Uniformitarianism and the Laramide Orogeny of the Wyoming Craton: The Present is the Key to the Past, and the Past…*

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Abstract

Seismic studies (COCORP, Deep Probe, and EarthScope BASE) have provided a better understanding of Laramide tectonism at deeper crustal levels. However, deformational mechanisms in the upper crust related to Laramide orogenesis remain unclear. Internal controls of Laramide tectonism in the upper crust have been proposed to be related to basement anisotropies, which may be linked to evolution of foreland arches at deeper crustal levels and structures seen at the surface. This study presents a structural and tectonic analysis of Precambrian anisotropies of the Wyoming craton and provides a hypothesis on the potential role of these features in Laramide orogenesis.

Anisotropies are generally oriented in three directions: north-northwest, west-northwest, and northeast. They have a complex and long history of deformation since the Precambrian, most recently, during the Laramide. This work provides evidence for development of long-lived Neoarchean zones of convergence dominantly directed from the southwest towards the craton forming north-northwest weakness zones, as shown from modern analogs. In addition, northeast-southwest-directed pure-shear compressional forces from convergence are postulated to have formed west-northwest- and northeast-trending anisotropies in the form of conjugate shears, again supported by modern convergence zone deformations.

It is proposed that these structures were reactivated throughout Laramide contraction, forming discrete zones of transpression that were displaced along a southwest- to northeast-directed Laramide deformational front. In the Wyoming transpressive zone,
west-northwest structures were displaced as reverse/left-lateral oblique-slip faults and, where connected, acted as lateral ramps facilitating major arch development along the north-northwest-trending structures. In the Montana transpressive zone, where north-northwest basement anisotropies are not present, reverse-sinistral slip occurred along west-northwest basement-seated faults without the associated vertical slip seen in Wyoming. Basement-seated faults are expressed at the surface as oblique, left-slip reverse faults (west-northwest deformational zones in Wyoming/Montana), high-angle right-slip faults (northeast deformational zones in Wyoming/Montana), and low-angle reverse faults/thrust faults (north-northwest arches generally only in Wyoming) that are interconnected in a convergent deformation system that likely includes the Black Hills. This deformation system is postulated to be a fundamental tectonic feature controlling formation of Laramide arches/uplifts of the Wyoming craton.

References Cited


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Hypothesis:

Laramide structures of the Wyoming craton formed in the Precambrian under a convergent tectonic regime and these basement structures were simply reactivated under a similar PHS during Laramide orogenesis.
Comparison to Precambrian Anisotropies of WC & Laramide Deformations?
South America Analogue

Precambrian-Age Anisotropies
Laramide Deformations

South America Analogue
Thinned Continental Lithospheric Mantle

Potential Zone of Mafic Underplating

Asthenosphere

Continental Lithospheric Mantle

Modified from Taboada et al., 2000
Laramide Deformations
What do we know?

- Arch thrusts “appear” to sole out into mid-crustal transition zone.
- Arch thrusts are “connected” via oblique-slip (sinistral/reverse) faults acting as lateral ramps facilitating horizontal thrust movement.
- Possible relationship between upper mantle and basement anisotropies beneath arches/uplifts:
  - For thrusts (= Archean magmatic arcs/subduction zones that have jumped and changed polarity through time; WRM/BHM)
  - For lateral ramps (= ?)
    - = synthetic conjugate shears connecting Archean magmatic arcs/subduction zones?

Stone, 1993
WY/MT
~ 2.7 Ga

Oceanic Crust

Oceanic Lithospheric Mantle

Asthenospheric Mantle

PNBFZ

Contiguous Crust

Lithospheric Tie

WC

Scale Approximate
Active Source Profile

Shotpoints

Deep Probe Profile (Snelson et al., 1998)

Modified from Worthington, et al., 2016
BASE 1 Tomography

Bighorn Basin

Bighorn Mountains

Powder River Basin

Depth (km)

Distance (km)

Velocity (km/s)

Alteration/mixing zone tomography courtesy of L.L. Worthington, 2016
Owl Creek Fault Zone

Convergent Deformation vs Crustal Detachment
Convergence Zone Evolution

A

LATE ARCHEAN

B

C

D

E

Not to Scale
LATEST ARCHEAN

Potential conduits for mafic underplating in the Archean and Proterozoic

Not to Scale
Convergent Deformation System

[Map of convergent deformation system with various geological features and numerical annotations indicating ages in Ga (Gigayears).]

- C (~ 2.8 Ga)
- D (~ 2.7 Ga)
- A (~ 3.0 Ga)
Summary

- Precambrian basement anisotropies **exist** across the Wyoming craton (N-NW, W-NW, NE)
- These anisotropies **correspond well** to surface structures
- Evidence of **left-shift** on the W-NW faults is **ubiquitous** across the craton
  - In Wyoming, where W-NW faults “**connect**” with N-NW structures, these faults facilitate Laramide thrusting as **sinistral, reverse-slip lateral ramps**
  - In Montana, N-NW basement anisotropies are not present; therefore, deformation is confined to **sinistral deformation zones** (transpressional)
- Basement anisotropies appear to be related to:
  - **Convergent plate margins** during the Archean
Summary Con’t

- Orientation of basement anisotropies were conducive to reactivation under NE-SW directed PHS during the Laramide

- The orientation of these features and deformation history create the “symmetry” observed across the Wyoming craton

- Further studies on the left-shift zones need to be conducted to understand mid- to lower-crustal/upper mantle relationships = DRIVER

- This cratonic model incorporates ideas from accepted/non-accepted models of Laramide orogenesis and requires minimal explanations for the various Laramide structures seen across the craton

= UNIFYING CONCEPT
All Truth Passes Through Three Stages
1. Ridicule
2. Violently Opposed
3. Accepted as being self-evident

Arthur Schopenhauer