The red Member of the Mazatzal Peak Quartzite and its contact with the underlying Maverick Shale in the Mazatzal Mountains of Arizona

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INTRODUCTION

The Mazatzal rock group is well exposed in the Barnhardt Canyon area of the northern region of the Mazatzal Mountains of Central Arizona. The red member of the Mazatzal Peak Quartzite is approximately 190 m thick, and lies above the Maverick Shale and the Deadman Quartzite, respectively, in the stratigraphic column (Doe and Karlstrom, 1991).

In this project, the basal 30 m of the Mazatzal Peak Quartzite and the upper 19 m of the Maverick Shale were studied. Specific segments of this succession were recorded (FIGURE 1) at two localities, Barnhardt Canyon and Shake Tree Canyon, located between Cactus Ridge and Sandy Saddle (R. Cox, this volume). All of these strata are of Proterozoic (1.7 b.y.) age (Doe and Karlstrom, 1991) and reflect minor deformation and sub-greenschist grade metamorphism (Cox and Lowe, 1996). Folding in the section is more common in the more malleable Maverick Shale.

The objective of this project is to determine the paleo-environments of the basal Mazatzal Peak Quartzite and upper Maverick shale. The data argue that the upper Maverick represents an off-shore environment, while the overlying Mazatzal is inter-tidal and shallow subtidal. Additionally, the study seeks to show the gradational nature of the contact, and the depositional relation of the two stratigraphic units.

MAVERICK SHALE

The upper 19 meters of the Maverick Shale is composed of inter-bedded shales and quartzites. Shale beds are flaggy, thinly laminated, and highly fractured. The color of the shales is brownish green to tan, and grain sizes are in the muddy-silt range. The sandstone colors are white to tan. The thinner quartzite layers (2-10 cm) tend to pinch laterally while the thicker off-white layers are locally laterally extensive. Compositionally, the sandstones are almost exclusively quartz, but chert, volcanic fragments, and metamorphosed marble and siltstone are also apparent. Sorting is moderately poor due to a significant muddy matrix. Individual quartz grains are well sorted, well rounded, and display overgrowths.

MAZATZAL PEAK QUARTZITE (RED MEMBER)

Results. In order to interpret the paleo-environment, sedimentological features and primary structures were analyzed to give a detailed sedimentological description and to reconstruct the basal 30 m of the quartzite. The features in the quartzite which stand out are its low mud content, clear evidence from primary sedimentary structures for frequent change in water depth, including periodic exposure to the air, and finally evidence for considerable changes in water velocities, including tidal flow reversals.

The Mazatzal Peak Quartzite is >95% quartz with apparent volcanic fragments, chert grains, and metamorphosed marble and siltstone fragments. Cox (1995) reports that feldspar is rare and is mostly microcline. Grains are well-rounded with distinct overgrowths, well-sorted, and almost entirely lacking a muddy matrix. The grain size ranges from 0.062 mm to clasts of up to a few mm with the least variation within beds. In some areas, 3-8 cm layers of 0.35-1 mm grain size quartz grains inter-finger with units of 0.062 mm-0.088 mm quartz grains.

Stratigraphically, the Mazatzal Peak Quartzite is locally laterally continuous. The majority of individual layers of both quartzites and shales extend horizontally for 10-15 m, usually the length of the outcrop. Mud layers and partings, however, pinch within outcrop distances with greater frequency than the quartzite. A few quartzite layers per 5 meters pinch or thin laterally, especially if bed thickness is controlled by the cross-bed sets. On a larger scale, comparing sites separated by miles, individual stratigraphic layers are nearly impossible to correlate.

Cross-bed sets are very common. Although tabular and trough cross-bedding are observed, the majority of sets are very low angle and seem to be laterally extensive combinations of trough and tabular types. Apparent dips on cross-bed laminations generally range between 5-15 degrees. Occasional fining up sequences occur between individual laminations, but more commonly, the entire set fines upward to very fine sand or siltstone. Thickness of individual cross-bed sets range from 4-30 cm, often depending on the thickness of other beds in the area of section.

Mud draping in some cross-beds accounts for apparent concave down cross-bedding or the truncation of laminations at the base rather than the typical tangential base of the sets.

Herringbone megaripples are present in a few places and were also noted by Trevena (Ronadh Cox, Mar 2, 1999). In many cases paleo-flow changes to the opposite direction between two adjacent layers. Trough cross-bed sets in several instances were observed to be anti-parallel. Generally, however, cross-beds in localized areas are oriented in similar directions (FIGURE 2).

Hummocky cross-stratifications have very low angle parallel bedding surfaces which alternate concavities that form an undulating pattern, often truncating at the base of the bed (accompanied by mud drapes), similar to those described by Swift et al. (1983). Beds range in thickness from 5 to 15 cm and are as long as 112 cm. (FIGURE 3)

About 8-12 meters above the contact, in most localities, the section is dominated by thin (2-12 cm) planar beds of quartzite, with regular layers of constant lateral thicknesses. Individual beds are generally graded, planar laminated, massive, or, rarely, tabular cross-beds. Graded beds show little internal sedimentary features and grain sizes of up to 1 mm (base) and as fine as 0.125 mm (top). Throughout the 30 m of basal Mazatzal Peak Quartzite, many beds with varying sedimentological structures fine upwards. Additionally, many of the massive or fining up planar beds have distinct, finely spaced horizontal laminations.

Ripples are common throughout the 30 m and continue at intervals for at least 50 to 60 meters above the 30 m section, I measured. Ripples are detectable almost exclusively in thin mud layers which rarely crop out into overhangs, hence, the exact stratigraphic spacing of ripple horizons is hard to determine. Where outcrop overhangs are present, slightly asymmetric oscillatory ripples can be seen, and these are common; they are occasionally visible in cross section. Most ripples are long crested, straight, parallel, and slightly asymmetric; however, examples of asymmetrical current and oscillatory wave ripples exist. Both ladder structures and interspersed long crested pinching ripples have been observed. Wavelengths range from 5-20 cm, while amplitudes range from 2 mm to 2.9 cm. Ripples are typically either part of an underlying cross-bed set or separated by thin mud laminations. Occasional fine grain quartzite partings have current lineations.

Bedding surfaces showing mud cracks are rarely seen and restricted to the soles of overhanging sand units (FIGURE 4), but mud chips seen in cross-views of the quartzite layers are very common. The mud chips are angular and display angular disc geometry; thus, they presumably originate from eroded mud cracks. Exposed mud cracks are non-polygonal to sub-polygonal and are present as primary, secondary, and tertiary crack systems. While some cracks are thin and random, others are interconnected with crack widths of up to 2 cm. Lengths of individual cracks range from 3-4 cm (more commonly) to 39 cm long. In one locality sub-polygonal mud cracks traverse a current influenced oscillatory ripple horizon. Some cracks are bulbous in the center and pinch at both ends.

Mud rip ups are scattered throughout the section, and often form entire horizons. The majority of individual rip up clasts are millimeters thick and a centimeter long. A few of the larger rip ups have been found to be imbricated. Commonly the rip ups are in the basal few centimeters of the quartzite bed, aligned in the form of an apparently broken up mud layer, but they may also be located sporadically throughout a bed at any orientation. The rip ups seem to indicate a mud layer which was aerially exposed, cracked, and the flakes of mud were picked up in the water flow and deposited in the overlying layer.

There is clear evidence for cut and fill erosion. In sections with cross-bedding and coarse grained layers, the bed below has been eroded into deeply and filled with planar laminations or massive quartzite from the bed above. Cut and fill is are often seen in conjunction with inter-fingering medium to coarse grain quartzites and thin (4-7 cm thick) planar bed sequences. Clear examples of reactivation surfaces and mud draping were recorded in a couple of locations (FIGURES 5 & 6). About 1.4 m above the contact with the Maverick Shale, mud laminations in a 8 cm quartzite bed mark soft sediment deformation, and 16 cm down section loading is evident (FIGURE 7). Load casts are present in several mud layers, reaching 8 cm in length and protruding less than 1 cm below the base of the bed.

Interpretations. Observations of the basal 30 m of the Mazatzal Peak Quartzite indicate an intertidal to subtidal depositional environment. According to Trevena (1979), Mazatzal group quartzites were deposited in a shallow marine environment with a close by crustal source area. Both water velocity and depth vary widely between thin (5-50 cm) quartzite layers and inter-bedded mud horizons. The presence of asymmetric current and wave ripples, cross-bedding, cut and fill, and hummocky cross-stratification provide evidence for subaqueous deposition. Mud cracks inter-bedded with subaqueous features (in the case of mud cracked ripples, they occupy the same horizon), dictate cyclical exposure of sediment to air and water. Mud horizons commonly overlie cross bedded quartzites, such that depositional conditions changed from moderate velocity deeper water to near stagnant shallow water to exposure to the air. These sequences, combined with the local lateral continuity of layers, strongly suggest a paleo-environment of tidal flats. Additionally, cut and fill structures and reactivation surfaces support a paleo-environment which is intermittent with dry spells and erosive tidal flooding. The long crested current influenced wave ripples and the herringbone cross laminations record tidal transgression and retreat. Cross-beds in a localized area commonly display unidirectional flow, suggesting that tidal inflow and outflow dominated different regions on the flats.

MAVERICK SHALE- MAZATZAL PEAK QUARTZITE CONTACT

Results. The contact between the Maverick Shale and the Mazatzal Peak Quartzite can be stratigraphically located within an abrupt 20-40 cm. Detailed logs of the contact zone reveal inter-bedded shales and quartzites in the contact region (FIGURE 8). It is hard to determine the exact location where the quartzite stops being distinctly Maverick Shale and becomes Mazatzal Peak. No apparent large scale shear zone divides the two units, nor does an obvious gap in section.

The sand to shale ratio changes significantly across the contact, with an upper Maverick value of 70:30 and a lower Mazatzal value of 95:5. The Maverick Shale quartzites have a higher percentage of quartz (~98% Qtz), are more poorly sorted, and have a greater percentage of matrix, than the Mazatzal Peak quartzites (90% Qtz). Additionally, the contact marks a blatant color change from tannish green with off-white quartzite layers in the Maverick to the salmon, reddish pink quartzites and brick-red, burgundy shales of the Mazatzal.

Sparse primary structures in the upper Maverick include rare hummocky cross-stratification, tabular and trough cross-beds, planar bedding, and cut and fill structures. The Maverick shale, unlike the Mazatzal, is dominated by pinching quartzite lenses and a lack of lateral continuity. Periodic 40-50 cm thick white quartzites provide the exception and remain continuous throughout the field of view.

Interpretations. The nature of the contact is gradational. Doe and Karlstrom (1991) record the Mazatzal Peak quartzite as conformably overlying the Maverick Shale. Individual thin quartzite layers in the contact zone display characteristics of both units, indicating deposition in a transitional paleo-environment.

Data shows that the paleo-environment clearly changed across the contact. The Maverick Shale represents a lower energy environment in relatively deep off-shore waters, suitable for deposits of well sorted shales. Trevena (1979) interprets the Maverick to be either an offshore to nearshore marine or lacustrine deposit, or a coarsening up delta sequence. The coarser grain size, abundant cross-beds, ripples, and mud cracks of the Mazatzal indicate a higher energy tidal setting with shallow water and frequent exposure above water. The red color of the Mazatzal Peak Quartzite indicates iron reduction at shallow water levels, while the greenish tint and lack of reddening in the Maverick suggests that the water depth prevented the shale from having a chance to reduce effectively.

CONCLUSION

The abrupt gradational contact between the two units records the transition from the offshore environment of the Maverick Shale to inter-tidal and tidal flat deposits of the Mazatzal Peak Quartzite. The individual sand grains in the Maverick and the Mazatzal are nearly identical. Both show grains that are well rounded, compositionally well sorted, and predominantly quartz with apparent chert, volcanics, marble, and siltstone. The Mazatzal quartzites stand out as mature, well-washed sands that lack a mud matrix while the Maverick has a significant mud matrix. From these results, it can be concluded that the tidal flats and intertidal deposits of the Mazatzal Peak quartzites are the source for the quartzite layers of the off-shore Maverick. The quartzite grains of the Maverick, nearly identical to those of the Mazatzal, were transported from the tidal region off-shore into the shales during periodic storms and were subsequently deposited with a mud matrix to form the quartzite layers of the Maverick. Mazatzal sands in a distant locality, the same age as the Maverick sands in the study area, provided a source of sediment for Maverick quartzite deposition. Therefore, I postulate that the Maverick-Mazatzal contact is time transgressive.

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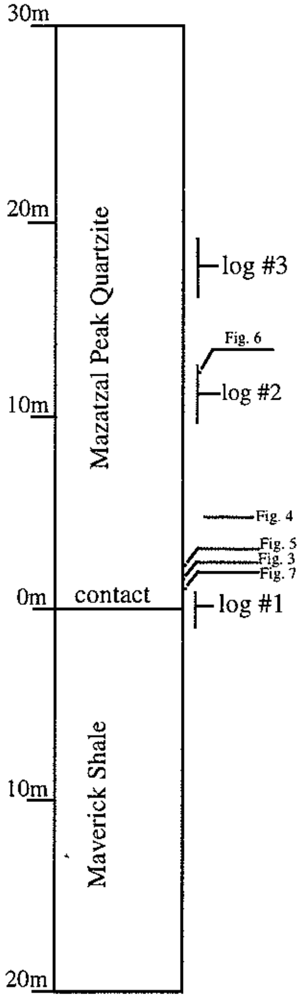

FIGURE 1: stratigraphic section studied

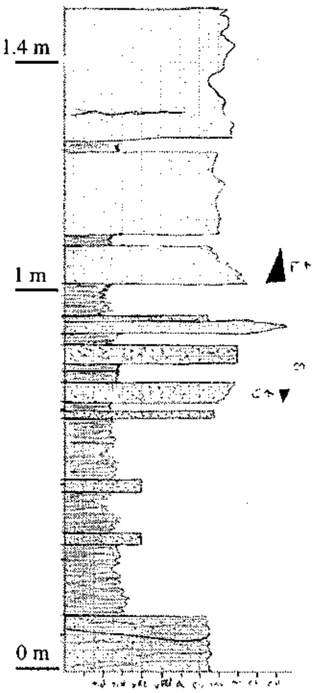

FIGURE 8: log #1 contact region

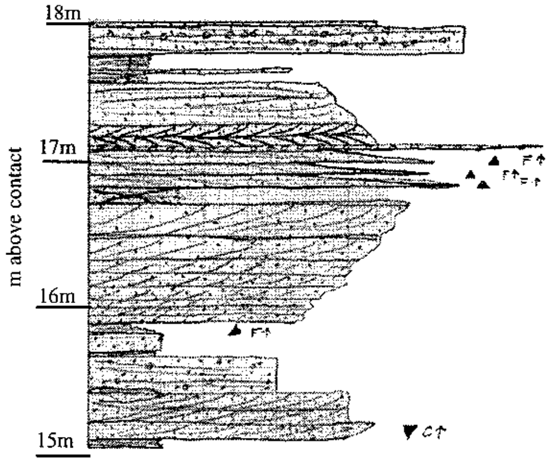

FIGURE 2: log #1 showing cross bedding & cross-stratification

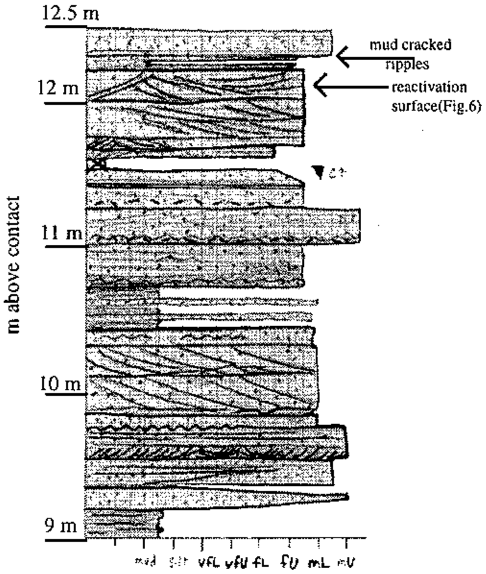

FIGURE 9: log #2

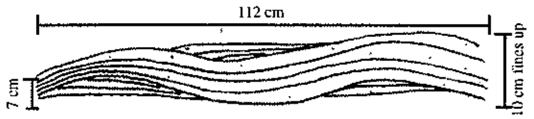

FIGURE 3: hummocky cross-stratification

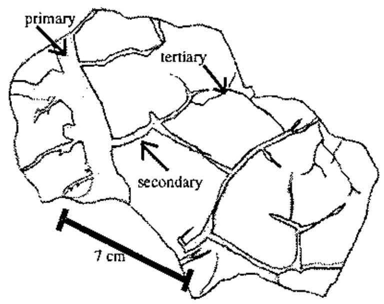

FIGURE 4: mudcracks

FIGURE 5: mud draped reactivation surface

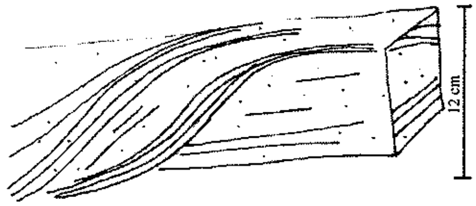

FIGURE 6: reactivation surface

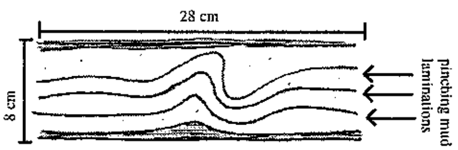

FIGURE 7: soft sediment deformation