.

Years BP (years before present):

The amount of time which has passed between the occurrence of an event and the year A.D. 1950.

Zone:

1) The combination of plant communities into a unique vegetation type that has a regional geographic distribution and is associated with specific climatic characteristics;
2) used in pollen diagrams as a basic unit for interpretation; each pollen zone represents a change in vegetation type and must include at least 2 pollen spectra.

Background Information

Knowledge of past landscapes and climate is an important element of interdisciplinary studies of the past. Although these types of investigations are valuable in and of themselves, they can provide essential information to archeologists who wish to better understand possible human-environment interactions. Such research also can provide useful insights into questions related to future climates and likely landscape responses (e.g., by looking at warm periods in the past, palynologists hypothesize that arctic tundra will disappear and be replaced by birch, poplar, and larch forests).

Many types of paleoenvironmental data are used to unravel the past. Here we focus on palynology, the study of microscopic pollen and spores (to simplify we will use only pollen in our discussion and examples). By taking cores from organic deposits, such as lakes or peats, palynologists can trace the vegetation history of a region by counting the numbers of pollen grains. Their percentages reflect the plants, and thus plant communities, that produced them. Unfortunately, there is not a one-to-one relationship between plants and pollen, although the greater the relative percentage of a given pollen type, the greater the number of plants on the landscape. Therefore, the first step in reconstructing the paleovegetation is determining the characteristic pollen "signature" that identifies modern vegetation types. The modern pollen rain is sampled from the most recent deposits in a lake or peat, for example from a 1-cm^3 specimen of sediment taken from the mud-water interface of a lake. The pollen percentages are plotted and then can be evaluated qualitatively (e.g., by comparing the pollen assemblages to a map of vegetation types) or using statistical analyses. Once the modern pollen-vegetation relationships are established, then paleovegetation can be inferred by searching for analogs of the ancient pollen samples to modern ones. Often this is done qualitatively, as we will do in our exercises, but standard statistical analyses are also used.

Because paleoclimatologists do not have thermometers or rain gages buried in their sites, they must rely on proxy data (i.e., data that indirectly reflects climate). Pollen is one of the best proxies because: 1) vegetation types are strongly controlled by climate; 2) the relationship between modern pollen assemblages and differing vegetation types is well established; and 3) pollen is an abundant and ubiquitous fossil. The first step for inferring paleoclimate is to determine the relationship of present-day vegetation and climate in the study region. This can be done by comparing gradients in maps of temperature or precipitation to vegetation maps (qualitative method) or by assigning modern climate values to the modern pollen sites (quantitative method). Next the fossil samples are counted and plotted in a pollen diagram. Based on the pollen assemblage, scientists then can interpret the past climate either qualitatively (e.g., cooler and drier than present) or with numerical values taken from the modern climate assignments.

The pollen data used in this module are not from actual sites cored during the Kuril Biocomplexity Project. However, the vegetation and climate maps are accurate. The pollen trends have been exaggerated somewhat to aid student interpretation, but they are accurate in showing the dynamic nature of past ecosystems, indicating that modern landscapes and climate conditions have not persisted throughout ancient times.

Introduction

The exercises are designed to allow students to explore basic concepts of ecology and climatology as applied to interpreting past environments. They will learn how to describe, compile, and interpret primary data spatially (across the Kuril Islands) and temporally (through tracing trends in vegetation and climate over the past 8,000 years). The lesson is divided into 2 parts, the first part dealing with modern environments and the second with paleoenvironments. The first part acquaints students with the vegetation and climate of the Kuril Islands and several palynological procedures (e.g., coring, sample analysis). The second part focuses on interpretation of a pollen diagram with associated vegetation and climate histories. The goal of these exercises is to illustrate how paleoenvironmental scientists approach problem-solving when trying to reconstruct vegetation and climate histories.

Activity 1: Climate and Vegetation; Modern Calibration

Students learn about the connection between climate and vegetation.

Warm Up:

Get the class to brainstorm about past environments. Would they expect past environments to be similar to today? An example may be the last ice age when Puget Sound and western Washington were covered in thick glacial ice. Ask students what they know about that period in the history of the state (how thick was the ice? How far south did it reach? What animals were around?). Introduce students to the idea that climate and landscapes are dynamic and changing. You may also discuss whether knowledge of past environments is of any use for understanding possible future climate and landscape changes. Have students come up with examples.

Procedure:

1. Use the slideshow included to introduce the following concepts:
    a. modern environmental analogs (the present is the key to the past)
    b. proxy data (we can not directly measure past temperatures or precipitation)
    c. climate and vegetation are connected in a specific way which differs in different regions
    d. pollen can be used to interpret past climate

2. Have students work on the first set of questions in small groups, then come together as a whole class to discuss their answers.

Activity 2: From Pollen to Past Vegetation and Climate

Students learn how palynologists interpret pollen percentages from the cores and practice doing that themselves.

Warm Up:

Review material from the previous day.

Procedure:

1. Hand out the table with modern pollen percentages by zone and the table with January and July temperatures by zone. The practice diagram should be projected onto the screen (PowerPoint slide 36). Student should determine how many vegetation changes happened during the 8,000 years in this diagram and interpret what past climate was like during these periods. This practice activity should be done together with the teacher in preparation for the next activity, done by students themselves, individually or in groups. Slide 37 shows the scientists' interpretation of this diagram. Here are the climatic interpretations:

a. Zone 3 represents modern climate conditions. The slight decline in oak pollen percentages associated with increases in spruce and tree birch pollen suggests a slight cooling, but not enough to change from one vegetation type to another. While perhaps indicating the Little Ice Age (the time in 1700-1800s when River Thames was covered with ice), additional samples need to be analyzed to confirm any possible cooling.

b. Zone 2 represents the warmest summer climate in our record. This warm period is found in many records in the Russian Far East and other areas of the Northern Hemisphere. The period is called the postglacial thermal maximum, referring to highest summer temperatures following the Ice Ages. Note that in our record January temperature is similar to modern, suggesting that unlike summer, Zone 2 winters were like today.

c. Zone 1 represents the coolest summer and winter climates represented in the pollen diagram. Although our record does not extend into the Ice Ages (>12,000 BP), the cooler than modern conditions in zone 1 (about 8,000 BP) suggest that global climates warmed slowly after the glacial period.

2. Hand out the individual worksheets with pollen percentages from core obtained in the Kuril Islands and an empty diagram (per person or per group) for graphing the percentages. After the diagrams are created, students (individually or in small groups) should use the tables they already have from previous exercise to answer the questions on the worksheet for Activity 2 and then discuss answers as a group.

Conclusion:

Have students tell you and the rest of the class about the climatic and vegetation history of the Kuril Islands.

Wrap Up:

Discuss what may cause climate change and why it is important to study climate change in the past.

Question 1:

If you wanted to live in the warmest area of the Kuril Islands during the summer, which island would you choose? The coolest island during summer? If you wanted to live in the warmest island during winter, would you have to move from your summer island? In each case, what type of vegetation would grow on your island?

Answer:

Mean July temperatures are coolest in the central and northern Kurils, where meadows and meadows with shrub thickets (Paramushir Island) are prevalent. With increased July temperature, birch forests establish on southern Urup and northern Iturup Islands. Moving southward in the archipelago, July temperature continues to increase, associated with the growth of conifer forests (southern Iturup and northern Kunashir Islands) and even further to the south with cool temperate forests (southern Kunashir Island). Thus, the warmest island would be southern Kunashir with forests of oak and other warm tree species. The coolest setting would be in any of the treeless, central and northern islands. In January, the islands are all located between the same isotherms (contour lines of temperature). Consequently, no one would have to move from their summer island. Additionally, the similarity in January temperature throughout the archipelago indicates the Kuril vegetation is insensitive to winter conditions.

Question 2:

Access to fresh water can be a problem in the Kuril archipelago, because some islands have no fresh water and other islands have only small streams. Rain and snow, of course, are also sources of fresh water. If you could not depend on a stream for water, which island(s) might you chose for a summer (winter) settlement, based on the map of July (January) precipitation? If you lived in the Kuril Islands 1,000 years ago, what other landscape elements might you consider in your winter settlement?

Answer:

The contours in the July precipitation map parallel the Kuril Islands, suggesting that any island is equally good concerning rain sources. This pattern also suggests that July rains have little influence on the vegetation. The January precipitation map shows more complex patterns. The wettest winter conditions occur in the meadowy portion of the central Kurils, whereas there is less snow fall in the temperate forests to the south. The birch and conifer forests are moderately wet. Although the central Kurils have the greatest snowfall, they also have no source of fire wood. Thus the decision of where to locate in the winter, if no streams are available, may be a compromise between areas where there are sufficient sources of snow and fuel, i.e., the conifer or birch forests in the southern islands.

Question 3:

If you were the chief palynologist, how would you summarize the qualitative vegetation-climate relationships for the other scientists working on the Kuril Biocomplexity Project? Hint: first give each vegetation zone a ranking (e.g., vegetation with the warmest July temperatures is given a rank of 1; coolest July temperatures a rank of 4). Rank only those climate variables that influence the vegetation. Provide a qualitative description (e.g., warm, wet summers; warmest, wettest winters) for each vegetation type.

Answer:

The contours for January temperature and July precipitation maps parallel the island chain and thus are factors that do not need to be considered. The rankings are provided in the table below.

Of the four maps, July temperature corresponds most closely with the distribution of the main vegetation zones in the Kuril Islands. This relationship is not surprising as temperature during the growing season is one of the main factors determining plant growth and plant biogeography. The January precipitation map suggests that winter precipitation also plays a role in the Kuril vegetation. Note that January precipitation does not correspond to vegetation zones as precisely as July temperature; thus the mixed rankings in the winter climate category.

Vegetation type	July temp. rank	Janurary precip. rank	Qualitative description
Meadows with thickets	4	1	Summer moderately cool, winter moderately wet
Meadow	5	2	Summer cool, winter wet
Birch forest	4	1/2	Summer moderately warm, winter wet
Conifer forest	3	2/3	Summer moderately warm, winter moderately wet
North temperate forest (Kunashir)	2	4	Summer warm, winter dry
South temperate forest (Hokkaido)	1	4	Summer warm, winter dry

Note to teacher:

Most students will expect July temperature to be a key factor in determining vegetation type, as summer is the growing season. However, they may be surprised that January and not July precipitation is important for the Kuril vegetation, especially as January precipitation is in the form of snow. The snow is important in two ways. Snow cover insulates shrubs and tree seedlings thereby protecting them from the cold winter temperatures. High January precipitation also helps build a snow pack, which will be a moisture source for the plants during late spring into early summer.

Question 1:

As the chief palynologist on the project, you have spent a month doing field work and 6 months in the laboratory. Now you are ready to interpret your data. In the provided template, first plot the pollen percentages from your spreadsheet. Do you see distinctive pollen assemblages for the different vegetation types? How many? What is the pollen “signature” for each vegetation zone?

Answer:

The main vegetation zones are differentiated by their pollen samples as follows:

Cool temperate forest:

Oak is the most frequent pollen taxon with a lower but important contribution by other “warmer” tree types such as magnolia, elm ,and maple. Grass pollen is low. Tree birch is below 20%. Spruce pollen is low to absent. Hokkaido has higher percentages of oak and other temperate tree types because climate is more favorable for the growth of these trees.

Conifer forest:

Spruce is the dominant pollen taxon with higher percentages of tree birch and shrub pine. Temperate tree pollen is absent, except for very low values of oak pollen. The grass percentage is also low.

Birch forest:

Tree birch pollen is most abundant with a modest percentage of shrub pine. Temperate tree pollen is absent with low values of spruce and grass pollen.

Meadow:

Grass pollen is the most common pollen taxon with other types absent or of low percentages.

Meadow with shrub thickets:

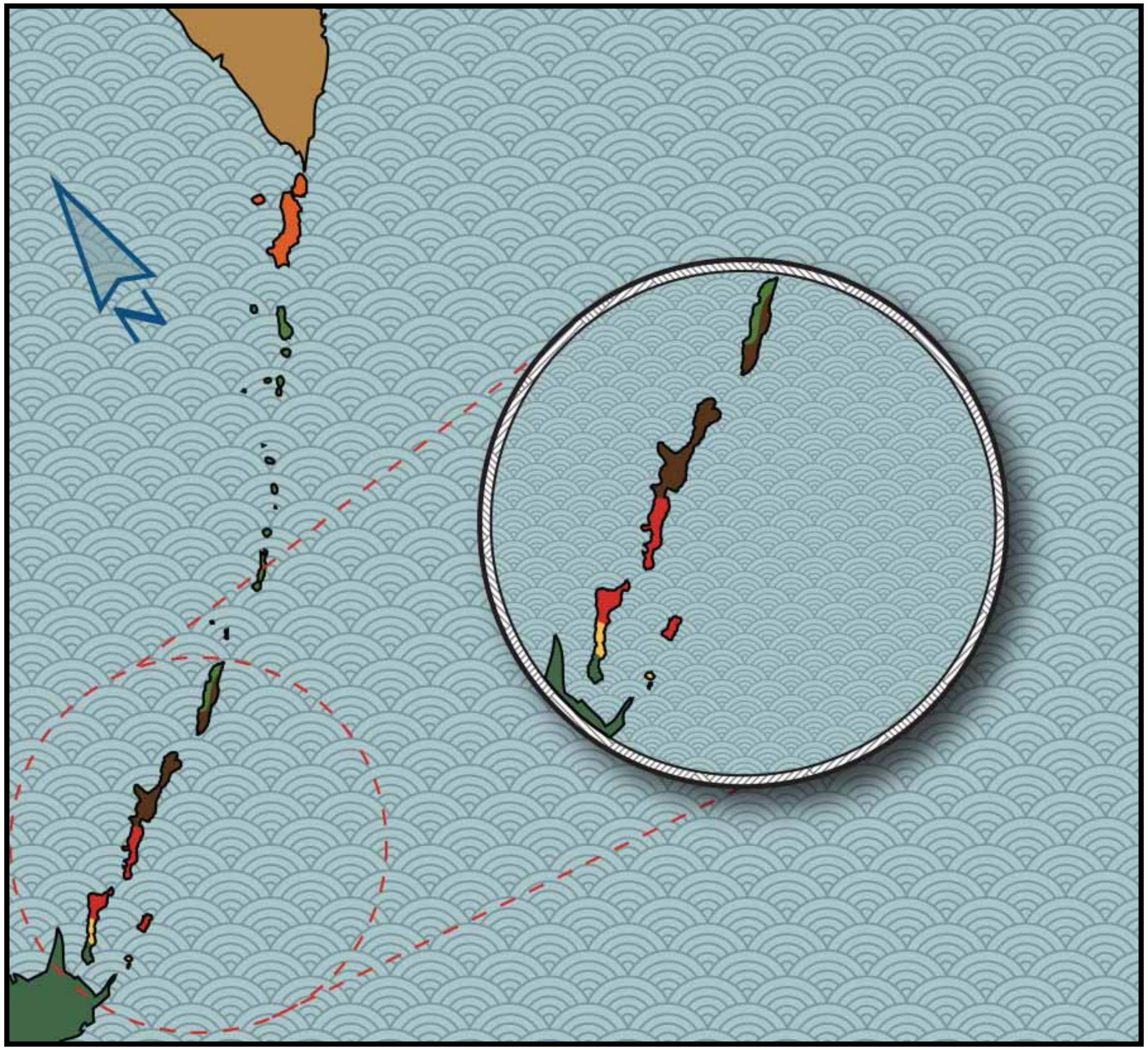
The highest pollen percentage of shrub pine characterizes this vegetation with a moderate percentage of grass pollen. Other illustrated taxa are low to absent.

Question 2:

Describe the vegetation history of your island for your colleagues. Use the handout called "Modern vegetation type & climate change by latitude" to determine how climate changes through the 8,000 years recorded in the core.

Student Worksheet guide

Part 1: Vegetation distribution map



Temperate forest
(oak, maple, elm, ash, magnolia, tree birch)

Temperate forest
(conifers)

Conifers
(fir, spruce, larch, shrub pine, tree birch)

Birch forest
(tree birch, shrub pine, shrub alder, bamboo)

Meadow
(herbs)

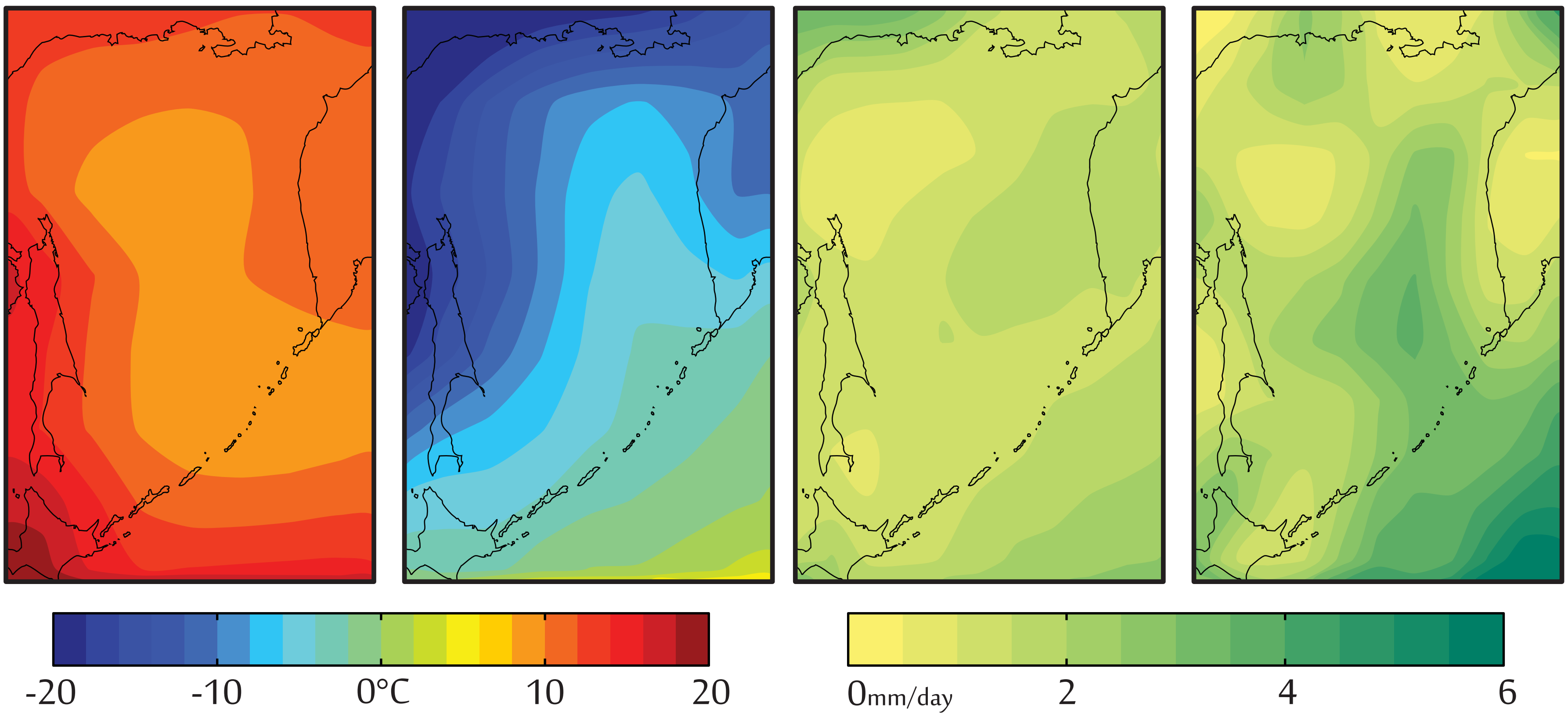
Meadow with high shrub thickets
(shrub pine, shrub alder, herbs)

Birch conifer forest

Student Worksheet guide

Part 1: July & Januray temperature & precipitation maps

July Temperature | January Temperature | July Precipitation | January Precipitation

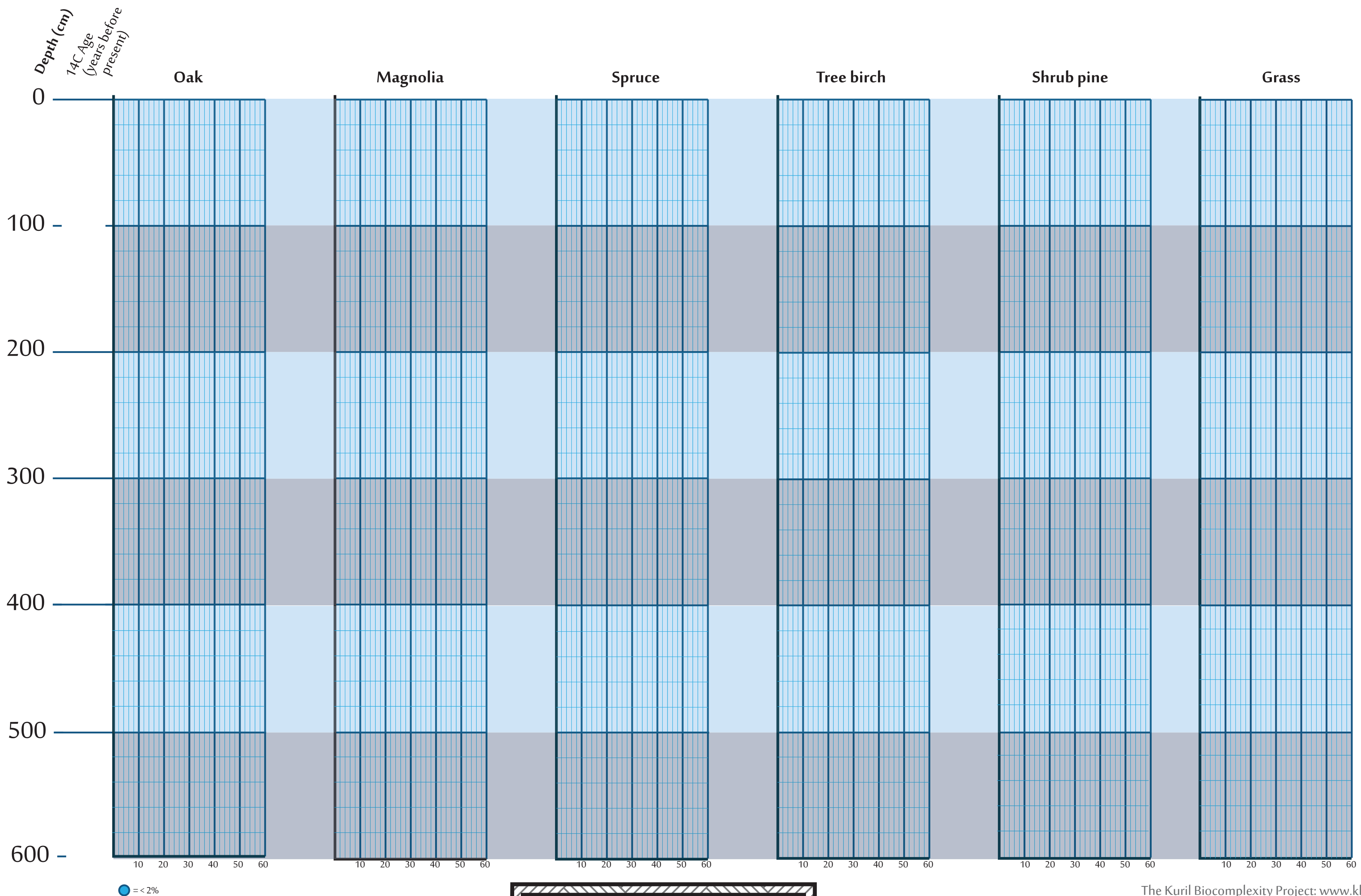


The Kuril Biocomplexity Project: www.kbp.org

Student Worksheet guide

Part 2: Paleoenviroment

Pollen Diagram Template



The Kuril Biocomplexity Project: www.kbp.org

Student Worksheet guide

Part 2: Paleoenviroment

Data

Pollen Percentages

Depth (cm)	oak	magnolia	spruce	tree birch	shrub pine	grass
0	0	0	1	40	23	10
10	0	0	1	37	20	8
20	0	0	0	35	20	10
25	0	0	0	30	22	10
30	0	0	0	25	25	15
40	0	0	0	28	25	12
50	0	0	1	37	23	8
60	0	0	0	40	20	10
80	0	0	0	40	20	10
100	0	0	1	40	21	9
120	0	0	1	40	22	12
140	0	0	1	40	20	10
160	0	0	2	37	18	8
180	0	0	5	35	20	10
190	0	0	30	20	15	5
200	0	0	37	20	15	5
210	0	0	40	20	15	5
230	30	5	7	13	12	3
240	33	5	5	12	13	3
250	35	5	5	15	15	5
270	50	7	0	10	5	3
290	55	10	0	7	5	3
320	60	15	0	5	2	3

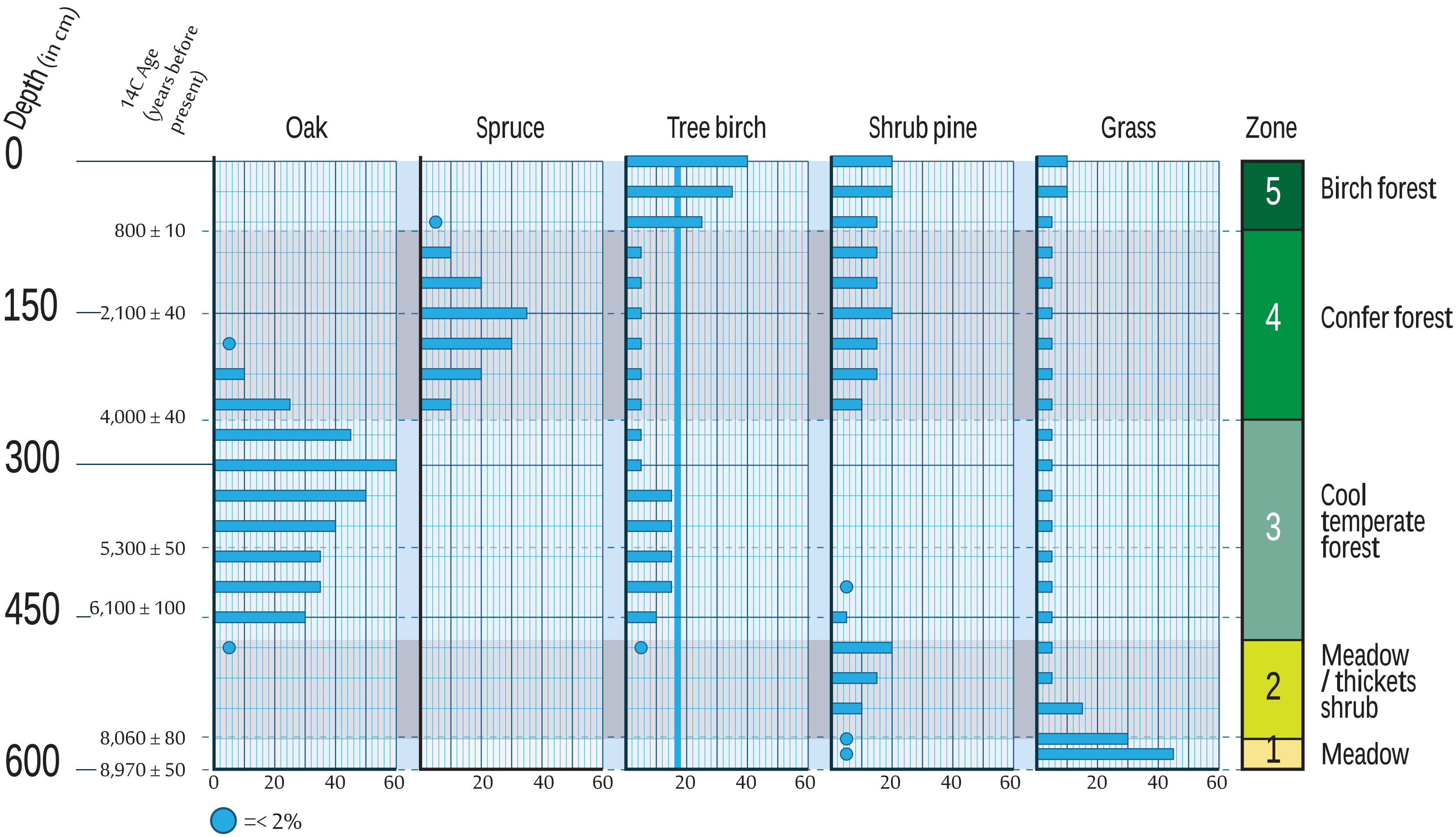
Depth (cm)	oak	magnolia	spruce	tree birch	shrub pine	grass
350	55	12	0	5	2	3
370	55	10	0	5	5	3
400	50	10	0	7	5	3
410	45	9	0	10	5	3
430	35	5	0	12	12	5
450	33	5	0	12	12	5
480	35	5	0	15	15	5
500	30	5	0	15	15	5
520	2	0	0	2	20	10
540	0	0	0	0	25	15
550	0	0	0	1	25	15
560	0	0	0	0	10	15
580	0	0	0	0	2	30
600	0	0	0	0	2	45

Radiocarbon Dates

Depth	Date	Error
75	500	10
125	2,100	40
250	4,000	75
370	5,300	60
420	6,100	100
560	8,060	80
600	8,970	50

Student Worksheet guide

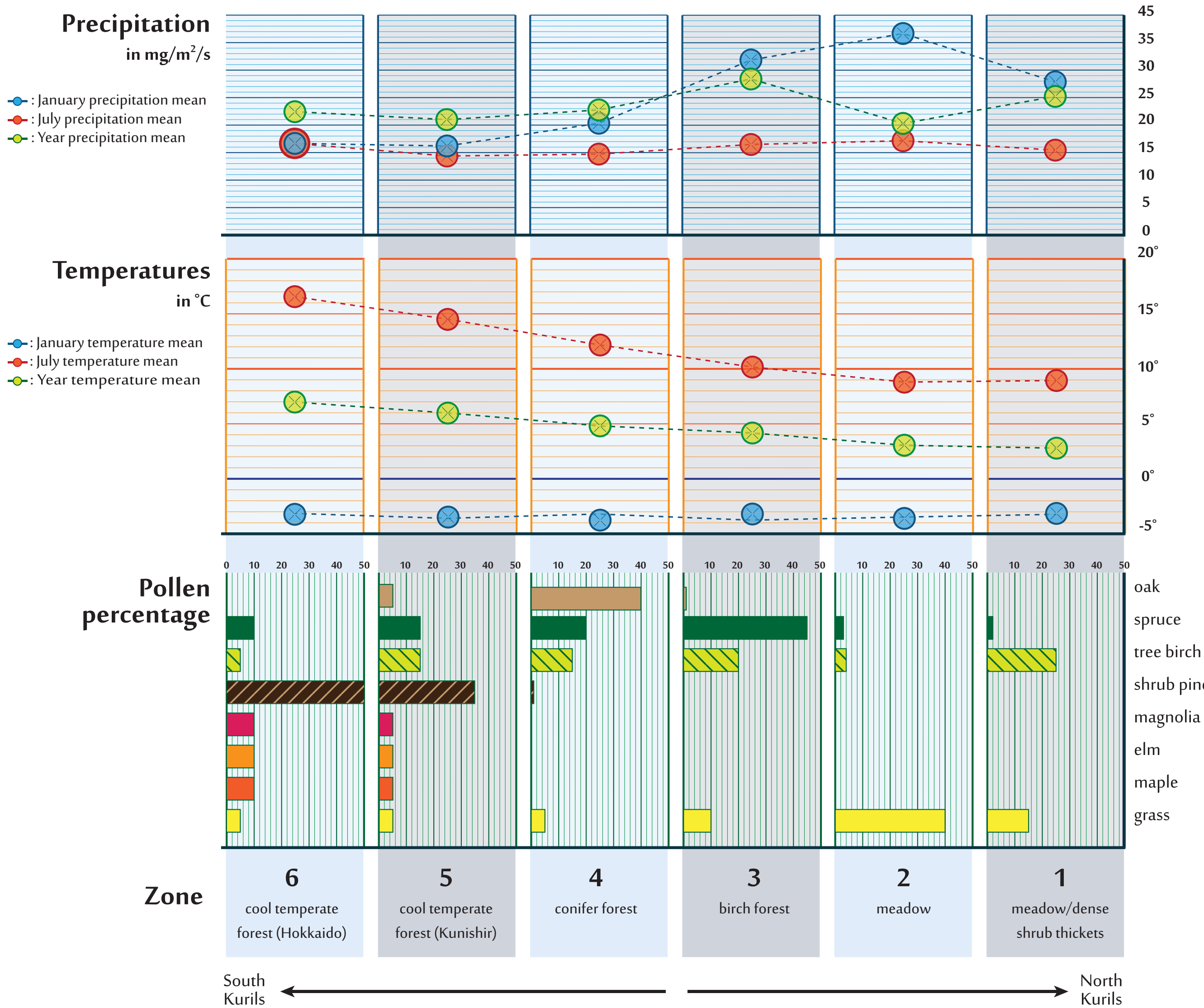
Answer plot of the exercise pollen core data
(with vegetation zones indicated)



Student Worksheet guide

Part 2: Paleoenviroment

Modern vegetation type & climate change by latitude



The Kuril Biocomplexity Project: www.kbp.org