Multi-dimensional Modeling of Ore Bodies

Making Sense of Empirical Data

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Part One: Michigan Standards Addressed

Mathematics/Strand V/Content Standard 2/High School

Benchmark 4

Analyze problems that can be modeled by functions, determine strategies for solving the problems and evaluate the adequacy of the solutions in the context of the problems.

Overview:
Students learn analytic thinking most effectively when it is studied in the context of problems and applications.

Lesson Goals:
Modeling involves identifying and selecting relevant features of a real-world situation, representing those features symbolically, analyzing and reasoning about the model and the characteristics of the situation, posing a model, and considering the accuracy and limitations of the model. In this activity students will study modeling in greater depth, generating and using data, to model ore body locations and generate a three-dimensional model of the area.

Mathematics/Strand III/Content Standard 3/High School

Benchmark 5

Employ investigations, mathematical models and simulations to make inferences and predictions to answer questions and solve problems.

Overview: We live in a sea of information. In order not to drown in the data that inundate our lives every day we must be able to process and transform data into useful knowledge. The ability to interpret data and to make predictions and decisions based on data is an essential basic skill for every individual.

Lesson Goals:

The students will analyze their model and make proposals as to where the mining company should sink a well for production.

Science/Strand V/Content Standard 4/High School

Benchmark 4

Explain how technology and scientific inquiry have helped us learn about the earth and universe.

Overview: The contemporary applications of mathematics in virtually every field of work and study rely on algebraic and analytic thinking and communication as fundamental tools.

Lesson Goals: The remoteness of objects in the earth and universe necessitates the use of sophisticated technologies to make even basic observations. Advancements in technology in mining include computer imaging/modeling, spectroscopes, and charged-coupled devices. The three dimensional computer simulation of the mine received in the Teachers' Earth Science Institute 2004 will be used to demonstrate to the students how a 3-D model was actually used in a mining operation.

Part Two: The Lesson Plan

Using Drill Core Sample Data

To Make Decisions about Mine Management

Day One: Generate Two-Dimensional Models of a Geologic Cross Section (One complete 55 minute class session.)

Objectives: The students will identify four different rock types in the strata and use this identification and data to construct a two dimensional geologic cross-section.

Materials:

Drill core samples	Data tables indicating depth and angles of the core samples	
Large graph paper	Colored pencils	Straight edge
Protractor	Twelve transparencies	Calculator

Procedure:

1. First determine the type of rock in each core sample. (2 points each)
    a. Unit A:_____
    b. Unit B:_____
    c. Unit C:_____
    d. Unit D:_____
    e. Unit E:_____

2. Determine a scale for the depth of the drill data. Make a y-axis. (5 points)

3. Assume the scale is completely horizontal. Determine a scale for the distance between drill holes. (5 points)

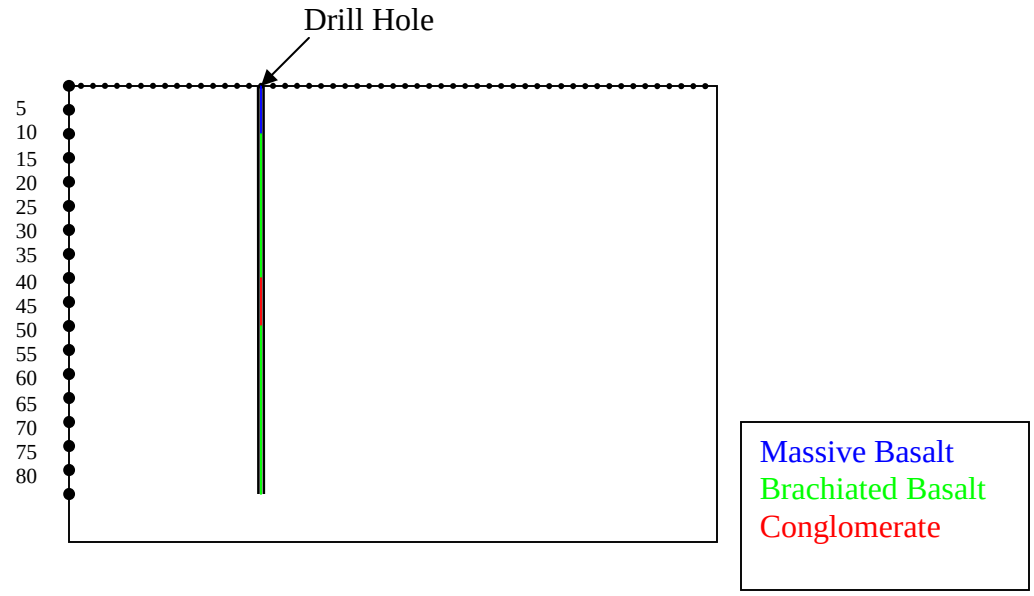
4. Mark the location of the drill holes on the graph paper. (10 points)

5. Mark the depths where the rock units meet under their respective drill hole for all five rock units. See example below. (40 points)

For Example: (*Your answer goes here)

Example: Core 80E (Drill hole is 80 ft east from baseline.)

Unit	Rock Type	Depth
A	*Massive Basalt	0-10
B	*Brachiated Basalt*	10-40
C	*Conglomerate*	40-50
D	*Brachiated Basalt*	50-80
		Bottom of hole



6. Connect the dots between similar contacts in all the drill hoes. Determine a legend and color in the regions suggested by the drill core data. (10 points)

7. Conclusion: Based on your cross-section, describe a possible geological progression of the deposition of rock layers. (20 points)

Drill Core Data

Core 0E

Unit	Rock Type	Depth
A		0-10
B		10-50
A		50-180
D		180-200
E		200-270
		Bottom of hole

Core 200E

Unit	Rock Type	Depth
A		0-45
B		45-85
A		85-215
D		215-235
E		235-300
		Bottom of hole

Core 600E

Unit	Rock Type	Depth
B		0-5
A		5-120
B		120-160
A		160-290
D		290-310
E		310-400
		Bottom of hole

Core 900E

Unit	Rock Type	Depth
B		0-60
A		60-175
B		175-215
A		215-345
D		345-365
E		365-400
		Bottom of hole

Day Two: Generate a Three-Dimensional Model of a Geological Cross Section (extended lab day: 130 minute session)

Objectives: The students will use data tables to construct a three dimensional geologic cross-section.

Pre-lab Discussion:

1. Moving the drilling rig is very expensive. How can mining companies minimize costs of drilling?
    a. Diagonal drilling, both at surface and below ground.
    b. How could the model be modified so that the angles could be taken into account?

2. What do mining companies do when they find a *possible* ore body?

    a. Considerations for an Underground Copper Mine
        i. Lowest mineable grade = 1% copper
        ii. Ore body must be greater than 15 feet thick.
        iii. Actual minimum cutoffs of ore grade depend on tonnage and economics. Open mines can have much lower ore grade cutoffs than underground mines.

Procedure:

1. Match baseline for data to the Plexiglas baseline.
2. Draw cross sections on large graph paper
3. Transfer sections from paper to Plexiglas sheets. Use the following code for rock types.
    a. Green ///// - Amygdaloidal Basalt
    b. Yellow /////- Conglomerate
    c. Blue ///// - Massive Basalt
    d. Red- Conglomerate or amygdaloidal basalt with possible ore
        i. Use + + + if grade of ore is more than 1%.
        ii. Use o o o if grade of ore is less than 1%.

From the analysis of these cross sections they will make a proposal to the mining company as to where to begin extraction for ore in the ore body.

PLATE #1 Drill Core Data

DRILLHOLE #1, Vertical, 100W

Depth	Rock Type	Assay
0-15	Conglomerate	0
15-35	Amygdaloidal Basalt	0
35-140	Massive Basalt	0
140-175	Conglomerate	0
175-180	Amygdaloidal Basalt	0
180-215	Massive Basalt	0
215-235	Amygdaloidal Basalt	0
235-315	Massive Basalt	0
315-325	Amygdaloidal Basalt	0
325-345	Massive Basalt	0
Bottom of hole		

DRILLHOLE #2, 60° W, 150E

Depth	Rock Type	Assay
0-5	Amygdaloidal Basalt	0
5-55	Massive Basalt	0
55-80	Amygdaloidal Basalt	0
80-165	Massive Basalt	0
165-190	Conglomerate	0
190-210	Amygdaloidal Basalt	0
210-290	Massive Basalt	0
290-315	Conglomerate	0
315-320	Amygdaloidal Basalt	0
320-345	Massive Basalt	0
345-365	Amygdaloidal Basalt	0
365-420	Massive Basalt	0
420-430	Amygdaloidal Basalt	0
430-450	Massive Basalt	0
Bottom of hole		

DRILLHOLE #3, 77° W, 150E

Depth	Rock Type	Assay
0-10	Amygdaloidal Basalt	0
10-70	Massive Basalt	0
70-100	Amygdaloidal Basalt	0
100-195	Massive Basalt	0
195-260	Conglomerate	0
260-280	Amygdaloidal Basalt	0
280-390	Massive Basalt	0
390-395	Amygdaloidal Basalt	0
395-435	Massive Basalt	0
435-450	Amygdaloidal Basalt	0
Bottom of hole		

DRILLHOLE #4 Vertical, 150E

Depth	Rock Type	Assay
0-10	Amygdaloidal Basalt	0
10-80	Massive Basalt	0
80-110	Amygdaloidal Basalt	0
110-225	Massive Basalt	0
225-265	Conglomerate	0
265-285	Amygdaloidal Basalt	0
285-415	Massive Basalt	0
415-420	Amygdaloidal Basalt	1.8% Cu
420-480	Massive Basalt	0
480-500	Amygdaloidal Basalt	0
500-595	Massive Basalt	0
595-605	Amygdaloidal Basalt	0
605-615	Massive Basalt	0
Bottom of hole		

DRILLHOLE #5, Vertical, 280E

Depth	Rock Type	Assay
0-95	Massive Basalt	0
95-130	Conglomerate	0
130-145	Amygdaloidal Basalt	0
145-220	Massive Basalt	0
220-250	Amygdaloidal Basalt	0
250-360	Massive Basalt	0
360-365	Conglomerate	0.8%
365-370	Conglomerate	0.8%
370-375	Conglomerate	0.6%
375-380	Conglomerate	0.5%
380-385	Conglomerate	0.4%
385-390	Conglomerate	0.6%
390-395	Conglomerate	0.7%
395-400	Conglomerate	0.7%
400-420	Amygdaloidal Basalt	0
420-555	Massive Basalt	0
555-560	Amygdaloidal Basalt	0
560-605	Massive Basalt	0
Bottom of hole		

DRILLHOLE #7, 67° W, 600E

Depth	Rock Type	Assay
0-75	Massive Basalt	0
75-110	Conglomerate	0
110-125	Amygdaloidal Basalt	0
125-210	Massive Basalt	0
210-220	Amygdaloidal Basalt	0
220-320	Massive Basalt	0
320-340	Conglomerate	0
340-350	Amygdaloidal Basalt	0
350-405	Massive Basalt	0
405-420	Amygdaloidal Basalt	0
420-500	Massive Basalt	0
500-505	Conglomerate	0.8%
390-395	Conglomerate	0.8%
395-400	Conglomerate	0.5%
400-420	Conglomerate	0.3%
420-555	Conglomerate	0.6%
555-560	Conglomerate	0.7%
560-605	Amygdaloidal Basalt	0

DRILLHOLE #6, 60° W, 600E

Depth	Rock Type	Assay
0-70	Massive Basalt	0
70-105	Conglomerate	0
105-125	Amygdaloidal Basalt	0
125-205	Massive Basalt	0
205-215	Amygdaloidal Basalt	0
215-305	Massive Basalt	0
305-340	Conglomerate	0
340-355	Amygdaloidal Basalt	0
355-405	Massive Basalt	0
405-425	Amygdaloidal Basalt	0
425-500	Massive Basalt	0
500-505	Conglomerate	4.0%
505-510	Conglomerate	2.7%
510-515	Conglomerate	0.9%
515-520	Conglomerate	1.9%
520-525	Conglomerate	3.2%
525-540	Amygdaloidal Basalt	0
540-550	Massive Basalt	0
Bottom of hole		

DRILLHOLE #8 Vertical, 600E

Depth	Rock Type	Assay
0-100	Massive Basalt	0
100-150	Conglomerate	0
150-170	Amygdaloidal Basalt	0
170-285	Massive Basalt	0
285-300	Amygdaloidal Basalt	0
300-340	Massive Basalt	0
Bottom of hole		

PLATE #2 Drill Core Data

DRILLHOLE #1, Vertical, 200W

Depth	Rock Type	Assay
0-15	Conglomerate	0
15-40	Amygdaloidal Basalt	0
40-145	Massive Basalt	0
145-165	Conglomerate	0
165-175	Amygdaloidal Basalt	0
175-210	Massive Basalt	0
210-235	Amygdaloidal Basalt	0
235-310	Massive Basalt	0
310-330	Amygdaloidal Basalt	0
330-350	Massive Basalt	0
Bottom of hole		

DRILLHOLE #2, 62° W, 120E

Depth	Rock Type	Assay
0-35	Massive Basalt	0
35-55	Amygdaloidal Basalt	0
55-145	Massive Basalt	0
145-175	Conglomerate	0
175-200	Amygdaloidal Basalt	0
200-265	Massive Basalt	0
265-275	Conglomerate	0
275-285	Amygdaloidal Basalt	0
285-315	Massive Basalt	0
315-330	Amygdaloidal Basalt	0
330-350	Massive Basalt	0
Bottom		

DRILLHOLE #3, Vertical W, 120E

Depth	Rock Type	Assay
0-45	Massive Basalt	0
45-70	Amygdaloidal Basalt	0
70-200	Massive Basalt	0
200-235	Conglomerate	0
235-270	Amygdaloidal Basalt	0
270-385	Massive Basalt	0
385-395	Amygdaloidal Basalt	1.8%
395-425	Massive Basalt	0
Bottom of hole		

DRILLHOLE #4 45°, 600E

Depth	Rock Type	Assay
0-70	Massive Basalt	0
70-105	Conglomerate	0
105-125	Amygdaloidal Basalt	0
125-200	Massive Basalt	0
200-225	Amygdaloidal Basalt	0
225-295	Massive Basalt	0
295-315	Conglomerate	0
315-325	Amygdaloidal Basalt	0
325-375	Massive Basalt	0
375-395	Amygdaloidal Basalt	0
395-470	Massive Basalt	0
470-480	Conglomerate	0.5%
480-490	Conglomerate	0.4%
490-495	Conglomerate	0.6%
495-520	Amygdaloidal Basalt	0
520-600	Massive Basalt	0
600-605	Amygdaloidal Basalt	2%
605-640	Massive Basalt	0
640-655	Amygdaloidal Basalt	0
655-680	Massive Basalt	0

DRILLHOLE #5, 57° W, 600E

Depth	Rock Type	Assay
0-70	Massive Basalt	0
70-105	Conglomerate	0
105-125	Amygdaloidal Basalt	0
125-200	Massive Basalt	0
200-230	Amygdaloidal Basalt	0
230-305	Massive Basalt	0
305-325	Conglomerate	0
325-340	Amygdaloidal Basalt	0
340-390	Massive Basalt	0
390-410	Amygdaloidal Basalt	0
410-485	Conglomerate	3.2%
485-490	Conglomerate	2.6%
490-495	Conglomerate	1.7%
495-500	Conglomerate	0.7%
500-505	Conglomerate	2.0
505-510	Conglomerate	2.6%
510-515	Conglomerate	2.8
515-540	Amygdaloidal Basalt	0
540-625	Massive Basalt	0
625-630	Amygdaloidal Basalt	0
630-665	Massive Basalt	0
665-680	Amygdaloidal Basalt	0

DRILLHOLE #7, 75° W, 600E

Depth	Rock Type	Assay
0-75	Massive Basalt	0
75-110	Conglomerate	0
110-125	Amygdaloidal Basalt	0
125-210	Massive Basalt	0
210-220	Amygdaloidal Basalt	0
220-320	Massive Basalt	0
320-340	Conglomerate	0
340-350	Amygdaloidal Basalt	0
350-405	Massive Basalt	0
405-420	Amygdaloidal Basalt	0
420-500	Massive Basalt	0
500-505	Conglomerate	0.8%
390-395	Conglomerate	0.8%
395-400	Conglomerate	0.5%
400-420	Conglomerate	0.3%
420-555	Conglomerate	0.6%
555-560	Conglomerate	0.7%
560-605	Amygdaloidal Basalt	0

DRILLHOLE #6, 65° W, 600E

Depth	Rock Type	Assay
0-70	Massive Basalt	0
70-105	Conglomerate	0
105-125	Amygdaloidal Basalt	0
125-205	Massive Basalt	0
205-215	Amygdaloidal Basalt	0
215-305	Massive Basalt	0
305-340	Conglomerate	0
340-355	Amygdaloidal Basalt	0
355-405	Massive Basalt	0
405-425	Amygdaloidal Basalt	0
425-500	Massive Basalt	0
500-505	Conglomerate	4.0%
505-510	Conglomerate	2.7%
510-515	Conglomerate	0.9%
515-520	Conglomerate	1.9%
520-525	Conglomerate	3.2%
525-540	Amygdaloidal Basalt	0
540-550	Massive Basalt	0
Bottom of hole		

DRILLHOLE #8 Vertical, 600E

Depth	Rock Type	Assay
0-100	Massive Basalt	0
100-150	Conglomerate	0
150-165	Amygdaloidal Basalt	0
165-285	Massive Basalt	0
285-315	Amygdaloidal Basalt	0
315-340	Massive Basalt	0
Bottom of hole		