THE GEOLOGY OF THE CENEZOIC SEDIMENTARY ROCKS IN THE ASH MEADOWS AREA, DEATH VALLEY, CALIFORNIA AND NEVADA: IMPLICATIONS IN TECTONIC EVOLUTION OF THE NORTHERN DEATH VALLEY REGION

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CHAPTER ONE

INTRODUCTION

The Death Valley Region lies in the southern Basin and Range Province of the southwestern United States (Figure 1). The province covers about 80,000 km^2 area between the southern Sierra Nevada and the Colorado. The area is characterized by a series of tilted fault blocks formed by normal faults that trend north-northeast to south-southwest. The rocks on the western side of the faults, the hanging wall block, are dropped down relative to the rocks on the eastern side of the fault, the footwall block. This extensional faulting forms a high topographic relief, which is the characteristic topography of the region.

Although most of the major structural features of the Death Valley region was outlined by Noble (1941) and Noble and Wright (1954), the detailed structural geology studies of the region were started in late 1960's. Hill and Troxel (1966) related most of the structural features in the region to dextral shearing along the strike-slip faults in the area, such as the Furnace Creek and Sheephead fault zones. Burchfiel

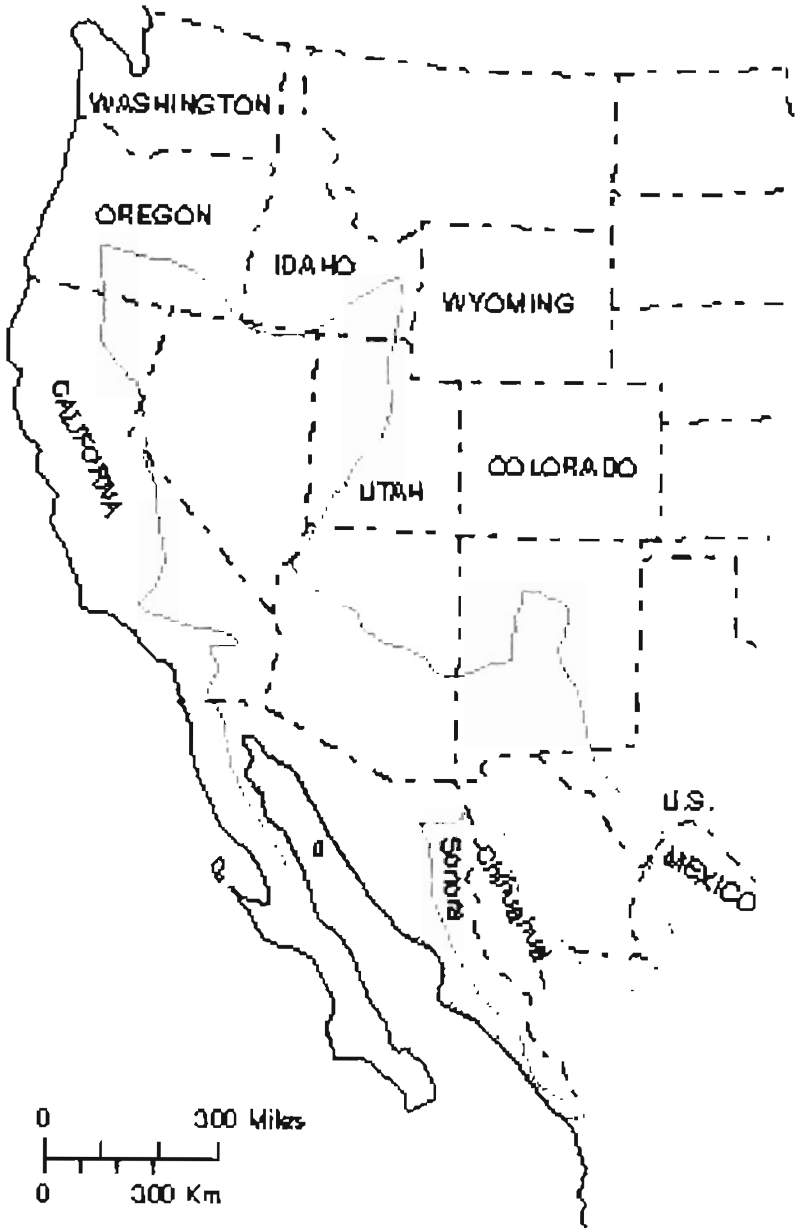


Figure 1. The Basin and Range Province in western North America is shaded in gray (After Harden, 1997).

and Stewart (1966) proposed a pull-apart-basin origin for the central Death Valley basin and emphasized the role of strike-slip faulting in its evolution.

Stewart et al. (1968) estimated that the amount of right-lateral displacement along the Furnace Creek fault zone is in the range of tens of kilometers. This estimate is based on the anomalous thickness differences in Precambrian and Paleozoic sedimentary rock units on opposite sides of the Furnace Creek fault zone. Wright and Troxel (1970) give an estimate of 50-km maximum right-lateral movement north of the northern end of Death Valley. They also estimate that there is no more than 10 km of right-lateral slip in the area of the Furnace Creek wash, along the Furnace Creek fault zone.

Wright and Troxel (1973) published a model for low-angle faulting in the region emphasizing the tilting of the mountain blocks and the relatively shallow dips of many normal faults. They suggested 30 to 50% extension of the upper crust, which is accommodated by normal faults that curve into a horizontal faults at depth.

Cemen et al. (1985) estimated that along the southern most 40 km of the Furnace Creek strike-slip fault zone the displacement ranges from zero to a few kilometers, increasing to the northwest, and a 50 kilometer displacement is possible in the northern Death Valley area (Figure 2). Stewart (1983) estimates this displacement is about 80 kilometers and is dissociated with the northwestward transport of the Panamint Mountains fault block along a low-angle detachment surface from an original location in the present Black Mountains and Greenwater Range (Figure 2).

Wernicke and Axen (1988) introduced the "rolling hinge" model, which suggests the existence of a steeply dipping segment along an otherwise low-angle detachment. Wernicke et al. (1988) suggest that the strike-slip faulting absorbed about 40 to 50 km of

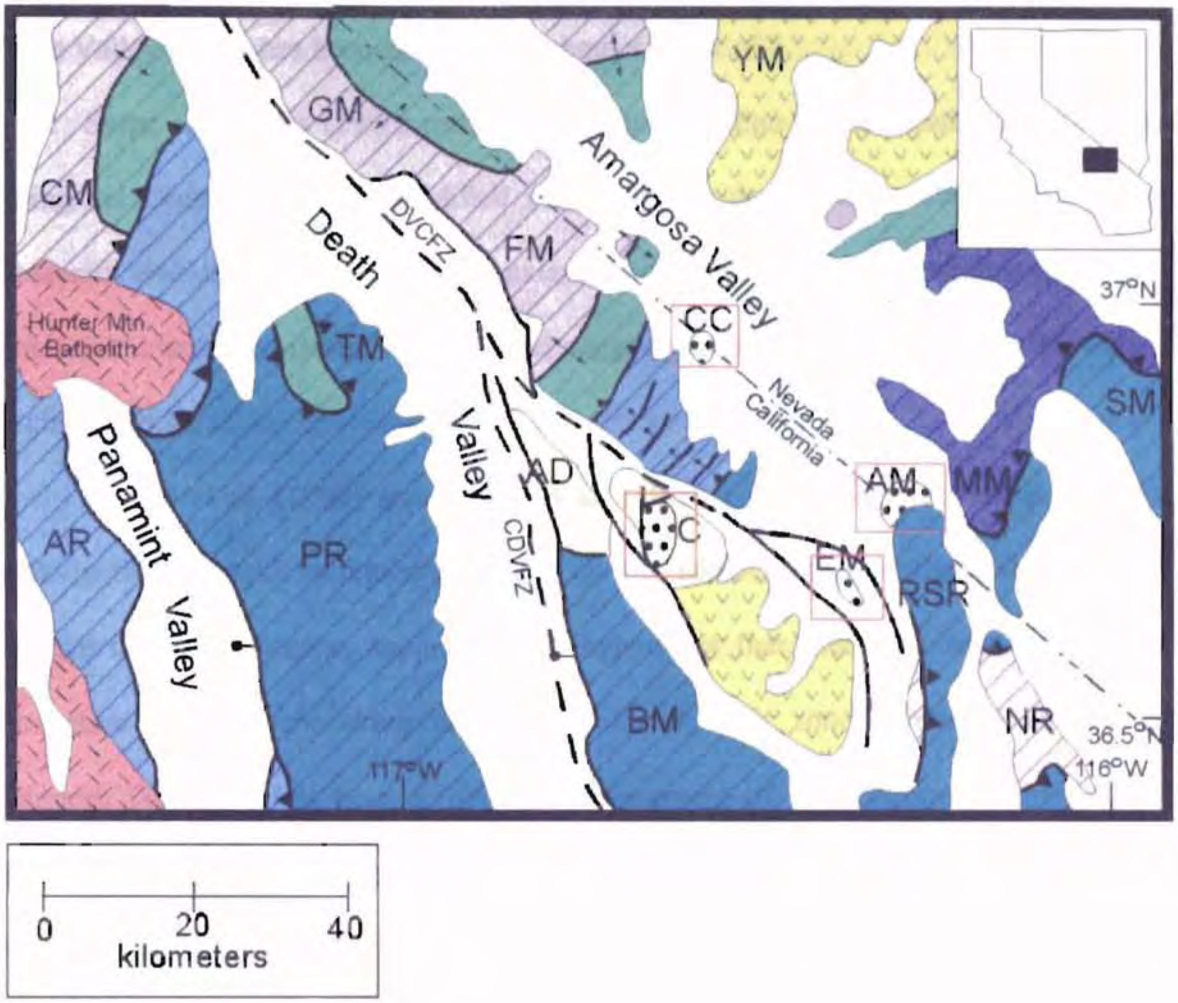


Figure 2. Geologic map of the Death Valley Region, California and Nevada (after Niemi et al., 2001). Abbreviations: CDVFZ- central Death Valley fault zone, DVFCZ- Death Valley-Furnace Creek fault zone, AR- Argus Range, BM- Black Mountains, GM- Grapevine Mountains, GR- Greenwater Range, KR- Kingston Range, MM- Montgomery Mountains, NR- Nopah Range, PR- Panamint Range, RSR- Resting Spring Range, SM- Spring Mountains, SP- Specter Range, SR- Spotted Range, TM- Tucki Mountain, YM- Yucca Mountain, AD- Artist Drive, AM- Ash Meadows, EM, Eagle Mountain, C- Ryan Section, CC- Chlorite Cliffs.

north-south shortening of the region during extension. They estimate that the crust in the Death Valley region has been extended by about a factor of 2.

Serpa and Pavlis (1996) reconstructed the evolution of the Death Valley region during the Cenozoic using a modified version of the dextral shear model. They use measured and hypothetical vertical axis rotation and suggest a two-stage, three-dimensional tectonic history. Their model suggests crustal thinning at 50 to 60% of the original thickness.

Cemen et al. (1999) and Wright et al. (1999) present evidence, based on their work in the Cenozoic sedimentary rocks on the northern and southern sides of the Furnace Creek fault zone, supporting the hypothesis that there has been around 50 kilometers displacement along the Furnace Creek fault zone. Niemi et al. (2001) estimates that there has been a 104-km displacement of the Cottonwood Mountains relative to the Resting Spring Range. They interpret that the Hunter Mountain Batholith was adjacent to the Eagle Mountain and Ash Meadows areas since granitic rock fragments of the Hunter Mountain Batholith are present in the sedimentary rocks that are exposed in the Eagle Mountain area. The last three studies discussed (Cemen et al., 1999; Wright et al., 1999; and Niemi et al., 2001) use sedimentological evidence to help reconstruct the tectonic history of the Death Valley region. However, the Cenozoic rocks that are well exposed in the Ash Meadows area of the northern end of the Resting Spring Range have remained relatively unstudied. This area has been mapped twice, once by Denny and Drews in 1965 and again by Cemen in 1983.

Research Objectives

The purpose of this thesis is to produce a detailed study of the Ash Meadows area in order to provide new data, which can be used to piece together the Cenozoic tectonic history of the Death Valley region. This data in turn will be interpreted to test the existing hypothesis of displacements along the Furnace Creek fault zone.

The rock fragment types and their percentages are compared to other sedimentary rocks of the same age. Studying the rock fragment types found in sedimentary rocks provide insight to the provenance of the sedimentary rocks and into the paleo-basin assemblage of the region during the Miocene. This helps to estimate the magnitude of crustal extension and help piece together the tectonic evolution of the Death Valley region. These studies will also make it easier to stratigraphically correlate rocks across the region. To accomplish these goals the area was mapped and additional evidence was gathered from stratigraphy, sedimentology and petrography.

If Serpa and Pravis (1996), Wright et al. (1999) and Cemen et al. (1999) are correct in estimating smaller 50-km displacements than it is expected that the Ash Meadows rocks have no or very little granitic rock fragments. If Niemi et al. is correct that 100 km of extension has occurred and the Hunter Mountain Batholith was very close, with in a few kilometers of the Ash Meadows area than there will be a large amount of granite rock fragments found in the Ash Meadows area.

Location of Study Area

The field area for the study is located in the Ash Meadows area of the Death Valley region. Ash Meadows is located at 36°17'30"N-36°20'N latitude and 116°15'W-

116°20'W longitude on the California-Nevada border (Figure 2). This area can be found on the Bole Spring Quadrangle, Nevada-California. Ash Meadows is east of Death Valley National Park and the Amargosa Desert and is on the northeastern side of Shadow Mountain, which is part of the Resting Spring Range.

Method of Study

The following tasks were performed during the course of the study:

1) Mapped the Ash Meadows area of California and Nevada.
2) Measured a stratigraphic section in the Ash Meadows area and collected rock samples from each rock unit in the section where the rock characteristics (grain size, cementation, coloring, etc.) changed.
3) Thin sections were prepared from the rock samples collected. A detailed petrographic analysis of each sample was preformed. The petrographic analysis included measuring the grain sizes in mm, observing the grain and cement mineralogy and calculating the percent porosity in each thin section.
4) Compared the Ash Meadows samples to petrographic analysis made from samples collected by Cemen along measured stratigraphic section he measured in the sedimentary successions exposed in the Eagle Mountain, Ryan, and Chlorite Cliff areas of the Death Valley region. These three sedimentary successions are approximately the same age as the Ash Meadows rocks.
5) In each thin section ten point counts were performed at ten randomly selected spots on the thin section slide. The micrometer scale bar that is found in the ocular lens of the microscope was used to count the percentage of the constituents at each point

count. The percentage of each constituent added to 100 percent for each point count. All ten point counts were then averaged together to create the average percentage of each constituent of the thin section. The grain size was measured using the micrometer scale bar and then classified using the Wentworth grain size scale.

6) Measured imbricated pebbles in the conglomerate and rotated the conglomerate beds back to horizontal on the Lambert equal-area stereo-net to find the original paleocurrent direction for the alluvial fan system.

7) Measured laminar crossbeds in Sandstone unit 1 and rotated the sandstone beds back to horizontal on the Lambert equal-area stereo-net to find the original paleocurrent direction for the stream systems.

8) Made a QRF ternary diagram with the normalized data of the percentage of Quartz, Feldspar, and Rock Fragments from all the thin sections of sandstone. Two more ternary diagrams were made with the normalized data of the different rock fragments from the thin sections of sandstones.

CHAPTER TWO

PROTEROZOIC TO THE MESOZOIC STRATIGRAPHY

This study is concerned mostly with Cenozoic tectono-stratigraphic development of the Ash Meadows area of the Northern Resting Spring Ranges. Therefore, Pre-Cenozoic rock units and structural evolution of the Death Valley region will only be discussed briefly. For detailed descriptions of the Pre-Cenozoic rock units and structural development of the region, the reader is referred to (1) Wright and Troxel, 1966; (2) Noble 1941; (3) Hamilton, 1987; (4) Hunt and Mabey, 1966; and (5) Tischler, 1955.

Proterozoic

The oldest rocks found thus far in the Death Valley region are 1,800 million years old. The oldest formation is the Johnnie Formation (Figure 3). Which is about 305 m thick in central Death Valley area and is mainly shale with interbedded dolomite and quartzite at the base of the formation (Hunt and Mabey, 1966).

Eon	PERIOD	EPOCH	FORMATION	LITHOLOGY	THICKNESS	AGE (Ma)
Cenozoic	Quaternary	Holocene		Fan gravel; silt and salt on floor of playa	100'	0.01
		Pleistocene		Fan gravel; silt and salt buried under floor of playa	2,000'	1.8
	Tertiary	Pliocene	Furnace Creek Formation	cemented gravel; silty and saliferous playa deposits, various salts	5,000'	5.3
		Miocene	Artist Drive Formation	cemented gravel; playa debris	5,000'	23.8
		Oligocene	Titus Canyon Formation	cemented gravel; mostly stream deposits	3,000'	33.7
Mesozoic	Triassic		Butte Valley Formation	metasediments & volcanics	8,000'	248
Paleozoic	Mis.	L	Perdido Formation	limestone	500'	342
		E	Tin Mountain Limestone	limestone	300'	354
	Devo.	L M	Lost Burro Formation	limestone, quartzite, and sandstone beds	500'	391
	Devo. Sil	E	Hidden Valley Dolomite	thick-bedded, light in color, fine grained dolomite	1400'	443
	Ordo.	L	Ely Springs Dolomite	massive black dolomite	500'	458
		M	Eureka Quartzite	massive quartzite	400'	470
		E	Pogonip Group	dolomite w/ limestone at base, shale in middle, dolomite at top	2200'	490
	Cambrian	Late	Nopah Formation	shale member base, dolomite member top	700'	
		Middle	Bonanza King Formation	thick-dedded arid massive dolomite	3600'	
			Carrara Formation	shaly and silty members w/ limestone members	1600'	
		Early	Zabriskie Quartzite	quartzite, mostly massive arid	800'	
Precambrian			Wood Canyon Formation	bottom unit quartzite, then shale, top unit dolomite	4000'	543
			Stirling Quartzite	well-bedded quartzite, some shale	4800'	
			Johnnie Formation	Mostly Shale, base inter-bedded dolomite & quartzite	1000'	

Figure 3. Stratigraphic Column for the Death Valley Region, California (after Hunt and Mabey, 1966 and Cemen and Wright, 1990).

The latest Proterozoic formation Stirling Quartzite Formation, overlies the Jonnei Formation. It is about 1463 m thick and is a well-bedded quartzite. The overlying Wood Canyon Formation is about 1219 m thick with a bottom unit of well-bedded quartzite. Its middle unit is shale in which a few scattered olenellid trilobites and archaeocyathids have been found. The top of the Wood Canyon is a unit made of dolomite and quartzite (Hunt and Mabey, 1966).

Paleozoic

The Zabriskie Quartzite Formation was deposited during the Early Cambrian and is a 244 m thick massive quartzite. The 488 m thick Carrara Formation follows the Zabriskie in time. The Carrara is Early and Middle Cambrian in age and has alterations of shaly and silty layers with some limestone layers. This formation is a transition between the underlying clastic units and the overlying carbonates (Hunt and Mabey, 1966).

The Bonanza King Formation is Middle and Late Cambrian in age and is 1,100 m thick (Cemen and Wright, 1990). The Bonanza King is mostly a thickly bedded to massive, dark colored dolomite. Also found in the Bonanza King is one limestone unit and two shale units. The Bonanza King is followed by the deposition of the 213 m thick Nopah Formation in the Late Cambrian (Cemen and Wright, 1990). The Nopah has a fossiliferous shale layer at the base and a thick dolomite layer at the top (Hunt and Mabey, 1966).

The beginning of the Ordovician is marked by the deposition of the Pogonip Group in Death Valley. The Pogonip is a dolomite, with some limestone at the base and a shale unit in the middle. It is 670 m thick and there are abundant gastropods in the dolomite and brachiopods in the lower limestone units (Hunt and Mabey, 1966).

The next formation is the Eureka Quartzite, which is Middle Ordovician in age. The Eureka is 122-m thick, massive quartzite, which becomes thinly bedded at the base and the top. The Ely Springs Dolomite follows the Eureka in time. The Ely Springs is 152 m thick and is a massive black dolomite that contains streptelasmatid corals and brachiopods (Hunt and Mabey, 1966).

The Silurian and Early Devonian is marked by the deposition of the Hidden Valley Dolomite. It is a thick-bedded, light colored dolomite that is 427 m thick. The Hidden Valley contains abundant crinoid stems (Hunt and Mabey, 1966).

The Lost Burro Formation is Middle and Late Devonian in age and has limestone, quartzite, and sandstone members it is about 152 m thick and contains abundant brachiopods and stromatoporoids (Hunt and Mabey, 1966).

The Tin Mountain Limestone overlies the Lost Burro Formation. It is about 90-m thick and is Early Mississipian in age(Cemen and Wright, 1990). There are brachiopods, corals, and crinoid stem fossils found in this formation (Hunt and Mabey, 1966). The next formation deposited in the area is the Perdido Formation, which is a 152-m thick limestone that was deposited during the Late Mississippian (Cemen and Wright, 1990).

CHAPTER THREE

EXTENSIONAL TECTONICS IN THE DEATH VALLEY REGION

The Death Valley region has a complex tectonic history from the late Proterozoic to present. Only Cenozoic extension will be briefly discussed since the Ash Meadows sedimentary section is closely related to extensional tectonics in the region.

Cenozoic Extensional Tectonics

The evidence of the extension in the Death Valley region include the presence of the metamorphic core complexes, associated detachment surfaces and normal faults. The metamorphic core complexes are usually interpreted as related to the ductile extension in the region with lasted from about 25 to 20 million years ago (Coney, 1983). Brittle extension in the Basin and Range is manifested by the presence of normal faults. In the Death Valley region, the normal faults tend to tilt Oligocene and some Miocene rock units as severely as older units and many cut rocks as young as Quaternary (Cemen et al., 1985).

Most studies of the Death Valley region center on a triangular crustal block between the northwest trending Furnace Creek fault zone and the mostly west-trending Garlock fault zone where the crust has been much more extended than the bordering crust to the northeast and south (Wright and Troxel, 1999). The Garlock fault is 100 km long and forms the principal geologic boundary between the Basin and Range province and the Mojave Desert (Walker and Glazner, 1999). Davis and Burchfiel (1973) interpreted the Garlock fault as a major strike-slip fault that separates the actively extending Basin and Range from the less extended Mojave Desert region. Davis and Burchfiel (1973) found that the Garlock fault is accommodating the strain gradient between the extensional deformation in the Basin and Range and the strike-slip faulting in the Mojave Desert. Pavlis and Serpa (1996) modified Davis and Burchfiel's description of the Garlock fault and said that the east end of the Garlock system did not serve as an intracontinental transform but instead was only one of a several left-lateral faults that transferred dextral shear into the Death Valley region.

The Furnace Creek fault zone (FCFZ) is a 200 km long right-lateral fault with an extensional component (Wright and Troxel, 1999). Much of the lateral movement on the FCFZ has been simultaneous with regional extension. Cemen et al. (1985) observed grooves and mullions on exposed Cenozoic fault surfaces in the region that are ordinarily oriented obliquely. This means that many of the normal and strike-slip faults of the region would be more accurately designated as oblique-slip, but dominated by either dip-slip or strike-slip. The FCFZ is a special type of divergent strike-slip zone because the crust on both sides of the fault is extended (Cemen et al. 1985). The Furnace Creek Basin, is located on the southwestern side of the FCFZ. The Cenozoic rocks in the

Furnace Creek basin is broken into three formations. They are from older to younger, (1) the Artist Drive, (2) Furnace Creek, and (3) Funeral Formations (Cemen and Wright, 1988).

CHAPTER FOUR

GEOLOGY OF THE ASH MEADOWS AREA

Introduction

Ash Meadows is a hilly area that is located to the east of the Armogosa Desert and to the north of the Resting Spring Range (Figure 4). This area contains rocks that have been dated at 13.2 Ma old. During this time of the mid-Miocene, extensional tectonism had already started in the Death Valley region. Exposed high areas to the north of the field area were eroded and transported to the south to yield what is now the Ash Meadows are.

Stratigraphy

During this study seven Cenozoic rock units were mapped in the Ash Meadows area. These seven units have a combined thickness of approximately 945-m (Plate 1). The contact between the Stirling Quartzite and the lowest Tertiary unit (a conglomerate) is an angular unconformity (Figure 5).

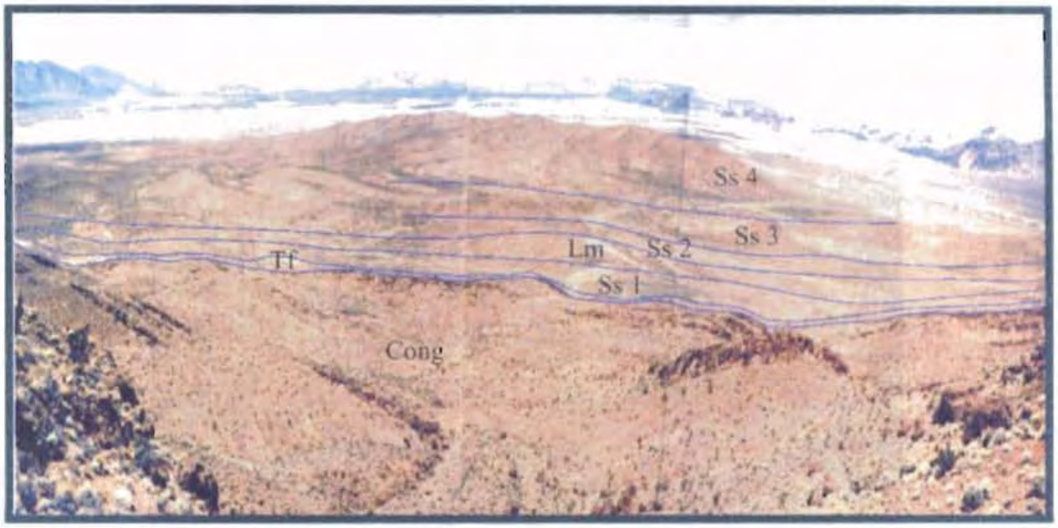


Figure 4. A picture of the Ash Meadows area with the bed boundaries drawn in, north is at the top of the picture. Cong= conglomerate, TF= Air-fall tuff, Ss 1= Sandstone 1, Lm= Limestone, Ss 2= Sandstone 2, Ss 3= Sandstone 3, and Ss4= Sandstone 4.

Figure 5. The basal unconformity between the Stirling Quartzite and the overlying conglomerate unit in the Ash Meadows area (the unconformity contact is the blue line.)

The conglomerate is 640 m thick and contains clasts that are five centimeters to about a meter in diameter. Above the conglomerate unit is a 15-m thick air-fall tuff unit that has been radiometrically (K/Ar) dated as 13.2 Ma old (Cemen, 1983). Following the deposition of the tuff, a fluvial system deposited Sandstone Unit 1 which is 44 m thick and is medium to coarse-grained. The next unit is a 48-m thick lacustrine limestone unit. When the lake receded, fluvial deposition began once more resulting in sandstone units 2 and 3. These units are 108 and 238 m thick, respectively. The upper boundary of sandstone 3 is an angular unconformity surface with sandstone 4, which was not measured in this study.

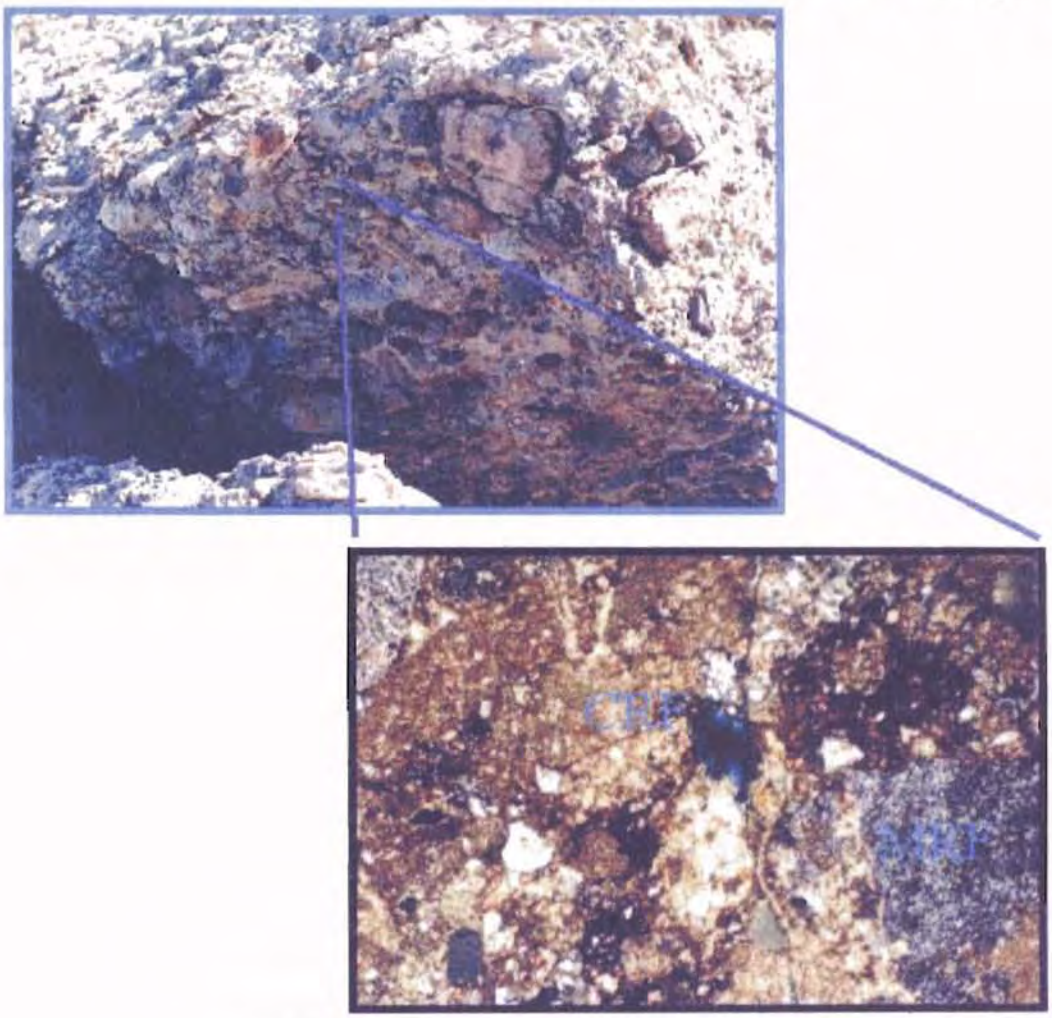
Conglomerate

The conglomerate unit is a red, gravel sized, poorly sorted, calcite cemented, massively bedded, polymictic conglomerate with clasts of quartzite, dolomite, and carbonate rock fragments (Figure 6). Alluvial fans are widespread, gently sloping masses of alluvium deposited by streams on a steep slope in an arid or semiarid region. An alluvial fan will have angular to very angular clasts, less than 30 percent depositional matrix, and will be located very close to the sediment source area. All three of these criteria match the conglomerate found in Ash Meadows, hence the conglomerate was deposited by an alluvial fan system.

The conglomerate unit forms the high hills in the south side of the field area. The unit contains cobble and boulder-sized clasts of the Paleozoic rocks. Red, very coarse-grained matrix-like sand holds the clasts together. Five samples were collected in areas

Conglomerate

The Conglomerate is a red, gravel sized, poorly sorted, calcite cemented, massively bedded, polymictic conglomerate with boulder to cobble sized clasts of Quartzite, Dolomite, and Carbonate Rocks Fragments.



CRF- Carbonate Rock Fragment, MRF- Metamorphic Rock Fragment

Figure 6. Pictures of AM27 from the Conglomerate in thin section (4x and XN) and outcrop. This sample was collected 609 m from the base of the Conglomerate.

where the conglomerate contains abundant matrix so that the types of grains between the clasts could be determined in thin section.

AM22 was collected 6 m up from the base of the conglomerate (Plate 1). It is a sub-angular, poorly sorted, sub-mature litharenite. The grain sizes are coarse to very coarse sand. The sample has 44.1% carbonate rock fragments, 24.5% metamorphic rock fragments, 2.0% sandstone rock fragments, 8.5% quartz, 5.0% chert rock fragments, and 13.9% calcite cement. The thin section also has 2.0% secondary porosity from intergranular, fracture, and enlarged pore porosity.

AM23 was collected 335 m up from the base of the conglomerate (Plate 1). It is a sub-angular, poorly sorted, sub-mature litharenite. The grain size ranges from coarse to very coarse sand. It has 56.1% carbonate rock fragments, 17.0% metamorphic rock fragments, 12.5% sandstone rock fragments, 4.5% quartz grains, and 9.3% calcite cement. The thin section also has 0.6% secondary porosity from intergranular, and fractures porosity.

AM-24 is from a thin sand unit in the conglomerate located 549 m from the base of the conglomerate (Figure 7). It is a sub-angular, well-sorted, mature litharenite. The grains are coarse to very coarse in size. It has 17.8% quartz, 60% carbonate rock fragments, 6.5% calcite cement, 3.9% hematite, and 11.8% secondary porosity from the dissolution of grains. It also has trace amounts of microcline, plagioclase, metamorphic rock fragments, volcanic rock fragments, and amphibole grains.

The carbonate and metamorphic rock fragments are from the underlying Paleozoic rocks. The volcanic rock fragments are from local volcanism at the time of

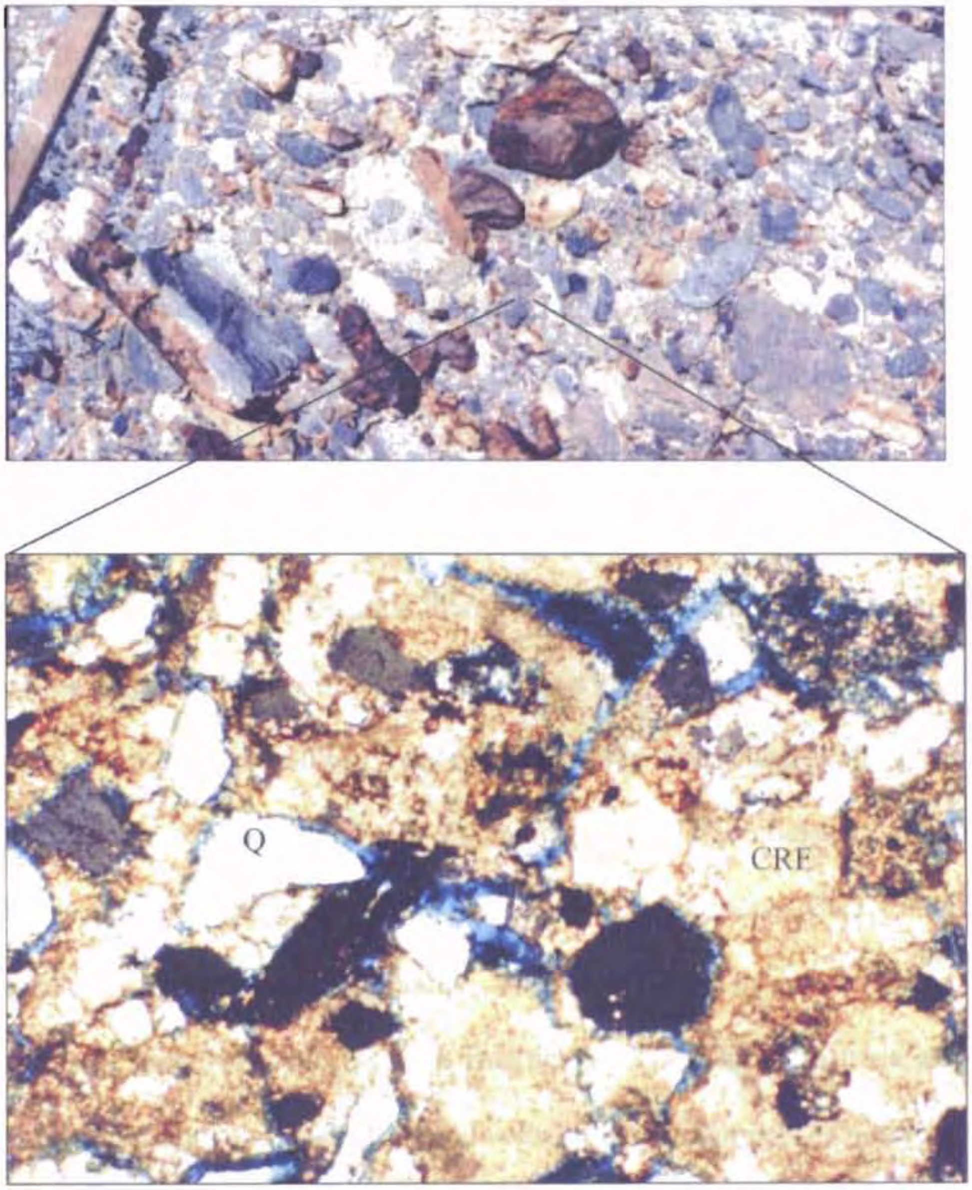


Figure 7. Thin section of AM24 (10x, XN) and outcrop photo, the sample was taken 549 m from the base of the Conglomerate. Q= Quartz, CRF= Carbonate Rock Fragment

deposition. The rock has a very deep red color to it, most likely this is from the 3.9% hematite present. This unit would have been deposited when the energy of the alluvial fan system had slowed down causing the deposition of sandstone instead of a conglomerate.

AM26 was collected 580-m from the base of the conglomerate (Plate 1). It is a sub-angular, poorly sorted, sub-mature litharenite, which is coarse to very coarse grained. It has 40.5% carbonate rock fragments, 49.5% metamorphic rock fragments, 2.3% quartz, and 7.7% calcite cement. The thin section also has trace amount of secondary porosity from intergranular, and fracture porosity. The alluvial fan stream system must have been eroding some of the Paleozoic metamorphic rocks, maybe a quartzite, during the time with AM26 was deposited, hence there is more metamorphic rock fragments than carbonate rock fragments found in this thin section.

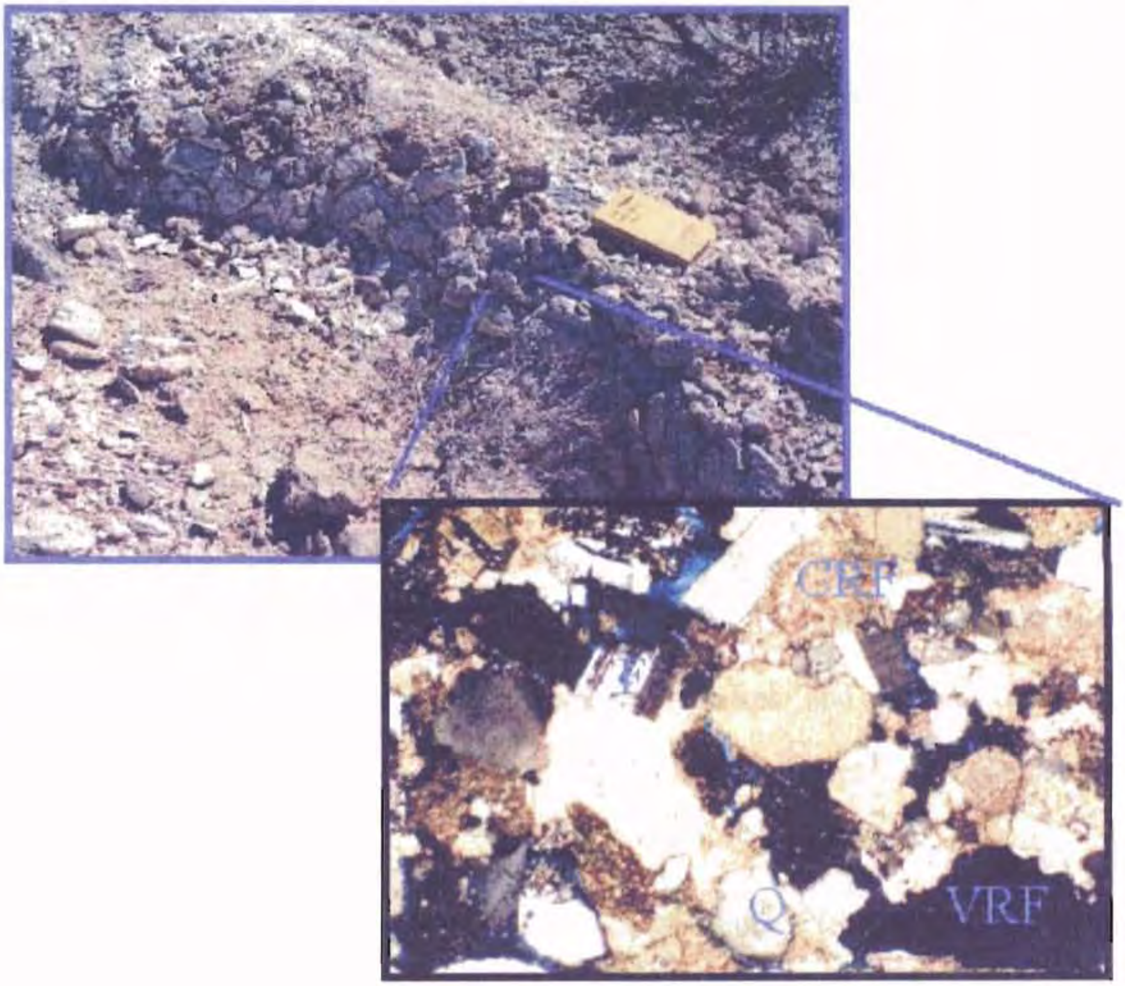
AM-27 was collected 609-m from the base of the unit (Plate 1). The sample is a sub-angular, poorly sorted, sub-mature litharenite, which has coarse to pebble sized grains. It has 1.9-% quartz grains, 4.9% sandstone rock fragments, 86.5% fossiliferous carbonate rock fragments, 1.5-% hematite, and 2.6% calcite cement. There is 2.6% primary porosity found between the rock fragments. There are also trace amounts of metamorphic rock fragments (quartzite), and volcanic rock fragments (volcanic glass).

Air-Fall Tuff

The air-fall tuff is of light olive-gray to greenish-gray, thinly bedded, volcanic rock unit (Figure 8), which is very recognizable on aerial photographs due to its white color. This unit is 15-m thick. During the deposition of the air-fall tuff a significant

Air-fall Tuff

The air-fall tuff is a light olive gray to greenish gray, thinly bedded, medium grained air-fall tuff.



CRF- Carbonate Rock Fragment, Q- Quartz,
F- Feldspar grain, VRF- Volcanic Rock Fragment

Figure 8. Two pictures of AM3 from the Air-fall Tuff in outcrop and thin section (10x, XN), this sample was collected at the base of the Air-fall Tuff unit.

amount of volcanism was occurring regionally. There was continued erosion of Paleozoic carbonates, which is evidenced by the tuff's constituents. AM3 was the only thin section made from this unit.

AM-3 is very close to the top of the unit; it was almost on the boarder of the air-all tuff unit and the first sandstone unit (Plate 1). It is a medium grained, sub-angular, moderately sorted, sub-mature litharenite. It has 24.1% quartz, 30.2% carbonate rock fragments, 8.3% volcanic rock fragments, 4.6% chalcedony rock fragments, 2.8% plagioclase, 20.9% calcite cement, 1.5-% hematite, and 7.6% primary porosity. There are also trace amounts of microcline, pyrite, and hornblende.

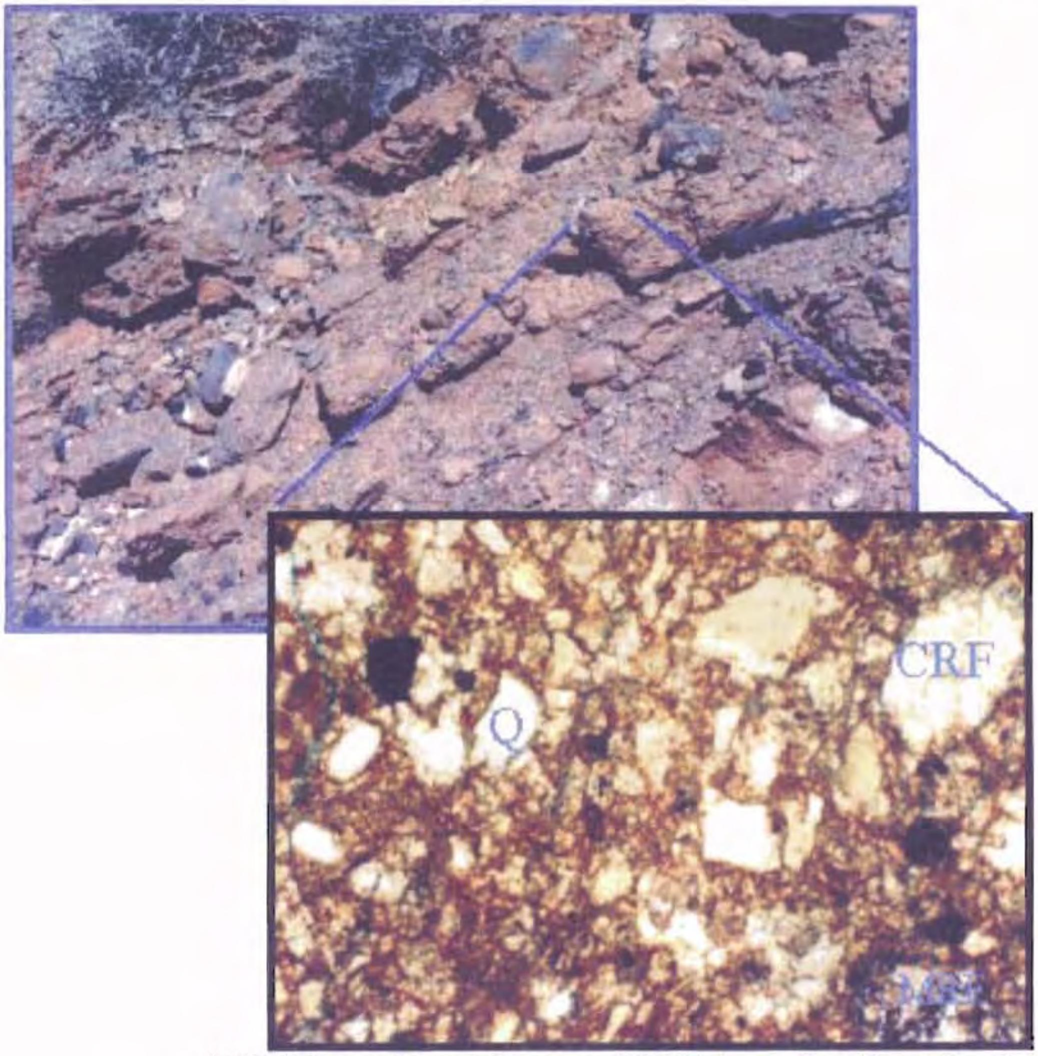
Sandstone 1

Sandstone unit one lies conformably on top of the air-fall tuff and consists of reddish-gray to tan litharenite. The unit ranges widely in grain size from fine sand to pebble conglomerate (Figure 9). Sandstone one is generally thinly bedded with calcite cement. The occurrence of fining upward sequences and laminar cross-beds demonstrates that the deposition of this unit was in a fluvial system. Three samples were taken from this unit.

AM4 was collected 12 cm from the base of Sandstone 1 (Figure 10). The rock in outcrop was reddish with course to pebble grains, poorly rounded, matrix supported with clast of Bananza King and the other Paleozoic rocks. The rock layers are 10 to 20 cm thick and have fining upward sequences. AM4 is a medium to very coarse grained, sub-angular, very poorly sorted, sub mature litharenite (Plate 1). It has 1-% quartz grains, 61% carbonate rock fragments, 9% sedimentary rock fragments, 4.5% metamorphic rock

Sandstone 1

Sandstone unit 1 is a reddish, gray, tan, fine grained to pebble clasts, poorly sorted, calcite cemented, thinly bedded, litharenite which is locally conglomeratic.



MRF- Metamorphic rock fragments, CRF- Carbonate Rock Fragment, Q- Quartz,

Figure 9. Pictures of Sandstone 1 in thin section and outcrop. This is sample AM6 the thin section is at 10x power and has the nickels crossed. This sample was collected 23 m from the base of Sandstone 1.

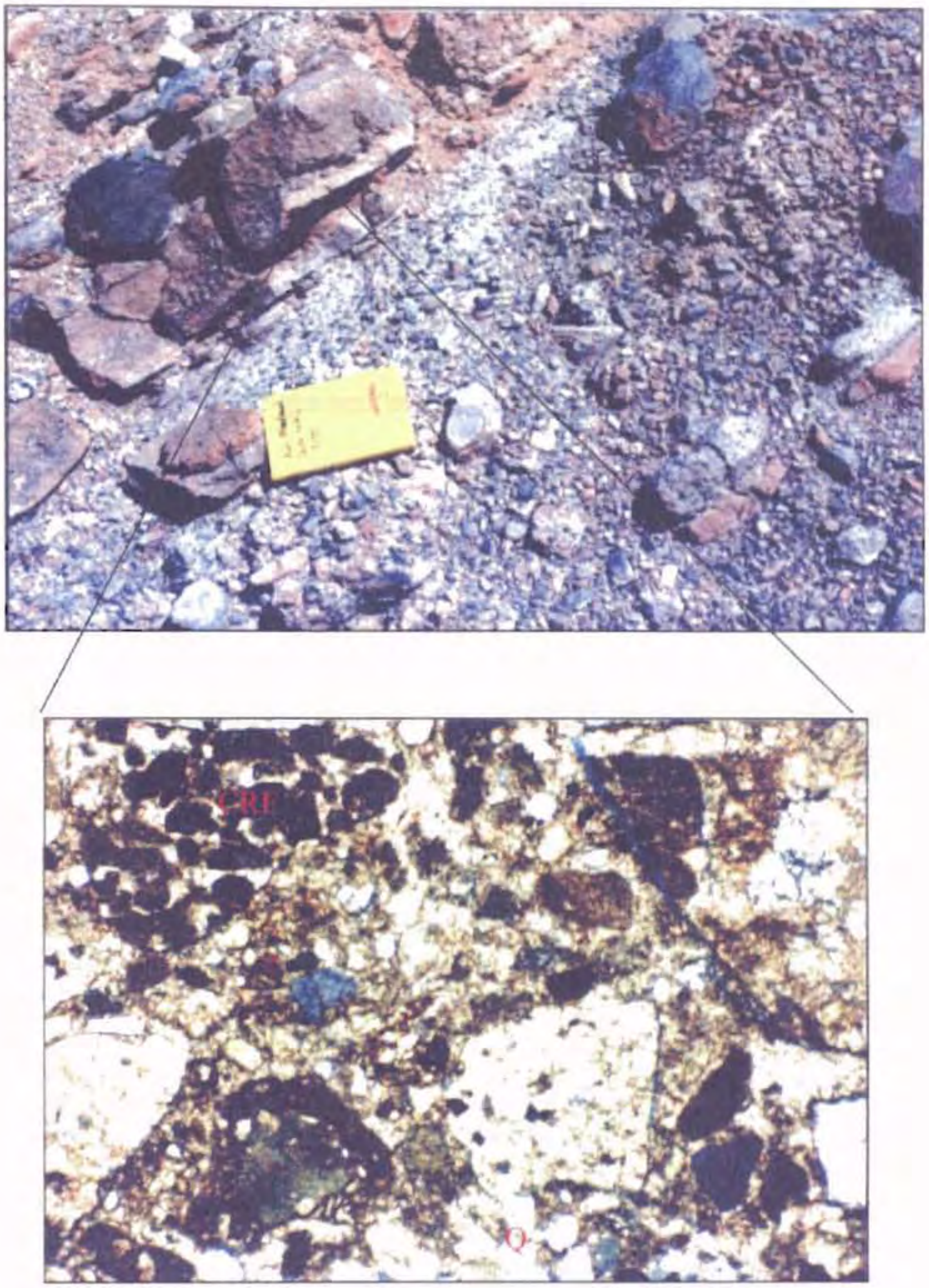


Figure 10. This is a picture of AM4 in thin-section (2.5x, CX) and outcrop. AM4 was collected 12 cm from the base of Sandstone 1. CRF= Carbonate rock fragments, Q= Quartz.

fragments, 0.3% zircon, 21.7% calcite cement, and 2.5% secondary porosity. The secondary porosity results from a combination of fracture and intragranular porosity. This sample was taken from the base of the unit that was coarser grained than the top of the unit, the unit is generally a fining upward sequence.

AM5 was collected 15 up from the base of Sandstone 1 (Plate 1). The rock is reddish white fine-grained sandstone, poorly sorted, very fissile sandstone with 12 to 30 cm thick layers. AM5 is a fine-grained, sub-angular, poorly sorted, sub mature litharenite (Plate 1). It has 6.1% quartz grains, 43.5% carbonate rock fragments, 45.1% calcite cement, 2.7% secondary porosity, 2.0% volcanic rock fragments, and 0.3% metamorphic rock fragments. The secondary porosity again results from fracture and intragranular porosity.

AM6 was collected 23 m from the base of Sandstone 1 (Plate 1). The rock is light red to red, medium to course grained sandstone with 30 to 50 cm thick layers. AM6 is a medium to fine grained, sub-angular, poorly sorted, sub-mature litharenite (Plate 1). It has 6.3% mono quartz, 74.3% carbonate rock fragments, 6.1% metamorphic rock fragments, 1.2% plagioclase, 0.1% hornblende, 0.3% hematite, 7.2% calcite cement, and 4.5% primary porosity. There is also a trace amount of sandstone rock fragments and secondary porosity from the dissolution of grains and enlarged pore spaces. There are not as many volcanic rock fragments found in this thin section, so there must have been a decrease in local volcanism at the time of the deposition of this rock or the drainage system changed. The rivers are continuing to erode the local Paleozoic rocks; there is still a lot of carbonate and metamorphic rock fragments in this thin section.

Lacustrine Limestone

This limestone is a light gray to tan, thinly bedded, wackestone (Figure 11). This unit is 48-m thick (Plate 1). There are still siliciclastics and volcanic rocks found in this unit, showing the volcanism and erosion of high areas was still occurring. There were no fossils or any additional evidence to show that it was a marine environment. This unit is therefor a lacustrine limestone deposite.

AM7 is the only thin section taken from the carbonate unit (Plate 1). It was collected 0.5 m from the base of the Lacustrine Limestone unit. The unit is white, fine grained, and has beds that are 5 to 20 cm thick. It has 85.7% carbonate grains, 4.8% quartz, 9.1% volcanic rock fragments, and 0.4% hornblende. There were also trace amounts of plagioclase and hematite. Porosity for this sample was very low.

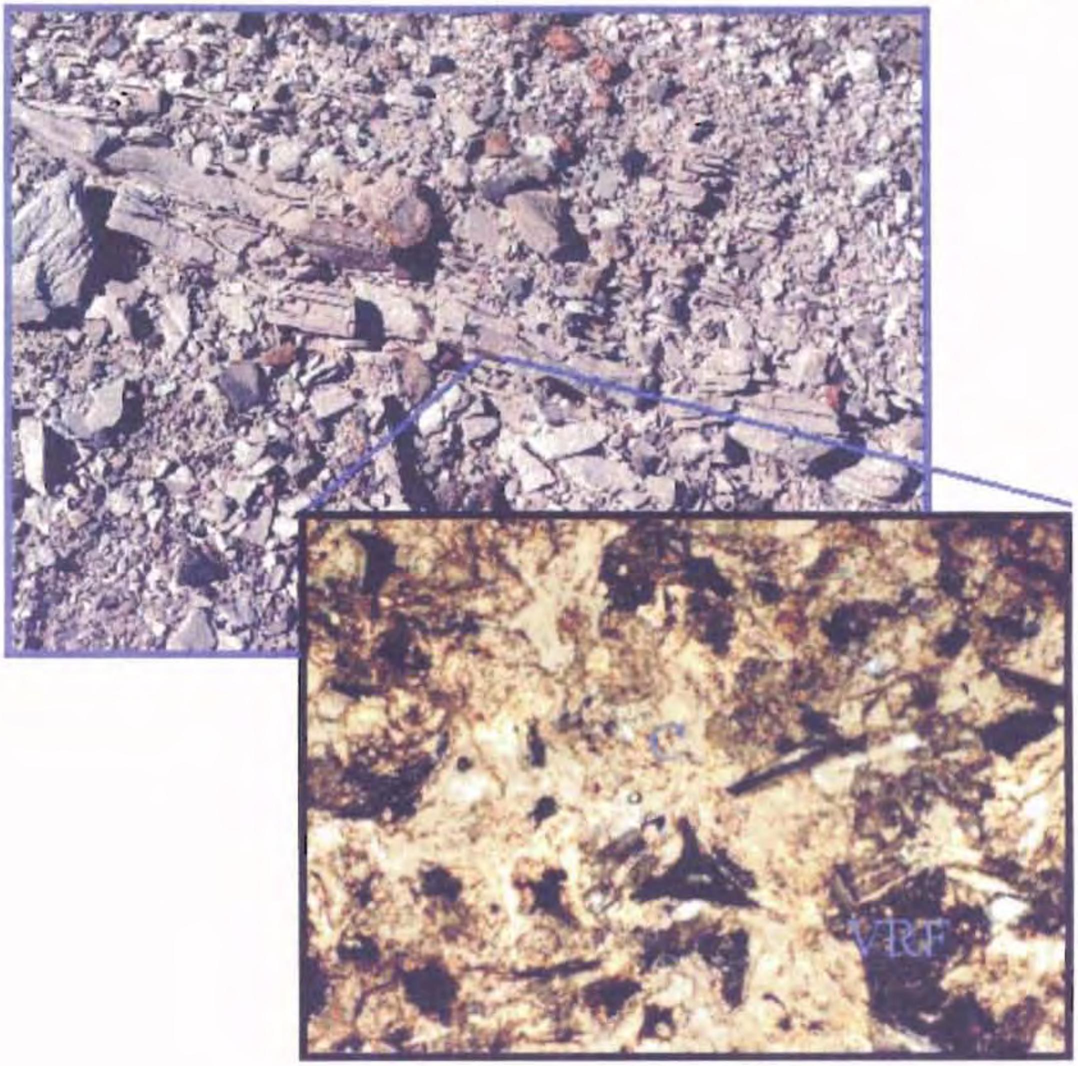
Sandstone 2

Sandstone 2 is a light gray to tan, medium grained, moderately sorted, calcite cemented, thin to massively bedded, litharenite (Figure 12). Sandstone 2 is very light and pale in color, almost white. In this unit there are faint traces of trough cross beds left behind by the fluvial system that deposited the sand. Three samples were collected from this unit, AM8, AM9, and AM10.

AM8 was collected 14-m from the base of Sandstone 2. The rock was white in color, fine grained, with layers that were 5 to 8 cm thick. The thin section is a medium grained, sub-rounded, well-sorted, mature litharenite (Plate 1). It has 15.6% monocrystaline quartz, 3.0% plagioclase, 33.6% carbonate rock fragments, 4.2% metamorphic rock fragments, 11.9% volcanic rock fragments, and 1.5% pyrite and 0.5% hornblende. There is 25.9% calcite cement and 3.8% primary porosity. There is also a

Lacustrine Limestone

The lacustrine limestone is a light gray, tan, thinly bedded wackestone.

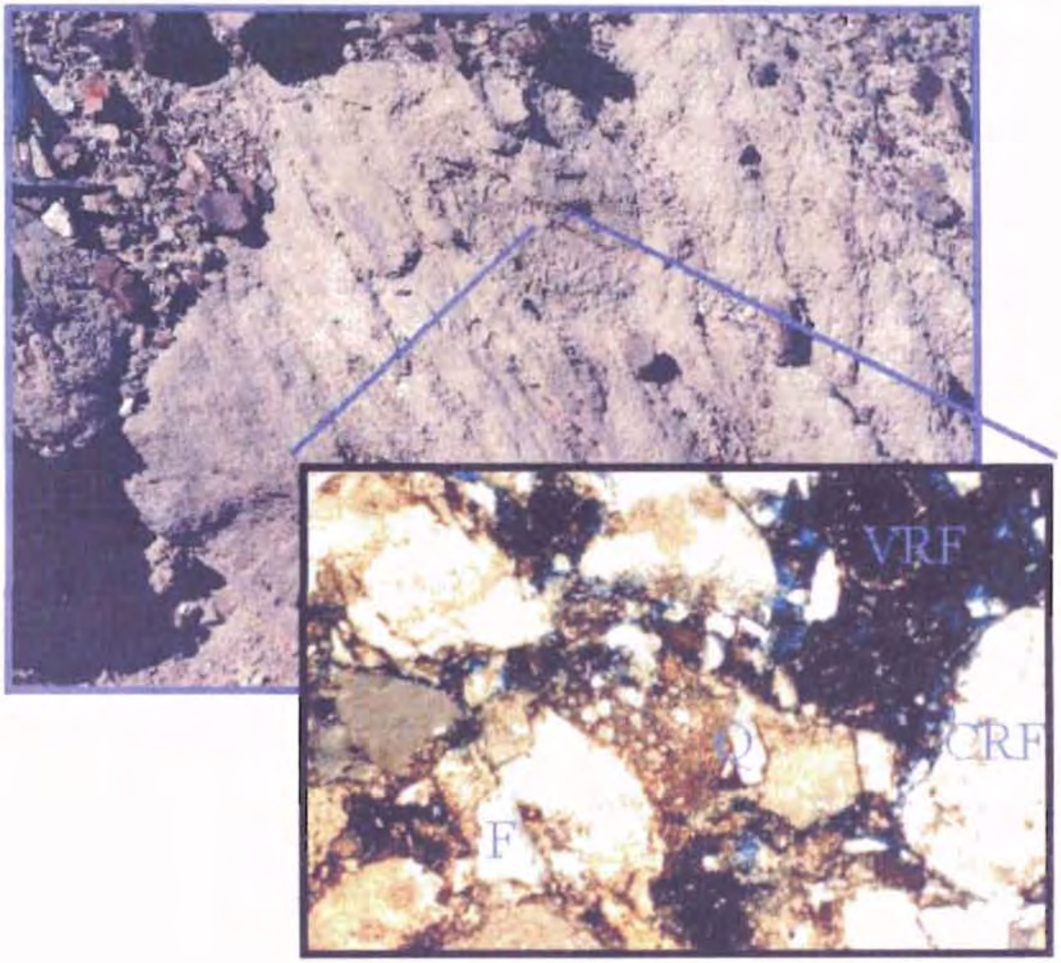


C- Calcite, VRF- Volcanic Rock Fragment

Figure 11. Pictures of AM7 from the Lacustrine Limestone in thin section (20x and XN) and outcrop. AM7 was collected 0.5 m from the base of the limestone unit.

Sandstone 2

Sandstone unit 2 is a light gray, tan, medium grained, moderately sorted, calcite cemented thin to massively bedded litharenite.



CRF- Carbonate Rock Fragment, Q- Quartz,
F- Feldspar grain, VRF- Volcanic Rock Fragment

Figure 12. Pictures of AM8 from Sandstone 2 in thin section (12x and XN) and outcrop. This was collected 14 m from the base of Sandstone 2.

trace amount of chalcedony rock fragments. The volcanic and carbonate rock fragments demonstrate the continued volcanism and erosion in the area.

AM9 was collected 18-m from the base of Sandstone 2. The rock was white in color, courser grained than in the layer that was sampled in AM8, with layers that were 8 to 13 cm thick. The thin section is a medium grained sub-angular to sub-rounded, moderately sorted, sub-mature litharenite (Plate 1). It has 20.3% monocrystaline quartz grains, 3.2% plagioclase, 27.95% carbonate rock fragments, 1.5% volcanic rock fragments, 2.3% metamorphic rock fragments, 0.5% sedimentary rock fragments, 1.6% hematite, 0.8% hornblende, and 35.9% calcite cement. There is 6.0% secondary porosity, which is from the dissolution of grains, intragranular porosity, fracture porosity, and honeycomb porosity.

AM10 was collected 40-m from the base of Sandstone 2 (Figure 13). The rock was white in color, medium grained, with layers that were 8 to 20 cm thick. The thin section is a medium grained sub-angular, moderately sorted, sub mature litharenite (Plate 1). It has 21.7% quartz, 11.1% plagioclase, 10.7% carbonate rock fragments, 7.7% volcanic rock fragments, 15.3% metamorphic rock fragments, 17.8% calcite cement and 1.8% hematite. It has 14% secondary porosity from intragranular and honeycomb porosity, dissolution of grains, and enlarged pores.

Sandstone 3

The boundary between sandstone 2 and sandstone 3 is easy to pick out because of the color changes. Sandstone 2 is very light and pale in color where sandstone 3 is

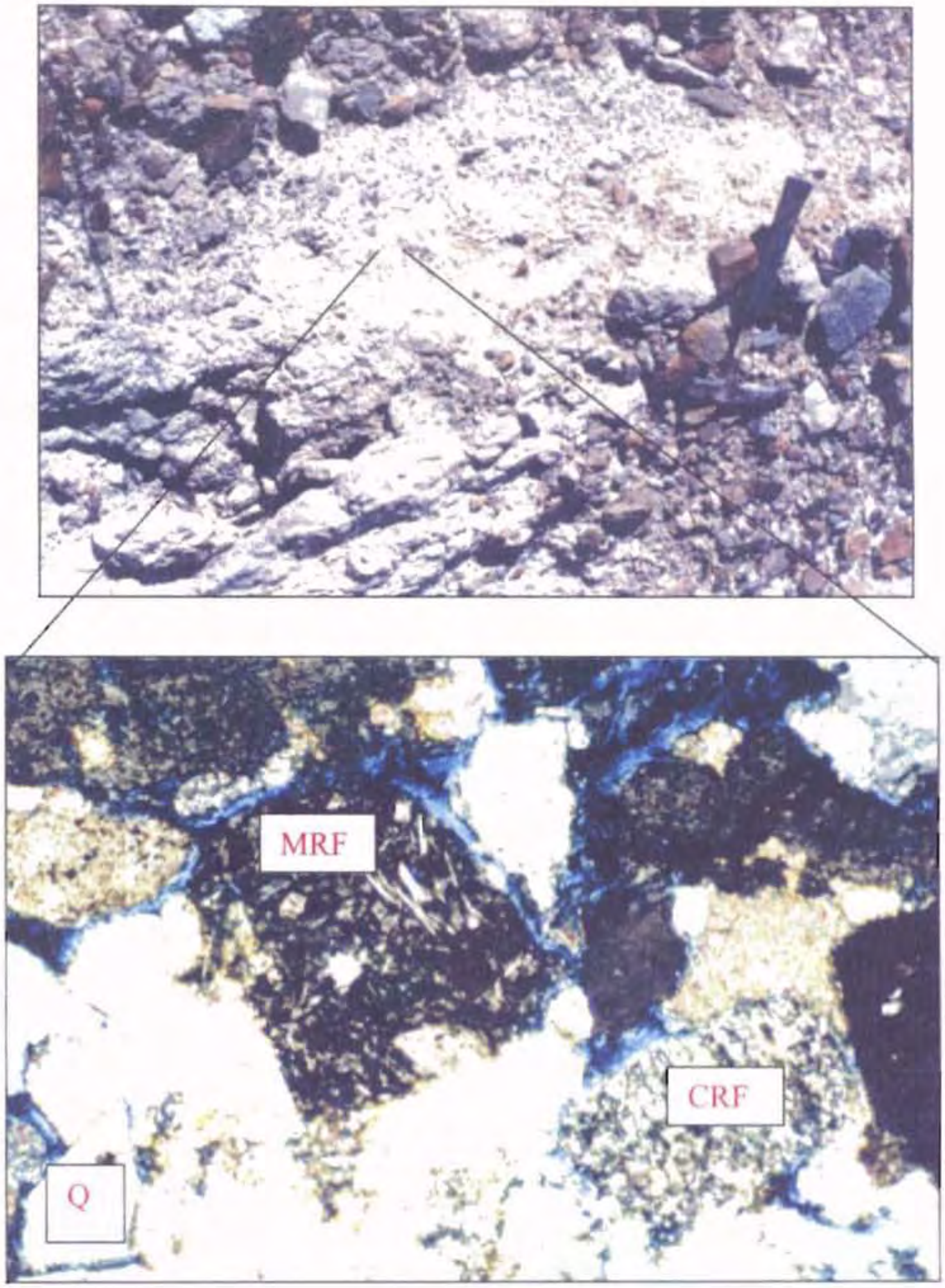


Figure 13. Pictures from AM10 in outcrop and thin section (10x and XN). AM 10 was collected 40 m from the base of Sandstone 2. Q= Quartz, MRF= metamorphic rock fragment, CRF= carbonate rock fragment.

yellowish in color (Figure 14). Sandstone 3 also has very nicely preserved trough cross beds.

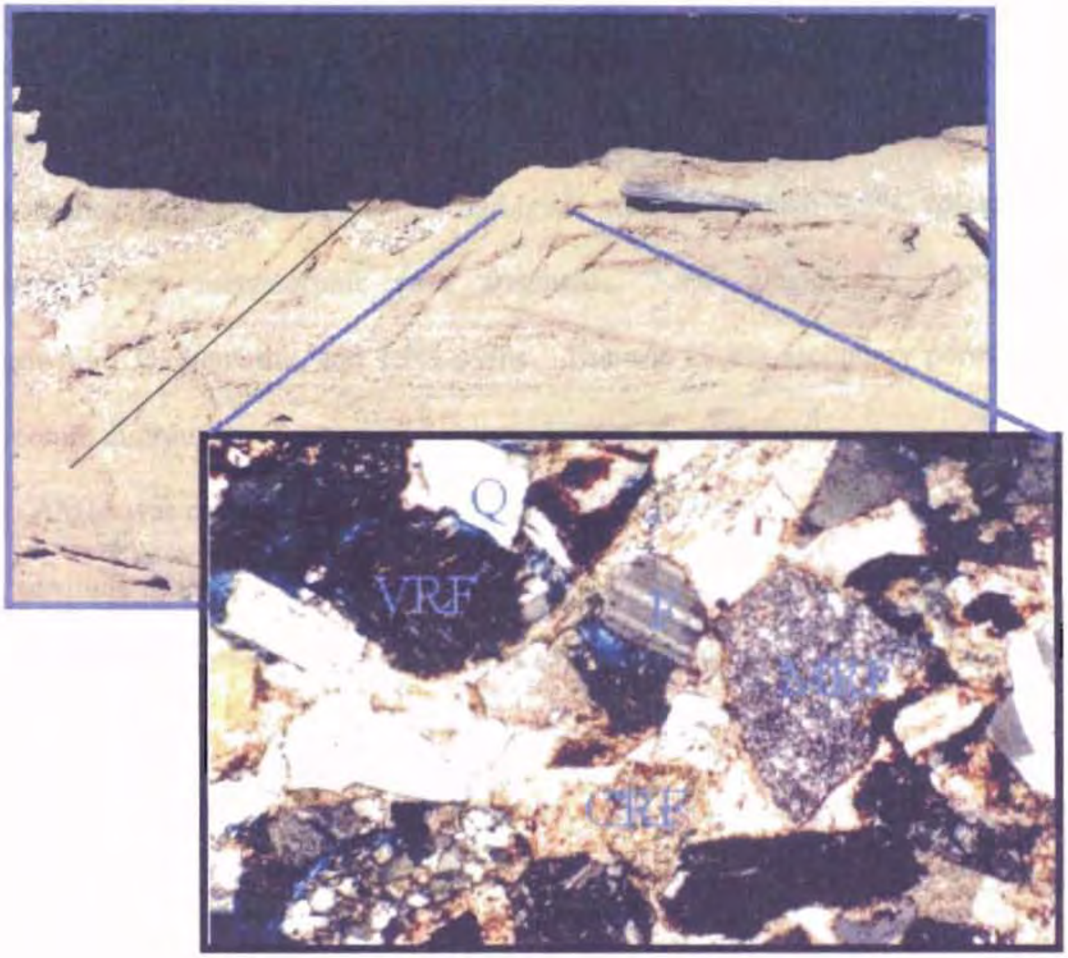
Sandstone 3 is yellowish tan, fine to coarse grained, moderately sorted, calcite cemented, thin to massively bedded, litharenite. At 780 m, this is the thickest sandstone unit and is the second youngest unit in the area. Tectonically, there were many events occurring at this time in the region, which are shown in this unit. There is an influx of granite fragments that were not encountered before, in addition to increased volcanic rock fragments in the area. In fact, the top layer of this unit is another air-fall tuff, AM29. In all there were nine thin sections taken from this unit, they are AM11, AM12, AM13, AM14, AM15, AM17, AM20, AM28, and AM29.

AM11 was collected 11-m from the base of Sandstone 3. The rock was yellow in color, fine grained, with layers that were 8 to 30 cm thick. AM11 is a fine-grained, sub-rounded, well-sorted, mature feldspathic litharenite (Plate 1). It has 19.3% monocrystaline quartz, 9.9% plagioclase, 17.9% volcanic rock fragments, 1-% carbonate rock fragments, 6.2% hematite, and 45.1% calcite cement. There is also 0.6% primary porosity. There is also a trace amount of microcline, biotite, zircon, and hornblende. This sandstone has more feldspar than the earlier samples. This is probably related to an increase in volcanism.

AM12 was collected 12-m from the base of Sandstone 3. The rock was yellow in color, medium grained, with layers that were 5 to 30 cm thick. AM12 is a medium grained, sub-angular, moderately sorted feldspathic litharenite (Plate 1). It has 9.9% monocrystaline quartz, 33.1% volcanic rock fragments, 2.2% metamorphic rock

Sandstone 3

Sandstone unit 3 is a yellowish tan, fine to coarse grained, moderately sorted, calcite cemented, thin to massively bedded litharenite.



CRF- Carbonate Rock Fragment, Q- Quartz,
F- Feldspar grain, VRF- Volcanic Rock Fragment,
MRF- Metamorphic Rock Fragments

Figure 14. Pictures of AM20 from Sandstone 3 in thin section (10x and XN) and outcrop. AM20 was collected 99 m from the base of Sandstone 3.

fragments, 19.9% calcite cement, 10.5% hematite, 16.0% plagioclase, 1.5% microcline, 1.0% biotite, and 5.9% secondary porosity. There is a trace amount of intergranular primary porosity (from volcanic rock fragments) and honeycomb, enlarged pores, dissolution of grains, and intergranular secondary porosity.

AM13 was collected 15-m from the base of Sandstone 3. The rock was yellow in color, course grained with some pebbles, with layers that were 5 to 8 cm thick. AM13 is a medium to coarse grained, sub-angular, well-sorted, mature litharenite (Plate 1). It has 45.1% monocrystaline quartz, 17.1% carbonate rock fragments, 4.5% volcanic rock fragments, 2.0% metamorphic rock fragments, 3.9% plagioclase, 0.6% quartz overgrowth, 5.3% hematite, and 1.7% pyrite. There is 19.8% secondary porosity from honeycomb, dissolution of grains, and enlarged pores.

AM14 was collected 18-m from the base of Sandstone 3. The rock was yellow in color, medium grained, well-cemented, with layers that were 30 to 50 cm thick. AM14 is a medium grained, sub-angular, moderately sorted sub-mature litharenite (Plate 1). It has 51.0% monocrystaline quartz, 3.8% plagioclase, 3.0% sandstone rock fragments, 9.0% carbonate rock fragments, 4.0% metamorphic rock fragments, 3.0% plutonic rock fragment, 1.5% volcanic rock fragments, 1.5% biotite, 1.5% hematite, and 7.2% calcite cement. This thin section also has 14.5% secondary porosity from dissolution of grains and enlarged pores. Also, plutonic rock fragments were seen in this sample.

AM15 was collected 32-m from the base of Sandstone 3 (Figure 15). The rock was yellow in color, medium grained, well cemented with layers that were 15 to 30 cm thick. AM15 is a fine-grained, sub rounded, moderately sorted sub-mature litharenite (Plate 1). It has 40.1% monocrystaline quartz, 5.7% plagioclase, 2.0% carbonate rock

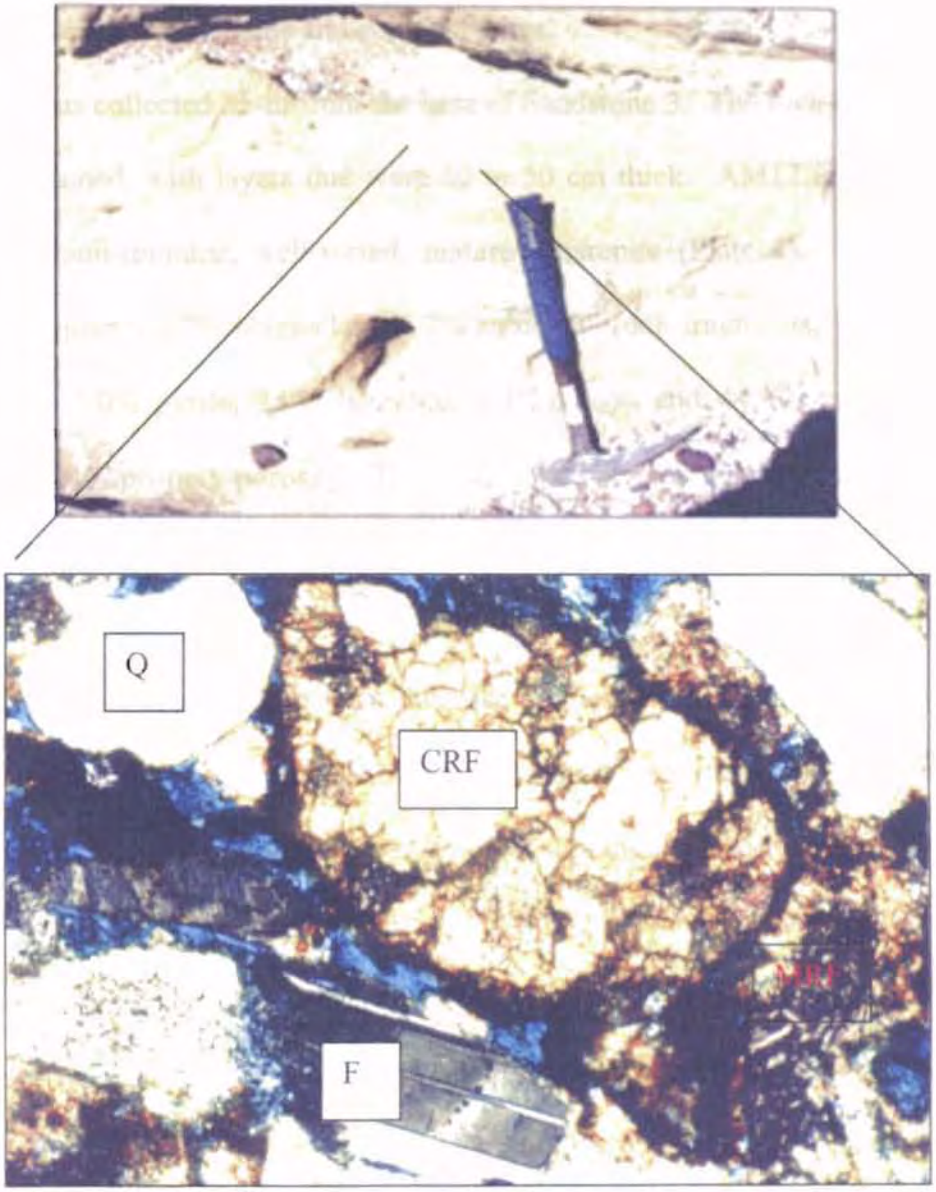


Figure 15. Pictures of AM15 from Sandstone 3 in outcrop and thin section (10x, XN). AM15 was collected 32 m from the base of Sandstone 3. Q= Quartz, CRF= Carbonate Rock Fragments, F= Feldspar, MRF= Metamorphic Rock Fragments.

fragments, 6.5% metamorphic rock fragments, 11.2% volcanic rock fragments, 2.0% hematite, and 25.3% calcite cement. The thin section also has 7.2% secondary porosity from dissolution of feldspar grains and enlarged pores.

AM17 was collected 35-m from the base of Sandstone 3. The rock was yellow in color, course grained, with layers that were 30 to 50 cm thick. AM17 is a medium to coarse grained, sub-rounded, well-sorted, mature litharenite (Plate 1). It has 33.2% monocrystaline quartz, 1.2% plagioclase, 7.7% carbonate rock fragments, 1.4% volcanic rock fragments, 3.0% pyrite, 2.0% hematite, 0.4% zircon and 44.9% calcite cement. There is also 11.4% primary porosity. There are also trace amounts of chalcedony rock fragments and hornblende. This shows there was a decrease in volcanism at the time of deposition.

AM20 was collected 99 m from the base of Sandstone 3. The rock layer that AM20 was collected from is yellow course grained sandstone with layers that were 30 to 50 cm thick. AM20 is a medium to coarse grained, sub-angular, moderately sorted, sub-mature feldspathic litharenite (Plate 1). It has 22% monocrystaline quartz, 22% plagioclase, 5% metamorphic rock fragments, 19% carbonate rock fragments, 16% volcanic rock fragments, 1% hematite, 10% calcite cement, and 5% porosity. Most of the porosity is primary, but there is some secondary from the dissolution of grains. There is also a trace amount of sandstone rock fragments, pyrite, zircon, hornblende, amphibole, chlorite clays, and mixed-layer clays (the clays were found in the pore spaces).

AM28 was collected 230 m from the base of Sandstone 3. The rock unit is yellow, medium grained sandstone with layers that are 30 to 50 cm thick. AM28 is a medium grained, sub-rounded, moderately sorted, sub-mature feldspathic litharenite

(Plate 1). It contains 42.1% monocrystaline quartz, 10.7% plagioclase, 8.2% sandstone rock fragments, 1.5-% carbonate rock fragments. 5.4% metamorphic rock fragments, 5.5% volcanic rock fragments, 1.0% hematite, and 1.0% pyrite. The thin section also contains 24.2% secondary porosity from the dissolution of grains and enlarged pores.

AM-29 is the final sample from Sandstone 3; it was collected 234 m from the base of the unit. The rock unit is fine-grained, pale white, yellow in color with layers 13 to 22 cm thick. It is a fine-grained, angular, moderately sorted, sub-mature volcanic ash flow (Plate 1). It has 3.4% monocrystaline quartz, 1.4-% plagioclase, 1.6% hematite, and 66.2% volcanic rock fragments. It has 27.4% primary porosity. There are also trace amounts of biotite, hematite, hornblende, and mixed-layered clays (found in the pore spaces). From looking at the type of plagioclase it is possible to determine the composition of the lava. It was probably a rhyolite/dacite volcanic type, but further analysis must be done before it is possible to determine the exact composition.

This top boundary is an angular unconformity between sandstone 3 and sandstone 4. Regional movement along normal faults caused the Ash Meadows beds to be tilted and new rocks to be deposited on top.

Sandstone 4

Sandstone 4 was not the major focus of this study, since it extends out of the field area. It sits unconformably on top of Sandstone 3. One thin section was taken just above the contact with sandstone 3. This unit is a light greenish-gray to tan fine-grained, moderately sorted, massively bedded volcanic litharenite (Figure 16).

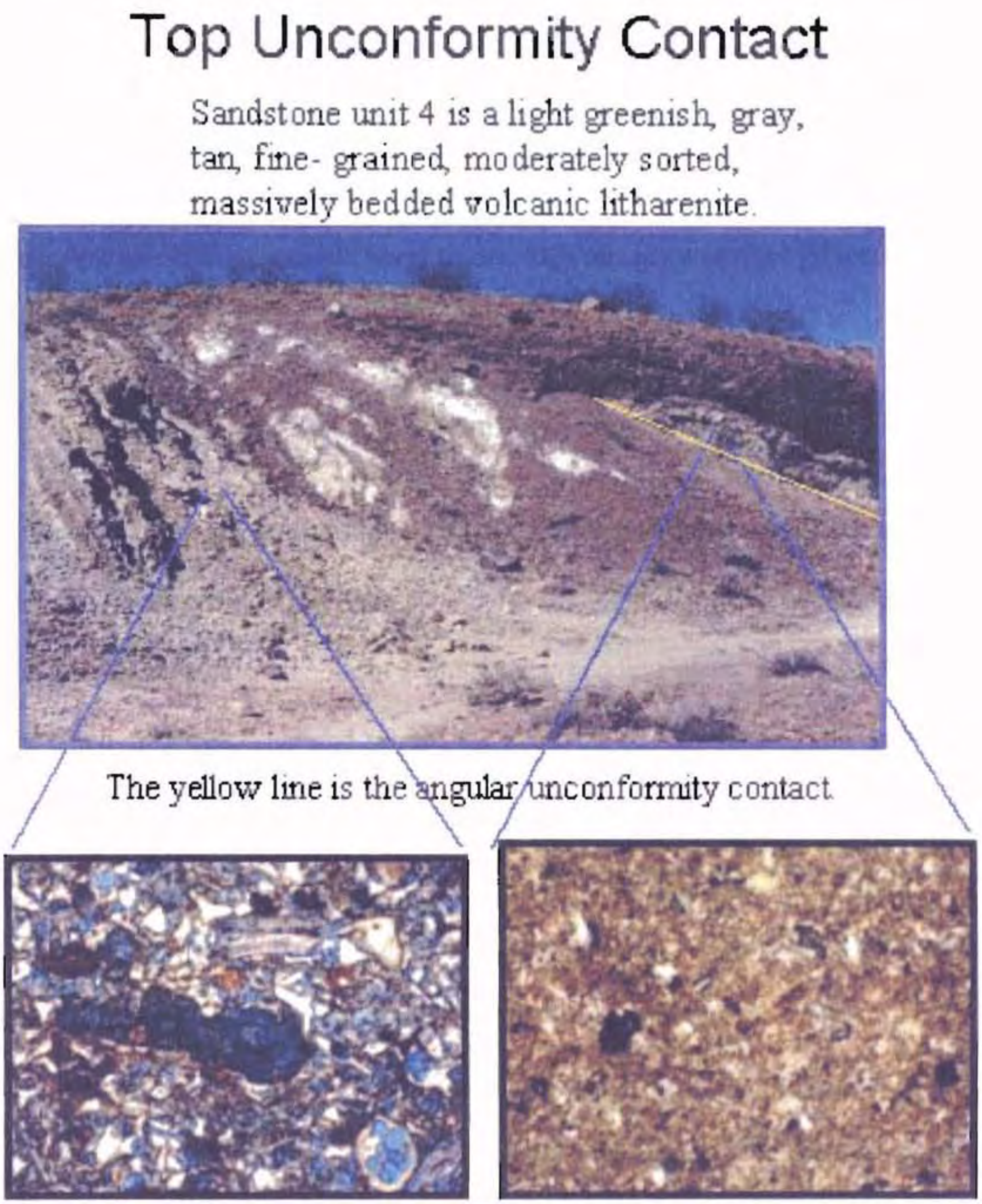


Figure 16. Three pictures of the unconformity contact between Sandstone 3 and Sandstone 4 in thin section and outcrop. The picture on the left is AM29 (4x, PP), which was collected 234 m from the base of Sandstone 3. The picture on the right is AM32 (10x, PP), which was collected 0.5 m from the base of Sandstone 4.

AM32 was collected 1/2 a meter from the base of Sandstone 4. It is pale yellow, tan fine-grained sandstone with layers 1 m thick. AM32 is a fine-grained, sub-angular, moderately sorted, sub-mature volcanic tuff (Plate 1). It has 10.2% quartz, 4.3% primary porosity, 3.6% hematite, and 82.2% volcanic rock fragments. There are also trace amounts of plagioclase, pyrite, and hornblende. This sample was finer grained than AM-29, but it looks like they may have similar volcanic compositions.

Paleocurrent Analysis

To find the paleocurrent direction of the depositional systems two sets of measurements were taken in the field. The trend and plunge of imbricated pebbles in the conglomerate were measured. Then I plotted the bedding plane and the pebbles on a Lambert equal-area stereo-net and rotated the bed back to horizontal. This gave me the paleoshere direction for the Alluvial fan. Figure 17 shows that the direction of flow of the alluvial fan system was to the northwest. Laminar crossbeds in Sandstone Unit 1 were measured and plotted on the Lambert equal-area stereo-net and rotated back to horizontal. This gives us the true direction of flow in the stream system. Figure 18 demonstrates that the direction of flow was from the northwest to the southeast.

This information helps three-dimensionally understand what the Ash Meadows area must have looked like during the Mid-Miocene. The southern and the western sides of the area would have been topographically high areas with a basin in the center. The Ash Meadows rocks were formed in an isolated basin, only much later the Armogosa Valley opened up like it is today.

Data Analysis

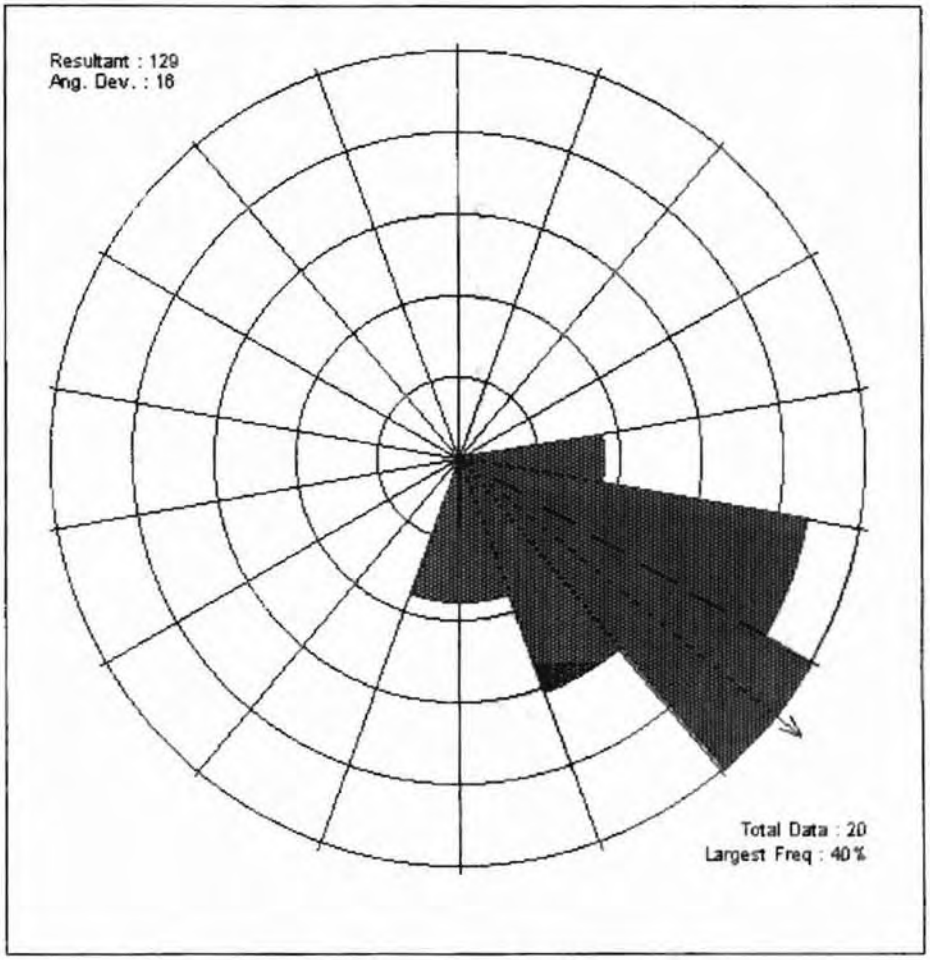


Figure 17. Rose diagram of the imbrication of pebbles in the conglomerate unit after the conglomerate bed has been rotated back to horizontal. This rose diagram demonstrates that the paleo-current direction was to the northwest at an average of N51W.

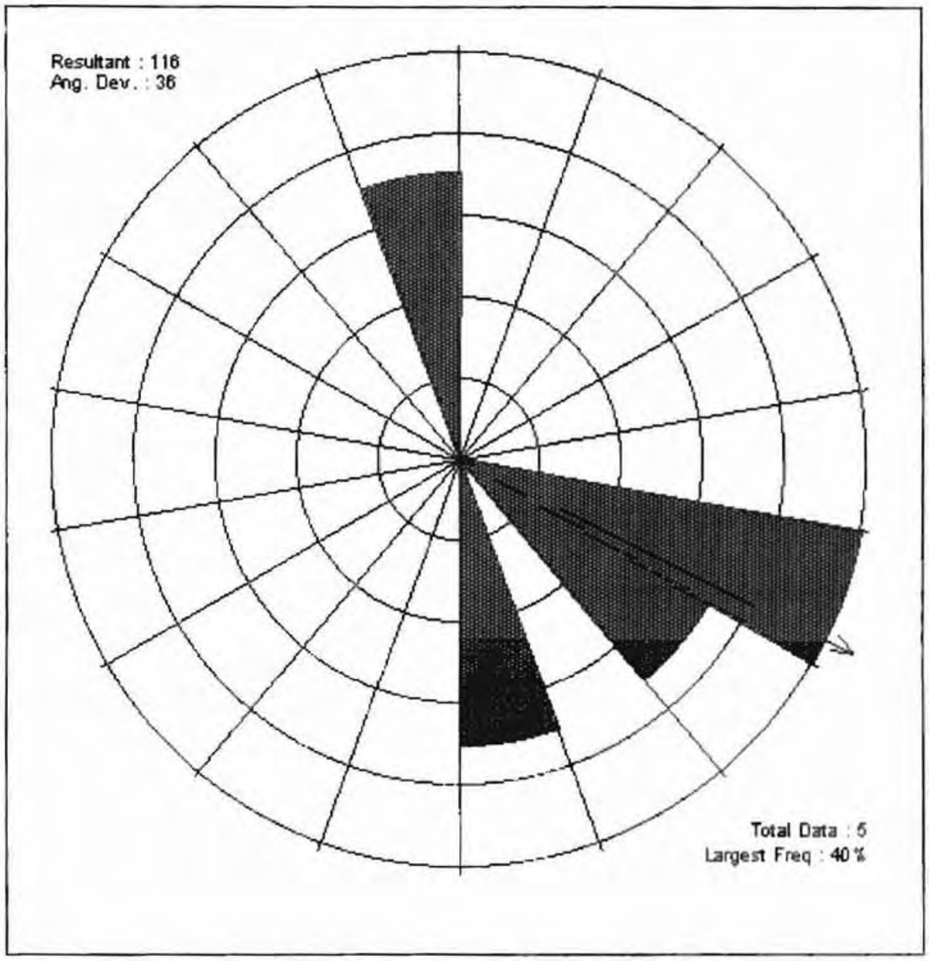


Figure 18. Rose diagram of laminar cross beds found in the sandstone unit 1 after the bed was rotated back to horizontal on the stareonet. This demonstrates that the stream system was flowing to the southeast at an average of S64E.

To analyze the rocks of the field area, tables were made using Microsoft Excel with each of the normalized percentage of rock fragments, feldspar grains, and quartz grains (Table 1). These were then plotted on ternary diagrams in Rock Works (Figure 19). This diagram shows that the each sandstone unit plots together, but separately from the other two units. Sandstone unit 1 is positioned in the lower right hand corner. This unit has more rock fragments than quartz or feldspar. Sandstone 2 plots a little closer to the quartz and feldspar sides, but still has a majority of rock fragments. Sandstone 3 has the largest range. This unit has more quartz and feldspar than the other two units. All of the samples lie in the litharenite side of the diagram, and some lie in the feldspathic litharenite side. This is because these rocks are not very mineralogically mature rocks. If they were mature sandstones they would plot in the quartz arenite tip of the ternary plot. Therefore, the Ash Meadows sandstone have not been reworked or transported very far, so the source area is relatively close.

The paleocurrent analysis suggests that the source areas were to the northeast for the sandstones and the southeast for the conglomerate. To determine the source area of the Ash Meadows sedimentary rocks, the rock fragments of the sandstones are analyzed. Table 2 shows the unnormalized percentages of all the different rock fragment types in each thin section. Table 3 shows the normalized data in three groups, metamorphic rock fragments, granitic rock fragments, and sedimentary plus volcanic rock fragments. The sedimentary rock fragments are the sandstone, siltstones, plus the carbonate rock fragments. Table 3 was imported into Rock Works to create Figure 20. Which shows that most of the rock fragments fall into the Sedimentary plus volcanic rock fragments category. AM10 has a high amount of metamorphic rock fragments compared to the

Unit	Thin Section	Quartz	Feldspar	Rock fragments	Total
1	AM6	7	1	92	100
1	AM4	2	0	98	100
1	AM5	12	0	88	100
2	AM8	23	4	73	100
2	AM10	33	17	51	100
2	AM9	36	6	58	100
3	AM20	26	26	48	100
3	AM13	59	5	36	100
3	AM12	16	28	56	100
3	AM11	40	21	39	100
3	AM17	76	3	21	100
3	AM28	57	15	28	100
3	AM15	61	9	30	100
3	AM14	68	5	27	100

Table 1. Normalized quartz, feldspar, and rock fragment percentages for the sandstone units in the Ash Meadows area.

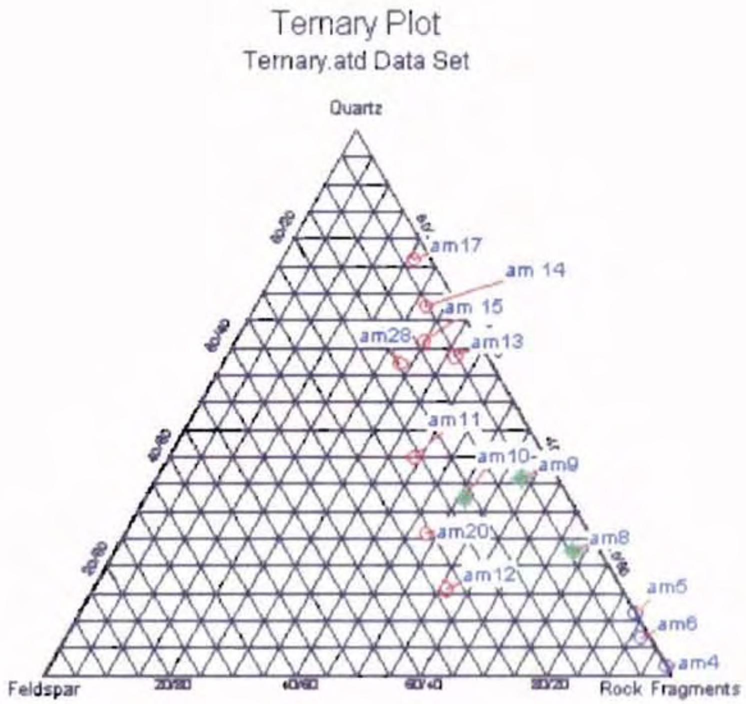


Figure 19. A ternary plot of the normalized data found in table 1. Blue circles are for sandstone 1, green symbol for sandstone 2, and red circle for sandstone 3.

unit		MetaRF	GRF	SedRF	CarbRF	VolcRF
1	AM6	6.1	0	0	74.3	0
1	AM4	4.5	0	9	61	0
1	AM5	0.3	0	0	43.5	2
2	AM8	4.2	0	0	33.6	11.9
2	AM10	2.3	0	0.5	27.9	1.5
2	AM9	15.3	0	0	10.7	7.6
3	AM20	5	0	0	19	16
3	AM13	2	0	0	17.1	4.5
3	AM12	2.2	0	0	0	33.1
3	AM11	0	0	0	1	9.9
3	AM17	0	0	0	7.7	1.4
3	AM28	5.4	0	8.2	1.5	5.5
3	AM15	6.5	0	0	2	11.2
3	AM14	4	3	3	9	1.5

Table 2. The unnormalized percentages of different types of rock fragments found in the sandstone units of the Ash Meadows area in thin section.

unit	Thin section	MetaRF	GRF	Sed+VolcRF
1	AM6	8	0	92
1	AM4	6	0	94
1	AM5	1	0	99
2	AM8	9	0	91
2	AM10	7	0	93
2	AM9	45	0	55
3	AM20	13	0	88
3	AM13	21	0	79
3	AM12	6	0	94
3	AM11	0	0	100
3	AM17	0	0	100
3	AM28	26	0	74
3	AM15	33	0	67
3	AM14	20	15	66

Table 3. The normalized percentages for metamorphic rock fragments, granitic rock fragments, and sedimentary plus volcanic rock fragments for the sandstone units of the Ash Meadows area.

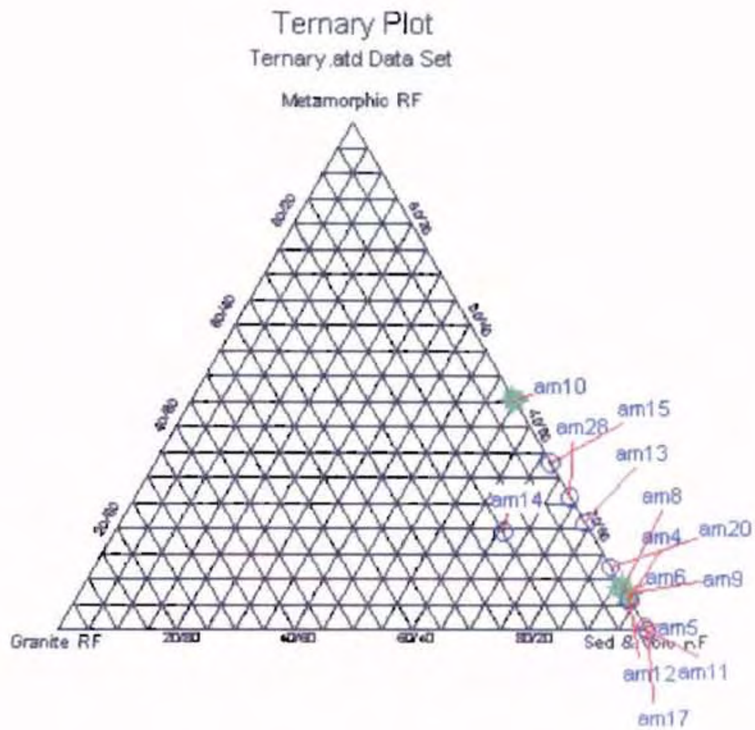


Figure 20. Ternary Plot of normalized percentages of the metamorphic rock fragments, granitic rock fragments, and sedimentary plus volcanic rock fragments from Table 3. Blue circles are for sandstone 1, green symbol for sandstone 2, and red circle for sandstone 3.

other samples. AM14 is the only sample with a significant amount of granitic rock fragments.

To see what other observations could be extracted from the data, Table 4 was constructed. Table 4 is the normalized percentage of granitic rock fragments, volcanic rock fragments, and sedimentary plus metamorphic rock fragments. This data was imported into Rock Works and Figure 21 was created. Figure 21 can be used to find out at which intervals the primary volcanic activity was occurring. In this case AM12, AM11, AM15, and AM20 all have higher levels of volcanic rock fragments. These are times when there was a higher level of volcanic activity in the area.

Each of these plots illustrates that there is very little granitic influence on the provenance. Is this true? A granitic fragment is simply quartz, plagioclase and orthoclase feldspar, muscovite, biotite, and amphiboles grown into each other. These pieces are very likely to be broken apart during transport from the granite body to the sedimentation area. In the Ash Meadows rocks, there are only trace amounts of complete granite pieces, but there are feldspars, biotites, muscovites, and amphiboles present. This lead to the conclusion that the source area did contain a granite body, but how far away that body is we cannot say. The proximity of the granite body was not an as important factor in provenance of the Ash Meadows rocks as the Paleozoic metamorphic and sedimentary rocks and the Tertiary volcanic rocks of the Death Valley region.

unit	Thin section	GRF	VolcRF	Sed+metaRF
1	AM6	0	0	100
1	AM4	0	0	100
1	AM5	0	4	96
2	AM8	0	24	76
2	AM10	0	5	95
2	AM9	0	23	77
3	AM20	0	40	60
3	AM13	0	19	81
3	AM12	0	94	6
3	AM11	0	91	9
3	AM17	0	15	85
3	AM28	0	27	73
3	AM15	0	57	43
3	AM14	15	7	78

Table 4. The normalized percentages for the granitic rock fragments, volcanic rock fragments, and the sedimentary plus metamorphic rock fragments in the sandstone units of the Ash Meadows area.

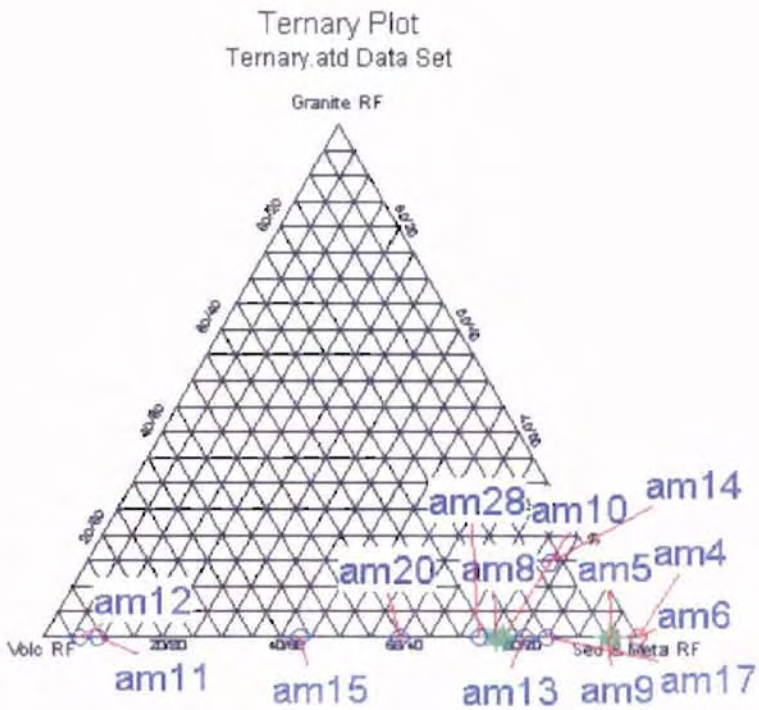


Figure 21. Ternary plot for the normalized percentages for the granitic rock fragments, volcanic rock fragments, and the sedimentary plus metamorphic rock fragments from Table 4. Blue circles are for sandstone 1, green symbol for sandstone 2, and red circle for sandstone 3.

CHAPTER FIVE

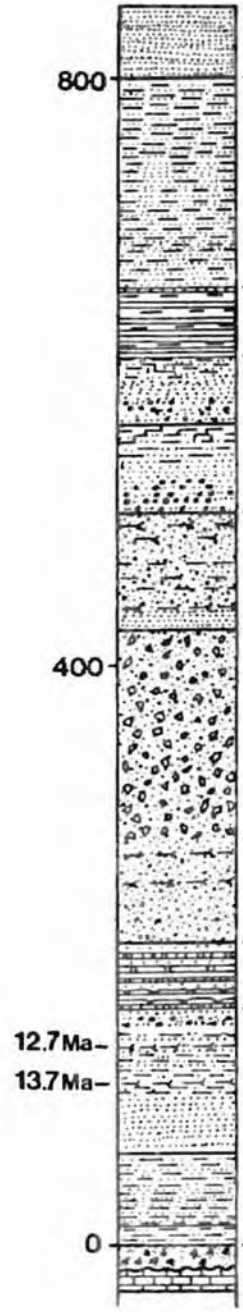
MIOCENE SEDIMENTARY ROCKS OF THE FURNACE CREEK WASH

Introduction

Three other groups of Miocene aged sedimentary rocks where studied, these include the Ryan sedimentary section of the Artist Drive Formation, the Eagle Mountain rocks, and the Chlorite Cliff rocks of the Titus Canyon Formation. These rocks were studied in thin section to determine their constituents so that they could later be compared to the Ash Meadows rocks. These areas have been mapped and stratigraphically measured by Cemen (Cemen, 1983, Cemen and Wright, 1988). The maps and stratigraphic columns will be used here along with the new thin section descriptions to describe each of the formations (Figures 22-28).

Artist Drive Formation

The Artist Drive Formation is found in the Furnace Creek basin. One exposure is near the Billie Mine, which is on the hills to the north of the town of Ryan (Figure 22-24). In this area, the basal breccia of the Artist Drive unconformably overlies the



11	Ss: grayish orange, v fn to md grnd, laminated to tn bdd, well to v well sorted, contains iron stains between laminae planes.
10	Ss, sandy sltst & sltst: ss: lt red to moderate red, v fn to fn grnd, well sorted laminated to tn bdd, calcite cmtd, shows iron stains on the bedding planes; sandy sltst: v pale orange to pale yellowish orange, v fn grnd; sltst: pale yellowish orange, tnly to tckly laminated, separable along the laminae planes.
9	Sltst, marl & gypsum: sltst: v pale orange to pale yellowish orange, tckly laminated to v tn bdd, calcite cmtd localy sandy; marl: v pale orange. Gypsum beds are 1" to 5" tck.
8	Ss & silty ss: ss: grayish orange crs to v crs grnd to cgltc md to tck bdd, calcite cmtd; silty ss: lt red to moderate red v tn to tn bdd, calcite cmtd. Contains oscillation ripples.
7	Cgl, cgltc ss, ss, silty ss & sltst: fining upward sequence; cgl & cgltc ss: grayish orange, md to tck bdd, calcite cmtd; grades into v pale orange, fn to v fn grnd, v tn to tn bdd, calcite cmtd, ss, silty ss & sltst.
6	Ss & tuffeceous ss: ss: lt red to moderate red, fn to md grnd, tn to md bdd, calcite cmtd; tuffeceous ss: lt greenish gray, fn to md grnd, tn to md bdd; contains pale green, msv bedded, about a ft tck, air-fall tuff.
5	Cgl: lt brown, md to tck bdd, fragments are pebble to cobble in size; set in lt brownish gray silty to sandy matrix. Clasts are derived mostly from the C Bonanza King Fm, C Carrara Fm, C Zabriskie Quartzite, Latest pC Stirling Quartzite, pC Johnie Formation. Also present are clasts of metamorphic rocks, Tertiary granite and Tertiary sandstone.
4	Ss, cgltc ss & cgl: ss: lt greenish gray, fn to v crs grnd to cgltc, tn to tck bdd, calcite cmtd, locally tuffeceous; Cgl: same as in subunit 5
3	Ss & lst: ss: greenish gray, fn to md grnd, tn to md bdd, calcite cmtd; lst: moderate orange pink to grayish orange, v tn to tn bdd, forms ledges, contains chert modulus.
2	Ss & silty ss: ss: Lt brown to grayish orange md to crs grnd, tn to md bdd, well sorted, calcite cmtd, locally siliceous, contains ripple marks; silty ss: moderate orange pink, v fn to fn grnd, v tn to tn bddd, calcite cmtd. Includes lt greenish gray, fn to md grnd, msv bdd, about a ft tck air-fall tuff.
1	Sltst & silty ss: grayish orange to dk yellowish orange, tn to md bdd, calcite cmtd, contains a v crs grnd, about a ft tck ss bd with abundant small-scale trough cross-bding. Includes scattered angular fragments of the underlying C Bonanza King Fm.

Figure 3: Measured columnar section of the lower sedimentary member of the Artist Drive Formation in the Billie Mine area. The member is divided into 20 subunits. Abbreviations used in descriptions: bd = bed; bdd = bedded; bding = bedding; cgl = conglomerate; cgltc = conglomeratic; cmtd = cemented; crs = coarse; dk = dark; fm = formation; fn = fine;

Figure 22. Bottom part of the measured columnar section of the Artist Drive (Cemen 1988)

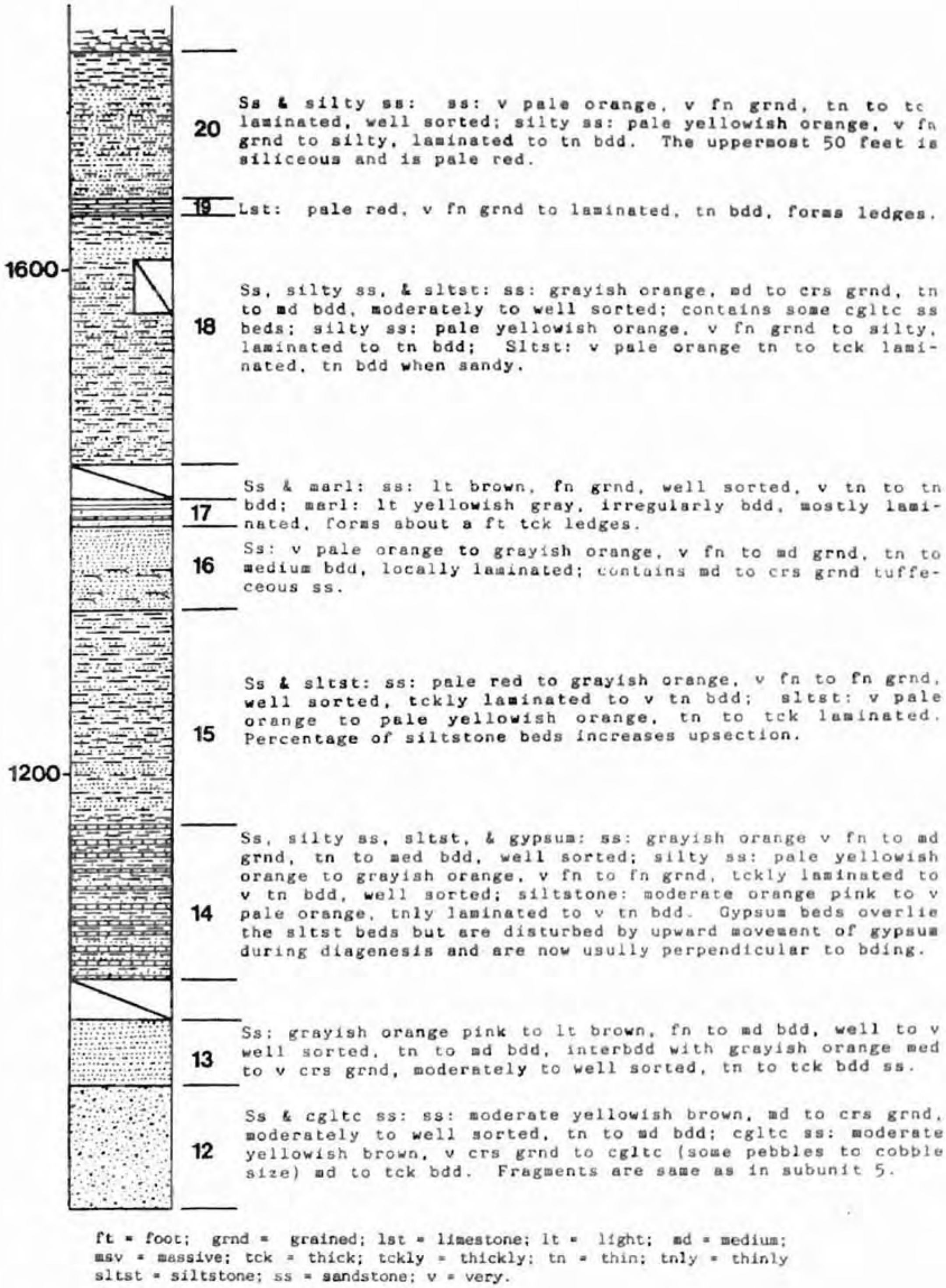


Figure 23. Top of measured columnar section of the Artist Drive (Cemen 1988).

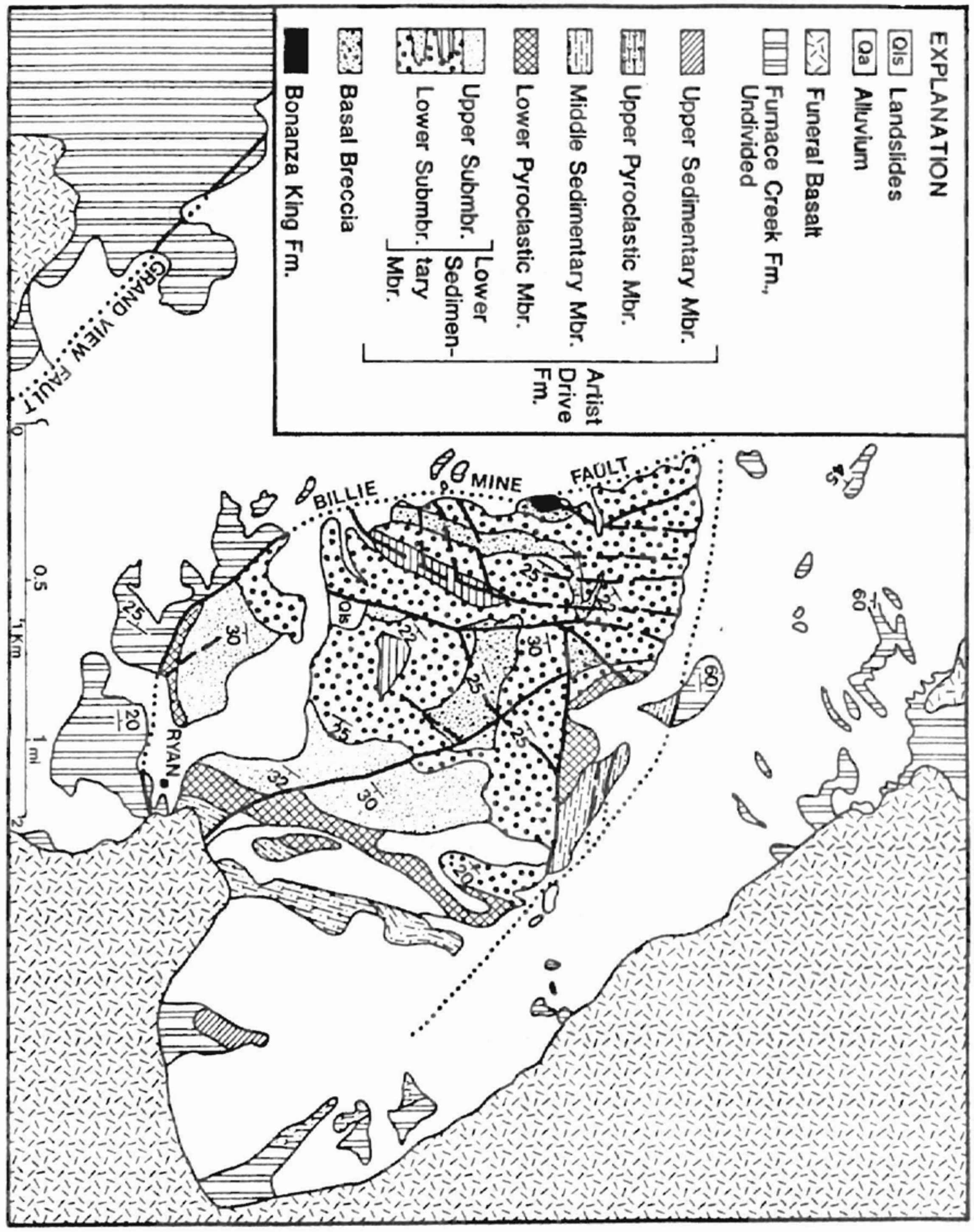


Figure 24. Geologic map of the Billie Mine area (Cemen 1988).

Cambrian Bonanza King Formation. The breccia is composed of very angular and very poorly sorted clasts of the underlying Bonanza King Formation in a red matrix. Above the breccia the lower sedimentary member is broken up into a lower submember and an upper submember. The lower submember is mostly fine to coarse-grained, light brown sandstone. The upper submember is mostly yellowish orange siltstone. Above the lower sedimentary member is the lower pyroclastic member, which is composed of massive tuff breccia. The middle sedimentary member is grayish orange or light brown in color and is composed of mudstone, sandstone and conglomerate. The upper pyroclastic member is a massive tuff breccia. The lower part of this member is pale blue green to pale greenish yellow and the upper part of this member is grayish pink to moderate pink. The upper sedimentary member is composed predominantly of conglomerate and basalt in the lower part and greenish and reddish volcanic detritus interbedded with lacustrine sandstone and mudstone. The tuff beds in this formation give radiometric dates of 14 to 7.5 Ma (Cemen and Wright, 1988).

The conglomerate and sedimentary rocks are composed of rock fragments from the Upper Proterozoic and Paleozoic rocks of the Death Valley region. From paleocurrent indicators Cemen and Wright (1988) found that the source area was to the south. This suggests that the Upper Proterozoic and Paleozoic rocks were exposed in the Black Mountains and Greenwater range where they are now absent (Cemen and Wright, 1988).

Seven thin sections from the Ryan section were examined in this study. Each sample is a litharenite with metamorphic, carbonate, granitic, and volcanic rock fragments.

RS10 is a coarse grained, sub-angular, moderately sorted, sub-mature litharenite. It has 22.7% monocrystaline quartz, 14.3% carbonate rock fragments, 7.2% metamorphic rock fragments, 19.6% granitic rock fragments, 8.1% volcanic rock fragments, 5.5% hematite, and 21.8% calcite cement.

RS20 is a medium grained, sub-angular, moderately sorted, sub-mature litharenite. It has 31.5% monocrystaline quartz, 6.0% plagioclase, 12.0% carbonate rock fragments, 5.0% metamorphic rock fragments, 11.8% granitic rock fragments, 3.5% volcanic rock fragments, 15.0% hematite, and 14.2% calcite cement.

RS22 is a medium to coarse grained, sub-angular, moderately sorted, sub-mature litharenite. It has 11.8% monocrystaline quartz, 17.4% carbonate rock fragments, 8.5% metamorphic rock fragments, 13.0% granitic rock fragments, 11.5% volcanic rock fragments, and 23.5% calcite cement. It also has 14.2% secondary porosity, but this could be exaggerated because of poor thin section preparation.

RS27 is a medium grained, sub-angular, moderately sorted, sub-mature litharenite. It has 15.5% monocrystaline quartz, 6.5% carbonate rock fragments, 13.0% metamorphic rock fragments, 1.5% granitic rock fragments, 3.0% chalcedony, 29.0% calcite cement, 3.5% hematite, and 28.0% secondary porosity. The porosity is probably over counted because of poor thin section preparation.

RS28 is a medium grained, sub-angular, moderately sorted, sub-mature litharenite. It has 30.0% monocrystaline quartz, 5.5% metamorphic rock fragments, 5.0% carbonate rock fragments, 11.5% granitic rock fragments, 2.0% volcanic rock fragments, 2.3% hematite, and 23.9% calcite cement. It also has 19.8% secondary porosity, but this high number is most likely from bad thin section preparation.

RS38 is a medium grained, sub-angular, moderately sorted, sub-mature litharenite. It has 17.5% monocrystaline quartz, 9.0% carbonate rock fragments, 4.0% metamorphic rock fragments, 13.5% granitic rock fragments, 3.5% volcanic rock fragments, 33.5% calcite cement, 1.0% hematite. It also has 18.0% secondary porosity, which could be overestimated because of poor thin section preparation.

RS123 is a fine to medium grained, sub-angular, moderately sorted sub-mature litharenite. It has 19.5% monocrystaline quartz, 10.0% carbonate rock fragments, 3.8% metamorphic rock fragments, 9.0% granitic rock fragments, 10.8% volcanic rock fragments, 2.5% hematite, and 42.9% calcite cement.

Eagle Mountain

Cemen described the Tertiary sedimentary rocks found on Eagle Mountain in 1983 (Figures 25-26). The sedimentary rocks unconformably overlie the Middle Cambrian Bonanza King Formation and are 660 feet thick. The Eagle Mountain rocks can be broken into six units. At the base there is a sedimentary breccia that is 130 feet thick. Cemen (1983) interprets the breccia as being deposited in an alluvial fan. The second unit is composed of two fining upward cycles and it 80 feet thick. These two subunits are fluvial in nature and one of them contains a rhyolitic air-fall tuff. The middle part of the section is 205 feet thick and is an interbedded conglomerate and sandstone in the lower part and a conglomerate in the upper part. Cemen (1983) interprets this unit to be another alluvial fan. The upper part of the Eagle Mountain rocks is 260 feet thick and is composed of two subunits. The lower subunit is a fine to medium grained yellow sandstone and the upper subunit is yellowish brown siliceous sandstone.

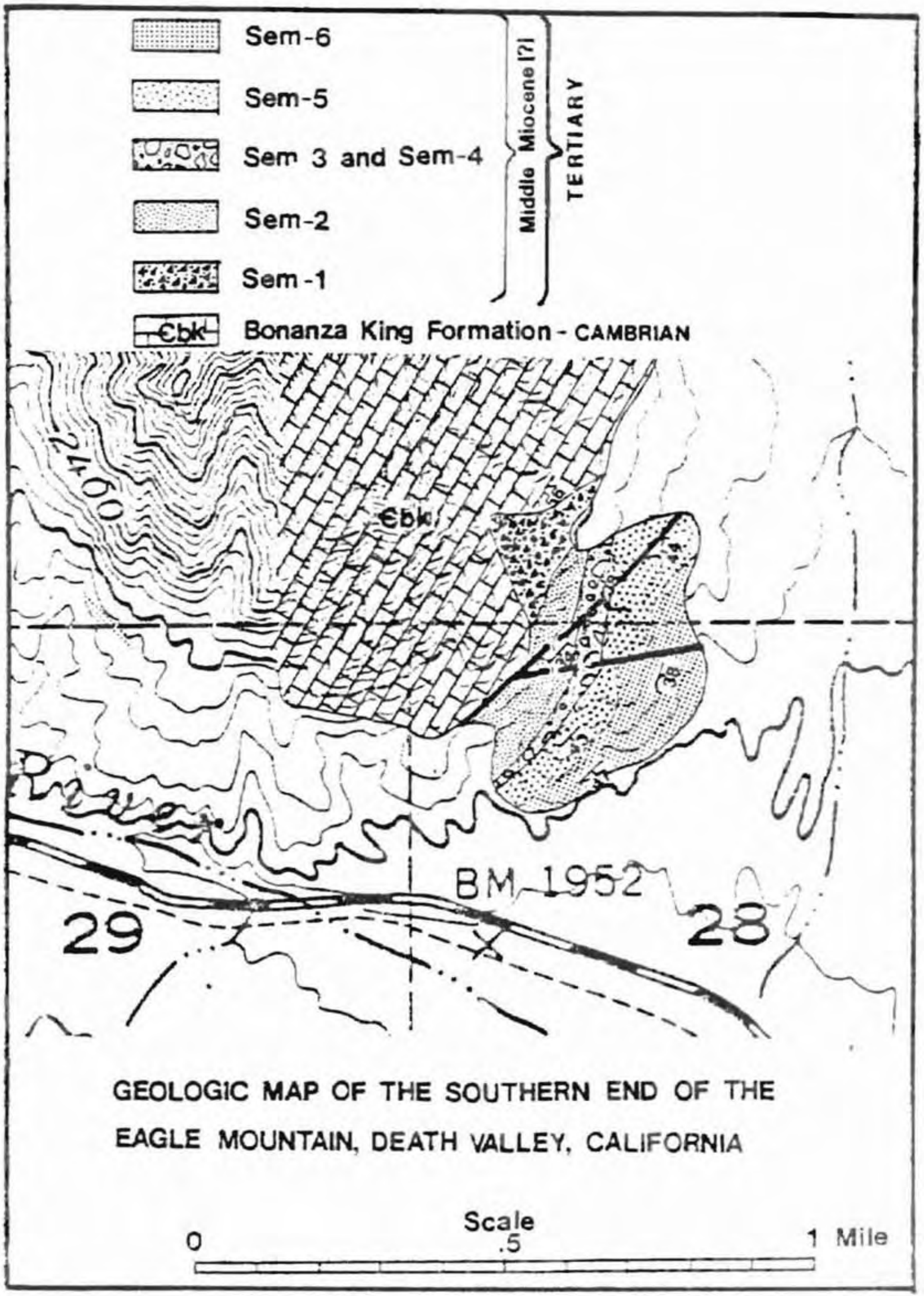
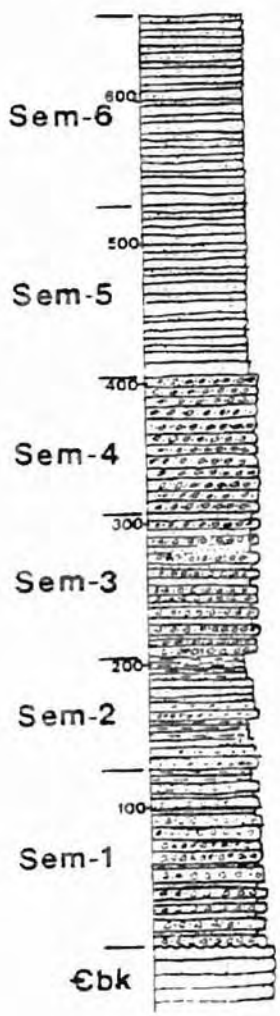


Figure 25. Map of the southern end of the Eagle Mountain (Cemen, 1983)



Sem-6: Siliceous Ss
V. pale orng (19YR 8/2) to pale yllwsh brn (10YR 6/2), v. fine to med grnd, thin to med bdd silica cemntd. .ocally contains white lenses of chert.

Sem-5: Yellow Ss.
Grysh orng (10YR 7/4) to dk yllwsh orng (10YR 6/6) fine to med brnd, thin to med bdd calcite cemntd. Contains oscillation ripple marks.

Sem-4: Cgl
Same as the cgls of Sem-3.

Sem-3: Cgl and Arkosic Ss
Arkosic ss: Pale red (5R 6/2) to mode red (5R 5/4) med to crs grnd, med to thick bdd, calcite cmtd. Contains quartz, fresh and altered feldspars and volcanic rock fragments.

Cgl: lt brn (10YR 6/4) to yllwsh brn (10YR 5/4) granule to cobble, v. anguair to ang, poorly to mod srtd, calcite cmtd. Contains abundant fragments of the Middle Cambrain Bonanza King Formation, and subordinate amounts of the Latest Precambrian Stirling, and Lower Paleozoic Eureka Quartzite and Tertiary(?) ss, and slts fragments. Contains lt brn (5YR 5/6) sandy matrix.

Sem-2: Cgl ss, ss and mudst(two fining upward cycles).
sandstone and mudstone; drk yllwsh orng (10YR 6/2) to mod yllwsh brn (10YR 5/4), thin bdd, calcite cmtd, intbdd with f. fine grnd red ss.

Arkosic ss; pale red (10 R 6/2) to pale rd purple (5RP 6/2) fine to crs grnd, thin to med bdd, calcite cmtd. Contains quartz, fresh and altered feldspars and volcanic rock fragments.

Cgl ss; grysh red (10R 4/2) to pale red (10R 6/2) v crs grnd to cgltx, med to thick bdd, calcite cmtd. Contains granules of Latest Precambrian and Lower Paleozoic Quartzite and Lower Paleozoic (Bonanza King ?) carbonate fragments. The subunit contains a one-foot thick pale grnsh yllw (10Y 8/2) rhyolitic air-fall tuff in the upper part

Sem-1: Breccia, sandstone and mudstone
Mudstone; mod rdsh orng (10R 6/6) to mod red (5R 3/4) thin bdd, calcite cmtd. Contains intbd granules of quartzite and lmst.

Sandstone; dk yllwsh orng (10YR 6/6) v fine to med grnd, med to thick bdd, calcite cmtd. Contains granule to pebble imbdc fragments of Stirling and Eureka Qtz, Bonanza King and Tert. ss and slst.

Breccia; lt brn (5YR 6/4) to mod brn (5YR 4/4) thick bdd to msu, v ang to subang, poorly srtd, calcite cmtd. Contains pebble to boulder clasts, derived entirely from the underlying Middle Cambrian Bonanza King Formation. Clasts 2 to 4 ft. in diameter. Contains lt brn (5 YR 6/4) v fine to med grnd sandy matrix.

Figure 26. Stratigraphic column of the southern end of Eagle Mountain (Cemen, 1983)

Cemen interprets the upper part of the Eagle Mountain rocks as being deposited in a small high-energy shallow basin.

Five thin sections were examined in this study. The lower the thin section number the lower the sample is in the stratigraphic section.

ES5 is a medium grained, sub-angular, moderately sorted, sub-mature, litharenite. It has 38.8% monocrystaline quartz, 4.0% plagioclase, 7.5% carbonate rock fragment, 3.5% metamorphic rock fragment, 7.4% granitic rock fragments, 1.3% volcanic rock fragment, 20.1% hematite cement, and 8.9% calcite cement. This sample also has 8.5% porosity. There is some primary intragranular porosity, and some secondary porosity from the dissolution of grains, mainly feldspar grains.

ES10 is a fine to medium grained, sub-angular, moderately sorted sub-mature litharenite. It has 19.8% monocrystaline quartz, 1.0% orthoclase, 35.2% carbonate rock fragment, 12.0% metamorphic rock fragment, 12.1% hematite cement, 13.4% calcite cement and 6.5% primary porosity. There was only a trace amount of granitic rock fragments found in this thin section.

ES11 is a medium to pebble grained, sub-angular, poorly sorted, sub-mature litharenite. This is a sample of the conglomerate. It has 1.0-% monocrystaline quartz, 81.5% carbonate rock fragments, 9.0% metamorphic rock fragments, and 8.5% calcite cement. There is only a trace amount of primary porosity. There were no granitic rock fragments found in this thin section.

ES12 is a fine-grained, sub-angular, moderately sorted, sub-mature litharenite. It has 23.1% monocrystaline quartz, 1.7-% plagioclase, 22.5% carbonate rock fragments, 6.3% metamorphic rock fragments, 2.0% volcanic rock fragments, 0.4 % muscovite, 25.5% hematite cement, and 17.5% calcite cement. This thin section also has 1.0% secondary porosity from dissolution of feldspar grains. There were no granitic rock fragments found in this thin section.

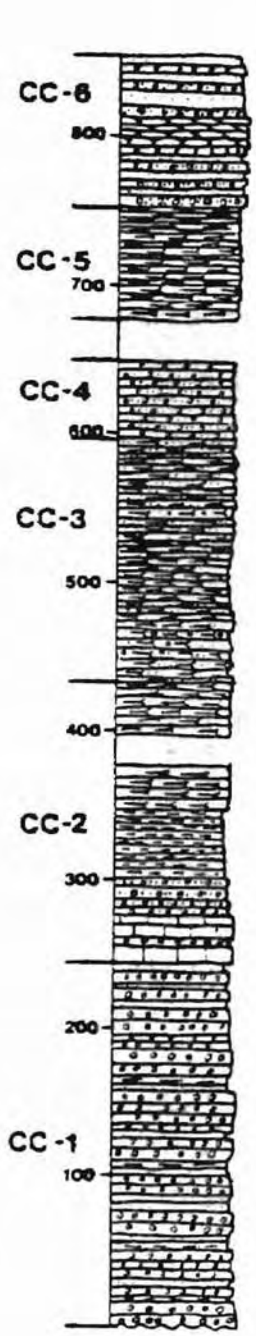
ES14 is a fine-grained, sub-angular, moderately sorted, sub-mature, litharenite. It has 11.3% monocrystaline quartz, 37.0% carbonate rock fragment, 0.4% muscovite, 15.3% hematite cement, and 32.2% calcite cement. This sample also has 3.8% primary porosity. There were no granitic rock fragments found in this thin section.

ES21 is a very fine grained, sub-angular, poorly sorted, sub-mature mudrock. It has 94.5% calcite detrital matrix, 2.9% monocrystaline quartz, and 2.6% hematite. There were no granitic rock fragments found in this thin section.

The lower numbered thin sections have granites while the higher numbers do not have granite rock fragments. ES5 has 7.4% granite rock fragments and ES10 has a trace amount of granite rock fragments.

Chlorite Cliffs

The Chlorite Cliffs area was stratigraphically measured and described by Cemen in 1983 (Figures 27 and 28). The thin section samples used from the Chlorite Cliffs area are from the Titus Canyon Formation of the Northern Funerals. The rocks exposed in this area are 1450 feet thick. The base of the formation at the Chlorite Cliffs area is a pebble to cobble sized conglomerate interbedded with greenish gray sandstone and red mudstone. Above the conglomerate the formation is composed of conglomerate, sandstone, mudstone, air-fall tuff and tuffaceous sandstone and minor proportions of



CC-6: Intrbdd cgl and ss.
Ss; lt brn (5YR 6/4), fine to crs grnd, thin to med bdd, calcite cmtd. Wthrs to grysh orng (10YR 7/4) to blksh red (5R 2/2).
Cgl; grysh grn (10GY 5/2) and 5G 5/2), subang to rndd, mod to well srtd. Contains Precambrian and Lower Paleozoic quartzite and Lower Paleozoic ls fragments. Also contains Permian cgl fragments.
This unit contains a 20 feet thick, pale olive (10Y 6/2), thin bdd to laminated banded chert. Wthrs to grysh orng (10YR 7/4).

CC-5: Air-fall tuff.
Wht (N9) to blush wht (5B9/1), v fine grnd, v thin to thin bdd. Locally Laminated. Locally intrbdd with drk yllwhs brn (10YR 4/2), v thin to thin bdd, silica cmtd sltst.

CC-4: Cgl.
Lt brn (5YR 6/4) to pale yllwsh brn (10YR 6/2), ang to rndd, poorly to well srtd. Contains abundant Tertiary volcanic rock fragments and subordinate Precambrian and Lower Paleozoic quartzite and Lower Paleozoic ls fragments.

CC-3: Tuffaceous ss and rhyloitic air-fall tuff.
Tuffaceous ss; pale olive (10Y 6/2) to pale grn (5G 7/2), med to v crs grnd, thin to thick bdd, calcite cmtd, wthrs grysh orng (10YR 7/4) to lt olive brn (5Y 5/6). Contains fragmental quartz, feldspar, biotite and rock.
Rhyolitic air-fall tuff; pale olive (10Y 6/2), thin to med bdd, wthrs dusky yllw (5Y 6/4). Locally altered to clay. Contains fragmental quartz, feldspar, biotite and rock.

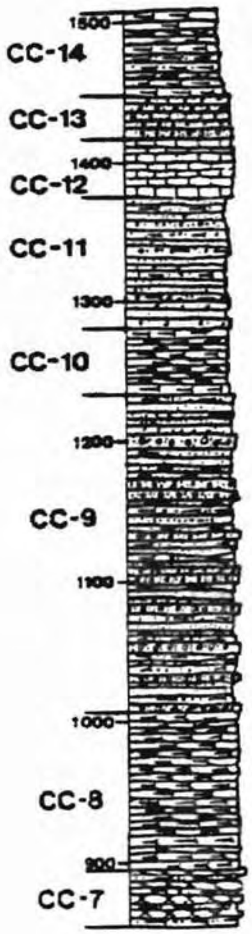
CC-2: Ls, cgl, mdst, rhyolitic air-fall tuff.
Tjyolitic air-fall tuff; mod grnsh yllw (10Y 7/4) to pale olive (10Y 6/2), v thinly to thin bdd, fractured. Contains fragmental quartz, feldspar, biotite and rock.
Mudstone; mod red (5R 5/4) and (5R 4/6), thin bdd, fractured calcite cmtd. Contains fragmental quartz, feldspar and biotite.
Cgl; lt gray (N7), rndd to well rndd, mod to well srtd. Contains Precambrian and Lower Paleozoic quartzite, and Lower Paleozoic ls clasts.
Ls; lt gry (N7) to pale red purple (5R 6/2), v thin to med bdd.

CC-1: Cgl, ss and mudstone.
ss; grnsh gry (5G 6/1), crs grnd to cgltic, med to thick bdd. Usually forms lenses, calcite cmtd.
Cgl; lt grnsh gry (5G 8/1) to grnsh gry (5G 6/1), med to thick bdd. Contains well rndd pebbles and cobbles. Contains fragments of Precambrian and Lower Paleozoic quartzite, Lower Paleozoic ls, Permian cgl and subordinate Tertiary volcanics.
Mudstone; dusky red (5R 3/4), thin bdd, calcite cmtd.

Figure 27. Bottom part of measured stratigraphic column of the Chlorite Cliffs section (Cemen, 1983)

CC-14: Itrbdd Rhyolitic Air-fall Tuff and Tffcs Ss.

CC-1r:Intrbdd rhyloitic air-fall tuff and tffcs ss.
Pale grnsh gry(5GY 8/1), fine to med grnd, thin to med bdd, intbdd with pale pink (5R8/2) thick bdd, crs grnd to conglomeratic, tffcs ss. Contains fragmental quartz, feldspar, biotite and rock. Tuff is radiometrically (K/Ar) dated as 12.6 m.y.old.



CC-13: Cgl.
Mod brn (5YR 3/4) to grysh brn (5YR 3/2) ang to subrdd, poorly to mod. srtd. Contains fragments of Precambrian and Lower Paleozoic quartzite, Lower Paleozoic ls, and Tertiary sediments and volcanics.

CC-12:
Grysh orng pink (5YR 7/2) thin to med bdd, locally laminated. Wthrs v pale orng (10YR 8/2).

CC-11: Ss and Cgl.
Grysh orng (10YR 7/4) to drk yllwsh orng (10YR 6/6), med grnd to conglomeratic, poorly to well srtd, thin to thick bdd, locally tuffaceous. Tuffaceous beds contain fragmental quartz, feldspar and biotite.and rock. Conglomeratic beds contain fragments of Precambrian and Lower Paleozoic quartzite, Lower Plaeozoic ls, and Tertiary sediments and volcanics.

CC-10: Rhyolitic air-fall tuff.
Pale grnsh yllw (10Y 8/2) to pale grn (5G7/2), fn to crs grnd, thin to med bdd. Contains fragmental quartz feldspar, biotite and rock.

CC-9: Intrbdd Cgl and ss.
ss; drk yllwsh orng (10YR 6/6), fine to crs grnd, thin to med bdd, mod to well srtd, calcite cmtd. Locally tuffaceous.
Cgl; pale yllwsh brn (10YR 6/2) to drk yllwsh brn (10YR 4/2) ang to subrndd, poorly to mod srtd. Contains fragments of Precambrian and Lower Paleozoic quartzite, Lower Paleozoic ls, and Tertiary sediments and volcanics.

CC-8: Rhyolitic air-fall tuff.
Wht (N9) to pale grnsh yllw (10Y 8/2), fine grnd, thin to med bdd. Contains fragmental quartz, feldspar, biotite and rock

CC-7: Intbdd tuffaceous ss and banded chert.
Tuffaceous ss; pale grnsh yllw (10Y 8/2), thin to med bdd, crs grnd to cgltic. Contains fragmental chert.
Banded Chert; pale olive (10Y 6/2) to lt grnsh gry (5GY 8/1), thin bdd. Wthrs to grysh orng (10YR 7/4) to drk yllwsh orng (10YR 6/6).

Figure 28. Top of stratigraphic column in the Chlorite Cliffs area (Cemen, 1983)

limestone. The tuff that overlies the Titus Canyon Formation in the Chlorite Cliff area has been radiometrically dated as 12.6 Ma (Cemen, 1983). Three thin sections were examined in this study, CC43, CC51, and CC56.

CC43 is a medium grained, sub-angular, moderately sorted, sub-mature litharenite. It has 44.7% monocrystaline quartz, 1.0-% microcline, 2.5% plagioclase, 5.0% sandstone rock fragments, 5.0% metamorphic rock fragments, 10.5% granitic rock fragments, 2.5% volcanic rock fragments, 2.0% muscovite, 2.5% chalcedony, 19.7% hematite, and 4.6% porosity.

CC51 is a medium grained, sub-angular, moderately sorted, sub-mature feldspathic litharenite. It has 24% monocrystaline quartz, 2.5% microcline, 3.0% orthoclase, 17.0% plagioclase, 13.5% carbonate rock fragments, 11.0% metamorphic rock fragments, 11.5% granitic rock fragments, 0.5% chalcedony, 6.0% hematite, and 11.0% primary porosity.

CC56 is a medium to coarse grained, sub-angular, moderately sorted, sub-mature litharenite. It has 33.8% monocrystaline quartz, 2.0% plagioclase, 4.0% sandstone rock fragments, 12.3% metamorphic rock fragments, 14.1% granitic rock fragments, 3.0% muscovite, 14.6% hematite, and 4.7% secondary porosity.

Data Analysis

The petrographic data from all of the three field areas were put into Table 5, which has the normalized percentages of quartz, feldspar, and rock fragments. The data from Table 5 was plotted on a ternary plot in Figure 29. All of the data plots together in Figure 29 except CC51 that has more feldspar.

Thin Section	Quartz	Feldspar	Rock fragments	Total
rs1	31.5	0	68.5	100
rs123	36.6	0	63.4	100
rs20	44.7	9.2	46.1	100
rs22	18.9	0	81.1	100
rs27	42.47	0	57.53	100
rs 28	55.5	0	44.5	100
rs38	36.8	0	63.2	100
cc56	43.5	2.6	53.9	100
cc43	62.7	4.9	32.4	100
cc51	29	27.3	43.7	100
es10	29.1	1.5	69.4	100
es12	41.5	3.1	55.4	100
es14	23.4	0	76.6	100
es5	62.1	6.4	31.5	100

Table 5. Normalized quartz, feldspar, and rock fragment percentages for the Ryan section, Chlorite Cliffs, and Eagle Mountain sandstones.

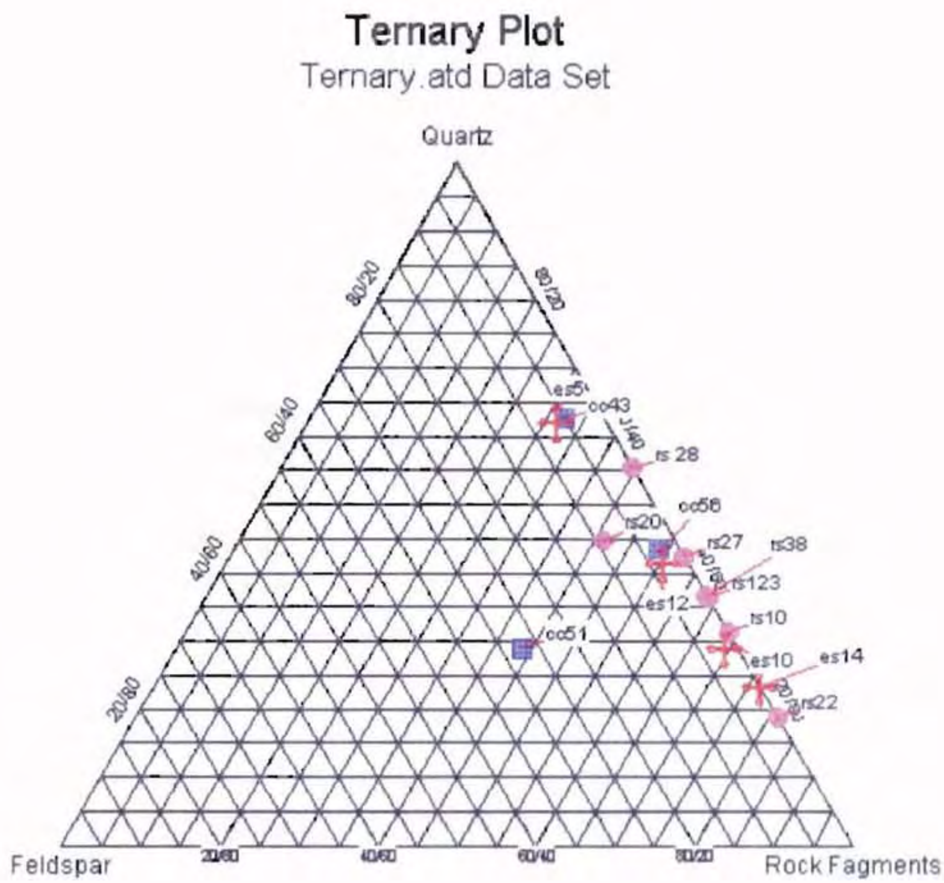


Figure 29. QRF Ternary Plot for Ryan section, Chlorite Cliffs, and Eagle Mountain sandstones from Table 5. The Ryan section is the pink dot, the Chlorite Cliffs sandstones are the blue square, and the Eagle Mountain sandstones are the red crosses.

Table 6 is all of the unnormalized data for the four types of rock fragments. Since there are four types of rock fragments and only three ends of a ternary plot Table 7 was set up to normalized the percentages of metamorphic rock fragments, granite rock fragments and sedimentary plus volcanic rock fragments. This data was plotted on a ternary plot in Figure 30. Figure 30 shows that the Ryan and Chlorite Cliff sections plot together with ES5 in the center of the plot. The Eagle Mountain section generally has more sedimentary and volcanic rock fragments.

Table 8 was set up with the normalized data of the volcanic rock fragments, granite rock fragments, and the sedimentary plus metamorphic rock fragments. This data is plotted in Figure 31; again the Ryan and Chlorite Cliff sections plot together in the center of the plot with ES5 and the rest of the Eagle Mountain section does not have any granitic rock fragments.

Summary

The three groups of rocks found in this part of the study are all located within a forty square kilometer area of each other (Figure 1) and are all roughly the same age, around 14-7 Ma. Each group of rocks has grains of metamorphic and sedimentary rock fragments from the Paleozoic rocks found in the Death Valley region and they also have volcanic rock fragments.

The lower members of the Eagle Mountain rocks as well as the Ryan section and Chlorite Cliff rocks have granite rock fragments, but the upper part of Eagle Mountain does not have granite rock fragments (Figures 30 and 31). The Ryan section has granitic

	MetaRF	GRF	SedRF	CarbRF	VolcRF
rs10	7.2	19.6	0	14.3	8.1
rs123	3.8	9	0	10	10.8
rs20	5	11.8	0	12	3.5
rs22	13	8.5	0	17.4	11.5
rs27	13	1.5	0	6.5	0
rs28	5.5	11.5	0	5	2
rs38	4	13.5	0	9	3.5
cc56	12.3	14.1	4	0	11.5
cc43	5	10.5	5	0	2.5
cc51	11	11.5	0	13.5	0
es10	12	0	0	35.2	0
es12	6.3	0	0	22.5	2
es14	0	0	0	37	0
es5	3.5	7.4	0	7.5	1.3

Table 6. The unnormalized percentages of different types of rock fragments found in the Ryan section, Chlorite Cliffs, and Eagle Mountain sandstones.

	MetaRF	GRF	Sed+VolcRF
rs10	15	40	46
rs123	11	27	62
rs20	16	37	48
rs22	26	17	57
rs27	62	7	31
rs28	23	48	29
rs38	13	45	42
cc56	29	34	37
cc43	22	46	33
cc51	31	32	38
es10	25	0	75
es12	20	0	80
es14	0	0	100
es5	18	38	45

Table 7. The normalized percentages for metamorphic rock fragments, granitic rock fragments, and sedimentary plus volcanic rock fragments for the Ryan Section, Chlorite Cliffs, and Eagle Mountain sandstones.

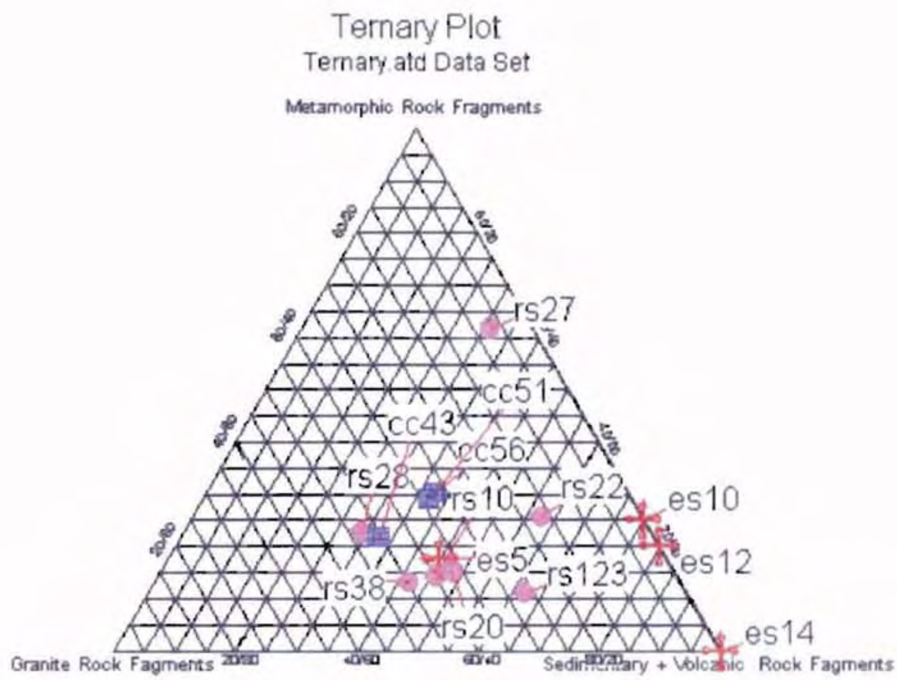


Figure 30. Ternary Plot of normalized percentages of the metamorphic rock fragments, granitic rock fragments, and sedimentary plus volcanic rock fragments from Table 7. The Ryan section is the pink dot, the Chlorite Cliffs sandstones are the blue square, and the Eagle Mountain sandstones are the red crosses.

	GRF	VolcRF	Sed+metaRF
rs10	40	16	44
rs123	27	32	41
rs20	37	11	53
rs22	17	23	60
rs27	7	0	93
rs28	48	8	44
rs38	45	12	43
cc56	34	27	39
cc43	46	11	43
cc51	32	0	68
es10	0	0	100
es12	0	6	94
es14	0	0	100
es5	38	7	56

Table 8. The normalized percentages of the granitic rock fragments, volcanic rock fragments, and the sedimentary plus metamorphic rock fragments for the Ryan Section, Chlorite Cliffs, and Eagle Mountain sandstones.

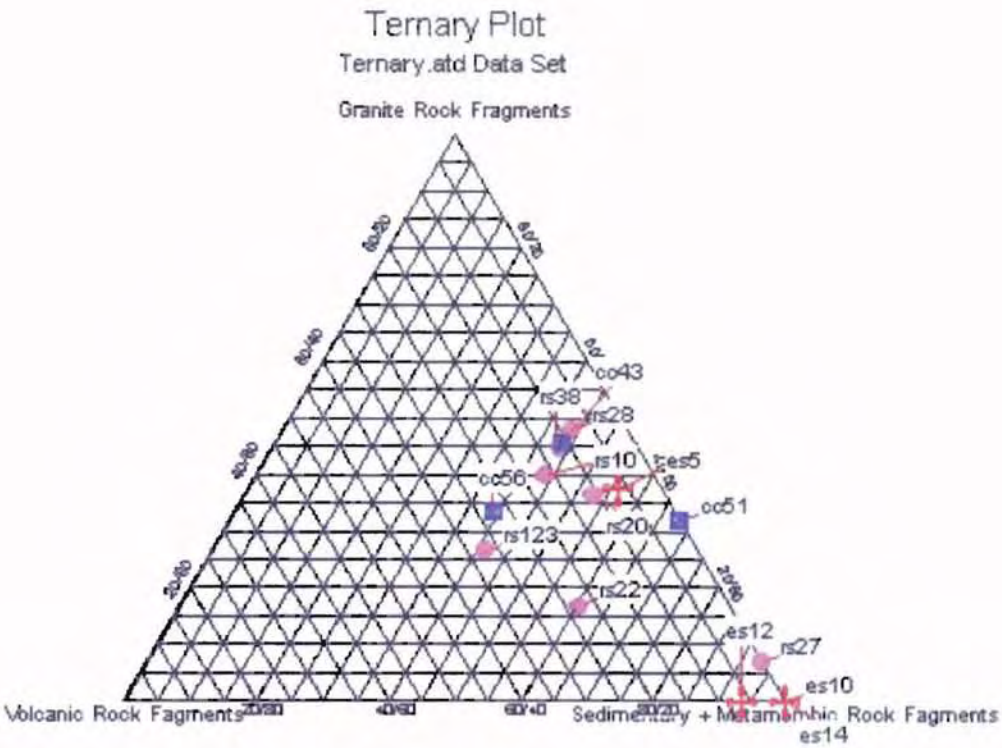


Figure 31. Ternary plot for the normalized percentages of the granitic rock fragments, volcanic rock fragments, and the sedimentary plus metamorphic rock fragments from Table 8. The Ryan section is the pink dot, the Chlorite Cliffs sandstones are the blue square, and the Eagle Mountain sandstones are the red crosses.

rock fragments with zebra texture, which looks the same as a sample taken from the Hunter Mountain Batholith in thin section (Figure 32).

Figure 32 includes pictures of granitic rock fragments from Ash Meadows, Ryan Section, Chlorite Cliff, and Eagle Mountain thin sections plus a picture of a thin section taken from the Hunter Mountain Batholith. The textures are all very similar and it is not possible to tell if they all are from the Hunter Mountain Batholith or not in this study. It would take a more detailed study in the different granite types and bodies found in the Death Valley region to figure this out. The Chlorite Cliff rocks have granitic fragments, but these possibly came from granite sources to the north of the area. The Eagle Mountain rocks have a southerly source area, therefore, the granitic fragments found in the lower units are likely from granite bodies to the south of Eagle Mountain.

To statistically correlate the amount of granitic rock fragments with each deposit grain size must be taken into account. One limitation of this study is the low sample size and the fact that each sample did not have the same grain sizes. Future studies of these topics in this area must try to sample rocks with similar grain sizes and think about the effect that grain size has on the type of rock fragments found in sandstone.

It is not possible to tell exactly where the granitic rock fragments came from, but since the Ryan section rocks have the most granitic rock fragments it is probable that the Ryan section was closest to the Hunter Mountain Batholith during deposition. It is also probable that the hypothesis presented by Nemei et al. (2001) is incorrect and that the Eagle Mountain rocks are not an alluvial fan deposit formed next to, and eroding, the Hunter Mountain Batholith. The Eagle Mountain rocks could have simply deposited in a fluvial system that carried a few larger pieces of granite into the area. Therefore, the 100-

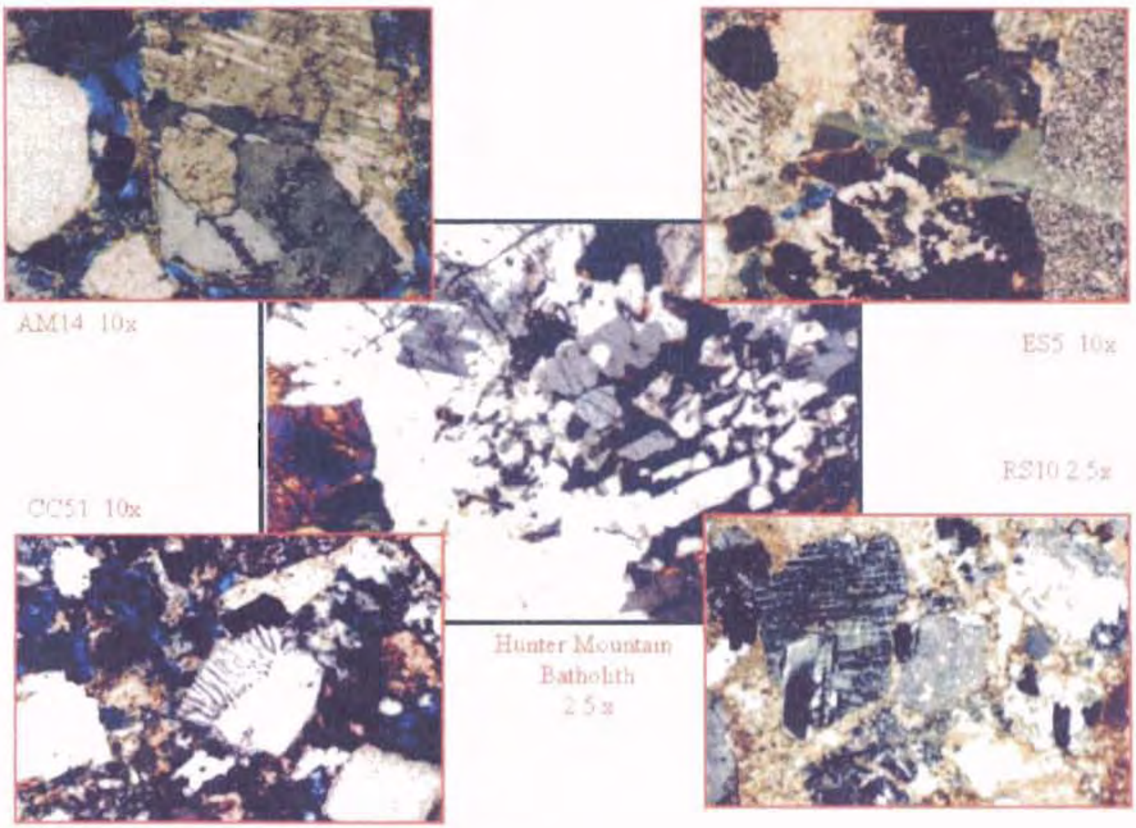


Figure 32. Pictures of granitic rock fragments from four thin sections from each study area and a picture a thin section taken from the Hunter Mountain Batholith.

km extension for the region that Nemei et al. predicts is an overestimate; this means that amount of extension in the region must be less than 100 km.

CHAPTER SIX

CONCLUSIONS

The conclusions of this study are as follows:

1. The sedimentary source was a high area to the northwest created by early extensional tectonic uplift in the Death Valley region for the sandstones and to the southeast for the alluvial fan deposite.
2. The rock fragments found in these rocks are Paleozoic rocks found in the Death Valley region and volcanic rock fragments from regional volcanic activity in the region.
3. The Ryan section outcrop of the Artist Drive Formation has a southerly and northwestern source area, which includes Paleozoic rocks of the Death Valley region, volcanic rock fragments, and granite rock fragments from the Hunter Mountain Batholith. The Ryan section and the Ash Meadows rocks are not correlatable and were not deposited in the same basin. There was most likely a topographic high separating the two areas during the middle and late Miocene. The sedimentation would have occurred before the opening of the Armogosa Valley.

4. The Chlorite Cliff sedimentary rocks are part of the Titus Canyon Formation and contain rock fragments from the Paleozoic rocks of the Death Valley Region, volcanic rock fragments, and granite rock fragments. The granite rock fragments most likely came from granite bodies to the north of the Chlorite Cliff area. These rocks are not correlatable with the Ash Meadows or the Ryan section rocks.
5. The Eagle Mountain sedimentary rocks contain rock fragments from the Paleozoic rocks of the Death Valley region and volcanic rock fragments. The rocks lower in the section contain granite rock fragments, but the upper rocks do not. A tectonic event may have cut off the granite rock fragment supply to the area during deposition of column of rocks.

The purpose of this thesis is to produce a detailed study of the Ash Meadows area in order to provide new data, which can be used to piece together the Cenozoic tectonic history of the Death Valley region. This study showed that the Ash Meadows sedimentary rocks where deposited as a result of the extensional tectonics of the Death Valley region during the Mid-Miocene. The extensional movements of the faults in area created a high area that was first eroded by an alluvial fan system creating the conglomerate at the base of the Ash Meadows section. Fluvial systems eroded the high areas to the northeast until created by movements along faults in the region. After the deposition of Sandstone Unit 3 movement along extensional faults caused the tilting of the whole package of units to the north and the top unconformity surface with Sandstone Unit 4 was created.

Future Studies

Future studies must take into account the grain sizes when trying to statistically examine the types of grains found in sandstones. A study that worked on matching the granitic rock fragments to a particular granitic body would help to identify what exactly the source areas are for these rocks are. Future studies will also want to use larger sample sizes and expand the study to other Tertiary deposits in the Death Valley region.

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APPENDIX

THIN SECTION NUMBER: AM22
DATE: 4/17/01
LOCATION: Conglomerate

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	8.5	.1-.2
Microcline		
Orthoclase		
Plagioclase		
Sandstone RF	2.0	.5
Carbonate RF	44.1	2
Metamorphic RF	24.5	.5-2
Plutonic RF		
Volcanic RF		
Chert	5.0	1
Biotite		
Hematite		
Calcite cement	13.9	.05
Porosity (secondary)	2.0	.05-.1

Matrix = 0 %	Normalized
Q= 8.5%	10.2%
F= 0%	0%
R= 75.6%	89.8%
Total 84.1%	**100%**

CLASSIFICATION
NAME: Litharenite (sedarenite)
TEXTURE
SPHERICITY: sub-angular
SORTING: poorly sorted
MATURITY: sub-mature

DESCRIPTION

AM22 is a sub-angular, poorly sorted, sub-mature litharenite. It has 44.1% carbonate rock fragments, 24.5% metamorphic rock fragments, 2.0% sandstone rock fragments, 8.5% quartz, 5.0% chert rock fragments, and 13.9% calcite cement. The thin section also has 2.0% secondary porosity from intergranular, fracture, and enlarged pores porosity.

SAMPLE ID: AM22

Point Counts:

	10	9	8	7	6	5	4	3	2	1	
8.5	10	0	10	20	0	0	10	20	5	10	Quartz
24.5	35	0	0	10	100	80	0	20	0	0	Meta RF
44.1	30	98	87	40	0	0	65	30	11	80	Carb RF
2.0	0	0	0	0	0	20	0	0	0	0	Sed RF
13.9	20	0	0	30	0	0	25	24	30	10	Calcite C
2.0	5	2	3	0	0	0	0	6	4	0	Porosity
5.0	0	0	0	0	0	0	0	0	50	0	Chert RF

THIN SECTION NUMBER: AM23
DATE: 4/17/01
LOCATION: Conglomerate

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	4.5	.1-.2
Microcline		
Orthoclase		
Plagioclase	T	.1
Sandstone RF	12.5	1
Carbonate RF	56.1	.1-2
Metamorphic RF	17.0	.5-.9
Plutonic RF		
Volcanic RF		
Muscovite		
Biotite		
Hematite		
Calcite cement	9.3	.05
Porosity (secondary)	0.6	.05-.1

Matrix = 0 %	Normalized
Q= 4.5%	5.0%
F= 0%	0%
R= 85.6%	95.0%
Total 90.1%	**100%**

CLASSIFICATION

NAME: Litharenite (sedarenite)

TEXTURE

SPHERICITY: sub-angular
SORTING: poorly sorted
MATURITY: sub-mature

DESCRIPTION

AM23 is a sub-angular, poorly sorted, sub-mature litharenite. It has 56.1% carbonate rock fragments, 17.0% metamorphic rock fragments, 12.5% sandstone rock fragments, 4.5% quartz, and 9.3% calcite cement. The thin section also has 0.6% secondary porosity from intergranular, and fracture porosity.

SAMPLE ID: AM23

Point Counts:

	10	9	8	7	6	5	4	3	2	1	
4.5	5	0	10	0	0	0	0	30	0	0	Quartz
56.1	95	100	63	10	85	85	63	60	0	0	Carb RF
17.0	0	0	0	85	0	0	0	0	85	0	Meta RF
12.5	0	0	10	0	0	0	15	0	0	100	Sed RF
0.6	0	0	2	0	0	2	2	0	0	0	Porosity
9.3	0	0	15	5	15	13	20	10	15	0	Calcite C

THIN SECTION NUMBER: AM24
DATE: 4/20/00
LOCATION: Conglomerate

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	17.8	.1-.4
Microcline	T	.1
Orthoclase	-	-
Plagioclase	T	.1
Sandstone RF	-	-
Carbonate RF	60	.1-.3
Metamorphic RF	T	.2
Plutonic RF	-	-
Volcanic RF	T	.1-.2
Muscovite	-	-
Biotite	-	-
Hematite	3.9	.05
Amphibole	T	.2
Calcite cement	6.5	.01
Porosity (secondary)	11.8	.02-.1

Matrix = 0 %	Normalized
Q= 17.8%	22.8%
F= 0 %	0%
R= 60 %	77.2%
Total 77.8%	**100%**

CLASSIFICATION

NAME: Litharenite (sedarenite)

TEXTURE

SPHERICITY: sub-angular
SORTING: well sorted
MATURITY: mature

DESCRIPTION

AM-24 is from a thin sand unit in the conglomerate. It is a sub-angular, well-sorted, mature litharenite. It has 17.8% mono quartz, 60% carbonate rock fragments, 6.5% calcite cement, 3.9% hematite, and 11.8% secondary porosity from the dissolution of grains. It also has trace amounts of microcline, plagioclase, metamorphic rock fragments, volcanic rock fragments, and amphibole grains. There must have been water moving through this rock with a high pH, because some of the quartz grains have been corroded.

SAMPLE ID: AM24

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
17.8	12	11	5	19	32	6	32	17	27	17	Quartz
60	63	69	60	47	49	82	47	53	60	70	Carb RF
11.8	13	15	17	14	12	4	5	15	10	13	Porosity
6.5	8	5	10	15	5	0	12	10	0	0	Calcite C
3.9	4	0	8	5	2	8	4	5	3	0	Hematite

THIN SECTION NUMBER: AM26
DATE: 4/17/01
LOCATION: Conglomerate

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	2.3	.1
Microcline		
Orthoclase		
Plagioclase		
Sandstone RF		
Carbonate RF	40.5	.1-1.5
Metamorphic RF	49.5	3
Plutonic RF		
Volcanic RF		
Chert RF	t	.1
Biotite		
Hematite		
Calcite cement	7.7	.05
Porosity (secondary)	t	.05-.1

Matrix = 0 %	Normalized
Q= 2.3%	2.5%
F= 0%	0%
R= 90%	97.5%
Total 92.3%	**100%**

CLASSIFICATION
NAME: Litharenite (sedarenite)
TEXTURE
SPHERICITY: sub-angular
SORTING: poorly sorted
MATURITY: sub-mature

DESCRIPTION

AM26 is a sub-angular, poorly sorted, sub-mature litharenite. It has 40.5% carbonate rock fragments, 49.5% metamorphic rock fragments, 2.3% quartz, and 7.7% calcite cement. The thin section also has trace amount of secondary porosity from intergranular, and fracture porosity.

SAMPLE ID: AM26

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
2.3	5	0	0	5	0	0	0	0	10	3	Quartz
40.5	70	0	0	20	0	100	60	0	70	85	Carb RF
49.5	0	100	100	60	100	0	35	100	0	0	Meta RF
7.7	25	0	0	15	0	0	5	0	20	12	Calcite C

THIN SECTION NUMBER: AM27
DATE: 4/24/00
LOCATION: Conglomerate

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	1.9	.2
Microcline	-	-
Orthoclase	-	-
Plagioclase	-	-
Sandstone RF	4.9	.6
Carbonate RF	86.5	.5-10
Metamorphic RF	T	.3
Plutonic RF	-	-
Volcanic RF	T	.1
Muscovite	-	-
Biotite	-	-
Hematite	1.5	.2
Calcite cement	2.6	.02
Porosity (secondary)	2.6	.1-.4

Matrix = 0 %	Normalized
Q= 1.9%	2.03%
F= 0 %	0%
R= 91.4%	97.97%
Total 93.3%	**100%**

CLASSIFICATION

NAME: Litharenite (sedarenite)

TEXTURE

SPHERICITY: sub-angular
SORTING: poorly sorted
MATURITY: sub-mature

DESCRIPTION

AM-27 is also found in the conglomerate unit. This unit has large clast of about six to one half of an inch big. The thin section was cut at a place that had a lot of matrix. The sample is a sub-angular, poorly sorted, sub-mature litharenite. It has 1.9% quartz, 4.9% sandstone rock fragments, 86.5% carbonate rock fragments with fossils found in them, 1.5% hematite, and 2.6% calcite cement. There is 2.6% primary porosity found between the rock fragments. There are also trace amounts of metamorphic rock fragments, and volcanic rock fragments. The metamorphic rock fragments are quartzite and the volcanic rock fragments are volcanic glass.

SAMPLE ID: AM27

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
1.9	0	2	0	5	3	0	9	0	0	0	Quartz
86.5	83	57	100	84	74	100	80	100	100	87	Carb RF
4.9	17	22	0	0	0	0	0	0	0	10	Sed RF
2.6	0	14	0	1	10	0	0	0	0	0	Porosity
2.6	0	5	0	5	3	0	11	0	0	2	Calcite C
1.5	0	0	0	5	10	0	0	0	0	0	Hematite

THIN SECTION NUMBER: AM3
DATE: 4/25/00
LOCATION: tuff

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	24.1	.1-.4
Microcline	t	.4
Orthoclase		
Plagioclase	2.8	.2
Sandstone RF		
Carbonate RF	30.2	.2-.6
Metamorphic RF		
Plutonic RF		
Volcanic RF	8.3	.2-.3
Chalcedony	4.6	3
pyrite	t	.1
Hematite	1.5	.1
hornblende	T	.2
Calcite cement	20.9	.2-.3
Porosity (secondary)	7.6	.01-.1

Matrix = 0 %	Normalized
Q= 24.1%	33.7%
F= 2.8%	3.9%
R= 43.1%	62.4%
Total 70%	**100%**

CLASSIFICATION
NAME: Litharenite (sedarenite)
TEXTURE
SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

AM-3 was found at the top of the first volcanic unit. This rock was on the boarder of the first volcanic unit and the first sandstone unit. It is a sub-angular, moderately sorted, sub-mature litharenite. It has 24.1% mono quartz, 30.2% carbonate rock fragments, 8.3% volcanic rock fragments, 4.6% chalcedony rock fragments, 2.8% plagioclase, 20.9% calcite cement, 1.5% hematite, and 7.6% primary porosity. There are also trace amounts of microcline, pyrite, and hornblende.

SAMPLE ID: AM3

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
24.1	42	10	0	15	25	18	39	28	30	34	Quartz
2.8	3	8	0	0	0	0	3	14	0	0	Plag
30.2	28	25	46	59	45	22	27	0	25	25	Carb RF
8.3	20	20	6	0	0	31	0	6	0	0	Volc RF
20.9	2	32	0	19	10	9	18	42	41	36	Calcite C
7.6	5	5	2	7	20	12	6	10	4	5	Porosity
1.5	0	0	0	0	0	8	7	0	0	0	Hematite
4.6	0	0	46	0	0	0	0	0	0	0	Chalcedony

THIN SECTION NUMBER: AM4
DATE: 5/9/00
LOCATION: Sandstone 1

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	1	.3
Microcline	t	1
Orthoclase		
Plagioclase	t	.35
Sandstone RF	9	2.5
Carbonate RF	61	.5-2
Metamorphic RF	4.5	1
Plutonic RF		
Volcanic RF		
Pyrite	t	.2
Hornblende	t	.5
Hematite	t	.1
zircon	0.3	.1
Calcite cement	21.7	0.5
Porosity (secondary)	2.5	.01-.1

Matrix = 0 %	Normalized
Q= 1%	1.74%
F= 0%	0%
R= 74.5%	98.26%
Total 75.5%	**100%**

CLASSIFICATION

NAME: Litharenite

TEXTURE

SPHERICITY: sub-angular
SORTING: very poorly sorted
MATURITY: sub-mature

DESCRIPTION

AM4 is a sub-angular, very poorly sorted, sub mature litharenite. It has 1% quartz, 61% carbonate rock fragments, 9% sedimentary rock fragments, 4.5% metamorphic rock fragments, 0.3% Zircon, 21.7% Calcite cement, and 2.5% secondary porosity. The secondary porosity is from fracture porosity and intergranular porosity.

SAMPLE ID: AM4

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
1	0	0	0	10	0	0	0	0	0	0	Quartz
61	30	88	75	55	97	100	0	70	65	30	Carb RF
21.7	43	5	22	33	0	0	10	29	25	50	Calcite C
2.5	2	7	0	2	3	0	0	1	10	0	Porosity
4.5	25	0	0	0	0	0	0	0	0	20	Meta RF
9	0	0	0	0	0	0	90	0	0	0	Sed RF
0.3	0	0	3	0	0	0	0	0	0	0	Zircon

THIN SECTION NUMBER: AM5
DATE: 5/9/00
LOCATION: Sandstone 1

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	6.1	.2
Microcline	t	.2
Orthoclase		
Plagioclase	t	.1-.4
Sandstone RF	t	1
Carbonate RF	43.5	.1-5
Metamorphic RF	0.3	1
Siltstone RF	0.3	1
Volcanic RF	2	.3
Muscovite		
Pyrite	t	.1
Hematite	0.3	.1
Calcite cement	45.1	.1
Porosity (secondary)	2.7	.1

Matrix = 0 %	Normalized
Q= 6.1%	11.6%
F= 0%	0%
R= 45.8%	88.4%
Total 51.9%	**100%**

CLASSIFICATION

NAME: Litharenite

TEXTURE

SPHERICITY: sub-angular
SORTING: poorly sorted
MATURITY: sub-mature

DESCRIPTION

AM5 is a sub-angular, poorly sorted, sub mature litharenite. It has 6.1% quartz, 43.5% carb RF, 45.1% calcite cement, 2.7% secondary porosity, 2.0% Volcanic RF, and 0.3% metamorphic RF. The secondary porosity is fracture porosity and intragranular porosity.

SAMPLE ID: AM5

Point Counts:

	10	9	8	7	6	5	4	3	2	1	
6.1	0	0	5	20	10	10	0	6	10	0	Quartz
43.5	100	80	30	30	20	20	30	30	20	75	Carb RF
45.1	0	10	63	44	70	50	62	62	66	24	Calcite C
2.7	0	10	2	3	0	0	5	2	4	1	Porosity
0.3	0	0	0	0	0	0	3	0	0	0	Hematite
2.0	0	0	0	0	0	20	0	0	0	0	Volc RF
0.3	0	0	0	3	0	0	0	0	0	0	Meta RF

THIN SECTION NUMBER: AM6
DATE: 4/23/00
LOCATION: Sandstone 1

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	6.3	.1-.3
Microcline		
Orthoclase		
Plagioclase	1.2	.3
Sandstone RF	t	1
Carbonate RF	74.3	.1-1
Metamorphic RF	6.1	.1-.5
Plutonic RF		
Volcanic RF		
Muscovite		
Hornblende	.1	.1
Hematite	.3	.1
Calcite cement	7.2	.05
Porosity	4.5	.05-.1

Matrix = 0 %	Normalized
Q= 6.3%	7.1%
F= 1.2%	1.3%
R= 80.4%	91.6%
Total 87.9%	**100%**

CLASSIFICATION
NAME: Litharenite (sedarenite)
TEXTURE
SPHERICITY: sub-angular
SORTING: poorly sorted
MATURITY: sub-mature

DESCRIPTION

AM-6 is a sub-angular, poorly sorted, sub-mature litharenite. It has 6.3% mono quartz, 74.3% carbonate rock fragments, 6.1% metamorphic rock fragments, 1.2% plagioclase, 0.1% hornblende, 0.3% hematite, 7.2% calcite cement, and 4.5% primary porosity. There is also a trace amount of sandstone rock fragments and secondary porosity from the dissolution of grains and enlarged pore spaces.

SAMPLE ID: AM6

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
6.3	0	0	5	2	19	0	5	37	0	0	Quartz
74.3	92	81	51	84	74	49	79	56	87	90	Carb RF
7.2	0	5	5	12	5	13	10	8	5	9	Calcite C
6.1	0	0	28	0	0	33	0	0	0	0	Meta RF
4.5	8	2	8	2	2	5	6	3	8	1	Porosity
0.1	0	0	0	0	0	0	0	1	0	0	Hornblende
0.3	0	0	3	0	0	0	0	0	0	0	Hematite
1.2	0	12	0	0	0	0	0	0	0	0	Plag

THIN SECTION NUMBER: AM8
DATE: 4/23/00
LOCATION: Sandstone 2

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	15.6	.1-.3
Microcline		
Orthoclase		
Plagioclase	3.0	.2-.5
Sandstone RF		
Carbonate RF	33.6	.4
Metamorphic RF	4.2	.3
Plutonic RF		
Volcanic RF	11.9	.5
Chalcedony	t	.2
Pyrite	1.5	.1
Hornblende	0.5	.3
Calcite cement	25.9	.1
Porosity (secondary)	3.8	.05

Matrix = 0 %	Normalized
Q= 15.6%	22.7%
F= 3.0%	4.4%
R= 49.7%	72.9%
Total 68.3%	**100%**

CLASSIFICATION
NAME: Litharenite (sedarenite)
TEXTURE
SPHERICITY: sub-rounded
SORTING: well sorted
MATURITY: mature

DESCRIPTION

AM-8 is a sub-rounded, well-sorted, mature litharenite. It has 15.6% mono quartz, 3.0% plagioclase, 33.6% carbonate rock fragments, 4.2% metamorphic rock fragments, 11.9% volcanic rock fragments, and 1.5% pyrite and 0.5% hornblende. There is 25.9% calcite cement and 3.8% primary porosity. There is also a trace amount of chalcedony rock fragments.

SAMPLE ID: AM8

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
15.6	5	10	0	65	5	10	20	0	36	5	Quartz
33.6	54	22	80	0	0	45	25	30	0	80	Carb RF
11.9	0	5	0	5	35	30	16	5	23	0	Volc RF
4.2	0	0	0	0	0	0	0	42	0	0	Meta RF
3.0	0	10	9	0	0	0	0	0	0	11	Plag
3.8	5	1	3	4	5	0	14	2	0	4	Porosity
25.9	24	52	8	26	52	15	20	21	41	0	Calcite C
1.5	7	0	0	0	3	0	5	0	0	0	Pyrite
0.5	5	0	0	0	0	0	0	0	0	0	Hornblende

THIN SECTION NUMBER: AM9
DATE: 5/9/00
LOCATION: Sandstone 2

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	20.3	.3
Microcline	t	.2
Orthoclase		
Plagioclase	3.2	.2-.3
Sandstone RF	0.5	.3
Carbonate RF	27.9	.3
Metamorphic RF	2.3	.2
Plutonic RF		
Volcanic RF	1.5	.3
Muscovite		
Biotite	t	.5
Hematite	1.6	.1
Zircon	t	.2
Hornblende	0.8	.4
Calcite cement	35.9	0.5
Porosity (secondary)	6.0	.05-.1

Matrix = 0 %	Normalized
Q= 20.3%	36.3%
F= 3.2%	5.6%
R= 32.2%	58.1%
Total 55.7%	**100%**

CLASSIFICATION

NAME: Litharenite

TEXTURE

SPHERICITY: sub-angular to sub-rounded
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

AM9 is a sub-angular to sub-rounded, moderately sorted, sub mature litharenite. It has 20.3% quartz, 3.2% plagioclase, 27.95 carbonate rock fragments, 1.5% volcanic rock fragments, 2.3% metamorphic rock fragments, 0.5% sedimentary rock fragments, 1.6% hematite, 0.8% hornblende, and 35.9% calcite cement. There is 6.0% secondary porosity, which is from the dissolution of grains, intragranualr porosity, fracture porosity, and honeycomb porosity.

SAMPLE ID: AM9

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
20.3	10	23	30	18	24	55	18	5	10	10	Quartz
27.9	30	25	44	20	25	5	25	40	42	25	Carb RF
1.5	0	5	0	2	0	0	5	3	0	0	Volc RF
35.9	32	32	24	49	37	35	34	36	33	47	Calcite C
6.0	8	15	2	8	3	5	5	3	5	6	Porosity
3.2	10	0	0	0	0	0	0	0	12	10	Plag
1.6	2	0	0	3	6	0	0	3	0	2	Hematite
2.3	0	0	0	0	0	0	13	10	0	0	Meta RF
0.5	0	0	0	0	5	0	0	0	0	0	Sed RF
0.8	8	0	0	0	0	0	0	0	0	0	hornblende

THIN SECTION NUMBER: AM10
DATE: 5/10/00
LOCATION: Sandstone 2

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	21.7	.1-.6
Microcline	T	.3
Orthoclase		
Plagioclase	11.1	.3-.5
Sandstone RF		
Carbonate RF	10.7	.5
Metamorphic RF	15.3	.3
Plutonic RF		
Volcanic RF	7.6	.3
Chalcedony	t	.5
Biotite	t	.5
Pyrite	t	.05-.1
Hematite	1.8	.1
chlorite	t	.3
Calcite cement	17.8	.1
Porosity (secondary)	14.0	.1

Matrix = 0 %	Normalized
Q= 21.7%	32.5%
F= 11.1%	16.7%
R= 33.6%	50.8%
Total 66.4%	**100%**

CLASSIFICATION

NAME: Litharenite

TEXTURE

SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

AM10 is a sub-angular, moderately sorted, sub mature litharenite. It has 21.7% quartz, 11.1% plagioclase, 10.7% carbonate rock fragments, 7.7% volcanic rock fragments, 15.3% metamorphic rock fragments, 17.8% calcite cement and 1.8% hematite. It has 14% secondary porosity from honeycomb, dissolution of grains, enlarged pores and intergranular porosity.

SAMPLE ID: AM10

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
21.7	40	33	38	0	30	14	0	3	25	34	Quartz
10.7	20	0	0	60	0	0	0	27	0	0	Carb RF
7.6	0	20	18	0	18	0	20	0	0	0	Volc RF
15.3	0	15	20	0	0	15	45	28	10	20	Meta RF
14.0	15	25	10	13	20	8	23	6	15	5	Porosity
11.1	5	0	1	27	18	5	0	28	20	7	Plag
17.8	20	7	13	0	14	48	4	8	30	34	Calcite C
1.8	0	0	0	0	0	10	8	0	0	0	Hematite

THIN SECTION NUMBER: AM11
DATE: 4/23/00
LOCATION: Sandstone 3

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	19.3	.1
Microcline	t	.1
Orthoclase		
Plagioclase	9.9	.1
Sandstone RF		
Carbonate RF	1.0	.1
Metamorphic RF		
Plutonic RF		
Volcanic RF	17.9	.1
Muscovite		
Biotite	t	.3
Hematite	6.2	.1
Zircon	t	.1
Hornblende	t	.1
Calcite cement	45.1	.05
Porosity (secondary)	.6	.03

Matrix = 0 %	Normalized
Q= 19.3%	39.9%
F= 9.9%	21%
R= 18.9%	39.1%
Total 48.1%	**100%**

CLASSIFICATION

NAME: Feldspathic Litharenite

TEXTURE

SPHERICITY: sub-rounded
SORTING: well sorted
MATURITY: mature

DESCRIPTION

AM-11 is a sub-rounded, well-sorted, mature feldspathic litharenite. It has 19.3% mono quartz, 9.9% plagioclase, 17.9% volcanic rock fragments, 1% carbonate rock fragments, 6.2% hematite, and 45.1% calcite cement. There is also 0.6% primary porosity. There is also a trace amount of microcline, biotite, zircon, and hornblende.

SAMPLE ID: AM11

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
19.3	15	40	15	10	10	20	20	18	20	25	Quartz
9.9	15	0	12	10	6	0	16	15	20	5	Plag
17.9	25	0	12	10	8	25	10	25	5	30	Volc RF
45.1	35	36	45	54	66	52	54	37	45	27	Calcite C
0.6	0	0	0	0	0	3	0	0	0	3	Porosity
6.2	10	3	8	16	10	0	0	0	5	10	Hematite
1.0	0	0	0	0	0	0	0	5	5	0	Carb RF

THIN SECTION NUMBER: AM12
DATE: 5/10/00
LOCATION: Sandstone 3

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	9.9	.2-.3
Microcline	1.5	.2
Orthoclase		
Plagioclase	16.0	.2-.3
Sandstone RF		
Carbonate RF	t	.2
Metamorphic RF	2.2	.2-.4
Plutonic RF		
Volcanic RF	33.1	.2
Muscovite	t	.4
Biotite	1.0	.3
Hematite	10.5	.1
Zircon	t	.1
Hornblende	T	.3
Calcite cement	19.9	.05
Porosity (secondary)	5.9	.05-.3

Matrix = 0 %	Normalized
Q= 9.9%	15.8%
F= 17.5%	28.0%
R= 35.3%	56.2%
Total 62.7%	**100%**

CLASSIFICATION
NAME: Feldspathic Litharenite
TEXTURE
SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

AM12 is a sub-angular, moderately sorted feldspathic litharenite. It has 9.9% quartz, 33.1% volcanic rock fragments, 2.2% metamorphic rock fragments, 19.9% calcite cement, 10.5% hematite, 16.0% plagioclase, 1.5% microcline, 1.0% biotite, and 5.9% secondary porosity. There is a trace amount of intergranular primary porosity (from volcanic rock fragments) and honeycomb, enlarged pores, dissolution of grains, and intergranular secondary porosity.

SAMPLE ID: AM12

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
9.9	18	20	7	0	3	0	20	10	16	5	Quartz
33.1	30	38	35	30	40	44	40	30	9	35	Volc RF
2.2	0	0	0	0	0	0	0	0	7	15	Meta RF
5.9	8	5	8	2	15	1	5	5	8	2	Porosity
19.9	21	18	27	23	19	30	15	23	20	3	Calcite C
10.5	15	5	3	10	10	5	0	10	7	40	Hematite
16.0	8	14	10	20	13	20	20	22	23	0	Plag
1.5	0	0	0	15	0	0	0	0	0	0	Microcline
1.0	0	0	10	0	0	0	0	0	0	0	biotite

THIN SECTION NUMBER: AM13
DATE: 5/15/00
LOCATION: Sandstone 3

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	45.1	.2-.3
Microcline	t	.3
Orthoclase		
Plagioclase	3.9	.2
Sandstone RF	t	.2
Carbonate RF	17.1	.7
Metamorphic RF	2.0	.3
Plutonic RF		
Volcanic RF	4.5	.2
Muscovite	t	.4
Biotite	t	.4
Pyrite	1.7	.1
Hematite	5.3	.1
Zircon	t	.1
Hornblende	t	.1-.3
Quartz overgrowth	0.6	.03
Feldspar overgrowth	t	.03
Calcite cement	t	.3
Porosity (secondary)	19.8	.05-.2

Matrix = 0 %	Normalized
Q= 45.1%	58.6%
F= 3.9%	5.1%
R= 23.56%	36.3%
Total 72.6%	**100%**

CLASSIFICATION
NAME: Litharenite
TEXTURE
SPHERICITY: sub-angular
SORTING: well sorted
MATURITY: mature

DESCRIPTION

AM13 is a sub-angular, well-sorted, mature litharenite. It has 45.1% quartz, 17.1% carbonate rock fragments, 4.5% volcanic rock fragments, 2.0% metamorphic rock fragments, 3.9% plagioclase, 0.6% quartz overgrowth, 5.3% hematite, and 1.7% pyrite.

There is 19.8% secondary porosity from honeycomb, dissolution of grains, and enlarged pores.

SAMPLE ID: AM13

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
45.1	37	52	78	54	40	25	45	21	75	24	Quartz
17.1	40	189	12	6	25	15	12	16	0	27	Carb RF
4.5	0	0	0	0	0	30	5	10	0	0	Volc RF
2.0	0	0	0	0	0	0	3	10	7	0	Meta RF
3.9	0	10	0	21	0	0	8	0	0	0	Plag
19.8	13	20	10	19	23	30	27	23	8	25	Porosity
0.6	0	0	0	0	0	0	0	0	0	6	Quartz overgrowth
5.3	0	0	0	0	12	0	0	13	10	18	Hematite
1.7	10	0	0	0	0	0	0	7	0	0	Pyrite

THIN SECTION NUMBER: AM14
DATE: 4/19/01
LOCATION: Sandstone 3

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	51.0	.2
Microcline		.3
Orthoclase		
Plagioclase	3.8	.2
Sandstone RF	3.0	1
Carbonate RF	9.0	.15
Metamorphic RF	4.0	.3
Plutonic RF	3.0	.4
Volcanic RF	1.5	.2
Muscovite	T	.3
Biotite	1.5	.3
Hematite	1.5	.1
Calcite cement	7.2	.1
Porosity (secondary)	14.5	.01-.05

Matrix = 0 %	Normalized
Q= 51.0%	67.8%
F= 3.8%	5.1%
R= 20.5%	27.1%
Total 75.3%	**100%**

CLASSIFICATION

NAME: Litharenite (sedarenite)

TEXTURE

SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

AM14 is a sub-angular, moderately sorted, sub-mature litharenite. It has 51.0% quartz, 3.8% plagioclase, 3.0% sandstone rock fragments, 9.0% carbonate rock fragments, 4.0% metamorphic rock fragments, 3.0% pltonic rock fragment, 1.5% volcanic rock fragments, 1.5% biotite, 1.5% hematite, and 7.2% calcite cement. This thin section also has 14.5% secondary porosity from dissolution of grains and enlarged pores.

SAMPLE ID: AM14

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
51.0	45	85	60	20	45	55	70	75	10	45	Quartz
9.0	0	0	0	55	35	0	0	0	0	0	Carb RF
4.0	25	0	15	0	0	0	0	0	0	0	Meta RF
1.5	0	0	0	0	15	0	0	0	0	0	Volc RF
14.5	25	5	10	5	5	30	15	20	25	5	Porosity
7.2	0	10	15	0	0	5	0	5	27	10	Calcite C
3.0	0	0	0	0	0	0	0	0	0	30	Sed RF
3.0	0	0	0	20	0	0	0	0	0	10	Granite
1.5	0	0	0	0	0	0	0	0	15	0	Biotite
3.8	5	0	0	0	0	10	0	0	23	0	Plag
1.5	0	0	0	0	0	0	15	0	0	0	Hemitite

THIN SECTION NUMBER: AM15
DATE: 4/19/01
LOCATION: Sandstone 3

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	40.1	.1-.2
Microcline	T	.2
Orthoclase		
Plagioclase	5.7	.1
Sandstone RF	T	1
Carbonate RF	2.0	.3
Metamorphic RF	6.5	.2
Plutonic RF		
Volcanic RF	11.2	.2
Muscovite	T	.2
Chalcedony	T	.2
Zircon	T	.1
Hematite	2.0	.05
Calcite cement	25.3	.02
Porosity (secondary)	7.2	.05

Matrix = 0 %	Normalized
Q= 40.1%	61.4%
F= 5.7%	8.7%
R= 19.7%	29.9%
Total 65.5%	**100%**

CLASSIFICATION
NAME: Litharenite
TEXTURE
SPHERICITY: sub rounded
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

AM15 is a sub rounded, moderately sorted, sub-mature litharenite. It has 40.1% quartz, 5.7% plagioclase, 2.0% carbonate rock fragments, 6.5% metamorphic rock fragments, 11.2% volcanic rock fragments, 2.0% hematite, and 25.3% calcite cement. The thin section also has 7.2% secondary porosity from dissolution of feldspar grains and enlarged pores.

SAMPLE ID: AM15

Point Counts:

	10	9	8	7	6	5	4	3	2	1	
40.1	60	30	35	70	45	30	63	0	25	43	Quartz
2.0	0	0	0	0	0	0	0	20	0	0	Carb RF
6.5	0	0	30	0	0	0	0	35	0	0	Meta RF
11.2	15	30	0	0	10	22	0	0	0	25	Volc RF
7.2	5	5	10	10	3	3	10	5	9	12	Porosity
25.3	20	25	25	20	42	34	17	30	30	10	Calcite C
5.7	0	10	0	0	0	11	0	0	36	0	Plag
2.0	0	0	0	0	0	0	10	10	0	0	Hemitite

THIN SECTION NUMBER: AM17
DATE:4/24/00
LOCATION: Sandstone 3

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	33.2	.3-.5
Microcline		
Orthoclase		
Plagioclase	1.2	.3
Sandstone RF		
Carbonate RF	7.7	.2
Metamorphic RF		
Plutonic RF		
Volcanic RF	1.4	.3
Chalcedony	t	.6
Pyrite	3.0	.1
Hematite	2.0	.1
Zircon	0.4	.1
Hornblende	t	.1
Calcite cement	44.9	.05
Porosity (secondary)	4.4	.5

Matrix = 0 %	Normalized
Q= 33.2%	76.3%
F= 1.2%	2.8%
R= 9.1%	20.9%
Total 43.5%	**100%**

CLASSIFICATION
NAME: Litharenite (sedarenite)
TEXTURE
SPHERICITY: sub-rounded
SORTING: well sorted
MATURITY: mature

DESCRIPTION

AM-17 is a sub-rounded, well-sorted, mature litharenite. It has 33.2% mono quartz, 1.2% plagioclase, 7.7% carbonate rock fragments, 1.4% volcanic rock fragments, 3.0% pyrite, 2.0% hematite, 0.4% zircon and 44.9% calcite cement. There is also 11.4% primary porosity. There are also trace amounts of chalcedony rock fragments and hornblende.

SAMPLE ID: AM17

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
33.2	20	15	27	30	20	54	43	15	36	20	Quartz
44.9	52	30	41	61	76	0	14	73	51	51	Calcite C
11.4	8	3	13	8	4	20	30	12	11	5	Porosity
7.7	20	22	15	0	0	0	0	0	0	20	Carb RF
2.0	0	0	0	0	0	14	0	0	2	4	Hematite
3.0	0	12	4	1	0	0	13	0	0	0	Pyrite
1.4	0	6	0	0	0	8	0	0	0	0	Volc RF
0.4	0	0	0	0	0	4	0	0	0	0	Zircon
1.2	0	12	0	0	0	0	0	0	0	0	Plag

THIN SECTION NUMBER: AM20
DATE:4/27/00
LOCATION: Sandstone 3

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	22	.4-.6
Microcline	t	.4
Orthoclase		
Plagioclase	T	.3
Sandstone RF	T	.2
Carbonate RF	19	.1-.2
Metamorphic RF	5	.2
Plutonic RF		
Volcanic RF	16	.3-.7
Pyrite	t	.1-.3
Biotite		
Hematite	1	.1-.3
Zircon	t	.2
Hornblende	t	.2
Amphiboles	t	.2
Calcite cement	10	.1
Porosity (secondary)	5	.1

Matrix = 0 %	Normalized
Q= 22%	26.1%
F= 22%	26.1%
R= 40%	47.8%
Total 84%	**100%**

CLASSIFICATION

NAME: Feldspathic Litharenite

TEXTURE

SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

AM-20 is a sub-angular, moderately sorted, sub-mature feldspathic litharenite. It has 22% quartz, 22% plagioclase, 5% metamorphic rock fragments, 19% carbonate rock fragments, 16% volcanic rock fragments, 1% hematite, 10% calcite cement, and 5% porosity. Most of the porosity is primary, but there is some secondary from the dissolution of grains. There is also a trace amount of sandstone rock fragments, pyrite, zircon, hornblende, and amphibole.

SAMPLE ID: AM20

Point Counts:

	6	**5**	**4**	**3**	**2**	**1**	
22	15	30	22	38	20	10	Quartz
5	0	7	7	0	15	0	Meta RF
10	6	15	14	10	7	13	Calcite C
19	35	0	0	30	10	40	Carb RF
16	10	35	15	11	19	5	Volc RF
5	4	3	2	4	12	2	Porosity
1	0	0	0	0	2	0	Hematite
22	30	10	40	7	15	30	Plag

THIN SECTION NUMBER: AM28
DATE: 4/18/01
LOCATION: Sandstone 3

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	42.1	.3
Microcline	T	.3
Orthoclase	T	.3
Plagioclase	10.7	.3
Sandstone RF	8.2	.3
Carbonate RF	1.5	.3
Metamorphic RF	5.4	.3
Plutonic RF		
Volcanic RF	5.5	.3
Muscovite	T	.2
Biotite	T	.5
Hematite	1.0	.1
Pyrite	1.0	.1
Calcite cement		
Porosity (secondary)	24.2	.05-.2

Matrix = 0 %	Normalized
Q= 42.1%	57.3%
F= 10.7%	14.5%
R= 20.6%	28.2%
Total 73.4%	**100%**

CLASSIFICATION

NAME: Feldspathic Litharenite

TEXTURE

SPHERICITY: sub-rounded
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

AM28 is a sub-rounded, moderately sorted, sub-mature feldspathic litharenite. It contains 42.1% quartz, 10.7% plagioclase, 8.2% sandstone rock fragments, 1.5% carbonate rock fragments, 5.4% metamorphic rock fragments, 5.5% volcanic rock fragments, 1.0% hematite, and 1.0% pyrite. The thin section also contains 24.2% secondary porosity from the dissolution of grains and enlarged pores.

SAMPLE ID: AM28

Point Counts:

	10	9	8	7	6	5	4	3	2	1	
42.1	50	30	55	30	55	25	45	35	35	61	Quartz
1.5	0	0	0	0	0	0	0	0	0	15	Carb RF
5.4	1	30	0	0	0	5	0	0	0	9	Meta RF
5.5	0	0	0	55	0	0	0	0	0	0	Volc RF
8.2	0	0	0	55	0	0	0	0	27	0	Sed RF
24.2	40	25	35	15	35	15	25	18	19	15	Porosity
1.0	0	0	0	0	0	0	0	0	10	0	Pyrite
10.7	0	15	15	0	0	0	30	47	0	0	Plag
1.0	0	0	0	0	10	0	0	0	0	0	Hemitite

THIN SECTION NUMBER: AM29
DATE: 4/21/00
LOCATION: Sandstone 3

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	3.4	.1-.2
Microcline		
Orthoclase		
Plagioclase	1.4	.1
Sandstone RF		
Carbonate RF		
Metamorphic RF		
Plutonic RF		
Volcanic RF	66.2	.1-.3
Muscovite		
Biotite	t	.1
Hematite	T	.1
Hornblende	t	.1
Mixed-Layered clays	t	.05
Porosity (secondary)	27.4	.05-.3

Matrix = 0 %	Normalized
Q= 3.4%	4.76%
F= 1.4%	1.96%
R= 66.2%	93.28%
Total 71%	**100%**

CLASSIFICATION
NAME: Volcanic Ash Flow
TEXTURE
SPHERICITY: angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

AM-29 is an angular, moderately sorted, sub-mature volcanic ash flow. It has 3.4% quartz, 1.4% plagioclase, 1.6% hematite, and 66.2% volcanic rock fragments. It has 27.4% primary porosity. There are also trace amounts of biotite, hematite, hornblende, and mixed-layered clays (found in the pore spaces).

SAMPLE ID: AM29

Point Counts:

	5	4	3	2	1	
3.4	0	10	0	5	2	Quartz
27.4	35	25	20	21	36	Porosity
66.2	60	65	77	74	55	Volc RF
1.4	0	0	0	0	7	Plag
1.6	5	0	3	0	0	Hematite

THIN SECTION NUMBER: AM32
DATE: 4/24/00
LOCATION: Sandstone 4

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	10.2	.1
Microcline		
Orthoclase		
Plagioclase	t	.5
Sandstone RF		
Carbonate RF		
Metamorphic RF		
Plutonic RF		
Volcanic RF	82.2	.05-.1
Pyrite	t	.2
Hornblende	t	.1
Hematite	3.6	.1
Calcite cement		
Porosity (secondary)	4.3	.05-.2

Matrix = 0 %	Normalized
Q= 10.2%	11.02%
F= 0%	0%
R= 88.2%	88.98%
Total 92.4%	**100%**

CLASSIFICATION

NAME: Volcanic Tuff

TEXTURE

SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

AM-32 is a sub-angular, moderately sorted, sub-mature volcanic tuff. It has 10.2% quartz, 4.3% primary porosity, 3.6% hematite, and 82.2% volcanic rock fragments. There are also trace amounts of plagioclase, pyrite, and hornblende.

SAMPLE ID: AM32

Point Counts:

	5	**4**	**3**	**2**	**1**	
10.2	8	10	15	8	10	Quartz
4.3	3	5	3	5	4	Porosity
3.6	3	0	0	0	15	Hematite
82.2	86	85	82	87	71	Volc RF

THIN SECTION NUMBER: ES21
DATE: 3/28/01
LOCATION: Eagle Mnt.

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	2.9	.05-.3
Microcline		
Orthoclase	T	.4
Plagioclase		
Sandstone RF		
Carbonate RF	T	.5
Metamorphic RF	T	.05-.5
Plutonic RF		
Volcanic RF		
Muscovite		
Biotite		
Hematite	2.6	.1
Detrital matrix (calcite)	94.5	.01
Porosity (secondary)	t	.05

Matrix = 94.5 %	Normalized
Q= 2.9%	100%
F= 0%	0%
R= 0%	0%
Total 2.9%	**100%**

CLASSIFICATION
NAME: mudrock
TEXTURE
SPHERICITY: sub-angular
SORTING: poorly sorted
MATURITY: sub-mature

DESCRIPTION

ES21 is a very fine grained, sub-angular, poorly sorted, sub-mature mudrock. It has 94.5% calcite detrital matrix, 2.9% quartz, and 2.6% hematite.

SAMPLE ID: ES21

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
94.5	93	96	90	96	89	92	98	96	98	97	matrix
2.9	2	0	7	0	6	3	2	4	2	3	Quartz
2.6	5	4	3	4	5	5	0	0	0	0	Hemitite

THIN SECTION NUMBER: ES5
DATE: 3/28/01
LOCATION: Eagle Mnt.

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	38.8	.2-.5
Microcline		
Orthoclase		
Plagioclase	4.0	.2
Sandstone RF		
Carbonate RF	7.5	.4
Metamorphic RF	3.5	.4
Plutonic RF	7.4	.5
Volcanic RF	1.3	.4
Muscovite		
Biotite		
Hematite cement	20.1	.03
Calcite cement	8.9	.03
Porosity (primary + secondary)	8.5	.1-.3

Matrix = 0 %	Normalized
Q= 38.8%	62.1%
F= 4.0%	6.4%
R= 19.7%	31.5%
Total 62.5%	**100%**

CLASSIFICATION
NAME: Litharenite

TEXTURE
SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

ES5 is a medium grained, sub-angular, moderately sorted, sub-mature, litharenite. It has 38.8% quartz, 4.0% plagioclase, 7.5% carbonate rock fragment, 7.4% plutonic rock fragments, 3.5% metamorphic rock fragment, 1.3% volcanic rock fragment, 20.1% hematite cement, and 8.9% calcite cement. This sample also has 8.5% porosity. There is some primary intragranular, and some secondary from the dissolution of grains, mainly feldspar grains.

SAMPLE ID: ES5

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
38.8	57	35	45	42	20	40	9	45	50	45	Quartz
7.5	0	0	0	0	35	0	40	0	0	0	Carb RF
3.5	0	35	0	0	0	0	0	0	0	0	Meta RF
7.4	0	0	5	37	0	15	0	0	17	0	Granite RF
8.5	20	15	5	6	5	2	3	7	10	12	Porosity
8.9	5	0	15	10	10	20	9	10	10	0	Calcite C
20.1	18	15	30	5	30	23	14	38	13	15	Hemitite C
1.3	0	0	0	0	0	0	0	0	0	13	Volc RF
4.0	0	0	0	0	0	0	25	0	0	15	Plag

THIN SECTION NUMBER: ES14
DATE: 3/28/01
LOCATION: Eagle Mnt.

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	11.3	0.05-.1
Microcline		
Orthoclase		
Plagioclase	T	.1
Sandstone RF		
Carbonate RF	37.0	.1-.5
Metamorphic RF	T	.1
Plutonic RF		
Volcanic RF		
Muscovite	0.4	.2-.3
Biotite		
Hematite cement	15.3	.03
Calcite cement	32.2	.03
Porosity (primary)	3.8	.02

Matrix = 0 %	Normalized
Q= 11.3%	23.4%
F= 0%	0%
R= 37.0%	76.6%
Total %	**100%**

CLASSIFICATION
NAME: Litharenite
TEXTURE
SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

ES14 is a fine-grained, sub-angular, moderately sorted, sub-mature, litharenite. It has 11.3% quartz, 37.0% carbonate rock fragment, 0.4% muscovite, 15.3% hematite cement, and 32.2% calcite cement. This sample also has 3.8% primary porosity.

SAMPLE ID: ES14

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
11.3	15	5	5	20	15	5	13	10	15	10	Quartz
37.0	45	50	30	35	50	25	40	40	30	25	Carb RF
3.8	6	2	2	4	3	3	4	6	5	3	Sed RF
15.3	15	10	13	10	10	18	15	22	20	20	Porosity
32.2	19	33	50	31	22	49	28	18	30	42	Calcite C
0.4	0	0	0	0	0	0	0	4	0	0	Hemitite

THIN SECTION NUMBER: ES11
DATE: 3/28/01
LOCATION: Eagle Mnt.

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	1.0	.2
Microcline		
Orthoclase		
Plagioclase	t	.1
Sandstone RF		
Carbonate RF	81.5	10
Metamorphic RF	9.0	.1-2
Plutonic RF		
Volcanic RF		
Muscovite	T	.1-.2
Biotite		
Hematite	T	.05
Calcite cement	8.5	.1
Porosity (primary)	T	.05

Matrix = 0 %	Normalized
Q= 1.0%	2%
F= 0%	0%
R= 90.5%	98%
Total 91.5%	**100%**

CLASSIFICATION

NAME: Litharenite

TEXTURE

SPHERICITY: sub-angular
SORTING: poorly sorted
MATURITY: sub-mature

DESCRIPTION

ES11 is a medium to pebble grained, sub-angular, poorly sorted, sub-mature litharenite. This is a sample of the conglomerate. It has 1.0% quartz, 81.5% carbonate rock fragments, 9.0% metamorphic rock fragments, and 8.5% calcite cement. There is only a trace amount of primary porosity.

SAMPLE ID: ES11

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
1.0	0	0	0	0	0	0	0	10	0	0	Quartz
81.5	80	100	95	90	100	100	100	50	0	100	Carb RF
9.0	0	0	0	0	0	0	0	5	85	0	Meta RF
8.5	20	0	5	10	0	0	0	35	15	0	Calcite C

THIN SECTION NUMBER: ES12
DATE: 3/28/01
LOCATION: Eagle Mnt.

CONSTITUENTS	**PERCENTAGE**	**mm SIZE**
Monocrystalline Quartz	23.1	.1
Microcline	T	.15
Orthoclase		
Plagioclase	1.7	.05
Sandstone RF		
Carbonate RF	22.5	.1-.2
Metamorphic RF	6.3	.1
Plutonic RF		
Volcanic RF	2.0	.1
Muscovite	0.4	.1
Chalcedony	t	.2
Hematite cement	25.5	.03
Calcite cement	17.5	.04
Porosity (secondary)	1.0	.05

Matrix = 0 %	Normalized
Q= 23.1%	41.5%
F= 1.7%	3.1%
R= 30.8%	55.4%
Total 55.6%	**100%**

CLASSIFICATION

NAME: Litharenite

TEXTURE

SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

ES12 is a fine-grained, sub-angular, moderately sorted, sub-mature litharenite. It has 23.1% quartz, 1.7% plagioclase, 22.5% carbonate rock fragments, 6.3% metamorphic rock fragments, 2.0% volcanic rock fragments, 0.4 % muscovite, 25.5% hematite cement, and 17.5% calcite cement. This thin section also has 1.0% secondary porosity from dissolution of feldspar grains.

SAMPLE ID:ES12

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
23.1	30	18	20	15	25	20	40	20	28	15	Quartz
22.5	10	30	20	50	30	5	15	0	30	35	Carb RF
6.3	0	12	5	5	0	30	0	0	0	11	Meta RF
1.0	3	0	0	0	1	0	0	2	2	2	Porosity
25.5	20	30	40	15	20	25	20	40	25	20	Hematite C
17.5	23	10	13	15	24	15	25	18	15	17	Calcite C
2.0	0	0	0	0	0	0	0	20	0	0	Volc RF
1.7	10	0	2	0	0	5	0	0	0	0	Plag
0.4	4	0	0	0	0	0	0	0	0	0	Muscovite

THIN SECTION NUMBER: CC51
DATE: 3/26/01
LOCATION: Chlorite Cliffs

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	24.0	.1-.4
Microcline	2.5	.1
Orthoclase	3.0	.2
Plagioclase	17.0	.2
Siltstone RF	T	.5
Carbonate RF	13.5	.3
Metamorphic RF	11.0	.3
Plutonic RF	11.5	.2
Volcanic RF	T	.2
Muscovite	T	.2
Chalcedony	0.5	.3
Hematite	6.0	.1
Calcite cement		
Porosity	11.0	.05

Matrix = 0 %	Normalized
Q= 24.0%	29.0%
F= 22.5%	27.3%
R= 36%	43.7%
Total 82.5%	**100%**

CLASSIFICATION

NAME: Feldspathic Litharenite

TEXTURE

SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

CC51 is a medium grained, sub-angular, moderately sorted, sub-mature feldspathic litharenite. It has 24% quartz, 2.5% microcline, 3.0% orthoclase, 17.0% plagioclase, 13.5% carbonate rock fragments, 11.0% metamorphic rock fragments, 11.5% plutonic rock fragments, 0.5% chalcedony, 6.0% hematite, and 11.0% primary porosity.

SAMPLE ID: CC51

Point Counts:

	10	9	8	7	6	5	4	3	2	1	
24.0	15	25	60	10	30	15	40	5	20	20	Quartz
11.0	20	5	0	15	30	10	0	20	10	0	Meta RF
11.5	20	25	0	0	0	0	40	0	30	0	Granite RF
11.0	15	10	15	10	15	5	5	10	10	15	Porosity
17.0	0	5	10	15	20	15	0	40	0	65	Plag
13.5	25	20	15	20	5	20	0	0	30	0	Carb RF
6.0	5	10	0	20	0	0	0	25	0	0	Hemitite
2.5	0	0	0	10	0	0	15	0	0	0	Microcline
3.5	0	0	0	0	0	30	0	0	0	0	K-spar
0.5	0	0	0	0	0	5	0	0	0	0	Chalcedony

THIN SECTION NUMBER: ES10
DATE: 3/26/01
LOCATION: Eagle Mnt.

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	19.8	.1-.3
Microcline		
Orthoclase	1.0	.3
Plagioclase	T	.1
Sandstone RF		
Carbonate RF	35.2	.3
Metamorphic RF	12.0	.4
Plutonic RF	T	.3
Volcanic RF	T	.2
Muscovite		
Biotite		
Hematite cement	12.1	.05
Calcite cement	13.4	.05
Porosity	6.5	.05

Matrix = 0 %	Normalized
Q= 19.8%	29.1%
F= 1.0%	1.5%
R= 47.2%	69.4%
Total 68%	**100%**

CLASSIFICATION
NAME: Litharenite
TEXTURE
SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION
ES10 is a fine to medium grained, sub-angular, moderately sorted, sub-mature litharenite. It has 19.8% quartz, 1.0% orthoclase, 35.2% carbonate rock fragment, 12.0% metamorphic rock fragment, 12.1% hematite cement, 13.4% calcite cement and 6.5% primary porosity.

SAMPLE ID: ES10

Point Counts:

	10	9	8	7	6	5	4	3	2	1	
19.8	15	45	0	50	25	0	15	30	18	0	Quartz
35.2	70	25	0	40	30	72	40	35	40	0	Carb RF
12.0	5	0	30	0	20	0	20	0	0	45	Meta RF
6.5	7	8	15	5	2	3	4	6	5	10	Porosity
12.1	3	5	5	5	18	25	15	20	25	0	Hemitite C
13.4	0	7	50	0	5	0	6	9	12	45	Calcite C
1.0	0	10	0	0	0	0	0	0	0	0	K-spar

THIN SECTION NUMBER: CC43
DATE: 3/26/01
LOCATION: Chlorite Cliffs

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	44.7	.05-.3
Microcline	1.0	.2
Orthoclase	T	.5
Plagioclase	2.5	.1-.3
Sandstone RF (mudripup)	5.0	2
Carbonate RF		
Metamorphic RF	5.0	.2
Plutonic RF	10.5	.7
Volcanic RF	2.5	.2
Muscovite	2.0	.4
chalcedony	2.5	.5
Hematite	19.7	.05
Calcite cement		
Porosity	4.6	.05

Matrix = 0 %	Normalized
Q= 44.7%	62.7%
F= 3.5%	4.9%
R= 23%	32.4%
Total 71.2%	**100%**

CLASSIFICATION
NAME: Litharenite
TEXTURE
SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

CC43 is a medium grained, sub-angular, moderately sorted, sub-mature litharenite. It has 44.7% quartz, 1.0% microcline, 2.5% plagioclase, 5.0% sandstone rock fragments, 5.0% metamorphic rock fragments, 10.5% plutonic rock fragments, 2.5% volcanic rock fragments, 2.0% muscovite, 2.5% chalcedony, 19.7% hematite, and 4.6% porosity.

SAMPLE ID: CC43

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
44.7	50	50	20	20	40	55	50	32	45	55	Quartz
5.0	0	0	0	0	10	30	10	0	0	0	Sed RF
5.0	15	15	0	0	0	0	20	0	0	0	Meta RF
2.5	0	0	0	0	15	0	0	10	0	0	Volc RF
10.5	0	0	20	60	0	5	0	0	20	0	Granite
4.6	5	5	5	3	5	0	5	8	10	0	Porosity
19.7	10	30	20	12	15	10	15	20	25	40	Hemitite
2.5	0	0	0	5	15	0	0	0	0	5	Plag
1.0	0	0	10	0	0	0	0	0	0	0	Microcline
2.5	0	0	25	0	0	0	0	0	0	0	Chalcedony
2.0	20	0	0	0	0	0	0	0	0	0	Muscovite

THIN SECTION NUMBER: CC56
DATE: 3/8/01
LOCATION: Chlorite Cliffs

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	33.8	.1-.2
Microcline	T	.1
Orthoclase	T	.2-.3
Plagioclase	2.0	.1-.2
Sandstone RF	4.0	.3-.5
Carbonate RF		
Metamorphic RF	12.3	.5-1
Plutonic RF	14.1	.7
Chert RF	T	1
Muscovite	3.0	.3
Biotite		
Hematite cement	14.6	.05-.1
Calcite cement		
Porosity (secondary)	4.7	.05

Matrix = 0 %	Normalized
Q= 33.8%	43.5%
F= 2.0%	2.6%
R= 41.9%	53.9%
Total 77.7%	**100%**

CLASSIFICATION
NAME: Litharenite
TEXTURE
SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

CC56 is a medium to coarse grained, sub-angular, moderately sorted, sub-mature litharenite. It has 33.8% quartz, 2.0% plagioclase, 4.0% sandstone rock fragments, 12.3% metamorphic rock fragments, 14.1% plutonic rock fragments, 3.0% muscovite, 14.6% hematite, and 4.7% secondary porosity.

SAMPLE ID: CC56

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
33.8	60	38	40	12	32	68	0	28	10	50	Quartz
4.0	0	10	0	0	0	30	0	0	0	0	Sed RF
12.3	25	40	40	0	0	0	0	0	10	8	Meta RF
11.5	0	0	0	0	0	0	75	0	0	40	Volc RF
14.1	0	0	12	59	50	0	0	20	0	0	Granite RF
4.7	2	10	5	4	5	2	3	12	2	2	Porosity
14.6	13	2	3	25	13	0	0	20	70	0	Hemitite C
3.0	0	0	0	0	0	0	22	0	8	0	Muscovite
2.0	0	0	0	0	0	0	0	20	0	0	plag

THIN SECTION NUMBER: RS28
DATE: 2/6/01
LOCATION: Ryan Section

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	30.0	.1-.3
Microcline	T	.4
Orthoclase	T	.4
Plagioclase	T	.2
Sandstone RF		
Carbonate RF	5.0	.3-.4
Metamorphic RF	5.5	.3
Plutonic RF	11.5	.4
Volcanic RF	2.0	.1-.2
Chalcedony	T	.3
Biotite		
Hematite	2.3	.05
Calcite cement	23.9	.05
Porosity (secondary)	19.8	.05-.1

Matrix = 0 %	Normalized
Q= 30%	55.5%
F= 0%	0%
R= 24%	44.5%
Total 54%	**100%**

CLASSIFICATION

NAME: Litharenite

TEXTURE

SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

RS28 is a medium grained, sub-angular, moderately sorted, sub-mature litharenite. It has 30.0% quartz, 5.5% metamorphic rock fragments, 5.0% carbonate rock fragments, 11.5% plutonic rock fragments, 2.0% volcanic rock fragments, 2.3% hematite, and 23.9% calcite cement. It also has 19.8% secondary porosity, but this high number is most likely from bad thin section preparation.

SAMPLE ID: RS28

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
30.0	25	20	35	15	25	75	35	30	20	20	Quartz
5.5	0	20	0	35	0	0	0	0	0	0	Meta RF
5.0	0	0	0	0	0	0	0	0	40	10	Carb RF
11.5	25	0	25	0	45	0	0	20	0	0	Granite RF
2.0	0	10	0	0	0	0	10	0	0	0	Volc RF
19.8	0	45	30	25	20	5	25	20	10	18	Porosity
23.9	46	5	10	25	10	20	24	25	27	47	Calcite C
2.3	4	0	0	0	0	0	6	5	3	5	Hemitite

THIN SECTION NUMBER: RS10
DATE: 1/25/01
LOCATION: Ryan Section

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	22.7	.05-.7
Poly Quartz	0.7	1.1
Microcline	T	1.1
Orthoclase	0.1	.1
Plagioclase	T	.2
Sandstone RF		
Carbonate RF	14.3	1
Metamorphic RF	7.2	.5
Plutonic RF	19.6	.5-2
Volcanic RF	8.1	1
Muscovite		
Biotite		
Hematite	5.5	.05
Calcite cement	21.8	.01
Porosity (secondary)	T	.3-.5

Matrix = 0 %	Normalized
Q= 22.7%	31.5%
F= 0.1%	0.1%
R= 49.2%	68.4%
Total 72%	**100%**

CLASSIFICATION
NAME: Litharenite
TEXTURE
SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

RS10 is a coarse grained, sub-angular, moderately sorted, sub-mature litharenite. It has 22.7% quartz, 14.3% carbonate rock fragments, 7.2% metamorphic rock fragments, 19.6% plutonic rock fragments, 8.1% volcanic rock fragments, 5.5% hematite, and 21.8% calcite cement.

SAMPLE ID: RS10

Point Counts:

	10	9	8	7	6	5	4	3	2	1	
22.7	47	12	0	15	3	45	32	22	14	37	M. Quartz
19.6	0	0	33	35	30	1	40	9	28	20	Granite RF
7.2	0	0	50	0	2	0	20	0	0	0	Meta RF
8.1	10	5	0	0	0	0	0	10	40	16	Volc RF
.1	0	1	0	0	0	0	0	0	0	0	K-spar
21.8	40	27	0	50	10	10	8	45	13	15	Calcite C
.7	0	0	0	0	0	0	0	0	0	7	P. Quartz
14.3	0	25	17	0	50	35	0	6	5	5	Carb RF
5.5	3	30	0	0	5	9	0	8	0	0	Hemitite

THIN SECTION NUMBER: RS123
DATE: 2/1/01
LOCATION: Ryan Section

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	19.5	.1-.3
Microcline		
Orthoclase	T	.4
Plagioclase	T	.2
Sandstone RF		
Carbonate RF	10.0	.2
Metamorphic RF	3.8	.3
Plutonic RF	9.0	.3-.4
Volcanic RF	10.8	.2-.3
Muscovite	1.5	.4-1
Biotite		
Hematite	2.5	.03
Calcite cement	42.9	.03
Porosity (secondary)	T	.1

Matrix = 0 %	Normalized
Q= 19.5%	36.6%
F= 0%	0%
R= 33.6%	63.4%
Total 53.1%	**100%**

CLASSIFICATION
NAME: Litharenite
TEXTURE
SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

RS123 is a fine to medium grained, sub-angular, moderately sorted, sub-mature litharenite. It has 19.5% quartz, 10.0% carbonate rock fragments, 3.8% metamorphic rock fragments, 9.0% plutonic rock fragments, 10.8% volcanic rock fragments, 2.5% hematite, and 42.9% calcite cement.

SAMPLE ID: RS123

Point Counts:

	10	9	8	7	6	5	4	3	2	1	
19.5	30	15	30	5	15	45	5	20	15	15	Quartz
9.0	0	20	0	45	0	0	25	0	0	0	Granite RF
10.8	0	0	0	10	20	3	25	10	0	40	Volc RF
3.8	0	0	25	0	5	0	0	0	0	8	Meta RF
42.9	65	50	40	30	40	17	30	60	65	32	Calcite C
2.2	5	5	5	0	0	0	0	10	0	0	Hemitite
1.5	0	0	0	0	0	0	0	0	10	5	muscovite
10.0	0	10	0	10	20	35	15	0	10	0	Carb RF

THIN SECTION NUMBER: RS20
DATE: 2/1/01
LOCATION: Ryan Section

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	31.5	.1-.4
Poly Quarz	T	.8
Orthoclase	0.5	.4
Plagioclase	6.0	.4
Sandstone RF		
Carbonate RF	12.0	.3
Metamorphic RF	5.0	.1-.3
Plutonic RF	11.8	.4
Volcanic RF	3.5	.3
Muscovite	T	.8
Chalcedony	0.5	.2
Hematite	15.0	.02
Calcite cement	14.2	.05-.1
Porosity (secondary)	T	.1

Matrix = 0 %	Normalized
Q= 31.5%	44.7%
F= 6.5%	9.2%
R= 32.3%	46.1%
Total 70.3%	**100%**

CLASSIFICATION
NAME: Litharenite
TEXTURE
SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

RS20 is a medium grained, sub-angular, moderately sorted, sub-mature litharenite. It has 31.5% quartz, 6.0% plagioclase, 12.0% carbonate rock fragments, 5.0% metamorphic rock fragments, 11.8% plutonic rock fragments, 3.5% volcanic rock fragments, 15.0% hematite, and 14.2% calcite cement.

SAMPLE ID: RS20

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
31.5	10	30	45	10	30	30	40	50	20	50	Quartz
11.8	10	28	10	0	30	0	30	0	10	0	Granite RF
5.0	15	10	15	0	0	0	0	0	0	10	Meta RF
3.5	25	0	0	0	0	0	0	0	10	0	Volc RF
12.0	10	20	0	35	10	25	10	10	0	0	Carb RF
14.2	10	12	15	5	20	15	10	25	15	15	Calcite C
15.0	20	0	15	15	10	5	5	10	45	25	Hemitite
0.5	0	0	0	0	0	0	0	5	0	0	Chalcedony
0.5	0	0	0	0	0	0	5	0	0	0	K-spar
6.0	0	0	0	35	0	25	0	0	0	0	Plag

THIN SECTION NUMBER: RS22
DATE: 2/6/01
LOCATION: Ryan Section

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	11.8	.3-1
Poly Quartz	T	1
Orthoclase		
Plagioclase		
Sandstone RF		
Carbonate RF	17.4	.6
Metamorphic RF	8.5	.3-1
Plutonic RF	13.0	.5
Volcanic RF	11.5	.3
Muscovite		
Biotite		
Hematite		
Calcite cement	23.5	.05-.1
Porosity (secondary)	14.2	.1

Matrix = 0 %	Normalized
Q= 11.8%	18.9%
F= 0%	0%
R= 50.4%	81.1%
Total 62.2%	**100%**

CLASSIFICATION
NAME: Litharenite
TEXTURE
SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

RS22 is a medium to coarse grained, sub-angular, moderately sorted, sub-mature litharenite. It has 11.8% quartz, 17.4% carbonate rock fragments, 8.5% metamorphic rock fragments, 13.0% plutonic rock fragments, 11.5% volcanic rock fragments, and 23.5% calcite cement. It also has 14.2% secondary porosity, but this could be exaggerated because of poor thin section preparation.

SAMPLE ID: RS22

Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
11.8	10	40	0	0	0	10	20	0	13	25	Quartz
17.4	20	0	0	70	65	5	0	0	14	0	Carb RF
11.5	0	0	15	0	0	30	0	0	70	0	Volc RF
13.0	5	20	0	0	0	20	10	50	0	25	Meta RF
8.5	20	20	40	0	5	0	0	0	0	0	Granite RF
23.6	15	5	20	23	15	30	50	50	3	25	Calcite C
14.2	30	15	25	7	15	5	20	0	0	25	Porosity

THIN SECTION NUMBER: RS27
DATE: 2/06/01
LOCATION: Ryan Section

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	15.5	.1-.4
Microcline		
Orthoclase		
Plagioclase		
Sandstone RF		
Carbonate RF	6.5	.3
Metamorphic RF	13.0	.2-.4
Plutonic RF	1.5	.3
Volcanic RF	T	.2-.5
Zircon	T	.5
Chalcedony	3.0	.2-.3
Hematite	3.5	.1
Calcite cement	29.0	.05
Porosity (secondary)	28.0	.1-.7

Matrix = 0 %	Normalized
Q= 15.5%	42.47%
F= 0%	0%
R= 21%	57.53%
Total 36.5%	**100%**

CLASSIFICATION

NAME: Litharenite

TEXTURE

SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

RS27 is a medium grained, sub-angular, moderately sorted, sub-mature litharenite. It has 15.5% quartz, 6.5% carbonate rock fragments, 13.0% metamorphic rock fragments, 1.5% plutonic rock fragments, 3.0% chalcedony, 29.0% calcite cement, 3.5% hematite, and 28.0% secondary porosity. The porosity is probably over counted because of poor thin section preparation.

SAMPLE ID: RS27

Point Counts:

	10	9	8	7	6	5	4	3	2	1	
15.5	30	0	10	25	10	5	35	10	20	10	Quartz
6.5	0	25	0	0	0	0	0	30	10	0	Carb RF
13.0	0	0	15	20	40	30	0	0	0	25	Meta RF
1.5	0	0	15	0	0	0	0	0	0	0	Granite RF
29.0	25	50	30	30	30	50	50	0	0	25	Calcite C
3.5	0	5	0	5	5	5	5	5	5	0	Hemitite
28.0	45	10	30	20	15	10	10	35	65	40	Porosity
3.0	0	10	0	0	0	0	0	20	0	0	Chalcedony

THIN SECTION NUMBER: RS38
DATE: 2/7/01
LOCATION: Ryan Section

CONSTITUENTS	PERCENTAGE	mm SIZE
Monocrystalline Quartz	17.5	.5-.7
Poly Quartz	T	.3
Microcline	T	.15
Orthoclase	T	.2
Plagioclase	T	.1
Sandstone RF		
Carbonate RF	9.0	.5
Metamorphic RF	4.0	.4
Plutonic RF	13.5	.3
Volcanic RF	3.5	.3
Zircon	T	.05
Chalcedony	T	.2
Hematite	1.0	.1
Calcite cement	33.5	.1
Porosity (secondary)	18.0	.1

Matrix = 0 %	Normalized
Q= 17.5%	36.8%
F= 0%	0%
R= 30%	63.2%
Total 47.5%	**100%**

CLASSIFICATION
NAME: Litharenite
TEXTURE
SPHERICITY: sub-angular
SORTING: moderately sorted
MATURITY: sub-mature

DESCRIPTION

RS38 is a medium grained, sub-angular, moderately sorted, sub-mature litharenite. It has 17.5% quartz, 9.0% carbonate rock fragments, 4.0% metamorphic rock fragments, 13.5% plutonic rock fragments, 3.5% volcanic rock fragments, 33.5% calcite cement, 1.0% hematite. It also has 18.0% secondary porosity, which could be overestimated because of poor thin section preparation.

SAMPLE ID:RS38

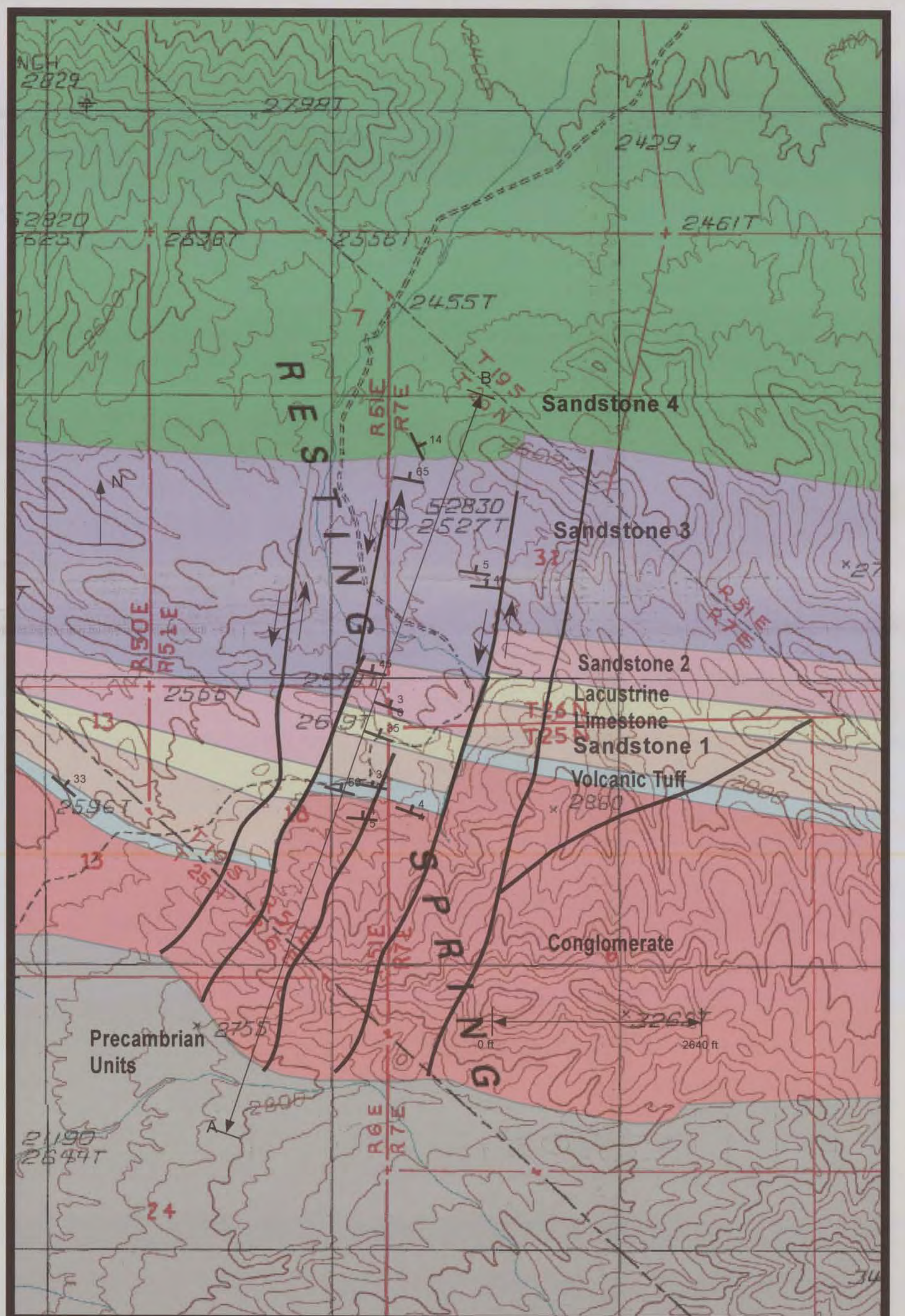
Point Counts:

	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
17.5	20	40	20	25	20	10	5	0	30	5	Quartz
4.0	20	0	0	0	0	0	0	15	5	0	Meta RF
9.0	10	30	0	0	0	0	0	50	0	0	Carb RF
3.5	10	0	0	0	15	10	0	0	0	0	Volc RF
13.5	0	10	35	0	0	20	30	0	0	40	Granite RF
33.5	20	20	10	70	40	40	35	5	65	30	Calcite C
1.0	0	0	0	5	0	0	0	5	0	0	Hemitite
18.0	20	0	35	0	25	20	30	25	0	25	Porosity

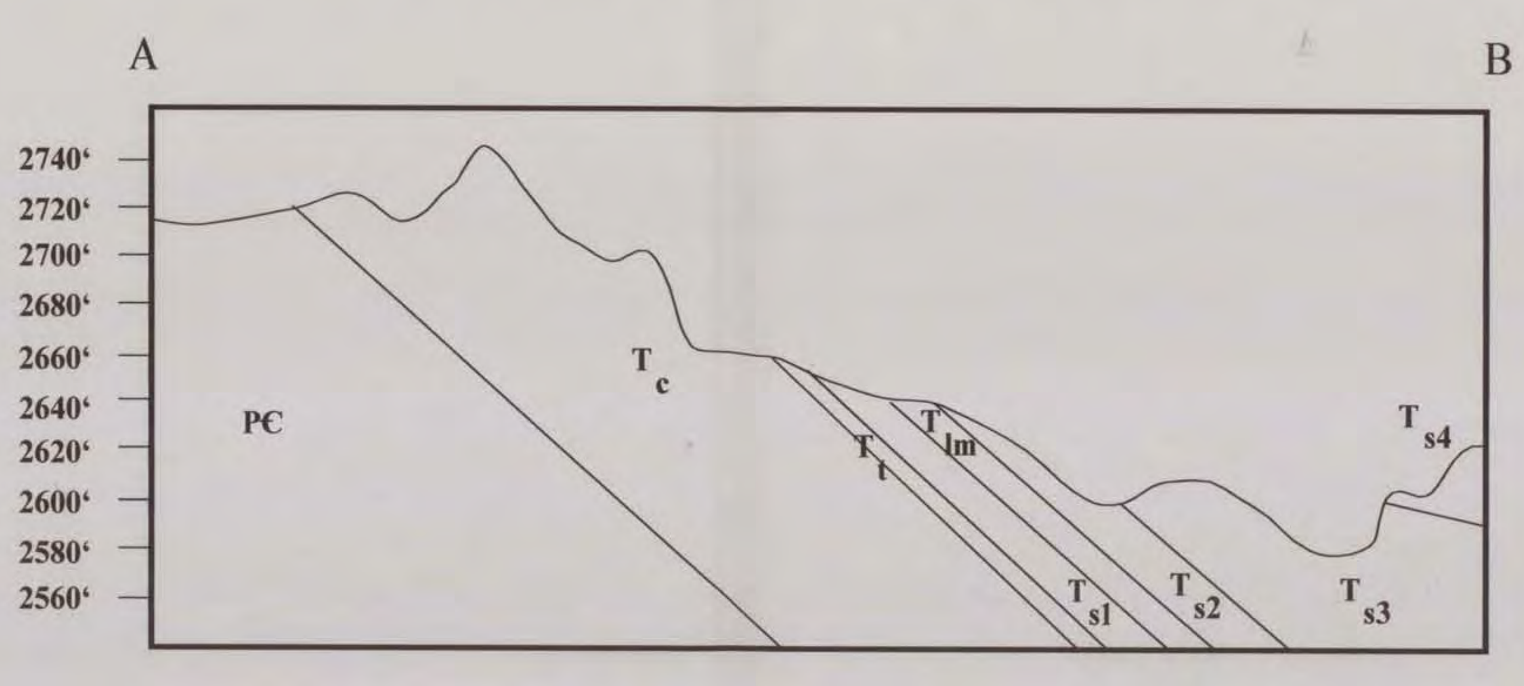
PLATE ONE

PLATE 1 THE GEOLOGY OF THE ASH MEADOWS AREA, DEATH VALLEY, CALIFORNIA AND NEVADA

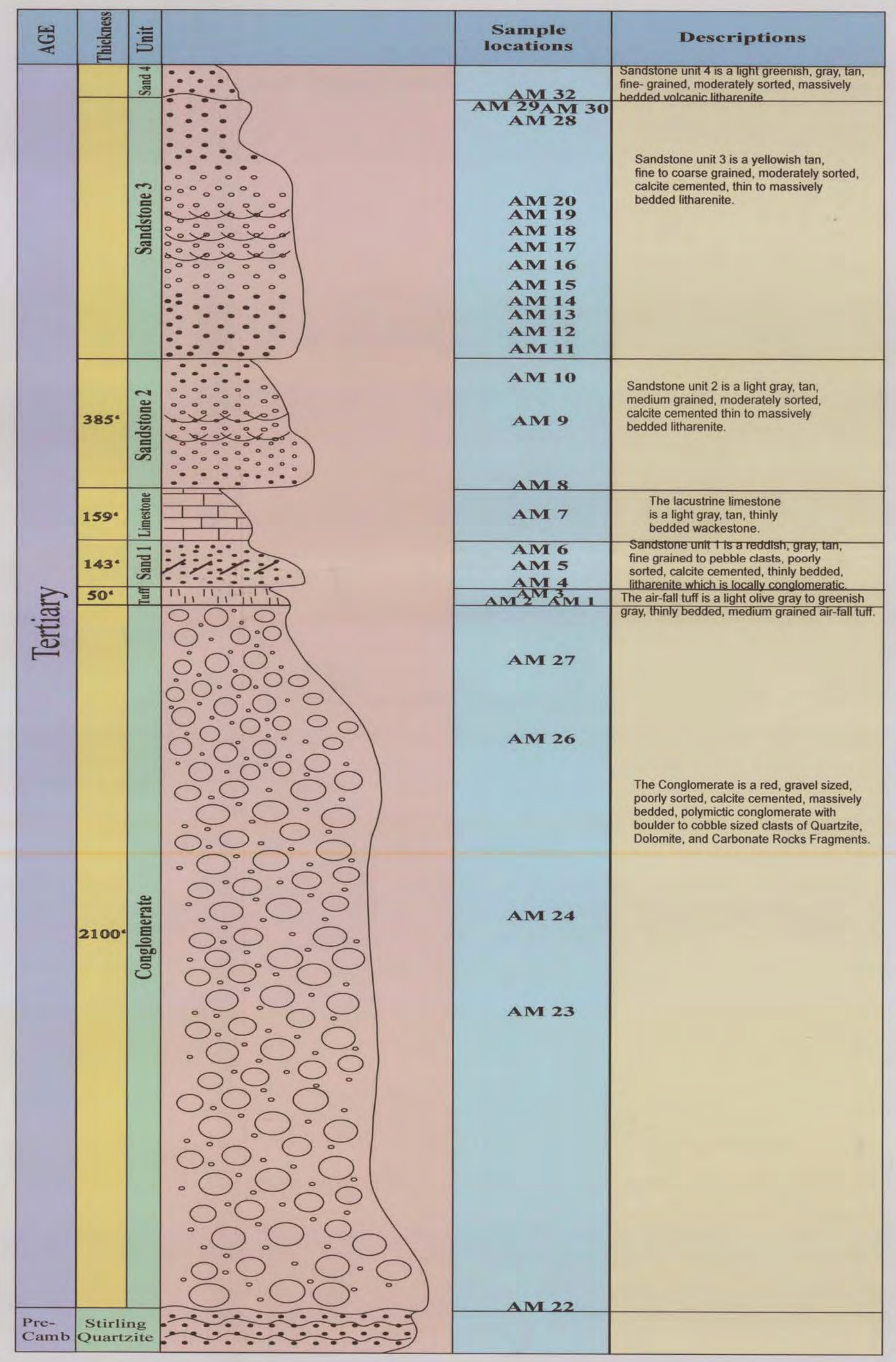
ASH MEADOWS GEOLOGIC MAP



Ash Meadows Cross Section A - B



ASH MEADOWS STRATIGRAPHIC COLUMN



VITA

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