Exercise 5
Biostratigraphy

Biostratigraphy is the subdiscipline of geology that is concerned with determining the relative ages of sedimentary rocks on the basis of their contained fossils. The practical application of biostratigraphy is **biostratigraphic correlation**: i.e., establishing the temporal equivalence of widely separate rock units on the basis of fossils.

Fossils are useful in relative age determination because the processes of evolution have produced a unique sequence of life forms through time. Every species of fossil plant, animal and protist has a definite **stratigraphic range**, the range in geologic time from its evolutionary origin to its extinction. Similarly, every interval of geologic time has been characterized by its own distinctive faunas and floras.

The age of a fossil-bearing sedimentary rock can be determined if the stratigraphic ranges of its contained fossils are known. For example, suppose that a particular trilobite species is known to have lived in late Cambrian time. It follows that any rock containing fossils of that particular trilobite must be late Cambrian in age. In practice, determining the precise stratigraphic ranges of fossil species can be quite involved. Nevertheless, the stratigraphic ranges of thousands of species are well known, and they can be used to correlate rocks with a precision that generally exceeds that of radiometric dating.

Part 1

Before fossils can be used to help determine the relative age of a sedimentary rock, their stratigraphic ranges must be known. The following exercise is a simplified example of how one might go about documenting the stratigraphic ranges of some fossil species in rocks of known ages, and then using that information to infer the ages of rocks in previously unexplored areas.

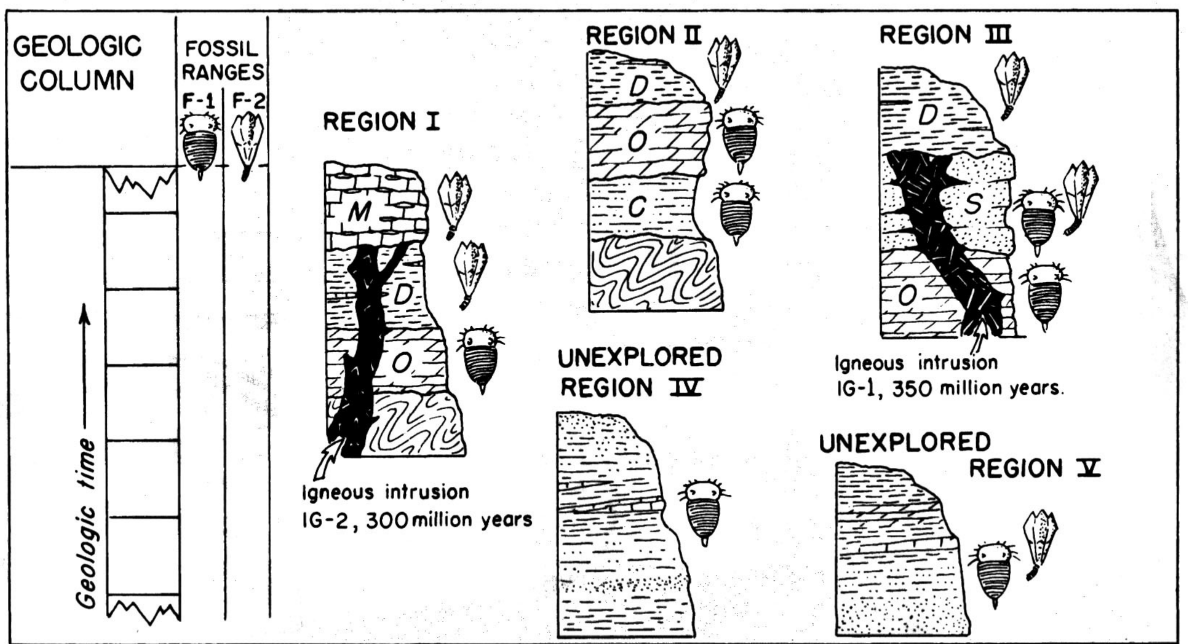


Figure 1—Occurrences of two fossil species at five separate localities. Ages of rocks in regions I, II, and III are known on the basis of independent evidence. Ages of rocks in regions IV and V must be determined on the basis of their contained fossils. Abbreviations: C = Cambrian; O = Ordovician; S = Silurian; D = Devonian; M = Mississippian (from Brice et al. 2001).

a. Use letter abbreviations to complete the geologic column at the left in Figure 1, with Cambrian at the bottom and Mississippian at the top.

b. Now, with your knowledge of the geologic time scale and the Principle of Superposition, use heavy vertical lines to show the stratigraphic ranges of species F-1 and F-2 in the two columns under the heading "Fossil Ranges." You can determine the stratigraphic ranges of these species by observing their occurrences in rocks of known ages in regions I, II and III.

c. Using the stratigraphic ranges of species F-1 and F-2, what inference can you make about the age of the fossil-bearing layers in region IV?

d. What inference can you make about the age of fossil-bearing strata in region V?

Part 2

Biostratigraphic correlation is usually accomplished by means of **biozones**, defined as *bodies of rock strata that are characterized by their distinctive association of fossils species*. The assumption is that a given biozone in one region is approximately the same age as the same biozone in a separate region, even if the regions are quite distant from one another.

Many kinds of biozones are recognized. The most widely used are the **taxon range biozone**, **concurrent range biozone**, and **interval biozone**.

- **Taxon range biozone** = body of strata corresponding to the total stratigraphic range of a specified fossil taxon (e.g., species or genus)
- **Concurrent range biozone** = body of strata corresponding to the overlapping stratigraphic ranges of two or more specified fossil taxa
- **Interval biozone** = body of strata corresponding to the interval between any two specified evolutionary events (e.g., interval between two extinction events; interval between two origination events; interval between an origination event and an extinction event).

Examples of these kinds of biozones are illustrated in Figure 2.

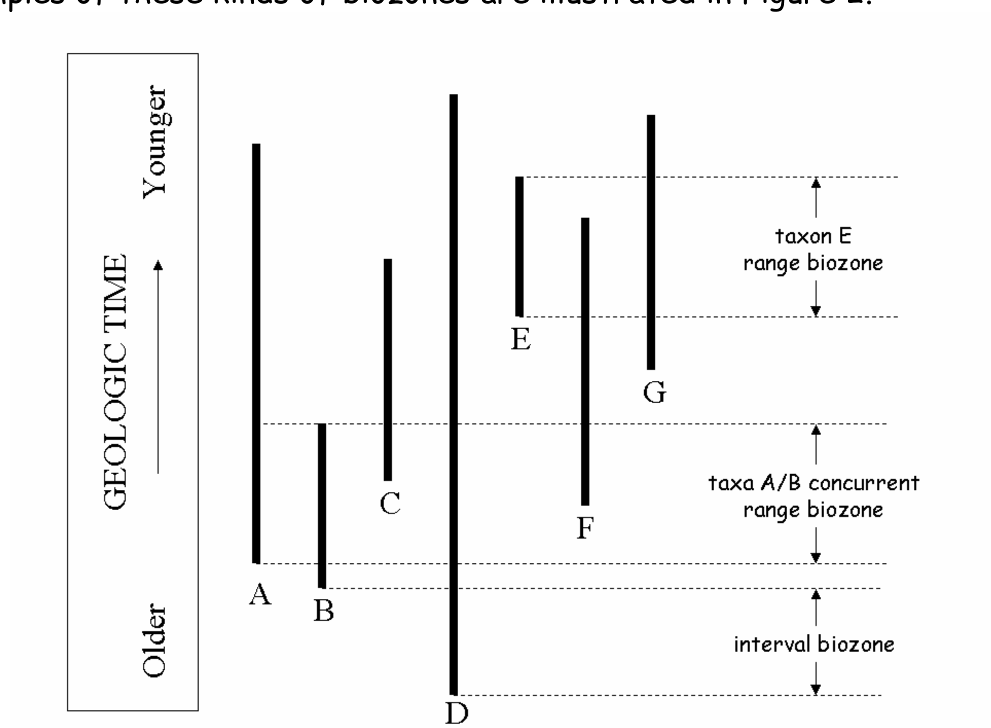


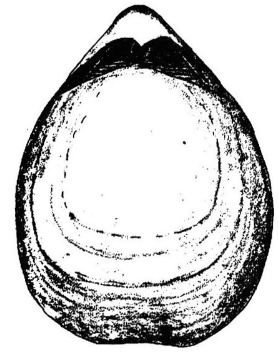
Figure 2—Different kinds of biozones defined on the basis of stratigraphic ranges of hypothetical fossil species A–G, depicted by heavy vertical lines. The interval biozone corresponds to the body of strata from the evolutionary origin of species D to the origin of species B.

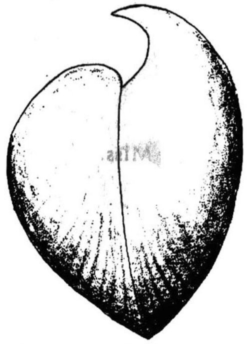
a. Illustrations of Paleozoic brachiopods, along with their known stratigraphic ranges, are given on the following two pages. Use the information on these pages to help you complete Table 1. Using pencil, shade in the stratigraphic range of each brachiopod genus listed.

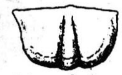
Table 1—Known stratigraphic ranges of selected Paleozoic brachiopod genera		*Stringocephalus*	*Mesolobus*	*Chonetes*	*Penicularis*	*Juresania*	*Athyris*	*Rafinesquina*	*Composita*	*Dielasma*	*Strophomena*	*Hustedia*	*Derbyia*	*Leptaena*	*Rensselaeria*	*Echinoconchus*	*Leptodus*	*Paraspirifer*	*Cyrtospirifer*	*Mucrospirifer*	*Spirifer*	*Punctospirifer*	*Cyrtina*	*Atrypa*	*Pentamerus*	*Neospirifer*	*Conchidium*
	upper																										
Permian	middle																										
	lower																										
	upper																										
Pennsylvanian	middle																										
	lower																										
	upper																										
Mississippian	middle																										
	lower																										
	upper																										
Devonian	middle																										
	lower																										
	upper																										
Silurian	middle																										
	lower																										
	upper																										
Ordovician	middle																										
	lower																										
	upper																										
Cambrian	middle																										
	lower																										

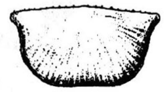
b. Once you have recorded the stratigraphic ranges of each genus, identify examples of: (1) a taxon range biozone; (2) a concurrent range biozone; and (3) an interval biozone. Draw the boundaries of each biozone and label it appropriately.

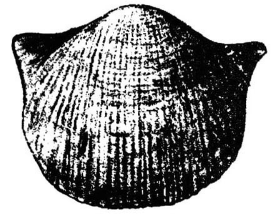
c. What is the geologic age of a rock sample that contains the brachiopods *Cyrtospirifer*, *Atrypa*, *Composita* and *Leptaena*?


Stringocephalus, M. Dev.


Stringocephalus, M. Dev.


Mesolobus,
M. Penn.–L. Perm.

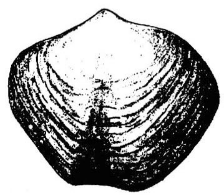

Chonetes,
Sil.–Perm.

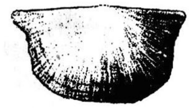

Penicularis L. Perm.

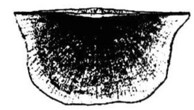

Juresania,
Penn.–L. Perm.

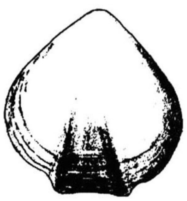

Juresania,
Penn. – L. Perm.

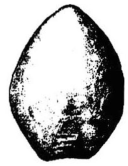

Kingena, Cret.


Athyris, Dev.–Trias.


Rafinesquina,
M. Ord.–U. Ord.


Rafinesquina,
M. Ord.–U. Ord.


Composita,
U. Dev.–Perm.


Dielasma,
U. Miss.–Perm.


Dielasma,
U. Miss.–Perm.


Strophomena,
M. Ord.–U. Ord.

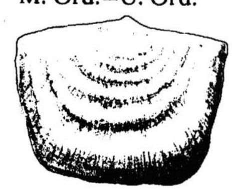

Strophomena,
M. Ord.–U. Ord.

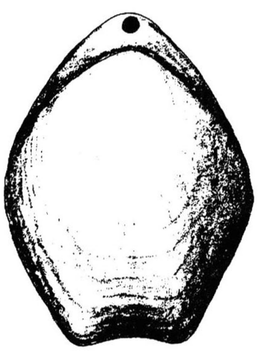

Composita,
U. Dev.–Perm.

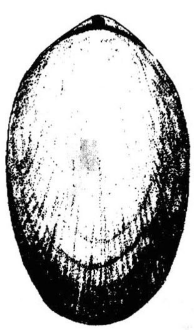

Hustedia,
Miss.–Perm.

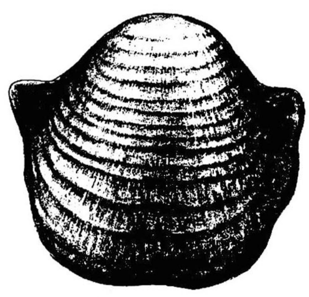

Derbyia,
Miss.–Perm.

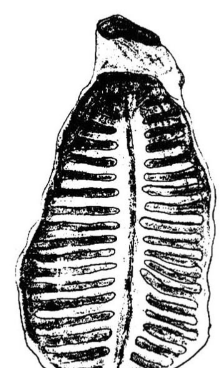

Derbyia,
Miss.–Perm.


Leptaena, M. Ord. – Dev.

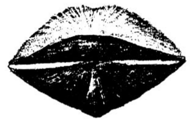

Terebratula, Cret.–Tert.


Rensselaeria, L. Dev.


Echinoconchus, Miss.

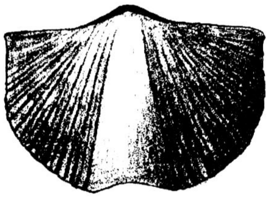

Leptodus, Perm.

Paraspirifer, L. Dev.–M. Dev.

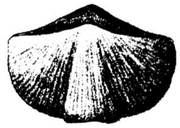


Cyrtospirifer, U. Dev.–L. Miss.

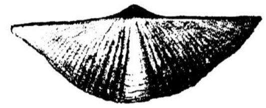
Mucrospirifer, M. Dev.



Paraspirifer, L. Dev.–M. Dev.

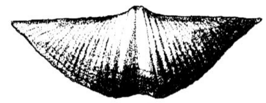


Cyrtospirifer, U. Dev.–L. Miss.

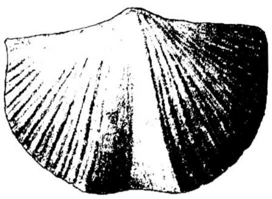


Mucrospirifer, M. Dev.

Cyrtospirifer, U. Dev.–L. Miss.



Mucrospirifer, M. Dev.

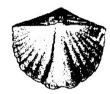


Paraspirifer, L. Dev.–M. Dev.

Spirifer, Miss.–M. Penn.

Spirifer, Miss.–M. Penn.

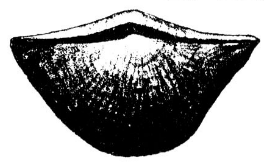
Cyrtina, Sil.–Perm.



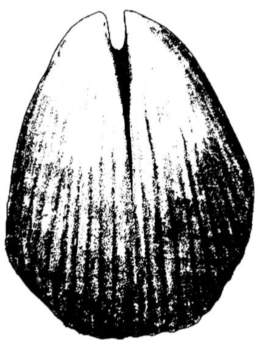
Cyrtina, Sil.–Perm.

Punctospirifer, Miss.–Perm.

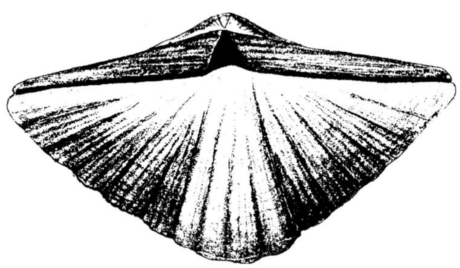
Punctospirifer, Miss.–Perm.



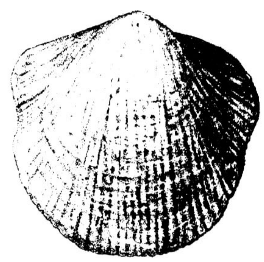
Atrypa, Sil.–Dev.



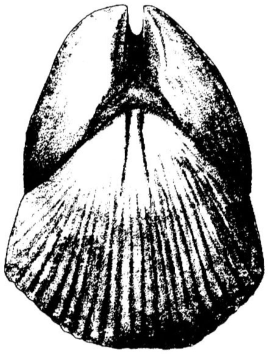
Pentamerus, Sil.



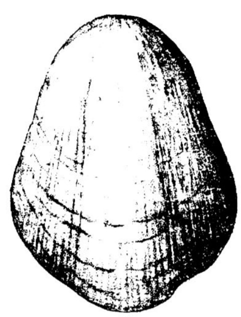
Neospirifer, Penn.–Perm.



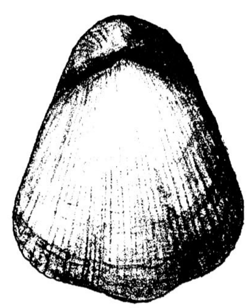
Atrypa, Sil.–Dev.



Pentamerus, Sil.



Conchidium, U. Ord.–L. Dev.



Conchidium, U. Ord.–L. Dev.

Part 3

Graphic correlation is a special biostratigraphic technique for correlating pairs of stratigraphic sections. The technique does not rely on biozones for correlation, but rather it utilizes the ranges of **all species** that occur in both of the stratigraphic sections being correlated.

In order to perform graphic correlation, one must ascertain the lowest observed occurrence and the highest observed occurrence of all fossil species that occur in both sections. These data, referred to as fossil "bases" and "tops," respectively, are then plotted on an X-Y graph and a line of correlation is fitted through the points. The line of correlation can be interpreted to relate a given level within one stratigraphic section to the exact temporal equivalent in the other section.

Examine Figures 3–6 for a clearer description of graphic correlation.

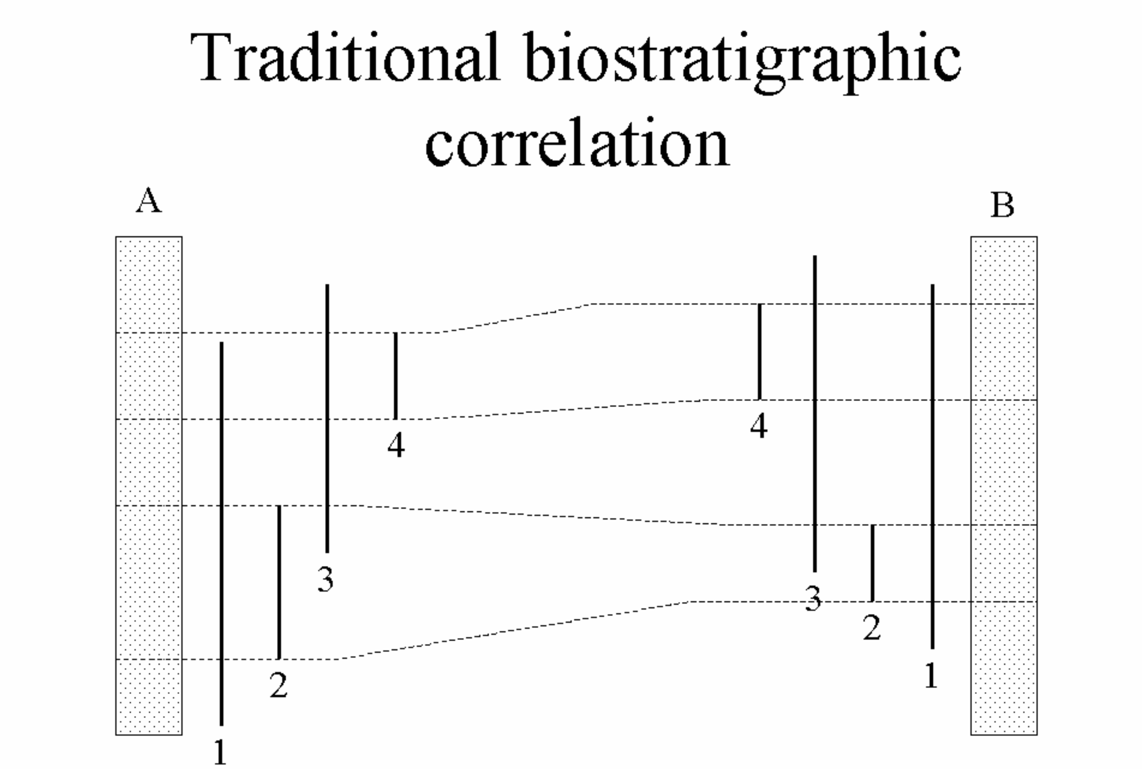


Figure 3—Two sections, A and B, can be correlated using traditional biozones, but precise correlation within biozones is not possible using traditional techniques.

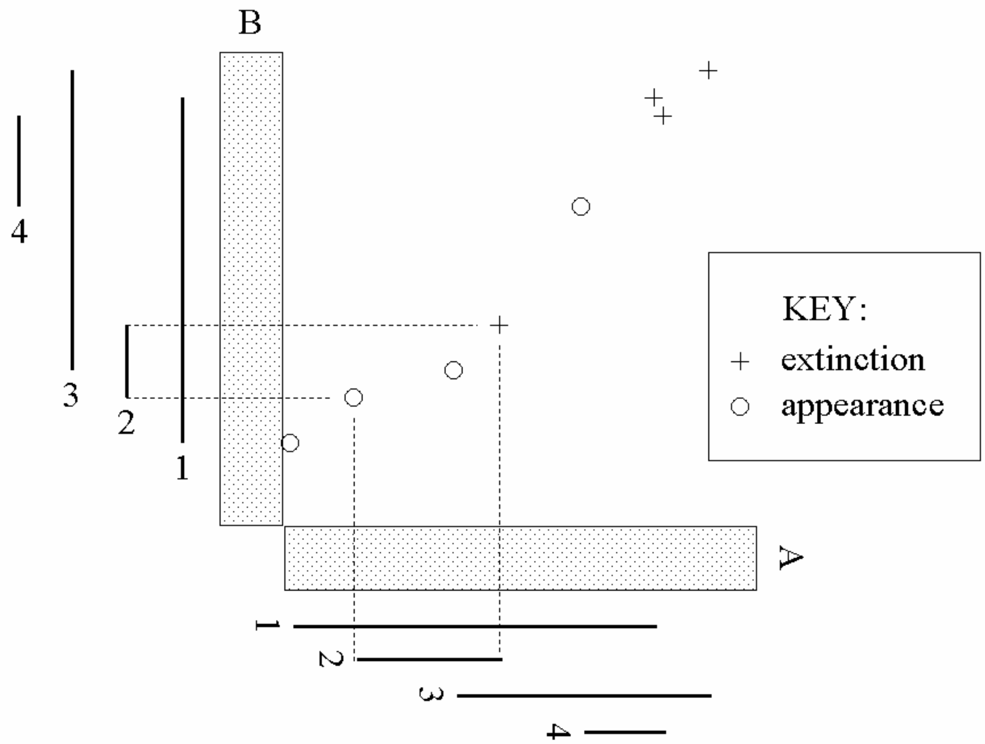


Figure 4—Graphic correlation plot of the same data as in Figure 3. Note that fossil “bases” (or evolutionary appearances) are plotted as circles and fossil “tops” (or extinctions) are plotted as pluses.

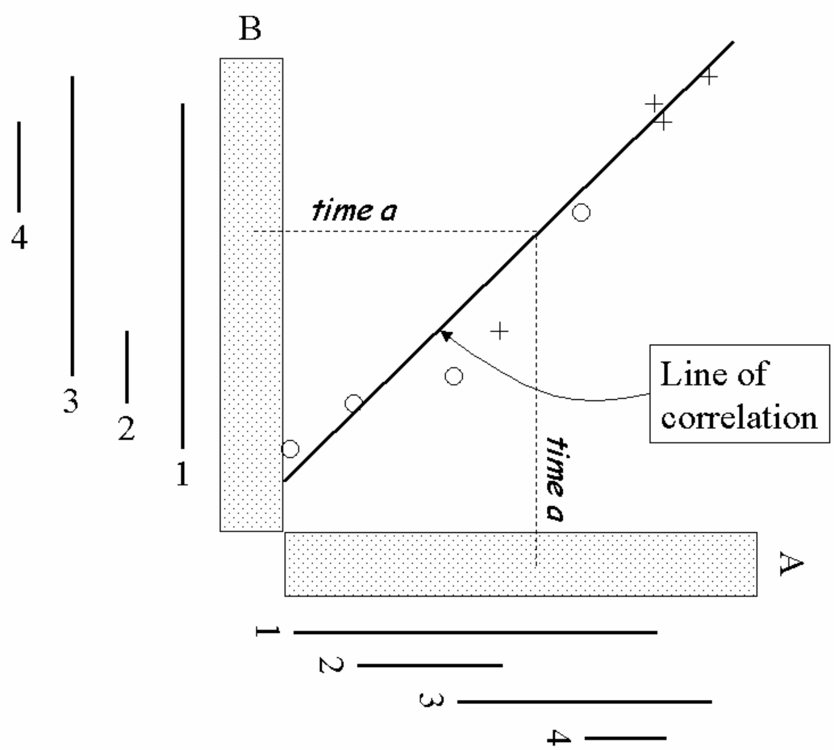


Figure 5—Line of correlation fitted through the data points from sections A and B. Any level in section A can be correlated with its exact temporal equivalent in section B by projecting to the line of correlation and then over to the other section.

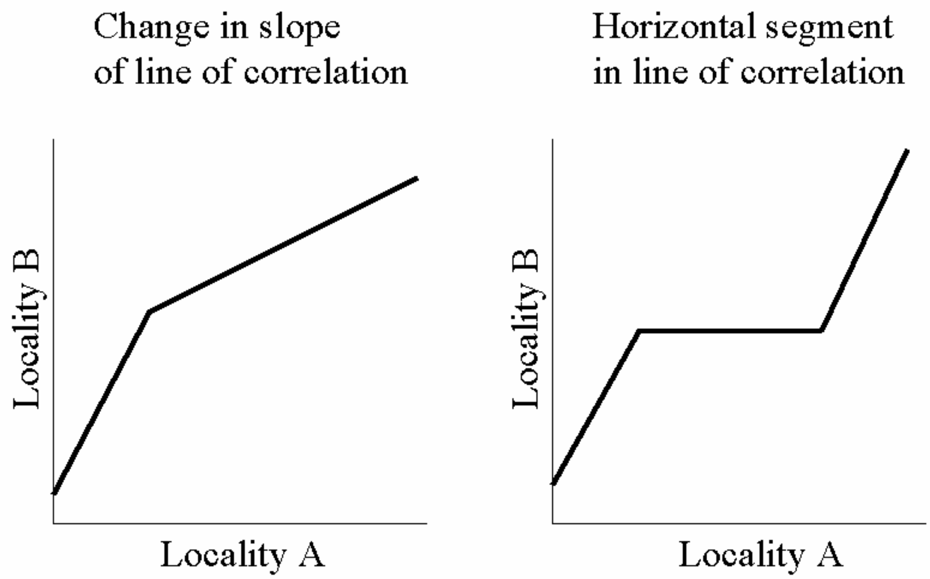


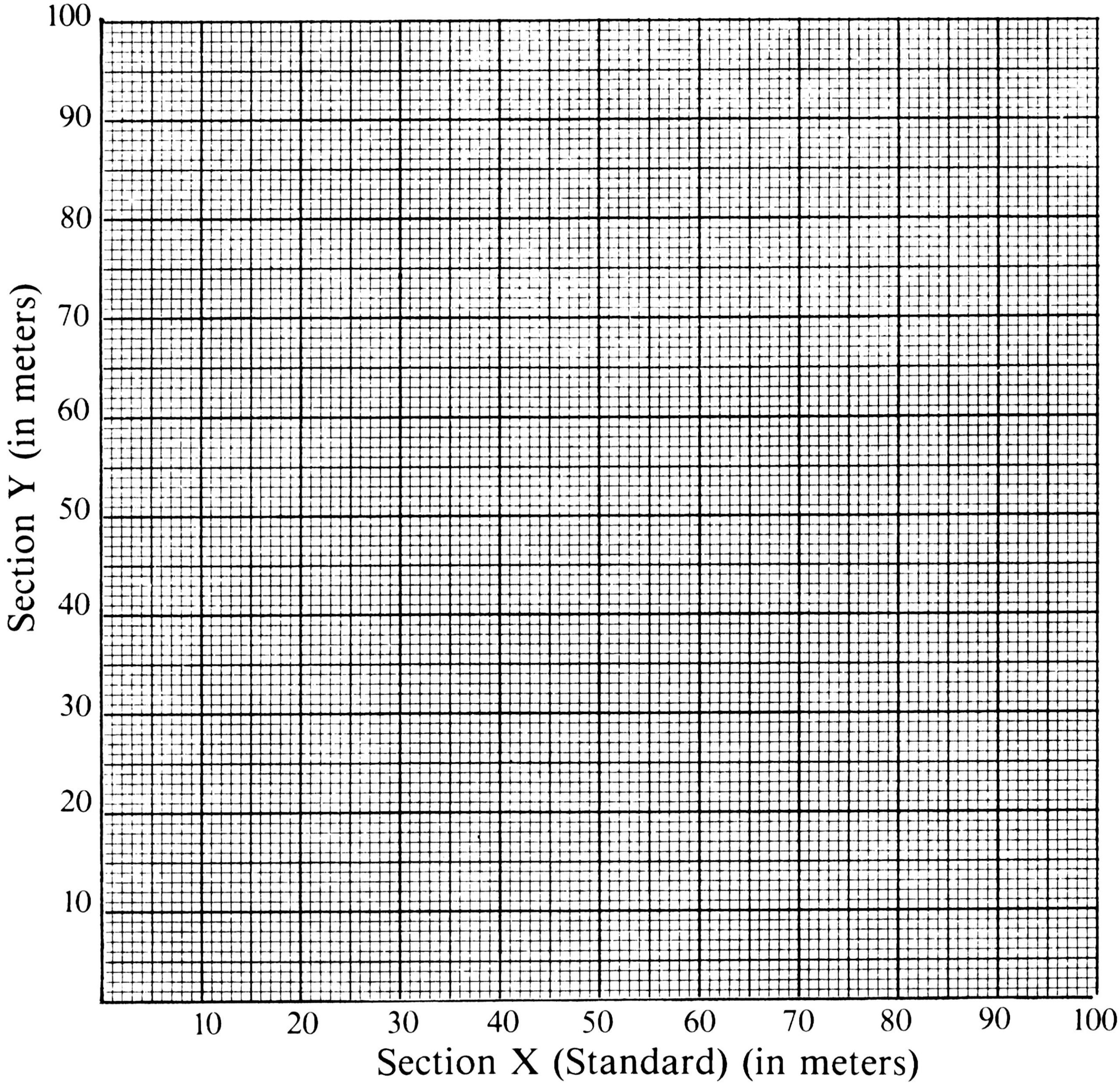
Figure 6—The line of correlation is not always a straight line. A change in the slope of the line of correlation signifies that sedimentation rates changed in one section relative to the other. For example, a perfect 45° line of correltation means that sedimentation rates in the two sections are exactly the same. A slope less than 45° means that sedimentation at Locality A (horizontal axis) occurred faster than at Locality B (vertical axis). Conversely, a slope greater than 45° means that sedimentation at Locality B was faster than at Locality A. A horizontal segment in the line of correlation signifies an unconformity or gap in sedimentation at Locality B. In other words, a finite thickness of strata at Locality A accumulated during an episode of non-deposition or erosion at Locality B.

a. Table 2 contains information on "bases" and "tops" of 11 fossil species that occur in two sections, X and Y. Plot these data on Graph A and then draw a line of correlation that best fits the distribution of data points.

Table 2—Bases and tops of 11 species at sections X and Y. Values in meters above base of section.

	Bases		**Tops**	
Species	**Section X**	**Section Y**	**Section X**	**Section Y**
1	15	5	49	23
2	21	14	94	53
3	27	12	99	58
4	16	10	80	47
5	32	18	83	54
6	42	28	91	63
7	54	24	68	38
8	53	34	79	58
9	57	32	86	51
10	69	34	85	43
11	43	23	81	51

Graph A



b. At which section, X or Y, was sedimentation occurring at the faster rate?

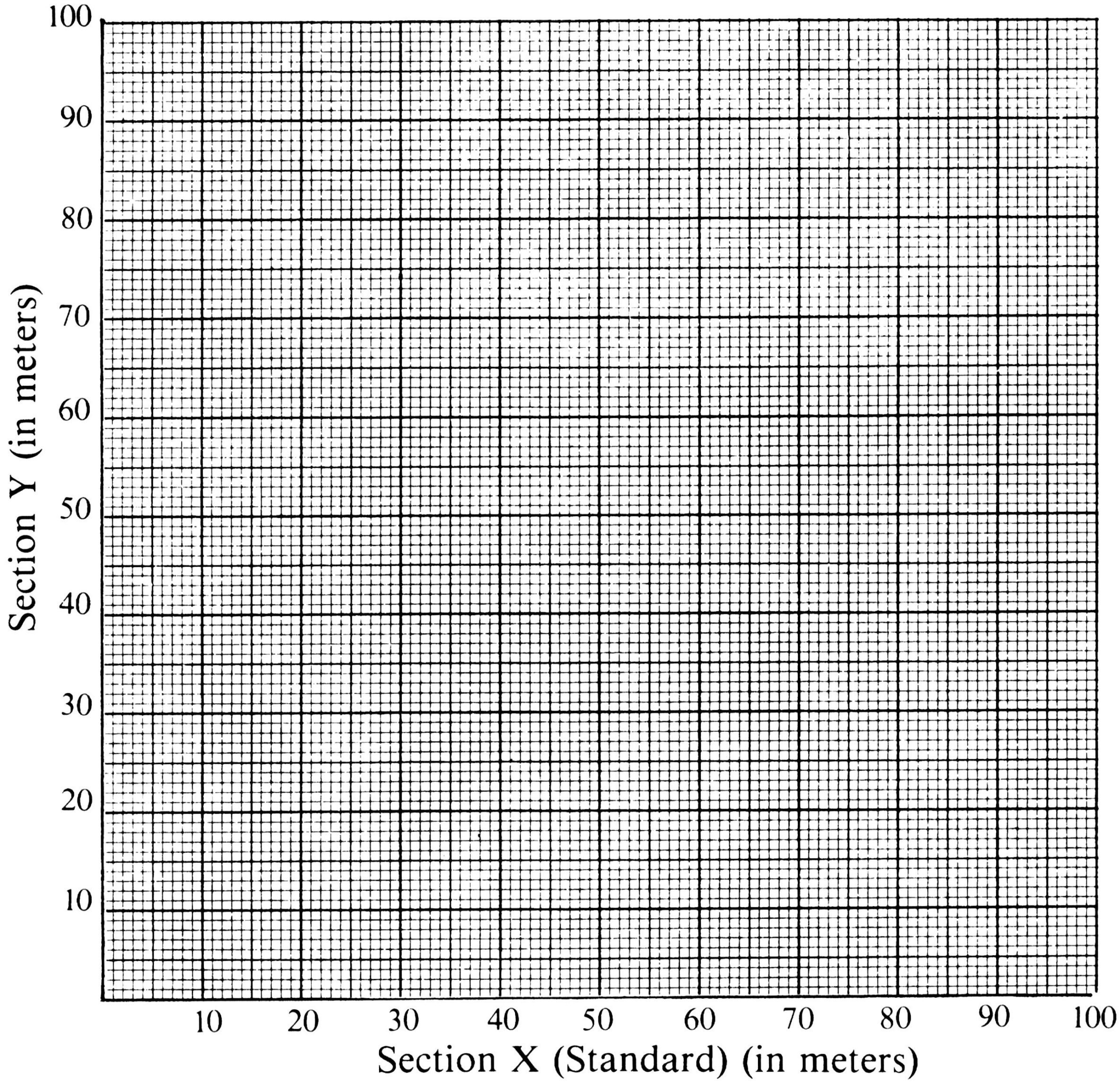
c. What level in section Y is exactly the same age as 50m in Section X?

d. Table 3 contains information on "bases" and "tops" for another group of 11 species from two more hypothetical sections, X and Y. Plot the data on Graph B, as before, and draw a line of correlation.

Table 3—Bases and tops of 11 species at sections X and Y. Values in meters above base of section.

Species	Bases		Tops	
	Section X	**Section Y**	**Section X**	**Section Y**
1	14	20	42	50
2	6	6	47	50
3	21	25	36	47
4	15	13	80	50
5	22	33	85	58
6	32	31	90	54
7	7	14	75	50
8	25	26	82	53
9	70	50	90	63
10	36	40	81	52
11	40	47	86	53

Graph B



e. Is the line of correlation a straight line, or is there a change in slope?

f. What does the line of correlation tell you about the rate of sedimentation in the lower part of section Y relative to the rate of sedimentation in the lower part of section X?

g. Examine the simple graphic correlation plot below. Assume that the line of correlation has been drawn correctly. Explain why some of the data points do not fall exactly on the line of correlation?