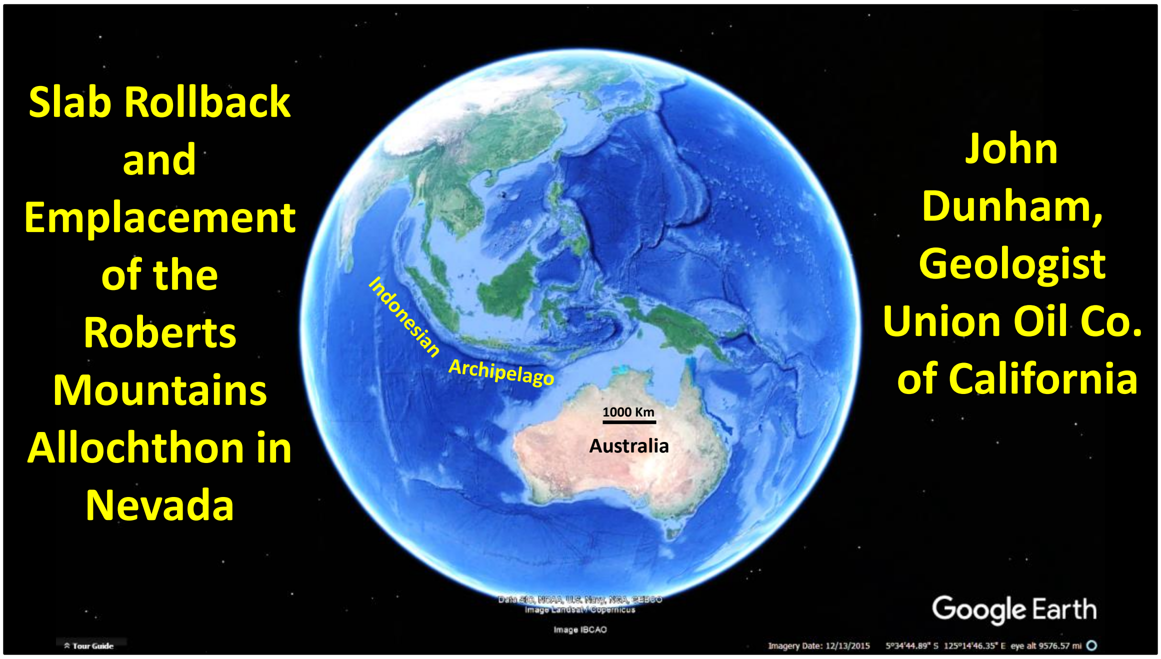


Slab Rollback and Emplacement of the Roberts Mountains Allochthon in Nevada

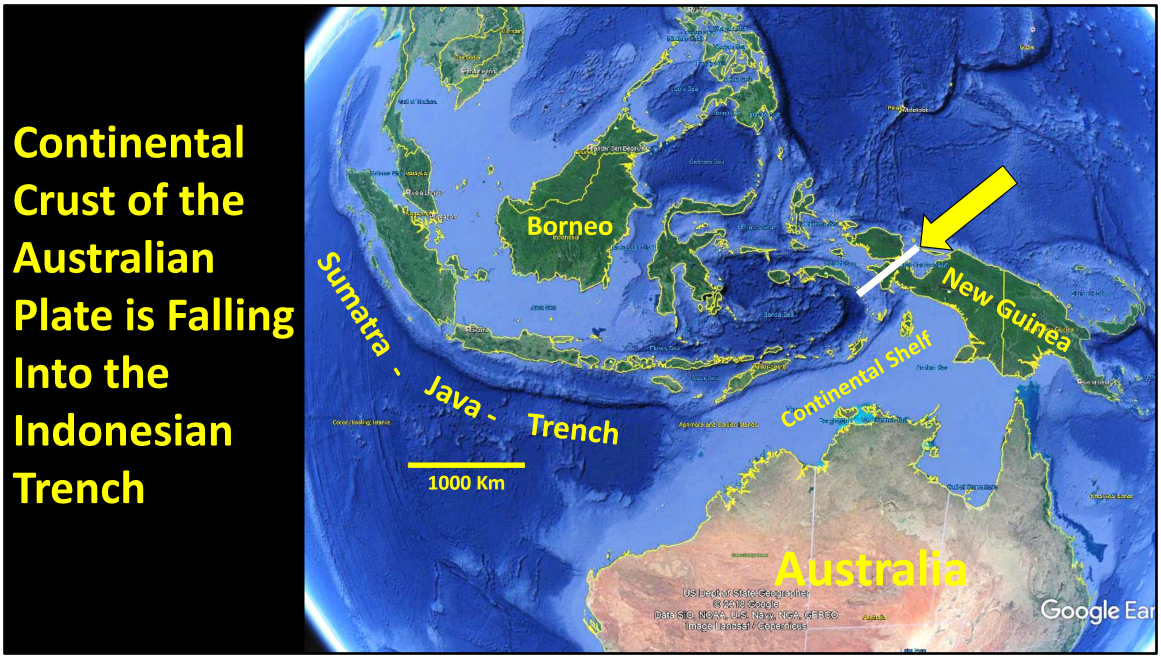
John Dunham, Geologist Union Oil Co. of California

This talk uses Recent analogs to illustrate how Slab Rollback may explain the first tectonic event to affect Western North America since rifting of Laurentia, the emplacement of the Roberts Mountains Allochthon.

Download GSA24_Allochthon at: https://Github.com/jdunham76/GSA24

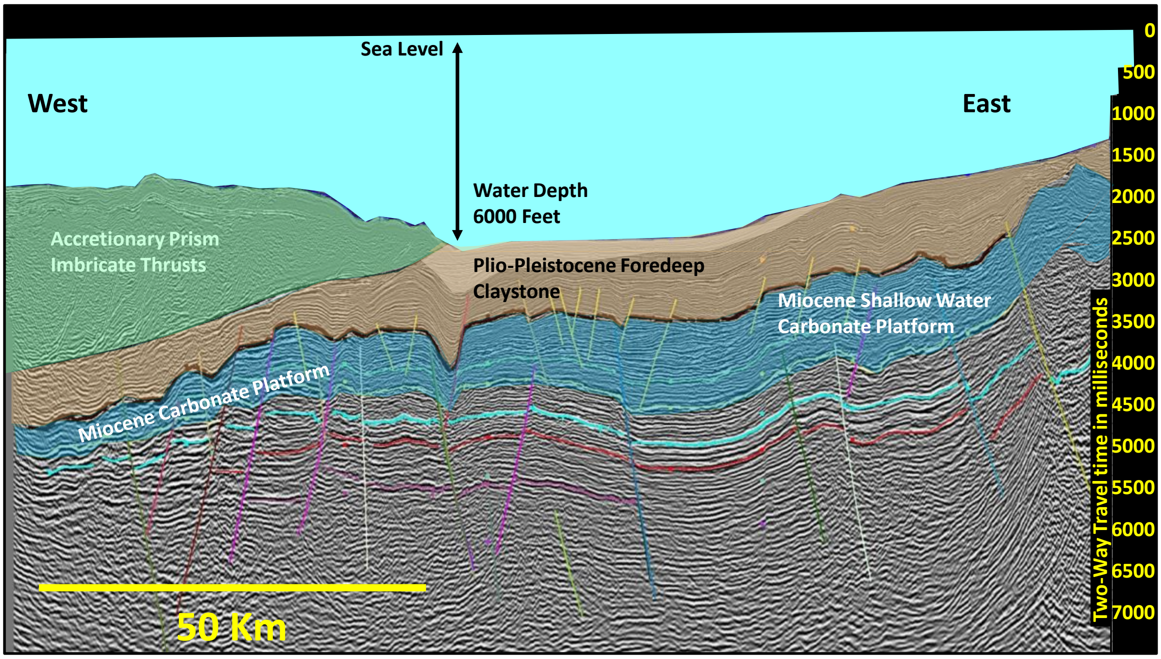
johndunham76@gmail.com

I don't object to photography, but this is the only photo you'll need to download this presentation. I will repeat this at the end of the talk.



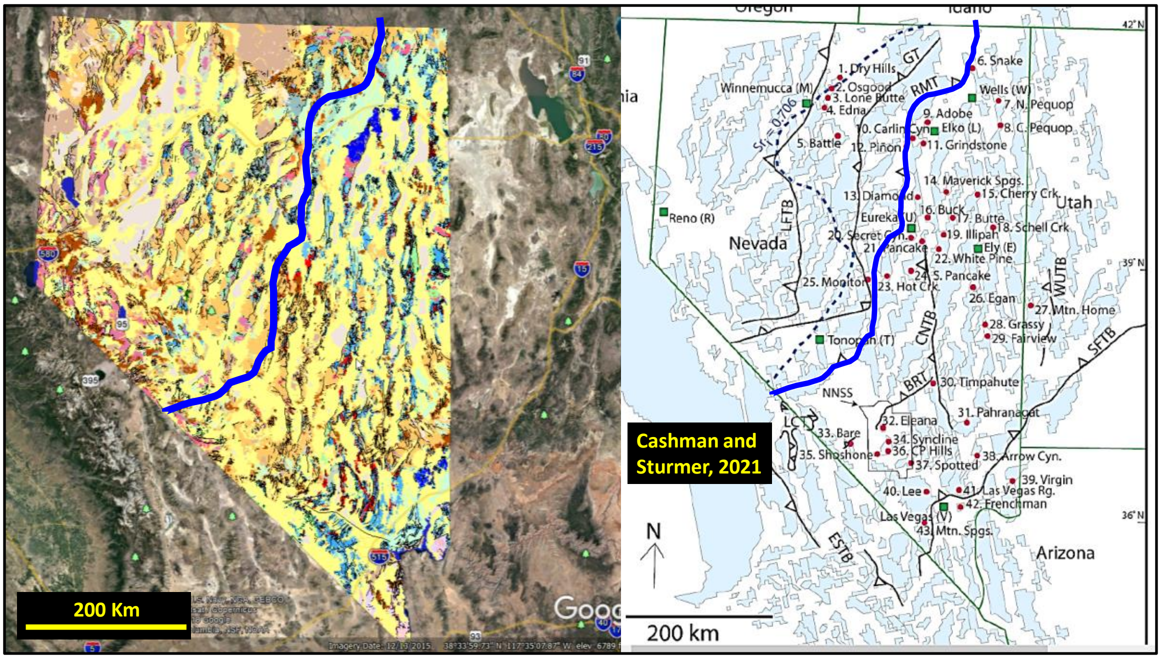
Continental Crust of the Australian Plate is Falling Into the Indonesian Trench

One of the best things about industry is that you get to see a lot of different projects, like this one that I worked on in Indonesia. Specifically, I was looking at the Western tip of New Guinea, where continental crust of the Australian plate is falling into the Eastern Indonesian subduction zone. The following slide is a seismic section located by the arrow.



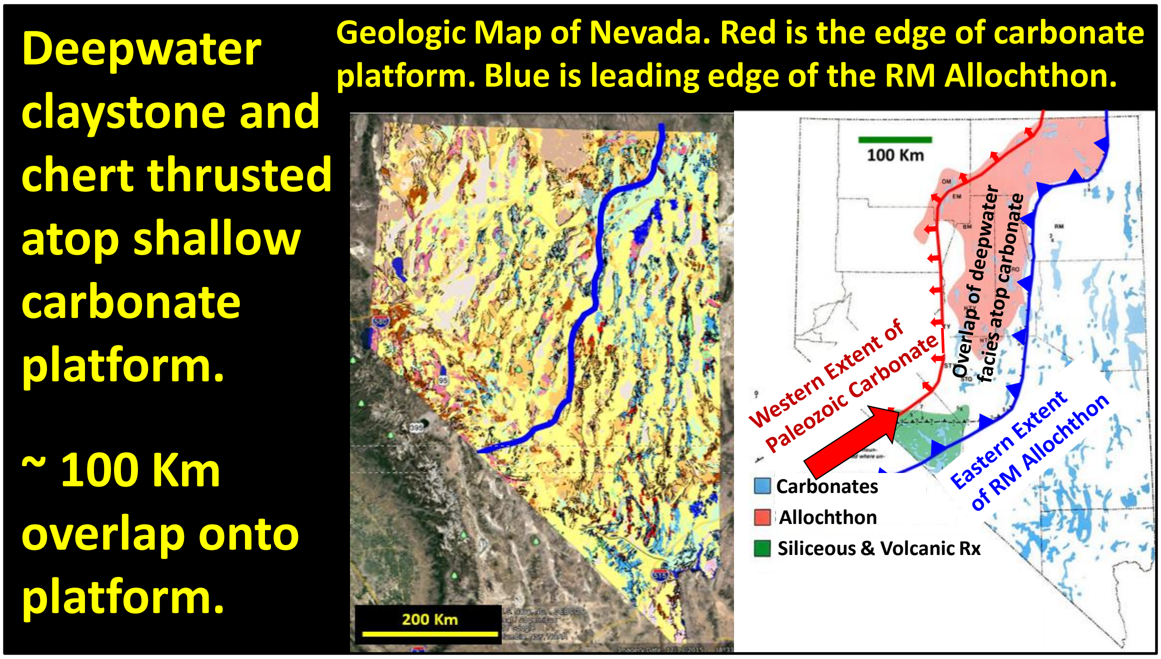
Data from exploration wells establish that a Miocene shallow-water carbonate platform is falling into the Banda Arc subduction zone. A detachment surface separates the subducting lower plate from an overlying accretionary prism of sediment scraped off the top of the descending plate. The Miocene carbonates were deposited in shallow water. However, as subsidence accelerated in the Pliocene due to descent into the trench, the carbonate platform stopped growing due to drowning and became overlain by deep-water Plio-Pleistocene mudstones.

As soon as I saw that seismic line, I knew that I had seen it before; here, in the Roberts Mountains. Analogs are important to geologists. The more different things you see, the more ideas you'll likely come up with. It's hard to visualize the concept of continental subduction without seeing examples of it, so I'll take you to the northwest shelf of Australia to let you see for yourselves.



Cashman and Sturmer, 2021

I'll start with a high-level view of the extent of the Roberts Mountains Allochthon. The map on the right is from Professor Cashman's 2021 paper, and the map on the left is a geologic map of Nevada projected onto Google Earth. The heavy blue line is the eastern edge of the Allochthon. I use Google Earth because it facilitates same-scale comparisons to other regions of the Earth, as shown in the following slides.

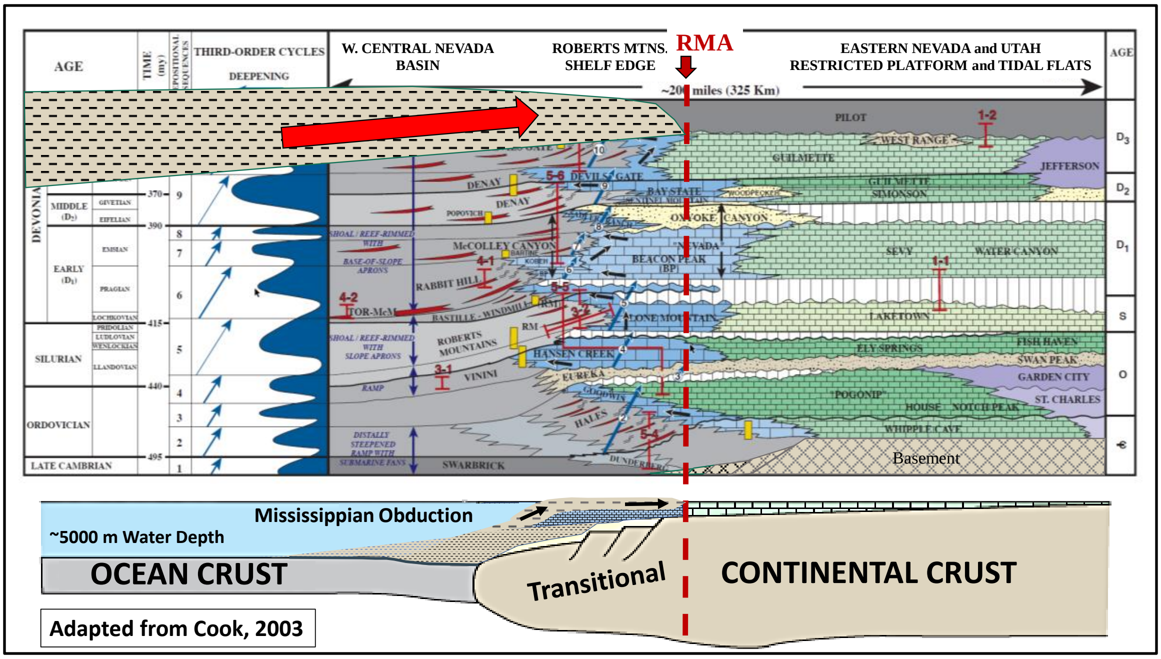


Deepwater claystone and chert thrusted atop shallow carbonate platform.

~ 100 Km overlap onto platform.

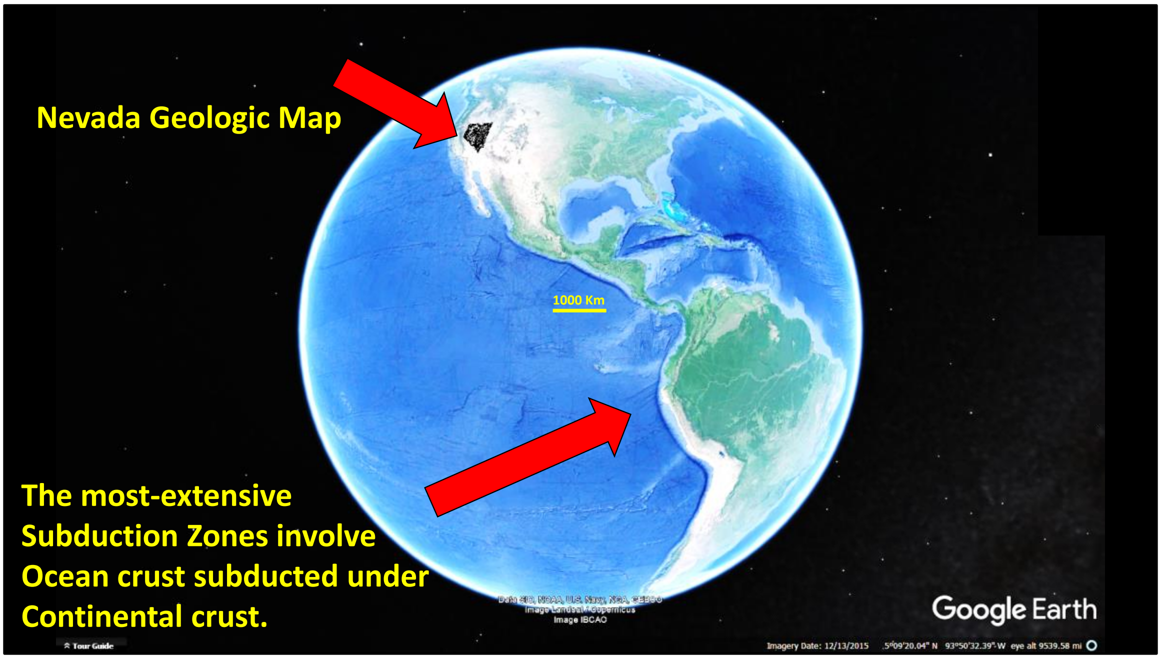
Geologic Map of Nevada. Red is the edge of carbonate platform. Blue is leading edge of the RM Allochthon.

The red line on the right-hand map shows the western extent of the shallow-water carbonate platform beneath the Allochthon, showing an overlap of about 100 kilometers of deep-water shale on top of shallow-water carbonate sediments.



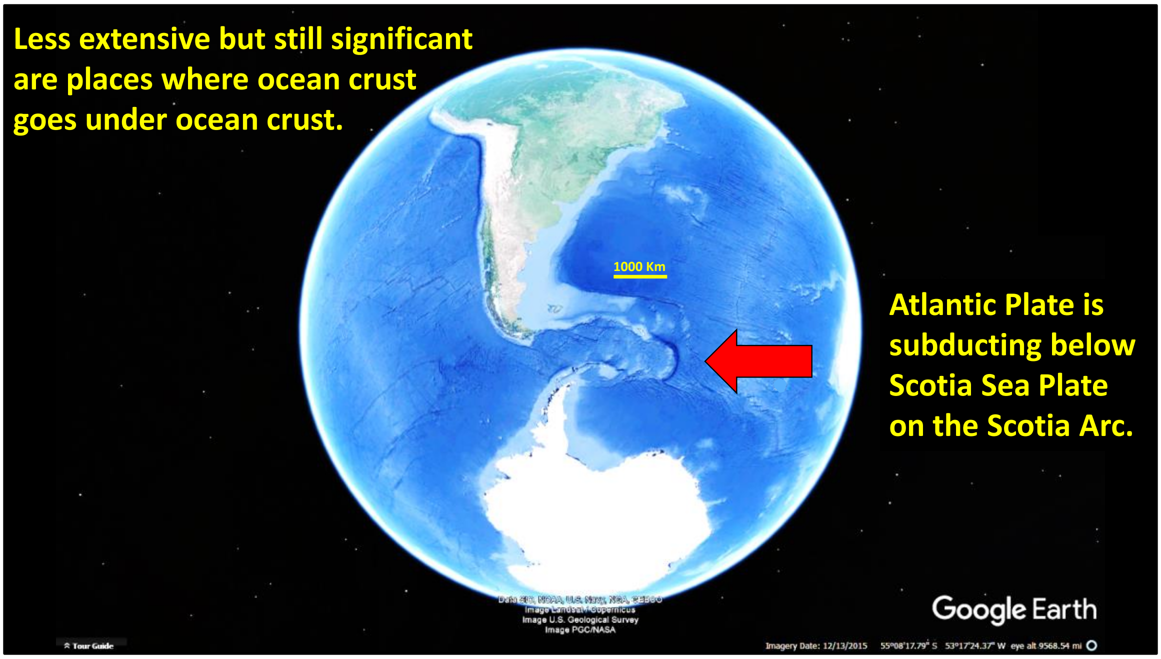
Adapted from Cook, 2003

The shales obducted onto the carbonate platform are not far-traveled. They are original continental rise and slope sediments that flanked the carbonate platform. The question is, how were they emplaced atop the carbonates?



The most-extensive Subduction Zones involve Ocean crust subducted under Continental crust.

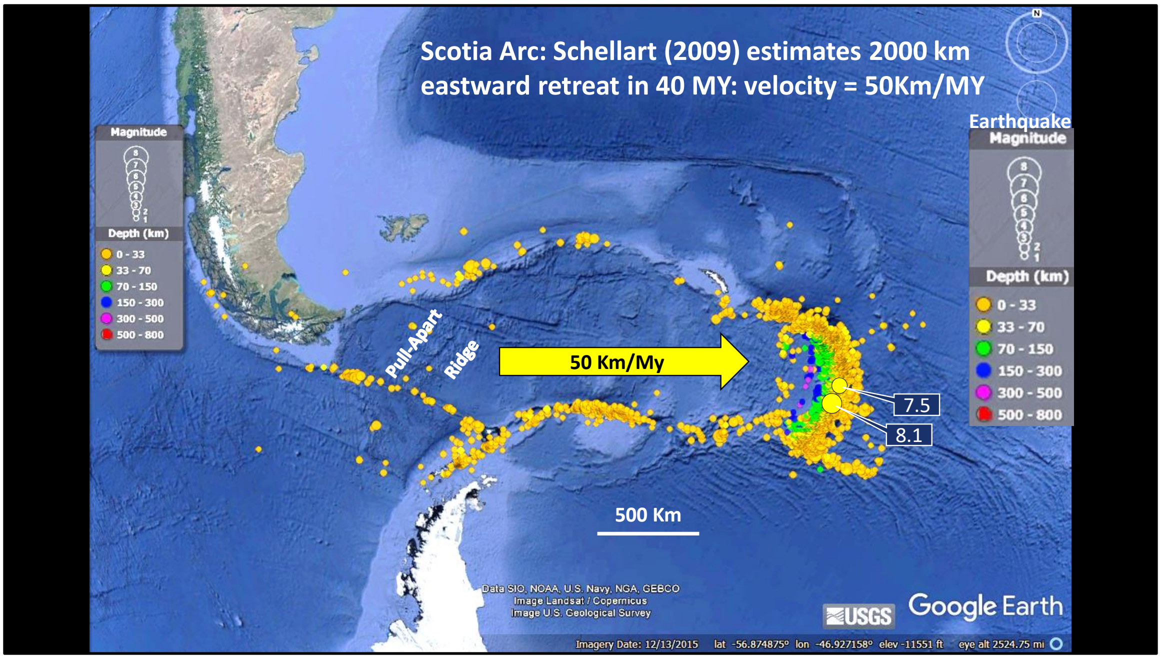
Here, the Nevada Geologic Map is compared globally to one of Earth's most familiar subduction zones, where oceanic crust subducts under continental crust.



Less extensive but still significant are places where ocean crust goes under ocean crust.

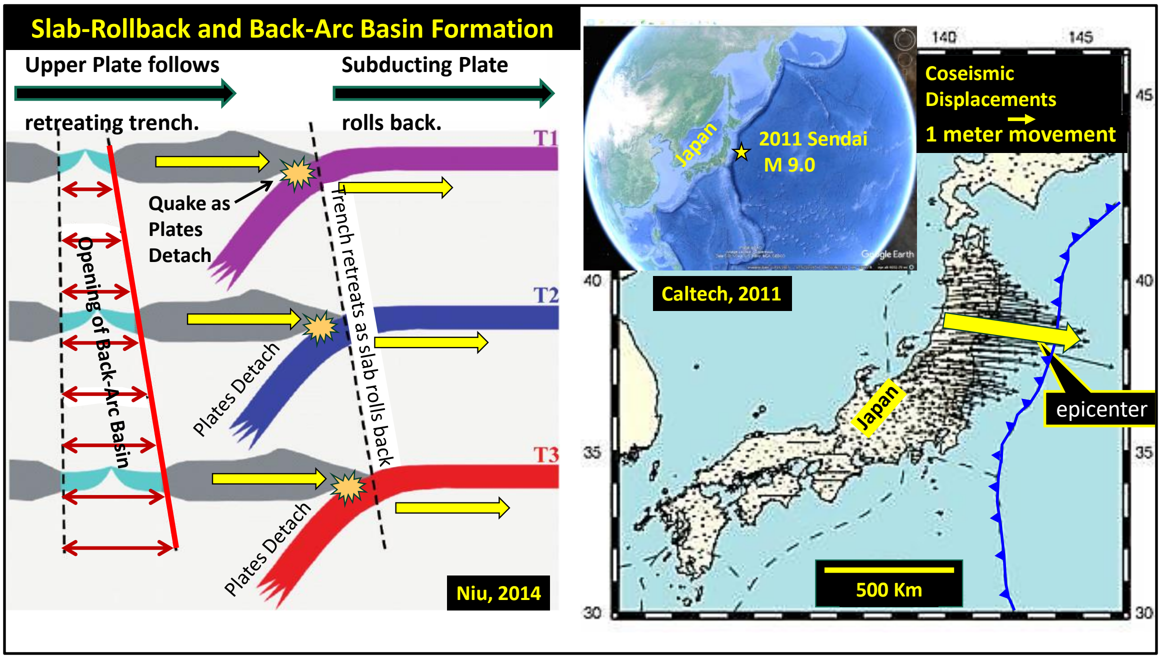
Atlantic Plate is subducting below Scotia Sea Plate on the Scotia Arc.

In other cases, ocean crust can subduct beneath ocean crust. Here, South Atlantic crust subducts below the Scotia Sea Plate at the Scotia Arc.



Scotia Arc: Schellart (2009) estimates 2000 km eastward retreat in 40 MY: velocity = 50Km/MY

Oceanic trenches actively migrate across plates of ocean crust at plate tectonic rates. Estimates from the Scotia Arc indicate 50 km of migration per million years. In the 300 million year history of the Laurentian passive margin, a trench like this could have migrated for 15,000 kilometers.

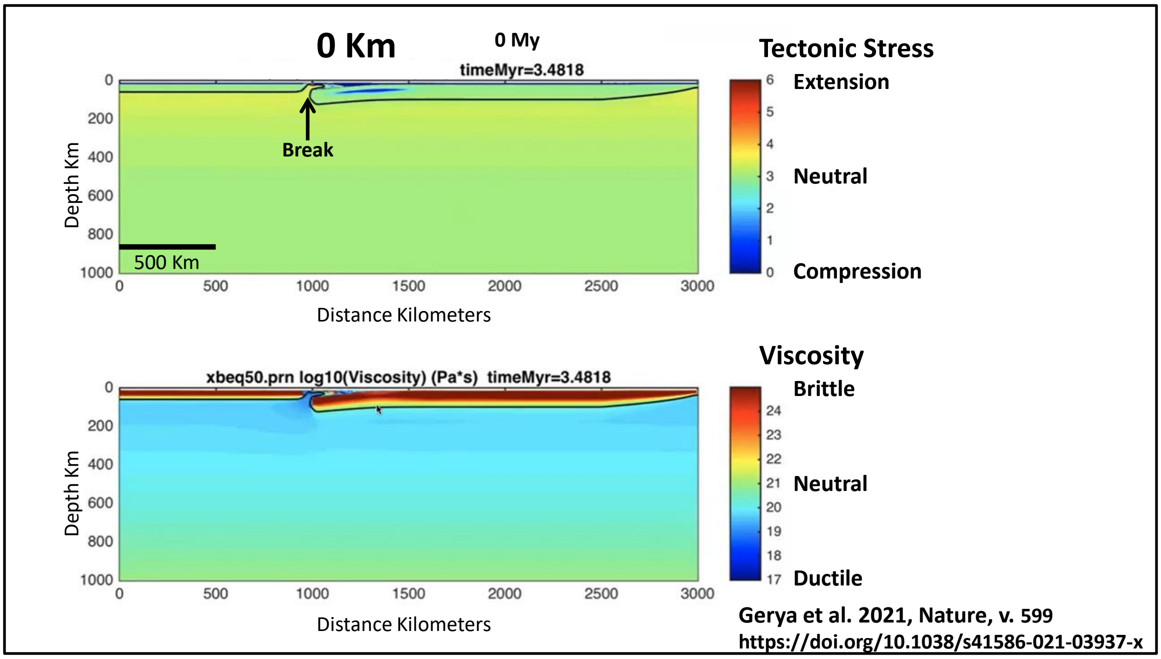


Slab-Rollback and Back-Arc Basin Formation

Niu, 2014

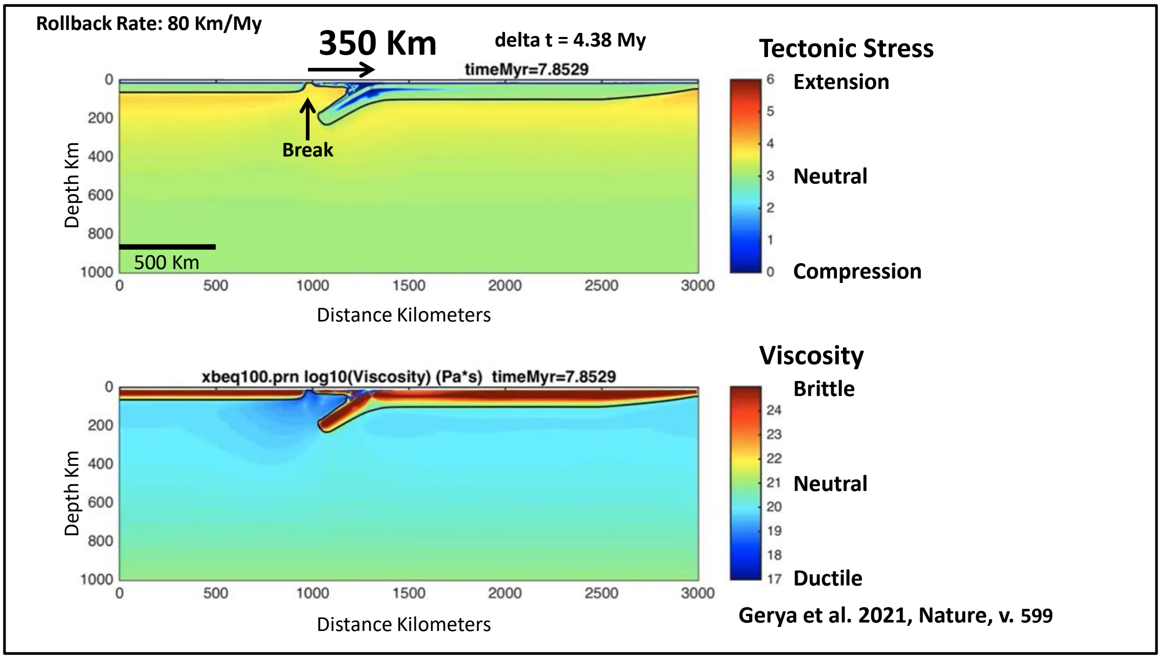
Caltech, 2011

Slab Rollback is the mechanism that drives the movement of Oceanic Trenches across the earth's surface. The hinge line of the subducting plate will move backward away from the trench over time. The map on the right shows GPS ground motion measurements following the magnitude 9 Sendai Earthquake. The quake occurred when the upper and lower plates of the subduction zone detached. The hinge line of the descending slab moved eastward, and at the same time, the upper plate instantaneously moved east up to 10 meters to take up the space left behind by the retreating lower plate. Island arcs are moving across oceanic plates at plate-tectonic time scales.



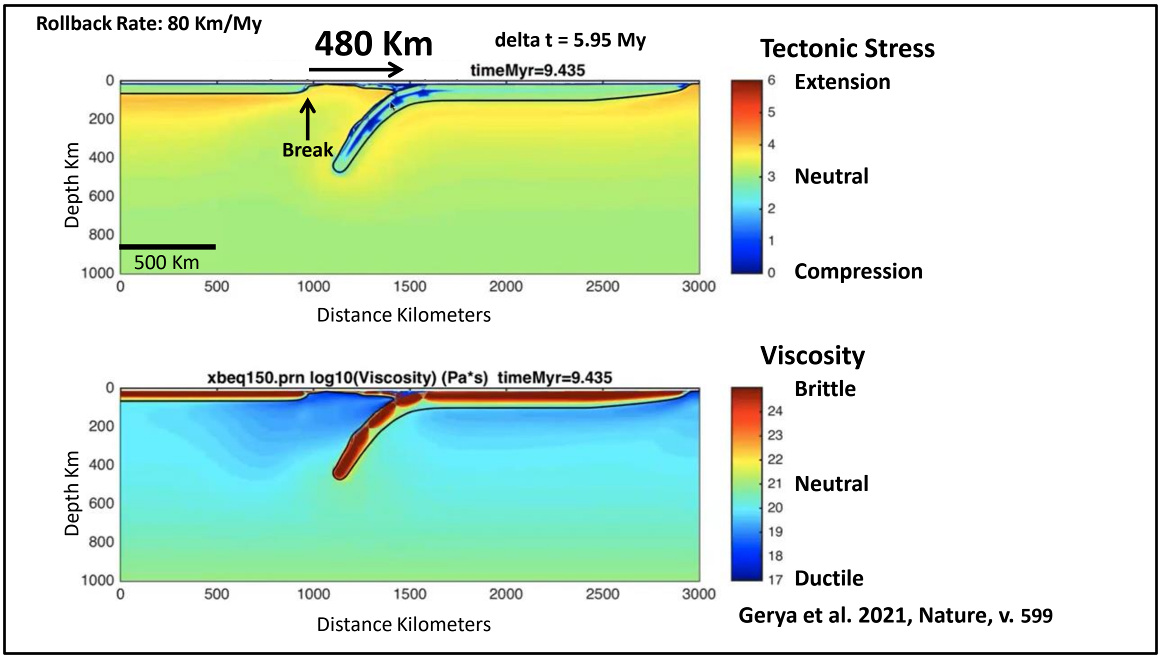
Gerya et al. 2021, Nature, v. 599
https://doi.org/10.1038/s41586-021-03937-x

Gerya generated a numeric model for the subduction of oceanic lithosphere. A cold, dense slab is negatively buoyant as it floats on the Asthenosphere. If anything causes a break in the slab, one edge of the break will begin to subside.



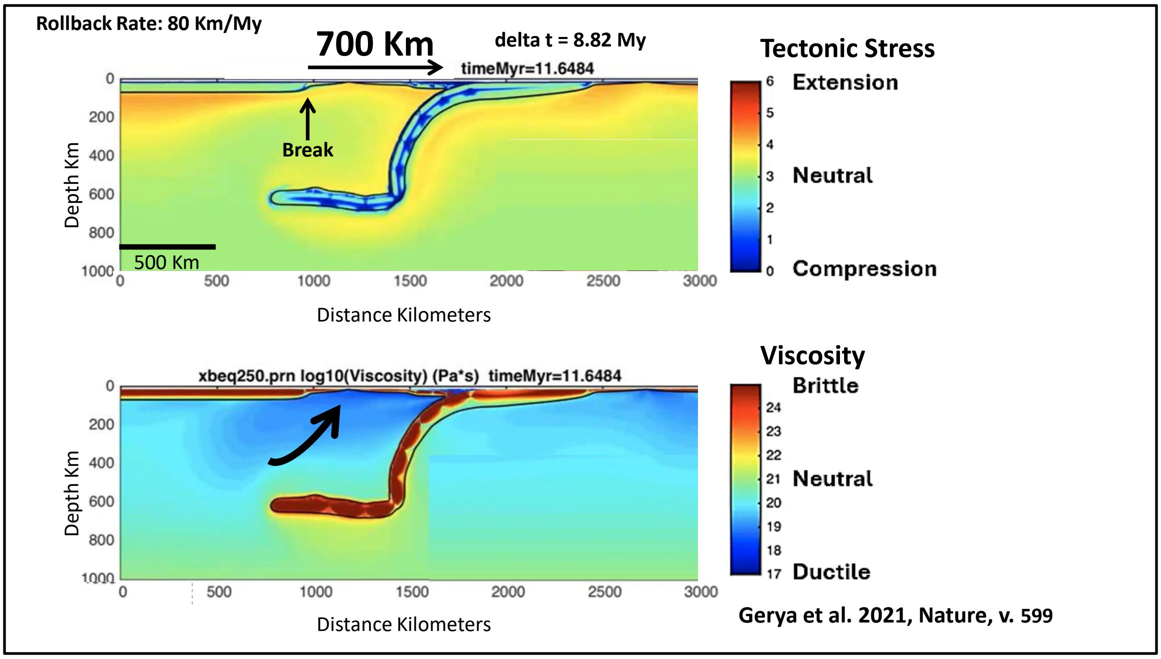
Gerya et al. 2021, Nature, v. 599

The subsiding plate flexes along a hinge line that moves back away from the break.



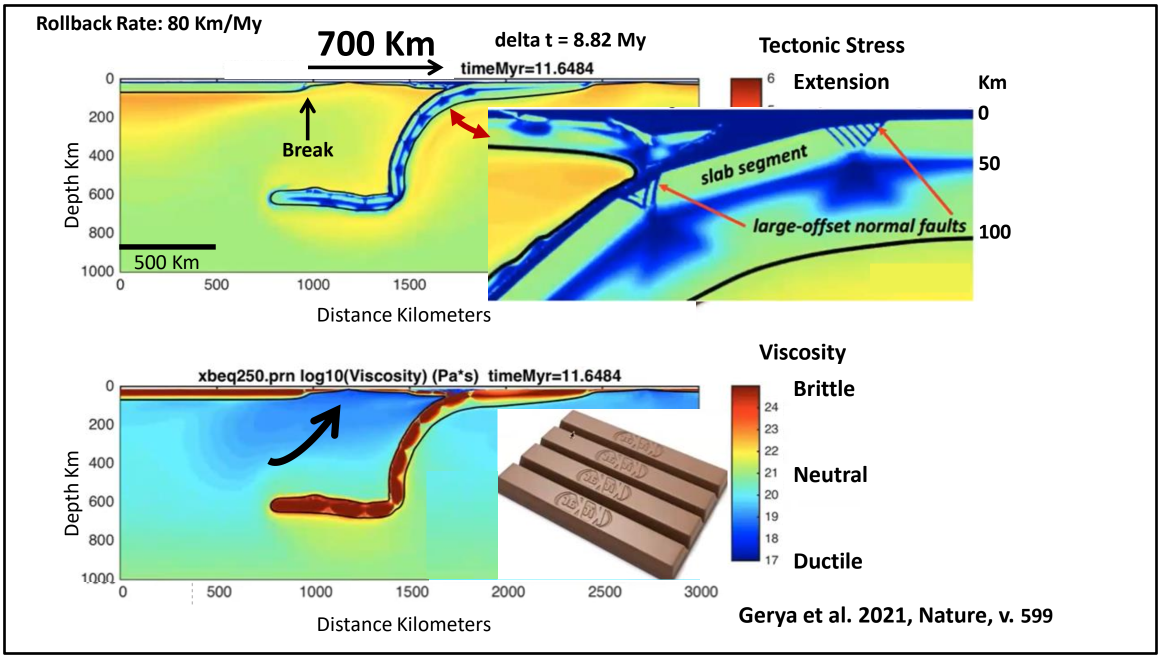
Gerya et al. 2021, Nature, v. 599

The subsiding plate continues to bend and roll back. The brittle slab bends by breaking into segments.



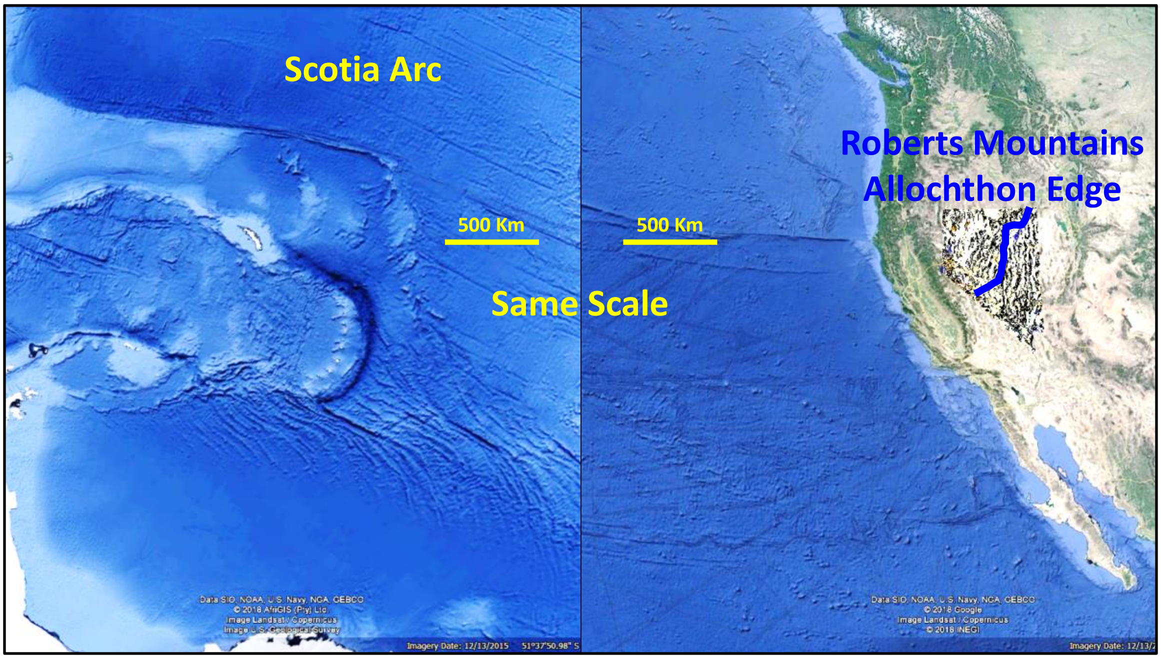
Gerya et al. 2021, Nature, v. 599

Eventually, the subducting slab has migrated hundreds to thousands of kilometers from the original break. Note how hot ductile asthenosphere rises into back-arc pull-apart ridges.

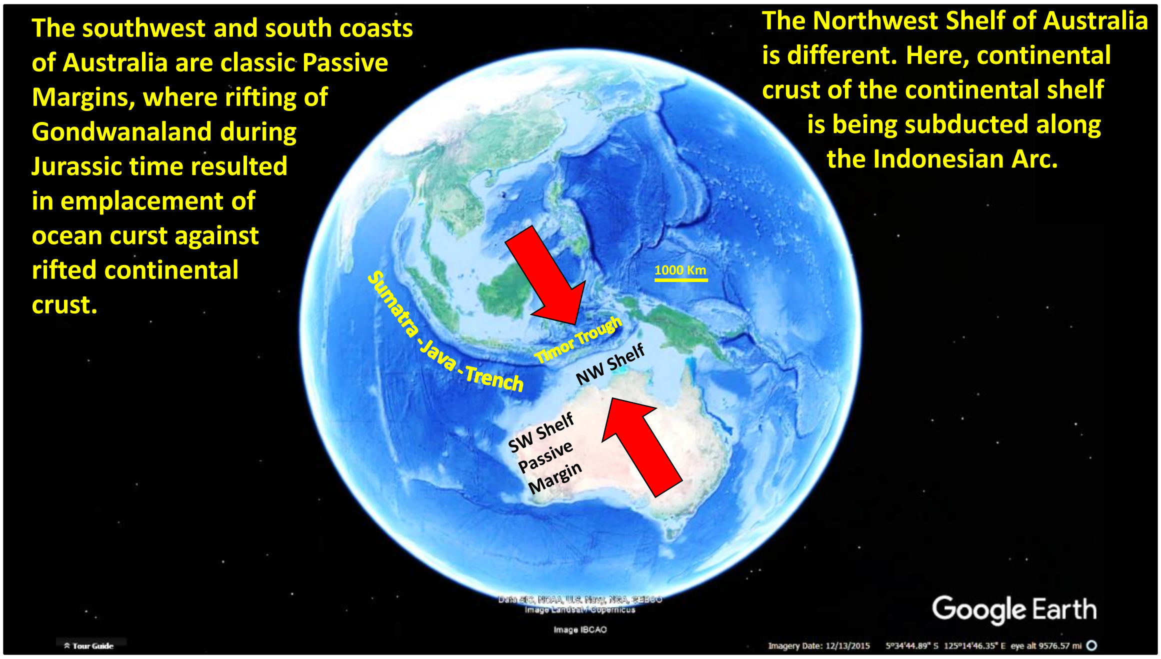


Gerya et al. 2021, Nature, v. 599

How does the brittle slab bend and subside? It breaks into segments. The process won't stop until it runs into something.



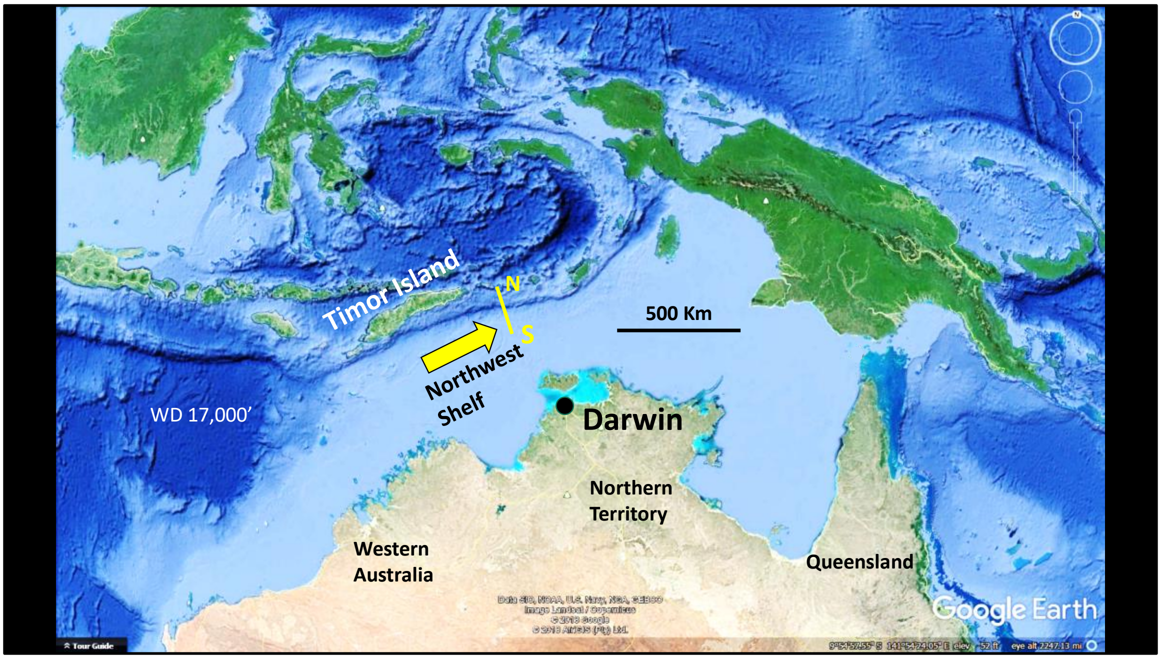
All the previous slides lead to this comparison of the extent of the Scotia Arc to the Roberts Mountains Allochthon at the same scale. What might happen if this arc reached a continental margin?



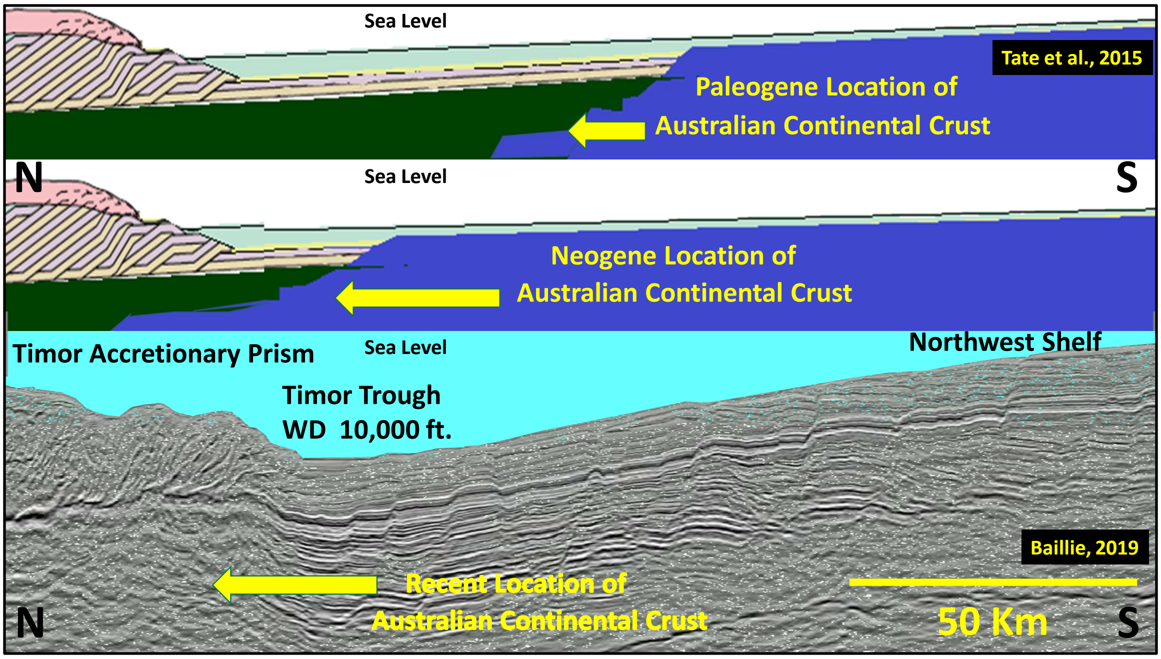
The southwest and south coasts of Australia are classic Passive Margins, where rifting of Gondwanaland during Jurassic time resulted in emplacement of ocean curst against rifted continental crust.

The Northwest Shelf of Australia is different. Here, continental crust of the continental shelf is being subducted along the Indonesian Arc.

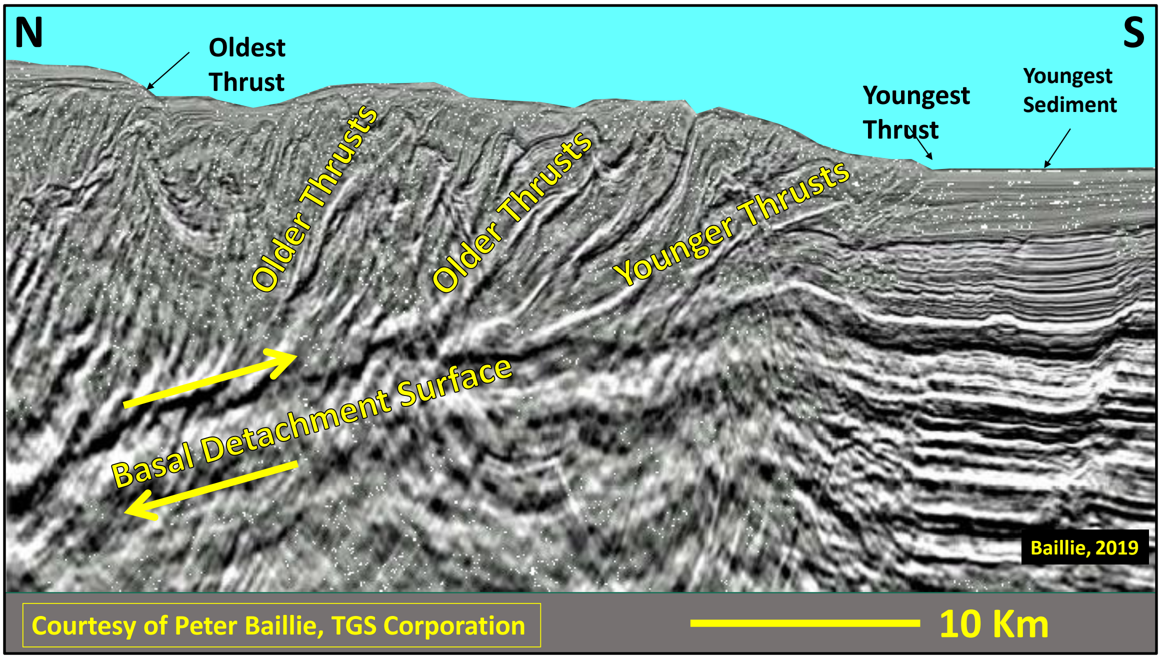
In the case of the Australian Plate, we don’t have to imagine what would happen. The northwest shelf of Australia has collided with the East Indonesia subduction zone. Australia rifted from Gondwanaland in Jurassic time and has migrated northward ever since. At the same time, the Indonesian subduction zone is moving south through the process of slab rollback. Simply by coincidence, these plates have encountered one another. The map shows that Australia’s south and southwestern coasts remain passive margins. Only the Northwest Shelf has encountered the Timor Trough in Recent time.



The yellow line shows the trace of a seismic line that extends from shallow water on the Northwest Shelf down into 10,000-foot water depths at the base of the Timor Trough.



Continental Crust of the Australian Northwest Shelf is falling into the Timor Trough. Deepwater sediment scrapes off the descending plate and piles up into an accretionary prism.

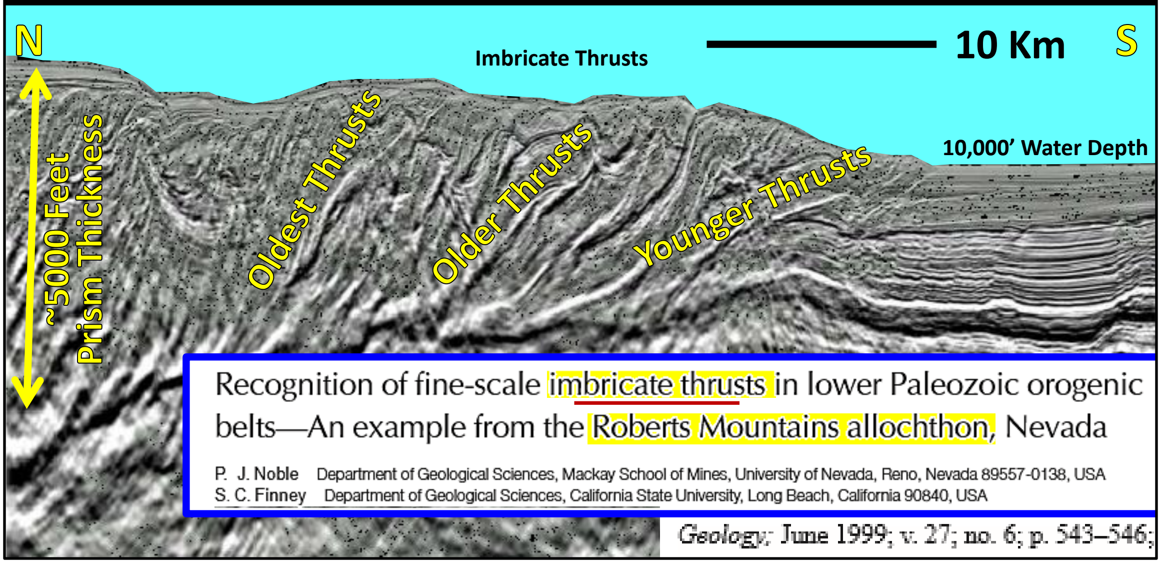


Courtesy of Peter Baillie, TGS Corporation

This detail of the Timor Accretionary Prism shows a classic sequence of forward-breaking thrusts rising from a basal detachment surface. The youngest thrust breaks the sea floor right at the bottom of the trench. Each young thrust lifts up all the older thrusts behind it to form an accretionary prism. The oldest sediment is stacked into the highest part of the prism, while the youngest sediment is cut by the youngest thrust at the bottom of the trench.

Timor Accretionary Prism

Courtesy of Peter Baillie, TGS Corporation

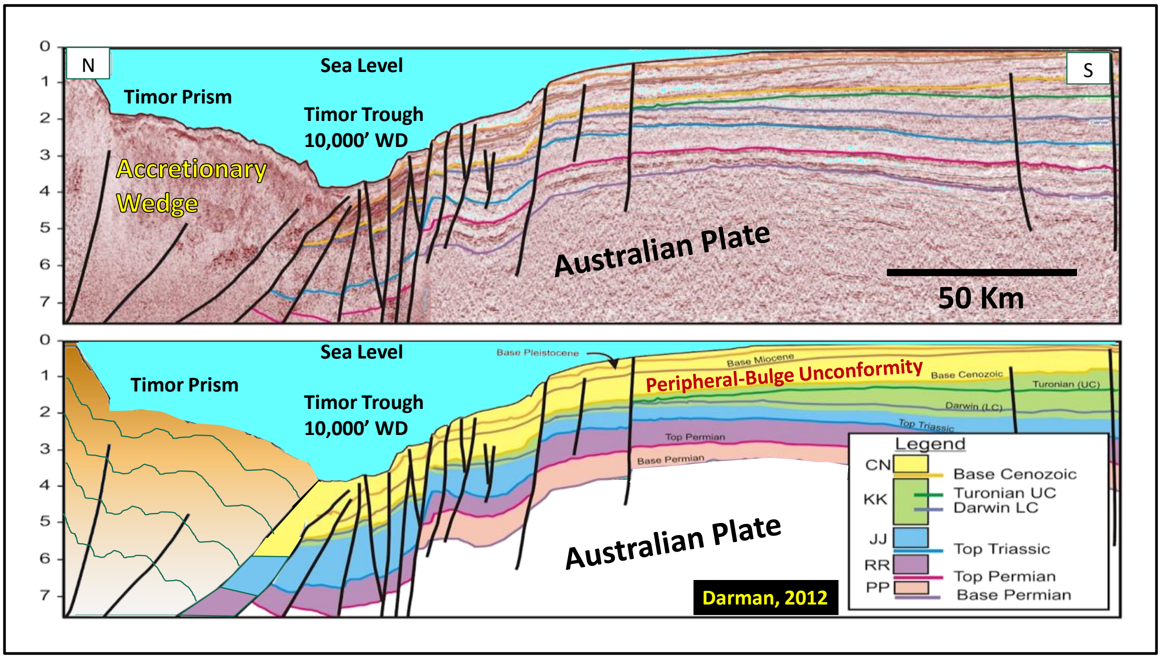


Recognition of fine-scale imbricate thrusts in lower Paleozoic orogenic belts—An example from the Roberts Mountains allochthon, Nevada

P. J. Noble Department of Geological Sciences, Mackay School of Mines, University of Nevada, Reno, Nevada 89557-0138, USA
S. C. Finney Department of Geological Sciences, California State University, Long Beach, California 90840, USA

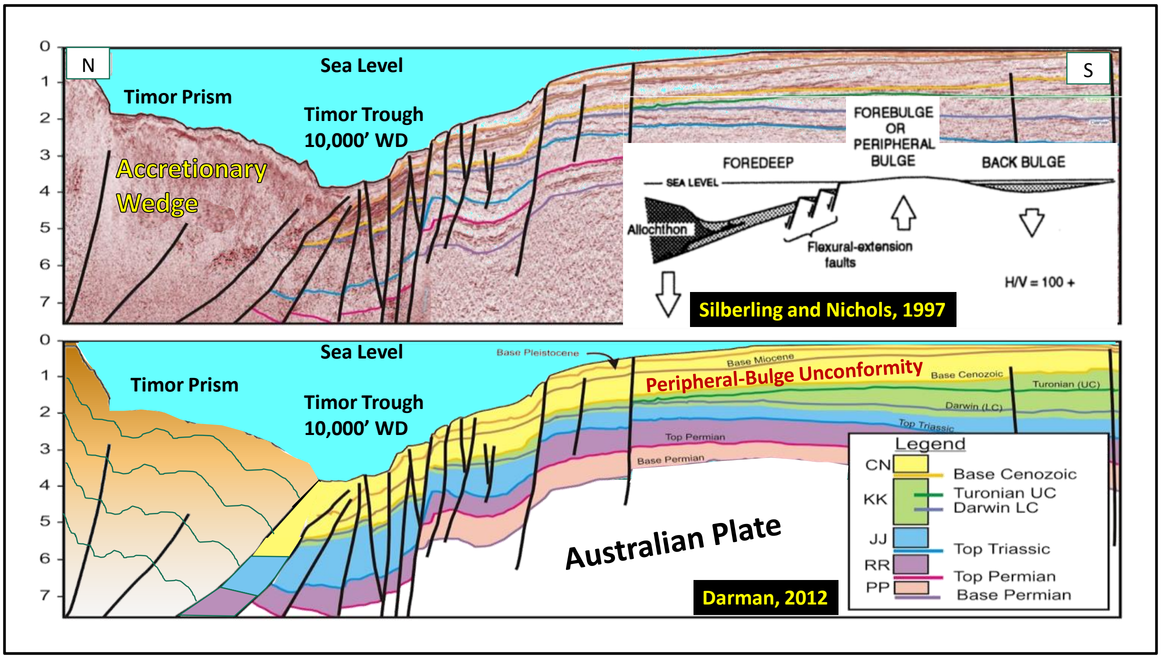
Geology; June 1999; v. 27; no. 6; p. 543–546;

Ted McKee of the USGS recognized that the Allochthon was a stack of imbricates when he mapped the Roberts Mountains Quadrangle in the 1970s. Noble and Finney published a detailed analysis that described the upper plate as a collection of imbricate thrusts rather than a single sheet. This geometry is consistent with an accretionary prism.



Darman, 2012

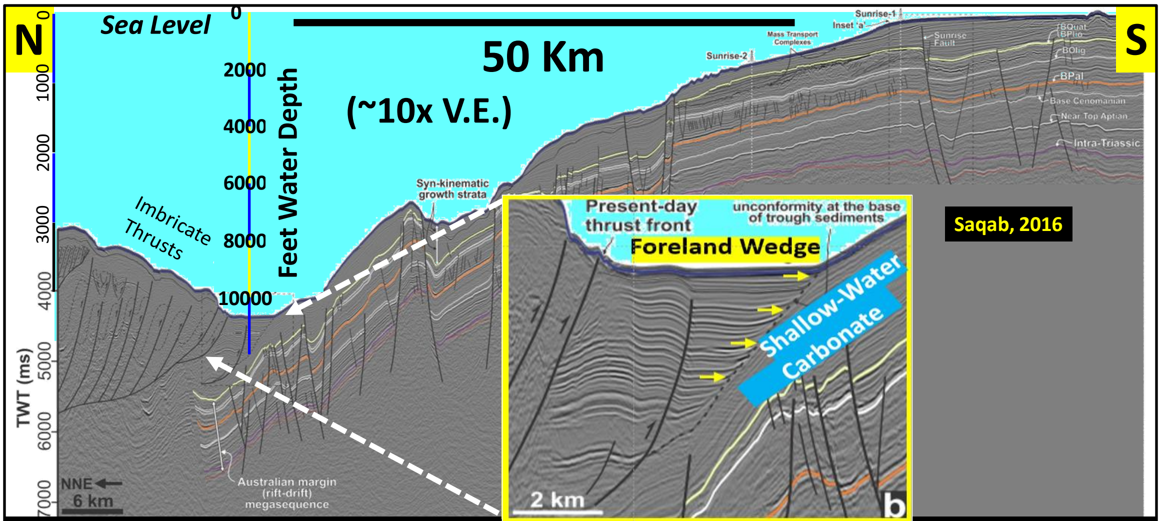
This line across the Timor Trough stretches for more than 300 kilometers, from water depths of a few meters on the shelf to more than 3,000 meters deep at the bottom of the trough. As the Australian plate descends, it bends toward the trench, and this flexing results in tension and normal faulting. Farther inward to the south, the flexing of the plate results in uplift of a broad Peripheral Bulge and consequent development of tectonic disconformities between successively younger sedimentary sequences. This line captures the essential characteristics of a passive margin as it encounters a subduction zone. Shallow-water carbonate sediments descend into deeper water and become overlain by deep-water mudstones; the mudstones scrape off and pile up as imbricates on top of the shallow-water carbonates.



Silberling and Nichols, 1997

Darman, 2012

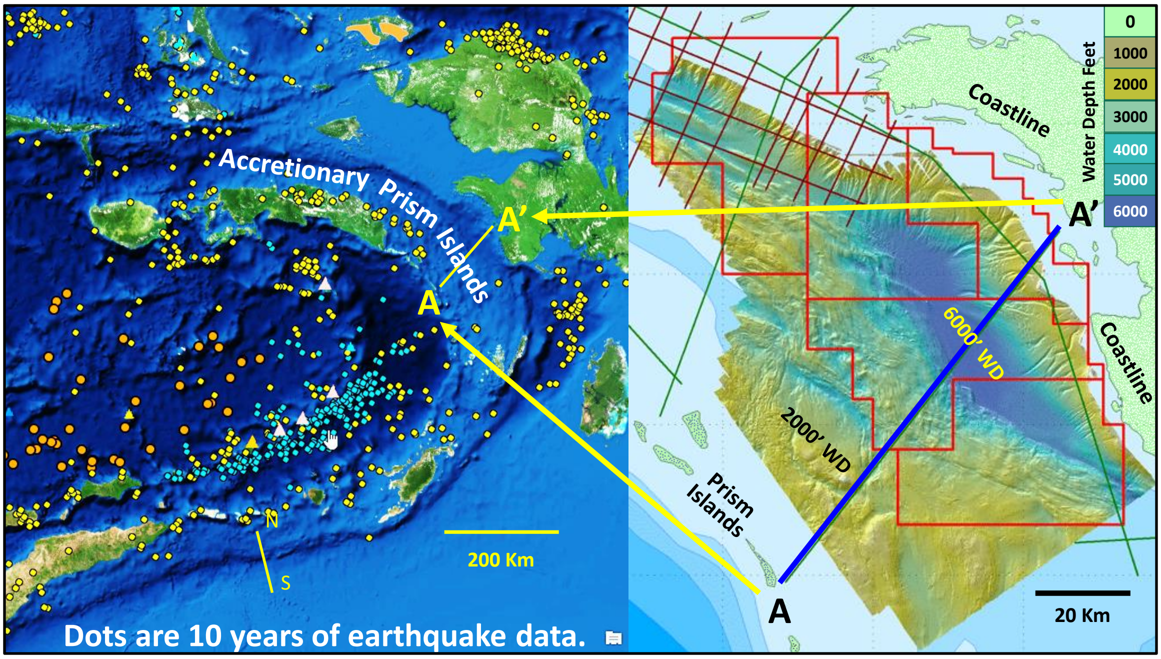
The insert by Silberling and Nichols shows a conceptual structure section through central Nevada at the time of the Antler Orogeny. The dates show that they did not see this seismic line, yet their geologic concept compares well to actual data from the Northwest Shelf.



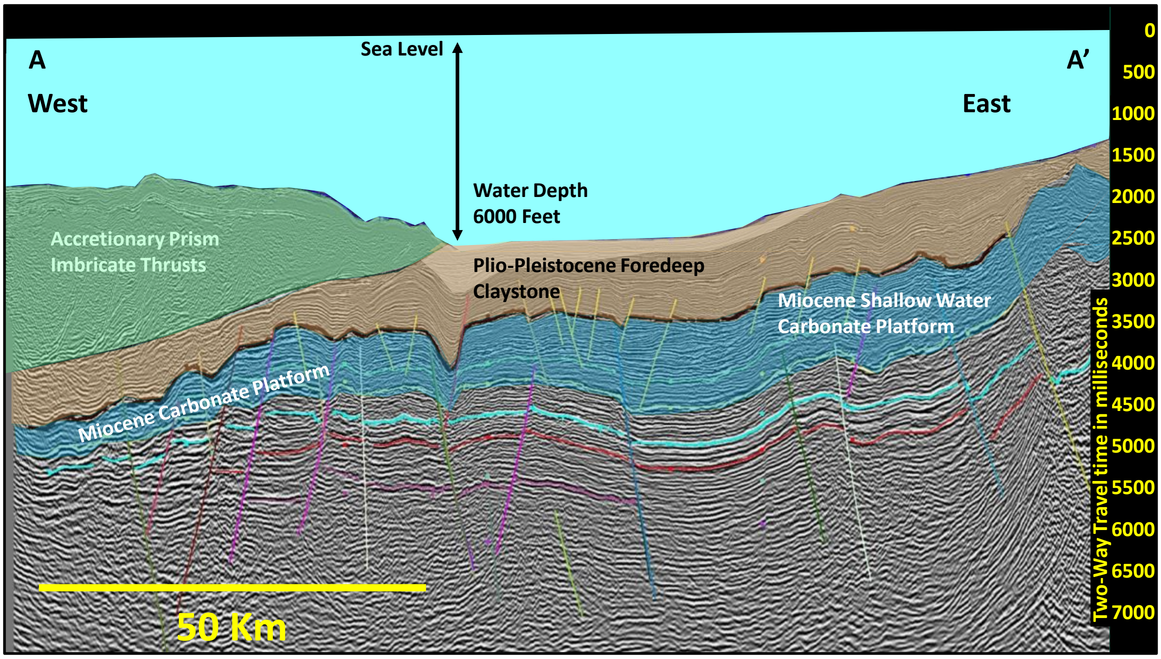
Saqab, 2016

Australian Continental Crust is falling into the Timor Trough. Shallow water shelf sediments are falling under imbricately thrusted deep-water sediments. The Foreland Wedge is bounded to the east by an angular unconformity where sediments deposited in over 10,000 feet water depth are onlapping against shallow water carbonates that are dipping into the trench. The west edge of the Foreland Wedge is the first thrust fault at the deformation front.

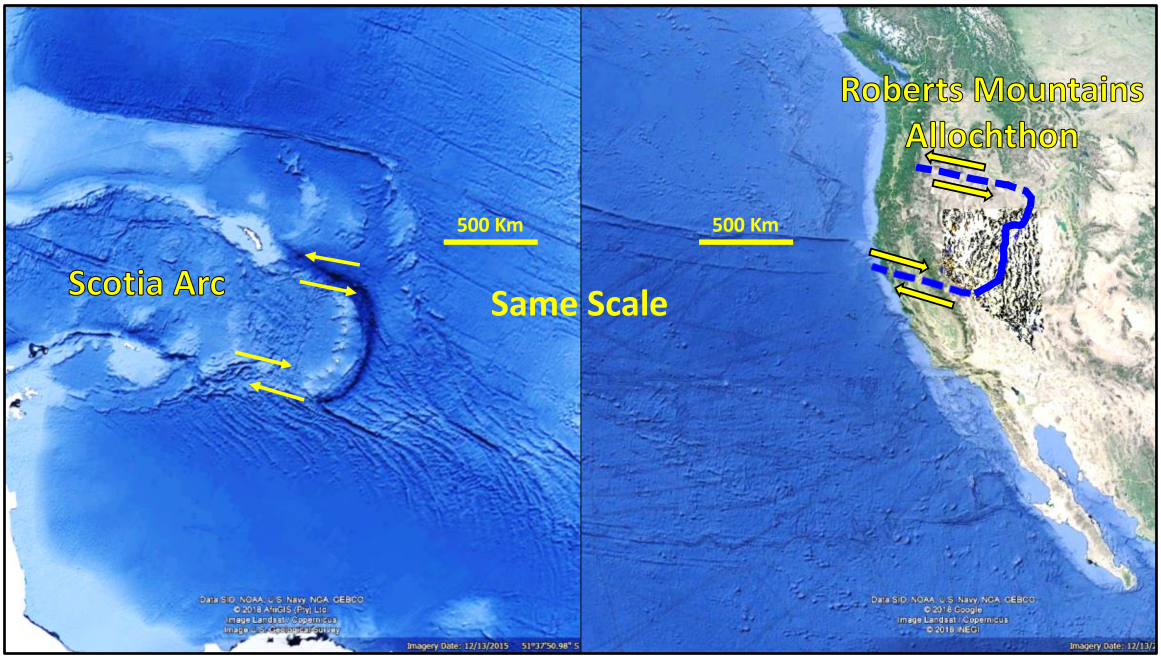
The Australian continental shelf is falling into the Timor Trough. Shallow shelf sediments are sliding under imbricately thrusted deep-water sediments. The plate descends from sea level to over 3,000 meters of water depth over a distance of less than 100 km. All the normal faults in the descending plate formed due to bending as the plate fell into the trench. The Foreland Wedge is deep-water sediment deposited in the bottom of the trench.



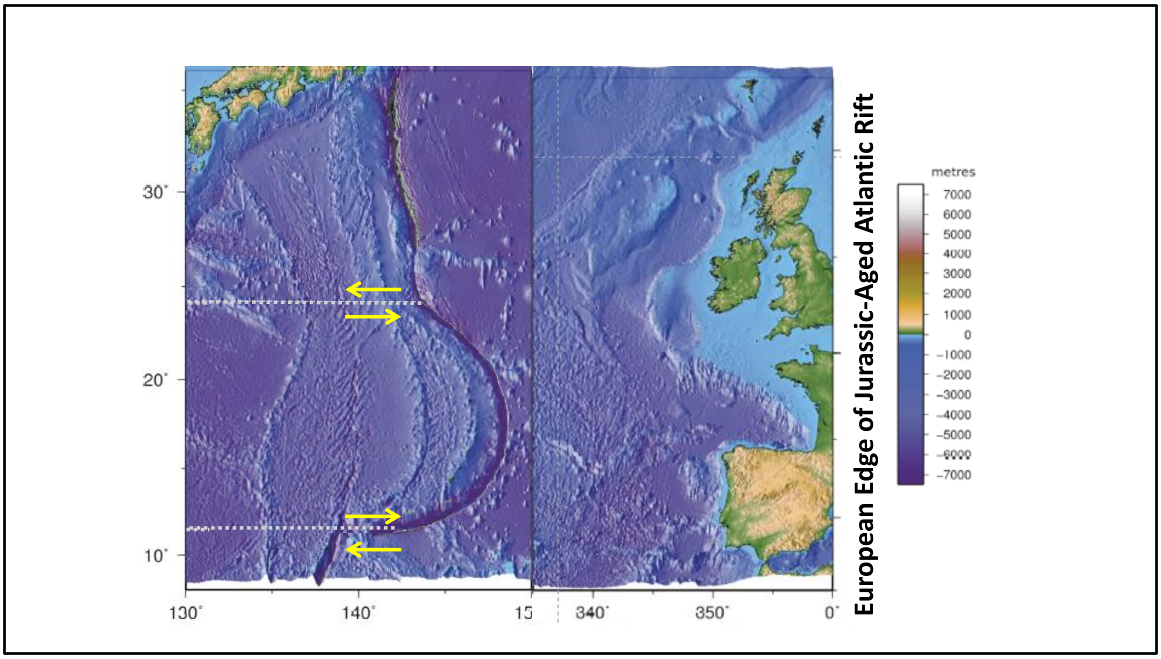
This map shows the location of a seismic section at the western tip of New Guinea. The water depth along the line ranges from sea level on the New Guinea coast at A' to over 2000 meters at the bottom of the Banda trough and then back up to sea level at location A, where the accretionary prism rises above sea level to form a chain of non-volcanic islands of uplifted deep-water sediment.



Data from exploration wells establish that a Miocene shallow-water carbonate platform is falling into the Banda Arc subduction zone. A detachment surface separates the subducting lower plate from an overlying accretionary prism of sediment scraped off the top of the descending plate. The Miocene carbonates grew in shallow water, but as subsidence accelerated in Pliocene time due to descent into the trench, the carbonate platform stopped growing due to drowning and became overlain by deep-water Plio-Pleistocene mudstones.

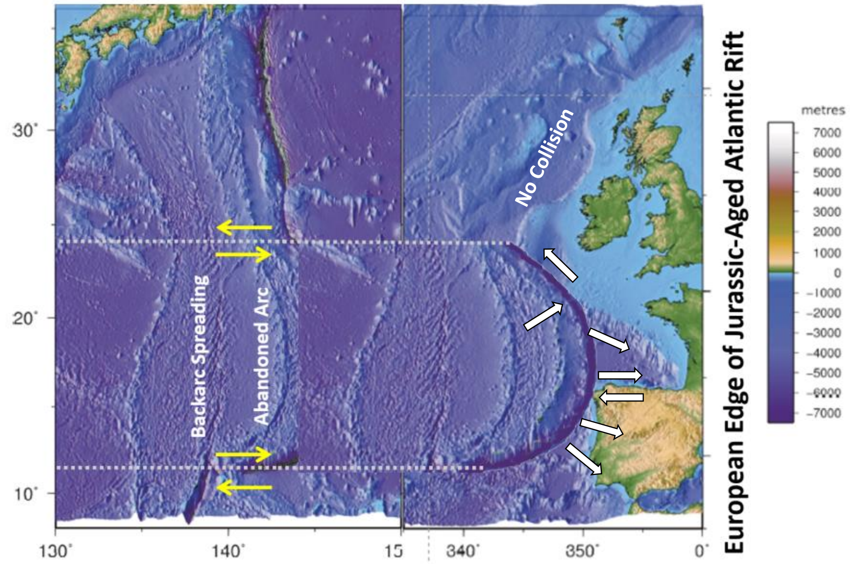


Arc-to-shelf collisions produce structures comparable to the imbricates obducted onto the Laurentian carbonate platform. This slide compares the Roberts Mountains Allochthon and the Scotia Arc subduction zone at the same scale. Though their precise location isn't known, there must be transforms at either end of the Roberts Allochthon.



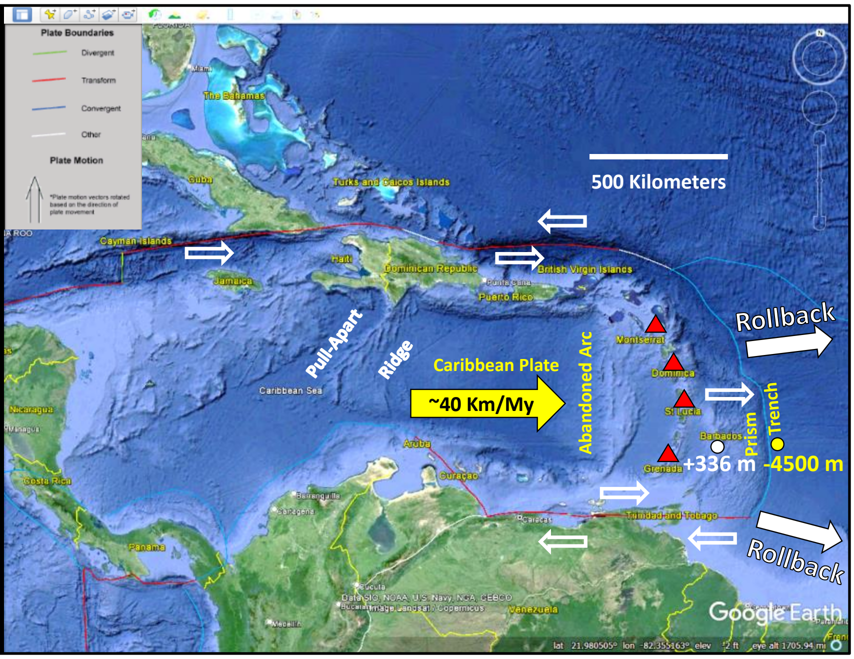
How could an arc travel toward a passive margin? Slab rollback drives the process. The geography of headlands and embayments on the continental margin determines the timing and angle of arc collision.

Orthogonal, Oblique, or Strike-Slip? It Depends on Original Shape of the Continental Margin

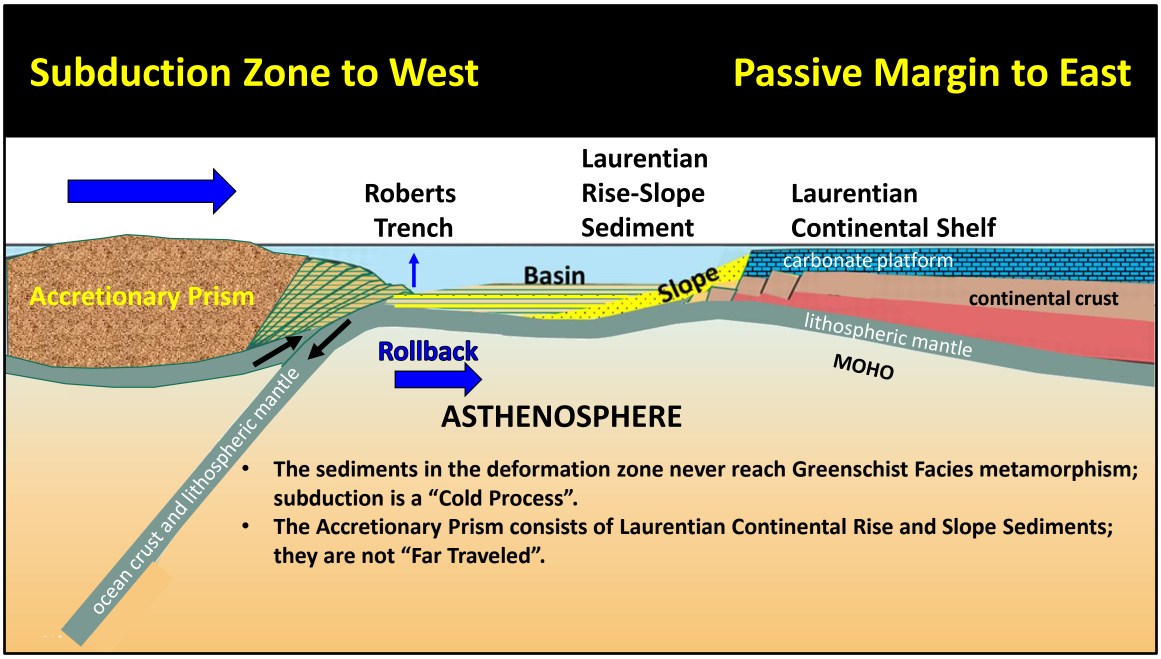


Whether the collision is orthogonal, oblique-slip, or pure strike-slip depends on the original shape of the continental margin.

Oblique Collision of South American Plate and Caribbean Plate driven by slab-rollback at the Lesser Antillies Trench.



The Caribbean Plate obliquely collides with South America. The elevation difference between the top of the Barbados Accretionary Prism and the bottom of the Antilles Trench is nearly 5,000 meters.



Subduction Zone to West **Passive Margin to East**

Roberts Trench

Laurentian Rise-Slope Sediment

Laurentian Continental Shelf

carbonate platform

Accretionary Prism

Basin

Slope

continental crust

lithospheric mantle

Rollback

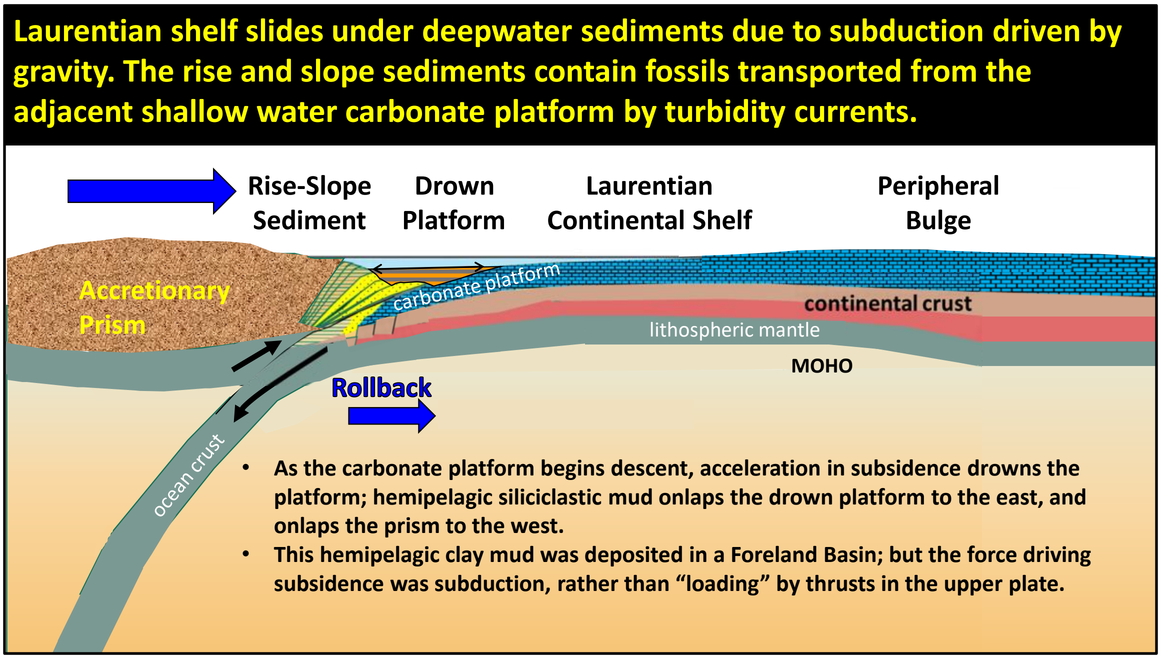
MOHO

ASTHENOSPHERE

ocean crust and lithospheric mantle

- The sediments in the deformation zone never reach Greenschist Facies metamorphism; subduction is a “Cold Process”.
- The Accretionary Prism consists of Laurentian Continental Rise and Slope Sediments; they are not “Far Traveled”.

A model for the evolution of the Roberts Mountains Allochthon: slab rollback causes a west-dipping subduction zone to retreat toward the Laurentian continental shelf. Sediments of the slope and basin contain material transported from the shelf.

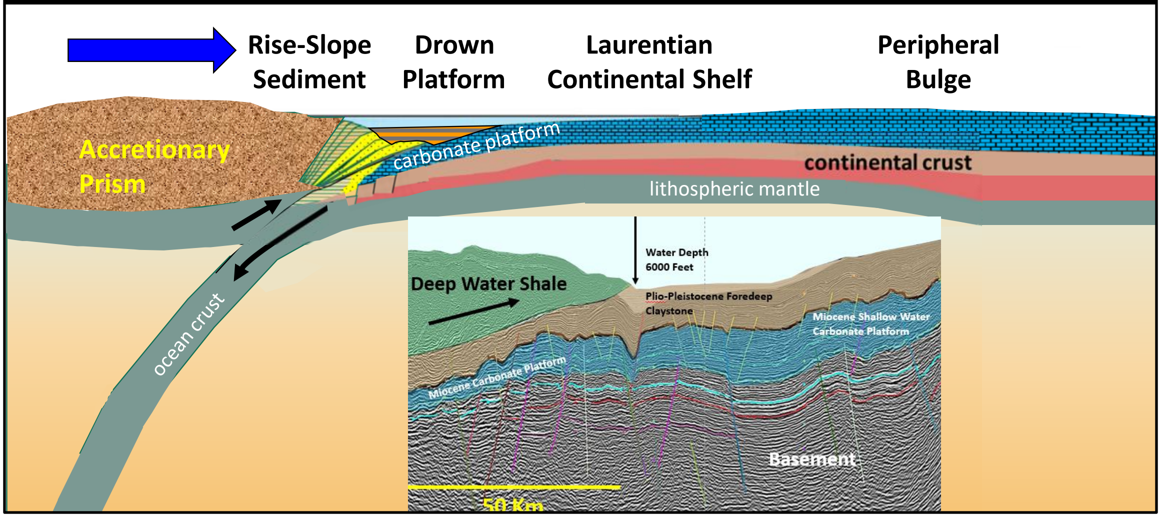


Laurentian shelf slides under deepwater sediments due to subduction driven by gravity. The rise and slope sediments contain fossils transported from the adjacent shallow water carbonate platform by turbidity currents.

- As the carbonate platform begins descent, acceleration in subsidence drowns the platform; hemipelagic siliciclastic mud onlaps the drown platform to the east, and onlaps the prism to the west.
- This hemipelagic clay mud was deposited in a Foreland Basin; but the force driving subsidence was subduction, rather than “loading” by thrusts in the upper plate.

The shallow-water carbonate platform descends into the trench and slides below the accretionary prism, resulting in emplacement of a stack of imbricately thrusted deep-water sediment atop shallow-water carbonate platform sediment. Gravity drives the process; the platform falls under the prism. Slab rollback pulled the prism eastward; while the platform fell westward into the trench.

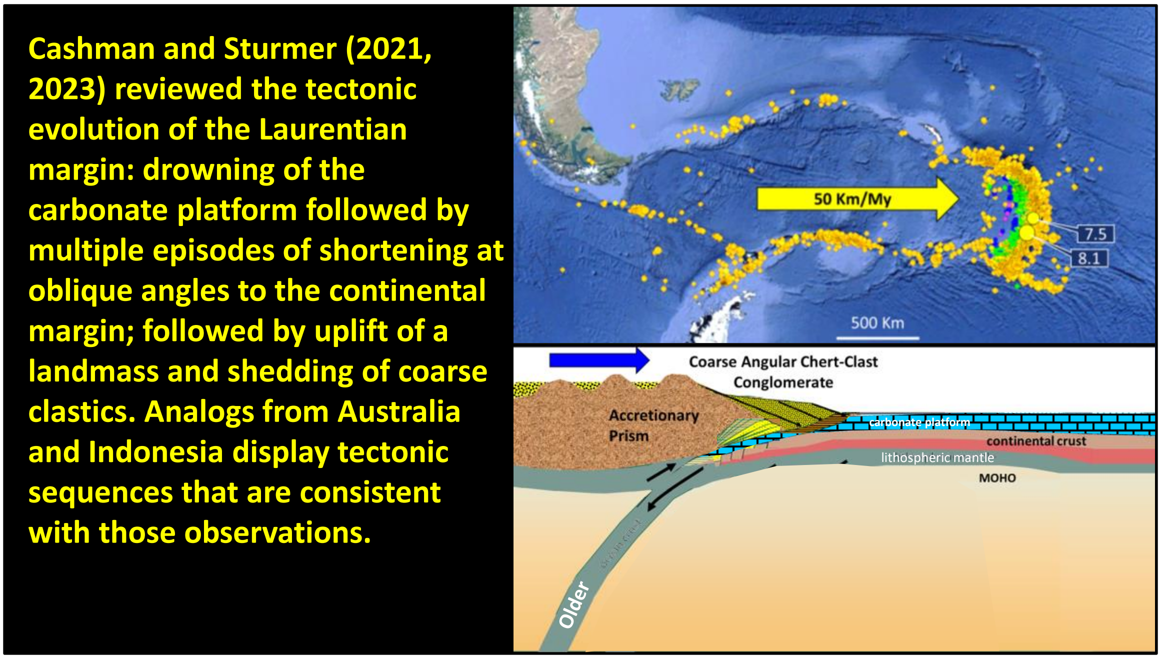
Laurentian shelf slides under deepwater sediments due to subduction driven by gravity. The rise and slope sediments contain fossils transported from the adjacent shallow water carbonate platform by turbidity currents.



This process is happening at continental margins in Recent time.

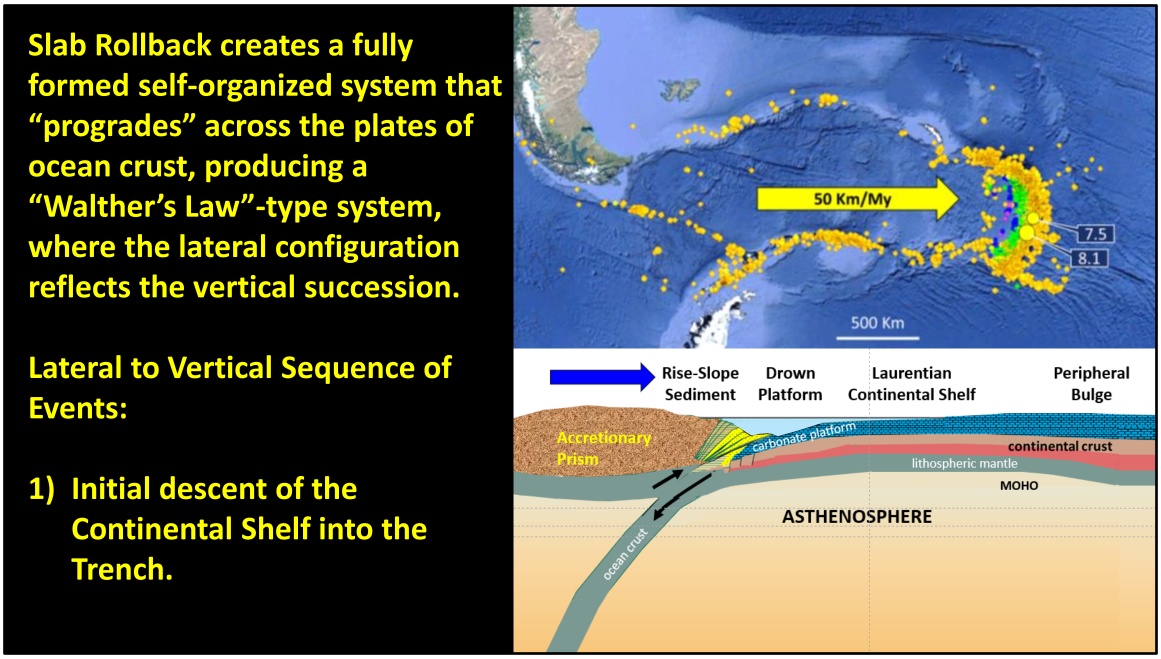
Carbonates in Simpson Park Range contain large fusilinids and abundant red and green chert clasts eroded from the Vinini Formation. This is analogous to subaerially exposed Timor and Barbados accretionary prisms.

Analogous to Timor Island, traces of an uplifted Pennsylvanian landmass in Nevada are seen in coarse “mollase” deposits containing eroded deep-water radiolarian chert clasts and shallow water fusilinid limestones.



Cashman and Sturmer (2021, 2023) reviewed the tectonic evolution of the Laurentian margin: drowning of the carbonate platform followed by multiple episodes of shortening at oblique angles to the continental margin; followed by uplift of a landmass and shedding of coarse clastics. Analogs from Australia and Indonesia display tectonic sequences that are consistent with those observations.

Cashman and Sturmer reviewed the tectonic evolution of the Laurentian margin, which included drowning of the carbonate platform, multiple episodes of shortening at oblique angles to the continental margin, uplift of a landmass, and shedding of coarse clastics. Analogs from Australia and Indonesia display tectonic sequences consistent with those observations.

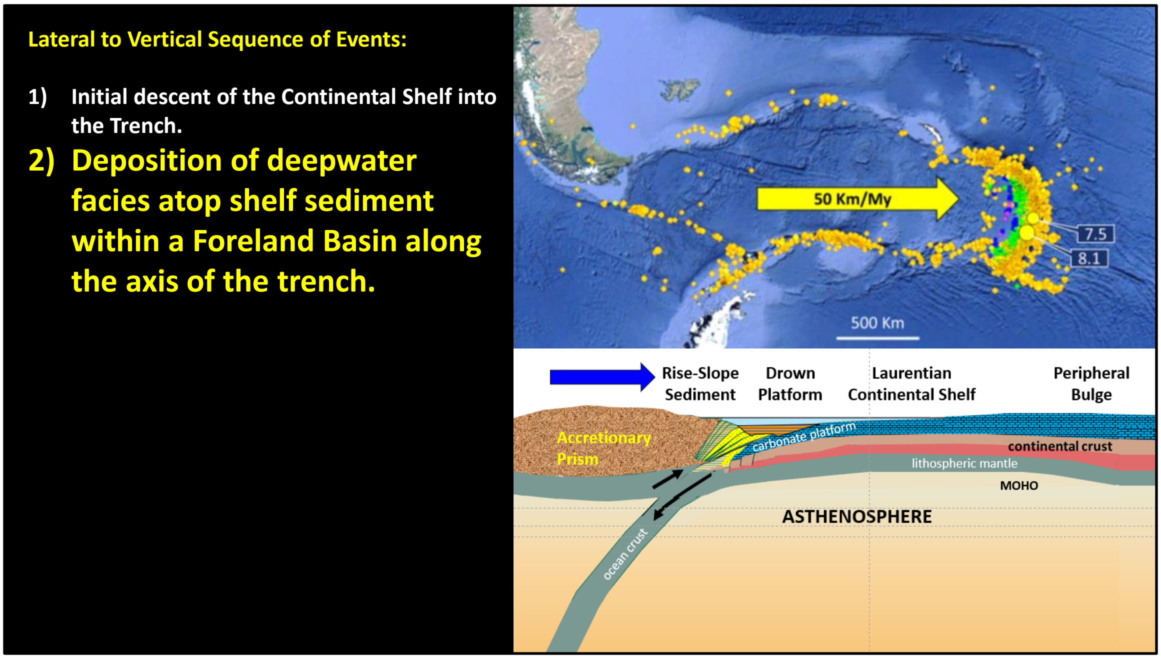


Slab Rollback creates a fully formed self-organized system that "progrades" across the plates of ocean crust, producing a "Walther's Law"-type system, where the lateral configuration reflects the vertical succession.

Lateral to Vertical Sequence of Events:

1) **Initial descent of the Continental Shelf into the Trench.**

Slab Rollback creates a fully formed self-organized system that "progrades" across the plates of ocean crust, producing a "Walther's Law"-type system, where the lateral configuration reflects the vertical succession. The Lateral to Vertical Sequence of Events is, first, the Initial descent of the Continental Shelf into the Trench.



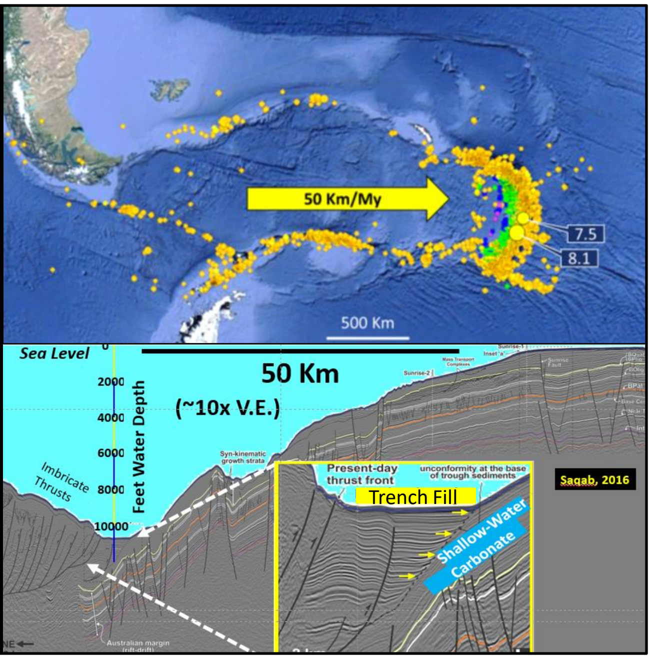
Lateral to Vertical Sequence of Events:

1) Initial descent of the Continental Shelf into the Trench.
2) **Deposition of deepwater facies atop shelf sediment within a Foreland Basin along the axis of the trench.**

Next stage is deposition of deepwater sediment atop the drown platform within a foreland basin that is actually a subduction trench.

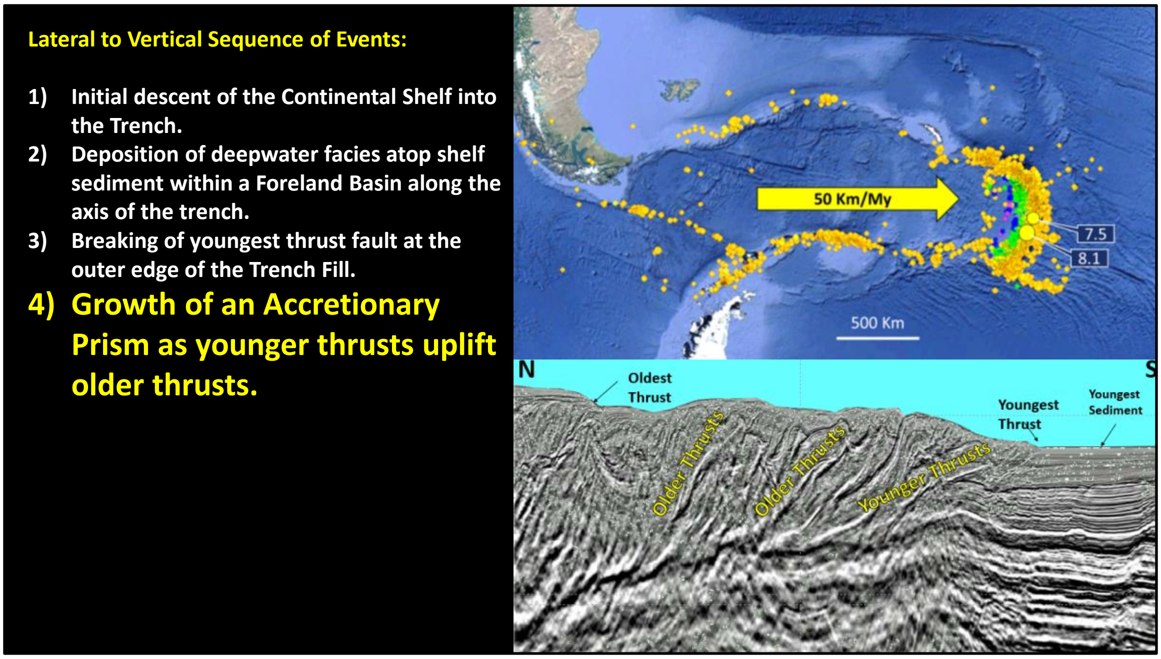
Lateral to Vertical Sequence of Events:

1) **Initial descent of the Continental Shelf into the Trench.**
2) **Deposition of deepwater facies atop shelf sediment within a Foreland Basin along the axis of the trench.**
3) **Breaking of youngest thrust fault at the outer edge of the Trench Fill.**



Saqab, 2016

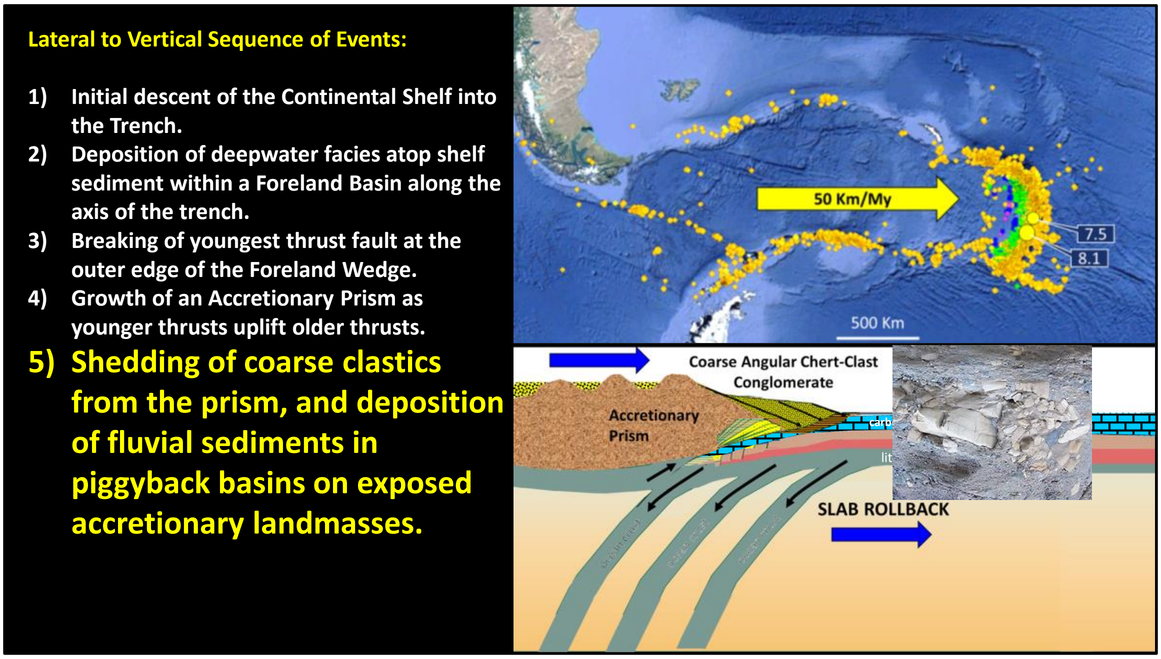
Next is breaking of the youngest thrust fault at the outer edge of the trench-fill.



Lateral to Vertical Sequence of Events:

1) Initial descent of the Continental Shelf into the Trench.
2) Deposition of deepwater facies atop shelf sediment within a Foreland Basin along the axis of the trench.
3) Breaking of youngest thrust fault at the outer edge of the Trench Fill.
4) **Growth of an Accretionary Prism as younger thrusts uplift older thrusts.**

This is followed by growth of an Accretiionary Prism as younger thrusts uplift older thrusts.



Lateral to Vertical Sequence of Events:

1) Initial descent of the Continental Shelf into the Trench.
2) Deposition of deepwater facies atop shelf sediment within a Foreland Basin along the axis of the trench.
3) Breaking of youngest thrust fault at the outer edge of the Foreland Wedge.
4) Growth of an Accretionary Prism as younger thrusts uplift older thrusts.
5) **Shedding of coarse clastics from the prism, and deposition of fluvial sediments in piggyback basins on exposed accretionary landmasses.**

The final phase involves shedding coarse clastics from the accretionary prism and deposition of fluvial sediments in piggyback basins atop the exposed accretionary landmass.

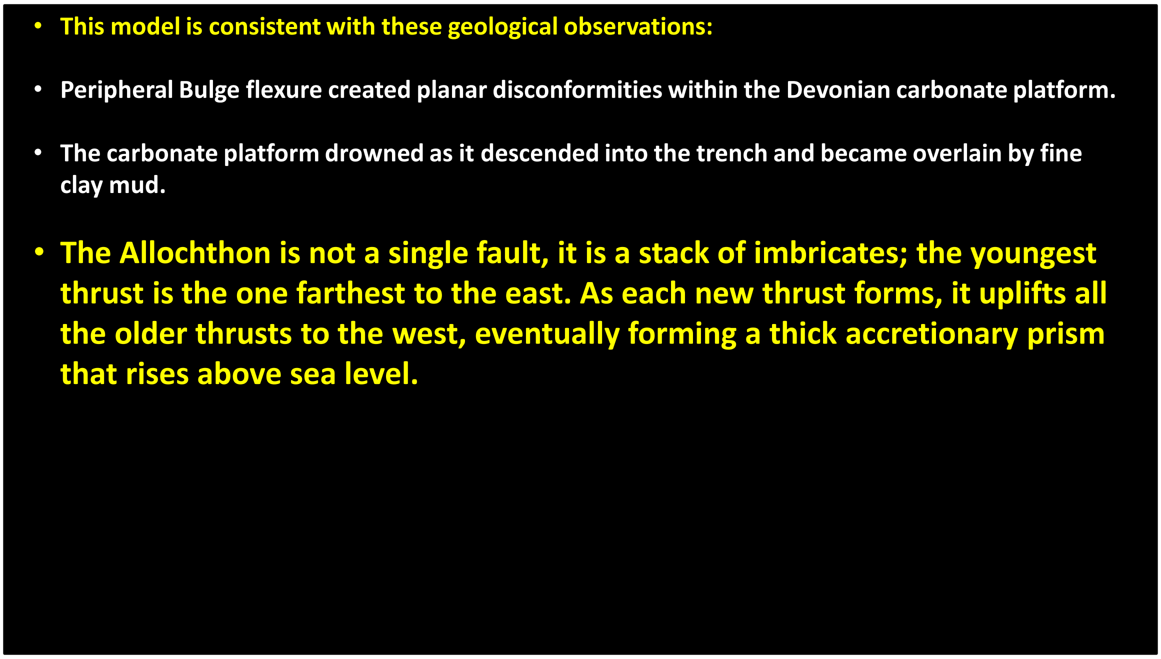
- **This model is consistent with these geological observations:**

- **Peripheral Bulge flexure created planar disconformities within the Devonian carbonate platform.**

This model is consistent with these geological observations: Peripheral Bulge flexure created planar disconformities within the Devonian Carbonate platform.

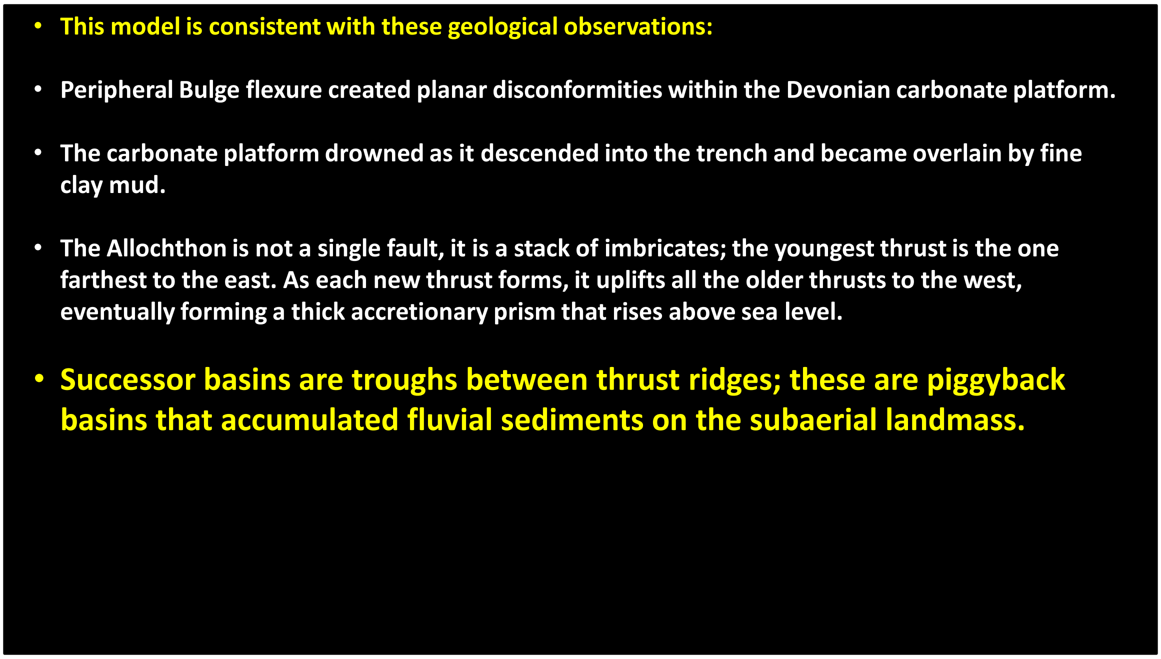
- **This model is consistent with these geological observations:**
- **Peripheral Bulge flexure created planar disconformities within the Devonian carbonate platform.**
- **The carbonate platform drowned as it descended into the trench and became overlain by fine clay mud.**

The carbonate platform became overlain by fine clay mud due to drowning as it began its descent into the trench.



- This model is consistent with these geological observations:
- Peripheral Bulge flexure created planar disconformities within the Devonian carbonate platform.
- The carbonate platform drowned as it descended into the trench and became overlain by fine clay mud.
- **The Allochthon is not a single fault, it is a stack of imbricates; the youngest thrust is the one farthest to the east. As each new thrust forms, it uplifts all the older thrusts to the west, eventually forming a thick accretionary prism that rises above sea level.**

The Allochthon is not a single fault, it is a stack of imbricates; the youngest thrust is the one farthest to the east. As each new thrust forms, it uplifts all the older thrusts to the west, eventually forming a thick accretionary prism that rises above sea level.



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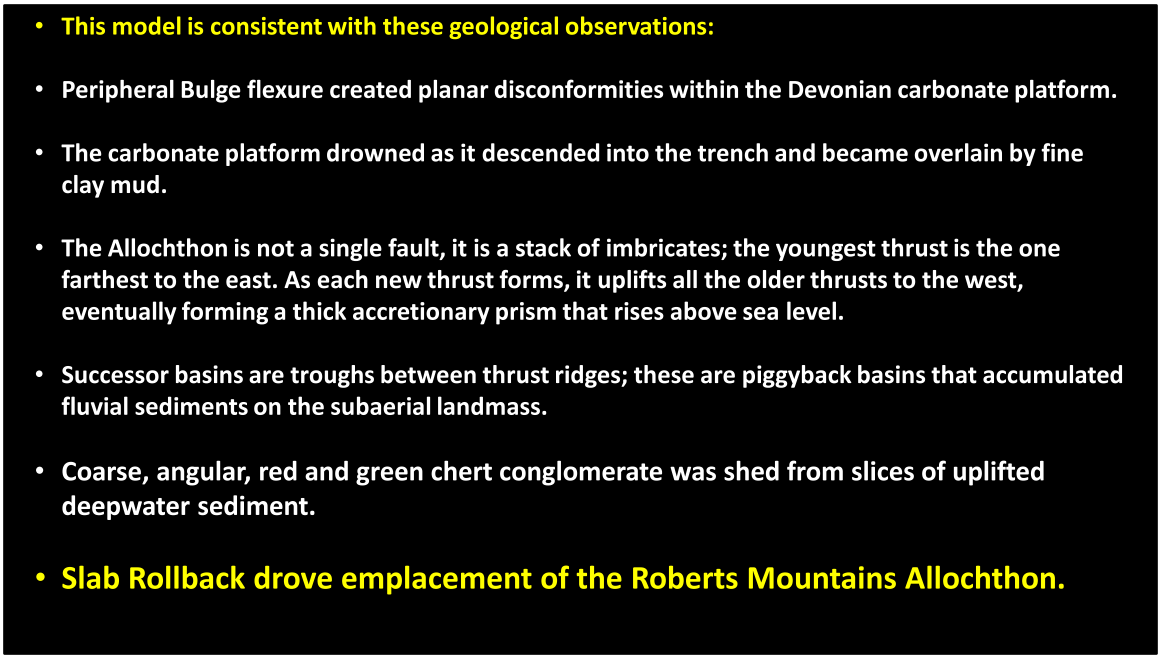
- **Coarse, angular, red and green chert conglomerate was shed from slices of uplifted deepwater sediment.**

Coarse, angular, red and green chert conglomerate was shed from slices of uplifted deepwater sediment.



- **This model is consistent with these geological observations:**
- **Peripheral Bulge flexure created planar disconformities within the Devonian carbonate platform.**
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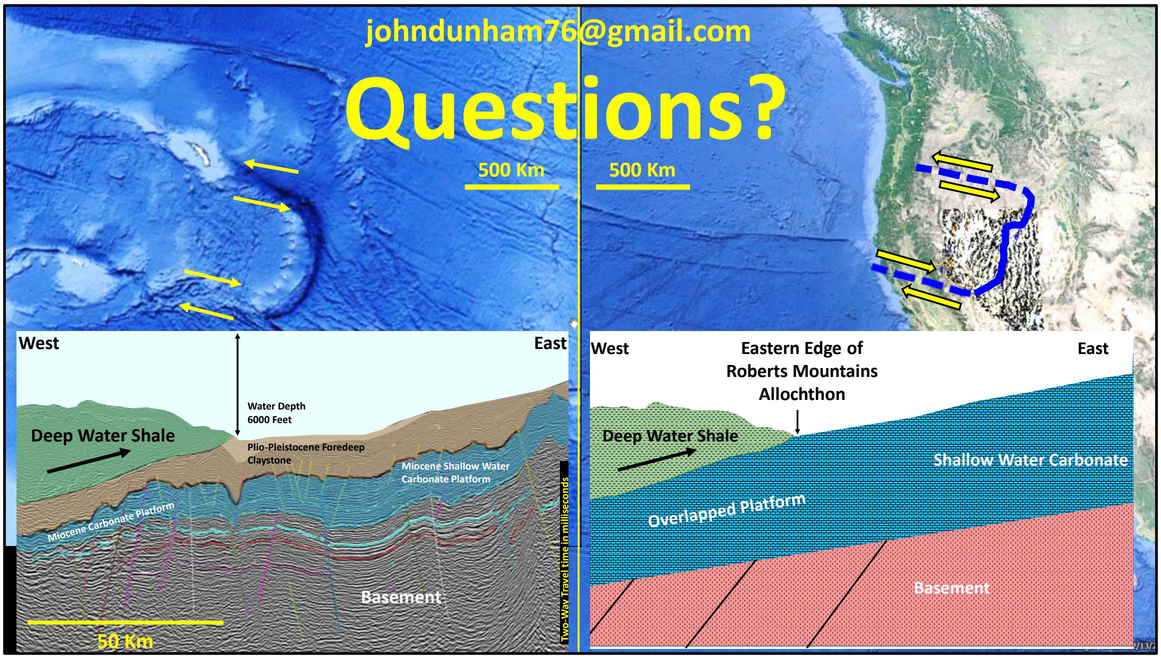
- **Successor basins are troughs between thrust ridges; these are piggyback basins that accumulated fluvial sediments on the subaerial landmass.**
- **Coarse, angular, red and green chert conglomerate was shed from slices of uplifted deepwater sediment.**
- **Slab Rollback drove emplacement of the Roberts Mountains Allochthon.**

This is the final interpretation: Slab Rollback drove the emplacement the Roberts Mountains Allochthon.



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Questions?

Are there any questions?

Download GSA24_Allochthon at:
https://Github.com/jdunham76/GSA24

johndunham76@gmail.com

You can use this link to download this presentation.

Backup Slides

As soon as I saw that seismic line, I knew that I had seen it before; here, in the Roberts Mountains. Analogs are important to geologists. The more different things you see, the more ideas you'll likely come up with. It's hard to visualize the concept of continental subduction without seeing examples of it, so I'll take you to the northwest shelf of Australia to let you see for yourselves.

Deep-sea origin of Ordovician pillow basalt and associated sedimentary rocks, northern Nevada: CHESTER T. WRUCKE, MICHAEL CHURKIN, CHRIS HEROPOULOS J, US. Geological Survey: GSA Bulletin, v. 89, p. 1272-1280

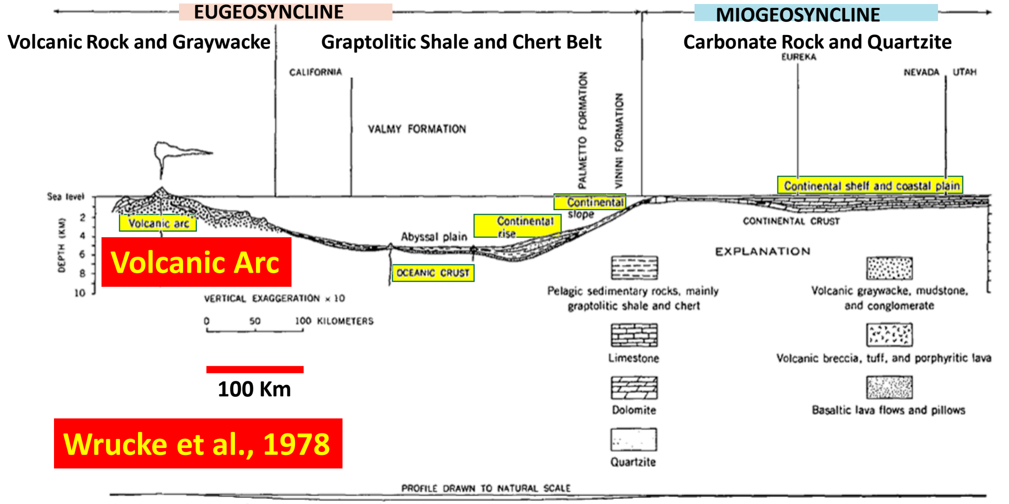
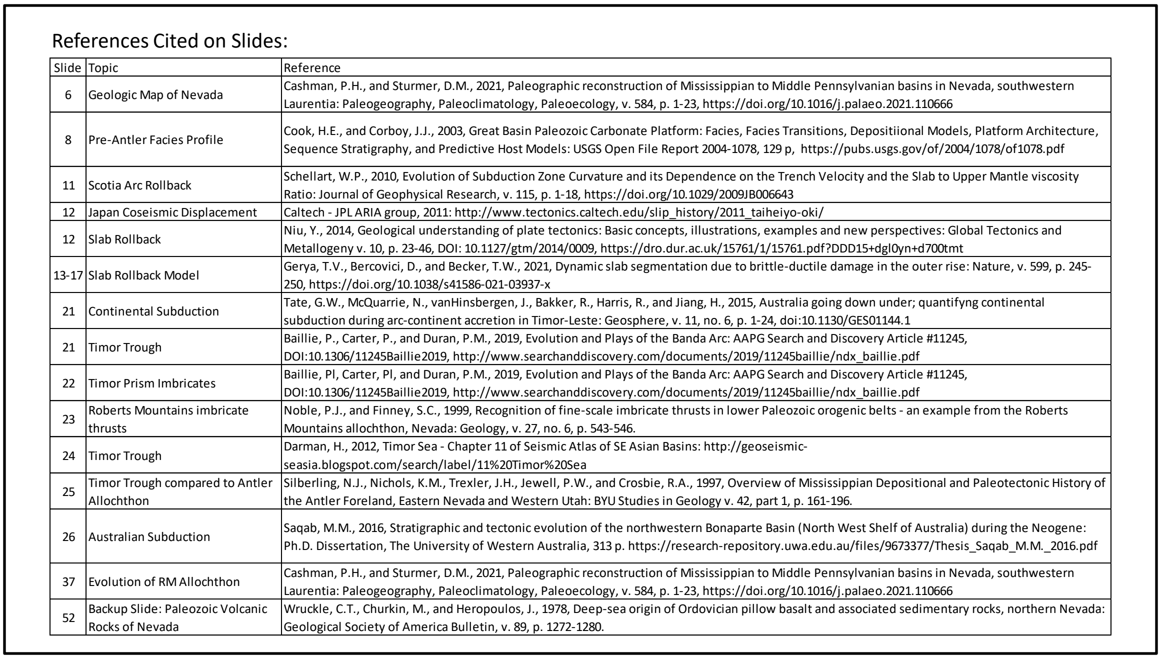


Figure 6. Cross section of western margin of North America in Late Ordovician time, showing Ordovician rocks reconstructed into tectonic-stratigraphic belts.

Paleozoic volcanic rocks are present west of the carbonate platform and accretionary prism. This prescient cross section was published in 1978 by the USGS; it has almost all the elements of this story, including the Volcanic Island Arc to the west. The only thing it lacks is a drawing of a west dipping subduction zone under the arc. It was compiled from the locations of Paleozoic volcanic rocks in Nevada and eastern California.



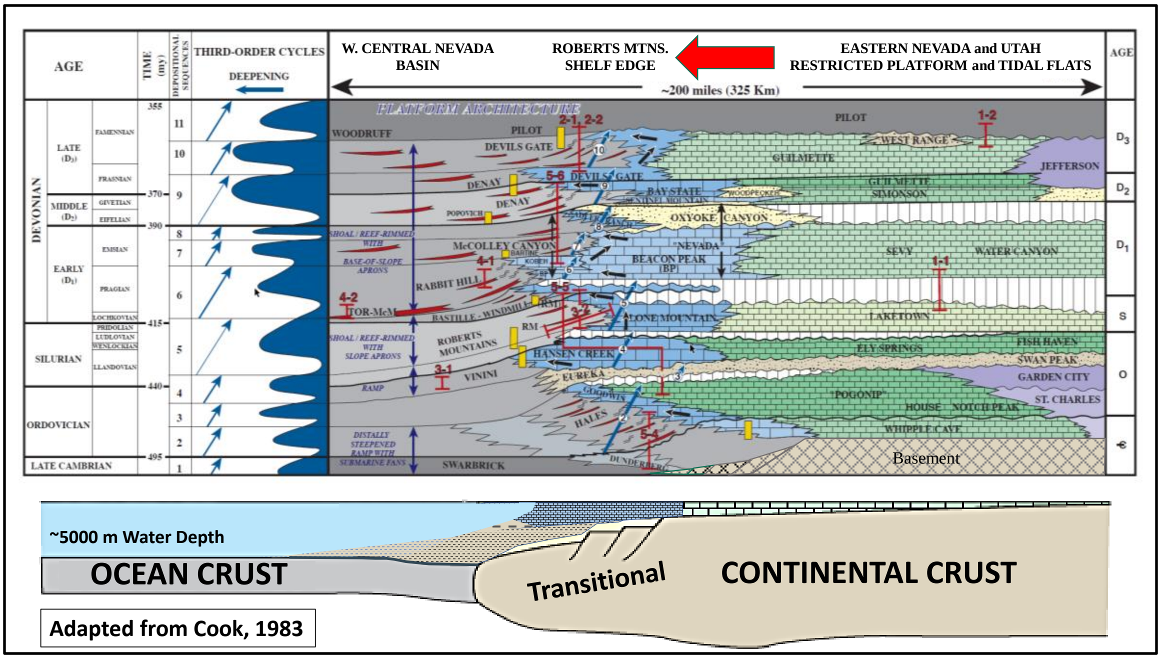
References Cited on Slides:

Slide	Topic	Reference
6	Geologic Map of Nevada	Cashman, P.H., and Sturmer, D.M., 2021, Paleographic reconstruction of Mississippian to Middle Pennsylvanian basins in Nevada, southwestern Laurentia: Paleogeography, Paleoclimatology, Paleoecology, v. 584, p. 1-23, https://doi.org/10.1016/j.palaeo.2021.110666
8	Pre-Antler Facies Profile	Cook, H.E., and Corboy, J.J., 2003, Great Basin Paleozoic Carbonate Platform: Facies, Facies Transitions, Depositiional Models, Platform Architecture, Sequence Stratigraphy, and Predictive Host Models: USGS Open File Report 2004-1078, 129 p, https://pubs.usgs.gov/of/2004/1078/of1078.pdf
11	Scotia Arc Rollback	Schellart, W.P., 2010, Evolution of Subduction Zone Curvature and its Dependence on the Trench Velocity and the Slab to Upper Mantle viscosity Ratio: Journal of Geophysical Research, v. 115, p. 1-18, https://doi.org/10.1029/2009JB006643
12	Japan Coseismic Displacement	Caltech - JPL ARIA group, 2011: http://www.tectonics.caltech.edu/slip_history/2011_taiheiyo-oki/
12	Slab Rollback	Niu, Y., 2014, Geological understanding of plate tectonics: Basic concepts, illustrations, examples and new perspectives: Global Tectonics and Metallogeny v. 10, p. 23-46, DOI: 10.1127/gtm/2014/0009, https://dro.dur.ac.uk/15761/1/15761.pdf?DDD15+dgl0yn+d700tmt
13-17	Slab Rollback Model	Gerya, T.V., Bercovici, D., and Becker, T.W., 2021, Dynamic slab segmentation due to brittle-ductile damage in the outer rise: Nature, v. 599, p. 245-250, https://doi.org/10.1038/s41586-021-03937-x
21	Continental Subduction	Tate, G.W., McQuarrie, N., vanHinsbergen, J., Bakker, R., Harris, R., and Jiang, H., 2015, Australia going down under; quantifyng continental subduction during arc-continent accretion in Timor-Leste: Geosphere, v. 11, no. 6, p. 1-24, doi:10.1130/GES01144.1
21	Timor Trough	Baillie, P., Carter, P., and Duran, P.M., 2019, Evolution and Plays of the Banda Arc: AAPG Search and Discovery Article #11245, DOI:10.1306/11245Baillie2019, http://www.searchanddiscovery.com/documents/2019/11245baillie/ndx_baillie.pdf
22	Timor Prism Imbricates	Baillie, Pl, Carter, Pl, and Duran, P.M., 2019, Evolution and Plays of the Banda Arc: AAPG Search and Discovery Article #11245, DOI:10.1306/11245Baillie2019, http://www.searchanddiscovery.com/documents/2019/11245baillie/ndx_baillie.pdf
23	Roberts Mountains imbricate thrusts	Noble, P.J., and Finney, S.C., 1999, Recognition of fine-scale imbricate thrusts in lower Paleozoic orogenic belts - an example from the Roberts Mountains allochthon, Nevada: Geology, v. 27, no. 6, p. 543-546.
24	Timor Trough	Darman, H., 2012, Timor Sea - Chapter 11 of Seismic Atlas of SE Asian Basins: http://geoseismic-seasia.blogspot.com/search/label/11%20Timor%20Sea
25	Timor Trough compared to Antler Allochthon	Silberling, N.J., Nichols, K.M., Trexler, J.H., Jewell, P.W., and Crosbie, R.A., 1997, Overview of Mississippian Depositional and Paleotectonic History of the Antler Foreland, Eastern Nevada and Western Utah: BYU Studies in Geology v. 42, part 1, p. 161-196.
26	Australian Subduction	Saqab, M.M., 2016, Stratigraphic and tectonic evolution of the northwestern Bonaparte Basin (North West Shelf of Australia) during the Neogene: Ph.D. Dissertation, The University of Western Australia, 313 p. https://research-repository.uwa.edu.au/files/9673377/Thesis_Saqab_M.M._2016.pdf
37	Evolution of RM Allochthon	Cashman, P.H., and Sturmer, D.M., 2021, Paleographic reconstruction of Mississippian to Middle Pennsylvanian basins in Nevada, southwestern Laurentia: Paleogeography, Paleoclimatology, Paleoecology, v. 584, p. 1-23, https://doi.org/10.1016/j.palaeo.2021.110666
52	Backup Slide: Paleozoic Volcanic Rocks of Nevada	Wruckle, C.T., Churkin, M., and Heropoulos, J., 1978, Deep-sea origin of Ordovician pillow basalt and associated sedimentary rocks, northern Nevada: Geological Society of America Bulletin, v. 89, p. 1272-1280.

References listed above

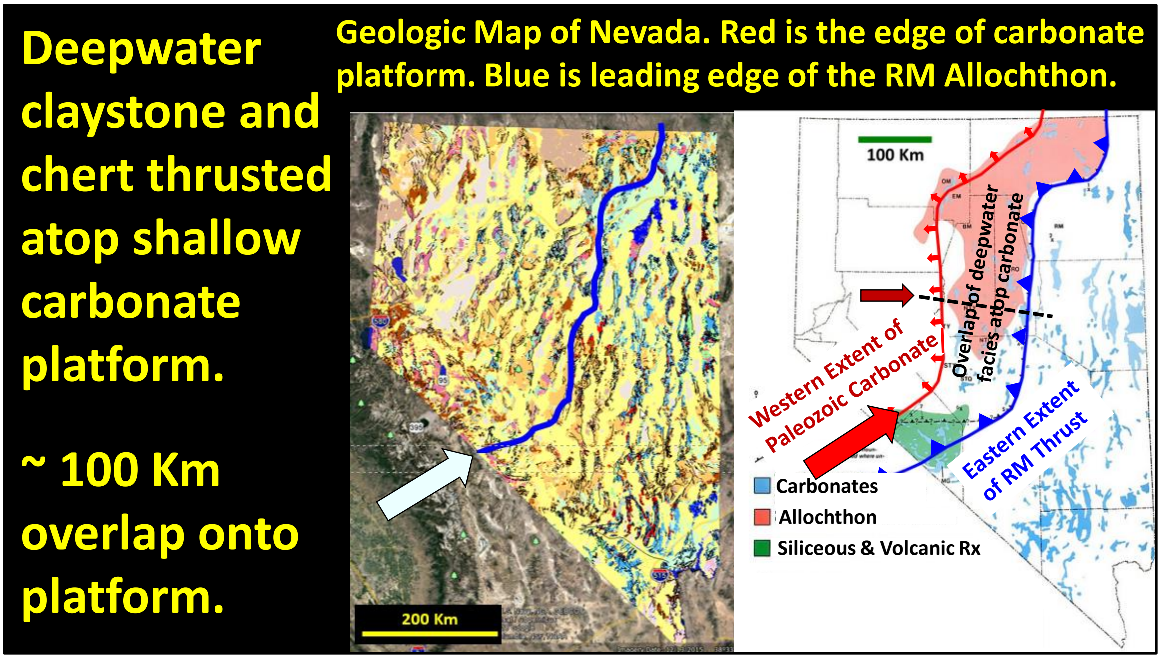
Old normal faults and transform faults flanking mid-ocean ridges are weak areas that could make a first break.

What causes the lithosphere to break? Old normal faults flanking ocean ridges are likely weak points; old transform faults form the edges of the subducting slab.



Adapted from Cook, 1983

Subduction stopped when full-thickness continental crust could no longer be consumed by the trench. The edge of the allochthon parallels the inner edge of transitional crust.

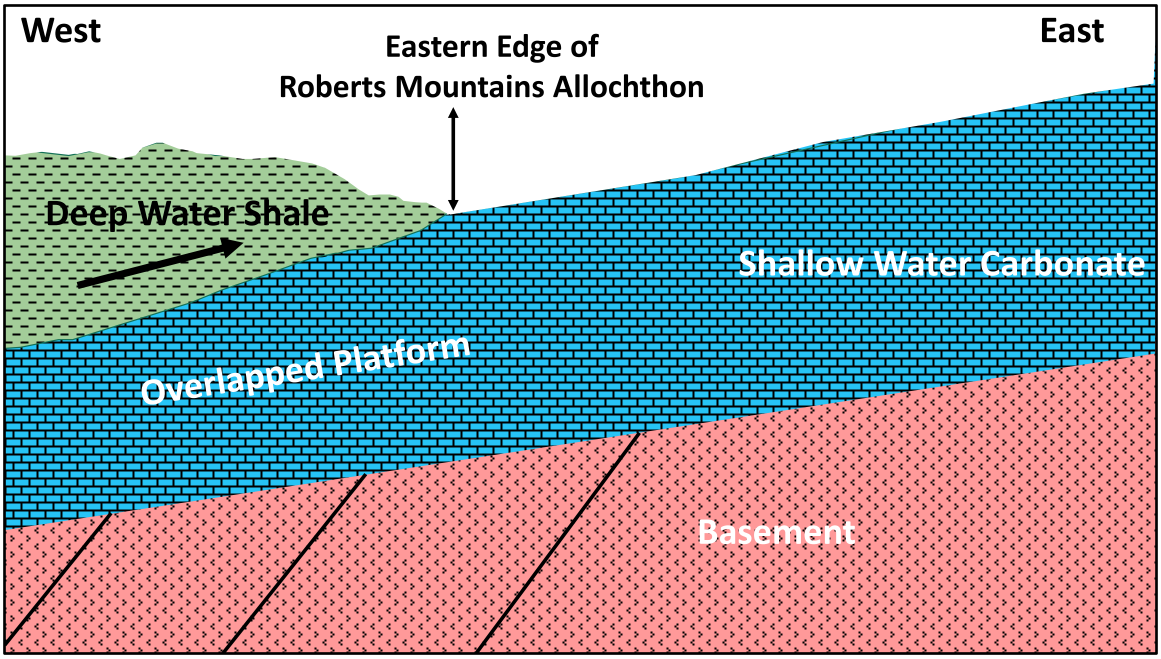


Deepwater claystone and chert thrusted atop shallow carbonate platform.

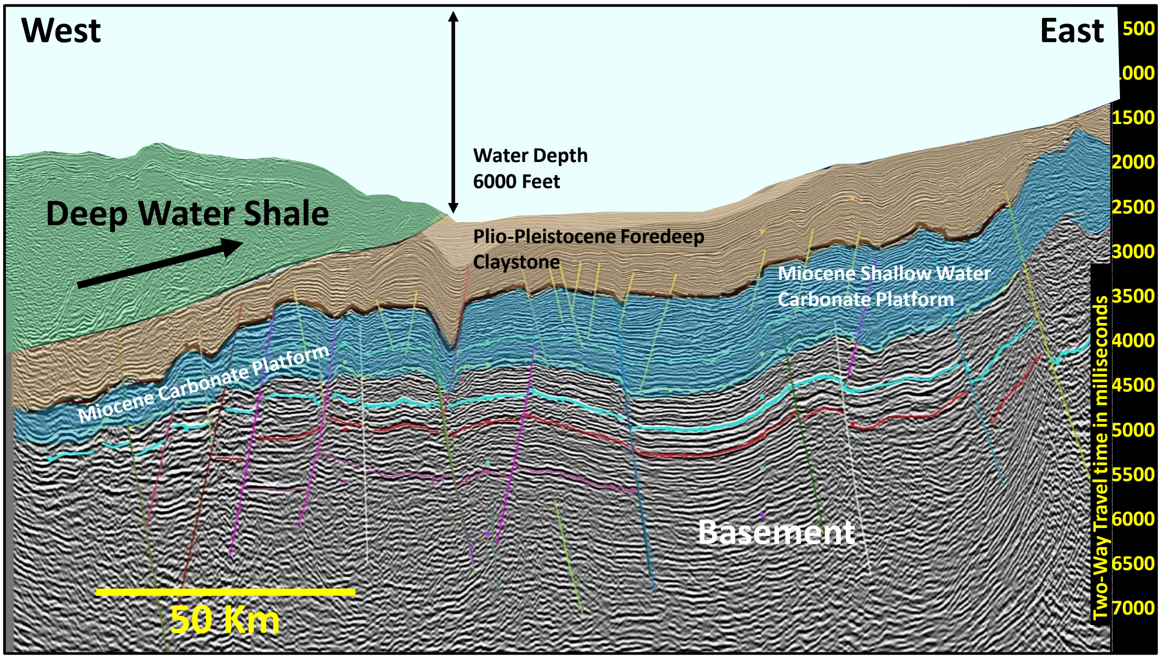
~ 100 Km overlap onto platform.

Geologic Map of Nevada. Red is the edge of carbonate platform. Blue is leading edge of the RM Allochthon.

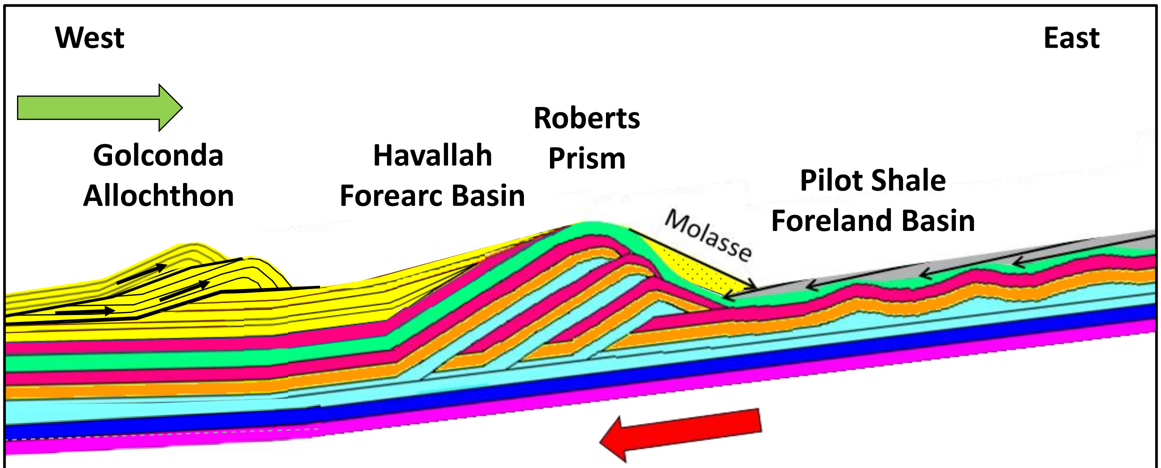
A cross section across the overlap might look like this slide:



Deepwater shale has been obducted up on top of the shallow water carbonate platform.



That's why when I looked at this seismic line, I thought it might be like something I had seen before.



Tens of millions years of "India-Style" momentum deforms the Havallah basin and induces breakage of younger east-verging thrust faults.