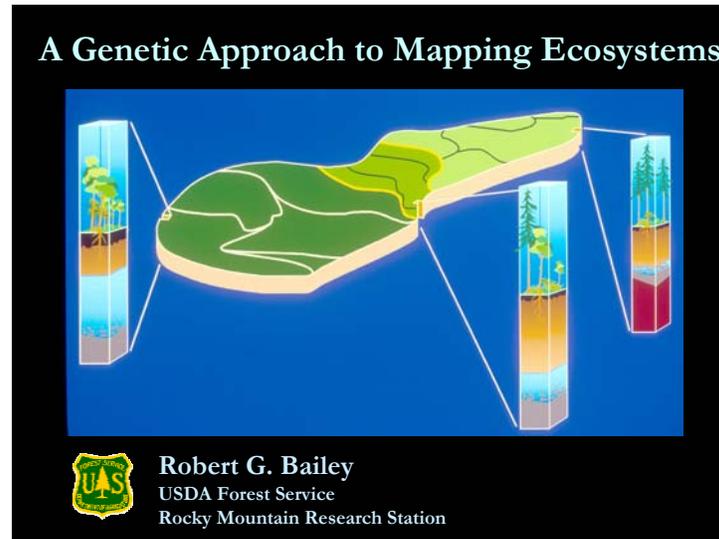


PowerPoint presentation given at the annual meeting of the Association of American Geographers, San Francisco, CA, April 17-21, 2007

Slide 1



A Genetic Approach to Mapping Ecosystems

Robert G. Bailey

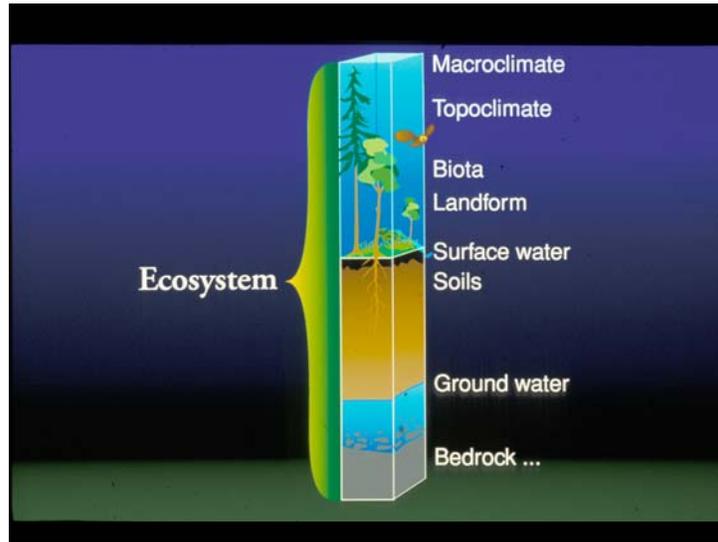
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Abstract

Criteria for delineating ecosystems on a scale-related basis are presented, based on the processes that operate to cause the spatial distribution of ecosystems from the regional scale (ecoregion) to the local, site scale. The units derived from this approach are termed genetic, in that they are predicated upon an understanding of the causal processes that control the pattern of ecosystems. Understanding spatial relationships between causal mechanisms and resultant patterns is a key to understanding ecosystem dynamics and how they respond to management.

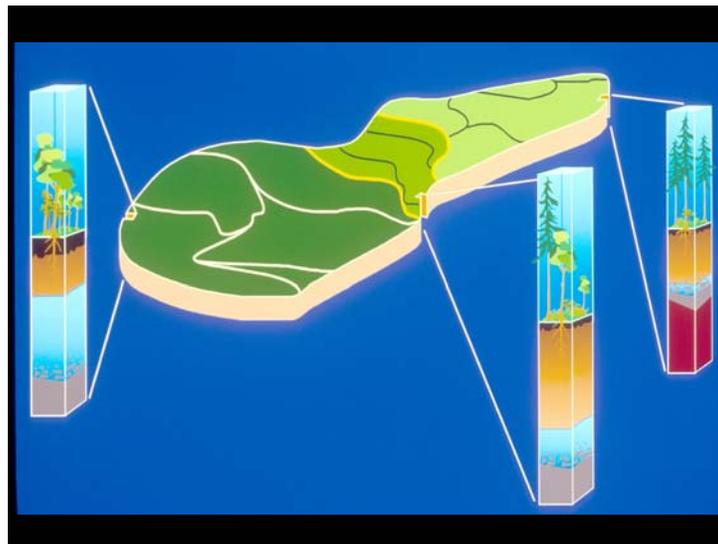
Slide 2



Introduction

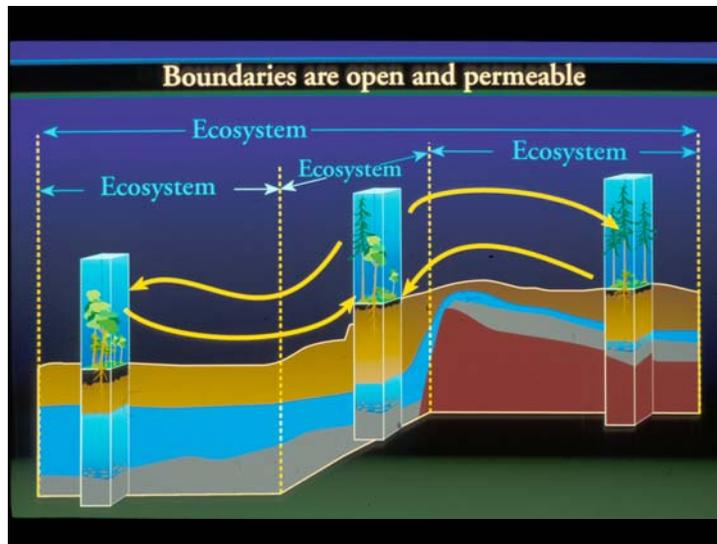
Public land-management agencies have been shifting from their focus on individual resources to a more holistic approach of managing *whole ecosystems*. In this approach vertical structure is examined, which is how the system components are integrated (or combined) at a site.

Slide 3



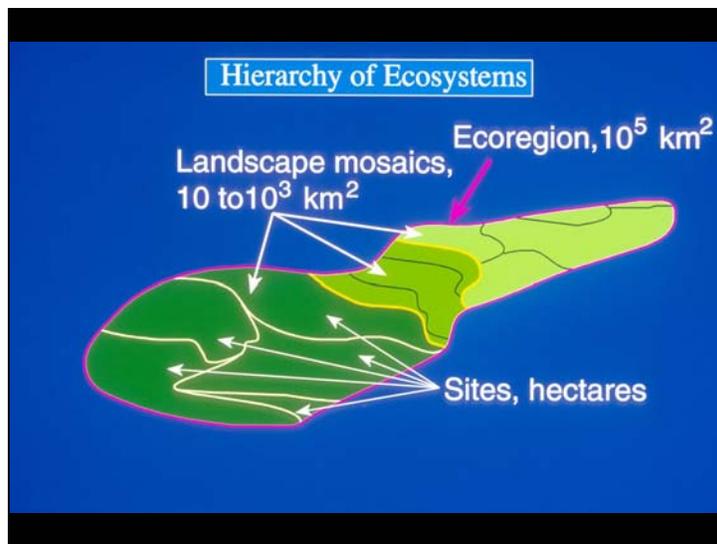
Boundaries between ecosystems occur where vertical structure changes. Historically, the ecosystem has been defined as a small homogeneous area.

Slide 4



Subdivision of land into system of different sizes is needed because (1) small systems are linked to form larger systems, (2) the larger is the environment of those within; therefore, altering a larger system may affect its smaller systems, and (3) understanding links between ecosystems at various scales is important for analyzing cumulative effects of action at one scale and its effects at another.

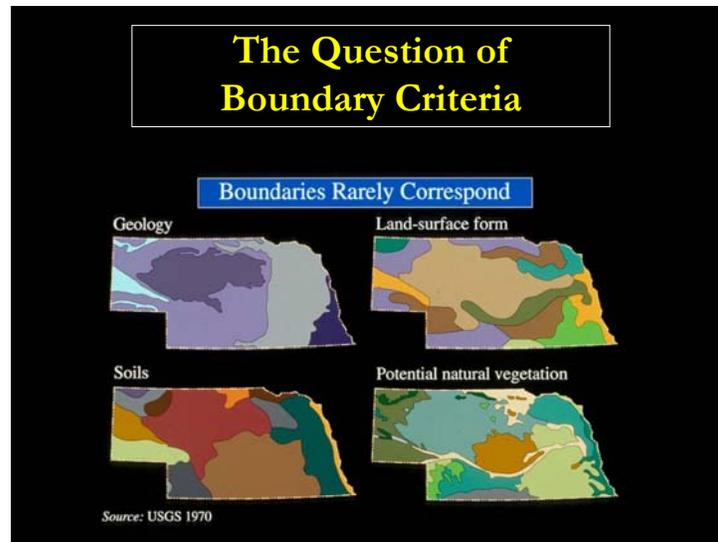
Slide 5



Scale of Ecosystem Units

Given this need, ecologists and geographers have been interested in hierarchical schemes of ecosystem units, such as the one shown here. The purpose of this presentation is to explain the logic and criteria for mapping such units.

Slide 6



The Question of Boundary Criteria

The fundamental question facing all ecological mappers is: *how are the boundaries of differently sized systems to be determined?* Different methods have been used to identify units where ecosystem components are integrated in a similar way, thereby classifying land as ecosystems. The problem is boundaries on different factor maps rarely correspond to each other.

Slide 7

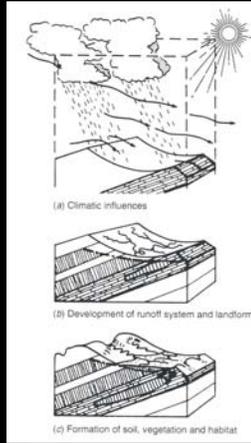
- **Overlaying maps or cluster analysis**
 - **Address neither causes nor why**

Further, overlay mapping techniques and cluster analysis address neither the causes that generate different ecosystem units nor why those units should be distinguished. *In this presentation I shall present these causes.*

Slide 8

The Genetic Approach

- Based on formative process
- Follows the cycle of landscape evolution
- Key to understanding response to management



From W.W. March, 2005. *Landscape Planning*, 4th ed. John Wiley.

Establishing a hierarchy of ecosystem boundaries should be based on understanding of the formative processes that operate to differentiate the landscape into ecosystems at various scales. The units derived from such an approach are termed “genetic” in that they follow the cycle of landscape evolution. **Understanding spatial relationships between causal mechanisms and resultant patterns is key to understanding how ecosystems respond to management.**

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Origins of the Genetic Approach

- Davis (1899)
- Herbertson (1905)
- Fenneman (1916-28)



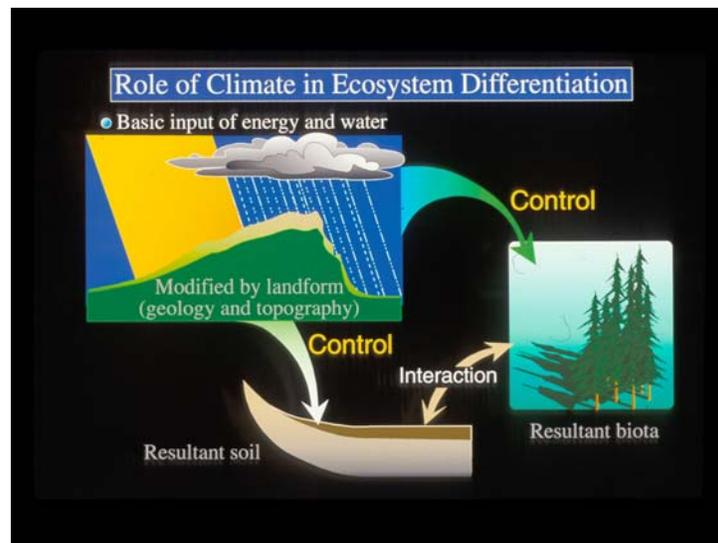
[See also: Dryer, C.R. (1919). Genetic geography. *Annals AAG* 10, 3-16; Sauer, C.O. (1925). The morphology of landscape. *U. Calif. Pub. in Geog.* 2, 19-53.]

The notion that process knowledge should define landscapes has a long history in geography. William Morris Davis (1899) argued for a genetic classification of landforms, and both Herbertson’s (1905) natural regions of the world and Fenneman’s (1916-28) physiographic divisions of the United States are based on rational observation of underlying processes.

Analysis of Controlling Factors

- Analyze, on a scale-related basis, the controlling factors that *cause* ecosystem patterns
- Use significant changes in controls as boundaries

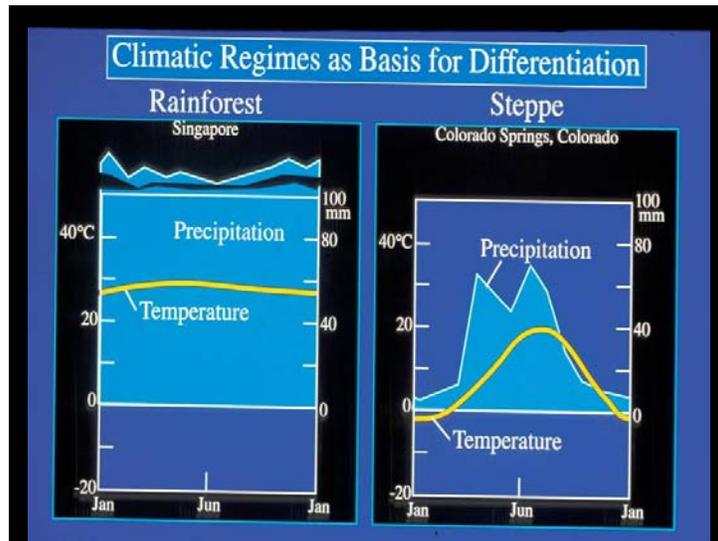
Building on this work, I developed and continue to refine a system of mapping ecosystems using the genetic approach (Bailey 1985, 1987, 1996). Delineating units involves analyzing the controlling factors that *cause* ecosystem patterns at various scales, and then using significant changes in controls as boundaries.



Role of Climate in Ecosystem Differentiation

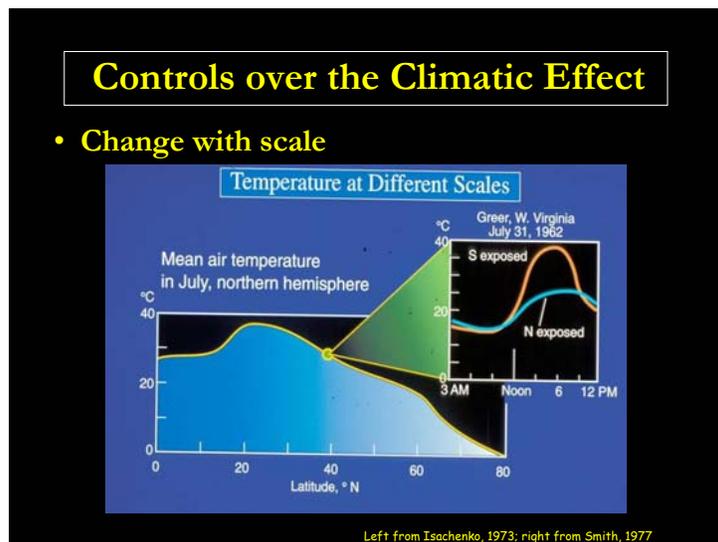
Climate, as a source of energy and water, acts as the primary control for ecosystem distribution. Landform modifies the climate and vice versa. This combination controls the patterns in dependent components, such as soil and biota. As the climate changes, the other components change in response. To a considerable extent, climatic factors determine ecosystem boundaries.

Slide 12

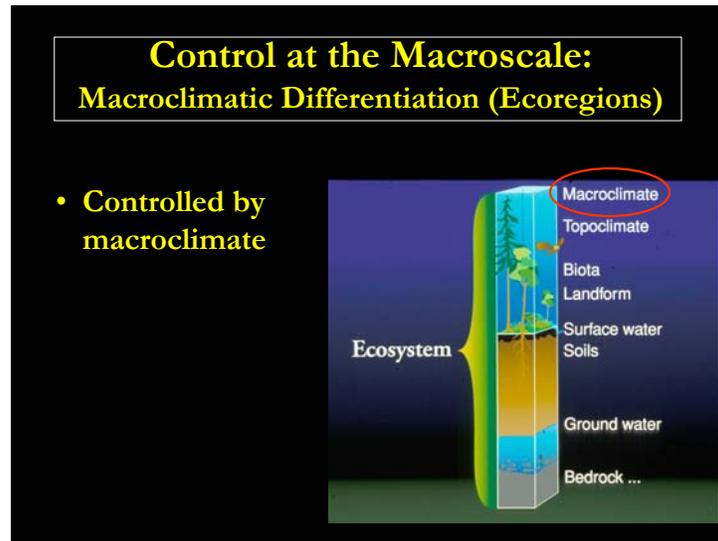


The most important of these is the *climatic regime*, defined as the seasonal fluxes of energy and moisture. As these fluxes change, the kinds and patterns of dominant life forms of plants and animals change, as do the soils. For example, tropical rainforests lack periodicity; mid-latitude steppes have seasons. We use differences in regime to differentiate ecosystems.

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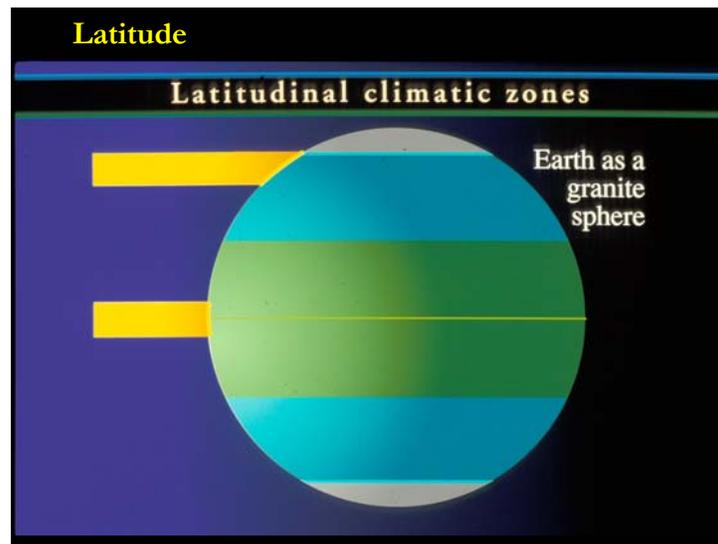


Controls over the climatic effect change with scale. For example, we can detect temperature differences over a thousand kilometers related to latitude or over a few hundred meters in mountains. Understanding these controlling factors and the scale at which they operate is key to setting ecosystem boundaries.



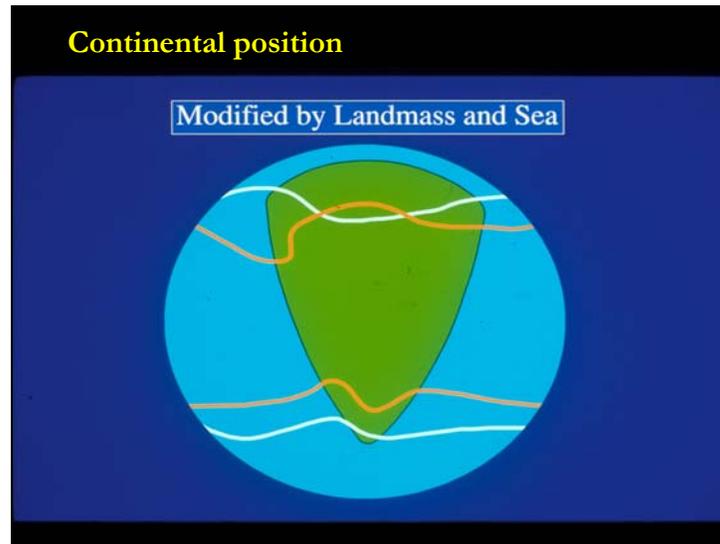
Control at the Macroscale: Macroclimatic Differentiation (Ecoregions)

At the macroscale ecosystem patterns are controlled by macroclimate (i.e., the climate that lies just beyond the local modifying irregularities of landform and vegetation). Several factors are involved:



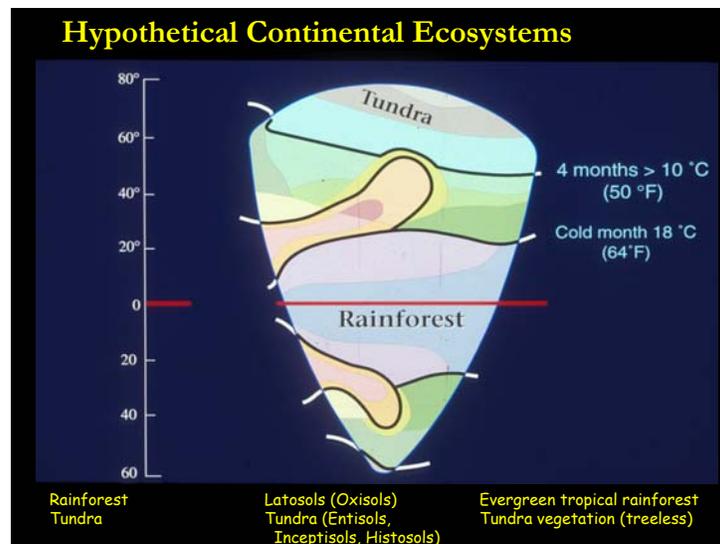
Latitude—the primary control of climate at the global level is variation in solar energy, which is related to latitude. If the Earth were of uniform composition, macroclimates would fall into neat latitudinal zones resulting from variation in the amount of solar radiation that reaches different latitudes. They would owe their differentiation to the varied effects of the sun, instead of the character of the surface.

Slide 16



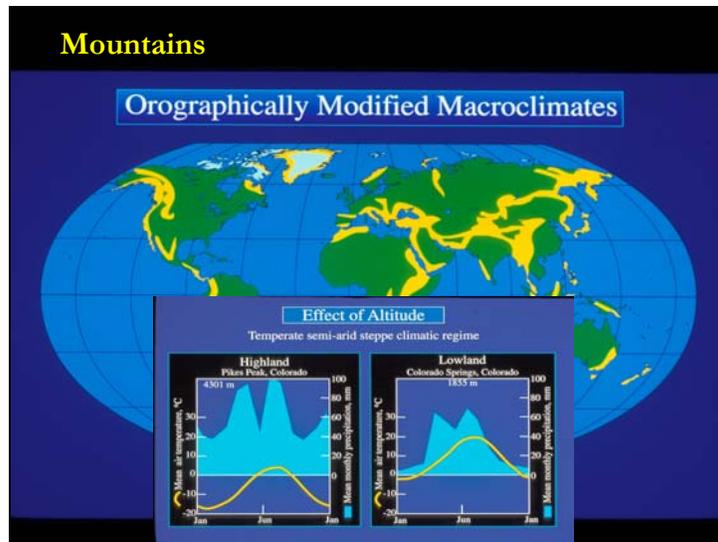
Continental position—because the Earth’s surface is divided between land and sea, each with quite different thermal characteristics, the climatic zones are “bent”.

Slide 17



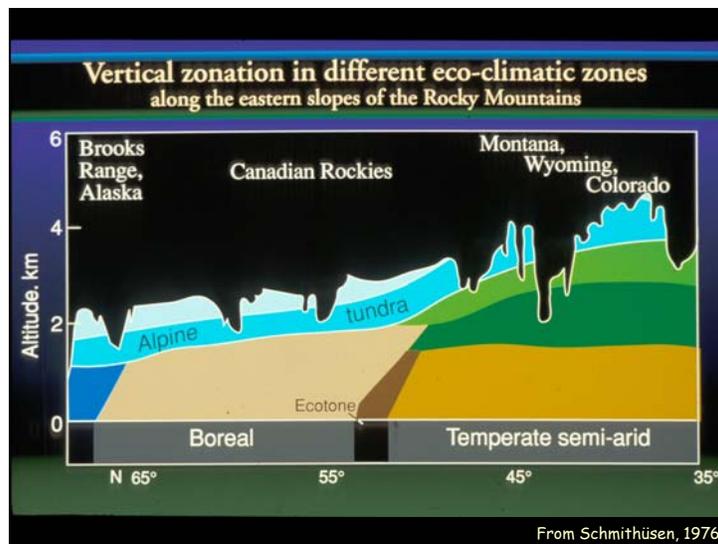
These effects combine to create a pattern of climatically controlled ecosystems which are depicted here as they would appear on a hypothetical continent of low, uniform elevation. In each climate, the developments of both the soil and the vegetation converge toward a characteristic family of types.

Slide 18



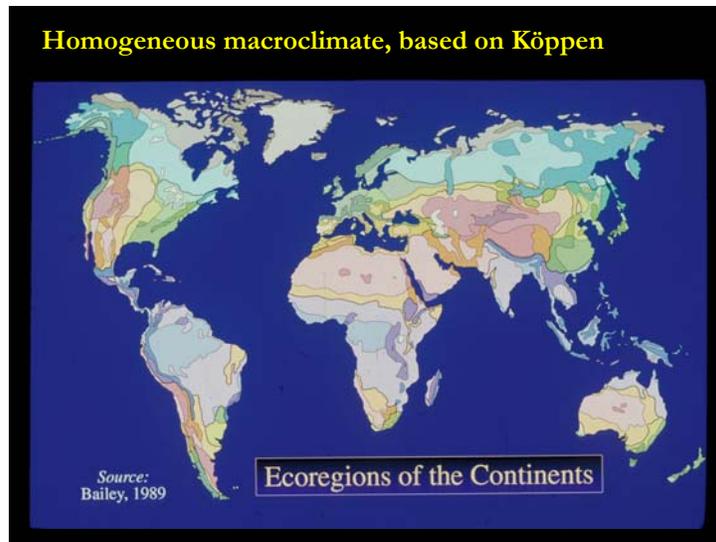
Mountains—the Earth’s landmasses are not, however, of low uniform elevation. The Earth’s internal energy creates mountains that are arranged without conforming at all to the orderly latitudinal zones of climate. They are cooler and moister than surrounding lowlands, and unbroken ranges of mountain are effective barriers to the passage of moisture.

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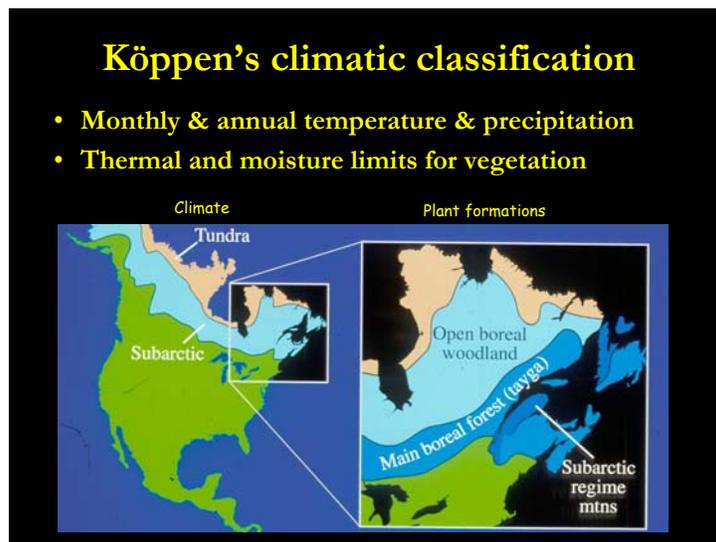
As a result of these lower temperatures and higher moistures, vertical belts of climate and vegetation occur. These will differ according to the climate zone in which the mountains are embedded.

Slide 20



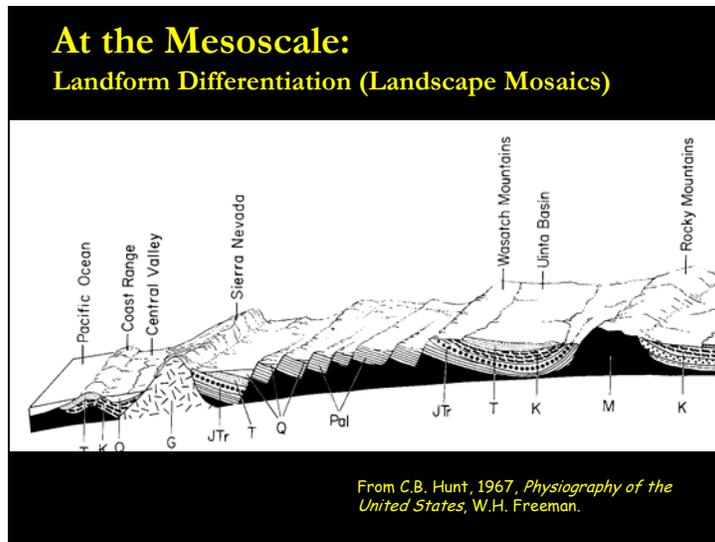
The combined effect of latitude, continental position, and mountains form the world's regional-scale ecosystems, or *ecoregions*. Boundaries are based on the climate rules of German geographer, Wladimir Köppen (1931).

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Köppen's system is based on seasonal variation in temperature and precipitation. The class boundaries are based on thermal and moisture limits for vegetation. Visible and tangible expressions of climate, such as vegetation, help locate the boundaries of climates. Generally, each climate is associated with one or more natural *plant formation* classes (without edaphic or land use influences being shown).

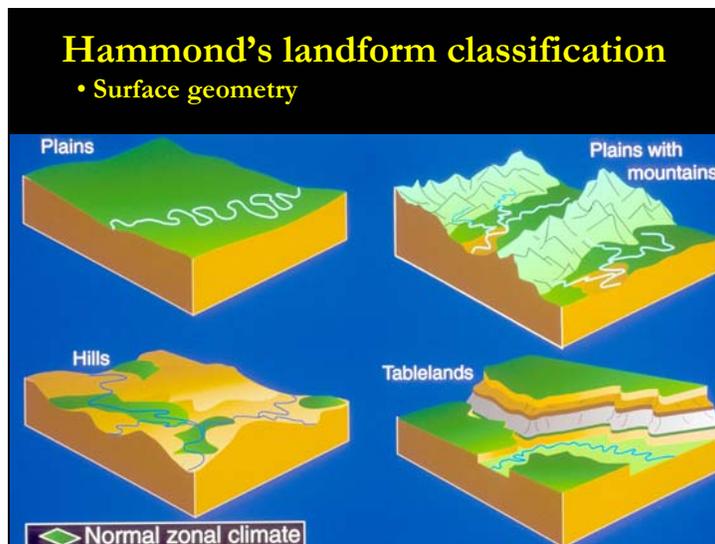
Slide 22



At the Mesoscale: Landform Differentiation (Landscape Mosaics)

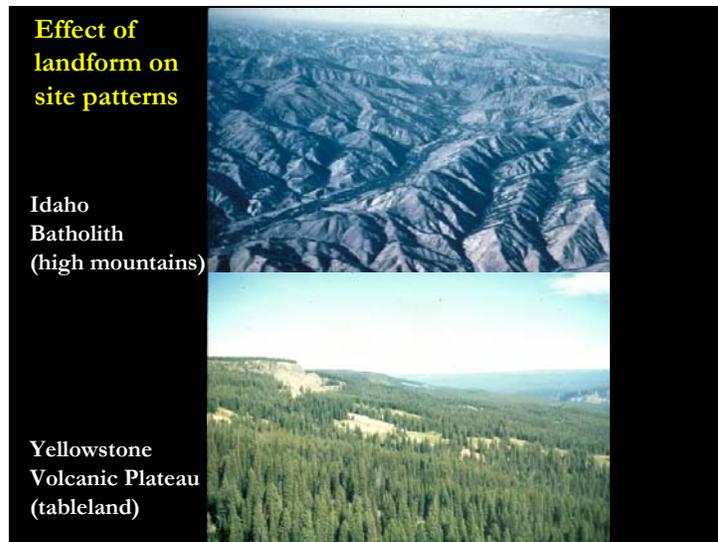
At the mesoscale within a macroclimate, several broad-scale landform patterns (topography and geology) may break up the zonal pattern. Landforms come in all scales. On a continental level, geologic structure is a dominant control factor in the evolution of landforms.

Slide 23



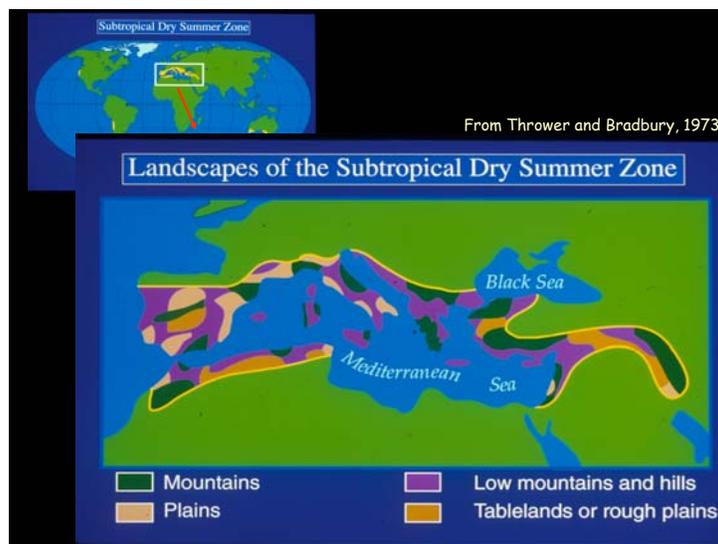
Hammond's 1954 landform classification (based on surface geometry) illustrates the results of this effect on zonal climate and provides a basis for further differentiation of ecosystems, known as *landscape mosaics*.

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According to the way it breaks up the zonal climate, a landform unit consists of different ecosystem patterns. For example, the Idaho Batholith (top) and the Yellowstone Volcanic Plateau are both highlands in a temperate steppe climate. These images show how different landforms in the same climate affect site patterns.

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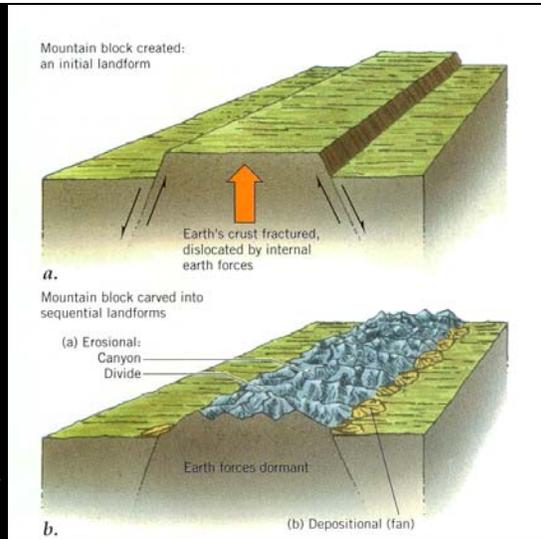


This map shows how various landscape mosaics are distributed in the subtropical dry summer zone in the Mediterranean region.

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**At the
Microscale:
Edaphic-
Topoclimatic
Differentiation
(Sites)**

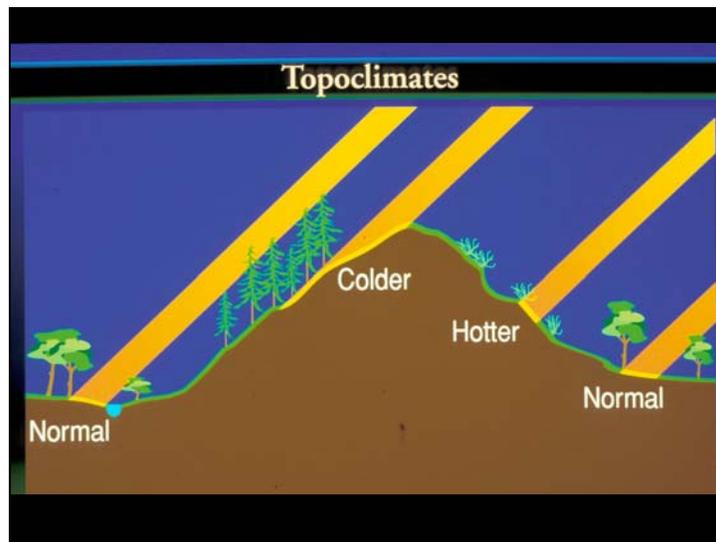
From A. Strahler &
A. Strahler,
1996, *Introducing
Physical Geography*,
John Wiley.



At the Microscale: Edaphic-Topoclimatic Differentiation

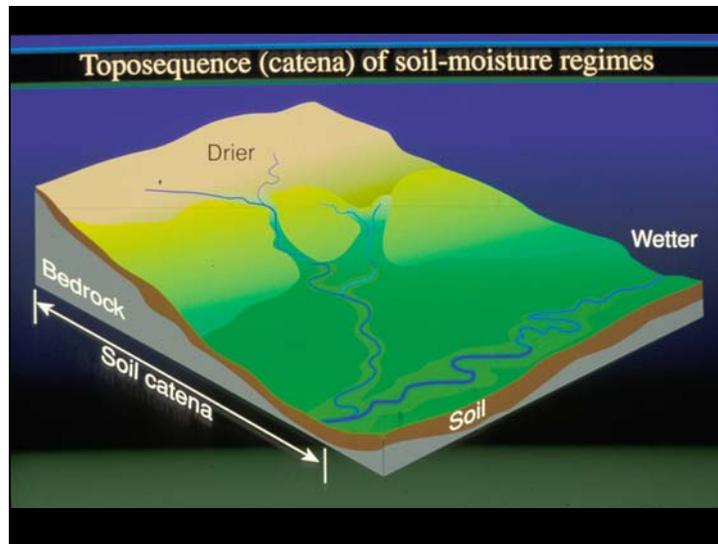
Although the distribution of ecoregions is controlled by macroclimate and broad-scale landform patterns, local differences are controlled by topography and ground conditions. The latter is the edaphic (related to soil) factor.

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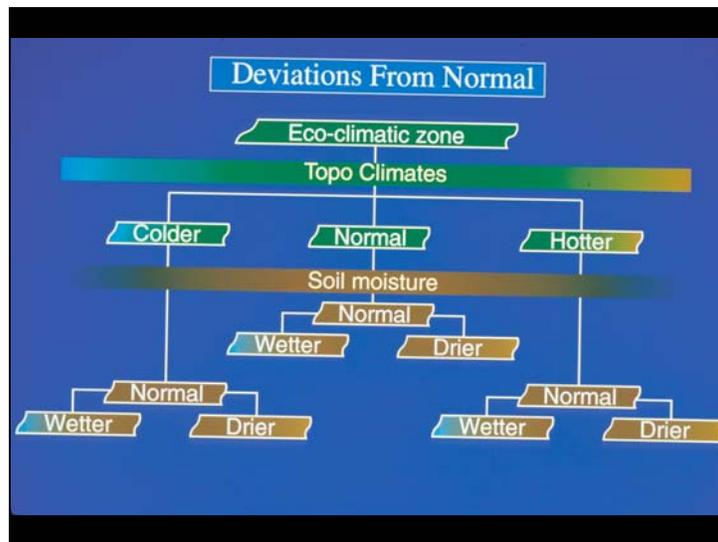
At the microscale patterns are controlled by small-scale variation in topography that cause variations in the amount of solar radiation received, which creates *topoclimates* (Thornthwaite 1954), and affect the amount of soil moisture. These topoclimates are subdivisions of the macroclimates.

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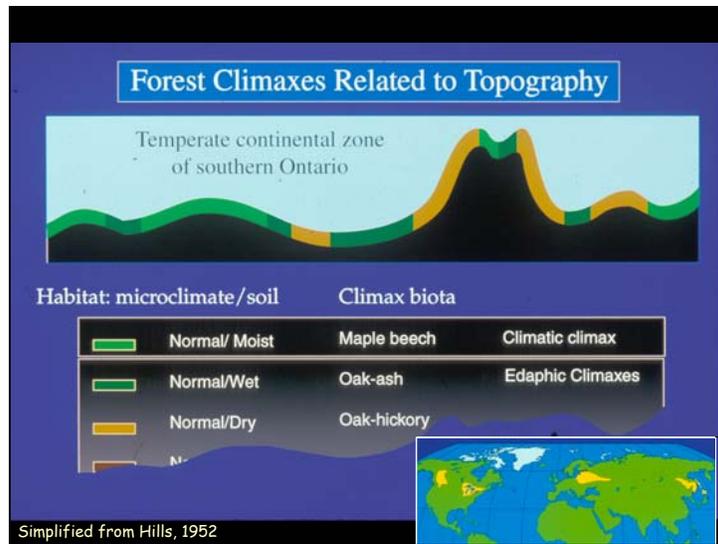
When we differentiate local sites within topoclimate, soil-moisture regimes provide the most significant segregation of the plant community. A sequence of moisture regimes, ranging from drier to wetter from the top to the bottom of a slope, may be referred to as a soil catena, or a toposequence.

Slide 29



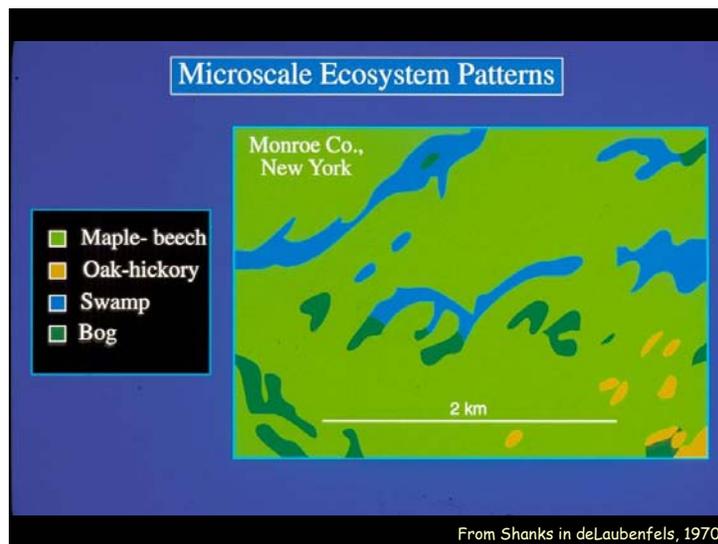
The genetic importance of landform is illustrated in this diagram. It shows how topoclimate-plus-slope position creates from the macroclimate (or eco-climatic zone) the pattern of local climates and soil moisture regimes. These variations will subsequently affect the biota, creating ecosystem *sites* as subdivisions of a larger zone.

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Here is an example of the patterns of sites formed by edaphic-topoclimatic differentiation in the temperate continental zone of southern Ontario, which also extends south into the northeastern United States. The light greens are normal (zonal) sites.

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The mapped pattern looks like this.

Slide 32

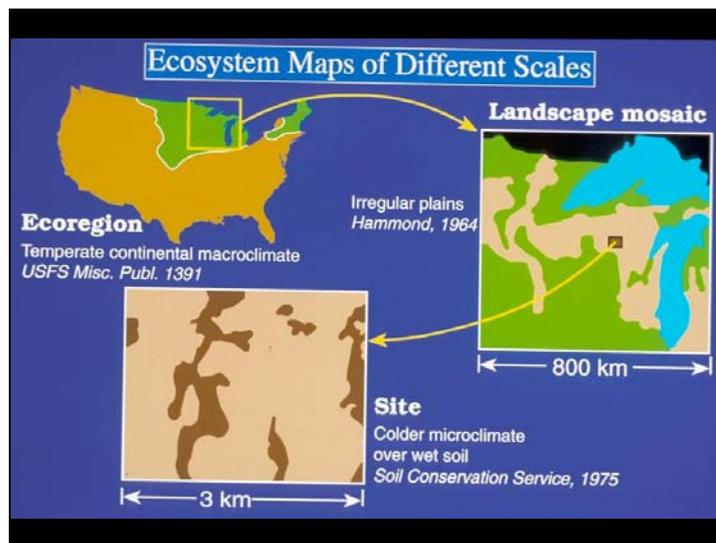
Summary of Mapping Criteria for Ecosystems at Different Scales		
Macro	Ecoregion or zone	Eco-climatic zone <i>Köppen, 1931</i>
Meso	Landscape mosaic	Land-surface form <i>Hammond, 1954</i>
Micro	Site	Microclimate and soil

Source: USFS Misc. Publ. 1465

Summary

Based on the foregoing analysis, mapping criteria may be identified.

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Most importantly, the criteria can be applied using existing information.

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Conclusions

- Regional ecosystems
 - Homogeneous macroclimate
- Landform modifies climate
 - Forms local ecosystems



Conclusions

All natural ecosystems are recognized by differences in climatic regime. Regional ecosystems are areas of homogeneous macroclimate. Landform is an important criterion for recognizing smaller divisions within macro ecosystems as it exerts the major control over climate (through aspect and steepness of slope) at meso and micro levels. Therefore, climate as modified by landform offers the logical basis for delineating ecosystems, both large and small.

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- Comparative system
- Predictability and thus extrapolation



Applications

A major emphasis in the genetic approach is on mechanisms that produce the pattern of ecosystem distribution. Understanding mechanisms allows for (1) a comparative system of ecosystems to be recognized, and (2) a certain degree of predictability and thus

extrapolation of information (e.g. outcome of land use) from one geographic area to another.

Slide 36

For more information:

- Bailey, R.G. 1985. The factor of scale in ecosystem mapping. *Environmental Management* 9, 271-276.
- Bailey, R.G. 1987. Suggested hierarchy of criteria for multi-scale ecosystem mapping. *Landscape and Urban Planning* 14, 313-319.
- Bailey, R.G. 1996. *Ecosystem Geography*. Springer, New York.
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- Godron, M. 1994. The natural hierarchy of ecological systems. F. Klijn (ed.), *Ecosystem Classification for Environmental Management*, 69-83.
- Isachenko, A.G. 1973. *Principles of Landscape Science and Physical-Geographic Regionalization*. Translated from Russian. Melbourne Univ. Press, Carlton.
- Klijn, F. & Udo de Haes, H.A. 1994. A hierarchical approach to ecosystems and its implications for ecological land classification. *Landscape Ecology* 9, 89-104.
- Leser, H. 1976. *Landschaftsökologie*, Ulmer, Stuttgart.
- Rowe, J.S. & Sheard, J.W. 1981. Ecological land classification: a survey approach. *Environmental Management* 5, 451-464.
- Walter, H. & Box, E. 1976. Global classification of natural terrestrial ecosystems. *Vegetatio* 32, 75-81.

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