Worldbuilding from Tectonic First Principles

Lindsay M. Schoenbohm* and Mitchell McMillan
Department of Chemical and Physical Sciences, University of Toronto Mississauga
*lindsay.schoenbohm@utoronto.ca

Capstone Project in a third-year undergraduate Tectonics Course

COURSE STRUCTURE

"I think having the map project announced at the beginning was crucial. Usually I went home from class thinking "Okay, how am I gonna [sic] put that on the map? Where should this feature/phenomenon occur on the map? Did we put anything like that on the map? It might be cool to have," and such." - ERS302 student

Basic Parameters

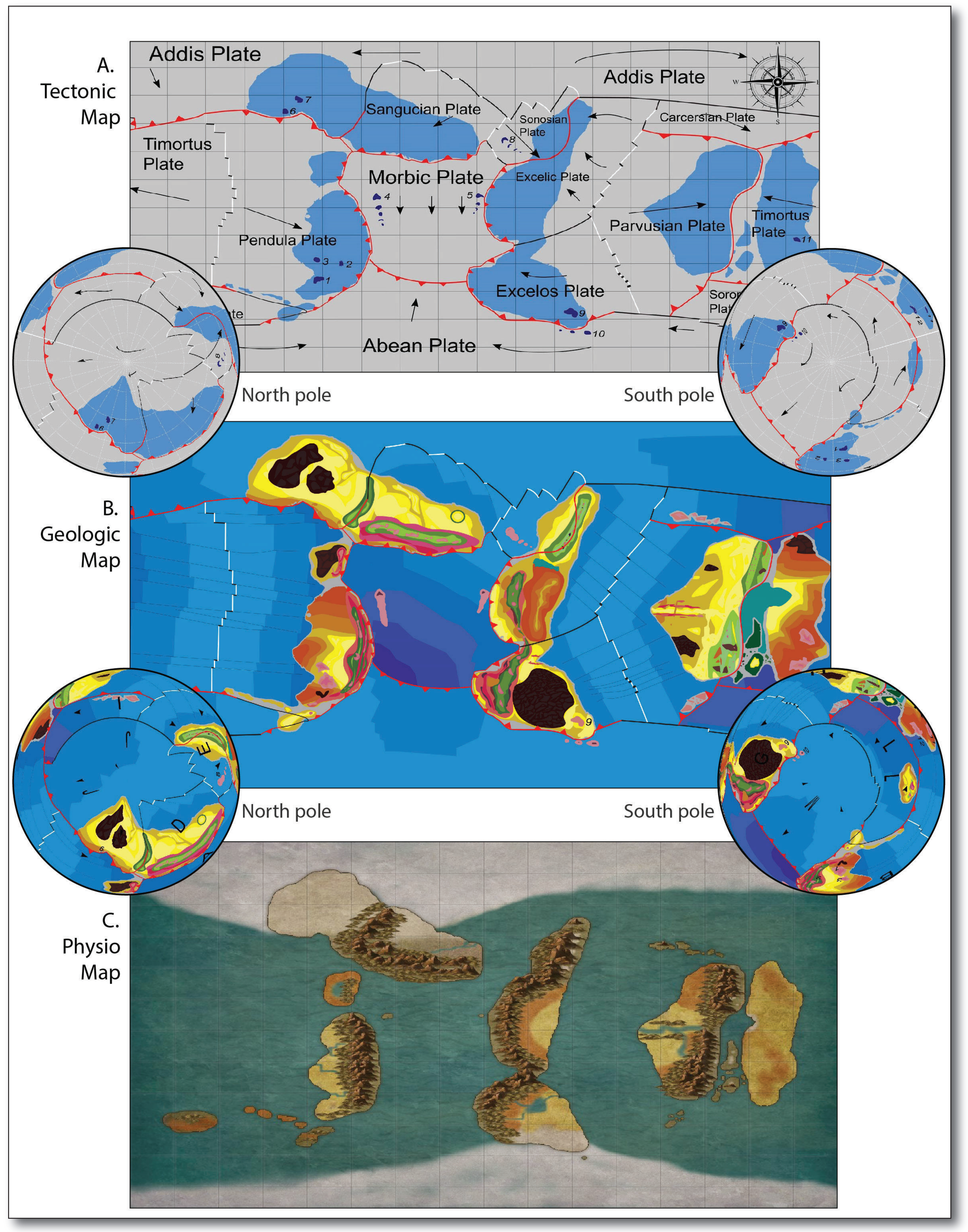
- 27 undergraduate students organized into seven groups
- 3rd and 4th year Earth Science Majors or Minors
- Winter term, 2018
- 35% of course mark
- scaffolded project
- integration with lecture, reading, and class discussion
- 6x TA meetings
- Self/Peer Evaluations
- Instruction in group dynamics, project management

Week	Activity	Task	Deliverables	Points (of 35)
1	In Class	Lecture: Intro to tectonics; Earth structure		
		Reading: Continental drift (Hallam, 1975)		
	TA Meeting	Establish team roles, contract, and résumé	Team contract	1
	Project	Begin tectonic map, draft initial plate boundaries and vectors		
2	In Class	Lecture: Geophysics primer; hotspots		
		Reading: Hotspots (DePaolo and Manga, 2003; Foulger and Natland, 2003)		
	Project Element	Work on plate boundaries and vectors		
3	In Class	Lecture: Plate motions; measuring plate velocity		
		Reading: Triple juctions (McKenzie and Morgan, 1969)		
		Exercise: plate motions		
	TA Meeting	Present draft tectonic map		
	Project	Add hotspots, complete tectonic map	Tectonic map/report	4
4	In Class	Lecture: Passive margins; mid-ocean ridges		
		Reading: Proto-rifting (Aragon-Arreola and Martin-Baraja, 2007)		
	TA Meeting	Self/peer evaluation; discuss geologic map	Self/peer evaluation	3
	Project	Begin geologic map, add seafloor/passive margins		
5	In Class	Lecture: Continental rifts; transform faults		
		Reading: Continental tranforms (Tapponnier et al., 1982)		
		Exercise: geometry of East African Rift and Basin and Range extensional province		
	Project	Add continental rifts/transforms		
6	In Class	Lecture: Subduction zones		
		Reading: Subduction zone coupling and climate (Lamb and Davis, 2003)		
	Project	Add subduction zones		
7	In Class	Lecture: Accretion; Cordilleran orogens		
		Reading: Baja-BC (Cowan et al., 1997)		
	TA Meeting	Self/peer evaluation; discuss geologic map	Self/peer evaluation	3
	Project	Add Cordilleran orogens		
8		Break for another assignent		
9	In Class	Lecture: Alpine/Himalayan orogens		
		Reading: Lower crustal flow (Beaumont et al., 2001)		
		Exercise: Models for extension in Tibet gallery walk		
	Project	Add Alpine orogens, start on physiographic map		
10	In Class	Lecture: Plate tectonics through time		
		Reading: Onset of modern plate tectonics (Condie and Kroner, 2008)		
	TA Meeting	Present draft geologic map; discuss poster presentation		
	Project	Add cratons, complete geologic map, work on physiographic map, work on poster	Geologic map/report	12
11	In Class	Lecture: Tectonics and climate, economic geology, hazards		
		Reading: Earthquakes and landscape evolution (Ouimet, 2010)		
	TA Meeting	Self/peer evaluation; present draft physiographic map and poster	Self/peer evaluation	3
	Project	Complete physiographic map, complete poster	Physiographic map/report	4
12	Project	Poster session	Poster and presentation	5

Software

- Kerika for project management (https://kerika.com/en/)
- GPlates for constructing tectonic map (https://www.gplates.org/index.html)
- Gprojector for projecting maps (https://www.giss.nasa.gov/tools/gprojector/)
- Drawing Program for making maps (e.g., Illustrator, Photoshop, Gimp, Inkscape)
- Inkarnate for drawing physiographic map (https://inkarnate.com/)

EXAMPLE PROJECT

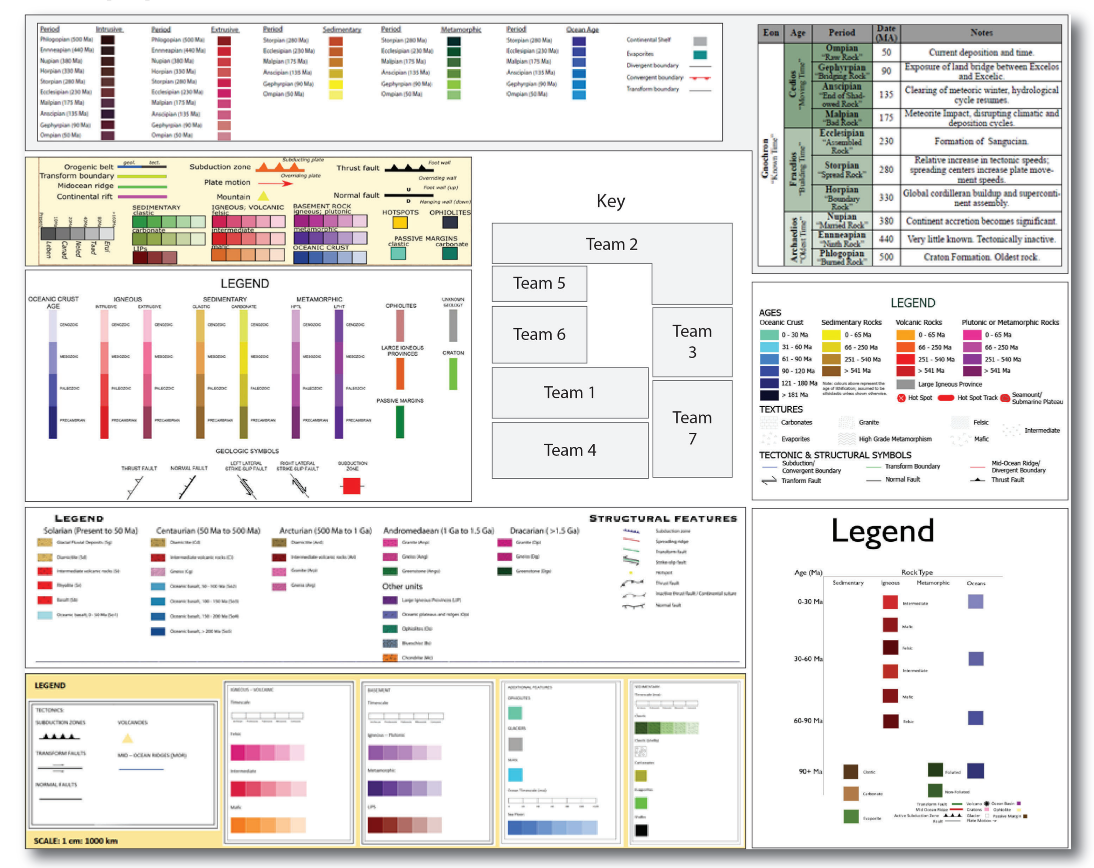


LEARNING OUTCOMES

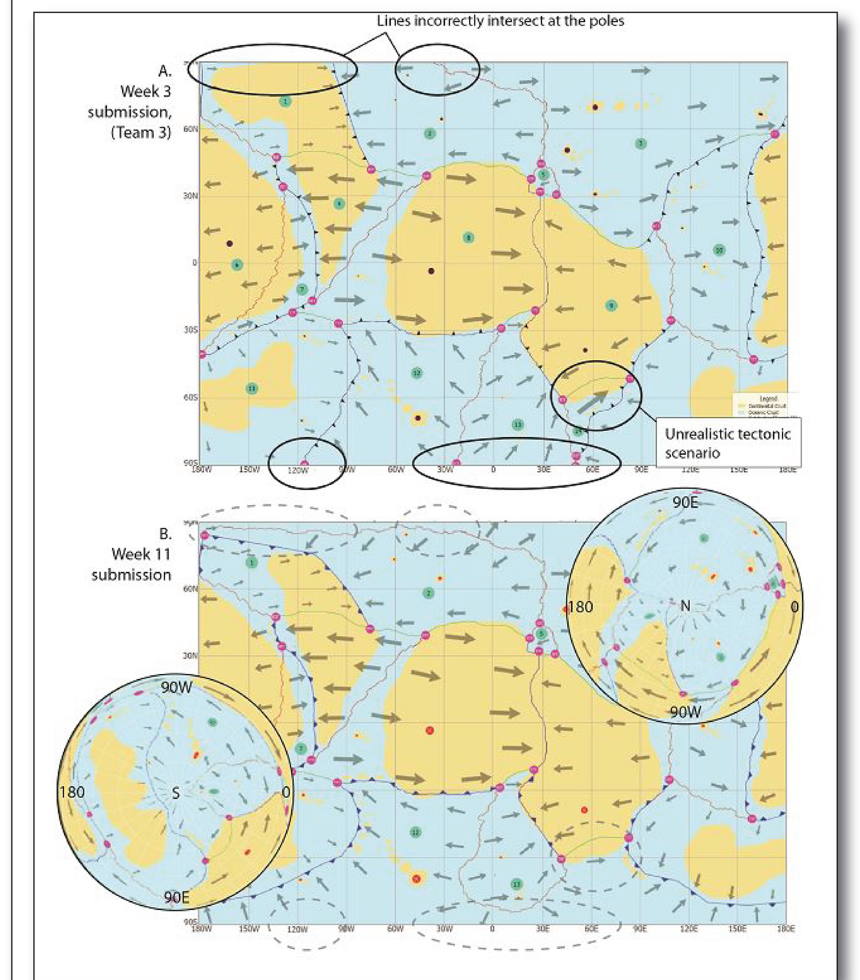
By the end of the course, the student will be able to:	Activity to achieve/assess outcome
Conceptualize spatial data (mental rotation)	Tectonic Map, Survey
Conceptualize temporal geologic change	Legend, Geologic Map, Survey
Develop critical thinking and problem solving skills	Tectonic and Geologic Map, Survey
Integrate complex concepts across multiple subjects	Geologic Map, Survey
Manage complex, team-based projects	Kerika Project Management, Peer- and Self-surveys, Survey

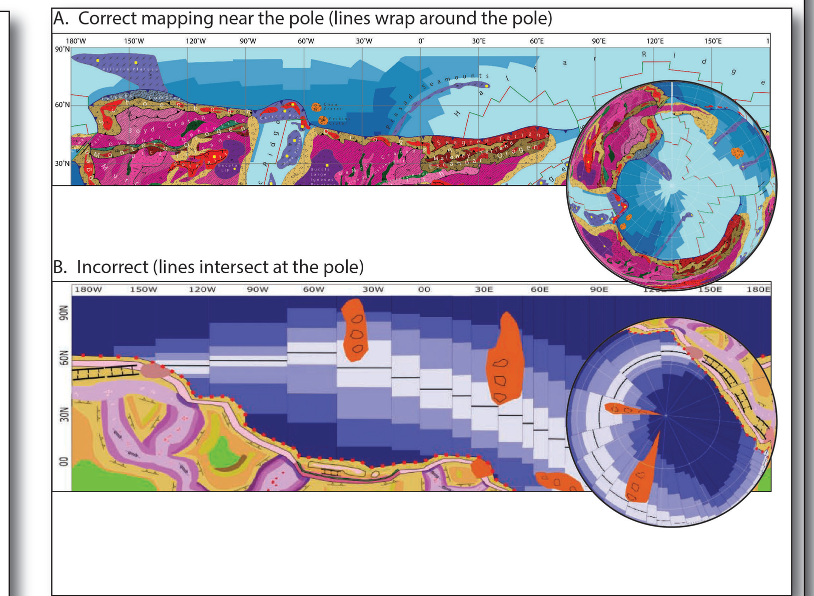
CONCEPTUALIZE TEMPORAL GEOLOGIC CHANGE

"It was difficult when trying to show a difference in time, especially for orogenic events since we limited the representation of time. this [sic] made it look like all the events occured [sic] around the same time." - ERS302 student



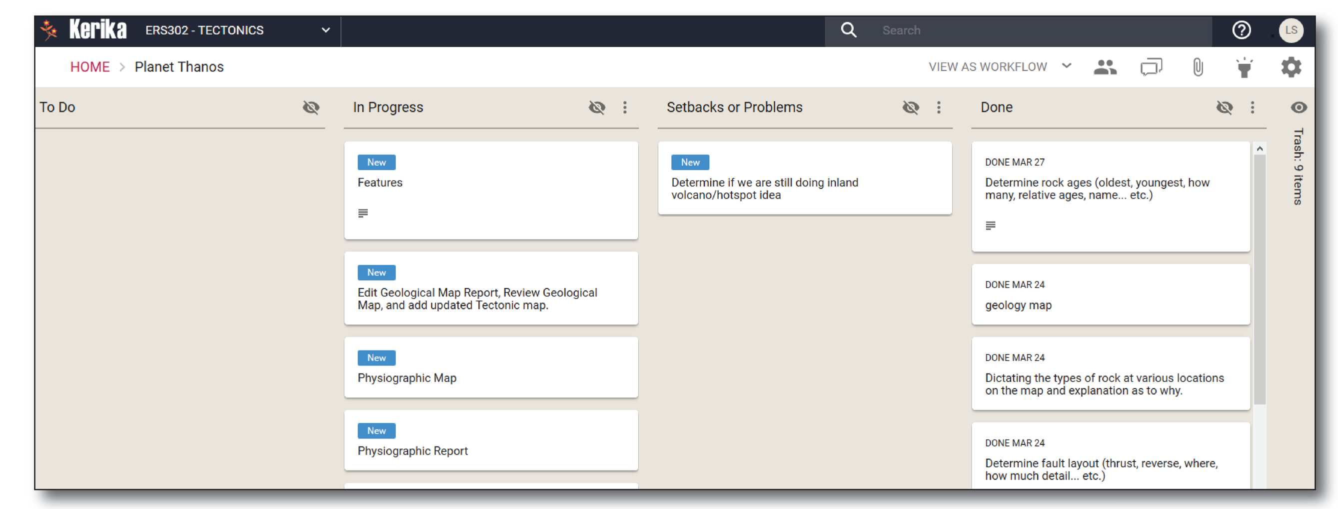
CONCEPTUALIZE SPATIAL DATA (MENTAL ROTATION)



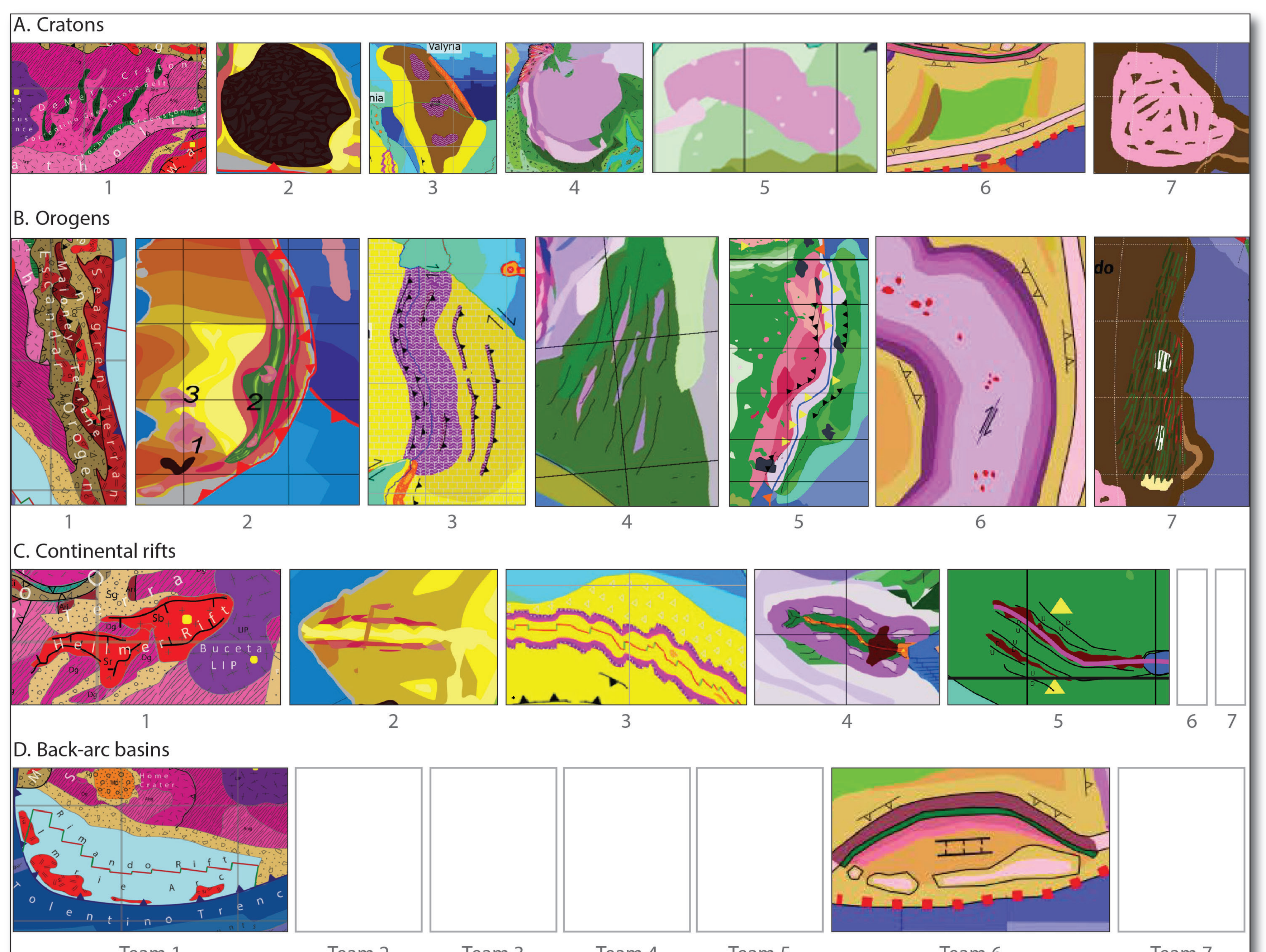


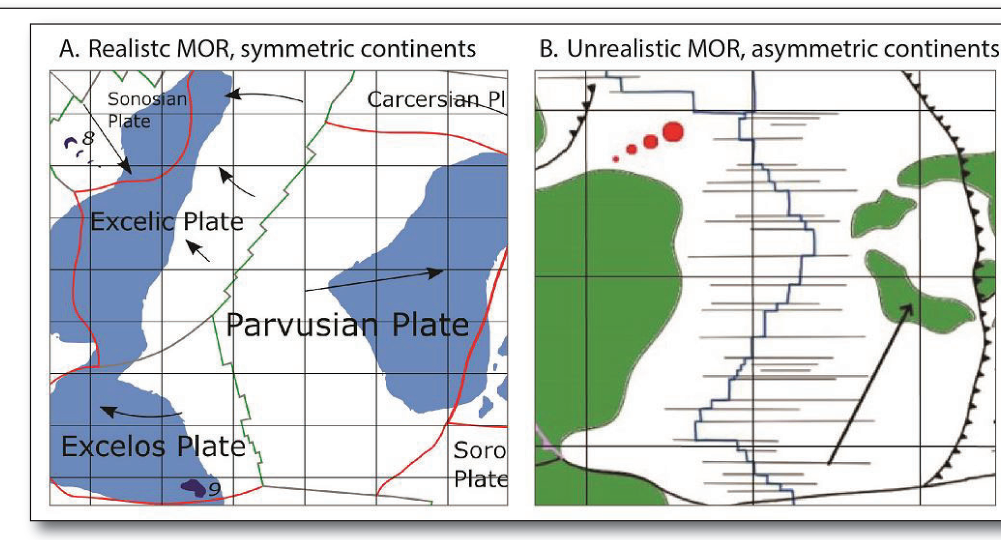
"We did not expect it to be simple, but we underestimated how difficult it would actually be to make all the plate interactions and triple junctions not only function but also make geological sense. All the relationships between a plate and its neighbours had to be taken into account which often led to difficulties. Also, it became difficult to try and picture what the poles would look like when working on a 2-D map so we often found ourselves making a small change to the 2-D map before projecting it onto a 3-D globe to check if it makes sense." - ERS302 student

MANAGE COMPLEX, TEAM-BASED PROJECTS



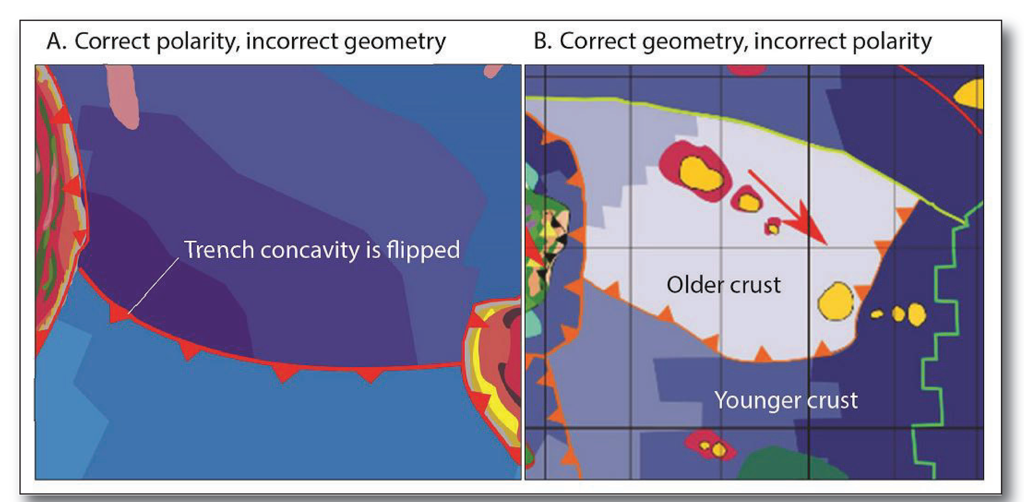
DEVELOP CRITICAL THINKING AND PROBLEM SOLVING SKILLS





"This assignment not only allowed us to apply what we know but then also gave us the chance to critically assess and question each one of our decisions and whether they made sense. If it did not, then we either needed to re-read our lecture notes and readings or perform further research to solve the problem at hand. It provided an opportunity for us to think critically instead of simply regurgitating what we know." - ERS302 student

"I did find it difficult [to decide the level of detail to include in our geologic map]. But we started adding to the maps early. And then kept adding more and more detail as we went along. The ending amount of detail is a culmination of a lot of mini sporadic moments of inspiration." - ERS302 student



INTEGRATE ACROSS MULTIPLE SUBJECTS

Number of responses	Subject	UTM Course Code/Title
6	Structural Geology	ERS202: Dynamic Earth
5	Sedimentary Geology	ERS211: Sedimentary Geology
4	Petrology	ERS203: Rock Forming Processes
4	Oceanography	ERS312: Oceanography
3	Geophysics	ERS303: Geophysics
2	Paleoclimatology	ERS412: Climate through time
1	Introductory Geology	ERS101/120: Planet Earth
1	Cryosphere	GGR317: The Cryosphere

CONCLUSIONS - SUCCESS?

Learning outcomes By the end of the course, the student will be able to:	Outcome achieved?
Conceptualize spatial data (mental rotation)	Yes – most maps were successful or corrected, survey responses reflect on these challenges. *Next time: require polar projections*
Conceptualize temporal geologic change	Maybe – not all groups created timescale; unsuccessful at depicting deep time in maps *Next time: require separate legend deliverable; organize reports chronologically*
Develop critical thinking and problem solving skills	Yes – maps were mostly successful with details, survey responses reflect on these challenges
Integrate complex concepts across multiple subjects	Yes – surveys report using structure, sedimentology, petrology, oceanography, geophysics *Next time: groups with different backgrounds*
Manage complex, team-based projects	Maybe – student fell behind on work, encountered problems with group dynamics *Next time: more interim deliverables; more instruction and checking on use of Kerika*

"One thing is to learn earth science theory and the other is to apply everything from previous courses (geology, climatology, cryology, geography, etc.) learned into a long-lasting project such as the World Building Assignment. This assignment not only allowed us to apply what we know but then also gave us the chance to critically assess and question each one of our decisions and whether they made sense. If it did not, then we either needed to re-read our lecture notes and readings or perform further research to solve the problem at hand. It provided an opportunity for us to think critically instead of simply regurgitating what we know." - ERS302 student