G202 - Overview of Scientific Methods / Techniques

I. Basic Perspectives

A. Scientific Method

1. Basic Observation (Data Collection = "Sensing the Environment")
2. Hypothesis / Working Model = a preliminary attempt at understanding a system
   a. Processes - Interactions - Mechanisms
3. Hypothesis / Model Testing
   a. Methodical Data Collection
4. Adjusting the Hypothesis / Reformulating the Model
   a. Data Supports or Rejects the Hypothesis
   b. Data does NOT Prove a Hypothesis
5. More Data Collection... goal = consistent results
6. Hypotheses lead to Theories; Theories lead to Scientific Facts or Beliefs

B. Observational vs. Experimental Science

1. Observation - passive data collection
2. Experimental - active data collection
   a. Experimental Design... with a purpose

C. Good Scientific Techniques

1. Unbiased Observation
   a. Organized / Thorough Note Taking
2. Understanding the Purpose of the Investigation
3. Hypothesis Formulation / Prediction
4. Hypothesis Testing through Experimental / Observational Design
   a. Controls = "known quantities of comparison"
5. Reporting Results
   a. Introduction
   b. Purpose
   c. Methods
   d. Data / Results
   e. Interpretation / Conclusion
   f. Recommendation for Further Research

II. Basic Mathematics Review

A. Decimal Fractions, basics and definitions

1. Decimal Fractions - a fraction whose deonominator is 10 or some multiple of 10 such as 100, 1000, 10000, etc.

2. We use a decimal point to denote a fraction/denominator. Numbers to the right of the decimal point are fractions less than 1 expresses in a decimal format. Numbers to the left of a decimal point are whole numbers of our counting system.

3. Fractional Form = 47/100 vs. Decimal Form = 0.47

4. Examples and place values

8/10 = 0.8   79/100 = 0.79   183/1000 = 0.83

5925/10000 = 0.5925

1st place to right of decimal = tenths
2nd place to right of decimal = hundredths
3rd place to right of decimal = thousandths
4th place to right of decimal = 10 thousandths
5th place to right of decimal = 100 thousandths
6th place to right of decimal = millionths

Number	Powers of 10	Exponential Form
1,000,000	= 10 x 10 x 10 x 10 x 10 x 10	= 10^6
100,000	= 10 x 10 x 10 x 10 x 10	= 10^5
10,000	= 10 x 10 x 10 x 10	= 10^4
1000	= 10 x 10 x 10	= 10^3
100	= 10 x 10	= 10^2
10	= 10	= 10^1
1	= 1	= 10^0
0.1	= 1/10	= 10^{-1}
0.01	= 1/10 x 1/10	= 10^{-2}
0.001	= 1/10 x 1/10 x 1/10	= 10^{-3}
0.0001	= 1/10 x 1/10 x 1/10 x 1/10	= 10^{-4}
0.00001	= 1/10 x 1/10 x 1/10 x 1/10 x 1/10	= 10^{-5}

B. THE METRIC SYSTEM AND CONVERSION

1. Metric system- developed in Europe (France) in 1700's, offered as an alternative to the British or English system of measurement. Metric measurement standards were established during an international conference, the metric system has generically come to be known as the SI or Systeme Internationale.

2. S.I./metric system involves measurements of length (meter), mass or weight (kilogram), temperature (celsius), time (second), and volume (litre).

3. Metric system based on powers of 10 and a decimal approach with prefixes attached to the basic units of measurment to indicate the power of 10 in question.

Greek prefixes > 1 base unit, Latin prefixes < 1 base unit (Metric System Based on Powers of 10)

1. Mega = 10^6 e.g. 1 megameter = $1x10^6$ meter
2. Kilo = 10^3 1 kilometer = $1x10^3$ meters
3. Hecto = 10^2 1 Hectometer = $1x10^2$ meters
4. Deka = 10^1 1 Dekameter = $1x10^1$ meters
5. Base unit = 10^0 1 meter = 1 x 10^0 meters
6. Deci = 10^{-1}
7. Centi = 10^{-2} and so on
8. Milli = 10^{-3}
9. Micro = 10^{-6}
10. Nanno = 10^{-9}
11. Pica = 10^{-12}

The movement of the decimal point to the left or right of the given quantity of a unit is all that is needed to change a given type of unit to the next higher or lower unit:

e.g. 1 m = 10 dm = 100 cm = 1000 mm = 1,000,000 um
1 m = 0.1 Dam = 0.01 Hm = 0.001 Km = 0.0000001 Mm

4. METRIC MEASUREMENT OF DISTANCE

a. Based on the meter (analogous to the yard in English system)

1 Km = 1000 m, 1 Hm = 100 m, 1 Dam = 10 m, 1 m = 1 m,
1 dm = 0.1 m, 1 cm = 0.01 m, 1 mm = 0.001 m, 1 um = 0.000001 m

b. Conversion of One metric unit to another

e.g. convert 8.9 km to m: 8.9 km $\frac{1000\text{ m}}{1\text{ km}}$ = 8900 m

e.g. convert 1230 m to km: 1230 m $\frac{1\text{ km}}{1000\text{ m}}$ = 1.23 km

5. METRICATION OF AREA

a. SI units: km^2, m^2, cm^2, etc.

b. Metric equivalent of Acre = Hectare (Ha) = 100 m x 100 m which equals 10,000 m^2; i.e. 10,000 m^2/Ha

e.g. determine the no. of hectares in a plot of land: 1.6 km x 1.2 km = 1600 m x 1200 m = 1,920,000 m^2 (1 Ha/10,000m^2)= 192 Ha

c. Examples of converting square metric units to other square metric units: e.g. km^2 to m^2.

6. METRICATION OF VOLUME

a. volume- the amount of space within a container or enclosed within a solid

b. SI units of volume: cubic meters which can be equated to litres.

c. Can use same metric-prefix approach as given for meters, can be used with litres as well

e.g. 1 l = 1000 ml = .001 kl and so on
e.g. convert 17 litres to milliters:
17 l (1000 ml/l) = 17,000 ml

d. E.g. of problems converting volume in metric system
(1) Find the volume in liters of a rectangular tank (lxwxh) 2 m x 20 dm x 28 cm

7. METRICATION OF MASS

a. Mass - measure of resistance to motion.
(1) Weight - measure of the force of gravity upon a given body.

Thus mass and weight are interchangeable under a given force of gravity, but may differ in cases of 2 different gravitational forces (e.g. a given mass will have different weights on the earth as compared to the moon (G moon = 1/6 G earth), but the mass or quantity of material occupying space will be same on earth as on the moon).

b. Metric unit of measuring mass = gram, kilogram, etc.
(1) converting from volume to capacity to weight:

1000 cu. cm = 1000 ml = 1000 gram of pure water
For pure water: 1 L = 1 Kg, thus 1 gm of water = 1 ml of water = 1 cu. cm

c. E.g. of metric conversions: convert 2700 mg to grams

2700 mg (1 gm/1000 mg) = 2.7 grams

8. METRIC MEASUREMENT OF TEMPERATURE

a. Metric unit = celsius, English unit = Farenheit
b. water freezes at 32° F = 0° C water boils at 212° F = 100° C

c. Conversion Factors:

(1) From C to F: $F = 9/5C + 32^\circ$
(2) From F to C: $C = 5/9(F - 32^\circ)$
(a) E.g. convert 40 C to F
$F = 9/5(40) + 32 = 104^\circ$ F

d. CONVERSION FROM ENGLISH SYSTEM TO METRIC AND VICE VERSA

(1) Conversion charts/factors given for units of length, area, volume, and weight/mass on p. 300.

(a) E.g. of conversion problems:

Given that 1 yard = 0.9144 m, how many meters are there in 100 yards?
100 yd (0.9144 m/1 yd) = 91.44 m.

III. A Note About Significant Digits

A. e.g. take the average of 123, 156, 178, and 198

(123 + 156 + 178 +198)/4 = 163.75
the "data" only have 3 significant digits, while the "result" has 5 significant digits

Significant digits of "result" must = "data", i.e. round 163.75 to 164

IV. Accuracy vs. Precision in Measurement

A. Accuracy = closeness of a measurement to the accepted "true value"
   1. Affected by systematic errors

B. Precision = "Repeatability of Measurements"
   1. aggreement of a number of measurements, when taken in repetition
   2. Degree of precision limited by measring device

APPENDIX 7

Table for length conversion

Unit	mm	cm	m	km	in	ft	yd	mi
1 millimeter	1	0.1	0.001	10^{-6}	0.0397	0.00328	0.00109	6.21×10^{-7}
1 centimeter	10	1	0.01	0.0001	0.3937	0.0328	0.0109	6.21×10^{-6}
1 meter	1000	100	1	0.001	39.37	3.281	1.094	6.21×10^{-4}
1 kilometer	10^{6}	10^{5}	1000	1	39,370	3281	1093.6	0.621
1 inch	25.4	2.54	0.0254	2.54×10^{-5}	1	0.0833	0.0278	1.58×10^{-5}
1 foot	304.8	30.48	0.3048	3.05×10^{-4}	12	1	0.333	1.89×10^{-4}
1 yard	914.4	91.44	0.9144	9.14×10^{-4}	36	3	1	5.68×10^{-4}
1 mile	1.61×10^{6}	1.01×10^{5}	1.61×10^{3}	1.6093	63,360	5280	1760	1

APPENDIX 8

Table for area conversion

Unit	cm^2	m^2	km^2	ha	in^2	ft^2	yd^2	mi^2	ac
1 sq. centimeter	1	0.0001	10^{-10}	10^{-8}	0.155	1.08×10^{-3}	1.2×10^{-4}	3.86×10^{-11}	2.47×10^{-8}
1 sq. meter	10^{4}	1	10^{-6}	10^{-4}	1550	10.76	1.196	3.86×10^{-7}	2.47×10^{-4}
1 sq. kilometer	10^{10}	10^{6}	1	100	1.55×10^{9}	1.076×10^{7}	1.196×10^{6}	0.3861	247.1
1 hectare	10^{8}	10^{4}	0.01	1	1.55×10^{7}	1.076×10^{5}	1.196×10^{4}	3.861×10^{-3}	2.471
1 sq. inch	6.452	6.45×10^{-4}	6.45×10^{10}	6.45×10^{-8}	1	6.94×10^{-3}	7.7×10^{-4}	2.49×10^{-10}	1.574×10^{7}
1 sq. foot	929	0.0929	9.29×10^{-8}	9.29×10^{-6}	144	1	0.111	3.587×10^{-8}	2.3×10^{-5}
1 sq. yard	8361	0.8361	8.36×10^{-7}	8.36×10^{-5}	1296	9	1	3.23×10^{-7}	2.07×10^{-4}
1 sq. mile	2.59×10^{10}	2.59×10^{6}	2.59	259	4.01×10^{9}	2.79×10^{7}	3.098×10^{6}	1	640
1 acre	4.04×10^{7}	4047	4.047×10^{-3}	0.4047	6.27×10^{6}	43,560	4840	1.562×10^{-3}	1

APPENDIX 9
Table for volume conversion

Unit	mL	liters	m^3	in^3	ft^3	gal	ac-ft	million gal
1 milliliter	1	0.001	10^{-6}	0.06102	3.53×10^{-5}	2.64×10^{4}	8.1×10^{-10}	2.64×10^{-10}
1 liter	10^{3}	1	0.001	61.02	0.0353	0.264	8.1×10^{-7}	2.64×10^{-7}
1 cu. meter	10^{6}	1000	1	61,023	35.31	264.17	8.1×10^{-4}	2.64×10^{-4}
1 cu. inch	16.39	1.64×10^{-2}	1.64×10^{-5}	1	5.79×10^{-4}	4.33×10^{-3}	1.218×10^{-8}	4.329×10^{-9}
1 cu. foot	28,317	28.317	0.02832	1728	1	7.48	2.296×10^{-5}	7.48×10^{6}
1 U.S. gallon	3785.4	3.785	3.78×10^{-3}	231	0.134	1	3.069×10^{-6}	10^{6}
1 acre-foot	1.233×10^{9}	1.233×10^{6}	1233.5	75.27×10^{6}	43,560	3.26×10^{5}	1	0.3260
1 million gallons	3.785×10^{9}	3.785×10^{6}	3785	2.31×10^{8}	1.338×10^{5}	10^{6}	3.0684	1

APPENDIX 10
Table for time conversion

Unit	sec	min	hours	days	years
1 second	1	1.67×10^{-2}	2.77×10^{-4}	1.157×10^{-5}	3.17×10^{-8}
1 minute	60	1	1.67×10^{-2}	6.94×10^{-4}	1.90×10^{-6}
1 hour	360	60	1	4.17×10^{-2}	1.14×10^{-4}
1 day	8.64×10^{4}	1440	24	1	2.74×10^{-3}
1 year	3.15×10^{7}	5.256×10^{5}	8760	365	1

V. Algebra Review

A. Essence of algebra - to write equations with variables, illustrating quantitative relationships between the variables.

1. e.g. Velocity = rate of change in position per unit time

a. V = d/t where v = velocity, d = distance, t = time
b. velocity units = m /sec in SI system

B. Unit Conversion and Unit Management

1. Keeping track of unit dimensions in equations is very important
2. Unit algebra is based on simple unit cancelling

E.g. Given the fractional equation: $4 * \frac{2}{4}$ (note here "*" = times)

since there is a 4 in the numerator and 4 in the denominator, we can short-cut by simply cancelling out the 4 above, and 4 below (4/4 = 1)... and we find that the equation is equal to 2.

By analogy, given the algebraic equation: $Y * \frac{2}{Y}$ (note here "*" = times)

since there is a "Y" in the numerator and Y in the denominator, we can short-cut by simply cancelling out the Y above, and Y below (Y/Y = 1).... and we find that the equation is equal to 2.

By analogy, given that 1 mile = 5280 ft, we can convert 20,000 ft to miles by using unit algebra:
1) set up the equation so that the units you are trying to cancel are in the numerator and denominator
2) check to see if the end unit is the one you're looking for....
$20{,}000 \text{ ft} * \frac{1 \text{ mile}}{5280 \text{ ft}}$ = 3.79 miles... in this case the ft / ft cancels, leaving miles as the unit

EXAMPLE TO TRY: given that 1 in = 2.54 cm, 1 ft = 12 in, and 1 mi = 5280 ft; How many centimeters are in 863 ft? Remember you are going from ft to cm, manage your units so that all cancel, except cm!

HOMEWORK TIPS: SHOW ALL YOUR UNITS, ORGANIZE THE UNITS AND CANCEL THEM OUT!!!

C. Algebraic Manipulation of Exponents
1. Negative Exponents
$a^{-n} = 1/a^n$
2. The zero power (any no. raised to the zero power = 1)
$a^0 = 1$
3. Power of one (any no. raised to the 1st power = that number)
$a^1 = a$
4. Multiplication (exponential nos. with the same base)
$a^m * a^n = a^{m+n}$
5. Division

$a^m/a^n = a^{m-n}$

6. Distribution

$(a*b)^n = a^n*b^n$

$(a^m)^n = a^{m*n}$

D. Dividing Fractions

1. When dividing by a fraction, invert the fraction and multiply
   e.g. 1/(1/4) = 1 * (4/1) = 4

2. Applying fraction division to unit algebra
   e.g. (m/sec)/sec = (m/sec)*(1/sec) = m/sec^2

E. Rearranging equations algebraically

1. By using simple algebra, equations can be re-arranged to solve for other unknowns:
2. Examples

Given velocity and time, how to figure distance traveled during the time period?
Velocity V = d/t rearranged to... multiply both sides of equation by t.... d = V*t

Given velocity and distance, how to figure time of travel?
Velocity V=d/t rearranged to... t = d/V

Given acceleration and time, how to figure velocity acquired during the time period?
Acceleration A = V/t rearranged to... multiply both sides of equation by t.... V = A*t
Example: you are driving a constant 50 km / hr for 35 minutes, how far have you traveled?

Example: you are accelerating in your car at 10 km/sec/sec for 90 sec, what is your velocity?

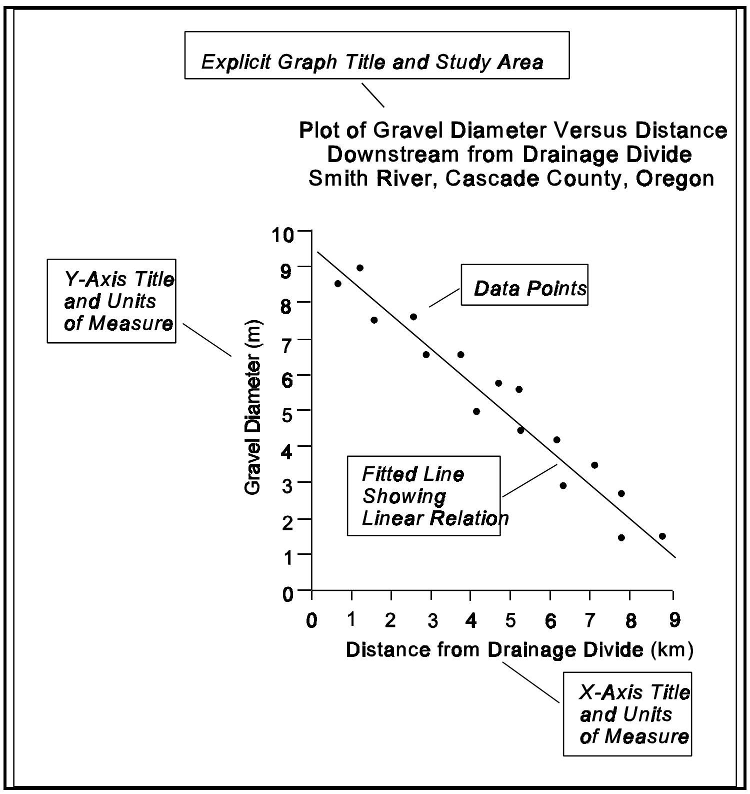
VI. Graphing Review

A. Purpose of Graphs - To visually illustrate data relationships

B. Axes
   1. Y axis = vertical axis (ordinate)
   2. X axis = horizontal axis (abscissa)

C. Example graph types
   1. X-Y Scatter Plots
   2. Bar Graphs

Elements of a Well-Designed Graph - For Example an X-Y Scatter Plot



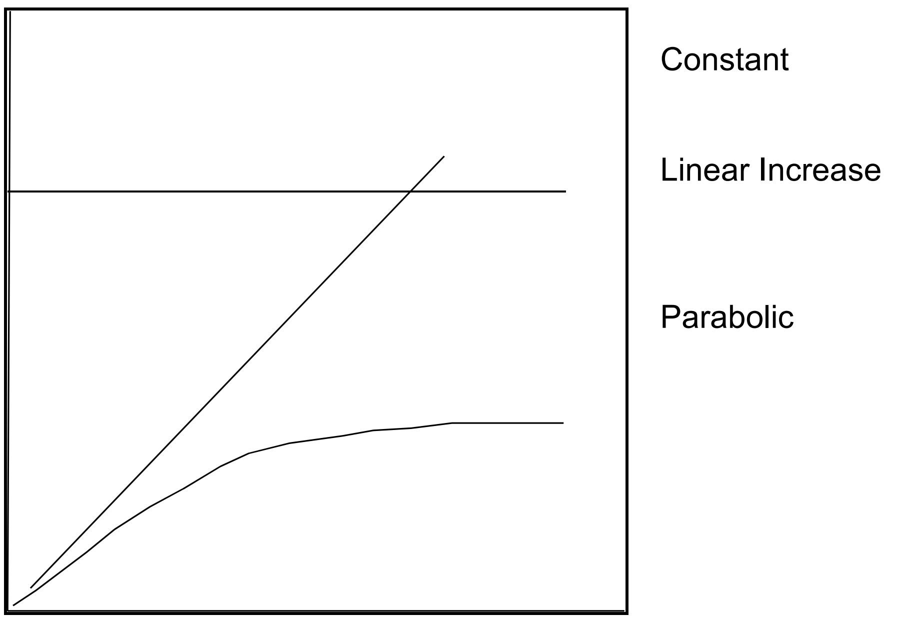
3. Dependent and Independent Variables

   a. In relating elements of a system together, we can identify dependent and independent variables
      (1) By convention, the dependent variable is plotted on the y-axis and independent variable on the x-axis

   b. Example above: It appears that gravel diameter changes systematically, decreasing in size in a down stream direction. Thus, gravel size is the dependent variable, position downstream is the independent variable. That is, gravel size depends on where you are in the river basin, relative to the drainage divide.

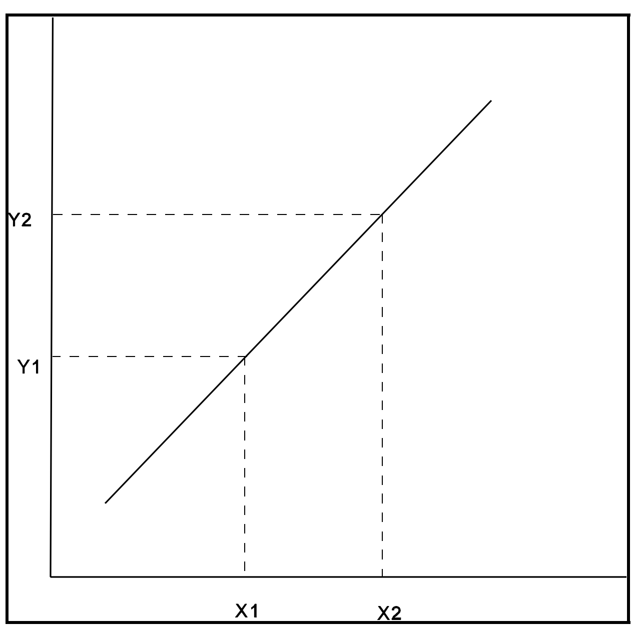
4. Graph Trends (see attached figures)

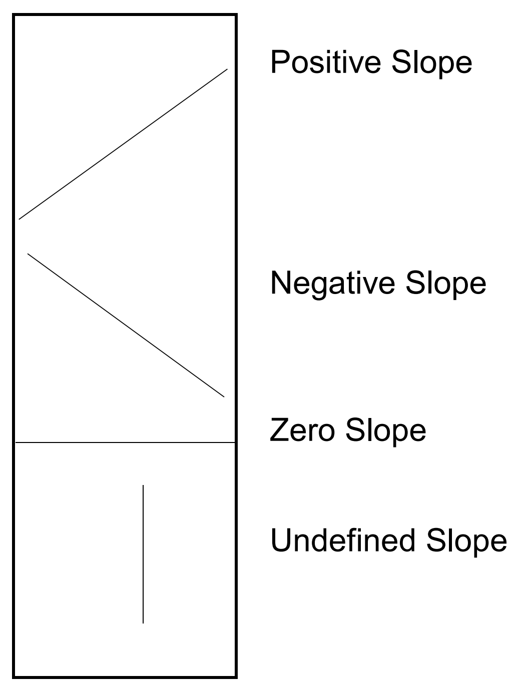
a. Linear Increase / Decrease
b. Constant
c. Parabolic (curvilinear) Increase / Decrease



5. Determining Slopes of Lines

a. slope of any line on a graph = rise / run = $(Y_2 - Y_1) / (X_2 - X_1)$





6. Significance of Calculating Line Slopes

a. distance vs. time

The slope of a distance vs. time plot: Y = distance, X = time, slope = m = $\Delta Y / \Delta X$ = distance / time = Velocity

b. velocity vs. time

The slope of a velocity vs. time plot: Y = velocity, X = time, slope = m = D Y / D X = velocity / time = Acceleration

c. Basic Form of Line Equation

(1) When data plot in a straight line, the algebraic equation of the line is in the following form:

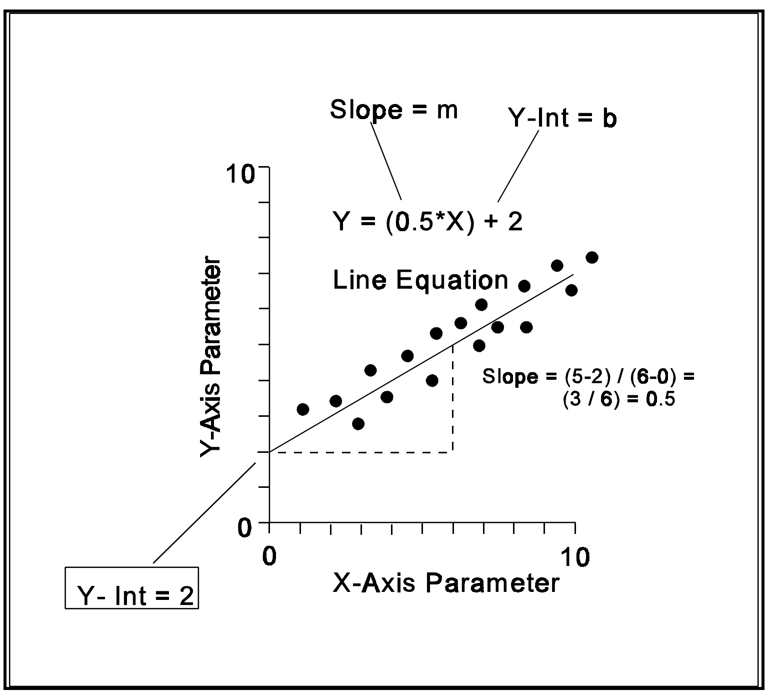
$$Y = mX + b$$

where Y is the Y-axis variable, X = X-axis variable, m = slope of the line, b = Y-intercept

m = slope of line = as determined above

Y-intercept = the y-value where the line intercepts the y-axis (see example below)

Example for Determining the Equation of a Line on a Graph



VII. Scientific Visualization and Geology

Comment: Geology is a very conceptual, 4-D science that involves spatial (3-D space) and temporal (time) relationships. Mapping and graphical visualization has historically comprised a very important component of the geological sciences. The following is a basic overview of techniques commonly used to visualize geologic relationships.

A. Maps and Map View

1. Map View - imaging the Earth by looking down on the surface from above (e.g. like flying over the landscape in an airplane)

a. Maps - 2-D representations of the Earth's surface, map topics can include
(1) geology
(2) vegetation
(3) topography (shape of the landscape)
(4) hydrology (streams, lakes)
(5) cultural features (e.g. roads, buildings)

b. Essential Elements of a Map
(1) Title, describing the type of map
(2) North Arrow (which direction is which)
(3) Scale
(4) Date

An Example Geologic Map is Shown on the Next Page

e:figures:fngeomap.srf

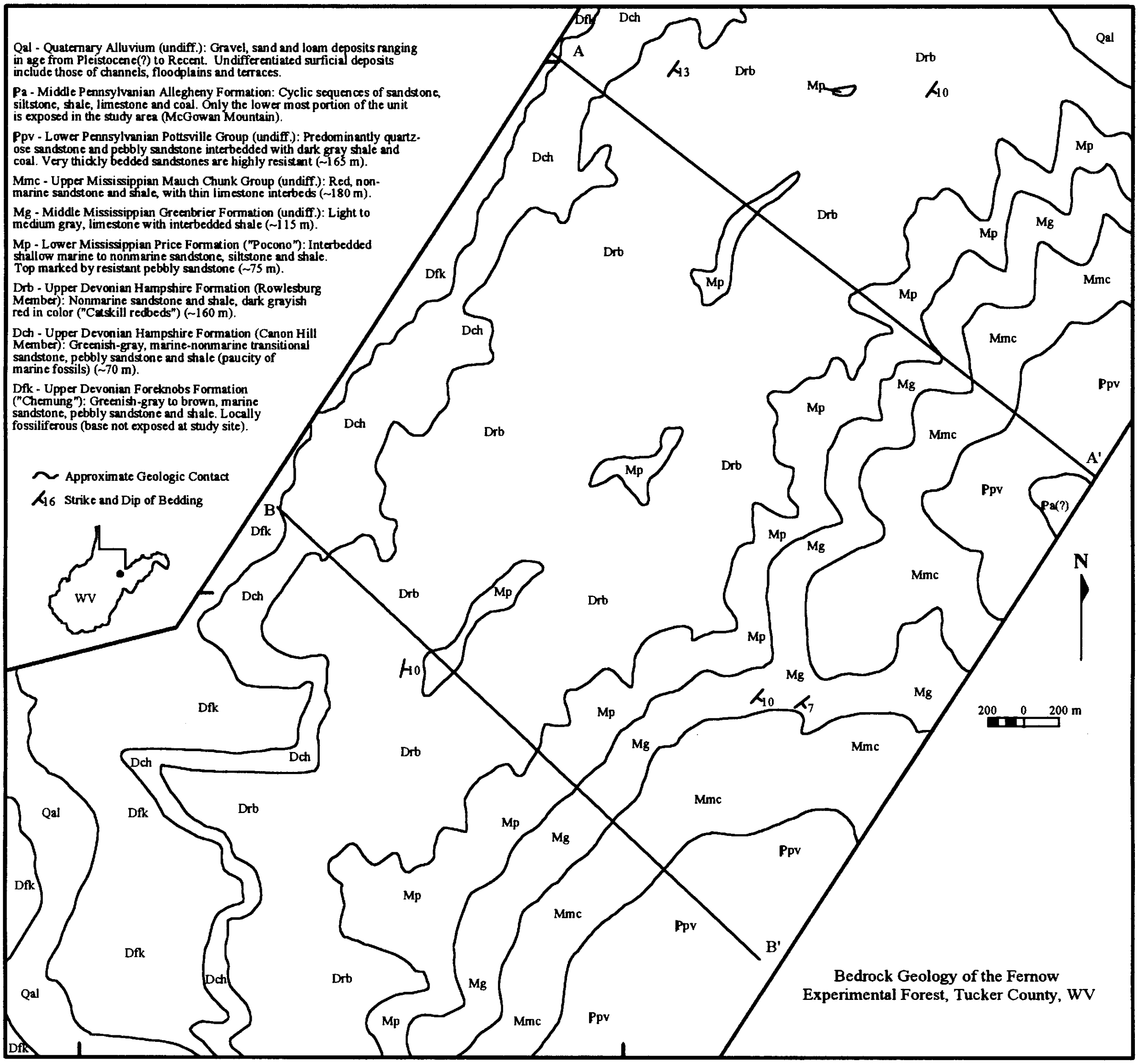


Figure 2-9. Bedrock geology of the Fernow Experimental Forest, Tucker County, West Virginia. Refer to Plate 2-2 for the 1:9,600 scale version. Cross-sections A-A' and B-B' are shown on Figure 2-10 and Plate 2-3.

B. Cross-Sections

1. Represent a "cut-away" or side view of the Earth, showing vertical spatial relations, at depth below the Earth's Surface

   a. Map View is from above the Earth
   b. Cross-Section View is looking at a slice of the Earth from the side

2. Common Use of Cross-Sections

   a. Showing the topographic profile of the Earth's surface
   b. Showing the types of rocks at depth below the Earth's Surface

An Example Cross-Section of the Previous Map is Illustrated on the Next Page...

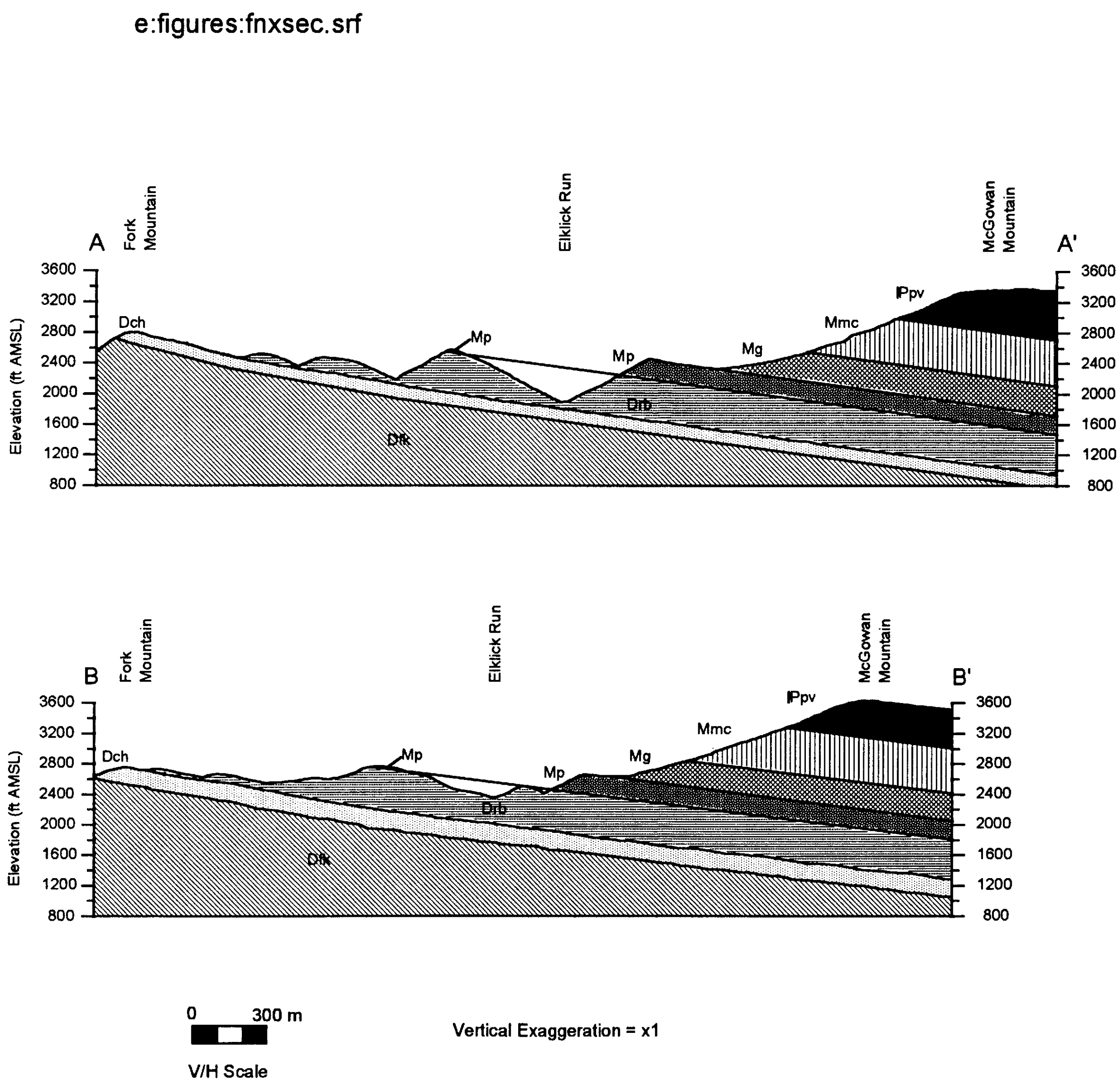
C. Conceptual Drawings

1. Conceptual Drawings - maps, cross-sections and block diagrams that illustrate spatial relations

   a. sketch maps / sketch cross-sections - a useful way to conceptualize relationships

   b. Block Diagrams - 3-D drawings illustrating top and side views of the Earth in 3 dimensions

Examples of Sketch Maps, Cross-Sections, and Block Diagrams are illustrated on the following pages.



IPpv - Lower Pennsylvanian Pottsville Group (undiff.): Predominantly quartzose sandstone and pebbly sandstone interbedded with dark gray shale and coal. Sandstone lithofacies are very thickly bedded, cross-stratified and erosionally resistant. Typically associated with very bouldery regolith and sandstone rubble land (clasts > 2 m diameter). The unit is approximately 150 m thick in the study area (Reger, 1923).

Mmc - Upper Mississippian Mauch Chunk Group (undiff.): Red, non-marine sandstone and shale, with thin limestone interbeds. Associated with red soils of the Calvin Series. Pedogenic features are similar to those of the Hampshire Formation (Rowlesburg Member). The unit has an estimated thickness of 180 m. The upper contact is commonly covered by large colluvial sandstone boulders of the overlying Pottsville Group.

Mg - Middle Mississippian Greenbrier Formation (undiff.): Light to medium gray limestone with interbedded shale. The unit has a total thickness of over 100 m in the study area (Reger, 1923). Greenbrier strata are associated with calcic soils of the Belmont Series and karst surface features.

Mp - Lower Mississippian Price (Pocono) Formation (undiff.): Comprised predominantly of brown and gray, coarse-grained sandstone and pebbly sandstone, medium to thick bedded. Typically associated with brown soils of the Dekalb Series. The unit has an estimated thickness of 75 m in the study area. The top of the Price Formation is marked by a resistant pebbly sandstone member that forms pronounced bedrock benches on the southeastern side of Elklick Run. Stratigraphic nomenclature is after Kammer and Bjerstedt (1986).

Drb - Upper Devonian Hampshire Formation, Rowlesburg Member: Interbedded nonmarine sandstone and shale, grayish red to bright red in color ("Catskill Redbeds"). Sandstone lithofacies are fine- to medium-grained and cross-bedded. Typically associated with red soils of the Calvin series. Thickness of the unit is approximately 160 m in the study area (nomenclature after Boswell and others, 1987).

Dch - Upper Devonian Hampshire Formation, Canon Hill Member: Predominantly olive-gray and brown, nonmarine sandstone with subordinate grayish-red interbeds. This unit was originally mapped as part of the "Chemung Group" by Reger (1923). Boswell and others (1987) interpreted the unit as a lower member of the Hampshire Formation, transitional between the fossiliferous marine strata ("Chemung" fauna) and the overlying continental red beds of the Rowlesburg Member. The unit has an estimated thickness of 70 m and includes a pebbly sandstone lithofacies mapped as "Hendricks sandstone" by Reger (1923). Typically associated with brown soils of the Dekalb series.

Dfk - Upper Devonian Foreknobs Formation (Greenland Gap Group): Interbedded olive-gray and yellowish-brown sandstone, siltstone and shale. This unit includes the fossiliferous, marine strata that were traditionally mapped as "Chemung Group" in West Virginia (e.g. Reger, 1923). The unit has an estimated thickness greater than 750 m in the vicinity of the study area (Reger, 1923). Typically associated with the Dekalb and Gilpin soils series.

Figure 2-10. Geologic cross-section drawn along lines A-A' and B-B'. See Plate 2-3 for 1:9,600 scale version. Refer to Figure 2-9 and Plate 2-2 for section lines. View is to the northeast.

Viscous Flow L_f/D_c - L_f = length of bare surface on displaced material, D_c is depth of concave segment

Tenuity L_m/L_c - indicates dispersion or cohesion of material during displacement

Fluidity Expected coverage of material on distinct slope - Varies with H_2O content

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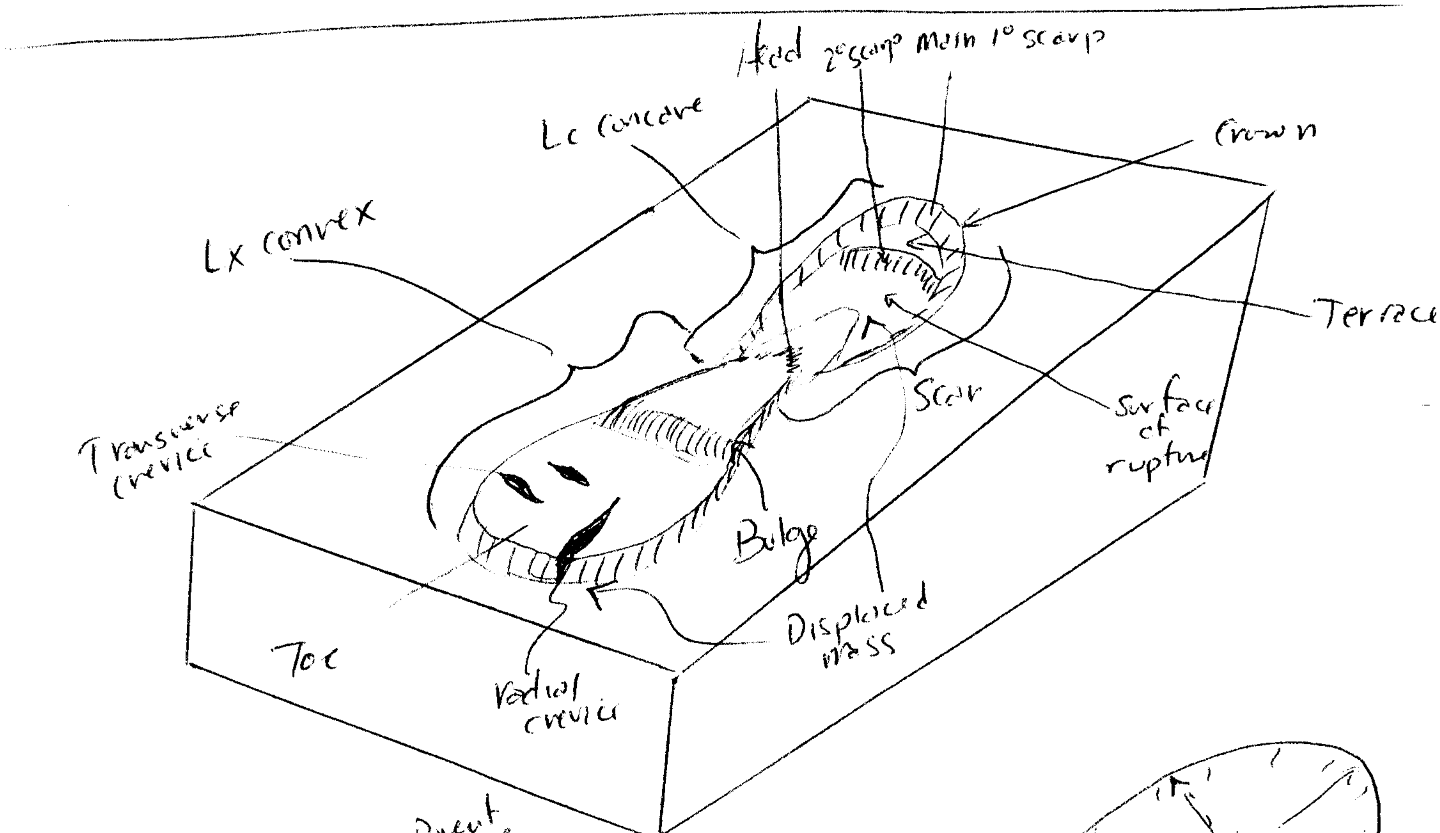

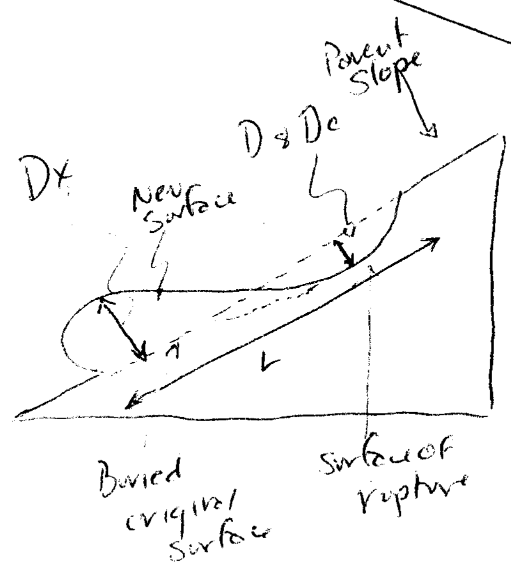

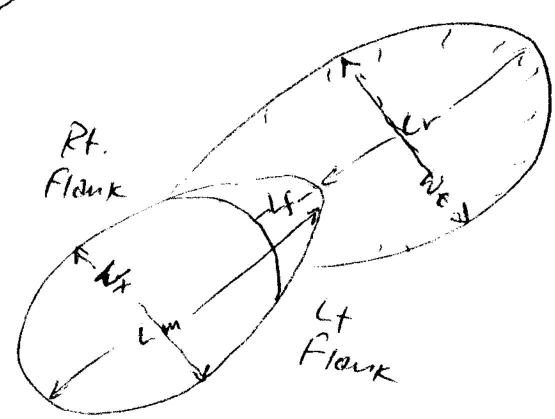

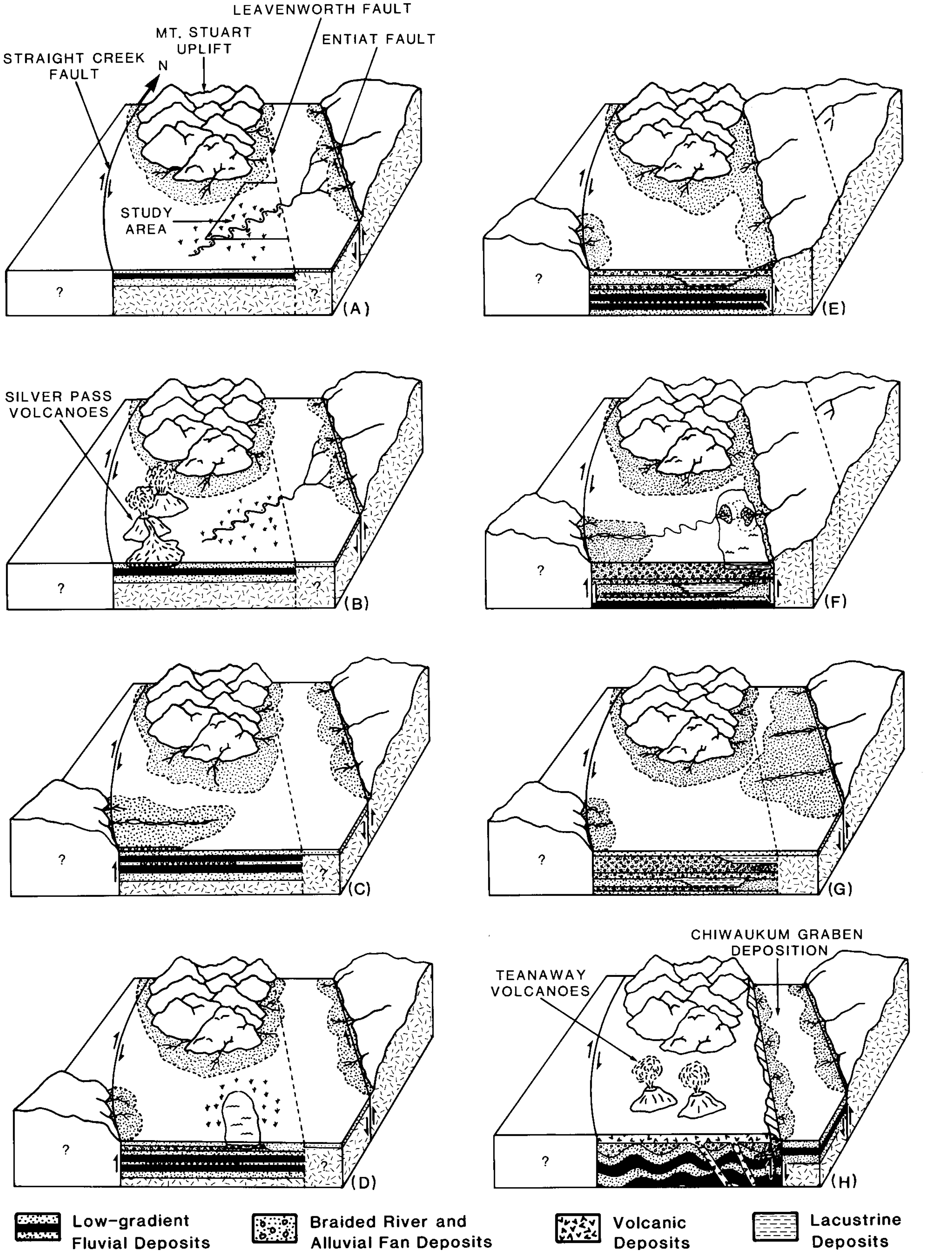

FIG. 17. Block diagrams illustrating inferred paleogeography of the Swauk Formation and geologic evolution of the Swauk Basin. Block A represents the early Eocene. Block B shows the 50–52 Ma extrusion of the Silver Pass Volcanic Member. Blocks C–G show middle Eocene deposition between Silver Pass time and ca. 47 Ma (Block H), the time of Teanaway volcanism. Tabor *et al.* (1984, Figs. 9A, B) and Johnson (1985, Fig. 11A) show much less detailed block diagrams of early Swauk Basin history. See text for discussion.