Taylor STRATIGRAPHIC AND LITHOLOGIC ANALYSIS OF THE CLARON FORMATION IN SOUTHWESTERN UTAH UGS MP 93-1

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ABSTRACT

Examination of the internal stratigraphy, facies, facies distribution, provenance, sedimentary structures, and the nature of the bounding contacts of a sedimentary package allows interpretations to be made about the depositional environment, depositional basin, and regional tectonics. Such an examination and resulting interpretations for the western portion of the Tertiary Claron Formation have been limited previously to small areas. Here, these characteristics of the Claron Formation are evaluated throughout the part of its distribution that now lies in the Basin and Range Province in southwestern Utah and easternmost Nevada (figure 1). The depositional environments are interpreted as fluvial (possibly alluvial) and lacustrine. These environments were restricted on the west and north by paleotopographic highlands that were, at least in part, formed by thrusts of the Mesozoic Sevier orogenic belt. The northern limit of the depositional basin during the Oligocene may have been formed by topographic highs related to Eocene or Oligocene normal faults or to Oligocene volcanism. In the Basin and Range Province, changes in the distribution and provenance of the Claron Formation record the change from post-Sevier orogeny tectonic quiescence to Oligocene volcanism and possibly extension.

Many of the data on which the interpretations presented here are based are presented in chapter 2.

INTRODUCTION

The Paleocene - Oligocene Claron Formation in the Basin and Range physiographic province of southwestern Utah is composed dominantly of sandstone and conglomerate interbedded with fresh-water sandy limestone. Most of the limestone probably was deposited in one of two lakes, one on the southeast edge and one on the west edge of the part of the Claron depositional basin that now lies in the Basin and Range Province. The lithology and mineralogy of conglomerate clasts and sand grains indicate a compound source area for the clastic rocks. The source areas include (1) the thrust sheets of the Cretaceous Sevier orogenic belt; (2) Mesozoic rocks that were the footwall to some of the thrusts and that underlie the Claron Formation in angular unconformity; (3) the Grapevine Wash Formation, a Cretaceous to early Tertiary alluvial-fan deposit; and (4) a volcanic source that probably was dominantly Oligocene tuffs. Intercalated tuffs and tuff-derived sandstones suggest the western and northern beds may be mostly Oligocene in age whereas well-dated Paleocene rocks are exposed to the east. This suggests a migration of the depositional basin which roughly coincides with the Oligocene onset of extension and volcanism to the north and northwest of the depositional basin.

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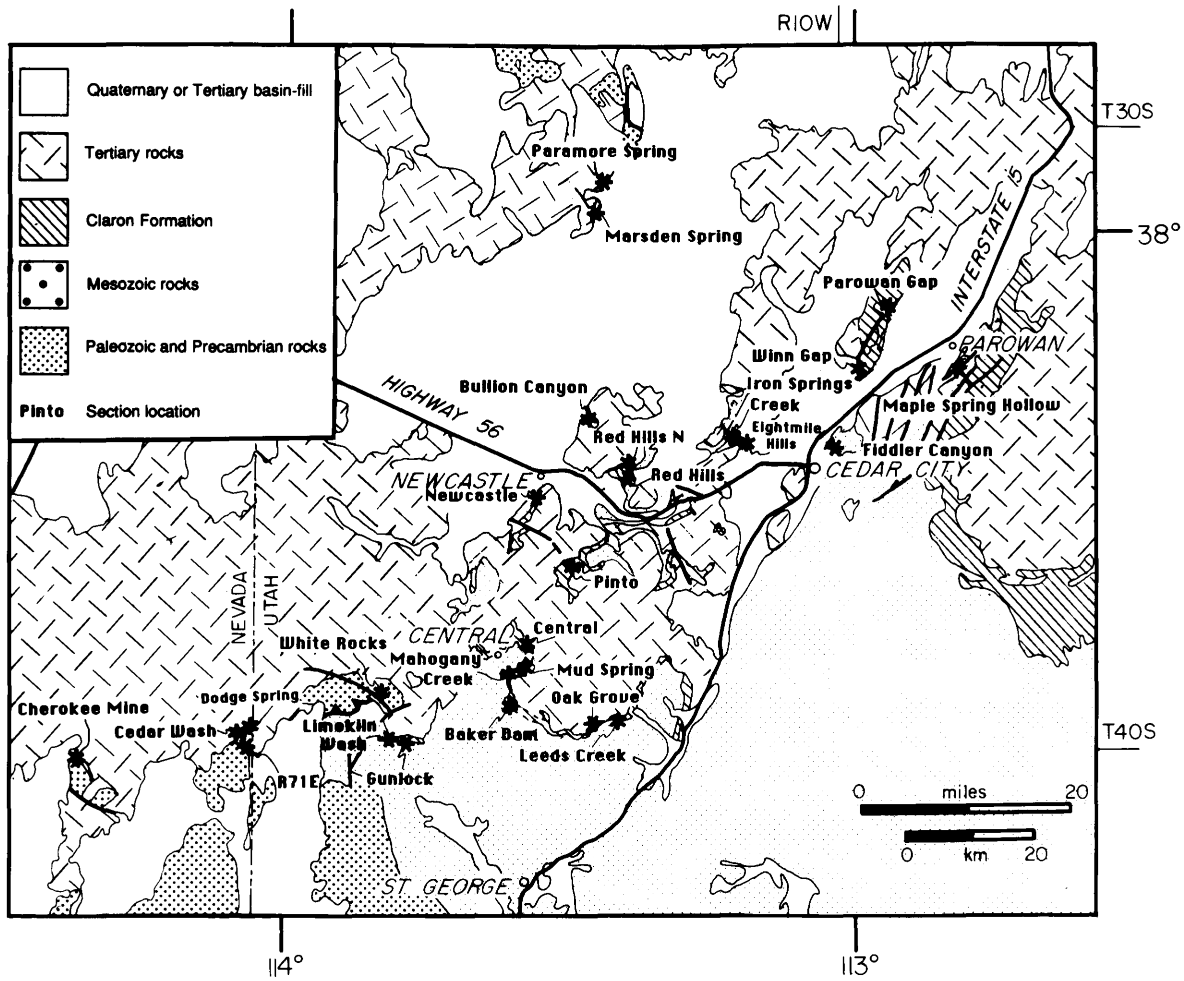

Figure 1a. Distribution of the Claron Formation, geographic place names, and ages of rocks in the region.

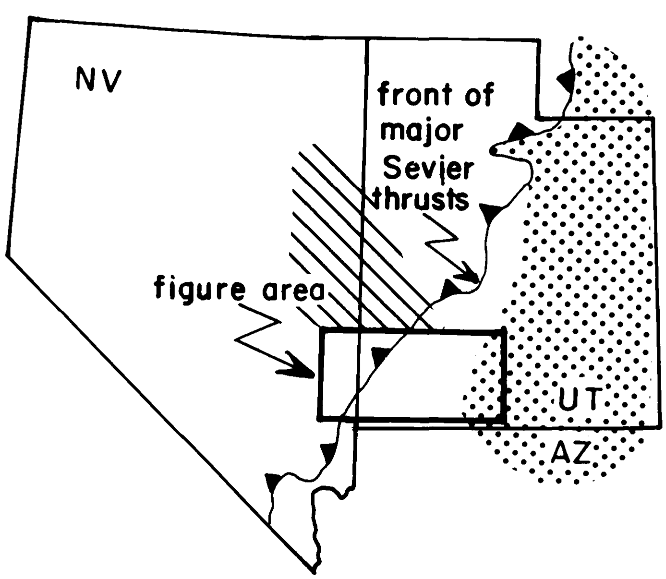

Figure 1b. Location of figure 1a and frontal thrust of Sevier orogenic belt. Stippled pattern indicates area of Laramide deformation. Ruled area indicates relevant area of Oligocene extension.

REGIONAL GEOLOGIC SETTING

The age of the Claron Formation has been questioned previously (c.f., Hintze, 1986), but new data suggest that the formation is dominantly Paleogene in age. Goldstrand (1990) reported a Paleocene age from the lower Claron Formation and locally the formation is underlain by the Cretaceous to Paleocene(?) Canaan Peak Formation. In addition, an Oligocene tuff is intercalated in the upper part of the formation and other Oligocene tuffs overlie the Claron (e.g., Blank, 1959; Hintze, 1986; Taylor, 1990; chapter 2). Therefore, the Claron Formation was deposited from the Paleocene into the Oligocene.

Thrust plates of the Cretaceous Sevier orogenic belt (Armstrong, 1968) lie dominantly to the west and north of the Claron basin (e.g., Bohannon, 1983; Wernicke and others, 1985; Best and others, 1987; Walker and Bartley, 1991). These thrust plates form most of the northern and northwestern boundaries of the lower part of the depositional basin (figure 1b). The Claron Formation laps some small thrusts that appear to be Sevier belt thrusts, for instance the small thrust exposed in Parowan Gap (for location see figure 1a; Threet, 1952). The Claron beds are not involved in this thrusting. Therefore, the Claron Formation postdates the Cretaceous Sevier orogenic activity.

During the Cretaceous and into the Tertiary the Laramide orogeny took place (Dickinson and Snyder, 1978; Cross, 1986; Brown, 1988; Hamilton, 1988). Deformation occurred in a 200 km wide belt generally east of the Sevier orogenic belt front. Most of the structures caused by this orogeny lie east or northeast of the study area and did not effect deposition of this part of the Claron (figure 1b).

Lacustrine and fluvial sedimentation was common in the region in the Paleogene. The Green River and Wasatch formations are the most widely known of these continental deposits (Nilsen and McKee, 1979). The Claron Formation, which also was deposited during this time, is at least in part equivalent to the Wasatch Formation.

Oligocene extensional tectonism has been documented near the edges of the Claron basin. Extension began just north of the region discussed here (figure 1b) at least as early as Oligocene (Taylor and others, 1989; Best and Christiansen, 1991; Taylor and Bartley, 1992). Rowley and others (1979) suggested that early differentiation between the High Plateaus of Utah and the Basin and Range Province began prior to deposition of the 29.5 m.y. Wah Wah Springs Formation. Best and others (1987) mapped pre-33 m.y. normal faults in the southern Needle Range (currently called the Indian Peak Range) and southern Pine Valley area of Utah. North and northwest of the Caliente caldera complex in Nevada, extension began prior to 31 m.y. (Bartley and others, 1988; Taylor and others, 1989, Taylor, 1990). This extension overlaps in time with deposition of part of the Claron Formation, but the Claron does not contain major syndepositional normal faults. Consequently, the northern limit of the Claron Formation may lie near the southern limit of Oligocene extension in the Great Basin.

In contrast, Cenozoic extension near the western edge of the Claron distribution did not begin until about 15 m.y. (Wernicke and others, 1988). Large-magnitude extension has occurred primarily between 15 and 11 m.y. in the Tule Springs Hills and Mormon Mountains (Wernicke and others, 1985, 1988). Consequently, all sides of the depositional basin have not undergone the same Cenozoic extensional history.

The eastern part of the depositional basin lies in the high plateaus region of southern Utah (Gregory, 1951; Mullet and others, 1988; Lundin, 1989). In that region the Claron Formation contains greater amounts of mudstone or shale (e.g., Goldstrand, 1990) than in the area examined here (figure 1). This difference suggests variation in depositional environment from west to east.

GENERAL STRATIGRAPHY

The general stratigraphy of the Claron Formation has been described in various locations. These include the Table Cliff Plateau which lies east of the area studied here, the Iron Springs district near Iron Springs Creek in the northern part of the study area, and the Beaver Dam Mountains near White Rocks and Limekiln Wash (figure 1a). The following summary of these descriptions provides the general lithologic and stratigraphic framework of the Claron Formation as well as background for understanding the regional lithologic variations.

Bowers (1972) subdivided the Wasatch Formation in the Table Cliff Plateau (here generally equivalent to the Claron Formation) into three parts: a lower pink limestone, a middle white limestone, and the upper variegated sandstone member. The pink limestone member consists of clastic limestone, with interbedded marl, calcareous siltstone, calcareous sandstone, and lenses of conglomerate. The base of the member is commonly a pebble to cobble conglomerate up to 10 m thick (Gregory, 1951; Bowers, 1972). Mullet and others (1988) suggested that much of the pink color comes from staining related to a sequence of paleosol horizons within the unit.

The white limestone member consists mostly of massive limestone with minor siltstone and mudstone interbeds (Bowers, 1972). The upper variegated sandstone member is only locally exposed (Lundin, 1989) and is composed of sandstone, siltstone, and mudstone (Bowers, 1972).

In the vicinity of the Iron Springs District the Claron Formation has been divided into five members (e.g., Mackin, 1954; Mackin and others, 1976; Mackin and Rowley, 1976). Short descriptions from Mackin and others (1976) of those five members are (from lowest to highest): Member A- Purplish-red limestone with minor interbedded shale and sandstone that are underlain by a 0-15 m thick basal conglomerate; Member B- Red shale, sandstone, conglomerate, and limestone; Member C- White sandstone, limestone, shale, and minor conglomerate; Member D- Massive white limestone; Member E- White sandstone and conglomerate that contain increasingly greater amounts of volcanic detritus upward.

In the Beaver Dam Mountains near Gunlock, Hintze (1986) provided a clear picture of the internal stratigraphy of the Claron. He recognized three members: the lowest contains white sandstone and orange conglomerate, the middle has mostly maroon mudstone with algal limestone beds, and the upper member consists of light-gray, fresh-water limestone.

A basal or near-basal conglomerate persists in most of the region. Goldstrand (1990) has called this conglomerate the Grand Castle member. This term is useful, however, some of the sections measured here do not contain such a conglomerate, for instance Fiddler Canyon 1, 2, & 3 (figures 1 and 2, see columns in chapter 2). In the Red Hills 2 section, the lowest exposed conglomerate is > 15 m above the base of the section.

The stratigraphic generalization from this work is a lower clastic portion, dominated by sandstone and calcareous sandstone, but containing interbedded conglomerate, limestone, and shale; a middle dominantly limestone part, and an upper clastic part which also contains mostly sandstone, but has interbeds of limestone, conglomerate, and shale (figure 2). In some sections, particularly those near the northern and western edges of the Claron distribution this generalization does not hold because the middle limestone unit is missing, but locally a younger, limestone unit is present (figure 2).

The upper clastic part of the Claron locally (e.g., White Rocks and Dodge Springs sections) contains an Oligocene tuff or volcaniclastic sandstone which appears to be derived from the tuff. The oldest of these tuffs is a bed equivalent to the ~29.5 m.y. Wah Wah Springs Formation (Best and others, 1973; Best and Grant, 1987).

Basal Unconformity

At the scale of the study area (figure 1) the Claron Formation lies unconformably on several different formations. The angle across the basal unconformity ranges from 0 to 50 degrees. Therefore it is a major bounding surface. The angular nature of the unconformity is only observable at the outcrop scale in some locations. Locally, the angular nature of this contact is easily seen at the Cherokee Mine and Parowan Gap sections (figure 1a).

Dominantly Mesozoic rocks underlie the unconformity, but locally Paleozoic or Cretaceous to Paleocene(?) formations underlie it. Locally the unconformity is a buttress unconformity as indicated by the pinching out of beds against it over distances of tens of meters or less (e.g., Fiddler Canyon sections in chapter 2, figure 3).

Evidence of subaerial exposure of the surface of the unconformity can be found in the vicinity of Fiddler Canyon where desiccation cracks have formed on sediments originally deposited as Cretaceous rocks (figure 4). The surface on which the desiccation cracks formed is parallel to bedding in the Claron, but is at an angle of >30 degrees to the bedding in the underlying Cretaceous rocks. This suggests subaerial exposure and deformation of the Sevier foreland basin after sometime in the Cretaceous and before deposition of the lower Claron Formation.

Regionally, there is a general trend of older Mesozoic units under the unconformity on the west and younger Mesozoic units under the unconformity on the east (figure 5). This trend is interrupted by Paleozoic rocks lying within the belts of Mesozoic rocks near the White Rocks section. These Paleozoic rocks appear to be part of a paleotopographic high that probably is the remainder of the Square Top Mountain thrust sheet (Hintze, 1986) of the Sevier orogenic belt. East of these Paleozoic rocks, near and north of the Gunlock section (figure 1a), a belt of Cretaceous to Paleocene(?) Grapevine Wash Formation underlies the Claron. There is a 0° to 10° angularity across the unconformity between these two formations (Hintze, 1986). The Grapevine Wash Formation appears to be a local dominantly conglomeratic unit (see Gunlock section in chapter 2) that was deposited only near the Square Top Mountain thrust (Hintze, 1986) and probably is an alluvial-fan deposit derived from the thrust plate.

The existence of the Square Top Mountain thrust sheet, the Grapevine Wash Formation, and a small thrust near Parowan Gap (figure 1a) (Threet, 1963) suggest some paleotopographic relief along the unconformity. Paleotopographic relief on the scale of tens of meters can be shown here. For instance, assuming that the base of the continuously exposed and lowest limestone was essentially horizontal in the Fiddler Canyon 1 and 2 sections, 11.3 meters of relief can be seen along the unconformity (figure 3). Greater paleotopographic relief can be seen in Parowan Gap (figure 1a).

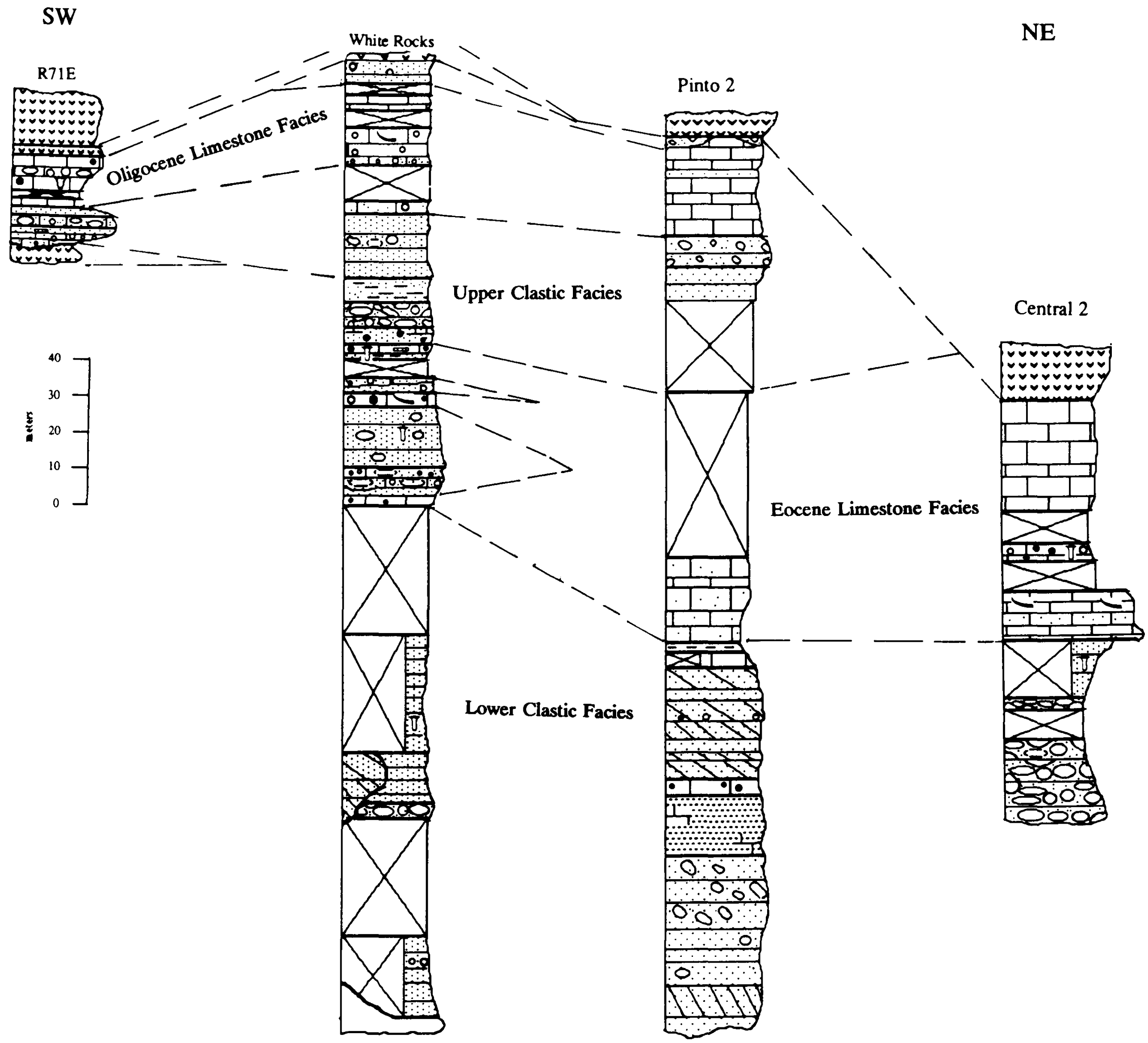

Figure 2. Diagram correlating general units in some measured stratigraphic sections. Section locations shown in figure 1a. Horizontal scale is not fixed. See explanation of symbols in chapter 2 for definition of symbols on this and all correlation diagrams.

Upper Contact

The upper contact of the Claron Formation is more complicated than the basal unconformity. This may be due to the longer persistence of the depositing lakes and streams in some places than in others.

The top of the sections at Oak Grove, Leeds Creek, Baker Dam, and Mahogany Creek (figures 1 and 5, chapter 2) are overlain by the igneous rocks called the Pine Valley Laccolith (Cook, 1957). The highest Claron beds, generally limestone, show signs of being heated, such as recrystallization and color changes in the limestone. This part of the upper contact would be intrusive and not depositional and therefore does not reflect regional depositional patterns.

The ~24 m.y. Leach Canyon Formation is the lowest widespread formation in the Quichapa Group (Mackin, 1960; Cook, 1965; Williams, 1967; Armstrong, 1970; Anderson and Rowley, 1975). It overlies the Claron in the following sections: Mud Spring 1, Mud Spring 2, Central 1, and Central 2. This same relationship was mapped a few miles south and southwest of Cedar City by Averitt (1967).

The ~25-26 m.y. Isom Formation is composed of tuffs with dominantly plagioclase phenocrysts as well as minor pyroxene and magnetite. It also contains a few intercalated lava flow beds (Mackin, 1960; Armstrong, 1970; Fleck and others, 1975; Anderson and Rowley, 1975). It overlies the Claron in the Dodge Spring 1, Dodge Spring 2, Dodge Spring 3, White Rocks, Newcastle, and R71E sections (figures 1 and 6).

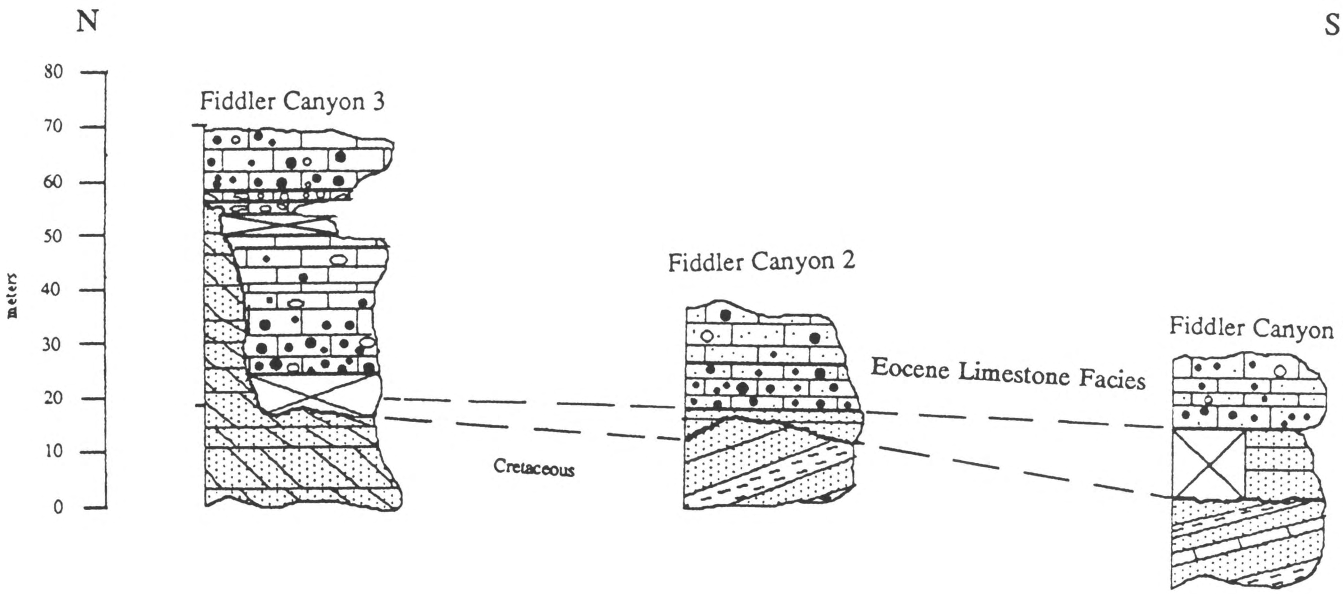

Figure 3. Diagram correlating stratigraphic sections near Fiddler Canyon. Note changes in units along basal unconformity and the small amount of paleotopographic relief along it. Detailed columns are in chapter 2. Horizontal scale is not fixed.

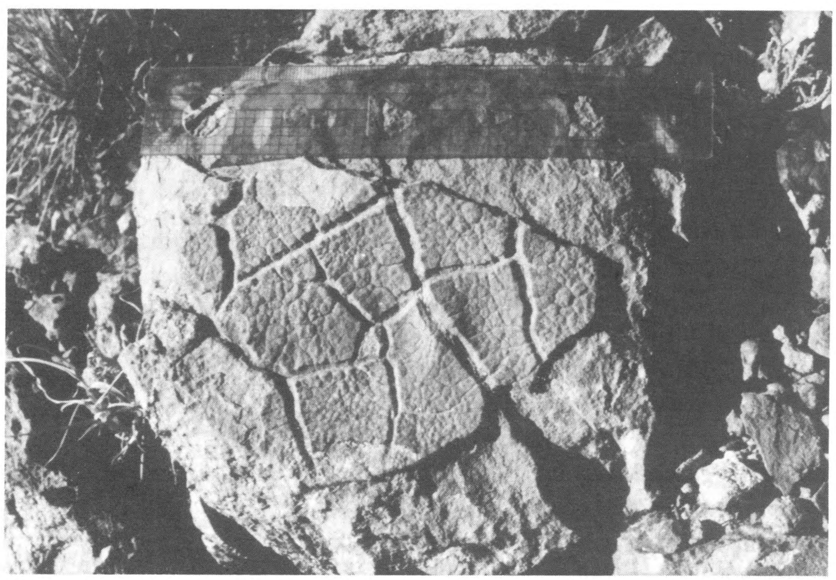

Figure 4. Photograph of desiccation cracks formed on Cretaceous rocks at the surface of the unconformity that underlies the Claron Formation. These features suggest that the surface of the unconformity was subaerially exposed prior to deposition of the Claron Formation. Photograph was taken near the Fiddler Canyon 2 stratigraphic section (chapter 2).

The Claron also is overlain by the Isom Formation in the Iron Springs District (Mackin and others, 1976) which is near the Iron Springs Creek and Eightmile Hills locations (figure 1a). This relationship has been reported in a number of other locations in the northern and eastern parts of the region (e.g., Averitt, 1967; Rowley and Threet, 1976; Mackin and others, 1976; Siders and others, 1990). However, at the Cherokee Mine section at least one Isom tuff is intercalated with lacustrine limestone typical of the Claron Formation.

The ~29.5 m.y. Wah Wah Springs Formation of the Needles Range Group also overlies the Claron in some locations (Best and others, 1973; Mackin and Rowley, 1976; Rowley and Threet, 1976; Best and Grant, 1987). Blank (1959) reported a Needles Range-type tuff intercalated with the Claron Formation in the Bull Valley Mountains northwest of the town of Central (figure 1a) and it appears to be the Wah Wah Springs Formation.

A thin unit which is the equivalent of the Wah Wah Springs Formation lies at the base of the measured section

R71E. Sandstones derived from it or similar dacitic tuffs were found within the Dodge Spring 3, White Rocks, and Cedar Wash sections.

These variations in the upper contact have presented problems in defining the upper limit of the Claron Formation (e.g., Hintze, 1986). The clastic and carbonate rocks intercalated with the tuffs and volcanogenic sandstones appear typical of the Claron Formation. Consequently, in areas of poor exposure it may not be possible to correctly distinguish which part(s) of the section is present.

The intercalation of volcanic rocks from the Wah Wah Springs and Isom Formations with Oligocene sediments presents a significant problem for the stratigraphic nomenclature because those formations are then within the Claron Formation. For this reason and because the volcanic units are everywhere thin within the depositional basin of the Claron Formation, I propose to call these units beds, for instance the Wah Wah Springs bed. In addition, I propose to distinguish the upper part which contains a tuff bed and/or volcaniclastic sandstone by informally calling it the Dodge Spring member of the Claron Formation. The name is derived from the Dodge Spring 3 section located near Dodge Spring, Utah (chapter 2).

I do not propose a separate formation name for this part of the section for three reasons. First, the name Claron Formation has been consistently applied to this volcanic-rich part of the section and it has been proven to be mappable (e.g., Blank, 1959; Mackin and Rowley, 1976). Second, the tuffs and related volcanogenic sandstones are commonly poorly exposed so they can be easily overlooked and the overlying or intercalated sandstones and limestones look like typical Claron Formation. Third, some of the beds in the southeastern part of the area where the tuffs and volcanogenic sandstones are lacking may be lateral equivalents of those that lie above the Wah Wah Springs Formation. In those places a separate formation distinction could not be made based on the rock itself as could be done where the volcanogenic units are present. However. detailed area mapping rather than the study of stratigraphic sections may indicate subdivision is possible.

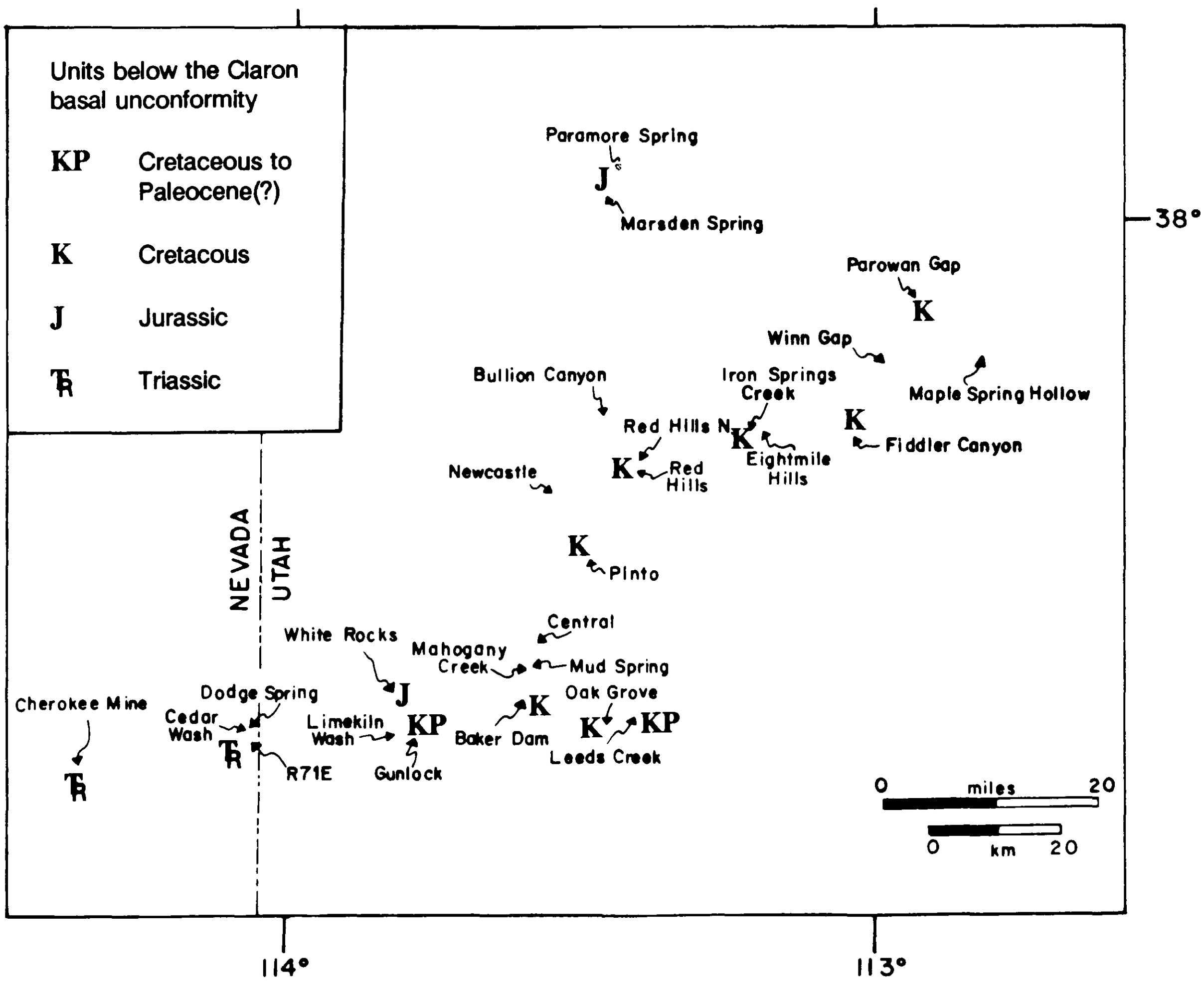

Figure 5. *Map showing units below the unconformity as determined at locations of measured sections and from available mapping cited in text.*

GENERAL LITHOLOGY AND DEPOSITIONAL ENVIRONMENTS

A lithologic continuum exists in the Claron Formation from conglomerate to pebbly sandstone, through sandstone to calcareous sandstone, and finally to limestone. Nevertheless the Claron Formation can be divided into clastic and limestone facies. The term clastic facies is used here to indicate sequences in which greater than 75% of the beds are conglomerate, sandstone, and/or shale.

Clastic Facies

The clastic facies is composed dominantly of sandstone, conglomeratic sandstone and conglomerate, but interbedded with them are minor amounts of limestone and rare shales. Laterally discontinuous beds are characteristic of this facies. It can be divided into the lower clastic facies and the upper clastic facies in the region from the Red Hills through Central to Limekiln Wash (figures 1a and 4). This division can be made most easily where the two are separated by a limestone facies. They can be separated on lithologic or petrographic criteria where some beds in the upper clastic facies contain > 10% volcanic detritus. The upper clastic facies is equivalent to the Dodge Spring member.

The conglomerate, sandy conglomerate, and conglomeratic sandstone beds contain clasts dominantly composed of carbonate, sandstone/quartzite, and/or chert. The ranges, in modal percent, for these clasts are: 1 - 79% carbonate, 0 - 87% quartzite/sandstone, and 0 - 73% chert. Locally quartz, chalcedony, or dark gray argillite clasts are present, generally in small amounts. However, quartz clasts make up to 32% of the clasts in one bed near Pinto (figure 1a). Most of the carbonate clasts are pieces of the Paleozoic formations that are exposed dominantly in Sevier belt thrust sheets that lie to the west and northwest including the Square Top Mountain thrust sheet. Many of the quartzite and sandstone clasts are from the Mesozoic formations that underlie the region although some may be from older quartzites (figures 1 and 4). The ratios among the clast types vary from bed to bed, but carbonate or quartzite/sandstone clasts generally occur in the greatest abundance (table 1; chapter 2). Clast imbrication occurs locally but is poorly developed.

Most of the conglomeratic units are matrix supported, but outcrop measurements indicate the matrix is between 19% and 71% of the rock (chapter 2). The average matrix is 47% of a unit, the median is 48%, and the mode is 44%. The matrix is generally sand to granule size and dominantly is composed of quartz. A minor amount of the matrix has rock fragments of sandstone/quartzite, carbonate, and chert.

Some of the conglomeratic units may be of debris-flow origin, however most of them are interpreted to be fluvial. This interpretation appears the most likely because most of the matrix-supported conglomerates grade laterally and/or vertically into sandstone over a distance of a meter or two. Many of these sandstones are cross bedded, suggesting a fluvial origin for them. This grading combined with the coarse grain size of the matrix suggests that the conglomerates originated as bar or intrachannel deposits.

The sandstone beds in the clastic facies generally are medium to very coarse grained, but fine-grained beds occur locally. Most contain calcite cement, micrite matrix, or both. The ratio of cement or matrix to sand grains has a wide range such that many beds are on the borderline between limestone and sandstone. The sand grains are composed of monocrystalline quartz (including undulose quartz), crystalline carbonate rock fragments, micrite rock fragments, polycrystalline quartz, peloids, chert, and sandstone/quartzite. Sand-size shell fragments, chalcedony, sutured quartz, and zircon are locally present in amounts less than 2%. Significantly, volcanogenic grains occur in some of the sandstones. They most commonly are slightly devitrified glass shards, but volcanic rock fragments and zoned, twinned feldspar also occur. These volcanic fragments were recognized in Claron sandstones by Mackin and others (1976) in the vicinity of the Eightmile Hills and Iron Springs Creek (figure 1a). The amount of volcanic detritus ranges from 0% through trace amounts up to ~40%, but 1 - 2% is most common (table 2; chapter 2). The higher amounts of volcanic detritus occur in sandstones of the Dodge Springs member.

Many of the sandstone beds are cross bedded and various types of cross beds are exposed. The most common type is planar tabular cross bedding that generally occurs as sets of cross strata in a vertical series of multiple beds (chapter 2). This style of cross bedding is typical of transverse bars. As is characteristic of transverse bars, these beds are of limited lateral extent. The same beds commonly are not present in sections measured only 100 to 300 m apart (chapter 2). Trough cross beds are the second most common type in the formation. They generally are small, usually less than a meter across.

Scours or small channels <1 m to 10 m wide are common. The channel and associated fill deposits are generally encased in sandstone. Scoured bases are common in the area of channels, but also occur along many of the sandstone beds. The channel size and lack of encasing or associated overbank-type fine-grained sediments suggests these channels may be second- or third-order channels within the first-order major channel.

In analogy with modern deposits, the domination of sandstone and conglomerate with a minor amount of fine- grained clastic sediment in the clastic facies suggests that it was deposited by a semi-arid fan, arid fan, or pebbly braided river.

Table 1. *Summary of clast count data from sections of the Claron Formation which shows the compositional variations in the conglomerates and sandy conglomerates. Section locations shown in figure 1a. The data are shown as histograms in chapter 2. arg = argillite, qtz = quartz, cha = chalcedony.*

Section	meters above base of measured section	quartzite/ sandstone %	carbonate %	chert %	other %
Baker Dam	54	51	26	6	4 qtz
Baker Dam	86	36	32	32	–
Central 1	46	64	18	9	–
Central 1	134	60	22	18	–
Central 2	3	67	13	20	–
Dodge Spring 1	6	13	3	3	trace arg.
Dodge Spring 2	13	19	77	2	2 cha
Iron Springs Creek 2	18	38	3	55	4 qtz
Leeds Creek	2	55	26	19	–
Mud Spring 1	29	48	21	30	2 qtz
Mud Spring 2	39	33	33	34	–
Newcastle	27	37	63	–	–
Oak Grove	72	20	29	43	8 qtz
Pinto 2	196	–	22	46	32 qtz
Red Hills 2	17	43	42	12	3 qtz
White Rocks	49	54	39	7	–
White Rocks	129	57	35	8	–

Limestone Facies

The limestone facies contains micrite, coarse clastic, and crystalline limestone beds that range in color from very light gray to medium gray, but light gray is most common. Sand-size quartz grains, usually floating, are typical. The beds range from laminated to massive, are a few centimeters to 2 m thick, and commonly exhibit bioturbation. Shell fragments, gastropod fossils, small stromatolites, and oncoids occur in various beds. The oncoids locally are up to 15 cm across and are particularly numerous in the vicinities of Leeds Creek and Fiddler Canyon (figure 1a).

Cumulate stromatolites, common in the area of Mud Spring, and Eocene gastropods of the genus *Viviparous,* common in the upper part of the limestone facies in the vicinity of Leeds Creek, suggest deposition of these limestone beds from standing bodies of fresh water. Oncoids and broken pieces of gastropod and bivalve shells (particularly common in the Red Hills) suggest that a lacustrine environment with some turbulence is more likely than a swamp environment.

Table 2. *Summary of selected compositional data from sandstones in the Claron Formation. Data given in percent. Note the variations in the amount of volcanic detritus in different beds. Data from chapter 2. Mono. qtz = monocrystalline quartz including undulose quartz; poly. qtz = polycrystalline quartz; CRF = carbonate rock fragments; VRF = volcanic rock fragments including slightly devitrified glass shards; SRF = sandstone and mudstone rock fragments.*

Section	Unit	mono. qtz	poly. qtz	CRF	Percent VRF	SRF
Central 1	14	27.5	2	5.2	–	0.2
Pinto 2	2	17.2	0.2	11.8	0.4	–
Bullion Canyon	7	80.0	trace	13.3	–	–
Red Hills 2	12	18.3	–	3.0	–	–
Red Hills 1	13	31.3	–	55.0	–	–
Red Hills 2	10	40.6	2.4	2.4	0.2	0.4
Iron Springs Creek 2	5	34.5	1.4	6.2	–	–
White Rocks	27	9.0	0.0	0.0	49.4	0.2

Many surfaces along the tops of limestone beds show evidence of subaerial exposure. The upper part of a bed interpreted to have been subaerially exposed typically has a broken-up or rubbly appearance with a slightly different material filling in the cracks. Paleosols are only rarely developed in the study region.

Crystalline, clastic, and micritic limestones may occur in the same sections. The crystalline limestones probably formed by chemical precipitation except locally where the heat from overlying volcanic rocks caused recrystallization. The micrite beds were formed in relation to biogenic activity, possibly algae, boring, or both. The clastic limestone formed by movement of existing calcareous material. Therefore, both precipitation and biogenic activity caused limestone formation at different times or in different parts of the Claron depositional basin

Massive matrix-supported conglomerate with micrite matrix (conglomeratic micrite) occurs but is rare compared with conglomerates with sandstone matrix. The conglomeratic micrite units commonly are one bed which is less than 3 meters thick. The clasts are composed of quartzite/ sandstone, carbonate, and chert, similar to those in conglomerates with a sandstone matrix.

Conglomeratic micrite is an unusual, but remarkable lithology. Such a unit occurs within a completely limestone sequence at Fiddler Canyon where it locally directly overlies the basal unconformity (figure 1a). At White Rocks, conglomeratic micrite occurs in a limestone-rich part of the clastic facies. This association with lacustrine rocks suggests lacustrine deposition is possible, however, the massive nature and lithology suggest a debris-flow origin. These beds probably were deposited as a subaqueous

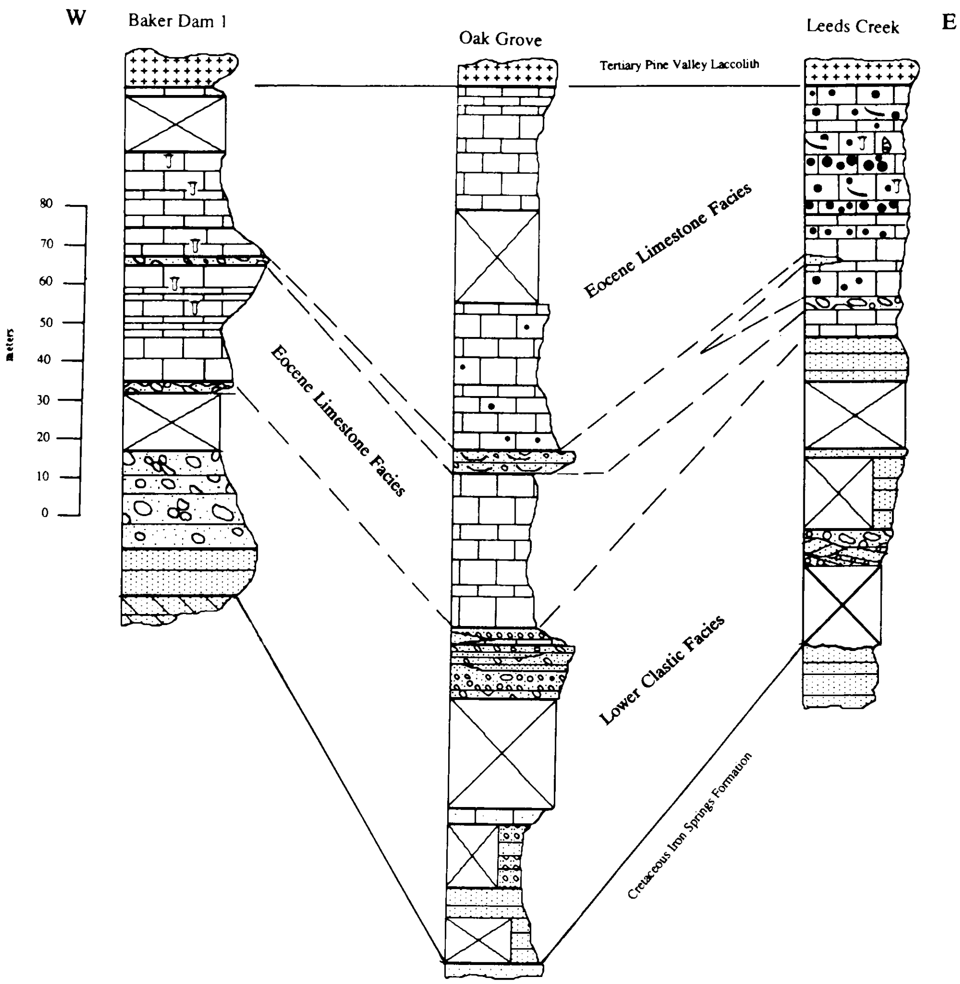

Figure 6. Correlation diagram of stratigraphic sections in the Pine Valley Mountains. Note large thickness of limestone facies which probably was deposited in an Eocene lake. Horizontal scale is not fixed. See figure 1a for locations.

debris-flow deposit. The micrite matrix suggests that the debris flow was derived within a standing body of fresh water. Therefore, these deposits probably represent resedimentation of this detritus.

The Lakes

The limestone facies that locally separates the upper and lower clastic facies is best developed in the region of the Central, Baker Dam, Leeds Creek, and Oak Grove sections (figure 6, chapter 2). In the latter 3, the tops of the stratigraphic sections are not exposed and the limestone facies is overlain by the Tertiary Pine Valley laccolith of Cook (1957). In the Oak Grove section, where it is thickest, 145.5 m of this facies is exposed.

A large lake probably occupied this region during deposition of much of the Claron Formation. Thin zones of limestone facies occur near the middle and in some cases the top of sections in the Newcastle, Pinto, Red Hills, and Eightmile Hills area suggesting that at times the lake encroached on this region or that at times additional small lakes formed in the area (figure 1a). In the Fiddler Canyon sections the limestone facies is at or near the base of the Claron. Either a stratigraphically lower lake existed here or the limestone facies was deposited by the same lake as that in the Oak Grove area and it records an eastward migration of the limits of Claron deposition and onlap of the limestone facies onto the basal unconformity.

The lake in this area is most likely Eocene in age. Gastropod fossils of the genus *Viviparous* and probably *Viviparous trochiformis* (identified by C. Feibel, 1990) were found in the upper part of the limestone facies in the Leeds Creek area. These fossils are similar to some known only from the Eocene part of the Flagstaff Formation which suggests that the upper part of this lake may be Eocene (La Rocque, 1960).

Limestone facies indicative of lacustrine deposition also crops out in the region from Dodge Spring to Cherokee mine (figure 1a). It appears that the limestone facies in this area is Oligocene in age rather than Eocene. In the Dodge Spring area the Claron Formation varies from 35 to 115 m thick and the limestone facies comprises the upper half or three quarters of the section. The lower part is composed of clastic facies (chapter 2). Here the limestone facies is directly overlain by the Oligocene Isom Formation. Locally a biotite-rich sandstone is intercalated with the limestone. The sandstone must have been derived from an Oligocene dacitic tuff because these tuffs are the only reasonable biotite-rich source in the region. In addition, at Cedar Wash a sandstone containing biotite, plagioclase, and hornblende is intercalated with the limestone facies rocks (figure 8). These minerals are common in the Pliocene Wah Wah Springs Formation and it is the probable source of the sandstone. Therefore, the limestone facies in this area probably is Oligocene.

Locally, the Oligocene tuffs are intercalated with Claron limestones in this region, also indicating an Oligocene age for a lake in this area. The bed that is the 29.5 Ma Wah Wah Springs Formation (Best and Grant, 1987) in the R71E area is overlain by limestone facies rocks which in turn are overlain by younger Oligocene tuffs (figure 7, chapter 2).

One member of the Oligocene Isom Tuff is intercalated with limestone facies rocks near Cherokee mine and another member overlies the rocks (figure 1a; chapter 2). Therefore, lacustrine deposition occurred during the Oligocene in the southwestern part of the area.

Because the Oligocene limestone facies is at or near the base of the thin Claron sections in the Dodge Spring to Cherokee mine area, it appears that this lake developed as the edge of the Claron depositional basin moved westward. Alternatively, a separate and unrelated basin may have developed in this area.

The Fluvial/Alluvial System

Sedimentary structures in the clastic facies indicate deposition in a braided stream or fan environment. Usually a braided stream contains:

successive planar tabular cross beds
trough cross stratification
scoured bases
channels.

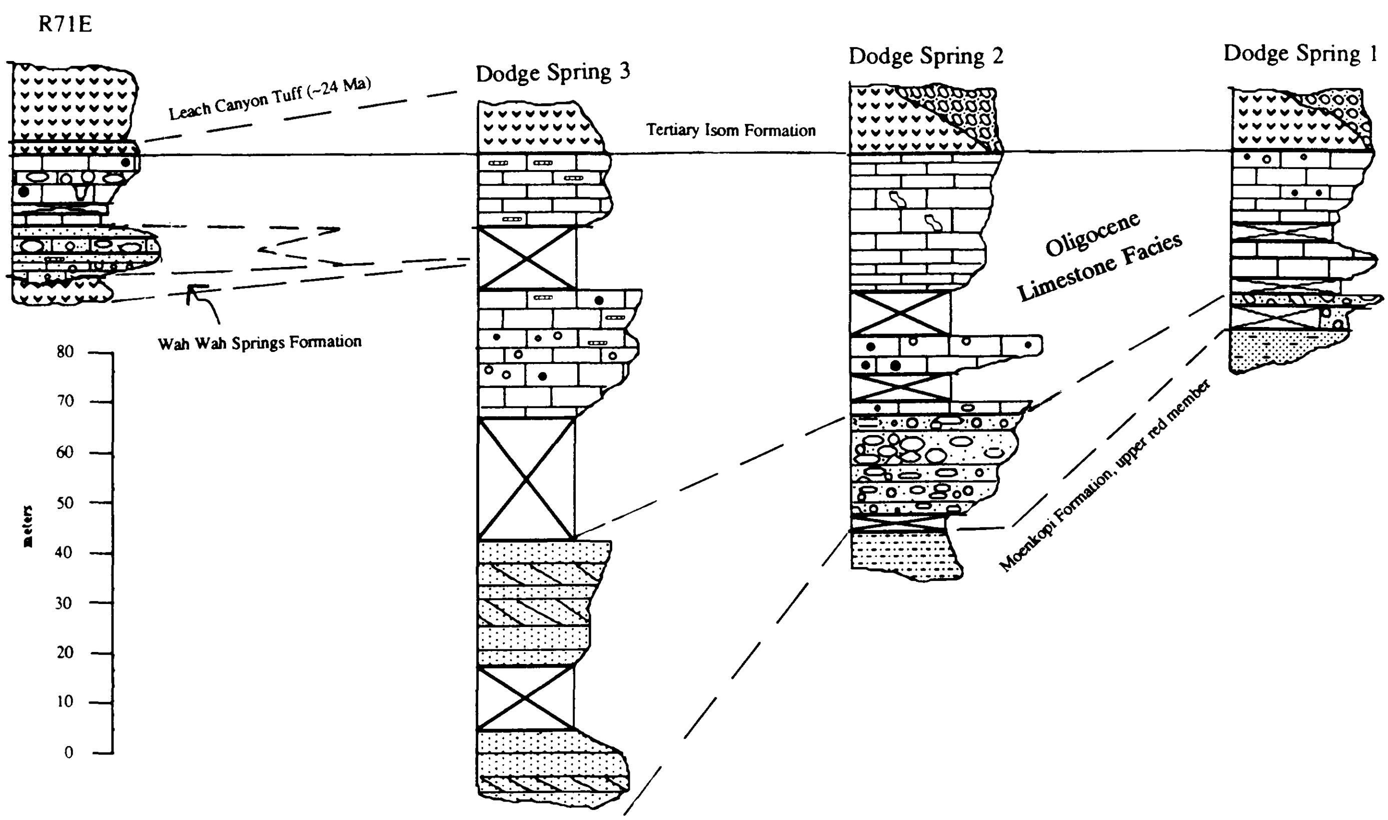

Figure 7. *Correlation diagram of sections near the Utah - Nevada state line. Note interbedded and overlying volcanic units, the Isom and Wah Wah Springs Formations. Section locations are shown in figure 1a and detailed stratigraphy is shown in chapter 2.*

All of these structures are common in the clastic facies, suggesting that most of this facies was deposited in a braided stream environment. Whether or not the braided stream was part of an alluvial fan is difficult to evaluate. The debris-flow deposits expected in an alluvial fan are rare except possibly in the upper part of the section at Bullion Canyon (figure 1a; chapter 2). The region has been extended by a number of post-depositional, Cenozoic normal faults and this makes determination of a fan-shaped deposit difficult.

Clastic facies rocks everywhere underlie limestone facies units except locally at Fiddler Canyon (figure 1a). This suggests that the fluvial system shifted its course either by an actual shift in the channel location or a retrograde movement of a fan. The presence of floating quartz grains, pebbles, and cobbles in the limestone facies rocks indicates that at least some of the fluvial material was deposited into and trapped in the lakes.

Mudrocks compose a larger part of the Claron in the eastern part of the area (Maple Spring Hollow to Parowan Gap) than in the rest of the region studied here. Mudstone, claystone, and shale also make up a large part of the Claron in the High Plateaus which lie east of Parowan and Cedar City (figure 1a; Gregory, 1951; Bowers, 1972, Goldstrand, 1990). This decrease in the proportion of coarse-grained clastic rocks generally from west to east suggests a change in the fluvial system from west to east. This change can be explained in two ways which are not necessarily mutually exclusive. First, the High Plateaus area could lie outside the first-order channel during deposition of the fine-grained rocks which then would represent overbank deposits. In the second explanation, the fine-grained rocks represent a natural downstream decrease in grain size. This explanation is supported by the direction of maximum clast size decrease toward the east and southeast in the conglomerates and sandy conglomerates (figure 9).

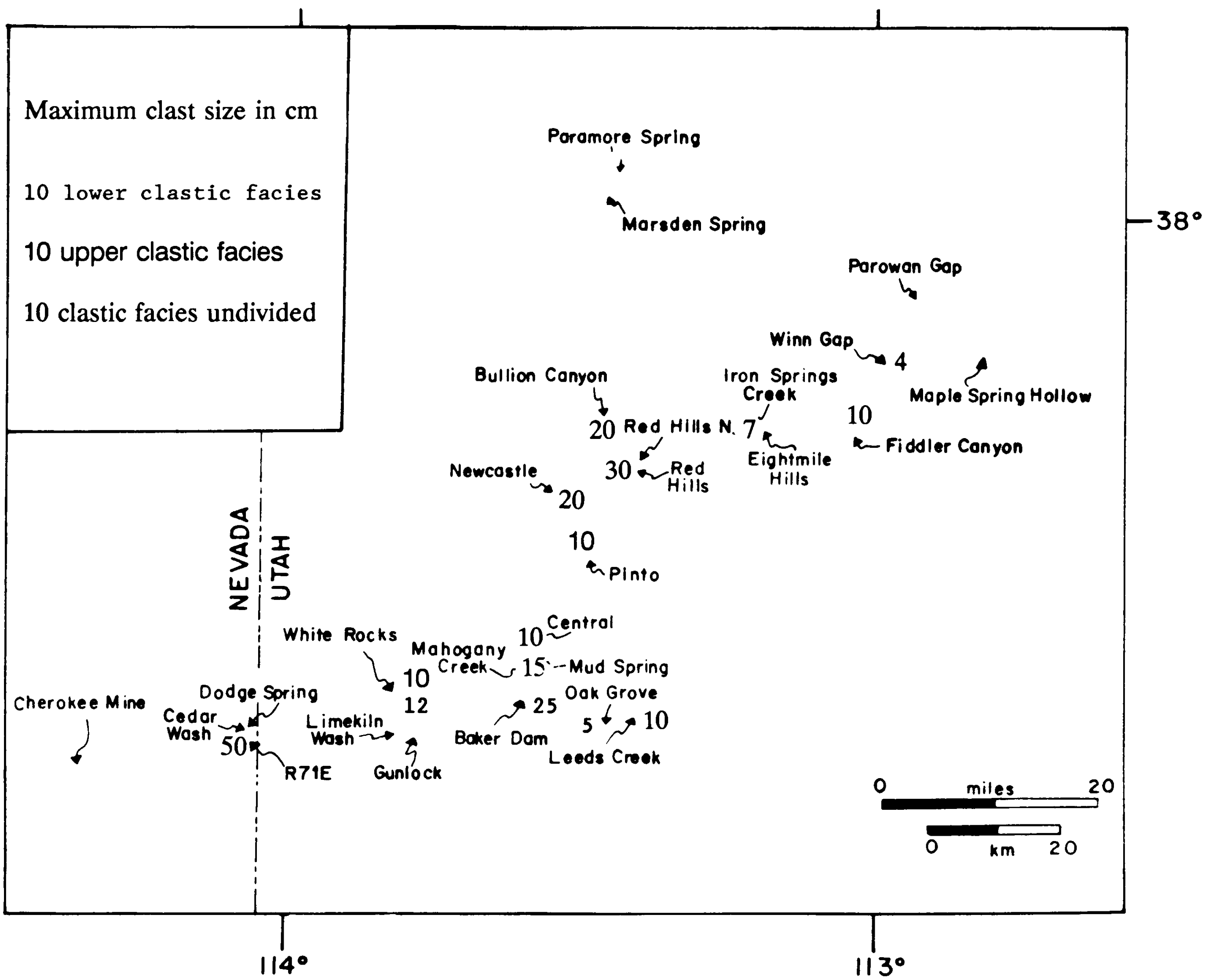

Figure 8. Map showing maximum clast size measured in the clastic facies at various locations. Note the general southward and eastward decrease in size.

PROVENANCE OF CLASTIC FACIES

The clasts of pebble and larger size as well as many of the sand-size grains indicate that the Paleozoic rocks exposed in the Sevier orogenic belt thrust sheets were the source for a significant amount of the Claron Formation. Based on lithology and fossil content, clasts can be identified as Mississippian-Pennsylvanian Bird Spring Formation limestone, Cambrian dolostone, and Devonian limestone. These formations occur in thrust sheets in the Mormon Mountains, the Wah Wah Mountains, and other areas to the north of Parowan (e.g., Armstrong, 1968; Hintze, 1980, 1986; Wernicke and others, 1985; Best and others, 1987; Walker and Bartley, 1991).

Many of the quartzite/sandstone clasts can be identified as Navajo Sandstone or Iron Springs Formation. Therefore, these Mesozoic formations and possibly others that underlie the Claron were also a source for some of the clastic detritus.

Chert is a common clast type in many of the conglomeratic beds (table 1). Some of the chert is various shades of gray and contains bits of carbonate attached to it. The attached carbonate and similarity in color to chert in some of the Paleozoic carbonate formations in the thrust sheets suggest that this chert was derived from them. However, some of the chert clasts are a characteristic yellow-brown color. Chert clasts of this color are most common in the Grapevine Wash Formation. The yellow-brown chert clasts in the Claron were never found to be larger than those in the Grapevine Wash Formation. Therefore, the Grapevine Wash Formation is a likely source for these clasts.

Differences in provenance between some of the clastic units are evident from the variations in clast count percentages and from the sand-size grains. The compositional variations in the clast counts (table 1) suggest heterogeneity within the thrust sheets or in the ratio of detritus derived from the underlying Mesozoic formations to that derived from the thrust sheets. For instance, a high sandstone/quartzite to carbonate ratio may indicate the Mesozoic formations were the source for more of the clasts in that bed and vice versa. The lack of systematic variation in the clast percentages suggests that the stream(s) tapped into these two different groups of source rocks at irregular intervals.

The sandstones and calcareous sandstones contain a

Figure 9. *Photograph of sandstone in the Cedar Wash area derived from the Oligocene Wah Wah Springs Formation.*

wide variety of grain types. As with the clasts, the percentage of each grain type is quite variable. The types of quartz grains include monocrystalline, undulose, polycrystalline, and sutured. Quartz grains with a single rounded quartz overgrowth occur in most units. The roundness of the overgrowths combined with the occurrence of present calcite cement or carbonate matrix suggest that these grains may have been derived from older sandstones or quartzites. The most likely sources for these are the Mesozoic sandstones and quartzites in the region, but older sources such as the Ordovician Eureka Quartzite and sandstone in the Bird Spring Formation are not ruled out.

Sand-size carbonate rock fragments are common and include both micritic and sparry types. The most likely sources for these grains are the Paleozoic carbonates in the Sevier belt thrust sheets. Clastic rock fragments are rare in the sandstones, but siltstone and sandstone grains occur in some beds. Possible sources for these grains are the Paleozoic and/or the Mesozoic clastic rocks.

Volcanic rock fragments of sand size and smaller, including both fine-grained phenocrystic grains and glass, occur in the lower part of the clastic facies in sections near Oak Grove, Dodge Spring, Red Hills, Pinto, and Fiddler Canyon (figure 1a). The volcanic detritus generally makes up less than 1% of the grains. Beds with higher and the highest amounts of volcanic grains occur in the Dodge Spring member near the top of sections in the vicinity of Cedar Wash, White Rocks, and Eightmile Hills (figure 1a).

There are three possible sources for these volcanic fragments: the syndepositional Oligocene volcanic rocks, the predepositional felsic volcanic clasts in the Cretaceous to Paleocene(?) Canaan Peak Formation, and the predepositional volcaniclastic material in some of the Mesozoic formations. In the upper clastic facies (Dodge Spring member) most of the grains are subangular to angular and some are hornblende or biotite which are easily weathered and are not resistant in transport. These features suggest little transport and that reworking is unlikely. Therefore the most likely source for the majority of the volcanic grains in the upper clastic facies is the Oligocene volcanic rocks.

Sandstones that contain hornblende and biotite are most common in the vicinity of sections where a bed equivalent to the Wah Wah Springs Formation, a dacitic tuff containing biotite and hornblende, is intercalated with the sedimentary beds of the Claron Formation. For instance, the Wah Wah Springs bed is intercalated with sediments in the area of section R71E and biotite- and volcanic rock fragment-rich sandstones occur in the Cedar Wash, Dodge Springs, and White Rocks area (figures 1 and 6). This further suggests that much of the volcanic detritus in the upper clastic facies is derived from the Oligocene volcanic rocks.

The volcanic detritus in the lower clastic facies probably was reworked from the older sedimentary deposits. Volcanic grains occur in the lower clastic facies below the Eocene limestone in the area of Leeds Creek and Oak Grove. Providing that the Eocene age is correct for the limestone, then one of the older sources must have provided the volcanic grains.

Compound Source Region

The provenance of the Claron Formation is complex. The clasts in the conglomeratic units indicate source areas in the Paleozoic rocks of the Sevier orogenic belt thrust sheets, the Mesozoic rocks that underlie the Claron and are the footwall to some of the thrusts, and a Cretaceous to early Tertiary alluvial-fan deposit whose source was thrust sheets. The sand grains confirm these source areas and also indicate a source of volcanic detritus (see chapter 2). The Oligocene tuffs are the most likely source for these volcanic grains in the Dodge Spring member, but below that they may have been cannibalized from the Canaan Peak Formation. Therefore, the Claron Formation had a compound source area.

Compound source areas for clastic deposits are not uncommon (e.g., DeCelles, 1988). It is predictable that a clastic unit deposited near the front of an extinct thrust belt and at the margin of a syndepositional volcanic and extensional belt would incorporate clasts and grains of diverse origin.

DISCUSSION AND TECTONIC IMPLICATIONS

Assuming that most of the volcanic detritus in the upper clastic facies of the Claron Formation came from Oligocene volcanic rocks, the distribution of beds with > 10% volcanic grains can be used to estimate what parts of the formation are Oligocene in age. Figure 2 suggests that much or all of the formation is Oligocene in the western and northern parts of the area (figure 1b). Goldstrand (1990) reported Paleocene pollen ages from the lower part of the Claron formation in the region near Baker Dam and Leeds Creek (figure 1a). Paleocene ages have also been reported from the High Plateaus region (e.g., Bowers, 1972). This suggests that between Paleocene and Oligocene the western limit of the Claron depositional basin migrated west and north.

The Claron Formation was deposited after the Cretaceous Sevier orogeny. It laps Sevier belt thrusts and the best age estimates for it are early Paleocene to Oligocene. Parts of the Claron Formation were deposited during Laramide deformation, however effects of that orogeny were small in this region.

In the Oligocene, sometime between 33 and 31 m.y. extension and volcanism began to take place to the north of the present Claron distribution (Best and Grant, 1987; Best and others, 1989; Taylor and others, 1989; Taylor, 1990). It was at about this time that the Claron basin migrated to the west and north. Therefore, it may be that the onset of extension or volcanism changed the paleogeography enough to cause this change in the depositional basin.

Anderson and Kurlich (1989) argued that a clastic unit containing volcanic detritus in the southern High Plateaus region should be designated as a separate unit from the Claron Formation. Such a designation does not appear to be necessary in the region studied here because Oligocene volcanic detritus appears to have been erupted into the depositional basin in the upper part and western part of the formation. Therefore the source change is related to a process that may have influenced, but did not cause formation of the Claron basin. Also, near Mount Claron in the vicinity of Red Hills, Eightmile Hills, and Iron Springs Creek it has been established that the Claron Formation contains volcanic detritus (Mackin, 1960; Mackin and others, 1976; chapter 2). Therefore, rocks called Claron near the type section contain volcanic detritus and that established formation definition has been followed in this study.

SUMMARY AND CONCLUSIONS

The Claron Formation was deposited during the time span of lower Paleocene into the Oligocene. The Claron Formation in the western and northern parts of its distribution may not contain Paleocene or even Eocene units.

The rocks in the Claron range from conglomerate to claystone and sandy limestone to crystalline limestone. Nevertheless, the formation can be divided into clastic and limestone facies. Locally, rocks of the limestone facies divide the clastic facies into upper and lower parts. The clastic facies is composed mainly of sandstone, conglomeratic sandstone, and conglomerate with subordinate mudstone. It was deposited in a braided stream environment. Whether or not the braided stream was part of an alluvial fan is difficult to ascertain.

Limestone facies rocks were deposited in two major lakes. The deposits of one are Eocene and are located near Oak Grove and Baker Dam (figure 1a). The other major lake was probably nearly entirely Oligocene and was located in the vicinity of Dodge Spring and Cherokee mine.

The clastic facies had a compound source area. Pebbles to boulders probably were derived from Paleozoic rocks of Sevier belt thrust sheets, Mesozoic rocks that are in part footwall to those thrusts, and the Cretaceous to early Tertiary Grapevine Wash Formation. The sand-size grains corroborate these source areas and indicate an additional source area that contains volcanic rocks composed in large part of glass. Based on rounding and mineralogy, the most likely source for the volcanic fragments in the upper clastic facies or Dodge Spring member is Oligocene tuffs that were erupted from vents north of the Claron basin. Some of these tuffs, particularly the Wah Wah Springs Formation and the Isom Formation, were deposited in part of the Claron basin. Consequently, the source of the volcanic detritus was that part of the volcanic bed which was erupted into the basin.

It is herein proposed to call the part of the Claron Formation containing volcanogenic sandstones and intercalated volcanic formations the Dodge Spring member of the Claron Formation. This solves the need for a separate name for parts of the unit with and without significant amounts of volcanic detritus, but does not require recognition of a separate unit where exposure may make that difficult.

The older part of the Claron Formation probably lies in the eastern part of the Claron distribution in figure 1a and on the High Plateaus. Based on the presence of small to large amounts of volcanogenic grains in sandstones and on local intercalation of a bed equivalent to the 29.5 m.y. Wah Wah Springs Formation and one member of the ~27 m.y. Isom Formation, much of the Claron Formation from the vicinity of Cherokee mine through Dodge Spring, Pinto, and to Iron Springs Creek is Oligocene in age. This westward and northward migration of the depositional basin roughly coincided with onset of extension and volcanism in the region. Therefore, the change in the depositional basin probably is the result of gentle warping caused by the change from tectonic quiescence across the region to active extension north of the Claron basin.

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REFERENCES CITED

Anderson, J. J., and Kurlick, R. A., 1989, Post-Claron Formation, pre-regional ash-flow tuff Early Tertiary stratigraphy of the southern high plateaus of Utah: Geological Society of America Abstracts with Programs, v. 21, p.

Anderson, J. J., and Rowley, P. D., 1975, Cenozoic stratigraphy of southwestern High Plateaus: Geological Society of America Special Paper 160, p. 1-52.

Armstrong, R. L, 1968, Sevier orogenic belt in Nevada and Utah: Geological Society of America Bulletin, v. 79, p. 429-458.

Armstrong, R.L., 1970, Geochronology of Tertiary igneous rocks, eastern Basin and Range province, western Utah, eastern Nevada and vicinity, U.S.A.: Geochimica et Cosmochimica Acta, v. 34, no. 2, p. 203-232.

Averitt, P., 1967, Geologic map of the Kanarraville quadrangle, Iron County, Utah: U. S. Geological Survey Quadrangle Map GQ-694.

Bartley, J.M., Axen, G.J., Taylor, W.J., and Fryxell, J.E., 1988, Cenozoic tectonics of a transect through eastern Nevada near 38°N latitude, *in* Weide, D.L., ed., Geological Society of America Cordilleran Section Field Trip Guidebook, p. 1-20.

Best, M. G., Shuey, R. T., Caskey, C. F., and Grant, S. K., 1973, Stratigraphic relations of members of the Needles Range Formation at type localities in southwestern Utah: Geological Society of America Bulletin, v. 84, p. 3269-3278.

Best, M. G., and Grant, S. K., 1987, Stratigraphy of the volcanic Oligocene Needles Range Group in southwestern Utah: U.S. Geological Survey Professional Paper 1433-A, p. 3-28.

Best, M.G., Morris, H. T., Kopf, R. W., and Keith, J. D., 1987, Geologic map of the southern Pine Valley area, Beaver and Iron counties, Utah: Miscellaneous Investigations Map I-1794, U.S. Geological Survey, Washington, D.C..

Best, M. G., Christiansen, E. H., and Blank, R. H., Jr., 1989, Oligocene caldera complex and calc-alkaline tuffs and lavas of the Indian Peak volcanic field, Nevada and Utah: Geological Society of America Bulletin, v. 101, p. 1076-1090.

Best, M. G., and Christiansen, E. H., 1991, Limited extension during peak Tertiary volcanism, Great Basin of Nevada and Utah: Journal of Geophysical Research, v. 96, no. B8, p. 13,509-13,528.

Blank, H. R., 1959, Geology of the Bull Valley district, Washington County, Utah: University of Washington, Seattle, unpublished Ph.D. thesis, 177 p.

Bohannon, R. G., 1983, Mesozoic and Cenozoic tectonic development of the Muddy, North Muddy, and northern Black Mountains, Clark County, Nevada, *in* Miller, D. M., Todd, V. R., and Howard, K. A., eds., Tectonic and stratigraphic studies in the eastern Great Basin: Geological Society of America Memoir 157, p. 125-148.

Bowers, W. E., 1972, The Canaan Peak, Pine Hollow, and Wasatch Formations in the Table Cliff region, Garfield County, Utah: U.S. Geological Survey Bulletin 1331-B, 39 p.

Brown, W. G., 1988, Deformational styles of the Laramide uplifts in the Wyoming foreland, *in* Schmidt, C. J., and Perry, W. J., Jr., eds., Interaction of the Rocky Mountain foreland and the Cordilleran thrust belt: Geological Society of America Memoir 171, p. 1-25.

Cook, E. F., 1957, Geology of the Pine Valley Mountains, Utah: Utah Geological and Mineral Survey Bulletin 58, 111 p.

Cook, E.F., 1965, Stratigraphy of Tertiary volcanic rocks in eastern Nevada: Nevada Bureau of Mines Report 11, 61 p.

Cross, T. A., 1986, Tectonic controls of foreland basin subsidence and Laramide style deformation, western United States, *in* Allen, P. A. and Homewood, P. eds., Foreland Basins: International Association of Sedimentologists Special Publication 8, p. 15-39.

DeCelles, P. G., 1988, Lithologic provenance modeling applied to the Late Cretaceous synorogenic Echo Canyon Conglomerate, Utah: A case of multiple source areas: Geology, v. 16, p. 1039-1043.

Dickinson, W. R., and Snyder, W. S., 1978, Plate tectonics of the Laramide orogeny: Geological Society of America Memoir 151, p. 355-366.

Fleck, R. J., Anderson, J. J., and Rowley, P. D., 1975, Chronology of mid-Tertiary volcanism, High Plateaus region, Utah, *in* Anderson, J. J., Rowley, P. D., Fleck, R. J., and Nairn, A. E. M., eds., Cenozoic Geology of Southwestern High Plateaus Region: Geological Society of America Special Paper 160, p. 53-62.

Goldstrand, P. M., 1990, Stratigraphy and Paleogeography of Late Cretaceous and Paleogene rocks of southwest Utah: Utah Geological and Mineral Survey Miscellaneous Publication 90-2, p. 1-58.

Gregory, H. E., 1951, The geology and geography of the Pansaugunt region, Utah: U.S. Geological Survey Professional Paper 226, 116 p.

Hamilton, W. B., 1988, Laramide crustal shortening, *in* Schmidt, C. J., and Perry, W. J., Jr., eds., Interaction of the Rocky Mountain foreland and the Cordilleran thrust belt: Geological Society of America Memoir 171, p. 27-39.

Hintze, L. F., 1980, Geologic map of Utah: Utah Geological and Mineral Survey, scale 1:500,000.

Hintze, L. F., 1986, Stratigraphy and structure of the Beaver Dam Mountains, southwestern Utah: Utah Geological Association Publication 15, p. 1-36.

La Rocque, Auréle, 1960, Molluscan faunas of the Flagstaff Formation of Central Utah: Geological Society of America Memoir 78, 100 p.

Lundin, E. R., 1989, Thrusting of the Claron Formation, Bryce Canyon region, Utah: Geological Society of America Bulletin, v. 101, p. 1038-1050.

Mackin, J. H., 1954, Geology and iron ore deposits of the Granite Mountain area, Iron County, Utah: U. S. Geological Survey Mineral Investigations Map MF-14.

Mackin, J. H., 1960, Structural significance of Tertiary volcanic rocks in southwestern Utah: American Journal of Science, v. 258, p. 81-131.

Mackin, J. H., Nelson, W. H., and Rowley, P. D., 1976, Geologic map of the Cedar City NW Quadrangle, Iron County, Utah: U.S. Geological Survey Quadrangle Map GQ-1295, scale 1:24,000.

Mackin, J. H., and Rowley, P. D., 1976, Geologic map of the Three Peaks Quadrangle, Iron County, Utah: U. S. Geological Survey Quadrangle Map GQ-1296.

Mullet, D. J., Wells, N. A., and Anderson, J. J., 1988, Unusually intense pedogenic modification of the Paleocene - Eocene Claron Formation of southwestern Utah: Geological Society of America Abstracts with Programs, v. 20, no. 5, p. 382.

Nilsen, T. H., and McKee, E. H., 1979, Paleogene paleogeography of the western United States, *in* Armentrout, J. M., Cole, M. R., and Terbest, H., Jr., eds., Cenozoic Paleogeography of the Western United States: S. E. P. M. Pacific Coast Paleogeography Symposium 3, p. 257-276.

Rowley, P. D., Steven, T. A., Anderson, J. J., and Cunningham, C. G., 1979, Cenozoic stratigraphic and structural framework of southwestern Utah: U.S. Geological Survey 1149, 22 p.

Rowley, P. D. and Threet, R. L., 1976, Geologic map of the Enoch Quadrangle, Iron County, Utah: U. S. Geological Survey Geologic Quadrangle Map GQ-1690.

Siders, M. A., Rowley, P. D., Shubat, M. A., Christenson, G. E., and Galyardt, G. L., 1990, Geologic map of the Newcastle Quadrangle, Iron County, Utah: U. S. Geological Survey Map GQ-1690.

Taylor, W. J., 1990, Magnitude and temporal relations of episodic Cenozoic extension in the North Pahroc and Seaman ranges, Nevada, *in* Wernicke, B. P., ed., Tertiary extensional tectonics near the latitude of Las Vegas: Geological Society of America Memoir 176, p. 181-193.

Taylor, W. J., and Bartley, J. M., 1992, Prevolcanic extensional breakaway fault and its geological implications for eastern Nevada and western Utah: Geological Association of America Bulletin, v. 104, p. 255-266.

Taylor, W. J., Bartley, J. M., Lux, D. L., and Axen, G. J., 1989, Timing of Tertiary extension in the Railroad Valley-Pioche Transect, Nevada: Constraints from $^{40}Ar/^{39}Ar$ ages of volcanic rocks: Journal of Geophysical Research, v. 94, p. 7757-7774.

Threet, R. L., 1952, Geology of the Red Hills area, Iron County, Utah: Ph.D. thesis, University of Washington, Seattle.

Threet, R. L., 1963, Structure of the Colorado Plateau margin near Cedar City, Utah, *in* Intermountain Association of Petroleum Geologists Guidebook to the Geology of Southwestern Utah, 12th Annual Field Conference, 1963: Salt Lake City, Utah Geological and Mineral Survey, p. 104-117.

Walker, J. D., and Bartley, J. M., 1991, New thrust fault correlations in the Beaver Lake Mountains, southern Utah, and regional correlation of Sevier thrusts: Geological Society of America Abstracts with Programs, v. 23, p. 107.

Wernicke, B., Walker, J. D., and Beaufait, M. S., 1985, Structural discordance between Neogene detachments and frontal Sevier thrusts, central Mormon Mountains, southern Nevada: Tectonics, v. 4, p. 213-246.

Wernicke, B., Axen, G. J., and Snow, J. K., 1988, Basin and Range extensional tectonics at the latitude of Las Vegas, Nevada: Geological Society Of America Bulletin, v. 100, p. 1738-1757.

Williams, P. L. 1967, Stratigraphy and petrography of the Quichapa Group, southwestern Utah and southeastern Nevada: Seattle, University of Washington Ph.D. thesis, 182 p.

CHAPTER 2

Stratigraphic and lithologic data from the Claron Formation in southwestern Utah

ABSTRACT

The Claron Formation is exposed in both the High Plateaus, Utah and in the Basin and Range Province in Utah and Nevada. Stratigraphic sections, clast counts, and point counts from the Claron Formation in the Basin and Range province and other units of similar age indicate vertical and lateral variations in rock type and in provenance. It is suggested that the younger part of the formation containing tuffs or sandstones with >10% volcanic fragments be called the Dodge Spring member.

INTRODUCTION

The Claron Formation has been recognized as a distinct and mappable unit for more than a century (Dutton, 1880; Leith and Harder, 1908). It was mapped in areas of the Basin and Range Province from the Clover Mountains, Nevada (near Cherokee mine), across southwestern Utah, and east to the Colorado Plateau (figure 10) (e.g., Cook, 1957; Blank, 1959; Threet, 1963; Mackin and Rowley, 1976; Hintze, 1986). It also is exposed in the High Plateaus region of Utah.

This data set was obtained mostly from the Basin and Range Province. Distinctly less mud was found in the Claron Formation in this area than was reported on the High Plateaus (cf. Bowers, 1972; Goldstrand, 1990). This difference is probably due to variation in depositional environment from west to east.

The formation is Paleocene to Oligocene in age (Rowley and others, 1979; Goldstrand, 1990). The Oligocene age is based on the intercalation of Oligocene tuffs such as the Wah Wah Springs and Isom Formations with Claron beds. The Oligocene beds compose more of the sections in the northern and western parts of the study area than elsewhere (figure 10; chapter 1).

Although the locations and general lithology of the formation are known, detailed information about the regional lithologic variations is scarce. Such information has many applications: for formation recognition, study of depositional environments, and study of the depositional basin. This survey of the Claron Formation in the Basin and Range Province (figure 10) resulted in the lithologic, petrographic, stratigraphic, and clast count data at the end of this chapter. This data set provides a regional picture of the internal stratigraphy as well as of the upper and lower contacts of the Claron. Sedimentological and paleontological evidence suggests that these rocks were deposited in lakes and streams.

LITHOLOGY AND SEDIMENTARY STRUCTURES

In general, the formation consists of freshwater and fluvial sandstone, limestone, conglomeratic sandstone, conglomerate, and shale. The conglomeratic units are matrix- or clast-supported with many near the borderline (see clast counts in columns section). The conglomerates usually have a sandstone matrix. A few are micrite matrix-supported. Most of these beds are located in a limestone-rich part of a section.

In general, the clasts are sandstone, quartzite, carbonate ±chert±quartz. The clast ratios are variable throughout the formation with no systematic vertical or geographic variation. An exception to this is the basal or near-basal conglomerates which may contain a high proportion of the formation under the basal unconformity.

GEOLOGIC RELATIONSHIPS OF UPPER AND LOWER CONTACTS

The attitudes of the rocks above and below the upper contact are essentially parallel. However, the upper contact is slightly complicated because the upper Claron Formation intertongues with tuffs of the Wah Wah Springs and Isom Formations which were erupted into the basin.

It is proposed to informally call the part of the Claron formation containing these tuffs or sedimentary horizons derived from them the Dodge Spring member of the Claron Formation. The name is derived from Dodge Spring, Utah and the Dodge Spring 3 section is a type section of the member. It contains a biotite-rich volcaniclastic sandstone

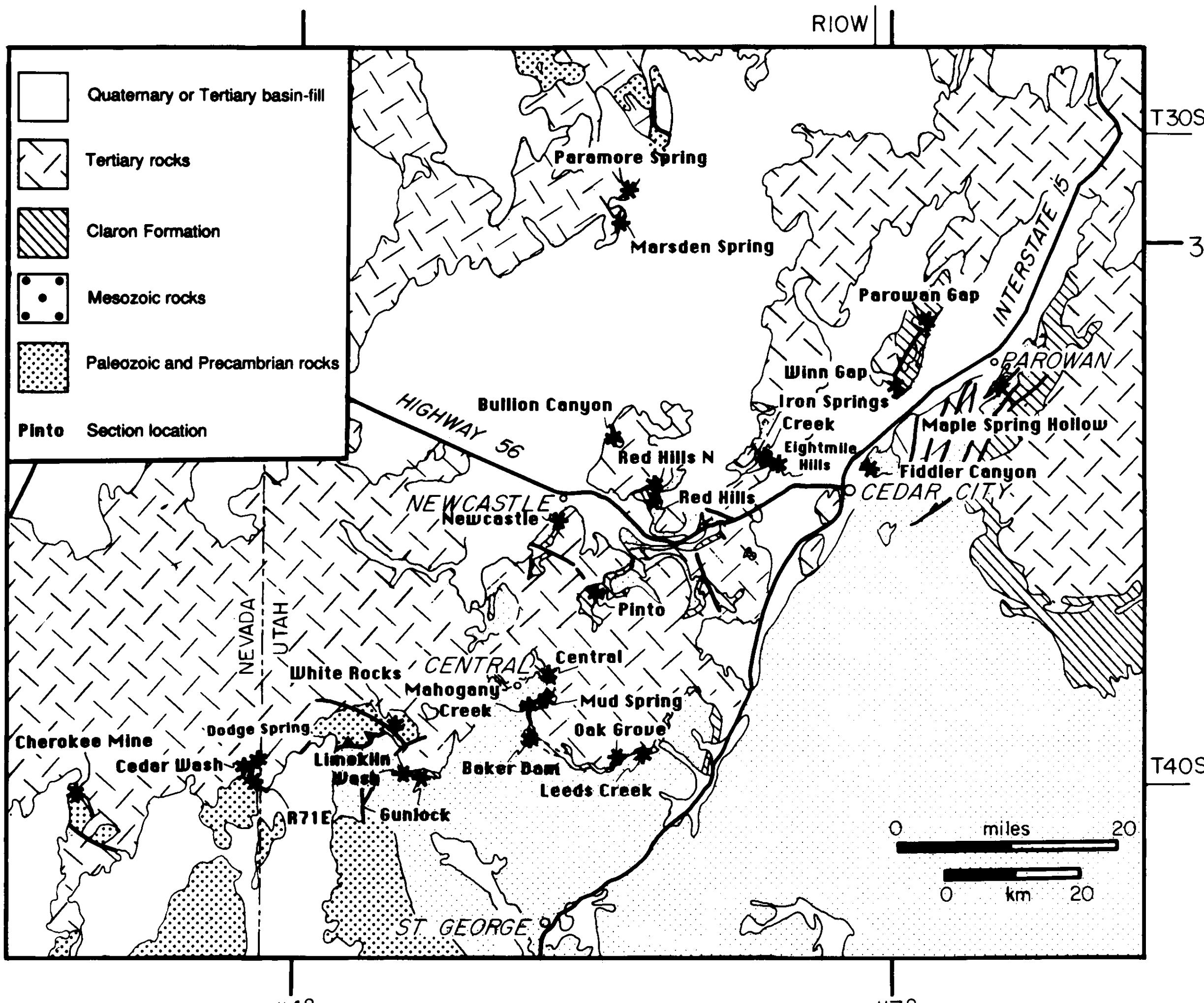


Figure 10. *Locations of stratigraphic columns in chapter 2.*

which defines the base of the member. This sandstone or a bed equivalent to the Wah Wah Springs Formation lies at the base of the member. The Dodge Spring member is equivalent to member E of Mackin and Rowley (1976).

The lower contact of the Claron Formation is a regional angular unconformity and major bounding surface. The angle across the unconformity varies between 0°and 50°.

SYNTHESIS OF DATA

New detailed stratigraphic columns, petrographic data, and clast counts are located at the end of this report. These data provide insight on the basal unconformity, upper contact, internal stratigraphy, and depositional environments of the Claron Formation.

Some generalizations were made to allow presentation of the sections at a reasonable scale. Most notably bedding thicknesses within units could not always be accurately represented on the columns.

ACKNOWLEDGMENTS

The Utah Geological Survey provided the funding for this study. I thank: L. F. Hintze for helpful conversations, a field trip to important localities, and providing unpublished maps; R. E. Anderson for providing an unpublished map showing important sections of the Claron Formation and helpful conversations in the planning stages of this project; M. A. Shubat for suggesting good localities for measuring sections; and G. D. Olson for field and laboratory assistance.

REFERENCES

Blank, H. R., 1959, Geology of the Bull Valley district, Washington County, Utah: University of Washington, Seattle, unpublished Ph.D. thesis, 177 p.

Bowers, W. E., 1972, The Canaan Peak, Pine Hollow, and Wasatch Formations in the Table Cliff region, Garfield County, Utah: U.S. Geological Survey Bulletin 1331-B, 39 p.

Cook, E. F., 1957, Geology of the Pine Valley Mountains, Utah: Utah Geological and Mineral Survey Bulletin 58, 111 p.

Dutton, C. E., 1880, Report on the geology of the high plateaus of Utah: U. S. Geographical and Geological Survey, Rocky Mountain Region.

Goldstrand, P. M., 1990, Stratigraphy and ages of the basal Claron, Pine Hollow, Canaan Peak, and Grapevine Wash Formations, southwest Utah: Utah Geological and Mineral Survey Open-File Report, 188 p.

Hintze, L. F., 1986, Stratigraphy and structure of the Beaver Dam Mountains, southwestern Utah: Utah Geological Association Publication 15, p. 1-36.

Leith, C. K., and Harder, E. C., 1908, The Iron Springs district, southern Utah: U. S. Geological Survey Bulletin 316-E, p. 359-375.

Mackin, J. H., and Rowley, P. D., 1976, Geologic map of the Three Peaks Quadrangle, Iron County, Utah: U. S. Geological Survey Quadrangle Map GQ-1296.

Rowley, P.D., Steven, T. A., Anderson, J. J., and Cunningham, C. G., 1979, Cenozoic stratigraphic and structural framework of southwestern Utah: U.S. Geological Survey Professional Paper 1149, 22 p.

Taylor, W. J., 1991, Internal stratigraphy, age, and tectonic implications of he Claron Formation in southwestern Utah: Geological Society of America Abstracts with programs, v. 23, no. 2, p. A103.

Threet, R. L., 1963, Structure of the Colorado Plateau margin near Cedar City, Utah, *in* Heylmun, E.B., editor, Guidebook to the geology of southwestern Utah, 12th Annual Field Conference: Salt Lake City, Intermountain Association of Petroleum Geologists, p. 104-117.

Explantion of symbols used on stratigraphic columns

- pisolites or oncoids
- plant fossil or replaced plant fossil
- gastropod fossil
- fossil shell or shell fragment
- root casts
- burrows
- trough cross beds
- hummocky cross beds
- planar cross beds or generic cross beds
- cumulate stromatolites
- clasts

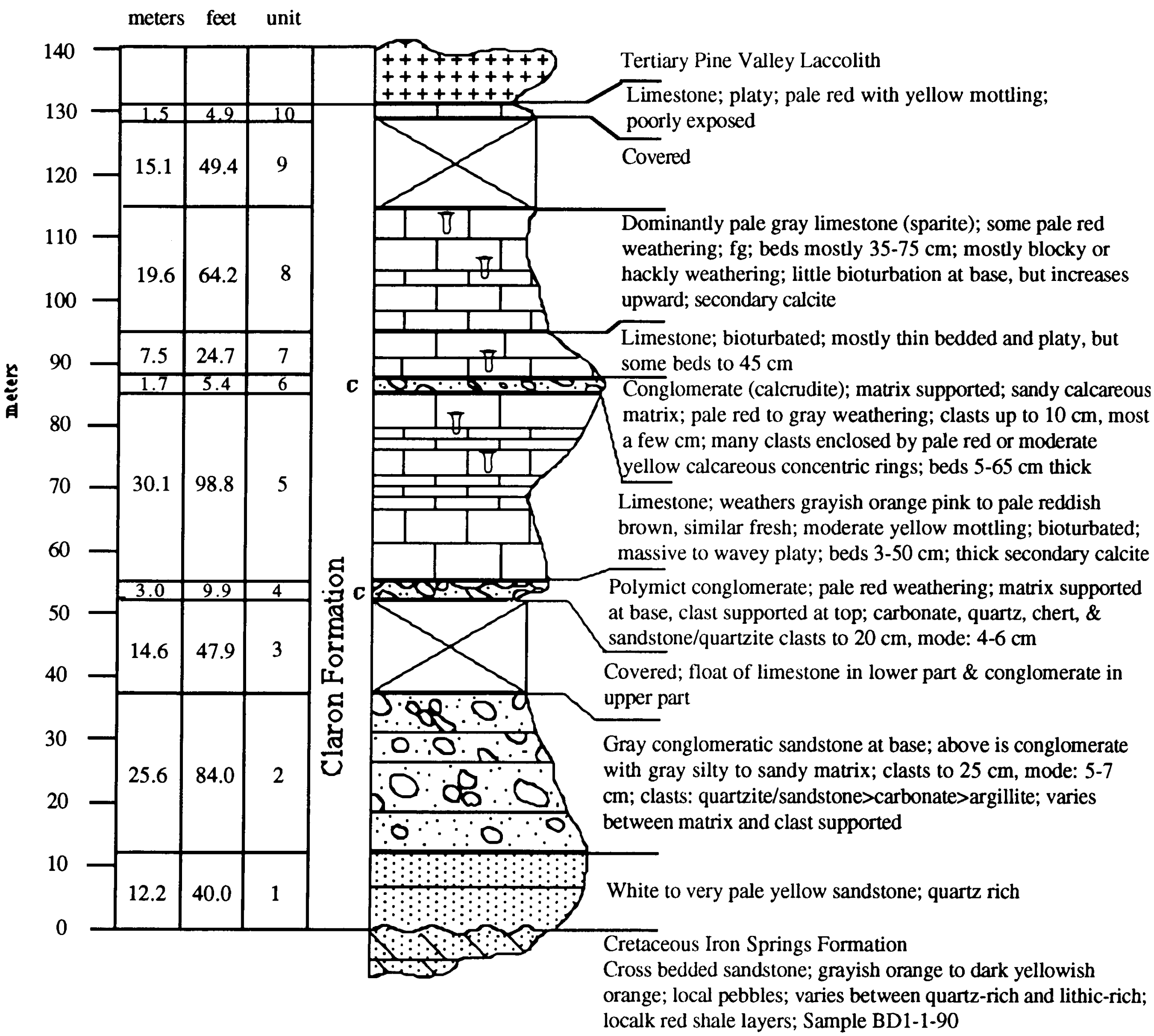
c	clast count site
vcg	very coarse grained
cg	coarse grained
mg	medium grained
fg	fine grained

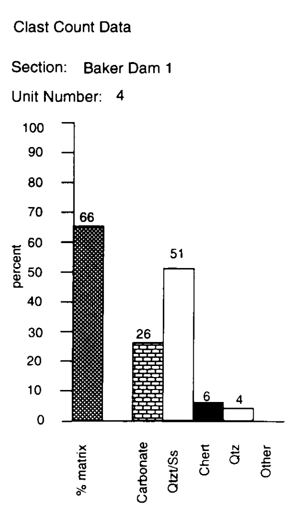
- Limestone
- Limestone with floating quartz sand grains
- matrix supported conglomerate
- clast supported conglomerate
- shale
- sandstone
- volcanic rocks
- igneous rocks
- covered interval

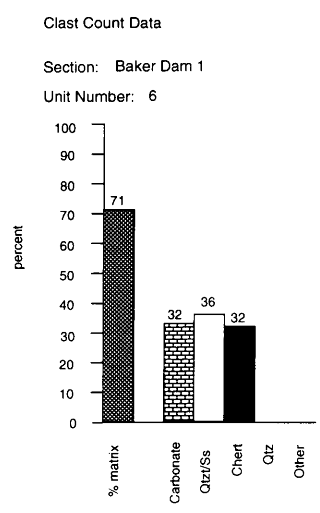
These lithologic symbols are combined to make symbols for rocks of intermediate compositions

Section: Baker Dam 1

Located in SW 1/4, sec. 13, T39S, R16W on the west side of the Pine Valley Mountains

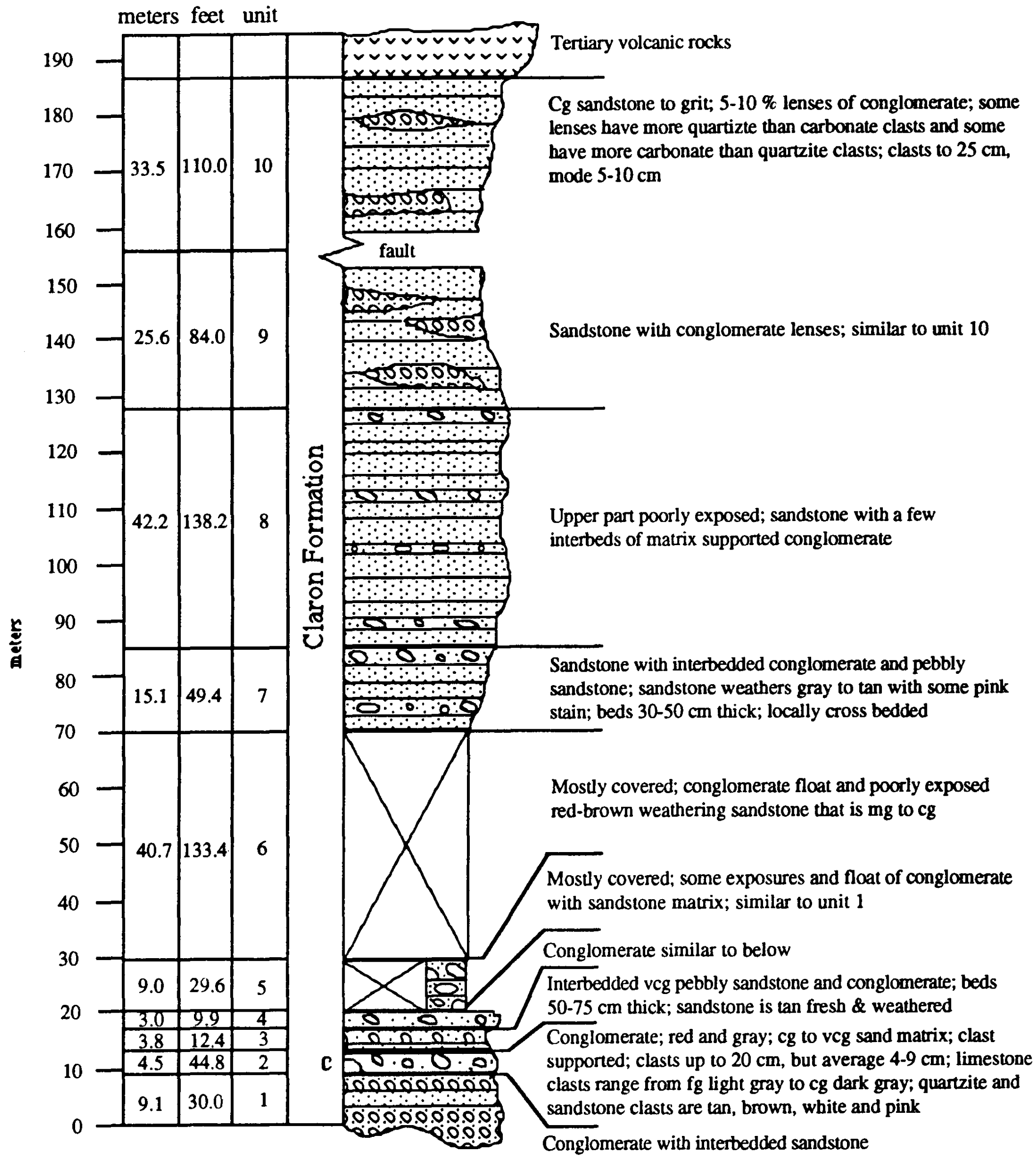






Section: Bullion Canyon

Silver Peak 7.5' Quadrangle, N1/2, NW1/4, SEC. 36, S1/2, SW1/4, SEC. 25, T35S, R15W



COMPOSITION DATA

Sample Number:	BC-1-89
Section:	Bullion Canyon
Unit:	7
Formation:	Claron

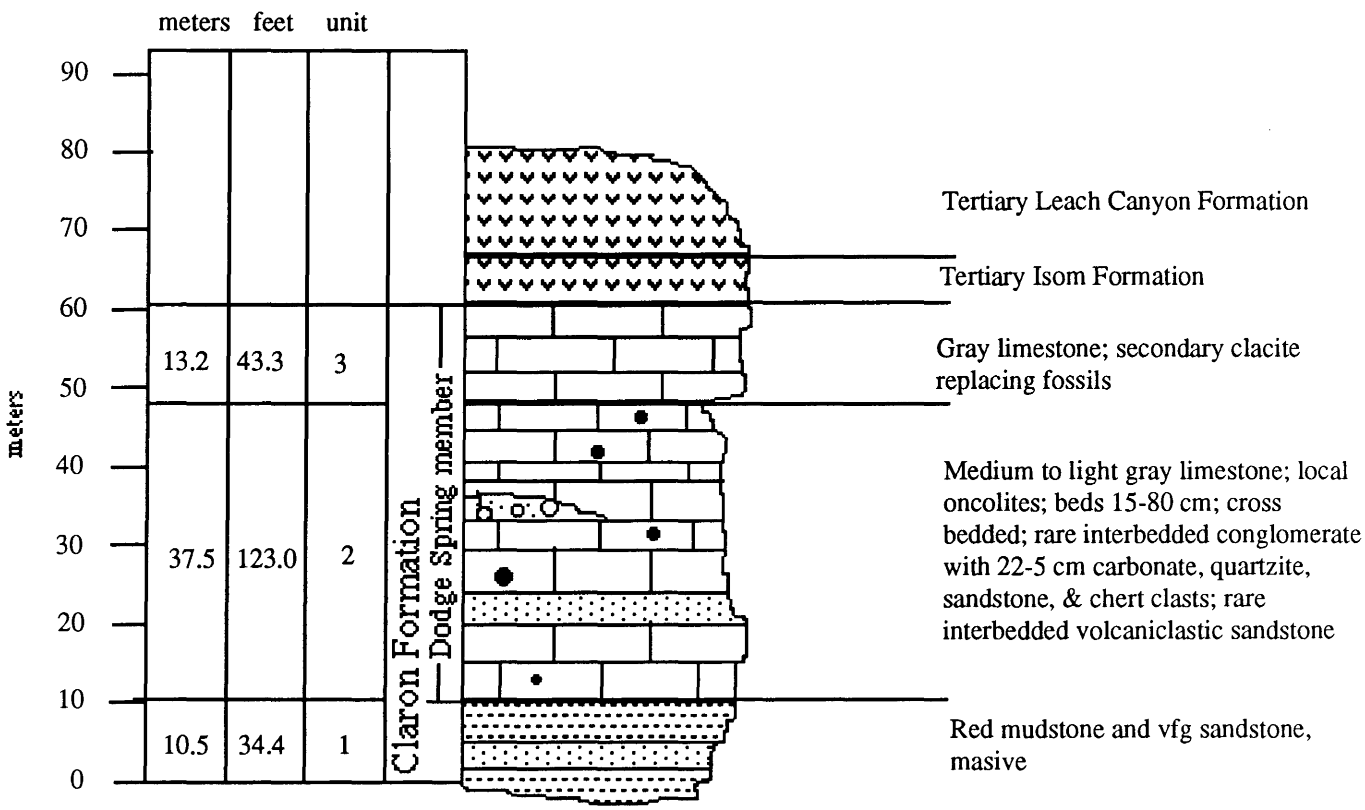
Grain Type	%
Monocrystalline quartz	80.0
Carbonate rock fragments	13.3
Pores	5.0
Chert	1.7
Zircon	trace
Polycrystalline quartz	trace
Total	100.0

Comments on thin section:

An accumulation of fine grains in one area.

Section: Cedar Wash

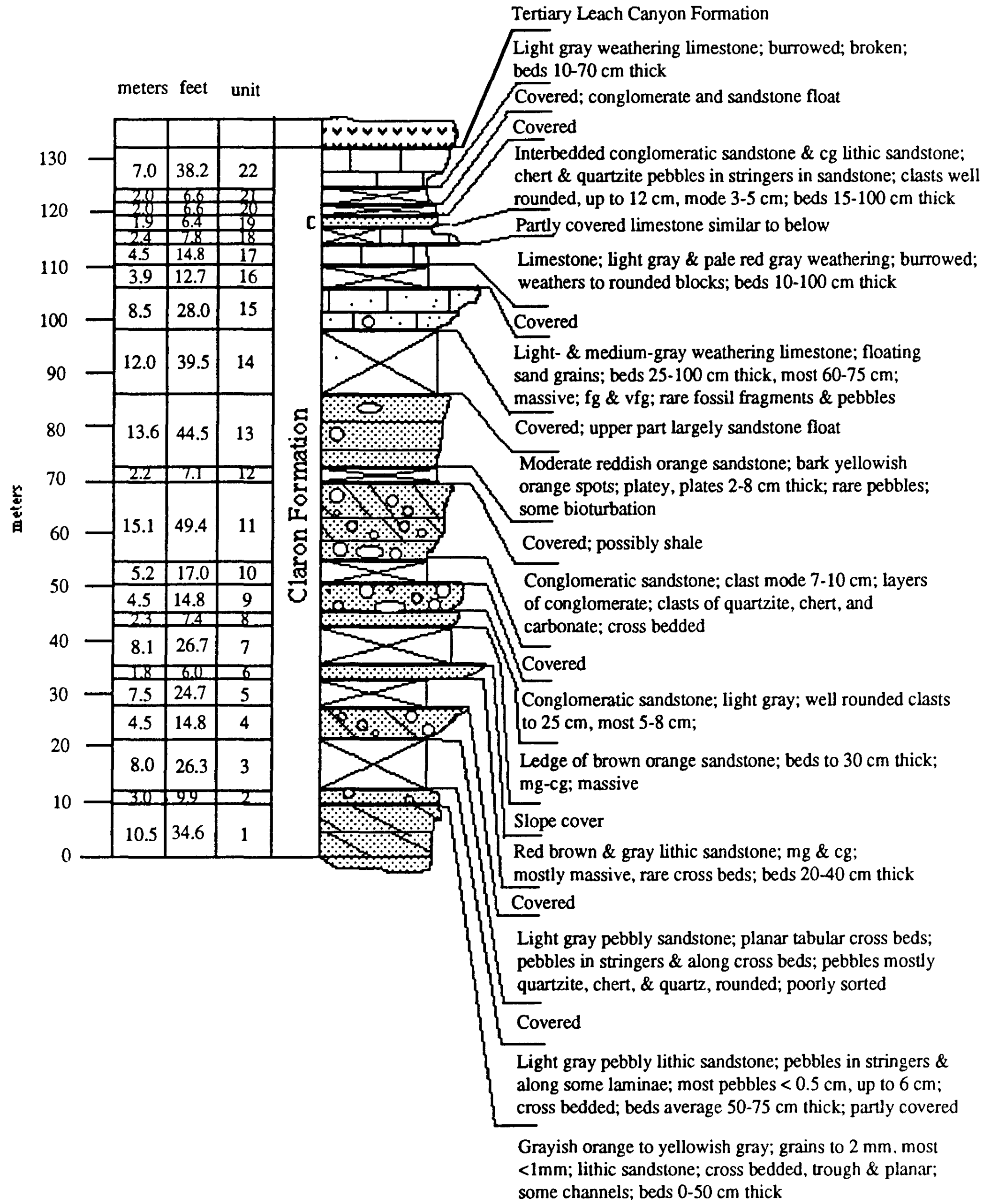
Dodge Spring 7.5' Quadrangle, SW1/4, SE1/4, sec. 18, T7S, R71E

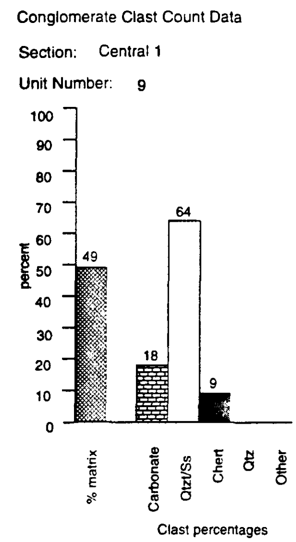


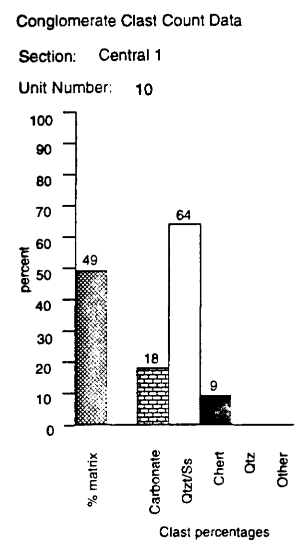
Poor exposure and local structure resulted in approximate thicknesses

Section: Central 1

Located ~2 miles east of the town of Central, just north of highway; Central East 7.5' Quadrangle, N 1/2, sec. 6, T39S, R15W (unserveyed), and S1/2, sec. 31, T38S, R15W







COMPOSITION DATA

Sample Number: C1-1-90
Section: Central 1
Unit: 5
Formation: Claron

Grain Type	%
Carbonate spar	46.5
Peloid/micrite grains	21.3
Chert	16.2
Monocrystalline quartz	5.3
Volcanic rock fragments	2.4
Sandstone	1.97
Polycrystalline quartz	1.68
Matrix (micrite)	1.6
Crystalline carbonate rock fragments	1.4
Sutured quartz	1.0
Opaques	0.6
Total	99.95

Comments on thin section: Some chert contains grain ghosts.

COMPOSITION DATA

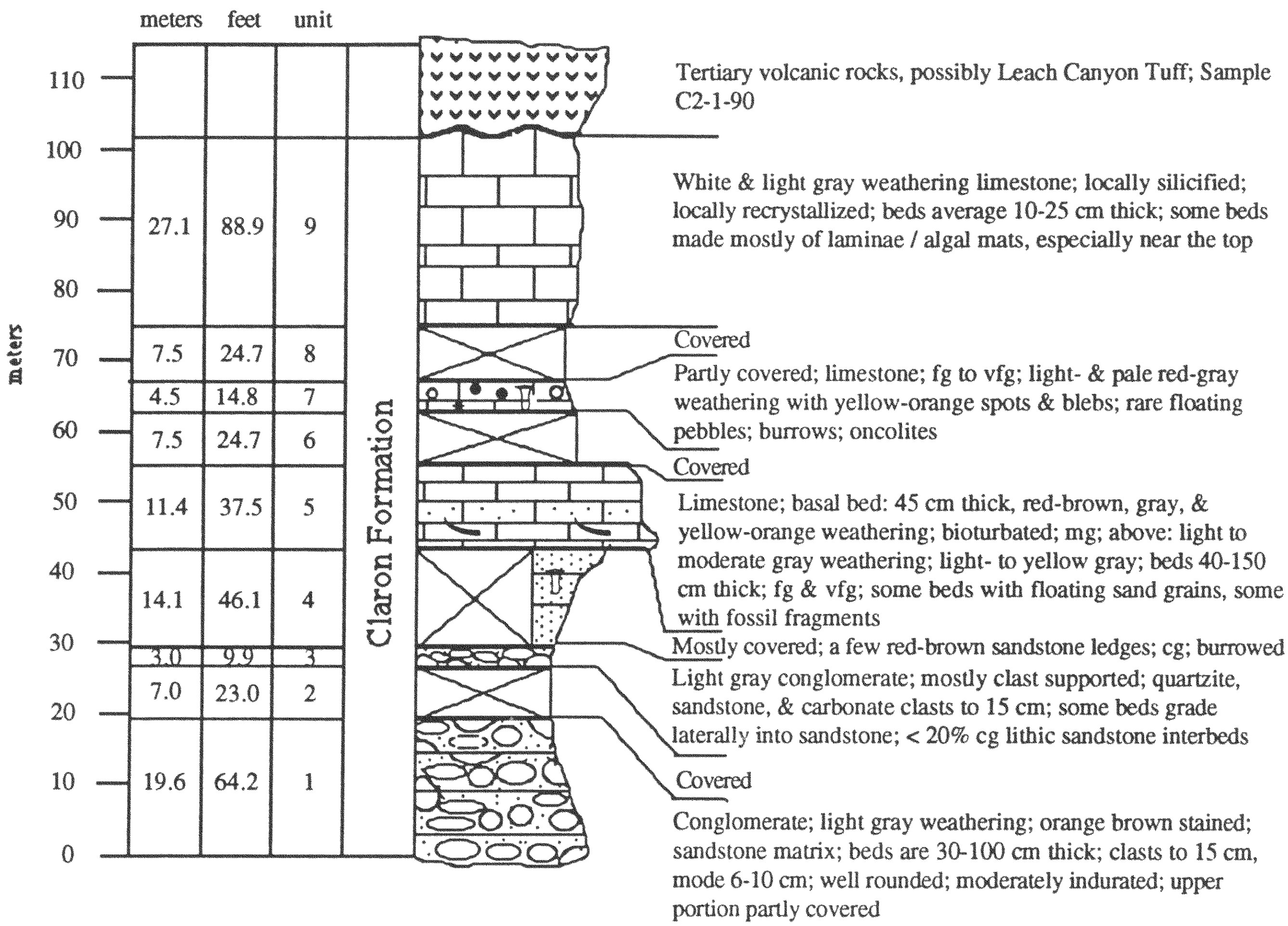
Sample Number: C1-2-90a
Section: Central 1
Unit: 14
Formaion: Claron

Grain Type	%
Micrite	51.0
Monocrystalline quartz	25.5
Spar	9.8
Carbonate rock fragments	5.2
Opaques (hematite)	2.4
Undulose quartz	2.0
Polycrystalline quartz	2.0
Chert	1.4
Sandstone/quartzite rock fragments	0.2
Total	99.5

Comments on thin section: Hematite stained; bioturbated; a few quartz grains with one quartz overgrowth.

Section: Central 2

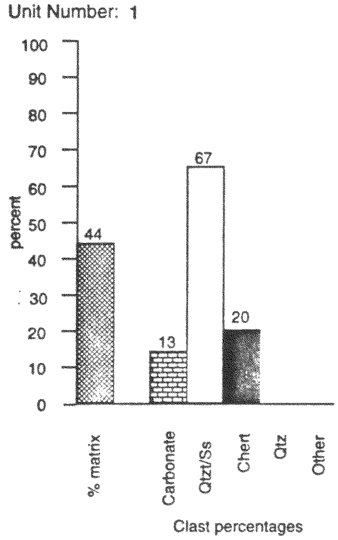
Located just east of the town of Central and north of highway on Central East 7.5' Quadrangle, NE 1/4, SW 1/4, sec. 31, T38S, R15W



Clast Count Data

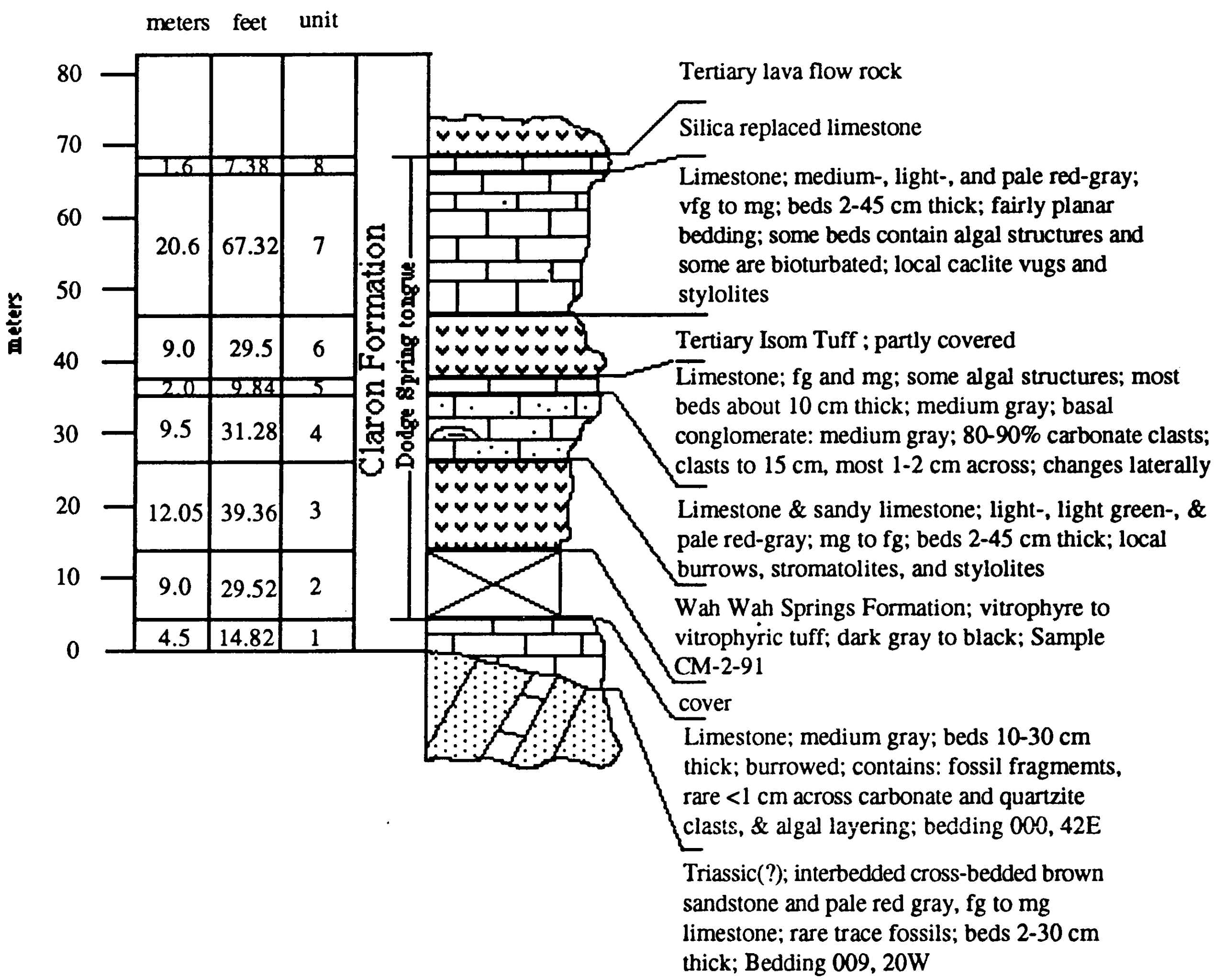
Section: Central 2

Unit Number: 1



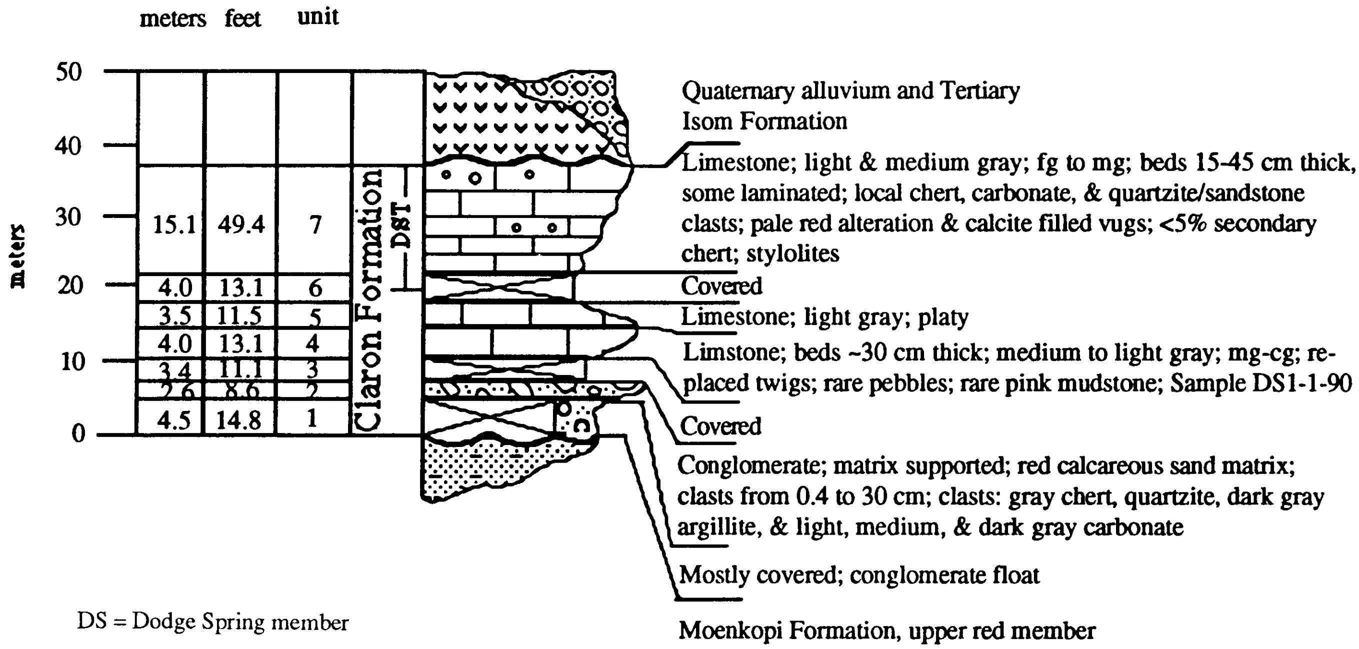
Section: Cherokee Mine

Located on Clover Mountain 1:100,000 Quadrangle on the southern side of the Clover Mountains in Nevada



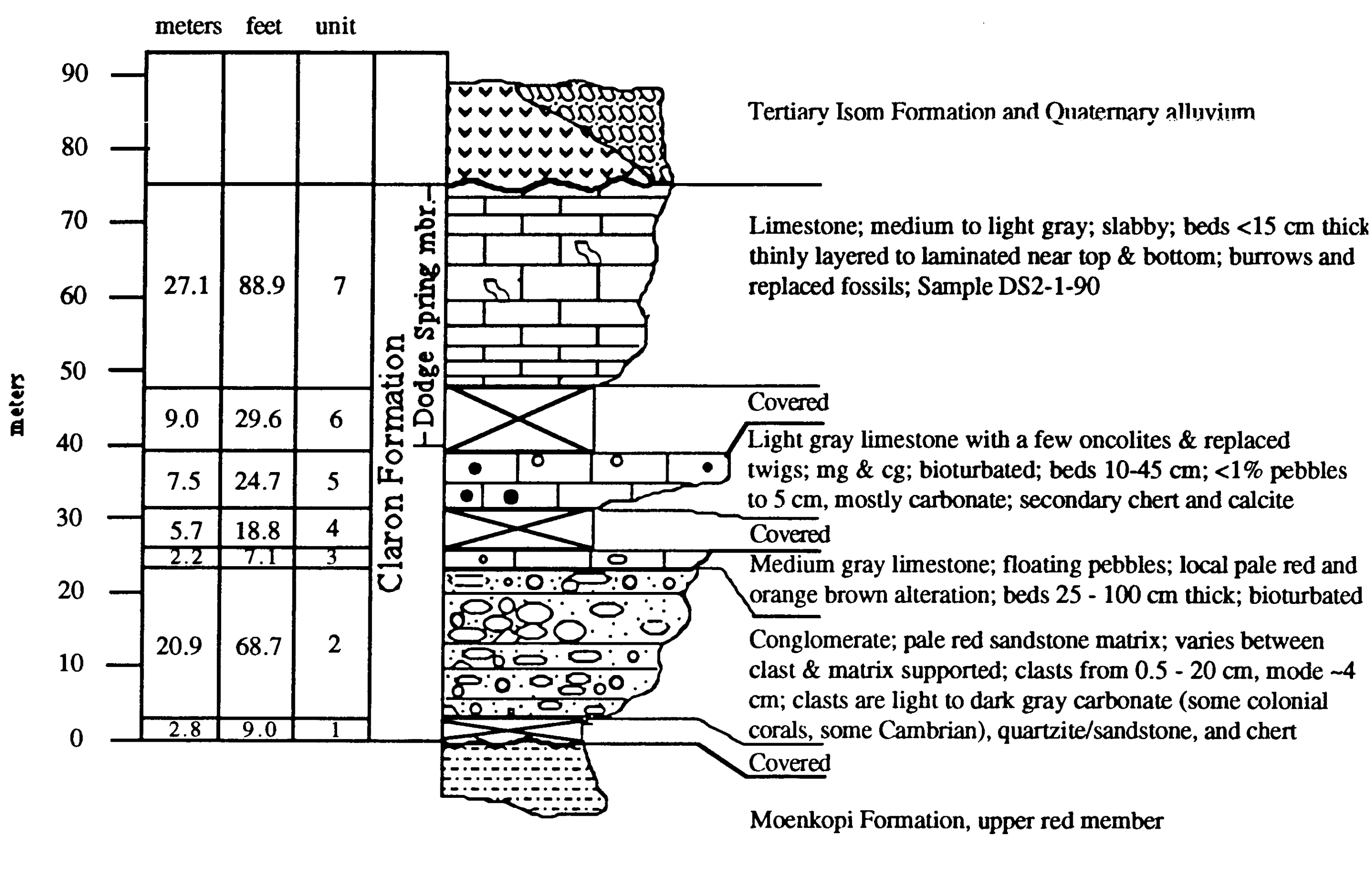
Section: Dodge Spring 1

Located in eastern Nevada; Dodge Spring 7.5' Quadrangle, SE 1/4, SE 1/4, sec. 30, T7S, R71E



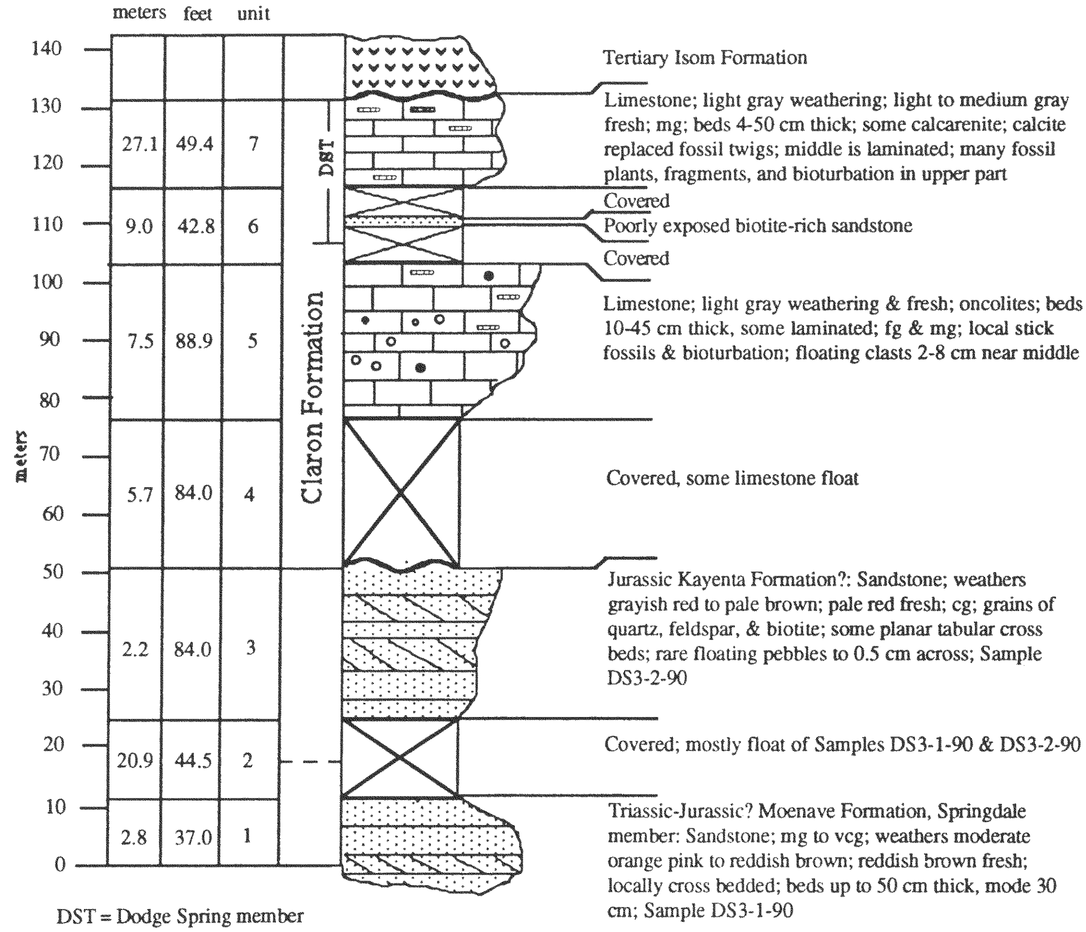
Section: Dodge Spring 2

Located in eastern Nevada, Dodge Spring 7.5' quadrangle, NE1/4, NE1/4, sec. 33, T7S, R71W



Section: Dodge Spring 3

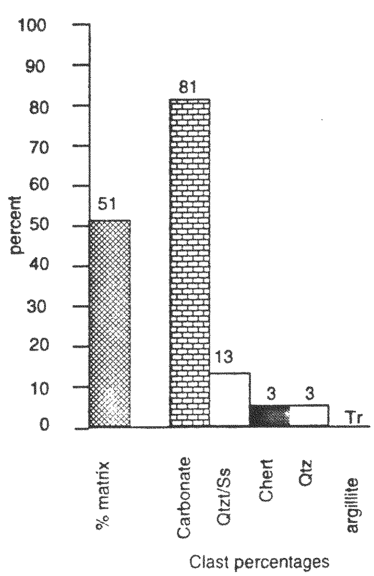
Located in eastern Nevada, Dodge Spring 7.5" Quadrangle, NW 1/4, SW 1/4, sec. 28, T7S, R71W



Clast Count Data

Section: Dodge Spring Quad. 1

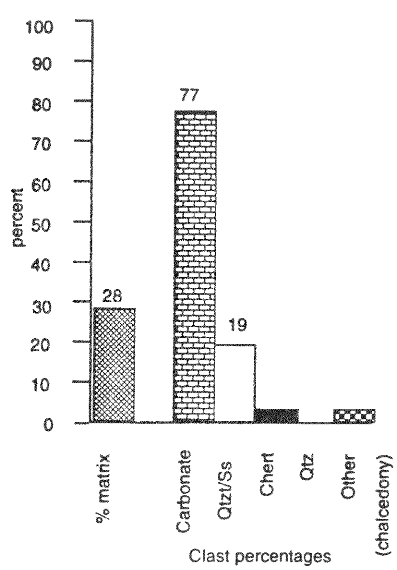
Unit Number: 1



Clast Count Data

Section: Dodge Spring Quad. 2

Unit Number: 2



COMPOSITION DATA

Sample Number:	DS3-2-90
Section:	Dodge Spring
Unit:	3
Formation:	Claron

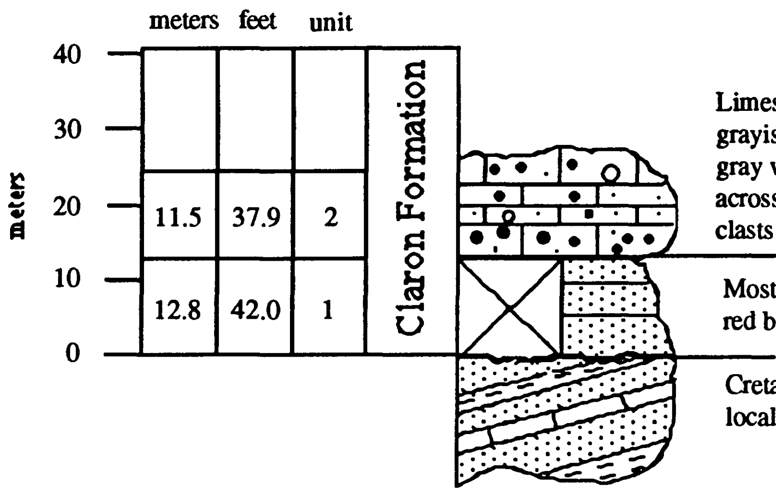
Grain Type	%
Monocrystalline quartz	26.4
Glass/volcanic rock fragments	19.9
Plagioclase	17.5
Mudstone (micrite)	6.3
Polycrystalline quartz	6.0
Opaques	5.2
Intrusive rock fragments	5.2
Undulose quartz	4.5
Pores	2.5
Sandstone	2.2
Chert	1.6
Matrix	1.6
Chalcedony	1.3
Total	100.2

Comments on thin section

A few quartz grains with quartz overgrowths.

Section: Fiddler Canyon 1

Located on Cedar City 7.5' Quadrangle, north northeast of Cedar City, NW1/4 section 36, T35S, R11W



Limestone; fg; weathers yellowish gray, pale yellow brown, grayish red, & pale red; similar colors fresh; dusky yellow & gray weathering oncolites up to 30% of bed; oncolites to 5 cm across, mode 1-2 cm; floating quartz sand grains; rare <5 cm clasts of sandstone, quartzite, & quartz; beds 30-100 cm thick

Mostly covered; poorly indurated fg sandstone that weathers red brown in dug pits

Cretaceous interbedded sandstone and shale; Sample FC1-1-90; local thin limestone

Compare this section with Fiddler Canyon 2 and note relief at base of Claron Formation

COMPOSITION DATA

Sample Number:	FC1-1-90
Section:	Fiddler Canyon 1
Unit:	1
Formation:	Claron

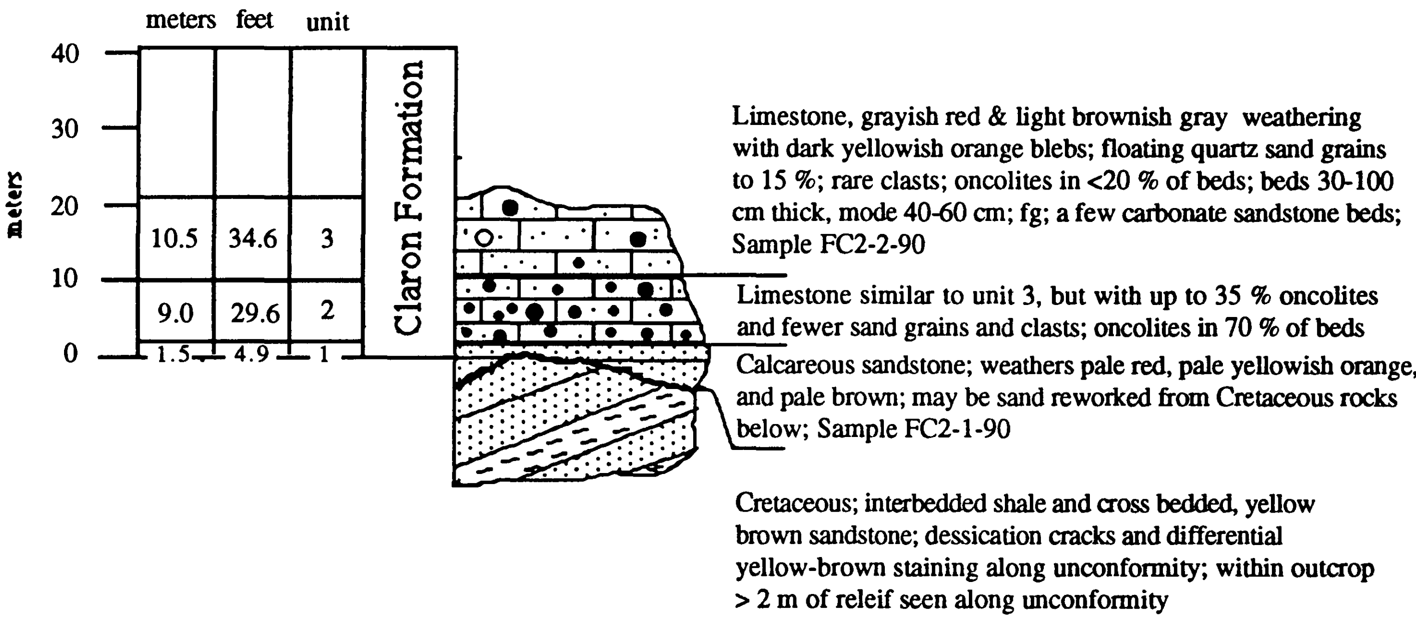
Grain Type	%
Monocrystalline quartz	44.2
Spar	25.4
Micrite	15.0
Sutured/polycrystalline quartz	4.4
Carbonate rock fragments	4.2
Chert	2.2
Undulose quartz	1.6
Volcanic rock fragments	1.4
Siltstone rock fragments	0.8
Sandstone/quartzite	0.6
Opaques	0.2
Chalcedony	trace
Total	100.0

Comments on thin section:

Some quartz grains with quartz overgrowths.

Section: Fiddler Canyon 2

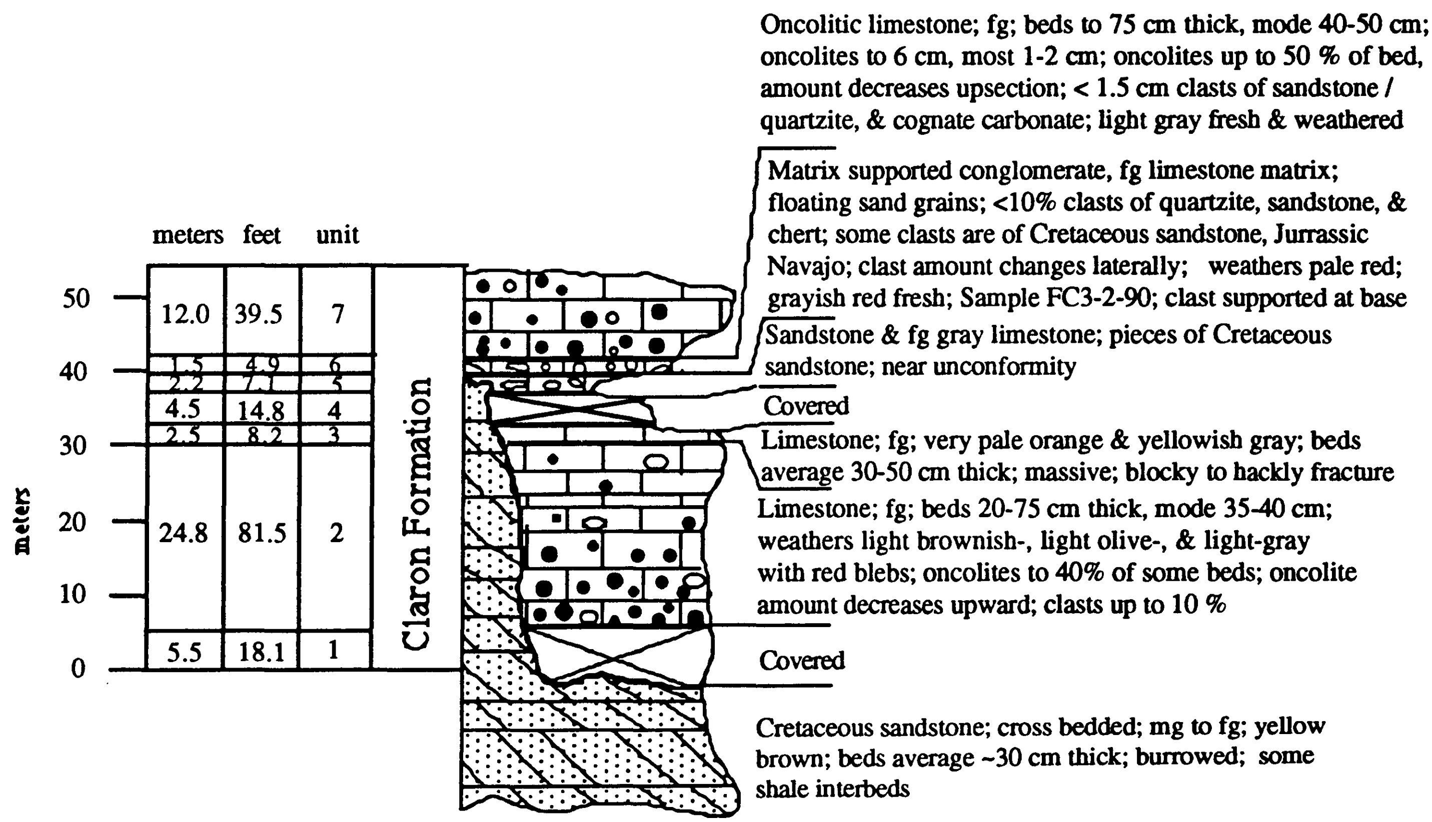
Located on Cedar City 7.5' Quadrangle, north northeast of Cedar City, NW1/4 section 36, T35S, R11W



Compare this section with Fiddler Canyon 1 and note relief at base of Claron Formation

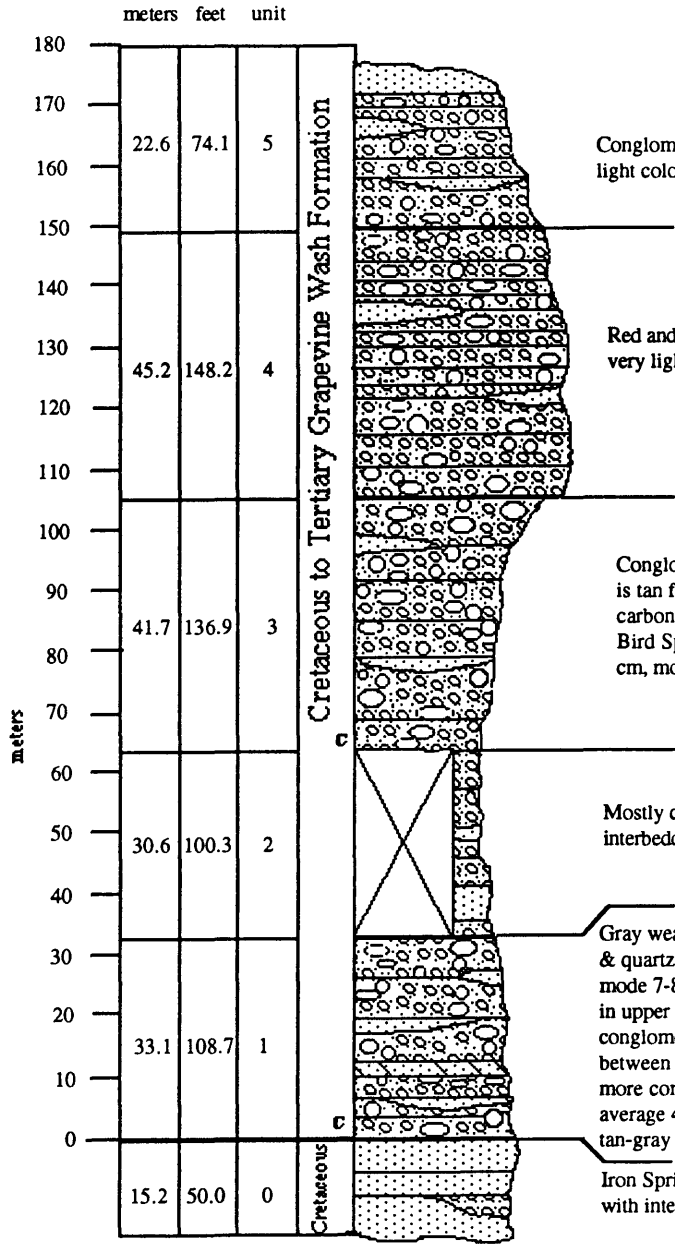
Section: Fiddler Canyon 3

Located north northeast of Cedar City, SE1/4 section 25, T35S, R11W



Section: Gunlock

Gunlock 7.5' Quadrangle, NW 1/4, NE 1/4, sec. 20, T40S, R17W



Conglomerate with clasts up to 61 cm across; interbedded light colored sandstone; Sample G1-2-89

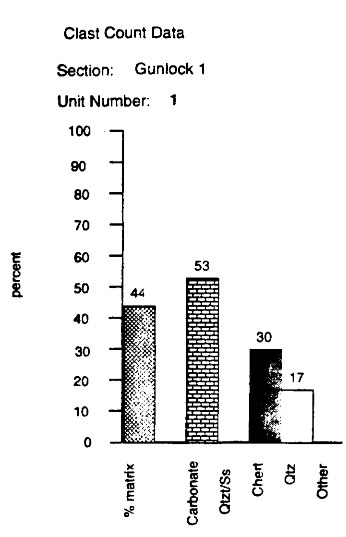
Red and gray weathering conglomerate with dark red and very light gray weathering sandstone lenses

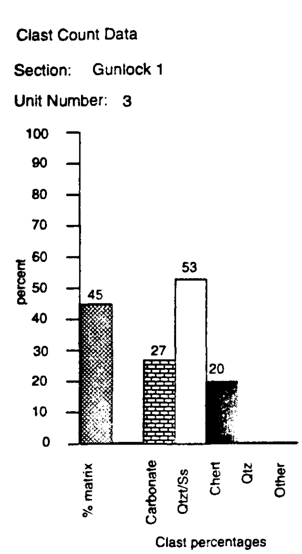
Conglomerate; red weathering; matrix supported; matrix is tan fresh, sand up to vcg; poorly sorted; clasts are carbonate, quartzite, and sandstone, with some of PM Bird Spring Fm. & some Mz sandstone; clasts up to 15 cm, mode 5-8 cm; interbedded lenses of sandstone

Mostly covered; lateral exposures and float suggest interbedded conglomerate and sandstone

Gray weathering conglomerate; clasts of chert, carbonate, & quartzite/sandstone; poorly sorted; clasts to 40 cm, mode 7-8 cm near base & 1.5-2 cm in some higher beds; in upper part & laterally are sandstone lenses; cross beds in conglomerate suggest bar forms; conglomerates vary between clast and matrix supported, but matrix supported more common; matrix is pink to gray cg sand to grit; beds average 40-80 cm thick; sandstone lenses weather gray, are tan-gray fresh; fg to cg, some are pebbly

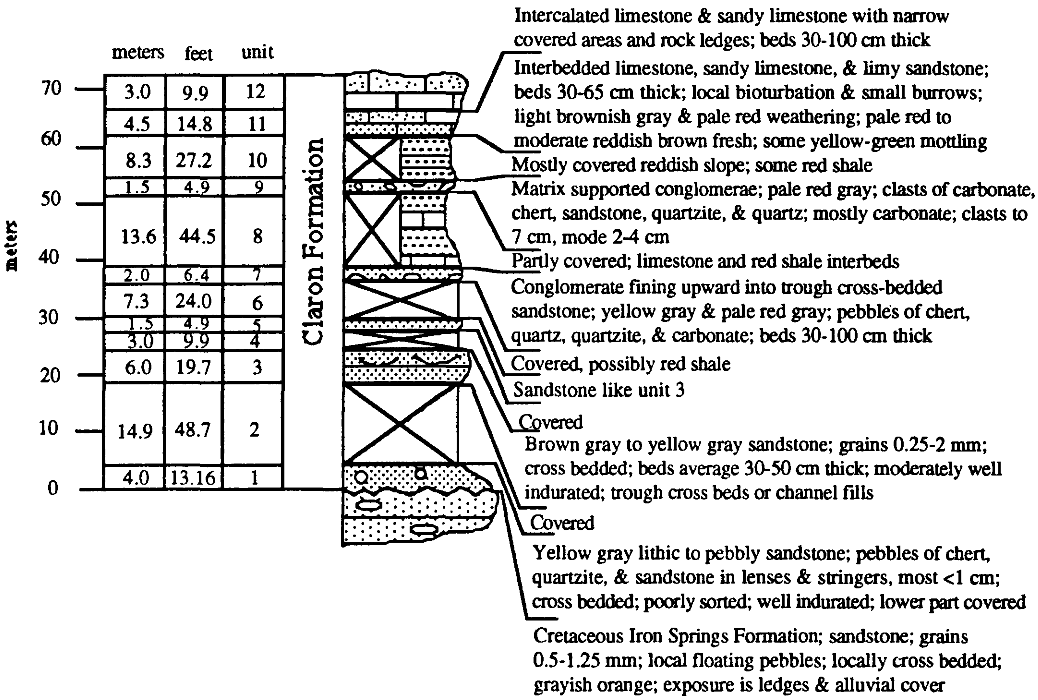
Iron Springs Formation; light colored sandstone beds with interbeds and lenses on conglomerate





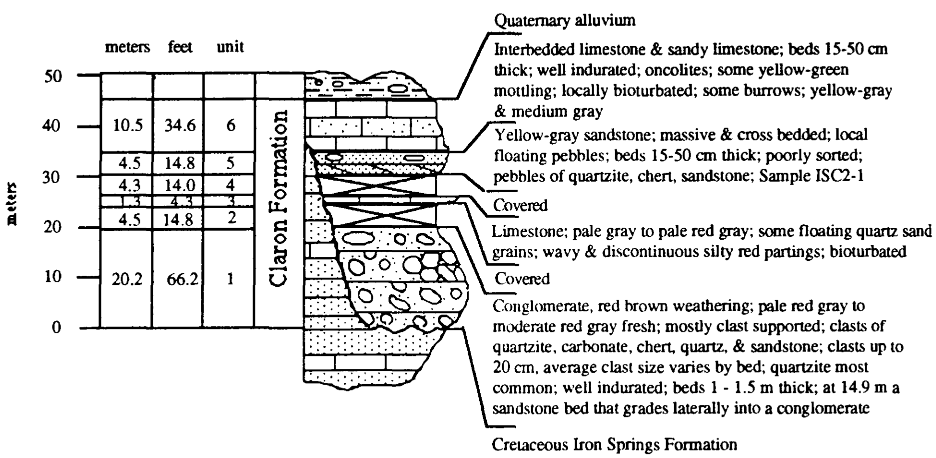
Section: Iron Springs Creek 1

Located near Iron Springs mining district, Cedar City 7.5' Quadrangle, NW 1/4, SE 1/4, sec. 28, T35S, R12W

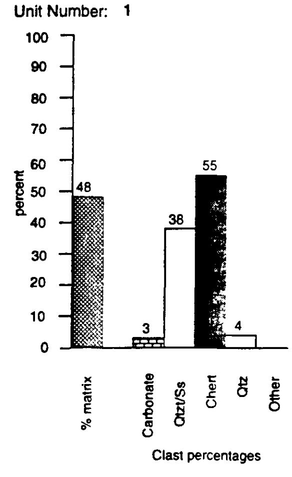


Section: Iron Springs Creek 2

Located near Iron Springs mining district, Cedar City 7.5' Quadrangle, NW 1/4, SW 1/4, sec. 28, T35S, R12W



Conglomerate Clast Count Data
Section: Iron Springs Creek 2
Unit Number: 1



COMPOSITION DATA

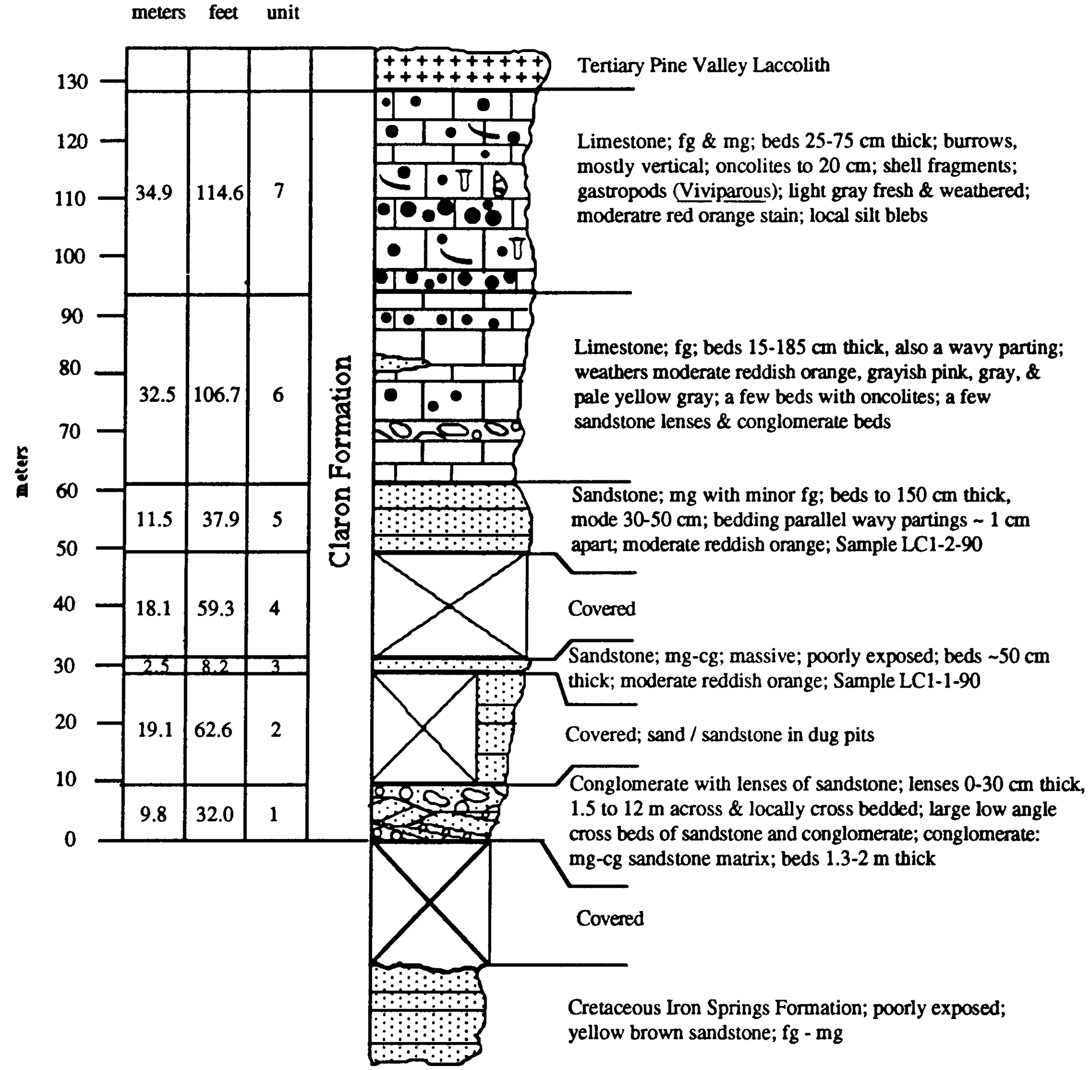
Sample Number: I S C2-1
Section: Iron Springs Creek
Unit: 5
Formation: Claron

Grain Type	%
Micrite	47.5
Monocrystalline quartz	27.05
Spar	9.2
Undulose quartz	7.4
Micrite grains	6.2
Polycrystalline/sutured quartz	1.4
Chert	1.2
Opaques	trace
Total	99.95

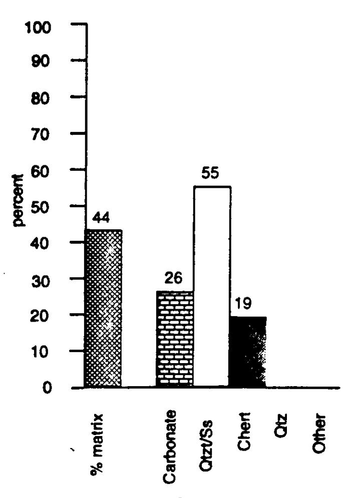
Comments on thin section:

Section: Leeds Creek

Located on east side of Pine Valley Mountains, west of town of Leeds, and near Oak Grove Campground, Signai Peak 7.5' Quadrangle, NE1/4, NW 1/4, sec. 9, T40S, R14W

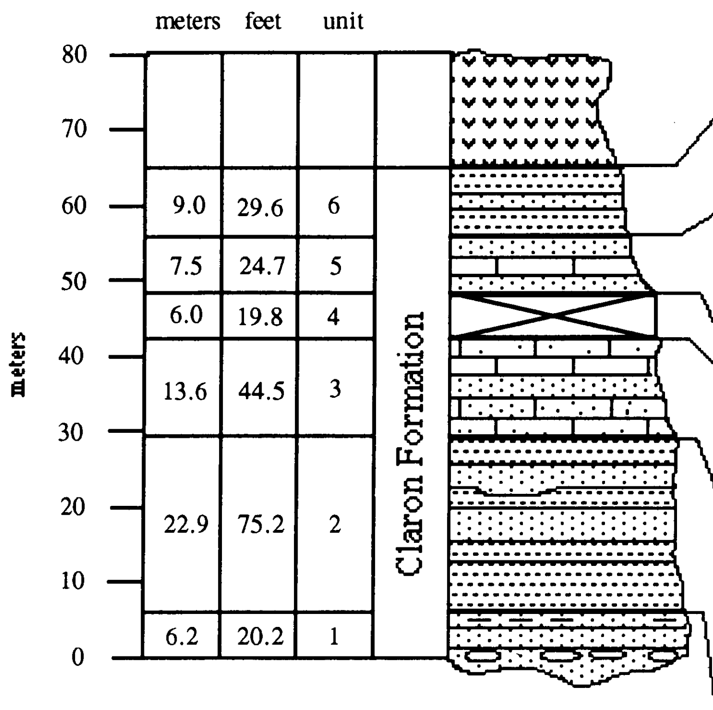


Clast Count Data
Section: Leeds Creek
Unit Number: 1



Section: Maple Spring Hollow 1

Located east of Parowan near west end of Parowan Canyon on Panguitch 1:100,000 sheet, in SE 1/4, SE 1/4, sec. 23, T34S, R9W



Tertiary volcanic rocks (mostly flow rock)

Float & isolated outcrops of mudstone (mostly claystone), sandy mudstone, & sandstone; mudstone > 80 %; light gray, moderate red orange to moderate orange pink; minor interbedded limestone

Very light gray to white, fg to vfg, blocky weathering limestone, beds 50-100 cm thick; interbedded with red-brown, mg-fg, calcareous sandstone, beds 15-25 cm thick & wavy; limestone becomes sandy laterally; sandstone ~ 3/5 of unit

Covered

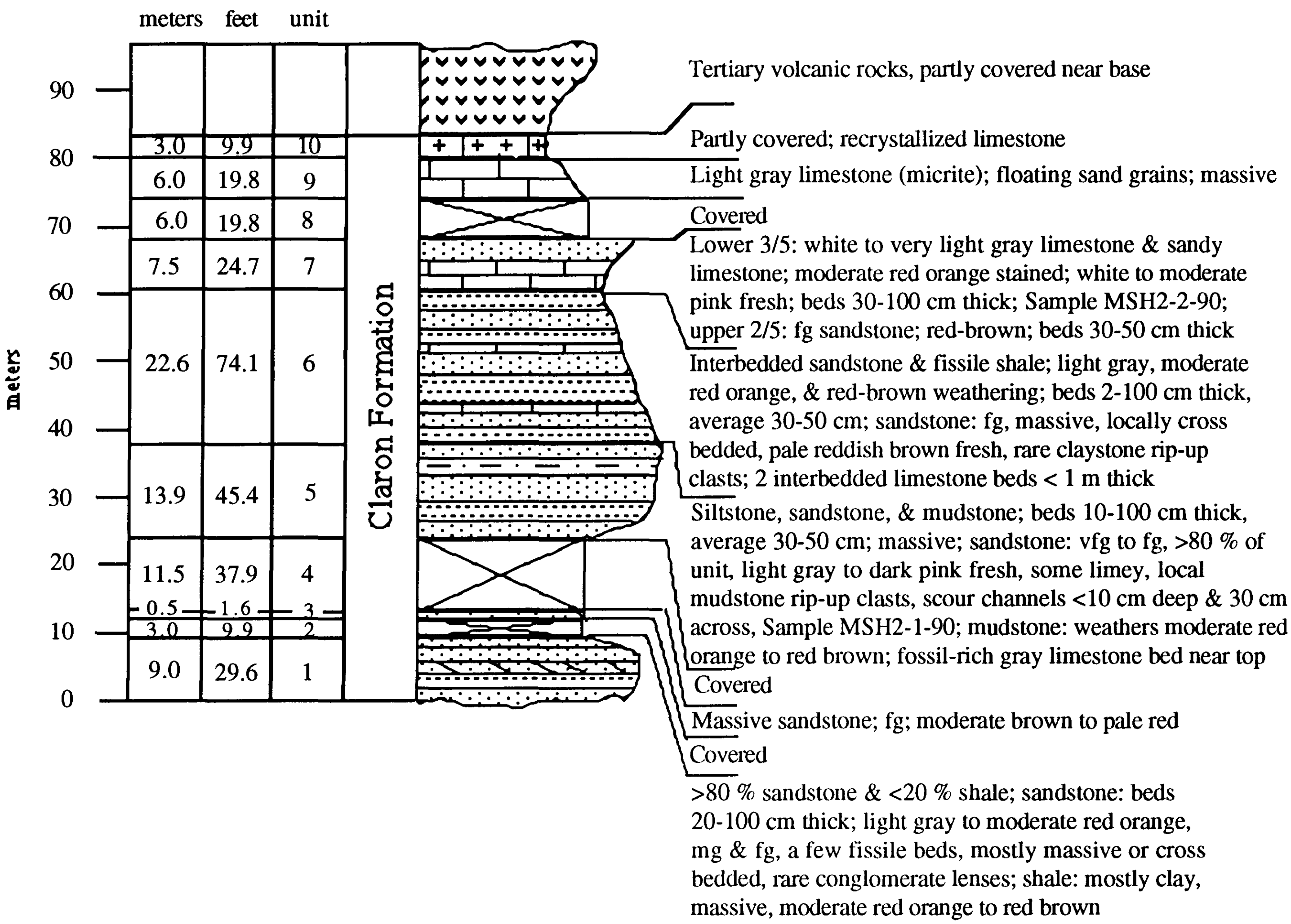
Interbedded calcareous sandstone, limestone, and sandy limestone; beds 10-100 cm thick; light gray, moderate red brown, & dark red brown; limestone is most of unit; at base is vfg limestone that is sandy near its base; Sample MSH1-3-90

Interbedded shale & sandstone; shale: ~75 % of unit, fissile, mostly clay, dark brown purple red to moderate orange red, beds 2-100 cm thick; sandstone: vfg to mg, moderate red orange & light gray, massive with channels < 1 m deep & < 2 m wide, channels or scours are cut into underlying bed, beds 25-75 cm thick, Sample MSH1-2-90; shale may stain upper part of underlying sandstone; stained zones are salty

Sandstone; fg & vfg; moderate reddish orange & light gray fresh and weathered; beds 50-200 cm thick; tops of some beds are conglomeratic sandstone with mostly quartzite / sandstone & chert clasts, a few carbonate clasts; sandstone is calcareous & massive; rare red shale interbeds; top is white to very light gray clay-rich santone; Sample MSH1-1-90

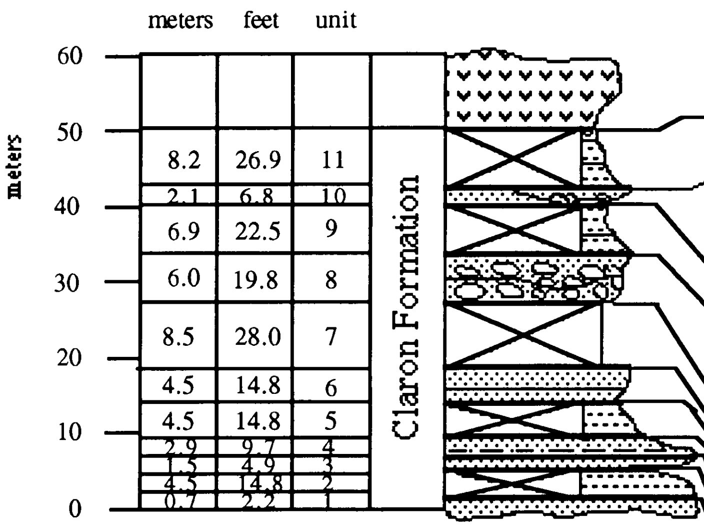
Section: Maple Spring Hollow 2

Located east of Parowan on northwest side of Maple Spring Hollow, on Panguitch 1:100,000 Quadrangle, in SE 1/4, SE 1/4, sec. 23, T34S, R9W



Section: Mud Spring 1

Located on Central East 7.5' Quadrangle and southeast of the town of Central, NW 1/4, NW 1/4, sec. 13, T39S, R16W



Tertiary volcanic rocks, possibly Leach Canyon Tuff; Sample MS1-3-90

Covered; red shale in dug pits; shale has some silt and sand grains; float of rounded pebbles & cobbles in top 1 m

Interbedded cg sandstone, pebbly sandstone, & conglomerate; light gray; channels; beds 0-50 cm thick, some fine upward; clasts up to 15 cm of quartzite, chert, & carbonate

Covered; sandy shale in dug pits

Light gray to orange brown conglomerate; some channels <1 m deep & up to a few m across; beds <1 m thick; some beds fine upward; <2 % interbedded sandstone; matrix & clast supported

Covered

Moderate reddish orange sandstone with dark yellowish orange spots; well indurated; beds 10-30 cm thick and massive; Sample MS1-2-90

Covered; red shaly sandstone or sandy shale in dug pits

Lower part: red massive shale; upper part: pale red gray sandstone; grains 0.25-2 mm; rare grains to 3 mm; massive; some bioturbation

Light gray sandstone; grains 0.25-2 mm; lithic; massive

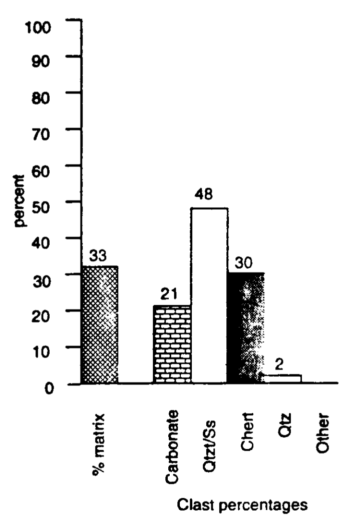
Covered; red shale in dug pits

Sandstone; calcite cemented; red brown; Sample MS1-1-90

Conglomerate Clast Count Data

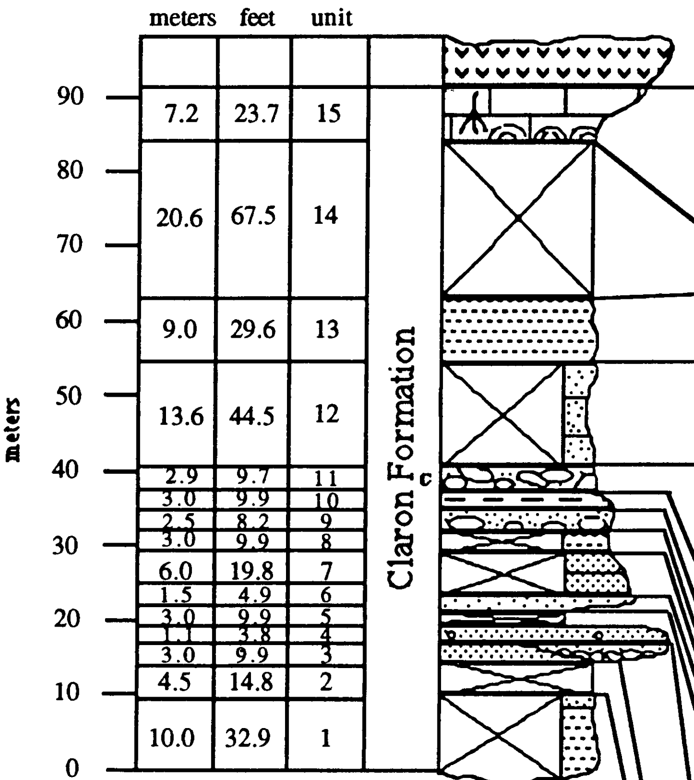
Section: Mud Spring 1

Unit Number: 9



Section: Mud Spring 2

Located on Central East 7.5' Quadrangle, southeast of town of Central, south of Santa Clara River, and north of Mahogany Creek, NW 1/4, NW 1/4, sec. 13, T39S, R16W



Tertiary volcanic rocks, possibly Leach Canyon Tuff; moderately welded tuff; locally basal part is poorly welded to unwelded; light gray; contains 30-40 % pebbles of chert, sandstone, quartzite, and carbonate

Limestone; white, light gray, & light brown; laminated to massive; recrystallized near top; fg to mg; algal mats & cummulate stromatolites, well developed near base; upper part brecciated or bioturbated; local root casts

Covered

Red shale with some yellow orange spots; massive to slightly fissile

Mostly covered; platy sandstone; plates <3 cm thick; lithic; light to pale gray fresh; pale red & red weathering; mg to cg, & interbedded fg; rare interbeds of shale & gray conglomerate

Light gray clast supported conglomerate; clasts to 20 cm; clast content similar to below; sandstone matrix; fining upward sequences; some clast imbrication; laterally grades into a sandstone; upper part covered

Shale; red; slightly fissile

Conglomerate overlain by pebbly sandstone; sandstone: weathers gray to orange brown; cg; conglomerate: weathers gray; clasts to 50 cm, mode 4-8 cm; sandstone matrix

Mostly covered; interbedded sandstone and conglomerate

Mostly covered; sandstone similar to unit 6

Lithic sandstone; moderate reddish orange, dark yellow-orange, & yellow gray weathering; same to slightly darker fresh; blocky weathering; massive; well indurated to friable; rare floating pebbles; small burrows; rare shale lenses

Covered

Lithic sandstone; moderate reddish orange, dark yellowish orange, & yellowish gray weathering; simiular fresh; rare floating pebbles, commonly chert; Sample MS2-1-90

Mg to cg sandstone, pebbly sandstone, & clast supported conglomerate; clasts to 15 cm, mode 3-5 cm; light gray & brown orange weathering; channels, some with fining upward fills; conglomerate in channel bottoms, as layers in fill, & lenses; sandstone is mostly massive

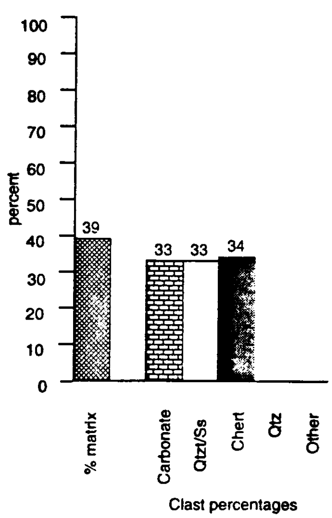
Covered

Mostly covered; dugs pits contain nearly white, poorly indurated claystone; upper 1 meter is gray lithic sandstone

Conglomerate Clast Count Data

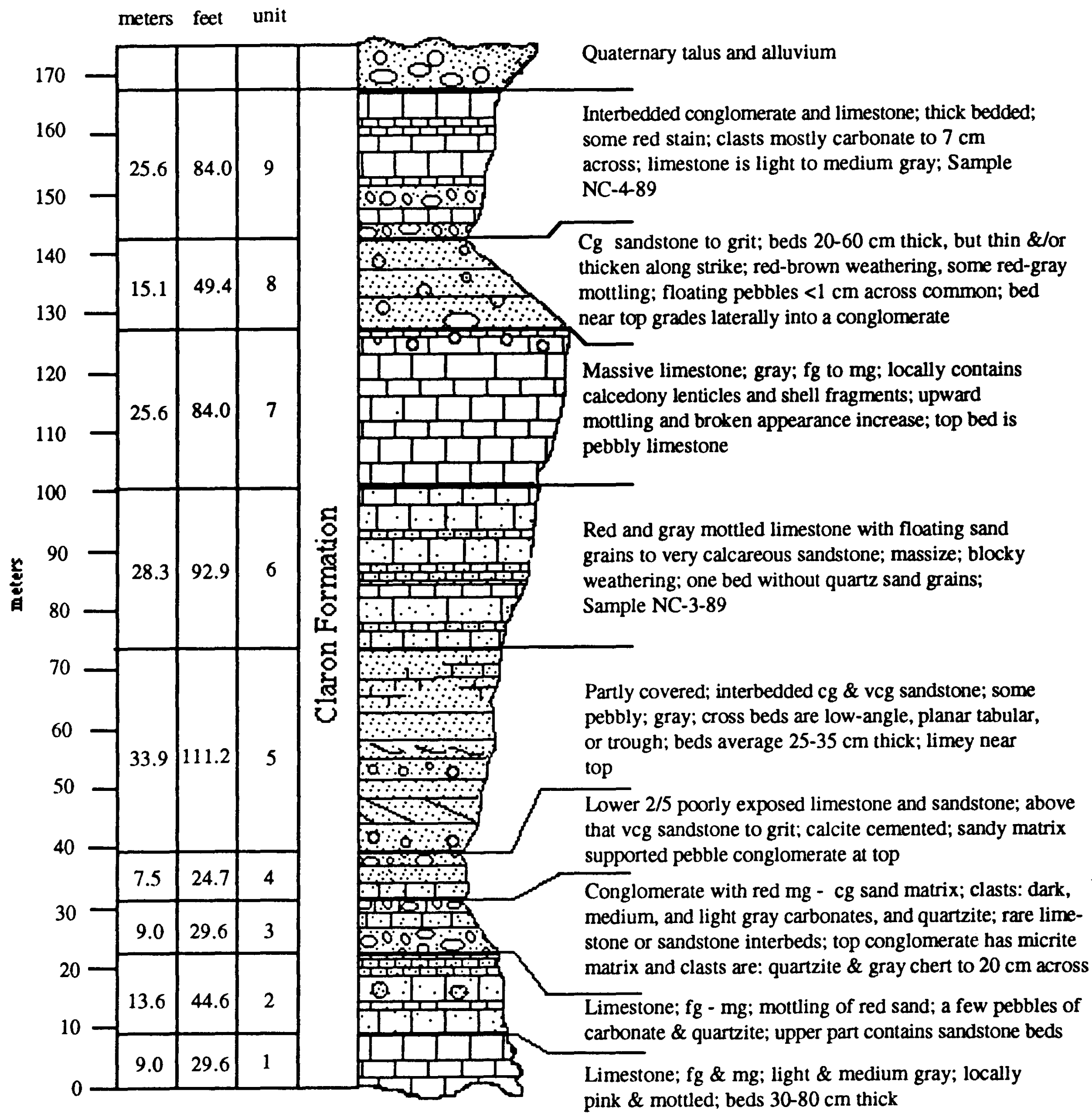
Section: Mud Spring 2

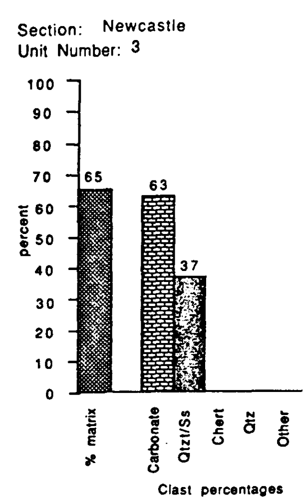
Unit Number: 10



Section: Newcastle

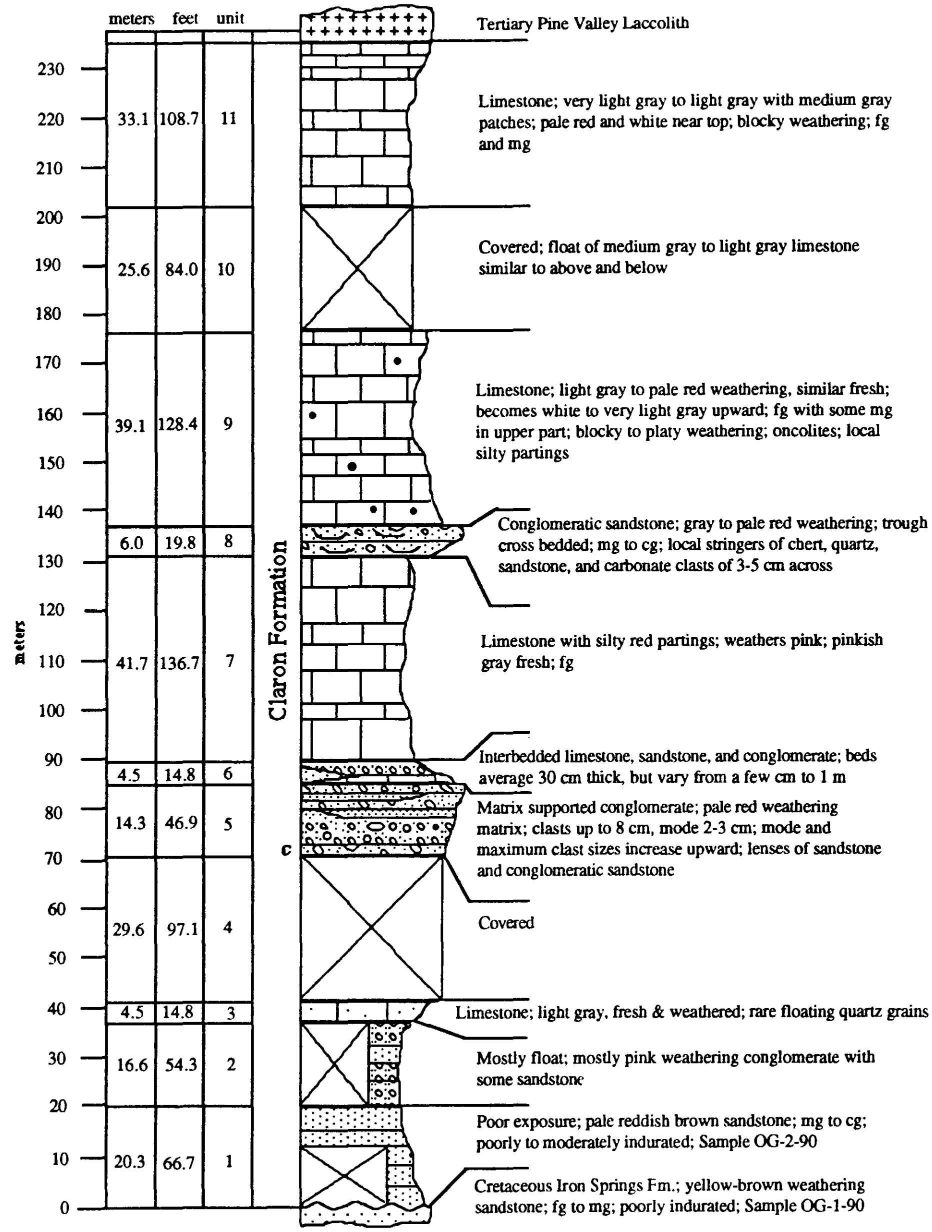
Located near the town of Newcastle, Newcastle 7.5' Quadrangle, sec. 20, T36S, R15W





Section: Oak Grove

Located in SW1/4, NW1/4, sec. 8, T40S, R14W; Pine Valley Mountains



COMPOSITION DATA

Sample Number:	OG-1-90a
Section:	Oak Grove
Unit:	0
Formation:	Iron Springs

Grain Type	%
Monocrystalline quartz	71.3
Pores	13.8
Carbonate matrix	9.0
Undulose quartz	2.4
Polycrystalline quartz	1.8
Chert	1.6
Zircon	trace
Opaques	trace
Total	99.9

Comments on thin section:

Some quartz grains with one quartz overgrowth.

COMPOSITION DATA

Sample Number:	OG-2-90
Section:	Oak Grove
Unit:	1
Formation:	Claron

Grain Type	%
Monocrystalline quartz	61.3
Pores	11.2
Micrite matrix	10.8
Spar	6.6
Undulose quartz	3.8
Polycrystalline quartz	2.6
Opaques	2.2
Chert	1.2
Glass	0.2
Total	99.9

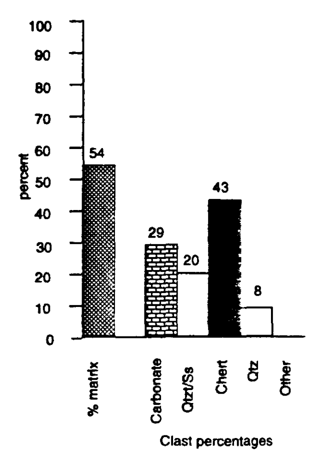
Comments on thin section

Some quartz grains with rounded overgrowths.

Clast Count Data

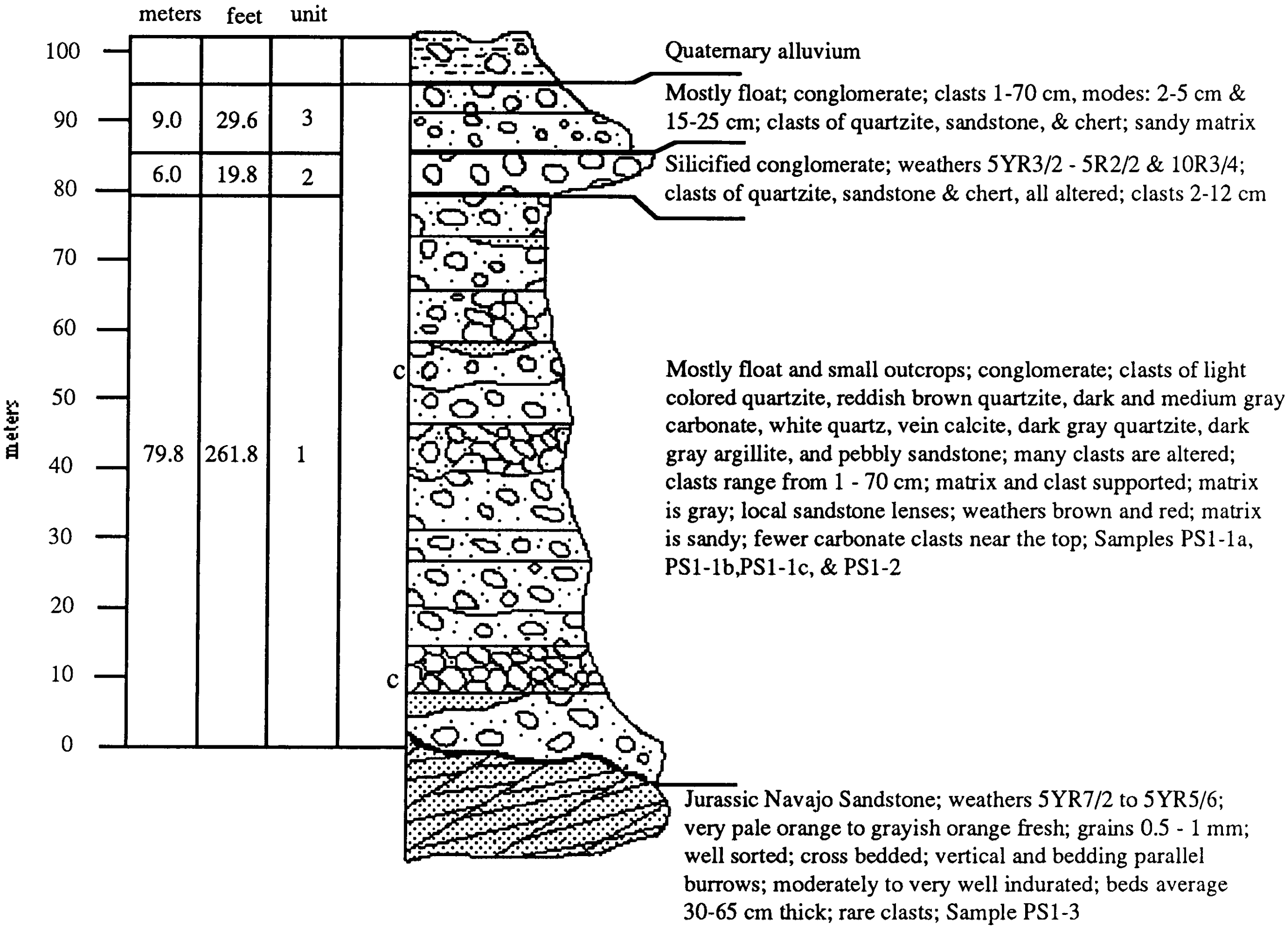
Section: Oak Grove

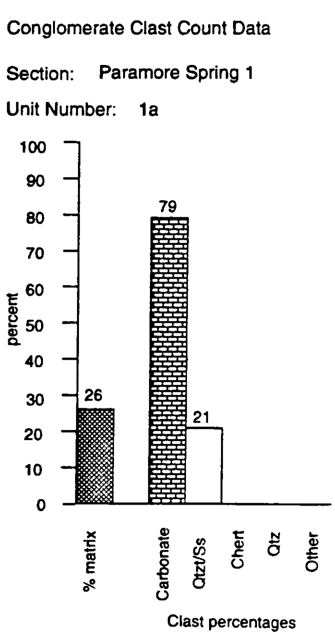
Unit Number: 4

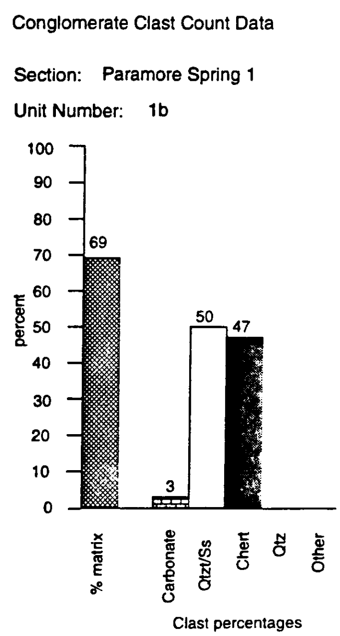


Section: Paramore Spring 1

Lund 7.5' Quadrangle, N1/2, SE1/4, and SW1/4, NE1/4, T31S, R14W

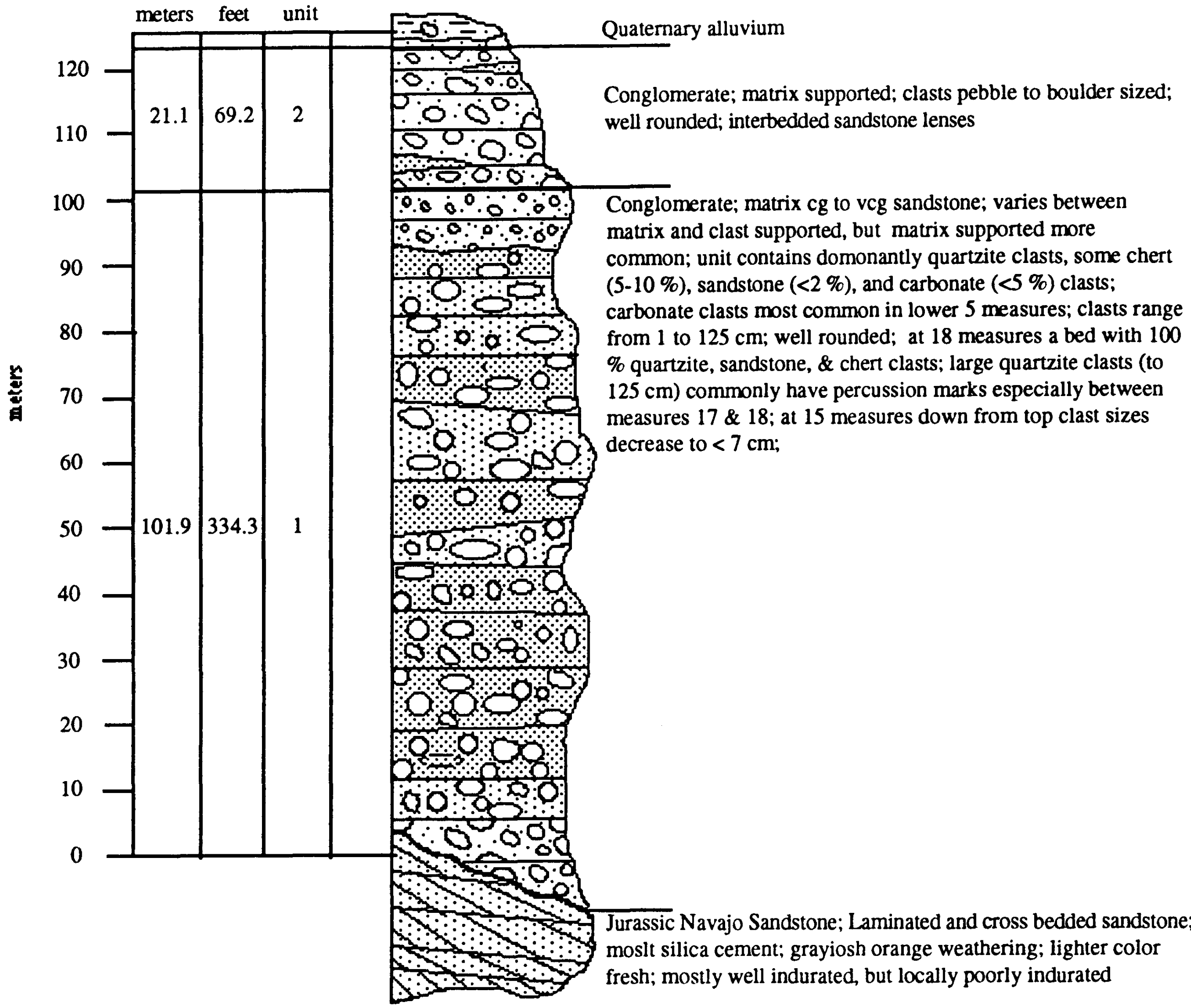


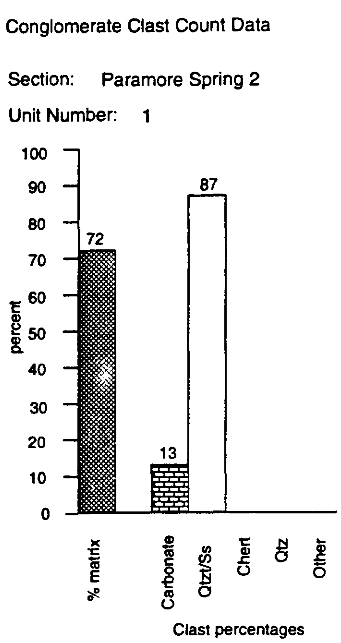


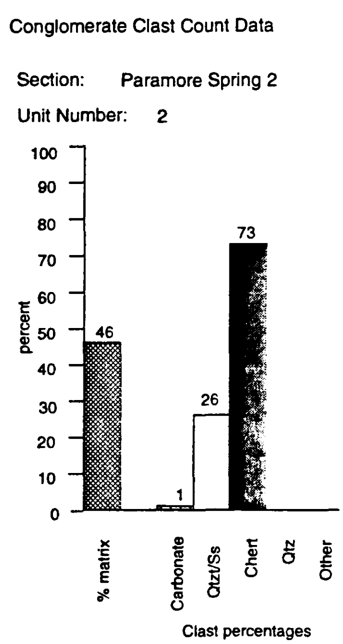


Section: Paramore Spring 2

Lund 7.5' Quadrangle, W1/2,SE1/4, and NE1/4, SW1/4, sec. 29, T31S, R14W

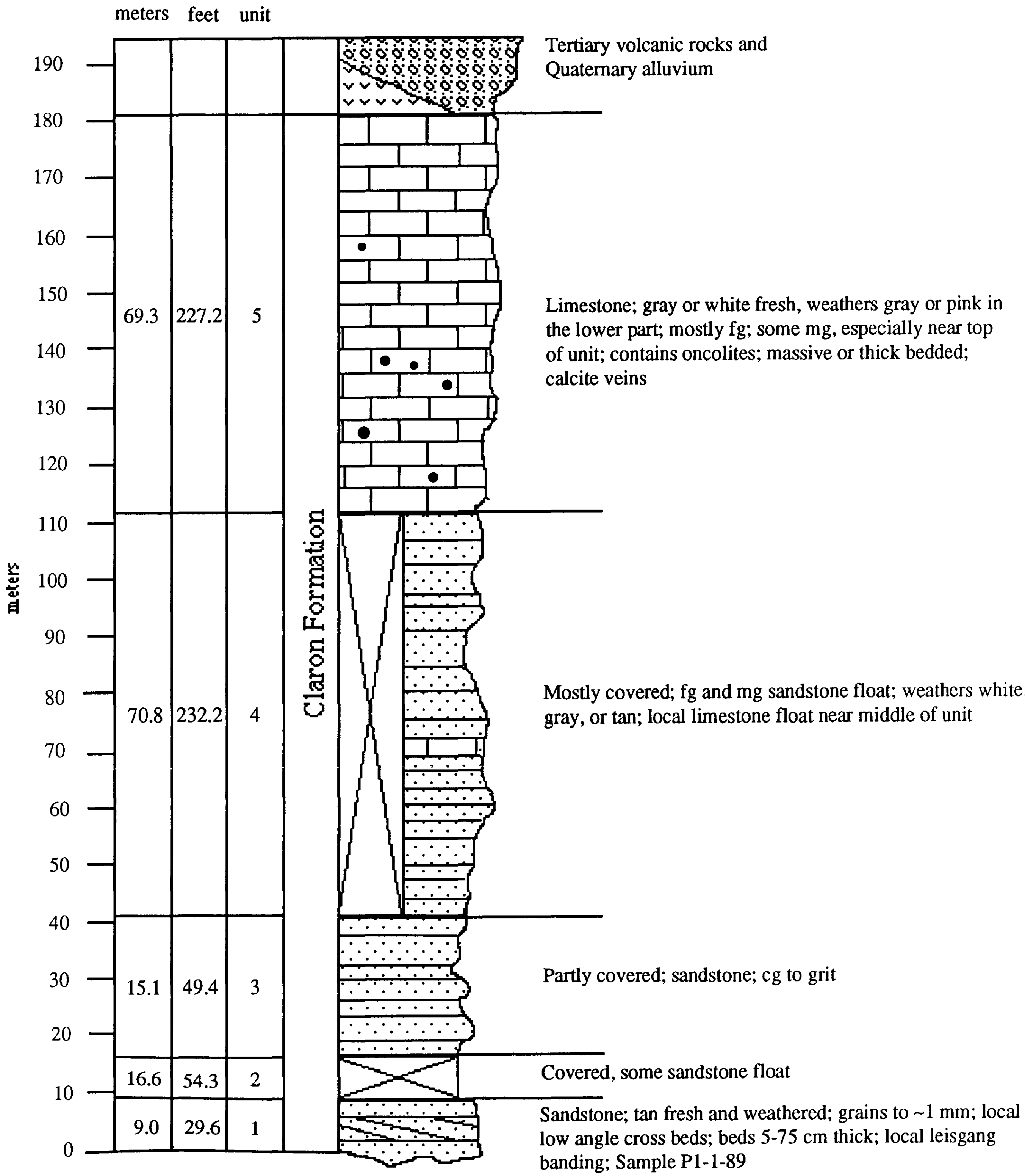






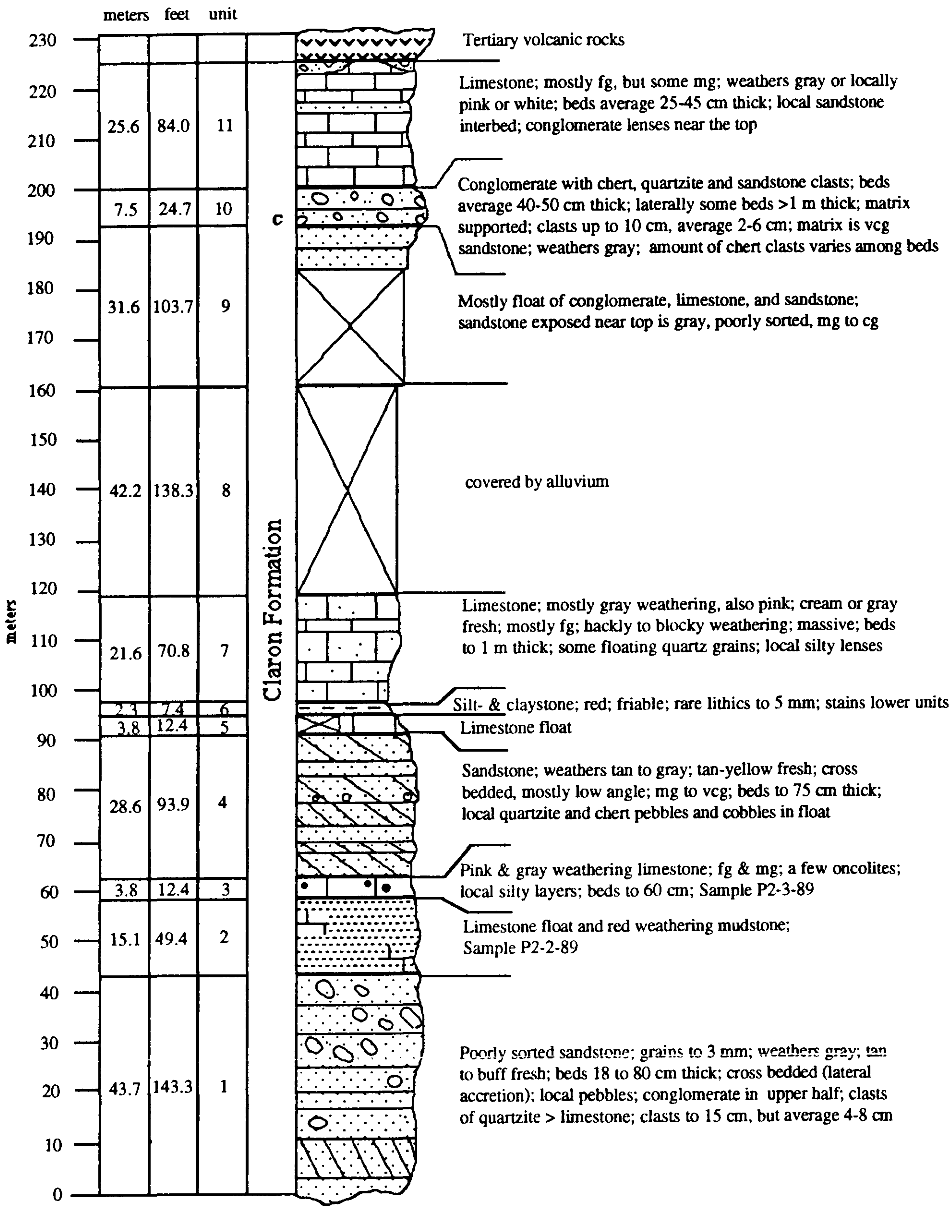
Section: Pinto 1

Near town of Pinto, Page Ranch 7.5' Quadrangle, NE 1/4, SW 1/4, sec. 29, T36S, R14W



Section: Pinto 2

Page Ranch 7.5' Quadrangle, SE1/4, NE1/4, and NE1/4, SE1/4, sec. 26, T37S, R15W



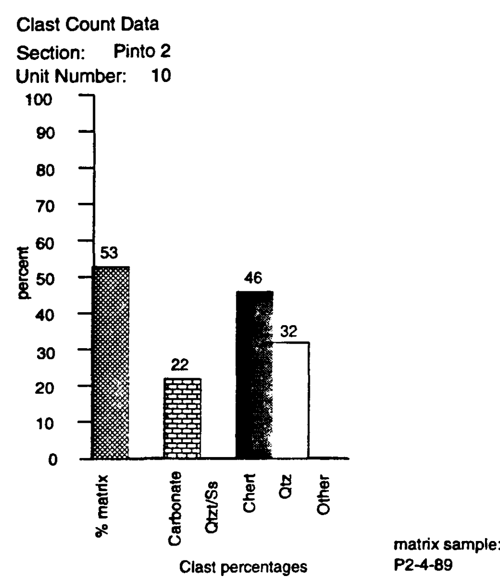
COMPOSITION DATA

Sample Number:	P2-1-89
Section:	Pinto 2
Unit:	2
Formation:	Claron

Grain Type	%
Calcite spar	66.0
Monocrystalline and undulose quartz	17.2
Micrite grains (including peloids)	11.8
Micrite matrix	2.8
Chert	1.2
Volcanic rock fragments	0.4
Opaques	0.4
Recrystallized quartz	0.2
Plagioclase	trace
Total	100.0

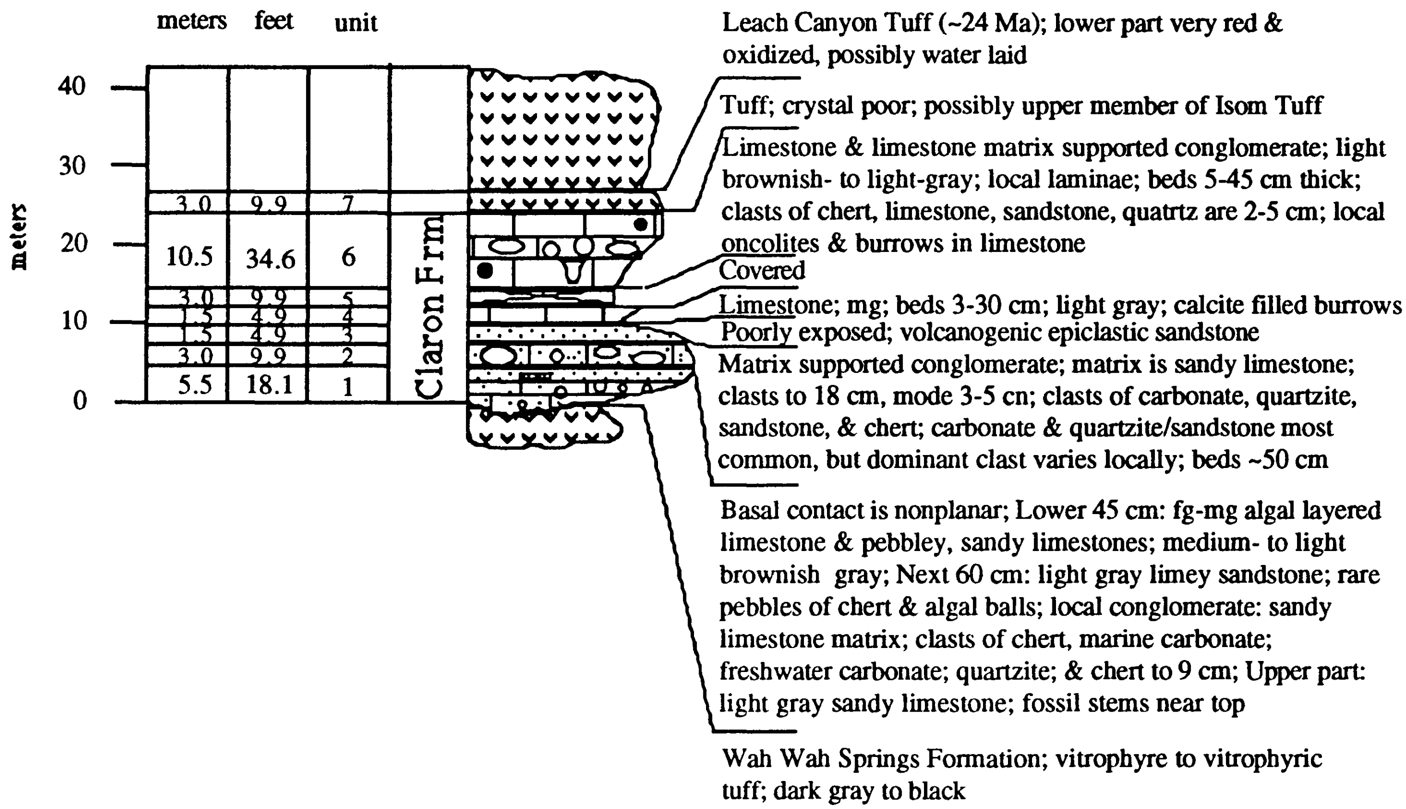
Comments on thin section:

Fine grained; laminated with different grain sizes in different laminae; some monocrystalline quartz grains with a quartz overgrowth; some ghost grains that are now spar.



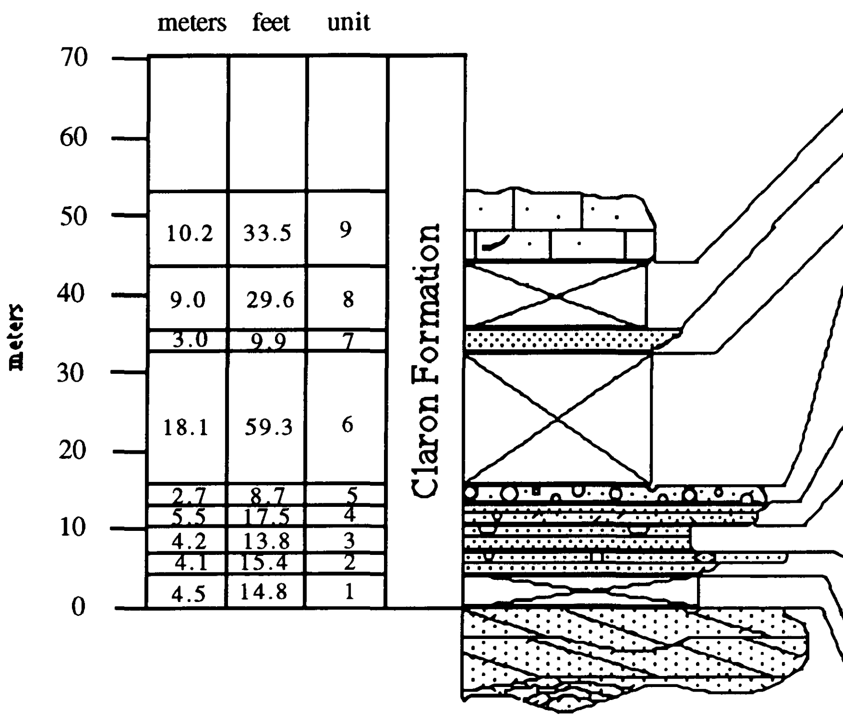
Section: R71E

Located on the Clover Mountain 1:100,000 Quadrangle on the south side of the Clover Mountains in Nevada
Dodge Springs 7.5' Quadrangle, S1/2, SE1/4, sec. 32, T7S, R71E and N1/2, NE1/4, sec. 5, T8S, R71E



Section: Red Hills 1

Located North of highway 56, ~8 miles E of Newcastle. Silver Peak 7.5' Quadrangle, NE 1/4, NE 1/4, sec. 22, T36S, R14W.



COMPOSITION DATA

Sample Number:	RH1-1-90
Section:	Red Hills
Unit:	7
Formation:	Claron

Grain Type	%
Monocrystalline quartz	55.1
Spar	31.1
Undulose quartz	3.0
Chert	3.0
Carbonate mud (micrite)	2.0
Polycrystalline quartz	1.6
Glass	1.1
Opaques	1.0
Carbonate rock fragments	1.0
Sandstone	.73
Chalcedony	.37
Total	100.0

Comments on thin section:

Carbonate cement; fine-grained carbonate rock fragments slightly compacted; spar ghosting other grains.

COMPOSITION DATA

Sample Number:	RH1-2-90
Section:	Red Hills 1
Unit:	13
Formation:	Claron

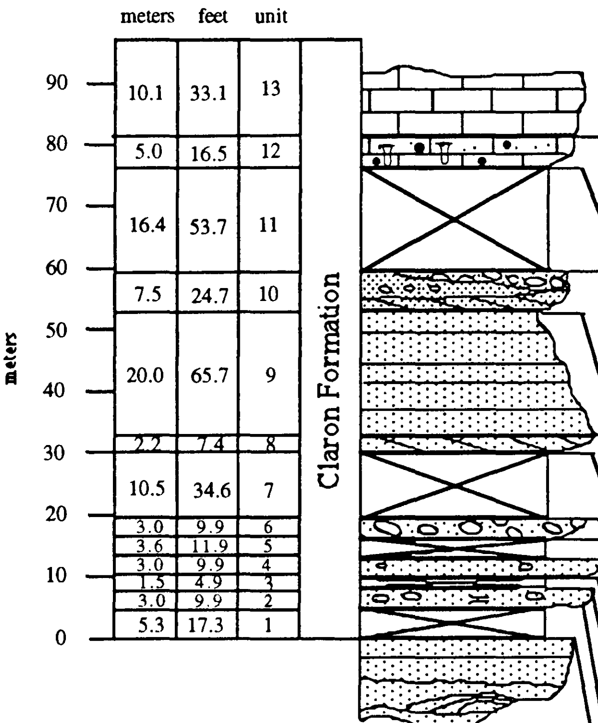
Grain Type	%
Micrite rock fragments and peloids	29.97
Monocrystalline quartz	26.38
Crystalline carbonate rock fragments	25.08
Carbonate matrix	11.07
Undulose quartz	4.89
Carbonate cement	1.63
Pores	0.64
Zircon	0.34
Total	100.00

Comments on thin section:

Some quartz grains with one quartz overgrowth.

Section: Red Hills 2

Located just north of highyway 56 and ~ 8 miles east of Newcastle, Utah, in NW 1/4, NW 1/4, sec. 22, T36S, R14W



Limestone; weathers red-gray; pale brown gray fresh; massive; bioturbated; rare floating pebbles; shell fragments

Limestone; olive gray to light gray; beds 7-50 cm thick; many oncolites, burrows, & fossil fragments; local laminations or cross beds; upward becomes rich in quartz sand grains; Sample RH2-4-90

Covered

Sandstone; mg & cg; laminated; floating pebbles & pebble stringers; brown-gray to pale red; beds 15-50 cm thick, vary laterally; cross bedded conglomerate with quartzite, sandstone & chert clasts in top 1 m; clasts to 30 cm; conglomerate is in a channel & may be a bar; Sample RH2-2-90

Mg to cg sandstone; pale pink gray or pale brown gray

Yellow-brown sandstone; grains 0.3-1.5 mm; planar cross beds; beds 20-75 cm thick; channels; soft sediment deformation

Covered

Conglomerate; light olive gray to yellow gray; sandstone matrix; both clast & matrix supported; clasts <12 cm, mode 2-5 cm; well rounded; some graded beds; cross bedded; local cut-&-fill; beds vary in thickness laterally; interbedded sandstone

Covered

Mg to cg sandstone; local floating pebbles < 1 cm; pale yellow-orange to dark yellow orange, fresh & weathered; beds 10-30 cm thick; some laminated and some cross bedded

Covered

Cg to pebbly sandstone; beds <1 m thick; cross bedded; yellow-brown, fresh & weathered; clasts of chert, quartzite, sandstone, carbonate, & quartz, most <25 cm; lenses & layers grade laterally in pebble amount

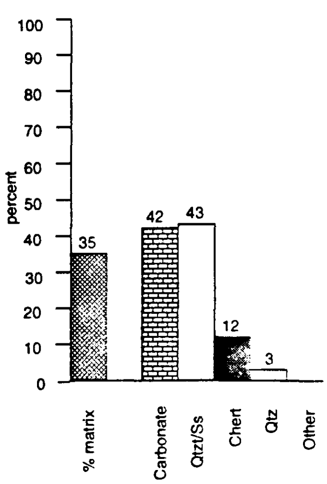
Covered

Cretaceous Iron Springs Formation; mg to cg sandstone; soft sediment deformation; hummocky cross beds; yellow-brown; friable; massive to ledgy weathering; Sample RH2-1-90

Conglomerate Clast Count Data

Section: Red Hills 2

Unit Number: 6



Clast percentages

COMPOSITION DATA

Sample Number:	RH2-2-90
Section:	Red Hills
Unit:	10
Formation:	Claron

Grain type	%
Monocrystalline quartz	40.6
Spar	27.5
Micrite	20.1
Chert	3.8
Opaques	2.6
Carbonate rock fragments	2.4
Polycrystalline quartz	2.4
Sandstone/quartzite rock fragments	0.4
Glass	0.2
Total	100.0

Comments on thin section:

A few quartz grains with one quartz overgrowth

COMPOSITION DATA

Sample Number:	RH2-4-90
Section:	Red Hills 2
Unit:	12
Formation:	Claron

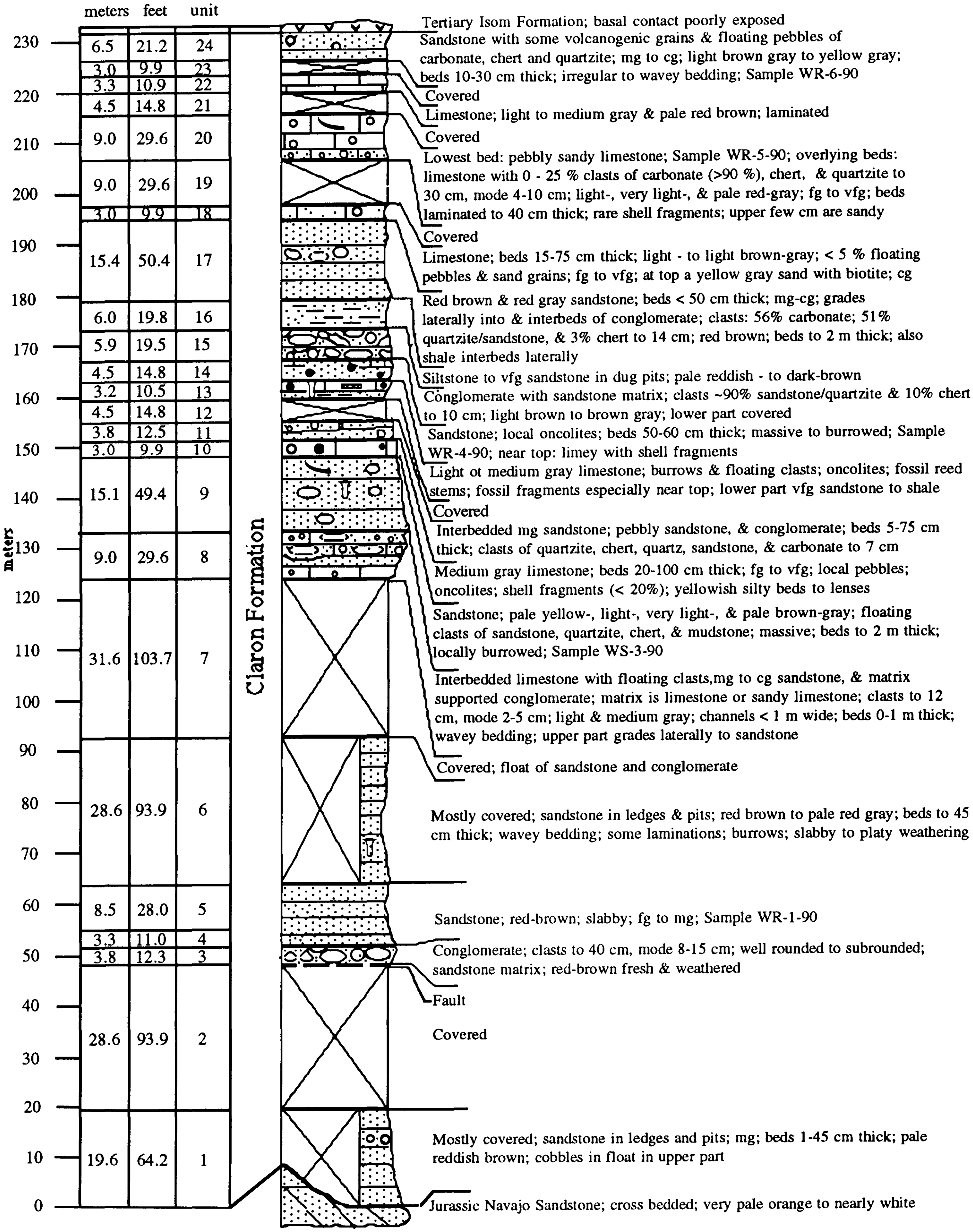
Grain Type	%
Peloids	42.8
Micrite	27.9
Quartz	18.3
Spar (cement)	7.4
Shell fragments	1.6
Carbonate rock fragments	1.4
Hematite	0.4
Chert	0.2
Chalcedony	trace
Zircon	trace
Total	99.0

Comments on thin section:

Carbonate matrix and cement; burrows; some peloids flattened.

Section: White Rocks

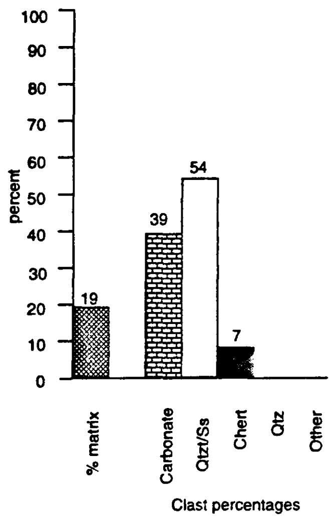
Maple Ridge 7.5' Quadrangle, NW1/4, SW1/4, sec. 23, E 1/2, SE 1/4, sec. 22, T39S, R18W



Clast Count Data

Section: White Rocks

Unit Number: 3



COMPOSITION DATA

Sample Number:	WR-1-90
Section:	White Rocks
Unit:	4
Formation:	Claron

Grain Type	%
Monocrystalline quartz	47.9
Spar	40.2
Pores	4.8
Chert	4.4
Opaques	2.0
Plagioclase	0.6
Carbonate matrix	trace
Total	99.9

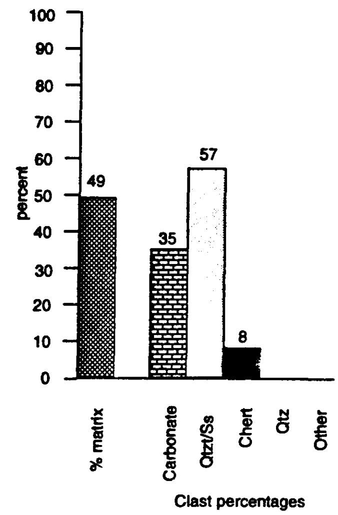
Comments on thin section

Carbonate matrix; a few grains with quartz overgrowths.

Clast Count Data

Section: White Rocks

Unit Number: 8



COMPOSITION DATA

Sample Number:	WR-5-90
Section:	White Rocks
Unit:	22
Formation:	Claron

Grain Type	%
Spar	56.0
Carbonate rock fragments	17.4
Chert	11.6
Opaques	5.6
Monocrystalline quartz	4.4
Glass	2.6
Carbonate matrix	1.2
Polycrystalline quartz	0.8
Sandstone/quartzite	0.4
Total	100.0

Comments on thin section:

COMPOSITION DATA

Sample Number:	WR-7-90
Section:	White Rocks
Unit:	27
Formation:	Claron

Grain Type	%
Partly devitrified glass grounmass/matrix	48.4
Plagioclase	32.9
Quartz	9.0
Biotite	5.2
Opaques	3.2
Volcanic rock fragments	1.0
Sandstone	0.2
Total	99.9

Comments on thin section:

Some plagioclase is zoned and some is twinned.

Section: Winn Gap

Summit 7.5' Quadrangle, N1/2, NW1/4, sec. 33, T34S, R10W