CHAPTER TWO

GEOLOGICAL CHARACTERIZATION

Purpose and Objectives

An important component of this study was to summarize the geology of the Mint Wash / Williamson Valley System (MWWVS). Geologic studies for the study area available to the public are limited. The results of this study have been combined with the results of previous studies to provide a cumulative summary of the known geology of the area. This study describes the basic geology of the Mint Wash / Williamson Valley area, including lithologies, structure and basin formation.

The geological characterization includes a geologic map (Plate 1), cross sections throughout the study area (Figures 5-9), fracture orientations of the Proterozoic granite (Figure 10), fault orientation, tectonic classification of the basin, a stratigraphic column (Figure 11), and stream bed mapping. These features provide insight on the geologic history of the area, as well as the causes for the formation of the basin.

Introduction

The MWWVS is located within the Transition Zone physiographic province (Figure 2). The Transition Zone represents a gradation from the Colorado Plateau to the Basin and Range physiographic province. The basin in the MWWVS shows morphological trends similar to those common in the Basin and Range (Figure 1).

The MWWVS has rocks from the Proterozoic eon, and Paleozoic and Cenozoic eras (Krieger 1967a and 1967b). The Mesozoic Era appears to have been a time of erosion or no active deposition for the area, as there are no lithologies of Mesozoic age (Krieger 1967a and 1967b).

Methods

Geologic Map

A geologic map was created and revised using traditional field mapping techniques as well as aerial photography. Aerial photography was available for the southern half of the field area and was provided by the National Forest Service (NFS 2000). Field mapping was conducted on 1:24,000 USGS quadrangles using a Brunton transit and a protractor to map the location of contacts relative to landmarks.

Krieger's (1967) 1:62,500 scale maps were used during several reconnaissance trips to verify the contacts that were easily accessible. Areas that were difficult to access were mapped during two, week-long field trips, and subsequently compared to the maps produced by

Krieger. Most of the alluvium was mapped in the field. Areas that were inaccessible were mapped using aerial photography. There were several areas where alluvium was not mapped by Krieger but was included in the map produced in this study due to the difference in scale between the two maps. Krieger's (1967) maps were found to be accurate and not many alterations were made except for some detail of the contacts along the Sullivan Buttes.

Most of the field mapping was completed during a week long field trip in August, 1999. Accessible areas were visited during monitoring trips. The geologic map was finalized during a week long field trip in July, 2000 and subsequent aerial photo interpretation in the office.

The geologic map was digitized in ArcView (ESRI 1999), using a large digitizing tablet and the hard copy quadrangles that were used in the field. The lithologies were represented as geo-referenced polygons in ArcView. Digital Elevation Models (DEM) for the area were provided by the Arizona Land Resource Information System (ALRIS 2000). The DEMs were imported to ArcView and contoured. The contoured surfaces were overlain by the digitized polygons representing the lithologies.

Cultural feature GIS data was also provided by the Arizona Land Resource Information System. These coverages were imported into ArcView, and overlay the contoured surface as well as the lithology coverages. The digital cultural feature data used in this map include washes, faults, and Universal Transverse Mercator (UTM) coordinates. These data provide landmark references for the lithologic mapping.

Cross Sections

The cross sections were created from surface maps and lithologic information recorded on driller's logs for several wells throughout the study area. The location of the wells were found using the ADWR well registry CD (ADWR 2000). The UTM coordinates for each of the wells were imported into ArcView and plotted on the contoured surface of the DEMs with a contour interval of 5 meters. The proximity of the wells to the contours was calculated, which gave a precision of 2.5 meters for the well elevations.

The lithologic changes identified in the driller's logs were interpreted using knowledge of the local geology provided by previous studies (Kreiger 1967). The stratigraphy between the wells along the section line was assumed using the stratigraphic relation of the wells and assuming that extensional tectonics were responsible for basin formation in the Tertiary.

Fracture Orientation

The average orientation of three sets of fractures within the granite was measured at several points throughout the Granite Mountain Wilderness Area. The measurements were taken to the north of the pluton apex at three sites where large outcrops of autochthonous granite were found (Figure 4). The measurements were taken

to the north of the pluton apex because these sites are in the direction of the field area relative to Granite Peak. The dominant fractures in a granite pluton are tension fractures and strike radially from the apex of the granite pluton (Castro 1984). Tension fractures provide insight on the emplacement of the granite pluton by striking radially from the granite pluton apex, and are the major conduit for fluid flow within a granite pluton (Larsson 1972). Shear fractures tend to have a smaller aperture than tension fractures and are usually less laterally extensive. Shear fractures usually strike perpendicular to tension fractures, and are responsible for dispersive fluid flow between the tension fractures (Larsson 1972).

Stream Bed Mapping

Grain-size analyses of the material within the washes were conducted. The sampling sites chosen are along the major washes within the study area. The sites within each wash were chosen based on proximity to the sediment source and the accessibility of the desired sites.

The samples were collected by digging a 2 foot hole in the middle of the wash. The stratigraphy of the material was described, then samples were collected representative of the described section. The samples were then dry sieved and weighed to determine the percent grain-size distribution of the material.

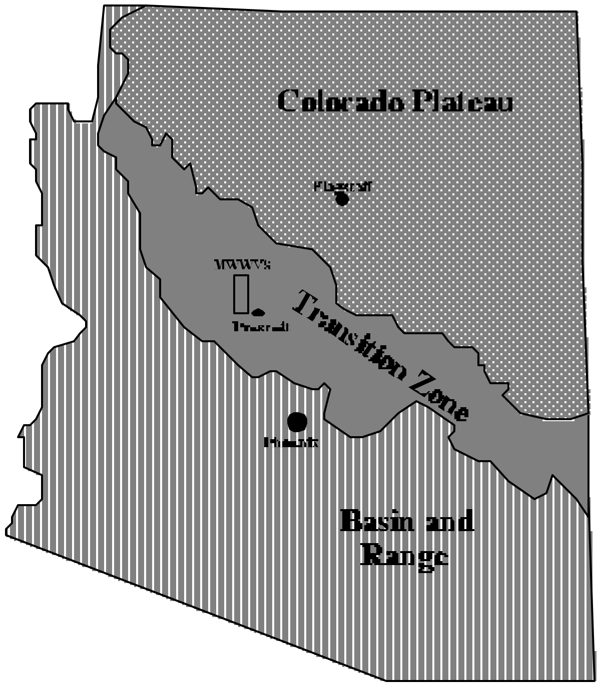

Figure 2. Physiographic provinces map of Arizona showing the location of the MWWVS.

Figure 3. Outcrop of Tertiary conglomerate in the MWWVS. Notice the cross bedding typical of fluvial environments. A-A’ is approximately 20 feet.

Results

The results of the geological characterization include a geologic map of the study area (Plate 1), cross sections throughout the study area (Figures 5-9), a stereonet of the fracture orientations for portions of the granite pluton (Figure 10), a stratigraphic column of the MWWVS (Figure 11), and a map showing the sampling locations for the grain-size distribution analyses within the major washes of the Mint Wash / Williamson Valley area (Figure 26).

Geologic Map

The geologic map is included as Plate 1. The map displays the lithologies found within the study area, and land surface contours at a 40 meter interval.

The areal distribution of the lithologies is clear in the geologic map. There are distinct zones of lithologies based on age and morphology. The southern portion of the study area is mainly Proterozoic granite (pCg), Proterozoic gneiss and schist (Yavapai Series) (pCy), or a combination of the two (pCgy), with some volcanic deposits to the east and west of Granite Mountain. The existing apex of the granite pluton is the crest of Granite Mountain. Granite Mountain has been specifically identified as a porphyritic quartz monzonite (Krieger 1967b). A recent age of 1.72 Ga was measured using U-Pb dating of zircon (Dewitt 1999). To the north and west of Granite Mountain (Plate 1) is a metamorphic belt, which is the location of most of the Yavapai metamorphic series (pCy) present in the MWWVS (Kreiger 1967b).

Williamson Valley begins to the northwest of the metamorphic belt. The dominant lithology within Williamson Valley is a Tertiary conglomerate that consists of the Paulden Formation and Perkinsville Unit. The conglomerate is fluvial based on common cross bedding

(Figure 3) (Buren 1992). The clasts in the conglomerate consist mainly of Proterozoic granite, gneiss, and schist, consistent with the description of one of the facies within the Paulden Formation.

Volcanic deposits are common in the northern portion of the MWWVS and consist of latite (Tl) and basalt (Tb) of Tertiary age. Volcanic deposits are centralized along the eastern boundary of the study area.

The concentration of Tertiary volcanic deposits and faults along the eastern boundary of the study area indicates that there was tectonic activity in this area during the Tertiary. The deposits are linear, and in the northern half of the area are coincidental with topographic relief. Previously mapped and inferred faults trend parallel to the topographic relief (Plate 1). The previously documented faults are defined as normal, which is consistent with the inferred faults, determined to be normal through the documented tectonic history, as well as the topographic relation and age of the units in contact at the faults.

The Sullivan Buttes represent the remnants of Tertiary volcanism. The dominant lithology of the buttes is Tertiary latite (Krieger 1967a and Krieger et al. 1971). At the surface the latite is highly eroded, however outcrops of Tertiary latite are visible along the flanks of the Sullivan Buttes.

Within the topographically higher Sullivan Buttes there are outcrops of Paleozoic and Proterozoic rocks. Williamson Valley consists of Tertiary conglomerate and Quaternary alluvium. Older lithologies along the buttes are topographically higher than younger lithologies in the basin, a scenario commonly related to extensional tectonism, mechanics that are known to occur in the region during the Tertiary.

Cross Sections

The location of the section lines are plotted on Figure 4. The cross sections include two section lines that trend along the main washes, one along Williamson Valley Wash (Figure 5) and the other along Mint Wash (Figure 6). Three more cross sections were created traversing the valley and the general direction of surface-water flow (Figures 7, 8 and 9). The location and extent of the section lines are based on the availability of subsurface data provided by well logs and interpretation of the geological conceptualization.

Section lines A-A' and B-B' show the transition from a complex geologic setting influenced by the granite pluton in section B-B', to a flat "layer cake" type of stratigraphy in Williamson Valley along A-A'. The granite underlies the Tertiary conglomerate in Williamson Valley, but there are no wells that penetrate the entire thickness of the conglomerate to the depth of the contact between the granite and the conglomerate in the lower half of Williamson Valley. Initial interpretation of aero-magnetic data indicates that a dense rock underlies the conglomerate at approximately 274 meters / 900 feet. It is inferred that this lithology is the Proterozoic granite. No Paleozoic rocks have been identified within Williamson Valley. The lower half of Williamson Valley may contain Paleozoic rocks that have not been exposed within the existing wells. Wells in the upper half of Williamson Valley indicate an unconformity with Proterozoic units in contact with Tertiary units. The thickness of the Paulden Formation in the MWWVS has been estimated at 900 feet (274 meters) based on an initial interpretation of aero-magnetic data recently collected by the United States Geological Survey (USGS) (Woodhouse 2000). Williamson Valley has been the site of fluvial deposition since the Tertiary Period (Buren 1992).

Tertiary conglomerate is found stratigraphically higher than the Tertiary volcanics as shown in Figures 7 and 8. This is likely the equivalent of the Perkinsville unit, which is younger than the Paulden Formation and the Tertiary volcanics (Buren 1992). The conglomerate within Williamson Valley may be a combination of the Paulden Formation and the Perkinsville unit. Tertiary volcanics can be used to differentiate between the Paulden Formation and the Perkinsville unit, but no volcanics have been identified within Williamson Valley to distinguish which conglomerate unit is present in the valley.

Section line C-C' shows the subsurface from Williamson Valley to the Sullivan Buttes (Figure 8). The cross section supports the hypothesis of extensional tectonics occurring between the buttes and the valley. Devonian Martin Formation and Mississippian Redwall Limestone have been documented to be tilted in the area. The orientation of the dip is towards the east on the eastern range bounding Williamson Valley. The tilt of the Martin Formation and the Redwall Limestone is consistent with the topographical dip along the western range bounding Williamson Valley. The stratigraphically lowest plane (oldest) along the tilted block is in contact with younger units, which is indicative of extensional tectonics. There are inferred normal faults which serve as indicators of extensional tectonics in cross sections D-D' and E-E' (Figures 9 and 10). The faults mapped on the cross sections have a general strike to the north, which is similar to orientations of normal faults in the adjacent Basin and Range physiographic province (Plate 1). Several of the faults in the Sullivan Buttes area were mapped by Krieger

(1967), the inferred faults throughout the rest of the study area were mapped in this study.

Fracture Orientation

A stereonet was created of the fractures that were measured in the Granite Mountain Wilderness (Figure 11). The three tension fractures that were measured in the field consistently have a strike to the northwest with high angle dips to the northeast. The three shear fractures are relatively perpendicular to the tension fractures with high angle dips to the southeast. These results were expected given the location of the sample sites relative to the apex of the pluton. The fault orientations that were measured are representative of the fractures at the outcrops where they were measured. The locations where the orientations were measured were selected based on the outcrop. Most of the granite at the surface of Granite Mountain is colluvium. The locations selected represent outcrops of autochthonous granite. A radial pattern of fractures would be concentric on a stereonet if there were fault orientation sites completely around the pluton apex. The sites of fracture orientation for this study were located only to the north of the pluton apex (Figure11) and therefore only show tension fracture orientations to the north. The tension fractures generally had larger apertures and were laterally more extensive then the shear fractures, but tend to be less abundant (Table 1).

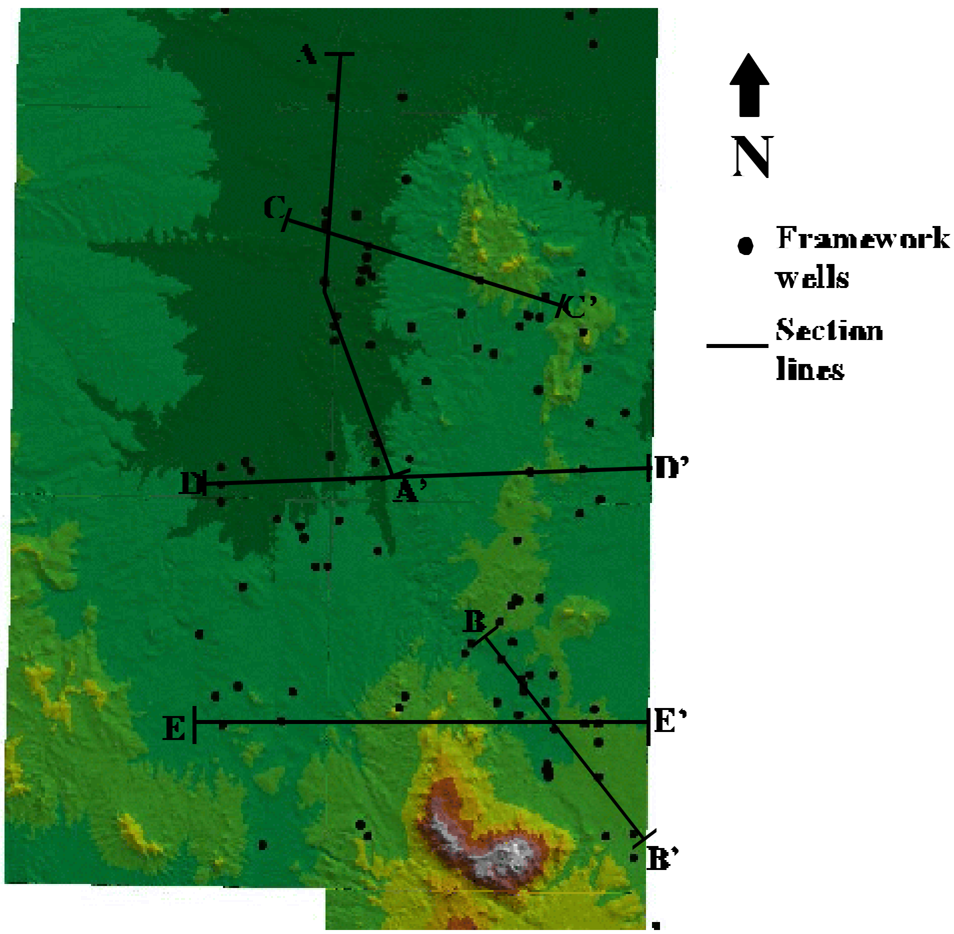

Figure 4. Location of the section lines in the MWWVS. AA' and BB' trend along the strike of the basin, and CC', DD' and EE' traverse the basin. Refer to Figure 19 for georeference.

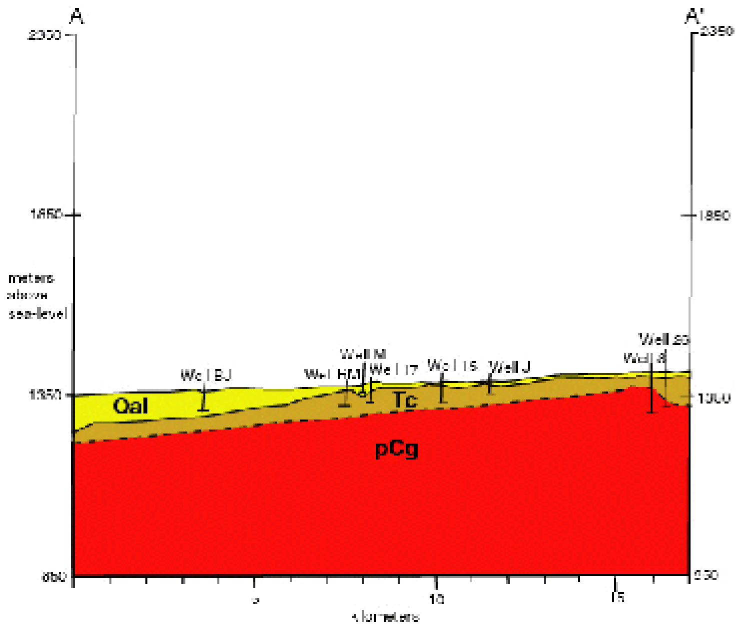

Figure 5 - Cross section A-A', MWWVS. Vertical exaggeration = 10X.

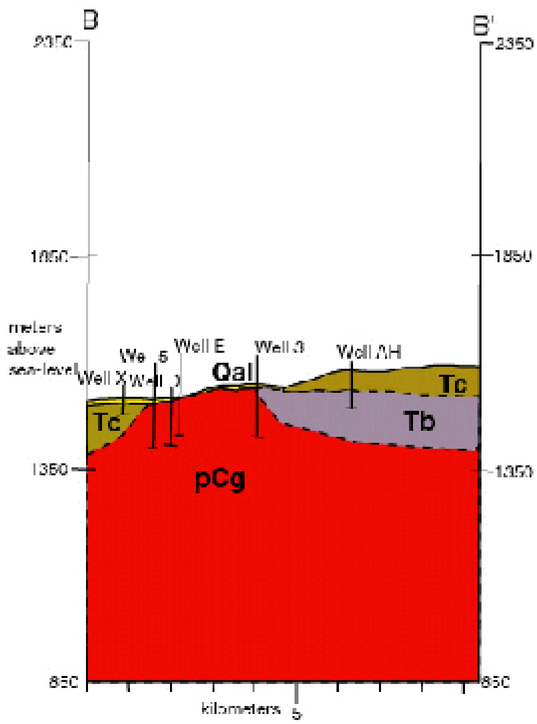

Figure 6 - Cross section B-B', MWWVS. Vertical exaggeration = 10X.

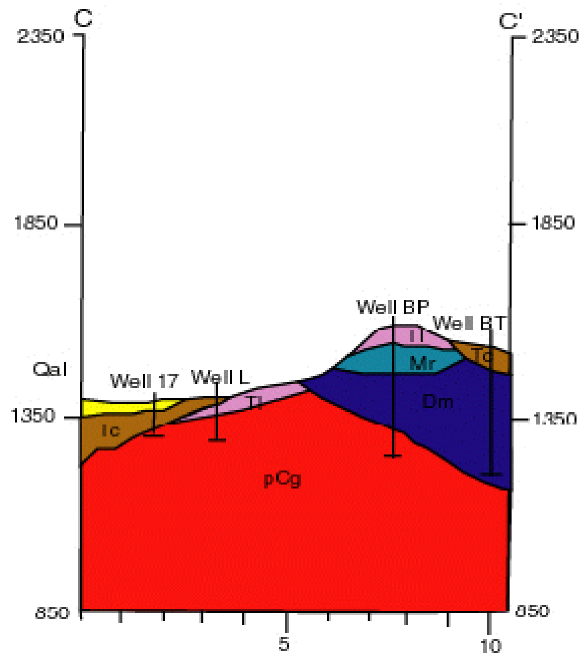

Figure 7 - Cross section C-C', MWWVS. Vertical exaggeration = 10X.

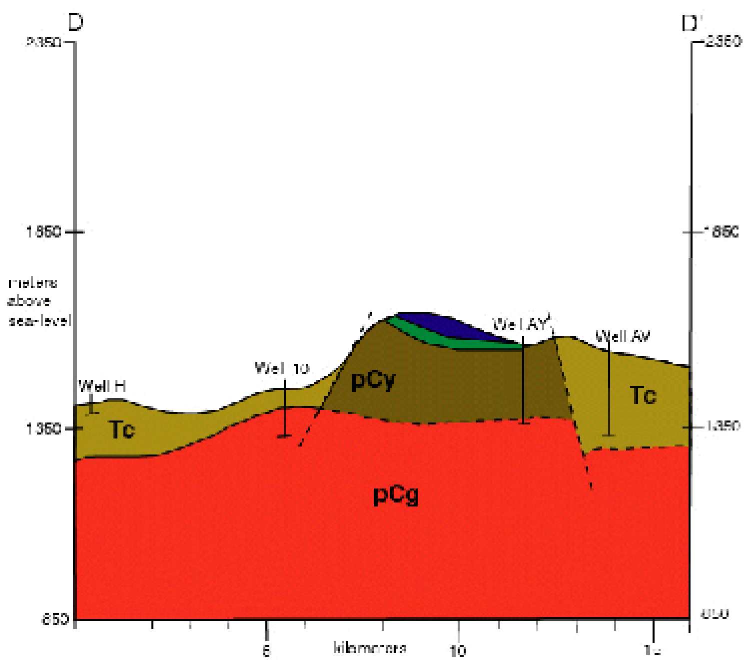

Figure 8 - Cross section D-D', MWWVS. Vertical exaggeration = 10X.

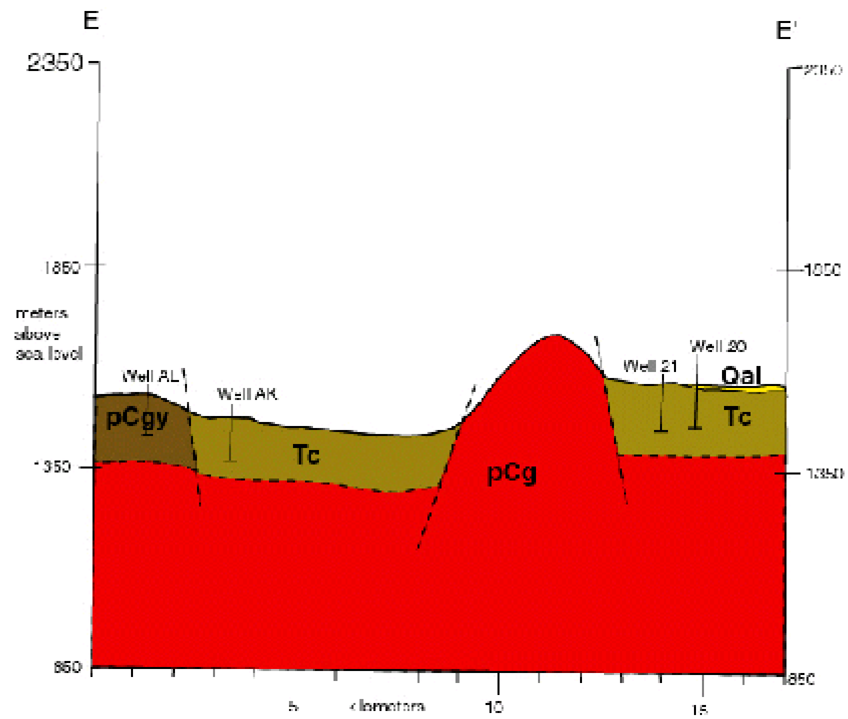

Figure 9 - Cross section E-E’, MWWVS. Vertical exaggeration = 10X.

Stream Bed Mapping

The results of the grain size analysis are included in Table 3. The sample sites are shown in Figure 26. Cobbles, pebbles and sand form the majority of the material at the sites closer to areas of high relief. The distribution grades towards finer grained materials away from the high relief, towards the valley. This distribution was expected due to the mechanics of sediment transport. Higher relief creates more kinetic energy with fluid motion, making the fluid capable of transporting larger material.

Conclusions

The geologic history of the area includes emplacement of a granite pluton into what is currently a metamorphic complex of gneiss and schist during the Proterozoic, at approximately 1.72 Ga (Dewitt 1999). There was a marine environment in the study area during the Paleozoic as demonstrated by the Devonian Martin Formation and Mississippian Redwall Limestone. The Martin Formation and Redwall Limestone units have been identified as marine environments in the area by several workers (Celestian 1979, Meader 1977, Smith 1974, Gutschick 1943 and Kent 1975). The geologic history of the area is summarized in a stratigraphic column showing lithologies present in the MWWVS (Figure 11).

Within Williamson Valley there are no outcrops of lithologies from the Mesozoic era, so there may have been a non-depositional setting during the Mesozoic, or post-depositional erosion. A fluvial environment was present during the Tertiary (Buren 1992). Volcanic activity and northeast-southwest extensional tectonics also occurred in the middle of the late Tertiary

(Krieger 1967 a and b, Krieger et al. 1971). The Quaternary is marked by alluvial deposition only within the active washes.

Normal faults are present throughout the MWWVS. Normal faults are most commonly found at gradient changes in the topography, and strike parallel to Williamson Valley. Several faults are found around Granite Mountain, and may be related to the granite emplacement.

Analyses of fracture orientations were measured at three outcrops exposing autochthonous granite. The orientation of the tension fractures trend radially from the crest of Granite Mountain, which is assumed to be the pluton apex. The fracture orientation is consistent with a model developed for fracture orientation resulting from pluton emplacement (Larsson 1972).

The basin morphology would suggest that Williamson Valley basin is a half graben. The half graben is formed by the normal fault between the Sullivan Buttes and Williamson Valley, and the low gradient slope from the apex of the basin up to the west forming the eastern flank of the Santa Maria Mountains (Plate 1). This basin is in the Transition Zone bounding the Basin and Range physiographic province. The tectonics that occurred in the region during the Tertiary supports the theory that Williamson Valley is a half graben.

Table 1. Fracture measurements from the Proterozoic granite in the Granite Mountain Wilderness Area, MWWVS.

Site Tension Fracture	**Orientation**	**Dip**	**Relative Aperture Size**	**Concentration (fracture/meter)**
1	67º	76º	large	6
2	10º	84º	small	13
3	32º	71º	large	5
Site Shear Fracture	**Orientation**	**Dip**	**Relative Aperture Size**	**Concentration (fracture/meter)**
1	129º	80º	small	11
2	122º	61º	large	7
3	114º	84º	small	6

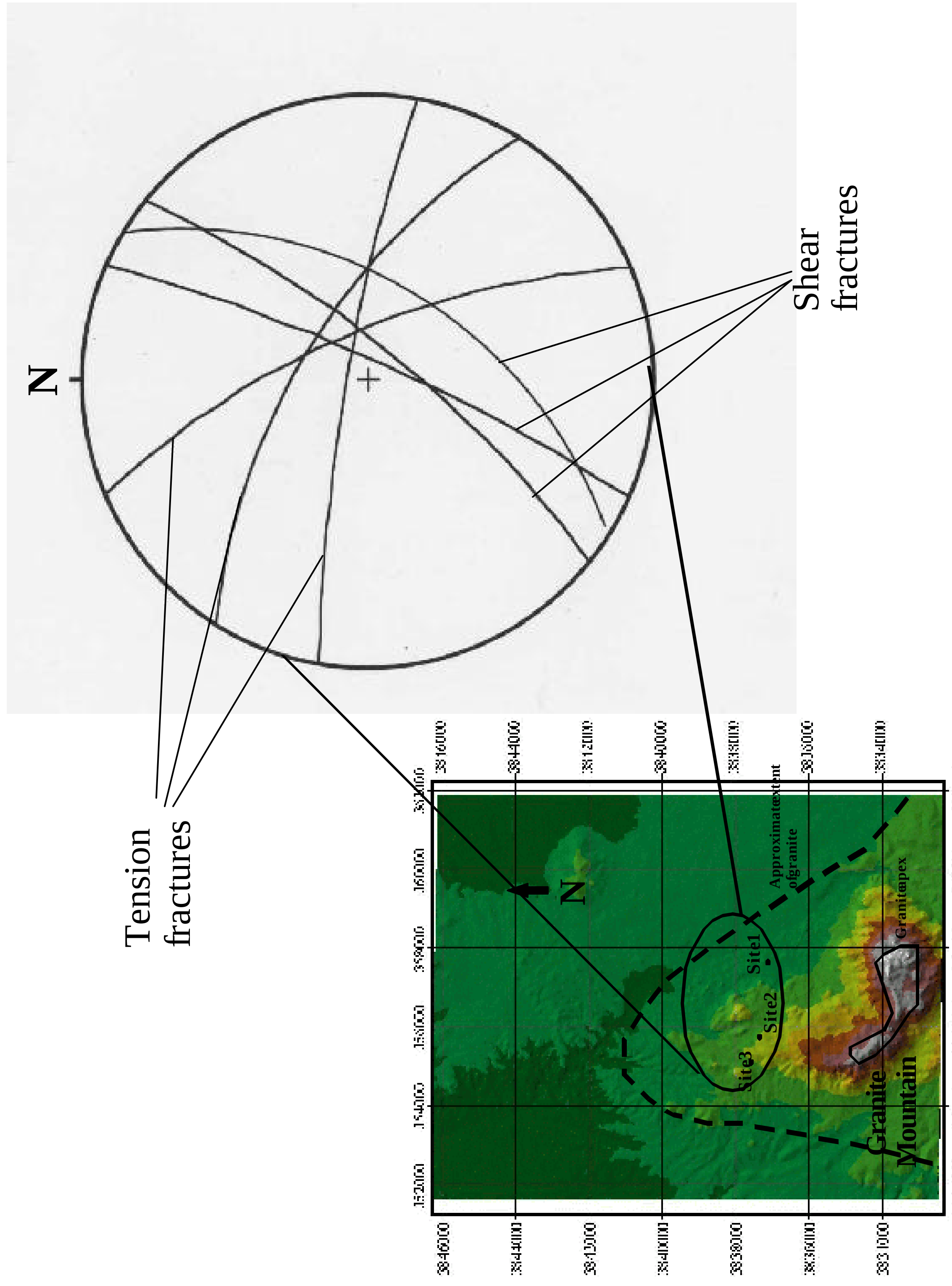

Figure 10 - Stereonet of the fracture orientations measured in the Proterozoic granite in the MWWVS.

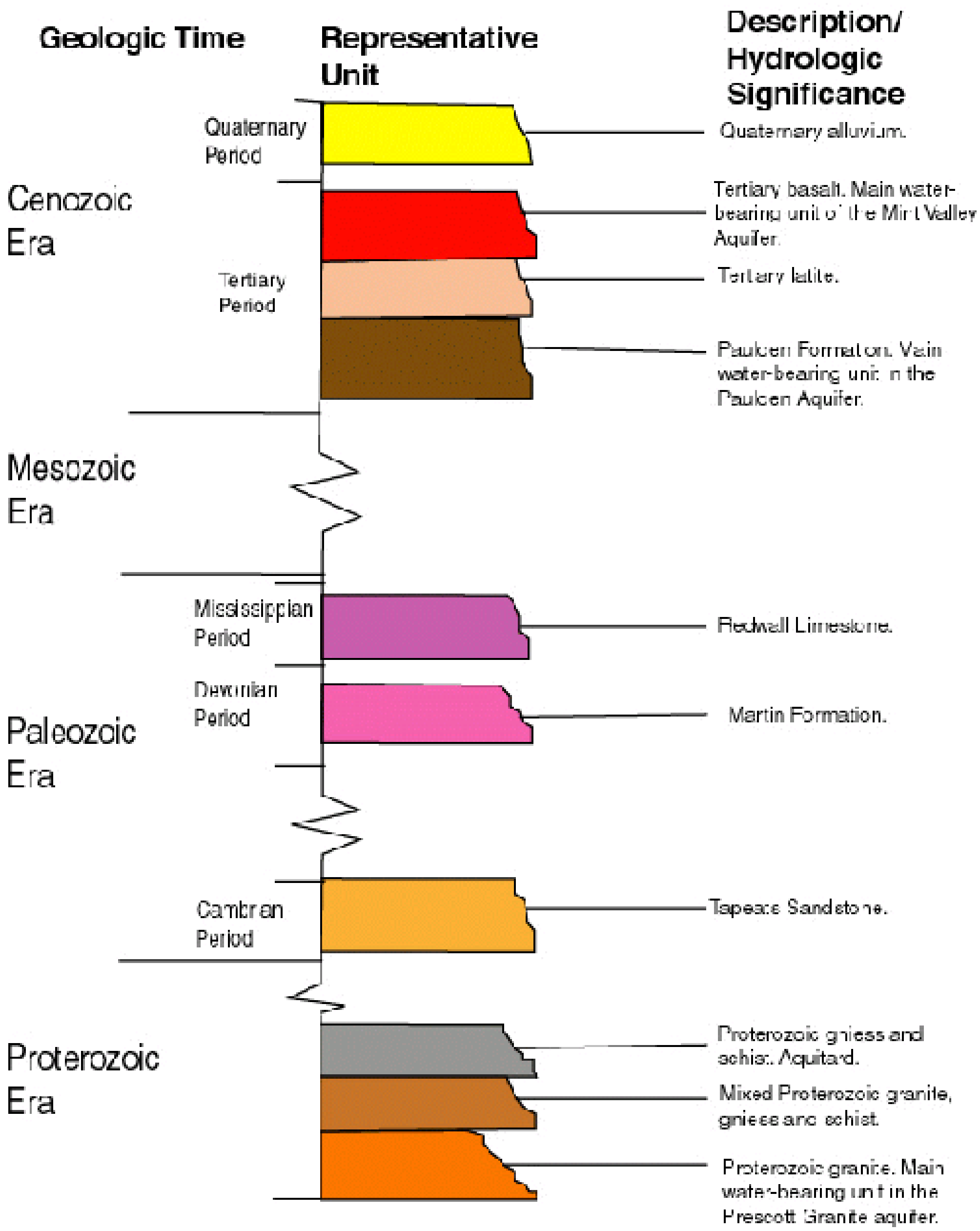

Figure 11 - Stratigraphic column for the MWWVS.