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# A WORKING HYPOTHESIS FOR ARIZONA'S OLDER PRECAMBRIAN HISTORY

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## STRATIGRAPHY

In Arizona, the Precambrian terrane is divided into "Younger Precambrian" (Apache group, Grand Canyon series) and "Older Precambrian" (everything else). The Younger Precambrian overlies the Older Precambrian with marked structural and metamorphic unconformity. To give an outline picture of the rocks we are concerned with, I will abstract the stratigraphy of the several areas where the rocks have been studied carefully. The stratal units are, in many cases, of unknown stratigraphic order.

**Mazatzal Mountains**

Wilson (1939). Yaeger greenstone: intermediate to basic volcanic rocks and intercalated sedimentary material, including red cherts and thin limestones (fault contact). Red Rock rhyolite: flows and agglomerate (fault contact). Alder series: shale, grit, quartzite, and conglomerate (fault contact). Deadman quartzite 90-800 feet, light-brown to gray quartzite, pebbly at base. Maverick shale 500-800 feet, gray to maroon shale. Mazatzal quartzite 3800 feet, light-brown to gray vitreous quartzite. City Creek series: shale and interbedded quartzite (fault contact). All of the rocks have suffered low-grade metamorphism.

**Diamond Butte quadrangle**

Gastil (1958). Basic volcanic flows and pyroclastic rocks, with slate and thin limestones and chert beds (fault contact). Alder formation: slate, wacke, conglomerate, quartzite, 5000+ feet. Flying W formation: conglomerate, keratophyre, rhyolite, basic pillow lava, 375-3200 feet. Houden formation: basal fine conglomerate, quartzite, and slate, 1200-1600 feet (believed by the author to equate to the Deadman-Maverick-Mazatzal sequence of Wilson). Board Cabin formation: conglomerate, wacke, volcanic sandstone, quartzite, basic volcanic porphyry and pillow lava, agglomerate, 250-1820 feet. Haigler formation: slate, wacke, conglomerate, basic volcanic rock, and a predominance of rhyolite tuff and flow rock, 4000+ feet. Oxbow Mountain rhyolite, 1250+ feet. Hell's Gate rhyolite, 10,000+(?) feet (fault contact). All formations are weakly metamorphosed.

**Jerome area, east of Shylock fault**

Anderson (1958). Goddes basalt: pillow lava with minor rhyolite flows. Buzzard rhyolite: rhyolite flows, breccia and tuff with minor basaltic agglomerate and flows. Brindle Pup andesite: porphyritic andesite flows (fault contact). Shea basalt: basaltic flows with tuffaceous sedimentary rocks and rhyolite flows and breccia. Deception rhyolite: rhyolite flows, breccia, and tuff, with andesitic agglomerate and flows. Grapevine Gulch formation: fine-grained tuffaceous rocks and cherty beds, lithic tuffaceous beds, volcanic breccia, dacite flows with minor andesite flows, jasper, and magnetite beds. None of these units can be placed in stratigraphic sequence.

**Jerome area, west of Shylock fault**

Anderson (1958). Green Gulch volcanics: andesite-basalt flows and fragmental rocks, andesitic and rhyolitic tuff and sedimentary rocks (fault contact). Chaparral volcanics: andesitic tuffaceous rocks and rhyolitic tuffaceous rocks (fault contact). Texas Gulch formation: rhyolite tuff and conglomerate and purple slate containing lenses of limestone (fault contact). Indian Hills volcanics: andesitic, basaltic, and rhyolite flows. Spud Mountain volcanics: andesitic breccia interbedded with sedimentary rocks, fine-grained andesitic tuffs, flows interbedded with rhyolite tuff. Iron King volcanics: andesite and basaltic flows, tuffaceous sedimentary rocks. The above sequence comprises 20-30,000 feet and is believed by Anderson to correlate with Wilson's Alder series. All have undergone low-grade metamorphism of Precambrian age.

**Bagdad area**

Anderson (1951). The oldest strata were andesitic basalt flows with minor sedimentary interbeds, 3000+ feet. This is overlain by rhyolite and rhyolite-andesite tuffaceous sediments and shale, thickness not given; and a third formation consisting of shale, sandy shale, and sandstone, 3000+ feet. All rocks now belong to the epidote-amphibolite facies. (?)

**Dragoon quadrangle**

Cooper and Silver (1954). Metamorphosed graywacke, subgraywacke, slate, conglomerate, tuff (?), silicic extrusives, and basalt with associated jasper beds, 9000-20,000 feet, all within the low-grade greenschist to amphibolite facies. Sequence not indicated.

**Globe area**

Ransome (1919). Pinal schist, consisting originally of quartzose sedimentary rocks.

**Ray-Miami**

Ransome (1919). Pinal schist, consisting originally of sandstone, graywacke, shaley sedimentary rocks, and rhyolite or quartz latite.

**Grand Canyon**

Campbell and Maxson (1938). Vishnu series: basalt, pillow lava, and thin interbeds of sandy clay, approximately 4000 feet; sandy clays, quartz sandstone, commonly cross-bedded and ripple marked, some beds ferruginous or slightly calcareous, a minimum of 25,000 feet.

In summary, every common facies of sedimentary rock, with the exception of thick carbonates, and all of the volcanic rocks from rhyolite to basalt are represented in the Older Precambrian of Arizona. The prevalence and thickness of rhyolite in the section is striking in comparison to post-Cambrian terranes. With the possible exception of the Grand Canyon, most of the strata described belong in the greenschist facies of regional metamorphism. Farther west in Arizona, for example the Cerbat Range (Thomas, 1953), the grade of metamorphism is higher. With the exception of the Jerome area, the structural trend in all of these areas is northeast-southwest, and in the Cerbat, Dragoon, and Diamond Butte areas the respective authors note a predominant plunge to the northeast, in some cases at high or even overturned angles.

If anywhere these greenschist rocks rest with marked structural and metamorphic unconformity upon a still older terrane, it has escaped the anxious search of many geologists. In areas such as the Diamond Butte quadrangle, the Older Precambrian rocks are so well preserved that in places delicate spiral structure in volcanic shards is retained. In such areas the existence of a gneissic or migmatitic basement rock could not be overlooked. Careful examination of the Older Precambrian conglomerates and sandstones in the Diamond Butte quadrangle (Gastil, 1958) failed to disclose any clasts or mineral grains necessarily of granitic or metamorphic origin.

## ISOTOPIC AGES

The plutonism, metamorphism, and deformation which distinguish the Older from Younger Precambrian are attributed to what Wilson (1939) named the "Mazatzal Revolution." Prior to 1961, all of the isotopic age determinations for Older Precambrian rocks in Arizona showed values between 1160 and 1550 million years, with 11 of the 14 dates falling between 1300 and 1450 million years (Damon, 1960, p. c-4). These appeared to correlate with similar values for southern Colorado, New Mexico, and Missouri (Aldrich, 1958), suggesting a province of related mineralgenesis extending diagonally across North America (Damon, 1961). However, since 1960 three different investigators, using independent isotopic methods, have determined metamorphic and plutonic ages in four widely separated parts of Arizona and adjacent Sonora of between 1660 and 1800 million years (Silver, 1961; Damon, 1962; Lanphere and Wasserburg, 1962). The same investigators, using the same methods, also report 7 new dates between 1240 and 1500 million years from Arizona and adjacent Southern California (Silver, 1962; Damon, 1962). It now remains uncertain whether this spread of dates indicates 500 million years of repeated mineralgenic activity, or a 1660-1800 million year event followed by differential loss of daughter isotopes. Lanphere (1961, 1962) suggests two events for southeastern California and adjacent Nevada and Arizona, one around 1350-1450 million years ago, and one between 1650 and 1800 million years ago. Damon (this guidebook), however, considers that the younger dates from central Arizona might be due to loss of daughter isotopes due to deep burial.

Working by analogy to other, better-understood orogenic belts, we might suspect that mineralgenesis was distributed throughout the life of the geosynclinal province, largely restricted to intervals of pronounced activity separated by tens or hundreds of millions of years. For example, the "Appalachian orogeny," in the broad sense, is no longer considered a terminal event of Appalachian geosyncline history, but rather a series of events occurring through the life span of the geosyncline.

Thus, despite the fact that field evidence has revealed no direct evidence of early plutonic-metamorphic activity in the Arizona Older Precambrian, the many fault contacts may conceal a complex history heretofore unsuspected.

## CONCLUSIONS

As a working hypothesis, I propose that all of the rocks described belong to a single geosynclinal sequence . . . as all of the Paleozoic rocks of the eastern North American border belong to the Appalachian geosynclinal sequence. Thus, we may expect that accumulation, deformation, metamorphism, and igneous intrusion extended over several-hundred million years, and that several unconformities, locally severe, may exist within the sequence. Perhaps our inability to find the pre-geosynclinal basement rock is due to the fact that accumulation began, not as in the Appalachian example upon a pre-existing continental basement, but upon the floor of the ocean, as suggested by Deitz (1962). If this is true, we can suggest a crude correlation of rock associations within the overall sequence based upon a somewhat hypothetical evolution of depositional facies. By this hypothesis, the oldest strata are basic volcanic rocks, ferruginous cherts, and thin limestones, presumably accumulated in deep or isolated water relatively free of non-volcanic detritus. Magmatic evolution in this primary stage produced some quartz-bearing rocks. After initial deformation, subaerial erosion of the uplifted blocks provided clastic detritus to a still unstable basin, so that shale, wacke, and conglomerate were deposited, along with a variety of volcanic rocks and volcanic sedimentary rocks. With time, quartz-bearing magma gained ascendancy over more mafic types, as reflected in the composition of sediments resulting from repeated uplift within the geosyncline. The cycle culminated with a general envelopment in granitic magma, some of which erupted onto the surface. The synorogenic rhyolites may grade imperceptably into granite and bear little evidence of the regional metamorphism and structural deformation that affected the earlier strata. There is evidence to support such an hypothesis, both in Precambrian geosynclines where the sequence has been mapped, and in such modern environments as Japan and the Philippines, where geosynclinal evolution is still in progress. This is my own adaptation of an hypothesis most recently expounded by Engle (1961).

The chart presented below illustrates a proposed correlation of Arizona's Older Precambrian rocks derived from considerations outlined in the preceding sections of this paper.

According to this hypothetical correlation, late Older Precambrian rocks are known only in the Mazatzal and Diamond Butte areas. If earlier (Pre-Deadman) metamorphism and plutonism occurred elsewhere within the province, there would be no way to discover its existence by mapping alone. Thus, it would not be surprising if the Middle and even Early rhyolitic eruptions were accompanied at depth by metamorphism and plutonism within portions of the "Mazatzal geosyncline." These early deformed belts could have remained elevated to provide source areas for sediments deposited in the remaining basins. Obviously, the key lies in further mapping, accompanied by mineral dating.

PROPOSED CORRELATION OF OLDER PRECAMBRIAN ROCKS IN ARIZONA

| | Diamond Butte | Mazatzal Mountains | Pinal area | Dragoon area | Jerome areas | Bagdad area | Grand Canyon |
|---|---|---|---|---|---|---|---|
| | Hell's Gate rhyolite | | | Mazatzal Revolution | | "terminal pulse" | |
| Late orogenic rhyolites, minor basic volcanics, & sedimentary rocks | Oxbow fm. Haigler fm. Board Cabin fm. | | | | | | |
| Pre-late orogenic quartz-rich clastic deposits | Houdon fm. | Mazatzal Maverick Deadman | | | | | |
| Unconformity; no associated metamorphism or plutonism recognized | | | | | | early phase? | |
| Middle rhyolites, varied volcanic & sedimentary rocks | Flying W fm. | Red Rock rhyolite (in part?) | rhyolite or quartz dacite | | Chaparral Green Gulch Iron King Spud Mtn. Indian Hills | | |
| Early shales, wacke, quartz sandstone, and conglomerate | Alder fm. | Alder series | sandstone, wacke, shaley beds | wackes, arkose, conglom. | Texas Gulch fm. | shale, sandy shale, sandstone | Vishnu series |
| Hypothetical disturbance | | | | | | | |
| Early rhyolites and andesites | ? | Red Rock(?) rhyolite (in part?) | | rhyolite | Ash Creek group rhyolites | rhyolite-andesite shale | |
| Early basic volcanic rocks & jasper | basalt, slate, thin limestone & cherts | Yaeger greenstone | | basalt, jasper | Grapevine Gulch fm. | basalt & thin sedimentary layers | basalt & thin shales |

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