Preliminary Sequence Stratigraphic Framework for a Mississippian Madison Group Shelf Margin, South Boulder Canyon, Southwest Montana*

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Search and Discovery Article #51555 (2019)**
Posted February 25, 2019

*Adapted from oral presentation given at 2018 AAPG Annual Convention & Exhibition, Salt Lake City, Utah, May 20-23, 2018
 DOI:10.1306/51555Gilhooly2019

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Abstract

A well exposed, near depositional-dip oriented Madison Group outcrop was studied at South Boulder Canyon in southwest Montana. These strata were deposited on the south flank of the central Montana trough and are placed into a sequence stratigraphic framework for the first time. The outcrop, nearly 300 meters thick, comprises moderately well-exposed Lodgepole Formation calcareous shales and argillaceous limestone, which grades upward into more resistant Mission Canyon Formation limestones. Thin, recessive-weathering beds of Late Mississippian - Early Pennsylvanian Amsden Formation cap the exposure.

Two complete and several partial Madison Group sections were measured, with bedding surfaces walked laterally and traced onto photopans. A series of polished outcrop slabs and thin sections aided in facies descriptions.

The Madison Group at South Boulder Canyon is interpreted in the context of Sonnenfeld's (1996) regional Mississippian sequence stratigraphic framework. This defined the Madison and related strata as six third-order depositional sequences within a second-order sequence. Parts of four of these third-order sequences are recognized at this outcrop, with bounding surfaces and internal facies architecture described for each. Individual sequences comprise lithofacies representing carbonate platform top, slope and basinal environments and range from less than 75 to over 100 meters in thickness. Proportions of platform top, slope, and basinal lithofacies between third order sequences varies relative to position within the second-order sequence. These sequences identified in outcrop were correlated to the adjacent subsurface and related to a relative sea level curve modified from Sonnenfeld (1996). Both long- and short-term sea level fluctuations are important in determining the relationship between accommodation space and sediment supply. The interplay of these factors influenced the change in Madison Group deposition, from ramp (Sequences 1 and 2) to flat-topped platform (Sequences 3 to 6).

Recognizing the facies architecture and offset within higher order sequences in outcrop provides important insights into the distribution of reservoir and non-reservoir lithologies at the oilfield scale. Our characterization of third order sequences from outcrop and subsurface in southwest Montana supports the regional Mississippian sequence stratigraphy of Sonnenfeld (1996).

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Husky Energy

PRELIMINARY SEQUENCE STRATIGRAPHIC FRAMEWORK FOR A MISSISSIPPIAN MADISON GROUP SHELF MARGIN, SOUTH BOULDER CANYON, SOUTHWEST MONTANA

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AAPG ANNUAL CONVENTION AND EXHIBITION, SALT LAKE CITY, UTAH; MAY 20-23 2018

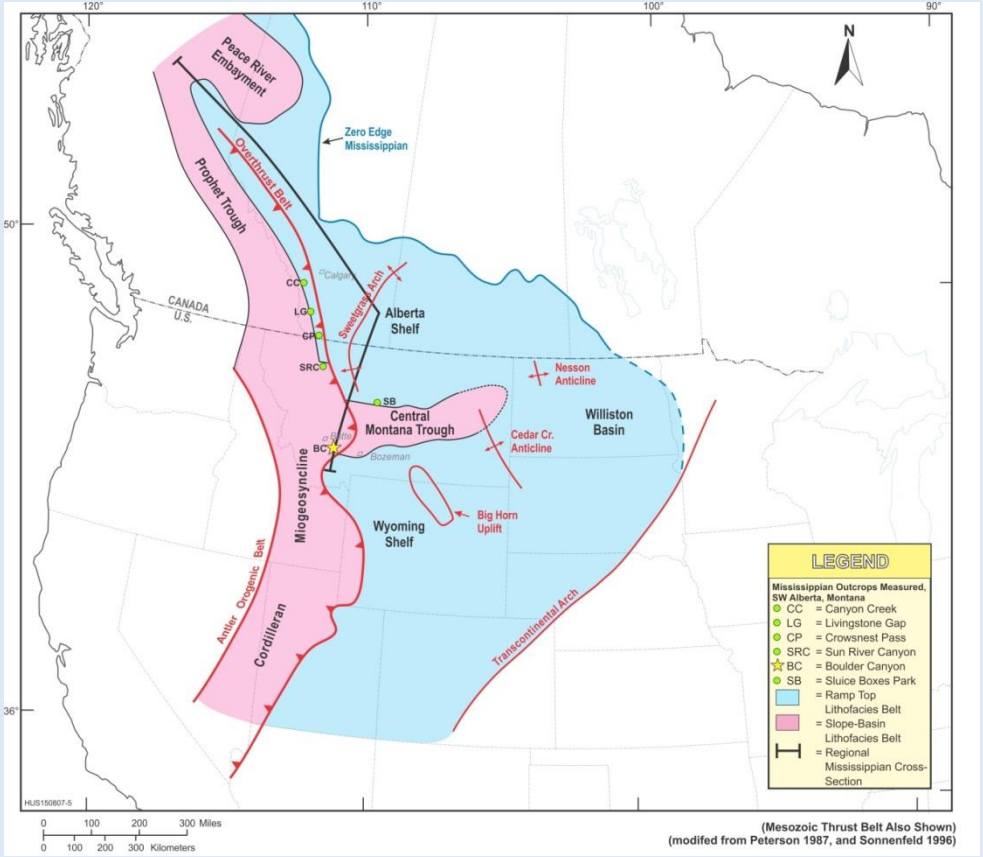
CONCLUSIONS

- Boulder Canyon outcrop displays development-scale exposure of reservoir, seal and baffle lithologies
- Reservoir continuity controlled by third-order stratigraphic architecture
- Targetting best reservoir zones requires understanding of second and third-order sequence architecture
- Seismic-scale geometries define margin location, not location of best reservoir

OUTLINE

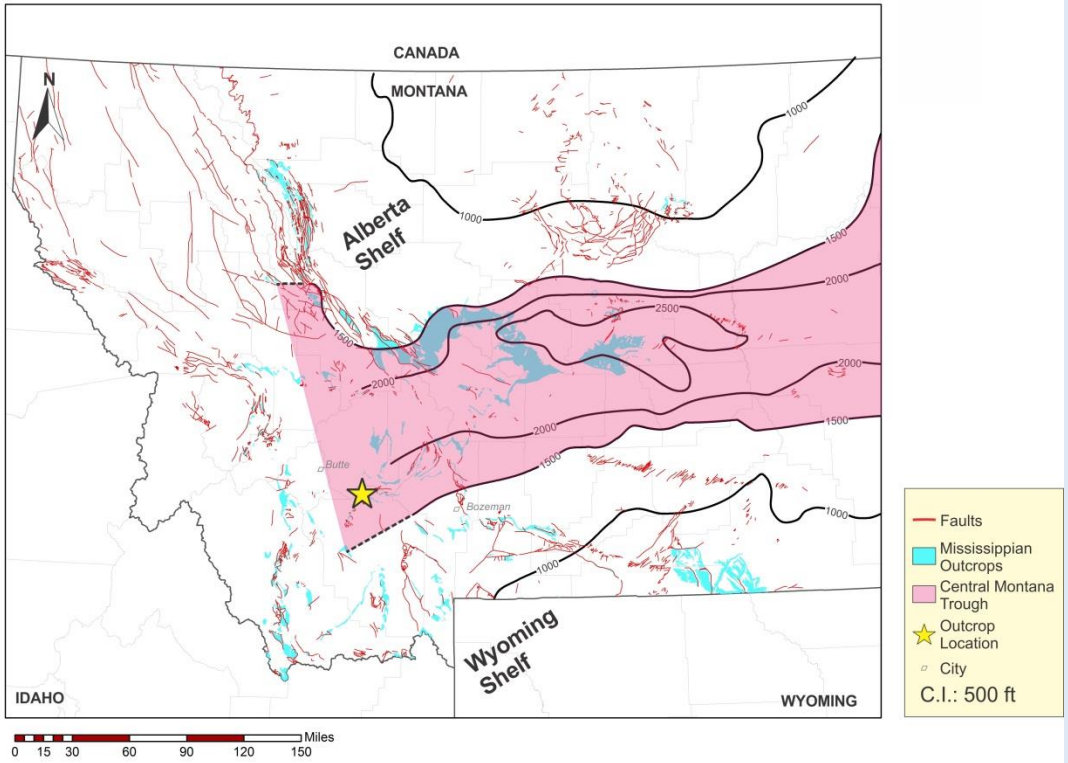
1. Regional paleogeography, Mississippian of Western North America
2. Paleogeographic setting of the study area, Southwest Montana
3. Regional sequence stratigraphy
4. Facies model
5. South Boulder Platform margin, stratigraphic architecture and evolution
6. So what? Spatial distribution of potential reservoir zones
7. Conclusions
8. Acknowledgements

REGIONAL MISSISSIPPIAN SETTING



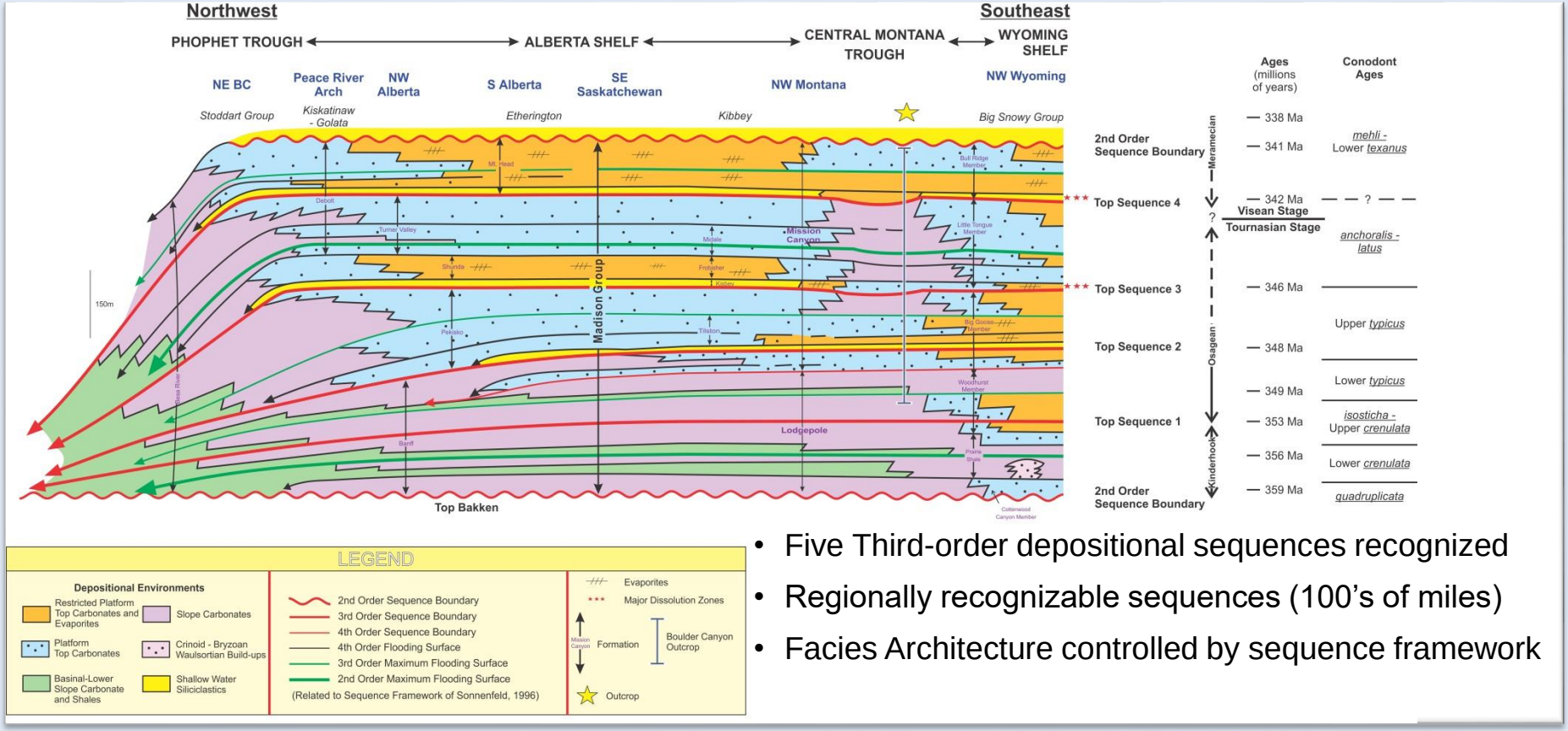
- Broad carbonate shelf with two major embayments
- Western margin faces into Paleo-Pacific ocean
- Undertook field work in six areas of Mississippian outcrops
- South Boulder Canyon the only known platform margin

MISSISSIPPIAN PALEOGEOGRAPHY, SOUTHWEST MONTANA



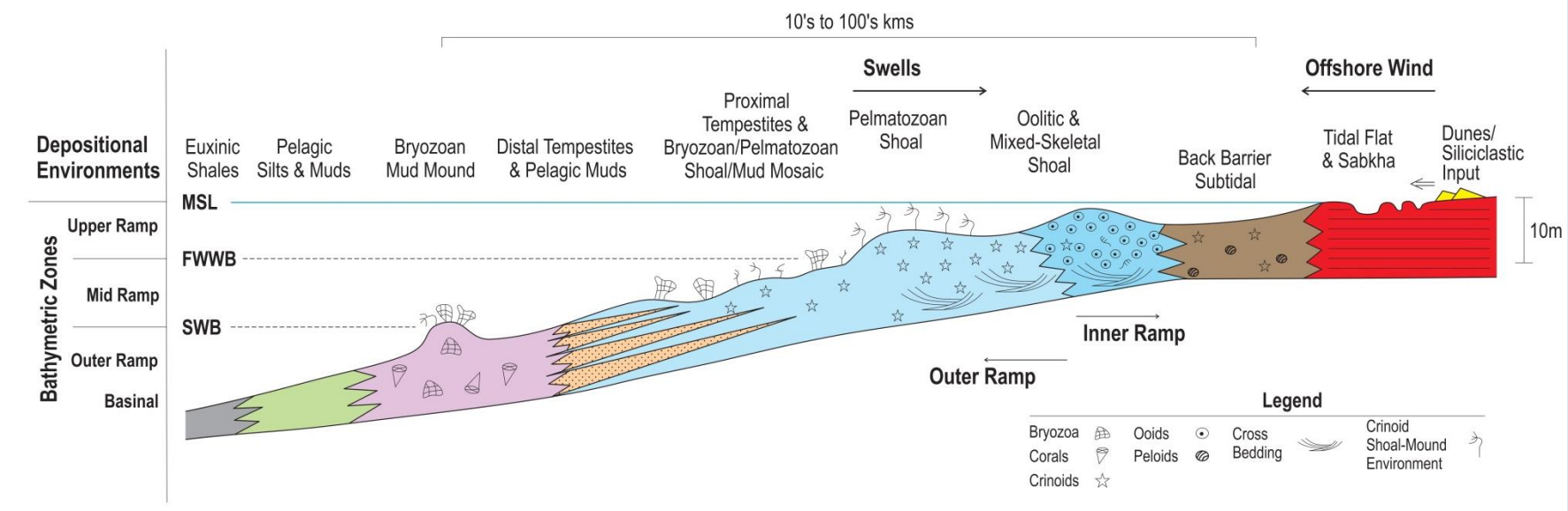
- South Boulder margin faces north into Central Montana Trough (CMT)
- Locally identified in previous regional geology compilations (eg. Rose 1976)
- Axis of CMT outlined by Mississippian isopach >1500 ft (modified from Maughan 1993)
- Marine conditions extended from the Paleo-Pacific east toward the Williston Basin with CMT
- Faults and Mississippian outcrops from Montana Bureau of Mines and Geology, Montana Geologic Maps, 2018
  http://www.mbmg.mtech.edu/storymaps/GeologicMaps.html
- South Boulder Canyon the only known CMT platform margin outcrop

REGIONAL MISSISSIPPIAN CROSS-SECTION



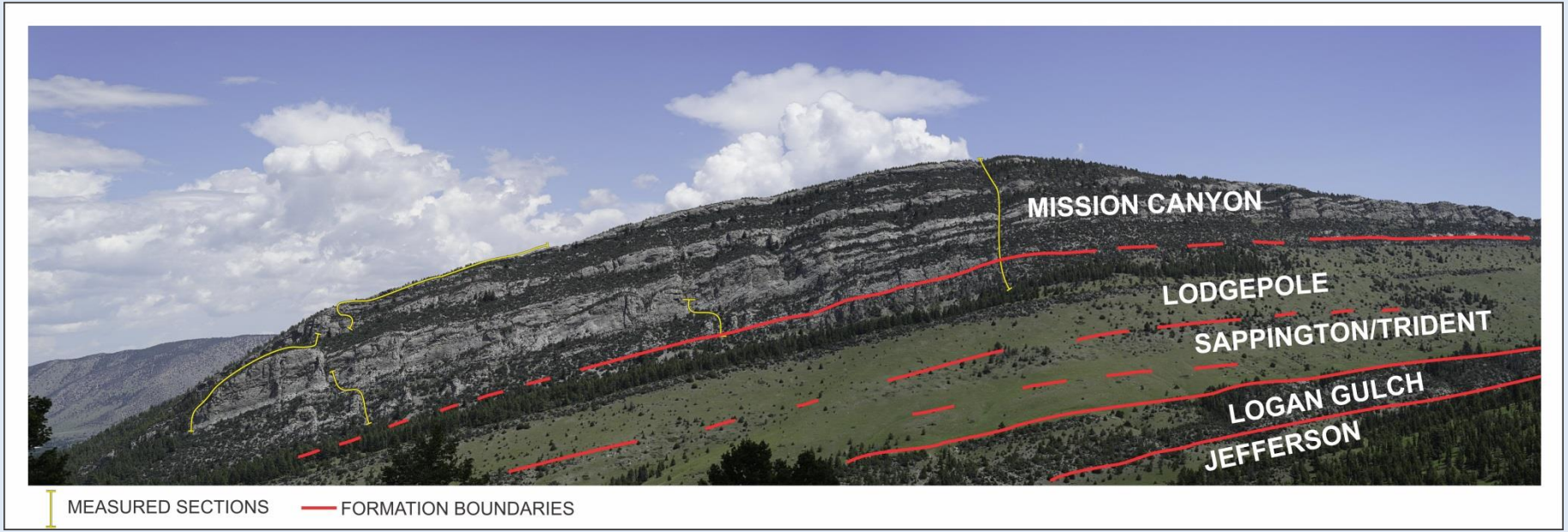
- Five Third-order depositional sequences recognized
- Regionally recognizable sequences (100's of miles)
- Facies Architecture controlled by sequence framework

MISSISSIPPIAN FACIES MODEL



- Dominantly a carbonate ramp system
- Major faunal elements: Pelmatozoans, Bryozoa, Rugose, Corals
- Minor oolitic component
- All these environments present at South Boulder Creek

BOULDER CANYON MONTANA: OVERVIEW FROM SOUTHWEST SHOWING FORMATIONS AND MEASURED SECTIONS

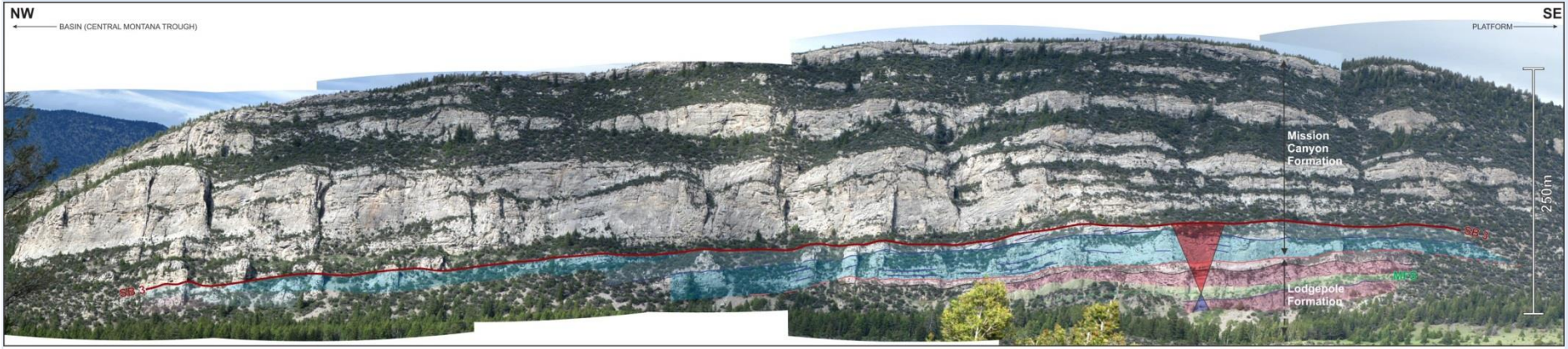


- Structural panel carries continuous, gently-dipping Paleozoic section
- Measured two complete, two partial Lodgepole-Mission Canyon sections
- “Seismic scale” outcrops displays third/fourth- order stratigraphic geometries

OVERVIEW, LODGEPOLE/MISSION CANYON SUCCESSION

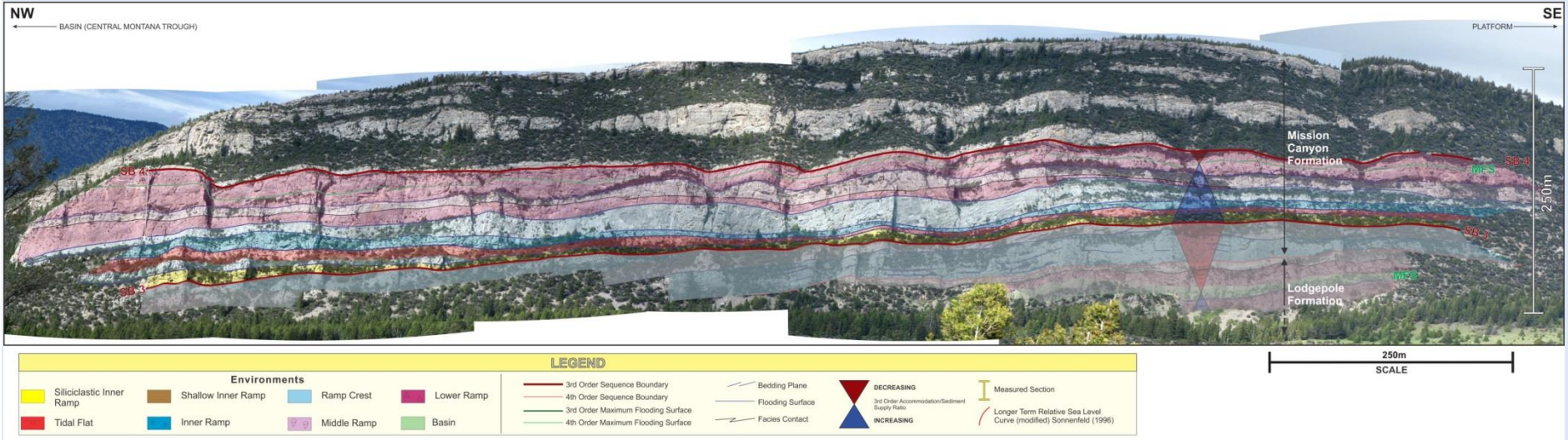
- North-facing platform margin displays impressive stratigraphic geometries
- Preserves Sonnenfeld (1996) sequences II-V
- Overall (second-order) progradational margin geometry with significant (third-order) variability

MISSISSIPPIAN SEQUENCE II



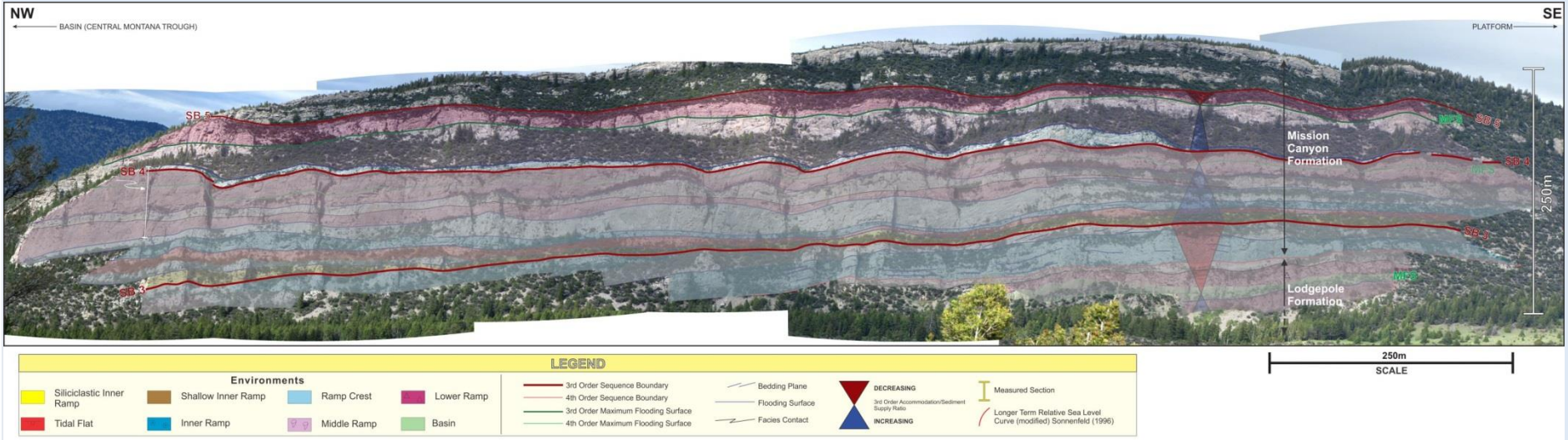
- Shoaling from Basin/Lower Ramp (Lodgepole) to Ramp Crest (Mission Canyon)
- Latest HST strongly progradational (subtly off-lapping)
- Overall low-angle depositional profile

MISSISSIPPIAN SEQUENCE III



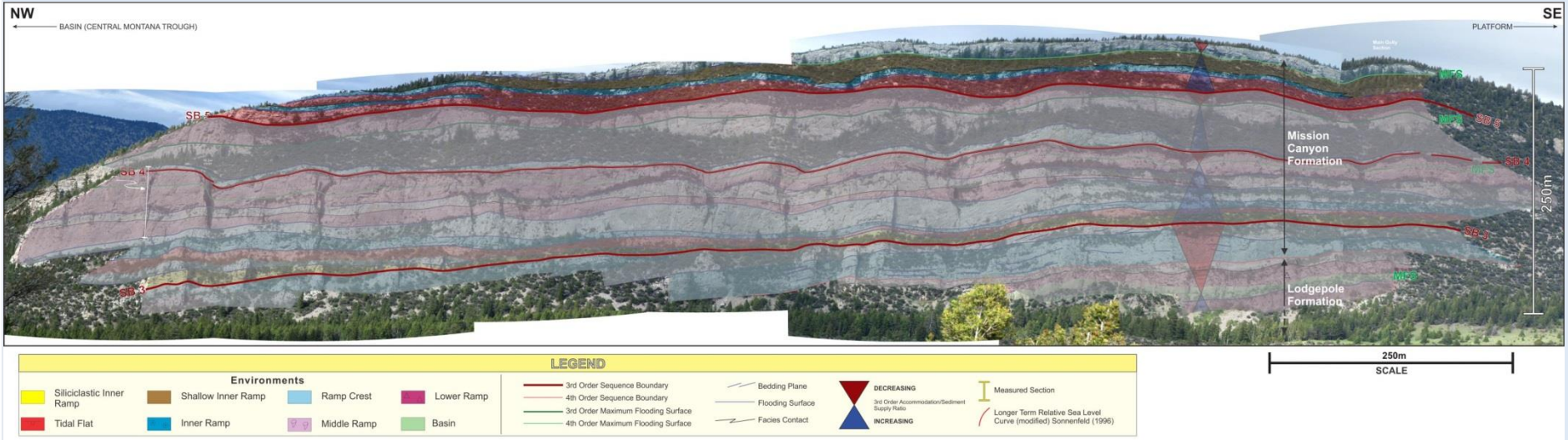
- Basal sequence boundary preserves reworked siliciclastics
- Early TST is broad aggradational ramp
- TST/ early HST dominantly mid-lower ramp, wedge-like geometry not an insitu Lowstand
- Poorly developed late HST

MISSISSIPPIAN SEQUENCE IV



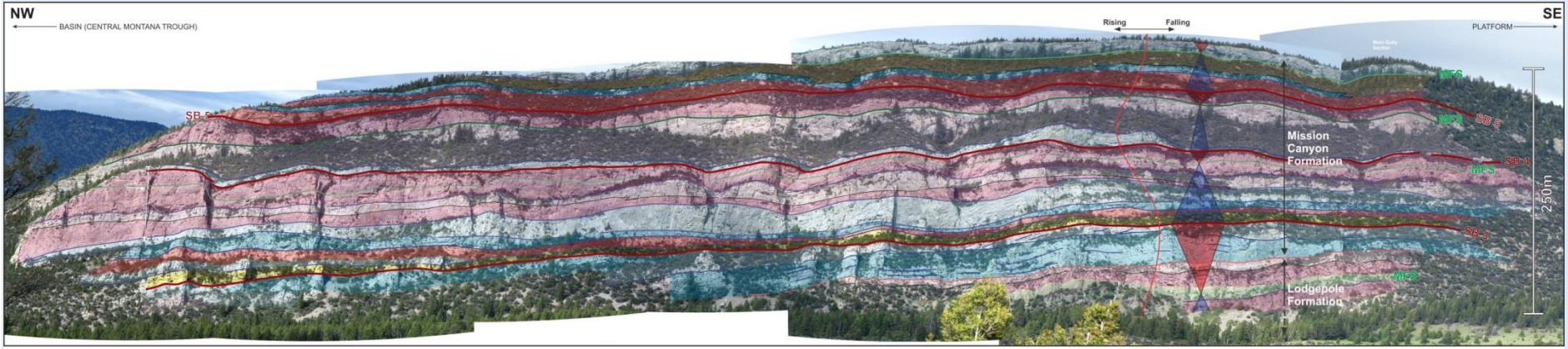
- Poorly developed ramp margin developed above sequence boundary
- Remainder of sequence dominantly transgressive showing influence of second order TST
- Poorly developed HST

MISSISSIPPIAN SEQUENCE V



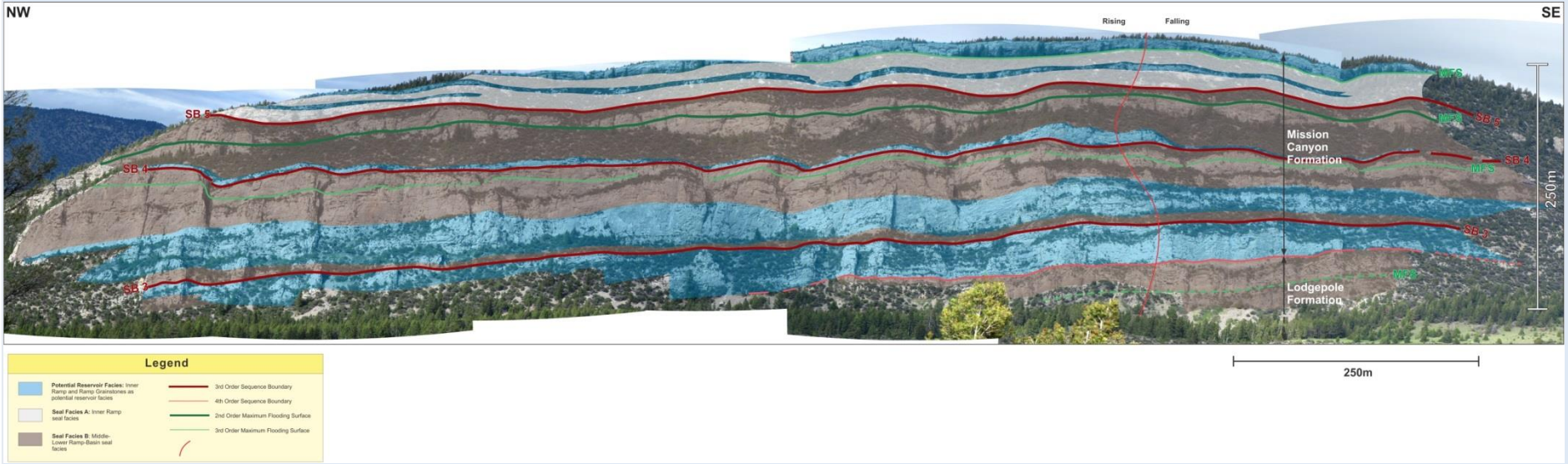
- Symmetrical stratigraphic architecture
- Well-developed Tidal Flat complex above sequence boundary
- HST a relatively thin Ramp Crest skeletal shoal

THIRD ORDER STRATIGRAPHIC ARCHITECTURE



- Overall aggradational appearance masks major transgression in Mississippian III and IV
- Relatively thin Ramp Margins and Inner Ramp generated large volumes of carbonate mud
- Stratigraphic geometries related to sea level change but not always what they seem

OVERVIEW, LODGEPOLE/MISSION CANYON SUCCESSION



- Ramp Crest and Inner Ramp Grainstones best potential reservoirs
- Major Shoal complexes in the Mississippian II and III separated by likely low-permeability baffle
- Mississippian IV and V reservoirs quite thin, spatially isolated
- Seismic stratigraphy may not have found main reservoir

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ACKNOWLEDGEMENTS

- Husky Energy for permission to present
- Jennifer Tuomi for drafting figures
- George Grader (University of Idaho) and Ted Doughty (Prisem Geoconsulting) for introducing the outcrop and assisting with field work
- Field Assistants Candace Brintnell, Clarke Campbell, Tim Gilbertson, Ryan Younkers