TECTONIC DEVELOPMENT OF THE MORONGO VALLEY BLOCK IN SOUTHERN CALIFORNIA—IMPLICATIONS FOR LATE QUATERNARY INTERACTIONS BETWEEN THE WESTERN PINTO MOUNTAIN FAULT ZONE AND THE SAN ANDREAS FAULT ZONE

Lecture Notes

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Slide 1: TITLE PAGE

- Good afternoon!
- In this presentation I present my current thoughts about the tectonic evolution of the Morongo Valley Block of the western Pinto Mountain fault zone.
- This model is a work-in-progress and subject to revision as necessary.

Slide 2: OUTLINE

1) We propose a model for the Morongo Valley Block that adds to and complements the work of the Kendrick et al. (2022) model
2) Summarize the regional tectonic setting.
3) Define the Morongo Valley Block.
4) Arm wave about how the San Andreas Fault Zone affected the orientation of the propagating Pinto Mtn fault zone.
5) Discuss the timing of Morongo Valley transtension.
6) Present a series of slides that shows the tectonic evolution of the Morongo Valley Block.

Slide 3: METHODS

- Interpretation of geologic maps and aerial imagery.
- Utilized faults from the USGS Quaternary fault and fold database as template for the model.
- Geologic mapping conducted by Hopson (1996), Gabriel (2017), and McNeil (2018).
- Infrared stimulated luminescence (IRSL) dating cited from Kendrick et al. (2015) and McNeil (2018). Carbon-14 dating by McNeil.
- ^{10}Be cosmogenic nuclide age dating cited from Gabriel (2017).

Slide 4: REGIONAL TECTONIC SETTING

- Figure illustrates regional tectonic setting
- Morongo Valley Block forms the western part of the PMFZ—shown in red—and located in the southern Mojave Block
- Mojave Block bound by San Andreas Fault Zone, Garlock Fault, and Soda-Avawatz-Granite-Bristol Mountains Fault System
- PMFZ is a sinistral fault within the Eastern California Shear Zone shown by the beige overlay.

Slide 4: REGIONAL TECTONIC SETTING
Continued

- N-S compression of the Mojave Block is undergoing forcing it to expand and move in an east-southeast direction.
- Red arrows show maximum and minimum stress axes (σ1 and σ3 respectively).
- Green arrows show approximate direction of Mojave crust transport relative to Coachella segment of SAFZ.
- Dark green half arrows show fault slip sense.

Slide 5: PINTO MOUNTAIN AND SAN ANDREAS FAULT ZONES

- The PMFZ extends from the San Andreas fault zone in an arcuate trace along the base of the Pinto Mountains for approximately 85 km.
- Morongo Valley Block shown in blue
- The PMFZ joins the what has been known as the Mission Creek Strand of the SAFZ at a complex multi-strand section at a 15–20-km-wide left-stepping restraining bend dominated by dextral, sinistral, and transpressive faulting.
- Here the SAFZ consists of six subparallel dextral strands that developed to bypass this left step.

Slide 5: PINTO MOUNTAIN AND SAN ANDREAS FAULT ZONES *Continued*

- Complicating this picture is the southern MiCS and MCS overlap.
- We will only be concerned with Mission Creek and Mill Creek strands of SAFZ because they are the only two strands that played any significant role interacting with the PMFZ.
- This combination of dextral, sinistral, and transpressive faulting created what has come to be known as the San Gorgonio structural knot by Jon Matti and several of his colleagues and which contributed to the uplift of the San Bernardino Mountains along east-west-trending thrust faults of the San Gorgonio Pass fault zone.

Slide 6: MORONGO VALLEY BLOCK

- Here is the MVB
- Showing locations of the communities of MV and YV.
- Morongo Valley, a transtensional basin in yellow
- The MVB is defined by
    - Two strands: northern strand PMF (Tom Dibblee) and southern strand MVF (Richard Proctor), which we are calling BMS and MVS.
    - MiCS-MCS

Slide 6: MORONGO VALLEY BLOCK
Continued

- Previous workers considered the Big Morongo strand the main strand, but Katherine Kendrick and her groups showed it to be the MVS (Kendrick et al. 2022).
- G, M, and K denote age sample locations of Gabriel, McNeil, and Kendrick et al. (2015).
- Point out proposed fault
- Point out anomalous bends in PMFZ
    - Bends in main strand near Yucca Valley; bending by MiCS
    - Bend in BMS, bending by MCS
    - Bend in MVS. Refer to insert. Appears to be offset.
- Faults color-coded to show what's known about their ages.
- Orange is <15,000 yrs, green is <130,000 yrs, black undifferentiated Quaternary

Slide 7: SEQUENCE OF TECTONIC EVENTS

➢ Comments

- Thin black lines denote modern MVB geometry.
- I’m mainly going to concentrate my discussion on the MVB, not outside it.
- Faults are color-coded: red active and black inactive
- Ages from Matti et al (2023)

Slide 7: SEQUENCE OF TECTONIC EVENTS
Continued

➢ Sequence of events

- Stage 1 — 1.5 Ma
- MVS active strand of PMFZ and MiCS active strand of SAFZ
- MVS propagating towards MiCS.
- We suggest that dextral slip by MiCS deflects MVS to SE

Slide 8: SEQUENCE OF TECTONIC EVENTS

- Stage 2 — post 1.5 Ma

- MVS displaces MiCS ~5 km

Slide 9: SEQUENCE OF TECTONIC EVENTS

- Stage 2.5 — post 1.5 Ma
- MVS displaces MiCS ~15 km
- This strand would be MVS according to Kendrick et al (2022) not MiCS

Slide 10: SEQUENCE OF TECTONIC EVENTS

- Stage 3 — post ~375 ka
- MCS replaces MiCS as active SAFZ strand
- Southern part follows MiCS trace
- Here we show MCS offsetting MVS some unknown distance

Slide 11: SEQUENCE OF TECTONIC EVENTS

- Stage 3.5 — post ~375 ka
- MCS active
- More MVS offset. Amount unknown.
- Although Matti et al 2023 suggests MVS abandoned, it seems reasonable that transtension of Morongo Valley is in progress?
- Probably pre-375 ka?
- BMS active?

Slide 12: SEQUENCE OF TECTONIC EVENTS

- ➢ Stage 4 — 125 ka
- ➢ BMS active and offsets MCS 1–1.25 km (Kendrick et al. 2015)
- ➢ BMS slip rate 10–12.5 mm/yr (Kendrick et al. 2015)
- ➢ Eastern part slowing to ~3 mm/yr by 89 ka? (Gabriel 2017).
- ➢ Morongo Valley transtension active?

Slide 13: SEQUENCE OF TECTONIC EVENTS

- Stage 4.5 — present
- Modern setting of Morongo Valley Block
- MiCS and MCS abandoned
- MVS probably abandoned
- BMS probably inactive

Slide 14: CONCLUSIONS

- Morongo Valley Block geometry is a consequence of the interactions of the western PMFZ with MiCS, and MCS of the SAFZ
- Tentatively suggest SE deflection of propagating MVS and BMS by dextral MiCS and MCS is consistent with the Mojave Block moving relative to the Pacific Plate along the SAFZ (Dixon and Xie 2018)
- Timing of Morongo Valley transtension unclear
- More work necessary to better understand tectonic history of MVB

Slide 15: ACKNOWLEDGEMENTS

Finally, I want to thank these people for their help. Keith Howard and Chris Menges reviewed my abstract and made helpful suggestions. Keith, Chris, Jonathan Matti, Stephanie Dudash, Katherine Kendrick, and John Platt have all been invaluable sharing data and influencing my thinking about the Pinto Mtn fault zone over the years. Finally, my wonderful and talented wife, Kim, who made helpful suggestions to the slide set. Thank you all!

Slide 16: THAT’S ALL FOLKS!

Afternoon photo showing part of Morongo Valley and Big Morongo Canyon backdropped by the San Bernardino Mts and Mt San Gorgonio. I took this photo while doing field work in Fall 1994. BMS trace shown in yellow. This photo also appeared in my 1998 *California Geology* paper.

Slides 17–21: REFERENCES

No entries