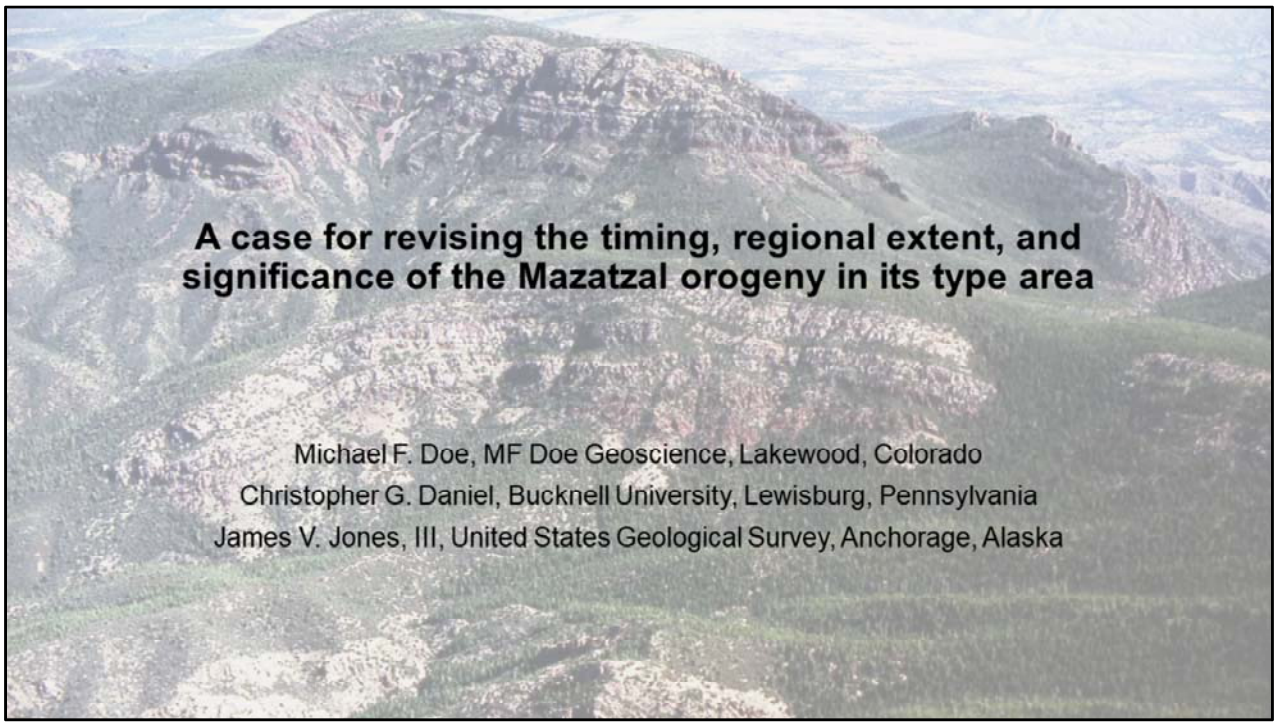


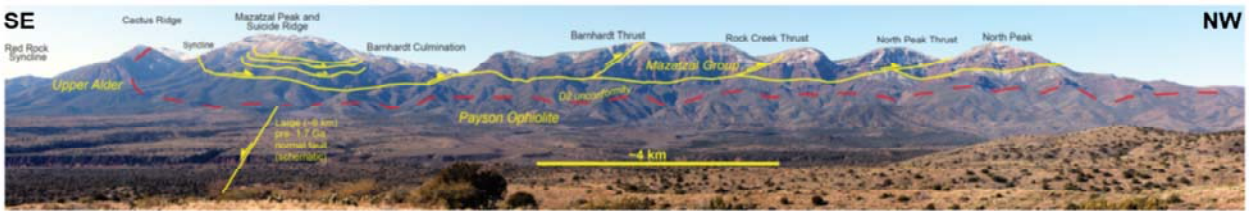
This presentation is designed to draw attention back to the type area where new geochronologic constraints warrant revising the timing of the Mazatzal orogeny to ca. 1471-1436 Ma. The term “Mazatzal orogeny” is widely used to describe regional deformation across southwest Laurentia roughly between ca. 1695-1580 Ma (Karlstrom and Bowring, 1988; Duebendorfer et al., 2015). The type area for the Mazatzal orogeny is located in the Mazatzal Mountains of central Arizona’s Tonto Basin (Wilson, 1922, 1937, 1939). Thought to have closely followed the northwest-directed shortening of the ca. 1700 Ma Yavapai orogeny (Karlstrom and Bowring, 1991), the coaxial deformation of the Mazatzal orogeny occurred after deposition of the Mazatzal Group quartzite and shale, and long before deposition of the Middle Mesoproterozoic Apache Group (Wilson, 1939). The early estimates on the timing of the Mazatzal orogeny in its type area, and starting in the middle 1960’s, bracketed timing of deformation roughly between 1715 and 1650 Ma (Silver, 1965, 1967). However, emphasis on this stage of deformation has shifted from Arizona to New Mexico, Colorado, and southern Wyoming where the Mazatzal orogeny was expanded spatially and temporally to ca. 1580 Ma (for example Bauer and Williams, 1994 and others).

Purpose of this talk:

Mazatzal orogeny is widely accepted as a ca. 1680-1650 Ma event.

Field evidence from the **type area of the Mazatzal orogeny** that supports timing of NW-directed contraction at ca. 1470-1436 Ma, contemporaneous with the 1490-1380 Ma Picuris orogeny in New Mexico

- Detrital zircon evidence from three regions of Tonto Basin
- Mazatzal Group likely deposited after 1660 Ma
- Reinterpretation does not discount or refute documented 1700-1580 Ma deformation, syn- or post-tectonic plutonism, or volcanism. But……



Northern Mazatzal Mountains, early morning view, looking southwest

In the following slides I will present field evidence regarding timing of the Mazatzal orogeny. The Mazatzal orogeny, for the last 40 years, has been presented initially as a 1695-1650 Ma event (Karlstrom and Bowring, 1991), and more recently expanded to 1580 Ma primarily based on timing relationships outside of Arizona (Duebendorfer et al., 2015). Today we present data that shows deformation attributed to the Mazatzal orogeny, in the type area, occurred between 1470-1436 Ma (Doe, 2014), contemporaneous with the 1490-1380 Ma Picuris orogeny reported in northern New Mexico (Daniel et al., 2013).

Evidence supporting the revised timing of the Mazatzal orogeny are based on correlative formations distributed over three areas of Tonto Basin in central Arizona. Mazatzal deformation involved the Mazatzal Group, post-1660 Ma deposits, disconformably overlain by the Yankee Joe Group that includes a maximum depositional age of 1470 Ma. It's important to note no changes are implied regarding observed or noted 1700-1580 Ma deformation, on-going post- and syn-tectonic plutonism and volcanism that occurred during and after across SW Laurentia. But, unless you have a cross-cutting relationship, you should be cautious about attributing a cause and timing of deformation until it is better defined. We only want to show the timing of the Mazatzal orogeny, in its type area, is contemporaneous with the Picuris orogeny.

The image on the bottom part of this slide shows the east face of the northern Mazatzal Mountains bathed in early morning light. This view is slightly oblique to the northwest transport direction of the fold and thrusts across the range. From left to right we see the Cactus Ridge syncline, Mazatzal Peak and Barnhardt Canyon. North of Barnhardt Canyon, thrusts follow flats along the top of the Maverick Shale and ramps through the competent Mazatzal Peak Quartzite. Where the Barnhardt Thrust reaches the skyline, a veneer of pelitic sediments conformably overlie the Mazatzal Peak Quartzite (Doe, 1991a; Doe and Karlstrom1991b; Doe, 2014). These sediments, the Hopi Springs Shale, are clearly cut and deformed by the Barnhardt Thrust (Doe, 1991) . Detrital zircon from the Hopi Springs Shale yield a maximum depositional age of the 1571 Ma (Doe, 2014). This basic field relationship casts doubt, in the type area, for a 1680-1650 Ma timing of the Mazatzal orogeny.

The Mazatzal orogeny defined:

Wilson (1937, 1939) proposed "after deposition of the Mazatzal quartzite and long before Apache sedimentation, the region underwent a profound crustal disturbance, termed the Mazatzal Revolution."

Silver (1965, 1967): The type-Mazatzal orogeny as defined by Wilson (1939) occurred within the interval 1715-1650 Ma (U-Pb).

Alternatively, Livingston (1969): Upper Salt River Canyon, the Mazatzal Revolution of Wilson (1939a) occurred after deposition of the Hess Canyon Group (correlated to the Mazatzal Group), ca.1425-1380+/-100 Ma (Rb-Sr), followed by deposition of the younger Precambrian Apache Group.

Karlstrom et al (1990): 1690-1650 Ma for the Mazatzal orogeny based on timing of the Slate Creek shear zone

Northern Mazatzal Mountains, early morning view, looking southwest

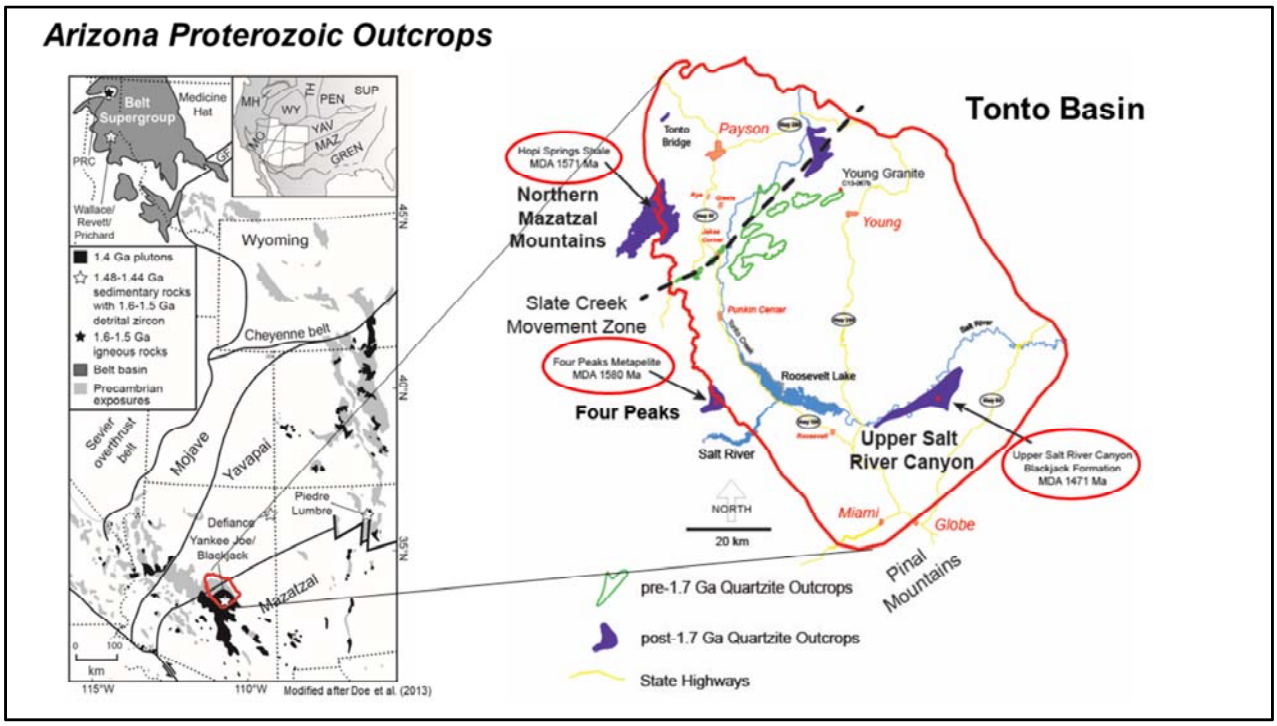
The Mazatzal orogeny term is derived from the term "Mazatzal Revolution" an event proposed by Eldred Wilson (1937; 1939). Wilson worked extensively in the Mazatzal Mountains from 1921 to 1936 (Wilson, 1922; 1937; 1939). The Mazatzal Revolution was defined as an event that occurred "After deposition of the Mazatzal quartzite and long before Apache sedimentation".

In the mid-1960's, Lee Silver utilized U-Pb isotopes to establish timing of the Mazatzal orogeny based on a cross-cutting relationship between 1650 Ma granites along the Slate Creek shear zone, and the 1715 Ma Red Rock Rhyolite (Silver, 1965; 1967). Silver assumed deformation along the Slate Creek shear zone occurred at the same time as the northwest directed shortening observed in the stratigraphically younger Mazatzal Group.

Alternatively, Livingston (1969), working on a deformed (post-1510 Ma, age of the underlying Redmond Formation) former Hess Canyon Group, a stratigraphic section correlated to the Mazatzal Group that was intruded by the post-tectonic Ruin granite, of the upper Salt River Canyon bracketed timing of the Mazatzal orogeny between 1425 and 1380+/-100 Ma.

Unfortunately, Livingston's Rb-Sr methods yielded a large error, and was likely regarded as less reliable ages than UPb methods. Even though the upper Salt River Canyon offered clear stratigraphic, structural, and igneous cross-cutting relationships, not present in the northern Mazatzal Mountains, the area was largely ignored for years regarding the timing of the event.

Later, Karlstrom et al. (1990) "confirmed" Silver's end of the Mazatzal orogeny based on a cross-cutting relationship within the Slate Creek shear zone between pre-1700 Ma folded quartzite and the "1650 Ma" granite near Young, Arizona. In the late 1980's, the Mazatzal Group in the northern Mazatzal Mountains was assumed to be deposited around 1700 Ma based upon the age of the underlying ca. 1705 Ma Red Rock Rhyolite. It fit well with the timing of deformation observed within the Slate Creek shear zone. The timing of deformation was bracketed between ca. 1690 Ma, the approximate end of the Yavapai orogeny and after the deposition of the Mazatzal Group.

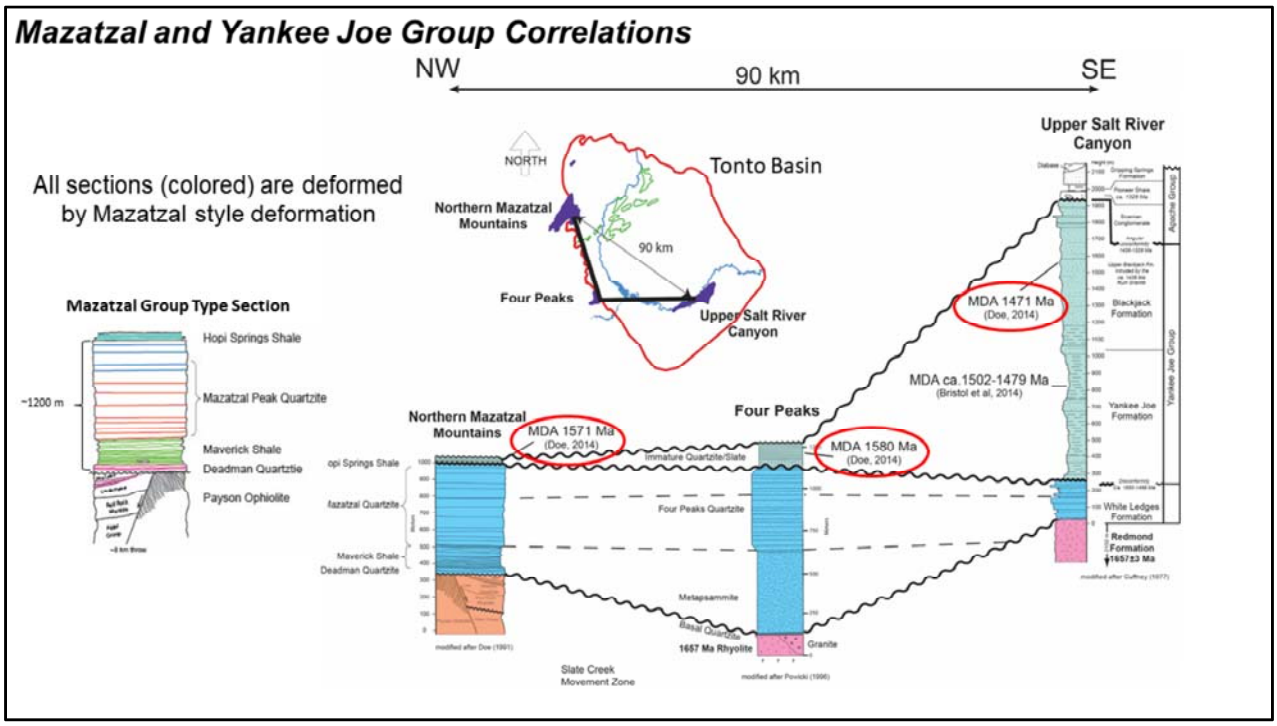


A little background. Between 1800-1000 Ma the craton grew southward from Archean core of the Laurentian craton (Whitmeyer and Karlstrom, 2007). This talk focuses on a transect representing a small section of growth from 1780-1100 Ma.

The Mazatzal Mountains are located in Tonto Basin of central Arizona 60 km east of Phoenix, Arizona. The basin lies within a physiographic region of Arizona called the Transition Zone. The Transition Zone separates the Basin and Range on the southwest from relatively flat-lying Paleozoic of the Colorado Plateau on the northeast. The Transition Zone is oriented NW-SE and exposes a wide swath of nearly continuous, 500 km transect of Proterozoic basement ranging in age from ca 1780-1100 Ma, with ages generally decreasing from NW to SE.

Tonto Basin is roughly 120 km long by about 80 km wide. The north and south Mazatzal Mountains straddle the western boundary of Tonto Basin and are transected by the Slate Creek shear zone which crosses the upper third of the basin. The west central part of Tonto basin features Roosevelt Lake which receives water from Tonto Creek on the north and the upper Salt River on the south. The upper Salt River Canyon contains, in part, the former Hess Canyon Group (Trevena, 1979) now subdivided into the Paleoproterozoic White Ledges Formation and the overlying Yankee Joe Group (Doe et al., 2012). This area holds critical new data

supporting revision of the timing of the Mazatzal Mountains (Doe, 2014).



A simplified version of the previous map is shown here. Below is a cross-basin stratigraphic correlation for the Mazatzal Group, Four Peaks quartzite, and White Ledges Formation. To the left is the type section of the Mazatzal Group of the northern Mazatzal Mountains.

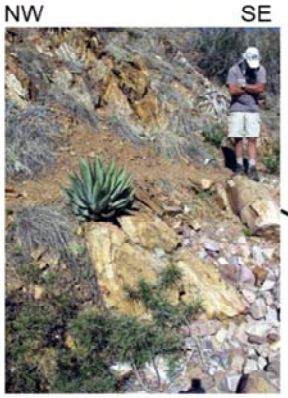
The Mazatzal Group is comprised of the basal Deadman quartzite, Maverick Shale, and Mazatzal Peak quartzite (Doe, 1991; 2014; Conway and Silver, 1989; Trevena, 1979; Wilson, 1922). Disconformably overlying the Mazatzal Group is the Hopi Springs shale (Doe, 1991). The basal Hopi Springs shale has a maximum depositional age of 1571 Ma (Doe, 2014). The correlated stratigraphic sections are colored, blue for the Mazatzal Group, and green for the Hopi Springs shale or Yankee Joe Group to simplify the correlations.

The Mazatzal Group rests on 1700-1730 Ma age units (Doe, 2014; Cox et al., 2002; Dann, 1997; Doe and Karlstrom, 1991) while both sections at Four Peaks (Mako et al., 2015) and the upper Salt River Canyon rest on 1657 Ma ash flow tuffs (Doe, 2014; Doe et al., 2012; Karlstrom et al., 1990). All of the Mazatzal Group and equivalents are characterized by increasingly mineralogic maturity upsection. The “white ledge” of the White Ledge Formation is a true orthoquartzite and likely represents a shore-line deposit (Doe, 2014).

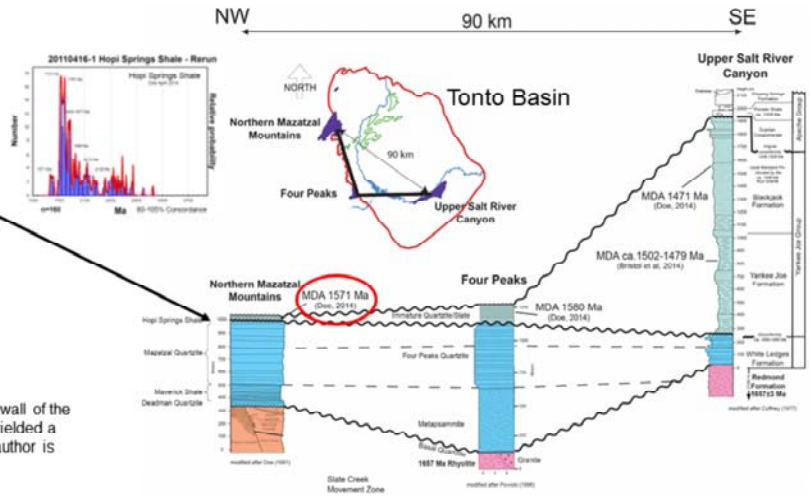
The White Ledge Formation is disconformably overlain by the Yankee Joe and Blackjack Formations, formerly comprising the Hess Canyon Group (Doe et al., 2012; Trevena, 1979; Cuffney, 1977). The Yankee Joe and Blackjack Formations yield abundant “magmatic-gap” age zircons ranging from around 1600-1470 (Doe et al., 2012; Doe et al, 2014; Doe, 2014). The former Hess Canyon Group is now the Paleoproterozoic White Ledges Formation and the Yankee Joe Group (Doe et al., 2012).

Lines of evidence for revising timing of the Mazatzal orogeny in it's type area:

- Hopi Springs Shale folded just below the Barnhardt thrust
- 1571 Ma Maximum Depositional Age (MDA) from the Hopi Springs Shale in the northern Mazatzal Mountains



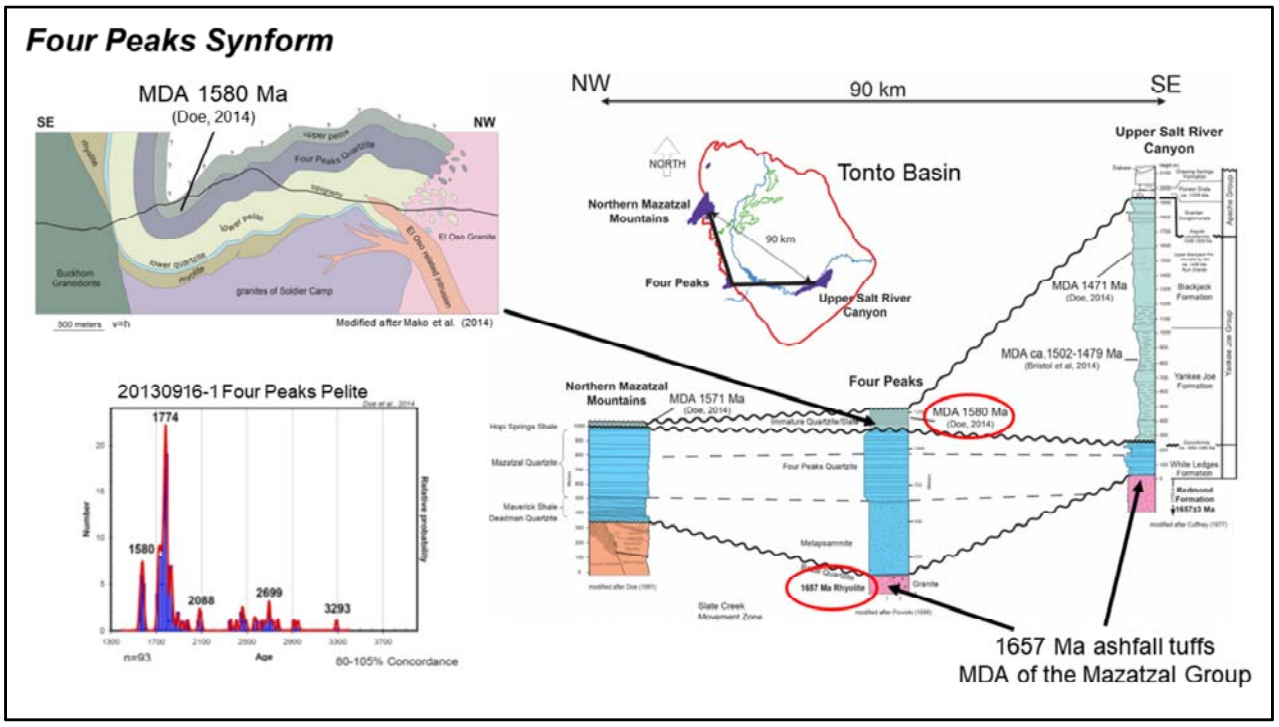
NW vergent folds in Hopi Springs Shale in the footwall of the Barnhardt Thrust near the sample location that yielded a **maximum depositional age of 1571 Ma**. The author is standing on the Arizona Trail.



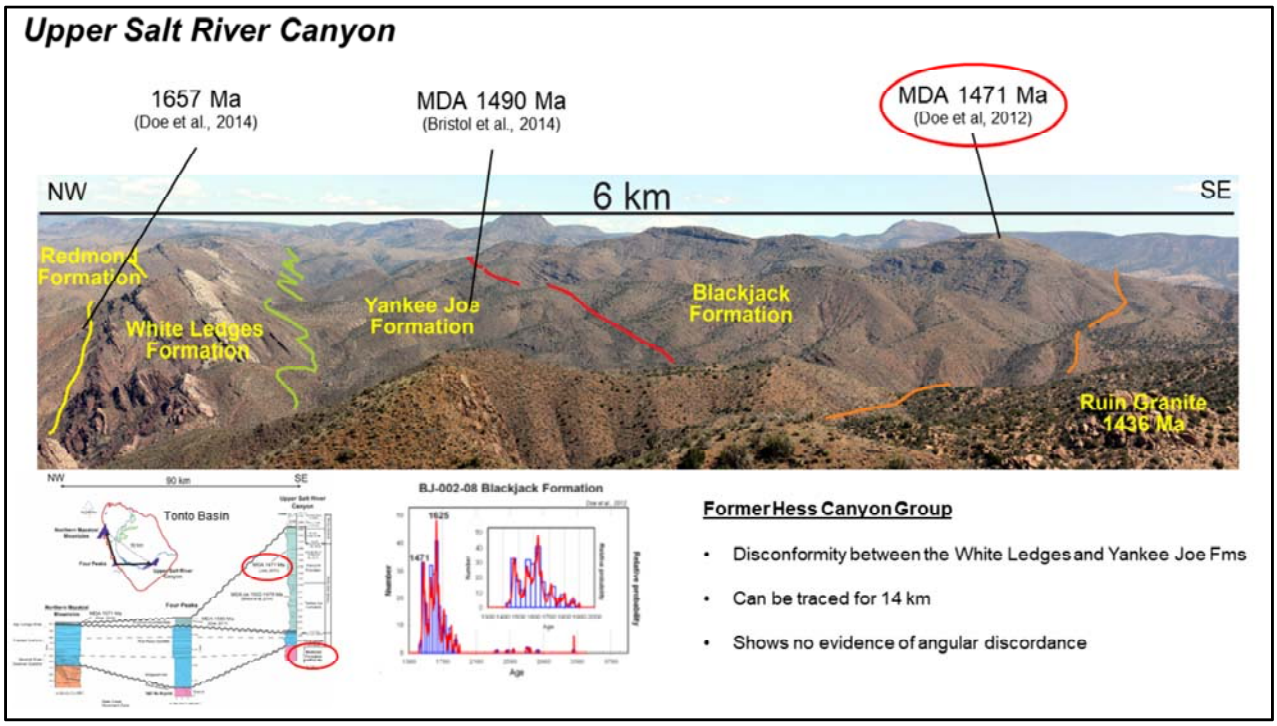
Several lines of evidence support revising timing of the Mazatzal orogeny in its type area. First, three maximum depositional ages obtained from pelitic sediments, across three Mountain ranges, involved in deformation classically attributed to the Mazatzal orogeny involve ages as young as 1471 Ma (Doe, 2014).

On the lower right are stratigraphic sections from the northern Mazatzal Mountains (Doe, 1991), Four Peaks (Powicki, 1996), and the upper Salt River Canyon (Doe, 2014; Doe et al., 2012), roughly a straight line distance of 90 km. The photo on the left shows folded sediments of the Hopi Springs Shale exposed beneath the Barnhardt thrust in the northern Mazatzal Mountains. The Hopi Springs shale occurs as erosional remnants along the crest of the northern Mazatzal Mountains. I am standing on the Arizona Trail (Doe, 2014). A sample of the Hopi Springs shale was collected to my left near the upper left part of the photo. Detrital zircons from these sediments yield a maximum depositional age of 1571 Ma (Doe, 2014).

An isoplot of the sampled Hopi Springs shale is shown to the right of the photograph. The plot shows a peak on the far left with an age of 1571 Ma, interpreted as a maximum depositional age for the Hopi Springs shale.



Four Peaks is formed by resistant ridges of quartzite folded into an inward plunging, northwest-vergent synform (Mako, 2015; Doe, 2014). The Four Peaks quartzite is deposited on a 1657 Ma ashflow tuff (Mako, 2015). Within the core of the synform, a sampled metapelite yielded a maximum depositional age of 1580 Ma shown in the isoplot (Mako, 2015; Doe, 2014).



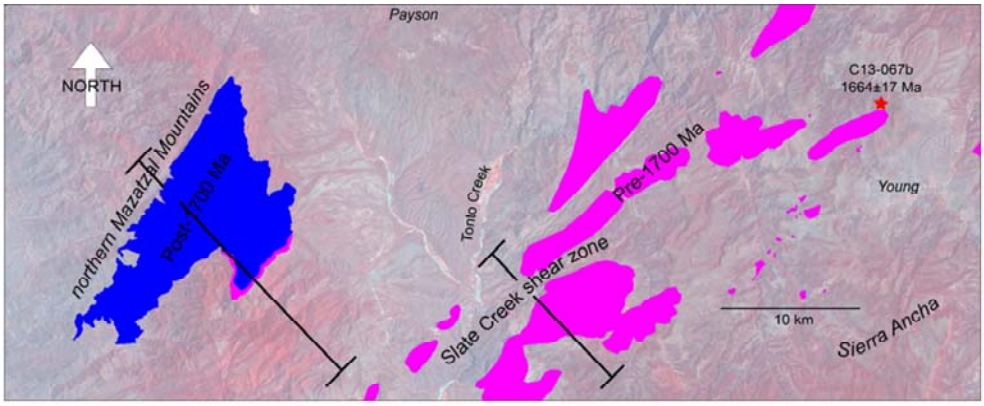
In the upper Salt River Canyon, the Paleoproterozoic White Ledges Formation (resting on the 1657 Ma Redmond Formation) is disconformably overlain by the Yankee Joe Group along a strike length of 14 km (Doe et al., 2014; Doe, 2014). The Yankee Joe Group is approximately 2 km thick. The entire section records top to the northwest contraction, dips southeast, and is intruded on the south by the 1436 Ma Ruin granite (Cuffney, 1977; Davis et al., 1981; Doe et al., 2012; Doe, 2014; Spencer et al., 2003). The highest sample possible from the Blackjack Formation yields a maximum depositional age of 1471 Ma. The Redmond, White Ledges, Yankee Joe, and Blackjack Formations are unconformably overlain by erosional remnants of the ca. 1320 Ma, and nearly flat-lying lower Apache Group.

Based on this section, the Mazatzal Group was deposited some time after 1657 Ma, and conformable deposition continued to 1470 Ma followed by the post-tectonic intrusion of the 1436 Ma Ruin granite (Spencer et al., 2003). Therefore, timing of the Mazatzal orogeny, as defined by Wilson (1939; Livingston, 1969), occurred ca. 1470-1436 Ma, contemporaneous with the timing of the Picuris orogeny of New Mexico.

How we got it wrong

Early estimates for timing of the Mazatzal orogeny, 1680-1650 Ma

- Based on a cross-cutting relationships between folded pre-1700 Ma sediments and post-tectonic 1664-1630 Ma granites located along Slate Creek shear zone
- Timing of deformation projected up, across D2 unconformity, to include the Mazatzal Group



Because of an absence of cross-cutting relationships in the Mazatzal Group, early estimates for timing of the Mazatzal orogeny were based on a cross-cutting relationship between stratigraphically deeper folded pre-1700 Ma sediments and a post-tectonic 1664+/-17 Ma (Mako et al., 2015) granite located near Young, Arizona, approximately 40 km east of the northern Mazatzal Mountains. The cross-cutting relationship was then projected up stratigraphic section, across the D2 unconformity, to include the folds and thrusts mapped in the Mazatzal Group (Karlstrom et al., 1990; Silver, 1965, 1967).

The next slide shows a schematic of two cross-sections, shown in black, that transect the northern Mazatzal Mountains and the Slate Creek shear zone.

How we got it wrong

Schematic cross-section across the northern Mazatzal Mountains and Slate Creek shear zone

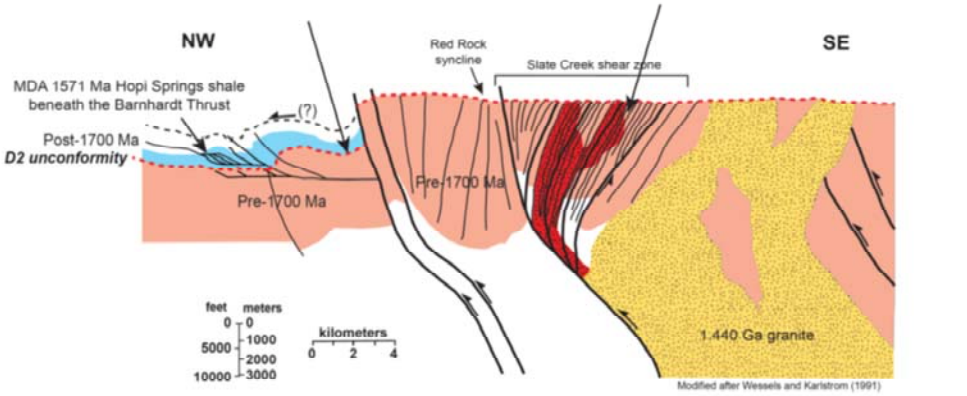
D2 unconformity:

»Developed during and after the Yavapai orogeny

»Preserved in the northern Mazatzal Mountains.

Sample location used to constrain the end of the Mazatzal orogeny:

» Granite at Young (1664± 17 Ma) per Mako (2014) intruded 1708-1701 Ma folded quartzite of the Houdon Formation



Regional correlations suggest the Mazatzal Group was deposited after 1657 Ma

This slide is a composite, schematic, cross-section drawn through the northern Mazatzal Mountains and Slate Creek shear zone. The section is colored to simplify. On the left, the Mazatzal Group and later, or post-1700 Ma sediments are colored in blue. Rocks, sedimentary and volcanic, older than 1700 Ma are colored in tan. I have highlighted two intrusions on the right. The red intrusion depicts the 1664+/-17 Ma granite near Young, Arizona (Mako et al., 2015), cross-cuts folded ca. 1708 – 1701 Ma Houdon quartzite along the Slate Creek shear zone. Note the red dashed line on the left half of the section. This is the D2 unconformity, a product of the ca. 1700 Ma Yavapai orogeny (Dann, 1997). On the right the D2 unconformity merges with present-day erosional surface over the Slate Creek shear zone.

In the 1980's and 90's, we looked for interbedded ash layers or igneous cross-cutting relationships within the Mazatzal Group to establish some sort of timing constraint. Unable to find any evidence, we were forced to look below the D2 unconformity where the cross-cutting relationship was identified within the Slate Creek shear zone. Unfortunately, we did not fully appreciate the age magnitude of the D2 unconformity and projected the timing relationship up section to include deformation of the Mazatzal Group (Karlstrom et al., 1990).

To summarize, early estimates for timing of the Mazatzal orogeny were based on

cross-cutting relationships between pre-1700 Ma folded sediments and volcanics within the Slate Creek shear zone and the ca 1665-1630 Ma granite along the Slate Creek shear zone and near Young, Arizona. An assumption was made that the Mazatzal Group was deposited ca. 1700 Ma therefore the cross-cutting relationship observed along the Slate Creek shear zone was projected up-section, across the D2 unconformity, to include the timing of folds and thrusts that deformed the Mazatzal Group (Karlstrom et al., 1990).

Summary

- Maximum depositional ages from pelites conformably-disconformably overlying the Mazatzal Group and correlative units show:
  - Regional correlations suggest the Mazatzal Group was deposited post-1657 Ma
  - Mazatzal deformation included 1571-1471 Ma Yankee Joe Group sediments
  - Timing for the Mazatzal orogeny, in its type area, is ca. 1470-1436 Ma, contemporaneous with timing of the ca. 1490-1380 Ma Picuris orogeny
  - Apache Group was deposited over a high-relief angular unconformity ca. 1320 Ma, following the Mazatzal orogeny and exhumation
- Early constraints on the timing of the Mazatzal orogeny were:
  - Based on cross-cutting relationships between folded pre-1700 Ma quartzite of the Alder Group and post-tectonic 1664-1630 Ma plutons located along the Slate Creek shear zone
  - Timing of ca. 1700-1650 Ma deformation was project up across the D2 unconformity of the Yavapai orogeny to include northwest folding and thrusting observed in the Mazatzal Group

Early attempts to constrain the timing of the Mazatzal orogeny were based on cross-cutting relationships between pre-1700 Ma units and post-tectonic granites, namely the 1664+/-17 Ma granite near Young, Arizona. This timing relationship, was projected up-section, across the D2 unconformity, where the Mazatzal Group was assumed to be a ca. 1700 Ma deposit and, placing the Mazatzal orogeny between 1690 and 1650 Ma.

However, maximum depositional ages of the 1570 Ma Hopi Springs Shale, the 1580 Ma Four Peaks metapelite, and the ca. 1470 Ma Yankee Joe Group suggests they are correlative. Because all of the sections are deformed in the “classic” style of the Mazatzal orogeny prior to intrusion of the 1436 Ma Ruin Granite, a new timing of the deformation for the Mazatzal orogeny, in the type area, is bracketing between 1470-1436 Ma followed by uplift and erosion where the Middle Mesoproterozoic Apache Group was deposited over a high relief topography starting ca. 1320 Ma. The timing of the Mazatzal orogeny was contemporaneous with the Picuris orogeny in New Mexico.

References:

Bauer, P.W., Williams, M.L., 1994, The age of Proterozoic orogenesis in New Mexico, U.S.A.:

Precambrian Research, v. 67, p. 349-356.

Conway, C.M., and Silver, L.T., 1989, Early Proterozoic rocks (1710-1615 Ma) in central to southeastern Arizona: Arizona Geological Society Digest, v. 17, p. 165-186.

Cox, R., Martin, M.W., Comstock, J.C., Dickerson, L.S., Ekstrom, I.L., and Sammons, J.H., 2002, Sedimentology, stratigraphy, and geochronology of the Proterozoic Mazatzal Group, central Arizona: Geological Society of America Bulletin, v. 114, no. 12, p. 1535-1549.

Cuffney, R.G., 1977, Geology of the White Ledges area, Gila County, Arizona: Unpublished Master's thesis, Colorado School of Mines, Golden, Colorado, 141 p.

Daniel, C.G., Pfeifer, L.S., Jones, J.V. III, and McFarlane, C.M., 2013, Detrital zircon evidence for non-Laurentian provenance, Mesoproterozoic (ca. 1490-1450 Ma) deposition and orogenesis in a reconstructed orogenic belt, northern New Mexico, USA: Defining the Picuris orogeny: Geological Society of America Bulletin, v. 125, n. 9-10, p. 1423-1441.

Dann, J.C., 1997, Pseudostratigraphy and origin of the early Proterozoic Payson Ophiolite, central Arizona: Geological Society of America Bulletin, v. 109, p. 347-365.

Davis, G.H., Showalter, S.R., Benson, G.S., and McCalmont, L.S., 1981, Guide to the geology of the Salt River Canyon region, Arizona: Arizona Geological Digest, v. 13, p. 48-97.

Doe, M.F., 2014. Reassessment of Paleo- and Mesoproterozoic Basin Sediments of Arizona: Implications for Tectonic Growth of Southern Laurentia and Global Tectonic Configurations (Ph.D. thesis). Colorado School of Mines, Golden, Colorado, p. 649.

Doe, M.F., Jones, J.V., Karlstrom, K.E., Dixon, B., Gehrels, G., and Pecha, M., 2013, Using detrital zircon ages and Hf isotopes to identify 1.48–1.45 Ga sedimentary basins and fingerprint sources of exotic 1.6–1.5 Ga grains in southwestern Laurentia: Precambrian Research, v. 231, p. 409–421, doi: 10.1016/j.precamres.2013.03.002.

Doe, M.F., Jones, J.V., Karlstrom, K.E., Thrane, K., Frei, D., Gehrels, G., and Pecha, M., 2012, Basin formation near the end of the 1.60–1.45 Ga tectonic gap in southern Laurentia: Mesoproterozoic Hess Canyon Group of Arizona and implications for ca. 1.5 Ga supercontinent configurations: Lithosphere, v. 4, p. 77–88, doi: 10.1130/L160.1.

Doe, M.F. and Karlstrom, K.E., 1991, Structural geology of an early Proterozoic foreland thrust belt, Mazatzal Mountains, Arizona *in* Karlstrom, K.E., 1991, Proterozoic Geology and Ore Deposits of Arizona, Arizona Geological Society Digest 19, p. 181-192.

Doe, M.F., 1991a, Structural geology of a Proterozoic foreland thrust system in the vicinity of Barnhardt Canyon, central Mazatzal Mountains, central Arizona: Unpublished MS Thesis,

Northern Arizona University, 91 p.

Doe, M.F., 1991b, Geologic map and cross-section of the central and northern Mazatzal Mountains, central Arizona (1:24,000): Arizona Geological Survey Contributed Map Series 91-J (two sheets).

Duebendorfer, E.M., 2015. Refining the early history of the Mojave-Yavapai boundary zone: rifting versus Arc accretion as mechanisms for Paleoproterozoic crustal growth in southwestern Laurentia. J. Geol. 123, 21–37
.
Karlstrom, K.E., and Bowring, S.A., 1991, Styles and timing of early Proterozoic deformation in Arizona; constraints on tectonic models: Arizona Geological Society Digest, v. 19, p. 1-10.

Karlstrom, K.E., and Bowring, S.A., 1988, Early Proterozoic assembly of tectonostratigraphic terranes in southwestern North America: Journal of Geology, v. 96, no. 5, p. 561-576.

Karlstrom, K.E., Doe, M.F., Wessels, R.L.., Bowring, S.A., Dann, J.C., and Williams, M.L., 1990, Juxtaposition of Proterozoic crustal blocks; 1.65-1.60 Ga Mazatzal Orogeny *in* Geologic Excursions through the Sonoran Desert region, Arizona and Sonora, Gehrels, G.E. and Spencer, J.E., eds, Arizona Geological Survey Special Paper 7, Fieldtrip Guidebook, 86th Annual Meeting, Tucson, Arizona, p. 114-122.

Livingston, D.W., 1969, Geochronology of older Precambrian rocks in Gila County, Arizona: Ph.D. dissertation, University of Arizona, Tucson, Arizona, 140 p.

Mako, C.A., Williams, M.L. Doe, M.F., and Karlstrom, K.E., 2013, Timing of Deformation at Four Peaks, Central Arizona: Geological Society of America Abstracts with Programs, v. 45, no. 7, p. 462.

Powicki, D.A., 1996, The structural and metamorphic geology of the Four Peaks area, southern Mazatzal Mountains, central Arizona [Master's thesis]: University of Massachusetts at Amherst, 81 p.

Silver, L.T, 1967, Apparent age relations in the older Precambrian stratigraphy of Arizona [abs.], in Burwash, R. A., and Morton, R. D., eds., Geochronology of Precambrian stratified rocks: Edmonton, University of Alberta, p. 87.

Silver, L.T, 1965, Mazatzal orogeny and tectonic episodicity [abs.]: Geological Society Special Paper 82, p. 185-186.

Spencer, J.E., Isachsen, C.E., Ferguson, C.A., Richard, S.M., Skotnicki, S.J., Wooden, J., Riggs, N.R., 2003, U-Pb isotope geochronologic data from 23 igneous rock units in central and southeastern Arizona: Arizona Geological Survey Open-File Report 03-08, 40 p.

Trevena, A.S., 1979, Studies in sandstone petrology; origin of the Precambrian Mazatzal Quartzite and provenance of detrital feldspar: Doctoral thesis, University of Utah, Salt Lake City, 390 p.

Wessels, R.L. and Karlstrom, K.E., 1991, Evaluation of the tectonic significance of the Proterozoic Slate Creek Shear Zone in the Tonto Basin Area *in* Karlstrom, K.E., 1991, Proterozoic Geology and Ore Deposits of Arizona: Arizona Geological Society Digest 19, p. 193-209.

Whitmeyer, S.J. and Karlstrom, K.E., 2007, Tectonic model for the Proterozoic growth of North America: Geosphere, v. 3, no. 4, p. 220–259.

Wilson, E.D., 1922, Proterozoic Mazatzal Quartzite of central Arizona: Pan-American Geology, v. 38, p. 299-312.

Wilson, E.D., 1937, The Pre-Cambrian Mazatzal Revolution in the central Arizona [Ph.D. thesis]: Cambridge, Massachusetts, Harvard University, 300 p.

Wilson, E.D., 1939, Pre-Cambrian Mazatzal revolution in central Arizona: Geological Society of America Bulletin, v. 50, p. 1113-1162.