

# Spatial Thinking in the New York State High School Earth Science Exam

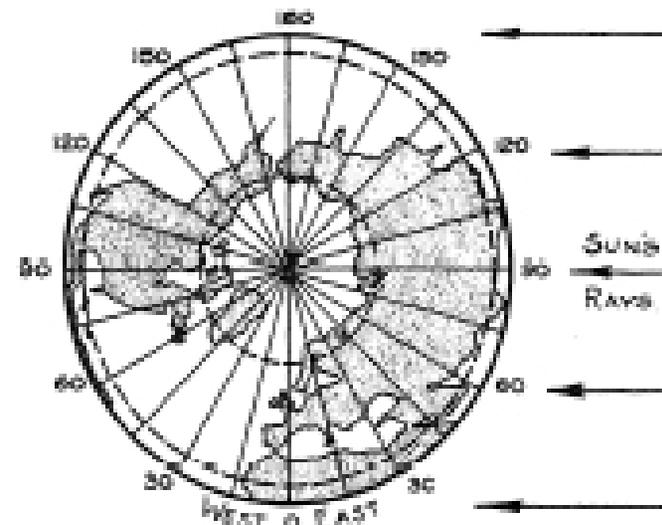
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Presented at the  
Geological Society of America Conference  
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From 1941 Earth Science Regents exam



GEO10-34994

## Professional Development to Improve the Spatial Thinking of Earth Science Teachers and Students

- Analyze released New York State Earth Science Regents exam items for spatial thinking:
    - What is abundant?
    - What is hard?
  - Pilot and evaluate a professional development program for Earth Science teachers piggy-backing on Earth2class
- 
- Expand spatial thinking professional development statewide and nationwide (?), leveraging move towards data-driven PD



# New York State Earth Science Regents Exam

- Year-long course: covers solid earth, atmosphere, oceans & space
- Usually taken in 8<sup>th</sup> or 9<sup>th</sup> grade
- Requires laboratory (1200 minutes)



## *Physical Setting/ Earth Science*

*Core Curriculum*

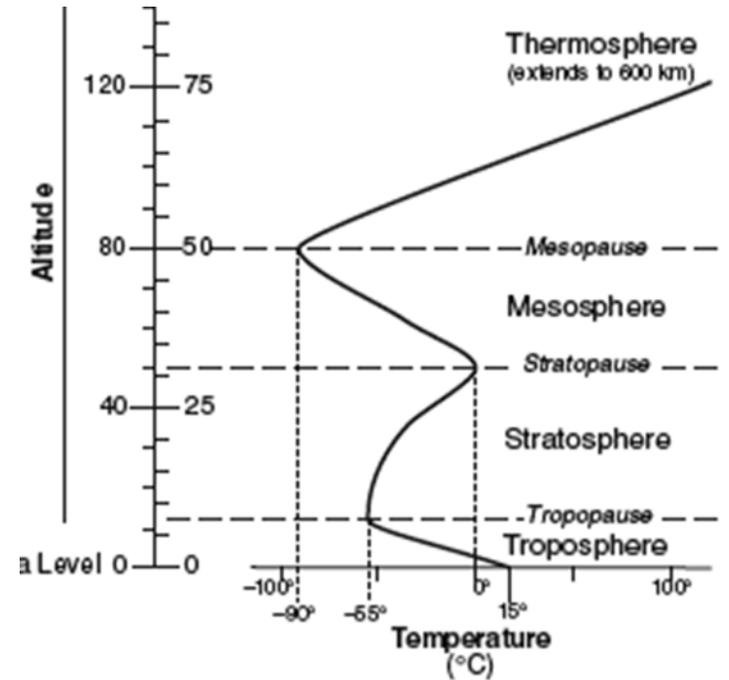
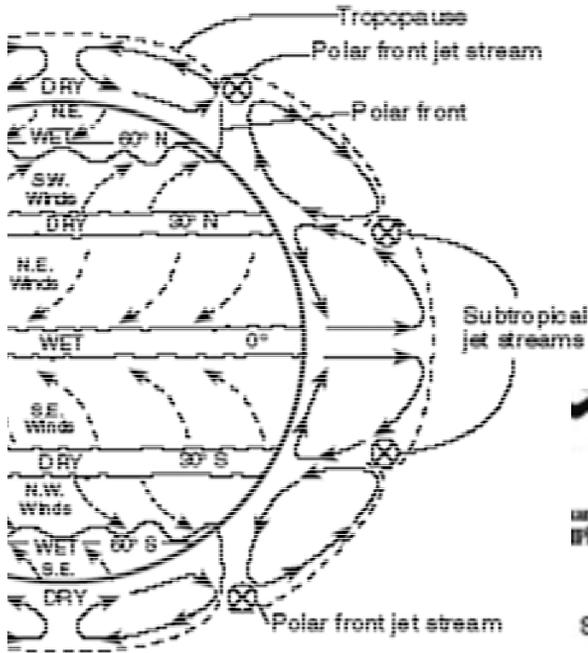
- Three hour exam
- Given since 1941; all items released
- 50 multiple choice + 34 or 35 constructed response
- Taken by 160,000+ students per year

# “Finding the Spatial” in Earth Science Regents Course



*Physical Setting/  
**Earth Science**  
Core Curriculum*

# New York Earth Science Reference Tables



16 page booklet

# “Finding the Spatial” in Earth Science Regents Exams

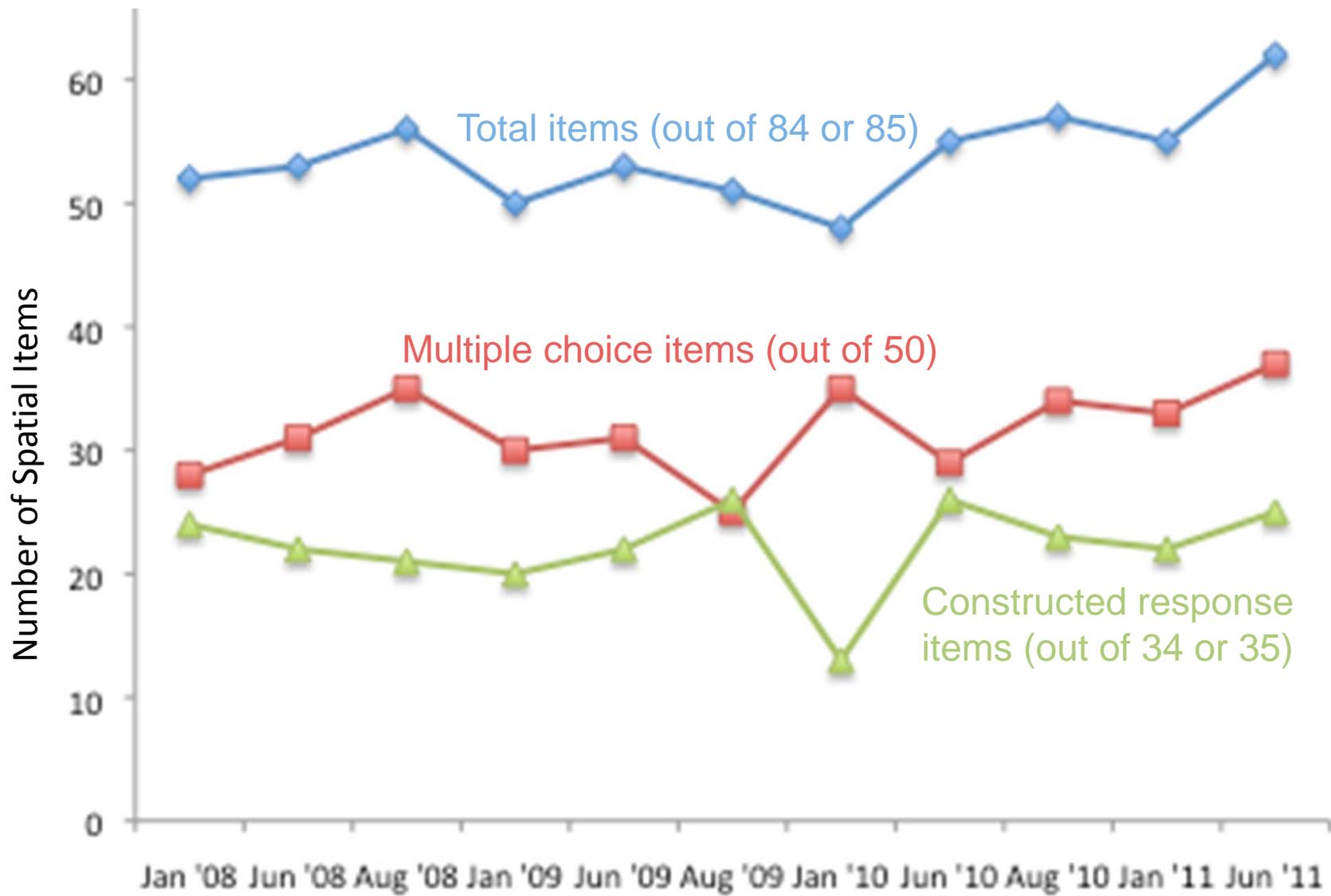
- Began with a holistic definition: “... thinking that finds meaning in the shape, size, orientation, location, direction or trajectory of objects, processes, or phenomena ... or the relative positions in space of multiple objects, processes, or phenomena.”
- Saturday work session with teachers: what did they think was spatial in the Earth Science Regents?
- Initial classification into spatial/non-spatial
- Gradual articulation of sub-categories:
  - Spatial concepts
  - Spatial representations
  - Spatial skills

## “Finding the Spatial” in Earth Science Regents Exams (2)

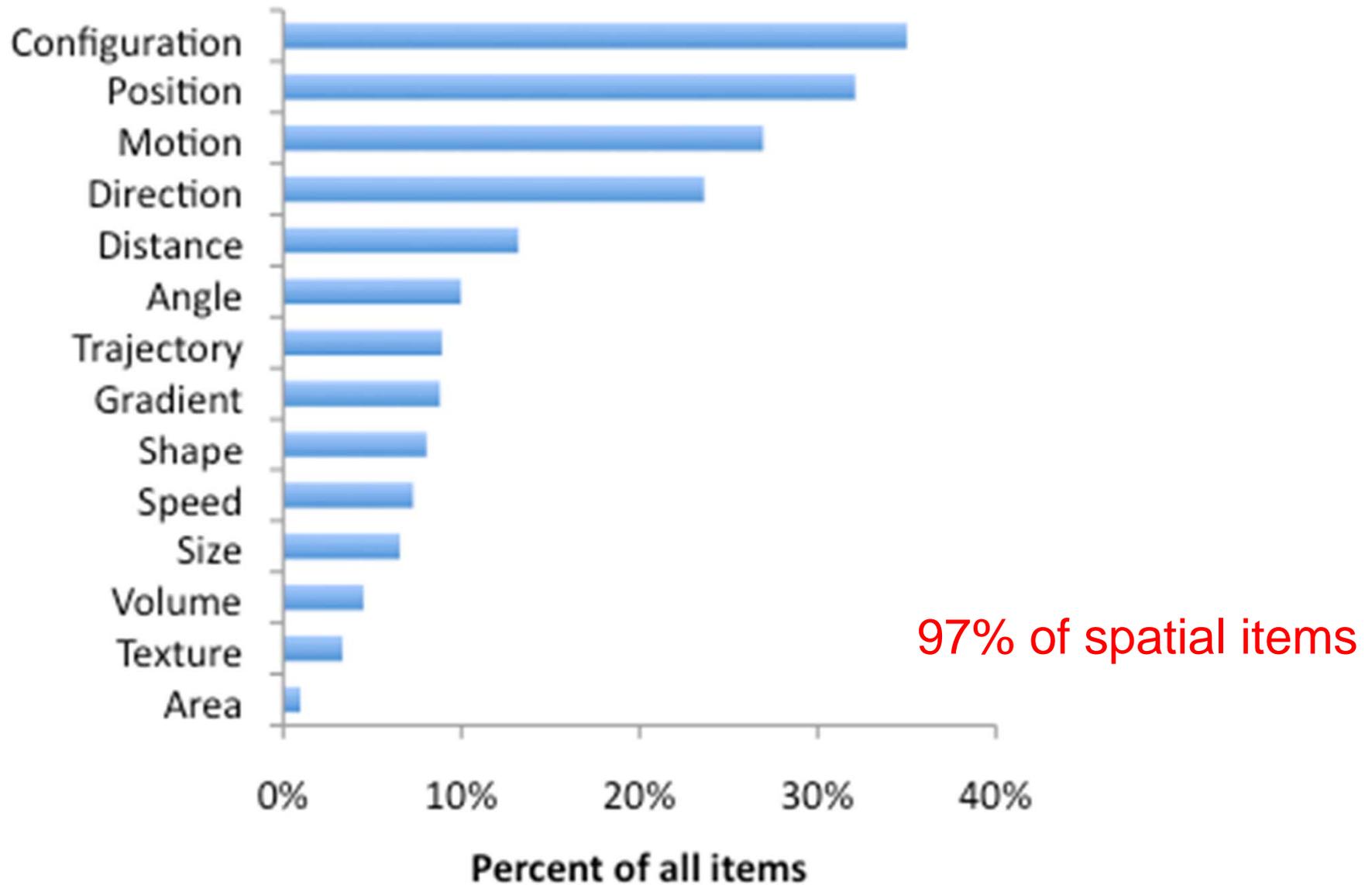
- Eleven exams coded: Jan 2008 through June 2011
- 931 items
- All items coded independently by Kastens and Pistolessi; differences reconciled by discussion
- Inter-rater consistency is 89.5% for spatial/non-spatial
- Biggest challenge was agreeing on exclusion criteria for trivially-spatial items. Item must require thinking as well as spatialness.

# Spatial thinking is abundant in Regents Earth Science Exam

- 63.6 % of all questions
- 63.3 % of the multiple choice questions
- 64.0 % of the constructed response questions



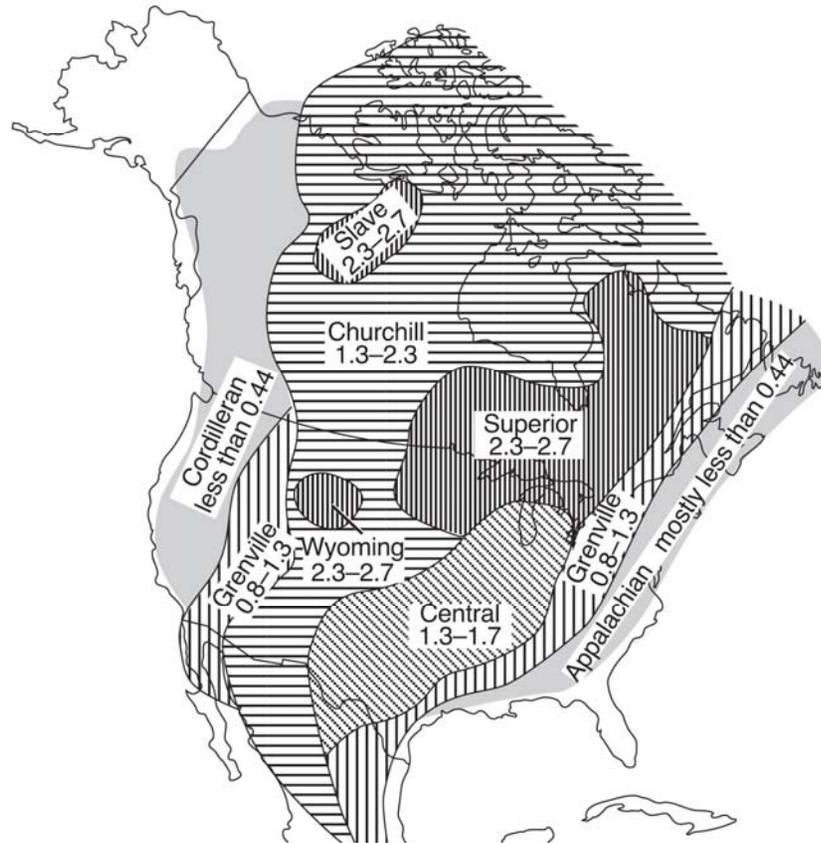
# Frequency of Spatial Concepts



# Configuration (SC-Cn)

33 The map below shows the names and ages of different bedrock formations in North America. The bedrock ages are shown in billions of years.

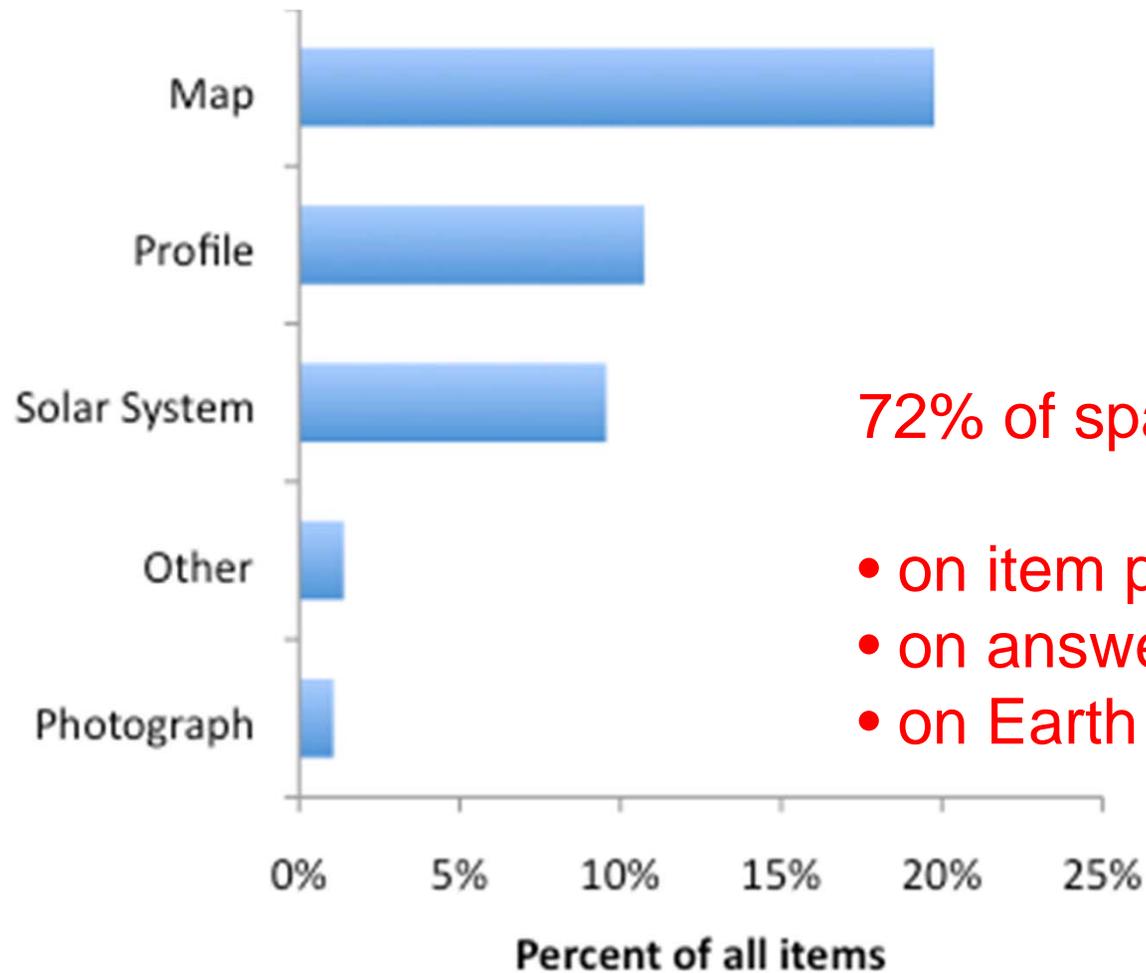
...relative position of two or more objects, attributes or phenomena...



The ages shown on the map suggest that the

- (1) oldest bedrock is located in the Churchill formation
- (2) youngest bedrock is located in the Wyoming formation
- (3) younger bedrock has been added to the east and west coasts of the continent
- (4) age of bedrock increases from west to east across the continent

# Frequency of Spatial Representations



72% of spatial items

- on item prompt
- on answer sheet
- on Earth Science Reference Table

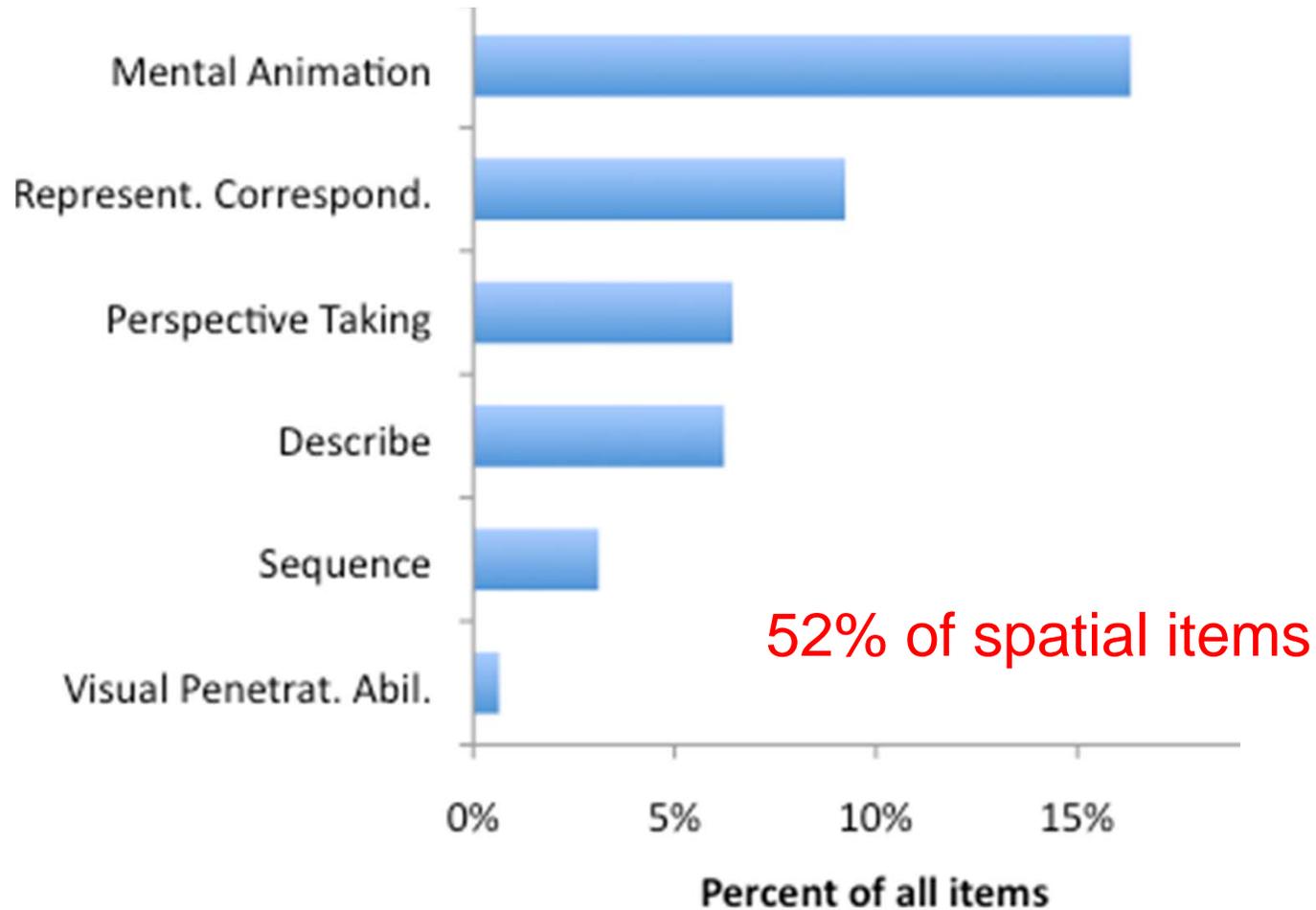
## Map (SR-Mp)

17 In which New York State landscape region have fossilized footprints of *Coelophysis* dinosaurs been found in the surface bedrock?

- (1) Allegheny Plateau
- (2) Tug Hill Plateau
- (3) Hudson-Mohawk Lowlands
- (4) Newark Lowlands

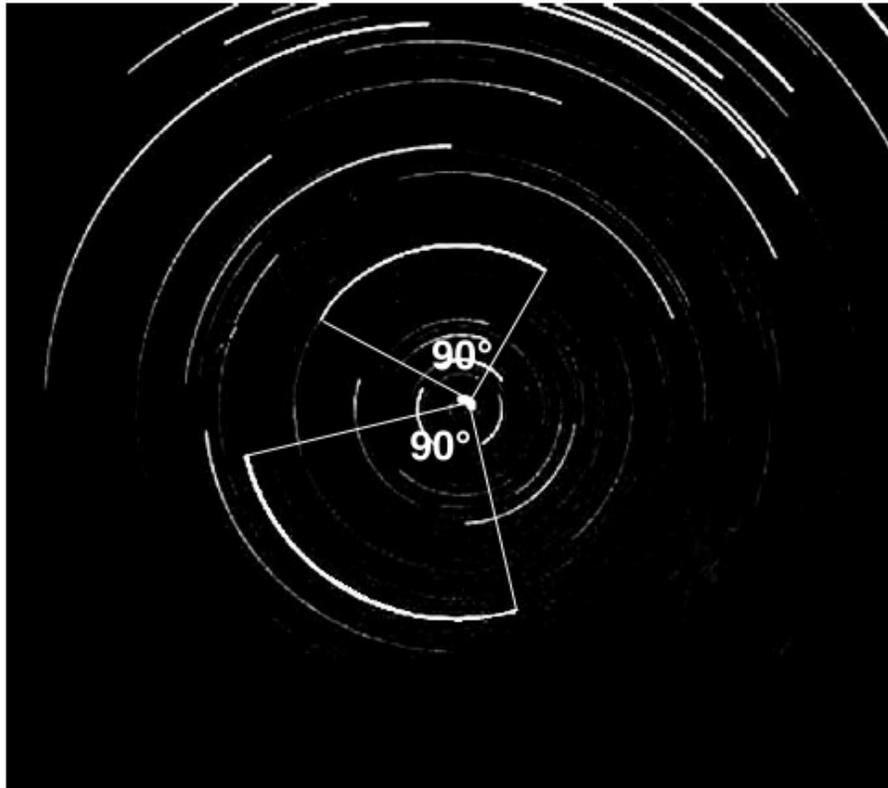
Timeline -> Bedrock geology map -> Landscape regions map

# Frequency of Spatial Skills subcodes:



# Mental animation (SS-MA)

2 A camera was placed in an open field and pointed toward the northern sky. The lens of the camera was left open for a certain amount of time. The result is shown in the photograph below. The angle of the arc through which two of the stars appeared to move during this time exposure is shown.



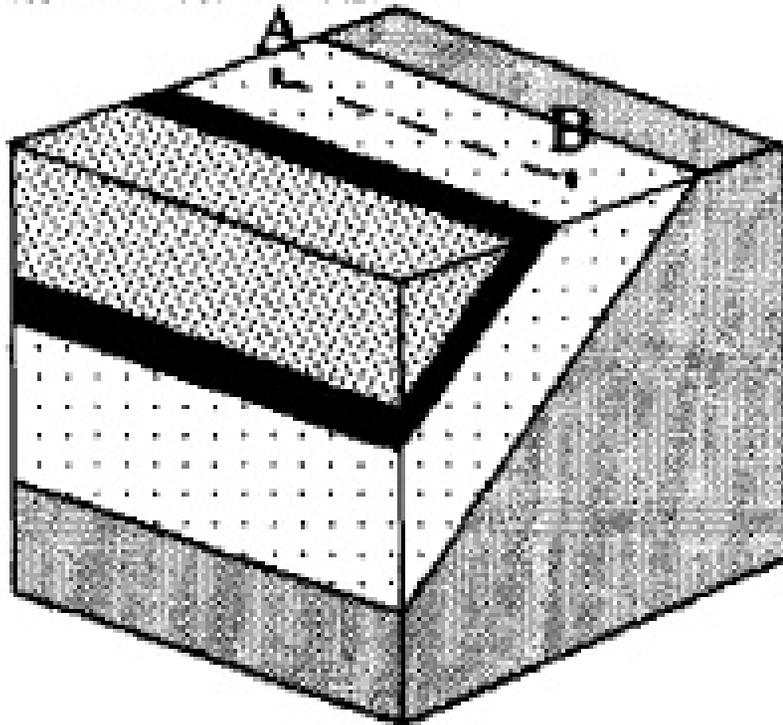
Student needs to or would benefit from envisioning that objects are moving or deforming and how they are moving or deforming...

How many hours was the lens left open to produce the photograph?

- (1) 12
- (2) 2

- (3) 6
- (4) 4

Visual Penetrative Ability is very minor (<1% of items)

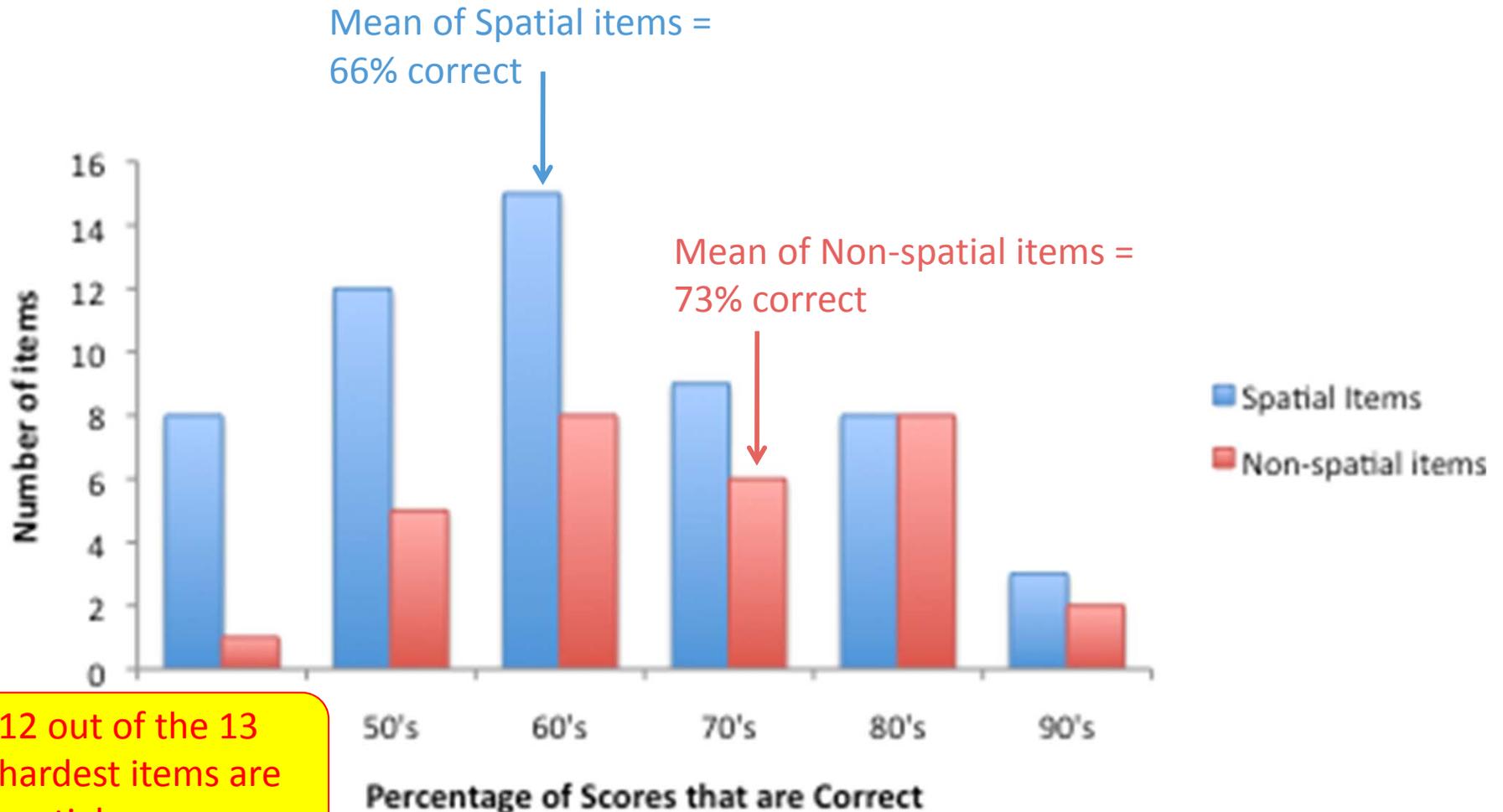


Kali, Y., & Orion, N. (1996). Spatial abilities of high-school students in the perception of geologic structures. *Jour of Research in Science Teaching*, 33, 369-391.

Draw the vertical cross-section between A and B.

# Difficulty of spatial versus non-spatial items

- 26 school districts in one BOCES region
- One exam (June 2010)



12 out of the 13 hardest items are spatial

# *Difficulty* of spatial versus non-spatial categories

- Hardest Spatial Concepts

- Trajectory (14 percentage points worse than average spatial item)
- Gradient (5 points worse)

- Hardest Spatial Representation

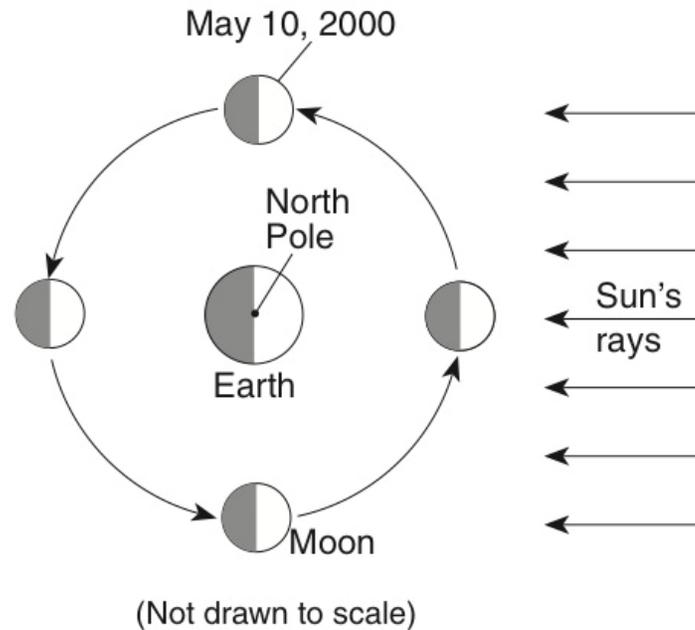
- Solar System (9 points worse)

- Hardest Spatial Skills

- Describe spatial phenomena (5 points worse)
- Perspective taking (4 points worse)

## Hard Spatial Item (44.9% correct)

34 The diagram below shows the Moon at four positions in its orbit around Earth as viewed from above the North Pole. The date of one of the four positions has been labeled.

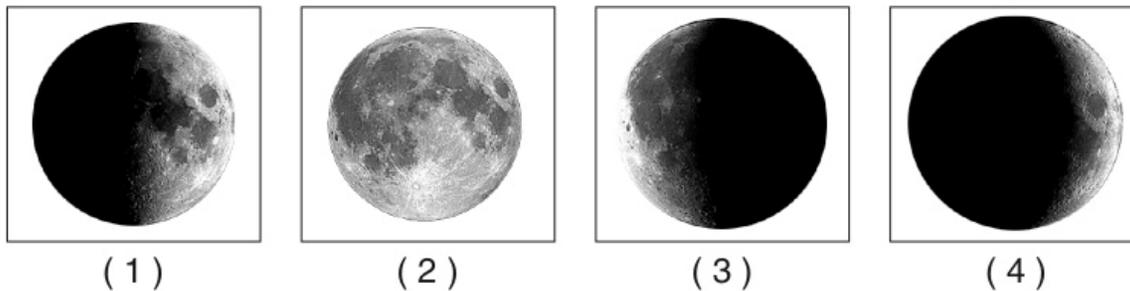


**SC: Trajectory**  
 SC: Motion  
 SC: Position  
 SC: Configuration

**SR: Solar System**  
 SR: Photograph

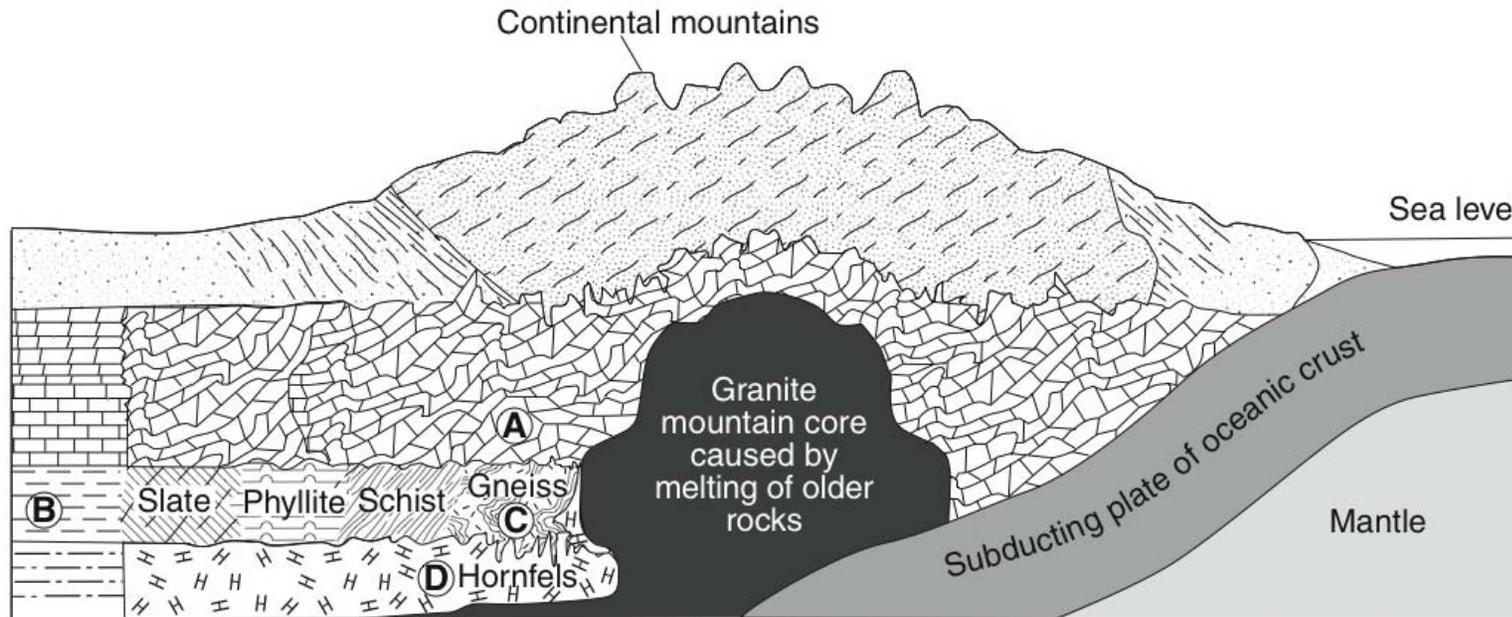
**SS: Perspective taking**  
 SS: Mental animation  
 SS: Representational  
 Correspond

Which photograph shows the appearance of the Moon as viewed by an observer in New York State on May 17, 2000?



## Hard Spatial Item (44.0% correct)

Base your answers to questions 78 through 81 on the cross section below, which shows the bedrock structure of a portion of the lithosphere. Letters A through D represent locations in the lithosphere.



(Not drawn to scale)

79 Explain why the type of rock changes between locations B and C. [1]

Allowed answers:

- Heat and pressure increase from B to C.
- Regional metamorphism is greatest at C.
- different grades of metamorphism

SC: Gradient

SC: Position

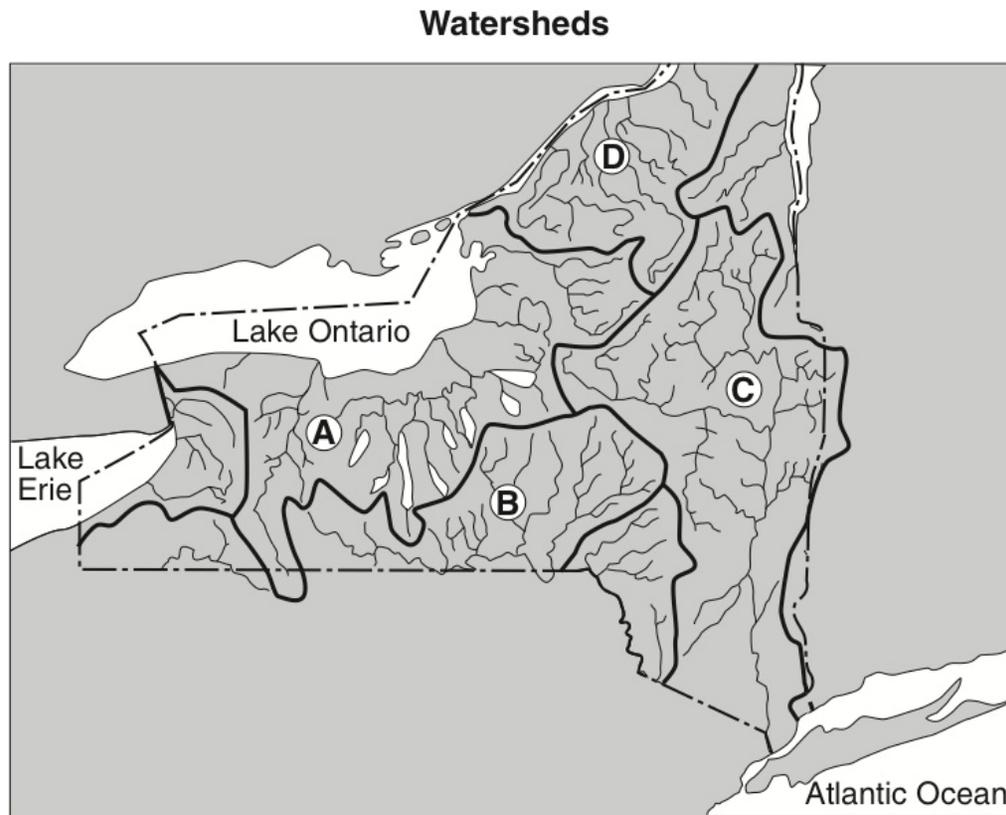
SC: Configuration

SR: Profile

SS: Describe

## Easy Spatial Item (93.1% correct)

25 The map below shows four watershed regions in New York State labeled A through D.



Which lettered section represents the watershed of the Mohawk and Hudson Rivers?

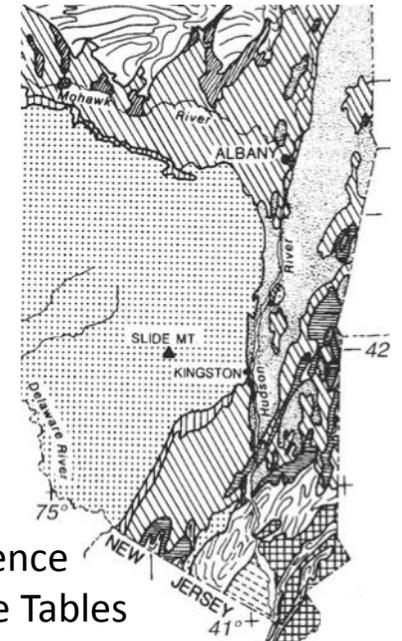
- (1) A
- (2) B

- (3) C
- (4) D

SC: Position

SR: Map

SS: Representational  
Correspondence



Earth Science  
Reference Tables

# Conclusions

- A wide range of spatial concepts, spatial representations, and spatial skills are being assessed on the Earth Science Regents.
- Configuration, position, motion and direction are the most frequently assessed spatial concepts.
- Mental animation and representational correspondence are the most frequently assessed spatial skills.
- Earth Science Reference Tables enable more challenging questions using spatial representations, especially maps & profiles
- Spatial questions are more difficult than non-spatial questions for students.
- Questions involving gradient, trajectory, and solar system diagrams are the most difficult (in a limited data set)

# Next Steps

*In progress:* Pilot and evaluate professional development on spatial thinking for local Earth Science teachers



*Dream:* Expand spatial thinking professional development statewide and nationwide (?), leveraging movement towards “data-driven” PD.



